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Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

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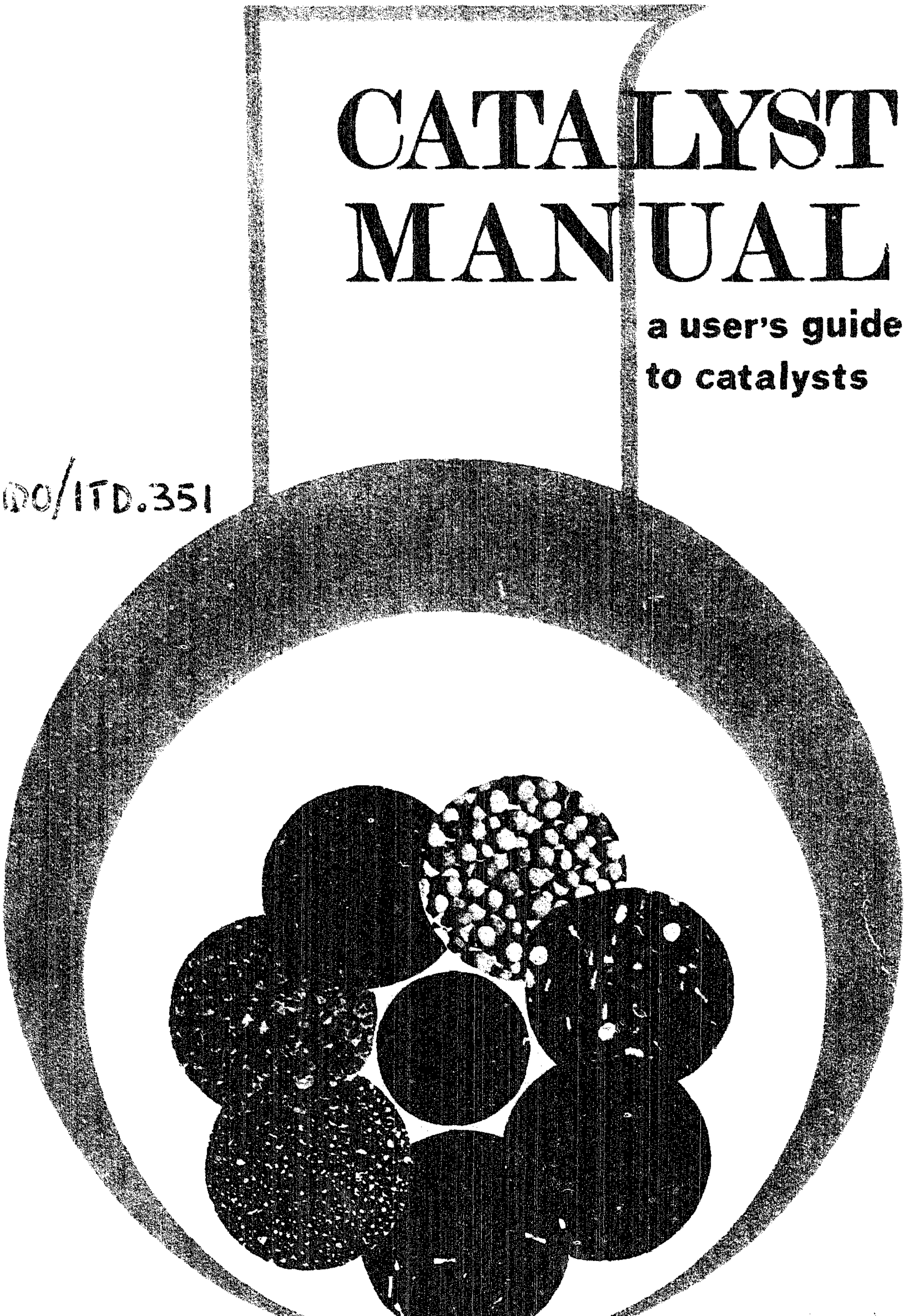

CATALYST MANUAL

a user's guide to catalysts

UNIDO/ITD.351

for the petrochemical and fertilizer industries

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CATALYST MANUAL

A USER'S GUIDE TO CATALYSTS
FOR THE PETROCHEMICAL
AND FERTILIZER INDUSTRIES

*

Compiled by the
JOINT UNIDO-ROMANIA CENTRE
Bucharest

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EXPLANATORY NOTES

Use of a hyphen (–) between dates representing years signifies the full period involved, including the beginning and end years, e.g. 1971–1973.

Reference to "tons" indicates metric tons, unless otherwise stated.

The following forms are used in tables:

A dash (–) indicates that the amount is nil or negligible.

A blank indicates that the item is not applicable.

The following abbreviations are used:

Å	ångström
ABD	apparent bulk density
ID	inner diameter
n.a.	not available
LHSV	liquid hourly space velocity
PV	pore volume
PVC	polyvinyl chloride
SA	surface area – specific surface
STRENGTH	crushing strength
TS	thermal stability
VHSV	volume hourly space velocity
WHSV	weight hourly space velocity

Te following terms are used in this manual:

Apparent bulk density (ABD). Two values may be calculated: packed and loose. Packed density is calculated from the weight obtained by filling a graduated cylinder in small increments, tapping the cylinder on a soft surface after each addition until a constant volume results. Loose density is calculated from the weight obtained by gently filling a graduated cylinder from a funnel without shock or tapping. In large-diameter reactors (low ratio of wall area to volume) the filling weight would be closely equivalent to the packed ABD. In small-diameter multi-tube reactors (high ratio of wall area to volume) the filling weight would be about median between packed and loose ABD. The data shown in this manual generally refer to packed ABD.

Carrier. A physical support for a catalyst deposited in or on it. A carrier may be catalytically active or inert. Support, mount, base are synonyms for carrier.

Life. The most important characteristic of a catalyst is its "life"; this represents the length of time it will function economically for the purpose intended. Naturally, this will depend also on the installation in which it (the catalyst) is used and on the manner of operation.

Micro-mesh sieve analysis. Method of determining partial size distribution of powders, finer than 100 microns in diameter; this method is the one generally recommended in the technical cards. A series of micro-mesh sieves are employed with screen openings of 20, 45, 60 and 80 microns. The dry method is used whenever possible but in some instances it may be necessary to use a compatible liquid for complete separation on the finer screens. At times, full wet screening is necessary.

Pore volume (PV). Includes all pore volumes larger than about 10 Å diameter; it usually is expressed as cubic centimetres per gram. The simplest procedure is to calculate from the porosity the volume of water absorbed per unit weight of dry sample. Immersion liquids other than water may also be used, applying to the calculations the specific gravity of the particular liquid. A more accurate procedure is the mercury-helium method. Crushing strength is an arbitrary measurement of the force needed to collapse a single tablet. The force can be applied either to the side or the end of the tablets. It is expressed in kg/cm^2 or in g/cm^2.

Space velocity. Volume of gas or liquid measured under specific conditions passing through unit volume of catalyst bed per unit time. It may be expressed as:

a) *volume hourly space velocity* (VHSV), representing the volume of reactant under standard temperature and pressure passing through a catalyst bed per hour and per volume, of catalyst bed;

b) *liquid hourly space velocity* (LHSV), representing the volume of liquid reactant under standard conditions of temperature and pressure, passing through a catalyst bed per hour and per volume of catalyst bed;

c) *weight hourly space velocity* (WHSV) representing weight of reactant under standard conditions of pressure and temperature passing through a catalyst bed per hour and per weight of catalyst bed.

Space velocity is expressed as h^{-1}.

Surface area (SA). The surface area per unit weight of a carrier or catalyst as measured by gas absorption, expressed in square metres per gram. A method of estimating surface area is the BET method, a procedure developed by Bunauer, Emmet and Teller from physical absorption isotherms.

Thermal stability (TS). The highest temperature to which the catalyst may be exposed and retain its catalytic activity.

Preface

The preparation of a manual listing world catalyst manufacturers for the use of fertilizer and petrochemical industries was seen as necessary in the recommendations of the "Expert Group Meeting on the Transfer of Know-How in the Production and Use of Catalysts", held at Bucharest, Romania, 26–30 June 1972 under the auspices of the United Nations Industrial Development Organization (UNIDO). At this meeting, it was noted that no single compilation existed, giving comprehensively the names and addresses of these manufacturers together with the types of catalysts produced for each of the petrochemical and fertilizer processes.

The task of compilation was undertaken by the Joint UNIDO-Romania Centre, Bucharest. In order to obtain the catalogues, pamphlets, leaflets and other kinds of documentary material needed to compile a manual of catalyst producers that would particularly benefit developing countries, a circular letter was dispatched to chambers of commerce and to industrial and national associations in 116 countries. Sixty per cent of these responded to the circular, recommending catalyst manufacturers in their respective countries.

A new series of circular letters was then sent to 300 companies. About 250 companies replied and 100 companies sent pamphlets and technical leaflets regarding their products. Of these companies, however, only 71 were producers of catalysts used in the fertilizer and petrochemical industries. An alphabetic index of these manufacturers, with their addresses, is given in chapter XXIV of this manual.

The documentation elicited by the enquiry was analysed and summarized, and for each type of catalyst a technical card was filled in. By pursuing correspondence with the various companies, every attempt was made to make the information as complete as possible, wherever it was found to be not comprehensive. The cards, however were filled in only with indications given by the manufacturers. The information given in the cards is presented in the annexes to this manual.

In the column showing the type of catalyst, the basic chemical component is given along with the code number, as mentioned in the catalogue of the manufacturing company. In characterization of the catalyst, only the indications given by the manufacturing company are stated, for the most part of general informative nature. The numerical values given for the respective parameters are to a large extent dependent on the determination method applied. At present, no standard methods exist; where companies have supplied the method, it is given in parentheses.

No technical cards were drawn up for the catalysts produced and delivered by companies on a licence basis. Peroxides, initiators, inhibitors and other types of chemical substances which might be improperly considered catalysts are not discussed in this manual, nor are the names of the companies producing such substances.

The manual comprises catalysts recommended by companies to be used in heterogeneous and homogeneous catalysis, classified according to the chemical process for which they were manufactured. Within a process there are sub-processes, and the types of catalyst, for example, copper or nickel, as well as the manufacturing company, are indicated in alphabetical order in chapter XXVI.

Each process is preceded by a short introduction regarding the process in itself, with data on the technical conditions of the recommended catalysts.

The introduction to this publication discusses the catalysts recommended by companies to be applied in ammonia, sulphuric and nitric acids plants, which are the main factors for the fertilizer industry. For ammonia production, the sequence of processes used in gas synthesis was taken into account: reforming, shift conversion, methanation and ammonia synthesis.

Desulphurization of the gases going to reforming is an important and necessary operation. Catalysts that might be used in this operation are indicated in chapter VII ("Desulphurization") *since it is impossible to recommend catalysts used in gas desulphurization for ammonia synthesis only. Thus, in order to choose the catalysts used for desulphurization, chapter VII should be consulted.*

Catalysts recommended by the respective companies for petrochemical processes are examined in chapter II. Only those catalysts were selected for these processes where express recommendations were given. It is possible that other catalysts indicated for the general processes, such as halogenation, oxidation and reforming, may be used for these special processes, but conclusions in this regard are not included in this study.

Homogeneous catalysis is discussed in chapter XVI. This classification of catalysts by main processes has been used because of the difficulty of examining and recommending catalysts for each chemical reaction, especially where the catalysts have a multipurpose application. By "main process" is understood any process that is a large consumer of catalyst in the chemical industry.

In the case of multipurpose catalysts, the characteristics given by the manufacturing company were included in only one technical card within a chemical process: for example in the case of a catalyst recommended for alkylation and isomerization, the characteristics were given in the technical card of the alkylation process, with an appropriate cross reference on the card given for the isomerization process.

Users should carry on extensive discussions with the catalyst manufacturer to obtain as precise information as possible as to the best correlation between the particle size of the catalyst and the diameter of the reactor, the most efficient quantity of the loaded catalyst, and other indications. Such discussions are advisable, since all catalogues state that the indications given are approximate and that they can be detailed with greater exactitude only when the company knows exactly the technological conditions of operation.

It must be mentioned that in this manual attention is focused on catalysts according to the type of reaction being catalyzed and not on the engineering or economic characteristics of the processes. It should be noted too, that the present work does not include the biochemical catalysts, the enzymes, that are essential to life itself.

Introduction

THE NATURE OF CATALYTIC REACTIONS

As kinetic information began to accumulate during the last century, it appeared that the rates of certain reactions were influenced by the presence of a material which itself was unchanged during the process. In 1838, J. J. Berzelius thoroughly reviewed these reactions and came to the conclusion that a "catalytic" force was in operation.

Among the reactions studied by Berzelius were the conversion of starch into sugar in the presence of acids, the decomposition of hydrogen peroxide in alkaline solutions, and the combination of hydrogen and oxygen on the surface of spongy platinum. In these examples, the acids, alkaline ions and spongy platinum were the materials which increased the rate, and yet were unchanged as the result of the reaction.

Although the concept of a catalytic force proposed by Berzelius has now been discarded, the term "catalysis" is retained to describe all processes in which the rate of a reaction is influenced by a substance that remains chemically nnaffected.

Although the catalyst is unchanged at the end of the process, there is no requirement that excludes its participation in the reaction. Indeed, present theories attempting to explain the activity of catalysts postulate that they do take part in the reaction.

From the concept of the energy of activation, the mechanism of catalysis would have to be such that the free energy of activation is lowered by the presence of the catalyst. In other words, a catalyst is effective in increasing the rate of a reaction because it makes possible an alternative mechanism, each step of which has a lower free energy of activation than that for the uncatalyzed process. For example, in the reaction between hydrogen and oxygen in the presence of spongy platinum, hydrogen combines with the spongy platinum to form an intermediate substance, which reacts with oxygen to provide the final product and reproduce the catalyst. It is required that the mechanism involving the platinum surface should occur at a faster rate than the reaction between the hydrogen and oxygen alone. The energies of activation for forming the intermediate compounds and fot their decomposition into the products are lower than that for the homogeneous combination of hydrogen and oxygen.

One other important characteristic of catalytic reactions is that a relatively small quantity of catalyst can cause conversion of a large quantity of reactants. The idea, however, that a small quantity of the catalyst can cause a large reaction does not mean that the catalyst concentration is unimportant. In fact, when the reaction does not involve a chain mechanism, it is generally true that the rate of the reaction is proportional to the concentration of the catalyst. This is perhaps most readily understood by considering the case of surface catalytic reactions.

A further property of catalytic reactions is that the position of equilibrium in a reversible reaction is not changed by the presence of the catalyst. If the equilibrium constant is unchanged by the presence of the catalyst, it is apparent that the ratio of the reaction-velocity constants for the forward and reverse reactions must be the same. Therefore, the catalyst for promoting the forward reaction must also be a catalyst for the reverse process. This has been verified in the study of the oxidation of sulphur dioxide. Thus platinum, which is an effective catalyst for the forward reaction, also has been found to accelerate the decomposition of sulphur trioxide.

Examples have been observed of so-called negative catalysis where the rate is decreased by the catalyst. Indeed, the definition of catalysis in its general form suggests only that the material has an influence on the rate of reaction.

Perhaps, the most reasonable theory of negative catalysis has been developed for chain reactions. It is postulated that the catalyst breaks the reaction chains or sequence of steps in the mechanism of the process. For example, nitric oxide reduces the rate of decomposition of acetaldehyde and ethyl ether. Apparently nitric oxide has the characteristic of combining with the free radicals involved in the reaction mechanism.

CLASSIFICATION OF CATALYTIC REACTIONS

Catalytic reactions are homogeneous or heterogeneous in nature depending upon the relations between the catalyst and the reactants.

The hydrolysis of an ester in an aqueous solution containing hydrogen ions is an example of homogeneous catalysis. The combination of hydrogen and oxygen to form water vapour in the presence of spongy platinum is heterogeneous since the platinum catalyst forms a separate phase from the reaction mixture. Heterogeneous catalysis need not involve only gas and solid phases. In emulsion polymerization, the reactants can be in the liquid phase and the catalyst in a solid phase or separate liquid phase.

Homogeneous catalytic reactions are subdivided into gaseous and liquid reactions.

The chamber process for the manufacture of sulphuric acid is an example of the former. Homogeneous liquid catalytic reactions are numerous and are widely used in industry. Most applications of this type are carried out in batch or continuous-tank reactors, such as the hydrolysis of organic esters in acid solutions and the nitration of aromatic liquids with nitric acid in the presence of sulphuric acid.

Heterogeneous reactions are of considerable significance to engineers. A few industrial applications of current importance are the oxidation of sulphur dioxide on vanadium pentoxide catalysts, the catalytic cracking of petroleum stocks using fixed or fluidized beds of solid catalysts, the oxidation of naphthalene to phthalic anhydride using vandium pentoxide catalyst and the manufacture of vinyl chloride by the reaction of acetylene and hydrogen chloride gas on a catalyst of mercuric chloride. In all these examples, the reaction mixture is in the gas phase. There are other cases where the reaction mixture is either in both the gas and the liquid phase or in the latter alone. For example, a desulphurization process for the removal of mercaptans and sulphides from petroleum stocks involves the flow of a liquid-phase reaction mixture over a solid catalyst.

The study of catalysis in such heterogeneous cases is closely being connected with the subject of surface chemistry, since surface processes play a dominant part in determining the kinetics of the reactions.

PHYSICAL PROPERTIES OF SOLID CATALYSTS

SURFACE AREA

The surface area is the sum of the external, or outer surface, plus the internal surface formed by walls of pores, cracks and crevices in the porous material. Usually, the inner part is of an order of magnitude greater than the outer surface. It is well known that increasing the surface area of a solid has a pronounced effect on its ability to adsorb gases and hence on its activity as a catalyst.

When carriers are used, in some instances the catalytic material does not impregnate all the interior surface of a porous catalyst carrier. In this case, the catalyst surface will consist of the external area plus the part of the inner surface covered with catalytic material. The surface area is determined by the BET method.

PORE SIZE

While a large surface area indicates a high activity, it is not safe to compare catalysts entirely on the basis of surface areas per unit mass because the interior surface of a porous catalyst may not be readily available for reaction.

There are many possible reasons for this. One of the most important is that the size of the openings or pores into the interior of a catalyst particle may be too small to allow easy access of the reactants to the inner surface. Hence it is not sufficient to know the surface area of the catalyst. In order to understand fully how reactions occur in pores, the following data must also be known: the average pore radius, the pore size distribution and the nature of the connexions between pores.

ACTIVITY

A large surface area is very desirable for the activity of catalytic material. If the activity of a catalyst for a specific reaction is defined as the amount of product produced per unit time per unit mass of catalyst, the activity will increase as surface area increases. However, the activity is frequently not directly proportional to the surface area. One reason is the inaccessibility of the interior due to small pore size. A direct proportionality is more likely to exist in comparing different batches of the same catalyst with the same reaction. Under these constant conditions, surface area is likely to be only variable. When different catalysts are compared for the same reaction, surface area is not as good a measurement of activity. One of the main reasons is based upon the concept that reaction occurs only on certain parts, i.e. active centres of the surface. If the fractions of the total surface that contain active centres are different for different catalysts, then activity will not be proportional to the surface.

CATALYST LIFE: CATALYST POISONS

In some reaction systems, the catalyst activity decreases so slowly that exchange for new material or regeneration is required only at long intervals. Examples are synthetic ammonia catalysts. On the other hand, cracking catalysts require frequent regeneration. The decrease in activity is due to poisons, deposited on the surface of the catalyst.

Poisons are substances existing in the reactant stream or produced by the reaction which lower the activity of the catalyst by deposition on the surface.

DEPOSITED POISONS

One example is the deposition of carbon on catalysts used in the petroleum industry. The carbon covers the active surface and partially plugs the pore entrances. It results in a less active surface and a decreased activity. This type of poisoning is partially reversible. Regeneration can be accomplished by burning off the carbon with air. If the poison is deposited as high-boiling hydrocarbon, the catalyst can be regenerated with steam.

CHEMISORBED POISONS

Compounds of sulphur and other materials are frequently chemisorbed on nickel, copper and platinum catalysts, thereby covering the active sites, which could adsorb reactant molecules.

CATALYST PREPARATION

The chemical composition of a catalyst does not alone determine activity. The physical properties of surface area, pore size and particle size greatly affect it. These properties are determined by the preparation procedure. A distinction must be made between preparations in which the entire material constitutes the catalyst and those in which the active agent is mounted on an inert material, i.e. the carrier. A catalyst corresponding to the first case is prepared by precipitation, gel formation or simple mixing of the components.

PRECIPITATION

Precipitation is a method for obtaining the solid material in porous form. The concentration of the aqueous solution, temperature, time of drying and calcining steps can influence the surface area and pore structure of the catalyst. Traces of impurities remaining from the washing may act as poisons.

GEL FORMATION

A special precipitation method is gel formation. A colloidal precipitate can be obtained from gels. The steps in the process are the same as for the precipitation method. Catalysts containing silica and alumina are especially suitable for preparation by gel formation, because their precipitates are colloids.

MIXING OF CATALYST COMPONENTS

The components of the catalyst are mixed with water, moulded to the desired grain size, dried and calcined. The proper particle size is finally obtained by grinding and sieving.

SELECTIVITY POISONS

It is known that some materials in the reactant stream will adsorb on the surface and then catalyze other undesirable reactions, thereby lowering the selectivity. The very small quantities of nickel, copper and iron in petroleum stocks can act as poisons in this way. The metal deposits on the catalyst act as a dehydrogenation catalyst, resulting in increased yields of hydrogen and coke and lower yields of gasoline.

STABILITY POISONS

These poisons are caused by the effect of water on the structure of the catalyst carrier. The temperature also has a pronounced effect on stability poisoning. Sintering and localized melting can occur as the temperature is increased. This changes the catalyst structure.

DIFFUSION POISONS

Entrained solids or fluids in the reactants form a solid residue on the catalyst and can cause this type of poisoning.

PROMOTERS AND INHIBITORS

A promoter is a substance added to the catalyst during its preparation which gives improved activity, selectivity and stability for a desired reaction. The promoter is present in small quantities and by itself has little activity.

An inhibitor has the opposite effect of a promoter when added in small quantities during catalyst manufacture. It causes poorer activity, stability or selectivity. Theoretically, inhibitors can be useful for reducing the activity of a catalyst in an undesirable side reaction.

Materials that are added to a reactant stream to improve the performance of a catalyst are called accelerators. They are the opposites of poisons. For example, steam added to the butene feed of a dehydrogenation reactor appears to reduce the amount of coke formed and increase the yield of butadiene.

PREPARATION OF CATALYSTS ON CARRIERS

Silica gel and alumina have very large surface areas. Hence they serve as carriers for those catalytic materials which are difficult to produce in a highly porous form. Carriers are also of value for obtaining a large surface area with a small quantity of an expensive active metal such as platinum, nickel or silver. The optimum amount of the active agent that should be impregnated on a carrier should be only a fraction or 1 per cent, or at most a few per cent of the mass of the carrier.

MISCELLANEOUS PROCEDURES

For preparing proprietary catalysts there are numerous special methods, such as the Raney-type catalysts, obtained by dissolving the aluminium out of an alloy of nickel, cobalt, or copper and aluminium, with an alkaline solution.

EVOLUTION OF CATALYSIS IN INDUSTRY

Catalysis holds an important part in the manufacture of many products of the petroleum and chemical industries such as refined gasolines, chemical fertilizers, synthetic fibres, synthetic rubber and synthetic polymers. From the three large subdivisions of catalysis — heterogeneous, homogeneous and enzymatic — the first plays the most important role. At present 70% of the catalytic processes applied in industry are heterogeneous. The development of the catalytic cracking process brought forth polypropylene, cis-polybutadiene, stereo-specific macromolecular products (according to Ziegler-Natta process). Other products include iso-paraffins, acrylonitrile, phthalic and maleic anhydride, and ethylene oxide. Ethylene oxide production reached about 800,000 tons in 1957 as compared to approximately 10 tons in 1930.

Catalysis in industry has been developed in three stages. During the first stage (1868—1913), most of the applications were in the inorganic chemical industry. The following processes were developed during this period: the catalytic process (Deacon) for chlorine production, the catalytic oxidation of ammonia to nitric acid (Oswald), ammonia synthesis from elements (Haber) and the oxidation of sulphur dioxide to trioxide for the manufacture of sulphuric acid.

During the second stage (1890—1940), the organic chemical industry used catalytic processes for the hydrogenation of edible oils, and methanol synthesis was developed. After 1920, petrochemistry appeared in the synthetic manufacture of alcohols and acetones. Ammonia synthesis was developed from methane gas.

In the third stage (1940 to the present), use of catalysts was extended to the petroleum industry and especially to the production of synthetic fuels. The *increasing demand for high-quality petroleum products has played a prime role in the development of cracking and reforming processes for the production of high-quality gasoline.*

Catalytic reforming was developed in 1950. It is now important and assures the production of aromatics, high-octane gasoline and inexpensive hydrogen for ammonia manufacture of hydrofining. The catalytic reforming process assures the simultaneous hydrogenation of naphthene to aromatics and isomerization of linear paraffins to iso-paraffins, avoiding as far as possible the cracking reactions, which diminish not only the gasoline yield but also the hydrogen one.

The catalysts used in this process have a multipurpose activity. They must react simultaneously with several raw materials containing a great number of hydrocarbons with a diversified chemical composition and different molecular structures and weight. Secondary reactions should be avoided as they lead to coke deposits on the catalyst, and to the partial or total loss of the catalyst activity.

In the countries of North and South America, Africa, Western Europe, the Middle East, Asia and the Pacific area there existed in 1970 a capacity of 304 million m^3 *catalytic reforming using platinum catalyst on an aluminium carrier having a capacity of 8,400 tons.*

For 1975, the capacity is expected to increase to 400 million m^3*, and catalyst requirements will reach 11,900 tons.*

The cracking process was developed similarly. In 1936, thermal cracking was important, and the gasoline produced had octane number 68. After 1936, the first catalytic cracking unit was set up.

CATALYST MANUFACTURING

Initially the catalysts were produced in the unit in which the catalytic processes were applied. The increasing demand for catalysts resulted in the development of catalyst manufacture plants within these units or in special catalyst plants.

Catalyst manufacture is complex because of the close relationship between the catalytic process and the catalyst applied. The catalyst represents the basic element of the catalytic process and it conveys to the process its peculiarity. The catalyst is a complex substance whose characteristics vary in importance depending on the user, manufacturer and researcher.

The user grants a high importance to the functional qualities of the catalyst, namely: activity, selectivity, stability, good mechanical and thermal strength, good regeneration, perfect reproductibility during manufacture and a reasonable price, which should not influence the economic efficiency of the applied catalytic process.

The manufacturer considers the catalyst as chemical material that must be produced and characterizes the catalyst by its composition and method of manufacturing namely: the nature of raw materials, the precipitation conditions, maturing, washing, drying, impregnation, calcination and activation, which are carefully controlled during the manufacturing process so that the final product meets the conditions requested by the user. The process must be perfectly reproducible.

The researcher is interested in all the characteristics wanted by the user and in those the manufacturer requires. He defines the catalyst by its texture, pore distribution, specific surface, structural density and gram density. He also examines certain electronic properties such as the energetic levels of electrons, and the superficial properties of the catalyst, especially in the reaction medium in which it will be used, namely the superficial state of oxido-reduction, the surface acidity or basicity, and the chemosorption properties by studying the nature of the relationships in the adsorbed phase, by determining the adsorption heat. All these aspects of the catalyst are not independent but, on the contrary, are complementary.

CATALYST CONSUMPTION

It is expected that the catalysts used in the heterogeneous catalytic processes of the crude-oil processing industry in the world, namely catalytic cracking, catalytic reforming and hydrofinishing, will record a total growth of about 70% in 1980 as compared to 1970 (from about 290,000 tons to about 490,000 tons). The distribution of this growth of catalyst consumption between the processes will be about: 40% for catalytic cracking catalysts; 110% for catalytic reforming catalysts; and 200% for hydrotreating catalysts.

For the fertilizer industry, the total consumption of catalysts for the production of ammonia and nitric and sulphuric acids will grow by about 146% in 1980 as compared to 1969 (from approximately 30,000 tons to 75,000 tons). If on the world scale during 1969—1980, the same consumption of ammonia, and nitric and sulphuric acids will be maintained as in 1969; the fertilizer industry will make use of about 74% of the entire quantity of catalysts necessary for the manufacture of these products in 1980.

The value of the total catalyst consumption for the production of ammonia, and nitric and sulphuric acids will increase to about 130 million United States dollars ($US) in 1980 as compared to about $US 59 million in 1969.

Part one

Heterogeneous catalysts for main industrial processes

I. AMMONIA PRODUCTION

The process of the production of ammonia consists essentially in reacting nitrogen and hydrogen under high pressure and temperature as per the following equation:

$$N_2 + 3H_2 \rightleftarrows 2NH_3$$

The nitrogen for ammonia synthesis is derived from the air. A wide variety of sources are used to supply the hydrogen. The biggest research and development effort in the ammonia industry is to obtain hydrogen at the lowest possible price. Today practically all new ammonia facilities obtain hydrogen from natural gas or petroleum.

There are exceptions — in isolated cases — where ammonia plants based on coke oven gas are still being considered, and a few plants are being built based on gasification of coal and other solid fuels. Generally, natural gas or petroleum fractions are preferred for hydrogen preparation. Selection of the particular process or feedstocks depends upon feedstock availability and the economics of the area in which the plants is to be built. However, when producing hydrogen from basic raw material such as natural gas, petroleum or coal, a complex plant is needed. In this process the following steps are required:

(a) *Sulphur removal.* Normally, sulphur is removed from the natural gas feedstock by activated carbon. In the case of naphtha, acid treating is used for bulk sulphur removal;

(b) *Hydrodesulphurization.* The vapourized naphtha in natural gas is mixed with a stream of gas which contains hydrogen. This gas may be obtained by recycle from the outlet of the reformer or it can be obtained, in the case of an ammonia synthesis plant, from the ammonia synthesis loop. The mixture is passed at a temperature of 350°—400°C over a combination of catalysts and the H_2S produced is absorbed in zinc oxide. For the catalysts recommended see chapter VII ("Desulphurization").

(c) *Conversion of hydrocarbons to synthesis gas.* Primary steam reforming and secondary reforming are processes used in converting hydrocarbons to synthesis gas (CO and H_2).

REFORMING

PRIMARY STEAM REFORMING

The sulphur-free naphtha vapour, mixed with steam is reformed in a tubular furnace. The basic reaction is:

$$C_nH_m + nH_2O \rightarrow nCO + \frac{2n + m}{2} H_2$$

When using methane as feedstock, the reaction is simplified to:

$$CH_4 + H_2O \rightarrow CO + 3H_2$$

The outlet temperature is in the range 750°—830°C. The higher temperatures are needed only when producing nitrogen-free hydrogen for methanol synthesis and hydrogenation purposes. For other purposes, such as town gas and ammonia synthesis gas, temperature is low.

CONVENTIONAL SECONDARY REFORMING

This is in effect a catalytic partial oxidation process using air and not oxygen. Air is added to the mixture leaving the primary reformer and burns with it, raising its temperature to about 1,250°C. The heated mixture then flows over a single bed catalyst. The methane present in the gas from the primary reformer is thus caused to react with the excess steam that is present. Because of the endothermic nature of the reaction, the temperature of the gas falls as it passes through the secondary reformer. The amount of air added is exactly that required to introduce the amount of nitrogen needed for ammonia synthesis (all the reactions that take place during reforming are listed in chapter XIV ("Reforming")).

Because of certain problems, such as carbon deposition, associated with earlier catalytic steam reforming, a number of processes have been developed to introduce oxygen into the reaction vessel to produce synthesis gas:

$$C_nH_m + \left(\frac{n}{2}\right) O_2 \rightarrow nCO + \left(\frac{m}{2}\right) H_2O$$

For methane:

$$CH_4 + \frac{1}{2}O_2 \rightarrow CO + 2H_2$$

In general, where natural gas or naphtha is available at a reasonable price, steam reforming is used. Partial oxidation processes are more suitable for countries that have fuel oil surpluses, a lack of low-priced natural gas and a higher relative requirement for naphtha in gasoline production.

The catalyst used in steam reforming usually contains 20—35% NiO, on a refractory support. Reformer catalyst's life is generally about five years.

SHIFT CONVERSION

CONVERSION OF CO TO CO_2 AND H_2

The gases from the reforming or partial oxidation units are sent to what is known as a shift converter, to convert the CO content of gas to CO_2 and H_2:

$$CO + H_2O \rightleftarrows CO_2 + H_2$$

The reaction is mildly exothermic, lower temperatures favouring more complete conversion of CO.

HIGH-TEMPERATURE CATALYST SYSTEM

The catalyst in general use is chromium promoted iron, formed by the co-precipitation of the oxides of the two metals. These catalysts normally operate in the range of 340°—550°C. The content of the catalyst is Fe_2O_3, but this is reduced to Fe_3O_4 in the plant convertors by the steam and H_2 mixture from the reformers. It usually contains a percentage of Cr_2O_3 to retard the sintering of the Fe_3O_4. In the past, the high-temperature CO-shift conversion system has normally been operated in two stages to obtain more complete conversion. In the high-temperature stage, carbon monoxide concentration can be dropped to 3 per cent.

LOW-TEMPERATURE SHIFT CONVERSION

Recent developments in catalyst technology have made fundamental changes in shift conversion design. Low-temperature catalysts with high activity have been developed. These catalysts are a mixture of the oxides of zinc, chromium and copper. They permit operation of the shift conversion unit at temperatures of 170°—290°C. In the low-temperature stage, the carbon monoxide concentration is brought down to 0.2%.

CARBON DIOXIDE REMOVAL

Before being sent to the ammonia synthesis unit, the carbon dioxide content of the gas stream must be removed. All processes for CO_2 removal are based upon the scrubbing of the gas with various solvents. The solvents can be reactive or non-reactive. The choice of the process depends on economics, the amount of CO_2 to be removed, and the final CO_2 content desired. Sulphur compounds not removed in an earlier stage are also removed by the CO_2 removal process.

FINAL PURIFICATION—METHANATION

In this process, both CO and CO_2 are hydrogenated to methane to less than 10 ppm by reaction with hydrogen over a nickel catalyst as per the following equations:

$$3H_2 + CO \rightarrow CH_4 + H_2O \qquad \Delta H = -49.2 \text{ kcal}$$

$$4H_2 + CO_2 \rightarrow CH_4 + 2H_2O \qquad \Delta H = -39.4 \text{ kcal}$$

Methanation is a highly exothermic process and where gases containing more than 1% of $CO + CO_2$ are being treated, it is usually necessary to recycle some of the cooled exit gas to dissipate the heat of reaction and maintain the catalyst below the normal operating temperature limit. The reaction is carried out at 1 to 50 atm, about 20,000 space velocity and about 400°C. Problems encountered in this process are S poisoning, carbon lay-down (450°—600°C), C_4 hydrocarbon formation, and loss in activity resulting from poor temperature control because of the high heat of reaction. The catalysts used are nickel catalysts promoted with alumina and iron catalysts. Methanation has replaced the copper liquor process in most new installations. Methanation is less expensive than copper liquor scrubbing, requires less equipment, is a cleaner plant and has a low operation cost.

Methanation is particularly suitable in plants using the new low-temperature shift conversion catalysts, or where the CO content has been reduced to a low level. For methanation a high-activity catalyst is required, metallic nickel being a usual active component produced in the converter by reduction of nickel oxide by hydrogen. The catalyst is used at pressures up to 30 atm and at temperatures of 250°—350°C.

Some catalysts used are alumina based and can be in the form of pellets, granules or extrusions; some also contain a cement binder. The lower concentrations of nickel (5—10%) can be obtained by impregnating alumina, but for higher concentrations (30%) which can be more active, the metal has to be introduced in other ways. Some containing chromia instead of alumina are particularly active for methanation.

AMMONIA SYNTHESIS

Ammonia is produced by the catalytic reaction of hydrogen and nitrogen at elevated temperatures and pressures. The principal variable distinguishing the different processes is the pressure. The catalyst used for ammonia synthesis is iron oxide promoted by one or four other acidic or alkaline oxides.

The iron oxide is magnetite (Fe_3O_4) although some catalysts have a portion of their iron oxide content as FeO. Promoted catalysts have the following oxides added at the time of manufacture:

Singly promoted: Al_2O_3
Doubly promoted: Al_2O_3, K_2O
Triply promoted: Al_2O_3, K_2O, CaO
Quadruply promoted: Al_2O_3, K_2O, CaO, MgO

Particle size of catalysts varies from 3 mm up to 23 mm but standard size is about 3—9 mm. Catalysts are supplied in two forms: oxidized and reduced. A catalyst's life is affected by a number of factors. One of the most significant is temperature; slow deactivation occurs above 530°C. Careful temperature control is important.

Another factor affecting the life of a catalyst is the impurities contained in the feed gas. Sulphur and chlorine cause permanent poisoning of catalyst, while carbon oxides and water cause semipermanent poisoning that can be partially reversed by reduction.

Methane and argon accumulating in the circulating gas do not poison the catalyst but reduce conversion by lowering the partial pressures of the reactants.

The life of the catalyst depends on the operating conditions and is generally from two to five years.

Work has been conducted to develop catalysts for conversion at room temperatures and atmospheric pressures. Dicyclopentadienyltitanum dichloride, promoted with ethylmagnesium halide, is being investigated. Rhodium and iridium complexes are being investigated that would break the durable triple linkage between two nitrogen atoms in gaseous form.

II. PETROCHEMICAL INDUSTRY

ACRYLONITRILE SYNTHESIS

Acrylonitrile ($H_2C = CH — CN$) is the most important representative of the acryl monomers, having multiple applications in the field of macromolecules. It enters into the composition of acryl synthetic fibres as a wool substitute.

The elastomers containing acrylonitrile present remarkable resistance to the action of chemical agents and good behaviour in the range of low temperatures. The technologies for acrylonitrile production having industrial importance are:

(a) From acetylene and hydrocyanic acid:

$$HC \equiv CH + HCN \xrightarrow{Cu_2Cl_2} H_2C = CH — CN \quad \Delta H = — 41.15 \text{ kcal/mol}$$

The reaction takes place in a liquid phase in the presence of a Nieuwland catalyst (aqueous solution of $Cu_2Cl_2 + NH_4Cl$);

(b) From propylene and nitrogen oxide:

$$4H_2C = CH — CH_3 + 6NO \rightarrow 4H_2C = CH — CN + 6H_2O + 3N_2$$

The gases of ammonia oxidation containing 15% NO and 83—84% N_2 react with an excess of propylene at 400° — 700°C in the presence of lead-containing catalysts (in the form of titanate, zirconate, stanate).

(c) From propylene, ammonia and oxygen. The reaction on which several important industrial processes are based and which differ among themselves on the catalyst need, is the following:

$$H_2C = CH — CH_3 + NH_3 + \frac{3}{2}O_2 \rightarrow H_2C = CH — CN + 3H_2O$$

$$\Delta H = — 123 \text{ kcal/mol}$$

In view of the importance of the process, numerous variants were elaborated, but they differed among themselves, especially with regard to the nature of the catalyst. Some information regarding these variants were selected from the patents literature:

(a) Bi, Sn, Sb molybdates and phosphomolybdates, phosphotungstates, Sb and U oxides on SiO_2 with activators — Sohio process, United States of America;

(b) Ti, Mn, Co, Bi, etc., phosphates or phosphoborates — Bayer process, Federal Republic of Germany;

(c) Fe, Bi phosphates — Shell process, the Netherlands;

(d) Sn molybdates — BASF process, Federal Republic of Germany.

FORMALDEHYDE SYNTHESIS

World production of formaldehyde currently amounts to some 5 million tons per year. Thus, formaldehyde has become an important raw material for the chemical industry.

Formaldehyde derivatives include mainly resins and glues for the wood, paper and textile processing industries, the major proportion being glues for manufacturing chip board and plywood.

More than 90% of the world formaldehyde output is produced by the catalytic oxidation of methanol in the presence of atmospheric oxygen. Two major processes are available for the catalytic conversion of methanol to formaldehyde: using silver catalyst; and using metal oxide catalyst (e.g. iron/molybdenum oxide).

In the process using silver catalyst, vaporized methanol and air are passed over silver crystals or silver gauze, the methanol concentration being above the explosion limit of methanol in air, i.e. above 36 vol. %. Formaldehyde is formed by combined dehydrogenation and oxidation of methanol.

OXIDATION/DEHYDROGENATION PROCESS (SILVER CATALYST)

Main reactions:

$$(1)\quad CH_3OH + \frac{1}{2}O_2 \rightarrow CH_2O + H_2O \qquad +36.8\ \text{kcal/mol}$$

$$(2)\quad CH_3OH \rightleftarrows CH_2O + H_2 \qquad -28.8\ \text{kcal/mol}$$

$$(3)\quad H_2 + \frac{1}{2}O_2 \rightarrow H_2O \qquad +5.8\ \text{kcal/mol}$$

Secondary reactions:

$$(4)\quad CH_3OH + 3/2\ O_2 \rightarrow CO_2 + 2H_2O \qquad +72\ \text{kcal/mol}$$

$$(5)\quad CH_2O + O_2 \longrightarrow CO_2 + H_2O \qquad +123\ \text{kcal/mol}$$

$$(6)\quad CH_2O \rightleftarrows CO + H_2 \qquad -\ 2\ \text{kcal/mol}$$

Apart from the main reactions according to equations (1) to (3), a number of undesired secondary reactions (equations (4) to (6)) take place which reduce the formaldehyde yield related to the methanol input. These losses are due in particular to the formation of carbon monoxide and carbon dioxide.

In most processes using silver catalysts, the methanol charged together with the process air is converted to formaldehyde only in part so that the product obtained must be freed of surplus methanol by distillation.

OXIDATION PROCESS (METAL OXIDE CATALYST)

$$CH_3OH + \frac{1}{2}O_2 \rightarrow CH_2O + H_2O \qquad +36.8\ \text{kcal/mol}$$

In formaldehyde processes using metal oxide catalysts, the formation of formaldehyde proceeds according to the equation, i.e. by oxidation of methanol as the highly selective catalysts largely suppress secondary reactions. Therefore, the yield is higher compared to silver catalyst processes. The methanol concentration in the methanol-air feed mixture is below the explosion limit, i.e. below 7—8 vol.%. The methanol is converted to formaldehyde, making distillation of the product unnecessary.

Processes using metal oxide catalysts are particularly suitable for small and medium-size production capacities of between 10,000 and 100,000 tons per year of formaldehyde. For larger capacities, processes using silver catalysts are employed. The choice of the process, however, is not only dependent on the plant capacity but on the specific conditions at the plant site.

COMBINED DEHYDROGENATION AND OXIDATION PROCESS OF METHANOL TO FORMALDEHYDE

The combined dehydrogenation and oxidation of methanol is shown in the following equations:

$$(1)\ CH_3OH + \frac{1}{2}O_2 \rightarrow HCHO + H_2O \quad \Delta R_H = +38\ \text{kcal/mol}$$

$$(2)\ CH_3OH \xrightarrow{\qquad\quad} HCHO + H_2 \quad \Delta R_H = -20\ \text{kcal/mol}$$

The first reaction is highly exothermic. Air is therefore added in such a quantity that about 60% of the methanol reacts according to equation (1), and the remainder according to equation (2).

The methanol charge is vaporized in a steam-heated evaporator by adding purified air. The methanol-air mixture is indirectly vaporized and is heated with steam up to 100°C in a connected heater. The conversion into formaldehyde takes place at a fixed silver bed catalyst at temperatures between 600° and 650°C.

To prevent any undesired secondary reactions, the hot reaction gases are quickly cooled in a waste-heat boiler arranged just below the catalyst. The greater portion of the condensable reaction mixture is condensed to formaldehyde solution in a subsequent heat exchanger.

The mixture with the non-condensed formaldehyde passes to a Raschig ring packed absorption column, and here the formaldehyde is first cooled by means of circulating cooled formaldehyde and then washed out by process water fed into the upper part of the column. The non-condensable and formaldehyde-free reaction gases (N_2, CO_2, CO etc.) are discharged into the atmosphere through exhaust gas pipes.

With a concentration of up to 42%, the formaldehyde solution can be drawn from the circulation system at the absorption column. With higher concentrations (up to 50%) a strip column is connected.

The instrumentation used in the plant permits supervision and control of the continuous process flow.

METHANOL OXIDATION PROCESS TO FORMALDEHYDE USING A SURPLUS OF AIR

The process air is compressed to about 1.2 atm abs by a radial blower and mixed with vaporized methanol. This mixture has about the following composition:

	Vol. %
N_2	73.1
O_2	19.3
CH_3OH	6.8
H_2O	0.8

The methanol-air mixture is heated to about 200°C in a heat exchanger with hot reactor effluent before it enters the reactor containing a multitude of tubes to hold the catalyst.

The methanol contained in the feed mixture is almost completely converted to formaldehyde in the presence of the catalyst or about 350°C. The heat developed during reaction is transferred to a heat carrier oil flowing around the catalyst tubes. The heat carrier oil is constantly circulated by a pump. The heat picked up by the oil is utilized in the oil cooler for generating steam. Part of this steam is used for vaporizing the feed methanol, while the balance is discharged as surplus steam. The rate of surplus steam is 350 kg per ton of 37% formaldehyde solution.

The reactor effluent is cooled to about 120°C in the heat exchanger before entering the absorber where the formaldehyde vapours are absorbed by water.

The absorber has two stages, the lower stage being packed with Pall rings and the upper stage provided with sieve trays. In the lower stage the aqueous formaldehyde solution is circulated and the absorption heat transferred to cooling water. The sieve trays in the upper stage of the absorber are also cooled with cooling water.

The process water required for absorbing the formaldehyde vapours is charged to the absorber top.

The finished formaldehyde solution is withdrawn downstream of the cooler and pumped to the storage tank.

By simple metering of the process water, formaldehyde solutions can be produced in concentrations of from 37 to 55 wt%. Distillation of this solution is not necessary.

With the installation of a few additional items of equipment it is possible to produce urea formaldehyde solutions instead of aqueous formaldehyde solutions. In this case, aqueous urea solution instead of process water is charged to the absorber top.

The production of urea formaldehyde solutions would be practicable, for instance, to increase the output of existing glue manufacturing plants.

MALEIC ANHYDRIDE SYNTHESIS

The use of maleic anhydride for the production of different types of polyester resins, alkyd resins, maleinized drying oils and various copolymers, for example with styrene, fumaric acid, tetrahydrophthalic anhydride amongst many, is well known. Pentaerythritol-maleic anhydride resins, too, may increase in use. On the other hand, the possibilities offered by the Diels-Alder synthesis foreshadow considerable further demand for maleic anhydride.

Due to its double function, the maleic anhydride molecule is ideally suited for chemical synthesis, because any atom in the molecule can be induced to react under specific conditions. Additionally, the double bond adjacent to two carboxylic groups shows almost the properties characteristic of unsaturated compounds.

In the hydrogenation of maleic anhydride, new technical implementations have been found. Succine acid, Butyrolactone and Tetrahydrofuran (THF) are three examples. Pyrrolidone, produced either from Butyrolactone or direct from maleic anhydride, represents the raw materials for polyamides (Nylon-4). This fibre has recently been introduced into the United States and has aroused much interest.

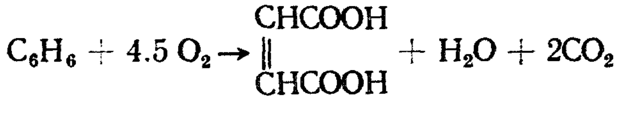
Polyester resins, which account for approximately 40—50% of maleic anhydride consumption, show excellent growth rates in the construction industry, for tanks and tubes, also in the transportation and electrical industry.

Benzene is catalytically oxidized to yield maleic anhydride in a manner similar to the production of phthalic anhydride by naphthalene or o-xylene oxidation.

Benzene presents a very stable configuration towards both thermal dissociation and oxidation. The primary effect of exposure of benzene to elevated temperature is the dissociation of the hydrogen atom accompanied by the joining of the residues to form a diphenyl, a more stable substance which may be recovered in good yield. Vapour-phase oxidation to phenol is possible and has been attained with comparatively low yields and conversions.

Phenol, however, does not present any great stability towards oxidation, and its commercial production by this method is somewhat limited at the present stage of development. Continued oxidation results in the formation of quinol and quinone, both of which have been identified in the vapour-phase oxidation products of benzene. High yields have not been attained, however, owing, no doubt, to the comparative instability of the ring at this stage of oxidation. Continued oxidation results in the rupture of the ring and leads to the formation of maleic acid, which may be obtained in good yields. The complete combustion of benzene thus probably involves the formation of quinone and maleic acid as the main points of stability before complete combustion products are reached.

The commercial production of maleic acid by oxidation of benzene has, in large measure, been due to the early work of Weiss and Downs on this particular reaction and of Gibbs and his associates at the Bureau of Chemistry in Washington on aromatic hydrocarbons in general.



$$C_6H_6 + 4.5\,O_2 \rightarrow \begin{array}{l}\text{CHCOOH}\\ \|\\ \text{CHCOOH}\end{array} + H_2O + 2CO_2$$

The stability of benzene and the fact that nine atoms of oxygen are required for the oxidation of a molecule of benzene to maleic anhydride necessitate the use of high air-to-hydrocarbon ratios in the oxidation. Thus, the theoretical requirement would be about 106 ft^3 of dry air at room temperature per pound of benzene oxidized to maleic anhydride. In practice, higher ratios than this are used (two to five times).

The heat theoretically liberated in the oxidation of benzene to maleic acid is about 10,500 Btu per lb of benzene reacting, and the heat released in the complete combustion of benzene is approximately 18,000 Btu per lb. In practice, where a certain quantity of the benzene may undergo complete combustion during the reaction, the heat released would be approximately 12,000 to 13,000 Btu per lb of benzene reacted. It is imperative that this reaction heat be removed from the catalyst zone and that the catalyst temperature be maintained at the proper operating level. Special means have been provided at the industrial scale plants to achieve an efficient heat removal.

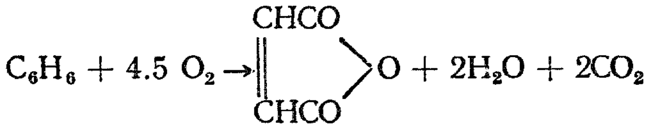
A variety of catalysts have been developed for this oxidation, and the oxides of the metals of the fifth and sixth groups of the periodic system have been particularly stressed. Of these, vanadium pentoxide has been shown to be one of the best when used in a single-component catalyst supported on an inert carrier. Vanadium pentoxide becomes active in promoting the oxidation reaction at a temperature of about 300°C, and reaches its maximum usefulness in the range of 400° to 500°C.

For years benzene has been the preferred raw material for maleic anhydride manufacture, although one manufacturer uses a mixture of butylenes and butadiene as feedstock. Actually, almost any four- or five-carbon organic chemical, except the paraffin hydrocarbons, yields maleic anhydride by vapour-phase oxidation over vanadium catalysts. Furfural, crotonaldehyde, and olefins are particularly satisfactory, but price still favours benzene.

Vapour-phase oxidation of olefins in the presence of vanadium pentoxide catalysts results in substantial yields of maleic anhydride which increase with the increase in molecular weight of the olefin. Thus, from pentene-2, trimethylene, technical amylene, methyl pentane, heptane, and octane, approximative relative conversions of 10, 25, 27 and 30%, respectively, were obtained from 5, 6, 7 and 8 C-atom olefins. Optimum temperatures of about 425°C were found for amylene oxidation.

Catalytic vapour-phase oxidation of m-xylene results in formation of maleic anhydride in yields comparable to those obtained from benzene. Relative to benzene, m-xylene requires more oxidation to convert it to maleic anhydride and, under the present circumstances, is a relatively more expensive raw material. Another potential source for the production of maleic acid is cyclohexane.

Benzene is catalytically oxidized to yield maleic anhydride in a manner similar to the production of phthalic anhydride



$$C_6H_6 + 4.5\ O_2 \rightarrow \begin{matrix} CHCO \\ \| \\ CHCO \end{matrix}\!\!>O + 2H_2O + 2CO_2$$

Compressed air is fed to a mixer where a measured stream of benzene is added under such conditions that the benzene is vaporized and the correct benzene-air ratio is obtained. The vapour mixture is blown through a multitubular reactor, containing a catalyst supported on an inert carrier (fixed bed catalyst). The reaction is highly exothermic, and, once initiated, it is self-supporting. A temperature of 450°—500°C is maintained by efficient heat removal by circulating fused salts across the tube banks in the oxidation reactor. The contact time is approximately 0.1 sec at about 1 atm pressure and the temperature is between 450° and 500°C. The reaction gases, consisting mostly of a maleic anhydride—maleic acid mixture, carbon dioxide, water, and some unreacted benzene, pass through a vapour cooler. This cooler acts as a heat exchanger and provides for the preheating of the air, benzene and the heating of the reactants and reaction products lines.

The plant design and layout for the oxidation stage is the same as for a phthalic anhydride plant.

The recovery apparatus differs from plant to plant and depends on the nature of the product desired. If maleic acid is to be the sole product, the cooled gases are adsorbed in water to yield about 40% maleic acid solution. After a purifying treatment using decolourizing carbon, the solution may be partially evaporated and crystallized to yield crystalline maleic acid. If fumaric acid is to be the final product, the maleic acid is isomerized to crystalline fumaric acid in an additional operation.

If maleic anhydride is to be the sole product, the cooled gases are passed through a partial condenser maintained at a temperature slightly above the melting point of maleic anhydride (60°C). Most of the maleic anhydride and maleic acid are condensed, and the remaining vapours pass to an absorber. Here the gases are absorbed in either aqueous or nonaqueous solvents. Hydrocarbons such as benzene or high-boiling esters may be used to absorb the anhydride, which may then be recovered by dehydration and distillation.

The bulk of maleic anhydride is recovered from the partial condensers and contains varying amounts of maleic acid. This is converted to anhydride by removing the water by vacuum or azeotropic distillation (using hydrocarbons, f.e. xylene). The removal of the water by direct heat is neither desirable nor practicable, since maleic acid gradually changes to fumaric acid when heated above its melting point. The crude maleic anhydride may be stored or packaged or first purified by vacuum distillation or sublimation. When using a vacuum distillation for purification, the distillate is passed on a flaking machine or pelletizer and the final product, in the form of flakes or pellets, is passed to a weighing and bagging machine.

It is also possible to recover fumaric acid directly from benzene oxidation gases, if the converter (oxidation reactor) exit gases are scrubbed with hydrochloric acid solution.

METHANOL SYNTHESIS

The synthesis of methanol from carbon monoxide and hydrogen is a reversible reaction:

$$CO + 2H_2 \rightleftarrows CH_3OH$$

The physical aspects of this problem are many and varied, but the combined application of physical and chemical principles has rapidly developed a variety of synthesis from water gas. The methanol, carbon monoxide and hydrogen equilibrium has been the subject of several investigations. The data obtained from these investigations show that the equilibrium constant is small, and that it decreases rapidly with temperature. Consequently, the temperature interval over which the synthesis is operative from a practical viewpoint, is not very large. At temperatures much below 300°C the rate of reaction is slow, so the capacity of the apparatus is small. Above 400°C, the equilibrium becomes too unfavourable. Despite the small values of the equilibrium constant, very satisfactory conversions are obtained. This is because of the decrease in volume attending the reaction, so that by the application of pressure, the reaction is driven to the right, or to higher conversion. Thus, at 350°C and 245 atm using the theoretical mixture, one vol. of carbon monoxide and two of hydrogen, the equilibrium yield is above 60%, whereas under exactly the same conditions, but working at 10 atm, the yield is less than 2%. The pressures used in the synthesis are usually from 200 to 300 atm.

Along with the synthesis of methanol, other side reactions are possible. Some of these are:

$$CO + 3H_2 \rightarrow CH_4 + H_2O$$

$$2CO + 2H_2 \rightarrow CH_4 + CO_2$$

$$2CO \rightarrow C + CO_2$$

Not only do these reactions consume carbon monoxide and hydrogen, they also make control more difficult, as they are more exothermic than the methanol reaction. In this synthesis a catalyst is selected that causes reduction principally to methanol. For the production of hydrogen, the operations are similar as those for the ammonia synthesis.

For the methanol synthesis the catalysts usually consist of metal and metallic oxide mixtures, the most common constituents being copper with oxides of zinc, chromium, manganese and aluminium. Zinc chromate is typical of the catalysts used.

For the synthesis of methanol alone, contact of the hot gases with iron should be avoided. In this case the reactors are lined, usually with copper or some other material not affecting the catalyst. The catalysts for pure methanol are usually susceptible to iron carbonyl, formed when carbon monoxide is in contact with iron. This impairs the catalyst's activity or else induces undesirable side reactions.

With the proper catalyst and the exclusion of sulphur and iron, methanol of a purity of 99% or better can be produced. The CO and H_2 necessary for methanol synthesis are obtained by steam reforming of methane or by steam reforming of hydrocarbons. The process sequence used to make methanol is about the same as for ammonia synthesis.

The greatest use of methanol is for the production of formaldehyde. It is also used for the manufacture of dimethylaniline, dimethylamine, methacrylates and miscellaneous solvents.

HYDROFORMYLATION (OXO REACTION)

Oxo reaction was developed in the course of research on the Fischer-Tropsch synthesis for the production of liquid fuels and chemicals from coal.

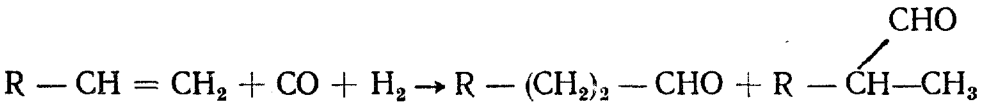
The reaction originally consisted of the treatment of an olefin with water gas ($H_2 + CO$) in the presence of a cobalt catalyst to produce aldehydes containing one carbon atom more than the starting compounds.

The reaction results in the addition of the units of formaldehyde H-CHO across the double bond. The synthesis was first carried out with ethylene. Diethyl ketone and propionaldehyde were obtained, and because both products contained a carbonyl or "oxo" group, the reaction was called the oxo-synthesis.

Later it was found that ketone production was relatively unimportant; aldehydes were almost always the principal product. Although the reaction was recognized as being an aldehyde synthesis, the name oxo was retained, probably for the sake of convenience and brevity.

Because the reaction consists of the addition of H and CHO, it is perhaps more accurate to call it formylation or better hydroformylation.

The oxo reaction is a special case of the introduction of carbon monoxide into an organic molecule, which produces aldehydes:



$$R - CH = CH_2 + CO + H_2 \rightarrow R - (CH_2)_2 - CHO + R - \overset{CHO}{CH} - CH_3$$

Hydroformylation may employ either a slurry process or a fixed bed.

Typical operating conditions for a slurry process are: 150°—200°C, at a 150—200 atm, with a synthesis gas (1 to 1 ratio of carbon monoxide to hydrogen) in contact with an olefin containing 3—5% catalyst.

The catalysts used are cobalt, iron and nickel carbonyls. Other patents indicate that calcium, magnesium and zinc are also catalysts for the oxo reactions.

Exothermic reaction is controlled by cooling and recycling, with perhaps 70% conversion in primary reactors supplemented by further conversion in secondary reactors.

Fixed bed processes under similar operating conditions eliminate the problem of catalyst separation from product, but require special cooling facilities to remove heat of reaction.

Partial hydrogenation of the aldehydes to alcohols may occur during hydroformylation, particularly at higher temperatures and with hydrogen-rich ratios in the synthesis gas. Complete reduction to alcohols is usually accomplished in a separate stage, using pure hydrogen. The catalyst (cobalt) used in the first stage, or other available hydrogenation catalysts, may be used. In either case it is considered necessary to remove all carbon monoxide and cobalt carbonyl prior to the hydrogenation.

The alcohols secured by the reduction are converted into detergents, plasticizers and other products.

PHTHALIC ANHYDRIDE SYNTHESIS

In the initial stage of industrial development, phthalic anhydride serves as a valuable raw material and intermediate product for local industrial enterprises, mainly in the field of plasticizers, paints and colourants, PVC products and plastic materials in general.

Phthalic anhydride is produced from naphthalene or o-xylene, or from mixtures of both products by air oxidation in vapour phase at elevated temperature with the aid of a catalyst. Mainly fixed bed catalysts are used, although some plants use a fluid catalyst bed process.

Main reactions take place in accordance with the following equations:

$$C_{10}H_8 + 4.5O_2 \rightarrow C_8H_4O_3 + 2CO_2 + 2H_2O$$

$$C_8H_{10} + 3O_2 \longrightarrow C_8H_4O_3 + 3H_2O$$

Several side reactions occur at elevated temperature and these side reactions lead to the formation of small quantities of naphthoquinone, maleic anhydride and CO_2 when naphthalene is used as feedstock, and of maleic anhydride when o-xylene is used as feedstock.

Considerable excess of air is used, up to three times that theoretically required. Thus, from 20 to 60 moles of air must be used per mole of naphthalene oxidized.

The reaction is very exothermic and specially designed catalytic reactors must be used to remove this heat efficiently and without disturbing the temperature equilibrium of the catalyst mass.

Approximately 5,000 calories per kilo of oxidized naphthalene and approximately 5,600 calories per kilo of oxidized o-xylene are released. This heat is continuously removed and utilized for the production of steam. The application of special catalyst carriers and the particular composition of the catalyst active mass allows speeds of 350—450 g of feedstock per litre of catalyst per hour resulting in effective yields of about 80% of the theoretical.

Catalysts similar to those mentioned for benzene oxidation to maleic anhydride are applicable to the naphthalene or o-xylene reaction. The published results have shown that vanadium and molybdenum oxides are efficient and active catalysts.

Vanadium pentoxide catalysts become active for the oxidation of naphthalene or o-xylene at temperatures of 360°—480°C, the optimum temperature being about 420°—480°C.

Another carrier recommended for vanadium catalyst is silica gel, prepared from potassium silicate and sulphuric acid. The catalyst contains 10% V_2O_5 and can be used in a fluidized bed reactor.

It has been claimed that mixtures of metal oxides form better catalysts than the oxides alone. For instance, a mixture of 85% vanadium pentoxide with 15% molybdenum oxide is claimed to be better than the vanadium oxide alone; and a mixture of 65% molybdenum oxide and 5% either manganese or calcium oxide still better.

Porous, granular, intimate mixtures of the trioxides of tungsten and molybdenum in molecular ratios between 10:1 and 1:10 have been described as effective oxidation catalysts.

The catalyst is of particular importance in the efficient operation of the reaction and, while an essential component is vanadium pentoxide on a special carrier, there are also certain additions and modifications which differentiate the various catalysts available and which have an appreciable effect on the over-all efficiency.

Of particular importance also is reactor engineering and reactor design.

STYRENE SYNTHESIS

Styrene (vinyl benzene) is commercially produced in large quantities by the dehydrogenation of ethylbenzene, which is obtained by the Friedel-Crafts reaction of ethylene and benzene in the presence of hydrogen chloride and $AlCl_3$ as a catalyst.

THE ALKYLATION OF BENZENE WITH ETHYLENE

$$C_6H_6 + CH_2 = CH_2 \rightleftarrows C_6H_5 - CH_2 - CH_3$$

(a) In the presence of $AlCl_3$ as a catalyst. The reaction is carried out at atmospheric pressure, at 90°—95°C. The presence of oxygen, carbon monoxide, acetylene, increases the consumed quantity of $AlCl_3$. The benzene must be of high purity, with a sulphur content $< 0.1\%$ and water content <30 ppm. The ethylene must not contain other olefins.

(b) The alkylation catalysed by phosphoric acid on solid support. The reaction is carried out in gaseous phase in the presence of phosphoric acid on Kieselguhr. In this process the conditions concerning the purity of ethylene are less severe.

THE OXIDATIVE DEHYDROGENATION OF ETHYLENE TO STYRENE

$$C_6H_5-CH_2-CH_3 \rightarrow C_6H_5-CH=CH_2+H_2 \quad \Delta H = +28.7 \text{ kcal/mol}$$

The reaction is carried out in the temperature range of 600°—630°C in adiabatic or isothermal reactors. The catalysts used are a mixture of metallic oxides (ZnO, Al_2O_3, CaO). The alumina in these catalysts acts as activator, the CaO catalyses the oxidation of carbon deposited on the catalyst.

The absence, or too small quantities, of aluminium oxide determine high reaction temperatures whereas too big quantities favour secondary reactions.

A higher basicity of catalyst is advantageous and it is obtained by addition of potassium salts (K_2SO_4 and K_2CrO_4). Under the reaction conditions these salts decompose into K_2O and Cr_2O_3 — a fact which implies an increase of the catalyst basicity and its activation. The catalysts applied in butylene dehydrogenation may also be used. For ethyl-benzene dehydrogenation, iron oxide with a carrier having K_2CO_3 as promotor can be used.

VINYL ACETATE MONOMER SYNTHESIS

Vinyl acetate is obtained by the addition of acetylene to acetic acid in the presence of a suitable catalyst:

$$CH\equiv CH + HOOC-CH_3 \rightarrow CH_3COOCH=CH_2$$

The reaction can take place in a liquid or vapour phase. A more recent procedure consists of treating the ethylene with acetic acid in the presence of an alkaline acetate, palladium chloride and of a redox system for the conversion of Pd in palladium chloride again. This procedure is in principle similar to the production of acetaldehyde from ethylene in the presence of palladium salts:

$$H_2C=CH_2+PdCl_2+2CH_3COONa \rightarrow H_2C=CNOOCCH_3+2NaCl+$$
$$+Pd+CH_3COOH$$

The presence of a redox system that will oxidize the metallic palladium again to palladium chloride is necessary to assure a continuous process.

Similar to the production of acetaldehyde from ethylene, the redox system is a cupric-cuprous chloride couple.

$$Pd+2Cu^{2+}+4Cl^- \longrightarrow PdCl_2 + 2CuCl$$

$$2CuCl+\frac{1}{2}O_2+2HCl \rightarrow 2CuCl_2+H_2O$$

The process for the production of vinyl acetate by acetylene addition to acetic acid, as has been mentioned, can be carried out in either a liquid or a gaseous phase.

For industry, the vapour phase process is of importance. High yields of 90—95% are obtained as compared to acetylene and of 93—99% as compared to acetic acid. Similarly, low percentages of secondary products and reduced corrosion are obtained.

The normally used catalyst is obtained by impregnating the active coal with zinc or cadmium acetate to a concentration of 20—50 parts of acetate to 100 parts of coal. Pumice, silica gel, active aluminium oxide and other substances with big specific surfaces are recommended as carriers.

The metallic salts are: zinc chloride (which gives the best results), mercury, magnesium, barium, copper, silver chlorides or acetates, mercury, silver or zinc phosphate, zinc or cadmium silicate. It is recommended impregnating the zinc catalysts with small quantities of $BiOI$ or BiI_3 and a little copper in order to enhance their activity. The presence of the catalyst is debatable due to the secondary reactions of the acetylene.

The role of zinc acetate is that of a co-catalyst towards coal. The catalyst activity is proportional to the specific surface and to the content of zinc acetate.

Trends towards improving catalyst life, yield and conversion are inclined to the use of metal chromates, silicates and the zinc salts of dicarboxylic acids. Silica, alumina or silica-alumina catalysts are proving to be superior.

The industrial synthesis of vinyl acetate from acetylene and acetic acid in gaseous phase consists of the following main stages:

(a) Acetylene drying and acetic acid evaporation;

(b) $C_2H_2 + CH_3COOH$ mixture and its heating up to the reaction temperature;

(c) Acetylene and acetic acid reaction;

(d) Condensation of the reaction products (unreacted acetylene) — recirculation is included;

(e) Separation of vinyl acetate and acetic acid from the reaction products.

To ensure longer catalyst life, it is necessary to use pure raw materials, to isothermally remove the reaction heat and to avoid superheating. As it was difficult to get an efficient lateral thermal transfer in the fixed bed catalyst reactor, the fluidized bed reaction was studied too.

In such a case it is recommended that an active coal catalyst with a granulation of 100—250 μ impregnated with zinc acetate 33% weight be used. The coal should have good mechanical properties in order to avoid the modification of its granulation by erosion.

VINYL CHLORIDE SYNTHESIS

Vinyl chloride ($H_2C{=}CHCl$) is processed to obtain polymers and copolymers (vinyl acetate, styrene, aryl esters, maleic esters).

The molecule of vinyl chloride consists of a hydrocarbonate rest and chlorine. In the industrial production of the vinyl chloride, the hydrocarbon rest comes from ethylene or from acetylene while the chlorine is introduced by the direct chlorination or by means of hydrochloric acid.

Vinyl chloride production usually comprises the following phases in a single industrial complex:

(a) Obtaining the raw material at the degree of purity imposed by the selected process;

(b) Vinyl chloride synthesis;

(c) Vinyl chloride separation and purification, generally followed by polymerization.

(a) The gases resulting from cracking go to a preliminary purification system, then to a separation and concentration of ethylene unit, and then to the final purification (removal of acetylene, water, carbon dioxide). For the acetylene removal (selective hydrogenation), catalysts like molybdenum sulphide (on activated aluminium oxide), cobalt molybdate, nickel derivatives and nickel-cobalt, and chromium are used.

Palladium and palladium-promoted catalysts are used for the hydrogenation of small amounts of acetylene present in the purified olefins. These catalysts are sensitive to sulphur poisoning and therefore the sulphur compounds have to be removed before hydrogenation;

(b) The main processes for vinyl choride synthesis are:

(i) Dehydrochlorination of the dichloroethane in a liquid or gaseous phase:

$$CH_2Cl - CH_2Cl \xrightarrow[550^\circ C]{\text{activated charcoal}} CH_2 = CHCl + HCl$$

$$CH_2Cl - CH_2Cl \xrightarrow[280^\circ C,\ 1\ \text{atm}]{BaCl_2\ \text{on activated charcoal}} CH_2 = CHCl + HCl$$

(ii) Addition of hydrogen chloride to acetylene in a liquid or gaseous phase:

$$C_2H_2 + HCl \xrightarrow[\text{activated charcoal}]{HgCl_2 \text{ on}} CH_2 = CHCl$$

(iii) Ethane chlorination or substitutive chlorination of ethylene.

Vinyl chloride can be obtained from dilute mixture of acetylene-ethylene.

The catalysts used in the dichloroethane dehydrochlorination process are metal chlorides and active coal. The conversion obtained depends on the nature of the catalyst and on temperature. Maximum efficiency is obtained by using active coal impregnated with 30% $BaCl_2$ at 350°C in the presence of 0.5% chlorine.

In the case of hydrogen chloride addition to acetylene, the catalysts used are charcoal, coke and pumice impregnated with the chlorides or oxides of some metals.

The catalyst with the most selective action is the mercury chloride deposited on the active coal, especially on coal having a high affinity towards the halogenating agent.

The life of a mercury chloride catalyst is determined to a great extent by the reactants' purity and especially their humidity, and by carrying the reaction in an isothermal regime.

The mercury chloride catalyst is activated by adding $CuCl_2$, $CeCl_2$, $ThCl_4$, ammonium metavanadate, phosphoric, sulphuric or chloric acids.

For the production of vinyl chloride by ethylene chlorination, the technical process is complicated due to the secondary reactions of addition and substitution. In some variants, the use of active coal catalysts impregnated with 10—25% $CaCl_2$ or $SrCl_2$ is indicated.

The production of vinyl chloride from a dilute mixture of acetylene-ethylene starts from a mixture of acetylene-ethylene obtained from the oxidative pyrolysis of petroleum cuts containing acetylene and ethylene in an almost equimolecular ratio.

The thermal cracking of the petroleum cuts takes place in the absence of catalysts. The acetylene reaction follows the addition scheme of hydrogen chloride on a mercury chloride catalyst.

The chlorination of ethylene is carried out in a dichloroethane solution with iron chloride as catalyst;

(c) The separation and purification of vinyl chloride take place according to similar procedures irrespective of the technology used for the production of vinyl chloride.

The sequence of operations is the following:

reaction gases → preliminary purification,
(drying, HCl removal)
↙ ↘
heavy cuts separation | light cuts separation, C_2H_2, etc.
→ fine purification → pure vinyl chloride.

In selecting one of the above processes all elements contributing to the price should be considered; it has been noticed, however, that the decisive factor is usually represented by the ethylene/acetylene ratio.

III. PRODUCTION OF ACIDS

NITRIC ACID

The manufacturing process for nitric acid is based on the catalytic oxidation of ammonia. It consists of nitrogen oxide production, its oxidation into superior oxides and their absorption into water; these partial processes can be expressed by the following reactions:

$$4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O \qquad \Delta H = -216.7 \text{ kcal}$$

$$2NO + O_2 \longrightarrow 2NO_2$$

$$3NO_2 + H_2O \rightarrow 2HNO_3 + NO$$

The short equation of the transformation process of ammonia into nitric acid can be expressed as:

$$NH_3 + 2O_2 \rightleftarrows HNO_3 + H_2O \quad \Delta H = -100.6 \text{ kcal}$$

By the catalytic oxidation of ammonia with oxygen the following main reactions are possible:

$$4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O \qquad \Delta H = -216.7 \text{ kcal (1)}$$

$$4NH_3 + 4O_2 \rightarrow 2N_2O + 6H_2O \qquad \Delta H = -263.9 \text{ kcal}$$

$$4NH_3 + 3O_2 \rightarrow 2N_2 + 6H_2O \qquad \Delta H = -303.1 \text{ kcal}$$

Secondary reactions can also take place without catalyst participation:

$$2NH_3 \longrightarrow N_2 + 3H_2 \qquad \Delta H = + 21.96 \text{ kcal}$$

$$2NO \longrightarrow N_2 + O_2 \qquad \Delta H = - 43.14 \text{ kcal}$$

$$4NH_3 + 6NO \rightarrow 5N_2 + 6H_2O \qquad \Delta H = -431.60 \text{ kcal}$$

Decomposition of ammonia into nitrogen and hydrogen can take place at high temperatures in the oxidation installation before passing over the catalyst.

Dilute nitric acid is obtained according to the reaction of the ammonia oxidation. In this respect, research has been undertaken to find selective action catalysts that will intensify only this reaction.

The research has established that the catalysts that give a high yield of transformation of ammonia into oxides in the 600°—1,000°C temperature range are platinum, its alloys and certain metal oxides.

Platinum and its alloys are considered the best catalysts for the selective oxidation of ammonia to nitrogen oxide. The catalytic oxidation process of ammonia starts with the activated adsorption of oxygen on the catalyst surface. It follows the activated adsorption of ammonia, the formation of unstable intermediate products, their decomposition, the formation of final products, and their denuding. The platinum adsorbs the oxygen very well, but it hardly adsorbs any of the nitrogen. For the oxidation of ammonia an excess of oxygen is necessary as this accelerates the reaction and favours an increased yield of nitrogen oxide. In the presence of a good quantity of excess oxygen, the adsorption capacity of nitrogen oxide and of water vapours by platinum is very low; thus the denuding of the reaction final products is facilitated.

Platinum catalysts or their alloys are used as sieves having 1,024—3,600 mesh/cm^2 and wire diameter of 0.045—0.09 mm. Good yields of transformation are obtained with platinum alloys-rhodium or platinum-palladium.

In order to replace expensive platinum catalysts with cheap non-platinum ones, almost all metal oxides were tested and the conclusion was that the most active were the iron, cobalt and silver oxides that have small additions (3—10%) of other metal oxides as activators (bismuth oxides, manganese bioxide). These catalysts were used under the form of rings with diameters of 6—8 mm. Sometimes catalysts consisting of a platinum sieve and a non-platinum catalyst layer are used. The processes carried out at atmospheric pressure take place at about 800°C while those carried out at high pressure take place at a temperature of 870°—900°C.

Poisons for catalytic sieves are: H_2S, H_3P, CO. Water vapours, H_2 and O_2 increase the degree of corrosion.

SULPHURIC ACID

Sulphuric acid is essential for all production branches; its manufacture is an indication of the industrial level of a country.

In the chemical industry, the biggest consumer is the fertilizer sector, the rapid growth of which represents the main reason for the steady rhythm of growth of sulphuric acid production.

Parallel with the production of fertilizers in the chemical industry, sulphuric acid is applied in organic synthesis (nitration, sulphonation, dyestuff production, medicaments, detergents, explosives, synthetic fibres), in the production of inorganic salts (sulphates, bichromates), pigments (titanium white) and insecticides, and in gas drying. Important quantities of sulphuric acid are also used in crude-oil refining, in the textile industry and in the extraction industry.

Initially, sulphur was the raw material used in sulphuric acid manufacture; later on pyrites were used, and more recently other sulphur-content raw materials and a series of sulphur secondary products resulting from various processes have been used.

The main technological processes for sulphuric acid production are: contact and chamber.

CONTACT PROCESS

The sulphurous or sulphur-content gases containing SO_2 are purified by the dry and wet method. The purified gases are then air-diluted, dried with concentrated sulphuric acid in a spraying tower, circulated by means of blowers, preheated and introduced in the contact oven where the catalytic oxidation takes place according to the reaction:

$$SO_2 + \frac{1}{2}O_2 \rightleftarrows SO_3 + 22.980 \text{ kcal}$$

The SO_3 gases are cooled down and absorbed in the concentrated sulphuric acid. Then oleum sulphuric acid or monohydrate is obtained, according to the reaction:

$$SO_3 + H_2O \rightarrow H_2SO_4$$

CHAMBER PROCESS

The sulphur-content gases and their dry purification have the same technological treatment as the contact method. The SO_2-content gases are sent to a filling tower where they are counter-currently washed (sulphuric acid and nitrogen oxides). The gases leaving the tower entrain the nitrogen oxides with which they enter the oxidation chamber where the formation of the sulphuric acid takes place according to reactions:

$$SO_2 + NO_2 + H_2O \rightarrow H_2SO_4 + NO$$

$$2NO + O_2 \rightarrow 2NO_2$$

$$NO_2 + NO \rightarrow N_2O_3$$

At the present stage of development, the contact process tends to replace more and more the chamber process.

In the contact process, the vanadium catalyst can oxidize the sulphur dioxide in industrial reactors without changing its quality at temperature ranges between 400° and 600°C. This corresponds to a large extent to the behaviour of the oxidation reaction, which is a reversible one. For this reason, the influence of temperature on the velocity of sulphur trioxide formation is characterized by the existence of an optimum temperature which is modified during the reaction and which assures its maximum speed.

The chemical composition of the catalyst is the main factor in determining its properties and especially its catalytic activity. The main transformation in the manufacture of sulphuric acid by the contact process, the catalytic oxidation of the sulphur dioxide, takes place in the adsorbed phase on the catalyst surface as a heterogeneous gas-solid catalytic reaction.

The interaction of the two phases takes place in a fixed and fluidized bed.

In present-day sulphuric acid manufacture, the old platinum catalyst is being replaced by the vanadium-base catalyst. This type of catalyst can be represented by the V_2O_5 — $(Na_2SO_4)K_2SO_4$ system on a SiO_2 base porous carrier. Vanadium compounds with a high activity can pass into inactive compounds (vanadyl sulphate) by decreasing the reaction temperature and into vanadyl vanadates by increasing the reaction temperature.

The alkaline salts and the carrier increase the stability period of the active compounds. The stabilizing action of the alkaline salts increases in the order Na, K, Rb, Cs.

At present, it is considered that in the V_2O_5 — K_2SO_4 system, the active components are mono-sulpho potassium vanadate ($K_2OSO_3V_2O_5$) or disulpho-potassium vanadate ($K_2O\ 2SO_3V_2O_5$).

Experimental research has shown that a similar action to that of the alkaline salts is undertaken by the Ba, Sn, Ag, Pb, Mn salts. The water vapours play the role of an activator up to the concentration that determines the condensation under the reaction conditions.

On the other hand, the As impurities and, to a lesser extend those of selenium, have a poisonous action. The dust and the sulphates that can be deposited from gases, covering the pores of the catalytic mass, have a noxious effect.

Part two

Heterogeneous catalysts for unit operations

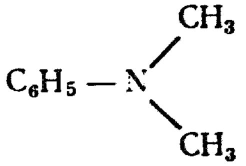
IV. ALKYLATION

Alkylation may be defined as the introduction of an alkyl or aralkyl radical, by substitution or addition, into an organic compound. Alkylation is of six general types, depending on the linkage effected:

(a) Substitution for hydrogen, in the hydroxyl group of an alcohol or a phenol. Here the alkyl is bound to oxygen:

$$C_2H_5 - O - C_2H_5; \quad C_6H_5 - O - CH_3$$

(b) Substitution for hydrogen attached to nitrogen. Here the alkyl is bound to trivalent nitrogen:

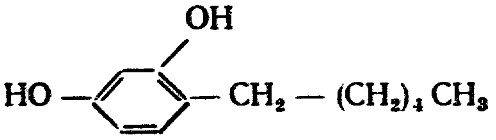


$$C_6H_5 - N\begin{matrix} CH_3 \\ CH_3 \end{matrix}$$

(c) Addition of an alkyl halide or an alkyl ester to a tertiary nitrogen:

$$C_6H_5 - \overset{+}{N}(CH_3)_3Cl^- \quad \text{(an electrostatic bond)}$$

(d) Substitution for hydrogen in carbon compounds. The carbon of the alkyl is bound to carbon of either aliphatic or aromatic compounds. This is carbon-to-carbon alkylation:



(e) Alkyl metallic compounds. Here the alkyl is bound to the metal:

$$Pb(C_2H_5)_4$$

(f) Miscellaneous alkylations. In mercaptan, the alkyl group is bound to sulphur; in the alkyl silanes, it is bound to silicon:

$$nC_{12}H_{25}SH; \quad C_2H_5SiCl_3$$

An examination of the products obtained as a result of alkylation shows that this unit process is used in the manufacture of anesthetics, antipyretics, alkaloids, antiseptics, detergents, dyes, explosives, flavours, hypnotics, intermediate compounds, lubricants, medicinal products, perfumes, photographic chemicals, plasticizers, plastics, resins, synthetic rubber, rubber chemicals (accelerators, antioxidants, modifiers and stabilizers), solvents, saporifics and synthetic gasoline.

An apparent characteristic of many alkylation and dealkylation reactions is their initial slowness. It is necessary to resort to catalysis for the reaction to proceed at a rate that will be commercially feasible. Mineral acids, such as sulphuric, phosphoric, hydrochloric and hydrofluoric, are widely employed, as are aluminium chloride, ferric chloride and boron fluoride.

The choice of a catalyst and alkylating agent for any commercial reaction from the large variety of available catalysts and alkylating agents depends upon the relative cost, as well as upon the equilibrium of the reaction, and the reaction rate which results from their use.

Alkylations are equilibrium reactions that are often characterized by position and structural isomerization. Alkylation reactions can be carried with $AlCl_3$ (Friedel—Crafts synthesis) and can be effected with alkyl, aralkyl and cycloparaffinic halides, olefins, alcohols and esters. In practically all instances, hydrogen chloride is a product of the reaction and it may reasonably be presumed that olefins, esters and, in many instances, alcohols are first transformed into alkyl halide complexes with $AlCl_3$ before entering into the alkylation reaction.

In dealkylation-realkylation, certain catalysts, especially aluminium and ferric chlorides, facilitate the removal of an alkyl group from a polyalkylated product. This happens particularly with ring systems; an industrial example is the reforming of the polyalkylated derivatives separated as the high-boiling fractions in the isopropylation of benzene to cumene.

V. CRACKING

The term "cracking" has attained rather broad usage: it encompasses the fission or splitting of any hydrocarbon in such a way that a carbon-carbon bond is ruptured. In the most common reaction, the craking of paraffins, the main reaction is one of dealkylation according to the general equation;

$$R_1CH_2 - CH_2 - R_2 \rightleftarrows R_1CH = CH_2 + R_2H$$

leading to the formation of an olefin and a lower paraffin.

Cracking generally leads to a variety of products since primary products may in turn undergo further splitting and various carbon-carbon bonds may be involved.

Catalysts active for splitting carbon-carbon bonds also appear to have activity for splitting carbon-hydrogen bonds.

Because of subsequent reactions such as polymerization and hydrogenation, the net heat effect in the cracking of gas oil is small. At low conversion it is endothermic, while at high conversion it is exothermic.

The cracking of gas oil or even higher-boiling petroleum fractions has assumed such a great economic importance in the past decade that it overshadows other catalytic processes in production capacity. Further evidence of the importance of cracking is the large volume of recent literature regarding the catalyst types.

SYNTHETIC SILICA-ALUMINA CATALYSTS

These catalysts can be regarded as the reaction product of silica gel and alumina. They are generally adopted for the first cracking units. They are manufactured in powder form for fluid cracking units or in bead or pellet form. There is much evidence that the active component is a surface compound or complex resulting from the reaction of surface silicic acid and alumina. Increased porosity appears to lead to increased catalyst stability and decreased attrition resistance.

SYNTHETIC SILICA-MAGNESIA CATALYSTS

These catalysts can be regarded as the surface reaction products of silica gel and magnesia. Unlike silica-alumina catalysts, silica-magnesia catalysts do not develop an appreciably increased pore diameter during usage. The resultant fine pore structure may account for the poor regeneration properties.

NATURAL CRACKING CATALYSTS

Along with synthetic silica-alumina cracking catalysts, natural cracking catalysts of similar composition find wide commercial use. These catalysts are mainly derived from montmorillonite and are acid treated to activate them (exchange other surface actions for hydrogen ions).

OTHER CATALYSTS

Other materials that show activity for cracking include silica-zirconia, silica-titania and fluorides or fluoborates on silica-alumina or alumina carriers.

CRACKING OF PURE HYDROCARBONS

The following generalizations are valid for the cracking of many paraffins, olefins, naphthenes and aromatics over silica-alumina and silica-zirconia-alumina catalysts:

(a) Carbon-carbon bond cracking is selective so that cracked products seldom have fewer than three carbon atoms;

(b) Comparison of catalytic cracking of paraffins with thermal cracking indicates the former to be 5 to 60 times as rapid, the ratio increasing with molecular weight;

(c) Lower saturated hydrocarbons are not appreciably isomerized or cracked under usual cracking conditions;

(d) Olefins are much more easily cracked than paraffins and also readily undergo isomerization and coke formation under cracking conditions. Diolefins and aromatic olefins are even more readily cracked, saturated, polymerized and converted to coke;

(e) Naphthenes are quite susceptible to catalytic cracking. The rate increases with molecular weight and is about 1,000 times that of thermal cracking. Final products are largely determined by secondary reactions;

(f) Wholly aromatic compounds such as benzene, diphenyl and naphthalene are practically inert under cracking conditions, whereas alkyl aromatics are readily cracked next to the ring to produce benzene etc., the ease of cracking increasing with size of the alkyl group.

VI. DEHYDROGENATION

This class of reactions includes all reaction in which hydrogen is a product, in which a hydrogen-hydrogen bond is broken or formed, with the exception of reactions in which both H_2 and H_2O are products (for example the synthesis of butadiene from ethyl alcohol).

The different reactions are:

(a) Dehydrogenation of paraffins to olefins and diolefins (butanes and butenes to butadiene);

(b) Dehydrogenation of ethylbenzene to styrene, of cumene to α-methyl styrene;

(c) Dehydrogenation of oxyorganic compounds (of alcohols to aldehydes and ketones).

Dehydrogenation of straight chain hydrocarbons is only favoured at temperatures higher than 600°C.

An important reaction of this class is butadiene synthesis from butenes, which are usually obtained by butane dehydrogenation. The most generally used catalysts for this purpose have a Fe_2O_3—MgO—K_2O composition. The reaction is carried out at 650°C or higher, in the presence of steam to prevent carbon deposition. Iron might be considered as the active agent, magnesia the bonder and carrier, while the function of the potassia is to catalyse the reaction of steam with incipient coke.

Chromia-alumina catalysts are generally used for conversion of butanes to butenes.

For the dehydrogenation of ethylbenzene to styrene, the ZnO — Cr_2O_3 — Al_2O_3 catalysts are used.

For another dehydrogenation reaction, the calcium-nickel catalysts are recommended.

VII. DESULPHURIZATION

In a typical desulphurization process, naphthas containing 80—300 ppm sulphur are purified to contents of 0.2 — 0.5 ppm maximum.

$$H_2S + ZnO \rightarrow ZnS + H_2O$$

$$COS + ZnO \rightarrow ZnS + CO_2$$

$$CS_2 + 2ZnO \rightarrow 2ZnS + CO_2$$

$$RS + 2H_2 \rightarrow RH_2 + H_2S$$

Reactions of this type, such as

$$C_2H_5SH + H_2 \rightarrow C_2H_6 + H_2S + 18 \text{ kcal},$$

find considerable application in converting the sulphur compounds in crude (sour) petroleum stocks to easily removable H_2S. Sulphur compounds decrease the octane rating of leaded gasoline and are also corrosive.

Many catalysts are severely poisoned by sulphur compounds and, hence, hydrodesulphurization and H_2S removal often carried out prior to the main catalytic process (for example, the reaction of natural gas with steam on Ni catalysts or naphtha reforming on Pt catalysts).

The desulphurization process is used in conjunction with many modern high-pressure reformers, in the naphtha pre-treaters in recently built town gas, lean gas and rich gas plants, as well as in a number of ammonia plants.

The contact of straight run or catalytically cracked naphthas with hydrogen over desulphurizing catalysts removes sulphur and oxygen and also reduces appreciably the concentration of nitrogen compounds and metal impurities. Such pre-treatment of feeds improves the octane rating and stability of the reformed product.

In hydrocracking, the removal of nitrogen and oxygen compounds from the feedstocks is an important function of desulphurizing catalysts. By reducing the sulphur content, hydrogen treatment over the desulphurizing catalysts improves colour, odour and stability of kerosene, tractor and diesel fuels, lubricating oils and other distillates. Gas oil feeds in catalytic cracking units can also be treated with hydrogen over such catalysts. It is claimed that the cracking stage coke deposits can be reduced by 50% and naphtha yields increased up to 20%.

In this chapter there have been also introduced the guard catalysts for low-temperature CO shift catalysts, because of their capacity for sulphur absorption. These guard catalysts are used before low-temperature CO shift catalysts and are normally installed immediately on the top of the bed of CO shift catalyst. The size of the guard beds will depend on the plant design and on the particular low-temperature shift duty. They require reduction of metal oxide before they are fully effective.

VIII. HALOGENATION AND DEHALOGENATION

All reactions involving gain or loss of halogens are classified in this group.

Halogenation is defined as the process whereby one or more halogen atoms are introduced into an organic compound. The fabrication of organic compounds containing fluorine. chlorine, bromine and iodine can be accomplished by a variety of methods. The conditions and procedures differ not only for each halogen, but also with the type and structure of the compound undergoing treatment.

The chlorine derivatives are by far the most important technical halogen compounds because of the greater economy in effecting their preparation. The bromine derivatives, however, sometimes have certain advantages because of the greater ease in effecting the replacement of this halogen in subsequent reactions or because it possesses certain desirable properties for pharmaceuticals or dyes.

The following examples show that halogenation may involve reactions of addition (1), substitution (2), or replacement (3) (e.g. of groups). The hydroxyl or sulphonic group:

$$(1)\quad HC \equiv CH + 2Cl_2 \xrightarrow{FeCl_3} Cl_2HC-CHCl_2$$

$$(2)\quad CH_3-COOH + Cl_2 \xrightarrow{P(red)} CH_2Cl-COOH + HCl$$

$$(3)\quad C_2H_5OH + HCl \xrightarrow{ZnCl_2} C_2H_5Cl + H_2O$$

From the preceding formulae, it becomes clear that each type of reaction may involve not only a specific halogenation agent but also a suitable catalyst. The catalysts, with the exception of carbon, are halogen carriers. Thus, iron, antimony and phosphorus, which are able to exist in two valences as halogen compounds, are used to a large extent, for they are less stable at the higher valence and give up part of their chlorine during the process.

In the presence of free chlorine, such compounds alternately add and give halogen to carry on the reaction.

Iodine and bromide, which are capable of forming mixed halogens with chlorine, are also frequently employed as catalysts in chlorination processes.

The halogenation agent may be the halogen, as in the addition of chlorine to benzene to form chlorobenzene, or the anhydrous acid as in the formation of vinyl chloride monomer, by reacting HCl and acetylene.

In the dechlorination process, chlorine is removed in the form of HCl followed by condensation and/or polymerization. The product could also be unsaturated compounds.

Examples of the principal reaction types are:

DIRECT HALOGENATION OF PARAFFINS

$$CH_4 + Cl_2 \rightarrow CH_3Cl + HCl + 33\ kcal$$

$$CH_4 + 2Cl_2 \rightarrow CH_2Cl_2 + 2HCl + 60\ kcal$$

$$CH_4 + 4Cl_2 \rightarrow CCl_4 + 4HCl + 127\ kcal$$

$$CH_4 + 4F_2 \rightarrow CF_4 + 4HF + 403\ kcal$$

CHLORINATION OF PARAFFINS WITH O_2 AND HCl

$$C_2H_6 + HCl + \frac{1}{2}O_2 \rightarrow C_2H_5Cl + H_2O + 41\ \text{kcal}$$

DEACON PROCESS

$$4HCl + O_2 \rightarrow 2Cl_2 + 2H_2O + 28\ \text{kcal}$$

FRIEDEL-CRAFTS REACTION

$$C_6H_6 + C_2H_5Cl \rightarrow C_6H_5C_2H_5 + HCl + 9\ \text{kcal}$$

IX. HYDROGENATION

Reduction is the term usually applied to a reaction in which oxygen is withdrawn from or hydrogen is added to a compound. In addition, other elements besides oxygen may be eliminated from a molecule by the action of hydrogen, the most common being nitrogen, sulphur, carbon and halogens.

Reduction may be performed in a variety of ways; the most important commercial method is the catalytic reduction by hydrogen.

In order to correlate and condense the innumerable and diversified examples of catalytic hydrogenation, the following arbitrary classification has been made that includes only four types of reactions:

(a) Reduction of an ethylenic linkage:

$$RCH = CHR' + H_2 \rightarrow RCH_2 \cdot CH_2R'$$

where R and R′ are aliphatic or aromatic groups;

b) Reduction of a carbonyl to an alcohol group, or to a hydrocarbon:

$$CO + 2H_2 \rightarrow CH_3OH$$

$$xCO + yH_2 \rightarrow \text{hydrocarbons} + \text{water}$$
$$(\text{or } CO_2)$$

(c) Reduction of a carboxyl to an alcohol group:

$$RCOOR' + 2H_2 \rightarrow RCH_2 - OH + R'\text{—}OH$$

where R is preferably an aliphatic or hydroaromatic group, and R′ is the same or a hydrogen atom;

(d) Hydrogenolysis or reactions involving molecular cleavage on the addition of hydrogen.

The hydrogenation of an ethylenic to a paraffinic linkage, can be accomplished usually in the presence of a nickel or nickel-containing catalyst and sometimes with platinum or palladium catalysts.

The hydrogenation of the carbonyl group in aldehydes, ketones, esters and acids can be reduced by hydrogen with catalysts either partially to give a hydroxyl group or entirely to give a hydrocarbon group. The partial reduction is characterized as mild hydrogenation. Ferric oxide, vanadium pentoxide and cerium oxide are promoters for the nickel-charcoal catalysts.

For the hydrogenation leading to hydrocarbon groups, the catalysts contain iron, nickel, copper and cobalt along with metallic oxides. Cobalt seems to be the best of the metals and the oxides of chromium, zinc, rare earths, aluminium, magnesium and manganese are used.

Formaldehyde, acetaldehyde as well as propionic, butyric and valeric aldehydes are reduced to the corresponding alcohols at about 100° to 150°C in the presence of a nickel catalyst.

The carboxyl group of esters and acids can be reduced to the corresponding hydroxyl group by the use of mild hydrogenating catalysts and hydrogen pressure generally of 100 atm or more. In general, the catalysts are of the type used in synthesizing methanol and higher alcohols. The reduction of the carboxyl group is most satisfactory in aliphatic or hydroaromatic compounds.

Hydrogenolysis involving cleavages of carbon-to-carbon bonds, refers particularly to cleavages in a molecule associated with the addition of hydrogen to the molecule. Hydrogenolysis is a term analogous to hydrolysis, alcoholysis, in which a double decomposition is accomplished:

$$C_2H_5 - O - H_5C_2 + H_2O \rightarrow 2\,C_2H_5OH \text{ (hydrolysis)}$$

$$C_2H_5O - H_5C_2 + H_2 \rightarrow C_2H_6 + C_2H_5OH \text{ (hydrogenolysis)}$$

This type of hydrogenation has certain applications in petroleum refining. In the hydrogenation of petroleum, coals and tars, the application pertains to the elimination of sulphur, nitrogen or oxygen and to the conversion of heavy, tarry or asphaltic substances to more desirable hydrocarbon products, usually of a more paraffinic or saturated type. In general, hydrogenolysis is favoured by increased temperature, higher hydrogen pressures ant the more vigorous type of hydrogenating catalysts. Frequently, in cases of carbon-to-oxygen cleavage, it may be desirable to incorporate a dehydrating catalyst with the hydrogenating catalyst. Examples of this type of catalysts are nickel-alumina and nickel-thoria.

Phenols and cresols can be reduced to the corresponding hydroaromatic or aromatic hydrocarbons, depending on the temperature, the pressure of hydrogen and the type of catalyst. Hydrocarbons, depending on the length of the chain or branching in the chain or the ring structure, under the combined action of hydrogen, catalysts and heat, undergo certain cleavages that involve the splitting off of groups or molecular fragments or the opening of ring structures.

These reactions are also of great technical importance, for they are probably the type of reaction occurring in the hydrogenation of heavy petroleum residues or asphaltic or aromatic base oils, whereby conversion takes place in high yields to stable, more volatile petroleum products such as gasoline and kerosene. Catalysts are essential to most hydrogenation reactions. The large bulk of hydrogenation reactions use hydrogen gas as the source of hydrogen. The function of the catalyst is to effect the over-all result of chemically combining the gaseous hydrogen with the substance capable of adding hydrogen to its molecular structure. It is the purpose of the catalyst to effect this combination along the desired path as quickly as possible.

Most hydrogenation catalysts are solid metals and metal oxides. The hydrogenation is effected at the surface of the catalyst, so a highly extended surface is essential.

Because an apparently small amount of substance such as halogens, sulphur, arsenic and sometimes metals of low melting point such as mercury, lead and tin, might poison the activity of a catalyst, it is necessary to use mixed-metal catalysts or promoted catalysts. More common mixtures with the well known types of catalysts are nickel-copper, nickel-alumina, copper-zinc oxide, copper chromium oxide, and, zinc oxide — chromium oxide. The use of combinations of almost all metals and metal oxides in the periodic system is described in the recent chemical and patent literature.

Hydrogenation catalysts are classified as vigorous hydrogenation catalysts and mild hydrogenation catalysts. Common vigorous hydrogenation catalysts are the nickel, cobalt, or iron types as well as molybdenum and tungsten oxides or sulphides and Raney nickel. Mild hydrogenation catalysts are able to carry out only one step at a time in a hydrogenation, or at least they do not permit the reaction to proceed to the hydrocarbon stage. They usually contain copper, zinc oxide, chromium oxide and manganese oxide, and may include some of the rarer elements as promoters. In addition, the noble metal catalysts such as platinum or palladium or their oxides belong to this class.

The synthesis of higher alcohols from water gas involves a condensation as well as a hydrogenation reaction. These so-called higher alcohol catalysts are usually of the mild hydrogenation type but contain some more alkaline materials, such as sodium, calcium or barium carbonates, or aluminium or magnesium oxides.

Other types of catalysts are capable of splitting out water from a molecule along with the hydrogenation but do not possess any appreciable cracking tendencies such as alumina, thoria, tungstic oxide or chromium oxide.

Molybdenum sulphide and especially tungsten disulphide are active catalysts for hydrogenating sulphur, oxygen and nitrogen-containing compounds at pressures of about 200 atm.

Hydrodesulphurization (chapter VII) and methanation (chapter II) are also hydrogenation reactions that are treated separately in this manual.

HYDROTREATING

Hydrotreating or hydrogen treating is a process applied generally to petroleum or coal products, to improve existing petroleum products or develop new uses and products, to convert inferior or low-grade materials such as heavy oils and tars into valuable petroleum products and to transform solid fuels such as lignites and coals into liquid fuels. Hydrotreating is also for the elimination of sulphur, nitrogen, oxygen, halides and trace metals from petroleum and coal products.

The treatment may be applied to stocks ranging from light naphthas to lubricating oils.

The hydrogen treating is also used as a pre-treatment to catalytic cracking to reduce coking by as much as 25%.

The distinguishing feature of these operations is that both the raw materials and finished products are very complex mixtures of relatively unknown compositions. All types and sizes of molecules are present along, with a variety of contaminating impurities. In the hydrogenation process. a variety of reactions may be occurring simultaneously and to varying degrees. Yet the final product may be satisfactory and meet all the required specifications.

These complicated mixtures are identified and recognized by certain properties, sometimes more physical than chemical in character. Hydrogenation may result in an upgrading of one or all of the properties of the material.

Catalysts not only must accelerate these hydrogenations but also must guide and direct the desired reactions and effect a balancing and harmonizing of many factors so that the correct over-all result is attained. They must also be able to operate on liquid, solid or gaseous materials, and, in addition, cause impurities that are common catalytic poisons, such as sulphur, oxygen and nitrogen, to be detached from their molecular linkages and removed as H_2S, H_2O or NH_3.

The elements of group 6 of the periodic system are very suitable, particularly molybdenum, tungsten and chromium, as oxides, suphides or more complicated mixtures with one another.

Hydrogenations involving petroleum, tar or coal are usually exothermic. The hydrogen consumed in the process depends on the difference in hydrogen content of the raw material and finished product and on the extent to which gases containing methane and other low-boiling hydrocarbons are formed.

AMMONOLYSIS

Amination by ammonolysis is the process of forming amines by the action of ammonia. By extension, the use of primary and secondary amines as aminating agents (aminolysis) is also included. Considering the behaviour of ammonia, the ammonolytic reactions may involve:

(a) Double decomposition, in which the NH_3 molecule is split into NH_2 and H fragments, the former becoming part of the newly formed amine, while the latter unites with the radical — Cl, — SO_3H, — NO_2 that is substituted;

(b) Dehydration, in which NH_3 serves as a dehydrant, and water and amines result from the ammonolysis of alcohols and from the hydroammonolysis of carbonyl compounds;

(c) Simple addition, in which both fragments of the NH_3 molecules enter the new compound as in the preparation of alkanolamines from alkylene oxides;

(d) Multiple activity, in which nascent or recycled amines compete with ammonia as a co-reactant resulting in the formation of secondary and tertiary amines by aminolysis.

Among the factors that accelerate or retard the replacement of atoms or radicals by the amino group are: solubility, agitation, the halogen derivative treated, the presence of nitro group, the temperature of amination and NH_3 concentration.

Compounds of metals following hydrogen in the electrochemical series, e.g. arsenic, copper and silver can advantageously be employed in the conversion of certain halogen compounds to amino derivatives.

Ammonolysis and aminolysis in the gas phase are generally exothermic except in the case of hydrocarbons. The ammonolysis of unsaturated carbonyl compounds in the presence of hydrogen is the most exothermic type. Reaction of phenols, alcohols and haloids with ammonia is only slightly exothermic. Aminolysis of alcohols is much more exothermic than the ammonolysis. Reactions of hydrocarbons with ammonia to form nitriles seem to be special cases in that they are extremely endothermic in nature.

Ammonolysis of aromatic hydrocarbons requires temperatures higher than 400°C. Ammonolysis can be carried out either in high-pressure autoclaves or in tubular reactors.

HYDROGENATION OF AROMATIC HYDROCARBONS

Reactions for the hydrogenation of aromatics are fairly exothermic. The reaction converting benzene to cyclohexane proceeds even at ambient temperature and moderate pressure in liquid phase. The speed of hydrogenation is tripled by an increase from 20° to 50°C.

Vapour-phase hydrogenation takes place at temperatures of about 200° to 250°C, and 1—10 atm to produce a product containing 0.1% benzene. Heat released at 250°C is 54 kcal/mol.

Other aromatics such as toluene and xylenes as well as ethyl-, propyl-, butyl- and other substituted benzenes can be hydrogenated to the corresponding hexahydrobenzenes when their vapours are passed with hydrogen over nickel catalysts maintained at temperatures from 150° to 200°C. In the case of napthalene or substituted naphthalenes, the product may be the tetra or decahydronaphthalene derivative.

Atmospheric pressures are usually employed in these vapour-phase hydrogenations, although higher hydrogen partial pressures are also suitable. With more substituent groups or with chains longer than butyl or amyl, secondary decomposition products resulting from cracking or the breaking of carbon-to-carbon linkages in the chain appear. In these cases, hydrogenating at lower temperatures but with higher hydrogen pressures and using platinum or nickel catalysts is more practical.

HYDROGENATION OF CARBON DOUBLE BONDS

General reaction: $R-CH=CH-R+H_2 \longrightarrow R-CH_2-CH_2-R'$ where R and R′ are aliphatic or aromatic groups.

In general, the hydrogen pressure need not be high, except when the hydrogenation is slow; then, increased pressure usually accelerates the reaction.

Since hydrocarbons are generally more volatile than the ester or acid of the same number of carbon atoms, a considerable number of these hydrogenations take place in the vapour phase simply by the vapourized compound and hydrogen being passed over the catalyst at a suitable temperature.

The lower-molecular-weight olefins, such as ethylene, propylene, butenes pentenes, hexenes and heptenes, are readily hydrogenated to the corresponding paraffin hydrocarbon in the vapour phase by passing the olefin and hydrogen over nickel at atmospheric pressure and temperatures of 100° to 200°C. At higher temperatures, side reactions involving cleavages in the hydrocarbon chain will occur.

It is advisable to use a considerable excess of hydrogen. Higher-molecular-weight olefins can also be hydrogenated in the vapour-phase in the presence of a nickel catalyst if they have sufficient volatility at the temperature for hydrogenation (150°—200°C). Otherwise the reduction is accomplished in a shaking or stirred autoclave in the liquid phase and hydrogen pressure (1—100 atm). Nickel catalysts are used and also platium or palladium black or their oxides, suspended in the liquid by the mechanical agitation. Aromatic hydrocarbons such as benzene, toluene, and xylenes as well as ethyl-, propyl-, butyl- and other 'substituted benzenes, can be reduced to the corresponding hexahydrobenzenes when their vapours are passed with hydrogen over nickel catalysts at temperatures of 150° to 200°C.

Atmospheric pressures are usually employed in these vapour-phase hydrogenations, although higher hydrogen partial pressures are also suitable.

With more substituent groups or with chains longer than butyl or amyl, secondary decomposition products appear resulting from cracking or the braking of carbon-to-carbon linkages in the chain. In these cases, platinum or nickel catalysts are recommended.

Cyclic hydrocarbons, other than five or six carbon rings, are hydrogenated with the opening of the ring or with the formation of five- or six-membered rings.

Thus, cyclopropane or trimethylene is readily reduced to propane when passed with hydrogen over nickel at 80° to 180°C.

Cyclobutane is hydrogenated at 180°C to butane in a similar manner, while cyclopentane and cyclohexane are not changed. These five- and six-membered rings are very stable and do not undergo any change except the usual degradative decompositions at higher temperatures. However, isomerization of six- to five-membered rings and vice versa can occur.

The hydrogenation of unsaturated acids and esters is not particularly adapted to vapour-phase reaction because of their low volatility. Most of these reductions are carried out in the liquid phase and at somewhat elevated hydrogen pressures. The types of catalysts employed are very similar to those used in saturating ethylenic linkages.

HYDROGENATION OF ESTERS AND ACIDS

General reaction $RCOO\ R' + 2H_2 \rightarrow RCH_2OH + R'OH$ where R is usually an aliphatic group, and R' is the same or a hydrogen atom.

The carboxyl group in esters and acids can be reduced to the corresponding hydroxyl group by the use of mild hydrogenating catalysts and hydrogen pressures of 100 atm or more. It is necessary that the hydrogenation conditions be controlled carefully in order to avoid dehydration of the alcohol — resulting in an olefin — or if the latter is further reduced by hydrogen, a paraffin hydrocarbon is formed. In general, the catalysts are of the type used in synthesizing methanol and higher alcohols. The reduction of the carboxyl groups is most satisfactory in aliphatic or hydroaromatic compounds. In the aromatic series, the reduction to alcohols also occurs, the best results being obtained when the carboxyl group is in an aliphatic chain. If the group is directly attached or near to an aromatic ring, side reactions usually accompany the reduction. These generally involve the reduction of the alcohol group to a hydrocarbon group. These side reaction are usually cases of hydrogenolysis. This type of hydrogenation has certain applications to problems of petroleum refining and to synthetic organic chemistry.

The process may be carried out in a batch system cr in a flow system, the latter being preferable.

The acid or ester, if solid, may be melted or may be dissolved in a solvent such as normal butyl alcohol or ethyl alcohol, and is then pumped into the reactor and over the catalyst. The catalyst in granular form is held in place in a heated tube capable of withstanding the pressure and temperature.

HYDROGENATION OF CARBONYL COMPOUNDS

General reaction $R\,CO\,R' + H_2 \rightarrow R\,CH\,OH\,R'$ where R is an aliphatic aromatic group and R′ may be the same or a hydrogen atom.

Carbon monoxide may be considered the simplest compound containing this group. Its hydrogenation leads to the synthesis of alcohols, ketones, acids and hydrocarbons, the last containing as many as several hundred carbon atoms. This is because carbon monoxide, in partial reduction,can yield compounds or molecular fragments, e.g. CH_2 which are capable of undergoing extensive condensation on the same catalysts that effect the initial hydrogenation.

Thus, from the simple substances carbon monoxide (and, in some cases, carbon dioxide) and hydrogen, practically unlimited synthesis are possible; the greatest problem associated with these reactions is the separation of individual compounds. Methane results when carbon monoxide and hydrogen in the proportion of 2 : 3 are passed over a nickel catalyst at ordinary pressure and temperatures of 200° to 250°C.

Higher hydrocarbons result from the reduction of carbon monoxide by hydrogen at atmospheric or low pressure with cobalt-containing catalysts. Fischer and Tropsch initiated this work in 1926. It may be considered a synthetic petroleum.

Aldehydes are reduced to the corresponding alcohols at about 100° to 150°C in the presence of a nickel catalyst. Methane and water are formed by, however, side reactions.

The reduction of ketones by hydrogen at elevated temperatures is also a reversible reaction. Thus in the case of acetone, at 218°C and atmospheric pressure, the hydrogenation is about only 30% complete.

The reduction of aldehydes is carried out in the presence of the catalysts as: nickel, platinum oxide, copper chromite, platinum with ferric chloride as promoter, at 1—200 in liquid phase.

HYDROGENATION OF NITRILES

Nitrile reduction is obtained by metallic sodium and alcohol and it leads to primary amines.

By the catalytic reduction of nitrile at heat with nickel or at cold with palladium next to the primary amines, the secondary amines are obtained. This is because hydrogen addition to the triple bond occurs in two stages:

$$RC \equiv N + 2[H] \rightarrow R{-}CH = NH + 2[H] \rightarrow R{-}CH_2{-}NH_2$$

The amines formed in the first stage are derivatives of aldehydes and they react with the primary amines to give condensation products (Shiff bases). In turn, these products are hydrogenated to secondary amines:

$$R-CH=NH+H_2NCH_2R \xrightarrow{-NH_3} RCH=NCH_2R \xrightarrow{+2(H)} RCH_2-NH-CH_2R$$

HYDROGENATION OF NITRO COMPOUNDS
(Hydrogenolysis of nitrogen-oxygen bonds)

Reactions of this type are usually very exothermic and equilibrium is generally favourable in the forward direction at all temperatures.

Liquid-phase processes are almost always used for the hydrogenolysis of nitroparaffins although there are a few exceptions. Considerable work has appeared on vapour-phase hydrogenolysis of nitroaromatics. Important applications of this reaction are the use of aniline for aniline dyes and xylidines for blending with aviation gasoline (for improved supercharged engine performance).

Fluid operation helps to solve one of the major problems of hydrogenolysis reactions — temperature control. Copper, nickel and oxides or sulphides of Mo, W, Ni and V are favourable for reactions of this type.

Since Ni is such an active catalyst for this purpose, reduction of the aniline to cyclohexane and ammonia is known to take place.

When a copper catalyst is used, the reaction is more moderate and the yields under optimum conditions are uniformly good.

HYDROGENATION REACTIONS (GENERAL)

Hydrogenation processes have been steadily increasing in size, variety and importance. The unit process of hydrogenation is becoming one of the most useful and widely used methods in organic synthesis.

It is possible to convert liquid fats into solid fats or, as it is often called, fat hardening. Both edible and non-edible fats are obtained from the hardening of fish oil or vegetable oils such as linseed, soybean and cottonseed oil by the addition of hydrogen under pressure.

The edible fats are used as lards and butter substitutes.

The soap industry is the largest consumer of non-edible hardened oils. Minor used are in leather dressings, electrical insulations and the manufacture of paints and pharmaceutical ointments.

Another development of importance to the soap industry is the manufacture of detergents. These products are sulphuric acid esters of long-chain aliphatic alcohols such as lauryl, cetyl and stearyl alcohols.

Instead of making the sodium salt of palmitic or stearic acid, as in ordinary soap manufacture, these acids are first reduced to the corresponding alcohols by hydrogenation at high pressure, and the alcohols then esterified with sulphuric acid.

A large number of organic chemicals, higher alcohols and aldehydes can be made from water gas or high-pressure hydrogenation of carbon monoxide.

This chapter comprises all the reactions that are not included in other specific hydrogenation processes.

SELECTIVE HYDROGENATION

Since many organic compounds can be hydrogenated to more than one product, it is often necessary not only that no other classes of reactions occur, but also that only the desired hydrogenation or dehydrogenation reactions take place.

The selective action may involve:

(a) Hydrogenation of one functional group but not another;

(b) Hydrogenation or dehydrogenation to the desired product but not further reaction to undesired products. Selective action may be obtained by several approaches.

USE OF OPTIMUM CONTACT TIME

In cases in which the desired product is capable of undergoing further reaction, such as the partial hydrogenation of acetylene to ethylene, contact time is of extreme importance. The shorter the time of contact, the less chance for further hydrogenation. Hence, it is important to have a catalyst which gives a narrow contact time distribution so that at optimum space velocity almost all molecules will have time enough to be converted but few will have time enough to react further.

ADJUSTMENT OF CONDITIONS FOR THERMODYNAMIC SELECTIVITY

By use of suitable temperature and pressure, it is sometimes possible to make the undesired reaction thermodynamically impossible while the desired reaction is favoured. The most commonly used approach is to find a catalyst which under some conditions will favour one reaction over the other. The Ni and Cu-Cr_2O_3 catalysts have selective action for hydrogenating various functional groups. Seldom is the nature of selective action clear, but certainly differences in catalyst and functional group geometry play an important role.

It has attributed the preferential activity of Cu-Cr_2O_3 for the hydrogenation of groups containing oxygen and the preferential activity of Ni for carbon-carbon unsaturation to selective absorption.

It must be realized however, that promoters such as alkalis and physical factors such as surface area and pore structure also play an important role in selective action.

X. ISOMERIZATION

Isomerization converts hydrocarbons or other organic compounds into products whose molecules have a different arrangement of atoms but the same number and kind of atoms.

There are many isomeric compounds and, therefore, many isomerization reactions. Some of the more important types are:

(a) *n*-butane $\rightleftarrows$ isobutane $\Delta H = -2.0$ kcal
(b) 1-butene $\rightleftarrows$ cis-2-butene $\Delta H = +1.7$ kcal
(c) *n*-butene $\rightleftarrows$ isobutene $\Delta H = +3.6$ kcal
(d) ethylbenzene $\rightleftarrows$ *o*-xylene $\Delta H = -2.6$ kcal
(e) ethylene oxide $\rightleftarrows$ acetaldehyde $\Delta H = +24$ kcal
(f) methylcyclopentane $\rightleftarrows$ cyclohexane $\Delta H = +3.9$ kcal

The conversion of straight chain to branched chain hydrocarbons is by far the most important type of isomerization reaction because of the much higher octane number of the latter. This reaction occurs during catalytic cracking of gas oil and naphtha reforming, in addition to the primary dehydrogenation and dealkylation reactions, and accounts to a major extent for the high octane number of the product.

Although this reaction, like alkylation, is usually carried out in the liquid phase, the vapour-phase process has not been entirely neglected. Low temperature (80°—150°C), moderate pressure (10—20 atm), with a supported acid-promoted aluminium chloride are commonly used. Equilibrium is generally less favourable at high temperature, though the temperature coefficient and heats of reaction are low.

Although acid-type catalysts are generally used for isomerization, even better conversion of normal paraffins to isoparaffins are obtained when both hydrogenation and acidic sites are present. Due to the technical importance of isobutane and the higher branched-chain paraffins in the production of high-octane motor fuels, the isomerization of normal paraffins has received intensive study, especially concerning diverse metal halides and combinations, continuous operating conditions and the use of fluid or molten catalysts.

XI. OXIDATION

In the organic chemical industry, oxidation constitutes one of the most powerful tools used in the synthesis of chemical compounds.

The oxidation processes are many and varied and are manifested in a variety of net effects. The principal types of oxidative reactions may be set forth as follows:

(a) Dehydrogenation as illustrated in the transformation of a primary alcohol to an aldehyde:

$$C_2H_5OH + \frac{1}{2}O_2 \rightarrow CH_3CHO + H_2O$$

or a secondary alcohol to a ketone:

$$CH_3 - CHOH - CH_3 + \frac{1}{2}O_2 \rightarrow CH_3 - CO - CH_3 + H_2O$$

(b) An atom of oxygen may be introduced into a molecule as illustrated by the oxidation of an aldehyde to an acid:

$$CH_3 - CHO + \frac{1}{2}O_2 \rightarrow CH_3 - COOH$$

or of hydrocarbon to an alcohol:

$$(C_6H_5)_3\ CH + \frac{1}{2}O_2 \rightarrow (C_6H_5)_3C - OH$$

(c) A combination of dehydrogenation and introduction of oxygen may occur, as in the preparation of an aldehyde from hydrocarbons:

$$CH_4 + O_2 \rightarrow CH_2O + H_2O$$

or the preparation of benzoic acid from benzyl alcohol:

$$C_6H_5 - CH_2OH + O_2 \rightarrow C_6H_5 - COOH + H_2O$$

(d) Dehydrogenation may also be accompanied by molecular condensation as in the case when two molecules of benzene form diphenyl or two molecules of toluene form stilbene:

$$2C_6H_6 + \frac{1}{2}O_2 \rightarrow C_6H_5 - C_6H_5 + H_2O$$

$$2C_6H_5CH_3 + O_2 \rightarrow C_6H_5 - CH = CH - C_6H_5 + 2H_2O$$

(e) Dehydrogenation, oxygen introduction and destruction of carbon linkages may all occur in the same process of oxidation, e.g. in the oxidation of naphthalene to phthalic anhydride:

$$C_{10}H_8 + 4.5O_2 \rightarrow C_8H_4O_3 + 2H_2O + 2CO_2$$

(f) Oxidation may be accomplished indirectly through the use of intermediate reactions:

$$C_6H_5 - CH_3 \rightarrow C_6H_5CCl_3 \xrightarrow{H_2O} C_6H_5 - COOH$$

$$CH_3 - OH + CO \rightarrow CH_3 - COOH$$

(g) Olefins may be oxidized under mild conditions to hydroxy derivatives and may be converted to aldehydes and carboxylic acids of lower molecular weight when stronger oxidizers are employed;

(h) Peroxidation occurs readily under certain conditions. Thus some reactions occur directly with air when catalyzed by ultra-violet irradiation;

(i) Amino compounds may be oxidized to azobenzene, *p*-amino phenol or nitrobenzene under moderate conditions, or the N-containing radical may be completely removed under drastic conditions. In this way, quinone is derived from aniline;

(j) Sulphur compounds may be oxidized by acid permanganate (the sulphide sulphur is oxidized to sulphonic groups).

In inorganic chemistry, two examples are the oxidation of ammonia for nitric acid production (chapter III) and the oxidation of SO_2 for the sulphuric acid production (chapter III).

The oxidation may be carried in liquid or vapour phase.

XII. POLYMERIZATION

The reaction that produces polymers is generally named polymerization. The polymers are substances consisting of molecules having a very high molecular weight which ranges from about 5,000 to many millions. High polymers consist of large molecules built up by chemical bonds. The macromolecules themselves consist of repeated low-molecular weight units. Each single unit is called a monomer, and a macromolecule composed of many monomers is called a polymer.

Many high molecular weight substances, such as rubber, cellulose, silk, wool, starch, natural resins and gums, exist in nature. Others can be produced synthetically and because of their industrially important properties are at present manufactured in large and every increasing quantities.

The conception of ordinary organic molecules linking up to give a polymer molecule poses the question of the nature of the reaction that produces such polymers and the types of molecules that are capable of undergoing these reactions.

In later investigations it was shown that one particular structural characteristic is common to all molecules able to participate in the formation of a polymer; the molecule must be bifunctional or polyfunctional, and essentially two types of reactions lead to the formation of very large molecules — polycondensation and addition polymerization.

A molecule is called bifunctional or polyfunctional if two or more reactive or functional groups either are present at the beginning of the reaction or appear in the course of it. Simple examples of polyfunctional molecules are hydroxy or amino acids, dialcohols or polyalcohols, diamines or polyamines, diacids or polyacids. These molecules interact with each other through their chemically active groups; but since two or more of them are located on each molecule, the reaction continues in two or three directions and linear or tridimensional molecules are formed.

Another type of bifunctionality is exhibited by a large group of molecules containing double or triple bonds.

The reactions leading to the formation of polymer molecules are polycondensation and addition polymerization.

In polycondensations, bifunctional or polyfunctional molecules condense with one another by repeatedly splitting off H_2O, NH_3, CH_2O, NaCl or other small molecules, as the reaction proceeds. Polycondensation proceeds fundamentally in the same manner as low-molecular condensation.

Addition polymerization, on the other hand, occurs among molecules containing double or triple bond, or bifunctional molecules resulting from the breaking of ring structures. No small molecules are liberated during this process. Polycondensations are typical step reactions, whereas the most important addition polymerizations are chain reactions.

In the large molecules resulting from an addition polymerization, either the recurring low-molecular units are the monomers themselves or two or more different monomers may copolymerize. Examples of industrial polycondensations are phenol-formaldehyde condensation producing phenolic resins, polycondensation between bifunctional alcohols and acids leading to alkyl resins and polyesters, polycondensation of diamines and dibasic acids leading to polyamides and the polycondensation leading to silicones.

The four possible methods of polymerization are in bulk (mass or block polymerization); in solution; in emulsion; and in suspension (pearl).

XIII. PURIFICATION

Generally, purification means nitrogen removal (denitrogenation), oxygen and traces of unsaturated hydrocarbons removal and sulphur removal (desulphurization).

For desulphurization see chapter VII. For unsaturated removal see chapter IX ("Hydrogenation"). This chapter also includes denitrogenation; desoxygenation reactions; the removal of CO_2, CO, ammonia and amines; and the purification by absorption, by combustion and by using molecular sieves.

Typical reactions of the reactive constituents with hydrogen and methane are:

$$2NO_2 + 4H_2 \rightarrow N_2 + 4H_2O$$

$$2NO + 2H_2 \rightarrow N_2 + 2H_2O$$

$$O_2 + 2H_2 \rightarrow 2H_2O$$

$$2NO_2 + CH_4 \rightarrow N_2 + CO_2 + 2H_2O$$

$$4NO + CH_4 \rightarrow 2N_2 + CO_2 + 2H_2O$$

$$2O_2 + CH_4 \rightarrow CO_2 + 2H_2O$$

Some of these reactions are hydrogenation reactions that take place in the presence of typical catalysts.

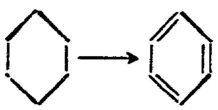
XIV. CATALYTIC REFORMING OF GASOLINE

Catalytic reforming as applied to the petroleum refining industry is defined as the conversion of either straight chain or cyclic hydrocarbons, boiling substantially within the gasoline range, in the presence of hydrogen and a precious metal catalyst, to produce motor fuels or aromatic hydrocarbons.

Motor fuel production via catalytic reforming usually involves the transformation of low octane naphthas to high octane hydrocarbons.

Aromatic hydrocarbon manufacture by catalytic reforming commonly converts paraffinic hydrocarbons to benzene, toluene and xylenes.

The catalytic reforming process for both motor fuels and aromatics incorporates the following simultaneous reactions:

Dehydrogenation of cyclohexane:  $+ 3H_2$

Isomerization of other naphthenes and their dehydrogenation to aromatics (pentane to isopentane)

Dehydrocyclization of paraffins

Hydrocracking

Isomerization of paraffins

Hydrogenation

aromatics ——→ naphthenes
olefins ——→ paraffins
aldehydes
ketones ——→ alcohols

Of much greater and of fast growing industrial importance for the production of hydrogen for the methanol or ammonia synthesis is the reaction in which C_1 to C_4 hydrocarbons are reformed with steam to produce hydrogen and carbon oxides (primary and secondary). At present, more hydrogen is made by this process.

Propane or other low-molecular weight hydrocarbons are reformed to give a mixture which is a good substitute for that normally supplied by the gas utility.

The reaction

$$C_nH_{2n+2} + nH_2O \rightarrow nCO + 2n + 1H_2$$

is endothermic, i.e., it is necessary to supply large amounts of heat to the reactor. Reforming operations are generally carried out with the aid of nickel catalysts at 550° to 850°C and 1—35 atm steam/gas ratio 2—10 and a hydrocarbon space velocity of 200 to 2,000.

The reforming of CH_4 with air according to the equation

$$CH_4 + \frac{1}{2}O_2 \rightarrow CO + 2H_2$$

is an autothermic reaction.

Catalyst problems are similar to those encountered in synthesis. Overheating of catalysts can readily occur if inlet feed is reduced too much without a corresponding reduction in heat input. This permanently deactivates commercial nickel catalysts when the temperature reaches about 1,050°C, probably owing to a loss in surface area. Nickel catalysts are also poisoned by very small amounts of sulphur gases (over about 4 ppm).

Aside from increasing methane equilibrium conversion and conversion rate, higher temperatures also increase the CO/CO_2 equilibrium ratio. In synthesis employing both CO and H_2 such as alcohol and hydrocarbon synthesis, high temperatures (800°—850°C) are used for the methane steam reaction to obtain the desired ratio of H_2/CO, while low temperature operation (700°—750°C) is favoured where only hydrogen and no carbon monoxide is, such as for ammonia synthesis. The recent literature indicates that ethane, propane and butane can be reformed as readily as methane over Ni catalysts though the steam/hydrocarbon ratio should be increased to prevent coke formation.

Reactions that take place during reforming are:

$CH_4 + H_2O \rightarrow CO + 3H_2$ (endothermic)

$CO + H_2O \rightarrow CO_2 + H_2$ (exothermic)

$CH_4 + 2H_2O \rightarrow CO_2 + 4H_2$ (endothermic)

$CO + 3H_2 \rightarrow CH_4 + H_2O$ (exothermic)

$CH_4 + CO_2 \rightarrow 2CO + 2H_2$ (endothermic)

$CH_4 + CO_2 \rightarrow CO + H_2 + H_2O + C$ (endothermic)

$2CH_4 \rightarrow C_2H_4 + 2H_2$ (endothermic)

XV. CATALYSTS FOR VARIOUS CHEMICAL REACTIONS

AMMONIA DISSOCIATION

Ammonia is dissociated like methanol for the production of inert gas. It is dissociated yielding a gas consisting of 75% hydrogen and 25% nitrogen by volume, and usually less than 0.1% residual free ammonia. Cracking occurs at about 1,000°C. The catalysts used must be resistant to sintering. The metals recommended as catalysts are nickel and iron. Generally, the catalysts used for the reforming of low molecular weight hydrocarbons can be recommended for ammonia dissociation.

CYCLIZATION (DEHYDROCYCLIZATION)

The conversion of aliphatic hydrocarbons containing six or more carbon atoms in a chain to the corresponding aromatic hydrocarbons is known as dehydrocyclization. The reaction sequence is believed to involve dehydrogenation of a paraffin to an olefin followed by ring closure and subsequent dehydrogenation of the ring compound to an aromatic. In many cases, isomerization reactions also take place.

Cyclizations not requiring isomerization proceed rapidly around 450°C. If isomerization is involved, temperatures above 500°C are usually required. Reaction under hydrogen pressure reduces the rate of formation of polymeric tars, thus extending the catalyst's life.

ESTERIFICATION

Esterification is a reversible reaction used to obtain esters. The reactions by which esters are produced may be divided into two groups: those in which two compounds react to give an ester a second compound, as is the case when an acid reacts with an alcohol (direct esterification), and those in which an ester is formed by the addition of one compound to another, as when ethylene is taken up by sulphuric acid.

In direct esterification, an alcohol reacts with an acid, either organic or inorganic:

$$CH_3COOH + HOC_2H_5 \rightleftarrows CH_3COOC_2H_5 + H_2O$$

$$C_2H_5OH + HNO_3 \rightleftarrows C_2H_5ONO_2 + H_2O$$

In all these cases, water, hydrogen chloride or sodium chloride appear as by-products.

In the second group are placed reactions in which esters are formed by the addition of two compounds.

Generally, these are:

(a) Esterification with inorganic acids:

$$C_2H_5OH + HNO_3 \rightarrow C_2H_5ONO_2 + H_2O$$

(b) Esterification with organic acids:

$$C_2H_5OH + HOCOCH_3 \rightleftarrows C_2H_5OCOCH_3 + H_2O$$

(c) Esterification of an ester:

$$CH_3COOC_2H_5 + HOCH_3 \rightleftarrows CH_3—COOCH_3 + HOC_2H_5$$

in which an alcohol displaces another alcohol; it is called alcoholysis, ester interchange or re-esterification. Alcoholysis is only a special case of esterification.

The most commonly used catalysts are sodium alcoholates and the strong acids.

(d) Alcoholysis:

$$CH_3COOC_2H_5 + C_5H_{11}COOH \rightleftarrows C_5H_{11}COOC_2H_5 + CH_3 — COOH$$

The counterpart of alcoholysis is acidolysis, in which one acid displaces another from its ester to form another ester.

Effective catalysts are: brom fluoride and mercury salts (are recommended for vinyl esters).

(e) Esters from acetylene (see vinyl acetate synthesis and vinyl chloride synthesis, chapter II).

(f) Esterification with ethylene oxide.

Ethylene oxide reacts with water to form glycol, with an alcohol to form a glycol ether, and with acetic acid to form glycol acetates. This reaction takes place in the presence of sulphuric acid or a similar catalyst. Aluminium above 150°C, under pressure and in the presence of catalysts, ethylene oxide and carbon dioxide combines to give ethylene carbonate.

(g) Esters from carbon monoxide:

$$CH_3 — OH + CO \rightarrow HCOOCH_3$$

In the presence of acids or of brom fluoride and at somewhat higher temperatures and under high pressure the product is an acid:

$$CH_3 — OH + CO \rightarrow CH_3 — COOH$$

Other important esters are cellulose acetate, glycerine trinitrate (nitroglycerine), cellulose nitrate (commonly called nitrocellulose).

HYDRATION (DEHYDRATION)

This class of reactions is limited herein to those in which water is tranferred, added or abstracted, in which gaseous hydrogen is not involved.

Dehydration may be either intramolecular (e.g. dehydration of an alcohol) or intermolecular (e.g. ester formation). Addition or removal of water from a compound may be accomplished by a catalyst.

A complicating factor in nearly all reactions of this class is the occurrence of competitive, secondary and side reactions. In the hydration of an olefin to an alcohol, for example, the olefin may also undergo polymerization and the alcohol may undergo dehydration to an ether or dehydrogenation to an aldehyde.

Substantially all hydration-dehydration catalysts have in common a strong affinity for water.

The prime example is alumina which has a water content of several percentage even at 600°C which can be attributed to chemisorption.

Next to alumina in point of usage for reactions in this class comes phosphoric acid or acid salts on various inert carriers. They also have a strong affinity for water. Other active catalysts include silica-alumina gel, various metal combinations with alumina and clays. Combining silica gel with tantalum, zirconium or hafnium proved most suitable for butadiene synthesis.

The hydration reactions are governed by pressures, temperature and mol ratio of reactants.

Sometimes high pressure is necessary to counteract dehydration tendency and promote hydration.

Among the reaction types in this class are the following:

(a) Alcohol synthesis:

$$CH_2 = CH_2 + H_2O \leftrightarrow CH_3 - CH_2OH \qquad \Delta H = -11 \text{ kcal/mol}$$

(b) Aldehyde synthesis:

$$HC \equiv CH + H_2O \leftrightarrow CH_3 - CHO \qquad \Delta H = -40 \text{ kcal/mol}$$

(c) Ketone synthesis:

$$2HC \equiv CH + 2H_2O \leftrightarrow CH_3 - CO - CH_3 + CO \qquad \Delta H = -85 \text{ kcal/mol}$$

(d) Ester synthesis:

$$CH_3{-}OH + HCOCOH \leftrightarrow HCOOCH_3 + H_2O \qquad \Delta H = -5.6 \text{ kcal/mol}$$

(e) Alkyl aryl synthesis: $ROH + H_2 \leftrightarrow RH + H_2O$

(f) Amine synthesis:

$$CH_3 - OH + NH_3 \leftrightarrow CH_3 - NH_2 + H_2O \qquad \Delta H = -5.7 \text{ kcal/mol}$$

(g) Amide synthesis:

$$CH_3 - COOH + NH_3 \leftrightarrow CH_3CONH_2 + H_2O \quad \Delta H = - 4 \text{ kcal/mol}$$

(h) Diene synthesis:

$$CH_3CHO + C_2H_5OH \rightarrow CH_2 = CH - CH = CH_2 + 2H_2O \ \Delta H = -13 \text{ kcal/mol}$$

In general, intramolecular dehydrations are endothermic and high equilibrium conversion is obtained only at high temperatures and low pressures. Intermolecular dehydration equilibrium is not in general markedly affected by temperature or pressure.

Part three

Homogeneous catalysts

XVI. HOMOGENEOUS CATALYSIS

Two broad classes of catalytic reactions are recognized: homogeneous and heterogeneous.

Known homogeneous catalytic reactions are either gas or liquid phase, preponderantly the latter; existence of solid phase reactions of this type is considered doubtful.

Homogeneous catalysis in the gas phase is comparatively rare, but a few exceptions may be noted:

(a) Nitric oxide is an industrial catalyst for the oxidation of sulphur dioxide. It has been shown that the reaction proceeds much more rapidly by the sequence:

$$2NO + O_2 \rightarrow 2NO_2$$

$$NO_2 + SO_2 \rightarrow NO + SO_3$$

(b) Decomposition of acetaldehyde, various ethers and nitrous oxide are strongly catalysed by iodine in the gas phase;

(c) Formation of hydrogen chloride from its elements is catalysed by sodium or potassium vapour. Several thousand molecules of HCl result from the reaction of a single metallic atom.

Liquid-phase homogeneous catalysis is common. Most widely investigated has been catalysis by ions, of which the most important type is acid and base catalysis. Processes catalysed by acids and bases include esterification, saponification, inversion, mutarotation, enolization and many oxidations and reductions. Rates of such reactions are expressed in terms of the generalized concept of acid and base. According to this definition, molecules able to furnish a proton are called acids, and those able to combine with the proton are called bases; these molecules may be ions or neutral. Thus acids and bases are related by the equation[1]):

$$\text{acid} \rightleftarrows \text{base} + H^+$$

Neutral salts in solution influence reactivity. It is to be expected that collisions of ions will be influenced by the ionic atmospheres, which are in turn affected by the presence of salts. Collisions between oppositely charged ions are increased by salts which favour electrostatic attraction and decreased by salts which modify the ionic atmosphere so that electrostatic attraction is decreased. This effect is correlated in terms of the ionic strength of the solution; its order of magnitude is rather less than that of most catalytic effects.

Nature of the solvent sometimes may affect the kinetics of a process. This may possibly be regarded as an example of catalysis. In some cases this effect is due to the influence of the solvent on the thermodynamic activity of the reactants. Solvating power, acid dielectric constant are pertinent properties. Where important molecules are concerned, reactions yielding products more polar than the reactants proceed better in polar solvents, while those with products less polar than the reactants proceed better in non-polar solvents.

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[1]) A catalyst in a homogeneous system is a substance that appears in the speed equation without appearing in the stoichiometric equation of the reaction. A more general definition of the catalyst in a homogeneous reaction would be a substance whose concentration appears in the speed equation at a higher power than in the stoichiometric equation. This definition includes also the more rare cases of self catalysis.

Part four

Catalyst carriers

XVII. CARRIERS

Only very rarely do commercial catalysts consist of a single component. The term "catalyst carrier" as used herein refers to a major catalyst constituent that serves as a base, support, carrier or binder for the active constituent but which by itself has little, if any, catalytic activity for the reaction in question.

The mechanical function of a carrier is to act as a base or framework for the catalytic component. It may serve to reduce shrinkage and lend physical strength.

Aside from its purely mechanical function, other possible desirable effects of a carrier include:

(a) Giving a larger exposed surface of active agent and thereby greater catalytic activity in cases in which this agent by itself has low surface area, or giving an equal surface area and activity with much less active material;

(b) Increasing catalyst stability by keeping fine crystals of the active constituent too far apart for sintering to occur;

(c) Favourably modifying the catalytic activity or selectivity, poison resistance etc. of the active constituent. In some cases surface compound or complex formation may take place between the carrier and the supported material giving a complex which has better catalytic properties per unit area than the latter. Silica-alumina and silica-magnesia cracking catalysts are in this category;

(d) Improving activity by increasing the accessibility of the active surface. This is important in many industrial catalytic processes in which the catalyst is used in the form of large granules, pellets or rings. Supports with large pores, such as diatomaceous earth would be expected to act in this manner. Physical structure has also been found to have an important effect on selectivity;

(e) The increase of active surface resulting from use of a carrier may result in a decrease in sensitivity to poisons;

(f) Catalysing one of the steps where there is a dual action mechanism; this is similar to the function of a dual action promoter except that the carrier acts also as a mechanical support for the other constituent;

(g) Helping to dissipate heat and prevent local over-heating which would cause sintering with resultant loss in active surface. High heat conductivity carriers are favoured for such purposes. In the catalytic oxidation of ethylene, metallic silver carriers are commonly used.

Because of pressure drops considerations, industrial vapour-phase catalysts are almost entirely of two types: powders, 20—300 microns, for fluid bed operations and granules, rings or pellets for fixed bed processes.

Among the factors to be considered in the selection of a carrier are:

Possible catalytic activity of the carrier component
Modification of the properties of the supported component by the carrier
Surface area
Porosity
Structure
Specific heat
Heat conductivity

Particle size
Density
Attrition resistance, hardness and compressive strength
Stability under reaction conditions

Although it is not easy to classify carrier materials, and some carriers can be "tailor-made" to have widely varying properties (e.g. silica gel), the best way to classify them seems to be on the basis of structure. The main classes of structure are: low-area carriers, high-area carriers, miscellaneous carriers and fibrous materials.

During the last few years the importance of the role of the catalyst carrier in heterogeneous catalyst systems has been more fully appreciated, if not completely understood. A very comprehensive range of catalyst carriers is now available from industry. The fact that there is now such a wide variety of catalyst carriers available to the research chemist gives rise to problems of catalyst carrier selection.

In the field of catalyst carriers it is convenient to classify them on the basis of their internal surface area as follows:

Low surface area (LSA):	less than 1.0 m^2/g
Intermediate surface area (ISA):	less than 1—100 m^2/g
High surface area (HSA):	greater than 100 m^2/g

LOW SURFACE AREA CATALYST CARRIERS

Under this classification a number of products are available which vary in both chemical and physical properties.

CHEMICAL PROPERTIES

Materials available include:

Pure alumina:	99 + % Al_2O_3
Alumina silica:	greater than 50% Al_2O_3
Silica alumina:	greater than 50% SiO_2
Pure silica:	99% SiO_2
True mullite:	stable alumina silica compound $3Al_2O_3.2SiO_2$
Silicon carbide:	80%—96% SiC
Titania:	90% TiO_2

SURFACE AREA (SA)

Even within this classification there is some scope for variation in surface area between 0.01 and 1.0 m^2/g. This property is dependent on the pore diameter and volume of pores present.

PORE SIZE DISTRIBUTION (PSD)

Products are available with pores in the range 1—1,500 microns.

OTHER PROPERTIES

Whilst porosity, water absorption and strength are important properties, they become to some extent fixed by the properties of surface area and pore size distribution. They are usually more than adequate for the catalyst manufacturer's production techniques.

SELECTION

When faced with the selection of a suitable catalyst carrier, the research chemist is to some extent spoilt for choice. By plotting catalyst performance (activity, conversion, yield, life) against average pore diameter and against surface area the research chemist will be able to optimize the catalysts carrier required.

APPLICATIONS

LSA catalyst carriers are used for reactions where controlled low activity is desired to produce an intermediate product. Typical reactions include:

Oxidation of ethylene to ethylene oxide
Oxidation of benzene to maleic anhydride
Oxidation of naphthalene/ortho-xylene to phthalic anhydride
Production of lean town gas
Steam reforming of hydrocarbons

INTERMEDIATE SURFACE AREA CATALYST CARRIERS

This product classification is probably the least used and least known. This is mainly due to the lack of commercially available products. Recent new ceramic technology makes available new products in this range for evaluation by the research chemist.

CHEMICAL PROPERTIES

Materials available include:

Pure alumina:	98% Al_2O_3 in various crystal forms
Alumina silica:	85% Al_2O_3
Titania:	92% TiO_2

PURE ALUMINA

These products are derived from the dehydration sequence of alumina hydrate. Alpha alumina trihydrate gives kappa and alpha alumina products within this surface area classification, but the surface area *versus* temperature characteristics of these raw materials make it difficult to control the surface area in the range 10—100 m^2/g. Alpha alumina monohydrate dehydration gives theta and alpha products in this surface area range and the surface area *versus* temperature characteristics allow much improved surface area control in the region 10—100 m^2/g.

PORE SIZE DISTRIBUTION

The average pore diameter of products increases with decrease in surface area.

SELECTION

When selecting carriers in this product range, it is obvious that one should choose at least two surface area ranges, e.g. 20—30 (alpha), 60—80 (alpha + theta). Further optimization may be possible by selection on the basis of surface area and average pore diameter particularly when pore diffusion limitation is expected.

HIGH SURFACE AREA CATALYST CARRIERS

This classification covers the largest volume of all catalyst carriers used in heterogeneous catalysts.

TABLE 1

LOW SURFACE AREA CATALYST CARRIERS: TYPICAL CHEMICAL ANALYSIS [a]

Al_2O_3	SiO_2	Fe_2O_3	TiO_2	CaO	MgO	Na_2O	K_2O	ZrO_2+HfO_2	SiC
				Aluminium oxide					
90.40	8.46	0.26	0.28	0.04	0.07	0.33	0.09	0.05	—
86.96	11.65	0.30	0.42	0.05	0.11	0.32	0.17	0.02	—
76.60	16.80	1.20	2.5	0.80	0.60	0.40	1.00	—	—
92.67	6.03	0.22	0.22	0.11	0.16	0.43	0.11	—	—
86.96	11.65	0.30	0.42	0.05	0.11	0.32	0.17	0.02	—
99.3	0.4	0.10	—	0.10	—	0.10	—	—	—
95.9	3.5	Tr.	Tr.	Tr.	Tr.	0.20	0.40	—	—
				Silicon carbide					
4.73	28.48	0.34	Tr.	0.24	0.06	0.23		—	65.8
				Silica					
3.1	96.0	0.26	0.26	0.04	0.11	0.16	0.07	—	—
0.8	96.9	0.10	—	—	0.10	0.50	(B_2O_3) 1.5%		—
									—
				Zirconium silicate					
2.97	32.33	0.17	0.20	0.16	0.25	0.01	0.06	63.84	—
2.97	32.33	0.17	0.20	0.16	0.25	0.01	0.06	63.84	—
				Mullite					
70.02	28.90	0.29	0.36	0.13	0.15	0.10	0.05	—	—
				Zirconia					
0.38	1.57	0.16	0.25	3.50	—	—	—	94.14	—

[a] All elements reported as metal oxides. Actual presence of the metals in the form of complex silicates and/or aluminates.

TABLE 2

LOW SURFACE AREA CATALYST CARRIERS: PHYSICAL PROPERTIES

Apparent porosity (%)	Water absorption (%)	Bulk density (g/cm^3)	Apparent specific gravity	Packing density (lb/ft^3)	Maximum attrition loss per hour (%)	Pores		Surface area (m^2/g)
						Diameter range (μm)	Percentage of pore volume in the range	
Aluminium oxide								
38–47	17–24	1.9–2.1	3.5–3.7	58–78	15	2–40	90	<1
43–52	21–30	1.7–1.9	3.5–3.7	55.73	15	3–60	90	<1
39–45	18–24	2.0–2.3	3.5–3.7	75–80	10	3–30	90	<1
42–48	20–26	1.7–1.9	3.5–3.7	64.71	15	3–60	90	<1
39–44	16–22	1.7–1.9	3.5–3.7	72–78	10	3–30	90	<1
36–42	15–20	2.0–2.2	3.4–3.6	63–83	10	2.30	80	<1
40–46	19–24	1.8–2.0	3.2–3.4	71–75	15	2–40	90	<1
35–40	15–19	2.1–2.3	3.4–3.7	72–80	12	2–40	85	<1
40–45	19–23	1.9–2.1	3.4–3.6	69–74	15	2–60	90	<1
36–44	15–21	2.0–2.4	3.5–3.8	77–84	10	2–40	85	<1
32–40	12–18	1.9–2.1	3.3–3.5	71–83	15	2–30	80	<1
31–36	12–16	2.0–2.2	3.3–3.5	78–84	5	2–30	80	<1
6–14	1–5	3.0–3.2	3.5–3.7	110–120	1	1–3	95	<1
48–54	25–31	2.0–2.4	3.5–3.8	58–65	15	4–70	95	<1
48–54	25–31	1.7–2.0	3.5–3.8	58–65	15	4–70	95	<1
40–44	16–20	2.2–2.4	3.9–4.0	85–89	12	1–20	95	<1
30–34	10–14	2.6–2.8	3.9–4.0	97–102	5	1–10	95	<1
Silicon carbide								
39–43	22–25	1.6–1.8	2.8–3.0	60–64	10	10–40	95	<1
42–48	26–30	1.5–1.8	2.8–3.0	54–62	10	10–40	95	<1
Silica								
35–39	22–26	1.3–1.5	2.3–2.4	59–63	5	1–5	90	<1
32–38	19–25	1.5–1.7	2.3–2.4	55–59	6	1–5	90	<1
48–52	44–48	1.0–1.2	2.1–2.3	42–46	—	—	—	<1
Zirconium silicate								
3–8	1–3	3.8–4.0	4.1–4.3	141–147	2	2–10	85	<1
24–32	7–12	3.0–3.4	4.4–4.6	112–121	5	—	—	<1
Mullite								
34–40	16–22	1.9–2.1	3.1–3.3	67–73	5	—	—	<1
34–40	16–22	1.9–2.1	3.1–3.3	64–70	5	—	—	<1
Zirconia								
42–47	12–16	3.0–3.3	5.5–5.8	103–110	22	—	—	<1

TABLE 3

LOW SURFACE AREA "MACROPORE" CATALYST CARRIERS: TYPICAL CHEMICAL ANALYSIS [a]

Al_2O_3	SiO_2	Fe_2O_3	TiO_2	CaO	MgO	Na_2O	K_2O	ArO_2 + HfO_2	SiC
Aluminium oxide									
84.7	13.4	0.20	0.30	0.02	0.04	0.60	0.70	–	–
83.0	14.0	0.40	0.30	0.50	0.50	0.60	0.70	–	–
85.5	12.4	0.20	0.10	0.60	0.40	0.30	0.50	–	–
Silicon carbide									
2.6	6.5	0.20	0.10	0.10	0.10	0.10	0.20	–	90.0
Zirconium silicate									
4.8	39.9	0.3	0.5	0.1	–	0.2	0.8	53.4	–
Mullite									
69.91	28.38	0.21	0.17	0.59	0.39	0.14	0.21	–	–
69.91	28.38	0.21	0.17	0.59	0.39	0.14	0.21	–	–

a/ All elements reported as metal oxides. Actual presence of the metals in the form of complex silicates and/or aluminates.

TABLE 4

LOW SURFACE AREA "MACROPORE" CATALYST CARRIERS: PHYSICAL PROPERTIES

Apparent porosity (%)	Water absorption (%)	Bulk density (g/cm³)	Apparent specific gravity	Packing density (lb/ft³)	Maximum attrition loss per hour (%)	Pores		Surface area (m²/g)
						Diameter range (µm)	Percentage of pore volume in the range	
Aluminium oxide								
53–59	33–39	1.5–1.7	3.3–3.6	53–59	6	100–1500	95	<1
55–61	37–43	1.4–1.6	3.3–3.6	50–56	8	100–1500	95	<1
55–61	37–43	1.4–1.6	3.3–3.6	44–48	10	100–1500	100	<1
43–47	20–24	1.8–2.0	3.5–3.8	63–67	15	20–180	100	<1
36–42	15–21	2.0–2.4	3.4–3.8	66–74	10	20–180	100	<1
Silicon carbide								
43–48	24–30	1.6–1.8	3.0–3.2	53–57	15	3–100	100	<1
Zirconium silicate								
44–48	19–23	2.0–2.3	3.9–4.1	63–67	5	–	–	<1
Mullite								
41–45	23–27	1.9–2.1	3.1–3.3	55–59	6	–	–	<1
41–45	23–27	1.6–1.9	3.0–3.2	55–59	6	–	–	<1

TABLE 5

INTERMEDIATE SURFACE AREA CATALYST CARRIERS: PHYSICAL PROPERTIES

Apparent porosity (%)	Water absorption (%)	Bulk density (g/cm³)	Apparent specific gravity	Packing density (lb/ft³)	Maximum attrition loss per hour (%)	Pores		Surface area (m²/g)
						Diameter range (μm)	Percentage of pore volume in the range	
				Aluminium oxide				
62–66	53–57	1.1–1.3	3.1–3.3	42–46	–	–	–	10–20
62–66	52–56	1.1–1.3	3.2–3.4	40–44	–	–	–	10–20
62–66	54–58	1.1–1.3	3.1–3.3	40–44	–	–	–	35–45
62–66	55–59	1.1–1.3	3.1–3.3	37–44	–	–	–	35–45

TABLE 6

INTERMEDIATE SURFACE AREA CATALYST CARRIERS: TYPICAL CHEMICAL ANALYSIS [a]

Al_2O_3	SiO_2	Fe_2O_3	TiO_2	CaO	MgO	Na_2O	K_2O	ZrO_2+HfO_2	SiC
				Aluminium oxide					
83.0	15.3	0.44	0.50	0.09	0.07	0.34	0.16	–	–

---

[a] All elements reported as metal oxides. Actual presence of the metals in the form of complex silicates and/or aluminates.

XVIII. CRYSTALLINE MATERIALS

Crystalline materials are produced in high temperature electric furnaces and further processed to meet demands of industry for purity, density, shape and size. These high temperature crystalline materials are available in granular and powdered form.

REGULAR FUSED ALUMINA (Al_2O_3)

Regular fused alumina is a hard brown grain, produced by fusing a mixture of calcined bauxite, coke, and iron filings in the Higgins electric arc furnace at a temperature above 3,630°F (2,000°C). During the process purification and crystallization of the grain takes place.

A typical chemical analysis is:

	Per cent (by difference)
Al_2O_3:	94.47
SiO_2:	1.70
Fe_2O_3:	0.20
TiO_2:	3.10
ZrO_2:	0.15
CaO:	0.08
MnO:	0.10
MgO:	0.20

The characteristics are:

Crystal form:	alpha alumina
Maximum usable temperature:	about 3,450°F(1,900°C)
Chemical nature:	amphoteric
Reaction with acids:	subject to mild attack by aqua regia and/or hydrofluoric acid
Reaction with alkalies:	very slight with strong hot solutions only
Oxidation-reduction effects:	none
True specific gravity:	3.95
Packing density:	110–128 lb/ft^3 depending on grain size and shape
Hardness (Knoop):	2,000
(Mohs):	9.0
Electrical resistivity:	10^{16} at 80°F (30°C) 10^5 at 1,650°F (900°C)

Two shapes are available. These grain shapes are determined by the degree of crushing and milling. The two shapes are: strong — a strong, block-shaped grain; and intermediate — a wedge-shaped grain intermediate between a stronger block shape and a weaker sliver shape.

The grain sizes are: crude — lumps 1 1/2″ and finer; and grit sizes — in either strong or intermediate shape.

Coarse		**to**		**Fine**
4				
6	20		70	120
8	24	46	80	
10		54		150
12	30	60	90	
14				180
16	36		100	220

WHITE FUSED ALUMINA (Al_2O_3)

There are many applications that demand high-purity white grain. White in colour, it is somewhat more refractory than regular fused alumina. This white grain is electrically fused from Bayer process alumina. Although considerably purer, its physical properties are comparable to regular grain.

A typical chemical analysis is:

	Per cent (by difference)
Al_2O_3:	99.28
SiO_2:	0.05
Fe_2O_3:	0.15
TiO :	0.02
Na_2O:	0.50

The characteristics are:	
Crystal form:	alpha alumina
Maximum usable temperature:	3,630°F (2,000°C)
Chemical nature:	amphoteric
Reaction with acids:	less attack than regular grain
Reaction with alkalis:	very slight with strong hot solutions
Oxidation-reduction effects:	none
True specific gravity:	3.97
Packing density:	approx. 107—119 lb/ft^3 depending on grain size
Hardness (Knoop):	2,000
(Mohs):	9.0
Electrical resistivity:	10^{16} at 80°F (30°C) 10^6 at 1,650°F (900°C)

The grain shape is wedge, intermediate between a strong or block shape and a weak or sliver one. The sizes are: crude — lumps 1 1/2″ and finer; and grit sizes.

Coarse		**to**		**Fine**
6	16		70	120
8	20	46	80	150
10	24	54		
12	30	60	90	180
14	36		100	220

FUSED MULLITE ($3Al_2O_3 \cdot 2SiO_2$)

Refractory products using mullite grain have good high temperature strength and thermal shock resistance. Mullite grain is an aluminium silicate ($3\ Al_2O_3 \cdot 2\ SiO_2$) fused in an electric furnace to insure complete reaction of

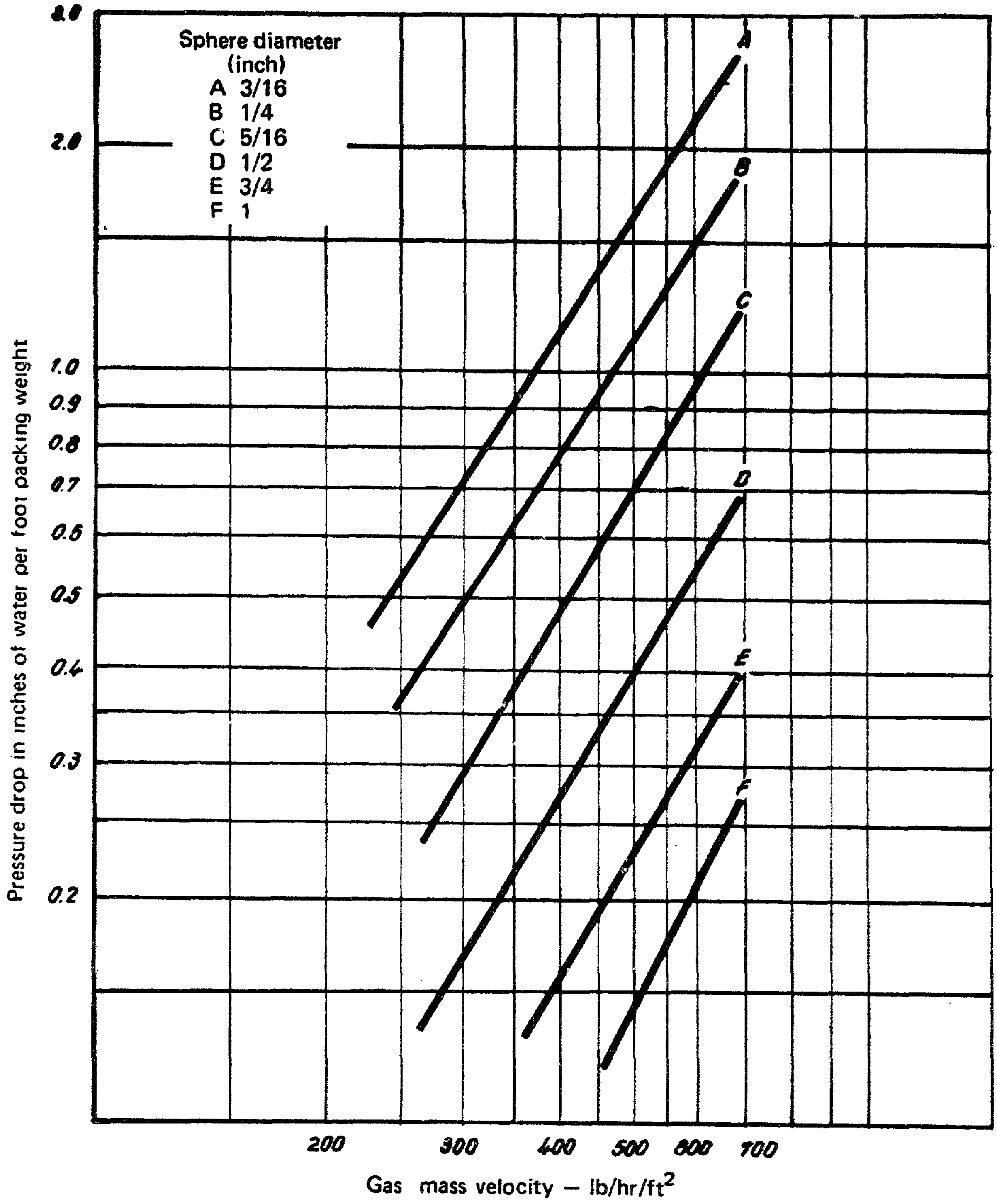

Figure 1. Pressure drop through fixed beds of spherical catalyst

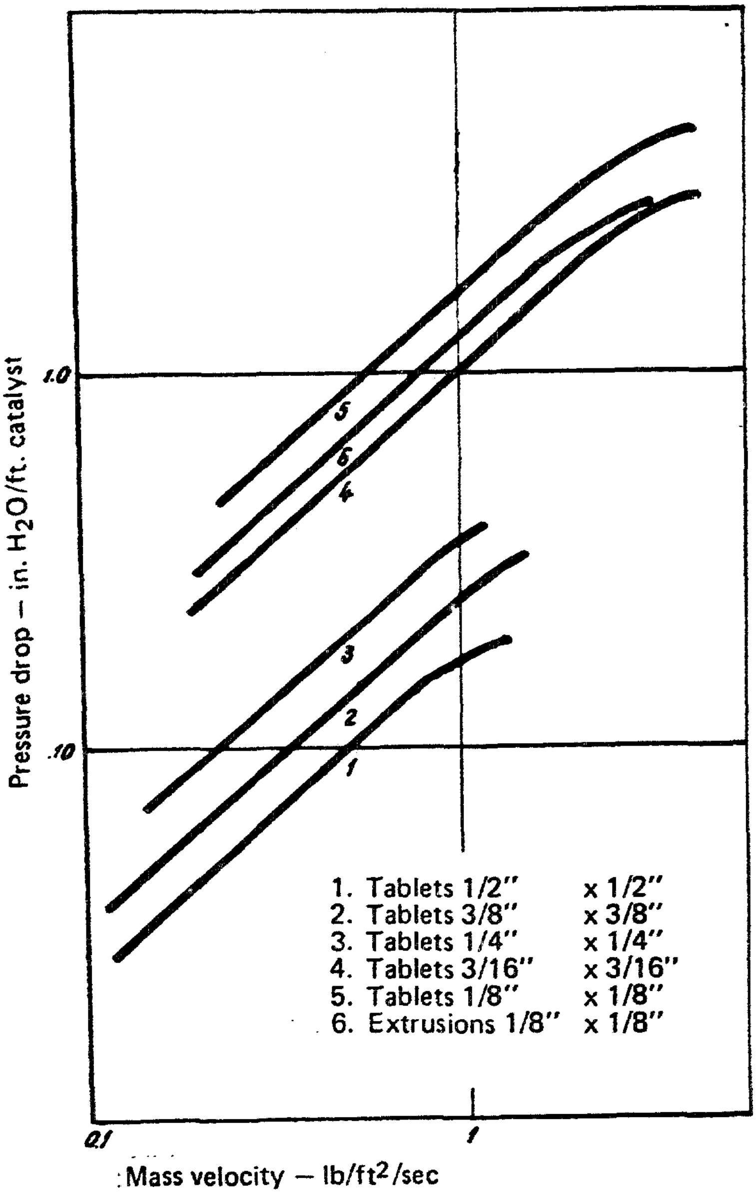

Figure 11. **Pressure drop per foot of catalyst tablets vs. mass velocity**

the raw materials. An excess of alumina is used in the fusion, causing the resultant composition to be on the high alumina side of theoretical mullite, that is, 72% Al_2O_3. Petrographic examination reveals about 2% free alumina and 1% glass. These factors enable mullite grain to remain in the crystalline form (i.e., no liquids are formed) up to the eutectic melting point 3,340°F (1,840°C) between mullite and alumina.

A typical chemical analysis is:

	Per cent (by difference)
Al_2O_3	75.10
SiO_2	24.35
Fe_2O_3	0.12
TiO_2	0.03
Na_2O	0.35
C	0.05

The characteristics are:

Crystal form:	orthorhombic (excess alumina-present as corundum)
Melting point:	congruently at 3,340°F (1,840°C)
Chemical nature:	slightly acid

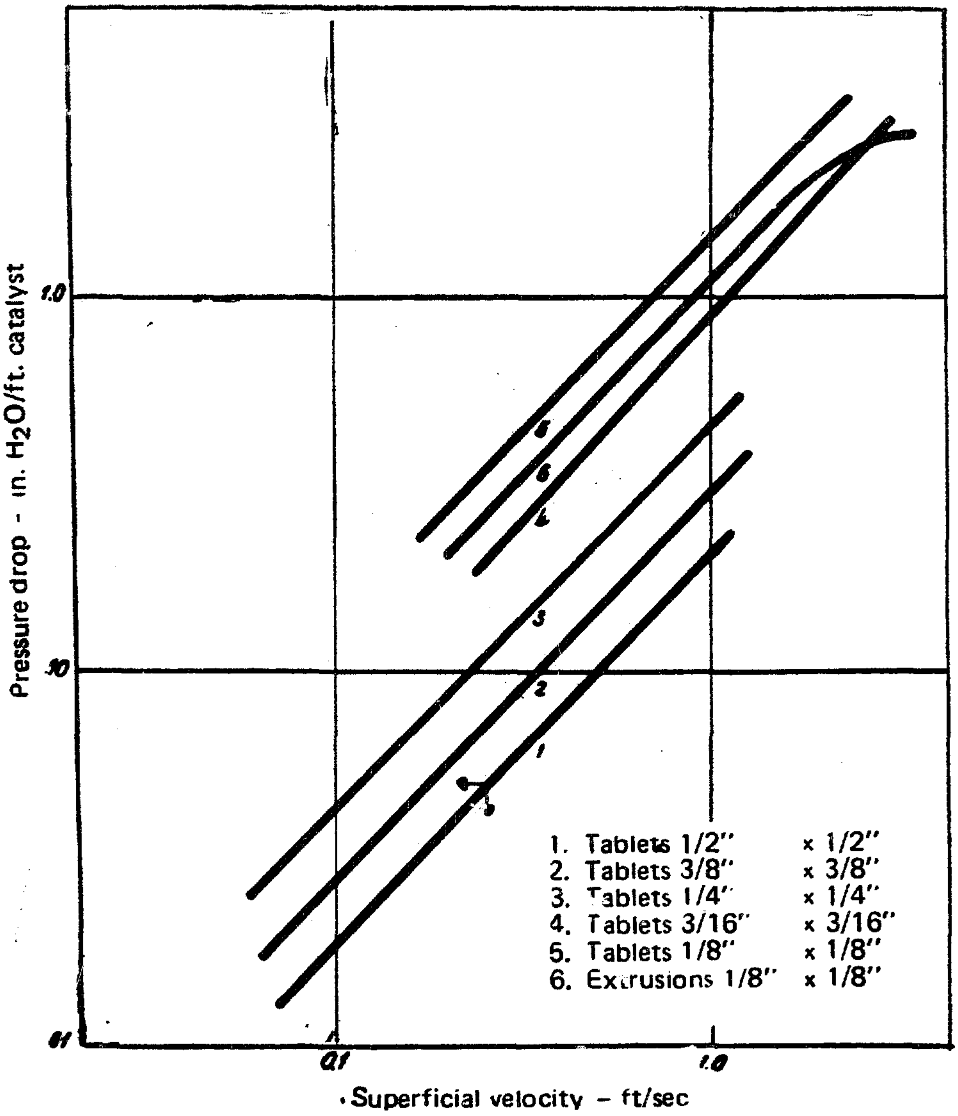

Figure III. **Average superficial velocity of air at 65°F vs. pressure drop per foot of catalyst tablets**

Reaction with acids, alkalis and general:	Insoluble in most acids attacked by molten alkalis and many basic slags
Maximum usable temperature:	3.340°F (1,840°C)
True specific gravity:	3.23
Packing density:	85 to 103 lb/ft^3 depending on grain size
Hardness (Knoop):	820
(Mohs):	7

TESTING PROCEDURES

PROCEDURE FOR DETERMINING APPARENT POROSITY, WATER ABSORPTION, APPARENT SPECIFIC GRAVITY AND SOLID BULK DENSITY

The equipment used is:

A rectangular stainless steel wire mesh basket (2 1/2" × 2" × 1" deep with wire handle) for holding sample
A balance weighing to nearest 0.1 g

A deep porcelain dish
A damp cloth
A small aluminium or plastic container

The testing procedure is as follows:

(1) Weigh dry wire mesh basket in air to nearest 0.1 g;

(2) Place about 80—100 g of dry carriers in basket and reweigh in air;

Note: This weight suggested for $\frac{1}{2}''$ size and smaller. weight per cubic foot 40—80 lb. For sizes larger than $\frac{1}{2}''$ or dense materials, sample weight 250 g;

(3) Subtract (1) from (2). This is dry weight of carriers in air. Call this weight "D";

(4) Fill porcelain dish with water and heat to boiling;

(5) Immerse wire basket containing carriers in the boiling water. Boil gently for 30 minutes;

Note: Keep carriers covered with water at all times during boiling. Do not let basket rest on bottom of porcelain dish.

(6) Remove porcelain dish from heat, place under cold water faucet and run in cold water until mass has cooled to room temperature;

(7) Remove wire mesh basket containing carriers from cold water and weigh entire mass suspended in water at room temperature;

(8) Weigh dry aluminium or plastic container in air;

(9) Soak a piece of cloth towel in water and wring out thoroughly by hand;

(10) Transfer sample from basket to damp cloth towel and blot lightly to remove all drops of surface water;

(11) Transfer sample to weighed aluminium or plastic container and weigh entire mass in air;

(12) Subtract weight (8) from weight (11) to get weight of saturated carriers. Call this weight "W";

(13) Weigh wire mesh basket submerged in water;

(14) Subtract weight (13) from weight (7) to get suspended weight of carriers. Call this weight "S".

The exterior volume (V) in cubic cm of the carriers is obtained by subtracting the suspended weight from saturated weight, thus:

$$V = W - S$$

The apparent porosity (P) expresses as a percentage the relationship of the volume of the open pores of the carrier to its exterior volume and it is calculated as follows:

$$P = \frac{W-D}{V} \times 100$$

The water absorption (A) expresses as a percentage the relationship of the weight of water absorbed to the weight of dry carriers. It is calculated as follows:

$$A = \frac{W-D}{D} \times 100$$

The apparent specific gravity (T) is that portion which is impervious to boiling water. It is calculated as follows:

$$T = \frac{D}{D-S}$$

The bulk density (B) in grams per cubic cm is the quotient of its dry weight divided by its exterior volume including pores. It is calculated as follows:

$$B = \frac{D}{V}$$

PROCEDURE FOR DETERMINING PACKING DENSITY (VOLUMETRIC BULK DENSITY)

The equipment used is:

A metal cone of the following dimensions:

90° angle at vertex
12 3/4″ diameter at top
$1\frac{1''}{2}$ diameter hole at bottom
1″ height from bottom of cone to top of weighing cylinder facilitated by three legs on outer surface of cone;
A metal base plate (10″ × 10″ × 1″ thick);
A standard 1/8 cubic foot grain density cam with following dimensions:
3 7/8″ ID at bottom
3 7/8″ ID at top
17 15/32″ inside height

(A multiplication factor should be applied to the results — as the grain density cam is slightly under 1/8 ft^3. This factor must be obtained for each container.)

The testing procedure is as follows:

(1) Weigh out 3—5 lb of carriers. This weight dependent on density of material to be tested. (Amount to weigh out should fill container half full.);

(2) Place grain density cam on 10″ × 10″ × 1″ thick steel plate. Steel plate must be placed on solid rigid surface. A concrete floor is advisable;

(3) Place metal cone on grain density cam;

(4) With one hand under $1\frac{1}{2}''$ cone opening pour the sample to be tested into cone;

(5) Release hand under cone opening allowing constant flow of carriers through $1\frac{1}{2}''$ cone opening into cylinder;

(6) Raise container $\frac{1}{2}''$ until it touches a bar clamped to a laboratory clamp stand. Allow to fall freely onto the steel plate. Repeat to a total of 10 drops;

(7) Repeat steps (1) through (5);

(8) Level overflowing cylinder with metal straight edge;

(9) Repeat step (6);

(10) Add additional carriers to fill grain density cam to overflow;

(11) Level overflowing cylinder with metal straight edge;

(12) Weigh contents of grain density cam and convert to weight per cubic foot using proper factor for cylinder.

PROCEDURE FOR DETERMINATION OF ABRASION RESISTANCE

This test is designed to measure how well catalyst carriers will resist abrasion. The abrasion loss is determined in terms of material finer than 10 mesh (0.07″ ± 0.1″ screen openings ten per inch) which is removed from the carriers by tumbling under controlled conditions.

The equipment used is:

A fibre drum with lid (Continental Can Company No T-158-2 X) with the following dimensions: outside diameter, 8 5/16″; inside diameter, 8″; inside length, 7″.

The inside surfaces of the bottom of the drum and the lid should be covered by discs of smooth wear resistant rubber 1/64″ thick, cemented to the respective surfaces by rubber cement (Goodyear Pliobond).

After attaching the rubber disc to the inside of the bottom of the drum, the entire inside wall of the container should be covered by one piece of ribbed rubber cemented to the walls by rubber cement. This rubber shall be attached so that the ribs are parallel to the length of the drum;

A laboratory ball mill rollers capable of rotating corrugated rubber lined drum charged with sample at 60 ± 1 rpm;

A 10 mesh wire screen (0.07″ ± .01″ screen openings 10 per inch);

A scale capable of weighing up to at least 10 lb to two decimal places.

The testing procedure is as follows:

(1) Weigh out sample of screened material and place this weighed sample in container. (Sample weight depends on size, shape and density. Sample weight is generally 5 lb, however, for "Macropore" series sample weight is $3\frac{1}{2}$ lb);

(2) Place lid on container and seal lid joint with 2″ wide rubber band;

(3) Place container and contents on rollers and rotate for 15 minutes at 60 rpm;

(4) After 15 minutes remove the container and empty all contents onto the 10 mesh wire screen;

(5) Shake screen by hand to remove all fines;

(6) Weigh material remaining on screen;

(7) Calculate per cent of loss for a total of 15 minutes;

(8) Replace pellets in corrugated rubber lined drum;

(9) Repeat steps (2), (3), (4), (5) and (6);

(10) Calculate per cent of cumulative loss of a total of 30 minutes;

(11) Repeat step (8);

(12) Repeat step (2);

(13) Replace container on rollers and rotate for 30 minutes at 60 rpm;

(14) Empty all the contents onto the 10 mesh wire screen;

(15) Repeat steps (5) and (6);

(16) Calculate per cent of cumulative loss for a total of 60 minutes.

XIX. CATALYST CARRIERS — PRESSURE DROP

EXPERIMENTAL TEST METHOD

All materials were loose filled in a 4.02 ID tube 2′ in length. The outer walls were pounded with a hammer until no more settling was observed. Additional make-up was added to top off the bed and the pounding repeated. Thus, all materials were tested at maximum packing density and minimum bed voidage for the imposed particle to tube geometry.

Pressure taps were installed in the column just above and below the bed. The pressure differential was observed by sighting through a cathetometer, a water filled manometer. The empty tower provided a negligible pressure drop of less than 0.01″ of water at a G equalling 1,000 pounds of air per hour per square foot. Use of the cathetometer allowed detection of a pressure drop of less than 0.04″ of water with excellent accuracy and reproducibility.

Pressure regulated plant compressed air was fed to two needle valves in parallel. These needle valves acted as critical flow orifices above a 25 psig supply pressure at the maximum back pressure created by the air line, column bed and gas meter. The open area of each needle valve was set at positions which would provide coverage of the flow regime desired. Both needle valves were calibrated individually and together to provide a straight line plot of superficial mass velocity as inlet pressure to the needle valve. Air was directed down through the bed. Air flow was measured using a standard 60 light gas meter.

All data were obtained by measuring the pressure differential over the bed data minimum of 15 values of superficial mass velocity. A disproportionately greater number of points were obtained at low superficial mass velocities for large particle sizes to average out any errors in reading the manometer at small pressure differentials.

A study was completed on pressure drop data for air flowing through packed beds of catalyst carriers. In this study all products tested were in dense packed beds 4″ in diameter and 2′ length. All materials were loose filled and the outer columns were pounded with a hammer until no more settling was observed. Additional make-up was added to top off the bed and the pounding repeated. Thus, all materials were tested at maximum packing density and minimum bed voidage for the imposed particle to tube geometry.

Table 7 shows pressure drop data for spheres, pellets, grooved pellets, rings, grooved rings and aggregate. Table 8 gives the properties of certain kinds of spheres. Spheres — pellets or granulates (grain) showing distinct properties can be composed to specification. The recommended packing for transportation by railway is jute or plastic bags; for transportation by sea, iron drums.

TABLE 7

PRESSURE DROP DATA FOR SPHERES, PELLETS, GROOVED PELLETS, RINGS, GROOVED RINGS AND AGGREGATE $\Delta P/L$ (INCHES OF WATER PER FOOT OF PACKED DEPTH)

Spheres	Gas mass velocity (Air) lb/hr/ft²									
	100	200	300	400	500	600	700	800	900	1000
1/8	0.31	0.84	1.6	2.4	3.5	4.7	6,1	7.4	9.2	11.0
3/16	0.17	0.46	0.88	1.4	2.0	2.8	3.6	4.4	5.5	6.7
1/4	0.097	0.27	0.54	0.84	1.3	1.7	2.2	2.7	3.4	4.1
5/16	0.075	0.22	0.43	0.68	0.99	1.4	1.9	2.3	2.9	3.5
3/8	0.059	0.19	0.38	0.61	0.90	1.3	1.7	2.1	2.6	3.1
1/2	0.042	0.13	0.25	0.40	0.59	0.82	1.1	1.4	1.8	2.1
1	0.011	0.036	0.075	0.13	0.19	0.27	0.35	0.44	0.55	0.68
Pellets										
1/8×1/8	0.39	1.0	1.9	2.9	4.2	5.6	7.4	9.1	11.0	14.0
3/16×3/16	0.21	0.59	1.13	1.79	2.6	3.4	4.5	5.5	6.9	8.3
1/4×1/4	0.15	0.46	0.82	1.3	1.9	2.6	3.4	4.2	5.2	6.5
3/8×3/8	0.088	0.26	0.51	0.81	1.2	1.7	2.2	2.7	3.4	4.1
Grooved pellets										
5/32×5/32	0.19	0.53	0.99	1.6	2.3	3.1	4.0	5.0	6.2	7.6
7/32×7/32	0.12	0.33	0.63	1.0	1.5	2.0	2.6	3.2	4.0	4.8
Rings										
1/8×5/16×5/16	0.089	0.26	0.49	0.78	1.2	1.6	2.1	2.7	3.4	4.2
3/16×3/8×7/16	0.052	0.16	0.31	0.51	0.78	1.1	1.5	1.9	2.4	3.0
1/4×1/2×1/2	0.040	0.12	0.24	0.39	0.59	0.84	1.1	1.4	1.8	2.2
Grooved rings										
1/8×5/16×5/16	0.069	0.16	0.32	0.52	0.78	1.1	1.4	1.8	2.3	2.8
Aggregate										
3/5 mesh	0.10	0.28	0.51	0.83	1.2	1.7	2.3	2.7	3.4	4.1

Note: All materials were tested at maximum packing density and minimum bed voidage for the imposed particle to tube geometry.

Gas temperature 77°F
Gas pressure 14.7 psi

Bed diameter 4.03″
Bed height 2′

TABLE 8

SPHERES: CHEMICAL AND PHYSICAL MATERIAL PROPERTIES (APPROXIMATE AVERAGE VALUES)

	Ceramic	Synthetic mullite	Aluminium oxide
Chemical analysis:			
Al_2O_3	23–26	75–77	95–97
SiO_2	69–72	20–22	2.5–3.5
$Na_2O + K_2O$	2.2–3.2	—	—
Na_2O	—	0.4	0.4
K_2O	—	2.4	0.2
$MgO + CaO$	0.06–0.68	—	—
MgO	—	0.5	0.4
CaO	—	0.5	0.4
Fe_2O_3	0.7–1.6	0.7	
No trace of other substances found			
Specific gravity	2.43	3.0	3.6
Bulk weight kg/l	1.4–1.25	1.75	2–2.1
Water absorption (percentage of weight)	0.053	2.0	2.0
Open porosity (percentage of volume)	0.127	3–7	3–7
Fire-resistive quality under pressure according to DIN 1064	ta 1330°C	—	—
	te 1510°C	—	—
Temperature resistance up to	1300°C	1300°C	1650°C
Free space in the filling-bed (per cent, approx.)	30	30	30
Catalytic neutrality	complete		
Resistance to thermal shock	sufficient in all qualities		
Resistance to temperature changes	excellent in all qualities		
Sphere pressure resistance 6 mm diam. 111 kp/sphere	12 mm diam. 114 kp/sphere	20 mm diam. 331 kp/sphere	25 mm diam. 450 kp/sphere

XX. WHITE CORUNDUM CATALYST CARRIERS

As a carrier for catalysts, fused alumina, and here particularly high-purity white corundum, is becoming increasingly important owing to its outstanding quality and regularity of supplies.

The general requirements of the properties of a suitable catalyst carrier, namely abrasion resistance, crushing strength, chemical inertness, thermal stability and good heat conductivity are largely fulfilled in the corundum catalyst carriers, which are therefore particularly suitable for many industrial catalytic processes using fixed bed or fluidized catalysts.

High-purity white corundum is an electrically fused, crushed and sieved alpha-alumina of the highest available purity. It is produced in an electric furnace by a special procedure from selected Bayer process calcined alumina (which itself is largely artificial corundum). The lump ingot is crushed and ground, followed by removal of residual magnetic material by magnetic separators and followed by grading into a great variety of size fractions, from 4 mesh per inch to micron sizes. It is pure white in colour and practically free from objectionable impurities, such as iron or silica. The absence of iron proves beneficial in the preparation of various oxidation catalysts where small amounts of iron cause a detrimental effect as poison to the catalyst activity. The silica-free catalyst carrier is especially suitable for secondary steam reforming where a silica-free type, or a type with a very low silica content, is required to prevent silica transport and contamination of subsequent equipment.

The excellent abrasion resistance, high crushing strength and the non-powdering structure of the corundum catalyst carriers prevents the plugging of the catalyst bed and the contamination of the catalyst and decreases the pressure drop, thus ensuring a longer life for the catalyst. They are capable of withstanding high process temperatures and severe thermal shock. Their high heat conductivity eliminates or greatly reduces the development of "hot spots".

The excellent chemical resistance against attacks by acids or alkalis and chemical inertness and absence of catalyst poisons characterizes the outstanding qualities of the corundum catalyst carriers. Consequently, high-purity white corundum (fused alumina Al_2O_3) can be strongly recommended as an ideal carrier for catalysts.

A further development in this field is the pre-impregnation or pre-coating of the catalyst carrier. For certain requirements, a catalyst carrier can be supplied in a selected grain size provided with pre-impregnation or pre-coating by various metal oxides thus forming a semi-finished product which can then be completed by the user. An example for such a pre-impregnated or pre-coated catalyst carrier is high-purity white corundum coated with vanadium, molybdenum or titanium.

ALUMINA

Alumina, the oxide of aluminium, occurs as corundum which is a hard crystalline mineral. The dark variety of corundum contains magnetite and is known as emery; clear transparent crystals tinted by other metallic oxides are gem stones such as ruby or sapphire. Alumina may be prepared by the ignition of aluminium hydroxide, ammonium alum etc., and from the various natural hydrated oxides of aluminium which occur in the minerals bauxite and gibbsite. Alumina is used in the manufacture of metallic alluminium and synthetic gems, as an abrasive, and in the manufacture of refractory materials. It is polymorphous, existing in a number of crystalline forms, close to the diamond in hardness and has the chemical formula Al_2O_3.

CORUNDUM

Corundum is a mineral composed of aluminium oxide, Al_2O_3, and in its finer varieties forms valuable gems such as ruby and sapphire. The massive form in combination with iron oxides and spinel is called emery. The name corundum is believed to be derived from Hindi (Korund), the mineral first being identified from India.

Next to diamond, corundum is the hardest known mineral (9 on Mohs scale), this being sufficient to separate it from all other minerals. The pure mineral is colourless, small amounts of impurities explaining the wide range of colours in nature. Ruby contains chromium, sapphire presumably iron or titanium; most corundum contains nearly 1% iron oxide. Silimanite, kyanite margarite, damourite and hydrated alumina minerals are common alteration products.

Artificial corundum has similar properties and has become the source of most pure abrasives.

Corundum crystallizes in the hexagonal system (rhombohedral class) showing considerable variety of habit, the commonest being acute hexagonal bipyramids, sometimes in barrel-shaped forms, or tabular owing to predominance of the basal form. Corundum has no true cleavage but a parting parallel, to the base and the rhombohedron, the latter a plane of lamellar twinning sometimes secondarily produced through pressure. Density is 3.95—4.0 g/cm^3, refringence (refraction) as high as 1.7686 (sodium light), melting point 2,040°C, dielectric (nonconductive) constant about 10. Corundum resists attack by acids or alkalis. Alumina-rich melts have great power of crystallization, making it difficult to preserve glasses of such composition. Single crystal alumina bodies can be formed into rods and bent at high temperatures, yet retain noncrystallinity. No other natural Al_2O_3 mineral is known but essentially anhydrous oxides are encountered in laboratory studies, differing distinctly from the alpha-Al_2O_3 or corundum phase into which they transform on heating to about 1,200°C the so-called beta-Al_2O_3 is actually $Na_2O \cdot 11Al_2O_3$ and is not a dimorph of corundum as long was thought.

ARTIFICIAL CORUNDUM[2]

Artificial corundum has the same properties as natural corundum or alpha alumina. The development of techniques around 1900 permitted the large-scale production of artificial corundum. In addition to being very hard

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[2] A. W. Wilkinson, "The production of synthetic abrasives", *Canadian Chemical Processing*, vol. 38, September 1954; A.L. Ball and A.A. Kline, "Application of abrasives", *ASTM Stand.*, bulletin 191 (July 1953).

(9 on Mohs' scale), artificial corundum is very strong. It fractures in such a way that new, sharp cutting points are continuously formed. It has low specific heat and thermal expansion.

Artificial corundum is sometimes known as fused bauxite, or fused alumina, and by trade names such as Alodur, Alundum, Borolon, Aloxite, Lionite and Oxaluma. Fused bauxite is made by melting calcined bauxite (composition approximately 86% Al_2O_3, 7% SiO_2, 3% Fe_2O_3, 3% TiO_2 and 1% water) with coke and metallic iron in electric arc furnaces of several tons capacity, at a temperature of about 2,200°C. Hanging graphite electrodes carry alternating current to the melt. Furnaces are of two types: batch — a removable conical shell on a flat, carbon-lined, wheeled base; and continuous — tilting furnaces from which small pigs can be poured. Furnace shells are water cooled. Large continuous furnaces may operate at several thousand kilowatts.

In batch furnaces, the coke reduces oxide impurities to elements, which unite the added iron to form magnetic ferro-silicon; this settles to the bottom, leaving the alumina in a much purified state. Carbon is eliminated as carbon monoxide (CO) which burns to the dioxide (CO_2) on leaving the furnace. When the furnace is fully charged, the electrodes are withdrawn, and before long the shell can be lifted off to allow the several tons ingot to cool. As it solidifies, the alumina crystallizes into a solid mass of large irregular crystals. Both batch and continuous procedures can be controlled to yield a product containing roughly 95% alumina, 1.5% silica, 0.5% ferric oxide and 3% titania.

The lump ingot is crushed and ground in jaw crushers, rolls and ball mills, followed by removal of residual magnetic material by magnetic separators. Grading into a large variety of size fractions, from 6 mesh per inch to micron sizes, is carried out by vibrating screens, hydroclassifiers and air separators. Fused bauxite is commonly deep reddish-brown in colour and translucent.

The production of white artificial corundum from Bayer process calcined alumina (which itself is largely artificial corundum) has continuously expanded. This employs essentially the same process as for calcined bauxite as described previously, but the starting purity of the alumina (99%) obviates the need of separtion of silicon and iron. Bayer alumina contains some soda, part of which combines with alumina to form so-called beta-alumina, actually $Na_2O.11Al_2O_3$, which is brittle and objectionable in the final product. It may be removed from the cooled batch pig by cooling the central and upper zones where it tends to segregate during crystallization. Other impurities imparting colour to the product are also objectionable. White fused alumina is crushed and sized as fused bauxite is. A special process involving fusion and crystallization in a water-decomposable matrix allows the development of small, sharp, separate crystals that can be recovered as such, avoiding the need of heavy crushing and sizing. Artificial corundum is also produced as a specialty product by slow accretion and controlled growth on a boule in an oxyhydrogen flame.

WHITE CORUNDUM (Al_2O_3)

White corundum is of high purity (fused alpha-alumina Al_2O_3), pure white, meticulously de-ironed, and produced from a selected Bayer process using highly calcined alumina. It is free of objectionable impurities which might prove to be poisonous to many types of catalysts. The sizes of the grains are controlled according to the most advanced techniques in this field and particular methods and criteria have been developed to ensure an excellent and continuously regular quality of the product.

A typical chemical analysis is:

	Per cent
Al_2O_3 (calculated)	99.68
Fe_2O_3	0.03
Na_2O	0.28
TiO_2	under 0.01

The available sizes (mesh) are:

4, 6, 8, 10, 12, 14, 16, 20, 24, 30, 36, 46, 54, 60, 70, 80, 90, 100, 120, 150, 180, 220, 240.

HIGH-PURITY WHITE CORUNDUM

The physical properties are:

Specific gravity	3.97
Hardness (Mohs scale)	9.0
Hardness (Knoop) K 100	2.050
Linear thermal expansion	0.55% (0°–600°C)
Maximal usable temperature	2,000°C(3,632°F)
Colour	pure white
Crystal form	alpha alumina

A typical chemical analysis is:

	Per cent (by difference)
Al_2O_3	99.63
SiO_2	0.04
Fe_2O_3	0.03
TiO_2	0.01
$CaO + MgO$	0.01
Na_2O	0.28
Magnetic iron	traces

Tables 9 and 10 show the number, weight, surface and pressure drop in example contact tubes of 20 and 24 mm diameter with a bed depth of 1 000 mm containing grain sizes 4, 6, 8 and 10[3].

TABLE 9

CONTACT TUBE, 20 mm DIAMETER, DEPTH OF BED 1,000 mm

	Grain size			
	4	6	8	10
Weight (kg)	0.515	0.540	0.565	0.590
Volume (m^3)	3.14×10^{-4}	3.14×10^{-4}	3.14×10^{-4}	3.14×10^{-4}
Number of grains	2 163	5 346	23 268	28 615
Surface (m^2)	0.35	0.507	0.888	1.131
Pressure drop m WC (at 0.5 kg/cm²)	4.970	4.985	4.990	4.993

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[3] See "A survey of developments in reactor technology (Reactors for catalytic gas phase processes)", paper prepared by O.F. Joklik (ID/WG.123/21).

TABLE 10

CONTACT TUBE, 24 mm DIAMETER, DEPTH OF BED 1,000 mm

	Grain size			
	4	6	8	10
Weight (kg)	0.855	0.880	0.910	0.940
Volume (m^3)	4.91×10^{-4}	4.91×10^{-4}	4.91×10^{-4}	4.91×10^{-4}
Number of grains	3 591	8 653	35 269	45 950
Surface (m^2)	0.58	0.796	1.345	1.810
Pressure drop m WC (at 0.5 kg/cm^2)	4.950	4.970	4.979	4.986

XXI. CATALYST CARRIERS DOPED WITH LANTHANIDES

Catalyst carriers doped with lanthanides are a further development in catalyst technology.

Regular catalyst carriers—high-purity white corundum (fused alumina Al_2O_3)—are widely used as catalyst carriers of outstanding quality. The doping of these carriers with lanthanides (the rare earths La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu) and, in some cases, with Y, to the extent of approximately 0.5 to 1.5% by weight is effectuated by adding the proper quantities of lanthanides to alumina and thus a very uniform and regular distribution of the lanthanides within the crystal structure is ensured.

Besides the high-purity white corundum doped with lanthanides, a wide range of catalyst carriers in well-defined, mathematic forms (spheres, pellets, rings, saddles etc.) made of ceramic or pure Al_2O_3, also doped with lanthanides to the extent of approximately 0.5 to 1.5% by weight is available. A percentage up to 5% by weight is possible for certain special carrier formulations. It is also possible to incorporate both alpha- and gamma-phases of alumina in the carrier in suitable and precisely defined proportions.

Alkylation
Catalytic conversion
Catalytic cracking
Catalytic oxidation
Catalytic reforming
Condensation
Dehydrogenation
Desulphurization
Hydrocracking
Hydrodealkylation
Hydrofining
Hydrogenation
Isomerization
Methanation
Shift conversion
Thermal cracking

Alumina in alpha-phase is considered to be a better carrier for certain types of catalyst (i.e. for reforming catalysts) than the alumina in gamma phase due to much higher structural stability and less acidic character of the former[4]. But alumina in gamma-phase is considered to be more active as catalyst carrier, most likely due to its much higher specific surface area[5].

Alumina in gamma-phase is believed to have a large number of acid sites (Lewis), measured by many workers[6]. The presence of acid sites is responsible for carbon deposition according to the mechanism discussed by Applebey and others[7].

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[4] T. Nicklin and R. Whittaker, Inst. Gas. Eng. Jour. **8**:15 (1968).

[5] Tatsuo Yamanaka, Jour. Sci. Research Inst. (Tokyo) **49**:243 (1955); A. Sedzimir, Rocz. Chem. **41**:655 (1967); M. Popowicz, W. Celler, E. Treszczanowicz and W. Romanowski, Przemysl. Chem. **42**:563 (1968); N. S. Repina and N.F. Ermolenko, Zh. Fiz. Khim. **42**:477 (1968); BASF, British patent No. 803,261 of 22 October 1958; J. Misra, D. K. Mukherjee and S. P. Sen, Technol. **7**: 231 (1970); D. K. Mukherjee, J. Misra, S. P. Sen and K. R. Chakravorthy, Technol. **8**:201 (1971).

[6] E. P. Parry, Jour Catalysis **2**:371 (1963); J. E. Mapes and R. P. Eischens, Jour. Phys. Chem. **58**:1059 (1954).

[7] W. G. Applebey, J. W. Gibson and J. M. Good, I. and E. C. Process Design and Development **1**:102 (1962).

Attempts were made to neutralize acid sites of such a catalyst by incorporating some basic components like alkali metal oxides[8]). Although the problem of carbon liberation at an economic steam/carbon ratio with such a catalyst could be avoided to some extent yet the activity is reported to be less with an alkalyzed catalyst[9]). In addition, the problem of loss of alkali from the catalyst during run is also reported[10]).

It is also observed that presence of the major amount of alumina in gamma-phase in catalysts makes the structure of the catalyst unstable due to phase transformation from gamma- to alpha-form, which is accompanied by shrinkage of pores and surface area.

Because of all these problems with alumina in gamma-phase, alumina in alpha-phase which is stable up to 1,500°C and possesses much less acid sites is preferred as a carrier material for certain types of catalysts (i.e. reforming catalysts). Such catalysts are believed to have a better stability.

The structures of both gamma- and alpha-forms of alumina have been discussed in detail by wells from which it is observed that while alumina in alpha-phase has a crystalline structure with hexagonal close-packed lattice, alumina in gamma-phase possesses defect spinel structure with cubic lattice having some vacant metal holes in it[11]). It is probably due to its defect structure that is responsible for a higher surface activity of alumina in gamma-phase than that of alumina in alpha-phase.

So it is probable to achieve a compromise between activity and stability by incorporating both aluminas in alpha- and gamma-phase in the carrier in suitable proportions, With this end view, investigations have been taken up by Misra, Mukherjee and Sen to study the effects of the presence of both alpha-and gamma-phases of alumina in the carrier of steam-naphtha reforming catalyst [12]). The results obtained show that the structural parameters, like crushing strength, pore volume and surface area, increase consistently with increasing concentration of alumina in gamma-phase in the carrier. Higher crushing strength, porosity and surface area of alumina in gamma-phase have also been reported by other authors [13]).

Again, it is observed that compressive strength, specific pore volume and specific surface area of the corresponding catalyst samples also increase steadily with increasing concentrations of alumina in gamma-phase. The percentage of pores in the smallest range, viz. between 4 and 175 Å, increases with the concentration of alumina in the gamma-phase while the same in the higher range, viz. between 500 and 75,000 Å decreases in the same direction.

All these changes in the structural parameters with increasing proportion of alumina in the gamma-phase are favourable for a catalyst.

The weak points of the carrier, i.e. of alumina in the gamma-phase with its defect spinel structure with cubic lattice having some vacant metal holes in it, may be overcome by incroporating rare earths — lanthanides — in the range of some 0.5 to 1.5% by weight. These incorporated rare earths, particularly Sm, Nd, La, and in certain cases Y, function to neutralize the acid sites thus contributing essentially to the prolonged life of the carrier and the catalyst and to its increase of mechanic and thermal stability and resistance.

Besides the merely internal function of the lanthanides in the crystal structure of the carrier, there is observed an increased catalytic activity of the ready-for-use catalyst, as very often and contrary to the general opinion

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[8]) Imperial Chemical Industries, Belgian patent No. 634,920 of 13 January 1964.

[9]) T. Ogura and T. Huzimura, Jour. Chem. Soc. Japan 60:139 (1939); Sydney P. S. Andrews, Ind. and Eng. Chem., Product and Research Development 8(3):321 (1969).

[10]) Sydney P. S. Andrews, *ibid.*

[11]) G. Hagg and G. Soderholm, Z. Physik. Chem. 29B:88 (1935); M. H. Jellinek and I. Fankuchen, Ind. Eng. Chem. 37:158 (1945).

[12]) J. Misra, D. K. Mukherjee and S. P. Sen, Technol. 7:231 (1970).

[13]) BASF, British patent No. 803,261 of 22 October 1958; H. M. Brennah, H. S. Seelig and R. W. Vander Haar, United States patent No. 2,892,799 of 30 June 1959; N. S. Repina and N. F. Ermolenko, Zh. Fiz. Khim. 42:477 (1968).

in this particular field the catalyst carrier has a catalytic effect by itself which increases the importance of a proper choice of the catalyst carrier for all catalytic reactions.

The increased catalytic activity of a catalyst using a carrier doped with lanthanides, the full mechanism being as yet unknown, may be explained by their ready acceptance and rejection of electrons because of their range of valences and consequently by their ability to form complex molecules. Another theory explains the phenomena by considering the catalyst as being and acting as a semi-conductor. Further experimental and analytical work is required to explain the inherent problems.

XXII. TOWER PACKINGS AS CATALYST CARRIERS

INTRODUCTORY REMARKS

In 1873 Robert Ilges built the first industrial packed tower, using a primitive type of packing[14]). Tower packings evolved naturally, from the knowledge that the best conditions for material or heat transfer between materials in the gas or vapour phase gravity could be provided: "By direct contact of the materials involved, on the largest possible surface (inter-face) in very fine sub-division"[14]).

Wherever a purely chemical reaction takes place in these mass-transfer processes, the time of contact between the reagents involved is of great, or even critical importance and has usually to be as long as possible.

In the course of development the fundamental principle became evident, that the results obtained, with economic running—and initial costs would approach the ideal: "In proportion to the extent to which the mathematical form of the packing element, the method of packing, the diameter and height of the column, the intensity and distribution of the gas stream were suited to the particular problem"[14]).

Tower packings of good, averge characteristics should meet, in general, the following conditions:

(a) Vapour must be distributed evenly, and with the maximum dispersion over the whole cross-section, throughout the height of the column;

(b) Vapours should be diverted, redistributed, thoroughly spread into the thinnest possible film and brought into the closest contact on the surface of the tower packings. The path of vapour, as compared with the empty column, must be increased a thousandfold by radial currents and centrifugal action, and by edging. Even when working with relatively high velocities, no entrainment must occur. The frictional resistance must be as low as possible, and the displacement of the packing, small (meaning the free area must be large);

(c) The tower packings must be resistant to attack; resistant to elevated temperatures and thermal shock; of considerable mechanical strength and resistance to abrasion; also of low bulk density.

It is evident that this multiplicity of requirements cannot be met by any one shape or constructional material of the packing. In practice, the chemical engineer or manufacturer has to compromise in choosing packings which will fulfill the majority of requirements, and which are economical at the same time.

Just as optimum conditions for most chemical and physical processes have been determined and are still being developed and brought to perfection, so have the forms of packing been improved and often developed to offer special properties. Here, as everywhere in industry, no finality has been reached, but new ideas and possibilites are being exploited by the invention, of new forms. The progress achieved is evident from a comparison of bulk volumes and surface obtained in various types of packings, as shown below.

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[14]) F. Stage, *Angewandte Chemie*, B (7): 178, (1947).

Packing body	Calculated surface referred to (approx. ft²/ft³)
Three-sided prism	194
Coke, pieces 1"—2"	409
Slats	646
Rectangular prisms	720
Quartz lumps about 1"	1,076
Raschig rings 1"×1"	2,370
Berl saddles 1"	2.800
Super Berl saddles 1"	3,320

Catalytic processes are characterized by changes of reaction velocity brought about by the presence of specific materials which neither appear in the end product nor participate in the reaction itself. Many theories have been developed on the cause of these contact or catalytic phenomena and the literature should be consulted on the subject. Fundamentally they can be explained by chemical and physical forces at the contact surface.

Scientific and experimental research have proved that the contact activity of a material increases in proportion to its accessibility to the reacting molecules. This can be achieved, as in the case of mass transfer processes taking place on packings, by the creation of a very large surface upon which the catalyst is distributed in a thin film. Therefore the carrier has to have a surface which will increase the contact surface of the catalyst.

Apart from highly porous mineral or carbonaceous catalyst carriers in the form of grain or powder (kieselguhr-gel-bauxite-clays, activated carbon) great success has been achieved in certain catalytic processes by the use of ceramic catalyst carriers (porcelain and earthenware) with well-defined geometric forms and with close control of mechanical properties and physical structure, for instance, size of pores, volume of pores, temperature resistance and mechanical strength. It is a further advantage for the granules to be made with a hydrodynamically suitable shape presenting maximum surface with good flow characteristics for contact with the materials to be catalysed. These carriers reduce resistance to the passage of gases through the catalyst layer and also help to promote the even distribution of gases.

For instance Berl saddles with their geometrically ideal form represent an ideal carrier for catalyst, if made in a suitably porous body. They not only provide the largest possible active surface for the finely dispersed catalyst, but are also very suitable for the catalyst, due to the particular shape of the rims.

ACIDUR[15] SPECIAL STONEWARE

This is the most extensively used construction material, possessing almost universal chemical resistance, particularly against all acids (with the exception of hydrofluoric and phosphoric acids and their compounds), in diluted or concentrated form at all chemical compositions. It also possesses very good physical properties as far as strength is concerned; also resistance to high temperature and thermal shock; excellent abrasion resistance against friction, and high tensile and compressive strength.

Resistence to alkalis is only limited. For instance, sodium and potassium hydroxide do not attack in concentrations of, for example, up to 10% at a temperature of 30°C. However, at increasing temperatures and concentrations attack takes place readily.

The raw materials are plastic clays of very high softening point and relatively low sintering point, consisting largely of silica and alumina, with only traces of iron oxide.

The basis for the excellent properties of this stoneware is the highly suitable composition of clays of definite chemical and physical resistance

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[15] Registered trade mark.

combined with a preparation suited to the requirements, comprising firing at 1,200°—1,300°C, thus producing a structure similar to that of glass and of a metallic hardness.

The stoneware has, naturally, a somewhat rough, reticulated surface, which is an important factor in the activation of the surface.

In special cases a smooth, glass-like surface glaze can be provided for the stoneware — so-called salt glaze. This is a sodium silicate glaze produced by the addition of sodium chloride during the burning process. It forms a chemical compound with the alumina and has the same chemical and physical resistance as the stoneware material itself.

It is equally possible to produce a stoneware which, by suitable combination of raw materials, possess a special resistance to high temperature, sudden thermal shock, or any other special property. Porous stoneware can be produced with virtually any degree of porosity up to an absorption of 50% by volume of water. Beyond that, it is possible to formulate materials, consisting almost entirely of pure silica or alumina. These variations are quite easily carried out and permit the optimum material specification for special requirements.

CHEMICAL RESISTANCE

The following determination is made with comminuted material according to the Seger method [16]):

The comminuted stoneware is sifted through standard sieves having 15 and 25 meshes per linear inch respectively. For the purpose of the examination, only grains that are passed by the coarser, and retained by the finer sieve are taken. These grains are freed from adhering dust particles by washing and dried till constant weight is reached. A sample of 100 g of the grains thus obtained is covered in a dish with 200 cm^3 of an acid mixture consisting of 25% sulphuric acid (sp. gr. 1.84); 10% nitric acid (sp. gr. 1.40); and 65% water.

The contents of the dish are boiled until water and nitric acid have completely evaporated. The remaining sulphuric acid is then kept for a further 15 minutes at a constant temperature of 250°C. After cooling, the contents of the dish are diluted, while stirring, with about 800 cc of water, to which 10 cc of nitric acid have been added. The contents of the dish are then brought to boiling once more, the acid liquor poured off, and the grains washed with water, until no more acid can be detected.

After drying, the loss of weight suffered by the grains is determined. On examination, the material showed a loss of weight of 0.0919%. The acid mixture after treatment, was practically clear, so that virtually no loss of material had been suffered by the grains and therefore the loss in weight can be ignored.

The analysis of the comminuted stoneware, after drying, was kept for 72 hours in hydrochloric acid of 22°Bé at 15—20°C, then washed and dried; it showed a loss of weight of 0.15%.

For practical purposes it can be said that the effect of acids on pulverised materials is negligible. This stoneware, therefore, is fully resistant against most acids and acid compounds; also against acid gases and vapours at all temperatures occurring in practice. The sole exception are hydrofluoric and phosphoric acids and their compounds.

ALKALI-RESISTANCE

As already said, the stoneware is only resistant against alkaline reagents at relatively low temperatures and concentrations.

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[16]) Method of the Ceramics Laboratory, Berlin.

TESTS WITH WHOLE PIECES17) (NON-COMMINUTED MATERIAL)

After immersing samples for 20 days in 10% caustic soda at room temperature, no loss of weight could be seen. After storage for the same period in similar concentrations of caustic soda, with the alkaline bath at constant temperature of 30°C, the lowest loss was 138% by weight; the highest loss was 187%. After storage for the same duration in the same concentration of caustic soda at a constant temperature of the liquid of 55°C, the loss amounted to 10.24%.

Further test of whole rings gave the following results:

Initial concentration of lye	**Concentration of lye after 23 days' immersion at room temperature**	**Loss in weight of ring after refluxing for 8 hours following 23 days' immersion**
(percentages)	(percentages)	(loss in weight)
5 NaOH	0.026	1.48
10 NaOH	0.021	3.09
20 NaOH	0.020	5.99
10 soda solution	0.004	

The good resistance of stoneware packing rings was apparent after exposing them for 311 days at 35°C in a stream of gas in which chlorinated compounds were prevalent, while at the same time continuously scrubbing with 5% caustic soda solution.

The physical properties are:

Bulk density:	2.44
Water absorption:	0.11% by weight
Apparent porosity:	0.26% by volume
True density:	2.57
Compressive strength, tested according to German Standard DIN 1604, average value:	43,000 lb/in²
Maximum pressure exerted upon the ring in horizontal position, on the upper most line, only, according to German Standard DIN 1604 average value:	432 lb/in²
Tensile strength:	185—285 lb/in²
Hardness, according to Mohs'scale:	7—8 (quartz hardness)
Refractoriness according to DIN 1063:	Seger Cone 29/30 = = 1,500°C

To ascertain resistance to alternating thermal shock (more than 20 cycles — conditions of the experiment) the material of the test was heated to 200°C; kept there for 1 hour; cooled rapidly in water at room temperature for 5 minutes; and repeated 20 times, after which the material under test was entirely unharmed and free from cracks.

As an example of the resistance to change in temperature which stoneware can withstand, the following case should be mentioned:

In a special travelling furnace called the Wander-Oven, the metal parts traversing the oven are supported on rings of 1″ × 1″ × 1/8″.

These rings are heated fairly rapidly to 1,100°C and cooled equally rapidly, without experiencing the least damage. This is continuously repeated under normal working conditions.

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17) The solubility in 10% soda solution was a fraction lower than in the case of caustic soda. The loss in weight of non-comminuted material in 15% caustic soda, after 40 hours immersion at a constant temperature of plus 80° was 5%.

STRESS CONDITIONS FOR RANDOM PACKED STONEWARE RINGS

The compressive strength of individual rings is so large that in the heights of packing occurring in practice it is not even approached, even on the theoretical assumption that one single ring is carrying the whole load of all rings vertically above it. The initial crushing of rings was found experimentally, according to the requirements of the German Standard DIN 1604 with the following loads:

Stoneware rings (inches)	Load (lb)
1 3/8×1 3/8×5/32	154
2×2×3/16	123
2 3/8×2 3/8×1/4	247
3 3/16×3 3/16×5/16	247

From this the following height of unsupported layers can be found as stated in the original:

Stoneware rings (inches)	Height (ft)
1 3/8×1 3/8×5/32	259
2×2×3/16	92
2 3/8×2 3/8×1/4	144
3 3/16×3 3/16×5/16	85

Under actual conditions the permissible height of packing is much higher than calculated, due to the fact that random packed rings, dependin, on their angle of repose, lose a considerable part of their own vertical thrus sideways to the wall of the column and due to the fact that in random packing some of the rings are lying parallel to the axis, so that the theoretical maximum pressure exerted on the lowest ring, can never really apply.

In those cases where the stoneware packing is stacked, the full specific compressive strength (43,000 lb/in^2) is effective, so that in this case there is virtually no upper limit at all.

In the case of packing rings with perforated walls, which, therefore, have only about 60% of the normal solid surface, the first fractures under the weight of the packing itself, in cases of packings of 2″ × 2″ × 3/16″ occurred as a height of 42 ft.

ANGLE OF REPOSE OF RANDOM PACKED RINGS

In connexion with the angle of repose for rings, the following data are of interest:

Inches	
1 3/8 × 1 3/8	36°
2 × 2	35°
2 3/8 × 2 3/8	40°

DURANIT[18] HARD PORCELAIN

In special cases, for instance when there is alternate exposure to acid and alkalis in low or medium concentration or when it is necessary to have raw material practically free from iron and chemically pure, hard porcelain is indicated.

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[18] Registered trade mark.

It is a material which is most suitable for the processing of highly sensitive materials or alkaline liquors (with a pH higher than 7) at their boiling points and in a number of similar cases, which cannot all be referred to here.

Equally useful is the white, glazed hard porcelain in cases where an absolutely smooth glasslike surface, free from porosity, is required. Chemically the composition of hard porcelain is as follows (partial chemical analysis):

	Approx. per cent
SiO_2	69
Al_2O_3	27
Fe_2O_2	0.32

CHEMICAL RESISTANCE AGAINST ACIDS

Determination with comminuted material according to the Seger method has been described above under "stoneware". The results:

After first test:	0.0146% loss in weight
After second test of the same material:	0.065% loss in weight

ALKALI RESISTANCE

The resuts of determination on comminuted material according to Seger method were:

With 27% caustic soda: 0.462% loss in weight

With 31% caustic potash: 0.5201% loss in weight

The results of determination on whole pieces (non-comminuted material) were:

Packing rings boiled 3 times in 8 hours in 5% caustic soda showed no evidence of any external change in the rings or any changes of the lye.

In another test, six rings, 1″ × 1″ × 1/8″, were dried at 110°C to constant weight. After this, exact measurements and weights of the individual rings were taken, and they were boiled for 8 hours in caustic soda of 15%. The result:

Ring	Loss in weight (gram)	Weight before analysis (percentage)
1	0.3392	2.44
2	0.2489	1.80
3	0.3153	2.22
4	0.2634	1.15
5	0.2514	1.86
6	0.2831	2.00
	1.7013	11.47
Average	0.283	1,91

After treatment with caustic soda as described, no changes in the dimensions of the rings were found. No wasting of the edges of the individual rings was evident. The surface of the rings was found to be merely somewhat dull. Microscopic examination also showed no substantial change in the nature of the surface or of the structure.

In yet another test, hard porcelain rings, 1″×1″×1/8″, were boiled once in 27% and once in 13.5% caustic soda under reflux. The result:

Concentration of lye by weight (percentage)	**Loss in weight (percentage) after** **3 hrs**	**7 hrs**	**11 hrs**
27	2.71	12.06	17.08
27	2.10	11.65	16.04
13.5	1.11	5.38	7.39
13.5	1.03	5.26	7.18

Finally, when hard procelain rings, 1″×1″×1/8″, were immersed for 20 days in a caustic soda solution of 10% concentration, kept at a constant temperature of 55°C, the average loss in weight was 0.627%, by weight.

PHYSICAL CONSTANTS

The physical constants of hard porcelain are:

Bulk density: 2.48
Water absorption: 0.00%
Apparent porosity: 0.00%
Compressive strength: 64.000 lb/in^2
Softening temperature: 1,500°C
Tensile strength: 3,420—4,550 lb/in^2
Transverse strength: 4.265—8,530 lb/in^2
Impact strength: 1.3—1.6 cm/kg/cm^2
Hardness (Mohs): 7—8
Water absorption under 50 atm for one hour: 0.0—0.5% by weight

CRUSHING RESISTANCE OF RANDOM PACKED HARD-PORCELAIN RINGS

The diametric compressive strength is 240 lb/in^2 in rings of 1″×1″×1/8″, as an average value (i.e. an actual load of 240 lb for the 1″ ring).

From this follows a strength equivalent to 105 ft height of column even on the assumption, which cannot arise in practice, that a single ring has to carry the whole load of superimposed rings. The actual compressive strength is very much higher.

Resistance to alternating thermal shock is in excess of 20 cycles between the limits of 0°—800°C.

XXIII. APPROXIMATE DATA FOR CATALYST CARRIERS

The pressure drop for stacked rings, which almost exclusively applies to the larger sizes for the larger towers, is generally of no importance. The total pressure drop is small and has no influence upon the total quantity of gas passed. An estimate is very difficult to give, even in cases of normal low gas velocities in larger towers, because the bouyancy and natural draught of hot gases is comparable with the relatively low resistance.

Considerable progress in reducing the necessary resistance has been made by the introduction of Berl saddles. This is shown by the comparison of pressure drop in a dry column of 3.28 ft packed height, through which air is passed at a velocity of 3.28 ft per second, calculated upon the free area of the column.

Size of tower packing (inches)	Pressure drop in inches W.G. Berl saddles, porcelain	Pressure drop in inches W.G. Raschig rings, porcelain
3/8	3.1	
5/16		5.6
5/8	1.65	2.64
1	0.87	1.30

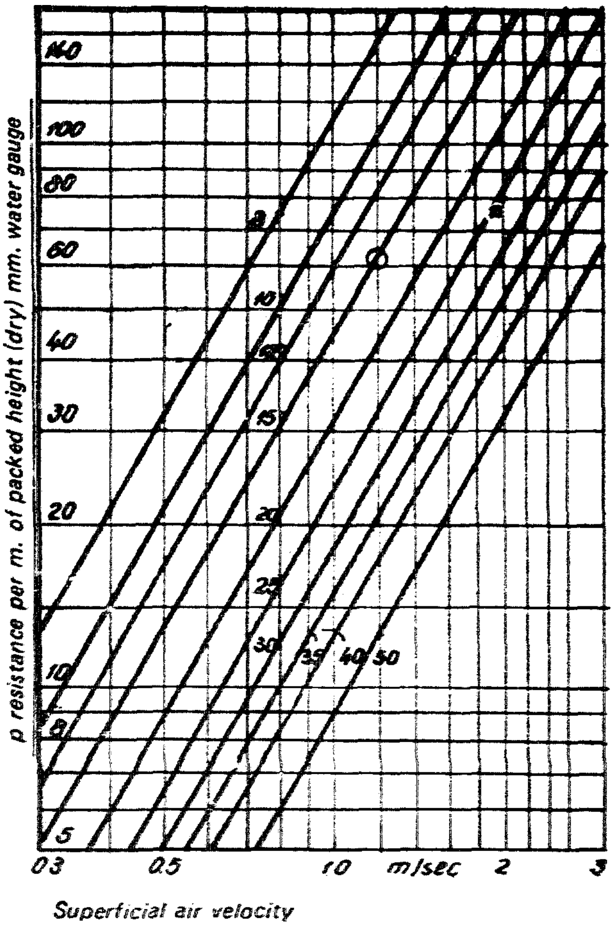


Figure IV. Resistance properties of dry packing body

Under conditions of equal resistance, Berl saddles provide a surface which is approximately 80% larger than that of Raschig rings. Similar differences in pressure drop is more evident in other sizes, and in wetted packed columns, in favour of Berl saddles. The reason lies in the better aero-dynamic, or streamlined form of Berl saddles. The difference in pressure drop is more evident with increase in gas velocity, that is taking into account the gas loading of a packed column. Berl saddles remain the shapes of lowest resistance.

Figure IV shows the resistance properties of a dry, packing body. The pressure drop refers to air of a density of 1.2 kg/m^3. When the gas density (γL) varies, the pressure drop >p also varies, at the rate of γ0.83. The pressure drop is directly proportional to the height of packing. The total values of pressure drop for packings of stoneware or hard porcelain.

TABLE 11

APPROXIMATE DATA FOR STONEWARE RINGS (RASCHIG TYPE)

Dimensions (inch)			Weight (lb/ft^3)		Total surface (approximately ft^2/ft^3)	
Outside diameter	Height	Wall thickness	Random packed	Stacked	Random packed	Stacked
3/16	3/16	3/64	56	—	305	—
5/16	5/16	1/16	53	—	167	—
3/8	3/8	5/64	50	—	134	—
1/2	1/2	5/64	45	—	110	—
5/8	5/8	5/64	44	—	101	—
3/4	3/4	3/32	40	—	85	—
1	1	1/8	38	—	59	—
1 3/16	1 3/16	5/32	37	—	52	—
1 3/8	1 3/8	5/32	34	52	43	64
1 5/8	1 5/8	5/32	32	49	38	58
2	2	13/64	32	42	33 1/2	46
2 3/8	2 3/8	1/4	33	42	24	32
2 3/8	2 3/8	5/16	39	45	24	32
2 3/4	2 3/4	9/32	33	42	22	29 1/2
3 1/8	3 1/8	5/16	34	49	18 1/2	24 1/2
3 1/8	3 1/8	13/32	36	51	18 1/2	24 1/2
4	4	13/32	28	39	13 1/2	20
4 3/4	4 3/4	1/2	26	36	10 1/2	14 1/2
6	6	5/8	—	37	—	13 1/2
8	8	5/8	—	28	—	10

TABLE 12

APPROXIMATE DATA FOR STONEWARE RINGS WITH PARTITION

Dimensions (inch)			Weight (lb/ft^3)		Total surface (approximately ft^2/ft^3)	
Outside diameter	Height	Wall thickness	Random packed	Stacked	Random packed	Stacked
2	2	13/64	36	53	36 1/2	53
2 3/8	2 3/8	1/4	37	56	27 1/2	40
2 3/4	2 3/4	9/32	36	54	26	36 1/2
3 1/8	3 1/8	5/16	35	50	24	33 1/2
4	4	13/32	33	45	20	27 1/2
4 3/4	4 3/4	1/2	31	42	14 1/2	27 1/2
6	6	5/8	—	49	—	20
8	8	5/8	—	37	—	13 1/2

TABLE 13

APPROXIMATE DATA FOR SOLID SPHERES IN STONEWARE

Diameter of spheres (inch)	Number of spheres (per ft^3)	Approximate weight (lb/ft^3)	Total surface (ft^2/ft^3)
13/64	225,000	74	191
5/16	55,300	75	119
13/32	28,300	76	96
1/2	14,500	66	70
5/8	8,380	74	64
3/4	3,540	75	48
1	1,810	75	38
1 3/16	1,050	75	32
1 3/8	625	71	251/2
2	225	75	19

TABLE 14

APPROXIMATE DATA FOR HARD PORCELAIN RINGS (RASCHIG TYPE)

Approximate size (inch)	Weight random packed (lb/ft^3)	Number of pieces per ft^3 random pieces	Total surface random packed (ft^2/ft^3)
1/4×3/64	57	113,000	274
5/16×3/64	49	38,500	183
13/32×1/16	47	20,000	134
1/2×5/64	46	11,600	122
5/8×5/64	42	6,200	94
3/4×5/64	40	2,800	91
1×1/8	37	1,400	67
1 3/16×1/8	35	850	58
1 3/8×5/32	34	525	43
2×13/64	32	170	33 1/2

TABLE 15

APPROXIMATE DATA FOR BERL SADDLES (WITH REINFORCED RIM) MADE OF STONEWARE AND HARD PORCELAIN ABRASION RESISTANT

Size (inch)	Active surface (ft^2/ft^3) random packed	Weight (lb/ft^3)	Number of pieces per ft^3 random packed	Packing factor
5/32×5/32	610	69	623,000	1.20
1/4×1/4	351	56	146,000	1.11
5/16×5/16	299	53	62,000	1.10
3/8×3/8	220	50	29,000	1.20
5/8×5/8	137	47	7,900	1.15
1×1	79	44	2,120	1.23
1 3/8×1 3/8	54	41	710	1.24
2×2	37	37	225	1.23

CARRIERS FOR CATALYSTS: TYPICAL PROPERTIES OF ALUMINAS AND SILICA-ALUMINAS

TABLE 16

	Fluid powders			Tablets			Extrudates			Beads[b] 1—2 mm	Tablets		Extrudates	
											Silica-alumina			
	Alumina grade A	High purity fluid[a] alumina	Alumina grade B	000-5P	000-3P	High purity CK-200	High purity CK-300	000-1.5E	000-3E		HA-3P	LA-3P	HA-1.5E	85/15 000-3E
Chemical properties														
Loss on heating 1 hr 1000°C wt%wb	23.5	29.7	33.2	3.2	6.1	1.2	1.5	7.3	2.5	1.6	2.6	3.6	4.6	1.16
SiO_2 wt%db	2.58	0.012	0.85	1.25	0.84	0.0050	0.0060	1.18	1.02	0.2	balance	balance	balance	18.1
Al_2O_3 wt%db	balance	balance	balance	balance	balance	balance	balance	balance	balance	balance	24.9	15.4	25.3	balance
Na_2O wt%db	0.028	0.0010	0.045	0.087	0.10	0.0004	0.0010	0.019	0.059	0.09	0.010	0.007	0.015	0.055
SO_4 wt%db	1.01	0.00	1.84	2.40	1.05	0.09	0.00	1.70	0.79	1.7	0.67	0.13	0.88	0.68
Fe wt%db	0.23	0.0074	0.019	0.020	0.024	0.0131	0.0100	0.023	0.046	0.05	0.017	0.016	0.028	0.47
Total other metals wt%db	—	0.0100	—	—	—	0.0100	0.100	—	—	—	—	—	—	—
Physical properties														
Particle diameter mm	—	—	—	4.6	3.2	3.0	1.5	1.5	2.5	1.5	3.0	3.1	1.6	2.5
Particle size bistridution														
— 140 micron wt%	94.4	100	98.2	—	—	—	—	—	—	—	—	—	—	—
— 105 micron wt%	75.9	—	69.6	—	—	—	—	—	—	—	—	—	—	—
— 74 micron wt%	50.0	99.8	40.9	—	—	—	—	—	—	—	—	—	—	—
— 40 micron wt%	25.5	96	5.9	—	—	—	—	—	—	—	—	—	—	—
Surface area m^2/g	303	336	327	265	266	145	180	276	252	240	428	485	407	334
Pore volume ml/g	0.51	0.55	1.55	0.90	0.81	0.40	0.45	0.53	0.58	0.95	0.60	0.55	0.67	0.59
Apparent bulk density g/ml	0.86	—	0.35	—	—	—	—	—	—	0.50	—	—	—	0.58
Estimated reactor density g/ml	—	—	—	0.48	0.54	0.50	0.60	0.64	0.58	0.52	0.58	0.57	0.47	0.50
Abrasion wt%	—	—	—	0.9	0.7	0.7	0.5-1.0	0.6	0.6	1.3	1.7	4.2	0.1	1.2
Attrition wt%	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Bulk crushing strength kg/cm^2	—	—	—	11.4	13.5	—	—	0.7	—	20.1	13.1	10.5	8.1	12
Average crushing strength lb	—	—	—	32.3	11.7	29	18	20.8	—	3.8	14.2	9.3	14.1	10
Average length mm	—	—	—	5	3	3.0	6	3.3	2.9	—	3	3	5.6	6

[a] Also available in average part size of 70 micron.

[b] Sizes available (mm): 0.4—0.7
0.7—1.0
1.0—2.0
2—3
3

Part five

Catalyst manufacturers

XXIV. ALPHABETICAL INDEX OF CATALYST MANUFACTURERS

AIR PRODUCTS AND CHEMICALS INC. (Houdry)
Five Executive Mall, Swedesford
Wayne, Pa. 19087, United States

AKZO CHEMIE B. V. Dpt. Ketjen Catalysts
(KETJEN)
P.O. Box 15, 1–3 Nieuwendammerkade
Amsterdam, Netherlands

ALLIED CHEMICAL CORPORATION
Speciality Chemicals Division
P.O. Box 70, Morristown
New Jersey 07960, United States

ALUMINIUM COMPANY OF AMERICA (ALCOA)
1501 Alcoa Building, Pittsburgh
Pennsylvania 15219, United States

AMERICAN CYANAMID COMPANY
Refinery Chemicals Dept.
Bound Brook, New Jersey 08805
United States

AMERICAN LAVA, 3 M Company
Technical Ceramic Products Division
and Manufacture
Cherokee Boulevard, Road Chattanooga
Tennessee, United States

ANDERSON DEVELOPMENT COMPANY
1415 East Michigan Street
Adrian, Michigan 49222, United States

AZOTE ET PRODUITS CHIMIQUES S.A. (APC)
Division produits chimiques-catalyseurs
62–68, rue Jeanne d'Arc,
75646 Paris, Cedex 13, France

BADISCHE ANILIN UND SODA FABRIK A.G. (BASF)
D 6700 Ludwigshafen
Federal Republic of Germany

BAYER A.G.
D 509 Leverkusen
Federal Republic of Germany

CALSICAT DIVISION, MALLINGRODT CHEMICAL WORKS
1707 Gaskell Avenue, Erie
Pennsylvania 16503, United States

CATALYSTS AND CHEMICALS INC. (CCI)
1227 So. Twelfth Street, P.O. Box 86
Louisville, Kentucky 40201
United States

CATALYSTS AND CHEMICALS INC: FAR EAST (CCIFE)
Sankaido Building 9–13, 1-chome
Akasaka, Minato-ku, Tokyo, Japan

CATALYSTS AND CHEMICALS EUROPE (CCE)
Place du Champ Mars 2
B 1050 Brussels, Belgium

CATALYSTS AND CHEMICALS INDIA (WEST ASIA) (CCIWA)
240 D, Naoroji Road
Bombay 1, India

CATALYSTS AND CHEMICALS INDUSTRIES CO. LTD (CCIC)
6–2, 2-chome, Otemachi
Chiyoda-ku, Tokyo, Japan

CATALYST DEVELOPMENT CORPORATION
59 Industrial Avenue, Little Ferry
New Jersey, United States

CHEMETRON CHEMICALS, Girdler
Catalysts Department
4900 Crittenden Drive, P.O. Box 337
Lousiville, Kentucky 40201
United States

CHEMICAL WORKS OF CZECHOSLOVAK-SOVIET FRIENDSHIP (CSF) (CHEZA CATALYSTS)
Zaluzi v Krusnych, Czechoslovakia

CHEMIE LINZ A. G.
St. Peter 224, P. O. Box 296
A 4021 Linz, Austria

CHEMVIRON S. A. (Subsidiary of Calgon Corporation, USA)
P.O. Box 17, Ixelles 1-B
1050 Brussels, Belgium

CIECH-NITRO PLAST
Ul. Jasna 12, Warsaw, Poland

COMBINATUL CHIMIC CRAIOVA
Craiova, Romania

COMPTOIR LYON ALLEMAND, LOUYOT ET CO.
13, rue de Montmorency
75003 Paris, France

JOSEPH CROSFIELD AND SONS LTD (CROSSFIELD CHEMICALS)
Bank Quay, Warrington, England

CYANAMID INTERNATIONAL, Division of American Cyanamid Co.
Wayne, New Jersey 07470, United States

DEGUSSA A.G., Catalysts Division
Zweigniederlassung Hanau, P.O. Box 622
D 6450 Hanau, Federal Republic of Germany

E. I. DU PONT DE NEMOURS AND CO.
Wilmington, Delaware 19898
United States

DR. E. DÜRRWÄCHTER DODUCO K.G. (DODUCO)
P.O. Box 245
D 6920 Sinsheim/Elsenz
Federal Republic of Germany

ENGELHARD SALES LTD, Chemical Division
Valley Road, Cinderford
Gloucester, England

ENGELHARD MINERALS AND CHEMICALS CORP.
113 Astor Street, Newark
New Jersey 07114, United States

FARBWERKE HOECHST A.G.
D 6230 Frankfurt/Main 80
Federal Republic of Germany

FERTILIZER CORPORATION OF INDIA (FCI)
Planning and Development Division
Sindri, Dhanbad, Bihar, India

GIRDLER-SÜDCHEMIE KATALYSATOR GmbH
Lenbachplatz 6, P.O.Box 201003
D 8 Munich, Federal Republic of Germany

GRACE DAVISON CHEMICAL, W. R. GRACE and CO
Davison Chemical Division
Baltimore, Maryland 21203, United States

GRILLO-WERKE A.G.
Duisburg, Hamborn
Federal Republic of Germany

THE HARSHAW CHEMICAL COMPANY
1945 East 97th Street
Cleveland, Ohio 44106, United States

HARSHAW CHEMIE B. V.
Strijkviertel 95, P. O. Box 19
De Meern, Netherlands

W.C. HERAEUS GmbH, Werksgruppe Metalle
D 645 Hanau, Federal Republic of Germany

HYDRONYL-NORTON LTD
King Street, Fenton,
Stoke-on-Trent ST4 2LT, England

IMPERIAL CHEMICAL INDUSTRIES LTD (ICI)
P.O. Box 1, Billingham
Teesside, England

ISC CHEMICALS LTD
St. Andrews Road, Avenmouth
Bristol BS11 9HP, England

KALI-CHEMIE ENGELHARD KATALYSATOREN GmbH
D 3000 Hannover, Federal Republic of Germany

KATALCO CORPORATION
180 North Michigan Avenue
Chicago, Illinois 60601, United States

KATALYSATORENWERKE HOUDRY-HÜLS GmbH
D 4370 Marl, Federal Republic of Germany

KAWAKEN FINE CHEMICALS CO. LTD
Ogura Bldg. 1—2—chome, Kofune-cho
Nihonbashi, Chuo-ku, Tokyo, Japan

KEMIRA OY
P.O. Box 330
SF 00101 Helsinki 10, Finland

KOCH LIGHT LABORATORIES LTD
Colnbrook, Bucks SL3 OBZ, England

KÖNIGSWARTER UND EBELL CHEMISCHE FABRIK GmbH
D 58 Hagen, Dieckstrasse 42
Federal Republic of Germany

LAPORTE INDUSTRIES LIMITED, General Chemical Division, Spence Works
Morrfield Road, Widness
Lancashire, England

VEB LEUNA WERKE „WALTER ULBRICHT"
422 Leuna 3, German Democratic Republic

M and T CHEMICALS INC.
American Lane, Greenwich
Connecticut 06830, United States

MINERALS AND CHEMICALS CORPORATION OF AMERICA
Menlo Park, New Jersey, United States

MONSANTO COMPANY
800 N. Lindbergh Blvd.
St. Louis Missouri 63166, United States

MONTEDISON S.P.A.
Piazza della Republica, 14/16
20124 Milan, Italy

NALCO CHEMICAL COMPANY, Petroleum Division, Refinery Chemicals
1800 Esperson Building
Houston, Texas 77002, United States and
4001 W. 71st St., Chicago,
Illinois 60629, United States

NISSAN CHEMETRON CATALYST LTD
2 fl. Shinjo Bldg., No. 9, 2-chome
Ta-cho, Kanda, Chiyod-ku, Tokyo, Japan

NORTON INC., Chemical Process Products Division
P.O. Box 350
Akron, Ohio 44309, United States

ÖSTERREICHISCHE HIAG WERKE A.G.
Glückgasse 2
A 1015 Vienna, Austria

POROCEL CORPORATION (Subsidiary of Engelhard Minerals and Chemicals Corp.)
Menlo Park, Edison, New Jersey
United States

PRESSURE CHEMICALS CO.
3419 Smalman St., Pittsburgh
Pennsylvania 15201, United States

PRICE PEARSON REFRACTORIES LIMITED
P.O. Box 9, Moor Street, Brierley Hill
Staffordshire DY5 3SY, England

RIKKIHAPPO OY
P.O. Box 10330, Helsinki 10, Finland

SAKAI CHEMICAL INDUSTRY CO. LTD
Ebisujima-cho,
Sakai City, Osaka, Japan

SHELL CHEMICAL COMPANY
One, Shell Plaza, P.O. Box 2463
Houston, Texas 77001, United States

SOCIÉTÉ CHIMIQUE DE LA GRANDE PAROISSE
(AZOTE ET PRODUITS CHIMIQUES)
8, rue Cognac-Jay
75007 Paris, France

SOCIÉTÉ FRANÇAISE DES PRODUITS POUR CATALYSE (PRO CATALYSE), Subsidiary of Rhone-Progil S.A., Institut Français du Petrole
6, rue Piccini, 75016 Paris, France

SOCIÉTÉ FRANÇAISE D'OXYCATALYSE OXY-FRANCE
(145, rue Pierre de Montreuil-sous-Bois
Seine), Paris, France

SOJUZCHIMEXPORT
Smolenskaja Sennaia 32–34, Moscow, USSR

STAUFFER CHEMICAL COMPANY, Speciality Chemical Division
Westport, Connecticut 06880, United States

STAUFFER CHEMICAL EUROPE A.A.
25, rue des Caroubiers
CH-1227 Geneva, Switzerland

STREM CHEMICALS INCORPORATED
150 Andover Street
Danvers, Massachusetts 01923, United States

TITANIUM INTERMEDIATES LIMITED
10 Stratton Street
London W1, England

TOHO TITANIUM CO. LTD
3 Aoi-cho, Akasaka, Na[illegible]-ku
Tokyo, Japan

HALDOR TOPSØE A/S
Telefonvej 6, Søborg, Denmark

TREIBACHER CHEMISCHE WERKE A. G. (TCW)
P.O. Box 31
A 9330 Treibach/Kärnten, Austria

UEB INDUSTRIES LTD
7–2, Kasumigaseki, 3-chome
Chiyoda-ku, Tokyo, Japan

UNICHEMA CHEMIE GmbH
P.O. Box 1280, D 4240 Emmerich/Rhein
Federal Republic of Germany

UNION CARBIDE CORPORATION, LINDE DIVISION
Molecular Sieves Products
270 Park Avenue
New York, New York 10017, United States

UNIVERSAL OIL PRODUCTS COMPANY (UOP)
Tokeneke Road
Darien, Connecticut 06820, United States

VEB CHEMISCHE WERKE BUNA
4212 Schkopau über Merseburg
German Democratic Republic

VEB FARBENFABRIK WOLFEN
444 Wolfen 1, German Democratic Republic

VEREINIGTE FÜLLPER-FABRIKEN GmbH UND CO (VFF)
Ransbach-Baumbach/Westerwald
Federal Republic of Germany

WAKO PURE CHEMICAL INDUSTRIES LTD
10 Doshomachi, 3-chome, Higashi-ku
Osaka, Japan

XXV. INDEX OF CATALYST MANUFACTURERS BY MAIN INDUSTRIAL PROCESSES

Steam reforming

APC
BASF
CCI
Craiova
FCI
Girdler
Grande Paroisse
Heraeus
ICI
Katalco
Leuna
Pro-catalyse
Topsøe

Low temperature shift

CCI
FCI
Girdler
ICI
Leuna
Topsøe

High temperature shift

APC
BASF
CCI
CSF
Craiova
FCI
Girdler
Grande Paroisse
ICI
Katalco
Leuna
Montedison
Topsøe
Ube

Methanation

BASF
CCI
Degussa
FCI
Girdler
Grande Paroisse
Harshaw
Hoechst
ICI
Katalco
Leuna
Pro-catalyse
Topsøe

Ammonia synthesis

APC
BASF
CCI
CSF
Craiova
Girdler
Grande Paroisse
ICI
Katalco
Montedison
Sojuzchimexport
Topsøe
Chemie Linz

Acrylonitrile

Akzo
Leuna

Formaldehyde

Degussa
Doduco
Girdler
Johnson Matthey
Leuna
Montedison
Topsøe
Hiag

Maleic anhydride

CDC
Montedison

Methanol

BASF
CCI
Degussa
Harshaw
ICI
Leuna
Montedison
Pro-catalyse
Topsøe

Oxo-synthesis

CCI
Girdler
Harshaw
Leuna

Phthalic anhydride

BASF
Cyanamid
Davison
TCW

Styrene

BASF
Buna
CCI
CSF
Girdler
Shell
Strem

Vinyl acetate

Bayer
Buna
CCI
Calsicat
Ciech
Craiova
Harshaw
Montedison
Strem

Vinyl chloride

BASF
Buna
Calsicat
CCI
Harshaw
Houdry
Montedison
Strem

Nitric acid

CCI
Comptoir Lyon
Engelhard
Johnson Matthey

Sulphuric acid

BASF
CCI
Cyanamid
Girdler
Grillo
ISC
Monsanto
Montedison
Rikkihappo
Topsøe
Wolfen

Alkylation

CCI
Allied Chemical
Davison
Girdler
Harshaw
Heraeus
Pro-catalyse
Strem
UCC/Linde

Fluid cracking

CCI
Cyanamid
Davison
Houdry
Minerals and Chemicals
Akzo

Hydrocracking

Harshaw
Nalco
Strem

Cat-cracking

Allied Chemical
CSF
Pro-catalyse
Strem

Fixed bed cat-cracking

Houdry

Dehydrogenation

BASF
CCI
CSF
Davison
Degussa
Doduco
Girdler
Harshaw
Houdry
Kawaken
Leuna
Pro-catalyse
Sakai
Strem

Sulphur removal

APC
CCI
FCI
Girdler
Grande Paroisse
Harshaw
Houdry
Katalco
Laporte
Leuna
Sakai
Topsøe

Desulphurization

CCI
Girdler
Grande Paroisse
Harshaw
Houdry
ICI
Katalco
Pro-catalyse

Hydrodesulphurization

Akzo
CCI
Cyanamid
Girdler
Grande Paroisse
Harshaw
Houdry
ICI
Katalco
Laporte
Leuna
Nalco
Pro-catalyse
Strem
Topsøe

Guards for LTS

CCI
FCI
ICI

Halogenation

Harshaw
Sakai

Dehalogenation

Harshaw

Dehydrochlorination

CCI
Strem

Hydrotreating

Akzo
CCI
CSF
Cyanamid
Pro-catalyse
Shell

Ammonolysis

Girdler
Harshaw
Hoechst
Leuna

Hydrogenation of aromatic hydrocarbons

Calsicat
Cyanamid
Davison
Degussa
Doduco
Engelhard
Girdler
Harshaw
Heraeus
Houdry
Pro-catalyse
Strem

Hydrogenation of carbonyl compounds

Calsicat
CCI
Ciech
Craiova
Crosfield
Degussa
Doduco
Hoechst
Girdler
Harshaw
Heraeus
Houdry
Strem
Unichema

Hydrogenation of carbon double bonds

BASF
Buna
Calsicat
Ciech
Crosfield
Degussa
Doduco
Girdler
Harshaw
Hoechst
Houdry
Kawaken
Leuna
Strem

Hydrogenation of esters and acids

Degussa
Doduco
Girdler
Harshaw
Houdry
Königswarter
Leuna
Sakai
Unichema

Hydrogenation of functional groups

Engelhard
Girdler
Leuna

Hydrogenation of nitriles

Davison
Harshaw

Heraeus
Houdry
Kawaken
Leuna
Strem
Unichema

Hydrogenation of nitrocompounds

CCI
Davison
Harshaw
Hoechst

Hydrogenation (general)

BASF
Bayer
Calsicat
CCI
CSF
Degussa
Doduco
Girdler
Harshaw
Heraeus
Houdry
ICI
Johnson Matthey
Kawaken
Pro-catalyse
Sakai
Strem
Unichema
UCC/Linde

Selective hydrogenation

BASF
Calsicat
CCI
Crosfield
Degussa
Girdler
Grande Paroisse
Harshaw
Hoechst
Houdry
ICI
Leuna
Strem
Sakai

Isomerization

Allied Chemical
BASF
Davison
Harshaw
Houdry
Kali-Engelhard
Leuna
Pressure Chemicals
Strem
UCC/Linde

Oxidation

Alcoa
Anderson
BASF
CCI
CDC
Degussa
Harshaw
Heraeus

Montedison
Leuna
Porocel
Pro-catalyse
Sakai
Shell
Strem
TCW

Polymerization

Allied Chemical
Anderson
CCI
Davison
Doduco
Harshaw
Houdry
M and T chemicals
Pressure Chemicals
Pro-catalyse
Stauffer
Strem
Toho Titanium
Texas Alkyls

Dimerization

Pressure Chemicals

Cyclic oligomerization

Strem

Purification by combustion

Alcoa
Degussa
Doduco

Purification of gases

CSF
Degussa
Doduco
Girdler
Grande Paroisse
Harshaw
Heraeus
ICI
Johnson Matthey
Kali-Engelhard
Leuna
Montedison
Pro-catalyse
Sakai
UOP
Wolfen

Purification by hydrotreating

BASF
CCI
Cyanamid
Grande Paroisse
Harshaw
Hoechst
Leuna

Denitrogenation

CCI
Degussa

Harshaw
Pro-catalyse

Desoxygenation

BASF
CCI
CSF
Doduco
Girdler
Grande Paroisse
Harshaw
Hoechst
Leuna

Steam reforming

APC
BASF
CCI
Cyanamid
FCI
Girdler
Grande Paroisse
Harshaw
Houdry
ICI
Kali-Engelhard
Katalco
Laporte
Leuna
Montedison
Price Pearson
Pro-catalyse
UCC/Linde

Petroleum refining

Harshaw

Ammonia dissociation

BASF
CCI
Doduco
FCI
Girdler
Harshaw
ICI
Pro-catalyse
Topsøe

Cyclization – dehydrocyclization

Harshaw
Leuna

Esterification-interesterification

CSF
Ciech
Girdler
Harshaw
Titanium Intermed.

Hydration – dehydration

Alcoa
BASF
CCI

CSF
Davison
Harshaw
Houdry
Leuna
Strem

Acid catalysed reactions

Girdler

Catalytic alumina

Alcoa

Hydroformylation (lst step Oxo-reaction)

Harshaw
Pressure Chemicals
Strem

Disproportionation

CSF
Ciech
Pressure Chemicals
Strem

Homogeneous catalysts

Anderson
Degussa
Harshaw
M + T Chemicals
Pressure Chemicals
Stauffer
Strem
Texas Alkyls

Carriers

Akzo
American Lava
Alcoa
BASF
Calsicat
CCI
CSF
Chemetron
DuPont
FCI
Grace
Heraeus
Houdry
Hydronyl-Norton
ICI
Laporte (Spence)
Leuna
Norton
TCW
VFF
Strem

XXVI. INDEX OF CATALYST MANUFACTURERS, INDICATING MAIN CATALYSTS PRODUCED BY COUNTRY

Austria

Chemie Linz A. G.
St. Peter 224
4020 Linz
Ammonia synthesis catalyst
Cracking catalysts

Österreichische Hiag Werke A.G.
Gluckgasse 2
1010 Vienna
Fox-Hiag Formaldehyde synthesis catalyst

Treibacher Chemische Werke A. G. (TCW)
P.O. Box 31
9330 Treibach
Oxidation catalysts (Phthalic anhydride catalyst)
Corundum catalyst carriers
Catalyst chemicals

Belgium

Catalysts and Chemicals Europe S.A. (CCE)
Place du Champs de Mars 2
1050 Brussels

Chemviron S. A.
Ixelles 1-B, P.O. Box 17
1050 Bruxelles

Bulgaria

Naftochim
11 August Street
Sofia, No. 6

Canada

Nalco Catalyst Co. Ltd
Edmonton, Alberta
Vistron Canada Ltd

Czechoslovakia

Chemical Works of Czechoslovak-Soviet Friendship (CSF)
Zaluzi v Krusnych Harach

Denmark

Haldor Topsøe A/S
Telefonvej 6, P.O. Box 49
2860 Søborg

Finland

Kemira Oy
P.O. Box 330
00101 Helsinki 10

Rikkihappo Oy
P.O. Box 10330
Helsinki 10
Sulphuric acid catalyst

France

Azote et produits chimiques S.A. (APC)
11, Avenue de Friedland
75008 Paris
Division produits chimiques — catalyseurs
62—68, rue Jeanne d'Arc
75646 Paris, Cedex 13
Catalysts for reforming, shift, ammonia synthesis, sulphur removal

Comptoir Lyon allemand, Louyot et Co.
13, rue de Montmorency 75003 Paris
Nitric acid catalyst

Pechiney
23, rue Balzac
75008 Paris

Pechiney-Saint Gobain
63, rue de Villiers
97 Neuilly-sur-Seine

Rhone-Poulenc (Ste. des usines chimiques)
22, avenue Montaigne
75008 Paris

Rhone-Progil
47, rue de Villiers
97 Neuilly-sur-Seine

Société chimique de la Grande Paroisse
(Azote et produits chimiques)
8, rue Cognacq-Jay
75007 Paris
Catalysts for reforming, shift, methanation, ammonia synthesis, sulphur removal, desulphurization, hydrodesulphurization, selective hydrogenation, purification of gases, purification by hydrotreating, desoxygenation

Société française des produits pour catalyse
(pro catalyse)
Subsidiary of Rhone-Progil S.A. — Institut français de petrole
6, rue Piccini
75016 Paris
Catalysts for reforming, methanation, methanol synthesis, alkylation, cat-cracking, dehydrogenation, desulphurization, hydrodesulphurization, hydrotreating, hydrogenation, oxidation, polymerization, purification of gases, denitrogenation, ammonia dissociation

Société française d'oxycatalyse oxy-france
145, rue Pierre de Montreuil
93 Montreuil-sous-Bois

German Democratic Republic

Veb Chemische Werke Buna
4212 Schkopau, Merseburg 49
Catalysts for styrene, vinyl chloride, hydrogenation

Veb Farbenfabrik Wolfen
444 Wolfen 1
Sulphuric acid catalyst

Veb Leuna Werke “Walter Ulbricht“
422 Leuna 3, Merseburg 430
Catalysts for reforming, shift, methanation, acrylonitrile, formaldehyde, methanol, oxo-synthesis, dehydrogenation, desulphurization, hydrogenation, isomerization, oxidation, purification of gases, hydration, catalyst carriers

Germany, Federal Republic of

Badische Anilin und Soda Fabrik A.G. (BASF)
6700 Ludwigshafen
Catalysts for reforming, shift, methanation, ammonia synthesis, methanol, phthalic anhydride, maleic anhydride, styrene, vinyl chloride, sulphuric acid, dehydrogenation, hydrogenation, isomerization, oxidation, purification by hydrotreating, desoxygenation, ammonia dissociation, hydration, catalyst carriers

Degussa, Deutsche Gold- und Silber-Scheideanstalt
Weissfrauenstrasse 9
6 Frankfurt
Catalysts for methanation, formaldehyde, methanol dehydrogenation, hydrogenation, oxidation, purification of gases, homogeneous catalysts

Dr. E. Dürrwächter Doduco K. G. (Doduco)
Doduco-Chemiewerk
P.O. Box 245
6920 Sinsheim/Elsenz
Catalysts for hydrogenation and purification of gases

Elektrochemische Werke
Höllriegelskreuth
8023 Münich

Farbenfabriken Bayer A.G.
509 Leverkusen
Catalysts for vinyl acetate, hydrogenation

Farbwerke Hoechst A.G.
6230 Frankfurt/Main — Hoechst

Girdler-Südchemie Katalysator GmbH
Lenbachplatz 6, P.O.Box 201003
8 Munich 2
Catalysts for hydrogen and synthesis gas manufacture, purification of gases, hydrogenation, dehydrogenation, sulphuric acid, formaldehyde, ammonia dissociation, alkylation dehydration and acid-catalyzed reactions

Grillo-Werke A.G.
Duisburg — Hamborn
Sulphuric acid catalyst

W. C. Heraeus GmbH
Heraeusstrasse 12—14
6450 Hanau
Catalysts for alkylation, hydrogenation, oxidation, purification of gases. Catalyst carriers.

Kali-Chemie A.G.
3 Hannover
Catalysts for the production of high-grade anti-knock gasoline and for special processes in the chemical industry. Catalytic cracking catalysts

Kali-Chemie Engelhard Katalysatoren GmbH
Hans Böckler Allee 20
3 Hannover
Catalysts for reforming, hydrogenation and isomerization. Precious metal catalysts for catalytic reduction of functional groups and for gas purification

Katalysatorenwerke Houdry-Hüls GmbH
4370 Marl
Catalysts for hydrogenation, dehydrogenation, hydrochlorination, reforming, hydration, dehydration, isomerization and polymerization

Königswarter und Ebell Chemische Fabrik GmbH
Dieckstrasse 42
5800 Hagen
Nickel catalysts for hydrogenation, especially for oil and fat hardening

Peroxid-Chemie GmbH
Dr. Gustav Adolf Strasse 3
8023 Höllriegelskreuth

Ruhrchemie A. G.
Bruchstrasse, P.O. Box 35
4200 Oberhausen 13 — Holten
Co-catalysts for hydrogenation and amination by hydrogenation

Süd-Chemie A.G.
Lenbachplatz 6
8 Munich

Taunus-Quarzit-Werke GmbH
Promenade 90
6380 Bad Homburg

Unichema Chemie GmbH
P.O. Box 1280
4240 Emmerich/Rhein

Vereinigte Füllkörper-Fabriken GmbH und Co. (VFF)
5412 Ransbach-Baumbach
Ceramic catalyst carriers
Wallace und Tiernan Chemie GmbH
8870 Günzburg

India

Catalysts and Chemicals India (West Asia), *(CCIWA)*
240 D, Naoroji Road
Bombay 1

Fertilizer Corporation of India Ltd (FCI)
Planning and Development Division
Sindri, Dhanbad, Bihar
Catalysts for reforming, shift, methanation, ammonia dissociation and desulphurization. Catalyst carriers

Italy

Montedison S.P.A.
Piazza della Repubblica 14/16
20125 Milan
Catalysts for shift, ammonia synthesis, formaldehyde, methanol, vinyl acetate, vinyl chloride, sulphuric acid, maleic anhydride, oxidation, purification of gases, steam reforming

Japan

Catalysts and Chemicals Inc. Far East

(CCIFE)
Sankaido Building 9–13, 1-chome,
Akasaka Minato-ku, Tokyo
Catalysts for petroleum refining, for manufacture of petrochemical products and for manufacture of gases

Catalysts and Chemicals Industries Co. Ltd (CCIC)
6–2, 2-chome, Otemachi,
Chiyoda-ku, Tokyo
Catalysts for petroleum refining, for manufacture of petrochemical products and for manufacture of inorganic chemicals

Hakko Kagaku Kogyo K.K.
Mitsui Bldg. no. 2, 4-chome
Nihonhashi, Hongoku-Cho
Chuo-Ku, Tokyo
Catalysts for manufacture of inorganic chemicals

Hashimoto Chemical Industries Co.
41, Nishi 4-Cho Shorinjimachi
Sakai-shi, Osaka
Catalysts for manufacture of inorganic chemicals

Kansai Catalyst Co.
5, 3-chome, Nakanoshima
Kita-Ku, Osaka
Catalysts for oils and fats processing, for manufacture of pharmaceuticals and foodstuffs and other catalysts

Kawaken Fine Chemicals Co.
1, 2-chome, Nihombashi Kozune-Cho
Chuo-Ku, Tokyo
Catalysts for manufacture of petrochemical products, for oils and fats processing and for manufacture of pharmaceuticals and foodstuffs

Kyushu Refractories Co.
Catalysts for manufacture of gases

Lederle Japan Ltd
Catalysts for fuel oil desulphurization

Mitsui Toatsu Chemicals Inc.
2-5, Kasusnigasaki 3-chome
Chyoda-Ku, Tokyo
Catalysts for manufacture of inorganic chemicals

Nihon Tokushu Kasei K.K.
8, 2-chome, Nihombashi Muro-machi
Chuo-Ku, Tokyo
Catalysts for the manufacture of inorganic chemicals

Nikki Chemical Co.
Shin Ohtemachi Bldg. 4, 2-chome
Ohic-Machi, Chiyoda-Ku, Tokyo
Catalysts for heavy crude oil desulphurization, for manufacture of petrochemical products, for manufacture of inorganic chemicals, for manufacture of gases, for oils and fats processing, for manufacture of pharmaceuticals and foodstuffs

Nikko Scientific and Chemical Industries Ltd
Catalysts for the manufacture of petrochemical products, for oils and fats processing, for the manufacture of pharmaceuticals and foodstuffs

Nikon Kagaku Sangyo Co.
20–5, 2-chome, Shitaya Daito-Ku, Tokyo
Catalysts for the manufacture of petrochemical products

Nippon Aluminium Alkils Ltd
70, 3-chome, Nisihimiyahuracho
Higashiyodagawa-Ku, Osaka
High-polymerization catalysts

Nippon Engelhard Ltd
Catalysts for the manufacture of petrochemical products, for the manufacture of inorganic chemicals and for the manufacture of pharmaceuticals and foodstuffs

Nippon Inorganic Colour and Chemical Co.
2-2, 1-chome Uchisaiwaicho
Chyoda-Ku, Tokyo
Catalysts for the manufacture of petrochemical products

Nippon Ketjen Co.
Niihama, Ehime Pref.
Catalysts for hydrodesulphurization, hydrogenation and hydrocracking

Nippon Shokubai Kagaku Kogyo Co.
Catalysts for manufacture of petrochemical products, for manufacture of inorganic chemicals

Nissan Chemetron Catalysts Ltd
2 fl. Shinjo Bldg., no. 9, 2-chome
Ta-cho, Kanda, Chiyoda-Ku, Tokyo
2, 1-chome, Nihombashi, Hon-cho
Chuo-Ku Tokyo
Catalysts for petroleum refining, for heavy crude oil desulphurization, for the manufacture of petrochemical products, high-polymerization catalysts, for the manufacture of inorganic chemicals, for the manufacture of gases, for oils and fats processing, for the manufacture of pharmaceuticals and foodstuffs and other catalysts

Oza Chemical Industry Co.
Catalysts for oils and fats processing

Sakai Chemical Industry Co.
1-26, 3-chome, Oike-cho, Suma-Ku, Kohe
Ebisuhima-cho, Sakai City, Osaka
Catalysts for oils and fats processing

Toho Titanium Co. Ltd
3 Aoi-cho, Akasaka, Minato-Ku, Tokyo

Toyo Stauffer Chemical Co.
High-polymerization catalysts, alkyl aluminium catalysts

Ube Industries Ltd
7-2, 3-chome, Kasumigaseki
Chiyoda-Ku, Tokyo
Catalysts for manufacture of inorganic chemicals

Wako Pure Chemical Industries Ltd
10, 3-chome, Dosha-machi
Higashi-Ku, Osaka
High-polymerization catalysts

Netherlands

Akzo Chemie B.V., Ketjen Catalysts
Nieuwendammerkade 1-3, P.O.Box 15
Amsterdam -- N.
Catalysts for fluid cracking, hydrotreating catalysts for desulphurization and hydrogenation; fluid hydroforming catalysts; acrylonitrile catalysts for the Sohio process

Harshaw Chemie B. V.
P.O. Box 19
De Meern
Catalysts for hydrogenation, dehydrogenation, dehydration, hydrotreating, halogenation and dehalogenation, organic syntheses, oxo-process, oxidation and gas purification

Poland

Ciech-Nitroplast
Ul. Jasna 12
Warsaw
Catalysts for vinyl acetate, hydrogenation of carbonyl compounds, hydrogenation of carbon double bonds, esterification and disproportionation

Romania

Combinatul Chimic Craiova
Craiova
Catalysts for reforming, shift, ammonia synthesis, vinyl acetate, hydrogenation of carbonyl compounds

Spain

Energia e Industrias Aragonesas S.A.
Avenida Calvo Sotelo 27
Madrid 4

Sweden

Kema Nord A. B.
P.O. Box 5042
10242 Stockholm

Switzerland

Linde Company, Union Carbide Europe S.A.
40, rue du Rhône
Geneva 3
Molecular sieves

Stauffer Chemical Europe S.A.
25, rue des Caroubiers
1227 Geneva

Union of Soviet Socialist Republics

Sojuzchimexport
Smolenskaja Sennaja 32–34
Moscow
Ammonia synthesis catalyst

United Kingdom of Great Britain and Northern Ireland

Anglo-Continental Fullers Earth Co. Ltd
1 Lloyds Avenue
London EC3

Crosfield Joseph and Sons Ltd
P.O. Box 26, Bank Quay
Warrington, Lancs.
Catalysts for hydrogenation of carbonil compounds and for hydrogenation of carbon double bonds. Catalysts for selective hydrogenation

Cyanamid of Great Britain
North West Wing, Bush House
Aldwych,London WC2

Engelhard Industries Ltd
St. Nicholas House, St. Nicholas Road
Sutton, Surrey

Chemical Division:
Valley Road
Cinderford, Glos.
Precious metals catalysts

Hydronyl-Norton Ltd
King Street, Fenton
Stoke-on-Trent
Catalyst carriers

Imperial Chemical Industries Ltd (ICI)
Imperial Chemical House, Milbank
London SW1
Agricultural Division – Catalysts:
P.O. Box 1
Billingham, Teesside
Catalysts for reforming, shift, methanation, ammonia synthesis, methanol, formaldehyde, desulphurization, hydrodesulphurization, guards for LTS, hydrogenation, purification of gases, ammonia dissociation, catalyst carriers

Imperial Smelting Corp. (N.S.C.) Ltd (ISC)
St. Andrew's Road
Avonmouth, Bristol
Sulphuric acid catalyst

Johnson Matthey Chemicals Ltd
74 Hatton Garden
London EC1

Koch Light Laboratories Ltd
Colnbrook, Bucks

Laporte Industries Ltd
Moorfield Road
Widnes, Lancs.
Catalysts for British Gas Council's catalystic rich gas process (CRG).
Catalysts for sulphur removal, hydrodesulphurization, steam reforming. Catalyst carriers

Monsanto Chemicals Ltd
Monsanto House, 10–18 Victoria Street
London SW1

Price Pearson Refractories Ltd
Moor Street, P.O. Box 9
Brierley Hill, Staffordshire
Catalysts for steam reforming

Titanium Intermediates Ltd
10 Stratton Street
London
Esterification catalysts

Universal Matthey Products Ltd
Underbridge Way, Brinesdown
Enfield, Middx.

United States of America

Activated Metals and Chemicals Inc.
P.O. Box 32
Sevierville, Tennessee 37862

Air Products and Chemicals Inc.
5 Executive Mall Bldg. 656 E Swedesford
Rd., Wayne, Pennsylvania 19087
Fluid bed and moving bed cracking catalysts, kaolin cracking catalysts. Catalysts for hydrogenation, dehydrogenation, hydrochlorination, reforming of naphtha, hydration, dehydration, isomerization and polymerization

Allied Chemical Corp., Industrial Chemicals Division
P.O. Box 1139 R, Morristown, New York
07960 · Catalysts for isomerization and polymerization. Alkylation, cat-cracking

Aluminium Company of America (ALCOA)
1501 Alcoa Building,
Pittsburgh, Pennsylvania 15219
Catalysts for oxidation, hydration, dehydration. Catalytic alumina

American Cyanamid Company, Refinery Chemicals Dept.
Bound Brook, New Jersey 08805
Catalysts for phthalic anhydride, sulphuric acid, fluid cracking, hydrodesulphurization, hydrotreating, hydrogenation, steam reforming

American Lava (3M Company),
Technical Ceramic Products Division
Cherokee Boulevard, Road Chattanooga Tennessee

Anderson Development Company
1415 East Michigan Street
Adrian, Michigan 49222
Catalysts for oxidation, polymerization and homogeneous catalysts

Calsicat Division, Mallinckrodt Chemical Works
1707 Gaskell Avenue, Erie,
Pennsylvania 16503
Catalysts for vinyl acetate, vinyl chloride, hydrogenation. Catalyst carriers

Catalyst Development Corporation (CDC)
59 Industrial Avenue, New Jersey
Catalysts for maleic anhydride, ethylene oxide

Catalysts and Chemicals Inc. (CCI)
1227 So. Twelfth Street, P.O. Box 86
Louisville, Kentucky 40201
Catalysts for reforming, shift, methanation, ammonia synthesis, methanol, oxo-synthesis, styrene, vinyl acetate, vinyl chloride, nitric acid, sulphuric acid, alkylation, fluid cracking, dehydrogenation, sulphur removal, desulphurization, hydrodesulphurization, guards for LTS, dehydrochlorination, hydrotreating, hydrogenation, oxidation, polymerization, denitrogenation, desoxygenation, steam reforming, ammonia dissociation, hydration. Catalyst carriers

Chemetron Corporation, Catalyst Division Girdler Catalysts Department
4900 Crittenden Drive, P.O. Box 337
Louisville, Kentucky 40201
Catalysts for reforming, shift, methanation, ammonia synthesis, formaldehyde, oxo-synthesis, styrene, sulphuric acid, alkylation, dehydrogenation, sulphur removal, desulphurization, hydrodesulphurization, ammonolysis, hydrogenation, purification of gases, desoxygenation, steam reforming, ammonia dissociation, esterification, acid catalyzed reactions

Cyanamid International
Wayne, New Jersey 07470

Cyanamid — Ketjen
Catalysts for steam-reforming

Grace Davison Chemical, Davison Chemical Division
Baltimore, Maryland 21203
Catalysts for fluid cracking, phthalic anhydride, dehydrogenation, hydrogenation, isomerization, polymerization, hydration, dehydration

Dow Chemical Company
2030 Abbott Road
Midland, Michigan 48640

E.I. Du Pont de Nemours and Co.
Wilmington, Delaware 19898

W. R. Grace and Company
6 Hannover Square
New York, New York 10006

Engelhard Minerals and Chemicals Corp.
113 Astor Street
Newark, New Jersey 07114
Precious metal catalysts for catalytic reduction of functional groups and for gas purification.
Catalysts for reforming, isomerization and hydrogenation

Engelhard Industries Division
429 Delaney Street
Newark, New Jersey 07114

Esso Research and Engineering Corp.
Multimetallic reforming catalyst

Harshaw Chemical Company
1945 East 97th Street
Cleveland, Ohio 44106
Catalysts for hydrogenation, dehydrogenation, dehydration, hydrotreating, halogenation and dehalogenation, organic syntheses, oxo-process, oxidation and gas purification

Houdry Division
5 Executive Mall, Swedesford Rd.
Wayne, Pennsylvania 19087

Houdry-Topsøe Co.
Bayport, Texas
Catalysts for ammonia synthesis, methanol, sulphuric acid and formaldehyde. Catalysts for desulphurization, shift and methanation

Jefferson Chemical Co. Inc.
P.O. Box 53300
Houston, Texas

Katalco Corporation
180 North Michigan Avenue
Chicago, Illinois 60601
Catalyst for SNG substitute natural gas (with British Gas Council).
Catalysts for reforming, shift, methanation, ammonia synthesis, sulphur removal, desulphurization, hydrodesulphurization, steam reforming

Laporte and Grace Co.
Catalysts for hydrodesulphurization. SNG catalyst

M and T Chemicals Inc.
Rahway, New York 07065
Catalysts for polymerization.
Homogeneous catalysts

Mallinckrodt Chemical Works
P.O. Box 5439
St. Louis, Missouri 63160

Mooney Chemicals Inc.
2301 Scranton Road
Cleveland, Ohio 44113
Catalysts for core binders

Monsanto Company
800 N. Lindbergh Boulevard
St. Louis, Missouri 63166

Minerals and Chemicals Corporation of America
Menlo Park, New Jersey

Nalco Chemical Company,
Petroleum Division, Refinery Chemicals
1800 Esperson Building
Houston, Texas 77002
4001 West 71st Street
Chicago, Illinois 60629
Hydrotreating catalysts. Catalysts for hydrodesulphurization.

Norton Inc., Norton Chemical Process Products Division
P.O. Box 350, Akron, Ohio 44309
Catalyst carriers

Noury Chemical Corporation
Burt, New York

Pressure Chemicals Co.
3419 Smalman St.
Pittsburgh, Pennsylvania 15201
Catalysts for isomerization, polymerization, disproportionation. Homogeneous catalysts

Shell Chemical Company
1 Shell Plaza, P.O. Box 2463
Houston, Texas 77001

Stauffer Chemical Company, Speciality Chemicals Division
Westport, Connecticut 06880

Industrial Chemical Division
299 Park Avenue
New York, New York 10017

Strem Chemicals Inc.
150 Andover Street, Danvers, Mass. 01923
Catalysts for styrene, vinyl acetate, vinyl chloride, hydrocracking, cat-cracking, dehydrogenation, dehydrochlorination, hydrogenation, cyclic oligomerization, hydration, hydroformylation, catalyst carriers

Union Carbide Corporation, Linde Division, Molecular Sieves Dept.
Old Saw Mill River Road
Tarrytown, New York 10591
Molecular, non-molecular sieve catalysts.
Noble and non-noble metal catalysts

Universal Oil Products
Company (UOP), Air Corporation Division
Tokeneke Road, Darien, Connecticut 06820
Vehicle exhaust emission control catalysts.
Purification of gases catalysts

Vistron Corporation (Standard Oil)
Ohio Catalyst for acrylonitrile synthesis

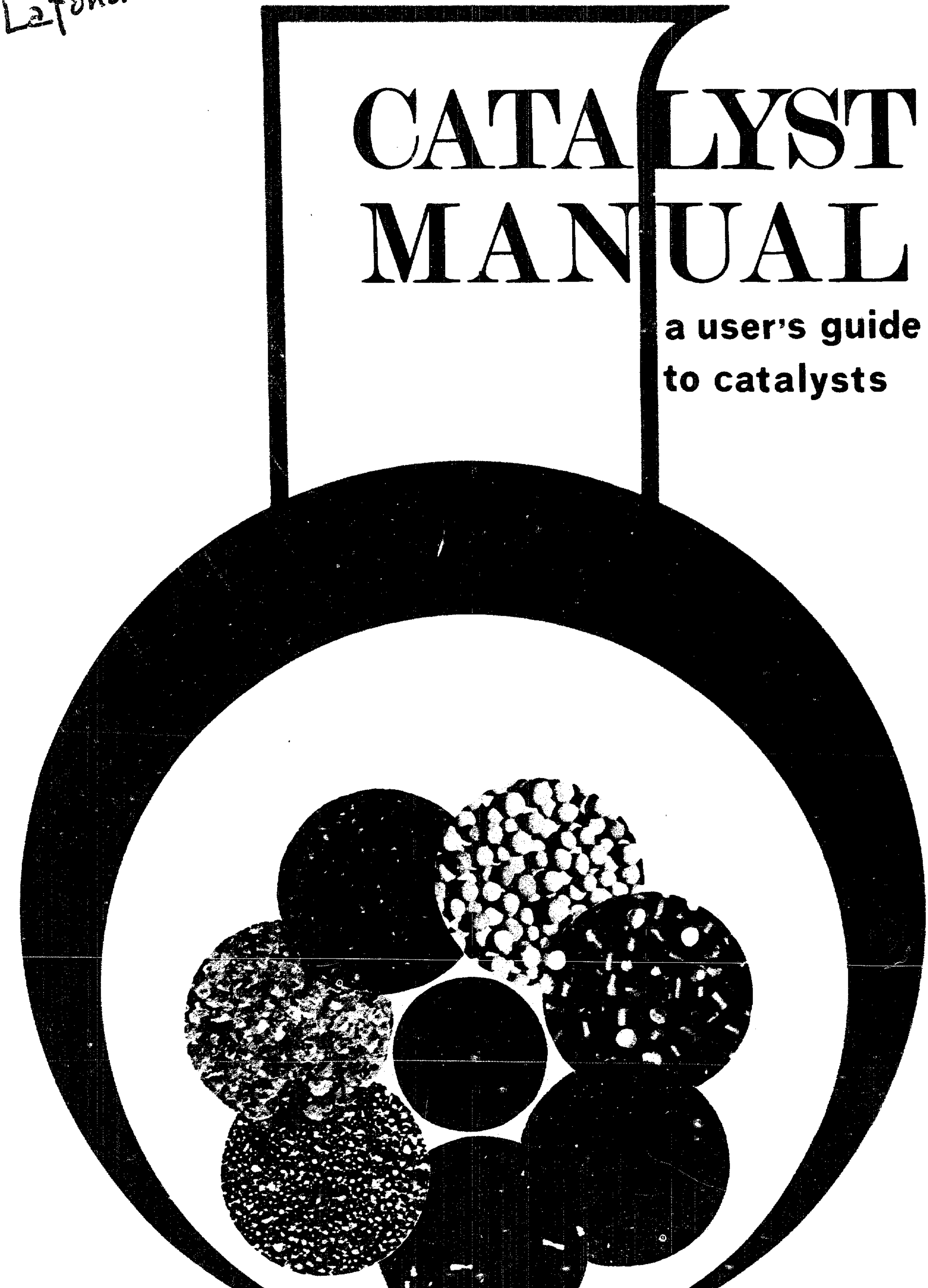
Witco Chemical Corporation, Balab Products
P.O. Box 1068
Burlingame, California 94010

11032
(2 of 2)

→ Lafond

CATALYST MANUAL

a user's guide to catalysts



for the petrochemical and fertilizer industries

* *

CATALYST MANUAL

A USER'S GUIDE TO CATALYSTS FOR THE PETROCHEMICAL AND FERTILIZER INDUSTRIES

ANNEXES

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Compiled by the
JOINT UNIDO-ROMANIA CENTRE
Bucharest

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Annex I

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Annex 1

Heterogeneous catalysts for main industrial processes

A. Ammonia production
B. Petrochemical industry
C. Production of acids

A. Ammonia production

Steam reforming
CO conversion (low temperature shift)
CO conversion (high temperature shift)
Methanation
Ammonia synthesis

Steam reforming

STEAM REFORMING OF NAPHTHA (PRIMARY)

TYPE OF CATALYST: *NICKEL MG-3C*

Manufacturer	Characteristics	Operating conditions	Remarks
Azote et Produits Chimiques S.A. (APC)	CONTENT: wt % Nickel CARRIER: ceramic material (magnesia) FORM: four-groove cylinders SIZE: Diameter (mm) 15 Length (mm) 15 ABD (g/cm^3) 1.2	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It has been developed for primary reforming of naphthas and is used in production of synthesis gas for ammonia, methanol, oxo alcohols manufacture, more generally hydrogen, reducing gases ($H_2 + CO$) or town gas. Used for continuous pressure steam reforming.

TYPE OF CATALYST: *NICKEL RG-5C*

Manufacturer	Characteristics	Operating conditions	Remarks
Azote et Produits Chimiques S.A. (APC)	CONTENT wt % Nickel CARRIER: ceramic material FORM: four-groove cylinders SIZE: Diameter (mm) 15 Length (mm) 15 ABD (g/cm^3) 1.3	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See MG-3C

REFORMING OF HYDROCARBONS

TYPE OF CATALYST: *NICKEL BASF G-1—10*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % Nickel 3 CARRIER: magnesium oxide FORM: approx. spherical SIZE: Diameter (mm) 18 ABD (g/cm^3) 1.5 TS (°C) up to 1,400	TEMPERATURE RANGE: 700°–1,000°C PRESSURE RANGE: n.a.	Reforming of hydrocarbons such as methane, LPG and LPF with steam and oxygen or air. Used at atmospheric or elevated pressure, in continuous and cyclic reforming processes for the production of town gas, inert gas and synthesis gas.

TYPE OF CATALYST: *NICKEL BASF G-1—11*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % Nickel 6 CARRIER: magnesium oxide FORM: approx. spherical SIZE: Diameter (mm) 18 ABD (g/cm^3) 1.5 TS (°C) up to 1,400	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See BASF G-1-10

TYPE OF CATALYST: *NICKEL BASF G-1—21*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % Nickel CARRIER: ceramic FORM: cylindrical rings SIZE: Diameter (mm) 16 ABD (g/cm^3) 1 STRENGTH (kg/cm^2) 300 TS (°C) up to 900	TEMPERATURE RANGE: 650°–850°C PRESSURE RANGE: n.a.	For the production of ammonia synthesis gas, methanol synthesis gas and hydrogen. The catalyst is used for reforming of lower hydrocarbons preferably methane with steam and carbon monoxide in tube reactors at atmospheric or elevated pressure.

STEAM REFORMING OF GASES

TYPE OF CATALYST: *NICKEL BASF G-1—30*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % Nickel CARRIER: ceramic FORM: pellets SIZE: Diameter (mm) 16 ABD (g/cm^3) 1.4 STRENGTH (kg/cm^2) 300 TS (°C) up to 1,200	TEMPERATURE RANGE: 600°–1,000°C PRESSURE RANGE: n.a.	The reaction may take place at atmospheric or elevated pressure. The catalyst can be used alone or together with other BASF reforming catalysts, e.g. BASF G-1-40. Reforming of gases containing methane, LPG and LPF with steam.

STEAM REFORMING OF HIGHER HYDROCARBONS (PRIMARY)

TYPE OF CATALYST: *NICKEL BASF G-1—31*			
Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % Nickel CARRIER: ceramic FORM: cylindrical rings SIZE: Diameter (mm) 16 Length (mm) 8 ABD (g/cm³) 1.1 STRENGTH (kg/cm²) >300 TS (°C) 1,200	TEMPERATURE RANGE: 600°–900°C PRESSURE RANGE: n.a.	The reaction may take place in type reactors, at atmospheric or elevated pressure, and the catalyst may be used by itself or together with an other BASF reforming catalyst (G-1-40). Application: production of hydrogen for hydrogenation purposes. Used in conjunction with BASF catalyst G-1-12 for the production of synthesis gas in secondary reformers.

STEAM REFORMING OF HYDROCARBONS

TYPE OF CATALYST: *NICKEL BASF G-1—40*			
Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % Nickel CARRIER: n.a. FORM: cylindrical rings SIZE: Diameter (mm) 16 ABD (g/cm³) 1.2 STRENGTH (kg/cm²) 300 (measured at the faces) TS (°C) up to 1,400	TEMPERATURE RANGE: 600°–1,000°C PRESSURE RANGE: n.a.	Preferably used in combination with other BASF reforming catalysts. Used for production of synthesis gas, town gas and hydrogen. Used also for reforming of higher hydrocarbons including light liquid petroleum fractions with steam at atmospheric or elevated pressure.

STEAM REFORMING OF HYDROCARBONS (PRIMARY)

TYPE OF CATALYST: *NICKEL BASF G-1—50*			
Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % Nickel CARRIER: n.a. FORM: cylindrical rings SIZE: Diameter (mm) 16 ABD (g/cm³) 1.1 STRENGTH (kg/cm²) 300 (measured at the faces) TS (°C) up to 1,000	TEMPERATURE RANGE: 600°–900°C PRESSURE RANGE: n.a.	Reforming of higher hydrocarbons including light liquid petroleum fractions with steam at atmospheric or elevated pressure. Preferably used in combination with an other BASF catalyst, e.g. BASF G-1-40.

STEAM REFORMING OF HYDROCARBONS

TYPE OF CATALYST: *NICKEL C-11*			
Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Nickel oxide 20–40 CARRIER: calcium silicate, aluminate, magnesium oxide FORM: rings, spheres, tablets SIZE (mm): 16× 9 (rings) 16×16 (rings) 19×18 (rings) 19×12 (rings) TS (°C) 1,300	TEMPERATURE RANGE: up to 1,300°C PRESSURE RANGE: n.a.	A class of steam hydrocarbon reforming catalysts for the production of hydrogen, ammonia, methanol and oxo synthesis gases, by promoting the reaction between low molecular weight hydrocarbons such as methane, refinery gases and LPG with steam and/or carbon dioxide at temperatures above 550°–650°C. Used in primary reforming.

TYPE OF CATALYST: *NICKEL C-11–2*			
Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Nickel oxide 35 CARRIER: all alumina carriers; no silica FORM: rings SIZE: Diameter (mm) 16 Length (mm) 16 ABD (g/cm³) 0.8	TEMPERATURE RANGE: 600 – 1,000°C PRESSURE RANGE: n.a.	Used in primary reforming.

TYPE OF CATALYST: *NICKEL C-11–2S*			
Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Nickel oxide CARRIER: all refractory carriers, not silica FORM: Raschig rings SIZE: Diameter (mm) 16 Length (mm) 10	TEMPERATURE RANGE: 600°– 1,000°C PRESSURE RANGE: 1–40 atm. SPACE VELOCITY: 1,000–7,000 h⁻¹	Used principally for reforming natural gas. It is the high activity version of the C-11-2 catalyst.

TYPE OF CATALYST: *NICKEL C-11—4*			
Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Nickel oxide 18–26 CARRIER: refractory FORM: tablets; rings SIZE: tablets rings Diameter (mm) 12.5,19 19 Length (mm) 12.5,19 15,19	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used in secondary reformers.

TYPE OF CATALYST: *NICKEL C-11—9*			
Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Nickel oxide CARRIER: high purity alumina FORM: rings SIZE (mm): 15.87×15.87×6.35 15.87×9.525×6.35 ABD (g/cm^3) 1.2–1.28 SA (m^2/g) 5–15 PV (cm^3/g) 0.2–0.3 STRENGTH (kg/cm^2) 40	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	A steam reforming catalyst (primary reformers) for production of ammonia, hydrogen, methanol synthesis gas, naphtha reforming and reducing gases for metallurgical application; it can also be used in oxo-alcohol and methanol synthesis plants where carbon dioxide is added to the reformer.

HIGH TEMPERATURE STEAM REFORMING OF HYDROCARBONS

TYPE OF CATALYST: *NICKEL C-14*			
Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Nickel oxide 4–7 CARRIER: high purity alumina FORM: irregular particles SIZE: Diameter (mm) 15.87 Length (mm) 2.54;3.17 ABD (g/cm^3) 1.312	TEMPERATURE RANGE: 1,010°–1,260°C PRESSURE RANGE: n.a.	It is used for promoting the reaction between steam and oxygen and/or carbon dioxide and low molecular weight hydrocarbons to produce hydrogen and synthesis gases for ammonia, methanol and other synthesis. Suitable for operation in the fixed bed (secondary reformers) employing high pressure reforming.

TYPE OF CATALYST: *CHROMIUM C-15*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Chrome oxide 4–8 CARRIER: high purity alumina FORM: spheres; irregular rings SIZE: Diameter (mm) 18.05 ABD (g/cm^3) 1.0–1.3	TEMPERATURE RANGE: 1,000°–1,430°C PRESSURE RANGE: 40 atm	The remarks of C-14 catalyst are valable also forC-15 catalyst. The activity of C-15 catalyst in its normal operating temperature range of 1,000°–1,430°C is equivalent to that of C-11-2 catalyst at temperature of 650°–930°C. It is used as high temperature steam hydrocarbon reforming catalyst.

STEAM REFORMING

TYPE OF CATALYST: *NICKEL NC-1*

Manufacturer	Characteristics	Operating conditions	Remarks
Combinatul Chimic Craiova	CONTENT wt % Nickel oxide 4.5–6.3 CARRIER: alumina FORM: cylinders SIZE: Diameter (mm) 12 Length (mm) 18 ABD (g/cm^3) 1.0–1.1 STRENGTH (kg/cm^2)15	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a. SPACE VELOCITY: 1,000 h^{-1}	Steam reforming of methane, in ammonia synthesis plants.

TYPE OF CATALYST: *NICKEL NC-2*

Manufacturer	Characteristics	Operating conditions	Remarks
Combinatul Chimic Craiova	CONTENT wt % Nickel oxide 7–10 CARRIER: refractory FORM: rings, cylinders SIZE: rings cylinders Diameter (mm) 16 12 Langth (mm) 16 12 ABD (g/cm^3) 0.75–1 STRENGTH (kg/cm^2) 250	TEMPERATURE RANGE: 800°C PRESSURE RANGE: n.a. SPACE VELOCITY: 1,000 h^{-1}	See NC-3.

TYPE OF CATALYST: *NICKEL NC-3*

Manufacturer	Characteristics	Operating conditions	Remarks
Combinatul Chimic Craiova	CONTENT wt % Nickel oxide 13—16 CARRIER: refractory FORM: rings, cylinders SIZE: Diameter (mm) 16;12 Length (mm) 16;12 ABD (g/cm^3) 0.75—1 STRENGTH (kg/cm^2) 250	TEMPERATURE RANGE: 800°C PRESSURE RANGE: n.a. SPACE VELOCITY: 1,000 h^{-1}	Steam reforming of methane for production of synthesis gas in ammonia and methanol synthesis plants.

TYPE OF CATALYST: *NICKEL NC-4*

Manufacturer	Characteristics	Operating conditions	Remarks
Combinatul Chimic Craiova	CONTENT wt % Nickel oxide 20—23 CARRIER: refractory FORM: rings, cylinders SIZE: Diameter (mm) 16;12 Length (mm) 16;12 ABD (g/cm^3) 0.75—1 STRENGTH (kg/cm^2) 250	TEMPERATURE RANGE: 750°C PRESSURE RANGE: n.a. SPACE VELOCITY: 1,000 h^{-1}	Used for obtaining hydrogen for ammonia, methanol and oxo synthesis.

TYPE OF CATALYST: *NICKEL NC-5*

Manufacturer	Characteristics	Operating conditions	Remarks
Combinatul Chimic Craiova	CONTENT wt % Nickel oxide 30—33 CARRIER: refractory FORM: rings, cylinders SIZE: Diameter (mm) 16;12 Length (mm) 16;12 ABD (g/cm^3) 0.75—1 STRENGTH (kg/cm^2) 250	TEMPERATURE RANGE: 750°C PRESSURE RANGE: n.a. SPACE VELOCITY: 1,000 h^{-1}	For production of synthesis gas in ammonia, methanol and oxo processes plants.

PRIMARY REFORMING OF NAPHTHA

TYPE OF CATALYST: *NICKEL CDRN 33A*

Manufacturer	Characteristics	Operating conditions	Remarks
Fertilizer Corporation of India (F.C.I.)	CONTENT wt % Nickel CARRIER: rugged alumina FORM: tablets, Raschig rings, cylindrical rods SIZE (mm): tablets: 10×10 Raschig rings: 17×17×6 16×16×16 16×16×10 cylindrical rods: 5×12 10×30 ABD (g/cm^3) 1–1.1 Steam: carbon ratio: 3.0–5.0	TEMPERATURE RANGE: 750°–850°C PRESSURE RANGE: 1.35 atm SPACE VELOCITY: 0.9 h^{-1}	It is suitable for primary reforming of naphtha for the production of ammonia synthesis gas. Liquid feed stock.

SECONDARY REFORMING OF NAPHTHA

TYPE OF CATALYST: *NICKEL CDRN 33C*

Manufacturer	Characteristics	Operating conditions	Remarks
Fertilizer Corporation of India (F.C.I.)	CONTENT wt % Nickel CARRIER: rugged alumina FORM: see CDRN 33A SIZE: see CDRN 33A	TEMPERATURE RANGE: 750°–1,200°C PRESSURE RANGE: up to 35 atm LIFE: more than 3 years SPACE VELOCITY: 500 h^{-1}	

STEAM REFORMING OF GASEOUS HYDROCARBONS

TYPE OF CATALYST: *NICKEL CDR 66A*

Manufacturer	Characteristics	Operating conditions	Remarks
Fertilizer Corporation of India (F.C.I.)	CONTENT wt % Nickel CARRIER: alumina FORM: see CDRN 33A SIZE: see CDRN 33A Steam: carbon ratio 2.5–4.0	TEMPERATURE RANGE: 700°–900°C PRESSURE RANGE: 35 atm SPACE VELOCITY: up to 1,200 h^{-1}	Used for production of ammonia synthesis gas. It is suitable for primary steam gas reforming.

TYPE OF CATALYST: *NICKEL CDR 66B*

Manufacturer	Characteristics	Operating conditions	Remarks
Fertilizer Corporation of India (F.C.I.)	CONTENT wt % Nickel CARRIER: alumina FORM: see CDRN 33A SIZE: see CDRN 33A	TEMPERATURE RANGE: n.a. PRESSURE RANGE: 35 atm SPACE VELOCITY: 5,000 h^{-1}	Suitable for secondary reforming where oxygen/air is added along with steam.

STEAM REFORMING OF HYDROCARBONS (SECONDARY)

TYPE OF CATALYST: *NICKEL G-31B*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Nickel 7 CARRIER: α Al_2O_3 FORM: lumps SIZE (mm): 15–18 ABD (g/cm^3) 0.95–1.0	TEMPERATURE RANGE: 600°–1,200°C PRESSURE RANGE: n.a.	The catalyst is recommended when carbon deposition on the catalyst may be encountered. The principal application for autothermic reforming furnaces. With similar application are G-31A, irregular lumps of 18–38 mm, G-31C, extrusions of 25×25 mm.

TYPE OF CATALYST: *CHROMIUM G-34*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT n.a. CARRIER: n.a. FORM: irreg. lumps, extrusions SIZE (mm): G-34A (irreg. lumps): 18—30 G-34B (irreg. lumps): 12–24 G-34C (extrusions): 25×25	TEMPERATURE RANGE: 1,300°–1,540°C PRESSURE RANGE: n.a.	Essentially similar to G-31 in application.

STEAM REFORMING OF HYDROCARBONS

TYPE OF CATALYST: *NICKEL G-56*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % G-56 G-56B Ni 15 25 S 0.03 0.04 SiO_2 0.2 0.2 CARRIER: n.a. FORM: rings, cylinders SIZE (mm): rings: 7×17×6 cylinders: 6×6;9×9 ABD (g/cm³) 0.85± 0.064	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for the reaction of hydrocarbons with steam, steam and carbon dioxide, steam and air, steam and oxygen or with air to produce hydrogen, ammonia synthesis gas, methanol synthesis gas, oxo synthesis gas, further hydrogen carbon oxide mixture, town gas and buffer gases. Primary reformers. G-29: a standard reforming catalyst has been largely replaced by G-56.

TYPE OF CATALYST: *NICKEL GPR-5; GPR-6*

Manufacturer	Characteristics	Operating conditions	Remarks
Grande Paroisse	CONTENT wt % NiO ZnO_2 MgO SiO_2 CARRIER: n.a. FORM: pellets SIZE: Diameter (mm) 15 STRENGTH (kg/cm²) 30–60 TS (°C) > 1,000	TEMPERATURE RANGE: higher than 1,000 C PRESSURE RANGE: 1–60 atm.	GPR-5 is used for steam reforming of natural gas. GPR-6 is used for steam reforming of hydrocarbons heavier than methane and unsaturated until and excluding C_5.

TYPE OF CATALYST: *NICKEL N-139; N-134*

Manufacturer	Characteristics	Operating conditions	Remarks
W.C. Heraeus GmbH	CONTENT wt % Nickel CARRIER: Al_2O_3 FORM: cylindrical tablets SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Steam reforming of hydrocarbons for production of synthesis gas.

GAS REFORMING

TYPE OF CATALYST: *NICKEL ICI 54-2, ICI 54 -2S*

Manufacturer	Characteristics	Operating conditions	Remarks
Imperial Chemical Industries Ltd. (I.C.I.)	CONTENT wt % Supported nickel oxide FORM: rings; pellets SIZE: Diameter (mm) 17 Length (mm) 11–17 ABD (g/cm^3) 1.0	TEMPERATURE RANGE: up to 1,000°C PRESSURE RANGE: up to 35 atm SPACE VELOCITY: 4,000–7,000 h^{-1}	It can also be used for some primary reforming duties. For secondary reforming in ammonia plants.

STEAM REFORMING

TYPE OF CATALYST: *NICKEL ICI 57—3: 57—4*

Manufacturer	Characteristics	Operating conditions	Remarks
Imperial Chemical Industries Ltd. (I.C.I.)	CONTENT wt % Supported nickel oxide CARRIER: n.a. FORM: rings; pellets SIZE: Diameter (mm) 17 Length (mm) 17 ABD (g/cm^3) 1.1	TEMPERATURE RANGE: up to 850°C PRESSURE RANGE: up to 35 atm	They are used for the primary reforming of methane, and other light hydrocarbons in tubular reformers. They are affected by sulphur, chlorine and arsenic compounds. Available as 57-3S and 57-4S.

STEAM REFORMING (SECONDARY REFORMING)

TYPE OF CATALYST: *NICKEL KATALCO 54—1*

Manufacturer	Characteristics	Operating conditions	Remarks
Katalco Corporation	CONTENT wt % Nickel oxide CARRIER: ceramic FORM: rings SIZE: Diameter (mm) 17 Length (mm) 17 ABD (g/cm^3) 0.8 TS (°C) 1,100	TEMPERATURE RANGE: n.a. PRESSURE RANGE: 1–28 atm LIFE: greater than 5 years SPACE VELOCITY (VHSV): 1,500–5,000 h^{-1}	Secondary reforming of light hydrocarbons in plant for production of ammonia synthesis gas.

STEAM REFORMING OF HYDROCARBONS

TYPE OF CATALYST: *NICKEL KONTAKT 9041*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht"	CONTENT wt % Nickel CARRIER: ceramic FORM: extrusions, cylinders SIZE: Diameter (mm) 12;14;16 Length (mm) 12;14;16 ABD (g/cm^3) 1.2±0.12 1±0.1	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for production of synthesis gas by autothermic reforming of methane, also for production of town gas.

STEAM REFORMING UNDER PRESSURE

TYPE OF CATALYST: *NICKEL GH-651; GH-652*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Promoted nickel CARRIER: special FORM: rings SIZE: Diameter (mm) 15–20	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	GH-651 is used for H_2 production. GH-652 is recommended for the production of synthesis gas used for the ammonia synthesis (primary reforming).

STEAM REFORMING OF HYDROCARBONS

TYPE OF CATALYST: *NICKEL RKN*

Manufacturer	Characteristics	Operating conditions	Remarks
Haldor Topsøe	CONTENT wt % Ni 25 SiO_2 <0.2 Other major components are oxides of magnesia and alumina CARRIER: n.a. FORM: rings SIZE: Diameter (mm) $\frac{13}{6}$ $\frac{13}{6}$ $\frac{16}{6}$ $\frac{19}{6}$ Length (mm) 7 13 16 15 ABD (g/cm^3) 0.8–0.9 STRENGTH (kg/cm^2) 300	TEMPERATURE RANGE: 400°–870°C PRESSURE RANGE: 17–40 atm	Used for the upper part of the reforming tubes, the catalyst will normally be delivered in a preactivated modification – RKNR.

TYPE OF CATALYST: *NICKEL RKS-1*

Manufacturer	Characteristics	Operating conditions	Remarks
Haldor Topsøe	CONTENT wt % Nickel oxide 17 CARRIER: magnesia-alumina-spinel FORM: rings SIZE: Diameter (mm) 3/19 and 6/9 Length (mm) 13–19 Axial direction: 300 Radial direction: 25	TEMPERATURE RANGE: 425°–1,350°C PRESSURE RANGE: up to 40 atm	It contains only 0.2 SiO_2. Fusion point: 2,000°C. There is a second version RKS-2 which contains only 9% Ni. RKS catalyst is well suited for use both at low temperatures in tubular reformers and at high temperatures, in secondary and autothermal reformers for the production of synthesis gas.

CO conversion (low temperature shift)

CO CONVERSION (SHIFT CONVERSION)

TYPE OF CATALYST: *COPPER AND ZINC C-18*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Copper oxide and zinc oxide in different weight percentage depending on type of catalyst CARRIER: alumina FORM: tablets SIZE: Diameter (mm) 6;3;4 Length (mm) 6;3;4 ABD (g/cm³) 1.28	TEMPERATURE RANGE: 177°–315°C PRESSURE RANGE: n.a.	A group of a low temperature shift catalyst. It is possible with these catalysts to produce high purity hydrogen and synthesis gas with only one stage of CO conversion and one stage of CO_2 removal.

TYPE OF CATALYST: *COPPER-ZINC C-18–1.03*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT of calcined base wt % CuO 25.3 ZnO/CuO ratio 2 Al_2O_3 30.0 Cr_2O_3 0.01 S <0.04 Na <0.10 Cl <0.01 CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It contains (in ppm): Sn 10–30 Pb 10–30 Ni 90–120 Fe 300 Low temperature conversion catalyst.

TYPE OF CATALYST: *COPPER-ZINC C-18–3.02*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT of calcined base wt % ZnO: CuO 2 CuO ±28 Al_2O_3 ±15 Cr_2O_3 <0.01 S <0.04 Na <0.10 Cl <0.01 CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 6.35 Length (mm) 3.175 ABD (g/cm³) 1.15 STRENGTH (kg/cm²) 9.0	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The catalyst contains in ppm 2gt Sn 0–10 Pb 0–10 Ni 40–60 Fe 250 Low temperature conversion catalyst.

TYPE OF CATALYST: *COPPER AND ZINC C-18-HC*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % 1:1 ratio of ZnO to CuO, 10% alumina for thermal stabilization CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	All C-18 catalysts are supplied with the metals in the oxide state and they must be reduced according to prescribed procedures, before being placed in service. C-18-HCA is an improved version of C-18-HC, having a smaller copper crystallite size which provides a higher copper surface area per unit volume of catalyst. Low temperature conversion catalysts.

TYPE OF CATALYST: *COPPER C-117*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Copper CARRIER: zinc oxide FORM: pellets SIZE: Diameter (mm) 4 ABD (g/cm³) 1.12±0.08	TEMPERATURE RANGE: 117°–288°C PRESSURE RANGE: 1–42 atm	Low temperature conversion catalyst.

TYPE OF CATALYST: *MIXED OXIDES CDLT-21*

Manufacturer	Characteristics	Operating conditions	Remarks
Fertilizer Corporation of India (F.C.I.)	CONTENT wt % Mixed oxides CARRIER: n.a. FORM: cylindrical tablets SIZE: Diameter (mm) 6 Length (mm) 6 ABD (g/cm³) 1.35	TEMPERATURE RANGE: 190°–270°C PRESSURE RANGE: 35 atm SPACE VELOCITY: 3,000 h⁻¹ (dry base)	Low temperature conversion catalyst.

TYPE OF CATALYST: *COPPER-ZINC C-66*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Copper-zinc oxide CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 6 Length (mm) 3 ABD (g/cm^3) 1	TEMPERATURE RANGE: 175°–260°C PRESSURE RANGE: n.a.	Available (in oxide form) either as G-66A (nominally 18% alumina and containing 0.272 g of active copper per cm^3) or as G-66B (alumina free, nominally containing 30% wt CuO). Both catalysts are supplied in pre-reduced and stabilized versions, designated G-66ARS and G-66 BRS. Sulphur, chlorine compounds and unsaturated hydrocarbons will cause a loss of activity. Low temperature conversion catalyst.

TYPE OF CATALYST: *COPPER ICI-52–1*

Manufacturer	Characteristics	Operating conditions	Remarks
Imperial Chemical Industries Ltd.	CONTENT wt % Copper oxide, zinc oxide CARRIER: alumina FORM: pellets SIZE: Diameter (mm) 5.4 Length (mm) 3.6 ABD (g/cm^3) 0.9	TEMPERATURE RANGE: 180°–250°C PRESSURE RANGE: up to 50 atm SPACE VELOCITY: 2,000–5,000 h^{-1}	Low temperature shift catalyst. It has high thermal stability but is affected by sulphur and chlorine compounds. The catalyst itself is partially self guarding but in some circumstances a special guard bed may be required.

TYPE OF CATALYST: *COPPER KONTAKT 1960*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht"	CONTENT wt% Copper oxide, chromium oxide and zinc oxide CARRIER: n.a. FORM: pellets SIZE: Diameter (mm) 5 ABD (g/cm^3) 1.3 ± 0.2 STRENGTH (kg/cm^2) 90 ± 30	TEMPERATURE RANGE: 200°–230°C PRESSURE RANGE: n.a.	Low temperature conversion catalyst.

TYPE OF CATALYST: *COPPER KONTAKT 1961*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht"	CONTENT wt % Copper oxide, chromium oxide, aluminium oxide, zinc oxide CARRIER: n.a. FORM: pellets SIZE: Diameter (mm) 5 ABD (g/cm^3) 1.3±0.2 STRENGTH (kg/cm^2) 200±50	TEMPERATURE RANGE: 200° – 260°C PRESSURE RANGE: n.a.	Low temperature conversion catalyst.

TYPE OF CATALYST: *COPPER KONTAKT 1962*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht"	CONTENT wt % Cooper oxide Zinc oxide Aluminium oxide CARRIER: n.a. FORM: cylindrical pellets SIZE: Diameter (mm) 5 Length (mm) 5 ABD (g/cm^3) 0.55±0.15 STRENGTH (kg/cm^2) 200±50	TEMPERATURE RANGE: 200° – 260°C PRESSURE RANGE: n.a.	Low temperature conversion catalyst.

TYPE OF CATALYST: *COPPER, ZINC AND CHROMIUM LSK*

Manufacturer	Characteristics	Operating conditions	Remarks
Haldor Topsøe	CONTENT wt % Oxides of copper, zinc and chromium CuO 0.2 g/cm^3 catalyst CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 4.5 Length (mm) 4.5 ABD (g/cm^3) 1.06 STRENGTH (kg/cm^2) 160	TEMPERATURE RANGE: 200° – 300°C PRESSURE RANGE: n.a.	Particle density 1.7 g/cm^3. Low temperature conversion catalyst.

CO conversion (high temperature shift)

CO CONVERSION (SHIFT CONVERSION)

TYPE OF CATALYST: *IRON-CHROMIUM H4 BCP5*

Manufacturer	Characteristics	Operating conditions	Remarks
Azote et Produits Chimiques SA (APC)	CONTENT wt % Iron oxide as Fe_2O_3 Chrome oxide as Cr_2O_3 Kalium oxide as K_2O CARRIER: n.a. FORM: cylindrical pellets SIZE: Diameter (mm) 6;11 Length (mm) 6; 8 ABD (g/cm^3) 1.8;1.6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Town gas detoxication. It is used for high temperature CO conversion.

TYPE OF CATALYST: *IRON-CHROMIUM BASF K-6–10*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % Graphite 2–3 Iron oxide and chrome oxide CARRIER: n.a. FORM: pellets SIZE: Diameter (mm) 6;9 Length (mm) 6;5 ABD (g/cm^3) 1.1 SA (m^2/g) 60 PV (cm^3/g) 0.4 STRENGTH (kg/cm^2) 250 (measured at the faces) TS (°C) up to 550	TEMPERATURE RANGE: 300°–500°C PRESSURE RANGE: n.a.	Used in high temperature CO conversion. Used for the production of synthesis gas and hydrogen and for the detoxification of town gas.

TYPE OF CATALYST: *COBALT-MOLYBDENUM BASF K8–11*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % Oxides of cobalt and molybdenum CARRIER: special FORM: extrusions SIZE: Diameter (mm) 4 ABD (g/cm^3) 0.75 TS (°C) up to 550	TEMPERATURE RANGE: 290°–500°C PRESSURE RANGE: 1–70 atm	At pressures above 70 atm it is used only in conjunction with partial oxidation by Texaco process. It is used for high temperature CO conversion.

TYPE OF CATALYST: *IRON CHROMIA C-12*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Cr_2O_3 and Fe_2O_3 CARRIER: n.a. FORM: tablets SIZE: Diameter (mm)9;9;9;6 Length (mm)4;6;9;6	TEMPERATURE RANGE: 343°–510°C PRESSURE RANGE: 1–45 atm	A class of carbon monoxide conversion at elevated temperatures with steam, in hydrogen-rich steams to form additional quantities of hydrogen. These catalysts are used also for: water gas generators steam hydrocarbon reformers controlled atmosphere generators partial oxidation processes purification of hydrogen following the steam iron process.

TYPE OF CATALYST: *IRON CHROMIA C-12–1*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Cr, as Cr_2O_3 9–11 Fe, as Fe_2O_3 77–81 Graphite 3–4 CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 6;9 Length (mm) 6;9 STRENGTH (kg/cm^2) (DWL) 6 mm tablets: 13.6–18.1 9 mm tablets: 16–20	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Reaction of carbon monoxide with steam at high temperature to produce hydrogen and carbon dioxide. It is recommended for non-severe operating conditions.

TYPE OF CATALYST: *IRON CHROMIA C-12–2*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Cr as Cr_2O_3 9–11 Fe as Fe_2O_3 77–81 Graphite 3–4 CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 6;3 Length (mm) 6;3 STRENGTH (kg/cm^2) (DWL) 6 mm tablets: 15.8–20 3 mm tablets: 18–22.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Reaction of carbon monoxide with steam to produce hydrogen and carbon dioxide. It is available for severe operating conditions (high temperatures).

TYPE OF CATALYST: *IRON CHROMIA C-12-3*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Cr as Cr_2O_3 9–11 Fe as Fe_2O_3 77–81 Graphite 3–4 CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 6;9 Length (mm) 6;9 STRENGTH (kg/cm^2) (DWL) 6 mm tablets: 18–25 9 mm tablets: 20–27	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Reaction of carbon monoxide with steam to produce hydrogen and carbon dioxide. It is available for severe operating conditions (high temperatures).

TYPE OF CATALYST: *IRON CHROMIA C-16*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Coprecipitated iron oxide, containing a binder to give it an added physical strength CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 6;9 Length (mm) 6;9	TEMPERATURE RANGE: n a. PRESSURE RANGE: n.a.	Used for the production of hydrogen by promoting reaction between steam and carbon monoxide, especially at elevated pressures.

TYPE OF CATALYST: *COBALT-MOLYBDENUM C-25*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Cobalt-molybdenum CARRIER: alumina FORM: tablets; extrusions SIZE: n.a.	TEMPERATURE RANGE : 316° – 538°C PRESSURE RANGE: n.a.	C-25 should be considered for use with process gases produced by coal gasification or by the partial oxidation of heavy sulphur containing feed stocks. High temperature CO conversion catalyst.

TYPE OF CATALYST: *IRON CHEZA 31—00*

Manufacturer	Characteristics	Operating conditions	Remarks
Chemical Works of CSF	CONTENT wt % Cr_2O_3 7 SO_3 1 Fe_2O_3 92 Cr_2O_3 is a promotor FORM: extrusions SIZE: Diameter (mm) 9;6 Length (mm) 10—20; ABD (g/cm^3) 1.5 STRENGTH (kg/cm^2) 8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a. LIFE: 2 or more years	Used for the industrial production of hydrogen or synthesis gas which are used for ammonia and methanol synthesis. It is a high temperature CO conversion catalyst.

TYPE OF CATALYST: *IRON CHEZA 31—01*

Manufacturer	Characteristics	Operating conditions	Remarks
Chemical Works of CSF	CONTENT wt % Cr_2O_3 7 SO_3 1 Fe_2O_3 92 Cr_2O_3 is a promotor FORM: tablets SIZE: Diameter (mm) 10 Length (mm) 8—10 ABD (g/cm^3) 1.5 STRENGTH (kg/cm^2) 200	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a. LIFE: 2 or more years	It is a more active modification of catalyst 31—00. Its advantage makes it possible to work at a lower temperature.

TYPE OF CATALYST: *IRON FC-1*

Manufacturer	Characteristics	Operating conditions	Remarks
Combinatul Chimic Craiova	CONTENT wt % Fe_2O_3 83—89 Cr_2O_3 8—12 FeO 0.2—0.6 Impurities 3.8—4.4 CARRIER: n.a. FORM: cylinders SIZE: Diameter (mm) 8—10 Length (mm) 5—30 ABD (g/cm^3) 1.1—1.2 STRENGTH (kg/cm^2) 8—10	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used in ammonia synthesis plants for conversion of carbon monoxide to carbon dioxide.

TYPE OF CATALYST: *IRON CHROMIA CDC-63*

Manufacturer	Characteristics	Operating conditions	Remarks
Fertilizer Corporation of India (F.C.I.)	CONTENT wt % Chromia promoted iron oxide CARRIER: n.a. FORM: cylindrical tablets SIZE: Diameter (mm) 6;10;10 Length (mm) 6;10;6 ABD (g/cm^3) 1.2	TEMPERATURE RANGE: 350°–530°C PRESSURE RANGE: up to 10 atm	CDC-63 series are used in high temperature CO conversion plants. The catalyst can be used in low as well as in high pressure installations. Available as: CDC-63A for operations at lower pressure up to 10 kg/cm^2; CDC-63B having low S content for use in plants where low temperature CO conversion (very susceptible to sulphur poisoning) is also in operation.

TYPE OF CATALYST: *IRON G-3B, G-3A, G-3BL*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Chromium promoted iron oxide CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 6;9;9 Length (mm) 6;9;6	TEMPERATURE RANGE: 315°–530°C PRESSURE RANGE: 1–60 atm	It is used in processes where high sulphur content is encountered. Type G-3A originally designated as G-3. G-3B is also available in a low sulphur containing version designated G-3BL. They are high temperature CO conversion catalysts.

TYPE OF CATALYST: *IRON-CHROMIUM CPC-5*

Manufacturer	Characteristics	Operating conditions	Remarks
Grande Paroisse	CONTENT wt % Fe as Fe_2O_3 Cr as CrO_3 CARRIER: n.a. FORM: pellets SIZE: Diameter (mm) 11	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	A good space velocity. High temperature conversion catalyst.

TYPE OF CATALYST: ***IRON ICI 15-4; ICI 15-5***

Manufacturer	Characteristics	Operating conditions	Remarks
Imperial Chemical Industries Ltd. (ICI)	CONTENT wt % Iron oxide and chromium oxide CARRIER: n a. FORM: pellets SIZE: ICI 15-4;15-5 Diameter (mm) 8.5;5.4 Length (mm) 10.5;3.6 ABD (g/cm^3) 1.35	TEMPERATURE RANGE: 330°—530°C PRESSURE RANGE: 50—100 atm	ICI 15—4 has a conventional level of activity. ICI 15 — 5 is a higher activity version. Both require initial reduction of the iron oxide (Fe_2O_3) to magnetite (Fe_3O_4). Their activity can however be affected by concentrations of halogens, but sulphur is not a poison in the normal sense.

TYPE OF CATALYST: ***IRON CHROMIA KATALCO 15—5***

Manufacturer	Characteristics	Operating conditions	Remarks
Katalco Corporation	CONTENT wt % Chromia promoted iron oxide CARRIER: n.a. FORM: cylindrical tablets SIZE: Diameter (mm) 10;6 Length (mm) 6;6 ABD (g/cm^3) 1.12	TEMPERATURE RANGE: 300°—500°C PRESSURE RANGE: 1—30 atm SPACE VELOCITY (VHSV): 1,000—1,200 h^{-1}	Conventional shift reaction at high temperature. For CO shift at low temperature Katalco 52—1, which is a zinc-oxide/copper oxide/alumina (200°—260°C), is available.

TYPE OF CATALYST: ***IRON KONTAKT 1026***

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht"	CONTENT wt % Fe_2O_3 (promoted with Cr_2O_3) Cr_2O_3 approx. 7% CARRIER: n.a. FORM: extrusions SIZE: Diameter (mm) 7—9; 10—12 Length (mm) 7—15; 10—15 ABD (g/cm^3) 1.4	TEMPERATURE RANGE: 360°—400°C PRESSURE RANGE: n.a.	It is used at low and high pressures and high temperatures.

TYPE OF CATALYST: *IRON KONTAKT 1030*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht"	CONTENT wt % Fe_2O_3(with Cr_2O_3 as promotor) 7 CARRIER: n.a. FORM: pellets SIZE: Diameter (mm) 9 Length (mm) 9	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used at high temperatures.

HIGH TEMPERATURE CO CONVERSION

TYPE OF CATALYST: *IRON MHTC*

Manufacturer	Characteristics	Operating conditions	Remarks
Montedison S.p.A.	CONTENT wt % Ferricoxide and chromia in the ratio of 10:1 FORM: pellets SIZE: Diameter (mm) 6–10 Length (mm) 6–8 ABD (g/cm^3) 1.2–1.25 PV (cm^3/g) 0.28–0.32 STRENGTH (kg/cm^2)20 (radial cm.)	TEMPERATURE RANGE: 330°–530°C PRESSURE RANGE: 1–40 atm LIFE: at least 5 years SPACE VELOCITY: 400–4,800 h^{-1}	Chlorine compounds act as poisons and their concentration in the gases should not be higher than 1 ppm.

CO CONVERSION (SHIFT CONVERSION)

TYPE OF CATALYST: *IRON SK AND SK-12*

Manufacturer	Characteristics	Operating conditions	Remarks
Haldor Topsøe	CONTENT wt % Chromium promoted iron oxide, in its highest oxidized state, i.e. Fe_2O_3 plus some graphite and a few per cent moisture CARRIER: n.a. FORM: cylindrical tablets SIZE: Diameter (mm) 6;9 Length (mm) 6;9 ABD (g/cm^3) 1.05 STRENGTH (kg/cm^2) 8	TEMPERATURE RANGE: 330°–470°C PRESSURE RANGE: 1–50 atm	Used for the conversion of carbon monoxide in hydrogen, ammonia, methanol, and town gas plants at high temperature. Particle density is about 1.7 g/cm^3. Sulphur compounds are the most common catalyst poisons. More severe poisons are chlorine compounds.

TYPE OF CATALYST: ***UBE CO CONVERSION***

Manufacturer	Characteristics	Operating conditions	Remarks
UBE Industries Ltd.	CONTENT n.a. CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 8–9.5 ABD (g/cm^3) 1.35 STRENGTH (kg/cm^2) (DWL) 20	TEMPERATURE RANGE: 320°–500°C PRESSURE RANGE: 1–30 atm LIFE: several years SPACE VELOCITY: 850 h^{-1}	It is a high temperature conversion catalyst.

Methanation

METHANATION

TYPE OF CATALYST: *NICKEL BASF R 1—10*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % Nickel oxide CARRIER: n.a. FORM: pellets SIZE: Diameter (mm) 5 Length (mm) 5 ABD (g/cm³) 0.9 STRENGTH (kg/cm²) 300 (measured at the faces) TS (°C) up to 500	TEMPERATURE RANGE: 180°—400°C PRESSURE RANGE: n.a.	Methanation of CO and CO_2 with simultaneous removal of oxygen. Purification of ammonia synthesis gas and hydrogen for hydrogenation purposes.

METHANATION OF CARBON OXIDES

TYPE OF CATALYST: *NICKEL C-13*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % C13-1: NiO on silica (spheres) 48 C13-2: NiO on silica (tablets) 40 C13-3: NiO on refractory cement (tablets and spheres) 32 CARRIER: alumina FORM: spheres SIZE: Diameter (mm) 4.5-7.5 ABD (g/cm³) 0.75	TEMPERATURE RANGE: 235°—455°C PRESSURE RANGE: 1—200 atm SPACE VELOCITY (VHSV): 3,000—8,000 h⁻¹	Methanation of small quantities of carbon oxides from hydrogen and ammonia synthesis gas.

CO METHANATION

TYPE OF CATALYST: *RUTHENIUM H-22P*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt % Precious metal content, usually of 0.1; 0.15; 1; 5; and 10% CARRIER: Al_2O_3 FORM: balls SIZE: Diameter (mm) 4—6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Precious metal (see content).

METHANATION

TYPE OF CATALYST: *NICKEL CDM-15*

Manufacturer	Characteristics	Operating conditions	Remarks
Fertilizer Corporation of India (F.C.I.)	CONTENT wt % Nickel oxide CARRIER: alumina FORM: tablets SIZE: Diameter (mm) 6×6 ABD (g/cm^3) 1.2	TEMPERATURE RANGE: 300°–400°C PRESSURE RANGE: up to 35 atm	Used in the production of high purity hydrogen and/or synthesis gas where low concentration of carbon oxides and oxygen are required. It can be used in the methanation reactions with occasional variations in temperature and pressure.

TYPE OF CATALYST: *NICKEL G-33, G-52*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Nickel 32–36 CARRIER: refractory oxide FORM: tablets SIZE: Diameter (mm) 5–6 Length (mm) 5–6 ABD (g/cm^3) 0.96 SA (m^2/g) 70 STRENGTH (kg/cm^2) 11	TEMPERATURE RANGE: 100°–260°C PRESSURE RANGE: 24–35 atm	It is also used for the saturation of aromatics. G-52 is a pre-reduced form of G-33. It is used in those plants where reduction facilities are not available. See hydrogenation of olefins and aromatics.

TYPE OF CATALYST: *NICKEL G-65, G-65K*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Nickel oxide Ni-G-65 25 Ni-G-65RS 27 S 0.04 CARRIER: n.a. FORM: tablets; spheres (G-65) (G-65K) SIZE: Diameter (mm) 6×6; 4.7×4.7 ABD (g/cm^3) 1.040	TEMPERATURE RANGE: 230°–480°C PRESSURE RANGE: 1–100 atm	Heat resistant catalysts. They are available in a pre-reduced and stabilized version designed as G-65RS and G-65KRS.

METHANATION OF CO

TYPE OF CATALYST: *NICKEL GPM 5*

Manufacturer	Characteristics	Operating conditions	Remarks
Grande Paroisse	CONTENT wt % NiO – SiO_2 – Al_2O_3 CARRIER: n.a. FORM: n.a. SIZE: Diameter (mm) 5–10	TEMPERATURE RANGE: 300°–500°C PRESSURE RANGE: n.a.	

METHANATION

TYPE OF CATALYST: *NICKEL Ni-0101 T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Nickel 44 present as hydrate CARRIER: Kieselguhr FORM: tablets SIZE(mm): n.a. ABD (g/cm^3) 1.2–1.3 STRENGTH (kg/cm^2) 5–7.7	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used for other hydrogenation reactions.

TYPE OF CATALYST: *NICKEL Ni-0301 T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Nickel 11 present as oxide CARRIER: activated alumina FORM: tablets SIZE: Diameter (mm) 3 ABD (g/cm^3) 1.2 SA (m^2/g) 64 PV (cm^3/g) 0.32 STRENGTH (kg/cm^2) 5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Also used for selective nitrogenation of di-olefins to mono-olefins.

TYPE OF CATALYST: *NICKEL RCH-18/10*

Manufacturer	Characteristics	Operating conditions	Remarks
Farbwerke Hoechst AG	CONTENT wt % Nickel 18 CARRIER: Al_2O_3 FORM: tablets SIZE: Diameter (mm) 6 Length (mm) 5	TEMPERATURE RANGE: 280°C PRESSURE RANGE: up to 25 atm	It must be reduced before use.

TYPE OF CATALYST: *NICKEL ICI 11--3*

Manufacturer	Characteristics	Operating conditions	Remarks
Imperial Chemical Industries Ltd. (I.C.I.)	CONTENT wt % Nickel oxide CARRIER: n.a. FORM: pellets SIZE: Diameter (mm) 5.4 Height (mm) 36 ABD (g/cm^3) 1.1	TEMPERATURE RANGE: 230°–450°C PRESSURE RANGE: up to 50 atm SPACE VELOCITY: 5,000–12,000 h^{-1}	It is also used in operation at pressure up to 250 atm. Must be protected from poisoning by sulphur, chlorine and arsenic compounds, if these are likely to be present in the inlet gas.

METHANATION OF CO

TYPE OF CATALYST: *NICKEL KATALCO 11—3*

Manufacturer	Characteristics	Operating conditions	Remarks
Katalco Corporation	CONTENT wt % Supported nickel oxide CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 5.4 Length (mm) 3.6 ABD (g/cm^3) 1.10	TEMPERATURE RANGE: 280°–420°C PRESSURE RANGE: 5–250 atm LIFE: about 3 years SPACE VELOCITY: 5,000–8,000 h^{-1}	It is used for removal of small amounts of CO, CO_2 and O_2 from hydrogen or synthesis gas streams. CO and CO_2 are reduced to methane. It is poisoned by sulphur.

PURIFICATION OF SYNTHESIS GAS (METHANATION)

TYPE OF CATALYST: *NICKEL-CHROME OXIDES KONTAKT 6540*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht"	CONTENT wt % Nickel oxide 48 Chrome oxide CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 5 Length (mm) 5 ABD (g/cm³)0.95–1.2 STRENGTH (kg/cm²) 150	TEMPERATURE RANGE: 150°–250°C PRESSURE RANGE: 1–300 atm	Used for the removal of CO, CO_2 and O_2; also in methanation process.

METHANATION

TYPE OF CATALYST: *NICKEL KONTAKT 6542*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht"	CONTENT wt % Ni, NiO, Cr_2O, Al_2O_3 CARRIER: alumina FORM: cylinders SIZE: Diameter (mm) 5 Length (mm) 5 ABD (g/cm³) 1±0.1 STRENGTH (kg/cm²) 200±50	TEMPERATURE RANGE: 180°–400°C PRESSURE RANGE: 1–300 atm	

PURIFICATION OF SYNTHESIS GAS (METHANATION)

TYPE OF CATALYST: *NICKEL KONTAKT 6543*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht"	CONTENT wt % Nickel oxide 30 CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 3 Length (mm) 3 ABD (g/cm³) 1.1 STRENGTH (kg/cm²) 350±80	TEMPERATURE RANGE: 220°–400°C PRESSURE RANGE: 1–300 atm	Removal of traces of O_2, CO, CO_2.

METHANATION OF CO

TYPE OF CATALYST: *NICKEL MT-15*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Nickel oxide CARRIER: alumina FORM: balls SIZE: Diameter (mm) 2–4; 4–6 ABD (g/cm^3) 0.95 SA (m^2/g) 100 PV (cm^3/g) 0.5 STRENGTH (kg/cm^2) >10	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Selective methanation of CO in CO_2, under pressure and high space velocity.

METHANATION OF CO AND CO_2

TYPE OF CATALYST: *NICKEL MT-25*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Nickel oxide CARRIER: special FORM: balls SIZE: Diameter (mm) 4-7; 6-8 ABD (g/cm^3) 1.25 SA (m^2/g) 80 PV (cm^3/g) 0.20 STRENGTH (kg/cm^2) >15	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Elimination of CO and CO_2 through conversion in CH_4, under pressure and with a high space velocity.

TYPE OF CATALYST: *NICKEL PKR*

Manufacturer	Characteristics	Operating conditions	Remarks
Haldor Topsøe	CONTENT wt % Nickel 14 CARRIER: ceramic based on alumina and silica FORM: spheres SIZE: n.a. ABD(g/cm^3) 0.9–0.95	TEMPERATURE RANGE: 250°–500°C PRESSURE RANGE: 24 atm SPACE VELOCITY (VHSV): 6,000 h^{-1}	Pre-reduced. Used for methanation of CO and CO_2 and for hydrogenation of O_2 in hydrogen or ammonia synthesis gas stream.

Ammonia synthesis

AMMONIA SYNTHESIS FROM NITROGEN AND HYDROGEN

TYPE OF CATALYST: *IRON R*

Manufacturer	Characteristics	Operating conditions	Remarks
Azote et Produits Chimiques S.A. (APC)	CONTENT wt % Magnetite promoted. As promotors: Al_2O_3; K_2O; CaO;MgO CARRIER: n.a. FORM: lumps SIZE (mm): 8×12; 12×21 ABD (g/cm^3) 2.4-2.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *IRON BASF S-6—10*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % Catalyst based on magnetite triply activated with K_2O, CaO and Al_2 O_3. State of oxidation: Fe_3O_4 CARRIER: n.a. FORM: grains of irregular shape SIZE: Diameter (mm) 3—6; 6—10; 14—20 ABD (g/cm^3)2.8—3.0 TS (°C) up to 530	TEMPERATURE RANGE: 380°—530°C PRESSURE RANGE: n.a.	Poisons: sulphur, chlorine compounds, O_2, CO, CO_2, H_2O vapours. Catalyst for high pressure synthesis of ammonia from nitrogen and hydrogen in all types of reactor.

TYPE OF CATALYST: *IRON BASF S-6—10 RED.*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % Catalysts based on magnetite triply activated with K_2O, CaO and Al_2O_3. State of oxidation: metallic iron CARRIER: n.a. FORM: grains SIZE: Diameter (mm): 3—6; 6—10; 14—20 ABD (g/cm^3) 2.1—2.3 TS (°C) up to 530	TEMPERATURE RANGE: 380°—530°C PRESSURE RANGE: n.a.	See BASF S-6—10.

TYPE OF CATALYST: *IRON C-73*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Multi-promoted iron oxides CARRIER: n.a. FORM: granules SIZE: Diameter (mm) 6—12 ABD (g/cm^3) 2.7	TEMPERATURE RANGE: 400°—600°C PRESSURE RANGE: 100—1,000 atm SPACE VELOCITY: 10,000—55,000 h^{-1}	C-73-1; C-73-2. These are triply-promoted iron catalysts. C-73-2 has a higher concentration of promotor than C-73-1. Manufactured and sold under license by Norsk-Hydro.

TYPE OF CATALYST: *IRON CHEZA 30—00*

Manufacturer	Characteristics	Operating conditions	Remarks
Chemical Works of CSF	CONTENT wt % Fe_3O_4 Activators: Al_2O_3, K_2O, CaO CARRIER: n.a. FORM: regular chips SIZE: Diameter (mm) 3—6 Length (mm) 6—10 ABD (g/cm^3) 2.6	TEMPERATURE RANGE: 390°—560°C PRESSURE RANGE: n.a.	The amount of poisons of oxygen compounds like CO no more than 10 ppm by volume.

TYPE OF CATALYST: *IRON FA-1*

Manufacturer	Characteristics	Operating conditions	Remarks
Combinatul Chimic Craiova	CONTENT wt % Iron promoted FeO/Fe_2O_3 ratio 0.45—1.00 Al_2O_3 3—4 CaO 2.5—3.5 K_2O 0.8—1.2 SiO_2 0.9—1.3 CARRIER: n.a. FORM: granules SIZE: Diameter (mm) 2—4 4—6 6—8 8—15 STRENGTH (kg/cm^2) 30—35	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *IRON GP-6 AND GP-7*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Iron oxide CARRIER: n.a. FORM: granules SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *IRON G-82*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Triply promoted iron oxide CARRIER: n.a. FORM: granules SIZE: Diameter (mm) 2 Length (mm) 8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It exhibits high temperature stability. It is poisoned slowly by free and combined oxygen, by sulphur compounds and by halogens.

TYPE OF CATALYST: *IRON GPS-6 AND GPS-7*

Manufacturer	Characteristics	Operating conditions	Remarks
Grande Paroisse	CONTENT wt % Melted and promoted Fe_3O_4. GPS-6 is quadriply promoted containing MgO, Al_2O_4, SiO_2 and K_2O. GPS-7 Contains Al_2O_3 and K_2O CARRIER: n.a. FORM: grains SIZE: Diameter (mm) 1—10; 2—12 Length (mm) — ABD (g/cm^3) 2.6	TEMPERATURE RANGE: 450°—475°C PRESSURE RANGE: 150—1,000 atm. LIFE: more than 2 years SPACE VELOCITY: 30,000 h^{-1}	It is recommended not to exceed 550°C. Pressure preferably between 250 and 350 atm.

TYPE OF CATALYST: *IRON GPS-8*

Manufacturer	Characteristics	Operating conditions	Remarks
Grande Paroisse	CONTENT wt % Melted and promoted Fe_3O_4 CARRIER: n.a. FORM: grains SIZE: Diameter (mm) 1–12	TEMPERATURE RANGE: 450°–475°C PRESSURE RANGE: 150–1,000 atm LIFE: more than 2 years	Similar to GPS-7

TYPE OF CATALYST: *IRON ICI 35–4*

Manufacturer	Characteristics	Operating conditions	Remarks
Imperial Chemical Industries Ltd	CONTENT wt % Multi-promoted magnetite composed of magnetite modified by controlled amounts of alumina, calcium potash and silica CARRIER: n.a. FORM: irregular granules	TEMPERATURE RANGE: 350°–550°C PRESSURE RANGE: 100–600 atm	It is poisoned by oxygen halogens and sulphur compounds, including sulphur in lubricating oils carried over from the compressors. Normal size ranges: A: 1.5– 3 mm B: 3– 4.5 mm C: 4.5– 6.5 mm D: 6– 9 mm E: 7– 9 mm F: 8–12 mm G: 12–21 mm

TYPE OF CATALYST: *IRON OXIDE KATALCO 35-4*

Manufacturer	Characteristics	Operating conditions	Remarks
Katalco Corporation	CONTENT wt % Consists essentially of magnetite (Fe_3O_4) multi-promoted by the addition of alumina, calcium and potash CARRIER: n.a. FORM: granules SIZE: Diameter (mm) 3–9 ABD (g/cm^3) 2.64	TEMPERATURE RANGE: 300°–550°C PRESSURE RANGE: 150–300 atm LIFE: 2–4 years	Other substances including silica are present in controlled amounts.

TYPE OF CATALYST: *IRON FNMS*

Manufacturer	Characteristics	Operating conditions	Remarks
Montedison S.p.A.	CONTENT wt % Iron oxides (approx. Fe_3O_4) 90 Promotors (mainly Al_2O_3, CaO, H_2O, SiO_2) 10 CARRIER: n.a. FORM: fused granules SIZE: Diameter (mm) 1.5−2.5 ABD (g/cm³) 2.55−2.80 Attrition loss: ~2%	TEMPERATURE RANGE: 350°−550°C PRESSURE RANGE: 100−600 atm LIFE: 3−4 years	Sulphur, arsenic, phosphorous, halogen compounds and some heavy metals cause permanent poisoning.

TYPE OF CATALYST: *IRON CATALYST CA-1*

Manufacturer	Characteristics	Operating conditions	Remarks
Sojuzchimexport U.S.S.R.	CONTENT n.a. CARRIER: n.a. FORM: spheres SIZE: 1−3; Diameter (mm) 3−5; 7−10 ABD (g/cm³) 2.5−3 TS (°C) up to 600	TEMPERATURE RANGE: 450°C PRESSURE RANGE: n.a. LIFE: not less than 3 years SPACE VELOCITY: 3,000 h⁻¹	It is produced in both reduced and non-reduced form.

TYPE OF CATALYST: *IRON OXIDE KM-I, KM-II, KM-VI*

Manufacturer	Characteristics	Operating conditions	Remarks
Haldor Topsøe	CONTENT wt % Iron oxide 90 Promotors 10 Non-reducible oxides, primarily of K, Ca and Al CARRIER: n.a. FORM: spheres SIZE: Diameter (mm) 1.5-23 ABD (g/cm³) 2.5−2.85	TEMPERATURE RANGE: 360°−550°C PRESSURE RANGE: 100−1,000 atm	KM: unreduced KMR: pre-reduced Two different KM types with different promotor content are manufactured. KM-I: operating temperature, 380°−550°C KM-II: operating temperature, 360°−480°C The choice between them depends on the operating conditions. They are available in various standard particle size: 1.5−3 mm; 4.5−8 mm; 6—10 mm; 8−12 mm: 12−21 mm and 16−23 mm.

TYPE OF CATALYST: *IRON KMR (PELLETED)*

Manufacturer	Characteristics	Operating conditions	Remarks
Haldor Topsøe	CONTENT wt % Consists of iron oxide of the approximate composition Fe_3O_4 and about 10% of promotors CARRIER: n.a. FORM: cylinders, rings SIZE: Diameter (mm) 6;OD/ID=13/6 Length (mm) 6;13 ABD (g/cm^3) 2.2–2.1	TEMPERATURE RANGE: 380°–550°C PRESSURE RANGE: n.a.	The promotors are non-reducible oxides primarily of K, Ca and Al.

TYPE OF CATALYST: *IRON LZ*

Manufacturer	Characteristics	Operating conditions	Remarks
Chemie Linz A.G.	CONTENT wt % FeO 31.5–34.5 Fe_2O_3 57.5–59.5 Al_2O_3 2.8– 3.0 CaO 3.2– 3.4 MgO 0.8– 1.2 K_2O 0.5– 0.6 SiO_2 0.4– 0.6 TiO_2 0.3– 0.4 CARRIER: n.a. FORM: grains of irregular shape SIZE: n.a. ABD (g/cm^3) 2.6–2.7 TS (°C) up to 620	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

B. Petrochemical industry

Acrylonitrile synthesis
Formaldehyde synthesis
Maleic anhydride synthesis
Methanol synthesis
Hydroformylation (oxo-reaction)
Phthalic anhydride synthesis
Styrene production
Vinyl acetate monomer synthesis
Vinyl chloride monomer synthesis

Acrylonitrile synthesis

ACRYLONITRILE SYNTHESIS

TYPE OF CATALYST: *BISMUTH-MOLYBDENUM A*

Manufacturer	Characteristics	Operating conditions	Remarks
Akzo Chemie B.V. Dpt. Ketjen Catalysts	CONTENT wt % Mo 14.8±1.0 Bi 24.1—0.5+1.6 Phosphorous 0.39±0.05 Silicon 23.4±1.0 CARRIER: silicon FORM: powder SIZE (mm): n.a. ABD (g/cm^3) 0.8—1 SA (m^2/g) 50—70 PV (cm^3/g) 0.18—0.25	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *BISMUTH-MOLYBDENUM KONTAKT 9421*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT wt % Bismuth oxide Molybdenum oxide and Silicon dioxide CARRIER: n.a. FORM: powder SIZE: n.a. ABD (g/cm^3) 1	TEMPERATURE RANGE: 430°—500°C PRESSURE RANGE: 1—3 atm	Oxidation of propylene.

Formaldehyde synthesis

FORMALDEHYDE SYNTHESIS

TYPE OF CATALYST: *GAUZE OF ELECTROLYTIC COPPER*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt % Copper FORM: gauze SIZE: Diameter of wire (mm) 0.25 Weight g/m^2 about 700	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Available as 64 mesh/cm^2.

TYPE OF CATALYST: *GAUZE OF ELECTROLYTIC COPPER*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt % Wire of copper FORM: gauze SIZE: Diameter of wire (mm) 0.25 Weight (g/cm^2) 700	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *ACTIVATED SILVER CRYSTALS*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt % Ag 99.9 FORM: crystals SIZE: Diameter (mm) 0.5—2.0 ABD (g/cm^3) 2.25	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for manufacture of aldehyde and ketones by oxidation of alcohols. They are used instead of silver gauze.

TYPE OF CATALYST: *SILVER GAUZE*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT n.a. FORM: sieve, 64 mesh/cm^2	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *SILVER SILARGON „N"*

Manufacturer	Characteristics	Operating conditions	Remarks
Doduco	CONTENT wt % Silver FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *SILVER*

Manufacturer	Characteristics	Operating conditions	Remarks
Johnson Mathey Chemicals Limited	CONTENT n.a. FORM: crystals or gauze SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used to a lesser extent in the manufacture of acetaldehyde.

TYPE OF CATALYST: *IRON-MOLYBDENUM G-105*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Iron-molybdenum oxides CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 4.5 Length (mm) 4.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *IRON-MOLYBDENUM KONTAKT 2410*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT wt % Iron oxide Molybdenum oxide CARRIER: none FORM: tablets SIZE: Diameter (mm) 4 Length (mm) 4 ABD (g/cm^3) 1.3±1 STRENGTH (kg/cm^2) 100±30	TEMPERATURE RANGE: 270°—330°C PRESSURE RANGE: atmospheric	

TYPE OF CATALYST: *IRON-MOLYBDENUM FM-3*

Manufacturer	Characteristics	Operating conditions	Remarks
Montedison S.p.A.	CONTENT wt % MoO_3 80 Fe_2O_3 20 binder free CARRIER: free FORM: cylinders; rings SIZE: cylinder rings Diameter (mm) 3.5 4×2 Length (mm) 3.5 3.5 ABD (g/cm^3) 0.93—1.10 PV (cm^3/g) 0.22—0.26 STRENGTH (kg/cm^2) 95	TEMPERATURE RANGE: 230°—310°C PRESSURE RANGE: n.a. LIFE: 1 year SPACE VELOCITY: 5,000—14,000 h^{-1}	The catalyst is currently used in both cooled and tubular converters, but it is also suited for use in different converter types.

TYPE OF CATALYST: *IRON-MOLYBDENUM FOX-HIAG*

Manufacturer	Characteristics	Operating conditions	Remarks
Österreichische HIAG Werke A.G.	CONTENT wt % Fe_2O_3 18—19 MoO_3 81—82 CARRIER: n.a. FORM: cylindrical pellets Diameter (mm) 4.1 Length (mm) 4.0—4.1 ABD (g/cm^3) 1.2 SA (m^2/g) (BET) 6 STRENGTH (kg/cm^2) 45 TS (°C) 400	TEMPERATURE RANGE: 350°—400°C PRESSURE RANGE: normal LIFE: 1—2 years	Side reactions are kept to a minimum.

TYPE OF CATALYST: *MOLYBDENUM AND IRON FK*

Manufacturer	Characteristics	Operating conditions	Remarks
Haldor Topsøe	CONTENT, wt % Molybdenum oxide 80 Iron oxide 20 Promotor: chromium oxide CARRIER: n.a. FORM: extrusions; rings; cylinders SIZE: rings cylinders Diameter (mm) 4.3/1.9 3.8 Length (mm) 3.5 3.85 ABD (g/cm^3) 0.90 1.05 STRENGTH (kg/cm^2) 70	TEMPERATURE RANGE: 250°—400°C PRESSURE RANGE: n.a. SPACE VELOCITY: 10,000 h^{-1}	The catalyst is very resistant to poisoning.

Maleic anhydride synthesis

MALEIC ANHYDRYDE SYNTHESIS

TYPE OF CATALYST: *VANADIUM SYN DAN CATALYST*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalyst Development Corporation (C.D.C.)	CONTENT wt % Promoted vanadia CARRIER: refractory oxides FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is designed to operate at high space velocities, high benzene feed concentration and high conversions.

TYPE OF CATALYST: *VANADIUM MOLYBDENUM MAT 5*

Manufacturer	Characteristics	Operating conditions	Remarks
Montedison S.p.A.	CONTENT mol V_2O_4 2 MoO_3 1 Na_2O 0.06 Support 88—89% CARRIER: alumina FORM: pellets SIZE: Diameter (mm) 5 Length (mm) 5 ABD (g/cm³) 1.1 PV (cm³/g) 0.2 STRENGTH (kg/cm²) 50—60 Attrition loss: 0.6—0.7%	TEMPERATURE RANGE: 340°—400°C PRESSURE RANGE: 1—2.5 atm LIFE: 2—3 years	It must be protected against air, damp and light. Impurities in the benzene can act as poisons. The following limits are advisable: paraffins: 0.3% ethylbenzene: 0.1% cumene and toluene: 0.02% tiophene + CS_2: 80 ppm (as elemental sulphur)

TYPE OF CATALYST: *TITANUM-VANADIUM-MOLYBDENUM BASF 04—30*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % Titanum dioxide with V_2O_5 and MoO_3 as active components CARRIER: n.a. FORM: irregular chips in different fractions SIZE: Diameter (mm) 3—6 (standard) ABD (g/cm³) 1.2	TEMPERATURE RANGE: 370°—380°C PRESSURE RANGE: n.a.	

Methanol synthesis

METHANOL SYNTHESIS (FROM CARBON MONOXIDE AND HYDROGEN)

TYPE OF CATALYST: *Zn BASF S-5—10*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % ZnO 65 CrO_3 14 Na <0.05 K <0.02 Fe <0.05 Ni <0.005 Mn <0.005 CARRIER: n.a. FORM: pellets; rings SIZE: *pellets* *rings* Diameter (mm) 5 10×4 Length (mm) 5 10 ABD (g/cm^3) 1.6—1.8 SA (m^2/g) 100 (after reduction) PV (cm^3/g) 0.2 (after reduction) STRENGTH (kg/cm^2) 500 (measured at the faces)	TEMPERATURE RANGE: 300°—400°C PRESSURE RANGE: above 200 atm	

TYPE OF CATALYST: *Zn-Cr C-70—2*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Zinc/Chrome oxide CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE 340°—400°C PRESSURE RANGE: 210—350 atm	Production of methanol by high temperature process.

TYPE OF CATALYST: *COPPER C-79—2*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Copper CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: 220°—300°C PRESSURE RANGE: 20—200 atm	Methanol synthesis at low temperature and pressures.

TYPE OF CATALYST: ***CHROMITE CATALYSTS***

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt % active metal chrome Cu 33—34 29—30 Ni 30—31 27—28 Co 39—40 31—32 Cd 46—47 23—24 Ag 64—65 18—19 Zn 46—47 32—33 Additives: Ba, Mn, Pd CARRIER: Al_2O_3; SiO_2; CaO FORM: powder; tablets SIZE: n.a. ABD (g/cm^3) 0.25—1.2	TEMPERATURE RANGE: 400°C PRESSURE RANGE: 300 atm	Used also in hydrocracking processes.

TYPE OF CATALYST: ***Zn-0302.T***

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % ZnO 74 CrO_3 23 CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 4; 6; 9	TEMPERATURE RANGE: 300°—400°C PRESSURE RANGE: 250—400 atm	

TYPE OF CATALYST: ***Zn-0308.T***

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % ZnO 74 Cr_2O_3 22 CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 6	TEMPERATURE RANGE: 300°—400°C PRESSURE RANGE: 250—400 atm	This is the reduced form of Zn-0302.T.

TYPE OF CATALYST: *Zn-0311.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % ZnO, CrO_3 CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 4; 6; 9 ABD (g/cm^3) 1.76 STRENGTH (kg/cm^2) 18	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Similar to Zn-0203.T. It is available to those users who prefer to reduce catalyst themselves.

TYPE OF CATALYST: *Zn-0312.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Cr_2O_3 22 CARRIER: n.a. FORM: n.a. SIZE: Diameter (mm) 4; 6; 9 ABD(g/cm^3) 1.6 SA (m^2/g) 130 PV (cm^3/g) 0.2 STRENGTH (kg/cm^2) 16	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Similar to Zn-0308.T. This is the reduced form of Zn-0311.T.

TYPE OF CATALYST: *ZINC-CHROMIUM ICI-25 SERIES*

Manufacturer	Characteristics	Operating conditions	Remarks
Imperial Chemical Industries Ltd. (ICI)	CONTENT wt % Zinc oxide Chromium oxide CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	A high pressure methanol synthesis catalyst.

TYPE OF CATALYST: *ZINC KONTAKT 617*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT wt % Mixed zinc oxide and chrome oxide. It contains Cr^{III} and also Cr^{IV} CARRIER: n.a. FORM: pellets SIZE: Diameter(mm) 5; 9 ABD (g/cm^3) 1.4±0.14; 1.30±0.13 STRENGTH (kg/cm^2) 500±100; 240±50	TEMPERATURE RANGE: 320°—390°C PRESSURE RANGE: 200—300 atm	It is a high pressure methanol synthesis catalyst.

TYPE OF CATALYST: *ZINC KONTAKT 618*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT wt % ZnO mixed with Zn-chromite It does not contain chrome as Cr^{VI} CARRIER: n.a. FORM: cylindrical pellets SIZE: Diameter (mm) 5; 9 Length (mm) 5; 9 ABD (g/cm^3) 1.60±0.15; 1.50±0.15 STRENGTH (kg/cm^2) 450±150; 300±150	TEMPERATURE RANGE: 320°—400°C PRESSURE RANGE: 200—300 atm	It is a high pressure methanol synthesis catalyst.

TYPE OF CATALYST: *ZINC-CHROMITE QF-4*

Manufacturer	Characteristics	Operating conditions	Remarks
Montedison S.p.A.	CONTENT wt % Binder free $ZnO+Cr_2O_3$ Its composition is strictly homogeneous. Attrition loss < 0.5% CARRIER: n.a. FORM: cylindrical pellets, rings SIZE: cylindrical pellets / rings Diameter (mm) 5—10 / 10×4 Length (mm) 5.3—8 / 8 ABD (g/cm^3) 1.6—1.7 PV (cm^3/g) 0.23—0.25 STRENGTH (kg/cm^2) 500—550	TEMPERATURE RANGE: 300°—400°C PRESSURE RANGE: 200—400 atm SPACE VELOCITY: 15,000—40,000 h^{-1} LIFE: 1 m^3 catalyst produces 25,000 tons of anhydrous methanol	

METHANOL SYNTHESIS

TYPE OF CATALYST: *ZINC CHROMITE BZC-21*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Active agent zinc chromite CARRIER: n.a. FORM: pellets SIZE: Diameter(mm) 10—12.5 Length (mm) 7 ABD (g/cm^3) 1.5 SA (m^2/g) 40—50 PV (cm^3/g) 0.9—0.12	TEMPERATURE RANGE: 360°C (<400°C) PRESSURE RANGE: 200—400 atm SPACE VELOCITY: 20,000—25,000 h^{-1}	Porosity: 27—30% Delivered pre-reduced.

METHANOL SYNTHESIS (FROM CARBON MONOXIDE AND HYDROGEN)

TYPE OF CATALYST: *ZINC AND CHROMIUM SMKR*

Manufacturer	Characteristics	Operating conditions	Remarks
Haldor Topsøe	CONTENT wt % Consists of oxides of zinc and chromium CARRIER: n.a. FORM: cylinders; rings SIZE: cylinders rings Diameter (mm) 5.7 10×4 Length (mm) 5.7 10 ABD (g/cm^3) 1.45 1.28 STRENGTH (kg/cm^2) 600 (axial crush)	TEMPERATURE RANGE: 330°—400°C PRESSURE RANGE: 200—400 atm SPACE VELOCITY (VHSV): 20,000—50,000 v/v/hr	Pre-reduced. Delivered in the reduced and fully active state. Attrition loss is less than 3%. Normally used in higher temperature process.

TYPE OF CATALYST: *LMK*

Manufacturer	Characteristics	Operating conditions	Remarks
Haldor Topsøe	CONTENT n.a. CARRIER: n.a. FORM: cylinders SIZE: Diameter (mm) 4.5; 6 Length (mm) 4.5; 6 ABD (g/cm^3) 1.2	TEMPERATURE RANGE: 220°—270°C PRESSURE RANGE: n.a.	The catalyst is offered under a cooperation agreement between Haldor Topsøe and the Japanese company Nihon Suiso (Nissui). Low temperature synthesis.

Hydroformylation (oxo-reaction)

SECOND STEP OF THE OXO-PROCESSES

TYPE OF CATALYST: *COBALT C-60 SERIES*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Cobalt CARRIER: Kieselguhr FORM: tablets or powder SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The oxo hydrogenation of aldehydes to alcohols and hydrogenation of propion aldehyde.

TYPE OF CATALYST: *COBALT G-103*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Co 40 CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 6 Length (mm) 6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	In many respects similar to G-61 nominally % Co 40. Available in pre-reduced form as G-103R. Form: powder, suspended in the desired liquid.

TYPE OF CATALYST: *COBALT Co-0101.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Co 35 as cobalt oxide CARRIER: Kieselguhr FORM: tablets SIZE: Diameter (mm) 5 ABD (g/cm^3) 1.14 SA (m^2/g) 130 PV (cm^3/g) 0.35 STRENGTH (kg/cm^2) 8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	A hydrogenation catalyst.

TYPE OF CATALYST: *COBALT Co-0108. T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Co 39 CARRIER: Kieselguhr FORM: tablets SIZE: Diameter (mm) 5 ABD (g/cm^3) 1.12 SA (m^2/g) 140 PV (cm^3/g) 0.4 STRENGTH (kg/cm^2) 6.8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for oxo-processes and other selective hydrogenation reactions.

TYPE OF CATALYST: *COBALT Co-0401.G.4—8*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Co 13 present as oxide CARRIER: silica FORM: granules SIZE: Diameter (mm) 4—8 ABD (g/cm^3) 0.48 SA (m^2/g) 1 PV (cm^3/g) 0.36	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for oxo-processes synthesis and for hydrogenation reactions.

TYPE OF CATALYST: *COBALT Co-0402.G.4—8*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Co 6 as cobalt oxide CARRIER: silica FORM: granules SIZE: Diameter (mm) 4—8 ABD (g/cm^3) 0.5 SA (m^2/g) 1 PV (cm^3/g) 0.38	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for oxo-processes synthesis and for hydrogenation reactions.

TYPE OF CATALYST: *COBALT Co-0403.G.4—8*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Co 20 as cobalt oxide CARRIER: silica FORM: granules SIZE: Diameter (mm) 4—8 Length (mm) n.a. ABD (g/cm^3) 0.48 SA (m^2/g) 6 PV (cm^3/g) 0.38	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *COBALT Co-0405 G.4—8*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Co 20 CARRIER: silica FORM: granules SIZE: Diameter (mm) 4—8 ABD (g/cm^3) 0.51 SA (m^2/g) 4 PV (cm^3/g) 0.49	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	A hydrogenation catalyst, reduced and stabilized.

TYPE OF CATALYST: *COBALT Co-0501.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Co 10 in oxide form CARRIER: activated alumina FORM: tablets SIZE: Diameter (mm) 3.2 ABD (g/cm^3) 0.96 SA (m^2/g) 60 PV (cm^3/g) 0.51 STRENGTH (kg/cm^2) 7.7	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *COPPER CHROMITE Cu-0203.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % CuO 80 or 78 Cr_2O_3 17 or 20 CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 1.4 ABD (g/cm^3) 2.16 STRENGTH (kg/cm^2) 12.7	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	This is tableted Cu-0202.P.

TYPE OF CATALYST: *COPPER CHROMITE Cu-0402.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % CuO 35 Cr_2O_3 38 BaO 10 CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 3.2 ABD (g/cm^3) 1.62 STRENGTH (kg/cm^2) 3.6—5.4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	This is tableted Cu-0401.P.

TYPE OF CATALYST: *COPPER CHROMITE Cu-1107.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % CuO 33 Cr_2O_3 38 BaO 9.5 CARRIER: n.a. FORM: tablets SIZE: Diameter(mm) 3.2 ABD (g/cm^3) 1.8 STRENGTH (kg/cm^2) 5.4—7.2	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	This is tableted Cu-1106.P.

TYPE OF CATALYST: *COPPER CHROMITE Cu-1808.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % CuO 42 Cr_2O_3 38 CARRIER: n.a. FORM: tablets SIZE: Diameter(mm) 3.2 ABD (g/cm^3) 1.3 STRENGTH (kg/cm^2) 4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	This is tableted Cu-1800.P.

TYPE OF CATALYST: *NICKEL Ni-0101.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni 44 Present as hydrate CARRIER: Kieselguhr FORM: tablets SIZE: Diameter (mm) 3;5;6 Length (mm) n.a. ABD (g/cm^3) 1.25—1.36 STRENGTH (kg/cm^2) 5—7.7	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for hydrogenation and methanation.

TYPE OF CATALYST: *NICKEL Ni-0104.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni 60 A ratio of reduced nickel to total nickel 0.60 CARRIER: Kieselguhr FORM: tablets SIZE: Diameter (mm) 3.2; 4.7; 6.3 ABD (g/cm^3) 1.2—1.44 SA (m^2/g) 150 PV (cm^3/g) 0.2 STRENGTH (kg/cm^2) 3.6—11.3	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Tableted form of Ni-0104.P.

SYNTHESIS OF HIGH ALCOHOLS (FROM CO AND H_2)

TYPE OF CATALYST: *ZINC (Isobutilolkontakt) KONTAKT 1132*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT wt % Mixture of hydroxichromate of zinc with small parts of alkali CARRIER: n.a. FORM: cylinders SIZE: Diameter (mm) 5; 9 Length (mm) 5; 9 ABD (g/cm^3) 1.5—1.8 1.4—1.7 STRENGTH (kg/cm^2) 500—600 220—270	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	In unreduced form it contains Cr^{VI}.

TYPE OF CATALYST: *COBALT KONTAKT 6801*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT wt % CoO $CoCO_3$ CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Simply mentioned in Leuna catalysts.

Phthalic anhydride synthesis

PHTHALIC ANHYDRIDE SYNTHESIS (BY OXIDATION OF NAPHTHALENE)

TYPE OF CATALYST: *VANADIUM CATALYST BASF 04–20*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % SiO_2 67 V_2O_5 4 K 6.4 SO_4 16.5 Loss on drying 3.5 CARRIER: SiO_2 FORM: grains SIZE (mm): n.a. ABD (g/cm^3) 0.67 SA (m^2/g) 220 PV (cm^3/g) 0.8	TEMPERATURE RANGE: 340°—380°C PRESSURE RANGE: n.a.	By the fluidized bed process. Used for naphthalene rich in sulphur or with low sulphur content, e.g. petronaphthalene. Grains for fluidized bed with following size distribution: <60 μ cca 2% >200 μ cca. 30% >300 μ cca. 0%

TYPE OF CATALYST: *AERO PAA-3*

Manufacturer	Characteristics	Operating conditions	Remarks
Cyanamid International	CONTENT n a. CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	A fluid-bed catalyst. The high activity and stability of the catalyst are matched by an improved resistance to sulphur poisoning.

TYPE OF CATALYST: *VANADIUM GRADE 902; GRADE 906*

Manufacturer	Characteristics	Operating conditions	Remarks
Davison Chemical Division, W.R. Grace & Co.	CONTENT wt % Vanadium CARRIER: special silica gel FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used in fluid-bed reactions.

Styrene production

SYNTHESIS OF STYRENE (BY DEHYDROGENATION OF ETHYLBENZENE)

TYPE OF CATALYST: *IRON BASF S-6—20*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % Fe_2O_3 as main constituent with activating additives FORM: extrusions SIZE: Diameter (mm) 5 ABD (g/cm^3) 1.3 STRENGTH (kg/cm^2) $\sim$10 (cutting method)	TEMPERATURE RANGE: 550°—600°C PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *IRON STYRENEKONTAKT K-35*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Chemische Werke Buna	CONTENT wt % Fe 58—62 FORM: extrusions SIZE: Diameter (mm) 5—10 Length (mm) 8—30 ABD (g/cm^3) 1.25—1.45	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a. LIFE: more than 1 year	

TYPE OF CATALYST: *IRON C-97*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Iron oxide promoted with chrome, vanadium and K FORM: extrusions; pellets SIZE (mm): extrusions 3.2—4.5, pellets 3—4 ABD (g/cm^3) 1.2	TEMPERATURE RANGE: 620°—640°C PRESSURE RANGE: n.a. SPACE VELOCITY (LHSV): 0.3—0.5 h^{-1}	Iroven catalyst. Available also as C-97-1

TYPE OF CATALYST: *IRON CHEZA 31—02*

Manufacturer	Characteristics	Operating conditions	Remarks
Chemical Works of C.S.F.	CONTENT wt % Cr_2O_3 5 K_2O 5 SO_3 max. 1 Fe_2O_3 the remainder Loss on ignition (600°C) max. 3% CARRIER: n.a. FORM: extrusions SIZE: Diameter (mm) 4; 8 Length (mm) 4—10; 8—15 ABD (g/cm^3) 1.5 STRENGTH (kg/cm^2) Diam. 4: 3 Kp/cm^2 Diam. 8: 5 Kp/cm^2	TEMPERATURE RANGE: 560°C PRESSURE RANGE: 1 atm SPACE VELOCITY: 0.5 h^{-1}	During the dehydrogenation water vapours are added.

TYPE OF CATALYST: *IRON G-64*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Cr_2O_3 2.5±0.5 K_2CO_3 26±2 Fe_2O_3 60±3 A potassium and chrome promoted iron catalyst CARRIER: n.a. FORM: extrusions SIZE: Diameter (mm) 3;4 ABD (g/cm^3) 1.280 SA (m^2/g) 5±2 STRENGTH (kg/cm^2) 1.359	TEMPERATURE RANGE: 600°—650°C PRESSURE RANGE: n.a. SPACE VELOCITY: 0.5 h^{-1}	Used also in the dehydrogenation of cumene to alfa-methyl styrene. It can be used in either adiabatic or isothermal systems.

TYPE OF CATALYST: *IRON G—84*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % See G-64 CARRIER: n.a. FORM: extrusions SIZE: Diameter (mm) 1.5; 3; 4.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Dehydrogenation of cumene to alfa-methyl styrene. More active than G-64 at lower temperatures. Ameliorated version of G-64.

TYPE OF CATALYST: *SHELL 105/205*			
Manufacturer	Characteristics	Operating conditions	Remarks
Shell Chemical Co.	CONTENT n.a. CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *NICKEL 28148*			
Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Incorporated	CONTENT wt % Nickel oxide 15 CARRIER: alumina FORM: pellets SIZE: Diameter (mm) 3 Length (mm) 3 SA (m^2/g) approx. 65	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See section on dehydrogenation.

Vinyl acetate monomer synthesis

VINYL ACETATE SYNTHESIS

TYPE OF CATALYST: *ZINC VINA KONTAKT VA-KONTAKT*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Chemische Werke Buna	CONTENT wt % A zinc salt mounted on active charcoal. Zn min. 6 CARRIER: active charcoal FORM: extrusions SIZE: Diameter (mm) 3—5 ABD (g/cm³) 0.6—0.8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The vinyl acetate is formed by the addition of acetylene to acetic acid.

TYPE OF CATALYST: *ZINC ACETATE C-76-1*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Zinc acetate CARRIER: carbon FORM: granules SIZE (mm): 4×10 mesh	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The vinyl acetate is formed by the addition of acetylene to acetic acid.

TYPE OF CATALYST: *ZINC CODE 183*

Manufacturer	Characteristics	Operating conditions	Remarks
Calsicat Division	CONTENT wt % Zinc acetate 11 CARRIER: carbon FORM: granules SIZE (mm): 4×10 mesh	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for the manufacture of vinyl acetate from acetylene and acetic acid.

TYPE OF CATALYST: *ZINC CATALYST ZO*

Manufacturer	Characteristics	Operating conditions	Remarks
Ciech Nitroplast Warszawa	CONTENT wt % Zinc acetate min. 26 FORM: granules SIZE: n.a. ABD (g/cm^3) 0.4—0.6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Synthesis from acetylene and acetic acid.

TYPE OF CATALYST: *ZINC ZAV-1*

Manufacturer	Characteristics	Operating conditions	Remarks
Combinatul Chimic Craiova	CONTENT wt % ZnO min. 15 CARRIER: activated charcoal FORM: n.a. SIZE: n.a. ABD (g/cm^3) 0.6—0.8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a. LIFE: 960 hours	

TYPE OF CATALYST: *ZN-0803, G. 4—10*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Zinc 10 present as acetate CARRIER carbon FORM: n.a. SIZE: n.a. ABD (g/cm^3) 0.7	TEMPERATURE RANGE: 170°—210°C PRESSURE RANGE: n.a.	The vinyl acetate is formed by the addition of acetylene to acetic acid.

TYPE OF CATALYST: *ZINC ACETATE MAVC*

Manufacturer	Characteristics	Operating conditions	Remarks
Montedison S.p.A.	CONTENT wt % Zinc acetate 30 Support 70 An acetate promotor has been added CARRIER: active carbon FORM: pellets SIZE: Diameter (mm) 3.8 Length (mm) 5.5 ABD (g/cm^3) 0.47—0.48 SA (m^2/g) 250 PV (cm^3/g) 0.79—0.80 Attrition loss: 0.1—0.2%	TEMPERATURE RANGE: 155°—220°C PRESSURE RANGE: 1.0—1.5 atm LIFE: ~ 4 months SPACE VELOCITY (VHSV): $\geqslant$ 230 h^{-1}	The catalyst is poisoned by sulphur and P. The vinyl acetate is produced by the conversion of acetylene.

TYPE OF CATALYST: *ZINC ACETATE MAVP*

Manufacturer	Characteristics	Operating conditions	Remarks
Montedison S.p.A.	CONTENT wt % Zinc acetate 30 Zinc 10.7 Acetate promotor CARRIER: active carbon FORM: pellets SIZE: Diameter (mm) 2 Length (mm) 4 ABD (g/cm^3) 0.74—0.75 SA (m^2/g) 60—70 PV (cm^3/g) 0.31—0.32 Attrition loss: 0.1—0.2%	TEMPERATURE RANGE: 160°—220°C PRESSURE RANGE: 1.0—1.5 atm LIFE: 400—450 kg vinyl acetate/1 kg catalyst SPACE VELOCITY: $\geqslant$ 357 S.T.P. Vol/catal. vol./hour	The catalyst is poisoned by H_2S and PH_3.

TYPE OF CATALYST: *ZINC 30130; 30270; 30285*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Incorporated	CONTENT wt % (1) 30130 Zn acetate on carbon: Zn 11% (2) 30270 Zinc oxide (3) 30285 Zinc oxide on alumina: ZnO 24% FORM: (1) mesh granules, (2) spheres, (3) pellets SIZE (mm): (1) mesh granules: 4×10 (2) spheres: 3×4 (3) pellets: 3×3 SA (m^2/g) (1) 60 (2) 35 (3) 46	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The catalysts are also used to oxidate alcohols to aldehydes and ketones.

TYPE OF CATALYST: *MERCURY 80207*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Incorporated	CONTENT wt % Mercuric chloride Hg 9—11 CARRIER: carbon FORM: granules SIZE (mm): 4×8 mesh SA (m^2/g) approx. 60	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used for the synthesis of vinyl chloride from acetylene.

Vinyl chloride monomer synthesis

VINYL CHLORIDE SYNTHESIS

TYPE OF CATALYST: *MERCURIC CHLORIDE BASF S-9—10*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % $HgCl_2$ 10 CARRIER: activated charcoal FORM: extrusions SIZE: Diameter (mm) 4 ABD (g/cm³) 0.42	TEMPERATURE RANGE: 100°—200°C PRESSURE RANGE: n.a.	Sulphur and phosphorus compounds damage this type of catalyst. It is used in the manufacture of vinyl chloride from acetylene and hydrogen chloride.

TYPE OF CATALYST: *MERCURIC CHLORIDE VC KONTAKT (SUBLIMATE KONTAKT, VINYL CHLORIDE KONTAKT)*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Chemische Werke Buna	CONTENT wt % $HgCl_2$ min. 6 CARRIER: activated charcoal FORM: extrusions SIZE: Diameter (mm) 4 ABD (g/cm³) 0.5—0.6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Gas phase synthesis of vinyl chloride from acetylene and hydrogen chloride.

TYPE OF CATALYST: *MERCURIC CHLORIDE CODE 171; 172; 175.*

Manufacturer	Characteristics	Operating conditions	Remarks
Calsicat Division	CONTENT wt % Mercuric chloride 10—12 CARRIER: carbon FORM: powder; SIZE: 4—6 mm mesh	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Application in manufacture of vinyl chloride from acetylene and HCl.

TYPE OF CATALYST: *PALLADIUM C-31—8*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Palladium CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 12 ABD (g/cm³) 0.48± 0.08	TEMPERATURE RANGE: 120°—200°C PRESSURE RANGE: n.a.	Used in Goodrich oxychlorination process. C_2H_2 removal from HCl gas by hydrogenation.

TYPE OF CATALYST: *COPPER C-72—1*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % $CuCl_2$, promoted with either sodium or potassium according to process requirements CARRIER: alumina FORM: powder, tablets SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	C-72 is principally used for oxychlorination of ethylene to ethylene dichloride and pyrolysis to vinyl chloride. It is used for fluidized bed applications (as powder) or for fixed bed (as tablets).

TYPE OF CATALYST: *COPPER Cu-0804.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Cu 7.7 CARRIER: activated alumina FORM: tablets SIZE: Diameter (mm) 6 ABD (g/cm³) 0.9 SA (m²/g) 100 PV (cm³/g) 0.36 STRENGTH (kg/cm²) 8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used in oxychlorination of ethylene to ethylene dichloride and pyrolysis to vinyl chloride. Used as chlorination catalyst.

TYPE OF CATALYST: *COPPER Cu-0905.P*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % $CuCl_2$ 10 CARRIER: activated alumina FORM: powder SIZE: n.a. ABD (g/cm^3) 0.96 SA (m^2/g) 180	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used in oxychlorination of ethylene to ethylene dichloride and pyrolysis to vinyl chloride. Used as chlorination catalyst.

TYPE OF CATALYST: *COPPER Cu-0905.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % $CuCl_2$ 10 CARRIER: activated alumina FORM: tablets SIZE: Diameter (mm) 3 ABD (g/cm^3) 0.96 SA (m^2/g) 59 PV (cm^3/g) 0.26 STRENGTH (kg/cm^2) 5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used also as chlorination catalyst. See Cu-0906.P

TYPE OF CATALYST: *MERCURIC CHLORIDE C-0301. G. 4—10*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % about 10% mercuric chloride CARRIER: activated carbon FORM: granules; extrusions SIZE: Diameter (mm) 4—10	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Available also as: C-0302. G.4-6 C-0308. G.4-10 C-0309. E.4-6 C-0310. E.6-8 It is used in the manufacture of vinyl chloride from acetylene and hydrogen chloride. Support various activated carbons, derived from such sources as nutshells, coal and petroleum coke.

TYPE OF CATALYST: *MERCURIC CHLORIDE H-7701*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % $HgCl_2$ 10 CARRIER: charcoal FORM: extrusions SIZE: Diameter (mm) 4 Length (mm) 3—7 ABD (g/cm^3) 0.43 SA (BET) (m^2/g) 800—1,000 PV (cm^3/g) 1	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used in the vinyl chloride synthesis by the addition of HCl to acetylene.

TYPE OF CATALYST: *MERCURIC CHLORIDE MCV-2*

Manufacturer	Characteristics	Operating conditions	Remarks
Montedison S.p.A.	CONTENT wt % $HgCl_2$ 10 Active carbon 90 Copper <20 ppm Other heavy metals <0.2 CARRIER: active carbon FORM: pellets SIZE: Diameter (mm) 4 Length (mm) 6—9 ABD (g/cm^3) 0.42—0.43 SA (m^2/g) 1,100 PV (cm^3/g) 1.0—1.1	TEMPERATURE RANGE: 100°—250°C PRESSURE RANGE: 1—2 atm LIFE: 4 months SPACE VELOCITY (VSHV): $\geqslant$ 130 h^{-1}	The vinyl chloride synthesis by the addition of HCl to acetylene.

TYPE OF CATALYST: *MERCURY 80207*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Incorporated	CONTENT wt % Mercuric chloride Hg 9—11 CARRIER: carbon FORM: granules SIZE: 4×8 mm mesh SA (m^2/g) approx. 60	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for conversion of acetylene to vinyl chloride and of acetylene to vinyl acetate.

C. Production of acids

Nitric acid production
Sulphuric acid production

Nitric acid production

SELECTIVE OXIDATION OF AMMONIA TO NITRIC ACID

TYPE OF CATALYST: *XC 120-1*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Experimental catalyst CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The proprietary nature and composition of this catalyst require special arrangements regarding its evaluation and eventual application.

TYPE OF CATALYST: *ALLOYS Pt–Rh.10 N_2–P.10*

Manufacturer	Characteristics	Operating conditions	Remarks
Comptoir Lyon-Alemand Louyot	CONTENT wt % Alloys Pt-Rh FORM: sieve SIZE: mesh/cm² 1,024 Diameter of wire (mm) 0.06 Weight (g/cm²) 400	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Impurities: Gold 70 ppm Iron 100 to 75 ppm Nickel 50 to 75 ppm Copper 50 to 75 ppm Silver 50 to 75 ppm Aluminium, Silicon, Magnesium, Calcium } total 50 to 100 ppm Lead, Bismuth, Antimony, Phosphor, Sulphur, Arsenic } indeterminable by emission spectrography

TYPE OF CATALYST: *ALLOYS Pt–Rh. 10 N_2 –P.10-S*

Manufacturer	Characteristics	Operating conditions	Remarks
Comptoir Lyon-Alemand Louyot	CONTENT wt % Alloys Pt-Rh FORM: sieve SIZE: mesh/cm² 1,000 Diameter of wire (mm) 0.076 Weight (g/cm²) 630	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Impurities: Gold 70 ppm Iron 100 to 75 ppm Nickel 50 to 75 ppm Copper 50 to 75 ppm Silver 50 to 75 ppm Aluminium, Silicon, Magnesium, Calcium } total 50 to 100 ppm Lead, Bismuth, Antimony, Phosphor, Sulphur, Arsenic } indeterminable by emission spectrography

OXIDATION OF AMMONIA IN THE MANUFACTURE OF NITRIC ACID

TYPE OF CATALYST: *ALLOYS Pt-Rh.5 N2—P.5*

Manufacturer	Characteristics	Operating conditions	Remarks
Comptoir Lyon-Alemand Louyot	CONTENT wt % Alloys Pt-Rh FORM: sieve SIZE: mesh/cm^2 1,024 Diameter of wire (mm) 0.06 Weight (g/cm^2) 400	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Impurities: See Pt-Rh.10N_2-P.10

TYPE OF CATALYST: *PLATINUM-RHODIUM DB-750*

Manufacturer	Characteristics	Operating conditions	Remarks
Engelhard Minerals Chemicals Corporation	CONTENT wt % Platinum 95 Rhodium 5 FORM: sieve SIZE: mesh/cm^2 1,024 Diameter of wire (mm) 0.06	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *Pt and Rh—Pt ALLOYL*

Manufacturer	Characteristics	Operating conditions	Remarks
Johnson Matthey Chemicals Limited	CONTENT wt% Platinum and rhodium — platinum alloy sieves FORM: sieves SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The same type of sieve is also used in the catalytic synthesis of hydrogen cyanide from methane ammonia and air ((Andrussow process).

Sulphuric acid production

SULPHURIC ACID MANUFACTURE

TYPE OF CATALYST: *VANADIUM BASF 04—11*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt% V_2O_5 thermally stable cca. 8 Alkali sulphate CARRIER: porous silica FORM: extrusions SIZE: Diameter (mm) 4; 6 ABD (g/cm^3) 0.55	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	In all conventional reactors from gases containing SO_2, e.g. gases obtained from burning sulphur. Used in wet catalysis.

TYPE OF CATALYST: *VANADIUM CF-101*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt% V_2O_5 K_2O CARRIER: Kieselguhr FORM: extrusions SIZE: Diameter (mm) 5 ABD (g/cm^3) 0.72	TEMPERATURE RANGE: 400°—620°C PRESSURE RANGE: n.a.	Oxidation of sulphur dioxide to sulphur trioxide.

TYPE OF CATALYST: *VANADIUM C-101—2*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt% V_2O_5 7.5—8.5 K_2O 10—13 S 11—13.6 Na 0.75—1.5 Balance: inert carrier Vanadium pentoxide with promotors CARRIER: innert FORM: pellets SIZE: Diameter (mm) 6 Length (mm) 6 ABD (g/cm^3) 0.8 SA (m^2/g) 2—4 PV (cm^3/g) 0.2—0.4 STRENGTH (kg/cm^2) 6.8—15.8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	CCI initiated production of C-101 in 1964 via a know-how agreement with Mechim (a Belgian firm). Oxidation of sulphur dioxide to sulphur trioxide.

TYPE OF CATALYST: *VANADIUM C-116*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt% V_2O_5 7.5—8.5 K_2O 10—13 S 11—13.6 Na 0.75—1.5 CARRIER: n.a. FORM: spheres SIZE: Diameter (mm) 4.5—7.5 ABD(g/cm^3) 0.6 SA (m^2/g) 5—10 PV (cm^3/g) 0.4—0.8 STRENGTH (kg/cm^2) 6.8	TEMPERATURE RANGE: 400°—625°C PRESSURE RANGE: near atm. SPACE VELOCITY: Will depend on number of beds and cooling arrangements.	Oxidation of sulphur dioxide to sulfur trioxide. Used in plants employing low pressure contact process.

TYPE OF CATALYST: *VANADIUM CF-116*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt% V_2O_5, K_2O CARRIER: Kieselguhr FORM: extrusions SIZE: Diameter (mm) 5 ABD (g/cm^3) 0.72	TEMPERATURE RANGE: 400°—620°C PRESSURE RANGE: n.a.	Oxidation of sulphur dioxide to sulphur trioxide.

TYPE OF CATALYST: *VANADIUM AERO CATALYST SA*

Manufacturer	Characteristics	Operating conditions	Remarks
Cyanamid International	CONTENT wt% V_2O_5 CARRIER: n.a. FORM: pellets SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *VANADIUM G-101*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt% A potassium-vanadium oxide catalyst CARRIER: silica FORM: spheres SIZE: Diameter (mm) 5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is based on a highly active anion exchanging cross-linked silica carrier, which gives it a low temperature activity.

TYPE OF CATALYST: *VANADIUM GRILLO V_2O_5*

Manufacturer	Characteristics	Operating conditions	Remarks
Grillo-Werke Aktiengesellschaft	CONTENT wt% V_2O_5 7.5 K_2O 12.0 Na_2O 1.0 CARRIER: specially treated silicic acid FORM: n.a. SIZE: Diameter (mm) 4; 6; 8 Ratio diam: 1:1; 1:12 ABD (g/cm^3) 0.480—0.530 SA (m^2/g) 5.8—6.3 POROSITY: 60% STRENGTH (kg/cm^2) 5.75 TS (°C) 600	TEMPERATURE RANGE: 480°—550°C PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *STANDARD GRADE (TYPE 589)*

Manufacturer	Characteristics	Operating conditions	Remarks
ISC Chemicals RTZ	CONTENT wt% V_2O_5 6.5±0.5 CARRIER: n.a. FORM: extruded cords SIZE: Diameter (mm) 5—6 Length (mm) 8—11 ABD (g/cm^3) 0.61 TS (°C) up to 620	TEMPERATURE RANGE: 380°—420°C PRESSURE RANGE: n.a. LIFE: 5 years (guarantee)	

TYPE OF CATALYST: *LOW BITE GRADE (TYPE 636)*

Manufacturer	Characteristics	Operating conditions	Remarks
ISC Chemicals RTZ	CONTENT wt% V_2O_5 6.5±0.5 CARRIER: n.a. FORM: extruded cords SIZE: Diameter (mm) 6 Length (mm) 8—11 ABD (g/cm³) 0.65 Attrition loss: less than 10% fines TS (°C) up to 620	TEMPERATURE RANGE: 380°—450°C PRESSURE RANGE: n.a. LIFE: 5 years (guarantee)	

TYPE OF CATALYST: *VANADIUM 210; 11; 29*

Manufacturer	Characteristics	Operating conditions	Remarks
Monsanto	CONTENT n.a. CARRIER: silica FORM: cylinders SIZE: Diameter (mm) 5.55—7 Length (mm) 8	TEMPERATURE RANGE: 415°—600°C PRESSURE RANGE: n.a. LIFE: 5 years	Type 11 was developed as a complement to type 210. Type 29 improves the physical form.

TYPE OF CATALYST: *VANADIUM KH_1-2*

Manufacturer	Characteristics	Operating conditions	Remarks
Montedison S.p.A.	CONTENT wt% SiO_2 68—70 V_2O_5 6—7 Binder free CARRIER: inert FORM: cylinders SIZE: Diameter (mm) 4—5 Length (mm) 4—5 ABD (g/cm³) 0.6 PV (cm³/g) 0.5 STRENGTH (kg/cm²) ⩾70	TEMPERATURE RANGE: 400°—610°C PRESSURE RANGE: n.a. LIFE: >10 years	

TYPE OF CATALYST: *VANADIUM RHV*

Manufacturer	Characteristics	Operating conditions	Remarks
Rikkihappo Oy Kemira Oy	CONTENT wt% RHV 49 and 59: 8—10 V_2O_5 and alkali RHV 67 and 107: 6—8 V_2O_5 and alkali The ratio is $K_2O:V_2O_5=2.5$ CARRIER: silica FORM: extrusions SIZE: Diameter (mm) 4—10 ABD (g/cm^3) 0.47—0.61 (depending upon the size of extrusions) TS (°C) 600 POROSITY: 65—70 (unactivated mass); 57—60 (after activation)	TEMPERATURE RANGE: 400°—420°C PRESSURE RANGE: n.a.	Specifications RHV-49; RHV-59; RHV-67; RHV-107

TYPE OF CATALYST: *VANADIUM VK SERIES; VK-38A (STANDARD CATALYST)*

Manufacturer	Characteristics	Operating conditions	Remarks
Haldor Topsøe	CONTENT wt% VK.38A tablets contain 65 g of V_2O_5 per litre of catalyst CARRIER: n.a. FORM: cylindrical tablets; rings SIZE: cylindrical tablets rings Diameter (mm) 6;9 10;4 Length (mm) 6;9 7 ABD (g/cm^3) 0.83 0.70 ±0.04 ±0.03 STRENGTH (kg/cm^2) 200—300	TEMPERATURE RANGE: 410°—650°C PRESSURE RANGE: n.a. SPACE VELOCITY: (VHSV) 2,000 h^{-1}	Delivered in the activated form. Recommended for conventional manufacture of sulphuric acid in single absorption as well as double absorption processes.

TYPE OF CATALYST: *VANADIA CATALYST WOLFEN*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Farbenfabrik Wolfen	CONTENT wt% V_2O_5 SiO_2 type H 5.5 69—72 type WN 7.5 60—62 type SZN 7.5 57—60 CARRIER: SiO_2 FORM: cylinders SIZE: Diameter (mm) 4,6,8,10 ABD (g/cm^3) 0.49—0.53 POROSITY: 55—57% STRENGTH (kg/cm^2) 40	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Available also in type N, STN.

Annex II

Heterogeneous catalysts for unit operations

A. Alkylation
B. Cracking — Hydrocracking
C. Dehydrogenation
D. Desulphurization
E. Halogenation (Dehalogenation)
F. Hydrogenation
G. Isomerization
H. Oxidation
I. Polymerization
J. Purification
K. Reforming
L. Catalysts for various chemical reactions

A. Alkylation

ALKYLATION AND ACYLATION

TYPE OF CATALYST: *ANHYDROUS ALUMINIUM CHLORIDE*

Manufacturer	Characteristics	Operating conditions	Remarks
Allied Chemicals	CONTENT n.a. CARRIER: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

ALKYLATION OF BENZENE AND PROPYLENE TO PRODUCE CUMENE

TYPE OF CATALYST: *PHOSPHORIC ACID CATALYST C 84-1; C 84-2*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT n.a. CARRIER: Kieselguhr FORM: spheres SIZE: Diameter (mm) 4.77—6.35 6.35—8.00 ABD (g/cm^3) 0.88 STRENGTH (kg/cm^2) 13.6—15.86	TEMPERATURE RANGE: 149°—232°C PRESSURE RANGE: 28—84 atm	C 84-1 is used in fixed bed adiabatic inversion. C 84-2 is used for tubular isothermal type reactor design.

1. ALKYLATION OF BENZENE WITH ETHYLENE TO PRODUCE ETHYLBENZENE

2. PRODUCTION OF C 12 TO C 16 ALKYL BENZENES

TYPE OF CATALYST: *ANHYDROUS ALUMINIUM CHLORIDE*

Manufacturer	Characteristics	Operating conditions	Remarks
Davison Chemical Division W.R. Grace and Co.	CONTENT wt % Anhydrous aluminium chloride FORM: powder or granules	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	(1) Ethylbenzene is an intermediate for styrene manufacture; (2) For use as intermediates for making synthetic detergents by sulphonation.

ALKYLATION REACTIONS

TYPE OF CATALYST: *SILICA ALUMINA GRADE 979*

Manufacturer	Characteristics	Operating conditions	Remarks
Davison Chemical Division W. R. Grace and Co.	CONTENT wt % Silica alumina FORM: extrusions SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Its general application is in reactions such as polymerization and esterification, where an acid catalyst is required.

ALKYLATION OF PHENOL AND CRESOL

TYPE OF CATALYST: *ACTIVATED MONTMORILLONITE. K SERIES: KSF, KSF/O, K10/SF, K10, K20, K306*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Aluminium hydrosilicate (ideal formula: $Al_2O_34SiO_2 . H_2O +$ $+ xH_2O$) FORM: powder SIZE: 80—90% pass through a sieve DIN 100 ABD (g/cm^3) 0.3—0.6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	They are produced by means of a special manufacturing process from the mineral montmorillonite. They belong to the acid catalyst, because of their function and their chemical constitution. They are used in esterification and dehydration reactions; splitting of cumene peroxide; formation of 1.3 dioxolanes. They are generally used in reactions which are otherwise catalysed with hydrogen acids (H_2SO_4, HCl, H_3PO_4, $HClO_4$ etc.) or with the so-called Lewis acids (BF_3, BCl_3, $AlCl_3$, $AlBr_3$, $SnCl_4$, $ZnCl_2$, $SbCl_3$).

TYPE OF CATALYST: *ACTIVATED MONTMORILLONITE KA; K306*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Aluminium hydrosilicate FORM: spheres SIZE: n.a. ABD (g/cm^3) 0.4—0.8 SA (BET) (m^2/g) 195 PV (cm^3/g) 0.6—0.7 STRENGTH (kg/cm^2) 4—5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	They are most suitable as catalyst carriers.

CONDENSATION OF AN ISOPARAFFIN (ISOBUTENE) WITH OLEFINS (PROPYLENE, BUTYLENE OR AMYLENE)

TYPE OF CATALYST: *ANHYDROUS HYDROFLUORIC ACID AHF*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % purity 99.9	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used in the petroleum industry to produce highly branched gas components with desirable stability properties and high octane number.

ALKYLATION IN LIQUID PHASE

TYPE OF CATALYST: *COPPER CHROMITE CATALYST N-207*

Manufacturer	Characteristics	Operating conditions	Remarks
W.C. Heracus GmbH	CONTENT wt % Copper chromite promotor CARRIER: Kieselguhr FORM: powder SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

ALKYLATION OF BENZENE BY PROPYLENE TO PRODUCE CUMENE

TYPE OF CATALYST: *PHOSPHORIC ACID AP-792*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % active agent P_2O_5 CARRIER: silica FORM: extrusions SIZE: Diameter (mm) 4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Can also be used for the production of gasolines, nonenes and dodecenes by polymerization of C_3 and C_4 cuts.

TYPE OF CATALYST: *ZEOLITES 14878; 14879; 14895; 14896*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Incorporated	CONTENT wt % (1) 14878 Type X Sodium ion (2) 14879 Type X Sodium ion (3) 14895 Type Y Sodium ion (4) 14896 Type Y Sodium ion FORM: (1) pellets; (2) powder; (3) extrusion; (4) powder SIZE: Diameter (mm) (1) 2; (3) 2 SA (m^2/g) high Water content: (1) 1.5% (2) approx. 2.5% (3) very low (4) approx. 60%	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Molecular sieves (large pore) Stability; moisture; sensitive Other applications: Aldol condensation Chloromethylation of aromatics Condensation of aldehydes with esters Dehydration of alcohols to olefins Dehydrocyclization reactions Hydration and ammonolysis of ethylene oxide Hydrogenation of olefins Polymerization of olefins.

TYPE OF CATALYST: *ZEOLITES 14880; 14891; 14838*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Incorporated	CONTENT wt % (1) 14880 Type Y ammonium ion (2) 14891 Type Y rare earth exchanged (3) 14838 Type L potassium ion FORM: (1) powder; (2) pellets; (3) powder SIZE: Diameter (mm) (2) 3 Length (mm) 6 SA (m^2/g) (1) high; (2) 550; (3) high Water content: (1) 60% (2) very low (3) approx. 33%	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Molecular sieves (large pore) See 14878.

TYPE OF CATALYST: ***NICKEL COPPER SK-400: SK-410***

Manufacturer	Characteristics	Operating conditions	Remarks
Union Carbide Corporation, Linde Molecular Sieve Catalysts	CONTENT anhydrous form wt % SK 400 SK 410 SiO_2 65.2±0.5 Al_2O_3 22.1±0.5 Na_2O 11.7±0.2 Cu — 1.0±0.02 Ni 1.0±0.02 Cl^- <0.05 Fl^- <0.05 FORM: tablets SIZE: Diameter (mm) 4 Length (mm) 4 ABD (g/cm^3) 0.65 SA (m^2/g) $>$ 500	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	They have interesting properties in the hydrodealkylation of alkyl substituted aromatics.

B. Cracking — Hydrocracking

- Fluid catalytic cracking
- Hydrocracking
- Catalytic cracking
- Fixed bed catalytic cracking

FLUID CATALYTIC CRACKING

TYPE OF CATALYST: *ZEOLITE SZ—C*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalyst and Chemical Industries Co. Ltd.	CONTENT (dry base) wt % Al_2O_3 14.8 Na_2O 0.020 Fe 0.023 SO_4 0.40 Loss on ignition 11.4 FORM: powder ABD (g/cm³) 0.49 SA (m²/g) 540 PV (cm³/g) 0.80	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Pore diameter: 59Å Particle size of micromesh sieve (microns) wt % Finer than: 20 2 30 8 40 18 80 80 105 95 149 100 Average size: 60 microns. Activity (micro) 750°C, 17 hrs. Steam deactivated conversion (vol. %): 68

TYPE OF CATALYST: *ZEOLITE SZ—H*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalyst and Chemical Industries Co. Ltd.	CONTENT (dry base) wt % Al_2O_3 29 Na_2O 0.025 Fe 0.023 SO_4 0.40 Loss on ignition 12.3 FORM: powder ABD (g/cm³) 0.43 SA (m²/g) 502 PV (cm³/g) 0,88	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Pore diameter: 70Å Particle size of micromesh sieve (microns) wt % Finer than: 20 2 30 8 40 18 80 80 105 95 149 100 Average size: 60 Activity (micro) 750°C, 17 hrs. Steam deactivated, conversion (vol. %): 70

TYPE OF CATALYST: *LOW ALUMINA*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalyst and Chemical Industries Co. Ltd.	CONTENT (dry base) wt % Al_2O_3 13.75 Na_2O 0.012 Fe 0.020 SO_4 0.33 Loss on ignition 11.0 FORM: powder ABD (g/cm³) 0.47 SA (m²/g) 560 PV (cm³/g) 0.73	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Pore diameter: 52Å Particle size of micro-mesh sieve (microns) wt % Finer than: 20 2 30 7 40 17 80 79 105 94 149 100 Average size: 61 Activity (UOP) Initial: 11 Thermal: 1

TYPE OF CATALYST: ***HIGH ALUMINA***

Manufacturer	Characteristics	Operating conditions	Remarks
Catalyst and Chemical Industries Co. Ltd.	CONTENT (dry base) wt % Al_2O_3 28.61 Na_2O 0.013 Fe 0.020 SO_4 0.30 Loss on ignition 10.8 FORM: powder ABD (g/cm³) 0.41 SA (m²/g) 511 PV (cm³/g) 0.93	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Pore diameter: 73Å Particle size of micro-mesh sieve (microns) — wt % Finer than: 20 — 2 30 — 8 40 — 18 80 — 79 105 — 94 149 — 100 Average size: 61 Activity (UOP): Initial: 104 Thermal: 170

TYPE OF CATALYST: ***SILICA-ALUMINA AEROCAT***

Manufacturer	Characteristics	Operating conditions	Remarks
American Cyanamid Company	CONTENT wt % Silica 87 Alumina 13 FORM: Spray-dried micro-spheres SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Maximizes gasoline production in petroleum fluid cracking units.

TYPE OF CATALYST: ***SILICA-ALUMINA AEROCAT TRIPLE A***

Manufacturer	Characteristics	Operating conditions	Remarks
American Cyanamid Company	CONTENT wt % Silica 75 Alumina 25 FORM: Spray-dried micro-spheres SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Maximizes gasoline production in petroleum operations and is more active than regular Aerocat fluid cracking catalyst.

TYPE OF CATALYST: *AEROCAT TRIPLE S-4*

Manufacturer	Characteristics	Operating conditions	Remarks
American Cyanamid Company	CONTENT wt % An active and selective molecular sieve catalyst containing the Y-type sieves CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Provides greater gasoline production.

TYPE OF CATALYST: *SILICA-ALUMINA AEROCAT 2000*

Manufacturer	Characteristics	Operating conditions	Remarks
American Cyanamid Company	CONTENT wt % It is a semi-synthetic cracking catalyst consisting of a mixture of clay and silica-alumina CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Maximizes gasoline production in petroleum operations but is less active than regular Aerocat fluid cracking catalyst.

TYPE OF CATALYST: *AEROCAT TS-150*

Manufacturer	Characteristics	Operating conditions	Remarks
American Cyanamid Company	CONTENT wt % Contains a high percentage of Y-type molecular sieves CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Tends to maximize gasoline production.

TYPE OF CATALYST: *AEROCAT TS-170*

Manufacturer	Characteristics	Operating conditions	Remarks
American Cyanamid Company	CONTENT wt % Contains a larger quantity of Y-type molecular sieves CARRIER: n.a. FORM: n.a. SIZE n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Tends to maximize gasoline production and improves selectivity.

TYPE OF CATALYST: *AEROCAT TS-260*

Manufacturer	Characteristics	Operating conditions	Remarks
American Cyanamid Company	CONTENT wt % Contains the highest amount of Y-type molecular sieves CARRIER: n.a. FORM: n.a. SIZE n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Also tends to maximize gasoline production and improves selectivity.

TYPE OF CATALYST: *SILICA-ALUMINA LOW ALUMINA*

Manufacturer	Characteristics	Operating conditions	Remarks
Davison Chemical Division, W.R. Grace and Co.	CONTENT (dry base) wt % Al_2O_3 13 SiO_2 86.8 Na_2O 0.04 Fe 0.04 SO_4 0.3 Ignition loss (817°C): 12 FORM: powder ABD (g/cm³) 0.44 PV (cm³/g) 0.77	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is available in the following particle sizes: Particle size of micromesh sieve (microns) — Grade (wt %): Coarse 13, Medium 13, Fine 13 0—20: 2, 2, 3 0—40: 13, 18, 21 0—80: 60, 70, 79 0—105: 88, 89, 93 0—149: 98, 98, 98 APS: 72, 64, 58 Long the standard in petroleum refining for medium-range operations.

TYPE OF CATALYST: *SILICA-ALUMINA HIGH ALUMINA*

Manufacturer	Characteristics	Operating conditions	Remarks
Davison Chemical Division, W.R. Grace and Co.	CONTENT (dry base) wt% Al_2O_3 25 SiO_2 74.6 Na_2O 0.05 Fe 0.04 SO_4 0.3 Ignition loss (816°C) 12 FORM: powder ABD (g/cm^3)0.39—0.46 PV (cm^3/g) 0.70—0.88 (both depending on particle size)	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Available in the following particle sizes: Particle size of micro-mesh sieve (microns) — Grade (wt%): Coarse 25, Medium 25, Fine 25 0—20 2 2 2 0—40 13 18 21 0—80 60 70 79 0—105 88 89 93 0—149 98 98 98 APS 72 64 58 The work horse prior to the zeolite catalysts, now finding application where feedstocks are extremely heavy and aromatic or where more balanced gasoline-light cycle oil requirements exist.

TYPE OF CATALYST: *SILICA-MAGNESIA SM-30*

Manufacturer	Characteristics	Operating conditions	Remarks
Davison Chemical Division, W.R. Grace and Co.	CONTENT (dry base) wt% Al_2O_3 14.0 MgO 20.8 SiO_2 63.4 Na_2O 0.05 Fe 0.11 SO_4 0.4 F 1.3 Ignition loss (817°C): 12 FORM: powder ABD (g/cm^3) 0.53 PV (cm^3/g) 0.57	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Particle size of micro-mesh sieve (microns) wt% 0—20 2 0—40 18 0—80 70 0—105 89 0—149 98 APS 64 Designed for the production of maximum yields of gasoline and light cycle oil, with improved stripping characteristics.

TYPE OF CATALYST: *ZEOLITE AGZ-50*

Manufacturer	Characteristics	Operating conditions	Remarks
Davison Chemical Division, W.R. Grace and Co.	CONTENT (dry base) wt% Al_2O_3 30.0 Na_2O 0.30 Fe 0.09 Ignition loss (816°C) 13 CARRIER: n.a. FORM: powder ABD (g/cm^3) 0.57 SA (m^2/g) 290 PV (cm^3/g) 0.47	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Attrition (Davison index): 20 (25 max.) Particle size of micro-mesh sieve (microns) wt% 0—20 2 0—40 13(15 max.) 0—80 65 APS 68

TYPE OF CATALYST: *ZEOLITE CBZ-1*

Manufacturer	Characteristics	Operating conditions	Remarks
Davison Chemical Division, W.R. Grace and Co.	CONTENT (dry base) wt% Al_2O_3 29.1 Na_2O 0.46 Fe 0.11 CARRIER: n.a. FORM: n.a. ABD (g/cm³) 0.47 SA (m²/g) 340 PV (cm³/g) 0.60	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It exhibits gasoline selectivity.

TYPE OF CATALYST: *ZEOLITE DZ-7*

Manufacturer	Characteristics	Operating conditions	Remarks
Davison Chemical Division, W.R. Grace and Co.	CONTENT (dry base) wt% Al_2O_3 35 Na_2O 0.28 Fe 0.20 Ignition loss (816°C) 13 CARRIER: n.a. FORM: powder ABD (g/cm³) 0.56 SA (m²/g) (500°C) 260 PV (cm³/g) 0.47	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Particle size of micro-mesh sieve (microns) — wt% 0—20 — 2 0—40 — 19 0—80 — 72 0—105 — 92 0—149 — 98 APS — 62 It improves gasoline yield.

TYPE OF CATALYST: *ZEOLITE XZ-25*

Manufacturer	Characteristics	Operating conditions	Remarks
Davison Chemical Division, W.R. Grace and Co.	CONTENT (dry base) wt% Al_2O_3 31.4 Na_2O 0.5 Fe 0.09 T.V. 12 CARRIER: n.a. FORM: powder ABD (g/cm³) 0.52 SA (m²/g) 335 PV (cm³/g) 0.60	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Davison attrition index: 3.0 Micro activity vol. % conversion: 86 Particle size (N.N. screens: medium grade) (microns) — wt% 0—20 — 2 0—40 — 18 0—80 — 70 APS — 64 It is particularly suited for applications that require an intermediate level of zeolite activity, that is, those requiring a balance between gasoline, light cycle oil and light olefins yields.

TYPE OF CATALYST: *ZEOLITE XZ-36*

Manufacturer	Characteristics	Operating conditions	Remarks
Davison Chemical Division, W.R. Grace and Co.	CONTENT (dry base) wt% Al_2O_3 36 Na_2O 0.07 Fe 0.09 Ignition loss (816°C) 12 CARRIER: n.a. FORM: powder ABD (g/cm^3) 0.55 SA (m^2/g) 269 PV (cm^3/g) 0.55	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Steam deactivated at 6.3 atm. and 577°C For 24 hrs: 88 Particle size of micro-mesh sieve (microns) wt% 0—20 2 0—40 19 0—80 72 0—105 92 0—149 98 APS 62

TYPE OF CATALYST: *SILICA-ALUMINA SEMI-SYNTHETIC*

Manufacturer	Characteristics	Operating conditions	Remarks
Davison Chemical Division, W.R. Grace and Co.	CONTENT (dry base) wt% Al_2O_3 32 SiO_2 66.4 Na_2O 0.05 Fe 0.11 SO_4 0.6 Ignition loss (817 °C) 12 FORM: powder ABD (g/cm^3) 0.47—0.52 PV (cm^3/g) 0.58—0.70	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Particle size of micro-mesh sieve (microns) Grade (wt%) S — S 0—20 2 0—40 13 0—80 60 0—105 88 0—149 98 APS 72 A clay-included catalyst, designed for low conversion operations where rapid turnover of catalyst is desired, as when processing high-metals-contaminated feedstock. Also frequently used in blends with zeolite catalysts to moderate activity.

FLUID BED CATALYTIC CRACKING

TYPE OF CATALYST: *SILICA-ALUMINA HOUDRY MINERAL HFZ-20*$^{T.M.}$

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt% Al_2O_3 55 SiO_2 43 Ignition loss 12 FORM: powder ABD (g/cm^3) 0.86—0.9	TEMPERATURE RANGE: n.a. PRESSURE RANGE n.a.	Particle size (microns) wt% 0—20 2.0 max. 0—40 10—15 0—80 78—85 0—105 93—97 0—149 99 min. Particle size average (APS) 58—64 Better gasoline selectivity.

TYPE OF CATALYST: *SILICA-ALUMINA HOUDRY MINERAL HFZ-23*$^{T.M.}$

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt% Al_2O_4 52 SiO_2 46 Ignition loss 10 FORM: powder ABD (g/cm^3) 0.86—0.9	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Particle size analysis: see HFZ-20 Gasoline selectivity. Improved octane levels.

MOVING BED CATALYTIC CRACKING

TYPE OF CATALYST: *ZEOLITE HOUDRY MINERAL HM-170*$^{T.M.}$

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt% Al_2O_3 45 SiO_2 53 Fe_2O_3 0.3 Other oxides 1.7 Ignition loss (760°C) 0.5—2.5 FORM: pellets SIZE: Diameter (mm) 4 Length (mm) 3—8 ABD (g/cm^3) 0.75—0.88 SA (BET) (m^2/g) 90—100	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Also in fixed bed applications. It is a workhorse high alumina cracking catalyst derived from kaolin clay. It is also applied in chemical reactions as a replacement for some synthetic silica-alumina catalysts. A specially treated variation — Houdry Mineral HM-171$^{T.M.}$

TYPE OF CATALYST: *ZEOLITE HOUDRY MINERAL HZ-1*^{R}

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt% Al_2O_3 45 SiO_2 53 Other 2 Ignition loss (760°C) 0.5—2.5 FORM: pellets SIZE: Diameter (mm) 4 Length (mm) 3—8 ABD (g/cm^3) 0.88—0.92 SA (m^2/g) 100—150	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used to maximize production of high octane gasoline as well as C_3 and C_4 olefins, from heavy feedstocks.

TYPE OF CATALYST: *ZEOLITE HOUDRY MINERAL HZ-2*$^{T.M.}$

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt% Al_2O_3 45 SiO_2 53 Other 2 Ignition loss (760°C) 0.5—2.5 FORM pellets SIZE: Diameter (mm) 4 Length (mm) 3—8 ABD (g/cm^3) 0.88—0.92 SA (m^2/g) 100—150	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is designed to maximize gasoline yield at the expense of coke and gas in operations where catalytic gasoline is the prime consideration.

FLUID CATALYTIC CRACKING

TYPE OF CATALYST: *ALUMINA KETJENCAT*^{R} *GRADE HA-HPV*

Manufacturer	Characteristics	Operating conditions	Remarks
Akzo Chemie B.V. Dpt. Ketjen Catalysts	CONTENT (dry base) wt% Al_2O_3 25 Na_2O 0.01 Fe 0.03 SO_4 1.0 Ignition loss (wet base, 1 hr 1000 °C) 12.0 CARRIER: n.a. FORM: powder ABD (g/cm^3) 0.37 (1 hr 600°C) SA (m^2/g) 540 (1 hr 600°C) PV (cm^3/g) 0.87	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Particle size (microns) wt% 0—20 3.0 0—40 18.0 0—80 64.5 0—105 86.0 0—149 98.5 High alumina, high pore volume.

TYPE OF CATALYST: *ALUMINA KETJENCAT*^{R} *GRADE HA-HS*

Manufacturer	Characteristics	Operating conditions	Remarks
Akzo Chemie B.V. Dpt. Ketjen Catalysts	CONTENT wt% Al_2O_3 25 Na_2O 0.03 Fe 0.03 SO_4 1.2 Ignition loss (1 hr 1000°C, wet base) 13.0 CARRIER: n.a. FORM: powder ABD (g/cm^3) 0.39 (1 hr 600°C) SA (m^2/g) 460 (1 hr 600°C) PV (cm^3/g) 0.88 (1 hr 600°C)	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	High pore diameter grades. Particle size of micro-mesh sieve (microns) wt% 0—20 4.0 0—40 20.0 0—80 65.0 0—105 85.0 0—149 98.5

TYPE OF CATALYST: *ALUMINA KETJENCAT^R HA-MF*

Manufacturer	Characteristics	Operating conditions	Remarks
Akzo Chemie B.V. Dpt. Ketjen Catalysts	CONTENT (dry base) wt% Al_2O_3 28.5 Na_2O 0.01 Fe 0.02 SO_4 0.07 SiO_2 balance Ignition loss (1 hr 1000°C) 14.0 FORM: powder ABD (g/cm^3) 0.40 SA (m^2/g) 500 PV (cm^3/g) 0.89	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Particle size of micro-mesh sieve (microns) wt% 0—20 0.6 0—40 17.0 0—80 73.5 0—105 91.0 0—149 99.0 High alumina medium fine.

TYPE OF CATALYST: *ALUMINA KETJENCAT^R HA-MPV*

Manufacturer	Characteristics	Operating conditions	Remarks
Akzo Chemie B.V. Dpt. Ketjen Catalysts	CONTENT (dry base) wt% Al_2O_3 25 Na_2O 0.01 Fe 0.03 SO_4 1.0 Ignition loss (1 h r1000°C, wet base) 12.0 FORM: powder ABD (g/cm^3) 0.40 (1 hr 600°C) SA (m^2/g) 540 (1 hr 600°C) PV (cm^3/g) 0.82	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	High alumina catalyst. Particle size (microns) wt% 0—20 3.0 0—40 18.0 0—80 64.5 0—105 86.0 0—149 98.5

TYPE OF CATALYST: *ALUMINA KETJENCAT^R HA-LPV*

Manufacturer	Characteristics	Operating conditions	Remarks
Akzo Chemie B.V. Dpt. Ketjen Catalysts	CONTENT (dry base) wt% Al_2O_3 25 Na_2O 0.01 Fe 0.03 SO_4 1.0 Ingition loss (1 hr 1,000°C, wet base) 12.0 CARRIER: n.a. FORM: powder ABD (g/cm^3) 0.42 (1 hr 600°C) SA (m^2/g) 540 (1 hr 600°C) PV (cm^3/g) 0.76 (1 hr 600°C)	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	High alumina catalyst. Particle size (microns) wt% 0—20 3.0 0—40 18.0 0—80 64.5 0—105 86.0 0—149 98.5

TYPE OF CATALYST: *ALUMINA KETJENCAT^R LA-LPV*

Manufacturer	Characteristics	Operating conditions	Remarks
Akzo Chemie B.V. Dpt. Ketjen Catalysts	CONTENT (dry base) wt% Al_2O_3 13.0 Na_2O 0.01 Fe 0.03 SO_4 0.8 Ignition loss (1 hr 1000°C, wet base) 14.0 CARRIER: n.a. FORM: powder ABD (g/cm^3) 0.40 (1 hr 600°C) SA (m^2/g) 600 (1 hr 600°C) PV (cm^3/g) 0.73 (1 hr 600°C)	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Particle size of micro-mesh sieve (microns) wt% 0—20 3.0 0—40 16.0 0—80 64.5 0—105 86.0 0—149 98.5 Low alumina, low pore volume.

TYPE OF CATALYST: *ZEOLITE KETJENCAT^R GRADE MZ-1*

Manufacturer	*Characteristics*	*Operating conditions*	*Remarks*
Akzo Chemie B.V. Dpt. Ketjen Catalysts	CONTENT (dry base) wt% Na_2O 0.05 Al_2O_3 13 SO_4 0.8 Fe 0.03 SiO_2 and rare oxide balance Ignition loss (1 hr 1000°C) 14 FORM: powder ABD (g/cm^3) 0.40 (1 h 600°C) SA (m^2/g) 600 (1 h 600°C) PV (cm^3/g) 0.75 (1 h 600°C)	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	A fully synthetic fluid cracking catalyst, containing a highly active zeolite, consisting of a compound containing rare earths and Y-type molecular sieves. Particle size of micro-mesh sieve (microns) wt% 0—20 3 0—40 16 0—80 65 0—105 86 0—149 98.5

TYPE OF CATALYST: *ZEOLITE KETJENCAT^R MZ-3*

Manufacturer	Characteristics	Operating conditions	Remarks
Akzo Chemie B.V. Dpt. Ketjen Catalysts	CONTENT (dry base) wt% Al_2O_3 23.0 Na_2O 0.16 Fe 0.03 SO_4 1.00 SiO_2 and rare earth oxides balance Ignition loss (1000°C) 14.0 FORM: powder ABD (g/cm^3) 0.43 SA (m^2/g) 550 PV (cm^3/g) 0.70	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It consists of a high proportion of molecular sieves, the Y-type. It belongs to the small group of high activity zeolite catalysts. Particle size of micro-mesh sieve (microns) wt% 0—20 3.0 0—40 20.0 0—80 70.0 0—105 90.0 0—149 99.0

TYPE OF CATALYST: ***KAOLIN CRACKING CATALYST***

Manufacturer	Characteristics	Operating conditions	Remarks
Minerals and Chemicals Corporation of America	CONTENT wt% SiO_2 52.9 Al_2O_3 45.0 Fe_2O_3 0.3 TiO_2 1.7 Na_2O <0.05 K_2O <0.05 FORM: pellets, Kaospheres ABD (g/cm^3) 0.78 SA (m^2/g) 95 PV (cm^3/g) 0.25	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Particle size of Taylor screen wt% on 3 mesh 0.0 on 6 mesh 99.5 through 6 mesh 0.5 For moving bed operations.

Hydrocracking

HYDROCRACKING REACTIONS

TYPE OF CATALYST: *NICKEL MOLYBDENUM HT-100 E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni oxide 3.890 Mo trioxide 16.890 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 1.588 Length (mm) n.a. ABD (g/cm^3) 0.608 SA (m^2/g) 190 PV (cm^3/g) 0.54 STRENGTH (kg/cm^2) 6—9	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The sulphided form of this catalyst is used in reforming, lube oil for purification, gas oil for catalytic cracking, furnace oil, diesel fuel, and kerosene for olefinic saturation, and residual stocks for sulphur and metal removal.

TYPE OF CATALYST: *NICKEL-TUNGSTEN Ni-4301.E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni 6 W 19 CARRIER: silica-alumina FORM: extrusions SIZE: Diameter (mm) 2 Length (mm) n.a. ABD (g/cm^3) 0.96 SA (m^2/g) 228 PV (cm^3/g) 0.37 STRENGTH(kg/cm^2) 6.3	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The sulphide form of this catalyst is used for hydrogenation where a cracking function is desired. It is used for saturation of mono and polycyclic aromatic compounds, denitrogenation and desulphurization.

TYPE OF CATALYST: *NICKEL-TUNGSTEN Ni-4303.E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni 6 W 19 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 2 Length (mm) n.a. ABD (g/cm^3) 0.784 SA (m^2/g) 152 PV (cm^3/g) 0.54 STRENGTH (kg/cm^2) 8	TEMPERATURE RANGE: n.a. PRESSURE RANGE n.a.	The sulphide form of this catalyst is used for general hydrogenation used for pretreatment of hydrocracker feedstocks, saturation of mono and polycyclic aromatic compounds, denitrogenation and desulphurization.

TYPE OF CATALYST: *NICKEL-TUNGSTEN Ni-4309.E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni 5 W 10 B as promotor 3 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 1.5; 2; 3 Length (mm) n.a. ABD (g/cm^2) 0.8—0.9 SA (m^2/g) 150 PV (cm^3/g) 0.3 STRENGTH (kg/cm^2) 9.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The sulphide form of this catalyst is used for high pressure catalytic cracker pretreatment.

TYPE OF CATALYST: *NICKEL-TUNGSTEN Ni-4401.E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % See Ni-4301. E CARRIER: silica-alumina FORM: extrusions SIZE: Diameter (mm) 2 Length (mm) n.a. ABD (g/cm^3) 0.944 SA (m^2/g) 212 PV (cm^3/g) 0.37 STRENGTH (kg/cm^2) 4.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	This is the sulphide form of Ni-4301.E.

TYPE OF CATALYST: *NICKEL-TUNGSTEN Ni-4403.E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % See Ni-4303. E CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 2 Length (mm) n.a. ABD (g/cm^3) 0.8 SA (m^2/g) 140 PV (cm^3/g) 0.48 STRENGTH (kg/cm^2) 8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	This is the sulphide form of Ni-4303.E.

HYDROPROCESSING (CRACKING AND AROMATIC SATURATION)

TYPE OF CATALYST: *NICKEL-TUNGSTEN NALCO NT-550*

Manufacturer	Characteristics	Operating conditions	Remarks
Nalco	CONTENT wt % WO$_3$ 20.2 NiO 5.1 alumina base balance CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) n.a. Length (mm) 3—1.5 ABD (g/cm^3)0.78—0.80 SA ((m^2/g) 250 PV (cm^3/g) 0.50 STRENGTH (kg/cm^2) 6—8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	This catalyst is formulated for difficult feedstocks such as lube stocks, heavy cycle oils and specialty distillates. The catalyst may be delivered also in form cf Sphericat 550.

HYDROCRACKING OF PARAFFINS

TYPE OF CATALYST: *NICKEL-TUNGSTEN 28 156*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Incorporated	CONTENT wt % NiO 6 WO$_3$ 19 CARRIER: silica-alumina FORM: extrusions SIZE: Diameter (mm) 2 Length (mm) n.a. ABD (g/cm^3) approx. 230	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	More acidic support than 28-153 with higher cracking activity.

Catalytic cracking

CATALYTIC CRACKING

TYPE OF CATALYST: *ANHYDROUS ALUMINIUM CHLORIDE*

Manufacturer	Characteristics	Operating conditions	Remarks
Allied Chemical	CONTENT n.a. CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Long chain hydrocarbons are split into shorter molecules.

CRACKING OF HYDROCARBONS

TYPE OF CATALYST: *NICKEL-COPPER CHEZA 32—02*

Manufacturer	Characteristics	Operating conditions	Remarks
Chemical Works of CSF	CONTENT wt % Ni 7 Cu 0.7 CARRIER: ceramic base FORM: extrusions SIZE: Diameter (mm) 10—12 Length (mm) 10—35 ABD (g/cm^3) 1.0 STRENGTH (kg/cm^2) 15	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for cracking methane, propane-butane, petroleum hydrocarbons for the production of city-gas. May be used in a cracking plant with a continuous or cyclic procedure.

TYPE OF CATALYST: *NICKEL G-3*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % NiO 2.8 CARRIER: alumina FORM: balls SIZE: Diameter (mm) 5—10; 10—15; 15—20; 20—25 ABD (g/cm^3) 1.6 PV (cm^3/g) 0.08 STRENGTH (kg/cm^2) 10—300	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	For the same utilizations it is recommended GV-3.

CRACKING REACTIONS

TYPE OF CATALYST: *ZIRCONIUM 40-200*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Incorporated	CONTENT wt % ZrO_2 98 Alumina 2 FORM: pellets SIZE: Diameter (mm) 3 Length (mm) 3 SA (m^2/g) approx. 50	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also recommended as dehydration catalyst.

Fixed bed catalytic cracking

FIXED BED CATALYTIC CRACKING

TYPE OF CATALYST: *SILICA-ALUMINA 2-CP*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Al_2O_3 12.4 SiO_2 87.3 Na_2O 0.25 FORM: pellets SIZE: Diameter (mm) 4 Length (mm) 4 ABD (g/cm^3) 0.54 SA (m^2/g) 375—400	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Pellet density: 0.86 g/cm^3 Real density: 2.2—2.4 g/cm^3 Porosity, vol %: 60 Adsorption, wt%: 65 Average pore diameter: 80Å To maximize liquid products.

TYPE OF CATALYST: *SILICA-ALUMINA 24-CP*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Al_2O_3 12.4 SiO_2 87.3 Na_2O 0.25 FORM: pellets SIZE: Diameter (mm) 4 Length (mm) 4 ABD (g/cm^3) 0.53 SA (m^2/g) 425—450	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Pellet density: 0.86 g/cm^3 Real density: 2.2—2.4 g/cm^3 Porosity, vol. %: 60 Adsorption, wt%: 60 Average pore diameter: 80Å To maximize liquid products.

TYPE OF CATALYST: *SILICA-ALUMINA 159-CP*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Al_2O_3 12.4 SiO_2 87.3 Na_2O 0.25 FORM: pellets SIZE: Diameter (mm) 4 Length (mm) 4 ABD (g/cm^3) 0.62 SA (m^2/g) 290—313	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Pellet density: 0.99 g/cm^3 Real density: 2.2—2.4 g/cm^3 Porosity, vol.%: 57 Adsorption, wt%: 58 Average pore diameter: 82Å Used to maximize liquid products.

TYPE OF CATALYST: *SILICA-ALUMINA 511-CP*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt% Al_2O_3 12.4 SiO_2 87.3 Na_2O 0.25 FORM: pellets SIZE: Diameter (mm) 4 Length (mm) 4 ABD (g/cm^3) 0.66 SA (m^2/g) 80	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Pellet density: 1.24 g/cm^3 Real density: 2.2—2.4 g/cm^3 Porosity, vol. %: 47 Adsorption, wt%: 38 Average pore diameter: 80Å Used to maximize liquid products.

TYPE OF CATALYST: *SILICA-ALUMINA 523-CP*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt% Al_2O_3 12.4 SiO_2 87.3 Na_2O 0.25 FORM: pellets SIZE: Diameter (mm) 4 Length (mm) 4 ABD (g/cm^3) 0.63 SA (m^2/g) 180—200	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Pellet density: 1.02 g/cm^3 Real density: 2.2—2.4 g/cm^3 Porosity, vol. %: 56 Adsorption, wt%: 55 Average pore diameter: 85Å Used to maximize liquid products.

C. Dehydrogenation

DEHYDROGENATION OF CYCLOHEXANOL TO CYCLOHEXANE

TYPE OF CATALYST: *ZINC BASF H-5—10*			
Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % ZnO active CARRIER: n.a. FORM: extrusions SIZE: Diameter (mm) 4; 6 ABD (g/cm^3) 1.4	TEMPERATURE RANGE: 300°—400°C PRESSURE RANGE: n.a.	

DEHYDROGENATION OF LINEAR HYDROCARBONS

TYPE OF CATALYST: *CHROMIUM C30-1*			
Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT n.a. CARRIER: alumina FORM: tablets SIZE: Diameter (mm) 3; 6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used principally for the dehydrogenation of C_4 hydrocarbons to the corresponding olefins.

DEHYDROGENATION OF ORGANIC MATERIALS

TYPE OF CATALYST: *COPPER-CHROMIUM*			
Manufacturer	Characteristics	Operating conditions	Remarks
Catalyst and Chemicals International	CONTENT wt % Copper-chromium co-precipitated as "copper-chromite" CARRIER: n.a. FORM: powder, passing 325 mesh screen SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Hydrogenation of esters and acids. Oxidation and dehydrogenation of organic materials.

DEHYDROGENATION REACTIONS

TYPE OF CATALYST: *MOLYBDENUM CHEZA 35—00*

Manufacturer	Characteristics	Operating conditions	Remarks
Chemical Works of C.S.F.	CONTENT wt % MoO_3 12 Na_2O 0.1 Loss by heating (650°C) 10 CARRIER: alumina FORM: tablets SIZE: Diameter (mm) 6; 10 Length (mm) 6; 8—10 ABD (g/cm^3) 0.8 STRENGTH (kg/cm^2) 200	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for the dehydrogenation of naphthene hydrocarbons to aromatics. It is used for hydrogenation of different hydrocarbon mixtures at medium pressures, and at hydrotreating reactions. Typical for their use is the hydrotreating of crude coaltar benzol.

TYPE OF CATALYST: *CHROMIA-ALUMINA GRADE 909*

Manufacturer	Characteristics	Operating conditions	Remarks
Davison Chemical Division, W.R. Grace and Co.	CONTENT wt % Chromium CARRIER: alumina FORM: spheres SIZE (mm): 5×8 mesh	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It can be used for the production of butylenes from butane and has also found application in the manufacture of mercaptans from H_2S and an olefin.

DEHYDROGENATION AND RING CLOSURE

TYPE OF CATALYST: *A FUSED MIXTURE OF $NaCl—AlCl_3$*

Manufacturer	Characteristics	Operating conditions	Remarks
Davison Chemical Division, W.R. Grace and Co.	CONTENT wt % NaCl $AlCl_3$ FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The mixture is used in the dyestuffs and insecticides industries, for effecting the dehydrogenation of labile hydrogen in certain compounds with the resultant ring closure.

DEHYDROGENATION OF ALCOHOLS TO ALDEHYDES

TYPE OF CATALYST: *SILVER D-71-P*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT n.a. CARRIER: asbestos FORM: fibres SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Epoxydation of olefins. Dehydrogenation of primary and secondary alcohols to aldehydes and ketones.

TYPE OF CATALYST: *COPPER-CHROMITE G-13*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Cu 42 Cr 26 CARRIER: n.a. FORM: tablets, powder SIZE (mm): tablets: 4.5×4.5; 6×4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	For mild dehydrogenation reactions.

TYPE OF CATALYST: *COPPER-CHROMITE G-22*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Cu 33 Cr 27 Ba as promotor 11 CARRIER: n.a. FORM: tablets, powder SIZE (mm): tablets: 4.5×4.5; 6×4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Barium helps to prevent complete catalyst reduction and extend useful life.

DEHYDROGENATION OF BUTANE TO BUTADIENE

TYPE OF CATALYST: *CHROMIUM-ALUMINA G-41*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Cr 7.5 CARRIER: high purity gamma alumina FORM: tablets; extrusions SIZE (mm): tablets: 4.5×4.5 extrusions: 3	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Recommended for the hydrodealkylation of toluene to benzene and hydrodealkylation of substituted naphthalenes to naphthalenes.

TYPE OF CATALYST: *IRON G-48*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT n.a. CARRIER: n.a. FORM: extrusions SIZE: Diameter (mm): 1.5—5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *CHROMIUM Cr-0205. T, SPEC.102*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Cr_2O_3 19 CARRIER: activated alumina FORM: tablets SIZE: Diameter (mm) 3 Length (mm) n.a. ABD (g/cm^3) 0.960 SA (m^2/g) 60 PV (cm^3/g) 0.29 STRENGTH (kg/cm^2) 8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *CHROMIUM Cr-1404.P*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Cr_2O_3 19 CARRIER: high activity alumina FORM: powder SIZE (mm): n.a. ABD (g/cm^3) 0.928 SA (m^2/g) 80—100 PV (cm^3/g) 0.50	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	A dehydrogenation catalyst for fluid bed use. Granulation (microns) — % 0—20 — 2 20—40 — 18 40—80 — 34 +80 — 46

TYPE OF CATALYST: *CHROMIUM Cr-1404.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Cr_2O_3 19 CARRIER: high activity alumina FORM: tablets SIZE: Diameter (mm) 3 Length (mm) n.a. ABD (g/cm^3) 1.152 SA (m^2/g) 80—100 PV (cm^3/g) 0.38 STRENGTH (kg/cm^2) 15.8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

DEHYDROGENATION

TYPE OF CATALYST: *CHROMIUM Cr-0104.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Cr_2O_3 5 CARRIER: activated alumina FORM: tablets SIZE: Diameter (mm) 3 ABD (g/cm^3) 1.08 SA (m^2/g) 160 PV (cm^3/g) 0.36 STRENGTH (kg/cm^2) 10.8	TEMPERATURE RANGE: n.a. PRESSURE RANGE n.a.	

TYPE OF CATALYST: *COBALT Co-0501.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Co 10, in oxide form CARRIER: activated alumina FORM: tablets SIZE: Diameter (mm) 3 Length (mm) n.a. ABD (g/cm^3) 0.960 SA (m^2/g) 60 PV (cm^3/g) 0.51 STRENGTH (kg/cm^2) 8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is a mild hydrogenation catalyst.

TYPE OF CATALYST: *CHROMIUM Cr-0101.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Cr_2O_3 12 MgO as promotor 2 CARRIER: activated alumina FORM: tablets SIZE: Diameter (mm) 3 ABD (g/cm^3) 0.992 SA (m^2/g) 45 PV (cm^3/g) 0.31 STRENGTH (kg/cm^2) 4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *CHROMIUM Cr-0105.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Cr_2O_3 9 K_2O 1.5 as promotor CARRIER: activated alumina FORM: tablets SIZE: Diameter (mm) 3 ABD (gcm^3) 1.08 SA (m^2/g) 67 PV (cm^3/g) 0.34 STRENGTH (kg/cm^2) 5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *ZINC ACTIMET*^{R} *261*

Manufacturer	Characteristics	Operating conditions	Remarks
Doduco	CONTENT wt % Activated zinc on carrier CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

DEHYDROGENATION OF PARAFFINS TO OLEFINS AND OLEFINS TO DIOLEFINS

TYPE OF CATALYST: *CHROMIUM Cr-0211.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Cr_2O_3 19 CARRIER: activated alumina FORM: tablets SIZE: Diameter (mm) 3 Length (mm) n.a. ABD (g/cm^3) 1.152 SA (m^2/g) 62 PV (cm^3/g) 0.30 STRENGTH (kg/cm^2) 9.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	A catalyst capable of selectivity for dehydrogenation of butane to butene. Formation of butene from butane is favoured at about atmospheric pressure, while butadiene is favoured at reduced pressures.

DEHYDROGENATION OF FUNCTIONAL GROUPS

TYPE OF CATALYST: *COPPER-CHROMITE Cu-0203T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % CuO 78 Cr_2O_3 20 CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 3 Length (mm) n.a. ABD (g/cm^3) 2.160 STRENGTH (kg/cm^2) 9	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Copper-chromite catalysts are capable of selectivity to hydrogenate or dehydrogenate functional groups in organic compounds without changing the unsaturation or the saturation in aromatic rings or alkyl chains.

TYPE OF CATALYST: *COPPER-CHROMITE Cu-0402.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % CuO 35 Cr_2O_3 38 BaO 10 CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 3 Length (mm) n.a. ABD (g/cm^3) 1.616 STRENGTH (kg/cm^2) 3.6—5.4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *COPPER-CHROMITE Cu-1107.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % CuO 33 Cr_2O_3 38 BaO 9 CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 3 Length (mm) n.a. ABD (g/cm^3) 1.808 STRENGTH (kg/cm^2) 9	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Some copper-chromite complexes contain barium as a stabilizing element. Barium stabilizes copper-chromite for hydrogenation by retarding reduction of the catalyst during use. However, unstabilized copper-chromite catalysts are often used successfully for hydrogenation. The unstabilized copper-chromites are sometimes preferred for dehydrogenation.

DEHYDROGENATION

TYPE OF CATALYST: *COPPER-CHROMITE Cu-1800.P*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % CuO 51 Cr_2O_3 47 CARRIER: n.a. FORM: powder SIZE: n.a. ABD (g/cm^3) 0.656 SA (m^2/g) 40 PV (cm^3/g) 0.76	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for fluid bed hydroforming and dehydrogenation.

TYPE OF CATALYST: *COPPER-CHROMITE Cu-1808.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % CuO 42 Cr_2O_3 38 CARRIER: n.a. FORM: tablets SIZE: n.a. ABD (g/cm^3) 1.328 STRENGTH (kg/cm^2) 3.6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for fluid bed hydroforming. This is tableted Cu-1800. P.

DEHYDROGENATION OF ALCOHOLS TO ALDEHYDES OR KETONES

TYPE OF CATALYST: *COPPER-CHROMITE Cu-2501.G4—10*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Copper 6 as copper carbonate CARRIER: silica FORM: granules SIZE: Diameter (mm) 4—10 Length (mm) n.a. ABD (g/cm^3) 0.480 SA (m^2/g) 4 PV (cm^3/g) 0.61	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	An alkaly promoted catalyst.

MODERATE DEHYDROGENATION

TYPE OF CATALYST: *IRON Fe-0301.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Fe_2O_3 20 CARRIER: activated alumina FORM: tablets SIZE: Diameter (mm) 3 Length (mm) n.a. ABD (g/cm^3) 0.992 SA (m^2/g) 41 PV (cm^3/g) 0.31 STRENGTH (kg/cm^2) 8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	A hydrogenation catalyst.

DEHYDROGENATION

TYPE OF CATALYST: *MOLYBDENUM Mo-0401.P*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Molybdenum 44 (in sulphide form) CARRIER: n.a. FORM: powder SIZE: n.a. ABD (g/cm^3) 0.816 SA (m^2/g) 19 PV (cm^3/g) 0.46	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for dehydrogenation, hydrogenation and desulphurization.

TYPE OF CATALYST: *MOLYBDENUM Mo-0502.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % MoO_3 10 CARRIER: activated alumina FORM: tablets SIZE: Diameter (mm) 3 Length (mm) n.a. ABD (g/cm^3) 0.976 SA (m^2/g) 64 PV (cm^3/g) 0.40 STRENGTH (kg/cm^2) 4.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *MOLYBDENUM Mo-1101.P*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % MoO_3 11 CARRIER: high activity alumina FORM: microspheroidal powder SIZE: n.a. ABD (g/cm^3) 1.088	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for fluid bed hydroforming and dehydrogenation.

DEHYDROGENATION OF ALCOHOLS TO ALDEHYDES AND KETONES

TYPE OF CATALYST: *MOLYBDENUM Mo-1201.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % MoO$_3$ 10 CARRIER: high activity alumina FORM: tablets SIZE: Diameter (mm) 3 Length (mm) n.a. ABD (g/cm^3) 0.848 SA (m^2/g) 160 PV (cm^3/g) 0.36 STRENGTH (kg/cm^2) 24	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for hydrogenation, dehydrogenation and hydroforming.

DEHYDROGENATION OF NAPHTHENES

TYPE OF CATALYST: *NICKEL Ni-0101.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni 44 (present as hydrate) CARRIER: Kieselguhr FORM: tablets SIZE: Diameter (mm) 3;5;6 Length (mm) n.a. ABD (g/cm^3) 1.2—1.34 STRENGTH (kg/cm^2) 5—7.7	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	At temperatures of about 275°C it must be reduced before use. Used for hydrogenation and methanation.

TYPE OF CATALYST: *NICKEL Ni-0104.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni 60 CARRIER: Kieselguhr FORM: tablets SIZE: Diameter (mm) 3;5;7 Length (mm) n.a. ABD (g/cm^3) 1.2—1.34 SA (m^2/g) 150 PV (cm^3/g) 0.2 STRENGTH (kg/cm^2) 3.6—11	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The ratio of reduced Nickel to total Nickel = 0.60. A hydrogenation catalyst reduced and stabilized but not pyrophoric as shipped.

TYPE OF CATALYST: *NICKEL Ni-1404.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni 68 CARRIER: proprietary FORM: tablets SIZE: Diameter (mm) 3;5 Length (mm) n.a. ABD (g/cm^3) 1—1.104 SA (m^2/g) 125 PV (cm^3/g) 0.35 STRENGTH (kg/cm^2) 4—7	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	A hydrogenation catalyst reduced and stabilized and not pyrophoric as shipped. Used for hydrogenation, hydrogenolysis and amination.

TYPE OF CATALYST: *PALLADIUM Pd-0501.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Pd 0.3 CARRIER: high activity alumina FORM: tablets SIZE: Diameter (mm) 3 Length (mm) n.a. ABD (g/cm^3) 0.88 SA (m^2/g) 186 PV (cm^3/g) 0.38 STRENGTH (kg/cm^2) 11	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

DEHYDROGENATION

TYPE OF CATALYST: *ZINC Zn-0602.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % ZnO 10 Cr_2O_3 10 CARRIER: activated alumina FORM: tablets SIZE: Diameter (mm) 3.175 Length (mm) n.a. ABD (g/cm^3) 1.088 SA (m^2/g) 141 PV (cm^3/g) 0.28 STRENGTH (kg/cm^2) 3	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *ZINC Zn-0701.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % ZnO 24 CARRIER: activated alumina FORM: tablets SIZE: Diameter (mm) 3 Length (mm) n.a. ABD (g/cm^3) 1.2 SA (m^2/g) 46 PV (cm^3/g) 0.25 STRENGTH (kg/cm^2) 4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

DEHYDROGENATION OF PARAFFINS TO OLEFINS

TYPE OF CATALYST: *CHROME-ALUMINA SERIES A, GRADE 25Z*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Cr_2O_3 17.5 min. Ignition loss (760°C) 2.0 max. CARRIER: alumina FORM: cylindrical; extrusions; pellets SIZE: Diameter (mm) 3 Length (mm) 4 ABD (g/cm^3) 0.960—1.1 SA (m^2/g) 45—70 STRENGTH (kg/cm^2) 7	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Important uses are in hydrocracking, hydrodealkylation, cyclization and aromatization.

DEHYDROGENATION OF ALCOHOLS

TYPE OF CATALYST: *COPPER H-1044*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Cu 22 $BaCrO_4$ 8 Cr_2O_3 2 Na_2O 0.5 SiO_2 61 Ignition loss (750°C) 0.5 FORM: extrusions SIZE: Diameter (mm) 4 Length (mm) 4—7 ABD (g/cm^3) 0.6 SA (BET) (m^2/g) 180—240 PV (cm^3/g) 0.7 STRENGTH (kg/cm^2) 50	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for the dehydrogenation of alcohols at high temperatures in the liquid phase, and also for the dehydrogenation of fatty esters to alcohols at temperatures of approx. 200°C.

TYPE OF CATALYST: *COPPER H-1201*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Cu 14 Cr 2 Silica 64 CARRIER: silica FORM: irregular granules SIZE: Diameter (mm) 4—7 ABD (g/cm^3) 1.0 SA (m^2/g) 15 PV (cm^3/g) 0.3	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for the dehydrogenation of ethanol. Excellent performance also in the hydrogenation of unsaturated aliphatic aldehydes.

TYPE OF CATALYST: *ZINC OXIDE H-2004*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % ZnO 79 Al_2O_3 4.5 Cr_2O_3 1.4 CaO 6.6 K_2O 3.3 SO_4 2.5 Ignition loss (650°C) 1—2 CARRIER: n.a. FORM: extrusions SIZE: Diameter (mm) 6 Length (mm) 5—10 ABD (g/cm^3) 1.4 SA (BET) (m^2/g) 10 PV (cm^3/g) 0.3	TEMPERATURE RANGE: 400°C PRESSURE RANGE: n.a.	Used for the dehydrogenation of secondary butanol and cyclohexanol.

TYPE OF CATALYST: *ZINC-OXIDE H-2499*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % ZnO 1 Al_2O_3 99 FORM: hollow cylinders SIZE: Diameter (mm) ID: 2 OD: 7—8 Length (mm) 15 ABD (g/cm^3) 0.53	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Suited for the fission of methanol.

DEHYDROGENATION OF CYCLOHEXANOL TO CYCLOHEXANE

TYPE OF CATALYST: *COPPER-RANEY CD*

Manufacturer	Characteristics	Operating conditions	Remarks
Kawaken Catalysts	CONTENT It is prepared from the alloy of approx. 50% copper and 50% aluminium FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Activated type CDT. A copper Raney catalyst characterized by the selective activity to carbonyl bond. Used also in hydrogenation (e.g. furfural to furfuryl alcohol).

DEHYDROGENATION OF BUTANE AND ISOBUTANE TO BUTADIENE

TYPE OF CATALYST: *CHROMIUM KONTAKT 6448*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT wt % Chromium oxide CARRIER: alumina FORM: spheres SIZE: Diameter (mm) 5 ABD (g/cm^3) 0.85—1.05	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

DEHYDROGENATION OF ISOBUTANE TO ISOBUTENE

TYPE OF CATALYST: *CHROMIUM DH-3*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Cr 10.5 ± 0.5 K 0.8 ± 0.1 Na_2O <0.5 Fe_2O_3 <0.05 Al_2O_3 (by difference) 100 Heating loss at 550°C 0.5 CARRIER: alumina FORM: balls SIZE: Diameter (mm) 2—4; 3—5; 5—7 ABD (g/cm^3) 0.9 ± 0.05 SA (m^2/g) 100 ± 20 PV (cm^3/g) 0.35 ± 0.05 STRENGTH particle: 10 kg	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used for the dehydrogenation of C_4 to butadiene.

DEHYDROGENATION IN VAPOUR PHASE

TYPE OF CATALYST: *Cu/Zn ST-230*

Manufacturer	Characteristics	Operating conditions	Remarks
Sakaj Chemical Co. Ltd.	CONTENT wt % Cu/Zn CARRIER: n.a. FORM: tablets SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *Cu/Zn CHROMITE ST-231*

Manufacturer	Characteristics	Operating conditions	Remarks
Sakaj Chemical Co. Ltd.	CONTENT wt % Cu/Zn/Cr CARRIER: n.a. FORM: tablets SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

DEHYDROGENATION OF ALKANES TO OLEFINS

TYPE OF CATALYST: *CHROMIA-ALUMINA 24020*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % Cr 7.5 Chromium oxide CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 3 SA (m^2/g) 179	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Dehydrogenation of ethylbenzene to styrene, synthesis of thiophenes from sulphur and alkanes. Desulphurization catalyst.

TYPE OF CATALYST: *CHROMIUM 24- 025*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % Chromium oxide 2—4 CARRIER: silica fibres FORM: long fibres SIZE: Length (mm) 6 SA (m^2/g) 15	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for the dehydrogenation of alkanes to olefins.

TYPE OF CATALYST: *NICKEL 28—148*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % NiO 15 CARRIER: alumina FORM: pellets SIZE: Diameter (mm) 3 Length (mm) 3 SA (m^2/g) approx. 65	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Dehydrogenation of ethylbenzene to styrene. Vapor phase oxidation of hydrocarbons. Hydrogenation of olefins selectivity in the presence of aromatics (reduced form).

TYPE OF CATALYST: *NICKEL 28—162*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % NiO 1—2 CARRIER: silica fibres FORM: long fibres SIZE: Length (mm) 6 SA (m^2/g) approx. 27	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used for the hydrogenation (reduced form) of olefins.

HYDROGENATION AND DEHYDROGENATION

TYPE OF CATALYST: *COPPER 29-037*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % Copper chromite non-promoted CuO 82 Cr_2O_3 17 CARRIER: n.a. FORM: powder SA (m^2/g) approx. 10	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Being non-promoted, it is more durable as dehydrogenation catalyst. For best results in dehydrogenation processes this catalyst should be pretreated; then it can be used effectively to form aromatics and heteroalcohols to aldehydes and ketones.

DEHYDROGENATION (OXIDATION) OF ALCOHOLS TO ALDEHYDES AND KETONES

TYPE OF CATALYST: *RHENIUM 75-215; 75-216; 75-220; 75-221*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % (1) 75215 (2) 75216 Rhenium 5 (3) 75220 (4) 75221 Rhenium 10 CARRIER: Carbon FORM: (1) powder; (2) granules; (3) powder; (4) granules SIZE: n.a. SA (m^2/g) high	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	They are also used for dehydrogenation of cyclohexanes to benzenes.

DEHYDROGENATION OF CYCLOHEXANES TO BENZENES

TYPE OF CATALYST: *IRON 26272*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % Iron oxide Fe_2O_3 20 CARRIER: alumina FORM: pellets SIZE: Diameter (mm) 3 Length (mm) 3 SA (m^2/g) approx. 40	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Catalyzes the conversion of alcohols to amines with ammonia. Desulphurization catalyst.

TYPE OF CATALYST: *MOLYBDENUM 42-150*			
Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % MoO_3 10—12 CARRIER: alumina FORM: pellets SIZE: Diameter (mm) 3 Length (mm) 4 SA (m^2/g) approx. 200	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used for the polymerization of olefins.

D. Desulphurization

- **Sulphur removal**
- **Desulphurization**
- **Hydrodesulphurization**
- **Guards for low temperature CO shift**

Sulphur removal

SULPHUR REMOVAL

TYPE OF CATALYST: *ZINC DF-220*

Manufacturer	Characteristics	Operating conditions	Remarks
Azote et Produits Chimiques S.A.	CONTENT wt % ZnO CARRIER: n.a. FORM: cylindrical extrusions SIZE: Diameter (mm) 6 Length (mm) 10—14 ABD (g/cm³) 1.25	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	High mechanical strength and great absorption capacity above 20%. The following compounds are totally removed: hydrogen sulphide, carbon disulphide, carbon sulphoxide, mercaptans.

TYPE OF CATALYST: *ZINC G-1*

Manufacturer	Characteristics	Operating conditions	Remarks
Azote et Produits Chimiques S.A.	CONTENT wt % ZnO CARRIER: n.a. FORM: cylindrical pellets SIZE: Diameter (mm) 6 Length (mm) 6 ABD (g/cm³) 1.45	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Naphtha and light hydrocarbon hydrodesulphurization. It reduces the sulphur content of the processed hydrocarbon to less than 1 ppm (about 0.2 ppm) and allows the use of a reducing gas high in carbon oxides, without the occurence of the exothermic methanation reactions. G-1 catalyst allows chlorine traces that may be present in the hydrocarbon to be fixed.

SULPHUR REMOVAL FROM VARIOUS FEEDSTOCKS

TYPE OF CATALYST: *IRON-CHROMIUM C9-1*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Iron and chromium oxides with a cement binder CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 4 Length (mm) 6	TEMPERATURE RANGE: 340°—450°C PRESSURE RANGE: n.a.	It serves as a non-regenerable desulphurization system.

SULPHUR REMOVAL

TYPE OF CATALYST: *ZINC OXIDE C 7—1; C 7—2*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT n.a. CARRIER: n.a. FORM: pellets SIZE: Diameter (mm) 4.762 ABD (g/cm^3) 1.120± 0.080	TEMPERATURE RANGE: 200°—400°C PRESSURE RANGE: not critical; no pressure limitations SPACE VELOCITY: up to 20,000 h^{-1}	C 7-1 and C 7-2 are nonregenerable.

TYPE OF CATALYST: *ZINC OXIDE CDZ-6*

Manufacturer	Characteristics	Operating conditions	Remarks
Fertilizer Corporation of India (FCI)	CONTENT n.a. CARRIER: n.a. FORM: cylindrical tablets; extrusions; spherical globules. SIZE (mm): cylindrical tablets: 6×6 extrusions: 5×10 spherical globules: 2×5 ABD (g/cm^2) 1.1—1.4	TEMPERATURE RANGE: 250°—410°C PRESSURE RANGE: ~35 atm.	Available as CDZ-6A that is suitable for desulphurization of hydrocarbon feedstock.

REMOVAL OF HYDROGEN SULPHIDE FROM SYNTHESIS GAS STREAMS

TYPE OF CATALYST: *IRON CDD-12*

Manufacturer	Characteristics	Operating conditions	Remarks
Fertilizer Corporation of India (FCI)	CONTENT n.a. CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is substitute for luxmasse or bog ore. It can be supplied either as ready mixed mass or rich iron oxide.

TYPE OF CATALYST: *ZINC G-72.C*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT n.a. CARRIER: n.a. FORM: spheres SIZE: Diameter (mm) 3—5 ABD (g/cm^3) 1.1	TEMPERATURE RANGE: 430°C PRESSURE RANGE: 1—50 atm.	Removal of hydrogen sulphide, carbonyl sulphides, mercaptans and organic sulphides. Organic sulphide removal is normal at 260—430°C. G-72. C will adsorb up to 20 weight per cent sulphur. It will reduce the sulphur content from 200 mg/Nm^3 to an exit concentration of less than 0.2 ppm.

TYPE OF CATALYST: *ZINC G-72.D*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Zinc oxide CARRIER: n.a. FORM: extrusions SIZE: Diameter (mm) 4 ABD (g/cm^3) 1.4	TEMPERATURE RANGE: 20°—430°C PRESSURE RANGE: 1—50 atm	Organic sulphide removal is normally done at 260—430°C. Removal of hydrogen sulphide, carbonyl sulphides, mercaptans and organic sulphides.

TYPE OF CATALIST: *COPPER G-108.A*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Copper oxide Cu 16 CARRIER: special silica FORM: spheres SIZE: Diameter (mm) 5	TEMPERATURE RANGE: 100°—300°C PRESSURE RANGE: n.a.	Applications: Chlorine and sulphur removal, hydrogen and oxygen removal, hydrogenation.

TYPE OF CATALYST: *COPPER G-108.B*			
Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Cu 30 CARRIER: special FORM: spheres SIZE: Diameter (mm) 5	TEMPERATURE RANGE: 100°—300°C PRESSURE RANGE: n.a.	It is recommended for the sulphur and chlorine removal.

REMOVAL OF ORGANIC SULPHUR COMPOUNDS

TYPE OF CATALYST: *IRON G-42*			
Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Promoted iron oxide CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 6 Length (mm) 6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for treating gas streams containing sulphur as H_2S, mercaptans, CS_2 or organic sulphide.

TYPE OF CATALYST: *DESULPHURIZATION MASS N-ODS*			
Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT n.a. CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

SULPHUR REMOVAL

TYPE OF CATALYST: *ZINC OXIDE*

Manufacturer	Characteristics	Operating conditions	Remarks
Grande Paroisse	CONTENT wt % Zinc oxide CARRIER: n.a. FORM: cylindrical pellets SIZE: Diameter (mm) 11 Length (mm) 5 ABD (g/cm^3) 1.5	TEMPERATURE RANGE: 250°—380°C PRESSURE RANGE: until 100 atm	It is used to stock sulphur in the state of H_2S, COS present in gases. Catalyst life depends on sulphur content of raw material to be worked.

TYPE OF CATALYST: *ZINC Zn-0401.E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % ZiO 100 FORM: extrusions SIZE: Diameter (mm) 4 ABD (g/cm^3) 1.2 SA (m^2/g) 7 PV (cm^3/g) 0.14 STRENGTH (kg/cm^2) 6.3	TEMPERATURE RANGE: up to 400°C PRESSURE RANGE: 4 atm	

TYPE OF CATALYST: *COBALT-MOLYBDENUM H-9410*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % (approx.) CoO 3 MoO_3 15 Al_2O_3 80 FORM: extrusions SIZE: Diameter (mm) 2.4 Length (mm) 3—6 ABD (g/cm^3) 0.85 SA (BET) (m^2/g) 330 STRENGTH (kg/cm^2) 44	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for the removal of sulphur, nitrogen and arsenic impurities from naphtha feedstocks for petrol reforming and aromatics production units. This catalyst may also be used for desulphurization fuel oils and gas oils and for the hydrogenation of olefins.

REMOVAL OF H_2S FROM GASES

TYPE OF CATALYST: *ZINC KATALCO 32—4*

Manufacturer	Characteristics	Operating conditions	Remarks
Katalco Corporation	CONTENT wt % Zinc oxide CARRIER: n.a. FORM: granules SIZE: Diameter (mm) 3—4 Length (mm) n.a. ABD (g/cm^3) 1.10	TEMPERATURE RANGE: 340°—450°C PRESSURE RANGE: 1—50 atm SPACE VELOCITY (VHSH): 400 h^{-1}	It is used for the removal of small concentrations of H_2S and organic sulphur compounds from gases.

SWEETING OF KEROSENE

TYPE OF CATALYST: *COPPER CUPROX*

Manufacturer	Characteristics	Operating conditions	Remarks
Laporte Industries Limited, General Chemical Division, Spence Works	CONTENT wt % A promoted supported copper catalyst CARRIER: n.a. FORM: granular SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is manufactured for use in the sweeting of mercaptan containing feeds.

REMOVAL OF HYDROGEN SULPHIDE

TYPE OF CATALYST: *LUXMASSE-IRON OXIDE*

Manufacturer	Characteristics	Operating conditions	Remarks
Laporte Industries Limited, General Chemical Division, Spence Works	CONTENT n.a. CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

SULPHUR REMOVAL

TYPE OF CATALYST: *ZINC KONTAKT 4010*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT wt % Highly active zinc oxide CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 5 ABD (g/cm^3) 1.2±0.15 STRENGTH (kg/cm^2) 90±20	TEMPERATURE RANGE: 350°—450°C PRESSURE RANGE: 1—50 atm	Desulphurization of synthesis gas.

TYPE OF CATALYST: *ZINC ST-300*

Manufacturer	Characteristics	Operating conditions	Remarks
Sakaj Chemical Industry Co. Ltd	CONTENT wt % Consists of base metals and occasionally noble metals CARRIER: n.a. FORM: tablets SIZE: n.a.	TEMPERATURE RANGE: 150°—400°C PRESSURE RANGE: n.a.	Applications: Deodorizing of exhausting solvent vapor from baking finish, printing, baking enamel wire, adhesive process etc.; Deodorizing of odorous gas from sewerage, oil and fats plants, craft pulp plant etc.

TYPE OF CATALYST: *ZINC OXIDE HTZ-3*

Manufacturer	Characteristics	Operating conditions	Remarks
Haldor Topsøe	CONTENT wt % Zinc oxide CARRIER: n.a. FORM: extrusions SIZE: Diameter (mm) 4 Length (mm) 4—6 ABD (g/cm^3) 1.4	TEMPERATURE RANGE: 350°—400°C PRESSURE RANGE: 1—48.4 atm	It is recommended for the removal of H_2S, CS_2 and also of organic sulphur. Examples: Removal of organic sulphur from natural gas. Removal of H_2S from naphtha.

TYPE OF CATALYST: *ZINC HTZ-3*

Manufacturer	Characteristics	Operating conditions	Remarks
Haldor Topsøe	CONTENT wt % Zinc oxide CARRIER: n.a. FORM: extruded cylinders SIZE: Diameter (mm) 4 Length (mm) 4—6 ABD (g/cm³) 1.4	TEMPERATURE RANGE: 350°—400°C PRESSURE RANGE: 1—50 atm	It is used for the removal of hydrogen sulphide, carbonyl sulphide and to a certain degree organic sulphur compounds from hydrocarbons and other gases such as feed gas to a low temperature shift catalyst. At ambiant temperatures only H_2S would be absorbed.

Desulphurization

DESULPHURIZATION

TYPE OF CATALYST: *COPPER-CHROMIA C-29*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Copper and chromia oxides CARRIER: aluminium oxide FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: 200°—350°C PRESSURE RANGE: 1—40 atm	Highly selective catalyst for the conversion of carbonyl sulphide without hydrogenating the olefins in the stream.

TYPE OF CATALYST: *IRON C-28*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT n.a. CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 6;10 Length (mm) 6;10	TEMPERATURE RANGE: 290°—370°C PRESSURE RANGE: n.a.	It is used for the removal of organic sulphur compounds from gas streams by the conversion of the organic sulphur to H_2S by hydrogenation and/or hydrolysis.

DESULPHURIZATION OF LIGHT HYDROCARBON GASES

TYPE OF CATALYST: *METAL PROMOTED ACTIVATED CARBON C 8-1; C 8-4*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT C 8-1 activated carbon contains 3—4 wt % metallic oxides (copper); C 8-4 activated carbon contins a combination of 15—17wt % metallic oxides CARRIER: activated carbon FORM: granules SIZE: (mm) 2.5;1.7—2 ABD (g cm³) approx. 0.61	TEMPERATURE RANGE: 15°—50°C PRESSURE RANGE: 0—45 atm SPACE VELOCITY: up to 200,000 Nm³ gas m³ carbon before regeneration	Are used as sulphur guard for methanation catalysts. Available as C 8-6 and C 8-7.

DESULPHURIZATION OF SYNTHESIS GAS STREAMS AND NATURAL GAS

TYPE OF CATALYST: *NOBLE METAL C53—2*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT n.a. CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: 149°—316°C PRESSURE RANGE: n.a.	It promotes the hydrolysis of organic sulphur compounds at low temperature.

DESULPHURIZATION OF GAS STREAMS

TYPE OF CATALYST: *ACTIVATED CARBON G-32 SERIES*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Activated charcoal unimpregnated or specially treated with metallic oxides CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	These activated carbons find application as catalysts supports. Selection of particular grade will be determined by operational requirement. Available as: G-32 granules (mm): 0.5—7; 2—5 G-32. E granules (mm): 0.5—7; 2—5 G-32. W: 12×30 mm mesh 4×10 mm mesh For fixed bed operations.

TYPE OF CATALYST: *ACTIVATED CARBON G-32.F*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT n.a. CARRIER: n.a. FORM: pellets SIZE: Diameter (mm) 8 Length (mm) 10 SA (m^2/g) 935 PV (cm^3/g) 0.81	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Sulphur removal by adsorption; for fixed bed operations. G-32.F is recommended for the removal of compressor oils from gas streams where the presence of such contaminates will interfere with subsequent operations downstreams.

TYPE OF CATALYST: *ACTIVATED CARBON G-32.H*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % A highly activated charcoal CARRIER: n.a. FORM: granules SIZE (mm): 4×8 mesh; 8×30 mesh SA (m^2/g) 700	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Sulphur removal by adsorption for fixed bed operations. G-32.H is a catalyst support, specifically recommended for use in the production of phosgene. It is used as a catalyst and catalyst support.

TYPE OF CATALYST: *ACTIVATED CARBON G-32.J*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT It is prepared by chemical impregnation of a physically strong highly absorbent activated coconut shell char. It contains appr. 5 wt% copper. FORM: granules SIZE (mm): 4×8 mesh; 8×30 mesh ABD (g/cm^3) 0.56—0.6 SA (m^2/g) 900 PV (cm^3/g) 0.6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	G-32.J is recommended for desulphurization of gas streams containing sulphur in the form of mercaptans, H_2S, CS_2 or other sulphur compounds. It is chloride free and non-corrosive.

TYPE OF CATALYST: *ACTIVATED CARBON G-32.P*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT A highly activated charcoal containing approx. 16% metallic oxides FORM: granules SIZE: Diameter (mm) 0.5—2.0; 2.0—5.0	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is especially recommended for removal of 10—20 ppm v/v H_2S from hydrocarbon streams.

DESULPHURIZATION

TYPE OF CATALYST: *DESULPHURIZATION MASS N—IDS*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT n.a. CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for the removal of inorganic sulphur compounds.

TYPE OF CATALYST: *PALLADIUM*

Manufacturer	Characteristics	Operating conditions	Remarks
Grande Paroisse	CONTENT wt % Pd 0.3—2.0 CARRIER: silico-aluminate FORM: cylindrical pellets SIZE: Diameter (mm) 3 Length (mm) 4 ABD (g/cm^3) 0.83	TEMPERATURE RANGE: 250°—380°C PRESSURE RANGE: until 100 atm LIFE: 5 years SPACE VELOCITY: 4—24 (LHSV) 800—4,800 (VSHV)	Used to mineralize sulphur in H_2S state.

DESULPHURIZATION OF REFINERY FEEDSTOCKS

TYPE OF CATALYST: *COBALT-MOLYBDENUM HT-300.S*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % CoO 3 MoO_2 13 CARRIER: alumina FORM: spherical SIZE: n.a. ABD (g/cm^3) 0.64 SA (m^2/g) 200 PV (cm^3/g) 0.75 STRENGTH (kg/cm^2) equivalent to extrusion at 6.34	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is recommended for desulphurization and denitrification of refinery feedstocks.

DESULPHURIZATION OF REFINERY PRODUCTS

TYPE OF CATALYST: *COBALT-MOLYBDENUM HT-400.E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % CoO 3 MoO_2 15 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 0.8;1.6;3.2 ABD (g/cm³) 0.8 SA (m^2/g) 220 PV (cm^3/g) 0.5 STRENGTH(kg/cm^2) 5.44	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for the desulphurization and denitrification of hydrocarbons.

DESULPHURIZATION OF JET FUELS

TYPE OF CATALYST: *NICKEL-TUNGSTEN Ni-4305.E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni 4.5 W 9.5 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 3 ABD (g/cm^3) 1.02 SA (m^2/g) 184 PV (cm^3/g) 0.53 STRENGTH(kg/cm^2) 7	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for hydrogenation of jet fuels, saturation of mono and polycyclic aromatic compounds, denitrogenation.

DESULPHURIZATION

TYPE OF CATALYST: *NICKEL-MOLYBDENUM HR*$^{T.M.}$ *811*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT n.a. CARRIER: n.a. FORM: n.a. SIZE: Diameter (mm) n.a. Length (mm) n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Removal of both sulphur and nitrogen.

TYPE OF CATALYST: *ZINC ICI 32 SERIES*

Manufacturer	Characteristics	Operating conditions	Remarks
Imperial Chemical Industries Ltd.	CONTENT wt % Zinc oxide CARRIER: n.a. FORM: n.a. SIZE: Diameter (mm) 3—4.7 Length (mm) n.a. ABD (g/cm^3) 1.1	TEMPERATURE RANGE: up to 450°C PRESSURE RANGE: up to 50 atm SPACE VELOCITY: 200—2,000 h^{-1} up to 20,000 h^{-1} (as a guard)	It is recommended for the removal of hydrogen sulphide and reactive organic sulphur compounds. ICI 32-4 is recommended as a guard for low temperature CO shift catalyst in plants with very high sulphur levels, but normal chlorine levels. Available as ICI 32-4.

TYPE OF CATALYST: *LEAD MaP*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Lead CARRIER: special FORM: balls SIZE: n.a. ABD (g/cm^3) 0.7	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used at high and low temperature for elimination of a few ppm of H_2S from industrial waste gases.

DESULPHURIZATION OF NATURAL GAS

TYPE OF CATALYST: *METAL OXIDES ON ACTIVATED CARBON KATALKO 7—1; 7—2*

Manufacturer	Characteristics	Operating conditions	Remarks
Katalco Corporation	CONTENT wt % 7—1 iron oxide 5—7 7—2 metal oxide about 14 CARRIER: activated carbon FORM: granules SIZE (mm) 12×30; 4×10 ABD (g/cm^3) 0.5—0.56	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Desulphurization of natural gas streams at ambiant temperature. 7—1 is suitable for removal of H_2S and other sulphur compounds, in low concentrations. 7—2 is suitable for removal of H_2S and other sulphur compounds, in higher concentrations up to about 50 ppm.

HYDRODESULPHURIZATION

TYPE OF CATALYST: *COBALT-MOLYBDENUM C-20-5*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % CoO 3.3—3.8 MoO_3 9.5—10.5 Na_2O 0.05 Fe_2O_3 0.2 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 1.5;3.2;5 ABD (g/cm^3) 0.7 SA (m^2/g) 175—225	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The catalyst is poisoned by arsenic. Principal uses: for pretreatment of feedstocks.

TYPE OF CATALYST: *COBALT-MOLYBDENUM C-20-6*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % CoO 3.3—3.8 MoO_3 13—15 Na_2O 0.05 Fe_2O_3 0.20 Chlorides 0.10 CARRIER: n.a. FORM: extrusions SIZE: Diameter (mm) 3.175; 2.1;1.6 ABD (g/cm^3) 0.48—0.64 SA (m^2/g) 175—225 PV (cm^3/g) 0.50—0.60 STRENGTH(kg/cm^2) (side crush) 9.06; 6.8; 4.53	TEMPERATURE RANGE: 280°—450°C PRESSURE RANGE: 7—105 atm SPACE VELOCITY (LHSV): 1—10 h^{-1}	Used for hydrotreating and stabilization of liquid petroleum fractions from light naphtha through heavy vacuum gas oils and lube stocks. Available also as C-20-6S. It is also used for hydrodenitrogenation.

TYPE OF CATALYST: *COBALT-MOLYBDENUM AGRO HDS-2; HDS-2A*

Manufacturer	Characteristics	Operating conditions	Remarks
Cyanamid International	CONTENT wt % CoO 3.0—4.0 MoO_3 14.15—16.0 SO_4 0.3 Na_2O 0.04 max. Fe_2O_3 0.05 max. Ignition loss 2.0 max. CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 1.5—3 Length (mm) n.a. ABD (g/cm^3) 0.49—0.57 SA (m^2/g) 270 PV (cm^3/g) 0.7 STRENGTH (kg/cm^2) 6.4—8.2 TS (°C) up to 540	TEMPERATURE RANGE: 371°C PRESSURE RANGE: 21 atm. SPACE VELOCITY (LHSV): 5 h^{-1}	It is used to promote desulphurization, denitrogenation, deoxigenation and saturation reactions. Arsenic and lead are the worst poisons.

TYPE OF CATALYST: *CHROMIUM-ALUMINA G-41*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT n.a. CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 6;5 Length (mm) 6;5	TEMPERATURE RANGE: 290°—450°C PRESSURE RANGE: n.a.	It has special application for removal of carbonil sulphide and carbon disulphide from coke oven gas.

TYPE OF CATALYST: *COBALT-MOLYBDENUM G-39*

Manufacturer	Characteristics	Operating conditions	Remarks
Cirdler	CONTENT n.a. CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 4.5 Length (mm) 4.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used for hydrodenitrification of petroleum stocks. Recommended for treatment of streams contamined with sulphur where conversion of the sulphur compounds to hydrogen sulphide and hydrogenation of the olefins can be accomplished simultanously.

HYDRODESULPHURIZATION OF HYDROCARBONS

TYPE OF CATALYST: *COBALT-MOLYBDENUM G-51*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % CoO 3.5 MoO_3 10 CARRIER: high purity alumina FORM: extrusions SIZE: Diameter (mm) 3;5 ABD (g/cm^3) 0.65 STRENGTH (kg/cm^2) 6 (DWL)	TEMPERATURE RANGE: 260°—400°C PRESSURE RANGE: 3.5—70 atm	Used principally for hydrodesulphurization of hydrocarbons where a material having maximum physical strength is not required and lower density is desirable with G-51, organic sulphur compounds can be reacted with hydrogen to produce H_2S and the corresponding hydrogenated hydrocarbon. H_2S can then be removed from the gas stream by reacting with G-72.

TYPE OF CATALYST: *COBALT-MOLYBDENUM G-35*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % CoO + MoO$_3$ 13.5 [CoO 3.5 MoO$_3$ 10] CARRIER: high purity alumina FORM: tablets SIZE: Diameter (mm) 4.5 Length (mm) 4.5 ABD (g/cm^3) 1.0 STRENGTH (kg/cm^2) (DWL) 14	TEMPERATURE RANGE: 260°—430°C PRESSURE RANGE: 3.5—70 atm.	It is also used for hydrodenitrification of petroleum stocks.

TYPE OF CATALYST: *COBALT-MOLYBDENUM G-51.C*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % CoO 3.5 MoO$_3$ 10 CARRIER: n.a. FORM: extrusion SIZE: Diameter (mm) 3—5 ABD (g/cm^3) 0.384 STRENGTH (kg/cm^2) 6.795	TEMPERATURE RANGE: 316°—400°C 600°—750°F PRESSURE RANGE: 21—70 atm.	It is also used for the denitrification of petroleum stocks. Used also for hydrogenation of olefins.

TYPE OF CATALYST: *COBALT-MOLYBDENUM G-76*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % CoO 3.5 MoO$_3$ 10 It also contains Ni. CARRIER: n.a. FORM: extrusions or tablets SIZE: extrusions tablets Diameter (mm) 3 3—4.5 Length (mm) 15 3—4.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for pretreating refinery gases to make them suitable for steam hydrocarbon reforming. Its applications are similar to G-51. However, when nitrogen removal is required, this catalyst is preferred.

TYPE OF CATALYST: *MOLYBDENUM-NICKEL G-88*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT, wt % NiO 3.5 MoO_3 15 CARRIER: n.a. FORM: tablets; extrusions SIZE: tablets extrusions Diameter (mm) 3—4.5 3—4.5 Length (mm) 3—4.5 15 or 3	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used for nitrogen removal.

HYDRODESULPHURIZATION

TYPE OF CATALYST: *PALLADIUM GPH-7*

Manufacturer	Characteristics	Operating conditions	Remarks
Grande Paroisse	CONTENT n.a. CARRIER: alumina FORM: balls SIZE: Diameter (mm) 3 Length (mm) n.a. TS (°C) $\leqslant 550$	TEMPERATURE RANGE: 200°—300°C PRESSURE RANGE: n.a. LIFE: over 2 years SPACE VELOCITY: up to 10,000 h^{-1}	It is used in natural gas hydrocarbons such as naphthas.

TYPE OF CATALYST: *COBALT-MOLYBDENUM CoMo-0401.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Cobalt oxide 3 Molybdenum oxide 9 CARRIER: alumina FORM: tablets SIZE: Diameter (mm) 3 ABD (g/cm^3) 0.96 SA (m^2/g) 160 PV (cm^3/g) 0.40 STRENGTH (kg/cm^2) 10	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for the desulphurization of hydrocarbons A silica promoted catalyst.

TYPE OF CATALYST: *COBALT-MOLYBDENUM CoMo-0402.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % CoO 3 MoO_3 15 CARRIER: alumina FORM: tablets SIZE: n.a. ABD (g/cm³) 1.2 SA (m²/g) 200 PV (cm³/g) 0.4 STRENGTH (kg/cm²) 10	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Also for denitrogenation by hydrotreating. A silica promoted catalyst.

TYPE OF CATALYST: *COBALT-MOLYBDENUM CoMo-0601.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % CoO 3 MoO_3 9 CARRIER: alumina FORM: tablets SIZE: Diameter (mm) 3 Length (mm) 3 ABD (g/cm³) 1.1 SA (m²/g) 160 PV (cm³/g) 0.4 STRENGTH (kg/cm²) 10	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	A non-silicated catalyst.

TYPE OF CATALYST: *COBALT-MOLYBDENUM H-9410*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % See Hydrogenation of olefins	TEMPERATURE RANGE: n.a. TEMPERATURE RANGE: n.a.	

TYPE OF CATALYST: *COBALT-MOLYBDENUM HR$^{T.M.}$-801*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT n.a. CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Low density catalyst;it is used to remove sulphur from naphthas, gas-oils, furnace oils and other similar refining operations.

TYPE OF CATALYST: *COBALT-MOLYBDENUM ICI 41—3; 41—4; 41—5; 41—6; 41—7*

Manufacturer	Characteristics	Operating conditions	Remarks
Imperial Chemical Industries	CONTENT wt % Cobalt oxide Molybdenum oxide CARRIER: alumina FORM: 41-5 pellets; 41-6/7 extrusions SIZE: pellets extrusions Diameter (mm) 5.4 3.2 Length (mm) 1.6 ABD (g/cm^3) 0.5—0.55	TEMPERATURE RANGE: 300°—400°C PRESSURE RANGE: up to 70 atm.	ICI 41-7 is a more active version of the catalyst 41-6. They are hydrotreating catalysts designed for use with the complete range of hydrocarbon fractions from natural gas to lube oils. They can also be used for the hydrogenolysis of oxygen, nitrogen and organometallic compounds. Under normal operation condition they do not saturate aromatic hydrocarbons.

TYPE OF CATALYST: *COBALT-MOLYBDENUM KATALCO 41—3; 41—4*

Manufacturer	Characteristics	Operating conditions	Remarks
Katalco Corporation	CONTENT wt % Cobalt oxide Molybdenum oxide CARRIER: alumina FORM: 41-3-tablets 41-4-extrusions SIZE: extrusions tablets Diameter (mm) 4 5.4 Length (mm) 3.6 ABD (g/cm^3) tablets: 0.96—1.02 extrusions: 0.8—0.88	TEMPERATURE RANGE: 570°—840°C PRESSURE RANGE: 1—70 atm. SPACE VELOCITY (LHSV): 0.2—5.0 h^{-1} (for petroleum fractions)	The main use is for the vapour phase; hydrodesulphurization of gases and petroleum fractions.

TYPE OF CATALYST: *COBALT-MOLYBDENUM KATALCO 41-6*

Manufacturer	Characteristics	Operating conditions	Remarks
Katalco Corporation	CONTENT wt % MoO_3 12.5 CoO 3.5 Na_2O 0.05 Fe 0.03 SiO_2 0.3 Al_2O_3 balance CARRIER: alumina FORM: extrusions; spheres SIZE: Diameter (mm) 2—3 ABD (g/cm^3) 0.48—0.72 SA (m^2/g) 260 PV (cm^3/g) 0.46—0.65 STRENGTH (kg/cm^2) 6	TEMPERATURE RANGE: 350°—370°C PRESSURE RANGE: 14—15 atm LIFE: 4—5 years SPACE VELOCITY (LHSV): 2.25 h^{-1}	It is a hydrotreating catalyst designed for use in units whose feedstock ranges from light petroleum gases through naphthas to lube oil. Hydrodesulphurization is the prime service, although the catalyst can be used for the hydrogenolysis of oxygen, nitrogen and organo-metallic compounds.

TYPE OF CATALYST: *COBALT-MOLYBDENUM KATALCO 41—7*

Manufacturer	Characteristics	Operating conditions	Remarks
Katalco Corporation	CONTENT wt % MoO_3 12.5 CoO 3.5 Na_2O 0.08 Fe 0.03 SiO_2 1.5 Al_2O_3 balance CARRIER: alumina FORM: extrusions; spheres SIZE: Diameter (mm) 2—3 ABD (g/cm^3) 0.48—0.72 SA (m^2/g) 270 PV (cm^3/g) 0.51—0.65 STRENGTH (kg/cm^2) 6	TEMPERATURE RANGE: 350°C PRESSURE RANGE: 14—15 atm LIFE: 4—5 years SPACE VELOCITY (LHSV): 2.25 h^{-1}	See Katalco 41—6.

TYPE OF CATALYST: *MOLYBDENUM-NICKEL KATALCO 50-2*

Manufacturer	Characteristics	Operating conditions	Remarks
Katalco Corporation	CONTENT wt % MoO_3 14.0 NiO 2.8—3.0 Na_2O 0.08 Fe 0.03 SiO_2 1.5 Al_2O_3 balance CARRIER: alumina FORM: extrusions; spheres SIZE: Diameter (mm) 2—3 ABD(g/cm^3) e:0.72; s:0.52 SA (m^2/g) e:270; s:260 PV (cm^3/g) e:0.51 s:0.57 STRENGTH (kg/cm^2) 6	TEMPERATURE RANGE: 300°—370°C PRESSURE RANGE: 30—35 atm LIFE: 5 years SPACE VELOCITY (LHSV): 3.0 h^{-1}	See Katalco 41—6 It is especially suitable for hydrotreating units where both desulphurization and denitrogenation are desired.

HYDRODESULPHURIZATION (HYDROTREATING)

TYPE OF CATALYST: *COBALT-MOLYBDENUM KETJENFINE^R 124-1.5E*

Manufacturer	Characteristics	Operating conditions	Remarks
Akzo Chemie B.V. Dpt. Ketjen Catalysts	CONTENT wt % (dry base) CoO 4.0 MoO_3 12.0 SiO_2 1.0 Na_2O 0.06 Fe 0.06 SO_4 2.0 Ignition loss (1 hr at 650°C): 1.5 wet base CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 1.5 Length (mm) 4 ABD (g/cm^3) 0.55—0.70 SA (BET) (m^2/g) 250 PV (cm^3/g) 0.65—0.50 STRENGTH(kg/cm^2) 12	TEMPERATURE RANGE: 300°—360°C PRESSURE RANGE: 20—50 atm SPACE VELOCITY (VHSV): 2.5—5 h^{-1}	Abrasion: 1.0% See Ketjenfine 124-3.P Available as: 124-1.5E LD (low density) 124-1.5E HD (high density).

TYPE OF CATALYST: *COBALT- MOLYBDENUM KETJENFINE^R 124-3E*

Manufacturer	Characteristics	Operating conditions	Remarks
Akzo Chemie B.V. Dpt. Ketjen Catalysts	CONTENT wt % (dry base) CoO 4.0 MoO_3 12.0 SiO_2 1.0 Na_2O 0.06 Fe 0.06 SO_4 2.0 Ignition loss (1 hr at 650°C) 1.5 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 2.5 Length (mm) 5.0 ABD(g/cm^3) 0.55—0.70 SA (BET) (m^2/g) 250 PV (cm^3/g) 0.65—0.50 STRENGTH (kg/cm^2) 11	TEMPERATURE RANGE: 300°—360°C PRESSURE RANGE: 20—50 atm SPACE VELOCITY (VSHV): 2.5—5 h^{-1}	Abrasion: 2% Estimated reactor density: 0.55—0.70 kg/l. See Ketjenfine 124-3.P Available as: 124-3E (LD-low density) 124-3E (HD-high density).

TYPE OF CATALYST: *COBALT-MOLYBDENUM KETJENFINE^R 124-3.P*

Manufacturer	Characteristics	Operating conditions	Remarks
Akzo Chemie B.V. Dpt. Ketjen Catalysts	CONTENT wt % (dry base) CoO 4.0 MoO_3 12.0 SiO_2 1.0 Na_2O 0.06 Fe 0.06 SO_4 2.0 Ignition loss (1 hr at 650°C): 1.5 CARRIER: alumina FORM: cylinders SIZE: Diameter (mm) 3 Length (mm) 3 ABD (g/cm^3) 12 SA (BET) (m^2/g) 225 PV (cm^3/g) 0.50 STRENGTH (kg/cm^2) 5.889	TEMPERATURE RANGE: 300°—360°C PRESSURE RANGE: 20—50 atm SPACE VELOCITY (VHSV): 2.5—5 h^{-1}	Abrasion: 1.5%. Estimated reactor density: 0.60 kg/l. The Ketjenfine 124 series are applied in the petroleum industry for the treatment of naphthas, kerosines, light and heavy gas-oils. Special applications: (1) Desulphurization of naphtha in sandwich type reactor systems for gas reforming; (2) Gas purification; (3) The H-oil process — to reduce the sulphur content in atmospheric residues by hydrogenation.

TYPE OF CATALYST: *COBALT-MOLYBDENUM KETJENFINE^R 124-5P*

Manufacturer	Characteristics	Operating conditions	Remarks
Akzo Chemie B.V. Dpt. Ketjen Catalysts	CONTENT wt % (dry base) CoO 4.0 MoO_3 12 SiO_2 1.0 Na_2O 0.06 Fe 0.06 SO_4 2.0 Ignition loss (1hr at 650°C): 1.5 wet base CARRIER: SiO_2 FORM: cylinders SIZE: Diameter (mm) 5 Length (mm) 5 ABD (g/cm^3) 12 SA (m^2/g) 225 PV (cm^3/g) 0.50 STRENGTH (kg/cm^2) 11,325	TEMPERATURE RANGE: 300°—360°C PRESSURE RANGE: 20—50 atm SPACE VELOCITY (VSHV): 2.5—5 h^{-1}	See Ketjenfine 124-3P Available also as 165-1.5E 16% Mo oxide and Co oxide, on 1.5 mm extrusions; density 0.70 g/cm^3.

TYPE OF CATALYST: *MOLYBDENUM-NICKEL KETJENFINE^R 153.E; 153–1.5E; 153–3E*

Manufacturer	Characteristics	Operating conditions	Remarks
Akzo Chemie B.V. Dpt. Ketjen Catalysts	CONTENT wt % (dry base) MoO_3 15.0 NiO 3.0 SiO_2 1.1 Na_2O 0.07 Fe 0.04 SO_4 2.0 Loss on heating (1 hr at 550°C) wet base 3.0 CARRIER: n.a. FORM: n.a. SIZE: Diameter (mm) 1.5;2.5 Length (mm)4—8;3—7 SA (BET) (m^2/g) 180 PV (cm^3/g) 0.5 STRENGTH (kg/cm^2)11	TEMPERATURE RANGE: 300°—360°C PRESSURE RANGE: 20—50 atm SPACE VELOCITY: (VHSV) 2.5—5 h^{-1}	For removal of nitrogen and polyaromatic compounds from mineral oils. These catalysts are particularly suited for treatment of cracked feedstocks.

TYPE OF CATALYST: *COBALT-MOLYBDENUM-NICKEL KETJENFINE^R 164-1.5R; 164—3E*

Manufacturer	Characteristics	Operating conditions	Remarks
Akzo Chemie B.V. Dpt. Ketjen Catalysts	CONTENT wt % (dry base) MoO_3 16.5 CoO 1.5 NiO 3.0 SiO_2 1.0 Na_2O 0.06 Fe 0.02 SO_4 2.0 Loss on heating (1 hr at 650°C): 2.0% CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 1.5;3 ABD (g/cm^3) 0.7 SA (BET) (m^2/g) 270 PV (cm^3/g) 0.48 STRENGTH (kg/cm^2) (side) 20	TEMPERATURE RANGE: 300°—360°C PRESSURE RANGE: 10—50 atm SPACE VELOCITY: (VSHV) 5.0 h^{-1}	It has an improved activity for sulphur removal, for denitrogenation, carbon-residue-reduction and colour improvement in any process for pretreating or treating gasolines, naphthas, middle distillates and/or distillate gas-oil. Also available as: 168—0.8;1.5E and 3E. 16% Mo oxide and 8% NiO + Co oxide on 1.5 and 3 mm extrusion form; density 0.69 g/cm^3.

HYDRODESULPHURIZATION

TYPE OF CATALYST: *COBALT-MOLYBDENUM COMOX 204*

Manufacturer	Characteristics	Operating conditions	Remarks
Laporte Industries Limited, General Chemical Division, Spence Works	CONTENT wt % on basis of material heated to 550°C CoO 2.9 MoO_3 14.6 SO_3 1.2 SiO_2 1.4 Na_2O+K_2O 0.03 Loss on ignition (550°C) 0.6 CARRIER: alumina FORM: tablets SIZE: Diameter (mm) 2.96 Length (mm) 2.07 SA (m^2/g) 265 STRENGTH (kg/cm^2) 8.1	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Removal of sulphur and nitrogen from naphtha feeds to reforming plants. COMOX may be used as catalyst for the carbon monoxide — hydrogen shift conversion when the gas containing carbon monoxide has a high sulphur and tar content and conventional shift catalysts would be quickly poisoned. In such applications COMOX may be regenerated many times without the loss of activity. COMOX and NIMOX are also used in the production of town gas.

TYPE OF CATALYST: *COBALT -MOLYBDENUM COMOX 224*

Manufacturer	Characteristics	Operating conditions	Remarks
Laporte Industries Limited, General Chemical Division, Spence Works	CONTENT wt % on basis of material heated to 550°C CoO 2.8 NoO_3 15.2 SO_3 1.2 SiO_2 1.5 Na_2O+K_2O 0.05 Loss on ignition (550°C) 2.0 CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 2.96 Length (mm) 2.97 SA (m^2/g) 270 STRENGTH (kg/cm^2) (piece) 26.7	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See COMOX 204 It is used for the removal of sulphur and nitrogen from naphtha feeds to reforming plants.

TYPE OF CATALYST: *COBALT-MOLYBDENUM COMOX 451*

Manufacturer	Characteristics	Operating conditions	Remarks
Laporte Industries Limited, General Chemical Division, Spence Works	CONTENT wt % on basis of material heated to 550°C CoO 3.7 MoO_3 12.8 Na_2O+K_2O 0.06 SiO_2 1.4 SO_3 1.6 Fe 0.03 Loss on calcination (550°C): 2 CARRIER: n.a. FORM: extrusions SIZE: Diameter (mm) 2.5—1.5 Length (mm) 4.69—3.17 ABD (g/cm^3) 0.58—0.60 SA (m^2/g) 300 PV (cm^3/g) 0.66 STRENGTH (kg/cm^2) (piece) 1.50—1.00	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See COMOX 204 Used for the removal of sulphur and nitrogen from naphtha feeds to reforming plants.

TYPE OF CATALYST: *COBALT-MOLYBDENUM COMOX 454*

Manufacturer	Characteristics	Operating conditions	Remarks
Laporte Industries Limited, General Chemical Division, Spence Works	CONTENT wt % on basis of material heated to 550°C CoO 3.6 MoO_3 12.7 SO_3 0.5 SiO_2 1.0 Na_2O+K_2O 0.06 Loss on ignition (550°C): 1.5 CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 2.96 Length (mm) 2,97 ABD (g/cm³) 0.61 SA (m²/g) 290 STRENGTH (kg/cm²) (piece) 5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for the removal of sulphur and nitrogen from naphtha feeds to reforming plants. See also COMOX 204.

TYPE OF CATALYST: *COBALT-MOLYBDENUM COMOX 471*

Manufacturer	Characteristics	Operating conditions	Remarks
Laporte Industries Limited, General Chemical Division, Spence Works	CONTENT wt % on basis of material heated to 550°C CoO 3.7 MoO_3 12.8 Na_2O+K_2O 0.06 SiO_2 1.4 SO_3 2.5 Fe 0.05 Loss on calcination (550°C): 2.0 CARRIER: n.a. FORM: extrusions SIZE: Diameter (mm) 2.5—1.5 Length (mm) 4.32—3.15 ABD (g/cm³) 0.75 SA (m²/g) 272 PV (cm³/g) 0.45 STRENGTH(kg/cm²) 2.05—1.35	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for the removal of sulphur and nitrogen from naphtha feeds to reforming plants. See COMOX 204. Other information for COMOX: Grade / % of CoO / % of MoO_3 / Form / Size (mm) 671 5.0 15.0 extrus. 1.5; 2.5 207 2.5 14.0 tabl. 5.0 210 2.5 14.0 tabl. 7.0 214 2.5 14.0 tabl. 10.0 304 3.5 10.0 tabl. 3.0 504 5.0 25.0 tabl. 3.0 604 5.0 15.0 tabl. 3.0 624 5.0 15.0 tabl. 3.0 724 4.5 11.0 tabl. 3.0

TYPE OF CATALYST: *COBALT-MOLYBDENUM COMOX 1661*

Manufacturer	Characteristics	Operating conditions	Remarks
Laporte Industries Limited, General Chemical Division, Spence Works	CONTENT wt % on basis of material heated to 550°C CoO 5.1 MoO_3 15.3 Na_2O+K_2O 0.06 SiO_2 1.4 SO_3 1.4 Fe 0.05 Loss on calcination (550°C): 2 CARRIER: n.a. FORM: extrusions SIZE: Diameter (mm) 2.5—1.5 Length (mm) 4.69—3.17 ABD (g/cm³) 0.66 SA (m²/g) 300 PV (cm³/g) 0.6 STRENGTH (kg/cm²) 2.0—1.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for the removal of sulphur and nitrogen from naphtha feeds to reforming plants. A catalyst based on Actal IV. For Actal IV, see „Carriers".

TYPE OF CATALYST: *NICKEL-MOLYBDENUM NIMOX 304*

Manufacturer	Characteristics	Operating conditions	Remarks
Laporte Industries Limited, General Chemical Division, Spence Works	CONTENT wt % on basis of material heated to 550°C NiO 3.7 MoO_3 10.3 Na_2O+K_2O 0.03 SO_3 1.2 WO_2 0.42 Loss on calcination (550°C): 0.6 CARRIER: high activity alumina FORM: tablets SIZE: Diameter (mm) 2.96 Length (mm) 2.97 SA (m^2/g) 265 STRENGTH (kg/cm^2) (piece) 8.1	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Removal of sulphur and nitrogen from naphtha feeds to reforming plants.

TYPE OF CATALYST: *NICKEL-MOLYBDENUM NIMOX 351*

Manufacturer	Characteristics	Operating conditions	Remarks
Laporte Industries Limited, General Chemical Division, Spence Works	CONTENT wt % on basis of material heated to 550°C NiO 3.7 MoO_3 10.2 Na_2O+K_2O 0.06 SiO_2 0.4 SO_3 1.8 Fe 0.05 Loss on calcination (550°C) 2.0 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 2.5;1.5 Length (mm) 6.0;4.0 ABD (g/cm^3) 0.59 SA (m^2/g) 280 PV (cm^3/g) 0.70 STRENGTH (kg/cm^2) (piece) 4.30—1.00	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Removal of sulphur and nitrogen from naphtha feeds.

TYPE OF CATALYST: *NICKEL-MOLYBDENUM NIMOX 371*

Manufacturer	Characteristics	Operating conditions	Remarks
Laporte Industries Limited, General Chemical Division, Spence Works	CONTENT wt % on basis of material heated to 550°C NiO 3.7 MoO_3 10.2 Na_2O+K_2O 0.06 SiO_2 0.4 SO_3 3.0 Fe 0.05 Loss on calcination (550°C) 2.0 CARRIER: n.a. FORM: extrusions SIZE: Diameter (mm) 2.5—1.5 Length (mm) 4.32—3,15 ABD (g/cm^3) 0.75 SA (m^2g) 272 PV (cm^3g) 0.45 STRENGTH (kg/cm^2) 2.05—1.35	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The removal of sulphur and nitrogen from naphtha feeds to reforming plants.

TYPE OF CATALYST: *NICKEL-MOLYBDENUM NIMOX 651*

Manufacturer	Characteristics	Operating conditions	Remarks
Laporte Industries Limited, General Chemical Division, Spence Works	CONTENT wt % on basis of material heated to 550°C NiO 5.2 MoO_3 15.3 Na_2O+K_2O 0.06 SiO_2 0.6 SO_3 1.8 Fe 0.05 Loss on calcination: 2.0 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 2.5—1.5 Length (mm) 6.0—4.0 ABD (g/cm³) 0.59 SA (m²/g) 280 PV (cm³/g) 0.70 STRENGTH (kg/cm²) 1.30—1	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The removal of sulphur and nitrogen from naphtha feeds to reforming plants. See COMOX 204. Other information for NIMOX: Nimox NiO MoO_3 Physical form 307 3.5 10.0 tablets (5 mm) 310 3.5 10.0 tablets (5 mm) 671 5.0 15.0 extrusions (1.5—2.5 mm F)

TYPE OF CATALYST: *COBALT-NICKEL-MOLYBDENUM CONIMOX 651*

Manufacturer	Characteristics	Operating conditions	Remarks
Laporte Industries Limited, General Chemical Division, Spence Works	CONTENT wt % CoO 2.7 NiO 2.6 MoO_3 15.4 Na_2O+K_2O 0.06 SiO_2 0.4 SO_3 1.8 Fe 0.05 Loss on calcination (550°C): 2.0 CARRIER: high activity alumina FORM: extrusions SIZE: Diameter (mm) 2.5—1.5 Length (mm) 5.4—3.7 ABD (g/cm³) 0.59—0.61 SA (m²/g) 280 PV (cm³/g) 0.43 STRENGTH (kg/cm²) 1.25—1.00	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for the removal of sulphur and nitrogen from naphtha feeds to reforming plants.

TYPE OF CATALYST: *COBALT-NICKEL-MOLYBDENUM CONIMOX 671*

Manufacturer	Characteristics	Operating conditions	Remarks
Laporte Industries Limited, General Chemical Division, Spence Works	CONTENT wt % on basis of material heated to 550°C CoO 2.7 NiO 2.6 MoO_3 15.4 Na_2O+K_2O 0.06 SiO_2 0.4 SO_3 3.0 Fe 0.05 Loss on calcination (550°C): 2 CARRIER: high activity alumina FORM: extrusions SIZE: Diameter (mm) 2.5—1.5 Length (mm) 5.05—3.55 ABD (g/cm³) 0.75 SA (m²/g) 275 PV (cm³/g) 0.55 STRENGTH (kg/cm²) 2.05—1.35	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for the removal of sulphur and nitrogen from naphtha feeds to reforming plants. Pore volume: 300Å—0.42 cm³/g.

TYPE OF CATALYST: *NICKEL-MOLYBDENUM KONTAKT 8198*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT wt % Nickel-molybdenum oxide CARRIER: alumina FORM: spheres SIZE: Diameter (mm) 3—4 ABD (g/cm³) 0.78—0.92 STRENGTH (kg/particle) 12	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used at mid-pressure.

TYPE OF CATALYST: *COBALT-MOLYBDENUM SPHERICAT 474*

Manufacturer	Characteristics	Operating conditions	Remarks
Nalco	CONTENT n.a. CARRIER: n.a. FORM: spheres SIZE: n.a. ABD (g/cm³) 0.48—0.6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See Nalcomo 474.

TYPE OF CATALYST: *NICKEL-MOLYBDENUM SPHERICAT 502*

Manufacturer	Characteristics	Operating conditions	Remarks
Nalco	CONTENT n.a. CARRIER: n.a. FORM: spheres SIZE: n.a. ABD (g/cm³) 0.4—0.6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See Nalco NM-502. It is used for the hydrotreating (desulphurization and denitrification).

TYPE OF CATALYST: *NICKEL-TUNGSTEN SPHERICAT 550*

Manufacturer	Characteristics	Operating conditions	Remarks
Nalco	CONTENT n.a. CARRIER: n.a. FORM: spheres SIZE: n.a. ABD (g/cm³) 0.4—0.6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See Nalco NT-500.

TYPE OF CATALYST: *NICKEL-MOLYBDENUM NALCO NM-502*

Manufacturer	Characteristics	Operating conditions	Remarks
Nalco	CONTENT wt % NiO 2.8 MoO_3 14.0 CARRIER: alumina FORM: extrusions; spheres SIZE: Diameter (mm) n.a. Length (mm) 3.2—1.5 ABD (g/cm³) 0.68—0.71 SA (m²/g) 270 PV (cm³/g) 0.55 STRENGTH (kg/cm²) 6—8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	This catalyst is recommended for service in hydrotreating units where both desulphurization and denitrogenation are desired. It is also used when nitrogen content of the feedstock must be reduced to a minimum; for saturation of olefins and aromatics too.

TYPE OF CATALYST: *NICKEL-TUNGSTEN NALCO NT-550*

Manufacturer	Characteristics	Operating conditions	Remarks
Nalco	CONTENT wt % WO_3 20.2 NiO 5.1 Alumina difference to 100% CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 2—3 ABD (g/cm³) 0.78—0.80 SA (m²/g) 250 PV (cm³/g) 0.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	This is especially formulated material for difficult service on lube stocks, cycle oils and speciality distillates, with cracking and aromatic saturation capabilities.

TYPE OF CATALYST: *COBALT-MOLYBDENUM-ALUMINA NALCOMO 471*

Manufacturer	Characteristics	Operating conditions	Remarks
Nalco	CONTENT wt % CoO 3.5 MoO_3 12.5 Alumina: by difference to 100% CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) n.a. Length(mm) 3—1.5 ABD (g/cm^3) 0.66—0.68 SA (m^2/g) 295 PV (cm^3/g) 0.55 STRENGTH (kg/cm^2) 6.342—8.152	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is suitable for application in units where feedstocks range from fuel oil to lube oil. It is highly suitable for application in hydrotreating where desulphurization is the prime service.

TYPE OF CATALYST: *COBALT-MOLYBDENUM-ALUMINA NALCOMO 474*

Manufacturer	Characteristics	Operating conditions	Remarks
Nalco	CONTENT wt % CoO 3.5 MoO_3 12.5 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) n.a. Length (mm) 3.175—1.58 ABD (g/cm^3) 0.68—0.70 SA (m^2/g) 280 PV (cm^3/g) 0.58 STRENGTH (kg/cm^2) 6—8	TEMPERATURE RANGE n.a. PRESSURE RANGE: n.a.	This catalyst is outstanding in feedstocks requiring maximum desulphurization, in the presence of elevated nitrogen content.

TYPE OF CATALYST: *COBALT-MOLYBDENUM HR-101*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % MoO_3 13.5 CoO 2.4 Na_2O <0.09 Fe_2O_3 <0.05 Al_2O_3 by difference to 100% Loss on ignition (550°C): <0.5 CARRIER: alumina FORM: balls SIZE: Diameter (mm) 2—4 ABD (g/cm^3) 0.85±0.05 SA (m^2/g) 225±40 PV (cm^3/g) 0.45±0.05 STRENGTH (kg/cm^2) 30	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for the hydrodesulphurization of gasoline, naphthas and kerosenes. Used also for the hydrodenitrification of the same feedstocks.

TYPE OF CATALYST: *COBALT-MOLYBDENUM HR-103*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % MoO_3 13.5 CoO 2.4 Na_2O <0.09 Fe_2O_3 <0.05 Al_2O_3 by diff. to 100% Loss on ignition (550°C): <1 CARRIER: alumina FORM: balls SIZE: Diameter (mm) 2—4; 3—5 Length (mm) n.a. ABD (g/cm^3) 0.70±0.04 SA (m^2/g) 225 ± 25 PV (cm^3/g) 0.58±0.05 STRENGTH (kg/cm^2) 12	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Hydrodesulphurization of gasoline, naphthas, kerosenes, gas-oils. Used also for the hydrodenitrification of gasolines, naphthas, kerosenes, gas-oils.

TYPE OF CATALYST: *COBALT-MOLYBDENUM HR-304*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % MoO_3 12 CoO 2.2 Na_2O 700 ppm Fe_2O_3 400 ppm Al_2O_3 by diff. to 100% Loss on ignition (550°C): 1 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 3; 2 Length (mm) n.a. ABD (g/cm^3) 0.60±0.05 SA (m^2/g) 280±30 PV (cm^3/g) 0.70±0.05 STRENGTH (kg/cm^2) 8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Hydrodesulphurization of gasolines, kerosenes, gas-oils. Used also for the hydrodenitrification of gasolines, naphthas, kerosenes, gas-oils and for the hydrotreatment of heavy feedstocks.

TYPE OF CATALYST: *COBALT-MOLYBDENUM HRF-101*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % CoO 2.4 MoO_3 13.5 Fe_2O_3 <0.5 Al_2O_3 by difference to 100% Loss on ignition (550°C): <1 CARRIER: high purity alumina FORM: beads SIZE: Length (mm) 1.5—2.4 ABD (g/cm^3) 0.9 SA (m^2/g) >250 STRENGTH(kg/cm^2) >30	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used for the hydrodenitrification of gasoline and naphthas. It is recommended for the hydrodesulphurization of gasoline and naphthas.

TYPE OF CATALYST: *Co-Mo-Ni HRF-121*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % MoO_3 12 NiO 2 CoO 2 CARRIER: high purity alumina FORM: balls SIZE: Diameter (mm) 1.25—2.5 ABD (g/cm^3) 0.9 SA (m^2/g) 250 PV (cm^3/g) 0.40 STRENGTH (kg/cm^2) >4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used for hydrodenitrification.

TYPE OF CATALYST: *MOLYBDENUM-NICKEL HR-143*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % MoO_3 >12 NiO >2.2 Na_2O <0.09 Fe_2O_3 <0.05 Al_2O_3 by difference to 100% Loss on ignition (550°C): <1 CARRIER: n.a. FORM: n.a. SIZE n.a. ABD(g/cm^3) 0.74±0.04 SA (m^2/g) 225±25 STRENGTH (kg/cm^2) 10	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Also used for denitrification of benzols, naphthas, kerosenes. It is used for pretreatment of reforming feedstocks and also in steam reforming.

TYPE OF CATALYST: *NICKEL-TUNGSTEN HR-151*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % NiO ⩾ 6.5 WO_3 ⩾ 12.5 Additives 0 Al_2O_3 by difference to 100% CARRIER: high purity alumina FORM: balls SIZE: Diameter (mm) 2—4 ABD (g/cm^3) 0.8 SA (m^2/g) 225 STRENGTH (kg/cm^2) >5	TEMPERATURE RANGE: 180°—300°C PRESSURE RANGE: 40—60 atm approx. SPACE VELOCITY: 1—2 h^{-1}	Used for the hydrotreatment of average distillates, solvent dearomatisation and improvement of kerosenes smoke paint.

TYPE OF CATALYST: *NICKEL-TUNGSTEN HR-153*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % NiO $\geqslant 4$ WO_3 $\geqslant 16$ Additives 0 Al_2O_3 by difference to 100% CARRIER: high purity alumina FORM: balls SIZE: Diameter (mm) 2—4 ABD (g/cm^3) 0.8 SA (m^2/g) 225 PV (cm^3/g) 0.50 STRENGTH (kg/cm^2) >5	TEMPERATURE RANGE: 180°—300°C PRESSURE RANGE: 40—60 atm approx. SPACE VELOCITY: 1—2 h^{-1}	Used for hydrotreatment of average distillates.

TYPE OF CATALYST: *NICKEL-TUNGSTEN HR-155*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % NiO $\geqslant 6.5$ WO_3 $\geqslant 12.5$ Additives 6 Al_2O_3 by difference to 100% CARRIER: high purity alumina FORM: balls SIZE: Diameter (mm) 2—4 ABD (g/cm^3) 0.8 SA (m^2/g) 225 PV (cm^3/g) 0.50 STRENGTH (kg/cm^2) >5	TEMPERATURE RANGE: 180°—300°C PRESSURE RANGE: 40—60 atm approx. SPACE VELOCITY: 1—2 h^{-1}	Hydrotreatment of average distillates. Production of low aromatic compounds, fuels, solvents, special oils from light distillates.

TYPE OF CATALYST: *COBALT-MOLYBDENUM 27048*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Incorporated	CONTENT wt % CoO 3.5 MoO_3 10 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 4 SA (m^2/g) approx. 244	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Other uses: Addition of H_2S to olefins to form mercaptans. Olefin disproportionation; Hydrogenation of naphthalene (sulphide form of the catalyst recommended).

TYPE OF CATALYST: *COBALT-MOLYBDENUM CMK-2*

Manufacturer	Characteristics	Operating conditions	Remarks
Haldor Topsøe	CONTENT wt % Cobalt oxide Molybdenum oxide CARRIER: alumina FORM: spheres SIZE: Diameter (mm) 2—5 Length (mm) n.a. ABD (g/cm^3)0.80—0.85 SA (BET) (m^2/g) 200	TEMPERATURE RANGE: 350°—400°C PRESSURE RANGE: 10—40 atm LIFE: more than 5 years	Hydrodesulphurization of naphtha or natural gas. See NMK-2.

HYDRODESULPHURIZATION OF NAPHTHA AND NATURAL GAS

TYPE OF CATALYST: *NICKEL-MOLYBDENUM NMK-2*

Manufacturer	Characteristics	Operating conditions	Remarks
Haldor Topsøe	CONTENT wt % Nickel oxide Molybdenum oxide CARRIER: alumina FORM: spheres SIZE: Diameter (mm) 2—5 ABD (g/cm^3) 0.80—0.85 SA (BET) (m^2/g) 200	TEMPERATURE RANGE: 350°—400°C PRESSURE RANGE: 10—40 atm LIFE: more than 5 years	It is used for hydrogenation of organic sulphur and nitrogen compounds. A special application is the use of the catalyst for hydrogenation of unsaturated hydrocarbons.

Guards for low temperature CO shift

GUARD FOR LOW TEMPERATURE CO SHIFT

TYPE OF CATALYST: *C-117*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Zinc oxide promoted CARRIER: none FORM: pellets SIZE: Diameter (mm) 4.762 ABD (g/cm^3) 1.12	TEMPERATURE RANGE: 120°—290°C PRESSURE RANGE: 1—40 atm SPACE VELOCITY: 20,000 v/h^{-1}	It is used to protect low temperature shift catalyst from poisoning. C-117-1 is composed of zinc and copper oxides plus a binder. It is used as a combination of sulphur and chloride guard adsorbent. They give protection against sulphur and also against chlorine.

TYPE OF CATALYST: *ZINC OXIDE CDZ-6.B*

Manufacturer	Characteristics	Operating conditions	Remarks
Fertilizer Corporation of India (F.C.I.)	CONTENT wt % CARRIER: n.a. FORM: cylindrical tablets; extrusions; spherical globules SIZE (mm): tablets: 6×6 extrusions: 5×10 globules: 2.5 ABD (g/cm^3) 1.1—1.4	TEMPERATURE RANGE: 190°—270°C PRESSURE RANGE: 35 atm	It is used as a guard catalyst against sulphide and chloride poisoning.

TYPE OF CATALYST :*COPPER-ZINC ICI 52-1.G*

Manufacturer	Characteristics	Operating conditions	Remarks
Imperial Chemical Industries Ltd	CONTENT wt % Copper oxide Zinc oxide CARRIER: alumina FORM: pellets SIZE: Diameter (mm) 5.4 Length (mm) 3.6 ABD (g/cm^3) 0.9	TEMPERATURE RANGE: 180°—250°C PRESSURE RANGE: up to 50 atm.	It is a modified version of the catalyst 52-1, ICI's low temperature shift catalyst. It is normally installed immediately on the top of the bed of catalyst 52-1.

TYPE OF CATALYST: *ICI 59-1*

Manufacturer	Characteristics	Operating conditions	Remarks
Imperial Chemical Industries Ltd.	CONTENT wt % Modified alumina CARRIER: n.a. FORM: pellets SIZE: Diameter (mm) 5.4 Length (mm) 3.6 ABD (g/cm^3) 1.1	TEMPERATURE RANGE: 150°—500°C PRESSURE RANGE: up to 50 atm SPACE VELOCITY: 5,000—20,000 h^{-1}	This is a new catalyst with a high chlorine absorption capacity. It has no activity for the shift reaction and is therefore not recommended for general use. It is recommended in plants with very high chlorine levels as a guard for the low temperature CO shift catalyst.

E. Halogenation (Dehalogenation)

Dehalogenation
Dehydrochlorination

TYPE OF CATALYST: *ALUMINA Al-1101. P*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Al_2O_3 90 (the balance being essentially moisture) CARRIER: n.a. FORM: powder SIZE: n.a. ABD (g/cm^3) 0.9	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *ALUMINIUM-FLUORIDE Al-1101. T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % AlF_3 85 FORM: tablets SIZE: Diameter (mm) 6.35 ABD (g/cm^3) 1.312 STRENGTH (kg/cm^2) 10	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	To add fluorine or HF to olefins.

TYPE OF CATALYST: *CHROMIUM Cr-0304. T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Cr_2O_3 33 CARRIER: silicated alumina FORM: tablets SIZE: Diameter (mm) 3.175 Length (mm) n.a. ABD (g/cm^3) 1.2 SA (m^2/g) 120 PV (cm^3/g) 0.26 STRENGTH (kg/cm^2) 18	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	To add fluorine or HF to olefins.

TYPE OF CATALYST: *SODIUM FLUORIDE Na 022-T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % NaF 99 CARRIER: n.a. FORM: porrous tablets SIZE: Diameter (mm) 3 Length (mm) n.a. ABD (g/cm^3) 1.040 SA (m^2/g) 1 PV (cm^3/g) 0.29 STRENGTH (kg/cm^2) 6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used to add fluorine or HF to olefins. It removes HF from gas streams by absorption.

CHLORINATION OF BENZENE TO PRODUCE CHLOROBENZENE

TYPE OF CATALYST: *COPPER Cu-0804. T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Cu 7.7 CARRIER: activated alumina FORM: tablets SIZE: Diameter (mm) 6.35 Length (mm) n.a. ABD (g/cm^3) 0.9 SA (m^2/g) 100 PV (cm^3/g) 0.36 STRENGTH (kg/cm^2) 8—8.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

CHLORINATION

TYPE OF CATALYST: *COPPER Cu-0905.P*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % $CuCl_2$ 10 CARRIER: activated alumina FORM: powder SIZE: n.a. ABD (g/cm^3) 0.960 SA (m^2/g) 80	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Copper chloride on various supports (Cu-0900 series) are also used to add Cl_2 or HCl to olefins.

TYPE OF CATALYST: *COPPER Cu-0905.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % $CuCl_2$ 10 CARRIER: activated alumina FORM: tablets SIZE: Diameter (mm) 3.175 Length (mm) n.a. ABD (g/cm^3) 0.960 SA (m^2/g) 59 PV (cm^3/g) 0.26 STRENGTH (kg/cm^2) 5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See Cu-0905.P.

TYPE OF CATALYST: *CUPRIC CHLORIDE ST-250*

Manufacturer	Characteristics	Operating conditions	Remarks
Sakaj Chemical Industry Co. Ltd.	CONTENT wt % $CuCl_2/Al_2O_3$ CARRIER: Al_2O_3 FORM: tablets SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Chlorination in vapour phase.

Dehalogenation

DEHALOGENATION

TYPE OF CATALYST: *BARIUM CHLORIDE Ba-0108.E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % $BaCl_2$ 27 CARRIER: carbon FORM: extrusions SIZE: Diameter (mm) 4 Length (mm) 6 ABD (g/cm^3) 0.544	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used to remove hydrogen chloride from chlorine containing hydrocarbons.

DEHYDROHALOGENATION REACTIONS

TYPE OF CATALYST: *RHENIUM 75201; 75204*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Incorporated	CONTENT wt % 75201 Rhenium 0.5 75204 Rhenium 5 CARRIER: alumina FORM: 75201: pellets 75204: powder SIZE: n.a. SA (m^2/g) high	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Also used for dehydrogenation of cyclohexanes to benzenes and reforming catalysts.

Dehydrochlorination

DEHYDROCHLORINATION

TYPE OF CATALYST: *BARIUM CHLORIDE* C-75—1			
Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT n.a. CARRIER: activated carbon FORM: irregular shapes 6—30 mesh SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for dehydrochlorination of linear chlorinated hydrocarbons.

F. Hydrogenation

Amonolysis
Hydrogenation of aromatic hydrocarbons
Hydrogenation of carbonyl compounds
Hydrogenation of carbon double bonds
Hydrogenation of esters and acids
Hydrogenation of functional groups (general)
Hydrogenation of nitriles
Hydrogenation of nitro-compounds
Hydrogenation reactions (general)
Selective hydrogenation
Hydrotreating reactions

Amonolysis

AMINATION OF ALCOHOLS

TYPE OF CATALYST: *COBALT G-61RS; G-62RS*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Cobalt on carrier G-61RS G-62RS Co 67±2 34.5±2 CARRIER: Kieselguhr; alumina (62RS) FORM: tablets(61RS); extrusions(62RS) SIZE: Diameter (mm) 5 Length (mm) 5 ABD (g/cm^3) 1.2±0.08 (tablets) 0.8±0.08 (extrusions) SA (m^2/g) 97;42 STRENGTH (kg/cm^2) 5.4;7	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Reduction of nitriles, carbonyls and aromatics. They are poisoned by CO, sulphur and halide compounds. It is designed for fixed bed operations using liquid, vapour or mixed phase feed. G-62RS is the prereduced and stabilized form of G-62. G-61RS is the prereduced and stabilized form of G-61.

TYPE OF CATALYST: *COBALT G-67; G-67RS*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Zirconium promoted cobalt G-67 G-67RS Co approx. 60 60±2 2.2±0.2 CARRIER: Kieselguhr FORM: tablets; extrusions SIZE: Diameter (mm) 5;5 ABD (g/cm^3) 1.2;1.0 SA (m^2/g) 65 STRENGTH (kg/cm^2) 7;4	TEMPERATURE RANGE: up to 400°C PRESSURE RANGE: n.a. LIFE: estimated to be in excess of one year	See G-61 and G-62. Available in oxide form and in prereduced and stabilized form, designated as G-67RS.

AMONOLYSIS OF ALCOHOLS WITH AMMONIA AND HYDROGEN TO AMINES

TYPE OF CATALYST: *NICKEL Ni-0107 T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni 56 CARRIER: Kieselguhr FORM: tablets SIZE: Diameter (mm) 4 Length (mm) 3 ABD (g/cm^3) 1.44 SA (m^2/g) 130 PV (cm^3/g) 0.18 STRENGTH (kg/cm^2) 4.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Ratio of reduced nickel to total nickel: 0.5.

TYPE OF CATALYST: *NICKEL Ni-0707 T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni 14 CARRIER: high activity alumina FORM: tablets SIZE: Diameter (mm) 3 Length (mm) 3 ABD (g/cm^3) 0.8 SA (m^2/g) 140 PV (cm^3/g) 0.38 STRENGTH (kg/cm^2) 10	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

AMONOLYSIS OF ALCOHOLS TO PRODUCE AMINES

TYPE OF CATALYST: *ALUMINIUM OXIDE — SILICIUM OXIDE KONTAKT 6067*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT wt % Mixed aluminium oxide and silicium oxide FORM: extrusions SIZE: Diameter (mm) 14 Length (mm) 10—20	TEMPERATURE RANGE: 370°—440°C PRESSURE RANGE: 0—200 atm	

AMONOLYSIS OF THE ALDEHYDES AND KETONES

TYPE OF CATALYST: *COBALT RCH/45/20TS; 45/20HS; 45/20PYR*

Manufacturer	Characteristics	Operating conditions	Remarks
Farbwerke Hoechst A.G.	CONTENT wt % RCH 45/20TS: Co 45 RCH 45/20HS: Co 43 RCH 45/20PYR: Co 46 CARRIER: Kieselguhr FORM: tablets; powder SIZE (mm): tablets: 6×5 ABD (g/cm^3) 0.5—1.0	TEMPERATURE RANGE: 100°—300°C PRESSURE RANGE: 40—250 atm	The reduction of nitriles to the respective amines.

Hydrogenation of aromatic hydrocarbons

HYDROGENATION OF BENZENE TO CYCLOHEXANE

TYPE OF CATALYST: *NICKEL CODE 235T*			
Manufacturer	Characteristics	Operating conditions	Remarks
Calsicat Division	CONTENT wt % Ni 40 CARRIER: alumina FORM: tablets SIZE: Diameter (mm) 3;6;4 Length (mm) 3;6;4 ABD (g/cm^3) 0.8 SA (m^2/g) 220 STRENGTH (kg/cm^2) 11 (individual particle)	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It can be used for the selective hydrogenation of aromatics to cycloparaffins.

SATURATION OF POLYAROMATICS

TYPE OF CATALYST: *NICKEL-MOLYBDENUM AERO HDS-3; AERO HDS-3A*			
Manufacturer	Characteristics	Operating conditions	Remarks
Cyanamid International	CONTENT wt% NiO 3—5 MoO_3 14.5—16.0 Na_2O max. 0.04 Fe max. 0.05 CARRIER: n.a. FORM: cylindrical extrusions SIZE: Diameter (mm) 2.5—3.8 ABD (g/cm^3) 0.72—0.8 SA (m^2/g) 200 PV (cm^3/g) 0.6 STRENGTH (kg/cm^2) 5.4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Particularly used for pretreating cat-cracker feedstocks and lube oils. It has selectivity for polyaromatics, olefins and nitrogen removal.

SATURATION OF AROMATICS

TYPE OF CATALYST: *NICKEL-MOLYBDENUM AERO HDS-9*			
Manufacturer	Characteristics	Operating conditions	Remarks
Cyanamid International	CONTENT wt% NiO 3.0—4.0 MoO_3 17.5—18.5 Na_2O 0.04 Fe 0.05 Loss on ignition: 2 CARRIER: n.a. FORM: cylindrical extrusions SIZE: Diameter (mm) 3.175 ABD (g/cm^3) 0.72—0.8 STRENGTH (kg/cm^2) 5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Recommended for processing stocks containing high percentages of nitrogen. For pretreatment of reformer feedstock when quality demands are stringent. For coker effluents. For cat-cracker feed preparation. For turbine fuel smoke-point improvement. For selected lube oil processing situations. For new ventures.

HYDROGENATION OF AROMATICS

TYPE OF CATALYST: *RANEY NICKEL GRADE 28*

Manufacturer	Characteristics	Operating conditions	Remarks
Davison Chemicals Division, W.R Grace and Co.	CONTENT wt% Ni 90 Al 9 Al_2O_3, Cu, Fe, Mg FORM: slurry in water 50% solid and 50% water SIZE: Diameter (mm) 70—40 microns SA (m^2/g) 80—100	TEMPERATURE RANGE: <150°C PRESSURE RANGE: n.a.	Also grade 4200. Used for reductive amination, aromatic hydrogenation, saturation of olefinic bonds, reduction of aldehydes to alcohols. Grade 200 (highly active nickel fine).

HYDROGENATION OF AROMATIC HYDROCARBONS

TYPE OF CATALYST: *Ni—Al ALLOY B-013*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt% Ni 49.5—5 Al_2O_3 max. 1.5 Fe max. 0.75 Al remainder FORM: fine powder SIZE: Diameter (mm) $<75.10^{-3}$ ABD (g/cm^3) 1.8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Application: Hydrogenation of terpenes, phenol and naphthalene.

NUCLEAR HYDROGENATION OF AROMATICS AND HETEROCYCLES

TYPE OF CATALYST: *RHODIUM G-10 S*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt% Rhodium CARRIER: active charcoal FORM: powder	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Precious metal content usually of 0.1, 0.15, 1, 5 and 10 per cent.

HYDROGENATION OF BENZENE AND PHENOL

TYPE OF CATALYST: *NICKEL ACTIMET^R 223*

Manufacturer	Characteristics	Operating conditions	Remarks
Doduco	CONTENT wt% Nickel CARRIER: silicic acid FORM: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *NICKEL ACTIMET^R 225; ACTIMET^R 229*

Manufacturer	Characteristics	Operating conditions	Remarks
Doduco	CONTENT wt% Nickel CARRIER: alumina FORM: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Sulphur resistant catalyst.

HYDROGENATION OF BENZENE TO CYCLOHEXANE OF HIGH PURITY

TYPE OF CATALYST: *PLATINUM SINCLAIR BAKER RD-260*

Manufacturer	Characteristics	Operating conditions	Remarks
Engelhard Minerals and Chemicals Corporation	CONTENT: wt% Pt 0.6 CARRIER: aluminium oxide FORM: extrusions SIZE: Diameter (mm) 1.5 Length (mm) 4.5 Density (g/cm^3) approx. 0.67	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Elaborated by Sinclair Research Inc. and by Baker Co., Newark

HYDROGENATION OF OLEFINS AND AROMATICS

TYPE OF CATALYST: *NICKEL G-87*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt% Ni 40 CARRIER: refractory oxide FORM: extrusions SIZE: Diameter (mm) 3 ABD (g/cm^3) 0.88 SA (m^2/g) 45 STRENGTH (kg/cm^2) 12 (dead weight load)	TEMPERATURE RANGE: 120°—260°C PRESSURE RANGE: 28—35 atm	It is also used for methanation and deoxygenation. It is available in both the oxidized state and the prereduced and stabilized form as G-87 RS.

HYDROGENATION OF BENZENE

TYPE OF CATALYST: *NICKEL Ni-0101.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt% Ni 44 present as hydrate CARRIER: Kieselguhr FORM: tablets SIZE (mm): 3×3×6 ABD (g/cm^3) 1.20—1.26 STRENGTH (kg/cm^2) 5—8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used for methanation.

TYPE OF CATALYST: *NICKEL Ni-0102.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt% Ni 55 (as NiO) CARRIER: Kieselguhr FORM: tablets SIZE: Diameter (mm) 3; 4; 6 Length (mm) 3; 4; 6 ABD (g/cm^3) 1.5—1.6 STRENGTH (kg/cm^2) 4.5—11.3	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for hydrogenation of naphthalene to tetraline or decaline.

TYPE OF CATALYST: *NICKEL Ni-0104.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt% Ni 58 CARRIER: Kieselguhr FORM: tablets SIZE: Diameter (mm) 3 Length (mm) 3 ABD (g/cm^3) 1.44 SA (m^2/g) 155—165 STRENGTH (kg/cm^2) 4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The tableted form of Ni-0104 P. Applications: hydrogenation of C = C and C=0 bonds; hydrogenation of nitrogen compounds; methanation.

TYPE OF CATALYST: *NICKEL Ni-0109.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt% Ni 60 CARRIER: Kieselguhr FORM: tablets SIZE: Diameter (mm) 6 Length (mm) 6 ABD (g/cm^3) 1.29—1.34 STRENGTH (kg/cm^2) 16	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Ratio of reduced nickel to total nickel: 0.75. Used for hydrogenation of naphthalene to tetraline or decaline.

HYDROGENATION OF AROMATIC HYDROCARBONS

TYPE OF CATALYST: *NICKEL Ni-0116.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt% Ni 60 CARRIER: Kieselguhr FORM: tablets SIZE (mm): 3×5×6 ABD (g/cm^3) 1.4—1.6 SA (m^2/g) 155—165 PV (m^3/g) 0.2 STRENGTH (kg/cm^2) 13	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for hydrogenation of naphthalene to tetraline or decaline and of benzene to cyclohexane.

TYPE OF CATALYST: *NICKEL Ni-1404.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt% Ni 68 CARRIER: proprietary FORM: tablets SIZE: Diameter (mm) 3 Length (mm) 3 ABD (g/cm^3) 1.2—1.3 SA (m^2/g) 132 PV (cm^3/g) 0.40 STRENGTH (kg/cm^2) 2—4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Other applications: Hydrogenation of olefins to paraffins; of carbonyl groups in aldehydes and ketones: Amonolysis of alcohols. It is used in fixed bed processes.

TYPE OF CATALYST: *NICKEL Ni-1406.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt% Ni 46 CARRIER: proprietary FORM: tablets SIZE: Diameter (mm) 4 Length (mm) 6 ABD (g/cm^3) 1.28 STRENGTH (kg/cm^2) 18	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for hydrogenation of naphthalene to tetraline or decaline.

SATURATION OF AROMATIC COMFOUNDS

TYPE OF CATALYST: *NICKEL-TUNGSTEN Ni-4301.E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt% Ni 6 W 19 CARRIER: silica-alumina FORM: extrusions SIZE: Diameter (mm) 2 Length (mm) 2 ABD (g/cm^3) 0.96 SA (m^2/g) 228 PV (cm^3/g) 0.37 STRENGTH (kg/cm^2) 6.3 (individual particle)	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The sulphided form of this catalyst is used for hydrogenation where a cracking function is desired. It is aslo used for denitrogenation and desulphurization. The sulphided form is Ni-4401.E.

TYPE OF CATALYST: *NICKEL-TUNGSTEN Ni-4303.E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni 6 W 19 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 2 Length (mm) 2 ABD (g/cm^3) 0.8 SA (m^2/g) 152 PV (cm^3/g) 0.54 STRENGTH (kg/cm^2) 8 (individual particle)	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The sulphided form of this catalyst is used for general hydrogenation. Used in the pretreatment of hydrocracker feedstock, saturation of mono and polycyclic aromatic compounds, denitrogenation and desulphurization. The sulphided form is Ni-4403.E.

TYPE OF CATALYST: *NICKEL-TUNGSTEN Ni-4305.E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni 4.5 W 9.5 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 3 Length (mm) 3 ABD (g/cm^3) 1.024 SA (m^2/g) 184 PV (cm^3/g) 0.53 STRENGTH (kg/cm^2) 7 (individual particle)	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The sulphided form of this catalyst (Ni-4405E) is used where a mildly acidic support is required. It is used for the hydrogenation of jet fuels, saturation of mono and polycyclic aromatic compounds, denitrogenation and desulphurization.

TYPE OF CATALYST: *NICKEL N-111; N-113; N-118*

Manufacturer	Characteristics	Operating conditions	Remarks
W.C.Heraeus GmbH	CONTENT wt % Nickel promotor CARRIER: Kieselguhr FORM: powder; tablets SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Also for methanation.

HYDROGENATION OF PHENOL TO CYCLOHEXANOL

TYPE OF CATALYST: *NICKEL H-1104*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Ni approx. 15 Cu 5 Cr 1 SiO_2 71 Loss on ignition (750°C): 2 CARRIER: SiO_2 FORM: irregular granules SIZE: Diameter (mm) 1—6 ABD (g/cm^3) 0.65 SA (m^2/g) (BET) 220 PV (cm^3/g) 0.7	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used also for the hydrogenation of olefinic and aromatic double bonds as well as of carbonyl groups of cyclic compounds. It may be used in gaseous as well as liquid phase reactions.

HYDROGENATION OF AROMATIC AND OLEFINIC HYDROCARBONS

TYPE OF CATALYST: *NICKEL H-1323*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Ni approx. 12 (as Nickel formate) SiO_2 approx. 65 Loss on drying approx. 3 CARRIER: SiO_2 FORM: extrusions SIZE: Diameter (mm) 4 Length (mm) 6—10 ABD (g/cm^3) 0.6 STRENGTH (kg/cm^2) 340	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The product to be hydrogenated should be free from chloride and sulphur.

HYDROGENATION OF AROMATICS

TYPE OF CATALYST: *NICKEL H-1321*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Ni 10 to 11% (as Ni formate) Cu approx. 3 Cr " 0.2 SiO_2 " 65 Loss on drying $\approx$ 1 CARRIER: SiO_2 FORM: extrusions SIZE: Diameter (mm) 4 Length (mm) 6—10 ABD (g/cm^3) approx. 0.6 STRENGTH (kg/cm^2) 190	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used in gas phase operations and it can be used for the hydrogenation of olefinic hydrocarbons.

TYPE OF CATALYST: *NICKEL LD 143*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % High purity alumina loaded with nickel CARRIER: alumina FORM: balls SIZE: Diameter (mm) 2—4 ABD (g/cm^3) 0.75 STRENGTH (kg/cm^2) 10 (individual particle)	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used for the hydrogenation of unsaturated hydrocarbons; of benzene to cyclohexane; for other hydrogenations like of diolefins and olefins.

HYDROGENATION OF AROMATIC HYDROCARBONS

TYPE OF CATALYST: *RANEY NICKEL 28189; 28192*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Incorporated	CONTENT wt % Raney nickel fine FORM: 50% slurry in water SA (m^2/g) high	TEMPERATURE RANGE: n.a. PRESSURE: RANGE: n.a.	Also used for the ring hydrogenation of anilines and phenols, hydrogenation of simple olefins, hydrogenation of olefins selectively when conjugated with aldehydes and ketones groups. Dehydrogenation (oxidation) of alcohols to aldehydes and ketones. Desulphurization catalyst. 28192 Raney nickel has a high activity.

TYPE OF CATALYST: *NICKEL - TUNGSTEN 28153*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Incorporated	CONTENT wt % NiO 6 WO_3 19 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 2 SA (m^2/g) approx. 150	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used also for hydrocracking of paraffins and cycloparaffins, denitrogenation and desulphurization.

Hydrogenation of carbonyl compounds

HYDROGENATION OF ALDEHYDES

TYPE OF CATALYST: *COPPER CHROMITE CODE 101*

Manufacturer	Characteristics	Operating conditions	Remarks
Calsicat Division	CONTENT wt % CuO 40 Cr_2O_3 41.5 Barium 7.2 (as stabilizer) CARRIER: n.a. FORM: powder SIZE: 90—100% through 325 mesh ABD (g/cm^3) 0.21 (Scott density) SA (m^2/g) 40—50	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Other applications: Hydrogenation of carbonyls, esters, imines. The addition of barium has been found to retard the reduction of the catalyst during use.

TYPE OF CATALYST: *COPPER CHROMITE CODE 102*

Manufacturer	Characteristics	Operating conditions	Remarks
Calsicat Division	CONTENT wt % CuO 44.6 Cr_2O_3 45.2 Barium 7.2 CARRIER: n.a. FORM: powder SIZE: 90—100% through 325 mesh ABD (g/cm^3) 0.21 (Scott density) SA (m^2/g) 20—30	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Other applications: Hydrogenation of carbonyls and esters.

TYPE OF CATALYST: *COPPER CHROMITE CODE 104*

Manufacturer	Characteristics	Operating conditions	Remarks
Calsicat Division	CONTENT wt % CuO: $CuCr_2O_4$ CuO 47 Cr_2O_3 47 CARRIER: n.a. FORM: n.a. SIZE: 90—100% through 325 mesh ABD (g/cm^3) 0.26—0.32 (Scott density) SA (m^2/g) 20—30	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used for the hydrogenation of carbonyls, esters and fatty acids.

HYDROGENATION OF ALDEHYDES AND KETONES

TYPE OF CATALYST: *NICKEL CODE 230 T*

Manufacturer	Characteristics	Operating conditions	Remarks
Calsicat Division	CONTENT wt % Ni 60 CARRIER: alumina FORM: tablets; cylinders SIZE: *tablets cylinders* Diameter (mm) 3;6 5 Length (mm) 3;6 5 ABD (g/cm^3) 1 SA (BET) (m^2/g) 150 PV (cm^3/g) 0.26	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It can be used for fixed bed applications.

HYDROGENATION OF CARBONYL GROUPS

TYPE OF CATALYST: *NICKEL CODE 237 T*

Manufacturer	Characteristics	Operating conditions	Remarks
Calsicat Division	CONTENT wt % Ni 60 CARRIER: proprietary FORM: tablets; cylinders SIZE: *tablets cylinders* Diameter (mm) 3;6 5 Length (mm) 3;6 5 SA (m^2/g) 150 STRENGTH (kg/cm^2) 8.1	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is recommended for fixed bed application, and for hydrogenation where resistance to sulphur contamination is important. It can be used for the hydrogenation of aromatics.

HYDROGENATION OF ALDEHYDES TO ALCOHOLS

TYPE OF CATALYST: *COPPER CHROMIUM C-47*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Copper and chromium oxides CARRIER: silica gel FORM: granules; extrusions SIZE: *granules extrusions* Diameter (mm) 5—9 3.1—4.7	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

HYDROGENATION OF ALDEHYDES (OXO PROCESS)

TYPE OF CATALYST: *COPPER-ZINC OXIDE C-61*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Zinc to copper ratio 2.1 CARRIER: pumice FORM: tablets SIZE: Diameter (mm) 3 Length (mm) 6	TEMPERATURE RANGE: 204°—260°C PRESSURE RANGE: up to 100 atm LIFE: Hydrogenation 3—6 months; Dehydrogenation: 1 year	It is used also for dehydrogenation reactions at 371°—399°C (as C-61-1).

HYDROGENATION OF KETONES

TYPE OF CATALYST: *RUTHENIUM C-56 SERIES*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Ruthenium 0.18—0.5 CARRIER: alumina FORM: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Other uses: hydrogenation of aniline from cyclohexylamine.

HYDROGENATION OF CARBONYL GROUPS

TYPE OF CATALYST: *COPPER CB*

Manufacturer	Characteristics	Operating conditions	Remarks
CIECH Nitroplast	CONTENT wt % Copper CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 10 Length (mm) 4 ABD (g/cm³) 0.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Hydrogenation of butene-2-al to butanol; and of ethylhexane-2-al to 2 ethylhexanol.

TYPE OF CATALYST: *COPPER CH-1*

Manufacturer	Characteristics	Operating conditions	Remarks
Combinatul Chimic Craiova	CONTENT wt % CuO 57 Fe_2O_3 0.2 MgO 0.4 SiO_2 42 CARRIER: diatomite FORM: pellets SIZE: Diameter (mm) 10 Length (mm) 6—10 STRENGTH (kg/cm^2) 4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The hydrogenation of crotonaldehyde to butanol.

HYDROGENATION OF d-GLUCOSE TO SORBITOL

TYPE OF CATALYST: *RANEY NICKEL NICAT S 52*

Manufacturer	Characteristics	Operating conditions	Remarks
Crosfield Chemicals	CONTENT n.a. FORM: n.a.	TEMPERATURE RANGE: 130°C PRESSURE RANGE: 20 atm LIFE: more than 20 hours	

HYDROGENATION OF CARBONYL GROUPS

TYPE OF CATALYST: *RANEY COPPER B-136*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt % Raney copper FORM: powder suspended in water SIZE: Diameter (mm) 50×10^{-3} ABD 0.6 kg Cu per kg of suspension	TEMPERATURE RANGE: 125°—150°C PRESSURE RANGE: n.a.	Other uses: Hydrogenation of nitriles, oximes and nitrocompounds and for the dehydrogenation of primary and secondary alcohols.

TYPE OF CATALYST: *RUTHENIUM H-10 H*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt % Ruthenium CARRIER: active charcoal FORM: powder SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Nuclear hydrogenation at high temperatures and pressures. Precious metal content usually 0.1%, 0.15%, 1%, 5% and 10%.

TYPE OF CATALYST: *PALLADIUM ACTIPAL*^{R}

Manufacturer	Characteristics	Operating conditions	Remarks
Doduco	CONTENT wt % Palladium black FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Hydrogenation of double bonds.

TYPE OF CATALYST: *NICKEL RCH: 52/35 TS; 50/35 TS*

Manufacturer	Characteristics	Operating conditions	Remarks
Farbwerke Hoechst AG	CONTENT wt % RCH 52/35 TS:Ni 52 RCH 50/35 TS:Ni 50 CARRIER: Kieselguhr FORM: powder; tablets SIZE: (mm) 6×5 ABD (g/cm^3) 0.5—1.0	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Other applications: Hydrogenation of the olefins to saturated hydrocarbons; Hydrogenation of phenol to cyclohexanol; Amonolysis of aldehydes and ketones; Hydrogenation of aromatic bonds. The catalysts can be used in gas or liquid phase.

REDUCTION OF OXO-ALDEHYDES TO ALCOHOLS

TYPE OF CATALYST: *COBALT G-103; G-103.R*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Co 40 FORM: G-103 (tablets) G-103.R (powder suspended in liquid) SIZE (mm): 6×6 (tablets)	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	In many respects similar to G-61. Used mainly for the reduction of oxo-aldehydes to the alcohols.

HYDROGENATION OF CARBONYL GROUPS

TYPE OF CATALYST: *COPPER CHROMITE Cu-0202.P*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % CuO 82 Cr_2O_3 17 FORM: powder ABD (g/cm^3) 0.88 SA (m^2/g) 10—13 PV (cm^3/g) 0.55	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used in selective hydrogenation of functional groups, without changing the unsaturation or saturation in aromatic rings or alkyl chains.

TYPE OF CATALYST: *COPPER CHROMITE Cu-0203.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % CuO 78 Cr_2O_3 20 FORM: tablets SIZE: Diameter (mm) 3 Length (mm) n.a. ABD (g/cm^3) 2.16 STRENGTH (kg/cm^2) 9	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	For fixed bed processes, for the hydrogenation of nitro-compounds to amines. Selective hydrogenation. Hydrogenation of functional groups. Catalyst for the second step in oxo processes. It is tableted form of Cu-0202.P.

TYPE OF CATALYST: *COPPER CHROMITE Cu-1107.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % CuO 33 Cr_2O_3 38 BaO 9 FORM: tablets SIZE: Diameter (mm) 3 Length (mm) 3 ABD (g/cm³) 1.8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	For fixed bed processes in the hydrogenation of nitro compounds to amines. It is also used for the dehydrogenation of functional groups and for the hydrogenation of aldehydes (the second step) in oxo-processes.

TYPE OF CATALYST: *COPPER CHROMITE N-201; N-202.D; N-203; N-208*

Manufacturer	Characteristics	Operating conditions	Remarks
W.C.Heraeus GmbH	CONTENT wt % Copper chromite CARRIER: Kieselguhr FORM: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	N-201 contains a promotor. They are used in vapour phase hydrogenation.

TYPE OF CATALYST: *COPPER H-1131*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Copper as active component modified with chromium. Cu (as carbonate) 11.5—12.5 Cr 0.5—0.6 Silica gel 70 Loss on drying: 1 FORM: irregular granules SIZE: Diameter (mm) 1—6 ABD (g/cm³) 0.6 SA (m²/g) 230 PV (cm³/g) 0.7	TEMPERATURE RANGE: 220°C PRESSURE RANGE: n.a.	

HYDROGENATION OF ALDEHYDES TO ALCOHOLS

TYPE OF CATALYST: *COBALT 27042*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % Cobalt metal prereduced and stabilized Co 39 CARRIER: Kieselguhr FORM: pellets SIZE: Diameter (mm) 5 Length (mm) 5 SA (m^2/g) 140	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	For immediate use. Oxo reduction catalyst.

HYDROGENATION OF CARBONYL GROUPS

TYPE OF CATALYST: *COPPER 29065*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % Copper oxide Cu 10—12 CARRIER: alumina FORM: pellets SIZE: Diameter (mm) 5 Length (mm) 3 SA (m^2/g) approx. 187	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

HYDROGENATION OF ALDEHYDES

TYPE OF CATALYST: *COPPER U-5T*

Manufacturer	Characteristics	Operating conditions	Remarks
Unichema Chemie GmbH	CONTENT wt % Cu 35 CARRIER: n.a. FORM: tablets SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The hydrogenation of furfural to furfuryl-alcohol, reduction of aldehydes and ketones, O_2 removal of gases. It is also a low temperature shift catalyst. For the hydrogenation of furfural to furfuryl-alcohol it is also recommended U-5, available as powder and containing ca. 37% Cu.

TYPE OF CATALYST: *NICKEL S-52*

Manufacturer	Characteristics	Operating conditions	Remarks
Unichema Chemie GmbH	CONTENT wt % Ni 95 CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Raney type catalyst used for the hydrogenation of glucose to sorbitol, of dinitrotoluenes to toluene diamines, and the reduction of aldehydes and ketones.

Hydrogenation of carbon double bonds

HYDROGENATION OF UNSATURATED COMPOUNDS

TYPE OF CATALYST: *NICKEL BASF H-1—10*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % Nickel oxide CARRIER: silica FORM: extrusions SIZE: Diameter (mm) 4 ABD (g/cm^3) 0.65	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

HYDROGENATION OF OLEFINIC BONDS

TYPE OF CATALYST: *PALLADIUM CODE 140; 141*

Manufacturer	Characteristics	Operating conditions	Remarks
Calsicat Division	CONTENT wt % 140 141 Palladium 0.2 0.5 CARRIER: granular carbon FORM: powder SIZE: mesh size U. S. screen 4—10 SA (m^2/g) 1,200 ABD (g/cm^3) 0.45	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Other applications: Hydrogenation of complex aldehydes in fixed bed.

HYDROGENATION OF UNSATURATED HYDROCARBONS

TYPE OF CATALYST: *COBALT-MOLYBDENUM C-49*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Cobalt oxide Molybdenum oxide CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 15 or 3 ABD (g/cm^3) 0.64	TEMPERATURE RANGE: 260°—427°C PRESSURE RANGE: 7—42 atm.	Specific applications are pretreatment of light hydrocarbons prior to steam hydrocarbon reforming; saturation of olefins; and organic sulphur conversion.

HYDROGENATION OF DOUBLE BONDS

TYPE OF CATALYST: *MIXED OXIDES HYDRIER KONTAKT 1059*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Chemische Werke Buna	CONTENT wt % Ni min. 6.4 Cu min. 1.6 Cr min. 0.3 Loss on ignition: max. 2 CARRIER: ceramic FORM: balls; extrusions SIZE (mm): *balls* *extrusions* 2—5;5—8 10 ABD (g/cm^3) 0.9—1.1	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Applications: Hydrogenation of aldol to 1.3 butanediol; of acetone to isopropanol; and of toluene to methylcyclohexane. In oxo synthesis processes.

PRESSURE HYDROGENATION OF UNSATURATED COMBINATIONS

TYPE OF CATALYST: *NICKEL NB*

Manufacturer	Characteristics	Operating conditions	Remarks
CIECH Nitroplast	CONTENT wt % NiO 37±2 CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 10 Length (mm) 7 max. ABD (g/cm^3) 0.8—1.1	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

HYDROGENATION IN LIQUID PHASE OF ETHYLENIC BONDS

TYPE OF CATALYST: *NICKEL NICAT NP/AC-60*

Manufacturer	Characteristics	Operating conditions	Remarks
Crosfield Chemicals	CONTENT wt % Ni 62±4 S as (SO_4) less than 5 parts per million CARRIER: pure silica FORM: powder ABD (g/cm^3) 0.54 SA (m^2/g) 200±10 PV (cm^3/g) 0.30±0.05	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Uses: Hydrogenation of ethylenic bonds —C=C— which may be subdivided into: (i) bonds between unsubstituted carbon atoms; (ii) bonds between substituted carbon atoms; (iii) terminal double bonds; (iv) molecules containing several double bonds. Hydrogenation of aromatic and heterocyclic rings; Hydrogenation of acetylenic bonds; Hydrogenation of the groups: $> C = O$ to $> CHOH$; $—C \equiv N$ Hydrogenation of oximes: $CR_2 = N - OH \rightarrow CHR_2NH_2 + H_2O$. Hydrogenation of nitroso compounds to amines and of nitro compounds to amines.

HYDROGENATION OF UNSATURATED COMPOUNDS

TYPE OF CATALYST: *NICKEL NICAT NP/AC-60.P; NC/AC-60.PT*

Manufacturer	Characteristics	Operating conditions	Remarks
Crosfield Chemicals	CONTENT wt % Ni 55 CARRIER: silica FORM: powder; tablets	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	NP/AC—60.P is used for liquid phase hydrogenation of unsaturated organic compounds and also for the reduction of carbonyl, nitrile, nitroso and other functional groups. NP/AC — 60.PT is the tableted form of NP/AC—60.P. It is used for gas phase hydrogenation of compounds similar to those described above.

TYPE OF CATALYST: *NICKEL NICAT NP/K-50.P; NICAT NP/K-50.PT*

Manufacturer	Characteristics	Operating conditions	Remarks
Crosfield Chemicals	CONTENT wt % Ni 50 CARRIER: Kieselguhr FORM: powder; tablets SIZE: Diameter (mm) 3	TEMPERATURE RANGE: 170°—180°C PRESSURE RANGE: 1—3 atm.	NICAT NP/K—50.P is used for the liquid phase hydrogenation of unsaturated organic compounds; powder. NICAT NP/K—50.PT is the tableted form of the first catalyst and it is recommended for gas phase hydrogenation of various unsaturated compounds and many functional groups.

HYDROGENATION OF ETHYLENIC BONDS

TYPE OF CATALYST: *NICKEL NICAT NP/T-502*

Manufacturer	Characteristics	Operating conditions	Remarks
Crosfield Chemicals	CONTENT wt % Ni 52±2 S as (SO_4) less than 5 parts per million CARRIER: pure silica FORM: black tablets SIZE: Diameter (mm) 4.7 Length (mm) 3.9 ABD (g/cm³) 0.96 SA (BET) (m²/g) 200±25	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a	Uses: Hydrogenation of single and multiethylenic bonds; Hydrogenation of aromatic and heterocyclic rings; Hydrogenation of acetylenic bonds; Hydrogenation of the groups $>C=O$ to $>CHOH$; Hydrogenation of the nitrile group: $-C\equiv N$; Hydrogenation of nitro groups to amines.

HYDROGENATION OF UNSATURATED BONDS

TYPE OF CATALYST: *RANEY NICKEL NICAT 101; NICAT 102*

Manufacturer	Characteristics	Operating conditions	Remarks
Crosfield Chemicals	CONTENT wt % Ni min. 85 pH supernated liquor 10.8 Na$_2$O content max. 0.3 FORM: suspension in water	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	NICAT 101 is recommended for hydrogenation of readily reducible groups such as ethylenic and acetylenic linkages as well as desulphurization and dehalogenation. NICAT 102 is recommended when a more specific catalyst is required such as in the hydrogenation of aldehydes, ketones, aromatic nuclei. The catalysts are pyrophoric in the dry state.

HYDROGENATION OF THE CARBON DOUBLE BOND

TYPE OF CATALYST: *RANEY COBALT B-133*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt % Cobalt FORM: powder suspended in water SIZE: Diameter (mm) max. 50×10^{-3} ABD 0.55 kg Co per kg of suspension	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Hydrogenation of benzene; reduction of dinitriles; hydrogenation of cyclohexenyl-acetonitrile; production of dibenzyl ether and toluene from benzyl alcohol; desulphurization of organic compounds. The catalyst also contains Al, Al$_2$O$_3$, Fe, traces of Ni. It is also a dehydrogenation catalyst.

HYDROGENATION OF MULTIPLE BONDS

TYPE OF CATALYST: *RANEY NICKEL B-113; B-114; B-115; B-213; B-313*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt % Raney nickel FORM: powder suspended in water SIZE: Diameter (mm) max. 50×10^{-3} ABD 0.5 kg Ni per kg of suspension	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Reduction of oxygen and nitrogen containing groups; hydrogenation of halogen and sulphur compounds; reductive amination; isomerization e.g. of allyl alcohol to propionic aldehyde; rearrangement e.g. from benzyl aldoxim to benzyl amide. The catalyst also contains Al, Al$_2$O$_3$, Fe and CO in traces. B-113 Z specially for sugar hydrogenations. B-113 CO selective hydrogenation of carbonyl compounds. B-113 Ni catalyst fine B-114 Ni catalyst medium B-115 Ni catalyst coarse B-113 Ni catalyst in tablets is used for reactions in gas and trickling stage.

TYPE OF CATALYST: *PALLADIUM E-10.N; E-10.R*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt % Palladium 5 CARRIER: activated charcoal FORM: powder SIZE: Diameter (mm) 4×10^{-2} ABD (g/cm^3) 0.3 SA (BET) (m^2/g) 700—800 PV (cm^3/g) 0.61	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Reduction of carbonyl compounds, nitro-derivatives and nitriles. Partial hydrogenations are possible in conjugated double bonds, triple bonds. Other palladium contents: 0.5%; 2.5%; 10%. E-10.R is used for the hydrogenation reactions in liquid phase. It is the reduced form of E-10.N.

TYPE OF CATALYST: *PALLADIUM E-20.R; E-22.P*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt % Metal content 0.1, 0.15, 1, 5, 10 CARRIER: gamma alumina FORM: powder; balls SIZE: Diameter (mm) 4—6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Reduction of carbonyl compounds, nitro-derivatives and nitriles. Partial hydrogenations are possible in conjugated double bonds, triple bonds and in many other cases. E-22.P is used for the hydrogenation in gas phase, catalytic combustion of organic substances at low temperatures for air purification (Decatox process).

TYPE OF CATALYST: *PLATINUM F-103.R*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt % Platinum CARRIER: active charcoal FORM: powder	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Reduction of carbonyl compounds, nitro-derivatives and nitriles.

HYDROGENATION OF CARBON MULTIPLE BOND

TYPE OF CATALYST: *NICKEL-ALUMINIUM ALLOY ACTIMET*^{R} *L*

Manufacturer	Characteristics	Operating conditions	Remarks
Doduco	CONTENT wt % Ni 50 Al 50 FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used in the reduction of the carbonyl group to primary or secondary alcohol, hydrogenation of nitriles, imines, oximes, and nitro compounds to amines. Hydrogenation of aromatic and heterocyclic systems.

HYDROGENATION OF CONJUGATED DOUBLE AND TRIPLE BONDS

TYPE OF CATALYST: *PALLADIUM ACTIPAL*^{R} *B*

Manufacturer	Characteristics	Operating conditions	Remarks
Doduco	CONTENT wt % Palladium CARRIER: barium sulphate FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

HYDROGENATION OF OLEFINS AND AROMATICS

TYPE OF CATALYST: *NICKEL G-33; G-52*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % G-33: Ni 32 G-52: Ni 36 Ni as nickel oxide CARRIER: silica-alumina FORM: tablets SIZE: G-33 G-52 Diameter (mm) 6 5 Length (mm) 6 5 ABD (g/cm^3) 0.96 SA (m^2/g) 70 STRENGTH (kg/cm^2) 11	TEMPERATURE RANGE: 120°—260°C PRESSURE RANGE: 24—35 atm.	G-33 is supplied in the oxidized form while G-52 is a prereduced and stabilized version of G-33. Since these Ni catalysts are easily poisoned, the feed stock must either be low in sulphur or desulphurized. They are widely used for production of cyclohexane from benzene, saturation of aromatics and olefins in solvent naphtha streams and for the hydrogenation of a variety of organic compounds. Also used as methanation and deoxygenation catalysts (oxygen removal).

TYPE OF CATALYST: *NICKEL G-49.A; G-49.B*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % G-49A G-49B Ni 60—64 54—60 CARRIER: Kieselguhr FORM: powder; tablets SIZE: Diameter (mm) 5 Length (mm) 3 ABD (g/cm^3) 0.4—0.9; 0.48—0.9 SA (m^2/g) 155; 244	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	G-80 is a modification of G-49.A. Both are recommended as economical replacement for sponge-nickel or noble-metal catalysts.

TYPE OF CATALYST: *NICKEL G-60*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Ni 35±2 Zr 1.5±0.3 Zirconium promoted nickel CARRIER: alumina FORM: tablets SIZE: Diameter (mm) 6 Length (mm) 6 ABD (g/cm^3) 0.96 SA (m^2/g) 60 STRENGTH (kg/cm^2) (DWL) 9	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	In prereduced and stabilized form the catalyst is designated as G-60.RS. Similar in composition and application to G-33. Zirconium promotor enhances the catalytic activity for some applications, particularly at lower temperatures.

TYPE OF CATALYST: *NICKEL G-69*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Zirconium promoted nickel Ni (powder) 52 Zr 2 Ni (tablets) 50 Zr 2 CARRIER: Kieselguhr FORM: powder; tablets SIZE: Diameter (mm) 5 Length (mm) 3 ABD (g/cm^3) 0.48—0.96 SA (m^2/g) 274 (tablets)	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Similar in composition and application to G-49. Available in reduced form G-69.R, with a nominal content of 55% Ni and 2% Zr. G-69.R is available as suspension of reduced powder or reduced tablets in the liquid of your choice. Zirconium improves low temperature activity for some applications.

HYDROGENATION OF METHYL-ACETYLENE AND PROPADIENE

TYPE OF CATALYST: *PALLADIUM G-55.A; G-55.B*			
Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Promoted palladium CARRIER: alumina FORM: G-55.A G-55.B *tablets* *extrusions* SIZE: Diameter (mm) 5 5 Length (mm) 5 — ABD (g/cm^3) 0.88 0.72	TEMPERATURE RANGE: 54°—177°C PRESSURE RANGE: 3—25 atm.	It can be used for adiabatic or isothermal reactors.

HYDROGENATION OF UNSATURATED COMPOUNDS

TYPE OF CATALYST: *PALLADIUM G-63*			
Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt% G-63.A: Pd 0.05 G-63.B: Pd 0.1 G-63.C: Pd 0.3 G-63.D: Pd 0.5 CARRIER: specially formulated refractory oxide FORM: tablets SIZE: Diameter (mm) 6 Length (mm) 6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for the hydrogenation of acetylene and olefins in gas streams, containing mixtures of carbon monoxide and hydrogen. Available as: G-63.A G-63.B G-63.C G-63.D

HYDROGENATION OF DIOLEFINS

TYPE OF CATALYST: *PALLADIUM G-68*			
Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt% Pd 0.5 Cr 0.5 Chrome promoted palladium CARRIER: gamma alumina FORM: tablets SIZE: Diameter (mm) 5 Length (mm) 5 ABD (g/cm^3) 0.88; 0.96 STRENGTH (kg/cm^2) (DWL average) 9—11	TEMPERATURE RANGE: 80°—180°C PRESSURE RANGE: 15—70 atm.	For the first stage hydrogenation of diolefins, in the gasoline boiling range fraction of product distillate, resulting from the pyrolysis of hydrocarbons.

HYDROGENATION OF OLEFINIC BONDS

TYPE OF CATALYST: *PALLADIUM G-74*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt% G-74.A: Pd 0.15 G-74.C: Pd 0.3 G-74.D: Pd 0.5 CARRIER: gamma alumina FORM: tablets SIZE: Diameter (mm) 4.5 Length (mm) 4.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Available as: G-74.A; G-74.C and G-74.D. It is used for removal of small quantities of oxygen from hydrogen containing gas streams. Conversely, G-74 is also recommended for removing trace quantities of hydrogen from oxygen streams.

TYPE OF CATALYST: *PALLADIUM G-75*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt% G-75.A: Pd 0.1 G-75.C: Pd 0.3 G-75.E: Pd 0.5 CARRIER: granular activated carbon FORM: granules SIZE (mm) 4×8 mesh	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Available in the following forms: G-75.A; G-75.C and G-75.E. It is used to remove oxygen from hydrogen streams or oxygen from inert gas streams.

HYDROGENATION OF UNSATURATED COMPOUNDS

TYPE OF CATALYST: *PALLADIUM G-77*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt% G-77.A: Pd 0.05 G-77.B: Pd 0.10 G-77.C: Pd 0.30 G-77.D: Pd 0.50 CARRIER: silica-alumina FORM: extrusions SIZE: Diameter (mm) 5 ABD (g/cm^3) 0.72	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Available as: G-77.A; G-77.B; G-77.C and G-77.D. Suitable especially for hydrogenation of acetylene, diolefins and olefins, in hydrogen stream containing high concentration of CO. It will not promote the methanation reaction. At temperatures below 300°C it will not promote hydrocracking of C_2 and of higher hydrocarbons. It is used for the hydrogenation of acetylenes, diolefins and olefins.

HYDROGENATION OF OLEFINS TO PARAFFINS

TYPE OF CATALYST: *NICKEL Ni-3210.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt% Ni 35 CARRIER: proprietary FORM: tablets SIZE: Diameter (mm) 5 Length (mm) 6 ABD (g/cm^3) 0.88—1.0 SA (m^2/g) 175 PV (cm^3/g) 0.45 STRENGTH (kg/cm^2) 9—20	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Especially applicable for trickle phase beds and aqueous systems. Other applications: hydrogenation of aromatic hydrocarbons and of carbonyl group.

TYPE OF CATALYST: *NICKEL Ni-3250.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt% Ni 50 CARRIER: proprietary FORM: tablets SIZE (mm): 3×5×6 ABD (g/cm^3) 1.05 SA (m^2/g) 150 PV (cm^3/g) 0.34 STRENGTH (kg/cm^2) 8—11	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	A slightly alkaline catalyst. It is also used for the hydrogenation of aromatic hydrocarbons, i.e. benzene to cyclohexane, naphthalene to tetraline; carbonyl group.

HYDROGENATION OF OLEFINS

TYPE OF CATALYST: *NICKEL RCH-55/5.TS; RCH-55/5.HS; RCH-55/5.PYR*

Manufacturer	Characteristics	Operating conditions	Remarks
Farbwerke Hoechst AG	CONTENT wt% RCH-55/5.TS: Ni 55 RCH-55/5.HS: Ni 53 RCH-55/5.PYR: Ni 57 CARRIER: Kieselguhr FORM: tablets; powder SIZE: *tablets* Diameter (mm) 6 Length (mm) 5 ABD (g/cm^3) 0.5—1.0	TEMPERATURE RANGE: 100°—200°C PRESSURE RANGE: 5—50 atm.	Other applications: Amonolysis of alcohols, aldehydes and ketones; Reduction of nitro-groups to respective amines; Hydrogenation of aromatic bonds, in gas or liquid phase; Hydrogenation of fats.

TYPE OF CATALYST: *NICKEL RCH-55/5.FS; RCH-55/10.TS*

Manufacturer	Characteristics	Operating conditions	Remarks
Farbwerke Hoechst AG	CONTENT wt% RCH-55/5.FS: Ni 21 RCH-55/10.TS: Ni 55 CARRIER: Kieselguhr FORM: powder; tablets; extrusions SIZE: Diameter (mm) extrusions: 10 ABD (g/cm^3) powder: 0.4 tablets and extrusions: 0.9	TEMPERATURE RANGE: 50°—200°C PRESSURE RANGE: 1—50 atm.	Other applications: Reduction of nitrogroups to the amines; Partial hydrogenation of unsaturated fats and oils.

TYPE OF CATALYST: *COBALT-MOLYBDENUM H-9410*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt% CoO approx. 3 MoO_2 15 Al_2O_3 80 Loss on ignition (550°C): 2 FORM: extrusions SIZE: Diameter (mm) 2—4 Length (mm) 3—6 ABD (g/cm^3) 0.85 SA (BET) (m^2/g) 330 STRENGTH (kg/cm^2) 44	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used for the removal of sulphur, nitrogen and arsenic impurities from naphtha feedstocks; for the desulphurization of fuel oils and gas oils.

HYDROGENATION OF UNSATURATED ALDEHYDES

TYPE OF CATALYST: *COPPER H-1102*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt% Copper 12 CARRIER: silica gel FORM: granules SIZE: Diameter (mm) 2—5 ABD (g/cm^3) 0.6 SA (m^2/g) 270 PV (cm^3/g) 0.7	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Copper catalyst modified with nickel and chromium.

TYPE OF CATALYST: *NICKEL H-1026*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt% Ni 32—33 Al_2O_3 20—21 ZnO 31—32 SiO_2 approx. 3.5 Graphite 2 FORM: tablets SIZE: Diameter (mm) 6 Length (mm) 6 ABD (g/cm³) 1.05 SA (m²/g) 120—130 PV (cm³/g) 0.4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Available in a reduced and stabilized state, as H-1026 roused for the hydrogenation of olefinic and aromatic hydrocarbons especially benzene and phenol.

TYPE OF CATALYST: *NICKEL H-1031*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt% Ni 45 Al_2O_3 25 SiO_2 12 Graphite 3 Na_2O 0.2 FORM: tablets SIZE: Diameter (mm) 6 Length (mm) 6 ABD (g/cm³) 1 SA (BET) (m²/g) 200—230 PV (cm³/g) 0.4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is suitable for gas phase as well as liquid phase (trickle) process at normal or high pressure.

TYPE OF CATALYST: *NICKEL H-1050.E; H-1050.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt% *H-1050.E* *H-1050.T* Ni approx. 46 approx. 46 SiO_2 approx. 35 approx. 36 Graphite — approx. 2 Loss on ignition (850°C) 6 7 FORM: extrusions; tablets SIZE: *extrusions* *tablets* Diameter (mm) 3 6 Length (mm) 3—6 6 ABD (g/cm³) 1.24 1.05 SA (m²/g) 250 240 PV (cm³/g) 0.3 0.2	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Are suitable for gas phase, as well as liquid phase (trickle) processes at normal and increased pressures. They are used especially for the hydrogenation of benzenes.

HYDROGENATION OF UNSATURATED HYDROCARBONS

TYPE OF CATALYST: *NICKEL H-1057*			
Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt% Ni 31 ZnO 32 SiO_2 27 Loss on ignition (850°C): 2 FORM: extrusions SIZE: Diameter (mm) 6 Length (mm) 4—10 ABD (g/cm^3) 0.85 SA (m^2/g) 110 PV (cm^3/g) 0.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It can be supplied, reduced and stabilized as H-1057.R or unreduced in the calcined state H-1057U. It is used for hydrogenation of halogen compounds containing olefinic and aromatic bonds.

HYDROGENATION OF α – METHYL-STYRENE TO CUMENE

TYPE OF CATALYST: *NICKEL H-1436*			
Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt% Ni 10—11 Al_2O_3 15—86 Loss on ignition (750°C): 1 CARRIER: gamma alumina FORM: extrusions SIZE: Diameter (mm) 4 Length (mm) 3—6 ABD (g/cm^3) 1.0 SA (BET) (m^2/g) 60 PV (cm^3/g) 0.4—0.45	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Average pore diameter: 300Å

HYDROGENATION OF UNSATURATED ORGANIC CARBONYL COMPOUNDS

TYPE OF CATALYST: *PALLADIUM H-1423*			
Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt% Pd 0.5 Al_2O_3 98 Na_2O 0.4 Loss on ignition: 1 FORM: extrusions SIZE: Diameter (mm) 3.2 or 4.0 ABD (g/cm^3) 0.85 SA (m^2/g) 80 PV (cm^3/g) 0.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used for the selective hydrogenation of carbon-carbon triple bond and a variety of hydrogenation processes.

HYDROGENATION OF CROTON ALDEHYDE

TYPE OF CATALYST: *PALLADIUM Pd-C*

Manufacturer	Characteristics	Operating conditions	Remarks
Kawaken Fine Chemicals Co. Ltd.	CONTENT wt% Pd 5 CARRIER: activated charcoal FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Also available for other palladium concentration such as 1%, 2%, 3%, 7% and 10%. Also recommendable for dehydrogenation of diethylamine to pyrolidine and for carbonyl removal of furfurol to furan.

HYDROGENATION OF THE UNSATURATED IMPURITIES IN THE PARAFFIN HYDROCARBONS

TYPE OF CATALYST: *NICKEL-TUNGSTEN KONTAKT 3076*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT wt% Mixed tungsten acid Nickel sulphide CARRIER: n.a. FORM: cylinders and extrusions SIZE: Diameter (mm) 10 Length (mm) 10 ABD (g/cm^3) 2.9±0.3 STRENGTH (kg/cm^2) 170±50	TEMPERATURE RANGE: 300°—320°C PRESSURE RANGE: approx. 200 atm.	

HYDROGENATION OF OLEFINS

TYPE OF CATALYST: *NICKEL 28139*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt% Ni 8 CARRIER: activated carbon FORM: granules SIZE: 4×8 mesh SA (m^2/g) high	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for ring hydrogenation of aromatic hydrocarbons, anilines and phenols. Air sensitive. Pre-reduced and stabilized for immediate use.

TYPE OF CATALYST: *NICKEL 28143*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt% Ni 60 CARRIER: Kieselguhr FORM: powder SA (m^2/g) approx. 100	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Air sensitive. Pre-reduced and stabilized for immediate use. It is also used for ring hydrogenation of aromatic hydrocarbons, anilines and phenols, of nitriles to amines. Dehydrogenation of cyclohexanes to benzenes.

TYPE OF CATALYST: *PALLADIUM 46190*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % Pd 10 CARRIER: activated carbon FORM: powder SA (m^2/g) approx. 1,150	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Also used for: Decarbonylation of formate esters to alcohols; Isomerization of olefins; Hydrogenation of aromatic nitro compounds to aromatic amines.

TYPE OF CATALYST: *PALLADIUM 46197; 46199; 46201; 46202; 46203*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt% 46197: Pd on Ba carbonate 46199: Pd on Ba sulphate 46201: Pd on Ca carbonate unpoisoned 46202: Pd on Ca carbonate, lead poisoned (Lindlar) 46203: Pd on Ca carbonate, lead and sulphur poisoned (Lindlar cat.) FORM: powder SA (m^2/g) high	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Application: Isomerization of olefins; hydrogenation of aromatic ketones to aromatic hydrocarbons; hydrogenation of acetylenes to CIS-ethylenes.

HYDROGENATION OF DIENES TO MONOENES

TYPE OF CATALYST: *PLATINUM 78142*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt% Platinum black FORM: powder SA (m^2/g) approx. 24	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

HYDROGENATION OF SIMPLE OLEFINS

TYPE OF CATALYST: *PLATINUM 78160; 78166*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt% Platinum 5 CARRIER: 78160 78166 activated carbon alumina FORM: powder SA (m^2/g) 1,023; 80—100	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	There are used also for: Dehydrogenation of cyclohexenes and cyclohexanes to benzenes and of cyclohexanols to phenols. Hydrogenation of aldehydes to alcohols.

HYDROGENATION OF OLEFINS

TYPE OF CATALYST: *RHODIUM 45181; 45183; 45186*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % 1) 45181: Rhodium on alumina; 0.5 2) 45183: Rhodium on alumina; 5 3) 45186: Rhodium on carbon 5 FORM: 1) pellets; 2) powder 3) powder SIZE: pellets Diameter (mm) 3 Length (mm) 3 SA (m^2/g) 1) high 2) 80—100 3) aprox. 1,050	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used also for hydrogenation of the aromatic nucleus of aromatic hydrocarbons, aromatic acids and aromatic esters; and for hydrogenation of nitriles to amines, etc.

Hydrogenation of esters and acids

HYDROGENATION OF ESTERS TO ALCOHOLS

TYPE OF CATALYST: *CHROMITE CATALYSTS*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt% Me ‖ O.Me ‖ Cr_2O_4 CARRIER: with or without Al_2O_3, SiO_2 or pumice FORM: powders or tablets SIZE: n.a. ABD (g/cm^3) 0.25—1.2	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The hydrogenation of carbon monoxide, of aldehydes and ketones, of unsaturated hydrocarbons, of heterocycles. Active metal (%) — Chrome content (%) Cu 33—34 29—30 Ni 30—31 27—28 Co 39—40 31—32 Cd 46—47 23—24 Ag 64—65 18—19 Zn 46—47 32—33

PRESSURE HYDROGENATION OF ESTERS

TYPE OF CATALYST: *COPPER CHROMITE ACTIMETR* [17]

Manufacturer	Characteristics	Operating conditions	Remarks
Doduco	CONTENT wt% CuO, Cr_2O_3 CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used also in the pressure hydrogenation of acids, ketones and aldehydes to alcohols.

HYDROGENATION OF OILS, FATS, AND FATTY ACIDS

TYPE OF CATALYST: *NICKEL ACTIMET*^{R} *„F"*

Manufacturer	Characteristics	Operating conditions	Remarks
Doduco	CONTENT wt% Nickel CARRIER: hardened fat FORM: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: ***NICKEL G-15***

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt% Nickel 25 Kieselguhr 10 Protective medium 65 CARRIER: Kieselguhr FORM: flakes	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is composed of electrolytically precipitated nickel, supported on Kieselguhr which has been dry reduced and suspended in a protective medium of hardened edible oil or tallow.

TYPE OF CATALYST: ***NICKEL G-53***

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt% Ni 23 Kieselguhr 13 Protective medium 60 CARRIER: Kieselguhr FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	A modified form of G-15. It is particularly suitable for difficult hydrogenation, such as of tallow, marine oils, fatty acids.

TYPE OF CATALYST: ***NICKEL G-70***

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt% Ni 25 Zr 1 Kieselguhr 14 Protective medium 60 CARRIER: Kieselguhr FORM: flakes	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Demonstrates selectivity for low as well as elevated temperature hydrogenations.

HYDROGENATION OF EDIBLE OILS AND OF FATTY ACIDS

TYPE OF CATALYST: *NICKEL G-111*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt% A nickel sub-sulphide on alumina suspended in a protective medium CARRIER: alumina FORM: suspension in edible oils	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is resistant to sulphur compounds.

TYPE OF CATALYST: *PALLADIUM G-109*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT, wt% Pd 1 Cr 1 CARRIER: alumina FORM: powder; tablets SIZE: *tablets* Diameter (mm) 4.5 Length (mm) 4.5 *powder*: free flowing	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

HYDROGENATION OF FATS: OILS AND FATTY ACIDS

TYPE OF CATALYST: *NICKEL Ni-0109F*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt% Ni 25—30 CARRIER: Kieselguhr FORM: flakes	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Protected by hardened oil.

HYDROGENATION OF FATTY OILS AND FATTY ACIDS

TYPE OF CATALYST: *NICKEL Ni-5000F RUFERT CATALYST*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt% Ni 25 CARRIER: hardened oil FORM: flakes	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also effective for hydrogenation of methyl esters, tall oils, fatty nitrogen compounds.

HYDROGENATION OF FATTY ESTERS TO ALCOHOLS

TYPE OF CATALYST: *COPPER H-1044*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt% Cu 22 $BaCrO_4$ 8 Cr_2O_3 2 Na_2O 0.5 SiO_2 61 Loss on ignition (750°C): 0.5 FORM: extrusions SIZE: Diameter (mm) 4 Length (mm) 4—7 ABD (g/cm^3) 0.6 SA (m^2/g) 180—240 PV (cm^3/g) 0.7 STRENGTH (kg/cm^2) 50	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used also for the dehydrogenation of alcohols at high temperature in the liquid phase. It is a copper catalyst modified by the addition of barium chromate.

HYDROGENATION OF ESTERS, ACIDS AND ALDEHYDES

TYPE OF CATALYST: *COPPER CHROMITE H-1001*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt% Cu 41 Cr 30 Ignition loss (750°C) 5—8 CARRIER: n.a. FORM: powder SIZE: Diameter (mm) 0.5—5 ABD (g/cm^3) 0.45—0.50	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used in the liquid phase under pressure.

HYDROGENATION OF FATTY ACIDS

TYPE OF CATALYST: *NICKEL KE/KTR*

Manufacturer	Characteristics	Operating conditions	Remarks
Königswarter Ebell	CONTENT wt% Ni approx. 19 SiO_2 10—12 Remainder: hard fat FORM: flakes	TEMPERATURE RANGE: max. 200°C PRESSURE RANGE: 2 atm.	

HYDROGENATION OF VEGETABLE FATS

TYPE OF CATALYST: *NICKEL KE/NP*

Manufacturer	Characteristics	Operating conditions	Remarks
Königswarter Ebell	CONTENT wt% Ni 25 (in hardened vegetable fat) FORM: flakes	TEMPERATURE RANGE: 140°—160°C PRESSURE RANGE: 0.5—1 atm.	The peroxide value should be close to zero.

HYDROGENATION OF OILS AND FATS

TYPE OF CATALYST: *NICKEL KE/NT*

Manufacturer	Characteristics	Operating conditions	Remarks
Königswarter Ebell	CONTENT wt% Ni 25 (in hardened tallow fat) FORM: flakes	TEMPERATURE RANGE: 170°—290°C PRESSURE RANGE: <2 atm.	Hydrogenation of oils and fats of vegetable as well as of animal origin.

HYDROGENATION OF FATTY ACIDS

TYPE OF CATALYST: *NICKEL KEITR II*

Manufacturer	Characteristics	Operating conditions	Remarks
Königswarter Ebell	CONTENT wt% Ni about 27 (in hard fat) FORM: flakes	TEMPERATURE RANGE: 120°—200°C PRESSURE RANGE: 5—15 atm.	

TYPE OF CATALYST: *COPPER CHROMITE KONTAKT 1968*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT wt% It contains barium as promotor. The mol ratio of components is: copper : chrome : barium 0.9 1 0.1 CARRIER: n.a. FORM: powder or tablets SIZE: Diameter (mm) 1—10	TEMPERATURE RANGE: 150°—330°C PRESSURE RANGE: 250—350 atm.	

TYPE OF CATALYST: *COPPER CHROMITE C-2*

Manufacturer	Characteristics	Operating conditions	Remarks
Sakaj Chemical Industry Co. Ltd	CONTENT wt% CuO approx. 50 Cr_2O_3 approx. 50 FORM: powder ABD (g/cm^3) 2.5±0.2	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Uses: Hydrogenation of fatty acids, their esters, aldehydes, ketones and furfurol; Manufacture of fatty alcohols; Dehydrogenation in liquid phase.

TYPE OF CATALYST: *COPPER CHROMITE C-3*

Manufacturer	Characteristics	Operating conditions	Remarks
Sakaj Chemical Industry Co. Ltd	CONTENT wt% CuO 46 Cr_2O_3 46 Ba 17 Other promotors FORM: powder ABD (g/cm^3) 2±0.2	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for: Hydrogenation of fatty acids, their esters, aldehydes, ketones, and furfurol; Manufacture of fatty alcohols; Dehydrogenation in liquid phase.

TYPE OF CATALYST: *COPPER CHROMITE C-5*

Manufacturer	Characteristics	Operating conditions	Remarks
Sakaj Chemical Industry Co. Ltd	CONTENT wt% CuO 46 Cr_2O_3 46 Mn 2.7 CARRIER: n.a. FORM: powder ABD (g/cm^3) 1.8±0.2	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Uses: Hydrogenation of fatty acids, their esters, aldehydes, ketones, and furfurol; Manufacture of fatty alcohols; Selective hydrogenation of fatty oils; Dehydrogenation in liquid phase.

HYDROGENATION OF OILS AND FATS

TYPE OF CATALYST: *FLAKE NICKEL CATALYSTS SO-100; SO-110*

Manufacturer	Characteristics	Operating conditions	Remarks
Sakaj Chemical Industry Co. Ltd	CONTENT wt% Ni approx. 18 CARRIER: Kieselguhr FORM: flakes	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	They are produced by dry process reduction of nickel salt mounted on refined Kieselguhr and dispersing in hardened oil and fats. Uses: Manufacture of general hardened oils; Hydrogenation of oil fats and fatty acids; Manufacture of edible hardened oils such as margine hase, shorteningstock. It is good for the hydrogenation under normal pressure.

HYDROGENATION OF FATTY ACIDS

TYPE OF CATALYST: *NICKEL PA; NPA*

Manufacturer	Characteristics	Operating conditions	Remarks
Unichema Chemie GmbH	CONTENT wt% PA: Ni 21 NPA: Ni 55 CARRIER: n.a. FORM: powder	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

HYDROGENATION OF EDIBLE OILS AND FATS

TYPE OF CATALYST: *NICKEL P, PS; COPPER U, U_4*

Manufacturer	Characteristics	Operating conditions	Remarks
Unichema Chemie GmbH	CONTENT wt% Ni ~ 21 Cu ~ 37—42 CARRIER: n.a. FORM: flakes (P;PS) powder (U;U_4)	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

Hydrogenation of functional groups (general)

CATALYTIC REDUCTION OF FUNCTIONAL GROUPS

TYPE OF CATALYST: *PRECIOUS METALS — SUPPORTED CATALYSTS*

Manufacturer	Carrier	Precious metal	Concentration	Remarks
Engelhard Minerals and Chemicals Corp.	Alumina powder	Platinum	5% and 10%	Most powder catalysts are finer than 200 mesh in particle size. When advantageous, powder catalysts can be supplied wet (50% H_2O). The platinum metals may be applied to carriers other than those listed here. The platinum metals may be applied in concentration other than that listed here. Where advantageous, various combinations of platinum metals may be co-supported on certain carriers. Normally available from stock.
	Alumina powder	Palladium	5% and 10%	
	Alumina powder	Rhodium	5%	
	Alumina powder	Ruthenium	5%	
	Carbon powder	Platinum	5% and 10%	
	Carbon powder	Palladium	1%,3%,5%,10%	
	Carbon powder	Rhodium	5%	
	Carbon powder	Ruthenium	5%	
	Calcium carbonate	Palladium	5% and 10%	
	Zinc carbonate	Palladium	5% and 10%	
	Barium sulphate	Palladium	5% and 10%	
	3.17 Alumina pellets	Platinum	0.5%	
	3.17 Alumina pellets	Palladium	0.5%	
	3.17 Alumina pellets	Rhodium	0.5%	
	3.17 Alumina pellets	Ruthenium	0.5%	
	12.7 Mesh carbon	Platinum	0.5% and 1%	
	Asbestos fibre	Platinum	1%,2%,5%,10%	
	Asbestos fibre	Palladium	1%,2%,5%,10%	

REDUCTION OF FUNCTIONAL GROUPS

TYPE OF CATALYST: *PRECIOUS METALS—UNSUPPORTED CATALYSTS*

Manufacturer	Characteristics	Operating conditions	Remarks
Engelhard Minerals and Chemicals Corp.	CONTENT wt % Platinum oxide (Adam's) Palladium oxide Platinum black Palladium black Osmium tetroxide (osmic acid)	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	DB 750 catalyst is also used in catalytic oxidation of ammonia to produce nitric acid. Platinum-rhodium gauze is also used for the production of hydrocyanic acid, an important material in the manufacture of plstics and synthetic fibres.

Gauzes	Wire diameter (mm)	Mesh per cm^2
Pure platinum	0.06	1,024
95% platinum, 5% rhodium	0.06	1,024
90% platinum, 10% rhodium (DB 750)	0.06	1,024
Fine silver	to various	specifications

HYDROGENATION OF FUNCTIONAL GROUPS

TYPE OF CATALYST: *NICKEL G-65*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Ni 27$\pm$2 (tablets) 18$\pm$2 (spheres) CARRIER: alumina FORM: tablets; spheres SIZE (mm) n.a. *tablets spheres* ABD (g/cm^3) 1.04 0.96 SA (m^2/g) 44 123 STRENGTH (kg/cm^2) (DWL) 11.3 TS (°C) 1,200	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Also used for methanation. Used for hydrogenation or hydrogenolysis of functional groups. Available in prereduced and stabilized form designed G-65 RS.

TYPE OF CATALYST: *NICKEL G-78*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Ni 57 CARRIER: special refractory oxide tablets SIZE: Diameter (mm) 6 Length (mm) 6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for hydrogenation or hydrogenolysis of functional groups. Similar to G-65. The prereduced and stabilized form is designated G-78 RS.

HYDROGENATION OF PHENOL TO CYCLOHEXANONE

TYPE OF CATALYST: *NICKEL KONTAKT 6524*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb. Leuna Werke „Walter Ulbricht“	CONTENT wt % Mixed nickel, nickel oxide Ni 45 CARRIER: aluminium oxide FORM: n.a. SIZE: n.a. ABD (g/cm^3) 0.650$\pm$0.06 STRENGTH (kg/cm^2) 150$\pm$50	TEMPERATURE RANGE: 140°—170°C PRESSURE RANGE: approx. 15 atm.	

Hydrogenation of nitriles

HYDROGENATION OF NITRILES

TYPE OF CATALYST: *RANEY COBALT GRADE 27; 27S*

Manufacturer	Characteristics	Operating conditions	Remarks
Davison Chemical Division, W.R. Grace and Co.	CONTENT n.a. FORM: slurry, 50% solid and 50% water	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used in the reduction of fatty nitriles to the corresponding primary amines.

HYDROGENATION OF UNSATURATED NITRILES TO UNSATURATED AMINES

TYPE OF CATALYST: *COPPER CHROMITE Cu-1800.P*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % CuO 51 Cr_2O_3 47 FORM: powder ABD (g/cm^3) 0.65 SA (m^2/g) 37 PV (cm^3/g) 0.76	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Other applications: Reduction of nitro compounds to amines (batch process). Dehydrogenation of alcohols to aldehydes. The unstabilized copper chromite is sometimes preferred for dehydrogenation.

HYDROGENATION OF NITRILES TO AMINES

TYPE OF CATALYST: *COPPER CHROMITE Cu-2000.P*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % CuO 54 Cr_2O_3 41 CARRIER: n.a. FORM: powder ABD (g/cm^3) 0.608 SA (m^2/g) 35 PV (cm^3/g) 1.13	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used for the hydrogenation (batch process) of nitro compounds.

HYDROGENATION OF NITRILES

TYPE OF CATALYST: *RANEY COBALT N-354*

Manufacturer	Characteristics	Operating conditions	Remarks
W.C.Heraeus GmbH	CONTENT wt % Raney Co FORM: powder	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

HYDROGENATION OF NITRILES TO AMINES

TYPE OF CATALYST: *COBALT H-1438*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Co 15 Mn } acti- 4.2 Ag } vators 0.23 CARRIER: Al_2O_3 FORM: spheres SIZE: Diameter (mm) 3—6 ABD (g/cm^3) 0.99	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is supplied in unreduced state as H-1438-U or reduced and stabilized as H-1438-R. The process is carried out in the presence of ammonia and under high pressure.

TYPE OF CATALYST: *COBALT H-1605*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Cobalt activated by manganese and silica Co approx. 27 Mn approx. 6—6.5 Ag approx. 0.33—0.35 Pumice 61—64 CARRIER: pumice FORM: irregular granules SIZE: Diameter (mm) 2—5 ABD (g/cm^3) 0.68—0.78 SA (BET) (m^2/g) approx. 10 PV (cm^3/g) 0.25—0.55	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is supplied either unreduced i.e. in the calcined state H-1605-U, or reduced and stabilized, H-1605-R. It is used by the trickle process carrying out the hydrogenation in the presence of ammonia and under high pressure.

TYPE OF CATALYST: *RANEY COBALT ODH; OF*

Manufacturer	Characteristics	Operating conditions	Remarks
Kawaken Fine Chemicals	CONTENT wt % ODH: Co 50 OF: Co 30 (and is further promoted by 3.5% manganese) FORM: powder SIZE (mm): 200—300 mesh	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	No secondary amine byproduct. The activated types are ODHT and OFT.

TYPE OF CATALYST: *COBALT 27045*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % Cobalt metal 60 zirconium-promoted CARRIER: Kieselguhr FORM: powder SA (m^2/g) 65	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Prereduced and stabilized for immediate use. Air sensitive.

HYDROGENATION OF NITRILES

TYPE OF CATALYST: *NICKEL KONTAKT 6500*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb. Leuna Werke „Walter Ulbricht“	CONTENT wt % Nickel, nickel oxide and silicium oxide Ni 70 FORM: tablets SIZE: Diameter (mm) 5 Length (mm) 5 ABD (g/cm^3) 1.20±0.25 STRENGTH (kg/cm^2) 180±50	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used in gas or fluid phase processes.

HYDROGENATION OF NITRILES AND OXIMES TO AMINES

TYPE OF CATALYST: *RANEY COBALT 27185*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT n.a. FORM: 50% slurry in water SA (m^2/g) high	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Ring hydrogenation of aromatic amines.

HYDROGENATION OF FATTY NITRILES TO FATTY AMINES

TYPE OF CATALYST: *NICKEL NICAT 101; NICAT 102*

Manufacturer	Characteristics	Operating conditions	Remarks
Unichema Chemie GmbH	CONTENT wt % Ni ~ 95 FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Raney type catalysts.

TYPE OF CATALYST: *NICKEL NPN*

Manufacturer	Characteristics	Operating conditions	Remarks
Unichema Chemie GmbH	CONTENT wt % Ni ~ 55 FORM: powder SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

Hydrogenation of nitro-compounds

HYDROGENATION OF AROMATIC NITRO-COMPOUNDS TO AROMATIC AMINES

TYPE OF CATALYST: *COBALT C-51*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Cobalt oxide CARRIER: refractory FORM: extrusions; tablets SIZE (mm): extrusions 3—5 tablets 4—9	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Available as C-51-1 and C-51-2. Mild hydrogenation catalyst used also for reduction of aldehydes (oxoprocess). It is also used for hydrogenation of adiponitrile to hexamethylene diamine.

HYDROGENATION OF NITRO-COMPOUNDS

TYPE OF CATALYST: *COBALT C-59*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Co 5—30 CARRIER: pumice FORM: granules SIZE: 6×10 mesh	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for the conversion of aldehydes to alcohols. C-60 series contains 40—60% cobalt on Kieselguhr.

HYDROGENATION OF DINITROAROMATIC COMPOUNDS

TYPE OF CATALYST: *RANEY COPPER GRADE 29*

Manufacturer	Characteristics	Operating conditions	Remarks
Davison Chemical Division, W.R. Grace and Co.	CONTENT wt % Raney copper CARRIER: n.a. FORM: slurry — 50% solid, 50% water	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Extremely selective for the conversion of a dinitroaromatic compound into an aminonitro-derivate.

HYDROGENATION OF NITRO-COMPOUNDS

TYPE OF CATALYST: *RANEY CHROMIUM — PROMOTED NICKEL RANEY^R 24*

Manufacturer	Characteristics	Operating conditions	Remarks
Davison Chemical Division, W.R. Grace and Co.	CONTENT n.a. FORM: powder SIZE: 70%; 0—40 microns	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is effective in the reduction of carbonyl groups to the corresponding alcohols.

TYPE OF CATALYST: *COBALT Co-1506.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Co 35 CARRIER: rugged proprietary alkaline SIZE: Diameter (mm) 3; 5; 6 Length (mm) 3; 5; 6 ABD (g/cm^3) 1.36—1.5 SA (m^2/g) 85 PV (cm^3/g) 0.24 STRENGTH (kg/cm^2) 8—14	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *COBALT Co-1606.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Co 85 CARRIER: rugged proprietary alkaline FORM: tablets SIZE: Diameter (mm) 5 Length (mm) 5 ABD (g/cm^3) 2.4 SA (m^2/g) 16 PV (cm^3/g) 0.13 STRENGTH(kg/cm^2) 11	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

HYDROGENATION OF NITRO-COMPOUNDS TO AMINES

TYPE OF CATALYST: *COPPER CHROMITE Cu-0402.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % CuO 35 Cr_2O_3 38 BaO 10 CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 3 Length (mm) 3 ABD (g/cm^3) 1.6 STRENGTH (kg/cm^2) 4.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Other applications: Hydrogenation of carbonyl groups; Dehydrogenation of functional groups; Hydrogenation of aldehydes (second step reaction) in oxo process. The powdered form of 0402.T is Cu-0401.P.

TYPE OF CATALYST: *COPPER CHROMITE Cu-1808.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % CuO 42 Cr_2O_3 38 CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 3 Length (mm) 3 ABD (g/cm^3) 1.28 STRENGTH (kg/cm^2) 3.6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Other applications: Hydrogenation of carbonyl groups; Dehydrogenation of aldehydes and ketones; Oxo process catalyst for the second step reaction. It is the tableted form of Cu-1800.P.

HYDROGENATION OF NITRO-COMPOUNDS

TYPE OF CATALYST: *NICKEL Ni-0104.P*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni 58 Ratio of reduced nickel to total nickel: 0.60 : 0.65 CARRIER: Kieselguhr FORM: powder	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Applications: Hydrogenation of nitriles to primary amines; unsaturated alkyl nitriles to unsaturated amines; nitroso-compounds to the corresponding amines; nitro-compounds to monoamines (batch process); fat oils and fatty acids.

REDUCTION OF NITRO-GROUPS

TYPE OF CATALYST: *NICKEL RCH-25/10-HS; RCH-12/10-HS*

Manufacturer	Characteristics	Operating conditions	Remarks
Farbwerke Hoechst AG	CONTENT wt % RCH-25/10-HS Ni 25 RCH-12/10-HS Ni 12 CARRIER: Kieselguhr FORM: tablets; powder SIZE (mm): tablets 6×5 ABD (g/cm^3) 0.5—1.0	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The hydrogenation of aldehydes and ketones to the primary or secondary alcohols.

Hydrogenation reactions (general)

HYDROGENATION REACTIONS

TYPE OF CATALYST: *RANEY NICKEL BASF H-1—50*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % Ni 81.3 SiO_2 0.4 Al_2O_3 11.0 Fe 0.4 CaO 1.1 O_2 1.5 (Probably combinated with Ni and iron) FORM: aqueous suspension with a solid content of about 57% Specific gravity of the suspension: 1.7—1.8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *COPPER BASF H-3—10*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % Copper oxide CARRIER: silica FORM: grains of irregular shape SIZE: Diameter (mm) 3—6 ABD (g/cm³) 0.650	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Other uses: Dehydrogenation of organic compounds.

TYPE OF CATALYST: *NICKEL 203.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Calsicat Division	CONTENT wt % Ni 58 Reduced and stabilized CARRIER: Kieselguhr FORM: tablets SIZE: Diameter (mm) 6; 3 Length (mm) 6; 3 ABD (g/cm³) 1.36 SA (BET) (m²/g) 200 PV (cm³/g) 0.25 STRENGTH (kg/cm²) 5 (individual particle)	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It can be used for fixed hydrogenation of aldehydes and ketones, and aromatic impurities from bulk organic streams. It can be supplied in unreduced form.

TYPE OF CATALYST: ***NICKEL 210.P***

Manufacturer	Characteristics	Operating conditions	Remarks
Calsicat Division	CONTENT wt % Ni 53—58 Reduced and stabilized CARRIER: Kieselguhr FORM: powder SIZE: 90—100% through 325 mesh ABD (g/cm^3) 0.32 SA (m^2/g) 240	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Applications: Hydrogenation of fatty nitrogen compounds is one major area of commercial applications.

TYPE OF CATALYST: ***NICKEL 215.F***

Manufacturer	Characteristics	Operating conditions	Remarks
Calsicat Division	CONTENT wt % Ni 25 Kieselguhr 15 Protective medium 60 CARRIER: Kieselguhr FORM: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The catalyst is suspended in a protective medium of hardened tallow or edible oil. Applications: Hydrogenation of inedible oils, fatty acids, nitriles, esters and other organic compounds.

TYPE OF CATALYST: ***NICKEL 230.P***

Manufacturer	Characteristics	Operating conditions	Remarks
Calsicat Division	CONTENT wt % Ni 58—65 Pre-reduced and stabilized CARRIER: alumina FORM: powder SIZE: 90 × 100% through 325 mesh ABD (g/cm^3) 0.3 SA (m^2/g) 165	TEMPERATURE RANGE: n.a PRESSURE RANGE: n.a.	It is capable of selectivity in the hydrogenation of fats and oils.

A VARIETY OF SLURRY HYDROGENATION

TYPE OF CATALYST: *PALLADIUM CODES 154; 162; 163; 165; 167; 168; 169*

Manufacturer	Characteristics	Operating conditions	Remarks
Calsicat Division	CONTENT wt % Palladium 3—5 Loss on drying (3 hr at 150°C): 50% CARRIER: powdered carbon FORM: n.a. ABD (g/cm³) 0.4 SA (m²/g) 1,100—1,300	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for the hydrogenation of carbon-carbon bonds, nitrogen compounds.

TYPE OF CATALYST: *PLATINUM CODES 131; 132; 135; 137*

Manufacturer	Characteristics	Operating conditions	Remarks
Calsicat Division	CONTENT wt % Pt 1—5 Loss on drying (3 hr at 150°C): 60—70 CARRIER: powdered carbon FORM: n.a. ABD (g/cm³) 0.4 SA (m²/g) 1,000—1,100	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Application: Hydrogenation of carbon-carbon bonds, reductive alkylation.

HYDROGENATION OF SULPHUR FREE PETROLEUM STOCK (AROMATIC CONCENTRATE)

TYPE OF CATALYST: *NICKEL C-46*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Nickel oxide varying in amounts of: NiO 30—59; NiO 22—42 CARRIER: silica-alumina; Kieselguhr FORM: tablets; extrusions SIZE: *tablets extrusions* Diameter (mm) 9.5;6.35 4.753 Length (mm) 6.35; 4.789 ABD (g/cm³) 0.64—0.92	TEMPERATURE RANGE: 65°—230°C PRESSURE RANGE: 4—35 atm. LIFE: one year or more SPACE VELOCITY: (LHSV) 0.5 to 5	Hydrogenation of mesityl oxide to MIBK, aldehyde to alcohols. C-46-4, C-46-5, C-46-6 nickel supported on silica-alumina; C-46-7 nickel on Kieselguhr; C-46-8 nickel on silica; C-46-3 nickel on alumina.

TYPE OF CATALYST: *NICKEL-PLATINUM C-53—1*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % A combination of nickel-platinum CARRIER: alumina FORM: tablets SIZE: Diameter (mm) 6 Length (mm) 6 ABD (g/cm^3) 0.96	TEMPERATURE RANGE: 340°—870°C PRESSURE RANGE: 1—70 atm.	It primarily is used for both nitrogen oxides removal from nitric acid tail gas streams to achieve decolorization and abatement.

TYPE OF CATALYST: *PLATINUM C-52 SERIES*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT n.a. CARRIER: carbon FORM: granules; powder SIZE (mm): granules 4×8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Synthesis of alcohols, amines and nitriles.

TYPE OF CATALYST: *PLATINUM C-53—3; 53—4; 53—5*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Pt 0.2—0.5 CARRIER: alumina FORM: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Operating conditions vary depending upon the individual application.

TYPE OF CATALYST: *COBALT CHEZA CATALYST 42—00*

Manufacturer	Characteristics	Operating conditions	Remarks
Chemical Works of CSF — CHEZA Catalysts	CONTENT A mixture of cobalt compounds with the addition of calcium and sodium compounds. CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 10; 6 Length (mm) 3—5; 4—6 ABD (g/cm^3) 1.5 STRENGTH (kg/cm^2) 150	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for hydrogenation reactions in the organic industry, ex. hydrogenation of aniline.

TYPE OF CATALYST: *Cu-CHROMIC OXIDE C-34/13*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt % Cu-chromic oxide CARRIER: without carrier or with Al_2O_3, SiO_2 or pumice FORM: powder; tablets SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Reduction of carboxylic acids (and derivatives), aldehydes and ketones to alcohols. Reduction of nitrobenzene to aniline. Hydrogenating cleavage of cyclic ethers. Oxidation of CO and hydrocarbons. Usually calls for increased pressures and temperatures.

TYPE OF CATALYST: *RANEY IRON B-139*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt % Raney iron FORM: powder suspended in water SIZE: Diameter (mm) 50×10^{-3} ABD 0.4 kg per kg of suspension	TEMPERATURE RANGE: 100°—133°C PRESSURE RANGE: 50—100 atm.	It can hydrogenate carbonyl, nitril, nitro-groups and acetylenic bonds.

ROSEMUND REACTION

TYPE OF CATALYST: *PALLADIUM E-50.F*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt % Palladium CARRIER: $BaSO_4$ FORM: powder	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Precious metal content usually 0.1%, 0.15%, 1%, 5% and 10%.

HYDROGENATION REACTIONS

TYPE OF CATALYST: *PALLADIUM BLACK*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt % Pd 96.5—98.5 O_2 1.6 H_2O 0.7 CARRIER: none FORM: powder ABD (g/cm^3) 5.6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The hydrogenations under pressure, or without pressure, in suspension. It is used for pharmaceutical synthesis and in analytical chemistry.

TYPE OF CATALYST: *PLATINUM OXIDE $PtO_2.H_2O$*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt % Pt 80—82 CARRIER: n.a. FORM: powder ABD (g/cm^3) 6.8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for mild hydrogenation.

TYPE OF CATALYST: *RANEY NICKEL ACTIMET*^{R}			
Manufacturer	**Characteristics**	**Operating conditions**	**Remarks**
Doduco	CONTENT FORM: aqueous suspension	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

HYDROGENATION OF ALIPHATIC COMPOUNDS

TYPE OF CATALYST: *PALLADIUM CARBONOR*^{R}			
Manufacturer	**Characteristics**	**Operating conditions**	**Remarks**
Doduco	CONTENT wt % Palladium CARRIER: active carbon FORM: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	CARBONOR catalyst is also used for the hydrogenation of alicyclic double and triple compounds, aromatic nitro-compounds, aromatic carbonyl compounds, nitriles, etc.

HYDROGENATION REACTIONS

TYPE OF CATALYST: *PALLADIUM CONTACTOL*^{R}			
Manufacturer	**Characteristics**	**Operating conditions**	**Remarks**
Doduco	CONTENT wt % $PdCl_2$ CARRIER: n.a. FORM: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

HYDROGENATION OF PHARMACEUTICAL PRODUCTS

TYPE OF CATALYST: *PLATINUM* *ACTIPLAT*^{R}*AG*

Manufacturer	Characteristics	Operating conditions	Remarks
Doduco	CONTENT wt % $PtO_2 \times H_2O$ (Adam's catalyst) FORM: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

HYDROGENATION REACTIONS

TYPE OF CATALYST: *PLATINUM* *ACTIPLAT*^{R} *M*

Manufacturer	Characteristics	Operating conditions	Remarks
Doduco	CONTENT wt % Platinum black FORM: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *PLATINUM* *SECOMET*^{R}

Manufacturer	Characteristics	Operating conditions	Remarks
Doduco	CONTENT wt % Platinum CARRIER: active carbon FORM: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

STEREOSPECIFIC HYDROGENATION

TYPE OF CATALYST: *RHODIUM RHODIOR^R*

Manufacturer	Characteristics	Operating conditions	Remarks
Doduco	CONTENT wt % Rhodium CARRIER: alumina FORM: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *RUTHENIUM RUTHENOR^R*

Manufacturer	Characteristics	Operating conditions	Remarks
Doduco	CONTENT wt % Ruthenium CARRIER: alumina FORM: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

HYDROGENATION REACTIONS

TYPE OF CATALYST: *COPPER CHROMITE G-13; G-22; G-22.C; G-89; G-79*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % G-13 G-22 G-22.C G-89 Cu 42 33.5 35 38 Cr 26.5 27.5 30 31 Ba — 11.5 8 — Mn — — — 3 FORM: powder; pellets; tablets SIZE (mm): pellets: 3×4 tablets: 4.5×4.5 powder: 95% passing through a 325 mesh screen.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	G-13 and G-22 are also used for the dehydrogenation. They are recommended for those applications requiring a mild hydrogenation catalyst. In powder form the catalysts are used for slurry operations. In tableted form they are used for fixed bed plants. G-79 is a barium promoted copper chromite catalyst available in powder and pellets form.

TYPE OF CATALYST: *NICKEL G-107*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Ni 25 Kieselguhr 12 Protective medium 66.5 FORM: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is a wet reduced nickel catalyst. Its outstanding characteristics are the extreme selectivity and activity. It is used for all hydrogenation as of soybean, tallow, machine oils and fatty acids.

TYPE OF CATALYST: *RANEY NICKEL G-104*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Nickel FORM: aqueous suspension containing 0.5 kg Ni/l suspension	TEMPERATURE RANGE: 20°—150 °C PRESSURE RANGE: n.a.	

SLURRY TYPE HYDROGENATION

TYPE OF CATALYST: *PALLADIUM G-71; G-81*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % G-71A G-71B G-71C Pd 1 3 5 CARRIER: activated carbon FORM: powder; wet cake ABD (g/cm^3) 0.432	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Mesh size (approximate): % through 100 mesh screen: 95 % through 325 mesh screen: 70 G-81 is similar to G-71. It is used for the hydrogenation of olefinic bonds.

TYPE OF CATALYST: *COBALT Co-0502.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Cobalt 18 (as oxide) CARRIER: activated alumina FORM: tablets SIZE: Diameter (mm) 3 Length (mm) 3 ABD (g/cm^3) 1.23 SA (m^2/g) 49 PV (cm^3/g) 0.38 STRENGTH(kg/cm^2)11	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *COBALT Co-0901.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Co 5 Cu 5 (as oxides) CARRIER: activated alumina FORM: tablets SIZE: Diameter (mm) 3 Length (mm) 3 ABD (g/cm^3) 1.07 SA (m^2/g) 59 PV (cm^3/g) 0.29 STRENGTH (kg/cm^2) 6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for the hydrogenation or decomposition reactions.

TYPE OF CATALYST: *COPPER CHROMITE Cu-1106.P; Cu-1110.P*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Cu=1106.P Cu=1110.P CuO 39 41 Cr_2O^3 43.5 46 BaO 10 9 FORM: powder ABD (g/cm^3) 0.48;0.65 SA (m^2/g) 47; 1 PV (cm^3/g) 0.76;0.92	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See Cu-1800.P and Cu-1402.P

TYPE OF CATALYST: *COPPER CHROMITE Cu-1402.P; Cu-1407.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Cu-1402.P Cu-1407.T CuO 40 37 Cr_2O_3 60 52 FORM: powder; tablets SIZE: Diameter (mm) 3 Length (mm) 3 ABD (g/cm^3) 1.16—1.68 SA (m^2/g) 10 PV (cm^3/g) 0.69	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See Cu-1800.P. Cu-1407.T is tableted form of Cu-1402.P. Copper chromite catalysts are capable of selectivity to hydrogenate or dehydrogenate functional groups in organic compounds without changing the unsaturation or saturation in aromatic rings or alkyl chains.

TYPE OF CATALYST: *IRON Fe-0303.P*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Fe_2O_3 20 CARRIER: high activity alumina FORM: powder ABD (g/cm^3) 1.1 SA (m^2/g) 105 PV (cm^3/g) 0.49	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	A fluid bed microspheroidal hydrogenation catalyst.

TYPE OF CATALYST: *NICKEL Ni-0104.G*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni 60 CARRIER: Kieselguhr FORM: granules ABD (g/cm^3) 1.04 SA (m^2/g) 110 PV (cm^3/g) 0.35	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	A hydrogenation catalyst particularly for trickle bed or liquid phase reactions.

TYPE OF CATALYST: *NICKEL Ni-0122.E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni 28 CARRIER: Kieselguhr FORM: extrusions SIZE: Diameter (mm) 1.6 Length (mm) 1.6 ABD (g/cm^3) 0.72 SA (m^2/g) 168 PV (cm^3/g) 0.53 STRENGTH (kg/cm^2) 4.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a	Ni-0123.F is recommended for the hydrogenation of fats, oils and fatty acids.

TYPE OF CATALYST: *NICKEL Ni-0302.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni 15 (in oxide form) CARRIER: activated alumina FORM: tablets SIZE: Diameter (mm) 3 Length (mm) 3 ABD (g/cm^3) 1.3 SA (m^2/g) 65 PV (cm^3/g) 0.20 STRENGTH (kg/cm^2)8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *NICKEL Ni–0502.F*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni 24 CARRIER: Kieselguhr FORM: flakes ABD (g/cm^3) 0.6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *NICKEL Ni-0704.E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % NiO 18 CARRIER: Kieselguhr FORM: extrusions SIZE: Diameter (mm) 4 Length (mm) 4 ABD (g/cm^3) 0.8 SA (m^2/g) 4 PV (cm^3/g) 0.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

BATCH PROCESS HYDROGENATION

TYPE OF CATALYST: *NICKEL Ni-1000.P*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni 50 Aluminium 50 FORM: powder ABD (g/cm^3) 2.2	TEMPERATURE RANGE: low to moderate PRESSURE RANGE: n.a.	Screen analysis: on 325 mesh 5% min. on 325 mesh 16% average through 325 mesh 84% average.

HYDROGENATION REACTIONS

TYPE OF CATALYST: *NICKEL Ni-1430.E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni 40 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 1.6 Length (mm) 1.6 ABD (g/cm^3) 0.64 SA (m^2/g) 160 PV (cm^3/g) 0.69 STRENGTH (kg/cm^2)4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *NICKEL Ni-1800.G-4-6*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % NiO 10 CuO 1 CARRIER: silica FORM: granules SIZE (mm): 4—6 mesh ABD (g/cm^3) 0.85 SA (m^2/g) 3	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *NICKEL Ni-3001.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni 49 Al 49 FORM: tablets SIZE: Diameter (mm) 5 Length (mm) 5 ABD (g/cm^3) 2.1 STRENGTH (kg/cm^2) 45.3	TEMPERATURE RANGE: low to moderate PRESSURE RANGE: n.a.	For fixed bed reactions.

TYPE OF CATALYST: *NICKEL Ni-3207.T; 3261.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % 3207.T: Ni 28 3261.T: Ni 58 CARRIER: proprietary FORM: tablets SIZE: Diameter (mm) 3 Length (mm) 5 ABD (g/cm^3) 1—1.3 STRENGTH (kg/cm^2) 5—14	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	They must be activated by reduction *in situ*.

TYPE OF CATALYST: ***PALLADIUM Pd-0501; 0505.T; 0509.T***

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Pd 0.3 CARRIER: high activity alumina FORM: tablets ABD (g/cm^3) 0.88 SA (m^2/g) 180—200 PV (cm^3/g) 0.38—0.40 STRENGTH (kg/cm^2) 11—15	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: ***NICKEL N-103; N-122. ARS***

Manufacturer	Characteristics	Operating conditions	Remarks
W.C. Heraeus GmbH	CONTENT wt % Nickel CARRIER: Kieselguhr FORM: powder	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Applications: Hydrogenation of oils, fats, aromatics.

TYPE OF CATALYST: ***RANEY NICKEL N-154; N-155***

Manufacturer	Characteristics	Operating conditions	Remarks
W.C. Heraeus GmbH	CONTENT wt % Raney nickel FORM: powder	TEMPERATURE RANGE: n.a PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *SUPPORTED NOBLE METAL CATALYSTS*

Manufacturer	Carrier / Metal	Activated charcoal	Asbestos	Silica	Alumina	Silicate of alumina	Quartz wool	Sulphate of Ba	Black	Oxide	Colloid
W.C. Heraeus GmbH	Pt	×	×	×	×	×	×	×	×	×	×
	Pd	×	×	×	×	×	×	×	×	×	×
	PdO	×									
	Rh	×		×	×	×				×	
	Ru	×		×	×	×				×	

TYPE OF CATALYST: *UNSUPPORTED CATALYSTS*

Manufacturer	Catalysts		Content	
W.C. Heraeus GmbH	2101	Platinum black (Pt)	Pt	98%
	S 2106	Platinum oxide (Adams'catalyst) ($PtO_2 . H_2O$)	Pt	80%
		Colloidal Platinum		
		Spongeous Platinum		
	2201	Palladium black (Pd)	Pd	98%
	3204	Palladium (II) oxide ($PdO . H_2O$)	Pd	85—87%
	S 2202	Palladium (II) chloride ($PdCl_2$)	Pd	60%
		Colloidal Palladium		
		Spongeous Palladium		
	4406	Rhodium (III) oxide (Rh_2O_2)	Rh	81.1%
	6502	Osmium (VIII) oxide (OsO_4)	Os	74.8%
	4503	Kalium osmate (VI) ($K_2(OsO_4) . 2H_2O$)	Os	51.6%
	4604	Ruthenium (IV) oxide (RuO_2)	Ru	76%
	3605	Ruthenium (IV) oxihydrate ($RuO_2 . H_2O$)	Ru	64%

TYPE OF CATALYST: *NICKEL H-1207*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Ni 8 CARRIER: silica FORM: irregular granules SIZE: Diameter (mm) 4—7 ABD (g/cm^3) 1.0	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for *in situ* reduction.

TYPE OF CATALYST: *NICKEL H-1328*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Ni 8 Nickel catalyst modified by Cu and Cr CARRIER: silicic acid FORM: extrusions SIZE: Diameter (mm) 6 ABD (g/cm^3) 0.6 SA (m^2/g) 120 PV (cm^3/g) 0.8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Available also in a reduced and stabilized form as H-1328 R.

TYPE OF CATALYST: *NICKEL HSC$^{T.M.}$-102*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % NiO 42 CARRIER: alumina FORM: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *PALLADIUM H-1799*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Pd up to 10 CARRIER: activated charcoal FORM: powder; extrusions SIZE: *powder extrusions* Diameter (mm) 2 Length (mm) 5 ABD g/cm^3) 0.30 0.40—0.60 SA (m^2/g) 500—800 600—900	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Especially used in noble metal hydrogenation where a large internal surface area is desirable. For batch operations the catalyst is used as a powder, whereas in continuous gas phase or trickle processes extrusions are preferred.

TYPE OF CATALYST: *NICKEL ICI-18 SERIES*

Manufacturer	Characteristics	Operating conditions	Remarks
Imperial Chemical Industries Ltd	CONTENT wt % Nickel oxide CARRIER: Kieselguhr FORM: pellets; powder SIZE: *pellets* Diameter (mm) 5.4 Length (mm) 3.6 ABD (g/cm^3) 1.2	TEMPERATURE RANGE: 150°—400°C PRESSURE RANGE: n.a.	They are recommended for powerful hydrogenations. Available as: 18—4 pellets and 18—9 powder. They are originally developed for the vapour phase hydrogenation of di-isobutene to iso-octane. Now they are used in a variety of reactions where total hydrogenation is required including saturation of aromatic nuclei, alcohol purification and methanation of carbon oxides.

TYPE OF CATALYST: *COPPER OXIDE/ZINC OXIDE ICI-29 SERIES*

Manufacturer	Characteristics	Operating conditions	Remarks
Imperial Chemical Industries Ltd	CONTENT wt % Copper oxide Zinc oxide CARRIER: n.a. FORM: pellets; powder SIZE: *pellets* Diameter (mm) 5.4 Length (mm) 3.6 ABD (g/cm^3) 1.9	TEMPERATURE RANGE: 250°—400°C PRESSURE RANGE: 1—100 atm.	They are used for mild hydrogenation — dehydrogenation reactions. Available as: ICI-29-2 pellets; 29—9 powder. They can also be used for the purification of gases especially for the removal of traces of oxygen and/or hydrogen and sulphur.

TYPE OF CATALYST: *NICKEL ICI-42 SERIES*

Manufacturer	Characteristics	Operating conditions	Remarks
Imperial Chemical Industries Ltd	CONTENT wt % Promoted nickel oxide CARRIER: Kieselguhr. FORM: pellets; powder SIZE: *pellets* Diameter (mm) 3—5.4 Length (mm) 3—3.6 ABD (g/cm^3) 1.2	TEMPERATURE RANGE: 150°—200°C PRESSURE RANGE: n.a.	They are recommended for powerful hydrogenations. Available a. · 42—1 pellets; 42—3 pellets; 42—9 powder. They are tolerant to traces of sulphur and CO but are slowly affected by both these poisons.

TYPE OF CATALYST: *JMC UNSUPPORTED CATALYSTS*

Manufacturer	Catalyst	Remarks
Johnson Matthey Chemicals Ltd	Adams' platinum oxide $PtO_2.H_2O$ Palladium oxide catalyst $PdO.H_2O$ Ruthenium oxide catalyst Iridium oxide catalyst Rhodium oxide catalyst Ruthenium-platinum mixed oxide Ruthenium-palladium mixed oxide Rhodium-palladium mixed oxide Platinum black Palladium black	Of all chemical reactions, hydrogenation is most commonly catalysed by platinum metal catalysts. Pd, Pt and Rh are extremely efficient catalysts for the hydrogenation of olefinic and acetylenic groups, but Ru and Ir catalysts are less active. Pt, Rh and Pd are good catalysts for certain oxidation reactions, dehydrogenation and hydrogen transfer reactions. Mixed oxides on reduction are often more active than either component oxide by itself.

TYPE OF CATALYST: *JMC SUPPORTED CATALYSTS*
I. *JMC STANDARD GRANULAR PELLETED AND RELATED CATALYSTS*

Manufacturer	Metal	Carrier	Form	Size	Remarks
Johnson Matthey Chemicals Ltd	Platinum	alumina	pellets	3.2 mm	Of all chemical reactions hydrogenation is most commonly catalysed by platinum metal catalysts. Pd, Pt and Rh are extremely efficient catalysts for the hydrogenation of olefinic and acetylenic groups, but Ru and Ir catalysts are less active. Pt, Rh and Pd are good catalysts for certain oxidation reactions, dehydrogenation and hydrogen transfer reactions. Mixed oxides on reduction are often more active than either component oxide by itself.
	Palladium	alumina	pellets	4.7 mm	
	Rhodium	alumina	pellets	6.4 mm	
	Ruthenium	alumina	granules	8—16 mesh	
	Ruthenium-palladium	alumina	—	—	
	Platinum	charcoal	granules	1—3 mm	
	Palladium	charcoal	granules	3—5 mm	
	Ruthenium	charcoal	granules	4—8 mesh	
	Platinum	asbestos	—	—	
	Palladium	asbestos	—	—	

TYPE OF CATALYST: II. *JMC SUPPORTED CATALYSTS*
JMC STANDARD POWDERED CATALYSTS

Manufacturer	Metal	Carrier	Remarks
Johnson Matthey Chemicals Ltd	Palladium[a,c]	charcoal	See JMC (I)
	Platinum[a]	charcoal	
	Ruthenium[a,b]	charcoal	
	Rhodium	charcoal	
	Palladium[b]	alumina	
	Platinum[b]	alumina	
	Ruthenium[b]	alumina	
	Rhodium[b]	alumina	
	Iridium[b]	alumina	
	Palladium	calcium carbonate	
	Iridium	calcium carbonate	
	Palladium	barium sulphate	

a) Available as dry powder or as a paste containing about 55% by weight of water.
b) Supplied in oxide form.
c) Also available unreduced.

HYDROGENATION REACTIONS

TYPE OF CATALYST: *RANEY NICKEL A 40*

Manufacturer	Characteristics	Operating conditions	Remarks
Kawaken Fine Chemicals Co. Ltd	CONTENT wt % Activated and packed in oil or wax. It is a porous catalyst having the same composition as ND. FORM: granules or flakes	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is suitable for difficult hydrogenations such as of tallows, marine oil, fatty acids. It is supplied in the state of oil or wax packed form.

TYPE OF CATALYST: *RANEY NICKEL ND*

Manufacturer	Characteristics	Operating conditions	Remarks
Kawaken Fine Chemicals Co. Ltd	CONTENT wt % Ni 40 Al 60 FORM: powder SIZE: 200—300 mesh	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for a wide range of hydrogenation: e.g. glucose to sorbitol, phenol to cyclohexanol, butylaldehyde to octanol, acetone to methylisobutyl-ketone. Activated type: NDT.

TYPE OF CATALYST: *RANEY NICKEL NDH*

Manufacturer	Characteristics	Operating conditions	Remarks
Kawaken Fine Chemicals Co. Ltd	CONTENT wt % Ni 50 Al 50 FORM: powder SIZE: 200—300 mesh	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The activated type is NDHT. It shows an anti-poisonous effect.

TYPE OF CATALYST: *RANEY NICKEL NP*

Manufacturer	Characteristics	Operating conditions	Remarks
Kawaken Fine Chemicals Co. Ltd	CONTENT A bit of poisonous lead metal besides 45% nickel FORM: powder SIZE:200—300 mesh	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used for dehalogenized hydrogenation. The activated type is NPT.

TYPE OF CATALYST: *RANEY NICKEL PL*

Manufacturer	Characteristics	Operating conditions	Remarks
Kawaken Fine Chemicals Co. Ltd	CONTENT wt % Ni 30 Fe 4 (as promotor) FORM: powder SIZE: 200—300 mesh	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The activated type is PLT. Rather recommendable in some cases such as for ketone acid to aminoacid, malonate to succinate and l-menthon to l-menthol reduction. Its uses are almost similar to ND catalyst.

TYPE OF CATALYST: *ADAMS' PLATINUM CATALYST*

Manufacturer	Characteristics	Operating conditions	Remarks
Kawaken Fine Chemicals Co. Ltd	CONTENT wt % PtO_2 FORM: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	For complex organic synthesis. Hydrogenation of all pyridine salts, streptomycine sulphate, succinic anhydride derivatives. Hydroisomerization of cis-stylbenes. Hydrogenolysis of unsaturated alcohols.

TYPE OF CATALYST: *NICKEL-ALUMINIUM PX*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Raney alloy CARRIER: special FORM: powder SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *NICKEL CHX-3*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT n.a. CARRIER: activated charcoal FORM: extrusions SIZE: Diameter (mm) 3	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used in gaseous phase and fixed bed.

TYPE OF CATALYST: *NICKEL LD-742*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Nickel CARRIER: SiO_2 FORM: extrusions SIZE: Diameter (mm) 4—6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for the hydrogenation of benzene to cyclohexane and general hydrogenation reactions in liquid phase.

SPECIFIC HYDROGENATION IN THE LIQUID PHASE

TYPE OF CATALYST: *NICKEL Ni–PS-2*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Ni >65 Loss on ignition: 5 CARRIER: special FORM: powder ABD (g/cm^3) 2.4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a. LIFE: several months	Average particle size: microns — % <20 — 5–20 20–100 — 50–65 100–315 — 25–35 >315 — 0–5 It can be used for hydrogenations generally done with Raney nickel, in hydrogenation of benzene into cyclohexane. Make up gas should not contain any H_2S or CO.

HYDROGENATION REACTIONS

TYPE OF CATALYST: *COPPER CHROMITE ST-202; ST-203; ST-205*

Manufacturer	Characteristics	Operating conditions	Remarks
Sakaj Chemical Industry Co. Ltd	CONTENT wt% Copper chromite Promotors: barium or manganese FORM: tablets SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Other uses: Dehydrogenation in vapour phase. Oxidation in vapour phase.

TYPE OF CATALYST: *NICKEL SN-100; SN-110*

Manufacturer	Characteristics	Operating conditions	Remarks
Sakaj Chemical Industry Co. Ltd	CONTENT wt % Ni 50 SN-100 contains a small amount of metal oxides (Cu, Al, Cr) as promotors. CARRIER: Kieselguhr FORM: powder SIZE: All through 150 mm mesh ABD (g/cm^3)2.7±0.2	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Uses in liquid phase: Hydrogenation of carbon to carbon double bonds. Full hardening and partial hydrogenation of oil and fats. Reduction of aldehydes and ketones. Hydrogenation of other organic compounds in liquid phase.

TYPE OF CATALYST: *NICKEL ST-101; ST-111*

Manufacturer	Characteristics	Operating conditions	Remarks
Sakaj Chemical Industry Co. Ltd	CONTENT wt % Ni 50 ST-101 contains a small amount of metal oxides (Cu, Al, Cr) as promotors. CARRIER: Kieselguhr FORM: tablets	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Uses in vapour phase. Full hardening and partial hydrogenation of oil and fats. Hydrogenation of aromatic rings. Hydrogenation of carbon to carbon double bonds. Reduction of aldehydes and ketones. Hydrogenation of other organic compounds in liquid phase.

TYPE OF CATALYST: *RANEY IRON 26375*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % Fe 50 Al 50 FORM: powder SA (m^2/g) high	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used as an alternative to Raney nickel and Raney cobalt.

HYDROGENATION – DEHYDROGENATION REACTIONS

TYPE OF CATALYST: *PLATINUM 78161; 78164; 78177*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT 78161: Pt 10% on activated carbon: 78164: Pt 0.5% on alumina; 78177: Pt 0.3% on gamma alumina coated on Dupont Torvex ceramic honeycomb. FORM: powder; pellets; discs SIZE: *pellets* Diameter (mm) 3 Length (mm) 3 SA (m^2/g) 78161: 2 78164: high 78177: 240	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Hydrochlorination catalyst. Hydrogenation of aliphatic aldehydes to alcohols.

TYPE OF CATALYST: *RUTHENIUM 44388; 44391; 44400; 44404*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % 44388: Ru 0.5% on alumina; 44391: Ru 5% on alumina; 44400: Ru 0.5% on carbon; 44404: Ru 5% on carbon FORM: pellets; powder; granules; powder SA (m^2/g) 44391: 80—100 44404: 1,150	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Hydrogenation of aliphatic aldehydes and ketones to alcohols in aqueous solution. Selective hydrogenation reactions. Oxidation reactions. Ring hydrogenation of aromatic esters, phenols and anilines. Hydrogenation of aromatic nucleus of aromatic amines.

TYPE OF CATALYST: *NICKEL NP; NPN; NPNT*

Manufacturer	Characteristics	Operating conditions	Remarks
Unichema Chemie GmbH	CONTENT wt % Ni 53—55	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	NP, NPN are available as powders; NPNT as tablets. NP and NPN are also used for hydrogenation of dinitrotoluenes to toluenediamines and of nitrobenzene to aniline. NPNT is also used for the hydrogenation of nitrobenzene to aniline, for the reduction of aldehydes and ketones and for methanation.

TYPE OF CATALYST: *PALLADIUM SK-300*

Manufacturer	Characteristics	Operating conditions	Remarks
Union Carbide Corp. Linde Molecular Sieve Catalysts	CONTENT wt % (anhydrous base) SiO_2 64.4±0.5 Al_2O_3 21.8±0.5 Na_2O 13.3±0.5 Cl^- <0.05 Fe^- <0.05 Pd 0.5±0.2 FORM: tablets SIZE: Diameter (mm) 4 Length (mm) 4 ABD (g/cm^3) 0.65 SA (m^2/g) >500	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is a molecular sieve type Y.

TYPE OF CATALYST: *PALLADIUM SK-310*

Manufacturer	Characteristics	Operating conditions	Remarks
Union Carbide Corp. Linde Molecular Sieve Catalysts	CONTENT wt % (anhydrous base) SiO_2 56.6±0.5 Al_2O_3 22.2±0.5 Na_2O 1.8±0.2 CaO 10.3±0.3 Cl^- <0.05 Fe^- <0.05 Pd 0.5±0.02 FORM: tablets SIZE: Diameter (mm) 4 Length (mm) 4 ABD (g/cm^3) 0.65 SA (m^2/g) >500	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is a calcium exchanged type Y.

Selective hydrogenation

SELECTIVE HYDROGENATION OF UNSATURATED COMPOUNDS

TYPE OF CATALYST: *PALLADIUM BASF H-0–10*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % Palladium CARRIER: special FORM: grains SIZE: Diameter (mm) 4 Length (mm) 5 ABD (g/cm^3) 0.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for selective hydrogenation of unsaturated compounds, e.g. acetylene in ethylene streams.

SELECTIVE HYDROGENATION

TYPE OF CATALYST: *NICKEL CODE 232.F*

Manufacturer	Characteristics	Operating conditions	Remarks
Calsicat Division	CONTENT wt % Ni 25 Support 15 Protective medium 60 CARRIER: proprietary FORM: flakes	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The protective medium is an edible oil. Selectivity in the hydrogenation of edible oils, fatty acids, nitriles, esters.

TYPE OF CATALYST: *PLATINUM CODE 138*

Manufacturer	Characteristics	Operating conditions	Remarks
Calsicat Division	CONTENT wt % Pt 0.3 CARRIER: alumina FORM: tablets SIZE: Diameter (mm) 3 Length (mm) 3 ABD (g/cm^3) 0.7 SA. (m^2/g) 156 STRENGTH (kg/cm^2) 8.6 (individual particle)	TEMPERATURE RANGE: n.a PRESSURE RANGE: n.a.	Applications: Liquid phase hydrogenation. Oxidation of organic pollutants in effluent gases.

TYPE OF CATALYST: *COBALT C-37*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Cobalt oxide CARRIER: refractory FORM: spheres SIZE: Diameter (mm) 4; 9	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Selective hydrogenation of acetylenes and dienes in sulphur-containing olefins streams.

TYPE OF CATALYST: *COPPER CHROMITE C-43-1; C-44-1; C-45-1*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Copper chromite C45-1 contains barium as stabilizer CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Applications: Hydrogenation and dehydrogenation of functional groups in preference to carbon-carbon bonds in aldehydes and ketones. Typical applications: Hydrogenation of nitrobenzene to aniline, crotonaldehyde to butyraldehyde and the production of high molecular weight alcohols from the corresponding fatty acids or esters.

SELECTIVE HYDROGENATION OF ACETYLENES FROM OLEFIN STREAMS

TYPE OF CATALYST: *NICKEL-COBALT-CHROMIUM C-[illegible]*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Nickel Cobalt Chromium CARRIER: alumina-silica FORM: spheres SIZE: Diameter (mm) 8—9 ABD (g/cm^3) 0.8	TEMPERATURE RANGE: 120°—320°C PRESSURE RANGE: 1—23 atm. LIFE: more than 5 years SPACE VELOCITY: 1,500—5,000 h^{-1}	It is used for the purification of ethylene to produce a grade suitable for the production of polyethylene. It may be used for the selective hydrogenation of acetylenic compounds in gas streams. The raw gas stream may contain CO, sulphur compounds, oxygen and a large excess of hydrogen.

SELECTIVE HYDROGENATION

TYPE OF CATALYST: *NICKEL OXIDE C-38-1*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Nickel oxide CARRIER: n.a. FORM: spheres SIZE: 3—8 mesh ABD (g/cm^3) 0.8	TEMPERATURE RANGE: 177°—288°C PRESSURE RANGE: 7 atm	Used for removal of olefins by hydrogenation. Used also for promoting the selective hydrogenation of butadiene and acetylene from sulphur-bearing butylene streams.

TYPE OF CATALYST: *PALLADIUM C-31-3; C-31-4; C-31-5; C-31-6; C-31-7; C-31-8*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Pd 0.07—0.41 CARRIER: alumina FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

SELECTIVE HYDROGENATION OF DIENES

TYPE OF CATALYST: *PALLADIUM C-31; C-31-1; C-31-1.A*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Pd 0.045—0.055 CARRIER: alumina FORM: extrusions; spheres SIZE: *spheres* Diameter (mm) 2.5—3.6 ABD (g/cm^3) 0.72—0.85	TEMPERATURE RANGE: 25°—250°C PRESSURE RANGE: 7—25 atm SPACE VELOCITY: 1000—3500 h^{-1}	Used for selective hydrogenation of propadiene from concentrated propylene streams. Used for propylene purification.

SELECTIVE HYDROGENATION

TYPE OF CATALYST: *PALLADIUM C-32*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Palladium CARRIER: low surface area refractory FORM: spheres SIZE: Diameter (mm) 9	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for hydrogenation of acetylenes and dienes from concentrated olefin streams.

SELECTIVE HYDROGENATION OF ACETYLENES AND DIENES

TYPE OF CATALYST: *PALLADIUM C-35*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Palladium CARRIER: alumina FORM: extrusions; tablets SIZE: Diameter (mm) 6.4× 3.2 ABD (g/cm^3) 0.72	TEMPERATURE RANGE: 40°—95°C PRESSURE RANGE: 3—35 atm. SPACE VELOCITY: 4000—7000 h^{-1}	Used for selective hydrogenation of acetylene from cracked gas stream. Composition: palladium mounted on an especially prepared carrier. Available as C-35-1, C-35-2, C-35-3.

SELECTIVE HYDROGENATION OF NITRILES AND CARBOXYLIC ACID

TYPE OF CATALYST: *RHODIUM C-55-1*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Rh 0.5 CARRIER: alumina FORM: spheres; extrusions; tablets SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The reduction of aldehydes at low temperature and pressure.

SELECTIVE HYDROGENATION

TYPE OF CATALYST: *RANEY COPPER RCU-5*

Manufacturer	Characteristics	Operating conditions	Remarks
Crossfield Chemicals	CONTENT wt % Cu 95—97 typical Na_2O 0.1 max. FORM: suspension in water	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Pyrophoric in the dry state. Dienes and trienes can be hydrogenated to monoenes. Carbonyl compounds can be hydrogenated to alcohols. Conversely, alcohols can be dehydrogenated to carbonyl compounds without hydrogenolysis.

TYPE OF CATALYST: *PALLADIUM ON RASCHIG RINGS*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt % Pd 5—10 CARRIER: Raschig rings FORM: rings SIZE: n.a. ABD (g/cm³) 0.52	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for the hydrogenation reactions in the gas phase.

SELECTIVE HYDROGENATION OF OLEFINS

TYPE OF CATALYST: *NICKEL - CHROME C-00/07*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt % Nickel chromic oxide CARRIER: without carrier or with Al_2O_3, SiO_2 or pumice FORM: powder; tablets SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Selective hydrogenation of olefins (fatty acids) preserving the carbonyl and carboxyl groups; conversion of butane and NH_3 to butylamine.

SELECTIVE HYDROGENATION OF ACETYLENE

TYPE OF CATALYST: *PALLADIUM G-58.A; G-58.B*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Palladium CARRIER: alumina FORM: tablets (G.58.A); extrusions (G.58.B) SIZE: Diameter (mm) 5 Length (mm) 5 ABD (g/cm³) 0.72—1.28	TEMPERATURE RANGE: 20°—180°C PRESSURE RANGE: 3.5—35 atm.	Selective hydrogenation of acetylene impurified and partially purified ethylene streams. Depending on the acetylene concentration it is used in adiabatic fixed bed or isothermal tube reactors.

SELECTIVE HYDROGENATION OF ACETYLENE IN RAW OLEFIN STREAMS

TYPE OF CATALYST: *PALLADIUM G-83*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Promoted palladium CARRIER: alumina FORM: tablets SIZE: Diameter (mm) 4 Length (mm) 4	TEMPERATURE RANGE: 60°—110°C PRESSURE RANGE: n.a. SPACE VELOCITY: up to 10000 h⁻¹	Especially suitable for isothermal tube reactors, in the range of 90°C.

SELECTIVE HYDROGENATION OF ACETYLENE

TYPE OF CATALYST: *PALLADIUM GPH-5*

Manufacturer	Characteristics	Operating conditions	Remarks
Grande Paroisse	CONTENT wt % Palladium CARRIER: alumina FORM: balls SIZE: Diameter (mm) 3 TS (°C) $\leqslant$550	TEMPERATURE RANGE: 100°—200°C PRESSURE RANGE: n.a. LIFE: 2 years SPACE VELOCITY (VHSV): up to 10000 h^{-1}	Other application: For hydrogenation of ethylene mixtures, eventually in presence of sulphur.

SELECTIVE HYDROGENATION

TYPE OF CATALYST: *NICKEL Ni-0301.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni 11 present as oxide CARRIER: activated alumina FORM: tablets SIZE: Diameter (mm) 3 Length mm) 3 ABD (g/cm^3) 1.1 SA (m^2/g) 64 PV (cm^3/g) 0.32 STRENGTH (kg/cm^2) 6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The sulphided form of this catalyst is used for the selective hydrogenation of diolefins to monolefins.

TYPE OF CATALYST: *NICKEL Ni-0304.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % NiO 32 CARRIER: active alumina FORM: tablets SIZE: Diameter (mm) 4 Length (mm) 4 ABD (g/cm^3) 1.4 SA (m^2/g) 52 PV (cm^3/g) 0.23 STRENGTH (kg/cm^2) 10 (individual particle)	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *NICKEL Ni-3201.F (NYSEL)*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % 25 or 30 fully active nickel protected by 60% stearine CARRIER: proprietary FORM: flakes	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Selectivity in the hydrogenation of edible oils, fatty acids, nitriles, esters and other organic compounds.

TYPE OF CATALYST: *COPPER RCH-20/35: RCH-60/35*

Manufacturer	Characteristics	Operating conditions	Remarks
Farbwerke Hoechst A.G.	CONTENT wt % RCH-20/35 Cu 21 RCH-60/35 Cu 60 CARRIER: SiO_2 FORM: tablets; powder SIZE: n.a. ABD (g/cm³) 0.4—0.9	TEMPERATURE RANGE: 100°—200°C PRESSURE RANGE: 4—50 atm.	Other applications: Hydrogenation of the olefins; of the carbonyl groups; selective hydrogenation of the unsaturated oils.

SELECTIVE HYDROGENATION OF UNSATURATED HYDROCARBONS

TYPE OF CATALYST: *COPPER H-1175*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Cu 11 Copper modified with chromium and MgO CARRIER: silica gel FORM: granules SIZE: Diameter (mm) 2—6 ABD (g/cm³) (packed) 0.7 PV (cm³/g) 0.6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

SELECTIVE HYDROGENATION OF ACETYLENE IN CRUDE ETHYLENE AND CRUDE PROPYLENE STREAMS

TYPE OF CATALYST: *PALLADIUM H-1100*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt% Pd 0.03 SiO_2 97 Loss on drying (120°C): 0.1 Loss on ignition (750°C): 2—3 CARRIER: silica FORM: irregular granules SIZE: Diameter (mm) 3—6 ABD (g/cm³) 0.47 SA (m²/g) 260 PV (cm³/g) 0.9	TEMPERATURE RANGE: 100°—250°C PRESSURE RANGE: n.a.	It may be used at normal, as well as at increased pressure.

SELECTIVE HYDROGENATION OF ALKINES

TYPE OF CATALYST: *PALLADIUM H-1424*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt% Pd 0.05 Al_2O_3 98.5 Na_2O 0.4 Loss on ignition: 0.9 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 3.2 Length (mm) 4—6 ABD (g/cm^3) 0.84 SA (m^2/g) 80 PV (cm^3/g) 0.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for the hydrogenation of acetylene, propene and vinyl acetylene in crude ethylene.

SELECTIVE HYDROGENATION OF ACETYLENE IN OLEFIN STREAMS

TYPE OF CATALYST: *PALLADIUM ICI-38 SERIES*

Manufacturer	Characteristics	Operating conditions	Remarks
Imperial Chemical Industries Ltd	CONTENT wt% Palladium CARRIER: alumina FORM: pellets SIZE: Diameter (mm) 5.4 Length (mm) 3.6 ABD (g/cm^3) 1.05	TEMPERATURE RANGE: 35°—100°C PRESSURE RANGE: up to 35 atm. (ICI-38—1) SPACE VELOCITY (VHSV): 2000—8000 h^{-1}	Available as ICI-38—1 and 38—3. It is used to remove acetylenes and dienes from separated C_2 and C_3 streams produced by steam cracking of hydrocarbons.

SELECTIVE HYDROGENATION OF PHENOL TO CYCLOHEXANE

TYPE OF CATALYST: *PALLADIUM KONTAKT 7720*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb. Leuna Werke „Walter Ulbricht“	CONTENT wt% Palladium CARRIER: a special aluminium oxide FORM: tablets SIZE: Diameter (mm) 5 ABD (g/cm^3) 1.0±0.15 STRENGTH (kg/cm^2) $\geqslant$ 800	TEMPERATURE RANGE: 130°—165°C PRESSURE RANGE: 1 atm.	

TYPE OF CATALYST: *PALLADIUM KONTAKT 7720/S*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb. Leuna Werke „Walter Ulbricht“	CONTENT wt% Palladium CARRIER: especially aluminium oxide FORM: extrusions SIZE: Diameter (mm) 3 Length (mm) 2—6 ABD (g/cm³) 1.0±0.15	TEMPERATURE RANGE: 130°—165°C PRESSURE RANGE: 1 atm.	

SELECTIVE HYDROGENATION

TYPE OF CATALYST: *PALLADIUM KONTAKT 7746*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb. Leuna Werke „Walter Ulbricht“	CONTENT wt% Palladium and iron oxide CARRIER: alpha alumina FORM: tablets SIZE: Diameter (mm) 5 or 10 ABD (g/cm³) 0.80—1.1 STRENGTH (kg/cm²) 150	TEMPERATURE RANGE: 80°—200°C PRESSURE RANGE: 25—30 atm.	

SELECTIVE HYDROGENATION OF ACETYLENE TO ETHYLENE

TYPE OF CATALYST: *PALLADIUM KONTAKT 7747*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb. Leuna Werke „Walter Ulbricht“	CONTENT wt% Palladium CARRIER: alpha alumina FORM: cylinders SIZE: Diameter (mm) 10—15 Length (mm) 10—15 ABD (g/cm³) 0.7—1.0 STRENGTH (kg/cm²) 50—100	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

SELECTIVE HYDROGENATION OF C_3 AND C_4 HYDROCARBONS

TYPE OF CATALYST: *PALLADIUM KONTAKT 7751*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb. Leuna Werke „Walter Ulbricht“	CONTENT wt% Promoted palladium CARRIER: alumina FORM: spheres; extrusions SIZE: Diameter (mm) 2—4 (spheres) 3 (extrusions) ABD (g/cm³) 1.0±0.15	TEMPERATURE RANGE: 10°—20°C PRESSURE RANGE: 5—15 atm.	It is used in fluid phase.

SELECTIVE HYDROGENATION

TYPE OF CATALYST: *PALLADIUM KONTAKT 7761*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb. Leuna Werke „Walter Ulbricht“	CONTENT wt% Palladium CARRIER: aluminium oxide FORM: extrusions SIZE: Diameter (mm) 3 Length (mm) 2—6	TEMPERATURE RANGE: 80°—250°C PRESSURE RANGE: 20—50 atm.	

TYPE OF CATALYST: *NICKEL SNX; ST-130*

Manufacturer	Characteristics	Operating conditions	Remarks
Sakaj Chemical Industry Co Ltd	CONTENT wt% Nickel sulphide CARRIER: Kieselguhr FORM: powder; tablets	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Selective hydrogenation in vapour phase.

TYPE OF CATALYST: *COPPER 29041*			
Manufacturer	**Characteristics**	**Operating conditions**	**Remarks**
Strem Chemicals Inc.	CONTENT wt% Copper chromite, barium promoted CuO 39.6 Cr_2O_3 41.7 BaO 8.6 CARRIER: n.a. FORM: powder SA (m^2/g) high	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Barium inhibits reduction of the catalyst thereby stabilizing it for use as hydrogenation catalyst. This catalyst selectively hydrogenates aromatic nitrocompounds to aromatic amines and carbonyl groups attached to an aromatic nucleus to either the carbonyl or methylene function. Olefinic groups attached to an aromatic nucleus are selectively hydrogenated. Unsaturated nitriles are selectively hydrogenated to unsaturated amines.

SELECTIVE HYDROGENATION OF AROMATIC NITRO-COMPOUNDS

TYPE OF CATALYST: *RANEY COPPER 29275*			
Manufacturer	**Characteristics**	**Operating conditions**	**Remarks**
Strem Chemicals Inc.	CONTENT n.a. FORM: 50% slurry in water SA (m^2/g) high	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

SELECTIVE HYDROGENATION OF SIMPLE OLEFINS

TYPE OF CATALYST: *PALLADIUM 46-183*			
Manufacturer	**Characteristics**	**Operating conditions**	**Remarks**
Strem Chemicals Inc.	CONTENT wt% Palladium black FORM: powder SA (m^2/g) approx. 23	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used also for the hydrogenation of aromatic ketones to aromatic hydrocarbons.

SELECTIVE HYDROGENATION

TYPE OF CATALYST: *PALLADIUM 46189*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt% Palladium 5 CARRIER: activated carbon FORM: powder SA (m^2/g) approx. 1050	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Also used for: Dehydrogenation reactions. Decarbonylation of aldehydes and acid chlorides to alkanes and alkyl halides respectively. Hydrogenation of aromatic nitro compounds to aromatic amines. Dehalogenation reactions.

TYPE OF CATALYST: *PALLADIUM 46-192; 46-195*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt% 46-192: Pd 0.5 46-195: Pd 5 CARRIER: alumina FORM: pellets (46—192); powder (46—195) SIZE (mm): pellets: 3×3 SA (m^2/g) 46-192: high 46-195: 80—100	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Applications: Isomerization of olefins. Oxidation of ethylene to vinyl acetate.

TYPE OF CATALYST: *PALLADIUM 46-205*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt% Pd 0.3—0.5 CARRIER: gamma alumina coated on Dupont Torvex ceramic honeycomb FORM: discs SIZE: Diameter (mm) 50 Thickness (mm) 25 SA (m^2/g) approx. 240	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See 46-189 and 46-192

TYPE OF CATALYST: *PALLADIUM 46-207*

Manufacture	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt% Pd 0.5 CARRIER: Kaolin (natural silica-alumina) FORM: pellets SIZE: n.a. SA (m^2/g) 90—100	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See 46-189

SELECTIVE HYDROGENATION OF SIMPLE OLEFINS

TYPE OF CATALYST: *PALLADIUM 46-211*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt% Palladium oxide CARRIER: n.a. FORM: powder SA (m^2/g) 225	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Also used for: Hydrogenation of aromatic ketones to aromatic hydrocarbons.

HYDROTREATING REACTIONS

TYPE OF CATALYST: *COBALT-MOLYBDENUM C-20-5; C-20-6*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt% CoO 3.3—3.8 MoO_3 13.5—15.5 Na_2O 0.05 Fe_2O_3 0.20 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 1.6; 3.2; 5 ABD (g/cm^3) 0.7 SA (m^2/g) 175—225 PV (cm^3/g) 0.5—0.6	TEMPERATURE RANGE: 288°—454°C PRESSURE RANGE: 7—105 atm.	Used for denitrification of hydrocarbons, the hydrogenation of petroleum fractions. Also for converting organic nitrogen and sulphur compounds to ammonia and H_2S. Stabilization of petroleum fractions.

TYPE OF CATALYST: *MOLYBDENUM CHEZA CATALYST 36—00; 36—01*

Manufacturer	Characteristics	Operating conditions	Remarks
Chemical Works of CSF	CONTENT wt% MoO_3 12 CoO 3 Na_2O max. 0.1 CARRIER: alumina FORM: 36—00 36—01 *tablets* *balls* SIZE: (mm) 10×8; 6×6 3 ABD (g/cm^3) 0.85 STRENGTH (kg/cm^2) 150; 2.5 per ball	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used also for hydrodesulphurization of crude oil fractions from petroleum. For hydrotreating of crude coal tar benzol, lubricating oils, paraffin waxes and similar products.

TYPE OF CATALYST: *COBALT-MOLYBDENUM AERO HDS-2*

Manufacturer	Characteristics	Operating conditions	Remarks
Cyanamid International	CONTENT wt% CoO 3—4 MoO_3 14.5—16.0 Na_2O max. 0.04 Fe max. 0.05 Loss on ignition: 2.0 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 3 Length (mm) 6 ABD (g/cm^3) 0.42 SA (m^2/g) 270 PV (cm^3/g) 0.7 STRENGTH (kg/cm^2) 7.2 TS (°C) 540	TEMPERATURE RANGE: 300°—370°C PRESSURE RANGE: 42 atm. SPACE VELOCITY (LHSV): 5 h^{-1}	It is used to promote desulphurization, denitrogenation, deoxygenation and saturation reactions.

TYPE OF CATALYST: *NICKEL-MOLYBDENUM AERO HDS-3*

Manufacturer	Characteristics	Operating conditions	Remarks
Cyanamid International	CONTENT wt% NiO 3.1 MoO_3 15 Na_2O 0.02 Fe 0.04 SO_4 0.3 SiO_2 0.1 Loss on ignition: 1.4 CARRIER: alumina FORM: extrusions Diameter (mm) 1.5; 3 Length (mm) 6 ABD (g/cm^3) 0.56 SA (m^2/g) 200 PV (cm^3/g) 0.6 STRENGTH (kg/cm^2) 7.7	TEMPERATURE RANGE: 300°—370°C PRESSURE RANGE: 42 atm. SPACE VELOCITY (LHSV): 5 h^{-1}	The catalyst is designed for use on feedstocks containing high percentages of nitrogen and polyaromatics compounds. It is adapted for the treatment of nitrogen containing naphthas, hydrogenation of cat-cracker feed and middle distillates and for giving improved colour in waxes.

HYDROTREATING OF COKER NAPHTHAS

TYPE OF CATALYST: *NICKEL-MOLYBDENUM KETJENFINE^R 153—1.5E*

Manufacturer	Characteristics	Operating conditions	Remarks
Akzo Chemie B.V. Dpt. Ketjen Catalysts	CONTENT wt% (dry base) NiO 3.0 MoO_3 15 SiO_2 1.0 Na_2O 0.06 Fe 0.06 SO_4 1.5 Loss on ignition (650°C) wet base: 3.0 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 1.5 Length (mm) 4.0 SA (m^2/g) 180 (1 hr at 600°C) PV (H_2O) (cm^3/g) 0.50 STRENGTH (kg/cm^2) 11	TEMPERATURE RANGE: 300°—380°C PRESSURE RANGE: 1—40 atm.	See Ketjenfine 153-3E

TYPE OF CATALYST: *NICKEL-MOLYBDENUM KETJENFINE^R 153—3E*

Manufacturer	Characteristics	Operating conditions	Remarks
Akzo Chemie B.V. Dpt. Ketjen Catalysts	CONTENT wt% (dry base) NiO 3 MoO_3 15 SiO_2 1 Na_2O 0.06 Fe 0.06 SO_4 1.5 Loss on ignition (650°C) wet base: 3 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 2.5 Length (mm) 5.0 ABD (g/cm^3) n.a. SA (m^2/g) 180 (1hr at 600°C) PV (H_2O)(cm^3/g) 0.50 STRENGTH(kg/cm^2) 11	TEMPERATURE RANGE: 300°—380°C PRESSURE RANGE: 1—40 atm.	The Ketjenfine 153 have been especially developed for removal of nitrogen and polyaromatic compounds from mineral oils. They are suited for treatment of cracked feedstocks such as coker naphthas and gas oils. catalytic cracker feedstocks and lube-oil basestocks.

MILD HYDROTREATING OF OILS

TYPE OF CATALYST: *NICKEL-MOLYBDENUM HR 344*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt% MoO$_3$ 13 NiO 2.5 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 1.5; 2; 3 STRENGTH (kg/cm^2) $\geqslant 12$	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Standard hydrofinishing charges with nitrogen compounds.

HYDROTREATMENT OF DISTILLATES

TYPE OF CATALYST: *NICKEL-TUNGSTEN HR 151—155*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT FORM: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See section on hydrodesulphurization.

TYPE OF CATALYST: *NICKEL-TUNGSTEN HR 356*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 1.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *COBALT-MOLYBDENUM SHELL 244*

Manufacturer	Characteristics	Operating conditions	Remarks
Shell Chemical Co.	CONTENT wt% Co 2.0—2.4 Mo 8.4—9.2 Na 0.1 Loss on ignition: max. 1.5 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 1.8—3 (average) ABD (g/cm^3) 0.61—0.74 SA (m^2/g) 180 PV (cm^3/g) 0.4 Side Plate Crush (kg) 11—12	TEMPERATURE RANGE: approx. 290°C PRESSURE RANGE: 35 atm. SPACE VELOCITY (LHSV): 2.3—4.2 h^{-1}	It is recommended for desulphurization of: straight run naphtha, kerosene, heating oil and diesel fuel, and heavy fuel oil. It is designed for the increased desulphurization requirements of naphthas and fuel oils called for by use of bimetallic reformer catalysts.

TYPE OF CATALYST: *NICKEL-MOLYBDENUM SHELL 214*

Manufacturer	Characteristics	Operating conditions	Remarks
Shell Chemical Co.	CONTENT wt% Ni 2.0—2.4 Mo 8.5—9.5 Na 0.1 Loss on ignition: max. 1.5 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 1.8—3 (average) ABD (g/cm^3) 0.64—0.77 SA (m^2/g) 180 PV (cm^3/g) 0.4 Side Plate Crush (kg) 11—12	TEMPERATURE RANGE: 300°—350°C PRESSURE RANGE: 20—100 atm. SPACE VELOCITY (LHSV): 0.9—5 h^{-1}	It is recommended for processing: Cocker products High nitrogen content naphthas High nitrogen content kerosene, heating oil and diesel fuel Lube oils, waxes and solvents. It is designed for multipurpose hydrotreating where maximum desulphurization, denitrogenation and polyaromatic saturation are not needed.

TYPE OF CATALYST: *NICKEL-MOLYBDENUM SHELL 324*

Manufacturer	Characteristics	Operating conditions	Remarks
Shell Chemical Co.	CONTENT wt% Ni 2.9 Mo 12.0 Na 0.1 CARRIER: high density alumina FORM: extrusions SIZE: Diameter (mm) 1.8—3 (average) ABD (g/cm^3) 0.8—0.95 SA (m^2/g) 180 PV (cm^3/g) 0.4 Side Plate Crush (kg) 4	TEMPERATURE RANGE: 320°—370°C PRESSURE RANGE: 38—70 atm. SPACE VELOCITY (LHSV): 1.2—4.8 h^{-1}	It is recommended for: Processing unsaturated and unstable streams such as cocker products, cracker products and pyrolysis gasolines; Catalytic cracker feed preparation; Heavy fuel oil desulphurization; Stocks with high nitrogen content; Smoke point improvement of turbine fuels; Pretreating naphthas for reformers using bimetallic catalysts; Lube oil treating.

G. Isomerization

ISOMERIZATION

TYPE OF CATALYST: *ANHYDROUS ALUMINIUM CHLORIDE*			
Manufacturer	Characteristics	Operating conditions	Remarks
Allied Chemical	CONTENT Aluminium chloride is used alone, with mixtures of other catalytic materials, or in complex with hydrocarbon solvents	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	There are a wide variety of chemical reactions in the petroleum industry which can use aluminium chloride as a catalyst. The more important of these are polymerization, alkylation, acylation and isomerization.

TYPE OF CATALYST: *ALUMINA BASF D-10—10*			
Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt% Al_2O_3 main constituent Na + K <0.1 Fe <0.1 Loss on ignition expressed in terms of dry catalyst 5 FORM: extrusions SIZE: Diameter (mm) 4 ABD (g/cm^3) 0.650 TS (°C) up to 500	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for diverse chemical reactions such as dehydration, isomerization.

SOMERIZATION OF n-BUTANE AND n-PENTANE TO ISOBUTANE AND ISOPENTANE

TYPE OF CATALYST: *ANHYDROUS ALUMINIUM CHLORIDE*			
Manufacturer	Characteristics	Operating conditions	Remarks
Davison Chemical Division, W.R. and Grace Co.	CONTENT wt% Anhydrous aluminium chloride FORM: crystalline solid or granular form	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The catalyst is used for production of C_{12} to C_{18} alkyl benzenes.

CONVERSION OF NORMAL BUTANE TO ISOBUTANE

TYPE OF CATALYST: *MOLYBDENUM ALUMINA Mo-1201.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt% MoO_3 10 CARRIER: high activity alumina FORM: tablets SIZE: Diameter (mm) 3.175 Length (mm) n.a. ABD (g/cm^3) 0.848 SA (m^2/g) 160 PV (cm^3/g) 0.36 STRENGTH (kg/cm^2) 8.607	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used also for hydrogenation, dehydrogenation and hydroforming.

TYPE OF CATALYST: *NICKEL TUNGSTEN Ni-4301.E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt% Nickel 6 Tungsten 19 CARRIER: silica-alumina FORM: tablets SIZE: Diameter (mm) 0.21 Length (mm) n.a. ABD (g/cm^3) 0.96 SA (m^2/g) 228 PV (cm^3/g) 0.37 STRENGTH (kg/cm^2) 6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The sulphide form of this catalyst is used for hydrogenation where a cracking function is desired. The catalyst is also used for saturation of mono-and polycyclic aromatic compounds, denitrogenation and desulphurization.

ISOMERIZATION

TYPE OF CATALYST: *SELENIUM POWDER*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt% Se min. 99 FORM: powder SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used also for oxidation, hydrogenation and polymer treatment.

CONVERSION OF NORMAL BUTANE TO ISOBUTANE

TYPE OF CATALYST: *TITANUM Ti-0102-T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt% TiO_2 86 CARRIER: alumina FORM: tablets SIZE: Diameter (mm) 3.175 Length (mm) n.a. ABD (g/cm^3) 1.392 SA (m^2/g) 70 PV (cm^3/g) 0.25 STRENGTH (kg/cm^2) 6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

ISOMERIZATION

TYPE OF CATALYST: *VANADIA V-0601.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt% V_2O_5 10 CARRIER: high activity alumina FORM: tablets SIZE: n.a. ABD (g/cm^3) 0.96 SA (m^2/g) 115 PV (cm^3/g) 0.28 STRENGTH (kg/cm^2) 9.06	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used also for oxidation.

TYPE OF CATALYST: *PHOSPHORIC ACID H-3301*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt% Phosphoric acid as active component CARRIER: silicic acid FORM: extrusions SIZE: Diameter (mm) 4 or 6 Length (mm) 3—8 or 6—15 ABD (g/cm^3) 0.5—0.9	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The catalyst dried at 110°C (H-3301-t) contains orthophosphoric acid whereas by calcinating at approx. 230°C (H-3301-c) condensed phosphoric acid is formed. It is also applied in hydration and polymerization reactions. *Content* *H-3301-t* (*wt%*) H_3PO_4 18 35 50 P_2O_5 13 25 36 SiO_2 81 64 49 H_2O 5 10 14 *Content* *H-3301-c* (*wt %*) H_3PO_4 18 35 50 P_2O_5 13 27 40 SiO_2 85 70 55 H_2O 2 3 5

TYPE OF CATALYST: *PALLADIUM SK-100*

Manufacturer	Characteristics	Operating conditions	Remarks
Union Carbide Corporation, Linde Molecular Sieve Catalysts	CONTENT wt % (anhydrous base) SiO_2 74.0 ± 0.5 Al_2O_3 25.0 ± 0.5 Cl^- $\leqslant 0.05$ F^- $\leqslant 0.05$ Pd 0.5 ± 0.02 Na_2O 1.5 ± 0.5 FORM: tablets SIZE: Diameter (mm) 4 Length (mm) 4 ABD (g/cm^3) 0.70 SA (m^2/g) > 500	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for the pentane-hexane isomerization. It is a decationized molecular sieve of Y type.

TYPE OF CATALYST: *PALLADIUM SK-110*

Manufacturer	Characteristics	Operating conditions	Remarks
Union Carbide Corporation, Linde Molecular Sieve Catalysts	CONTENT wt % (anhydrous base) SiO_2 69.0 ± 0.5 Al_2O_3 23.3 ± 0.5 Na_2O 2.4 ± 0.2 Cl^- $\leqslant 0.05$ F^- $\leqslant 0.05$ Mn 5.2 ± 0.2 Pd 0.5 ± 0.02 FORM: tablets SIZE: Diameter (mm) 4 Length (mm) 4 ABD (g/cm^3) 0.6 SA (m^2/g) >500	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is a partially decationized, partially magnese exchanged type Y, used *for the pentane-hexane isomerization.*

H. Oxidation

CATALYTIC ALUMINA

TYPE OF CATALYST: *ALUMINA TABULAR ALUMINA T-61*

Manufacturer	Characteristics	Operating conditions	Remarks
Aluminium Company of America (ALCOA)	CONTENT wt % Al_2O_3 99.5 Na_2O 0.02 Fe_2O_3 0.06 SO_3 0.09 CaO 0.06 Loss on ignition (1,100°C): 0.0 FORM: granular SIZE:* 4—48 mesh (0.004—0.2 mm) Diameter (mm) 6—12 Length (mm) n.a. ABD (g/cm^3) 1.9—2.2 SA (m^2/g) 0.04 PV (cm^3/g) 0.015	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Tabular alumina is suited for catalytic applications such as oxidation reactions. Fixed bed operations use granular tabular alumina T-61. Powder forms are available for fluid processes. If balled forms are desired, then tabular alumina T-164 would be the product indicated.

* Tyler standard screen scale sieves.

OXIDATION REACTIONS

TYPE OF CATALYST: *COPPER-CHROMIUM C-43*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Copper and chromium co-precipitaded as „copper chromite" FORM: powder SIZE: passing 325 mesh screen	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for hydrogenation of esters and acids, oxidation and dehydrogenation of organic materials.

OXIDATION OF ETHYLENE TO ETHYLENE OXIDE

TYPE OF CATALYST: *SILVER SYN DOX*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalyst Development Corporation (C.D.C.)	CONTENT wt % Silver CARRIER: refractory oxides FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Oxidation of ethylene using either air or oxygen. It is employed in a recycle process.

OXIDATION OF HYDROCARBONS

TYPE OF CATALYST: *COPPER CHROMITE*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt % Cu 33—34 Cr 29—30 FORM: powder or tablets SIZE: n.a. ABD (g/cm^3) 0.35	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Also pellets on Al_2O_3, SiO_2 and pumice stone as carriers.

TYPE OF CATALYST: *NICKEL CHROMITE*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt % Ni 33—34 Cr 27—28 CARRIER: without Al_2O_3, SiO_2 or pumice FORM: powder SIZE: n.a. ABD (g/cm^3) 0.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Available also as tablets.

OXIDATION REACTIONS

TYPE OF CATALYST: *MANGANESE Mn-0201.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % MnO_2 12 CARRIER: activated alumina FORM: tablets SIZE: Diameter (mm) 3 Length (mm) n.a. ABD (g/cm^3) 1.12 SA (m^2/g) 69 PV (cm^3/g) 0.23 STRENGTH, (kg/cm^2) 15.8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *MANGANESE Mn-0501.G6-10*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Manganese 2 (present in oxide form) CARRIER: silica FORM: granules SIZE: Diameter (mm) 6—10 ABD (g/cm^3) 0.48 SA (m^2/g) 258 PV (cm^3/g) 0.97	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *SELENIUM POWDER*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Se min. 99	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See chapter on isomerization.

TYPE OF CATALYST: *SILVER Ag-0103.E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Reduced silver 4 CARRIER: inert alumina FORM: extrusions SIZE: Diameter (mm) 3 Length (mm) n.a. ABD (g/cm^3) 1.13 SA (m^2/g) 0.5 PV (cm^3/g) 0.03	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *SILVER Ag-0105.E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Reduced silver 8 CARRIER: inert alumina FORM: extrusions SIZE: Diameter (mm) 3 Length (mm) n.a. ABD (g/cm^3) 1.36 SA (m^2/g) 1.5 PV (cm^3/g) 0.07	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *SILVER Ag-0107.E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Reduced silver 11 CARRIER: inert support FORM: extrusions SIZE: Diameter (mm) 3 Length (mm) n.a. ABD (g/cm^3) 1.4 SA (m^2/g) 0.5 PV (cm^3/g) 0.01	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *VANADIUM V-0301.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % V_2O_5 10 CARRIER: activated alumina FORM: tablets SIZE: Diameter (mm) 3 Length (mm) n.a. ABD (g/cm^3) 0.95 SA (m^2/g) 78 PV (cm^3/g) 0.33 STRENGTH (kg/cm^2) 4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *VANADIUM V-0501.S*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % V_2O_5 10 CARRIER: inert alumina FORM: spheres SIZE: Diameter (mm) 6 Length (mm) n.a. ABD (g/cm^3) 1.28 SA (m^2/g) 1	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *VANADIUM V-0601.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % V_2O_5 10 CARRIER: high activity alumina FORM: tablets SIZE: Diameter (mm) 3 Length (mm) n.a. ABD (g/cm^3) 0.9 SA (m^2/g) 115 PV (cm^3/g) 0.28 STRENTGH (kg/cm^2) 12	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *VANADIUM V-0701.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % V_2O_5 10 CARRIER: silica alumina FORM: tablets SIZE: Diameter (mm) 3.1 Length (mm) n.a. ABD (g/cm^3) 0.9 SA (m^2/g) 139 PV (cm^3/g) 0.45 STRENGTH (kg/cm^2) 10.4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *VANADIUM V-0802.S*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % V_2O_5 10 CARRIER: alumina FORM: spheres SIZE: Diameter (mm) 3.2 Length (mm) n.a. ABD (g/cm^3) 0.98 SA (m^2/g) 214 PV (cm^3/g) 0.34 STRENGTH (kg/cm^2) 12.23	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *VANADIUM V-1001.E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % V_2O_5 6 MoO_3 3 CARRIER: inert alpha alumina FORM: extrusions SIZE: Diameter (mm) 5 Length (mm) n.a. ABD (g/cm^3) 1.13 SA (m^2/g) 1	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *VANADIUM V-1002.E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % V_2O_5 6 MoO_3 3 CARRIER: inert alpha alumina FORM: extrusions SIZE: Diameter (mm) 5 Length (mm) n.a. ABD (g/cm^3) 1.13 SA (m^2/g) 1	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

PARTIAL OXIDATION OF HYDROCARBONS

TYPE OF CATALYST: *NICKEL N-174*

Manufacturer	Characteristics	Operating conditions	Remarks
W.C. Heraeus GmbH	CONTENT wt % Nickel CARRIER: special FORM: cylindrical rings SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

SULPHUR RECOVERY (CLAUS PROCESS)

TYPE OF CATALYST: *CHROMIUM KONTAKT 6301*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht"	CONTENT n.a. CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 8 Length (mm) 8—12	TEMPERATURE RANGE: 280°—360°C PRESSURE RANGE: n.a.	Chrome is present as chrome oxide III and VI.

TYPE OF CATALYST: *ALUMINA-POROCEL SULPHUR RECOVERY CATALYST*

Manufacturer	Characteristics	Operating conditions	Remarks
Porocel Corporation, Engelhard Minerals and Chemicals Corp.	CONTENT wt % Alumina 88—92 CARRIER: high alumina, activable bauxite FORM: n.a. SIZE: (mesh grade) 2/4 and 4/8 ABD (g/cm^3) 0.82—0.86 SA (m^2/g) 220—240 STRENGTH (kg/cm^2) 0.82—0.86	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *ALUMINA CR*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Al_2O_5 >95 Na_2O <0.1 Loss on ignition (1000°C): 4 CARRIER: high purity alumina FORM: balls SIZE: Diameter (mm) 5—10 Length (mm) n.a. ABD (g/cm^3) 0.75 SA (m^2/g) 300 STRENGTH (kg/cm^2) 15	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for sulphur recovery from H_2S. Available as: CRS-21 and CRS-32

TYPE OF CATALYST: *ALUMINA DR*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Al_2O_3 >95 Total Na_2O content <0.5 Loss on ignition (1000°C): 4 CARRIER: highly pure alumina FORM: balls SIZE: Diameter (mm) 5—10 ABD (g/cm^3) 0.75 SA (m^2/g) 300 STRENGTH (kg/cm^2) 15	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a. LIFE: longer than 6 years	Used for sulphur recovery from H_2S.

OXIDATION IN LIQUID PHASE

TYPE OF CATALYST: *PALLADIUM ST-800*

Manufacturer	Characteristics	Operating conditions	Remarks
Sakaj Chemical Industry Co. Ltd	CONTENT wt % Palladium CARRIER: n.a. FORM: tablets SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

ETHYLENE OXIDE PRODUCTION

TYPE OF CATALYST: *SHELL 809/829*			
Manufacturer	Characteristics	Operating conditions	Remarks
Shell Chemical Co.	CONTENT n.a. CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

OXIDATION OF ALCOHOLS TO ALDEHYDES

TYPE OF CATALYST: *COPPER 29028*			
Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % Copper carbonate 6 CARRIER: silica FORM: granules SIZE (mm) 4—10 mesh SA (m^2/g) 4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used for selective hydrogenation of aromatic nitro compounds to aromatic amines.

OXIDATION REACTIONS

TYPE OF CATALYST: *MANGANESE 25139*			
Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % MnO_2 19 CARRIER: alumina FORM: pellets SIZE: Diameter (mm) 3 Length (mm) 3 SA (m^2/g) approx. 70	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

OXIDATION OF PRIMARY ALCOHOLS TO ALDEHYDES

TYPE OF CATALYST: *MANGANESE 35136*			
Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % Manganese dioxide activated CARRIER: n.a. FORM: powder SIZE: n.a. SA (m^2/g) high	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Applications: Oxidation of secondary alcohols to ketones.

OXIDATION REACTIONS

TYPE OF CATALYST: *SILVER 47250; 47700*			
Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % Ag 4 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 3 SA (m^2/g) approx. 1	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Applications: Vapour phase oxidation of alcohols to aldehydes. Hydration of ethylene oxide. 47700 is a Raney silver catalyst, available as 50% slurry in water.

VAPOUR PHASE OXIDATION OF HYDROCARBONS

TYPE OF CATALYST: *VANADIUM 23.400; 23.409; 23.411*			
Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % V_2O_5 (a) 23.400 10 (b) 23.409 2—3 (c) 23.411 4 CARRIER: (a) alumina (b) silica fibres (c) silica gel FORM: (a) pellets; (b) long fibres; (c) fluidized powder SIZE: n.a. SA (m^2/g) (a) 78; (b) 62; (c) high	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

I. Polymerization

POLYMERIZATION

TYPE OF CATALYST: *ANHYDROUS ALUMINIUM CHLORIDE*

Manufacturer	Characteristics	Operating conditions	Remarks
Allied Chemicals	CONTENT See chapter on alkylation	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Low boiling hydrocarbons gases are converted into lubricants and motor oils.

POLYMERIZATION OF ISOBUTYLENE

TYPE OF CATALYST: *PHOSPHORIC ACID C-82*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Phosphoric acid CARRIER: activated carbon FORM: granules SIZE (mm): 4—12 mesh	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

POLYMERIZATION OF OLEFINS (PROPYLENES AND BUTYLENES)

TYPE OF CATALYST: *PHOSPHORIC ACID C-84*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Acid content (as H_3PO_4 100%): available 19—26 total 67—75 CARRIER: Kieselguhr FORM: spheres SIZE: Diameter (mm) 5—6; 6—8 Length (mm) n.a. ABD (g/cm^3) 0.88 STRENGTH (kg/cm^2) 13.6; 15.86	TEMPERATURE RANGE: 149°—232°C PRESSURE RANGE: 28—84 atm.	Another large and increasing application is in the alkylation of benzene and propylene to produce cumene. In addition, there is a sizeable use of this catalyst for selectively producing linear olefins. The catalysts operate excellently in either isothermal, tubular reactors or adiabatic multibed chamber units (C-84-1) and (C-84-2). Certain compounds that may be present in the feed can have a deleterious effect on catalyst performance: nitrogen, sulphur, caustic dienes and acetylenes.

MANUFACTURE OF LIQUID POLYBUTENE

TYPE OF CATALYST: *ANHYDROUS ALUMINIUM CHLORIDE*

Manufacturer	Characteristics	Operating conditions	Remarks
Davison Chemical Division, W.R. Grace and Co.	CONTENT wt % See chapter on alkylation	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Copolymerization of isobutylene and isoprene to produce butyl rubber. Low molecular weight thermoplastic resins. From petroleum refinery C_4 hydrocarbon steams containing isobutylene.

POLYMERIZATION REACTIONS

TYPE OF CATALYST: *H_3PO_4 ACTIMET 291*

Manufacturer	Characteristics	Operating conditions	Remarks
Doduco	CONTENT wt % Phosphoric acid CARRIER: SiO_2 FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used also for hydration and isomerization.

CROSSLINKING AGENT FOR POLYMERS

TYPE OF CATALYST: *CHROMIUM CHLORIDE*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Chromium chloride CARRIER: n.a. FORM: crystals SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used as crosslinking agent for polymers in oil drilling muds.

POLYMERIZATION REACTIONS

TYPE OF CATALYST: *PHOSPHORIC ACID CATALYST H-3301*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % See chapter on isomerization	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

POLYMERIZATION OF C_3 AND C_4 FOR THE PRODUCTION OF HEPTENES

TYPE OF CATALYST: *P_2O_5 AP-792; AP-794*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % P_2O_5 CARRIER: SiO_2 FORM: extrusions SIZE: Diameter (mm) 4 Length (mm) n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	AP-792 is used for the alkylation of benzene by propylene. AP-794 is used for the polymerization of C_3 and C_4 cuts for the production of nonenes, dodecenes, gasolines.

POLYMERIZATION REACTIONS

TYPE OF CATALYST: *ANTIMONY TRICHLORIDE*

Manufacturer	Characteristics	Operating conditions	Remarks
Stauffer Chemical Company	CONTENT wt % Antimony trichloride FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used in the manufacture of antimony compounds, match heads and pyrotechnics; as a catalyst in fluorocarbon preparation, rubber polymerization, izomerization, alkylation and cracking; as a mordant and fireproofing for textile and for bronzing of iron and blackening of zinc.

POLYMERIZATION OF OLEFINS

TYPE OF CATALYST: *VANADIUM TRICHLORIDE*

Manufacturer	Characteristics	Operating conditions	Remarks
Stauffer Chemical Company	CONTENT wt % Vanadium trichloride CARRIER: n.a. FORM: powder SIZE: n.a. DENSITY (g/cm^3) 0.72—0.96	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used as an olefin polymerization catalyst in combination with an aluminium alkyl and in the preparation of vanadium dichloride and organovanadium compounds.

POLYMERIZATION

TYPE OF CATALYST: *TITANIUM TRICHLORIDE TAC*

Manufacturer	Characteristics	Operating conditions	Remarks
Toho Titanium Co. Ltd.	CONTENT Molecular ratio $TiCl_3$: $AlCl_3$ 3:1 FORM: powder SIZE: n.a. ABD (g/cm^3) 0.7—1.1 TS (°C) 150 (in an inert atmosphere)	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Types of TAC: TAC 100 TAC 101 (standard TAC 121 type) TAC 131 TAC 141 TAC 191 Used for the production of polypropylene. The catalyst is obtained by a special treatment, given to raw product, obtained by reduction of titanium tetrachloride with metallic aluminium. True specific gravity: 2.6 g/cm^3.

PRODUCTION OF POLYETHYLENE TEREPHTHALATE

TYPE OF CATALYST: *ANTIMONY M&T CATALYST S21*

Manufacturer	Characteristics	Operating conditions	Remarks
M&T International N.V.	CONTENT wt % Antimony $\geqslant$ 38 Iron max $\leqslant$ 100 ppm Sulphate max. $\leqslant$ 100 ppm Chloride max. 100 ppm FORM: white to off-white moist crystalyne solid ABD (g/cm^3) 0.1	TEMPERATURE RANGE: 124°—147°C PRESSURE RANGE: n.a. PURITY: $\geqslant$ 95% STABILITY: hydrolytically unstable	It is a polycondensation catalyst for batch and continuous operations, for fast generation of high intrinsic viscosity polymer.

J. Purification

Purification of gases
Purification by combustion
Purification by hydrotreating
Denitrogenation
Desoxygenation

Purification of gases

CATALYTIC ALUMINA

TYPE OF CATALYST: *ACTIVATED ALUMINA F-7*

Manufacturer	Characteristics	Operating conditions	Remarks
Aluminium Company of America (ALCOA)	CONTENT wt % Al_2O_3 84.0 Na_2O 0.90 Fe_2O_3 0.08 SiO_2 0.09 Nickel formate 2.5 FORM: granular SIZE: Diameter (mm) 12.7—25.4 25.4—50.8 ABD (g/cm³) 0.83—0.82	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	F-7 is made by impregnating F-1 with approx. 2.5% nickel formate. It is used as a catalyst for production of controlled atmospheres in heat treating furnaces.

PURIFICATION

TYPE OF CATALYST: *COBALT MOLYBDENUM BASF M-8—10*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % MoO_3 13.5 CoO 5 SiO_2 2 SO_4 3 Na_2O 0.7 Remainders: carriers CARRIER: Al_2O_3 FORM: extrusions; pellets SIZE: Diameter (mm) 1.5 and 3; 3 and 5 Length (mm) 3; 5 ABD (g/cm³) 0.65; 0.68 SA (BET) (m²/g) 220 PV (cm³/g) 0.5 (titration method) STRENGTH: Extrusions: at right angles to direction of extrusions: 1.6 kg/cm² Pellets: bursting pressure at the faces: 300 kg/cm² TS (°C) up to 500	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Pressure hydrogen refining of petroleum derivatives of all types and boiling ranges, for reduction of sulphur, nitrogen and oxygen compounds, to remove metallic impurities and for hydrogenation of unsaturated compounds.

TYPE OF CATALYST: *MOLYBDENUM BASF M-8—30*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % MoO_3 15 SO_4 3 Na_2O 0.7 Remainder: Al_2O_3 Loss on ignition: 2 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 5 ABD (g/cm³) 0.66 SA (BET) (m²/g) 200 PV (cm³/g) 0.5 TS (°C) up to about 500	TEMPERATURE RANGE: 300°—400°C PRESSURE RANGE: n.a.	Pressure refining of crude benzene.

TYPE OF CATALYST: *NICKEL-MOLYBDENUM C 20—7*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT n.a. CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 3.175; 1.6 Length (mm) n.a. ABD (g/cm^3) 0.8	TEMPERATURE RANGE: 288°—399°C PRESSURE RANGE: 7—105 atm.	Used for hydrotreating, hydrodenitrification, stabilization and saturation of polyaromatics in petroleum fractions. Available also as C 20-8.

GAS PURIFICATION

TYPE OF CATALYST: *COPPER CHEZA 43—00*

Manufacturer	Characteristics	Operating conditions	Remarks
Chemical Works of CSF	CONTENT wt % Cu 15 Na_2O max. 0.1 Loss on ignition (650°C): max. 10 CARRIER: Al_2O_3 FORM: tablets SIZE: Diameter (mm) 10 Length (mm) 6—10 ABD (g/cm^3) 0.7 STRENGTH (kg/cm^2) 150	TEMPERATURE RANGE: 300°—600°C PRESSURE RANGE: n.a. SPACE VELOCITY (VHSV): 500 — 1,000 h^{-1}	It is used for catalytic burning flammable gases in inert gases by the addition of oxygen at least a minimum stoichiometric ratio to the present flammable gases.

TYPE OF CATALYST: *NICKEL-TUNGSTEN CHEZA 34—00*

Manufacturer	Characteristics	Operating conditions	Remarks
Chemical Works of CSF	CONTENT wt % WO_3 25—30 NiO 5—7 Na_2O 0.1 CARRIER: Al_2O_3 FORM: tablets SIZE: Diameter (mm) 10 Length (mm) 0—20 ABD (g/cm^3) 0.9 STRENGTH (kg/cm^2) 200	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	For the refining of hydrocarbons from oxygen, nitrogen, sulphur, arsen compounds.

CATALYTIC AIR PURIFICATION

TYPE OF CATALYST: *DOPED Cu-CHROMIC OXIDE A-38.MK*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT n.a. CARRIER: γ Al_2O_3 FORM: balls SIZE: Diameter (mm) 4—6 Length (mm) n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The other use is combustion of gases.

GAS PURIFICATION, e.g. OF H_2, N_2 AND NOBLE GASES

TYPE OF CATALYST: *PALLADIUM E-56.H PURICAT*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt% Palladium CARRIER: aluminium silicate FORM: tablets SIZE: Diameter (mm) 5 Length (mm) 3 ABD (g/cm^3) 0.7 STRENGTH (kg/cm^2) 50	TEMPERATURE RANGE: room temperature to 400°C PRESSURE RANGE: n.a. LIFE: 10,000 hours	Detonating gas reaction at room temperature (production of protective gas); H_2O_2 recombination in boiling water-reactors. Precious metal content usually 0.1%, 0.15%, 1%, 5% and 10%.

AIR PURIFICATION

TYPE OF CATALYST: *PALLADIUM E-293.P*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt% Palladium CARRIER: Al_2O_3 FORM: bodies SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	For purification of air (Decatox^{R} process). Precious metal content usually 0.1%, 0.15%, 1%, 5% and 10%.

PURIFICATION OF ORGANIC GASES AND VAPOURS

TYPE OF CATALYST: *PLATINUM PLATINUM ASBESTOS*

Manufacturer	Characteristics	Operating conditions	Remarks
Doduco	CONTENT wt% Platinum CARRIER: asbestos FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

PURIFICATION OF GAS STREAM

TYPE OF CATALYST: *PALLADIUM G-75*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt% Palladium CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See chapter on hydrogenation of olefinic bonds.

TYPE OF CATALYST: *PALLADIUM G-77*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt% Palladium CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See chapter on hydrogenation of acetylene, diolefins.

TYPE OF CATALYST: *PLATINUM G-43*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Pt 0.1 Ni 3 CARRIER: alumina FORM: tablets SIZE: Diameter (mm) 5 Length (mm) 5 ABD (g/cm^3) 1 SA (m^2/g) 212 STRENGTH (kg/cm^2) (DWL) no less than 15	TEMPERATURE RANGE: 860°C PRESSURE RANGE: n.a. LIFE: more than 8 years	Suitable for removal of higher concentrations of oxygen, hydrogen and nitrogen oxide.

GAS PURIFICATION

TYPE OF CATALYST: *MOLECULAR SIEVES ALITE 150; 180*

Manufacturer	Characteristics	Operating conditions	Remarks
Grande Paroisse	CONTENT n.a. CARRIER: n.a. FORM: powder; granules SIZE: Diameter (mm) (granules) 1.8—3 ABD (g/cm^3) 0.850 SA (m^2/g) (powder) 500 Pore diameter: 6 Å	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See Alite 1030. They possess a structure similar to a natural zeolite-mordenite (Alite 150). Alite 180 is the acid form of the Alite 150.

TYPE OF CATALYST: *MOLECULAR SIEVES ALITE 1030, 1040, 1050*

Manufacturer	Characteristics	Operating conditions	Remarks
Grande Paroisse	CONTENT wt % Molar ratio Si/Al: 2 SiO_2 41—43 Al_2O_3 34—35.5 Na_2O 3.5—17 CaO 15—1.5 CARRIER: n.a. FORM: extrusions SIZE: Diameter (mm) 1.6—3 Length (mm) n.a. STRENGTH (kg/cm^2) 8—12 Pore diameter: 3—5 Å	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	They are molecular sieves, a synthetic zeolite type A. They are used in fluid bed or fixed bed processes. Applications: air purification; as catalyst carrier; for the reforming, hydrocracking and cracking processes.

PURIFICATION OF GAS STREAM

TYPE OF CATALYST: *COPPER Cu-1900.S*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt% CuO 5 CARRIER: high fired inert alumina FORM: spheres SIZE: Diameter (mm) 1.2 SA (m^2/g) 1 PV (cm^3/g) 0.07	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Removal of oxygen, carbon monoxide or hydrogen from gas streams.

PURIFICATION

TYPE OF CATALYST: *NICKEL Ni-4303.E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt% Nickel 6 Tungsten 19 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 2.1 Length (mm) n.a. ABD (g/cm^3) 0.8 SA (m^2/g) 152 PV (cm^3/g) 0.54	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for the pretreatment of hydrocracker feedstocks, denitrification and desulphurization.

TYPE OF CATALYST: *NICKEL TUNGSTEN Ni-4301.E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt% Nickel 6 Tungsten 19 CARRIER: silica-alumina FORM: extrusions SIZE: Diameter (mm) 2.1 Length (mm) n.a. ABD (g/cm^3) 0.96 SA (m^2/g) 228 PV (cm^3/g) 0.37	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for the pretreatment of hydrocracker feedstocks, saturation of cyclic aromatic compounds, denitrogenation and desulphurization.

TYPE OF CATALYST: *NICKEL TUNGSTEN Ni-4309.E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt% Nickel 5 Tungsten 10 Boron 3 (promotor) CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 1.6; 2.1; 3.2 ABD (g/cm^3) 0.9 SA (m^2/g) 150 PV (cm^3/g) 0.3	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Pressure hydrogen refining of petroleum derivatives of all types and boiling ranges; for reduction of sulphur, nitrogen and oxygen compounds; for removal of metallic impurities; for hydrogenation of unsaturated compounds. Used for high pressure catcracker pretreatment.

GAS PURIFICATION (THE DEOXO PRINCIPLE)

TYPE OF CATALYST: *DEOXO D; DN; DS; M*

Manufacturer	Characteristics	Operating conditions	Remarks
W.C.Heraeus GmbH	CONTENT n.a. CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	D, DN — for removal of oxygen from hydrogen or from gases containing hydrogen. DS — same as D, DN, but for wet gases. M — for removal of hydrogen, from oxygen or from gases containing oxygen.

GAS PURIFICATION

TYPE OF CATALYST: *L; D; R; P; T; S*

Manufacturer	Characteristics	Operating conditions	Remarks
W.C. Heraeus GmbH	CONTENT Noble metals, noble metals mixture or non-noble metals CARRIER: ceramic FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Application: L is used in lacquer plants; D is used as purifier of Diesel exhaust gases; R is used for gas purification; P is used in impregnating plants; T is used as a dryer; S has diverse applications.

EXHAUST GAS PURIFICATION

TYPE OF CATALYST: *NEW HONEYCOMB-SHAPED CATALYST*

Manufacturer	Characteristics	Operating conditions	Remarks
W.C. Heraeus GmbH	CONTENT n.a. CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: 600°—750°C PRESSURE RANGE: n.a.	

PURIFICATION

TYPE OF CATALYST: *NICKEL RCH-52/35.TS*

Manufacturer	Characteristics	Operating conditions	Remarks
Farbwerke Hoechst AG	CONTENT wt % Ni 52 CARRIER: Kieselguhr FORM: powder; tablets SIZE: Diameter (mm) 6 Length (mm) 5 ABD (g/cm^3) 0.5; 1	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Refining of feedstocks which contain poisons in big quantities. See also RCH-50/35.TS.

CHLORINE REMOVAL

TYPE OF CATALYST: *ICI-59–1; 59–3*

Manufacturer	Characteristics	Operating conditions	Remarks
Imperial Chemical Industries Ltd	CONTENT n.a. CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See chapter on desulphurization. Guards for low temperature CO shift.

TYPE OF CATALYST: *PLATINUM KCE-3010.A*

Manufacturer	Characteristics	Operating conditions	Remarks
Kali Chemie Engelhard	CONTENT wt % Platinum CARRIER: n.a. FORM: extrusions SIZE: Diameter (mm) 4 Length (mm) 10 ABD (g/cm³) 1	TEMPERATURE RANGE: 400°—800°C PRESSURE RANGE: n.a.	See KCE-3795.A

TYPE OF CATALYST: *PLATINUM KCE-3366*

Manufacturer	Characteristics	Operating conditions	Remarks
Kali Chemie Engelhard	CONTENT wt % Pt 0.1 CARRIER: special FORM: extrusions SIZE: Diameter (mm) 2.5 Length (mm) 2.5 ABD (g/cm³) 0.9	TEMPERATURE RANGE: 400°—800°C PRESSURE RANGE: n.a.	See KCE-3795.A

TYPE OF CATALYST: *PLATINUM KCE-3778; KCE-3778.A*

Manufacturer	Characteristics	Operating conditions	Remarks
Kali Chemie Engelhard	CONTENT wt % Pt 0.05 CARRIER: clay/alumina FORM: extrusions SIZE: Diameter (mm) 4 Length (mm) 4—10 ABD (g/cm³) 1—1.07	TEMPERATURE RANGE: 400°—800°C PRESSURE RANGE: n.a.	See KCE-3795.A

TYPE OF CATALYST: *PLATINUM KCE-3795; KCE-3795.A*

Manufacturer	Characteristics	Operating conditions	Remarks
Kali Chemie Engelhard	CONTENT wt % Pt 0.1 CARRIER: clay/alumina FORM: extrusions SIZE: Diameter (mm) 4 Length (mm) 4—10 ABD (g/cm^3) 1	TEMPERATURE RANGE: 400°—800°C PRESSURE RANGE: n.a.	The KCE catalysts are used for catalytic removal of CO_2, CO, H_2, H_2S (burning to SO_2), organic sulphur, ammonia, amines, cyanhydric acid.

EXHAUST GAS PURIFICATION

TYPE OF CATALYST: *PLATINUM PTX*

Manufacturer	Characteristics	Operating conditions	Remarks
Kali Chemie Engelhard	CONTENT wt % Pt CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Also PTX.4 PTX.5 PTX.6

PURIFICATION OF GASES

TYPE OF CATALYST: *COPPER KONTAKT 4492*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT wt % Copper oxide CARRIER: magnesium silicate FORM: tablets SIZE: Diameter (mm) 5 Length (mm) n.a. ABD (g/cm^3) 0.95 STRENGTH (kg/cm^2) 450±50	TEMPERATURE RANGE: <120°C PRESSURE RANGE: n.a.	Removal of traces of O_2 and CO. It can also be used in hydrogenation and desulphurization process.

TYPE OF CATALYST: *NICKEL KONTAKT 6525*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT wt % Nickel oxide CARRIER: alumina FORM: tablets SIZE: Diameter (mm) 5 Length (mm) n.a. ABD (g/cm^3) 0.7—1.1 STRENGTH (kg/cm^2) 80—100	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Removal of traces of O_2 and CO from Ar, N_2, CO_2.

PURIFICATION OF EXHAUST GASES

TYPE OF CATALYST: *PLATINUM KONTAKT 7713*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT wt % Platinum CARRIER: γ alumina FORM: spheres SIZE: Diameter (mm) 4—6 Length (mm) n.a. ABD (g/cm^3) 0.75—0.85 SA (m^2/g) 170—200 PV (cm^3/g) 0.3—0.5 STRENGTH (kg/cm^2) 7	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Also Kontakt 7713/TK. Spheres of 2—4 mm diameter: ABD (g/cm^3) 0.58—0.65 SA (m^2/g) 170—200 PV (cm^3/g) 0.3—0.5 STRENGTH (kg/cm^2) 12.

PURIFICATION OF GASES

TYPE OF CATALYST: *ADSORBENT MASS MIP-2*

Manufacturer	Characteristics	Operating conditions	Remarks
Montedison S.p.A.	CONTENT wt % Sulphur 10 Activated carbon 90 CARRIER: activated carbon FORM: pellets SIZE: (mm) 2×4 ABD (g/cm^3) 0.56 SA (m^2/g) 750	TEMPERATURE RANGE: 0°—100°C PRESSURE RANGE: 1—30 atm. SPACE VELOCITY: (VHSV) 1000 — 10000 h^{-1}	Adsorbent for the mercury removal from gases.

TYPE OF CATALYST: *ADSORBENT MASS MIS-2*

Manufacturer	Characteristics	Operating conditions	Remarks
Montedison S.p.A.	CONTENT wt % Sulphur 10 Activated carbon 90 CARRIER: activated carbon FORM: extrusions SIZE: Diameter (mm) 4 Length (mm) 6—9 ABD (g/cm^3) 0.40 SA (m^2/g) 1,100	TEMPERATURE RANGE: 0°—100°C PRESSURE RANGE: 1—30 atm. SPACE VELOCITY (VHSV): 1,000—10,000 h^{-1}	Adsorbent for the mercury removal from gases.

PURIFICATION OF WASTE GASES

TYPE OF CATALYST: *COPPER DO-3*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Copper oxide CARRIER: alumina FORM: balls SIZE: Diameter (mm)2—4; 4—6 Length (mm) n.a. ABD (g/cm^3) 0.9 SA (m^2/g) 130 PV (cm^3/g) 0.5 STRENGTH (kg/cm^2) > 10	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Elimination of O_2 and/or CO in a gas containing H_2. Methanation.

PURIFICATION OF INDUSTRIAL WASTE GASES

TYPE OF CATALYST: *COPPER PC-183 PROTOXAL*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Copper oxide CARRIER: alumina FORM: balls SIZE: Diameter (mm) 2—4; 4—6 Length (mm) n.a. ABD (g/cm^3) 0.7 SA (m^2/g) 130 PV (cm^3/g) 0.6 STRENGTH (kg/cm^2) >5	TEMPERATURE RANGE: 100°—450°C PRESSURE RANGE: n.a.	It is also used for the elimination of solvents and for methanation.

PURIFICATION OF WASTE GASES

TYPE OF CATALYST: *COPPER-PALLADIUM DO-4*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Palladium Copper oxide CARRIER: alumina FORM: balls SIZE: Diameter (mm) 2—4; 4—6 Length (mm) n.a. ABD (g/cm^3) 0.7 SA (m^2/g) 250 PV (cm^3/g) 0.6 STRENGTH (kg/cm^2) >10	TEMPERATURE RANGE: 70°—225°C PRESSURE RANGE: n.a.	DO-5 has the same use. Elimination of CO and H_2 in a gas with injection of O_2. Methanation.

PURIFICATION OF INDUSTRIAL WASTE GASES

TYPE OF CATALYST: *CHROMIUM PC-173 PROTOXAL*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Cr_2O_3 CARRIER: alumina FORM: balls SIZE: Diameter (mm) 2—4; 4—6 Length (mm) n.a. ABD (g/cm^3) 0.7 SA (m^2/g) 260 PV (cm^3/g) 0.6 STRENGTH (kg/cm^2) >5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Uses: Elimination of hydrocarbons-post combustion of engine gases. Methanation.

TYPE OF CATALYST: *MANGANESE PC-193 PROTOXAL*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Mn_2O_3 CARRIER: alumina FORM: balls SIZE: Diameter (mm) 2—4; 4—6 Length (mm) n.a. ABD (g/cm^3) 0.7 SA (m^2/g) 130 PV (cm^3/g) 0.6 STRENGTH (kg/cm^2) > 5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Elimination of hydrocarbons.

PURIFICATION OF WASTE GASES

TYPE OF CATALYST: *NICKEL PALLADIUM PC-247*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Nickel oxide Palladium CARRIER: alumina FORM: balls SIZE: Diameter (mm) 6—10 Length (mm) n.a. ABD (g/cm^3) 0.75 SA (m^2/g) 30 PV (cm^3/g) 0.5 STRENGTH (kg/cm^2) >15	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Special for aluminium plant waste gases methanation.

TYPE OF CATALYST: *PALLADIUM DO-2*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Palladium CARRIER: alumina FORM: balls SIZE: Diameter (mm) 2—5; 5—8 Length (mm) n.a. ABD (g/cm^3) 0.75 SA (m^2/g) 300 PV (cm^3/g) 0.5 STRENGTH (kg/cm^2) >10	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Elimination of O_2 and/or H_2 in a gas with less than 5000 ppm CO. Methanation.

DEODORIZATION

TYPE OF CATALYST: *BASE METALS ST-500*

Manufacturer	Characteristics	Operating conditions	Remarks
Sakaj Chemical Industry Co. Ltd.	CONTENT Base metals, carrier and occasionally noble metals CARRIER: n.a FORM: tablets SIZE: n.a.	TEMPERATURE RANGE: 150°—400°C PRESSURE RANGE: n.a.	Use for deodorizing of exhausting solvent vapour from baking finish, printing baking enamel wire, adhesive process; deodorizing of odorous gas from sewerage, oil and fats, plant, craft pulp plant.

FOR CATALYTIC ODOUR CONTROL INSTALLATIONS

TYPE OF CATALYST: *PLATINUM FAMILY ALL METAL CATALYSTS*

Manufacturer	Characteristics	Operating conditions	Remarks
UOP, Air Correction Division	CONTENT Metals of the platinum family firmly bonded on the support ribbon CARRIER: thin alloy ribbon which is crimped FORM: mat form SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a. LIFE: 3—5 years	All metal catalysts elements destroy odours by converting oven exhaust fumes to clean, odourless gases in a single-step combustion reaction.

PURIFICATION OF GASES

TYPE OF CATALYST: *ZEOSORB 3A; 4A; 5A; 10X; 13X; 51M*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Farbenfabrik Wolfen	CONTENT Synthetic zeolites (molecular sieves) Metal alumo-silicates CARRIER: n.a. FORM: extrusions, powders, balls SIZE (mm): powder: 10^{-3} balls: 1.6—2.2; 2.2—2.5; extrusions: 2, 3, 4, 5, 6 Length (mm) 5—15 ABD (g/cm^3) 0.5—0.8 STRENGTH (kg/cm^2) 20—263	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Drying agents, adsorbents, gas separation by selective adsorption, purification of gaseous hydrocarbons and inert gases. Selective separation of normal paraffins C_5—C_8 from benzene fractions. Desulphurization agents.

Purification by combustion

FLAMELESS GAS COMBUSTION (INFRARED LAMP)

TYPE OF CATALYST: *Pd E-71.P*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT n.a. CARRIER: asbestos FORM: fibre SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Precious metal content usually 0.1%, 0.15%, 1%, 5% and 10%.

TYPE OF CATALYST: *Pt F-71.P*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT n.a. CARRIER: asbestos FORM: fibre SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Precious metal content usually 0.1%, 0.15%, 1%, 5% and 10%.

COMBUSTION OF GASES AND VAPOURS AT HIGH TEMPERATURE

TYPE OF CATALYST: *PALLADIUM ACTIPAL*^{R}

Manufacturer	Characteristics	Operating conditions	Remarks
Doduco	CONTENT n.a. CARRIER: n.a. FORM: Raschig rings SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

COMBUSTION AT HIGH TEMPERATURE

TYPE OF CATALYST: *PALLADIUM* *PALLADIUM-ASBESTOS*			
Manufacturer	Characteristics	Operating conditions	Remarks
Doduco	CONTENT n.a. CARRIER: asbestos FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

Purification by hydrotreating

PURIFICATION BY HYDROTREATING

TYPE OF CATALYST: *NICKEL MOLYBDENUM HDS-3; HDS-3A*

Manufacturer	Characteristics	Operating conditions	Remarks
Cyanamid International	CONTENT wt % NiO 3.0—4.0 MoO_3 14.5—16.0 Na_2O max. 0.04 Loss on ignition: max. 2.0 CARRIER: n.a. FORM: extrusions SIZE: Diameter (mm) 1.5—3 ABD (g/cm^3) 0.6—0.7 SA (m^2/g) 180 PV (cm^3/g) 0.6 STRENGTH (kg/cm^2) 6.7—7.7	TEMPERATURE RANGE: 200°—400°C PRESSURE RANGE: 10—60 atm. SPACE VELOCITY (LHSV): 5 h^{-1}	Used for removal of nitrogen and polyaromatics saturation. It is particularly adapted for hydrotreating of naphthas containing nitrogen. Selective for polyaromatics, olefins and nitrogen removal.

TYPE OF CATALYST: *NICKEL MOLYBDENUM AERO HDS-9; HDS-9A*

Manufacturer	Characteristics	Operating conditions	Remarks
Cyanamid International	CONTENT wt % NiO 3.0—4.0 MoO_3 17.5—18.5 Na_2O max. 0.04 Fe max. 0.05 Loss on ignition: max. 2.0 CARRIER: n.a. FORM: extrusions SIZE: Diameter (mm) 1.2—2.5 Length (mm) n.a. ABD (g/cm^3) 0.7—0.8 STRENGTH (kg/cm^2) min. 5.5	TEMPERATURE RANGE: 300°—370°C PRESSURE RANGE: 50 atm.	Applications: Recommended for: (a) Processing stocks containing high percentages of nitrogen; (b) Pretreatment of reformer feedstock when quality demands are stringent; (c) Cocker effluents; (d) Cat-Cracker feed preparation; (e) Turbine fuel smoke point improvement; (f) Selected lube oil processing situations; (g) New ventures.

DECOMPOSITION OF HYDROCARBONS

TYPE OF CATALYST: *ZIRCONIUM GPE-5*

Manufacturer	Characteristics	Operating conditions	Remarks
Grande Paroisse	CONTENT wt % ZrO_2—MgO and additives CARRIER: alumina FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for the decomposition of hydrocarbons of which propane, butane refinery gas and naphtha rich in ethylene.

PURIFICATION BY HYDROTREATING

TYPE OF CATALYST: *NICKEL MOLYBDENUM HT-100.E*

Manufacturer	Characteristics	*Operating conditions*	Remarks
Harshaw	CONTENT wt % NiO 3.8 MoO$_3$ 16.8 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 1.6; 3 ABD (g/cm^3) 0.608 SA (m^2/g) 190 PV (cm^3/g) 0.54 STRENGTH (kg/cm^2) 6.3—9	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The sulphided form of this catalyst is used in hydrotreating naphtha for reforming, lube oil for purification, gas oil for catalytic cracking furnace oil, diesel fuel, for sulphur and metals removal. Silica promoted.

PURIFICATION OF HYDROCARBONS

TYPE OF CATALYST: *NICKEL TUNGSTEN KONTAKT 8378*

Manufacturer	Characteristics	*Operating conditions*	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT wt % NiO, WO$_3$ CARRIER: aluminium silicate FORM: cylinders SIZE: Diameter (mm) 10 Length (mm) 10 ABD (g/cm^3) 0.8 STRENGTH (kg/cm^2) 480	TEMPERATURE RANGE: 360°—420°C PRESSURE RANGE: 70—150 atm.	

Denitrogenation

PURIFICATION

TYPE OF CATALYST: *NICKEL MOLYBDENUM BASF M-8—20*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % MoO_3 10 NiO 4 CARRIER: activated alumina FORM: extrusions; pellets SIZE: Diameter (mm) 1.5; 3 Length (mm) 3; 5 ABD (g/cm^3) 0.6; 0.76 SA (BET) (m^2/g) 200 PV (cm^3/g) 0.5 STRENGTH (kg/cm^2): *extrusions*: at right angles to direction of extrusion: 1.3 *pellets*: bursting pressure at the faces: 300 TS (°C) up to about 500	TEMPERATURE RANGE: 280°—400°C PRESSURE RANGE: n.a.	Used for deoxidation, desulphurization, denitrification.

NITROGEN OXIDE REMOVAL

TYPE OF CATALYST: *PLATINUM-NICKEL C-53—1*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Platinum and nickel CARRIER: alumina FORM: tablets SIZE: Diameter (mm) 6 Length (mm) 6 ABD (g/cm^3) 0.96	TEMPERATURE RANGE: 340°—870°C PRESSURE RANGE: 1—10 atm.	Used in the processes for nitrogen oxide removal and power recovery from nitric acid tail gas streams.

REMOVAL OF NITRIC OXIDE

TYPE OF CATALYST: *PALLADIUM-RUTHENIUM EH-22.P*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT n.a. CARRIER: γ Al_2O_3 FORM: balls SIZE: Diameter (mm) 4—6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Precious metal content usually 0.1%, 0.15%, 1%, 5% and 10%. It is used for the purification of synthesis gas.

DENITROGENATION OF HYDROCARBONS BY HYDROTREATING

TYPE OF CATALYST: *COBALT-MOLYBDENUM CoMo-0603.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % CoO 3 MoO_3 9 CARRIER: alumina FORM: tablets SIZE: Diameter (mm) 3 Length (mm) 3 ABD (g/cm^3) 1.2 SA (m^2/g) 166 PV (cm^3/g) 0.40 STRENGTH (kg/cm^2) 10	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used for desulphurization. A non-silicated catalyst.

AIR POLLUTION CONTROL

TYPE OF CATALYST: *PLATINUM HONEY CATALYST*

Manufacturer	Characteristics	Operating conditions	Remarks
Johnson Matthey Chemicals Ltd	CONTENT wt % Platinised ceramic honey combination CARRIER: ceramic FORM: blocks SIZE (mm) 30×30	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Reduces the effluent nitrogen oxide gases in nitric acid plants.

HYDRODENITRIFICATION

TYPE OF CATALYST: *COBALT-MOLYBDENUM HR-304*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % CoO 5 MoO_3 13 SiO_2 1 SO_4 1 Na_2O <0.6 Al_2O_3 balance to 100 Loss on ignition (550°C): <1% CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 1.5—2.5 ABD (g/cm^3) 0.65 SA (m^2/g) 300 PV (cm^3/g) 0.5 STRENGTH (kg/cm^2) 13	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for hydrodesulphurization and hydrodenitrification of gasolines, naphthas, kerosenes, gas-oils and heavy cuts.

HYDRODENITRIFICATION OF KEROSENE, GAS-OILS, HEAVY CUTS

TYPE OF CATALYST: *COBALT-MOLYBDENUM HR-306*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT n.a. CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 1.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

HYDRODENITRIFICATION

TYPE OF CATALYST: *NICKEL-COBALT-MOLYBDENUM HRF-121*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See chapter on hydrodesulphurization.

HYDRODENITRIFICATION OF HEAVY CUTS (ATMOSPHERIC RESIDUES)

TYPE OF CATALYST: *NICKEL-MOLYBDENUM HRF-141*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % MoO_3 12 NiO 3.5 CARRIER: alumina FORM: balls SIZE: Diameter (mm) 1.25—2.5 ABD (g/cm^3) 0.9 SA (m^2/g) 250 PV (cm^3/g) 0.40 STRENGTH (kg/ball) >4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

HYDRODENITRIFICATION

TYPE OF CATALYST: *NICKEL-MOLYBDENUM HR-143*			
Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See chapter on hydrodesulphurization.

TYPE OF CATALYST: *NICKEL-MOLYBDENUM HR-346*			
Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT n.a. CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 1.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

Desoxygenation

REMOVAL OF OXYGEN FROM HYDROGEN, NITROGEN, ARGON

TYPE OF CATALYST: *PALLADIUM CHEZA 40—00*

Manufacturer	Characteristics	Operating conditions	Remarks
Chemical Works of CSF	CONTENT wt % Palladium CARRIER: Al_2O_3 FORM: balls SIZE: Diameter (mm) 2—4 ABD (g/cm³) 0.7	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

DESOXYGENATION OF INERT GAS STREAM BY HYDROGENATION OF O_2

TYPE OF CATALYST: *PALLADIUM C-54—1; C-54—7*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Palladium CARRIER: alumina FORM: spheres SIZE: n.a. ABD (g/cm³) 0.7	TEMPERATURE RANGE: 20°—400°C PRESSURE RANGE: 1—50 atm.	

REMOVAL OF O_2, H_2 OR CO_2 FROM VARIOUS GASES

TYPE OF CATALYST: *COPPER ACTIMET 13*

Manufacturer	Characteristics	Operating conditions	Remarks
Doduco	CONTENT n.a. CARRIER: alumina FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used for dissociation of methanol (production of inert gas).

REMOVAL OF OXYGEN FROM N_2

TYPE OF CATALYST: *PALLADIUM DEDUX*

Manufacturer	Characteristics	Operating conditions	Remarks
Doduco	CONTENT n.a. CARRIER: alumina FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used also for the removal of oxygen from H_2 and other gases.

ELIMINATION OF OXYGEN

TYPE OF CATALYST: *PLATINUM COEX*

Manufacturer	Characteristics	Operating conditions	Remarks
Doduco	CONTENT n.a. CARRIER: alumina FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used also for the oxidation of hydrocarbons, carbon monoxide etc.

PURIFICATION

TYPE OF CATALYST: *PLATINISED QUARTZWOOL*

Manufacturer	Characteristics	Operating conditions	Remarks
Doduco	CONTENT n.a. CARRIER: quartzwool FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Oxidizing catalyst, for instance flameless propane condensation.

REMOVAL OF OXYGEN

TYPE OF CATALYST: *COPPER G-108.A; G-108.B*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % G—108.A: Cu 16 G—108.B: Cu 30 CARRIER: special silica FORM: spheres SIZE: Diameter (mm) 5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	These catalysts are used for removing traces of oxygen from reducing gases or viceversa, in cyclic or continuous systems.

REMOVAL OF HYDROGEN AND OXYGEN

TYPE OF CATALYST: *PALLADIUM G-74*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT n.a. CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See chapter on hydrogenation of olefinic bonds.

GAS PURIFICATION (DESOXYGENATION)

TYPE OF CATALYST: *COPPER-MAGNESIUM GPD-5*

Manufacturer	Characteristics	Operating conditions	Remarks
Grande Paroisse	CONTENT wt % CuO, MgO, Al_2O_3, ZrO_2 CARRIER: n.a. FORM: pellets SIZE: Diameter (mm) 12—14	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	For action of hydrogen on oxygen of fumes to render them inert.

REMOVAL OF OXYGEN OR HYDROGEN FROM GAS STREAM

TYPE OF CATALYST: *COPPER Cu-0307.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % CuO 99 CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 3 Length (mm) 3 ABD (g/cm^3) 1.4 SA (m^2/g) 5 PV (cm^3/g) 0.26 STRENGTH (kg/cm^2) approx. 10	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

REMOVAL OF OXYGEN FROM GAS STREAM

TYPE OF CATALYST: *COPPER Cu-0803.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % CuO 10 CARRIER: high activity alumina FORM: tablets SIZE: Diameter (mm) 3 Length (mm) 3 ABD (g/cm^3) 0.85 SA (m^2/g) 137 PV (cm^3/g) 0.42 STRENGTH (kg/cm^2) 12	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It removes trace amounts of oxygen.

DESOXYGENATION

TYPE OF CATALYST: *NICKEL RCH-50/35.TS*

Manufacturer	Characteristics	Operating conditions	Remarks
Farbwerke Hoechst AG	CONTENT wt % Nickel 50 CARRIER: Kieselguhr FORM: powder; tablets SIZE: Diameter (mm) 6 Length (mm) 5 ABD (g/cm^3) 0.5 (powder) 1 (tablets)	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It can also be used for hydrogenation of olefins to saturated hydrocarbons; of aromatic hydrocarbons; of phenol.

TYPE OF CATALYST: *NICKEL RCH-55/5.PYR*

Manufacturer	Characteristics	Operating conditions	Remarks
Farbwerke Hoechst AG	CONTENT wt % Ni 57 CARRIER: Kieselguhr FORM: tablets SIZE: Diameter (mm) 6 Length (mm) 5 ABD (g/cm^3) 0.8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for desoxygenation of hydrocarbons; for the refining of paraffins by hydrogenation; to remove oxygen from various gases.

OXIDATIVE PURIFICATION OF WASTE GASES

TYPE OF CATALYST: *PALLADIUM KONTAKT 7791*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT wt % Palladium CARRIER: metallic FORM: cuttings SIZE: Diameter (mm) 0.1—0.3 Length (mm) 2—5 ABD (g/cm^3) 0.2±0.03	TEMPERATURE RANGE: 300°—500°C PRESSURE RANGE: n.a.	It is used for the purification of waste gases, by combustion.

TYPE OF CATALYST: *PLATINUM KONTAKT 7790*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT wt % Platinum CARRIER: n.a. FORM: cuttings SIZE: Diameter (mm) 0.1—0.3 Length (mm) n.a. ABD (g/cm^3) 0.2	TEMPERATURE RANGE: 600°—800°C PRESSURE RANGE: n.a.	Purification of waste gases containing solvents from varnishing shops.

K. Reforming

Steam reforming
Petroleum refining
Naphtha reforming

Steam reforming

CYCLIC STEAM REFORMING OF LIGHT HYDROCARBONS

TYPE OF CATALYST: *NICKEL DaN and DN*			
Manufacturer	**Characteristics**	**Operating conditions**	**Remarks**
Azote et produits chimiques S.A.	CONTENT wt % Nickel CARRIER: alumina FORM: rings; cylinders SIZE Diameter (mm) 15; 6 Length (mm) 15 ABD (g/cm^3) 1.3—1.4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	DaN catalyst enables the processing of either naphthas or natural gas. DN is used in many town gas plants.

CYCLIC STEAM REFORMING OF FUEL OILS AND NAPHTHAS

TYPE OF CATALYST: *NICKEL SIN*			
Manufacturer	**Characteristics**	**Operating conditions**	**Remarks**
Azote et produits chimiques S.A.	CONTENT wt % Nickel CARRIER: silica-alumina FORM: cylinders SIZE: Diameter (mm) 15 Length (mm) 15 ABD (g/cm^3) 1.45	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See Nickel YN.

CYCLIC STEAM REFORMING OF GASEOUS HYDROCARBONS

TYPE OF CATALYST: *NICKEL XN*			
Manufacturer	**Characteristics**	**Operating conditions**	**Remarks**
Azote et produits chimiques S.A.	CONTENT wt % Nickel CARRIER: silica-alumina FORM: cylinders SIZE: Diameter (mm) 15 Length (mm) 15 ABD (g/cm^3) 1.25	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	XN is highly suitable for cyclic cracking of natural gases from various sources and of methane rich industrial gases.

CYCLIC REFORMING OF LOW SULPHUR NAPHTHAS

TYPE OF CATALYST: *NICKEL YCN*

Manufacturer	Characteristics	Operating conditions	Remarks
Azote et produits chimiques S.A.	CONTENT wt % Nickel CARRIER: magnesia FORM: cylinders SIZE: Diameter (mm) 15 Length (mm) 15 ABD (g/cm^3) 1.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The support for YCN has been specially developed to avoid any combination of nickel.

CYCLIC STEAM REFORMING OF FUEL OILS AND NAPHTHAS

TYPE OF CATALYST: *NICKEL YN*

Manufacturer	Characteristics	Operating conditions	Remarks
Azote et produits chimiques S.A.	CONTENT wt % Nickel CARRIER: magnesia FORM: nodules SIZE: Diameter (mm) 10—20 Length (mm) n.a. ABD (g/cm^3) 1.85	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used in the cyclic operation of town gas plants for direct production of gas of gross heating value.

AUTOTHERMIC STEAM REFORMING OF HYDROCARBONS

TYPE OF CATALYST: *PLATINUM-NICKEL DaNS*

Manufacturer	Characteristics	Operating conditions	Remarks
Azote et produits chimiques S.A.	CONTENT wt % Platinum-nickel active elements CARRIER: n.a. FORM: rings SIZE: Diameter (mm) 15.6 Length (mm) 15 ABD (g/cm^3) 1.3	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	DaNS catalyst is a dual purpose catalyst used as a „shock bed" associated with XN catalyst in autothermic reforming plants. It carries out both the exothermic oxidation of a portion of the hydrocarbon and allows the simultaneous initiation of the endothermic reforming reaction which is going on, in the presence of XN catalyst placed just above.

REFORMING OF HYDROCARBONS

TYPE OF CATALYST: *NICKEL BASF G-1—12*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % Ni 3 CARRIER: high mechanical and thermal stability FORM: spheres SIZE: Diameter (mm) 18 Length (mm) n.a. ABD (g/cm^3) 1.8 TS (°C) up to 1,400	TEMPERATURE RANGE: 700°—1,200°C PRESSURE RANGE: n.a.	The catalyst is employed in continuous and cyclic reforming processes for the production of town gas and synthesis gas. It is used at atmospheric or elevated pressure. It is used for the reforming of hydrocarbons such as methane, LPG and LPF with steam and oxygen or air.

STEAM REFORMING OF HYDROCARBONS

TYPE OF CATALYST: *NICKEL C-11—6.A*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % NiO 5±0.2 CARRIER: alumina FORM: Raschig rings SIZE (mm) 15×15×16 ABD (g/cm^3) 1.296 STRENGTH (kg/cm^2) 1,500	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It has been developed for the cyclic reforming of liquid or gaseous hydrocarbons, which may contain sulphur to produce gas of gross heating value. The catalyst is poisoned by Bi, lead, arsenic, alkaline metals, H_2SO_4.

TYPE OF CATALYST: *NICKEL C-11—6.B*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Ni 3 CARRIER: magnesia FORM: nodules SIZE: Diameter (mm) 10—20 ABD (g/cm^3) 1.840 SA (m^2/g) 0.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	A cyclic reforming catalyst for the cyclic reforming of fuel oils and sulphur containing naphthas. The catalyst poisons are lead, arsenic ,vanadium and alkaline metals.

STEAM REFORMING OF NAPHTHA

TYPE OF CATALYST: *NICKEL C-11—7*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International (from 1964); Grande Paroisse (from 1955)	CONTENT wt % NiO CARRIER: alumino-silica FORM: Raschig rings SIZE: Diameter (mm) 16; 16 Length (mm) 16; 10 ABD (g/cm^3) 1.6	TEMPERATURE RANGE: below 1,000°C PRESSURE RANGE: 1—40 atm. LIFE: 5 years SPACE VELOCITY: 0.5—3 h^{-1}	Used in externally fired tubes packed with catalyst for production of rich gases. The catalyst loading composes C-11 — 7 at the inlet and C-11—9 at the outlet.

PRIMARY REFORMING OF NAPHTHA

TYPE OF CATALYST: *NICKEL CD—RN-33.B*

Manufacturer	Characteristics	Operating conditions	Remarks
Fertilizer Corporation of India (FCI)	CONTENT wt % Nickel CARRIER: rugged alumina FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: 800°—900°C PRESSURE RANGE: up to 35 atm. SPACE VELOCITY: 0.5—0.9 h^{-1}	It is recommended for steam reforming naphtha for production of methanol synthesis gas, or hydrogen where very low residual methane content is desired.

STEAM REFORMING OF HYDROCARBONS

TYPE OF CATALYST: *NICKEL G-56.H*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % 1 2 T Ni 17—20 13—15 15 Alkali 0.5 — — SiO_2 <0.2 <0.2 <0.2 CARRIER: high pure calcinated alumina FORM: rings SIZE (mm): 15.8×15.8×6.35 ABD (g/cm^3) 0.9 STRENGTH (kg/cm^2) (DWL) 40—50	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	G-56.H is used in the high pressure reforming of refinery off-gas, or LPG and light naphtha. It is a high bulk density version of G-56.HT.

STEAM REFORMING OF HYDROCARBONS

TYPE OF CATALYST: *NICKEL G-90*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % G-90.A G-90.B G-90.C Ni 7 11 15 S max. 0.02 0.02 0.02 SiO_2max. 0.2 0.2 0.2 CARRIER: n.a. FORM: rings, cylindrical tablets, extruded pellets SIZE (mm): 19.05×19.05 15.85×15.85 15.85×9.51	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The Girdler G-90 series has been developed for those steam reforming of hydrocarbons whose application require an extremely rugged catalyst.

TYPE OF CATALYST: *NICKEL G-131*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Ni 15 U (as promotor) 9 CARRIER: rugged alumina FORM: rings SIZE (mm): 15×15×6 15×10×6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used in the most severe cases, for example in units using butane feed or with feed containing olefins or sulphur traces.

STEAM REFORMING OF C_6 HYDROCARBONS

TYPE OF CATALYST: *NICKEL GPR-7*

Manufacturer	Characteristics	Operating conditions	Remarks
Grande Paroisse	CONTENT wt % NiO on special support and additives CARRIER: n.a. FORM: pellets SIZE: Diameter (mm) 1.5 Length (mm) n.a. TS (°C) up to 1,200	TEMPERATURE RANGE: higher than 1,000°C PRESSURE RANGE: 1—60 atm.	

TYPE OF CATALYST: *NICKEL Ni-0901.S*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % NiO 5 CARRIER: inert alumina-silica FORM: spheres SIZE: Diameter (mm) 10; 12; 19; 25.4 ABD (g/cm^3) 1.2 SA (m^2/g) 1	TEMPERATURE RANGE: 980°C PRESSURE RANGE: n.a.	Endothermic generators. The quantitive relationship of these various gases is directly related to the ratio of the original air-gas mixture. This catalyst is used to reform low molecular weight hydrocarbons.

TYPE OF CATALYST: *NICKEL Ni-0910.S*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % NiO 10 CARRIER: alumino-silica FORM: spheres SIZE: Diameter (mm) 25.4 ABD (g/cm^3) 1.264 SA (m^2/g) 1	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used to reform low molecular weight hydrocarbons.

TYPE OF CATALYST: *NICKEL Ni-0912.S*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni oxide 5 Mg (as promotor) 1.2 CARRIER: inert alumina FORM: spheres SIZE: Diameter (mm) 25.4 Length (mm) n.a. ABD (g/cm^3) 1.248 SA (m^2/g) 1	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *NICKEL Ni-0914.R*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % NiO 1.5 CARRIER: inert alumina-silica FORM: rings SIZE: Diameter (mm) 19.05 ABD (g/cm^3) 1.088 SA (m^2/g) 1	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *NICKEL Ni-1901.G-2—1*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % NiO 3 CARRIER: activated alumina FORM: granules SIZE: n.a. ABD (g/cm^3) 0.848	TEMPERATURE RANGE: 1,000°—1,200°C PRESSURE RANGE: n.a.	Used for exothermic generators. The catalyst is used to aid in the reforming of hydrocarbons at about 1,200°C operating temperature for lean gas as low as 1,050°C for rich gas. The quantitative relationship of the various gases is directly related to the ratio of the original air-gas mixture.

TYPE OF CATALYST: *NICKEL Ni-2002.C Spec. 103*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % NiO 5 CARRIER: inert alumina FORM: cubes SIZE: Length (mm) 25.4 ABD (g/cm^3) 0.608	TEMPERATURE RANGE: approx. 980°C PRESSURE RANGE: n.a.	Endothermic generators.

STEAM REFORMING

TYPE OF CATALYST: *NICKEL ICI-57—1; 57—3; 57—4*

Manufacturer	Characteristics	Operating conditions	Remarks
Imperial Chemical Industries Ltd (ICI)	CONTENT wt % Supported nickel oxide CARRIER: n.a. FORM: rings, pellets SIZE: Diameter (mm) 17 Length (mm) 11—17 ABD (g/cm^3) 1.1	TEMPERATURE RANGE: up to 850°C PRESSURE RANGE: up to 35 atm.	Used for primary reforming of methane and other light hydrocarbons on tubular reformers. See also ammonia synthesis.

TYPE OF CATALYST: *NICKEL KATALCO 22.625; 22.635*

Manufacturer	Characteristics	Operating conditions	Remarks
Katalco Corporation	CONTENT wt % Supported nickel oxide (a) 22.625: NiO 24—27 (b) 22.635: NiO 34—37 CARRIER: n.a. FORM: Raschig rings SIZE (mm): (a): 18×18×6 15×15×6 (b): 15×15×6 15×10×6 18×18×6 ABD (g/cm^3) 1.04—1.12	TEMPERATURE RANGE: 700°—850°C PRESSURE RANGE: 1—25 atm. SPACE VELOCITY (VSHV): 1,500—5,000 h^{-1}	Steam reforming of light hydrocarbons. It is available in several sizes and concentration levels of active nickel.

TYPE OF CATALYST: *NICKEL CRG-7; MSC-7*

Manufacturer	Characteristics	Operating conditions	Remarks
Laporte Industries Ltd, General Chemical Division, Spence Works	CONTENT wt % CRG-7 nickel on alumina MSC-7 nickel on established magnesia CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	For catalytic rich gas process, for the manufacture of rich gas from naphtha. CRG-7 was developed in cooperation with the Gas Council. MSC-7 was developed in collaboration with Stazione Sperimentale per i Combustibili, Milano.

TYPE OF CATALYST: *NICKEL KONTAKT 9024*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT wt % NiO 1.2 CARRIER: ceramic, magnesium oxide FORM: grains SIZE: Diameter (mm) 10—20 ABD (g/cm^3) 1.55±0.15	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used to produce town gas.

TYPE OF CATALYST: *PLATINUM — ALUMINA KONTAKT 8813*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT wt % F 0.55 Kontakt 8813—6: Pt 0.57 Kontakt 8813—4: Pt 0.4 CARRIER: high activity γ alumina FORM: spheres SIZE: Diameter (mm) 2—4 SA (m^2/g) 170—200 PV (cm^3/g) 0.5—0.6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Available as: Kontakt 8813-4 Kontakt 8813-6

TYPE OF CATALYST: *PLATINUM KONTAKT 8815*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT wt % Platinum CARRIER: high activity alumina FORM: extrusions SIZE: Diameter (mm) 2 Length (mm) n.a. ABD (g/cm^3) 0.7±0.07	TEMPERATURE RANGE: 490°—515°C PRESSURE RANGE: 25—45 atm	It is used for production of fuels with high octane number and aromatic hydrocarbons.

TYPE OF CATALYST: *PLATINUM–RHENIUM KONTAKT 8816*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht"	CONTENT wt % Bimetallic catalyst CARRIER: high activity alumina FORM: extrusions SIZE: Diameter (mm) 2 Length (mm) n.a. ABD (g/cm^3) 0.7± 0.07 SA (m^2/g) 300	TEMPERATURE RANGE: 490°—520°C PRESSURE RANGE: 20—45 atm.	

STEAM REFORMING OF HYDROCARBONS

TYPE OF CATALYST: *NICKEL MRH-3*

Manufacturer	Characteristics	Operating conditions	Remarks
Montedison S.p.A.	CONTENT wt % NiO 3—5—10 CARRIER: high alumina content FORM: cylindrical extrusions SIZE: Diameter (mm) 5 Length (mm) 10 ABD (g/cm^3) 0.82—0.85 PV (cm^3/g) 0.35—0.38 STRENGTH (kg/cm^2) 30 (axial); 15 (radial) TS (°C) $\leqslant$ 1150	TEMPERATURE RANGE: 400°—1,100°C PRESSURE RANGE: $\leqslant$3 atm. LIFE: 5 years SPACE VELOCITY (VHSV): 800—3,500 h^{-1}	Steam oxygen methane reforming.

TYPE OF CATALYST: *NICKEL M*

Manufacturer	Characteristics	Operating conditions	Remarks
Chemie Linz A.G.	CONTENT wt % Nickel CARRIER: Al_2O_3; SiO_2 FORM: spheres SIZE: Diameter (mm) 15—20 Length (mm) n.a. ABD (g/cm^3) 1.6—1.8 TS (°C) max. 1,400	TEMPERATURE RANGE: 800°—900°C PRESSURE RANGE: 5 atm. LIFE: 1 year SPACE VELOCITY: 450—900 h^{-1}	It is used for the reforming of hydrocarbons in the presence of water vapour, carbon dioxide, air and oxygen (either individual or in mixtures).

STEAM HYDROCARBONS REFORMING

TYPE OF CATALYST: *NICKEL S*

Manufacturer	Characteristics	Operating conditions	Remarks
Chemie Linz A.G.	CONTENT wt % Nickel CARRIER: Al_2O_3; SiO_2 FORM: spherical SIZE: Diameter (mm) 15—20 Length (mm) n.a. ABD (g/cm^3) 1.4—1.6 TS (°C) up to 1,100	TEMPERATURE RANGE: 750°C PRESSURE RANGE: up to 5 atm. LIFE: 1 year SPACE VELOCITY: 550—1,000 h^{-1}	This catalyst is also suitable for reforming substances of low sulphur content. It can be used for both continuous and cyclic processes. See also „M".

CYCLIC LOW PRESSURE REFORMING

TYPE OF CATALYST: *NICKEL NA-50*

Manufacturer	Characteristics	Operating conditions	Remarks
Price Pearson Refractories Limited, Catalyst Division	CONTENT wt % Ni 5 SiO_2 2 CARRIER: alpha alumina FORM: Raschig rings SIZE: Diameter (mm) 32 Length (mm) 32 ABD (g/cm^3) 1.23	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is suitable for all types of cyclic plant reforming distillate or natural gas.

TYPE OF CATALYST: *NICKEL-URANIUM NUA-52*

Manufacturer	Characteristics	Operating conditions	Remarks
Price Pearson Refractories Limited, Catalyst Division	CONTENT wt % Ni 5 U 2 SiO 2 CARRIER: alpha alumina FORM: Raschig rings SIZE: Diameter (mm) 32 (ID: 12) Length (mm) 32 ABD (g/cm^3) 1.23	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See NA 50.

STEAM REFORMING OF HYDROCARBONS

TYPE OF CATALYST: *NICKEL G-1; G-2*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Nickel CARRIER: alumina FORM: balls SIZE: Diameter (mm) 5—10; 10—15 Length (mm) n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: usual	It is recommended for cyclic and autothermic processes.

STEAM REFORMING

TYPE OF CATALYST: *NICKEL G-3; GV-3*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Al_2O_3 ~97 Ni ~3 Fe <0.03 Na_2O <0.05 CARRIER: high purity alumina FORM: balls SIZE: Diameter (mm) 5—10;10—15 15—20;20—25 Length (mm) n.a. ABD (g/cm^3) 1.6±0.1 SA (m^2/g) <5 PV (cm^3/g) 0.08—0.15 STRENGTH (kg/cm^2) 100—300	TEMPERATURE RANGE: 650°—850°C PRESSURE RANGE: n.a. LIFE: 16,000—32,000 hours SPACE VELOCITY: 1,000 h^{-1}	It is recommended for the production of gas with a calorific value of 3,000 to 4,500 kcal/m^3 in autothermic and cyclic processes.

STEAM REFORMING OF NAPHTHA OR NATURAL GAS

TYPE OF CATALYST: *NICKEL GV-6*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Al_2O_3 ~94 Ni ~6 Fe <0.03 Na_2O <0.05 Loss on ignition (1,000°C): <0.5 CARRIER: high purity alumina FORM: balls SIZE: Diameter (mm) 5—10;10—15; 15—20;20—25 Length (mm) n.a. ABD (g/cm^3) 1.35±0.1 SA (m^2/g) 5 PV (cm^3/g) 0.15—0.20 STRENGTH (kg/cm^2) 100—200	TEMPERATURE RANGE: 650°—850°C PRESSURE RANGE: n.a. LIFE: 16,000—32,000 hrs. SPACE VELOCITY: 1,250 h^{-1}	Cyclic and autothermic processes.

PETROLEUM REFINING

TYPE OF CATALYST: *PLATINUM NAPH-TANE 135-E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Platinum monometallic reforming catalyst Pt 0.35 CARRIER: n.a. FORM: extrusions SIZE: Diameter (mm) 1.5 Length (mm) n.a. ABD (g/cm^3) 0.64 SA (m^2/g) 200 PV (cm^3/g) 0.6 STRENGTH (kg/cm^2) 7	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	This catalyst is used in conventional catalytic reforming units to convert naphtha to motor fuel and/or aromatics. Harshaw is associated with the Institute français du pétrole (IFP) as North American marketing and manufacturing agent for their subsidiary companies offering the Naph-Tane family of mono- and bimetallic catalyst.

TYPE OF CATALYST: *PLATINUM NAPH-TANE 160-E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT Same as Naph-Tane 135 except that this catalyst contains 0.6% Pt CARRIER: n.a. FORM: n.a. SIZE: Diameter (mm) 1.5 Length (mm) n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See Naph-Tane 135-E.

TYPE OF CATALYST: *PLATINUM NAPH-TANE 220-E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Platinum bimetallic catalyst Pt 0.20 A proprietary promotor CARRIER: n.a. FORM: extrusions SIZE: Diameter (mm) 1.5 Length (mm) n.a. ABD (g/cm^3) 0.656 SA (m^2/g) 200 PV(cm^3/g) 0.6 STRENGTH (kg/cm^2) 7	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used in the catalytic reforming of hydrocarbons where high octane product is desired in conjunction with low pressure operation.

TYPE OF CATALYST. *PLATINUM NAPH-TANE 235-E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT Same as Naph-Tane 220 except that this catalyst contains 0.35% Pt CARRIER: n.a. FORM: n.a. SIZE: Diameter (mm) 1.5 Length (mm) n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *PLATINUM NAPH-TANE 260-E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT Same as Naph-Tane 220, except that this catalyst contains 0.60% Pt and a greater concentration of proprietary promotor CARRIER: n.a. FORM: n.a. SIZE: Diameter (mm) 1.5 Length (mm) n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

REFINING OF PETROLEUM DERIVATIVES

TYPE OF CATALYST: *NICKEL-MOLYBDENUM KONTAKT 8197*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT wt % NiO MoO_3 CARRIER: n.a. FORM: cylinders SIZE: Diameter (mm) 10 Length (mm) 10 ABD (g/cm^3) 0.9—1.2 STRENGTH (kg/cm^2) 350—375	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Also KONTAKT 8197/S in the form of extrusions 7 mm diameter and ABD of 0.75 g/cm^3. By means of this catalytic treatment, sulphur, nitrogen and oxygen compounds are reduced.

TYPE OF CATALYST: *NICKEL-MOLYBDENUM KONTAKT 8199.K*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT wt % NiO. MoO_3 CARRIER: aluminium oxide FORM: spheres SIZE: Diameter (mm) 3—4 ABD (g/cm^3) 0.8	TEMPERATURE RANGE: 300°—400°C PRESSURE RANGE: 20—50 atm.	KONTAKT 8199/S: Also extrusions of 3—4 mm diameter, 4—6 mm length, and ABD of 0.9 g/cm^3.

Naphtha reforming

REFORMING

TYPE OF CATALYST: *PLATINUM CYANAMID KETJEN CK-300; CK-303; CK-304; CK-306*

Manufacturer	Characteristics	Operating conditions	Remarks
Cyanamid International	CONTENT wt % Pt 0.3—0.4—0.6 Cu 0.002 Fe 0.012 Na, K 0.002 Si 0.006 As 0.0001 Cl 0.6 N 0.0065 CARRIER: n.a. FORM: n.a. SIZE: Diameter (mm) 1.2 Length (mm) 4 ABD (g/cm^3) 0.67 SA (m^2/g) 180 PV (cm^3/g) 0.5 STRENGTH (kg/cm^2) 3.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It also contains Ag, Cr, Mg, Sn, Co, Au in a proportion of 0.002 wt %.

PETROLEUM REFORMING

TYPE OF CATALYST: *PLATINUM ALUMINA 182-CP*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Series 182-CP A B Metal content 0.5 1 Ignition loss (760°C) max. 2.5 CARRIER: alumina FORM: pellets SIZE: Diameter (mm) 6.1; 10.1; 16.1 Length average 1—1.5 times the diameter of pellet ABD (g/cm^3) 0.75—0.78 SA (m^2/g) 225	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Platinum catalyst is used for reforming, dehydrogenation, isomerization. The early large sacle industrial applications of platinum catalyst were in the field of petroleum refining for the conversion of naphtha cuts into motor gasoline and aromatics.

TYPE OF CATALYST: *PLATINUM-ALUMINA 183-CP*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Series 183-CP A B Metal content 0.5 1 Ignition loss (760 C): max. 2.5 CARRIER: alumina FORM: pellets SIZE: Diameter (mm) 6.1; 10.1;16.1 Length 1—1.5 times the diameter of pellet ABD (g/cm^3) 0.8 SA (m^2/g) 80	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See 182—CP.

TYPE OF CATALYST: *PLATINUM-ALUMINA 538-CP*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Series 538-CP A B Metal content 0.5 1 Ignition loss (760°C): max. 2.5 CARRIER: alumina FORM: pellets SIZE: Diameter (mm) 6.1; 10.1; 16.1 Length 1—1.5 times the diameter of pellet ABD (g/cm^3) 0.8 SA (m^2/g) 165	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See 182-CP.

NAPHTHA REFORMING

TYPE OF CATALYST: *PLATINUM HOUDRY$^{T.M.}$ TYPE 3-G*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Pt 0.3—0.75 Ignition loss (760°C): 1.7 CARRIER: alumina FORM: pellets SIZE: Diameter (mm) 2.4 Length (mm) n.a. ABD (g/cm^3) 0.85 SA (m^2/g) 225 STRENGTH (kg/cm^2) 6.3	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	In naphtha reforming processes both for gasoline and aromatic production. It has also found applications in other hydrogenation type reactions.

TYPE OF CATALYST: *PLATINUM TYPE 3-H*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Pt 0.3—0.75 Ignition loss (760°C): 1.9 CARRIER: alumina FORM: pellets SIZE: Diameter (mm) 2.4 Length (mm) n.a. ABD (g/cm^3) 0.84 SA (m^2/g) 215 STRENGTH (kg/cm^2) 5.4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See Houdry 3-G.

TYPE OF CATALYST: *BIMETALLIC HOUDRY*$^{T.M.}$ *HR-71*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Ignition loss (760°C): 2.5 CARRIER: n.a. FORM: pellets SIZE: Diameter (mm) 1.5 Length (mm) n.a. ABD (g/cm^3) 0.45—0.48 SA (m^2/g) 240 STRENGTH (kg/cm^2) 4.53	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is resistant to modest amount of sulphur on the feed. For high octanes.

TYPE OF CATALYST: *PLATINUM HOUDRY*$^{T.M.}$ *TYPE 3-K*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Pt 0.3—0.75 Ignition loss (760°C): 1.9 CARRIER: alumina FORM: pellets SIZE: Diameter (mm) 1.5 Length (mm) n.a. ABD (g/cm^3) 0.69 SA (m^2/g) 250 STRENGTH (kg/cm^2) 2.2	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See Houdry 3-G.

TYPE OF CATALYST: *PLATINUM HOUDRY TYPE 3-L*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Pt 0.3—0.75 Ignition loss (760°C): 2.0 CARRIER: alumina FORM: pellets SIZE: Diameter (mm) 1.5 Length (mm) n.a. ABD (g/cm^3) 0.85 SA (m^2/g) 200 STRENGTH (kg/cm^2) 5.4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See Houdry 3-G.

FUEL OILS REFORMING

TYPE OF CATALYST: *PLATINUM ATLANTIC 16*

Manufacturer	Characteristics	Operating conditions	Remarks
Kali-Chemie Engelhard	CONTENT wt % Pt 0.55 CARRIER: silica-alumina FORM: extrusions SIZE: Diameter (mm) 1.5 Length (mm) 4.5 ABD (g/cm^3) 0.61	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Elaborated by The Atlantic Refining Co. and Engelhard Industries Inc.

TYPE OF CATALYST: *PLATINUM E-301; E-302*

Manufacturer	Characteristics	Operating conditions	Remarks
Kali-Chemie Engelhard	CONTENT wt % E 301 E 302 Pt 0.6 0.35 CARRIER: aluminium oxide FORM: extrusions SIZE: Diameter (mm) 1.5 Length (mm) 4.5 ABD (g/cm^3) 0.67	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The catalyst was elaborated by Sinclair Research Laboratories Inc., New-York and Baker and Co., Newmark.

NAPHTHA REFORMING

TYPE OF CATALYST: *PLATINUM RG-101*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Pt 0.6±0.02 Cl approx. 0.5 Heating loss (550°C) 0.5 F approx. 0.4 B 500 ppm; Al_2O_3 diff. to 100% Fe_2O_3 500 ppm Na_2O 300 ppm Pb 10 ppm Cu 120 ppm As 5 ppm Si 200 ppm CARRIER: alumina FORM: balls SIZE: Diameter (mm) 1.25—2.5 ABD (g/cm^3) 0.75±0.05 SA (m^2/g) 320±40 PV (cm^3/g) 0.52±0.05	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used in various processes for raising the octane number of naphthas and production of aromatics.

TYPE OF CATALYST: *PLATINUM RG-402; RG-404*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Pt 0.6 Loss on ignition (1,100°C): <5% CARRIER: high purity alumina FORM: extrusions SIZE: Diameter (mm) 1.2—2.2 ABD (g/cm^3) 0.6 SA (m^2/g) 200 PV (cm^3/g) 0.60 STRENGTH (kg/cm^2) >4	TEMPERATURE RANGE: 480°—530°C PRESSURE RANGE: usual	Used for the production of aromatics.

TYPE OF CATALYST: *PLATINUM RG-422; RG-432; RG-442*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Promoted platinum CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 1.2 Length (mm) n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Are recommended as well for the increase of the octane number and for the production of the aromatics.

TYPE OF CATALYST: *PLATINUM RG-412; RG-414*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Pt 0.35 Loss on ingnition (1,100°C): <5% CARRIER: high purity alumina FORM: extrusions SIZE: Diameter (mm) 1.2—2.2 ABD (g/cm^3) 0.6 SA (m^2/g) 200 PV (cm^3/g) 0.60 STRENGTH (kg/cm^2) >4	TEMPERATURE RANGE: 480°—530°C PRESSURE RANGE: usual	Used for the production of aromatics.

TYPE OF CATALYST: *PLATINUM RG-452; RG-454*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Promoted platinum CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 1.2—2 Length (mm) n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Are recommended as well for increase of the octane number and for production of aromatics.

TYPE OF CATALYST: *PLATINUM RG-451; RG-461*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Promoted platinum CARRIER: alumina FORM: balls SIZE: Diameter (mm) 1.8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	They are recommended as well for the increase of the octane number and for the production of aromatics.

TYPE OF CATALYST: *PLATINUM SK-200*

Manufacturer	Characteristics	Operating conditions	Remarks
Union Carbide Corporation, Linde Molecular Sieve Catalysts	CONTENT wt % (anhydrous base) SiO_2 65.6±0.5 Al_2O_3 22.3±0.5 Na_2O 1.8±0.2 CaO 10.3±0.3 Cl^- <0.05 F^- <0.05 Pt 0.5±0.02 FORM: tablets SIZE: Diameter (mm) 4 Length (mm) 4 ABD (g/cm^3) 0.65 SA (m^2/g) >500	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is a calcium exchanged molecular sieve type Y.

L. Catalysts for various chemical reactions

Ammonium dissociation
Cyclization — dehydrocyclization
Esterification — interesterification
Hydration — dehydration

Ammonium dissociation

AMMONIA DISSOCIATION

TYPE OF CATALYST: *NICKEL BASF G-1—22*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % Nickel CARRIER: ceramic FORM: cylindrical rings SIZE: Diameter (mm) 16 Length (mm) n.a. ABD (g/cm^3) 1 STRENGTH (kg/cm^2) 300 (measured at the faces) TS (°C) up to 900	TEMPERATURE RANGE: 650°—850C° PRESSURE RANGE: n.a.	Splitting ammonia to produce inert gas, e.g. in the electrical industry (production of electronic valves) and in the metal-working industry (production of sheet metal for transformers and galvanizing metal).

TYPE OF CATALYST: *IRON C-17—1*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Iron oxide CARRIER: refractory alumina FORM: spheres SIZE: Diameter (mm) 19 Length (mm) n.a. ABD (g/cm^3) 1.22	TEMPERATURE RANGE: 700—1,040°C PRESSURE RANGE: 1—35 atm. SPACE VELOCITY (VHSV): 1,500—2,000 h^{-1}	Catalytic dissociation of NH_3 for production of H_2 gas suitable for variety of uses. C-17-1-01 uses iron as active ingredient; C-17-1-02 uses nickel as active ingredient.

TYPE OF CATALYST: *NICKEL C-17—2*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Nickel oxide CARRIER: refractory alumina FORM: spheres SIZE: Diameter (mm) 19 Length (mm) n.a. ABD (g/cm^3) 1.22	TEMPERATURE RANGE: 700°—1,040°C PRESSURE RANGE: n.a. SPACE VELOCITY (VHSV): 1,500—2,000 h^{-1}	Lower pressures favour more complete dissociation at lower temperatures. The rugged carrier of the C-17 catalyst contributes to long useful life.

TYPE OF CATALYST: *NICKEL ACTIMET*^{R} *41*

Manufacturer	Characteristics	Operating conditions	Remarks
Doduco	CONTENT wt % Nickel on carrier CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for the production of inert gas.

TYPE OF CATALYST: *NICKEL CDA-9*

Manufacturer	Characteristics	Operating conditions	Remarks
FCI Catalysts	CONTENT wt % Nickel CARRIER: alumina FORM: cylindrical tablets SIZE: Diameter (mm) 6 Length (mm) 6 ABD (g/cm^3) 1.1—1.2	TEMPERATURE RANGE: 600°—1,000°C PRESSURE RANGE: n.a. SPACE VELOCITY: up to 1,000 h^{-1}	The catalyst is highly active (with close approach to equilibrium and resistant to thermal sintering).

TYPE OF CATALYST: *IRON G-47*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT An iron oxide catalyst, containing 2.5% Fe CARRIER: rugged FORM: spheres SIZE: Diameter (mm) 6—25 Length (mm) n.a. ABD (g/cm^3) 1.21—1.28	TEMPERATURE RANGE: 870°—980°C PRESSURE RANGE: near atmospheric SPACE VELOCITY (VHSV): 2,000 h^{-1}	

TYPE OF CATALYST: *NICKEL G-29*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT n.a. CARRIER: n.a. FORM: cylinders; Raschig rings SIZE: Diameter (mm) 12;19; 15×15	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See chapter on Reforming.

TYPE OF CATALYST: *NICKEL G-56*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT n.a. CARRIER n.a. FORM: Raschig rings; tablets SIZE (mm): *Rings* *Tablets* 17×17×6 6×6 16×16×6 9×9 17×10×6 12×12	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See chapter on Reforming. Available as G-56 B and G-56 H cylinders with diameters of 12.7 mm and 19 mm.

TYPE OF CATALYST: *IRON Fe-1401.S*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Fe_2O_3 5 CARRIER: high fixed inert alumina FORM: spheres SIZE: Diameter (mm) 10 Length (mm) n.a. ABD (g/cm^3) 1.2 SA (m^2/g) 1 PV (cm^3/g) 0.06 STRENGTH (kg/cm^2) 2.7	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a	Used also to reform low molecular weight hydrocarbons.

TYPE OF CATALYST: *NICKEL Ni-0901.S*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni 5 (present as oxide) CARRIER: alumina-silica FORM: spheres SIZE: Diameter (mm) 9.6; 12.7; 18.6; 25.4 ABD (g/cm^3) 1.2 SA (m^2/g) 1	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Ammonia is dissociated yielding a gas consisting of 75% hydrogen and 25% nitrogen by volume and usually less than 0.1% residual free ammonia. The cracking occurs at about 1,000°C.

TYPE OF CATALYST: *NICKEL Ni-0910.S*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni 10 (present as nickel oxide) CARRIER: alumina-silica FORM: spheres SIZE: Diameter (mm) 25.4 Length (mm) n.a. ABD (g/cm^3) 1.2 SA (m^2/g) 1	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used also to reform low molecular weight hydrocarbons.

TYPE OF CATALYST: *NICKEL ICI-27—1; ICI-47—1*

Manufacturer	Characteristics	Operating conditions	Remarks
Imperial Chemical Industries Ltd	CONTENT wt % Nickel oxide CARRIER: alumina FORM: 27-1 *irregular granules*; 47-1 *pellets* SIZE: Diameter (mm) 4.8—9.5 5.4 ABD (g/cm^3) 1.1	TEMPERATURE RANGE: ICI 27—1: 850°C ICI 47—1: 450°C PRESSURE RANGE: n.a.	Both types are most active when the nickel oxide is reduced to nickel.

TYPE OF CATALYST: ***NICKEL G-4***

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % NiO 4 CARRIER: alumina FORM: balls SIZE: n.a. ABD (g/cm^3) 1.6 PV (cm^3/g) 0.08 TS (°C) 100—300	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: ***PELLETED IRON DNK***

Manufacturer	Characteristics	Operating conditions	Remarks
Haldor Topsøe	CONTENT n.a. CARRIER: ceramic FORM: cylinders; rings SIZE: *cylindres* *rings* Diameter (mm) 6 10/4 Length (mm) 6 7 ABD (g/cm^3) 1.6 1.35	TEMPERATURE RANGE: 550°—800°C PRESSURE RANGE: n.a.	

Cyclization-dehydrocyclization

DEHYDROCYCLIZATION

TYPE OF CATALYST: *CHROME ALUMINA Cr-0205.T, spec. 102*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Cr_2O_3 19 CARRIER: activated alumina FORM: tablets SIZE: Diameter (mm) 4 Length (mm) n.a. ABD (g/cm^3) 0.96 SA (m^2/g) 60 PV (cm^3/g) 0.29 STRENGTH (kg/cm^2) 8.6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used in dehydrogenation of butane to butadiene.

TYPE OF CATALYST: *CHROME ALUMINA Cr-0211.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Cr_2O_3 19 CARRIER: activated alumina SIZE: Diameter (mm) 4 Length (mm) n.a. ABD (g/cm^3) 1.15 SA (m^2/g) 0.3 STRENGTH (kg/cm^2) 9.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See chapter on dehydrogenation. Capable of selectivity for the dehydrogenation of butane to butene.

TYPE OF CATALYST: *MOLYBDENUM ALUMINA Mo-1201.T; Mo-1201.TV*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT n.a. CARRIER: n.a. FORM: n.a. SIZE: Diameter (mm) 3.2 Length (mm) n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See chapter on dehydrogenation.

DEHYDROCYCLIZATION OF n-PARAFFINS

TYPE OF CATALYST: *CHROMIUM KONTAKT 6450*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT wt % Cr_2O_3 CARRIER: alumina FORM: spheres SIZE: Diameter (mm) 3—5 Length (mm) n.a. ABD (g/cm^3) 0.85±0.1	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used also for dehydrogenation of butane to butadiene.

Esterification-interesterification

ESTERIFICATION REACTIONS

TYPE OF CATALYST: *ALUMINA Al-0104.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Al_2O_3 99 FORM: tablets SIZE: Diameter (mm) 3; 4; 5; 6.35 ABD (g/cm^3) 0.604—0.928 SA (m^2/g) 80—100 PV (cm^3/g) 0.28—0.33 STRENGTH (kg/tablet) 4—11	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used commercially as a catalyst support drying agent and for dehydration reactions.

TRANSESTERIFICATION OF ESTERS

TYPE OF CATALYST: *BORON TRIFLUORIDE DIHYDRATE*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT See chapter on isomerization CARRIER: n.a. FORM: fuming hygroscopic liquid SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Catalyst for polymerization, resin curing. For the production of high price esters.

INTERESTERIFICATION OF TRI-GLYCERIDE FATS

TYPE OF CATALYST: *SODIUM METHYLATE*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Sodium methylate 87 CARRIER: n.a. FORM: powder SIZE: 150 mesh	TEMPERATURE RANGE: 50°—100°C PRESSURE RANGE: n.a.	The catalyst is inactivated by the adition of water or acid.

ACRYLIC ESTER ALCOLYSIS

TYPE OF CATALYST: *ORGANIC TITANIUM COMPOUNDS TIL*			
Manufacturer	Characteristics	Operating conditions	Remarks
Titanium Intermediates Ltd	CONTENT n.a. CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Catalytic applications of organic titanium compounds: (a) polyester manufacture; (b) ester and plasticizer manufacture (by direct route); (c) ester manufacture (by ester interchange); (d) silicone manufacture and applications (particularly for textile water proofing); (e) curing of epoxy resins.

Hydration-dehydration

DEHYDRATION REACTIONS

TYPE OF CATALYST: *BASF D-10—10*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT See chapter on isomerization	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	For dehydration, isomerization and diverse chemical reactions.

TYPE OF CATALYST: *ALUMINA C-1*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Al_2O_3 Na_2O less than 0.05 CARRIER: n.a. FORM: tablets; extrusions SIZE: Diameter (mm) 3—12 Length (mm) n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for hydration, dehydration and catalyst support.

TYPE OF CATALYST: *ALUMINA C-2*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Al_2O_3 Na_2O 0.3 CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 5—12 Length (mm) n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for hydration, dehydration and as catalyst support.

HYDRATION — DEHYDRATION REACTIONS

TYPE OF CATALYST: *ALUMINIUM OXIDE CHEZA 33—00*

Manufacturer	Characteristics	Operating conditions	Remarks
Chemical Works of CSF	CONTENT wt % $Na_2O + K_2O$ 0.1 Fe_2O_3 0.1 SiO_2 0.9 SO_3 0.5 NO_3 1.5 Al_2O_3 the remainder Loss by heating (1,200°C) 10 CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 10; 6 Length (mm) 6—8; 6 ABD (g/cm³) 0.75 STRENGTH (kg/cm²) 200	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used also in dehydrogenation reactions. It may be used as a carrier for the preparation of different impregnated catalysts. Under certain circumstances it may be used as a drying, adsorption agent for gases, eventually liquids.

HYDRATION

TYPE OF CATALYST: *ALUMINIUM CHEZA 33—01*

Manufacturer	Characteristics	Operating conditions	Remarks
Chemical Works of CSF	CONTENT wt % $Na_2O + K_2O$ 0.05 Fe_2O_3 0.05 SiO_2 0.3 SO_3 0.5 NO_3 0.5 Al_2O_3 the remainder Loss by heating (1,200°C): 5 CARRIER: n.a. FORM: balls SIZE: Diameter (mm) 2—4 Length (mm) n.a. ABD (g/cm³) 0.7 STRENGTH (kg/cm²) 2 (tested by the edge of a knife)	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See CHEZA 33—00

DENYDRATION

TYPE OF CATALYST: *ACTIVATED ALUMINA F-1*

Manufacturer	Characteristics	Operating conditions	Remarks
Aluminium Company of America (ALCOA)	CONTENT wt % Al_2O_3 92 Na_2O 0.90 Fe_2O_3 0.08 SiO_2 0.09 CARRIER: n.a. FORM: granular SIZE: 6—100 mesh (3.3—1.27 mm) Diameter (mm) 6—12 Length (mm) n.a. ABD (g/cm³) 0.83—0.88 SA (m²/g) 210 STRENGTH (kg/cm²) 25	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Although primarily used as a desicant, activated alumina F-1 finds applications as a catalyst in such reactions as the destructive dehydration of alcohols in which a typical soda content of 0.9% is not harmful.

DEHYDRATION REACTIONS

TYPE OF CATALYST: *SILICA-ALUMINA GRADE 970; 980*

Manufacturer	Characteristics	Operating conditions	Remarks
Davison Chemical Division W.R. Grace and Co.	CONTENT Modified silica-alumina, 13% alumina or 25% alumina with the balance silica FORM: pellets SIZE: Diameter (mm) 3; 4 Length (mm) n.a. SA (m^2/g) 970—980 100—500	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	They are also used as catalyst supports.

TYPE OF CATALYST: *ALUMINA Al-0104.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT Activated alumina containing 99% Al_2O_3 CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 3.175; 3.96; 4.762; 6.35; 9.525 ABD (g/cm^3) 0.6—0.9 (depending on size) SA (m^2/g) 80—100 PV (cm^3/g) 0.28—0.33 STRENGTH (kg/cm^2) 4—11	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used commercially as a catalyst support, drying agent for dehydration reactions.

TYPE OF CATALYST: *ALUMINA Al-1404.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % High activity alumina containing 97% Al_2O_3 CARRIER: n.a. FORM: tablets SIZE: n.a. ABD (g/cm^3) 0.064—0.880 SA (m^2/g) 180—200 PV (cm^3/g) 0.42—5.1 STRENGTH (kg/cm^2) 11—28	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used as a catalyst support, drying agent and for dehydration reactions.

TYPE OF CATALYST: *TUNGSTEN W-0101.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % WO_3 10 CARRIER: activated alumina FORM: tablets SIZE: Diameter (mm) 3 Length (mm) n.a. ABD (g/cm^3) 0.944 SA (m^2/g) 75 PV (cm^3/g) 0.37 STRENGTH (kg/cm^2) 5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *TUNGSTEN W-0602.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % WO_3 95 FORM: tablets SIZE: Diameter (mm) 3 Length (mm) n.a. ABD (g/cm^3) 1.728 SA (m^2/g) 17 PV (cm^3/g) 0.19 STRENGTH (kg/cm^2) 4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *TUNGSTEN W-0801.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % WO_3 10 CARRIER: high activity alumina FORM: tablets SIZE: Diameter (mm) 3 Length (mm) n.a. ABD (g/cm^3) 1.008 SA (m^2/g) 145 PV (cm^3/g) 0.36 STRENGTH (kg/cm^2) 9.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

DEHYDRATION REACTIONS (ESTERIFICATION)

TYPE OF CATALYST: *ALUMINA H-0423*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Al_2O_3 90 Loss on ignition (850°C): 10 CARRIER: n.a. FORM: tablets; extrusions SIZE: Diameter (mm) 4 Length (mm) n.a. ABD (g/cm^3) 0.95—0.80 SA (BET) (m^2/g) 190—200 PV (cm^3/g) 0.42—0.48	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It can also be used as carrier in the manufacturing of catalysts for various purposes.

HYDRATION REACTIONS

TYPE OF CATALYST: *PHOSPHORIC ACID H-3301*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT See chapter on isomerization	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a	See chapter on isomerization.

TYPE OF CATALYST: *ALUMINIUM KONTAKT 5780/S*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht"	CONTENT wt % Al_2O_3 94—98 Na_2O 0.1 max. FORM: extrusions SIZE: Diameter (mm) 5 Length (mm) 5—10 ABD (g/cm^3) 0.65±0.10	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used as a carrier and a drying agent, and also for the dehydration of alcohols.

TYPE OF CATALYST: *TUNGSTEN 74300; 74311*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % Tungsten oxide (a) 74300: WO_3 95 (b) 74311: WO_3 10 CARRIER: n.a. FORM: pellets SIZE: Diameter (mm) 3 Length (mm) 3 SA (m^2/g) (a) 17 (b) 145	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	They are used for dehydration of alcohols, denitrogenation, hydrocracking and hydrotreating.

Annex III

Homogeneous catalysts

A. Disproportionation reactions
B. General reactions
C. Hydroformylation
D. Isomerization
E. Oxidation reactions
F. Polymerization

A. Disproportionation reactions

DISPROPORTIONATION PROCESS OF ABIETIC ACID

TYPE OF CATALYST: *PALLADIUM PK-11*

Manufacturer	Characteristics	Operating conditions	Remarks
CIECH Nitroplast	CONTENT wt % Pd 2.3—2.5 CARRIER: n.a. FORM: grains SIZE: Diameter (mm) 0.4—0.6 Length (mm) n.a. ABD (g/cm^3) 0.4—0.6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is applied in fluid phase of the disproportion process of abietic acid contained in the resin of coniferous trees, which is used for production of resin soaps being the emulsifier of polymerization of butadiene from styrene.

DISPROPORTIONATION OF OLEFINS

TYPE OF CATALYST: *METAL CARBONYLS*

Manufacturer	Characteristics	Operating conditions	Remarks
Pressure Chemical Co.	CONTENT (a) Ruthenium carbonyl $Ru_3(CO)_{12}$ (b) Tungsten hexacarbonyl $W(CO)_6$ CARRIER: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	(a) Orange solid: M.p. 150°C (dec) Air stable (b) White solid: M.p. 175°C (dec) Air stable

TYPE OF CATALYST: *TUNGSTEN 74-220*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % Tungsten carbonyl $W(CO)_6$ FORM: white solid SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Stability: air stable.

HYDROGENATION OF NITROBENZENE TO ANILINE

TYPE OF CATALYST: *RUTHENIUM 44-180; 44-185; 44-588*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % (a) 44—180 Ruthenium (II) acetylacetcnate $Ru(C_5H_7O_2)_3$ (b) Ruthenium carbonyl $Ru_3(CO)_{12}$ (c) Ruthenium (III) trichloride hydrate FORM: (a) red-brown solid; (b) orange solid; (c) black solid SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Other applications: Hydrogenation of nitrobenzene to aniline in the presence of carbon monoxide and hydrogen; Hydrogenation of activated olefins; Linear oligomerization and co-oligomerization of olefins; Stability: all air stable.

B. General reactions

HOMOGENEOUS CATALYSIS, GENERAL REACTIONS

TYPE OF CATALYST: KA

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT n.a. CARRIER: n.a. FORM: powder; spheres SIZE: n.a. ABD (g/cm^3) 0.8—0.9 (spheres) 0.48—0.50 (powder) SA (BET) (m^2/g) 195 PV (cm^3/g) 0.6—0.7 STRENGTH (kg/cm^2) 4—5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Based on SiO_2. It is also most suitable as a catalyst carrier. Moisture: 1—3%. Average pore diameter: 100 Å Hardness: 6—10%. Read density: 2.2 g/cm^3.

TYPE OF CATALYST: *K SERIES*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT The catalyst is produced from the mineral Montmorillonite CARRIER: n.a. FORM: powder SIZE: n.a. ABD (g/cm^3) 0.3—0.6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The K-series are activated montmorillonite clays. They are ideal for many reactions catalyzed by hydrogen acids or Lewis acid salts. The following catalysts are produced: KSF, KSF/G, K_{10}, K_{10}/SF, K20, K306, KA. K306 and KA can also be supplied as spheres, with a bulk density of 0.4—0.8 g/cm^3.

C. Hydroformylation

HYDROFORMYLATION (FIRST STEP OF THE OXOPROCESS)

TYPE OF CATALYST: *COBALT ACETATE*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Co 23 FORM: hydrated granular crystal ABD (g/cm^3) 0.88	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *COBALT NAPHTHENATE*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Co 6 (in any compatible petroleum solvent) FORM: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *COBALT OCTASOL — COBALT 2 ETHYL HEXOAT*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Co 6 or 12 (in any compatible petroleum solvent specified by customer) FORM: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *COBALT SULPHATE*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Co 21 FORM: hydrated red crystal ABD (g/cm^3) 1.3	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *COBALT THALLATE*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Co 6 (in any compatible petroleum solvent specified by customer) FORM: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *METAL CARBONYLS*

Manufacturer	Characteristics	Operating conditions	Remarks
Pressure Chemical Co.	CONTENT wt % (a) Cobalt carbonyl $Co_2(CO)_8$ (b) Manganese carbonyl $Mn_2(CO)_{10}$	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	(a) Dark orange solid: M.p. 51°—52°C (dec) Heat and air sensitive (b) Yellow solid: M.p. 153°—155°C Heat and air sensitive Volatile in steam Soluble in most organic solvents.

HYDROFORMYLATION OF OLEFINS (OXO PROCESS)

TYPE OF CATALYST: *COBALT 27040*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % Cobalt carbonyl $Co_2(CO)_8$ FORM: dark orange solid	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Other applications: Carboxylation of olefins; Hydrogenation of aldehydes to alcohols; Isomerization of olefins, hydrogenation of olefins; Cyclic oligomerization of acetylenes to benzenes etc.; Stability: air sensitive, heat sensitive.

HYDROFORMYLATION OF OLEFINS TO ALDEHYDES

TYPE OF CATALYST: *RHODIUM 45—188; 45—225*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % (a) 45-188 Rhodium (III) trichloride hydrate $RhCl_3 \times H_2O$ (b) 45-225 Trichlorotris (pyridine) rhodium (III) $RhCl_3(C_5H_5N)_3$ FORM: (a) dark red solid (b) orange-yellow solid	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Other applications: Low pressure carbonylation of methanol to acetic acid; Isomerization of olefins; Co-oligomerization of ethylene and butadiene to hexadiene; Stability: both air stable.

D. Isomerization

ISOMERIZATION

TYPE OF CATALYST: *BORON TRIFLUORIDE*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Compressed gas BF$_3$ 99.55 Boron trifluoride dihydrate: fuming hygroscopic liquid CARRIER: n.a. FORM: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Catalyst for organic condensation (compressed gas). Dihydrate-catalyst used also for polymerization, resin curing.

ISOMERIZATION OF OLEFINS

TYPE OF CATALYST: *METAL CARBONYL*

Manufacturer	Characteristics	Operating conditions	Remarks
Pressure Chemical Co.	CONTENT wt % (a) Iron pentacarbonyl Fe(CO)$_5$ (b) Di-iron nonacarbonyl Fe$_2$(CO)$_9$ (c) Tri-iron dodecacarbonyl Fe$_3$(CO)$_{12}$ (d) Molybdenum hexacarbonyl Mo(CO)$_6$	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	(a) Redish-brown liquid: B.p. 103°C/760 mm Heat and air sensitive (b) Golden-orange solid: M.p. 100°C (dec) Heat and air sensitive (c) Greenish-black solid: M.p. 140°C (dec) Heat and air senitive (d) White solid: M.p. volat 150°C (dec) Air stable.

TYPE OF CATALYST: *IRON* (a) *26250*; (*b*) *25264*; (*c*) *26280*; (*d*) *26090*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % (a) Iron dodecacarbonyl Fe$_3$(CO)$_{12}$ (b) Iron nonacarbonyl Fe$_2$(CO)$_9$ (c) Iron pentacarbonyl Fe(CO)$_5$ (d) Cyclopentadienyl-iron dicarbonyl-dimer [C$_5$H$_5$Fe(CO)$_2$]$_2$ FORM: (a) black solid; (b) orange-yellow solid; (c) orange liquid; (d) purple red solid.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Other applications: Cyclic oligomerization of acetylenes to benzenes; Dimerization of norbornadiene; Carbonylation of olefins to alcohols in the presence of H$_2$O; For the addition of carbon tetrachloride and CO to olefins. Stability: (a) Air sensitive; (b) Air sensitive, heat sensitive (store cold); (c) Air sensitive, heat sensitive (store cold); (d) Air stable.

TYPE OF CATALYST: *MOLYBDENUM 42040; 42135*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % (a) Cyclopentadienyl molybdenum tricarbonyl dimer: $[C_5H_5Mo(CO)_3]_2$ C = 39.7 (b) Molybdenum carbonyl: $Mo(CO)_6$ C=27.2 FORM: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Applications: (a) Addition of carbon tetrachloride to olefins; (b) Isomerization of olefins, disproportionation of olefins. Epoxidation of olefins with organic hydroperoxides. Stability: (a) Air-sensitive; (b) Air-stable.

TYPE OF CATALYST: *RHODIUM 45027; 45045*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % (a) Chlorobis (ethylene) rhodium (I) dimer (b) Chlorodicarbonyl rhodium (I) dimer FORM: (a) rust coloured solid; (b) red solid.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Other applications: Dimerization of ethylene to butenes; Hydroformylation of olefins; Hydrogenation of aldehydes to alcohols; Low pressure carbonylation of methanol to acetic acid. Stability: both, air sensitive (store cold).

ISOMERIZATION OF NON-CONJUGATED OLEFINS TO CONJUGATED ONES

TYPE OF CATALYST: *PLATINUM 78148*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % Platinum (II) chloride $PtCl_2$ Pt 72.7 FORM: brown solid	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used for the hydrogenation of olefins.

E. Oxidation reactions

OXIDATION REACTIONS

TYPE OF CATALYST: *MANGANESE CATRON MB-11*

Manufacturer	Characteristics	Operating conditions	Remarks
Anderson Development Co.	CONTENT wt % Mn 10—11 P 12—14 CARRIER: n.a. FORM: waxy solid melting in the range of 100°—120°C SIZE: n.a. TS (°C) 200	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It contains manganese in the form of an organometallic polymer with phosphorus. Aliphatic hydrocarbons may be converted into aldehydes and acids, alcohols into aldehydes, acids into ketones and aldehydes and esters into unsaturates and ethers. Chlorination and nitration of aromatics and carbohydrates may be enhanced by traces of CATRON MB-11. It serves as an effective oil soluble drying agent for air-cured coatings.

OXIDATION OF ETHYLENE TO ACETALDEHYDE

TYPE OF CATALYST: *PALLADIUM CHLORIDE*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt % $PdCl_2$ 15—20 FORM: solution in water	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used for the oxidation of propylene to acetone.

OXIDATION OF OLEFINS

TYPE OF CATALYST: *PALLADIUM 46178; 46185*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % (a) Palladium (II) acetate $Pd(O_2CH_3)_2$ (b) Palladium (II) chloride $Pd\ Cl_2$ FORM: (a) brown solid; (b) rust coloured solid	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Other applications: Oxidation of ethylene to vinyl acetate; Carbonylation of olefins; Carbonylation of amines to isocyanates; Synthesis of allylic esters from allylic chlorides in the presence of acetate ion. Stability: both, air stable.

F. Polymerization

POLYMERIZATION OF OLEFINS

TYPE OF CATALYST: *FERROCENE (DICYCLOPENTADIENYL IRON)*			
Manufacturer	Characteristics	Operating conditions	Remarks
Anderson Development Co.	CONTENT wt % *powder crystals* Benzene insoluble (max., %) 2 0.2 Non-volatile matter (max. %) 5 0.4 FORM: crude powder; purified crystals Melting point (°C): 170 (powder); 171—172 (crystals) ABD (g/cm^3) 1.49	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It has been used: To promote oxidation performance of fuels; As a stabilizer for organosilicon polymers; To provide an inexpensive source of organometallic substance for building new special purpose derivatives and polymers.

POLYMERIZATION

Manufacturer: Ethyl Corporation	TYPE OF CATALYST						
	Trimethyl aluminium TMA	Triethyl aluminium TEA	Diisobutyl aluminium hydride DIBAH	Triisobutyl aluminium TIBA	Diethyl aluminium chloride DEAC	Diisobutyl aluminium chloride DIBAC	Remarks
Formula	$(CH_3)_3Al$	$(C_2H_5)_3Al$	$(i\text{-}C_4H_9)_2AlH$	$(i\text{-}C_4H_9)_3Al$	$(C_2H_5)_2AlCl$	$(i\text{-}C_4H_9)_2AlCl$	Aluminium alkyls, catalyst components for polymerization of olefins in the manufacture of synthetic rubber and plastics and for specific olefin syntheses. Alkylation and reducing agents
Formula weight	72.09	114.17	142.22	198.33	120.56	176.67	
Theoretical composition:							
Al wt %	37.4	23.6	19.0	13.6	22.4	15.3	
Chlorine wt %	—	—	—	—	29.4	20.1	
Density (g/ml at 25°C)	0.7478	0.8324	0.7990	0.7823	0.9709	0.9118	
Freezing point (°C)	15.3	ca —46	—80	1	—74	—40	
Boiling point (°C)	127	187	275	212	214	289	
Vapour pressure, (mm Hg) at:							
25°C	12	—	—	—	—	—	
60°C	69	0.8	0.01	1.8	1.9	0.03	
100°C	323	13	0.3	16	17	0.6	

POLYMERIZATION REACTIONS

TYPE OF CATALYST: *BORON TRIFLUORIDE DIHYDRATE*			
Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT n.a. FORM: fuming hygroscopic liquid	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for resin curing.

TYPE OF CATALYST: *BORON TRIFLUORIDE PHOSPHORIC ACID*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT n.a. FORM: fuming liquid	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for alkylation and polymerization reactions. Boron trifluoride complexes catalysts for polymerization and condensation modifying reactivity of BF_3.

PRODUCTION OF POLYETHYLENE TEREPHTHALATE

TYPE OF CATALYST: *ANTIMONY-BASED M&T CATALYST S-24*

Manufacturer	Characteristics	Operating conditions	Remarks
M&T International NV	CONTENT wt % Antimony min. 56 Chloride max. 100 ppm Iron max. 100 ppm Sulphate max. 100 ppm FORM: white crystalline solid	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a. PURITY: $\geqslant 95\%$	Polycondensation catalyst for polyester manufacture.

TYPE OF CATALYST: *ANTIMONY M&T CATALYST S-22*

Manufacturer	Characteristics	Operating conditions	Remarks
M&T International NV	CONTENT wt % Antimony $\geqslant 11.5$ Iron $\leqslant 100$ ppm Sulphate $\leqslant 100$ ppm FORM: amber liquid VISCOSITY at 25°C: 105 cs Specific gravity at 25°C: 1.02—1.04 Flash point: 232°C Freezing point: —2°C (max.)	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a. PURITY: $\geqslant 95\%$	Catalyst S-22 is a non-volatile liquid, may be used for continuous polyester production.

TYPE OF CATALYST: *TRIBUTYL ANTIMONITE M& T CATALYST S-23*

Manufacturer	Characteristics	Operating conditions	Remarks
M& T International N V	CONTENT wt % Tributyl antimonite min. 95 Antimony min. 33.9 Chloride 100 ppm Sulphate 100 ppm Iron 100 ppm FORM: water white liquid VISCOSITY at 25°C: 7.67 cs Specific gravity at 25°C: 1.26 Flash point: 102°C Freezing point: —60°C	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a. PURITY: ⩾95 %	Catalyst S-23, with a low viscosity, low freezing point liquid, is suitable for batch or continuous processes, for polyethylene terephthalate manufacture.

POLYMERIZATION OF OLEFINS

TYPE OF CATALYST· *METALOCENES*

Manufacturer	Characteristics	Operating conditions	Remarks
Pressure Chemical Co.	CONTENT wt % (a) Ferrocene $(C_5H_5)_2Fe$ (b) Nickelocene $(C_5H_5)_2Ni$ (c) Biscyclopentadienyltitanium dichloride $(C_5H_5)_2TiCl_2$ (d) Biscyclopentadienylvanadium dichloride $(C_5H_5)_2VCl_2$	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	(a) Orange solid: M.p. 173°C Air stable (b) Dark green solid: M.p. 173—174°C Air sensitive (c) Red solid: M.p. 289—291°C Air stable (d) Green solid M.p. 250°C Air sensitive

TYPE OF CATALYST: *NICKEL CARBONYL*

Manufacturer	Characteristics	Operating conditions	Remarks
Pressure Chemical Co.	CONTENT wt % $Ni(CO)_4$ 34.37 Ni Critical temperature: 200°C Melting point: —25°C Boiling point: 42.6°C Critical pressure: 30atm.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is exceedingly toxic. Other applications: Carboxylation of acetylenes to acrylates; Carbonylation of alkyl halides; Cyclic oligomerization of acetylenes.

POLYMERIZATION REACTIONS

TYPE OF CATALYST: *TRI N-BUTYL ANTIMONITE*

Manufacturer	Characteristics	Operating conditions	Remarks
Stauffer Chemical Co.	CONTENT wt % $(C_4H_9O)_3Sb$ FORM: colourless liquid DENSITY(g/cm^3) 2.99	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used as a flame retardant, a cross linking agent for other antimony compounds and a catalyst for the production of polyesters.

TYPE OF CATALYST: *TRI n-BUTYL VANADATE*

Manufacturer	Characteristics	Operating conditions	Remarks
Stauffer Chemical Co.	CONTENT wt % $V(O)\ (C_4H_9O)_3$ FORM: clear yellow-brown liquid DENSITY (g/cm^3) 0.97	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used as an EPDM polymerization catalyst in combination with an aluminium alkyl halide.

TYPE OF CATALYST: *TRI ETHYL VANADATE*

Manufacturer	Characteristics	Operating conditions	Remarks
Stauffer Chemical Co.	CONTENT wt % $V(O)\ (C_2H_5O)_3$ FORM: clear yellow-brown liquid DENSITY (g/cm^3) 1.06	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used as an EPDM polymerization catalyst in combination with an aluminium alkyl halide.

TYPE OF CATALYST: *TETRAALKYL TITANATES*

Manufacturer	Characteristics	Operating conditions	Remarks
Stauffer Chemical Co.	CONTENT wt % (a) $(C_3H_7O)_4Ti$ (b) $(C_4H_9O)_4Ti$ (c) $(C_8H_{17}O)_4Ti$ (d) $(C_7H_7O)_4Ti$ FORM: liquid DENSITY (g/cm^3) (a) 0.94 (b) 0.99 (c) 0.89 (d) —	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used as a polymerization catalyst in combination with an aluminium alkyl, a transesterification and esterification catalyst, an adhesion promotor, a resin modifier, and in the preparation of heat resistant coatings and water repellent finishes.

TYPE OF CATALYST: *TITANIUM TETRACHLORIDE*

Manufacturer	Characteristics	Operating conditions	Remarks
Stauffer Chemical Co.	CONTENT wt % $TiCl_4$ FORM: colourless liquid DENSITY (g/cm^3) 1.7	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used as a polymerization catalyst in combination with an aluminium alkyl, as an intermediate in the production of titanium dioxide, in the textile industry.

TYPE OF CATALYST: *TITANIUM TRICHLORIDES*

Manufacturer	Characteristics	Operating conditions	Remarks
Stauffer Chemical Co.	CONTENT wt % Titan. trichl. H $TiCl_3$ Titan. trichl. 1.1 $(TiCl_3)_3AlCl_3$ Titan. trichl. 1.2 $(TiCl_3)_3AlCl_3$ Titan. trichl. 2.1 $(TiCl_3)_3AlCl_3$ FORM: powder SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Grade H is used in systems in which stereospecificity is not important; Grade 1.1 is used to produce stereospecific polymers with a broad particle size distribution; Grade 1.2 produces stereospecific polymers with narrower particle size distribution; Grade 2.1 produces polymer in high yield with small particle size. Normally used in combination with an aluminium alkyl (Ziegler-Natta system) to produce polymers.

TYPE OF CATALYST: *VANADIUM OXYCHLORIDE*

Manufacturer	Characteristics	Operating conditions	Remarks
Stauffer Chemical Co.	CONTENT wt % $VO\,Cl_3$ FORM: light yellow liquid DENSITY (g/cm^3) 1.8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used as an olefin polymerization catalyst in combination with an aluminium alkyl and in the synthesis of trialkoxy and alkoxy chloro vanadates.

TYPE OF CATALYST: *VANADIUM TETRACHLORIDE*

Manufacturer	Characteristics	Operating conditions	Remarks
Stauffer Chemical Co.	CONTENT wt % VCl_4 FORM: red-brown liquid DENSITY (g/cm^3) 1.8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used as an olefin polymerization catalyst in combination with an aluminium alkyl, a source of high purity vanadium metal, a chlorinating agent and an intermediate in the preparation of organovanadium compounds.

TYPE OF CATALYST: *VANADIUM TRISACETYLACETONATE*

Manufacturer	Characteristics	Operating conditions	Remarks
Stauffer Chemical Co.	CONTENT wt % $V(C_5H_7O)_3$ FORM: brown solid DENSITY (g/cm^3) 0.48	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used as an olefin polymerization catalyst in combination with an aluminium alkyl and as an additive to Ziegler catalyst system for production of polypropylene and ethylene propylene elastomers.

CYCLIC OLIGOMERIZATION OF ACETYLENES TO BENZENES

TYPE OF CATALYST: *CHROMIUM 24012*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % Benzene chromium tricarbonyl $C_6H_6Cr(CO)_3$ FORM: yelow solid	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Application: Stereoselective hydrogenation of 1.4 and 1.3—dienes by 1.4—addition to form cis-monoenes; Air-stable.

CYCLYC OLIGOMERIZATION OF ACETYLENE

TYPE OF CATALYST: *NICKEL 28115; 28130*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % (a) Nickel carbonyl $Ni(CO)_4$ (b) Nickelocene bis (cyclopentadienyl) Nickel $(C_5H_5)_2Ni$ FORM: (a) colourless liquid; (b) dark-green solid	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Other applications: Carboxylation of acetylenes to acrylates; Carbonylation of allyl halides; Dimerization of ethylene. Stability: (a) Air sensitive, heat sensitive; (b) Air sensitive. Toxicity: (a) high

POLYMERIZATION OF OLEFINS

TYPE OF CATALYST: *TITANIUM 22115; 22118; 22020*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % (a) Titanium (IV) tetrachloride $TiCl_4$ (b) Titanium (III) trichloride $TiCl_3$ (c) Titanocene dichloride $(C_5H_5)_2TiCl_2$ FORM: (a) colourless liquid; (b) purple solid; (c) red solid	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Other applications: Hydrogenation of conjugated dienes to alkanes; Linear oligomerization and polymerization of olefins. Stability: (a) and (b): air senstive; (c): air stable.

TYPE OF CATALYST: *VANADIUM 23225; 23020*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % (a) Vanadium (III) acetylacetonate $V(C_5H_7O_2)_3$ (b) Vanadocene dichloride $(C_5H_5)_2VCl_2$ FORM: (a) brown solid; (b) green solid	TEMPERATURE RANGE: n. a. PRESSURE RANGE: n. a.	Other applications: Epoxidation of olefins; Selective hydrogenation of conjugated dienes to monoenes. Stability: both air sensitive.

POLYMERIZATION REACTIONS

TYPE OF CATALYST: *ALUMINIUM ALKYLS*

Manufacturer	Characteristics	Operating conditions	Remarks
Texas Alkyls Inc.	CONTENT wt % DEAC — Diethylaluminium chloride; DEAL-E— Diethylaluminium ethoxide; DEAL-I — Diethylaluminium iodide; DIBAC — Diisobutylaluminium chloride	TEMPERATURE RANGE: n. a. PRESSURE RANGE: n. a.	Others: DIBAL-H — Diisobutylaluminium hydride; EADC — Ethylaluminium dichloride; MONIBAC — Monoisobutylaluminium dichloride; ISOPRENYL — Isoprenylaluminium; TEAL — Triethylaluminium; TIBAR — Triisobutylaluminium; TEB — Triethyl borane. Catalyst components for olefin and diene polymers, including polypropylene, polyethylene, polybutadiene, polyisoprene, ethylene-propylene copolymers and terpolymers.

Annex IV

Carriers

CATALYTIC ALUMINA

TYPE OF CATALYST: *ALUMINA TABULAR ALUMINA T-71*

Manufacturer	Characteristics	Operating conditions	Remarks
Aluminium Company of America (ALCOA)	CONTENT wt % Al_2O_3 99.5 Na_2O 0.01 Fe_2O_3 0.06 SiO_2 0.04 SO_3 0.09 CaO 0.06 Loss on ignition (1,100°C): 0.0 FORM: granular SIZE: 4—8 mesh (4—1.3 mm) Diameter (mm) 12.5—25.3 Length (mm) n.a. ABD (g/cm³) 1.2—1.3 SA (m²/g) 0.5 PV (cm³/g) 0.15—0.20	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is a porous alumina having 35—50% porosity. It is used primarily as a low surface area catalyst or catalyst support. It may be used as an aggregate in insulating castable refractories.

CARRIER

TYPE OF CATALYST: *THERMA COMB^R BRAND ALSIMAG 795; ALSIMAG 843*

Manufacturer	Characteristics	Operating conditions	Remarks
American Lava 3M Company, Technical Ceramic Products Division	CONTENT wt % ALSIMAG 795: cordierite ($2MgO2Al_2O_3$ $5SiO_2$) ALSIMAG 843: lithia-alumina-silica FORM: n.a. SA (m²/g) 0.07—0.1 STRENGTH(kg/cm²) 141—195 (parallel to passages); 6.3 5 (perpendicular to passages)	TEMPERATURE RANGE: 1,200°C PRESSURE RANGE: n.a.	See ALSIMAG 614.

TYPE OF CATALYST: *ALPHA ALUMINA THERMA COMB^R BRAND ALSIMAG 614; ALSIMAG 776*

Manufacturer	Characteristics	Operating conditions	Remarks
American Lava 3M Company, Technical Ceramic Products Division	CONTENT wt % Alpha alumina FORM: corrugated ceramics	TEMPERATURE RANGE: 1,200°—1,538°C PRESSURE RANGE: n.a.	Catalyst supports in air pollution control, equipment for odour control, nitric acid tail gas, fume abatement, heat exchangers, flame arrestors, laminar flow gas mixers. Basic structure: A.H.C. Honey comb B. SC. Split Cell.

TYPE OF CATALYST: *SILICA BASF D-11—10*			
Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % SiO_2 main constituent Na + K approx. 0.6 Fe 0.15 Loss on ignition (dry base): 2—4 FORM: extrusions SIZE: Diameter (mm) 4—6 ABD (g/cm^3) 0.43 TS (°C) 550	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used for diverse chemical reactions.

TYPE OF CATALYST: *SILICA BASF D-11—11*			
Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % SiO_2 main constituent Na + K <0.05 Fe <0.06 Loss on ignition (dry base): 1—2 FORM: extrusions SIZE: Diameter (mm) 4—6 Length (mm) n.a. ABD (g/cm^3) 0.43 TS (°C) 700	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used for diverse chemical reactions.

CALSICAT DIVISION

ALUMINA SUPPORTS FOR EXPERIMENTAL USES

TYPICAL PROPERTIES

Calsicat 1/8″ tableted alumina supports

Type	SA m²/g(1)	ABD g/cm³(2)	PV cm³/g (3)	CS lbs. (4)	% of pores			
					>1μ	.1μ to 1μ	.01μ to.1 μ	<.01μ
A	200	.80	.50	20	2	10	5	83
B	160	.80	.50	15	3	13	6	78
C	50	.95	.44	15	3	20	57	20
D	5	1.25	.23	32	4	66	30	0
AA	215	.63	.70	25	2	1	35	62
BB	170	.65	.64	22	2	2	45	51
BC	150	.70	.63	20	1	4	68	26
CC	30	.93	.40	25	1	61	30	8
DD	9	1.00	.35	38	1	79	20	0

%SiO_2	A — D	.01	AA — DD	.12
%Na_2O	A — D	.005	AA — DD	.07

(1) Surface area by BET

(2) Bulk density, loose packing

(3) Pore volume by H_2O absorption

(4) Crush strength

CATALYST CARRIERS

Manufacturer: Catalysts and Chemicals International

Remarks: The catalyst carriers and supports described find a host of industrial catalytic applications when various active metals are added normally by impregnation

Designation	Principal components	Form	Size (in)	Surface area (m²/g)	Pore volume (cm³/g)	Density (lb/ft³)
CS-201	Silica alumina	tablets	1/4×1/4	500—600	0.80	32±3
CS-201-4	Alumina	Raschig rings	1/2×3/8××3/16	300	0.70	30±3
CS-300	Calcium aluminate	rings	1×0.6 and 3/4×3/4	100	0.30	45±5
CS-301	Alumina	spheres	1/4×3/4	1—2	0.10	130±10
CS-303	Alumina	Raschig rings	5/8×1/4 3/8 and5/8	5—10	0.20	65±5
CS-330	Alumina	extrusions	1/8 and 1/16	150±25	0.4—0.5	45±5
CS-330-2	Alumina	tablets	1/4×1/4	150±25	0.30	65±5
CS-331	Alumina	extrusions	1/8 and 1/16	300	0.80	30±3
CS 331-3	Alumina	extrusions	1/8 and 1/16	~360	~0.76	~38
CS-331-4	Alumina	extrusions	1/8 and 1/16	~350	~1.09	~43
CS-331-5	Alumina	extrusions	1/8 and 1/16	~320	~1.10	~26
CS-360	Silica alumina	spheres	1/3	~2	~0.20	~48

CARRIER

TYPE OF CATALYST: *ALUMOGEL 44—00*

Manufacturer	Characteristics	Operating conditions	Remarks
Chemical Works of CSF	CONTENT wt % Activated alumina Na_2O max. 0.8 SiO_2 max. 0.9 Fe_2O_3 max. 0.1 Loss by heating to 1,100°C: max. 7 FORM: balls SIZE: Diameter (mm) 3—5; 5—8 Length (mm) n.a. ABD (g/cm³) 0.9—0.9 STRENGTH (kg/cm²) 3	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used as dryer for gases and liquids.

TYPE : Activated carbon[a]	Content	SA (m²/g)	Applications	Remarks
Chemiviron S6L	Bituminous coal	1,000—12,000	Liquid phase applications	Granules 8× 30 mesh
Chemiviron Filtrasorb 200	Bituminous coal	1,000—12,000		
Chemiviron BPL & VCL	Bitumnious coal	1,200—1,400	Vapor phase applications: solvent recovery; carrier	
Chemiviron PAC & RB	Bituminous coal	800—1,000		
Chemiviron SC II	Coconut shell	1,150—1,250	Vapor phase applications: removal of organic sulphur compounds in fixed bed, selective adsorption of hydrocarbon fractions; removal of aromatics, purification of CO_2, acetylene, H_2, compressed air	
Chemiviron SC XII	Coconut shell	900—1,100		
Darco S 51	Lignite	500—550		
Darco S 60	Lignite	750—800		
Darco XB	Wood	950—1,000		
Hydro Darco	Lignite	550—650		
Nuchar Aqua	Pulp mill residue	550—650		
Nuchar C	Pulp mill residue	1,050—1,100		
Nuchar (various)	Pulp mill residue	300—1,400		
Norit (various)	Wood	700—1,400		
Type CA-1	Coal		Liquid phase applications-decolorization	Granules of 12×40 mesh
Type CP-6	Coal		Liquid phase applications-purification of vitamin solutions	Granules of 14×40 mesh
Type BPL & BPX	Coal		Vapor phase applications	

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[a] Chemiviron's granular activated carbons were developed by the Pittsburgh Activated Carbon Division of Calgon Corporation

TYPE OF CATALYST: ***INERT CATALYST BED SUPPORT***

Manufacturer	Characteristics	Operating conditions	Remarks
Fertilizer Corporation of India (F.C.I.)	CONTENT wt % Al_2O_3 main constituent 95—99.5 Na+K Fe FORM: spherical balls; extrusions SIZE: *balls extrusions* Diameter (mm) 3—38; 6—25 ABD (g/cm³) 1.2—1.5 TS (°C) 1,600	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used to protect catalyst beds.

TYPE OF CATALYST: *DAVISON MULLITE*

Manufacturer	Characteristics	Operating conditions	Remarks
Grace Davison Chemicals	CONTENT Thermally fused spheres of combined alumina and silica FORM: pellets	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used in the hydrocarbon processing industry. It is chemically inert.

TYPE OF CATALYST: *N-608; N-611; N-631*

Manufacturer	Characteristics	Operating conditions	Remarks
W.C. Heraeus GmbH	CONTENT wt % N-608: SiO_2 N-611: Al_3O_3 N-631: SiO_2/Al_2O_3 FORM: N-608: extrusions N-611 and N-631: tablets SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *H-0401*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Al_2O_3 90 SiO_2 0.05 Na_2O 0.4 Loss on ignition (at 750°C) : 9 FORM: extrusions SIZE: Diameter (mm) 4 Length (mm) 2—10 ABD (g/cm³) 0.9 SA (m²/g) 200 PV (cm³/g) 0.42	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Mean pore diameter 85Å.

TYPE OF CATALYST: *H-0403*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Al_2O_3 94—97 SiO_2 0.05 Na_2O 0.4—0.6 Loss on ignition (at 750°C): 6 FORM: extrusions SIZE: Diameter (mm) 2.4; 3.2; 4.0 Length (mm) 3—7 DENSITY (g/cm^3) 0.81—0.84 SA (m^2/g) 320—350 PV (cm^3/g) 0.52—0.56	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used as dryer for gases and fluids.

TYPE OF CATALYST: *H-0407*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Al_2O_3 98—99 SiO_2 0.05 Na_2O 0.4 Loss on ignition (at 750°C): 0.5 FORM: extrusions Diameter (mm) 4.0 Length (mm) 2—10 ABD (g/cm^3) 0.8 SA (m^2/g) 0.49	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Mean pore diameter 250Å. H-0407 contains about 10—15% γ and little η Al_2O_3.

TYPE OF CATALYST: *H-0408*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Al_2O_3 99 SiO_2 0.05 Na_2O 0.4 Loss on ignition (at 750°C): 0.5 FORM: extrusions SIZE: Diameter (mm) 4 Length (mm) 2—10 ABD (g/cm^3) 0.8 SA (m^2/g) 170 PV (cm^3/g) 0.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Mean pore diameter 120Å. H-0408 consists essentially of γ Al_2O_3.

TYPE OF CATALYST: *H-0418*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Al_2O_3 94—97 SiO_2 0.05 Na_2O 0.4—0.6 Loss on ignition (at 750°C): 2—6 CARRIER: n.a. FORM: extrusions SIZE: Diameter (mm) 2.4; 3.2; 4.0 Length (mm) 3—8 DENSITY (g/cm^3) 0.81—0.84 SA (m^2/g) 410—450 PV (cm^3/g) 0.52—0.54	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used as dryer for gases and fluids.

TYPE OF CATALYST: *ALUMINA ICI-12—1; ICI-12—2; ICI-13—1*

Manufacturer	Characteristics	Operating conditions	Remarks
Imperial Chemical Industries Ltd	CONTENT wt % Alumina FORM: powder; pellets SIZE: *pellets* Diameter (mm) 4—5.4 Length (mm) 3—3.6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	ICI-12—1 and 12—2: pellets; ICI-13—1: powder. They are medium area alumina catalysts largely used as supports in the production of noble metal catalysts. 12—1 and 12—2 are robust pellets and retain their strength during impregnation steps.

TYPE OF CATALYST: *ALUMINA ICI-13*

Manufacturer	Characteristics	Operating conditions	Remarks
Imperial Chemical Industries Ltd	CONTENT wt % Alumina FORM: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: ***ACTIVATED ALUMINA ACTAL***

Manufacturer	Characteristics	Operating conditions	Remarks
Laporte Industries Limited (Peter Spence)	CONTENT wt % Al_2O_3 85 residual H_2O 12 SO_3 3 Traces only of Na_2O, SiO_2, Fe_2O_3 and NH_3 FORM: granules; pellets SIZE (mm): *granules* *pellets* 12—6 11.1 6—3 7.9 3—1.5 5.6 1.5—0.7 3.2 ABD (g/cm^3) 0.61–0.66 0.875–0.925 SA (BET) (m^2/g) 275 n.a. PV(cm^3/g) 0.37 n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	In particular it is used for dehydration of ethanol to ethylene and also in the recovery of sulphur from refinery gases using the Claus reaction. Pelleted ACTAL is specially suitable for drying under high pressure and under conditions where rapid changes in pressure are likely to take place. Its use virtually eliminates the formation of dust.

TYPE OF CATALYST: ***ALUMINIUM OXIDE CATALYST KONTAKT 5780***

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT wt % Al_2O_3 93—99 SiO_2 <0.1 Fe_2O_3 <0.1 Na_2O <0.1 Halogen free FORM: n.a. ABD (g/cm^3) 0.5—1 SA (BET) (m^2/g) 200—300 PV (cm^3/g) 0.4—0.1	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used as carrier in γ and η active form and in inactive form α. As catalyst in dehydration of alcohols and as adsorbent.

TYPE OF CATALYST: ***ALUMINIUM OXIDE CATALYST KONTAKT 5704***

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT n.a. FORM: spheres SIZE: Diameter (mm) 3—5 ABD (g/cm^3) 0.95± 0.15 SA (m^2/g) 250	TEMPERATURE RANGE: 180°—250°C PRESSURE RANGE: n.a.	It is also used as dryer for gases.

TYPE OF CATALYST: *CERAMIC HONEYCOMB TORVEX*

Manufacturer	Characteristics	Operating conditions	Remarks
E.I. Du Pont de Nemours and Co. (Inc.)	CONTENT wt % ceramic	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Typical catalytic abatement system application with Torvex are in fume abatement equipment for the oxidation of hydrocarbon fumes or the reduction of nitrogen oxide fumes.

TYPE OF CATALYST: *COLLOIDAL SILICA LUDOX^R AS AND HS*

Manufacturer	Characteristics	Operating conditions	Remarks
E.I. Du Pont de Nemours and Co. (Inc.)	CONTENT wt % Stabilizing ammonium counter ion SiO_2 30 SiO_2/Na_2O 120 NaCl 0.002 Na_2SO_4 0.003 SIZE: 13—14.10^{-6} SA (m^2/g) 210—230	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used in petroleum refining as catalyst binder or support.

TYPE OF CATALYST: *ALPHA ALUMINA 13—075; 13—081*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % Al_2O_3 99.5 FORM: granules SIZE (mm): 6 — 8 mesh (13—081); 28 — 48 mesh(13—075)	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Low surface area alumina which are highly inert materials. They are also used for diluting catalyst beds, and packing inlet and outlet sections of tubular reactors.

TYPE OF CATALYST: *CARBON 06-005; 06-010; 06-014*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % (a) activated carbon (b) activated carbon (c) carbon fibers FORM: (a) granules; (b) powder; (c) 3.6 mm fibers SA (m^2/g) (a) and (b): high; (c): 300 PV (cm^3/g) (c): 0.4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It should be used in a non-oxidizing medium.

CARRIER (HIGH SURFACE AREA)

TYPE OF CATALYST: *ALPHA ALUMINA TRIHYDRATE 13—100*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % Al_2O_3 64.9 Combined-H_2O 34.7 Na_2O 0.35 FORM: powder	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	In addition is used as drying agent and dehydration catalyst.

TYPE OF CATALYST: *GAMMA ALUMINA 13—250*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % Al_2O_3 98 H_2O 2 FORM: powder SA (m^2/g) approx. 105	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used as drying agent and dehydration catalyst.

TYPE OF CATALYST: *GAMMA ALUMINA 13—255*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % Al_2O_3 98 FORM: pellets SIZE: Diameter (mm) 3 Length (mm) 3 SA (m^2/g) approx. 100	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See 13—250.

TYPE OF CATALYST: *GAMMA ALUMINA HIGH ACTIVITY 13—261*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % Al_2O_3 96 FORM: pellets SIZE: Diameter (mm) 3 Length (mm) 3 SA (m^2/g) approx. 200	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See 13-250.

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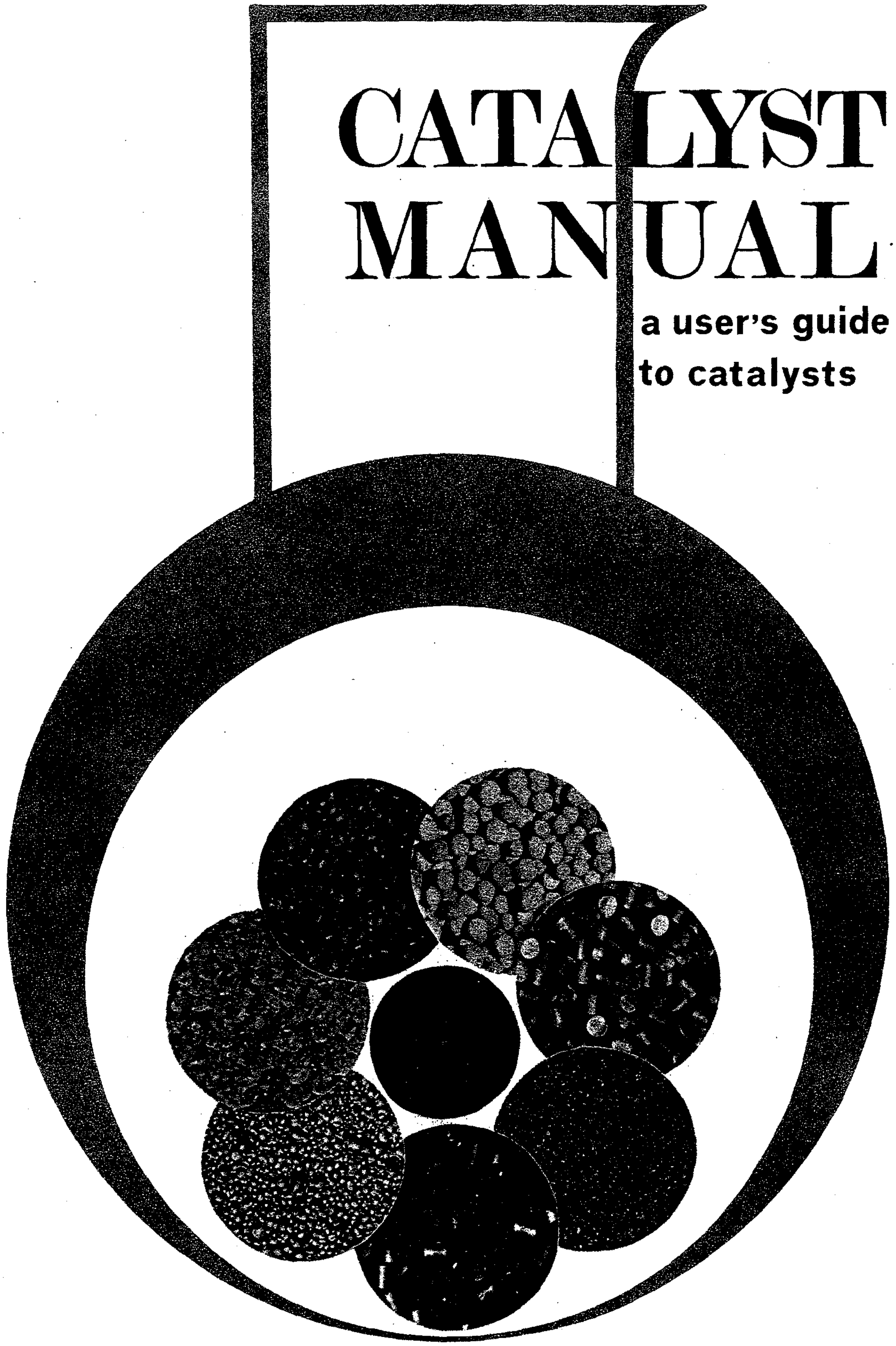
CATALYST MANUAL

a user's guide
to catalysts



for the petrochemical and fertilizer industries

★ ★

CATALYST MANUAL

A USER'S GUIDE TO CATALYSTS FOR THE PETROCHEMICAL AND FERTILIZER INDUSTRIES

ANNEXES

* *

Compiled by the
JOINT UNIDO-ROMANIA CENTRE
Bucharest

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Annex 1

Heterogeneous catalysts for main industrial processes

A. Ammonia production
B. Petrochemical industry
C. Production of acids

A. Ammonia production

Steam reforming

CO conversion (low temperature shift)

CO conversion (high temperature shift)

Methanation

Ammonia synthesis

Steam reforming

STEAM REFORMING OF NAPHTHA (PRIMARY)

TYPE OF CATALYST: *NICKEL MG-3C*

Manufacturer	Characteristics	Operating conditions	Remarks
Azote et Produits Chimiques S.A. (APC)	CONTENT: wt % Nickel CARRIER: ceramic material (magnesia) FORM: four-groove cylinders SIZE: Diameter (mm) 15 Length (mm) 15 ABD (g/cm³) 1.2	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It has been developed for primary reforming of naphthas and is used in production of synthesis gas for ammonia, methanol, oxo alcohols manufacture, more generally hydrogen, reducing gases ($H_2 + CO$) or town gas. Used for continuous pressure steam reforming.

TYPE OF CATALYST: *NICKEL RG-5C*

Manufacturer	Characteristics	Operating conditions	Remarks
Azote et Produits Chimiques S.A. (APC)	CONTENT wt % Nickel CARRIER: ceramic material FORM: four-groove cylinders SIZE: Diameter (mm) 15 Length (mm) 15 ABD (g/cm³) 1.3	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See MG-3C

REFORMING OF HYDROCARBONS

TYPE OF CATALYST: *NICKEL BASF G-1—10*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % Nickel 3 CARRIER: magnesium oxide FORM: approx. spherical SIZE: Diameter (mm) 18 ABD (g/cm³) 1.5 TS (°C) up to 1,400	TEMPERATURE RANGE: 700°–1,000°C PRESSURE RANGE: n.a.	Reforming of hydrocarbons such as methane, LPG and LPF with steam and oxygen or air. Used at atmospheric or elevated pressure, in continuous and cyclic reforming processes for the production of town gas, inert gas and synthesis gas.

TYPE OF CATALYST: *NICKEL BASF G-1—11*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % Nickel 6 CARRIER: magnesium oxide FORM: approx. spherical SIZE: Diameter (mm) 18 ABD (g/cm^3) 1.5 TS (°C) up to 1,400	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See BASF G-1-10

TYPE OF CATALYST: *NICKEL BASF G-1—21*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % Nickel CARRIER: ceramic FORM: cylindrical rings SIZE: Diameter (mm) 16 ABD (g/cm^3) 1 STRENGTH (kg/cm^2) 300 TS (°C) up to 900	TEMPERATURE RANGE: 650°—850°C PRESSURE RANGE: n.a.	For the production of ammonia synthesis gas, methanol synthesis gas and hydrogen. The catalyst is used for reforming of lower hydrocarbons preferably methane with steam and carbon monoxide in tube reactors at atmospheric or elevated pressure.

STEAM REFORMING OF GASES

TYPE OF CATALYST: *NICKEL BASF G-1—30*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % Nickel CARRIER: ceramic FORM: pellets SIZE: Diameter (mm) 16 ABD (g/cm^3) 1.4 STRENGTH (kg/cm^2) 300 TS (°C) up to 1,200	TEMPERATURE RANGE: 600°—1,000°C PRESSURE RANGE: n.a.	The reaction may take place at atmospheric or elevated pressure. The catalyst can be used alone or together with other BASF reforming catalysts, e.g. BASF G-1-40. Reforming of gases containing methane, LPG and LPF with steam.

STEAM REFORMING OF HIGHER HYDROCARBONS (PRIMARY)

TYPE OF CATALYST: *NICKEL BASF G-1—31*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % Nickel CARRIER: ceramic FORM: cylindrical rings SIZE: Diameter (mm) 16 Length (mm) 8 ABD (g/cm³) 1.1 STRENGTH (kg/cm²) >300 TS (°C) 1,200	TEMPERATURE RANGE: 600°–900°C PRESSURE RANGE: n.a.	The reaction may take place in type reactors, at atmospheric or elevated pressure, and the catalyst may be used by itself or together with an other BASF reforming catalyst (G-1-40). Application: production of hydrogen for hydrogenation purposes. Used in conjunction with BASF catalyst G-1-12 for the production of synthesis gas in secondary reformers.

STEAM REFORMING OF HYDROCARBONS

TYPE OF CATALYST: *NICKEL BASF G-1—40*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % Nickel CARRIER: n.a. FORM: cylindrical rings SIZE: Diameter (mm) 16 ABD (g/cm³) 1.2 STRENGTH (kg/cm²) 300 (measured at the faces) TS (°C) up to 1,400	TEMPERATURE RANGE: 600°–1,000°C PRESSURE RANGE: n.a.	Preferably used in combination with other BASF reforming catalysts. Used for production of synthesis gas, town gas and hydrogen. Used also for reforming of higher hydrocarbons including light liquid petroleum fractions with steam at atmospheric or elevated pressure.

STEAM REFORMING OF HYDROCARBONS (PRIMARY)

TYPE OF CATALYST: *NICKEL BASF G-1—50*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % Nickel CARRIER: n.a. FORM: cylindrical rings SIZE: Diameter (mm) 16 ABD (g/cm³) 1.1 STRENGTH (kg/cm²) 300 (measured at the faces) TS (°C) up to 1,000	TEMPERATURE RANGE: 600°–900°C PRESSURE RANGE: n.a.	Reforming of higher hydrocarbons including light liquid petroleum fractions with steam at atmospheric or elevated pressure. Preferably used in combination with an other BASF catalyst, e.g. BASF G-1-40.

TYPE OF CATALYST: *NICKEL C-11*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Nickel oxide 20–40 CARRIER: calcium silicate, aluminate, magnesium oxide FORM: rings, spheres, tablets SIZE (mm): 16× 9 (rings) 16×16 (rings) 19×18 (rings) 19×12 (rings) TS (°C) 1,300	TEMPERATURE RANGE: up to 1,300°C PRESSURE RANGE: n.a.	A class of steam hydrocarbon reforming catalysts for the production of hydrogen, ammonia, methanol and oxo synthesis gases, by promoting the reaction between low molecular weight hydrocarbons such as methane, refinery gases and LPG with steam and/or carbon dioxide at temperatures above 550°–650°C. Used in primary reforming.

TYPE OF CATALYST: *NICKEL C-11–2*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Nickel oxide 35 CARRIER: all alumina carriers; no silica FORM: rings SIZE: Diameter (mm) 16 Length (mm) 16 ABD (g/cm³) 0.8	TEMPERATURE RANGE: 600°–1,000°C PRESSURE RANGE: n.a.	Used in primary reforming.

TYPE OF CATALYST: *NICKEL C-11–2S*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Nickel oxide CARRIER: all refractory carriers, not silica FORM: Raschig rings SIZE: Diameter (mm) 16 Length (mm) 10	TEMPERATURE RANGE: 600°–1,000°C PRESSURE RANGE: 1–40 atm. SPACE VELOCITY: 1,000–7,000 h⁻¹	Used principally for reforming natural gas. It is the high activity version of the C-11-2 catalyst.

TYPE OF CATALYST: *NICKEL C-11—4*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Nickel oxide 18—26 CARRIER: refractory FORM: tablets; rings SIZE: tablets rings Diameter (mm) 12.5,19 19 Length (mm) 12.5,19 15,19	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used in secondary reformers.

TYPE OF CATALYST: *NICKEL C-11—9*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Nickel oxide CARRIER: high purity alumina FORM: rings SIZE (mm): 15.87×15.87×6.35 15.87×9.525×6.35 ABD (g/cm^3) 1.2—1.28 SA (m^2/g) 5÷15 PV (cm^3/g) 0.2—0.3 STRENGTH (kg/cm^2) 40	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	A steam reforming catalyst (primary reformers) for production of ammonia, hydrogen, methanol synthesis gas, naphtha reforming and reducing gases for metallurgical application; it can also be used in oxo-alcohol and methanol synthesis plants where carbon dioxide is added to the reformer.

HIGH TEMPERATURE STEAM REFORMING OF HYDROCARBONS

TYPE OF CATALYST: *NICKEL C-14*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Nickel oxide 4—7 CARRIER: high purity alumina FORM: irregular particles SIZE: Diameter (mm) 15.87 Length (mm) 2.54;3.17 ABD (g/cm^3) 1.312	TEMPERATURE RANGE: 1,010°—1,260°C PRESSURE RANGE: n.a.	It is used for promoting the reaction between steam and oxygen and/or carbon dioxide and low molecular weight hydrocarbons to produce hydrogen and synthesis gases for ammonia, methanol and other synthesis. Suitable for operation in the fixed bed (secondary reformers) employing high pressure reforming.

TYPE OF CATALYST: *CHROMIUM C-15*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Chrome oxide 4–8 CARRIER: high purity alumina FORM: spheres; irregular rings SIZE: Diameter (mm) 18.05 ABD (g/cm^3) 1.0–1.3	TEMPERATURE RANGE: 1,000°–1,430°C PRESSURE RANGE: 40 atm	The remarks of C-14 catalyst are valable also forC-15 catalyst. The activity of C-15 catalyst in its normal operating temperature range of 1,000°–1,430°C is equivalent to that of C-11-2 catalyst at temperature of 650°–930°C. It is used as high temperature steam hydrocarbon reforming catalyst.

STEAM REFORMING

TYPE OF CATALYST: *NICKEL NC-1*

Manufacturer	Characteristics	Operating conditions	Remarks
Combinatul Chimic Craiova	CONTENT wt % Nickel oxide 4.5–6.3 CARRIER: alumina FORM: cylinders SIZE: Diameter (mm) 12 Length (mm) 18 ABD (g/cm^3) 1.0–1.1 STRENGTH (kg/cm^2) 15	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a. SPACE VELOCITY: 1,000 h^{-1}	Steam reforming of methane, in ammonia synthesis plants.

TYPE OF CATALYST: *NICKEL NC-2*

Manufacturer	Characteristics	Operating conditions	Remarks
Combinatul Chimic Craiova	CONTENT wt % Nickel oxide 7–10 CARRIER: refractory FORM: rings, cylinders SIZE: rings cylinders Diameter (mm) 16 12 Langth (mm) 16 12 ABD (g/cm^3) 0.75–1 STRENGTH (kg/cm^2) 250	TEMPERATURE RANGE: 800°C PRESSURE RANGE: n.a. SPACE VELOCITY: 1,000 h^{-1}	See NC-3.

TYPE OF CATALYST: ***NICKEL NC-3***

Manufacturer	Characteristics	Operating conditions	Remarks
Combinatul Chimic Craiova	CONTENT wt % Nickel oxide 13—16 CARRIER: refractory FORM: rings, cylinders SIZE: Diameter (mm) 16;12 Length (mm) 16;12 ABD (g/cm^3) 0.75–1 STRENGTH (kg/cm^2) 250	TEMPERATURE RANGE: 800°C PRESSURE RANGE: n.a. SPACE VELOCITY: 1,000 h^{-1}	Steam reforming of methane for production of synthesis gas in ammonia and methanol synthesis plants.

TYPE OF CATALYST: ***NICKEL NC-4***

Manufacturer	Characteristics	Operating conditions	Remarks
Combinatul Chimic Craiova	CONTENT wt % Nickel oxide 20–23 CARRIER: refractory FORM: rings, cylinders SIZE: Diameter (mm) 16;12 Length (mm) 16;12 ABD (g/cm^3) 0.75–1 STRENGTH (kg/cm^2) 250	TEMPERATURE RANGE: 750°C PRESSURE RANGE: n.a. SPACE VELOCITY: 1,000 h^{-1}	Used for obtaining hydrogen for ammonia, methanol and oxo synthesis.

TYPE OF CATALYST: ***NICKEL NC-5***

Manufacturer	Characteristics	Operating conditions	Remarks
Combinatul Chimic Craiova	CONTENT wt % Nickel oxide 30–33 CARRIER: refractory FORM: rings, cylinders SIZE: Diameter (mm) 16;12 Length (mm) 16;12 ABD (g/cm^3) 0.75–1 STRENGTH (kg/cm^2) 250	TEMPERATURE RANGE: 750°C PRESSURE RANGE: n.a. SPACE VELOCITY: 1,000 h^{-1}	For production of synthesis gas in ammonia, methanol and oxo processes plants.

PRIMARY REFORMING OF NAPHTHA

TYPE OF CATALYST: *NICKEL CDRN 33A*

Manufacturer	Characteristics	Operating conditions	Remarks
Fertilizer Corporation of India (F.C.I.)	CONTENT wt % Nickel CARRIER: rugged alumina FORM: tablets, Raschig rings, cylindrical rods SIZE (mm): tablets: 10×10 Raschig rings: 17×17×6 16×16×16 16×16×10 cylindrical rods: 5×12 10×30 ABD (g/cm^3) 1–1.1 Steam: carbon ratio: 3.0–5.0	TEMPERATURE RANGE: 750°–850°C PRESSURE RANGE: 1.35 atm SPACE VELOCITY: 0.9 h^{-1}	It is suitable for primary reforming of naphtha for the production of ammonia synthesis gas. Liquid feed stock.

SECONDARY REFORMING OF NAPHTHA

TYPE OF CATALYST: *NICKEL CDRN 33C*

Manufacturer	Characteristics	Operating conditions	Remarks
Fertilizer Corporation of India (F.C.I.)	CONTENT wt % Nickel CARRIER: rugged alumina FORM: see CDRN 33A SIZE: see CDRN 33A	TEMPERATURE RANGE: 750°–1,200°C PRESSURE RANGE: up to 35 atm LIFE: more than 3 years SPACE VELOCITY: 500 h^{-1}	

STEAM REFORMING OF GASEOUS HYDROCARBONS

TYPE OF CATALYST: *NICKEL CDR 66A*

Manufacturer	Characteristics	Operating conditions	Remarks
Fertilizer Corporation of India (F.C.I.)	CONTENT wt % Nickel CARRIER: alumina FORM: see CDRN 33A SIZE: see CDRN 33A Steam: carbon ratio 2.5–4.0	TEMPERATURE RANGE: 700°–900°C PRESSURE RANGE: 35 atm SPACE VELOCITY: up to 1,200 h^{-1}	Used for production of ammonia synthesis gas. It is suitable for primary steam gas reforming.

TYPE OF CATALYST: ***NICKEL CDR 66B***

Manufacturer	Characteristics	Operating conditions	Remarks
Fertilizer Corporation of India (F.C.I.)	CONTENT wt % Nickel CARRIER: alumina FORM: see CDRN 33A SIZE: see CDRN 33A	TEMPERATURE RANGE: n.a. PRESSURE RANGE: 35 atm SPACE VELOCITY: 5,000 h^{-1}	Suitable for secondary reforming where oxygen/air is added along with steam.

STEAM REFORMING OF HYDROCARBONS (SECONDARY)

TYPE OF CATALYST: ***NICKEL G-31B***

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Nickel 7 CARRIER: α Al_2O_3 FORM: lumps SIZE (mm): 15–18 ABD (g/cm^3) 0.95–1.0	TEMPERATURE RANGE: 600°–1,200°C PRESSURE RANGE: n.a.	The catalyst is recommended when carbon deposition on the catalyst may be encountered. The principal application for autothermic reforming furnaces. With similar application are G-31A, irregular lumps of 18–38 mm, G-31C, extrusions of 25×25 mm.

TYPE OF CATALYST: ***CHROMIUM G-34***

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT n.a. CARRIER: n.a. FORM: irreg. lumps, extrusions SIZE (mm): G-34A (irreg. lumps): 18—30 G-34B (irreg. lumps): 12–24 G-34C (extrusions): 25×25	TEMPERATURE RANGE: 1,300°–1,540°C PRESSURE RANGE: n.a.	Essentially similar to G-31 in application.

TYPE OF CATALYST: *NICKEL G-56*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % G-56 G-56B Ni 15 25 S 0.03 0.04 SiO_2 0.2 0.2 CARRIER: n.a. FORM: rings, cylinders SIZE (mm): rings: 7×17×6 cylinders: 6×6;9×9 ABD (g/cm^3) 0.85± 0.064	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for the reaction of hydrocarbons with steam, steam and carbon dioxide, steam and air, steam and oxygen or with air to produce hydrogen, ammonia synthesis gas, methanol synthesis gas, oxo synthesis gas, further hydrogen carbon oxide mixture, town gas and buffer gases. Primary reformers. G-29: a standard reforming catalyst has been largely replaced by G-56.

TYPE OF CATALYST: *NICKEL GPR-5; GPR-6*

Manufacturer	Characteristics	Operating conditions	Remarks
Grande Paroisse	CONTENT wt % NiO ZnO_2 MgO SiO_2 CARRIER: n.a. FORM: pellets SIZE: Diameter (mm) 15 STRENGTH (kg/cm^2) 30−60 TS (°C) $>$ 1,000	TEMPERATURE RANGE: higher than 1,000 C PRESSURE RANGE: 1−60 atm.	GPR-5 is used for steam reforming of natural gas. GPR-6 is used for steam reforming of hydrocarbons heavier than methane and unsaturated until and excluding C_5.

TYPE OF CATALYST: *NICKEL N-139; N-134*

Manufacturer	Characteristics	Operating conditions	Remarks
W.C. Heraeus GmbH	CONTENT wt % Nickel CARRIER: Al_2O_3 FORM: cylindrical tablets SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Steam reforming of hydrocarbons for production of synthesis gas.

GAS REFORMING

TYPE OF CATALYST: *NICKEL ICI 54-2, ICI 54—2S*

Manufacturer	Characteristics	Operating conditions	Remarks
Imperial Chemical Industries Ltd. (I.C.I.)	CONTENT wt % Supported nickel oxide FORM: rings; pellets SIZE: Diameter (mm) 17 Length (mm) 11—17 ABD (g/cm^3) 1.0	TEMPERATURE RANGE: up to 1,000°C PRESSURE RANGE: up to 35 atm SPACE VELOCITY: 4,000—7,000 h^{-1}	It can also be used for some primary reforming duties. For secondary reforming in ammonia plants.

STEAM REFORMING

TYPE OF CATALYST: *NICKEL ICI 57—3; 57—4*

Manufacturer	Characteristics	Operating conditions	Remarks
Imperial Chemical Industries Ltd. (I.C.I.)	CONTENT wt % Supported nickel oxide CARRIER: n.a. FORM: rings; pellets SIZE: Diameter (mm) 17 Length (mm) 17 ABD (g/cm^3) 1.1	TEMPERATURE RANGE: up to 850°C PRESSURE RANGE: up to 35 atm	They are used for the primary reforming of methane, and other light hydrocarbons in tubular reformers. They are affected by sulphur, chlorine and arsenic compounds. Available as 57-3S and 57-4S.

STEAM REFORMING (SECONDARY REFORMING)

TYPE OF CATALYST: *NICKEL KATALCO 54—1*

Manufacturer	Characteristics	Operating conditions	Remarks
Katalco Corporation	CONTENT wt % Nickel oxide CARRIER: ceramic FORM: rings SIZE: Diameter (mm) 17 Length (mm) 17 ABD (g/cm^3) 0.8 TS (°C) 1,100	TEMPERATURE RANGE: n.a. PRESSURE RANGE: 1—28 atm LIFE: greater than 5 years SPACE VELOCITY (VHSV): 1,500—5,000 h^{-1}	Secondary reforming of light hydrocarbons in plant for production of ammonia synthesis gas.

STEAM REFORMING OF HYDROCARBONS

TYPE OF CATALYST: *NICKEL KONTAKT 9041*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht"	CONTENT wt % Nickel CARRIER: ceramic FORM: extrusions, cylinders SIZE: Diameter (mm) 12;14;16 Length (mm) 12;14;16 ABD (g/cm^3) 1.2±0.12 1±0.1	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for production of synthesis gas by autothermic reforming of methane, also for production of town gas.

STEAM REFORMING UNDER PRESSURE

TYPE OF CATALYST: *NICKEL GH-651; GH-652*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Promoted nickel CARRIER: special FORM: rings SIZE: Diameter (mm) 15–20	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	GH-651 is used for H_2 production. GH-652 is recommended for the production of synthesis gas used for the ammonia synthesis (primary reforming).

STEAM REFORMING OF HYDROCARBONS

TYPE OF CATALYST: *NICKEL RKN*

Manufacturer	Characteristics	Operating conditions	Remarks
Haldor Topsøe	CONTENT wt % Ni 25 SiO_2 <0.2 Other major components are oxides of magnesia and alumina CARRIER: n.a. FORM: rings SIZE: Diameter (mm) $\frac{13}{6}$ $\frac{13}{6}$ $\frac{16}{6}$ $\frac{19}{6}$ Length (mm) 7 13 16 15 ABD (g/cm^3)0.8–0.9 STRENGTH (kg/cm^2) 300	TEMPERATURE RANGE: 400°–870°C PRESSURE RANGE: 17–40 atm	Used for the upper part of the reforming tubes, the catalyst will normally be delivered in a preactivated modification — RKNR.

TYPE OF CATALYST: ***NICKEL RKS-1***

Manufacturer	Characteristics	Operating conditions	Remarks
Haldor Topsøe	CONTENT wt % Nickel oxide 17 CARRIER: magnesia-alumina-spinel FORM: rings SIZE: Diameter (mm) 3/19 and 6/9 Length (mm) 13–19 Axial direction: 300 Radial direction: 25	TEMPERATURE RANGE: 425°–1,350°C PRESSURE RANGE: up to 40 atm	It contains only 0.2 SiO_2. Fusion point: 2,000°C. There is a second version RKS-2 which contains only 9% Ni. RKS catalyst is well suited for use both at low temperatures in tubular reformers and at high temperatures, in secondary and autothermal reformers for the production of synthesis gas.

CO conversion (low temperature shift)

CO CONVERSION (SHIFT CONVERSION)

TYPE OF CATALYST: *COPPER AND ZINC C-18*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Copper oxide and zinc oxide in different weight percentage depending on type of catalyst CARRIER: alumina FORM: tablets SIZE: Diameter (mm) 6;3;4 Length (mm) 6;3;4 ABD (g/cm^3) 1.28	TEMPERATURE RANGE: 177°–315°C PRESSURE RANGE: n.a.	A group of a low temperature shift catalyst. It is possible with these catalysts to produce high purity hydrogen and synthesis gas with only one stage of CO conversion and one stage of CO_2 removal.

TYPE OF CATALYST: *COPPER-ZINC C-18—1.03*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT of calcined base wt % CuO 25.3 ZnO/CuO ratio 2 Al_2O_3 30.0 Cr_2O_3 0.01 S <0.04 Na <0.10 Cl <0.01 CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It contains (in ppm): Sn 10– 30 Pb 10– 30 Ni 90–120 Fe 300 Low temperature conversion catalyst.

TYPE OF CATALYST: *COPPER-ZINC C-18—3.02*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT of calcined base wt % ZnO: CuO 2 CuO ±28 Al_2O_3 ±15 Cr_2O_3 <0.01 S <0.04 Na <0.10 Cl <0.01 CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 6.35 Length (mm) 3.175 ABD (g/cm^3) 1.15 STRENGTH (kg/cm^2) 9.06	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The catalyst contains in ppm 2gt Sn 0–10 Pb 0–10 Ni 40–60 Fe 250 Low temperature conversion catalyst.

TYPE OF CATALYST: *COPPER AND ZINC C-18-HC*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % 1:1 ratio of ZnO to CuO, 10% alumina for thermal stabilization CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	All C-18 catalysts are supplied with the metals in the oxide state and they must be reduced according to prescribed procedures, before being placed in service. C-18-HCA is an improved version of C-18-HC, having a smaller copper crystallite size which provides a higher copper surface area per unit volume of catalyst. Low temperature conversion catalysts.

TYPE OF CATALYST: *COPPER C-117*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Copper CARRIER: zinc oxide FORM: pellets SIZE: Diameter (mm) 4 ABD (g/cm^3) 1.12±0.08	TEMPERATURE RANGE: 117°—288°C PRESSURE RANGE: 1—42 atm	Low temperature conversion catalyst.

TYPE OF CATALYST: *MIXED OXIDES CDLT-21*

Manufacturer	Characteristics	Operating conditions	Remarks
Fertilizer Corporation of India (F.C.I.)	CONTENT wt % Mixed oxides CARRIER: n.a. FORM: cylindrical tablets SIZE: Diameter (mm) 6 Length (mm) 6 ABD (g/cm^3) 1.35	TEMPERATURE RANGE: 190°—270°C PRESSURE RANGE: 35 atm SPACE VELOCITY: 3,000 h^{-1} (dry base)	Low temperature conversion catalyst.

TYPE OF CATALYST: *COPPER-ZINC C-66*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Copper-zinc oxide CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 6 Length (mm) 3 ABD (g/cm^3) 1	TEMPERATURE RANGE: 175°—260°C PRESSURE RANGE: n.a.	Available (in oxide form) either as G-66A (nominally 18% alumina and containing 0.272 g of active copper per cm^3) or as G-66B (alumina free, nominally containing 30% wt CuO). Both catalysts are supplied in pre-reduced and stabilized versions, designated G-66ARS and G-66 BRS. Sulphur, chlorine compounds and unsaturated hydrocarbons will cause a loss of activity. Low temperature conversion catalyst.

TYPE OF CATALYST: *COPPER ICI-52—1*

Manufacturer	Characteristics	Operating conditions	Remarks
Imperial Chemical Industries Ltd.	CONTENT wt % Copper oxide, zinc oxide CARRIER: alumina FORM: pellets SIZE: Diameter (mm) 5.4 Length (mm) 3.6 ABD (g/cm^3) 0.9	TEMPERATURE RANGE: 180°—250°C PRESSURE RANGE: up to 50 atm SPACE VELOCITY: 2,000—5,000 h^{-1}	Low temperature shift catalyst. It has high thermal stability but is affected by sulphur and chlorine compounds. The catalyst itself is partially self guarding but in some circumstances a special guard bed may be required.

TYPE OF CATALYST: *COPPER KONTAKT 1960*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht”	CONTENT wt% Copper oxide, chromium oxide and zinc oxide CARRIER: n.a. FORM: pellets SIZE: Diameter (mm) 5 ABD (g/cm^3) 1.3± 0.2 STRENGTH (kg/cm^2) 90 ± 30	TEMPERATURE RANGE: 200°—230°C PRESSURE RANGE: n.a.	Low temperature conversion catalyst.

TYPE OF CATALYST: *COPPER KONTAKT 1961*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht"	CONTENT wt % Copper oxide, chromium oxide, aluminium oxide, zinc oxide CARRIER: n.a. FORM: pellets SIZE: Diameter (mm) 5 ABD (g/cm^3) 1.3±0.2 STRENGTH (kg/cm^2) 200±50	TEMPERATURE RANGE: 200°—260°C PRESSURE RANGE: n.a.	Low temperature conversion catalyst.

TYPE OF CATALYST: *COPPER KONTAKT 1962*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht"	CONTENT wt % Cooper oxide Zinc oxide Aluminium oxide CARRIER: n.a. FORM: cylindrical pellets SIZE: Diameter (mm) 5 Length (mm) 5 ABD (g/cm^3) 0.55±0.15 STRENGTH (kg/cm^2) 200±50	TEMPERATURE RANGE: 200°—260°C PRESSURE RANGE: n.a.	Low temperature conversion catalyst.

TYPE OF CATALYST: *COPPER, ZINC AND CHROMIUM LSK*

Manufacturer	Characteristics	Operating conditions	Remarks
Haldor Topsøe	CONTENT wt % Oxides of copper, zinc and chromium CuO 0.2 g/cm^3 catalyst CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 4.5 Length (mm) 4.5 ABD (g/cm^3) 1.06 STRENGTH (kg/cm^2) 160	TEMPERATURE RANGE: 200°—300°C PRESSURE RANGE: n.a.	Particle density 1.7 g/cm^3. Low temperature conversion catalyst.

CO conversion (high temperature shift)

CO CONVERSION (SHIFT CONVERSION)

TYPE OF CATALYST: *IRON-CHROMIUM H4 BCP5*			
Manufacturer	Characteristics	Operating conditions	Remarks
Azote et Produits Chimiques SA (APC)	CONTENT wt % Iron oxide as Fe_2O_3 Chrome oxide as Cr_2O_3 Kalium oxide as K_2O CARRIER: n.a. FORM: cylindrical pellets SIZE: Diameter (mm) 6;11 Length (mm) 6; 8 ABD (g/cm^3) 1.8;1.6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Town gas detoxication. It is used for high temperature CO conversion.

TYPE OF CATALYST: *IRON-CHROMIUM BASF K-6—10*			
Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % Graphite 2—3 Iron oxide and chrome oxide CARRIER: n.a. FORM: pellets. SIZE: Diameter (mm) 6;9 Length (mm) 6;5 ABD (g/cm^3) 1.1 SA (m^2/g) 60 PV (cm^3/g) 0.4 STRENGTH (kg/cm^2) 250 (measured at the faces) TS (°C) up to 550	TEMPERATURE RANGE: 300^0-500^0C PRESSURE RANGE: n.a.	Used in high temperature CO conversion. Used for the production of synthesis gas and hydrogen and for the detoxification of town gas.

TYPE OF CATALYST: *COBALT-MOLYBDENUM BASF K8—11*			
Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % Oxides of cobalt and molybdenum CARRIER: special FORM: extrusions SIZE: Diameter (mm) 4 ABD (g/cm^3) 0.75 TS (^{0}C) up to 550	TEMPERATURE RANGE: 290^0-500^0C PRESSURE RANGE: 1—70 atm	At pressures above 70 atm it is used only in conjunction with partial oxidation by Texaco process. It is used for high temperature CO conversion.

TYPE OF CATALYST: *IRON CHROMIA C-12*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Cr_2O_3 and Fe_2O_3 CARRIER: n.a. FORM: tablets SIZE: Diameter (mm)9;9;9;6 Length (mm)4;6;9;6	TEMPERATURE RANGE: 343°–510°C PRESSURE RANGE: 1–45 atm	A class of carbon monoxide conversion at elevated temperatures with steam, in hydrogen-rich steams to form additional quantities of hydrogen. These catalysts are used also for: water gas generators steam hydrocarbon reformers controlled atmosphere generators partial oxidation processes purification of hydrogen following the steam iron process.

TYPE OF CATALYST: *IRON CHROMIA C-12–1*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Cr, as Cr_2O_3 9–11 Fe, as Fe_2O_3 77–81 Graphite 3– 4 CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 6;9 Length (mm) 6;9 STRENGTH (kg/cm^2) (DWL) 6 mm tablets: 13.6–18.1 9 mm tablets: 16–20	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Reaction of carbon monoxide with steam at high temperature to produce hydrogen and carbon dioxide. It is recommended for non-severe operating conditions.

TYPE OF CATALYST: *IRON CHROMIA C-12–2*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Cr as Cr_2O_3 9–11 Fe as Fe_2O_3 77–81 Graphite 3– 4 CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 6;3 Length (mm) 6;3 STRENGTH (kg/cm^2) (DWL) 6 mm tablets: 15.8–20 3 mm tablets: 18–22.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Reaction of carbon monoxide with steam to produce hydrogen and carbon dioxide. It is available for severe operating conditions (high temperatures).

TYPE OF CATALYST: *IRON CHROMIA C-12—3*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Cr as Cr_2O_3 9—11 Fe as Fe_2O_3 77—81 Graphite 3— 4 CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 6;9 Length (mm) 6;9 STRENGTH (kg/cm^2) (DWL) 6 mm tablets: 18—25 9 mm tablets: 20—27	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Reaction of carbon monoxide with steam to produce hydrogen and carbon dioxide. It is available for severe operating conditions (high temperatures).

TYPE OF CATALYST: *IRON CHROMIA C-16*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Coprecipitated iron oxide, containing a binder to give it an added physical strength CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 6;9 Length (mm) 6;9	TEMPERATURE RANGE: n a. PRESSURE RANGE: n.a.	Used for the production of hydrogen by promoting reaction between steam and carbon monoxide, especially at elevated pressures.

TYPE OF CATALYST: *COBALT-MOLYBDENUM C-25*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Cobalt-molybdenum CARRIER: alumina FORM: tablets; extrusions SIZE: n.a.	TEMPERATURE RANGE: 316°—538°C PRESSURE RANGE: n.a.	C-25 should be considered for use with process gases produced by coal gasification or by the partial oxidation of heavy sulphur containing feed stocks. High temperature CO conversion catalyst.

TYPE OF CATALYST: *IRON CHEZA 31—00*

Manufacturer	Characteristics	Operating conditions	Remarks
Chemical Works of CSF	CONTENT wt % Cr_2O_3 7 SO_3 1 Fe_2O_3 92 Cr_2O_3 is a promotor FORM: extrusions SIZE: Diameter (mm) 9;6 Length (mm) 10—20; ABD (g/cm^3) 1.5 STRENGTH (kg/cm^2) 8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a. LIFE: 2 or more years	Used for the industrial production of hydrogen or synthesis gas which are used for ammonia and methanol synthesis. It is a high temperature CO conversion catalyst.

TYPE OF CATALYST: *IRON CHEZA 31—01*

Manufacturer	Characteristics	Operating conditions	Remarks
Chemical Works of CSF	CONTENT wt % Cr_2O_3 7 SO_3 1 Fe_2O_3 92 Cr_2O_3 is a promotor FORM: tablets SIZE: Diameter (mm) 10 Length (mm) 8—10 ABD (g/cm^3) 1.5 STRENGTH (kg/cm^2) 200	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a. LIFE: 2 or more years	It is a more active modification of catalyst 31—00. Its advantage makes it possible to work at a lower temperature.

TYPE OF CATALYST: *IRON FC-1*

Manufacturer	Characteristics	Operating conditions	Remarks
Combinatul Chimic Craiova	CONTENT wt % Fe_2O_3 83—89 Cr_2O_3 8—12 FeO 0.2—0.6 Impurities 3.8—4.4 CARRIER: n.a. FORM: cylinders SIZE: Diameter (mm) 8—10 Length (mm) 5—30 ABD (g/cm^3) 1.1—1.2 STRENGTH (kg/cm^2) 8—10	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used in ammonia synthesis plants for conversion of carbon monoxide to carbon dioxide.

TYPE OF CATALYST: *IRON CHROMIA CDC-63*

Manufacturer	Characteristics	Operating conditions	Remarks
Fertilizer Corporation of India (F.C.I.)	CONTENT wt % Chromia promoted iron oxide CARRIER: n.a. FORM: cylindrical tablets SIZE: Diameter (mm) 6;10;10 Length (mm) 6;10;6 ABD (g/cm^3) 1.2	TEMPERATURE RANGE: 350°–530°C PRESSURE RANGE: up to 10 atm	CDC-63 series are used in high temperature CO conversion plants. The catalyst can be used in low as well as in high pressure installations. Available as: CDC-63A for operations at lower pressure up to 10 kg/cm^2; CDC-63B having low S content for use in plants where low temperature CO conversion (very susceptible to sulphur poisoning) is also in operation.

TYPE OF CATALYST: *IRON G-3B, G-3A, G-3BL*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Chromium promoted iron oxide CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 6;9;9 Length (mm) 6;9;6	TEMPERATURE RANGE: 315°–530°C PRESSURE RANGE: 1–60 atm	It is used in processes where high sulphur content is encountered. Type G-3A originally designated as G-3. G-3B is also available in a low sulphur containing version designated G-3BL. They are high temperature CO conversion catalysts.

TYPE OF CATALYST: *IRON-CHROMIUM CPC-5*

Manufacturer	Characteristics	Operating conditions	Remarks
Grande Paroisse	CONTENT wt % Fe as Fe_2O_3 Cr as CrO_3 CARRIER: n.a. FORM: pellets SIZE: Diameter (mm) 11	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	A good space velocity. High temperature conversion catalyst.

TYPE OF CATALYST: *IRON. ICI 15-4; ICI 15-5*

Manufacturer	Characteristics	Operating conditions	Remarks
Imperial Chemical Industries Ltd. (ICI)	CONTENT wt % Iron oxide and chromium oxide CARRIER: n a. FORM: pellets SIZE: ICI 15-4;15-5 Diameter (mm) 8.5;5.4 Length (mm) 10.5;3.6 ABD (g/cm³) 1.35	TEMPERATURE RANGE: 330°–530°C PRESSURE RANGE: 50–100 atm	ICI 15–4 has a conventional level of activity. ICI 15 – 5 is a higher activity version. Both require initial reduction of the iron oxide (Fe_2O_3) to magnetite (Fe_3O_4). Their activity can however be affected by concentrations of halogens, but sulphur is not a poison in the normal sense.

TYPE OF CATALYST: *IRON.CHROMIA KATALCO 15—5*

Manufacturer	Characteristics	Operating conditions	Remarks
Katalco Corporation	CONTENT wt % Chromia promoted iron oxide CARRIER: n.a. FORM: cylindrical tablets SIZE: Diameter (mm) 10;6 Length (mm) 6;6 ABD (g/cm³) 1.12	TEMPERATURE RANGE: 300°–500°C PRESSURE RANGE: 1–30 atm SPACE VELOCITY (VHSV): 1,000—1,200 h^{-1}	Conventional shift reaction at high temperature. For CO shift at low temperature Katalco 52–1, which is a zinc-oxide/copper oxide/alumina (200°–260°C), is available.

TYPE OF CATALYST: *IRON KONTAKT 1026*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht"	CONTENT wt % Fe_2O_3 (promoted with Cr_2O_3) Cr_2O_3 approx. 7% CARRIER: n.a. FORM: extrusions SIZE: Diameter (mm) 7–9; 10–12 Length (mm) 7–15; 10–15 ABD (g/cm³) 1.4	TEMPERATURE RANGE: 360°–400°C PRESSURE RANGE: n.a.	It is used at low and high pressures and high temperatures.

TYPE OF CATALYST: ***IRON KONTAKT 1030***

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht"	CONTENT wt % Fe_2O_3(with Cr_2O_3 as promotor) 7 CARRIER: n.a. FORM: pellets SIZE: Diameter (mm) 9 Length (mm) 9	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used at high temperatures.

HIGH TEMPERATURE CO CONVERSION

TYPE OF CATALYST: ***IRON MHTC***

Manufacturer	Characteristics	Operating conditions	Remarks
Montedison S.p.A.	CONTENT wt % Ferricoxide and chromia in the ratio of 10:1 FORM: pellets SIZE: Diameter (mm) 6–10 Length (mm) 6–8 ABD (g/cm^3) 1.2–1.25 PV (cm^3/g) 0.28–0.32 STRENGTH (kg/cm^2)20 (radial cm.)	TEMPERATURE RANGE: 330°–530°C PRESSURE RANGE: 1–40 atm LIFE: at least 5 years SPACE VELOCITY: 400–4,800 h^{-1}	Chlorine compounds act as poisons and their concentration in the gases should not be higher than 1 ppm.

CO CONVERSION (SHIFT CONVERSION)

TYPE OF CATALYST: ***IRON SK AND SK-12***

Manufacturer	Characteristics	Operating conditions	Remarks
Haldor Topsøe	CONTENT wt % Chromium promoted iron oxide, in its highest oxidized state, i.e. Fe_2O_3 plus some graphite and a few per cent moisture CARRIER: n.a. FORM: cylindrical tablets SIZE: Diameter (mm) 6;9 Length (mm) 6;9 ABD (g/cm^3) 1.05 STRENGTH (kg/cm^2) 8	TEMPERATURE RANGE: 330°–470°C PRESSURE RANGE: 1–50 atm	Used for the conversion of carbon monoxide in hydrogen, ammonia, methanol, and town gas plants at high temperature. Particle density is about 1.7 g/cm^3. Sulphur compounds are the most common catalyst poisons. More severe poisons are chlorine compounds.

TYPE OF CATALYST: ***UBE CO CONVERSION***

Manufacturer	Characteristics	Operating conditions	Remarks
UBE Industries Ltd.	CONTENT n.a. CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 8–9.5 ABD (g/cm^3) 1.35 STRENGTH (kg/cm^2) (DWL) 20	TEMPERATURE RANGE: 320°–500°C PRESSURE RANGE: 1–30 atm LIFE: several years SPACE VELOCITY: 850 h^{-1}	It is a high temperature conversion catalyst.

Methanation

METHANATION

TYPE OF CATALYST: *NICKEL BASF R 1—10*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % Nickel oxide CARRIER: n.a. FORM: pellets SIZE: Diameter (mm) 5 Length (mm) 5 ABD (g/cm^3) 0.9 STRENGTH (kg/cm^2) 300 (measured at the faces) TS (°C) up to 500	TEMPERATURE RANGE: 180°—400°C PRESSURE RANGE: n.a.	Methanation of CO and CO_2 with simultaneous removal of oxygen. Purification of ammonia synthesis gas and hydrogen for hydrogenation purposes.

METHANATION OF CARBON OXIDES

TYPE OF CATALYST: *NICKEL C-13*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % C13-1: NiO on silica (spheres) 48 C13-2: NiO on silica (tablets) 40 C13-3: NiO on refractory cement (tablets and spheres) 32 CARRIER: alumina FORM: spheres SIZE: Diameter (mm) 4.5-7.5 ABD (g/cm^3) 0.75	TEMPERATURE RANGE: 235°—455°C PRESSURE RANGE: 1—200 atm SPACE VELOCITY (VHSV): 3,000—8,000 h^{-1}	Methanation of small quantities of carbon oxides from hydrogen and ammonia synthesis gas.

CO METHANATION

TYPE OF CATALYST: *RUTHENIUM H-22P*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt % Precious metal content, usually of 0.1; 0.15; 1; 5; and 10% CARRIER: Al_2O_3 FORM: balls SIZE: Diameter (mm) 4—6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Precious metal (see content).

METHANATION

TYPE OF CATALYST: *NICKEL CDM-15*

Manufacturer	Characteristics	Operating conditions	Remarks
Fertilizer Corporation of India (F.C.I.)	CONTENT wt % Nickel oxide CARRIER: alumina FORM: tablets SIZE: Diameter (mm) 6×6 ABD (g/cm^3) 1.2	TEMPERATURE RANGE: 300°–400°C PRESSURE RANGE: up to 35 atm	Used in the production of high purity hydrogen and/or synthesis gas where low concentration of carbon oxides and oxygen are required. It can be used in the methanation reactions with occasional variations in temperature and pressure.

TYPE OF CATALYST: *NICKEL G-33, G-52*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Nickel 32–36 CARRIER: refractory oxide FORM: tablets SIZE: Diameter (mm) 5–6 Length (mm) 5–6 ABD (g/cm^3) 0.96 SA (m^2/g) 70 STRENGTH (kg/cm^2) 11	TEMPERATURE RANGE: 100°–260°C PRESSURE RANGE: 24–35 atm	It is also used for the saturation of aromatics. G-52 is a pre-reduced form of G-33. It is used in those plants where reduction facilities are not available. See hydrogenation of olefins and aromatics.

TYPE OF CATALYST: *NICKEL G-65, G-65K*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Nickel oxide Ni-G-65 25 Ni-G-65RS 27 S 0.04 CARRIER: n.a. FORM: tablets; spheres (G-65) (G-65K) SIZE: Diameter (mm) 6×6; 4.7×4.7 ABD (g/cm^3) 1.040	TEMPERATURE RANGE: 230°–480°C PRESSURE RANGE: 1–100 atm	Heat resistant catalysts. They are available in a pre-reduced and stabilized version designed as G-65RS and G-65KRS.

METHANATION OF CO

TYPE OF CATALYST: *NICKEL GPM 5*

Manufacturer	Characteristics	Operating conditions	Remarks
Grande Paroisse	CONTENT wt % $NiO - SiO_2 - Al_2O_3$ CARRIER: n.a. FORM: n.a. SIZE: Diameter (mm) 5–10	TEMPERATURE RANGE: 300°–500°C PRESSURE RANGE: n.a.	

METHANATION

TYPE OF CATALYST: *NICKEL Ni-0101 T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Nickel 44 present as hydrate CARRIER: Kieselguhr FORM: tablets SIZE(mm): n.a. ABD (g/cm^3) 1.2–1.3 STRENGTH (kg/cm^2) 5–7.7	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used for other hydrogenation reactions.

TYPE OF CATALYST: *NICKEL Ni-0301 T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Nickel 11 present as oxide CARRIER: activated alumina FORM: tablets SIZE: Diameter (mm) 3 ABD (g/cm^3) 1.2 SA (m^2/g) 64 PV (cm^3/g) 0.32 STRENGTH (kg/cm^2) 5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Also used for selective nitrogenation of di-olefins to mono-olefins.

TYPE OF CATALYST: *NICKEL RCH-18/10*

Manufacturer	Characteristics	Operating conditions	Remarks
Farbwerke Hoechst AG	CONTENT wt % Nickel 18 CARRIER: Al_2O_3 FORM: tablets SIZE: Diameter (mm) 6 Length (mm) 5	TEMPERATURE RANGE: 280°C PRESSURE RANGE: up to 25 atm	It must be reduced before use.

TYPE OF CATALYST: *NICKEL ICI 11—3*

Manufacturer	Characteristics	Operating conditions	Remarks
Imperial Chemical Industries Ltd. (I.C.I.)	CONTENT wt % Nickel oxide CARRIER: n.a. FORM: pellets SIZE: Diameter (mm) 5.4 Height (mm) 36 ABD (g/cm^3) 1.1	TEMPERATURE RANGE: 230°—450°C PRESSURE RANGE: up to 50 atm SPACE VELOCITY: 5,000—12,000 h^{-1}	It is also used in operation at pressure up to 250 atm. Must be protected from poisoning by sulphur, chlorine and arsenic compounds, if these are likely to be present in the inlet gas.

METHANATION OF CO

TYPE OF CATALYST: *NICKEL KATALCO 11—3*

Manufacturer	Characteristics	Operating conditions	Remarks
Katalco Corporation	CONTENT wt % Supported nickel oxide CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 5.4 Length (mm) 3.6 ABD (g/cm^3) 1.10	TEMPERATURE RANGE: 280°—420°C PRESSURE RANGE: 5—250 atm LIFE: about 3 years SPACE VELOCITY: 5,000—8,000 h^{-1}	It is used for removal of small amounts of CO, CO_2 and O_2 from hydrogen or synthesis gas streams. CO and CO_2 are reduced to methane. It is poisoned by sulphur.

PURIFICATION OF SYNTHESIS GAS (METHANATION)

TYPE OF CATALYST: *NICKEL-CHROME OXIDES KONTAKT 6540*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht"	CONTENT wt % Nickel oxide 48 Chrome oxide CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 5 Length (mm) 5 ABD (g/cm^3)0.95–1.2 STRENGTH (kg/cm^2) 150	TEMPERATURE RANGE: 150°–250°C PRESSURE RANGE: 1–300 atm	Used for the removal of CO, CO_2 and O_2; also in methanation process.

METHANATION

TYPE OF CATALYST: *NICKEL KONTAKT 6542*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht"	CONTENT wt % Ni, NiO, Cr_2O, Al_2O_3 CARRIER: alumina FORM: cylinders SIZE: Diameter (mm) 5 Length (mm) 5 ABD (g/cm^3) 1±0.1 STRENGTH (kg/cm^2) 200±50	TEMPERATURE RANGE: 180°–400°C PRESSURE RANGE: 1–300 atm	

PURIFICATION OF SYNTHESIS GAS (METHANATION)

TYPE OF CATALYST: *NICKEL KONTAKT 6543*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht"	CONTENT wt % Nickel oxide 30 CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 3 Length (mm) 3 ABD (g/cm^3) 1.1 STRENGTH (kg/cm^2) 350±80	TEMPERATURE RANGE: 220°–400°C PRESSURE RANGE: 1–300 atm	Removal of traces of O_2, CO, CO_2.

METHANATION OF CO

TYPE OF CATALYST: *NICKEL MT-15*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Nickel oxide CARRIER: alumina FORM: balls SIZE: Diameter (mm) 2–4; 4–6 ABD (g/cm^3) 0.95 SA (m^2/g) 100 PV (cm^3/g) 0.5 STRENGTH (kg/cm^2) >10	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Selective methanation of CO in CO_2, under pressure and high space velocity.

METHANATION OF CO AND CO_2

TYPE OF CATALYST: *NICKEL MT-25*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Nickel oxide CARRIER: special FORM: balls SIZE: Diameter (mm) 4-7; 6-8 ABD (g/cm^3) 1.25 SA (m^2/g) 80 PV (cm^3/g) 0.20 STRENGTH (kg/cm^2) >15	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Elimination of CO and CO_2 through conversion in CH_4, under pressure and with a high space velocity.

TYPE OF CATALYST: *NICKEL PKR*

Manufacturer	Characteristics	Operating conditions	Remarks
Haldor Topsøe	CONTENT wt % Nickel 14 CARRIER: ceramic based on alumina and silica FORM: spheres SIZE: n.a. ABD(g/cm^3) 0.9–0.95	TEMPERATURE RANGE: 250°–500°C PRESSURE RANGE: 24 atm SPACE VELOCITY (VHSV): 6,000 h^{-1}	Pre-reduced. Used for methanation of CO and CO_2 and for hydrogenation of O_2 in hydrogen or ammonia synthesis gas stream.

Ammonia synthesis

AMMONIA SYNTHESIS FROM NITROGEN AND HYDROGEN

TYPE OF CATALYST: *IRON R*

Manufacturer	Characteristics	Operating conditions	Remarks
Azote et Produits Chimiques S.A. (APC)	CONTENT wt % Magnetite promoted. As promotors: Al_2O_3; K_2O; CaO;MgO CARRIER: n.a. FORM: lumps SIZE (mm): 8×12; 12×21 ABD (g/cm³) 2.4-2.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *IRON BASF S-6—10*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % Catalyst based on magnetite triply activated with K_2O, CaO and Al_2O_3. State of oxidation: Fe_3O_4 CARRIER: n.a. FORM: grains of irregular shape SIZE: Diameter (mm) 3—6; 6—10; 14—20 ABD (g/cm³)2.8—3.0 TS (°C) up to 530	TEMPERATURE RANGE: 380°—530°C PRESSURE RANGE: n.a.	Poisons: sulphur, chlorine compounds, O_2, CO, CO_2, H_2O vapours. Catalyst for high pressure synthesis of ammonia from nitrogen and hydrogen in all types of reactor.

TYPE OF CATALYST: *IRON BASF S-6—10 RED.*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % Catalysts based on magnetite triply activated with K_2O, CaO and Al_2O_3. State of oxidation: metallic iron CARRIER: n.a. FORM: grains SIZE: Diameter (mm): 3—6; 6—10; 14—20 ABD (g/cm³) 2.1—2.3 TS (°C) up to 530	TEMPERATURE RANGE: 380°—530°C PRESSURE RANGE: n.a.	See BASF S-6—10.

TYPE OF CATALYST: *IRON C-73*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Multi-promoted iron oxides CARRIER: n.a. FORM: granules SIZE: Diameter (mm) 6—12 ABD (g/cm^3) 2.7	TEMPERATURE RANGE: 400°—600°C PRESSURE RANGE: 100—1,000 atm SPACE VELOCITY: 10,000—55,000 h^{-1}	C-73-1; C-73-2. These are triply-promoted iron catalysts. C-73-2 has a higher concentration of promotor than C-73-1. Manufactured and sold under license by Norsk-Hydro.

TYPE OF CATALYST: *IRON CHEZA 30—00*

Manufacturer	Characteristics	Operating conditions	Remarks
Chemical Works of CSF	CONTENT wt % Fe_3O_4 Activators: Al_2O_3, K_2O, CaO CARRIER: n.a. FORM: regular chips SIZE: Diameter (mm) 3—6 Length (mm) 6—10 ABD (g/cm^3) 2.6	TEMPERATURE RANGE: 390°—560°C PRESSURE RANGE: n.a.	The amount of poisons of oxygen compounds like CO no more than 10 ppm by volume.

TYPE OF CATALYST: *IRON FA-1*

Manufacturer	Characteristics	Operating conditions	Remarks
Combinatul Chimic Craiova	CONTENT wt % Iron promoted FeO/Fe_2O_3 ratio 0.45—1.00 Al_2O_3 3—4 CaO 2.5—3.5 K_2O 0.8—1.2 SiO_2 0.9—1.3 CARRIER: n.a. FORM: granules SIZE: Diameter (mm) 2—4 4—6 6—8 8—15 STRENGTH (kg/cm^2) 30—35	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *IRON GP-6 AND GP-7*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Iron oxide CARRIER: n.a. FORM: granules SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *IRON G-82*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Triply promoted iron oxide CARRIER: n.a. FORM: granules SIZE: Diameter (mm) 2 Length (mm) 8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It exhibits high temperature stability. It is poisoned slowly by free and combined oxygen, by sulphur compounds and by halogens.

TYPE OF CATALYST: *IRON GPS-6 AND GPS-7*

Manufacturer	Characteristics	Operating conditions	Remarks
Grande Paroisse	CONTENT wt % Melted and promoted Fe_3O_4. GPS-6 is quadriply promoted containing MgO, Al_2O_4, SiO_2 and K_2O. GPS-7 Contains Al_2O_3 and K_2O CARRIER: n.a. FORM: grains SIZE: Diameter (mm) 1—10; 2—12 Length (mm) — ABD (g/cm^3) 2.6	TEMPERATURE RANGE: 450°—475°C PRESSURE RANGE: 150—1,000 atm. LIFE: more than 2 years SPACE VELOCITY: 30,000 h^{-1}	It is recommended not to exceed 550°C. Pressure preferably between 250 and 350 atm.

TYPE OF CATALYST: *IRON GPS-8*

Manufacturer	Characteristics	Operating conditions	Remarks
Grande Paroisse	CONTENT wt % Melted and promoted Fe_3O_4 CARRIER: n.a. FORM: grains SIZE: Diameter (mm) 1–12	TEMPERATURE RANGE: 450°–475°C PRESSURE RANGE: 150–1,000 atm LIFE: more than 2 years	Similar to GPS-7

TYPE OF CATALYST: *IRON ICI 35–4*

Manufacturer	Characteristics	Operating conditions	Remarks
Imperial Chemical Industries Ltd.	CONTENT wt % Multi-promoted magnetite composed of magnetite modified by controlled amounts of alumina, calcium potash and silica CARRIER: n.a. FORM: irregular granules	TEMPERATURE RANGE: 350°–550°C PRESSURE RANGE: 100–600 atm	It is poisoned by oxygen halogens and sulphur compounds, including sulphur in lubricating oils carried over from the compressors. Normal size ranges: A: 1.5– 3 mm B: 3– 4.5 mm C: 4.5– 6.5 mm D: 6– 9 mm E: 7– 9 mm F: 8–12 mm G: 12–21 mm

TYPE OF CATALYST: *IRON OXIDE KATALCO 35-4*

Manufacturer	Characteristics	Operating conditions	Remarks
Katalco Corporation	CONTENT wt % Consists essentially of magnetite (Fe_3O_4) multi-promoted by the addition of alumina, calcium and potash CARRIER: n.a. FORM: granules SIZE: Diameter (mm) 3–9 ABD (g/cm^3) 2.64	TEMPERATURE RANGE: 300°–550°C PRESSURE RANGE: 150–300 atm LIFE: 2–4 years	Other substances including silica are present in controlled amounts.

TYPE OF CATALYST: *IRON FNMS*

Manufacturer	Characteristics	Operating conditions	Remarks
Montedison S.p.A.	CONTENT wt % Iron oxides (approx. Fe_3O_4) 90 Promotors (mainly Al_2O_3, CaO, H_2O, SiO_2) 10 CARRIER: n.a. FORM: fused granules SIZE: Diameter (mm) 1.5–2.5 ABD (g/cm^3) 2.55–2.80 Attrition loss: ~2%	TEMPERATURE RANGE: 350°–550°C PRESSURE RANGE: 100–600 atm LIFE: 3–4 years	Sulphur, arsenic, phosphorous, halogen compounds and some heavy metals cause permanent poisoning.

TYPE OF CATALYST: *IRON CATALYST CA-1*

Manufacturer	Characteristics	Operating conditions	Remarks
Sojuzchimexport U.S.S.R.	CONTENT n.a. CARRIER: n.a. FORM: spheres SIZE: Diameter (mm) 1–3; 3–5; 7–10 ABD (g/cm^3) 2.5–3 TS (°C) up to 600	TEMPERATURE RANGE: 450°C PRESSURE RANGE: n.a. LIFE: not less than 3 years SPACE VELOCITY: 3,000 h^{-1}	It is produced in both reduced and non-reduced form.

TYPE OF CATALYST: *IRON OXIDE KM-I, KM-II, KM-VI*

Manufacturer	Characteristics	Operating conditions	Remarks
Haldor Topsøe	CONTENT wt % Iron oxide 90 Promotors 10 Non-reducible oxides, primarily of K, Ca and Al CARRIER: n.a. FORM: spheres SIZE: Diameter (mm) 1.5-23 ABD (g/cm^3) 2.5–2.85	TEMPERATURE RANGE: 360°–550°C PRESSURE RANGE: 100–1,000 atm	KM: unreduced KMR: pre-reduced Two different KM types with different promotor content are manufactured. KM-I: operating temperature, 380°–550°C KM-II: operating temperature, 360°–480°C The choice between them depends on the operating conditions. They are available in various standard particle size: 1.5–3 mm; 4.5–8 mm; 6—10 mm; 8–12 mm; 12–21 mm and 16–23 mm.

TYPE OF CATALYST: *IRON KMR (PELLETED)*

Manufacturer	Characteristics	Operating conditions	Remarks
Haldor Topsøe	CONTENT wt % Consists of iron oxide of the approximate composition Fe_3O_4 and about 10% of promotors CARRIER: n.a. FORM: cylinders, rings SIZE: Diameter (mm) 6;OD/ID=13/6 Length (mm) 6;13 ABD (g/cm^3) 2.2–2.1	TEMPERATURE RANGE: 380°–550°C PRESSURE RANGE: n.a.	The promotors are non-reducible oxides primarily of K, Ca and Al.

TYPE OF CATALYST: *IRON LZ*

Manufacturer	Characteristics	Operating conditions	Remarks
Chemie Linz A.G.	CONTENT wt % FeO 31.5–34.5 Fe_2O_3 57.5–59.5 Al_2O_3 2.8– 3.0 CaO 3.2– 3.4 MgO 0.8– 1.2 K_2O 0.5– 0.6 SiO_2 0.4– 0.6 TiO_2 0.3– 0.4 CARRIER: n.a. FORM: grains of irregular shape SIZE: n.a. ABD (g/cm^3) 2.6–2.7 TS (°C) up to 620	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

B. Petrochemical industry

Acrylonitrile synthesis
Formaldehyde synthesis
Maleic anhydride synthesis
Methanol synthesis
Hydroformylation (oxo-reaction)
Phthalic anhydride synthesis
Styrene production
Vinyl acetate monomer synthesis
Vinyl chloride monomer synthesis

ACRYLONITRILE SYNTHESIS

TYPE OF CATALYST: *BISMUTH-MOLYBDENUM A*

Manufacturer	Characteristics	Operating conditions	Remarks
Akzo Chemie B.V. Dpt. Ketjen Catalysts	CONTENT wt % Mo 14.8±1.0 Bi 24.1—0.5+1.6 Phosphorous 0.39±0.05 Silicon 23.4±1.0 CARRIER: silicon FORM: powder SIZE (mm): n.a. ABD (g/cm^3) 0.8—1 SA (m^2/g) 50—70 PV (cm^3/g) 0.18—0.25	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *BISMUTH-MOLYBDENUM KONTAKT 9421*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT wt % Bismuth oxide Molybdenum oxide and Silicon dioxide CARRIER: n.a. FORM: powder SIZE: n.a. ABD (g/cm^3) 1	TEMPERATURE RANGE: 430°—500°C PRESSURE RANGE: 1—3 atm	Oxidation of propylene.

FORMALDEHYDE SYNTHESIS

TYPE OF CATALYST: *GAUZE OF ELECTROLYTIC COPPER*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt % Copper FORM: gauze SIZE: Diameter of wire (mm) 0.25 Weight g/m² about 700	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Available as 64 mesh/cm².

TYPE OF CATALYST: *GAUZE OF ELECTROLYTIC COPPER*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt % Wire of copper FORM: gauze SIZE: Diameter of wire (mm) 0.25 Weight (g/cm²) 700	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *ACTIVATED SILVER CRYSTALS*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt % Ag 99.9 FORM: crystals SIZE: Diameter (mm) 0.5—2.0 ABD (g/cm³) 2.25	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for manufacture of aldehyde and ketones by oxidation of alcohols. They are used instead of silver gauze.

TYPE OF CATALYST: *SILVER GAUZE*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT n.a. FORM: sieve, 64 mesh/cm^2	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *SILVER SILARGON „N"*

Manufacturer	Characteristics	Operating conditions	Remarks
Doduco	CONTENT wt % Silver FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *SILVER*

Manufacturer	Characteristics	Operating conditions	Remarks
Johnson Mathey Chemicals Limited	CONTENT n.a. FORM: crystals or gauze SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used to a lesser extent in the manufacture of acetaldehyde.

TYPE OF CATALYST: *IRON-MOLYBDENUM G-105*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Iron-molybdenum oxides CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 4.5 Length (mm) 4.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *IRON-MOLYBDENUM KONTAKT 2410*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT wt % Iron oxide Molybdenum oxide CARRIER: none FORM: tablets SIZE: Diameter (mm) 4 Length (mm) 4 ABD (g/cm^3) 1.3±1 STRENGTH (kg/cm^2) 100±30	TEMPERATURE RANGE: 270°—330°C PRESSURE RANGE: atmospheric	

TYPE OF CATALYST: *IRON-MOLYBDENUM FM-3*

Manufacturer	Characteristics	Operating conditions	Remarks
Montedison S.p.A.	CONTENT wt % MoO_3 80 Fe_2O_3 20 binder free CARRIER: free FORM: cylinders; rings SIZE: cylinder rings Diameter (mm) 3.5 4×2 Length (mm) 3.5 3.5 ABD (g/cm^3) 0.93—1.10 PV (cm^3/g) 0.22—0.26 STRENGTH (kg/cm^2) 95	TEMPERATURE RANGE: 230°—310°C PRESSURE RANGE: n.a. LIFE: 1 year SPACE VELOCITY: 5,000—14,000 h^{-1}	The catalyst is currently used in both cooled and tubular converters, but it is also suited for use in different converter types.

TYPE OF CATALYST: *IRON-MOLYBDENUM FOX-HIAG*

Manufacturer	Characteristics	Operating conditions	Remarks
Österreichische HIAG Werke A.G.	CONTENT wt % Fe_2O_3 18—19 MoO_3 81—82 CARRIER: n.a. FORM: cylindrical pellets Diameter (mm) 4.1 Length (mm) 4.0—4.1 ABD (g/cm^3) 1.2 SA (m^2/g) (BET) 6 STRENGTH (kg/cm^2) 45 TS (°C) 400	TEMPERATURE RANGE: 350°—400°C PRESSURE RANGE: normal LIFE: 1—2 years	Side reactions are kept to a minimum.

TYPE OF CATALYST: *MOLYBDENUM AND IRON FK*

Manufacturer	Characteristics	Operating conditions	Remarks
Haldor Topsøe	CONTENT, wt % Molybdenum oxide 80 Iron oxide 20 Promotor: chromium oxide CARRIER: n.a. FORM: extrusions; rings; cylinders SIZE: rings cylinders Diameter (mm) 4.3/1.9 3.8 Length (mm) 3.5 3.85 ABD (g/cm^3) 0.90 1.05 STRENGTH (kg/cm^2) 70	TEMPERATURE RANGE: 250°—400°C PRESSURE RANGE: n.a. SPACE VELOCITY: 10,000 h^{-1}	The catalyst is very resistant to poisoning.

Maleic anhydride synthesis

MALEIC ANHYDRYDE SYNTHESIS

TYPE OF CATALYST: *VANADIUM SYN DAN CATALYST*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalyst Development Corporation (C.D.C.)	CONTENT wt % Promoted vanadia CARRIER: refractory oxides FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is designed to operate at high space velocities, high benzene feed concentration and high conversions.

TYPE OF CATALYST: *VANADIUM MOLYBDENUM MAT 5*

Manufacturer	Characteristics	Operating conditions	Remarks
Montedison S.p.A.	CONTENT mol V_2O_4 2 MoO_3 1 Na_2O 0.06 Support 88—89% CARRIER: alumina FORM: pellets SIZE: Diameter (mm) 5 Length (mm) 5 ABD (g/cm³) 1.1 PV (cm³/g) 0.2 STRENGTH (kg/cm²) 50—60 Attrition loss: 0.6—0.7%	TEMPERATURE RANGE: 340°—400°C PRESSURE RANGE: 1—2.5 atm LIFE: 2—3 years	It must be protected against air, damp and light. Impurities in the benzene can act as poisons. The following limits are advisable: paraffins: 0.3% ethylbenzene: 0.1% cumene and toluene: 0.02% tiophene + CS_2: 80 ppm (as elemental sulphur)

TYPE OF CATALYST: *TITANUM-VANADIUM-MOLYBDENUM BASF 04—30*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % Titanum dioxide with V_2O_5 and MoO_3 as active components CARRIER: n.a. FORM: irregular chips in different fractions SIZE: Diameter (mm) 3—6 (standard) ABD (g/cm³) 1.2	TEMPERATURE RANGE: 370°—380°C PRESSURE RANGE: n.a.	

Methanol synthesis

METHANOL SYNTHESIS (FROM CARBON MONOXIDE AND HYDROGEN)

TYPE OF CATALYST: *Zn BASF S-5—10*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % ZnO 65 CrO_3 14 Na <0.05 K <0.02 Fe <0.05 Ni <0.005 Mn <0.005 CARRIER: n.a. FORM: pellets; rings SIZE: *pellets* *rings* Diameter (mm) 5 10×4 Length (mm) 5 10 ABD (g/cm^3) 1.6—1.8 SA (m^2/g) 100 (after reduction) PV (cm^3/g) 0.2 (after reduction) STRENGTH (kg/cm^2) 500 (measured at the faces)	TEMPERATURE RANGE: 300°—400°C PRESSURE RANGE: above 200 atm	

TYPE OF CATALYST: *Zn-Cr C-70—2*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Zinc/Chrome oxide CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE 340°—400°C PRESSURE RANGE: 210—350 atm	Production of methanol by high temperature process.

TYPE OF CATALYST: *COPPER C-79—2*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Copper CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: 220°—300°C PRESSURE RANGE: 20—200 atm	Methanol synthesis at low temperature and pressures.

TYPE OF CATALYST: *CHROMITE CATALYSTS*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt % active metal / chrome Cu 33—34 29—30 Ni 30—31 27—28 Co 39—40 31—32 Cd 46—47 23—24 Ag 64—65 18—19 Zn 46—47 32—33 Additives: Ba, Mn, Pd CARRIER: Al_2O_3; SiO_2; CaO FORM: powder; tablets SIZE: n.a. ABD (g/cm^3) 0.25—1.2	TEMPERATURE RANGE: 400°C PRESSURE RANGE: 300 atm	Used also in hydrocracking processes.

TYPE OF CATALYST: *Zn-0302.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % ZnO 74 CrO_3 23 CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 4; 6; 9	TEMPERATURE RANGE: 300°—400°C PRESSURE RANGE: 250—400 atm	

TYPE OF CATALYST: *Zn-0308.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % ZnO 74 Cr_2O_3 22 CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 6	TEMPERATURE RANGE: 300°—400°C PRESSURE RANGE: 250—400 atm	This is the reduced form of Zn-0302.T.

TYPE OF CATALYST: *Zn-0311.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % ZnO, CrO_3 CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 4; 6; 9 ABD (g/cm^3) 1.76 STRENGTH (kg/cm^2) 18	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Similar to Zn-0203.T. It is available to those users who prefer to reduce catalyst themselves.

TYPE OF CATALYST: *Zn-0312.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Cr_2O_3 22 CARRIER: n.a. FORM: n.a. SIZE: Diameter (mm) 4; 6; 9 ABD(g/cm^3) 1.6 SA (m^2/g) 130 PV (cm^3/g) 0.2 STRENGTH (kg/cm^2) 16	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Similar to Zn-0308.T. This is the reduced form of Zn-0311.T.

TYPE OF CATALYST: *ZINC-CHROMIUM ICI-25 SERIES*

Manufacturer	Characteristics	Operating conditions	Remarks
Imperial Chemical Industries Ltd. (ICI)	CONTENT wt % Zinc oxide Chromium oxide CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	A high pressure methanol synthesis catalyst.

TYPE OF CATALYST: *ZINC KONTAKT 617*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT wt % Mixed zinc oxide and chrome oxide. It contains Cr^{III} and also Cr^{IV} CARRIER: n.a. FORM: pellets SIZE: Diameter(mm) 5; 9 ABD (g/cm^3) 1.4 ± 0.14; 1.30 ± 0.13 STRENGTH (kg/cm^2) 500 ± 100; 240 ± 50	TEMPERATURE RANGE: 320°—390°C PRESSURE RANGE: 200—300 atm	It is a high pressure methanol synthesis catalyst.

TYPE OF CATALYST: *ZINC KONTAKT 618*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT wt % ZnO mixed with Zn-chromite It does not contain chrome as Cr^{VI} CARRIER: n.a. FORM: cylindrical pellets SIZE: Diameter (mm) 5; 9 Length (mm) 5; 9 ABD (g/cm^3) 1.60 ± 0.15; 1.50 ± 0.15 STRENGTH (kg/cm^2) 450 ± 150; 300 ± 150	TEMPERATURE RANGE: 320°—400°C PRESSURE RANGE: 200—300 atm	It is a high pressure methanol synthesis catalyst.

TYPE OF CATALYST: *ZINC-CHROMITE QF-4*

Manufacturer	Characteristics	Operating conditions	Remarks
Montedison S.p.A.	CONTENT wt % Binder free $ZnO+Cr_2O_3$ Its composition is strictly homogeneous. Attrition loss $< 0.5\%$ CARRIER: n.a. FORM: cylindrical pellets, rings SIZE: cylindrical pellets / rings Diameter (mm) 5—10 / 10×4 Length (mm) 5.3—8 / 8 ABD (g/cm^3) 1.6—1.7 PV (cm^3/g) 0.23—0.25 STRENGTH (kg/cm^2) 500—550	TEMPERATURE RANGE: 300°—400°C PRESSURE RANGE: 200—400 atm SPACE VELOCITY: 15,000—40,000 h^{-1} LIFE: 1 m^3 catalyst produces 25,000 tons of anhydrous methanol	

METHANOL SYNTHESIS

TYPE OF CATALYST: *ZINC CHROMITE BZC-21*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Active agent zinc chromite CARRIER: n.a. FORM: pellets SIZE: Diameter(mm) 10—12.5 Length (mm) 7 ABD (g/cm³) 1.5 SA (m²/g) 40—50 PV (cm³/g) 0.9—0.12	TEMPERATURE RANGE: 360°C (<400°C) PRESSURE RANGE: 200—400 atm SPACE VELOCITY: 20,000—25,000 h⁻¹	Porosity: 27—30% Delivered pre-reduced.

METHANOL SYNTHESIS (FROM CARBON MONOXIDE AND HYDROGEN)

TYPE OF CATALYST: *ZINC AND CHROMIUM SMKR*

Manufacturer	Characteristics	Operating conditions	Remarks
Haldor Topsøe	CONTENT wt % Consists of oxides of zinc and chromium CARRIER: n.a. FORM: cylinders; rings SIZE: cylinders rings Diameter (mm) 5.7 10×4 Length (mm) 5.7 10 ABD (g/cm³) 1.45 1.28 STRENGTH (kg/cm²) 600 (axial crush)	TEMPERATURE RANGE: 330°—400°C PRESSURE RANGE: 200—400 atm SPACE VELOCITY (VHSV): 20,000—50,000 v/v/hr	Pre-reduced. Delivered in the reduced and fully active state. Attrition loss is less than 3%. Normally used in higher temperature process.

TYPE OF CATALYST: *LMK*

Manufacturer	Characteristics	Operating conditions	Remarks
Haldor Topsøe	CONTENT n.a. CARRIER: n.a. FORM: cylinders SIZE: Diameter (mm) 4.5; 6 Length (mm) 4.5; 6 ABD (g/cm³) 1.2	TEMPERATURE RANGE: 220°—270°C PRESSURE RANGE: n.a.	The catalyst is offered under a cooperation agreement between Haldor Topsøe and the Japanese company Nihon Suiso (Nissui). Low temperature synthesis.

Hydroformylation (oxo-reaction)

SECOND STEP OF THE OXO-PROCESSES

TYPE OF CATALYST: *COBALT C-60 SERIES*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Cobalt CARRIER: Kieselguhr FORM: tablets or powder SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The oxo hydrogenation of aldehydes to alcohols and hydrogenation of propion aldehyde.

TYPE OF CATALYST: *COBALT G-103*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Co 40 CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 6 Length (mm) 6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	In many respects similar to G-61 nominally % Co 40. Available in pre-reduced form as G-103R. Form: powder, suspended in the desired liquid.

TYPE OF CATALYST: *COBALT Co-0101.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Co 35 as cobalt oxide CARRIER: Kieselguhr FORM: tablets SIZE: Diameter (mm) 5 ABD (g/cm^3) 1.14 SA (m^2/g) 130 PV (cm^3/g) 0.35 STRENGTH (kg/cm^2) 8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	A hydrogenation catalyst.

TYPE OF CATALYST: *COBALT Co-0108.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Co 39 CARRIER: Kieselguh FORM: tablets SIZE: Diameter (mm) 5 ABD (g/cm^3) 1.12 SA (m^2/g) 140 PV (cm^3/g) 0.4 STRENGTH (kg/cm^2) 6.8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for oxo-processes and other selective hydrogenation reactions.

TYPE OF CATALYST: *COBALT Co-0401.G.4—8*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Co 13 present as oxide CARRIER: silica FORM: granules SIZE: Diameter (mm) 4—8 ABD (g/cm^3) 0.48 SA (m^2/g) 1 PV (cm^3/g) 0.36	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for oxo-processes synthesis and for hydrogenation reactions.

TYPE OF CATALYST: *COBALT Co-0402.G.4—8*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Co 6 as cobalt oxide CARRIER: silica FORM: granules SIZE: Diameter (mm) 4—8 ABD (g/cm^3) 0.5 SA (m^2/g) 1 PV (cm^3/g) 0.38	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for oxo-processes synthesis and for hydrogenation reactions.

TYPE OF CATALYST: *COBALT Co-0403.G.4—8*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Co 20 as cobalt oxide CARRIER: silica FORM: granules SIZE: Diameter (mm) 4—8 Length (mm) n.a. ABD (g/cm^3) 0.48 SA (m^2/g) 6 PV (cm^3/g) 0.38	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *COBALT Co-0405.G.4—8*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Co 20 CARRIER: silica FORM: granules SIZE: Diameter (mm) 4—8 ABD (g/cm^3) 0.51 SA (m^2/g) 4 PV (cm^3/g) 0.49	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	A hydrogenation catalyst, reduced and stabilized.

TYPE OF CATALYST: *COBALT Co-0501.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Co 10 in oxide form CARRIER: activated alumina FORM: tablets SIZE: Diameter (mm) 3.2 ABD (g/cm^3) 0.96 SA (m^2/g) 60 PV (cm^3/g) 0.51 STRENGTH (kg/cm^2) 7.7	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *COPPER CHROMITE Cu-0203.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % CuO 80 or 78 Cr_2O_3 17 or 20 CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 1.4 ABD (g/cm^3) 2.16 STRENGTH (kg/cm^2) 12.7	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	This is tableted Cu-0202.P.

TYPE OF CATALYST: *COPPER CHROMITE Cu-0402.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % CuO 35 Cr_2O_3 38 BaO 10 CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 3.2 ABD (g/cm^3) 1.62 STRENGTH (kg/cm^2) 3.6—5.4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	This is tableted Cu-0401.P.

TYPE OF CATALYST: *COPPER CHROMITE Cu-1107.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % CuO 33 Cr_2O_3 38 BaO 9.5 CARRIER: n.a. FORM: tablets SIZE: Diameter(mm) 3.2 ABD (g/cm^3) 1.8 STRENGTH (kg/cm^2) 5.4—7.2	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	This is tableted Cu-1106.P.

TYPE OF CATALYST: *COPPER CHROMITE Cu-1808.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % CuO 42 Cr_2O_3 38 CARRIER: n.a. FORM: tablets SIZE: Diameter(mm) 3.2 ABD (g/cm^3) 1.3 STRENGTH (kg/cm^2) 4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	This is tableted Cu-1800.P.

TYPE OF CATALYST: *NICKEL Ni-0101.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni 44 Present as hydrate CARRIER: Kieselguhr FORM: tablets SIZE: Diameter (mm) 3;5;6 Length (mm) n.a. ABD (g/cm^3) 1.25—1.36 STRENGTH (kg/cm^2) 5—7.7	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for hydrogenation and methanation.

TYPE OF CATALYST: *NICKEL Ni-0104.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni 60 A ratio of reduced nickel to total nickel 0.60 CARRIER: Kieselguhr FORM: tablets SIZE: Diameter (mm) 3.2; 4.7; 6.3 ABD (g/cm^3) 1.2—1.44 SA (m^2/g) 150 PV (cm^3/g) 0.2 STRENGTH (kg/cm^2) 3.6—11.3	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Tableted form of Ni-0104.P.

SYNTHESIS OF HIGH ALCOHOLS (FROM CO AND H_2)

TYPE OF CATALYST: *ZINC (Isobutilolkontakt) KONTAKT 1132*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht"	CONTENT wt % Mixture of hydroxichromate of zinc with small parts of alkali CARRIER: n.a. FORM: cylinders SIZE: Diameter (mm) 5; 9 Length (mm) 5; 9 ABD (g/cm³) 1.5—1.8 1.4—1.7 STRENGTH (kg/cm²) 500—600 220—270	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	In unreduced form it contains CrVI.

TYPE OF CATALYST: *COBALT KONTAKT 6801*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht"	CONTENT wt % CoO $CoCO_3$ CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Simply mentioned in Leuna catalysts.

Phthalic anhydride synthesis

PHTHALIC ANHYDRIDE SYNTHESIS (BY OXIDATION OF NAPHTHALENE)

TYPE OF CATALYST: *VANADIUM CATALYST BASF 04—20*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % SiO_2 67 V_2O_5 4 K 6.4 SO_4 16.5 Loss on drying 3.5 CARRIER: SiO_2 FORM: grains SIZE (mm): n.a. ABD (g/cm^3) 0.67 SA (m^2/g) 220 PV (cm^3/g) 0.8	TEMPERATURE RANGE: 340°—380°C PRESSURE RANGE: n.a.	By the fluidized bed process. Used for naphthalene rich in sulphur or with low sulphur content, e.g. petronaphthalene. Grains for fluidized bed with following size distribution: $<60\ \mu$ cca 2% $>200\ \mu$ cca. 30% $>300\ \mu$ cca. 0%

TYPE OF CATALYST: *AERO PAA-3*

Manufacturer	Characteristics	Operating conditions	Remarks
Cyanamid International	CONTENT n a. CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	A fluid-bed catalyst. The high activity and stability of the catalyst are matched by an improved resistance to sulphur poisoning.

TYPE OF CATALYST: *VANADIUM GRADE 902; GRADE 906*

Manufacturer	Characteristics	Operating conditions	Remarks
Davison Chemical Division, W.R. Grace & Co.	CONTENT wt % Vanadium CARRIER: special silica gel FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used in fluid-bed reactions.

Styrene production

SYNTHESIS OF STYRENE (BY DEHYDROGENATION OF ETHYLBENZENE)

TYPE OF CATALYST: *IRON BASF S-6—20*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % Fe_2O_3 as main constituent with activating additives FORM: extrusions SIZE: Diameter (mm) 5 ABD (g/cm^3) 1.3 STRENGTH (kg/cm^2) ~10 (cutting method)	TEMPERATURE RANGE: 550°—600°C PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *IRON STYRENEKONTAKT K-35*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Chemische Werke Buna	CONTENT wt % Fe 58—62 FORM: extrusions SIZE: Diameter (mm) 5—10 Length (mm) 8—30 ABD (g/cm^3) 1.25—1.45	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a. LIFE: more than 1 year	

TYPE OF CATALYST: *IRON C-97*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Iron oxide promoted with chrome, vanadium and K FORM: extrusions; pellets SIZE (mm): extrusions 3.2—4.5, pellets 3—4 ABD (g/cm^3) 1.2	TEMPERATURE RANGE: 620°—640°C PRESSURE RANGE: n.a. SPACE VELOCITY (LHSV): 0.3—0.5 h^{-1}	Iroven catalyst. Available also as C-97-1

TYPE OF CATALYST: *IRON CHEZA 31—02*

Manufacturer	Characteristics	Operating conditions	Remarks
Chemical Works of C.S.F.	CONTENT wt % Cr_2O_3 5 K_2O 5 SO_3 max. 1 Fe_2O_3 the remainder Loss on ignition (600°C) max. 3% CARRIER: n.a. FORM: extrusions SIZE: Diameter (mm) 4; 8 Length (mm) 4—10; 8—15 ABD (g/cm^3) 1.5 STRENGTH (kg/cm^2) Diam. 4: 3 Kp/cm^2 Diam. 8: 5 Kp/cm^2	TEMPERATURE RANGE: 560°C PRESSURE RANGE: 1 atm SPACE VELOCITY: 0.5 h^{-1}	During the dehydrogenation water vapours are added.

TYPE OF CATALYST: *IRON G-64*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Cr_2O_3 2.5±0.5 K_2CO_3 26±2 Fe_2O_3 60±3 A potassium and chrome promoted iron catalyst CARRIER: n.a. FORM: extrusions SIZE: Diameter (mm) 3;4 ABD (g/cm^3) 1.280 SA (m^2/g) 5±2 STRENGTH (kg/cm^2) 1.359	TEMPERATURE RANGE: 600°—650°C PRESSURE RANGE: n.a. SPACE VELOCITY: 0.5 h^{-1}	Used also in the dehydrogenation of cumene to alfa-methyl styrene. It can be used in either adiabatic or isothermal systems.

TYPE OF CATALYST: *IRON G—84*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % See G-64 CARRIER: n.a. FORM: extrusions SIZE: Diameter (mm) 1.5; 3; 4.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Dehydrogenation of cumene to alfa-methyl styrene. More active than G-64 at lower temperatures. Ameliorated version of G-64.

TYPE OF CATALYST: ***SHELL 105/205***

Manufacturer	Characteristics	Operating conditions	Remarks
Shell Chemical Co.	CONTENT n.a. CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: ***NICKEL 28148***

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Incorporated	CONTENT wt % Nickel oxide 15 CARRIER: alumina FORM: pellets SIZE: Diameter (mm) 3 Length (mm) 3 SA (m^2/g) approx. 65	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See section on dehydrogenation.

Vinyl acetate monomer synthesis

VINYL ACETATE SYNTHESIS

TYPE OF CATALYST: *ZINC VINA KONTAKT VA-KONTAKT*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Chemische Werke Buna	CONTENT wt % A zinc salt mounted on active charcoal. Zn min. 6 CARRIER: active charcoal FORM: extrusions SIZE: Diameter (mm) 3—5 ABD (g/cm^3) 0.6—0.8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The vinyl acetate is formed by the addition of acetylene to acetic acid.

TYPE OF CATALYST: *ZINC ACETATE C-76—1*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Zinc acetate CARRIER: carbon FORM: granules SIZE (mm): 4×10 mesh	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The vinyl acetate is formed by the addition of acetylene to acetic acid.

TYPE OF CATALYST: *ZINC CODE 183*

Manufacturer	Characteristics	Operating conditions	Remarks
Calsicat Division	CONTENT wt % Zinc acetate 11 CARRIER: carbon FORM: granules SIZE (mm): 4×10 mesh	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for the manufacture of vinyl acetate from acetylene and acetic acid.

TYPE OF CATALYST: *ZINC CATALYST ZO*

Manufacturer	Characteristics	Operating conditions	Remarks
Ciech Nitroplast Warszawa	CONTENT wt % Zinc acetate min. 26 FORM: granules SIZE: n.a. ABD (g/cm^3) 0.4—0.6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Synthesis from acetylene and acetic acid.

TYPE OF CATALYST: *ZINC ZAV-1*

Manufacturer	Characteristics	Operating conditions	Remarks
Combinatul Chimic Craiova	CONTENT wt % ZnO min. 15 CARRIER: activated charcoal FORM: n.a. SIZE: n.a. ABD (g/cm^3) 0.6—0.8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a. LIFE: 960 hours	

TYPE OF CATALYST: *ZN-0803, G. 4—10*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Zinc 10 present as acetate CARRIER carbon FORM: n.a. SIZE: n.a. ABD (g/cm^3) 0.7	TEMPERATURE RANGE: 170°—210°C PRESSURE RANGE: n.a.	The vinyl acetate is formed by the addition of acetylene to acetic acid.

TYPE OF CATALYST: *ZINC ACETATE MAVC*

Manufacturer	Characteristics	Operating conditions	Remarks
Montedison S.p.A.	CONTENT wt % Zinc acetate 30 Support 70 An acetate promotor has been added CARRIER: active carbon FORM: pellets SIZE: Diameter (mm) 3.8 Length (mm) 5.5 ABD (g/cm^3) 0.47—0.48 SA (m^2/g) 250 PV (cm^2/g) 0.79—0.80 Attrition loss: 0.1—0.2%	TEMPERATURE RANGE: 155°—220°C PRESSURE RANGE: 1.0—1.5 atm LIFE: ~ 4 months SPACE VELOCITY (VHSV): $\geqslant$ 230 h^{-1}	The catalyst is poisoned by sulphur and P. The vinyl acetate is produced by the conversion of acetylene.

TYPE OF CATALYST: *ZINC ACETATE MAVP*

Manufacturer	Characteristics	Operating conditions	Remarks
Montedison S.p.A.	CONTENT wt % Zinc acetate 30 Zinc 10.7 Acetate promotor CARRIER: active carbon FORM: pellets SIZE: Diameter (mm) 2 Length (mm) 4 ABD (g/cm^3) 0.74—0.75 SA (m^2/g) 60—70 PV (cm^3/g) 0.31—0.32 Attrition loss: 0.1—0.2%	TEMPERATURE RANGE: 160°—220°C PRESSURE RANGE: 1.0—1.5 atm LIFE: 400—450 kg vinyl acetate/1 kg catalyst SPACE VELOCITY: $\geqslant$ 357 S.T.P. Vol/catal. vol./hour	The catalyst is poisoned by H_2S and PH_3.

TYPE OF CATALYST: *ZINC 30130; 30270; 30285*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Incorporated	CONTENT wt % (1) 30130 Zn acetate on carbon: Zn 11% (2) 30270 Zinc oxide (3) 30285 Zinc oxide on alumina: ZnO 24% FORM: (1) mesh granules, (2) spheres, (3) pellets SIZE (mm): (1) mesh granules: 4×10 (2) spheres: 3×4 (3) pellets: 3×3 SA (m^2/g) (1) 60 (2) 35 (3) 46	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The catalysts are also used to oxidate alcohols to aldehydes and ketones.

TYPE OF CATALYST: *MERCURY 80207*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Incorporated	CONTENT wt % Mercuric chloride Hg 9—11 CARRIER: carbon FORM: granules SIZE (mm): 4×8 mesh SA (m^2/g) approx. 60	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used for the synthesis of vinyl chloride from acetylene.

VINYL CHLORIDE SYNTHESIS

TYPE OF CATALYST: *MERCURIC CHLORIDE BASF S-9—10*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % $HgCl_2$ 10 CARRIER: activated charcoal FORM: extrusions SIZE: Diameter (mm) 4 ABD (g/cm^3) 0.42	TEMPERATURE RANGE: 100°—200°C PRESSURE RANGE: n.a.	Sulphur and phosphorus compounds damage this type of catalyst. It is used in the manufacture of vinyl chloride from acetylene and hydrogen chloride.

TYPE OF CATALYST: *MERCURIC CHLORIDE VC KONTAKT (SUBLIMATE KONTAKT, VINYL CHLORIDE KONTAKT)*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Chemische Werke Buna	CONTENT wt % $HgCl_2$ min. 6 CARRIER: activated charcoal FORM: extrusions SIZE: Diameter (mm) 4 ABD (g/cm^3) 0.5—0.6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Gas phase synthesis of vinyl chloride from acetylene and hydrogen chloride.

TYPE OF CATALYST: *MERCURIC CHLORIDE CODE 171; 172; 175.*

Manufacturer	Characteristics	Operating conditions	Remarks
Calsicat Division	CONTENT wt % Mercuric chloride 10—12 CARRIER: carbon FORM: powder; SIZE: 4—6 mm mesh	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Application in manufacture of vinyl chloride from acetylene and HCl.

TYPE OF CATALYST: *PALLADIUM C-31—8*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Palladium CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 12 ABD (g/cm^3) 0.48± 0.08	TEMPERATURE RANGE: 120°—200°C PRESSURE RANGE: n.a.	Used in Goodrich oxychlorination process. C_2H_2 removal from HCl gas by hydrogenation.

TYPE OF CATALYST: *COPPER C-72—1*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % $CuCl_2$, promoted with either sodium or potassium according to process requirements CARRIER: alumina FORM: powder, tablets SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	C-72 is principally used for oxychlorination of ethylene to ethylene dichloride and pyrolysis to vinyl chloride. It is used for fluidized bed applications (as powder) or for fixed bed (as tablets).

TYPE OF CATALYST: *COPPER Cu-0804.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Cu 7.7 CARRIER: activated alumina FORM: tablets SIZE: Diameter (mm) 6 ABD (g/cm^3) 0.9 SA (m^2/g) 100 PV (cm^3/g) 0.36 STRENGTH (kg/cm^2) 8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used in oxychlorination of ethylene to ethylene dichloride and pyrolysis to vinyl chloride. Used as chlorination catalyst.

TYPE OF CATALYST: *COPPER Cu-0905.P*

Manufecturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % $CuCl_2$ 10 CARRIER: activated alumina FORM: powder SIZE: n.a. ABD (g/cm^3) 0.96 SA (m^2/g) 180	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used in oxychlorination of ethylene to ethylene dichloride and pyrolysis to vinyl chloride. Used as chlorination catalyst.

TYPE OF CATALYST: *COPPER Cu-0905.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % $CuCl_2$ 10 CARRIER: activated alumina FORM: tablets SIZE: Diameter (mm) 3 ABD (g/cm^3) 0.96 SA (m^2/g) 59 PV (cm^3/g) 0.26 STRENGTH (kg/cm^2) 5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used also as chlorination catalyst. See Cu-0906.P

TYPE OF CATALYST: *MERCURIC CHLORIDE C-0301. G. 4—10*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % about 10% mercuric chloride CARRIER: activated carbon FORM: granules; extrusions SIZE: Diameter (mm) 4—10	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Available also as: C-0302. G.4-6 C-0308. G.4-10 C-0309. E.4-6 C-0310. E.6-8 It is used in the manufacture of vinyl chloride from acetylene and hydrogen chloride. Support various activated carbons, derived from such sources as nutshells, coal and petroleum coke.

TYPE OF CATALYST: *MERCURIC CHLORIDE H-7701*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % $HgCl_2$ 10 CARRIER: charcoal FORM: extrusions SIZE: Diameter (mm) 4 Length (mm) 3—7 ABD (g/cm^3) 0.43 SA (BET) (m^2/g) 800—1,000 PV (cm^3/g) 1	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used in the vinyl chloride synthesis by the addition of HCl to acetylene.

TYPE OF CATALYST: *MERCURIC CHLORIDE MCV-2*

Manufacturer	Characteristics	Operating conditions	Remarks
Montedison S.p.A.	CONTENT wt % $HgCl_2$ 10 Active carbon 90 Copper <20 ppm Other heavy metals <0.2 CARRIER: active carbon FORM: pellets SIZE: Diameter (mm) 4 Length (mm) 6—9 ABD (g/cm^3) 0.42—0.43 SA (m^2/g) 1,100 PV (cm^3/g) 1.0—1.1	TEMPERATURE RANGE: 100°—250°C PRESSURE RANGE: 1—2 atm LIFE: 4 months SPACE VELOCITY (VSHV): $\geqslant$ 130 h^{-1}	The vinyl chloride synthesis by the addition of HCl to acetylene.

TYPE OF CATALYST: *MERCURY 80207*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Incorporated	CONTENT wt % Mercuric chloride Hg 9—11 CARRIER: carbon FORM: granules SIZE: 4×8 mm mesh SA (m^2/g) approx. 60	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for conversion of acetylene to vinyl chloride and of acetylene to vinyl acetate.

C. Production of acids

Nitric acid production
Sulphuric acid production

Nitric acid production

SELECTIVE OXIDATION OF AMMONIA TO NITRIC ACID

TYPE OF CATALYST: *XC 120-1*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Experimental catalyst CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The proprietary nature and composition of this catalyst require special arrangements regarding its evaluation and eventual application.

TYPE OF CATALYST: *ALLOYS Pt—Rh.10 N_2—P.10*

Manufacturer	Characteristics	Operating conditions	Remarks
Comptoir Lyon-Alemand Louyot	CONTENT wt % Alloys Pt-Rh FORM: sieve SIZE: mesh/cm^2 1,024 Diameter of wire (mm) 0.06 Weight (g/cm^2) 400	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Impurities: Gold 70 ppm Iron 100 to 75 ppm Nickel 50 to 75 ppm Copper 50 to 75 ppm Silver 50 to 75 ppm Aluminium, Silicon, Magnesium, Calcium: total 50 to 100 ppm Lead, Bismuth, Antimony, Phosphor, Sulphur, Arsenic: indeterminable by emission spectrography

TYPE OF CATALYST: *ALLOYS Pt—Rh, 10 N_2 —P.10-S*

Manufacturer	Characteristics	Operating conditions	Remarks
Comptoir Lyon-Alemand Louyot	CONTENT wt % Alloys Pt-Rh FORM: sieve SIZE: mesh/cm^2 1,000 Diameter of wire (mm) 0.076 Weight (g/cm^2) 630	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Impurities: Gold 70 ppm Iron 100 to 75 ppm Nickel 50 to 75 ppm Copper 50 to 75 ppm Silver 50 to 75 ppm Aluminium, Silicon, Magnesium, Calcium: total 50 to 100 ppm Lead, Bismuth, Antimony, Phosphor, Sulphur, Arsenic: indeterminable by emission spectrography

OXIDATION OF AMMONIA IN THE MANUFACTURE OF NITRIC ACID

TYPE OF CATALYST: *ALLOYS Pt-Rh.5 N2—P.5*

Manufacturer	Characteristics	Operating conditions	Remarks
Comptoir Lyon-Alemand Louyot	CONTENT wt % Alloys Pt-Rh FORM: sieve SIZE: mesh/cm^2 1,024 Diameter of wire (mm) 0.06 Weight (g/cm^2) 400	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Impurities: See Pt-Rh.10N_2-P.10

TYPE OF CATALYST: *PLATINUM-RHODIUM DB-750*

Manufacturer	Characteristics	Operating conditions	Remarks
Engelhard Minerals Chemicals Corporation	CONTENT wt % Platinum 95 Rhodium 5 FORM: sieve SIZE: mesh/cm^2 1,024 Diameter of wire (mm) 0.06	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *Pt and Rh—Pt ALLOYL*

Manufacturer	Characteristics	Operating conditions	Remarks
Johnson Matthey Chemicals Limited	CONTENT wt% Platinum and rhodium — platinum alloy sieves FORM: sieves SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The same type of sieve is also used in the catalytic synthesis of hydrogen cyanide from methane ammonia and air ((Andrussow process).

SULPHURIC ACID MANUFACTURE

TYPE OF CATALYST: *VANADIUM BASF 04—11*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt% V_2O_5 thermally stable cca. 8 Alkali sulphate CARRIER: porous silica FORM: extrusions SIZE: Diameter (mm) 4; 6 ABD (g/cm^3) 0.55	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	In all conventional reactors from gases containing SO_2, e.g. gases obtained from burning sulphur. Used in wet catalysis.

TYPE OF CATALYST: *VANADIUM CF-101*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt% V_2O_5 K_2O CARRIER: Kieselguhr FORM: extrusions SIZE: Diameter (mm) 5 ABD (g/cm^3) 0.72	TEMPERATURE RANGE: 400°—620°C PRESSURE RANGE: n.a.	Oxidation of sulphur dioxide to sulphur trioxide.

TYPE OF CATALYST: *VANADIUM C-101—2*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt% V_2O_5 7.5—8.5 K_2O 10—13 S 11—13.6 Na 0.75—1.5 Balance: inert carrier Vanadium pentoxide with promotors CARRIER: innert FORM: pellets SIZE: Diameter (mm) 6 Length (mm) 6 ABD (g/cm^3) 0.8 SA (m^2/g) 2—4 PV (cm^3/g) 0.2—0.4 STRENGTH (kg/cm^2) 6.8—15.8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	CCI initiated production of C-101 in 1964 via a know-how agreement with Mechim (a Belgian firm). Oxidation of sulphur dioxide to sulphur trioxide.

TYPE OF CATALYST: *VANADIUM C-116*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt% V_2O_5 7.5—8.5 K_2O 10—13 S 11—13.6 Na 0.75—1.5 CARRIER: n.a. FORM: spheres SIZE: Diameter (mm) 4.5—7.5 ABD(g/cm^3) 0.6 SA (m^2/g) 5—10 PV (cm^3/g) 0.4—0.8 STRENGTH (kg/cm^2) 6.8	TEMPERATURE RANGE: 400°—625°C PRESSURE RANGE: near atm. SPACE VELOCITY: Will depend on number of beds and cooling arrangements.	Oxidation of sulphur dioxide to sulfur trioxide. Used in plants employing low pressure contact process.

TYPE OF CATALYST: *VANADIUM CF-116*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt% V_2O_5, K_2O CARRIER: Kieselguhr FORM: extrusions SIZE: Diameter (mm) 5 ABD (g/cm^3) 0.72	TEMPERATURE RANGE: 400°—620°C PRESSURE RANGE: n.a.	Oxidation of sulphur dioxide to sulphur trioxide.

TYPE OF CATALYST: *VANADIUM AERO CATALYST SA*

Manufacturer	Characteristics	Operating conditions	Remarks
Cyanamid International	CONTENT wt% V_2O_5 CARRIER: n.a. FORM: pellets SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *VANADIUM G-101*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt% A potassium-vanadium oxide catalyst CARRIER: silica FORM: spheres SIZE: Diameter (mm) 5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is based on a highly active anion exchanging cross-linked silica carrier, which gives it a low temperature activity.

TYPE OF CATALYST: *VANADIUM GRILLO V_2O_5*

Manufacturer	Characteristics	Operating conditions	Remarks
Grillo-Werke Aktiengesellschaft	CONTENT wt% V_2O_5 7.5 K_2O 12.0 Na_2O 1.0 CARRIER: specially treated silicic acid FORM: n.a. SIZE: Diameter (mm) 4; 6; 8 Ratio diam: 1:1; 1:12 ABD (g/cm^3) 0.480—0.530 SA (m^2/g) 5.8—6.3 POROSITY: 60% STRENGTH (kg/cm^2) 5.75 TS (°C) 600	TEMPERATURE RANGE: 480°—550°C PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *STANDARD GRADE (TYPE 589)*

Manufacturer	Characteristics	Operating conditions	Remarks
ISC Chemicals RTZ	CONTENT wt% V_2O_5 6.5±0.5 CARRIER: n.a. FORM: extruded cords SIZE: Diameter (mm) 5—6 Length (mm) 8—11 ABD (g/cm^3) 0.61 TS (°C) up to 620	TEMPERATURE RANGE: 380°—420°C PRESSURE RANGE: n.a. LIFE: 5 years (guarantee)	

TYPE OF CATALYST: *LOW BITE GRADE (TYPE 636)*

Manufacturer	Characteristics	Operating conditions	Remarks
ISC Chemicals RTZ	CONTENT wt% V_2O_5 6.5±0.5 CARRIER: n.a. FORM: extruded cords SIZE: Diameter (mm) 6 Length (mm) 8—11 ABD (g/cm^3) 0.65 Attrition loss: less than 10% fines TS (°C) up to 620	TEMPERATURE RANGE: 380°—450°C PRESSURE RANGE: n.a. LIFE: 5 years (guarantee)	

TYPE OF CATALYST: *VANADIUM 210; 11; 29.*

Manufacturer	Characteristics	Operating conditions	Remarks
Monsanto	CONTENT n.a. CARRIER: silica FORM: cylinders SIZE: Diameter (mm) 5.55—7 Length (mm) 8	TEMPERATURE RANGE: 415°—600°C PRESSURE RANGE: n.a. LIFE: 5 years	Type 11 was developed as a complement to type 210. Type 29 improves the physical form.

TYPE OF CATALYST: *VANADIUM KH_1-2*

Manufacturer	Characteristics	Operating conditions	Remarks
Montedison S.p.A.	CONTENT wt% SiO_2 68—70 V_2O_5 6—7 Binder free CARRIER: inert FORM: cylinders SIZE: Diameter (mm) 4—5 Length (mm) 4—5 ABD (g/cm^3) 0.6 PV (cm^3/g) 0.5 STRENGTH (kg/cm^2) ⩾70	TEMPERATURE RANGE: 400°—610°C PRESSURE RANGE: n.a. LIFE: >10 years	

TYPE OF CATALYST: *VANADIUM RHV*

Manufacturer	Characteristics	Operating conditions	Remarks
Rikkihappo Oy Kemira Oy	CONTENT wt% RHV 49 and 59: 8—10 V_2O_5 and alkali RHV 67 and 107: 6—8 V_2O_5 and alkali The ratio is $K_2O:V_2O_5=2.5$ CARRIER: silica FORM: extrusions SIZE: Diameter (mm) 4—10 ABD (g/cm^3) 0.47—0.61 (depending upon the size of extrusions) TS (°C) 600 POROSITY: 65—70 (unactivated mass); 57—60 (after activation)	TEMPERATURE RANGE: 400°—420°C PRESSURE RANGE: n.a.	Specifications RHV-49; RHV-59; RHV-67; RHV-107

TYPE OF CATALYST: *VANADIUM VK SERIES; VK-38A (STANDARD CATALYST)*

Manufacturer	Characteristics	Operating conditions	Remarks
Haldor Topsøe	CONTENT wt% VK.38A tablets contain 65 g of V_2O_5 per litre of catalyst CARRIER: n.a. FORM: cylindrical tablets; rings SIZE: cylindrical tablets rings Diameter (mm) 6;9 10;4 Length (mm) 6;9 7 ABD (g/cm^3) 0.83 0.70 ±0.04 ±0.03 STRENGTH (kg/cm^2) 200—300	TEMPERATURE RANGE: 410°—650°C PRESSURE RANGE: n.a. SPACE VELOCITY: (VHSV) 2,000 h^{-1}	Delivered in the activated form. Recommended for conventional manufacture of sulphuric acid in single absorption as well as double absorption processes.

TYPE OF CATALYST: *VANADIA CATALYST WOLFEN*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Farbenfabrik Wolfen	CONTENT wt% V_2O_5 SiO_2 type H 5.5 69—72 type WN 7.5 60—62 type SZN 7.5 57—60 CARRIER: SiO_2 FORM: cylinders SIZE: Diameter (mm) 4,6,8,10 ABD (g/cm^3) 0.49—0.53 POROSITY: 55—57% STRENGTH (kg/cm^2) 40	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Available also in type N, STN.

Annex II

Heterogeneous catalysts for unit operations

A. Alkylation
B. Cracking — Hydrocracking
C. Dehydrogenation
D. Desulphurization
E. Halogenation (Dehalogenation)
F. Hydrogenation
G. Isomerization
H. Oxidation
I. Polymerization
J. Purification
K. Reforming
L. Catalysts for various chemical reactions

A. Alkylation

ALKYLATION AND ACYLATION

TYPE OF CATALYST: *ANHYDROUS ALUMINIUM CHLORIDE*

Manufacturer	Characteristics	Operating conditions	Remarks
Allied Chemicals	CONTENT n.a. CARRIER: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

ALKYLATION OF BENZENE AND PROPYLENE TO PRODUCE CUMENE

TYPE OF CATALYST: *PHOSPHORIC ACID CATALYST C 84-1; C 84-2*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT n.a. CARRIER: Kieselguhr FORM: spheres SIZE: Diameter (mm) 4.77—6.35 6.35—8.00 ABD (g/cm^3) 0.88 STRENGTH (kg/cm^2) 13.6—15.86	TEMPERATURE RANGE: 149°—232°C PRESSURE RANGE: 28—84 atm	C 84-1 is used in fixed bed adiabatic inversion. C 84-2 is used for tubular isothermal type reactor design.

1. ALKYLATION OF BENZENE WITH ETHYLENE TO PRODUCE ETHYLBENZENE
2. PRODUCTION OF C 12 TO C 16 ALKYL BENZENES

TYPE OF CATALYST: *ANHYDROUS ALUMINIUM CHLORIDE*

Manufacturer	Characteristics	Operating conditions	Remarks
Davison Chemical Division W.R. Grace and Co.	CONTENT wt % Anhydrous aluminium chloride FORM: powder or granules	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	(1) Ethylbenzene is an intermediate for styrene manufacture; (2) For use as intermediates for making synthetic detergents by sulphonation.

ALKYLATION REACTIONS

TYPE OF CATALYST: *SILICA ALUMINA GRADE 979*

Manufacturer	Characteristics	Operating conditions	Remarks
Davison Chemical Division W. R. Grace and Co.	CONTENT wt % Silica alumina FORM: extrusions SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Its general application is in reactions such as polymerization and esterification, where an acid catalyst is required.

ALKYLATION OF PHENOL AND CRESOL

TYPE OF CATALYST: *ACTIVATED MONTMORILLONITE, K SERIES: KSF, KSF/O, K10/SF, K10, K20, K306*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Aluminium hydrosilicate (ideal formula: $Al_2O_34SiO_2.H_2O + + xH_2O$) FORM: powder SIZE: 80—90% pass through a sieve DIN 100 ABD (g/cm³) 0.3—0.6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	They are produced by means of a special manufacturing process from the mineral montmorillonite. They belong to the acid catalyst, because of their function and their chemical constitution. They are used in esterification and dehydration reactions; splitting of cumene peroxide; formation of 1.3 dioxolanes. They are generally used in reactions which are otherwise catalysed with hydrogen acids (H_2SO_4, HCl, H_3PO_4, $HClO_4$ etc.) or with the so-called Lewis acids (BF_3, BCl_3, $AlCl_3$, $AlBr_3$, $SnCl_4$, $ZnCl_2$, $SbCl_3$).

TYPE OF CATALYST: *ACTIVATED MONTMORILLONITE KA; K306*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Aluminium hydrosilicate FORM: spheres SIZE: n.a. ABD (g/cm³) 0.4—0.8 SA (BET) (m²/g) 195 PV (cm³/g) 0.6—0.7 STRENGTH (kg/cm²) 4—5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	They are most suitable as catalyst carriers.

CONDENSATION OF AN ISOPARAFFIN (ISOBUTENE) WITH OLEFINS (PROPYLENE, BUTYLENE OR AMYLENE)

TYPE OF CATALYST: *ANHYDROUS HYDROFLUORIC ACID AHF*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % purity 99.9	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used in the petroleum industry to produce highly branched gas components with desirable stability properties and high octane number.

ALKYLATION IN LIQUID PHASE

TYPE OF CATALYST: *COPPER CHROMITE CATALYST N-207*

Manufacturer	Characteristics	Operating conditions	Remarks
W.C. Heracus GmbH	CONTENT wt % Copper chromite promotor CARRIER: Kieselguhr FORM: powder SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

ALKYLATION OF BENZENE BY PROPYLENE TO PRODUCE CUMENE

TYPE OF CATALYST: *PHOSPHORIC ACID AP-792*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % active agent P_2O_5 CARRIER: silica FORM: extrusions SIZE: Diameter (mm) 4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Can also be used for the production of gasolines, nonenes and dodecenes by polymerization of C_3 and C_4 cuts.

TYPE OF CATALYST: *ZEOLITES 14878; 14879; 14895; 14896*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Incorporated	CONTENT wt % (1) 14878 Type X Sodium ion (2) 14879 Type X Sodium ion (3) 14895 Type Y Sodium ion (4) 14896 Type Y Sodium ion FORM: (1) pellets; (2) powder; (3) extrusion; (4) powder SIZE: Diameter (mm) (1) 2; (3) 2 SA (m^2/g) high Water content: (1) 1.5% (2) approx. 2.5% (3) very low (4) approx. 60%	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Molecular sieves (large pore) Stability; moisture; sensitive Other applications: Aldol condensation Chloromethylation of aromatics Condensation of aldehydes with esters Dehydration of alcohols to olefins Dehydrocyclization reactions Hydration and ammonolysis of ethylene oxide Hydrogenation of olefins Polymerization of olefins.

TYPE OF CATALYST: *ZEOLITES 14880; 14891; 14838*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Incorporated	CONTENT wt % (1) 14880 Type Y ammonium ion (2) 14891 Type Y rare earth exchanged (3) 14838 Type L potassium ion FORM: (1) powder; (2) pellets; (3) powder SIZE: Diameter (mm) (2) 3 Length (mm) 6 SA (m^2/g) (1) high; (2) 550; (3) high Water content: (1) 60% (2) very low (3) approx. 33%	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Molecular sieves (large pore) See 14878.

HYDRODEALKYLATION

TYPE OF CATALYST: *NICKEL COPPER SK-400; SK-410*

Manufacturer	Characteristics	Operating conditions	Remarks
Union Carbide Corporation, Linde Molecular Sieve Catalysts	CONTENT anhydrous form wt % SK 400 SK 410 SiO_2 65.2±0.5 Al_2O_3 22.1±0.5 Na_2O 11.7±0.2 Cu — 1.0±0.02 Ni 1.0±0.02 Cl^- <0.05 Fl^- <0.05 FORM: tablets SIZE: Diameter (mm) 4 Length (mm) 4 ABD (g/cm^3) 0.65 SA (m^2/g) $>$ 500	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	They have interesting properties in the hydrodealkylation of alkyl substituted aromatics.

B. Cracking — Hydrocracking

Fluid catalytic cracking
Hydrocracking
Catalytic cracking
Fixed bed catalytic cracking

Fluid catalytic cracking

FLUID CATALYTIC CRACKING

TYPE OF CATALYST: *ZEOLITE SZ—C*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalyst and Chemical Industries Co. Ltd.	CONTENT (dry base) wt % Al_2O_3 14.8 Na_2O 0.020 Fe 0.023 SO_4 0.40 Loss on ignition 11.4 FORM: powder ABD (g/cm³) 0.49 SA (m²/g) 540 PV (cm³/g) 0.80	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Pore diameter: 59Å Particle size of micromesh sieve (microns) wt % Finer than: 20 2 30 8 40 18 80 80 105 95 149 100 Average size: 60 microns. Activity (micro) 750°C, 17 hrs. Steam deactivated conversion (vol. %): 68

TYPE OF CATALYST: *ZEOLITE SZ—H*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalyst and Chemical Industries Co. Ltd.	CONTENT (dry base) wt % Al_2O_3 29 Na_2O 0.025 Fe 0.023 SO_4 0.40 Loss on ignition 12.3 FORM: powder ABD (g/cm³) 0.43 SA (m²/g) 502 PV (cm³/g) 0,88	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Pore diameter: 70Å Particle size of micromesh sieve (microns) wt % Finer than: 20 2 30 8 40 18 80 80 105 95 149 100 Average size: 60 Activity (micro) 750°C, 17 hrs. Steam deactivated, conversion (vol. %): 70

TYPE OF CATALYST: *LOW ALUMINA*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalyst and Chemical Industries Co. Ltd.	CONTENT (dry base) wt % Al_2O_3 13.75 Na_2O 0.012 Fe 0.020 SO_4 0.33 Loss on ignition 11.0 FORM: powder ABD (g/cm³) 0.47 SA (m²/g) 560 PV (cm³/g) 0.73	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Pore diameter: 52Å Particle size of micro-mesh sieve (microns) wt % Finer than: 20 2 30 7 40 17 80 79 105 94 149 100 Average size: 61 Activity (UOP): Initial: 110 Thermal: 125

TYPE OF CATALYST: *HIGH ALUMINA*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalyst and Chemical Industries Co. Ltd.	CONTENT (dry base) wt % Al_2O_3 28.61 Na_2O 0.013 Fe 0.020 SO_4 0.30 Loss on ignition 10.8 FORM: powder ABD (g/cm^3) 0.41 SA (m^2/g) 511 PV (cm^3/g) 0.93	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Pore diameter: 73Å Particle size of micro-mesh sieve (microns) wt % Finer than: 20 2 30 8 40 18 80 79 105 94 149 100 Average size: 61 Activity (UOP): Initial: 104 Thermal: 170

TYPE OF CATALYST: *SILICA-ALUMINA AEROCAT*

Manufacturer	Characteristics	Operating conditions	Remarks
American Cyanamid Company	CONTENT wt % Silica 87 Alumina 13 FORM: Spray-dried micro-spheres SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Maximizes gasoline production in petroleum fluid cracking units.

TYPE OF CATALYST: *SILICA-ALUMINA AEROCAT TRIPLE A*

Manufacturer	Characteristics	Operating conditions	Remarks
American Cyanamid Company	CONTENT wt % Silica 75 Alumina 25 FORM: Spray-dried micro-spheres SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Maximizes gasoline production in petroleum operations and is more active than regular Aerocat fluid cracking catalyst.

TYPE OF CATALYST: ***AEROCAT TRIPLE S-4***

Manufacturer	Characteristics	Operating conditions	Remarks
American Cyanamid Company	CONTENT wt % An active and selective molecular sieve catalyst containing the Y-type sieves CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Provides greater gasoline production.

TYPE OF CATALYST: ***SILICA-ALUMINA AEROCAT 2000***

Manufacturer	Characteristics	Operating conditions	Remarks
American Cyanamid Company	CONTENT wt % It is a semi-synthetic cracking catalyst consisting of a mixture of clay and silica-alumina CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Maximizes gasoline production in petroleum operations but is less active than regular Aerocat fluid cracking catalyst.

TYPE OF CATALYST: ***AEROCAT TS-150***

Manufacturer	Characteristics	Operating conditions	Remarks
American Cyanamid Company	CONTENT wt % Contains a high percentage of Y-type molecular sieves CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Tends to maximize gasoline production.

TYPE OF CATALYST: *AEROCAT TS-170*

Manufacturer	Characteristics	Operating conditions	Remarks
American Cyanamid Company	CONTENT wt % Contains a larger quantity of Y-type molecular sieves CARRIER: n.a. FORM: n.a. SIZE n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Tends to maximize gasoline production and improves selectivity.

TYPE OF CATALYST: *AEROCAT TS-260*

Manufacturer	Characteristics	Operating conditions	Remarks
American Cyanamid Company	CONTENT wt % Contains the highest amount of Y-type molecular sieves CARRIER: n.a. FORM: n.a. SIZE n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Also tends to maximize gasoline production and improves selectivity.

TYPE OF CATALYST: *SILICA-ALUMINA LOW ALUMINA*

<table>
<tr><th>Manufacturer</th><th>Characteristics</th><th>Operating conditions</th><th>Remarks</th></tr>
<tr>
<td>Davison Chemical Division, W.R. Grace and Co.</td>
<td>CONTENT (dry base) wt %
Al_2O_3 13
SiO_2 86.8
Na_2O 0.04
Fe 0.04
SO_4 0.3
Ignition loss (817°C): 12
FORM: powder
ABD (g/cm^3) 0.44
PV (cm^3/g) 0.77</td>
<td>TEMPERATURE RANGE:
n.a.
PRESSURE RANGE:
n.a.</td>
<td>It is available in the following particle sizes:
<table>
<tr><th rowspan="2">Particle size of micromesh sieve (microns)</th><th colspan="3">Grade (wt %)</th></tr>
<tr><th>Coarse 13</th><th>Medium 13</th><th>Fine 13</th></tr>
<tr><td>0—20</td><td>2</td><td>2</td><td>3</td></tr>
<tr><td>0—40</td><td>13</td><td>18</td><td>21</td></tr>
<tr><td>0—80</td><td>60</td><td>70</td><td>79</td></tr>
<tr><td>0—105</td><td>88</td><td>89</td><td>93</td></tr>
<tr><td>0—149</td><td>98</td><td>98</td><td>98</td></tr>
<tr><td>APS</td><td>72</td><td>64</td><td>58</td></tr>
</table>
Long the standard in petroleum refining for medium-range operations.</td>
</tr>
</table>

TYPE OF CATALYST: *SILICA-ALUMINA HIGH ALUMINA*

Manufacturer	Characteristics	Operating conditions	Remarks
Davison Chemical Division, W.R. Grace and Co.	CONTENT (dry base) wt% Al_2O_3 25 SiO_2 74.6 Na_2O 0.05 Fe 0.04 SO_4 0.3 Ignition loss (816°C) 12 FORM: powder ABD (g/cm^3)0.39—0.46 PV (cm^3/g) 0.70—0.88 (both depending on particle size)	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Available in the following particle sizes: Particle size of micro-mesh sieve (microns) — Grade (wt%): Coarse 25, Medium 25, Fine 25 0—20 2 2 2 0—40 13 18 21 0—80 60 70 79 0—105 88 89 93 0—149 98 98 98 APS 72 64 58 The work horse prior to the zeolite catalysts, now finding application where feedstocks are extremely heavy and aromatic or where more balanced gasoline-light cycle oil requirements exist.

TYPE OF CATALYST: *SILICA-MAGNESIA SM-30*

Manufacturer	Characteristics	Operating conditions	Remarks
Davison Chemical Division, W.R. Grace and Co.	CONTENT (dry base) wt% Al_2O_3 14.0 MgO 20.8 SiO_2 63.4 Na_2O 0.05 Fe 0.11 SO_4 0.4 F 1.3 Ignition loss (817°C): 12 FORM: powder ABD (g/cm^3) 0.53 PV (cm^3/g) 0.57	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Particle size of micro-mesh sieve (microns) wt% 0—20 2 0—40 18 0—80 70 0—105 89 0—149 98 APS 64 Designed for the production of maximum yields of gasoline and light cycle oil, with improved stripping characteristics.

TYPE OF CATALYST: *ZEOLITE AGZ-50*

Manufacturer	Characteristics	Operating conditions	Remarks
Davison Chemical Division, W.R. Grace and Co.	CONTENT (dry base) wt% Al_2O_3 30.0 Na_2O 0.30 Fe 0.09 Ignition loss (816°C) 13 CARRIER: n.a. FORM: powder ABD (g/cm^3) 0.57 SA (m^2/g) 290 PV (cm^3/g) 0.47	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Attrition (Davison index): 20 (25 max.) Particle size of micro-mesh sieve (microns) wt% 0—20 2 0—40 13(15 max.) 0—80 65 APS 68

TYPE OF CATALYST: *ZEOLITE CBZ-1*

Manufacturer	Characteristics	Operating conditions	Remarks
Davison Chemical Division, W.R. Grace and Co.	CONTENT (dry base) wt% Al_2O_3 29.1 Na_2O 0.46 Fe 0.11 CARRIER: n.a. FORM: n.a. ABD (g/cm^3) 0.47 SA (m^2/g) 340 PV (cm^3/g) 0.60	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It exhibits gasoline selectivity.

TYPE OF CATALYST: *ZEOLITE DZ-7*

Manufacturer	Characteristics	Operating conditions	Remarks
Davison Chemical Division, W.R. Grace and Co.	CONTENT (dry base) wt% Al_2O_3 35 Na_2O 0.28 Fe 0.20 Ignition loss (816°C) 13 CARRIER: n.a. FORM: powder ABD (g/cm^3) 0.56 SA (m^2/g) (500°C) 260 PV (cm^3/g) 0.47	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Particle size of micro-mesh sieve (microns) wt% 0—20 2 0—40 19 0—80 72 0—105 92 0—149 98 APS 62 It improves gasoline yield.

TYPE OF CATALYST: *ZEOLITE XZ-25*

Manufacturer	Characteristics	Operating conditions	Remarks
Davison Chemical Division, W.R. Grace and Co.	CONTENT (dry base) wt% Al_2O_3 31.4 Na_2O 0.5 Fe 0.09 T.V. 12 CARRIER: n.a. FORM: powder ABD (g/cm^3) 0.52 SA (m^2/g) 335 PV (cm^3/g) 0.60	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Davison attrition index: 3.0 Micro activity vol. % conversion: 86 Particle size (N.N. screens: medium grade) (microns) wt% 0—20 2 0—40 18 0—80 70 APS 64 It is particularly suited for applications that require an intermediate level of zeolite activity, that is, those requiring a balance between gasoline, light cycle oil and light olefins yields.

TYPE OF CATALYST: *ZEOLITE XZ-36*

Manufacturer	Characteristics	Operating conditions	Remarks
Davison Chemical Division, W.R. Grace and Co.	CONTENT (dry base) wt% Al_2O_3 36 Na_2O 0.07 Fe 0.09 Ignition loss (816°C) 12 CARRIER: n.a. FORM: powder ABD (g/cm^3) 0.55 SA (m^2/g) 269 PV (cm^3/g) 0.55	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Steam deactivated at 6.3 atm. and 577°C For 24 hrs: 88 Particle size of micro-mesh sieve (microns) — wt% 0—20 — 2 0—40 — 19 0—80 — 72 0—105 — 92 0—149 — 98 APS — 62

TYPE OF CATALYST: *SILICA-ALUMINA SEMI-SYNTHETIC*

Manufacturer	Characteristics	Operating conditions	Remarks
Davison Chemical Division, W.R. Grace and Co.	CONTENT (dry base) wt% Al_2O_3 32 SiO_2 66.4 Na_2O 0.05 Fe 0.11 SO_4 0.6 Ignition loss (817 °C) 12 FORM: powder ABD (g/cm^3) 0.47—0.52 PV (cm^3/g) 0.58—0.70	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Particle size of micro-mesh sieve (microns) — Grade (wt%) S — S 0—20 — 2 0—40 — 13 0—80 — 60 0—105 — 88 0—149 — 98 APS — 72 A clay-included catalyst, designed for low conversion operations where rapid turnover of catalyst is desired, as when processing high-metals-contaminated feedstock. Also frequently used in blends with zeolite catalysts to moderate activity.

FLUID BED CATALYTIC CRACKING

TYPE OF CATALYST: *SILICA-ALUMINA HOUDRY MINERAL HFZ-20*$^{T.M.}$

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt% Al_2O_3 55 SiO_2 43 Ignition loss 12 FORM: powder ABD (g/cm^3) 0.86—0.9	TEMPERATURE RANGE: n.a. PRESSURE RANGE n.a.	Particle size (microns) — wt% 0—20 — 2.0 max. 0—40 — 10—15 0—80 — 78—85 0—105 — 93—97 0—149 — 99 min. Particle size average (APS) 58—64 Better gasoline selectivity.

TYPE OF CATALYST: *SILICA-ALUMINA HOUDRY MINERAL HFZ-23*$^{T.M.}$

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt% Al_2O_4 52 SiO_2 46 Ignition loss 10 FORM: powder ABD (g/cm^3) 0.86—0.9	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Particle size analysis: see HFZ-20 Gasoline selectivity. Improved octane levels.

MOVING BED CATALYTIC CRACKING

TYPE OF CATALYST: *ZEOLITE HOUDRY MINERAL HM-170*$^{T.M.}$

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt% Al_2O_3 45 SiO_2 53 Fe_2O_3 0.3 Other oxides 1.7 Ignition loss (760°C) 0.5—2.5 FORM: pellets SIZE: Diameter (mm) 4 Length (mm) 3—8 ABD (g/cm^3) 0.75—0.88 SA (BET) (m^2/g) 90—100	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Also in fixed bed applications. It is a workhorse high alumina cracking catalyst derived from kaolin clay. It is also applied in chemical reactions as a replacement for some synthetic silica-alumina catalysts. A specially treated variation — Houdry Mineral HM-171$^{T.M.}$

TYPE OF CATALYST: *ZEOLITE HOUDRY MINERAL HZ-1*^{R}

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt% Al_2O_3 45 SiO_2 53 Other 2 Ignition loss (760°C) 0.5—2.5 FORM: pellets SIZE: Diameter (mm) 4 Length (mm) 3—8 ABD (g/cm^3) 0.88—0.92 SA (m^2/g) 100—150	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used to maximize production of high octane gasoline as well as C_3 and C_4 olefins, from heavy feedstocks.

TYPE OF CATALYST: *ZEOLITE HOUDRY MINERAL HZ-2*$^{T.M.}$

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt% Al_2O_3 45 SiO_2 53 Other 2 Ignition loss (760°C) 0.5—2.5 FORM pellets SIZE: Diameter (mm) 4 Length (mm) 3—8 ABD (g/cm^3) 0.88—0.92 SA (m^2/g) 100—150	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is designed to maximize gasoline yield at the expense of coke and gas in operations where catalytic gasoline is the prime consideration.

FLUID CATALYTIC CRACKING

TYPE OF CATALYST: *ALUMINA KETJENCAT*^{R} *GRADE HA-HPV*

Manufacturer	Characteristics	Operating conditions	Remarks
Akzo Chemie B.V. Dpt. Ketjen Catalysts	CONTENT (dry base) wt% Al_2O_3 25 Na_2O 0.01 Fe 0.03 SO_4 1.0 Ignition loss (wet base, 1 hr 1000 °C) 12.0 CARRIER: n.a. FORM: powder ABD (g/cm^3) (1 hr 600°C) 0.37 SA (m^2/g) (1 hr 600°C) 540 PV (cm^3/g) 0.87	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Particle size (microns) wt% 0—20 3.0 0—40 18.0 0—80 64.5 0—105 86.0 0—149 98.5 High alumina, high pore volume.

TYPE OF CATALYST: *ALUMINA KETJENCAT*^{R} *GRADE HA-HS*

Manufacturer	Characteristics	Operating conditions	Remarks
Akzo Chemie B.V. Dpt. Ketjen Catalysts	CONTENT wt% Al_2O_3 25 Na_2O 0.03 Fe 0.03 SO_4 1.2 Ignition loss (1 hr 1000°C, wet base) 13.0 CARRIER: n.a. FORM: powder ABD (g/cm^3) (1 hr 600°C) 0.39 SA (m^2/g) (1 hr 600°C) 460 PV (cm^3/g) (1 hr 600°C) 0.88	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	High pore diameter grades. Particle size of micro-mesh sieve (microns) wt% 0—20 4.0 0—40 20.0 0—80 65.0 0—105 85.0 0—149 98.5

TYPE OF CATALYST: *ALUMINA KETJENCAT^R HA-MF*

Manufacturer	Characteristics	Operating conditions	Remarks
Akzo Chemie B.V. Dpt. Ketjen Catalysts	CONTENT (dry base) wt% Al_2O_3 28.5 Na_2O 0.01 Fe 0.02 SO_4 0.07 SiO_2 balance Ignition loss (1 hr 1000°C) 14.0 FORM: powder ABD (g/cm^3) 0.40 SA (m^2/g) 500 PV (cm^3/g) 0.89	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Particle size of micro-mesh sieve (microns) wt% 0—20 0.6 0—40 17.0 0—80 73.5 0—105 91.0 0—149 99.0 High alumina medium fine.

TYPE OF CATALYST: *ALUMINA KETJENCA T^R HA-MPV*

Manufacturer	Characteristics	Operating conditions	Remarks
Akzo Chemie B.V. Dpt. Ketjen Catalysts	CONTENT (dry base) wt% Al_2O_3 25 Na_2O 0.01 Fe 0.03 SO_4 1.0 Ignition loss (1 h r1000°C, wet base) 12.0 FORM: powder ABD (g/cm^3) 0.40 (1 hr 600°C) SA (m^2/g) 540 (1 hr 600°C) PV (cm^3/g) 0.82	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	High alumina catalyst. Particle size (microns) wt% 0—20 3.0 0—40 18.0 0—80 64.5 0—105 86.0 0—149 98.5

TYPE OF CATALYST: *ALUMINA KETJENCAT^R HA-LPV*

Manufacturer	Characteristics	Operating conditions	Remarks
Akzo Chemie B.V. Dpt. Ketjen Catalysts	CONTENT (dry base) wt% Al_2O_3 25 Na_2O 0.01 Fe 0.03 SO_4 1.0 Ingition loss (1 hr 1,000°C, wet base) 12.0 CARRIER: n.a. FORM: powder ABD (g/cm^3) 0.42 (1 hr 600°C) SA (m^2/g) 540 (1 hr 600°C) PV (cm^3/g) 0.76 (1 hr 600°C)	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	High alumina catalyst. Particle size (microns) wt% 0—20 3.0 0—40 18.0 0—80 64.5 0—105 86.0 0—149 98.5

TYPE OF CATALYST: *ALUMINA KETJENCAT^R LA-LPV*

Manufacturer	Characteristics	Operating conditions	Remarks
Akzo Chemie B.V. Dpt. Ketjen Catalysts	CONTENT (dry base) wt% Al_2O_3 13.0 Na_2O 0.01 Fe 0.03 SO_4 0.8 Ignition loss (1 hr 1000°C, wet base) 14.0 CARRIER: n.a. FORM: powder ABD (g/cm^3) 0.40 (1 hr 600°C) SA (m^2/g) 600 (1 hr 600°C) PV (cm^3/g) 0.73 (1 hr 600°C).	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Particle size of micro-mesh sieve (microns) wt% 0—20 3.0 0—40 16.0 0—80 64.5 0—105 86.0 0—149 98.5 Low alumina, low pore volume.

TYPE OF CATALYST: *ZEOLITE KETJENCAT^R GRADE MZ-1*

Manufacturer	Characteristics	Operating conditions	Remarks
Akzo Chemie B.V. Dpt. Ketjen Catalysts	CONTENT (dry base) wt% Na_2O 0.05 Al_2O_3 13 SO_4 0.8 Fe 0.03 SiO_2 and rare oxide balance Ignition loss (1 hr 1000°C) 14 FORM: powder ABD (g/cm^3) 0.40 (1 h 600°C) SA (m^2/g) 600 (1 h 600°C) PV (cm^3/g) 0.75 (1 h 600°C)	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	A fully synthetic fluid cracking catalyst, containing a highly active zeolite, consisting of a compound containing rare earths and Y-type molecular sieves. Particle size of micro-mesh sieve (microns) wt% 0—20 3 0—40 16 0—80 65 0—105 86 0—149 98.5

TYPE OF CATALYST: *ZEOLITE KETJENCAT^R MZ-3*

Manufacturer	Characteristics	Operating conditions	Remarks
Akzo Chemie B.V. Dpt. Ketjen Catalysts	CONTENT (dry base) wt% Al_2O_3 23.0 Na_2O 0.16 Fe 0.03 SO_4 1.00 SiO_2 and rare earth oxides balance Ignition loss (1000°C) 14.0 FORM: powder ABD (g/cm^3) 0.43 SA (m^2/g) 550 PV (cm^3/g) 0.70	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It consists of a high proportion of molecular sieves, the Y-type. It belongs to the small group of high activity zeolite catalysts. Particle size of micro-mesh sieve (microns) wt% 0—20 3.0 0—40 20.0 0—80 70.0 0—105 90.0 0—149 99.0

TYPE OF CATALYST: ***KAOLIN CRACKING CATALYST***

Manufacturer	Characteristics	Operating conditions	Remarks
Minerals and Chemicals Corporation of America	CONTENT wt% SiO_2 52.9 Al_2O_3 45.0 Fe_2O_3 0.3 TiO_2 1.7 Na_2O <0.05 K_2O <0.05 FORM: pellets, Kaospheres ABD (g/cm^3) 0.78 SA (m^2/g) 95 PV (cm^3/g) 0.25	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Particle size of Taylor screen wt% on 3 mesh 0.0 on 6 mesh 99.5 through 6 mesh 0.5 For moving bed operations.

HYDROCRACKING REACTIONS

TYPE OF CATALYST: *NICKEL MOLYBDENUM HT-100 E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni oxide 3.890 Mo trioxide 16.890 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 1.588 Length (mm) n.a. ABD (g/cm³) 0.608 SA (m²/g) 190 PV (cm³/g) 0.54 STRENGTH (kg/cm²) 6—9	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The sulphided form of this catalyst is used in reforming, lube oil for purification, gas oil for catalytic cracking, furnace oil, diesel fuel, and kerosene for olefinic saturation, and residual stocks for sulphur and metal removal.

TYPE OF CATALYST: *NICKEL-TUNGSTEN Ni-4301.E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni 6 W 19 CARRIER: silica-alumina FORM: extrusions SIZE: Diameter (mm) 2 Length (mm) n.a. ABD (g/cm³) 0.96 SA (m²/g) 228 PV (cm³/g) 0.37 STRENGTH(kg/cm²) 6.3	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The sulphide form of this catalyst is used for hydrogenation where a cracking function is desired. It is used for saturation of mono and polycyclic aromatic compounds, denitrogenation and desulphurization.

TYPE OF CATALYST: *NICKEL-TUNGSTEN Ni-4303.E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni 6 W 19 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 2 Length (mm) n.a. ABD (g/cm³) 0.784 SA (m²/g) 152 PV (cm³/g) 0.54 STRENGTH (kg/cm²) 8	TEMPERATURE RANGE: n.a. PRESSURE RANGE n.a.	The sulphide form of this catalyst is used for general hydrogenation used for pretreatment of hydrocracker feedstocks, saturation of mono and polycyclic aromatic compounds, denitrogenation and desulphurization.

TYPE OF CATALYST: *NICKEL-TUNGSTEN Ni-4309.E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni 5 W 10 B as promotor 3 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 1.5; 2; 3 Length (mm) n.a. ABD (g/cm^2) 0.8—0.9 SA (m^2/g) 150 PV (cm^3/g) 0.3 STRENGTH (kg/cm^2) 9.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The sulphide form of this catalyst is used for high pressure catalytic cracker pretreatment.

TYPE OF CATALYST: *NICKEL-TUNGSTEN Ni-4401.E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % See Ni-4301. E CARRIER: silica-alumina FORM: extrusions SIZE: Diameter (mm) 2 Length (mm) n.a. ABD (g/cm^3) 0.944 SA (m^2/g) 212 PV (cm^3/g) 0.37 STRENGTH (kg/cm^2) 4.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	This is the sulphide form of Ni-4301.E.

TYPE OF CATALYST: *NICKEL-TUNGSTEN Ni-4403.E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % See Ni-4303. E CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 2 Length (mm) n.a. ABD (g/cm^3) 0.8 SA (m^2/g) 140 PV (cm^3/g) 0.48 STRENGTH (kg/cm^2) 8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	This is the sulphide form of Ni-4303.E.

HYDROPROCESSING (CRACKING AND AROMATIC SATURATION)

TYPE OF CATALYST: *NICKEL-TUNGSTEN NALCO NT-550*

Manufacturer	Characteristics	Operating conditions	Remarks
Nalco	CONTENT wt % WO_3 20.2 NiO 5.1 alumina base balance CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) n.a. Length (mm) 3—1.5 ABD (g/cm^3)0.78—0.80 SA ((m^2/g) 250 PV (cm^3/g) 0.50 STRENGTH (kg/cm^2) 6—8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	This catalyst is formulated for difficult feedstocks such as lube stocks, heavy cycle oils and specialty distillates. The catalyst may be delivered also in form of Sphericat 550.

HYDROCRACKING OF PARAFFINS

TYPE OF CATALYST: *NICKEL-TUNGSTEN 28-156*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Incorporated	CONTENT wt % NiO 6 WO_3 19 CARRIER: silica-alumina FORM: extrusions SIZE: Diameter (mm) 2 Length (mm) n,a. ABD (g/cm^3) approx. 230	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	More acidic support than 28-153 with higher cracking activity.

Catalytic cracking

CATALYTIC CRACKING

TYPE OF CATALYST: *ANHYDROUS ALUMINIUM CHLORIDE*

Manufacturer	Characteristics	Operating conditions	Remarks
Allied Chemical	CONTENT n.a. CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Long chain hydrocarbons are split into shorter molecules.

CRACKING OF HYDROCARBONS

TYPE OF CATALYST: *NICKEL-COPPER CHEZA 32—02*

Manufacturer	Characteristics	Operating conditions	Remarks
Chemical Works of CSF	CONTENT wt % Ni 7 Cu 0.7 CARRIER: ceramic base FORM: extrusions SIZE: Diameter (mm) 10—12 Length (mm) 10—35 ABD (g/cm³) 1.0 STRENGTH (kg/cm²) 15	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for cracking methane, propane-butane, petroleum hydrocarbons for the production of city-gas. May be used in a cracking plant with a continuous or cyclic procedure.

TYPE OF CATALYST: *NICKEL G-3*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % NiO 2.8 CARRIER: alumina FORM: balls SIZE: Diameter (mm) 5—10; 10—15; 15—20; 20—25 ABD (g/cm³) 1.6 PV (cm³/g) 0.08 STRENGTH (kg/cm²) 10—300	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	For the same utilizations it is recommended GV-3.

CRACKING REACTIONS

TYPE OF CATALYST: *ZIRCONIUM 40-200*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Incorporated	CONTENT wt % ZrO_2 98 Alumina 2 FORM: pellets SIZE: Diameter (mm) 3 Length (mm) 3 SA (m^2/g) approx. 50	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also recommended as dehydration catalyst.

Fixed bed catalytic cracking

FIXED BED CATALYTIC CRACKING

TYPE OF CATALYST: *SILICA-ALUMINA 2-CP*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Al_2O_3 12.4 SiO_2 87.3 Na_2O 0.25 FORM: pellets SIZE: Diameter (mm) 4 Length (mm) 4 ABD (g/cm^3) 0.54 SA (m^2/g) 375—400	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Pellet density: 0.86 g/cm^3 Real density: 2.2—2.4 g/cm^3 Porosity, vol %: 60 Adsorption, wt%: 65 Average pore diameter: 80Å To maximize liquid products.

TYPE OF CATALYST: *SILICA-ALUMINA 24-CP*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Al_2O_3 12.4 SiO_2 87.3 Na_2O 0.25 FORM: pellets SIZE: Diameter (mm) 4 Length (mm) 4 ABD (g/cm^3) 0.53 SA (m^2/g) 425—450	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Pellet density: 0.86 g/cm^3 Real density: 2.2—2.4 g/cm^3 Porosity, vol. %: 60 Adsorption, wt%: 60 Average pore diameter: 80Å To maximize liquid products.

TYPE OF CATALYST: *SILICA-ALUMINA 159-CP*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Al_2O_3 12.4 SiO_2 87.3 Na_2O 0.25 FORM: pellets SIZE: Diameter (mm) 4 Length (mm) 4 ABD (g/cm^3) 0.62 SA (m^2/g) 290—313	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Pellet density: 0.99 g/cm^3 Real density: 2.2—2.4 g/cm^3 Porosity, vol.%: 57 Adsorption, wt%: 58 Average pore diameter: 82Å Used to maximize liquid products.

TYPE OF CATALYST: *SILICA-ALUMINA 511-CP*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt% Al_2O_3 12.4 SiO_2 87.3 Na_2O 0.25 FORM: pellets SIZE: Diameter (mm) 4 Length (mm) 4 ABD (g/cm^3) 0.66 SA (m^2/g) 80	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Pellet density: 1.24 g/cm^3 Real density: 2.2—2.4 g/cm^3 Porosity, vol. %: 47 Adsorption, wt%: 38 Average pore diameter: 80Å Used to maximize liquid products.

TYPE OF CATALYST: *SILICA-ALUMINA 523-CP*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt% Al_2O_3 12.4 SiO_2 87.3 Na_2O 0.25 FORM: pellets SIZE: Diameter (mm) 4 Length (mm) 4 ABD (g/cm^3) 0.63 SA (m^2/g) 180—200	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Pellet density: 1.02 g/cm^3 Real density: 2.2—2.4 g/cm^3 Porosity, vol. %: 56 Adsorption, wt%: 55 Average pore diameter: 85Å Used to maximize liquid products.

C. Dehydrogenation

DEHYDROGENATION OF CYCLOHEXANOL TO CYCLOHEXANE

TYPE OF CATALYST: *ZINC BASF H-5—10*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % ZnO active CARRIER: n.a. FORM: extrusions SIZE: Diameter (mm) 4; 6 ABD (g/cm^3) 1.4	TEMPERATURE RANGE: 300°—400°C PRESSURE RANGE: n.a.	

DEHYDROGENATION OF LINEAR HYDROCARBONS

TYPE OF CATALYST: *CHROMIUM C30-1*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT n.a. CARRIER: alumina FORM: tablets SIZE: Diameter (mm) 3; 6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used principally for the dehydrogenation of C_4 hydrocarbons to the corresponding olefins.

DEHYDROGENATION OF ORGANIC MATERIALS

TYPE OF CATALYST: *COPPER-CHROMIUM*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalyst and Chemicals International	CONTENT wt % Copper-chromium coprecipitated as "copper-chromite" CARRIER: n.a. FORM: powder, passing 325 mesh screen SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Hydrogenation of esters and acids. Oxidation and dehydrogenation of organic materials.

DEHYDROGENATION REACTIONS

TYPE OF CATALYST: *MOLYBDENUM CHEZA 35—00*

Manufacturer	Characteristics	Operating conditions	Remarks
Chemical Works of C.S.F.	CONTENT wt % MoO_3 12 Na_2O 0.1 Loss by heating (650°C) 10 CARRIER: alumina FORM: tablets SIZE: Diameter (mm) 6; 10 Length (mm) 6; 8—10 ABD (g/cm^3) 0.8 STRENGTH (kg/cm^2) 200	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for the dehydrogenation of naphthene hydrocarbons to aromatics. It is used for hydrogenation of different hydrocarbon mixtures at medium pressures, and at hydrotreating reactions. Typical for their use is the hydrotreating of crude coaltar benzol.

TYPE OF CATALYST: *CHROMIA-ALUMINA GRADE 909*

Manufacturer	Characteristics	Operating conditions	Remarks
Davison Chemical Division, W.R. Grace and Co.	CONTENT wt % Chromium CARRIER: alumina FORM: spheres SIZE (mm): 5×8 mesh	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It can be used for the production of butylenes from butane and has also found application in the manufacture of mercaptans from H_2S and an olefin.

DEHYDROGENATION AND RING CLOSURE

TYPE OF CATALYST: *A FUSED MIXTURE OF NaCl—AlCl$_3$*

Manufacturer	Characteristics	Operating conditions	Remarks
Davison Chemical Division, W.R. Grace and Co.	CONTENT wt % NaCl $AlCl_3$ FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The mixture is used in the dyestuffs and insecticides industries, for effecting the dehydrogenation of labile hydrogen in certain compounds with the resultant ring closure.

DEHYDROGENATION OF ALCOHOLS TO ALDEHYDES

TYPE OF CATALYST: *SILVER D-71-P*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT n.a. CARRIER: asbestos *FORM:* *fibres* SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Epoxydation of olefins. Dehydrogenation of primary and secondary alcohols to aldehydes and ketones.

TYPE OF CATALYST: *COPPER-CHROMITE G-13*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Cu 42 Cr 26 CARRIER: n.a. FORM: tablets, powder SIZE (mm): tablets: 4.5×4.5; 6×4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	For mild dehydrogenation reactions.

TYPE OF CATALYST: *COPPER-CHROMITE G-22*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Cu 33 Cr 27 Ba as promotor 11 CARRIER: n.a. FORM: tablets, powder SIZE (mm): tablets: 4.5×4.5; 6×4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Barium helps to prevent complete catalyst reduction and extend useful life.

DEHYDROGENATION OF BUTANE TO BUTADIENE

TYPE OF CATALYST: *CHROMIUM-ALUMINA G-41*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Cr 7.5 CARRIER: high purity gamma alumina FORM: tablets; extrusions SIZE (mm): tablets: 4.5×4.5 extrusions: 3	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Recommended for the hydrodealkylation of toluene to benzene and hydrodealkylation of substituted naphthalenes to naphthalenes.

TYPE OF CATALYST: *IRON G-48*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT n.a. CARRIER: n.a. FORM: extrusions SIZE: Diameter (mm): 1.5—5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *CHROMIUM Cr-0205.T, SPEC.102*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Cr_2O_3 19 CARRIER: activated alumina FORM: tablets SIZE: Diameter (mm) 3 Length (mm) n.a. ABD (g/cm^3) 0.960 SA (m^2/g) 60 PV (cm^3/g) 0.29 STRENGTH(kg/cm^2) 8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *CHROMIUM Cr-1404.P*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Cr_2O_3 19 CARRIER: high activity alumina FORM: powder SIZE (mm): n.a. ABD (g/cm³) 0.928 SA (m²/g) 80—100 PV (cm³/g) 0.50	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	A dehydrogenation catalyst for fluid bed use. Granulation (microns) — % 0—20 — 2 20—40 — 18 40—80 — 34 +80 — 46

TYPE OF CATALYST: *CHROMIUM Cr-1404.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt. % Cr_2O_3 19 CARRIER: high activity alumina FORM: tablets SIZE: Diameter (mm) 3 Length (mm) n.a. ABD (g/cm³) 1.152 SA (m²/g) 80—100 PV (cm³/g) 0.38 STRENGTH (kg/cm²) 15.8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

DEHYDROGENATION

TYPE OF CATALYST: *CHROMIUM Cr-0104.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Cr_2O_3 5 CARRIER: activated alumina FORM: tablets SIZE: Diameter (mm) 3 ABD (g/cm³) 1.08 SA (m²/g) 160 PV (cm³/g) 0.36 STRENGTH (kg/cm²) 10.8	TEMPERATURE RANGE: n.a. PRESSURE RANGE n.a.	

TYPE OF CATALYST: *COBALT Co-0501.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Co 10, in oxide form CARRIER: activated alumina FORM: tablets SIZE: Diameter (mm) 3 Length (mm) n.a. ABD (g/cm^3) 0.960 SA (m^2/g) 60 PV (cm^3/g) 0.51 STRENGTH (kg/cm^2) 8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is a mild hydrogenation catalyst.

TYPE OF CATALYST: *CHROMIUM Cr-0101.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Cr_2O_3 12 MgO as promotor 2 CARRIER: activated alumina FORM: tablets SIZE: Diameter (mm) 3 ABD (g/cm^3) 0.992 SA (m^2/g) 45 PV (cm^3/g) 0.31 STRENGTH (kg/cm^2) 4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *CHROMIUM Cr-0105.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Cr_2O_3 9 K_2O 1.5 as promotor CARRIER: activated alumina FORM: tablets SIZE: Diameter (mm) 3 ABD (gcm^3) 1.08 SA (m^2/g) 67 PV (cm^3/g) 0.34 STRENGTH (kg/cm^2) 5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *ZINC ACTIMET^{R} 261*

Manufacturer	Characteristics	Operating conditions	Remarks
Doduco	CONTENT wt % Activated zinc on carrier CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

DEHYDROGENATION OF PARAFFINS TO OLEFINS AND OLEFINS TO DIOLEFINS

TYPE OF CATALYST: *CHROMIUM Cr-0211.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Cr_2O_3 19 CARRIER: activated alumina FORM: tablets SIZE: Diameter (mm) 3 Length (mm) n.a. ABD (g/cm^3) 1.152 SA (m^2/g) 62 PV (cm^3/g) 0.30 STRENGTH (kg/cm^2) 9.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	A catalyst capable of selectivity for dehydrogenation of butane to butene. Formation of butene from butane is favoured at about atmospheric pressure, while butadiene is favoured at reduced pressures.

DEHYDROGENATION OF FUNCTIONAL GROUPS

TYPE OF CATALYST: *COPPER-CHROMITE Cu-0203 T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % CuO 78 Cr_2O_3 20 CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 3 Length (mm) n.a. ABD (g/cm^3) 2.160 STRENGTH (kg/cm^2) 9	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Copper-chromite catalysts are capable of selectivity to hydrogenate or dehydrogenate functional groups in organic compounds without changing the unsaturation or the saturation in aromatic rings or alkyl chains.

TYPE OF CATALYST: *COPPER-CHROMITE Cu-0402.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % CuO 35 Cr_2O_3 38 BaO 10 CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 3 Length (mm) n.a. ABD (g/cm^3) 1.616 STRENGTH (kg/cm^2) 3.6—5.4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *COPPER-CHROMITE Cu-1107.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % CuO 33 Cr_2O_3 38 BaO 9 CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 3 Length (mm) n.a. ABD (g/cm^3) 1.808 STRENGTH (kg/cm^2) 9	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Some copper-chromite complexes *contain barium* as a stabilizing element. Barium stabilizes copper-chromite for hydrogenation by retarding reduction of the catalyst during use. However, unstabilized copper-chromite catalysts are often used successfully for hydrogenation. The unstabilized copper-chromites are sometimes preferred for dehydrogenation.

DEHYDROGENATION

TYPE OF CATALYST: *COPPER-CHROMITE Cu-1800.P*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % CuO 51 Cr_2O_3 47 CARRIER: n.a. FORM: powder SIZE: n.a. ABD (g/cm^3) 0.656 SA (m^2/g) 40 PV (cm^3/g) 0.76	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for fluid bed hydroforming and dehydrogenation.

TYPE OF CATALYST: *COPPER-CHROMITE Cu-1808.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % CuO 42 Cr_2O_3 38 CARRIER: n.a. FORM: tablets SIZE: n.a. ABD (g/cm^3) 1.328 STRENGTH (kg/cm^2) 3.6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for fluid bed hydroforming. This is tableted Cu-1800. P.

DEHYDROGENATION OF ALCOHOLS TO ALDEHYDES OR KETONES

TYPE OF CATALYST: *COPPER-CHROMITE Cu-2501.G4—10*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Copper 6 as copper carbonate CARRIER: silica FORM: granules SIZE: Diameter (mm) 4—10 Length (mm) n.a. ABD (g/cm^3) 0.480 SA (m^2/g) 4 PV (cm^3/g) 0.61	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	An alkaly promoted catalyst.

MODERATE DEHYDROGENATION

TYPE OF CATALYST: *IRON Fe-0301.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Fe_2O_3 20 CARRIER: activated alumina FORM: tablets SIZE: Diameter (mm) 3 Length (mm) n.a. ABD (g/cm^3) 0.992 SA (m^2/g) 41 PV (cm^3/g) 0.31 STRENGTH (kg/cm^2) 8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	A hydrogenation catalyst.

DEHYDROGENATION

TYPE OF CATALYST: *MOLYBDENUM Mo-0401.P*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Molybdenum 44 (in sulphide form) CARRIER: n.a. FORM: powder SIZE: n.a. ABD (g/cm³) 0.816 SA (m²/g) 19 PV (cm³/g) 0.46	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for dehydrogenation, hydrogenation and desulphurization.

TYPE OF CATALYST: *MOLYBDENUM Mo-0502.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % MoO_3 10 CARRIER: activated alumina FORM: tablets SIZE: Diameter (mm) 3 Length (mm) n.a. ABD (g/cm³) 0.976 SA (m²/g) 64 PV (cm³/g) 0.40 STRENGTH (kg/cm²) 4.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *MOLYBDENUM Mo-1101.P*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % MoO_3 11 CARRIER: high activity alumina FORM: microspheroidal powder SIZE: n.a. ABD (g/cm³) 1.088	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for fluid bed hydroforming and dehydrogenation.

DEHYDROGENATION OF ALCOHOLS TO ALDEHYDES AND KETONES

TYPE OF CATALYST: *MOLYBDENUM Mo-1201.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % MoO_3 10 CARRIER: high activity alumina FORM: tablets SIZE: Diameter (mm) 3 Length (mm) n.a. ABD (g/cm^3) 0.848 SA (m^2/g) 160 PV (cm^3/g) 0.36 STRENGTH (kg/cm^2) 24	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for hydrogenation, dehydrogenation and hydroforming.

DEHYDROGENATION OF NAPHTHENES

TYPE OF CATALYST: *NICKEL Ni-0101.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni 44 (present as hydrate) CARRIER: Kieselguhr FORM: tablets SIZE: Diameter (mm) 3;5;6 Length (mm) n.a. ABD (g/cm^3) 1.2—1.34 STRENGTH (kg/cm^2) 5—7.7	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	At temperatures of about 275°C it must be reduced before use. Used for hydrogenation and methanation.

TYPE OF CATALYST: *NICKEL Ni-0104.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni 60 CARRIER: Kieselguhr FORM: tablets SIZE: Diameter (mm) 3;5;7 Length (mm) n.a. ABD (g/cm^3) 1.2—1.34 SA (m^2/g) 150 PV (cm^3/g) 0.2 STRENGTH (kg/cm^2) 3.6—11	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The ratio of reduced Nickel to total Nickel = =0.60. A hydrogenation catalyst reduced and stabilized but not pyrophoric as shipped.

TYPE OF CATALYST: *NICKEL Ni-1404.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni 68 CARRIER: proprietary FORM: tablets SIZE: Diameter (mm) 3;5 Length (mm) n.a. ABD (g/cm^3) 1—1.104 SA (m^2/g) 125 PV (cm^3/g) 0.35 STRENGTH (kg/cm^2) 4—7	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	A hydrogenation catalyst reduced and stabilized and not pyrophoric as shipped. Used for hydrogenation, hydrogenolysis and amination.

TYPE OF CATALYST: *PALLADIUM Pd-0501.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Pd 0.3 CARRIER: high activity alumina FORM: tablets SIZE: Diameter (mm) 3 Length (mm) n.a. ABD (g/cm^3) 0.88 SA (m^2/g) 186 PV (cm^3/g) 0.38 STRENGTH (kg/cm^2) 11	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

DEHYDROGENATION

TYPE OF CATALYST: *ZINC Zn-0602.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % ZnO 10 Cr_2O_3 10 CARRIER: activated alumina FORM: tablets SIZE: Diameter (mm) 3.175 Length (mm) n.a. ABD (g/cm^3) 1.088 SA (m^2/g) 141 PV (cm^3/g) 0.28 STRENGTH (kg/cm^2) 3	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *ZINC Zn-0701.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % ZnO 24 CARRIER: activated alumina FORM: tablets SIZE: Diameter (mm) 3 Length (mm) n.a. ABD (g/cm^3) 1.2 SA (m^2/g) 46 PV (cm^3/g) 0.25 STRENGTH (kg/cm^2) 4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

DEHYDROGENATION OF PARAFFINS TO OLEFINS

TYPE OF CATALYST: *CHROME-ALUMINA SERIES A, GRADE 25Z*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Cr_2O_3 17.5 min. Ignition loss (760°C) 2.0 max. CARRIER: alumina FORM: cylindrical; extrusions; pellets SIZE: Diameter (mm) 3 Length (mm) 4 ABD (g/cm^3) 0.960—1.1 SA (m^2/g) 45—70 STRENGTH (kg/cm^2) 7	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Important uses are in hydrocracking, hydrodealkylation, cyclization and aromatization.

DEHYDROGENATION OF ALCOHOLS

TYPE OF CATALYST: *COPPER H-1044*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Cu 22 $BaCrO_4$ 8 Cr_2O_3 2 Na_2O 0.5 SiO_2 61 Ignition loss (750°C) 0.5 FORM: extrusions SIZE: Diameter (mm) 4 Length (mm) 4—7 ABD (g/cm^3) 0.6 SA (BET) (m^2/g) 180—240 PV (cm^3/g) 0.7 STRENGTH (kg/cm^2) 50	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for the dehydrogenation of alcohols at high temperatures in the liquid phase, and also for the dehydrogenation of fatty esters to alcohols at temperatures of approx. 200°C.

TYPE OF CATALYST: *COPPER H-1201*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Cu 14 Cr 2 Silica 64 CARRIER: silica FORM: irregular granules SIZE: Diameter (mm) 4—7 ABD (g/cm^3) 1.0 SA (m^2/g) 15 PV (cm^3/g) 0.3	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for the dehydrogenation of ethanol. Excellent performance also in the hydrogenation of unsaturated aliphatic aldehydes.

TYPE OF CATALYST: *ZINC OXIDE H-2004*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % ZnO 79 Al_2O_3 4.5 Cr_2O_3 1.4 CaO 6.6 K_2O 3.3 SO_4 2.5 Ignition loss (650°C) 1—2 CARRIER: n.a. FORM: extrusions SIZE: Diameter (mm) 6 Length (mm) 5—10 ABD (g/cm^3) 1.4 SA (BET) (m^2/g) 10 PV (cm^3/g) 0.3	TEMPERATURE RANGE: 400°C PRESSURE RANGE: n.a.	Used for the dehydrogenation of secondary butanol and cyclohexanol.

TYPE OF CATALYST: *ZINC-OXIDE H-2499*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % ZnO 1 Al_2O_3 99 FORM: hollow cylinders SIZE: Diameter (mm) ID: 2 OD: 7—8 Length (mm) 15 ABD (g/cm^3) 0.53	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Suited for the fission of methanol.

DEHYDROGENATION OF CYCLOHEXANOL TO CYCLOHEXANE

TYPE OF CATALYST: *COPPER-RANEY CD*			
Manufacturer	Characteristics	Operating conditions	Remarks
Kawaken Catalysts	CONTENT It is prepared from the alloy of approx. 50% copper and 50% aluminium FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Activated type CDT. A copper Raney catalyst characterized by the selective activity to carbonyl bond. Used also in hydrogenation (e.g. furfural to furfuryl alcohol).

DEHYDROGENATION OF BUTANE AND ISOBUTANE TO BUTADIENE

TYPE OF CATALYST: *CHROMIUM KONTAKT 6448*			
Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT wt % Chromium oxide CARRIER: alumina FORM: spheres SIZE: Diameter (mm) 5 ABD (g/cm^3) 0.85—1.05	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

DEHYDROGENATION OF ISOBUTANE TO ISOBUTENE

TYPE OF CATALYST: *CHROMIUM DH-3*			
Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Cr 10.5±0.5 K 0.8±0.1 Na_2O <0.5 Fe_2O_3 <0.05 Al_2O_3 (by difference) 100 Heating loss at 550°C 0.5 CARRIER: alumina FORM: balls. SIZE: Diameter (mm) 2—4; 3—5; 5—7 ABD (g/cm^3) 0.9±0.05 SA (m^2/g) 100±20 PV (cm^3/g) 0.35±0.05 STRENGTH/particle: 10 kg	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used for the dehydrogenation of C_4 to butadiene.

DEHYDROGENATION IN VAPOUR PHASE

TYPE OF CATALYST: *Cu/Zn ST-230*

Manufacturer	Characteristics	Operating conditions	Remarks
Sakaj Chemical Co. Ltd.	CONTENT wt % Cu/Zn CARRIER: n.a. FORM: tablets SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *Cu/Zn CHROMITE ST-231*

Manufacturer	Characteristics	Operating conditions	Remarks
Sakaj Chemical Co. Ltd.	CONTENT wt % Cu/Zn/Cr CARRIER: n.a. FORM: tablets SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

DEHYDROGENATION OF ALKANES TO OLEFINS

TYPE OF CATALYST: *CHROMIA-ALUMINA 24020*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % Cr 7.5 Chromium oxide CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 3 SA (m^2/g) 179	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Dehydrogenation of ethylbenzene to styrene, synthesis of thiophenes from sulphur and alkanes. Desulphurization catalyst.

TYPE OF CATALYST: *CHROMIUM 24—025*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % Chromium oxide 2—4 CARRIER: silica fibres FORM: long fibres SIZE: Length (mm) 6 SA (m^2/g) 15	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for the dehydrogenation of alkanes to olefins.

TYPE OF CATALYST: *NICKEL 28—148*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % NiO 15 CARRIER: alumina FORM: pellets SIZE: Diameter (mm) 3 Length (mm) 3 SA (m^2/g) approx. 65	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Dehydrogenation of ethylbenzene to styrene. Vapor phase oxidation of hydrocarbons. Hydrogenation of olefins selectivity in the presence of aromatics (reduced form).

TYPE OF CATALYST: *NICKEL 28—162*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % NiO 1—2 CARRIER: silica fibres FORM: long fibres SIZE: Length (mm) 6 SA (m^2/g) approx. 27	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used for the hydrogenation (reduced form) of olefins.

HYDROGENATION AND DEHYDROGENATION

TYPE OF CATALYST: *COPPER 29-037*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % Copper chromite non-promoted CuO 82 Cr_2O_3 17 CARRIER: n.a. FORM: powder SA (m^2/g) approx. 10	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Being non-promoted, it is more durable as dehydrogenation catalyst. For best results in dehydrogenation processes this catalyst should be pretreated; then it can be used effectively to form aromatics and heteroalcohols to aldehydes and ketones.

DEHYDROGENATION (OXIDATION) OF ALCOHOLS TO ALDEHYDES AND KETONES

TYPE OF CATALYST: *RHENIUM 75-215*; *75-216*; *75-220*; *75-221*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % (1) 75215 (2) 75216 Rhenium 5 (3) 75220 (4) 75221 Rhenium 10 CARRIER: Carbon FORM: (1) powder; (2) granules; (3) powder; (4) granules SIZE: n.a. SA (m^2/g) high	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	They are also used for dehydrogenation of cyclohexanes to benzenes.

DEHYDROGENATION OF CYCLOHEXANES TO BENZENES

TYPE OF CATALYST: *IRON 26272*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % Iron oxide Fe_2O_3 20 CARRIER: alumina FORM: pellets SIZE: Diameter (mm) 3 Length (mm) 3 SA (m^2/g) approx. 40	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Catalyzes the conversion of alcohols to amines with ammonia. Desulphurization catalyst.

TYPE OF CATALYST: *MOLYBDENUM 42–150*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % MoO_3 10—12 CARRIER: alumina FORM: pellets SIZE: Diameter (mm) 3 Length (mm) 4 SA (m^2/g) approx. 200	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used for the polymerization of olefins.

D. Desulphurization

Sulphur removal
Desulphurization
Hydrodesulphurization
Guards for low temperature CO shift

SULPHUR REMOVAL

TYPE OF CATALYST: *ZINC DF-220*

Manufacturer	Characteristics	Operating conditions	Remarks
Azote et Produits Chimiques S.A.	CONTENT wt % ZnO CARRIER: n.a. FORM: cylindrical extrusions SIZE: Diameter (mm) 6 Length (mm) 10—14 ABD (g/cm³) 1.25	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	High mechanical strength and great absorption capacity above 20%. The following compounds are totally removed: hydrogen sulphide, carbon disulphide, carbon sulphoxide, mercaptans.

TYPE OF CATALYST: *ZINC G-1*

Manufacturer	Characteristics	Operating conditions	Remarks
Azote et Produits Chimiques S.A.	CONTENT wt % ZnO CARRIER: n.a. FORM: cylindrical pellets SIZE: Diameter (mm) 6 Length (mm) 6 ABD (g/cm³) 1.45	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Naphtha and light hydrocarbon hydrodesulphurization. It reduces the sulphur content of the processed hydrocarbon to less than 1 ppm (about 0.2 ppm) and allows the use of a reducing gas high in carbon oxides, without the occurence of the exothermic methanation reactions. G-1 catalyst allows chlorine traces that may be present in the hydrocarbon to be fixed.

SULPHUR REMOVAL FROM VARIOUS FEEDSTOCKS

TYPE OF CATALYST: *IRON-CHROMIUM C9-1*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Iron and chromium oxides with a cement binder CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 4 Length (mm) 6	TEMPERATURE RANGE: 340°—450°C PRESSURE RANGE: n.a.	It serves as a non-regenerable desulphurization system.

SULPHUR REMOVAL

TYPE OF CATALYST: *ZINC OXIDE C 7—1; C 7—2*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT n.a. CARRIER: n.a. FORM: pellets SIZE: Diameter (mm) 4.762 ABD (g/cm^3) 1.120± 0.080	TEMPERATURE RANGE: 200°—400°C PRESSURE RANGE: not critical; no pressure limitations SPACE VELOCITY: up to 20,000 h^{-1}	C 7-1 and C 7-2 are nonregenerable.

TYPE OF CATALYST: *ZINC OXIDE CDZ-6*

Manufacturer	Characteristics	Operating conditions	Remarks
Fertilizer Corporation of India (FCI)	CONTENT n.a. CARRIER: n.a. FORM: cylindrical tablets; extrusions; spherical globules. SIZE (mm): cylindrical tablets: 6×6 extrusions: 5×10 spherical globules: 2×5 ABD (g/cm^2) 1.1—1.4	TEMPERATURE RANGE: 250°—410°C PRESSURE RANGE: ~35 atm.	Available as CDZ-6A that is suitable for desulphurization of hydrocarbon feedstock.

REMOVAL OF HYDROGEN SULPHIDE FROM SYNTHESIS GAS STREAMS

TYPE OF CATALYST: *IRON CDD-12*

Manufacturer	Characteristics	Operating conditions	Remarks
Fertilizer Corporation of India (FCI)	CONTENT n.a. CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is substitute for luxmasse or bog ore. It can be supplied either as ready mixed mass or rich iron oxide.

SULPHUR REMOVAL

TYPE OF CATALYST: *ZINC G-72.C*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT n.a. CARRIER: n.a. FORM: spheres SIZE: Diameter (mm) 3—5 ABD (g/cm³) 1.1	TEMPERATURE RANGE: 430°C PRESSURE RANGE: 1—50 atm.	Removal of hydrogen sulphide, carbonyl sulphides, mercaptans and organic sulphides. Organic sulphide removal is normal at 260—430°C. G-72. C will adsorb up to 20 weight per cent sulphur. It will reduce the sulphur content from 200 mg/Nm³ to an exit concentration of less than 0.2 ppm.

TYPE OF CATALYST: *ZINC G-72.D*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Zinc oxide CARRIER: n.a. FORM: extrusions SIZE: Diameter (mm) 4 ABD (g/cm³) 1.4	TEMPERATURE RANGE: 20°—430°C PRESSURE RANGE: 1—50 atm	Organic sulphide removal is normally done at 260—430°C. Removal of hydrogen sulphide, carbonyl sulphides, mercaptans and organic sulphides.

TYPE OF CATALIST: *COPPER G-108.A*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Copper oxide Cu 16 CARRIER: special silica FORM: spheres SIZE: Diameter (mm) 5	TEMPERATURE RANGE: 100°—300°C PRESSURE RANGE: n.a.	Applications: Chlorine and sulphur removal, hydrogen and oxygen removal, hydrogenation.

TYPE OF CATALYST: *COPPER G-108.B*			
Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Cu 30 CARRIER: special FORM: spheres SIZE: Diameter (mm) 5	TEMPERATURE RANGE: 100°—300°C PRESSURE RANGE: n.a.	It is recommended for the sulphur and chlorine removal.

REMOVAL OF ORGANIC SULPHUR COMPOUNDS

TYPE OF CATALYST: *IRON G-42*			
Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Promoted iron oxide CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 6 Length (mm) 6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for treating gas streams containing sulphur as H_2S, mercaptans, CS_2 or organic sulphide.

TYPE OF CATALYST: *DESULPHURIZATION MASS N-ODS*			
Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT n.a. CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

SULPHUR REMOVAL

TYPE OF CATALYST: *ZINC OXIDE*

Manufacturer	Characteristics	Operating conditions	Remarks
Grande Paroisse	CONTENT wt % Zinc oxide CARRIER: n.a. FORM: cylindrical pellets SIZE: Diameter (mm) 11 Length (mm) 5 ABD (g/cm^3) 1.5	TEMPERATURE RANGE: 250°—380°C PRESSURE RANGE: until 100 atm	It is used to stock sulphur in the state of H_2S, COS present in gases. Catalyst life depends on sulphur content of raw material to be worked.

TYPE OF CATALYST: *ZINC Zn-0401.E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % ZiO 100 FORM: extrusions SIZE: Diameter (mm) 4 ABD (g/cm^3) 1.2 SA (m^2/g) 7 PV (cm^3/g) 0.14 STRENGTH (kg/cm^2) 6.3	TEMPERATURE RANGE: up to 400°C PRESSURE RANGE: 4 atm	

TYPE OF CATALYST: *COBALT-MOLYBDENUM H-9410*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % (approx.) CoO 3 MoO_3 15 Al_2O_3 80 FORM: extrusions SIZE: Diameter (mm) 2.4 Length (mm) 3—6 ABD (g/cm^3) 0.85 SA (BET) (m^2/g) 330 STRENGTH (kg/cm^2) 44	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for the removal of sulphur, nitrogen and arsenic impurities from naphtha feedstocks for petrol reforming and aromatics production units. This catalyst may also be used for desulphurization fuel oils and gas oils and for the hydrogenation of olefins.

REMOVAL OF H_2S FROM GASES

TYPE OF CATALYST: *ZINC KATALCO 32—4*

Manufacturer	Characteristics	Operating conditions	Remarks
Katalco Corporation	CONTENT wt % Zinc oxide CARRIER: n.a. FORM: granules SIZE: Diameter (mm) 3—4 Length (mm) n.a. ABD (g/cm^3) 1.10	TEMPERATURE RANGE: 340°—450°C PRESSURE RANGE: 1—50 atm SPACE VELOCITY (VHSH): 400 h^{-1}	It is used for the removal of small concentrations of H_2S and organic sulphur compounds from gases.

SWEETING OF KEROSENE

TYPE OF CATALYST: *COPPER CUPROX*

Manufacturer	Characteristics	Operating conditions	Remarks
Laporte Industries Limited, General Chemical Division, Spence Works	CONTENT wt. % A promoted supported copper catalyst CARRIER: n.a. FORM: granular SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is manufactured for use in the sweeting of mercaptan containing feeds.

REMOVAL OF HYDROGEN SULPHIDE

TYPE OF CATALYST: *LUXMASSE-IRON OXIDE*

Manufacturer	Characteristics	Operating conditions	Remarks
Laporte Industries Limited, General Chemical Division, Spence Works	CONTENT n.a. CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *ZINC KONTAKT 4010*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht"	CONTENT wt % Highly active zinc oxide CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 5 ABD (g/cm^3) 1.2±0.15 STRENGTH (kg/cm^2) 90±20	TEMPERATURE RANGE: 350°—450°C PRESSURE RANGE: 1—50 atm	Desulphurization of synthesis gas.

TYPE OF CATALYST: *ZINC ST-300*

Manufacturer	Characteristics	Operating conditions	Remarks
Sakaj Chemical Industry Co. Ltd	CONTENT wt % Consists of base metals and occasionally noble metals CARRIER: n.a. FORM: tablets SIZE: n.a.	TEMPERATURE RANGE: 150°—400°C PRESSURE RANGE: n.a.	Applications: Deodorizing of exhausting solvent vapor from baking finish, printing, baking enamel wire, adhesive process etc.; Deodorizing of odorous gas from sewerage, oil and fats plants, craft pulp plant etc.

TYPE OF CATALYST: *ZINC OXIDE HTZ-3*

Manufacturer	Characteristics	Operating conditions	Remarks
Haldor Topsøe	CONTENT wt % Zinc oxide CARRIER: n.a. FORM: extrusions SIZE: Diameter (mm) 4 Length (mm) 4—6 ABD (g/cm^3) 1.4	TEMPERATURE RANGE: 350°—400°C PRESSURE RANGE: 1—48.4 atm	It is recommended for the removal of H_2S, CS_2 and also of organic sulphur. Examples: Removal of organic sulphur from natural gas. Removal of H_2S from naphtha.

TYPE OF CATALYST: *ZINC HTZ-3*

Manufacturer	Characteristics	Operating conditions	Remarks
Haldor Topsøe	CONTENT wt % Zinc oxide CARRIER: n.a. FORM: extruded cylinders SIZE: Diameter (mm) 4 Length (mm) 4—6 ABD (g/cm^3) 1.4	TEMPERATURE RANGE: 350°—400°C PRESSURE RANGE: 1—50 atm	It is used for the removal of hydrogen sulphide, carbonyl sulphide and to a certain degree organic sulphur compounds from hydrocarbons and other gases such as feed gas to a low temperature shift catalyst. At ambiant temperatures only H_2S would be absorbed.

DESULPHURIZATION

TYPE OF CATALYST: *COPPER-CHROMIA C-29*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Copper and chromia oxides CARRIER: aluminium oxide FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: 200°—350°C PRESSURE RANGE: 1—40 atm	Highly selective catalyst for the conversion of carbonyl sulphide without hydrogenating the olefins in the stream.

TYPE OF CATALYST: *IRON C-28*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT n.a. CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 6;10 Length (mm) 6;10	TEMPERATURE RANGE: 290°—370°C PRESSURE RANGE: n.a.	It is used for the removal of organic sulphur compounds from gas streams by the conversion of the organic sulphur to H_2S by hydrogenation and/or hydrolysis.

DESULPHURIZATION OF LIGHT HYDROCARBON GASES

TYPE OF CATALYST: *METAL PROMOTED ACTIVATED CARBON C 8—1; C 8—4*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT C 8-1 activated carbon contains 3—4 wt % metallic oxides (copper); C 8-4 activated carbon contins a combination of 15—17wt % metallic oxides CARRIER: activated carbon FORM: granules SIZE: (mm) 2.5;1.7—2 ABD (g/cm^3) approx. 0.61	TEMPERATURE RANGE: 15°—50°C PRESSURE RANGE: 0—45 atm SPACE VELOCITY: up to 200,000 Nm^3 gas/m^3 carbon before regeneration	Are used as sulphur guard for methanation catalysts. Available as C 8-6 and C 8-7.

DESULPHURIZATION OF SYNTHESIS GAS STREAMS AND NATURAL GAS

TYPE OF CATALYST: *NOBLE METAL C53—2*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT n.a. CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: 149°—316°C PRESSURE RANGE: n.a.	It promotes the hydrolysis of organic sulphur compounds at low temperature.

DESULPHURIZATION OF GAS STREAMS

TYPE OF CATALYST: *ACTIVATED CARBON G-32 SERIES*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Activated charcoal unimpregnated or specially treated with metallic oxides CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	These activated carbons find application as catalysts supports. Selection of particular grade will be determined by operational requirement. Available as: G-32 granules (mm): 0.5—7; 2—5 G-32. E granules (mm): 0.5—7; 2—5 G-32. W: 12×30 mm mesh 4×10 mm mesh For fixed bed operations.

TYPE OF CATALYST: *ACTIVATED CARBON G-32.F*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT n.a. CARRIER: n.a. FORM: pellets SIZE: Diameter (mm) 8 Length (mm) 10 SA (m²/g) 935 PV (cm³/g) 0.81	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Sulphur removal by adsorption; for fixed bed operations. G-32.F is recommended for the removal of compressor oils from gas streams where the presence of such contaminates will interfere with subsequent operations downstreams.

TYPE OF CATALYST: *ACTIVATED CARBON G-32.H*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % A highly activated charcoal CARRIER: n.a. FORM: granules SIZE (mm): 4×8 mesh; 8×30 mesh SA (m^2/g) 700	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Sulphur removal by adsorption for fixed bed operations. G-32.H is a catalyst support, specifically recommended for use in the production of phosgene. It is used as a catalyst and catalyst support.

TYPE OF CATALYST: *ACTIVATED CARBON G-32.J*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT It is prepared by chemical impregnation of a physically strong highly absorbent activated coconut shell char. It contains appr. 5 wt% copper. FORM: granules SIZE (mm): 4×8 mesh; 8×30 mesh ABD (g/cm^3) 0.56—0.6 SA (m^2/g) 900 PV (cm^3/g) 0.6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	G-32.J is recommended for desulphurization of gas streams containing sulphur in the form of mercaptans, H_2S, CS_2 or other sulphur compounds. It is chloride free and non-corrosive.

TYPE OF CATALYST: *ACTIVATED CARBON G-32.P*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT A highly activated charcoal containing approx. 16% metallic oxides FORM: granules SIZE: Diameter (mm) 0.5—2.0; 2.0—5.0	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is especially recommended for removal of 10—20 ppm v/v H_2S from hydrocarbon streams.

DESULPHURIZATION

TYPE OF CATALYST: *DESULPHURIZATION MASS N—IDS*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT n.a. CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for the removal of inorganic sulphur compounds.

TYPE OF CATALYST: *PALLADIUM*

Manufacturer	Characteristics	Operating conditions	Remarks
Grande Paroisse	CONTENT wt % Pd 0.3—2.0 CARRIER: silico-aluminate FORM: cylindrical pellets SIZE: Diameter (mm) 3 Length (mm) 4 ABD (g/cm^3) 0.83	TEMPERATURE RANGE: 250°—380°C PRESSURE RANGE: until 100 atm LIFE: 5 years SPACE VELOCITY: 4—24 (LHSV) 800—4,800 (VSHV)	Used to mineralize sulphur in H_2S state.

DESULPHURIZATION OF REFINERY FEEDSTOCKS

TYPE OF CATALYST: *COBALT-MOLYBDENUM HT-300.S*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % CoO 3 MoO_2 13 CARRIER: alumina FORM: spherical SIZE: n.a. ABD (g/cm^3) 0.64 SA (m^2/g) 200 PV (cm^3/g) 0.75 STRENGTH (kg/cm^2) equivalent to extrusion at 6.34	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is recommended for desulphurization and denitrification of refinery feedstocks.

DESULPHURIZATION OF REFINERY PRODUCTS

TYPE OF CATALYST: *COBALT-MOLYBDENUM HT-400.E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % CoO 3 MoO_2 15 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 0.8;1.6;3.2 ABD (g/cm^3) 0.8 SA (m^2/g) 220 PV (cm^3/g) 0.5 STRENGTH(kg/cm^2) 5.44	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for the desulphurization and denitrification of hydrocarbons.

DESULPHURIZATION OF JET FUELS

TYPE OF CATALYST: *NICKEL-TUNGSTEN Ni-4305.E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni 4.5 W 9.5 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 3 ABD (g/cm^3) 1.02 SA (m^2/g) 184 PV (cm^3/g) 0.53 STRENGTH(kg/cm^2) 7	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for hydrogenation of jet fuels, saturation of mono and polycyclic aromatic compounds, denitrogenation.

DESULPHURIZATION

TYPE OF CATALYST: *NICKEL-MOLYBDENUM $HR^{T.M.}$ 811*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT n.a. CARRIER: n.a. FORM: n.a. SIZE: Diameter (mm) n.a. Length (mm) n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Removal of both sulphur and nitrogen.

TYPE OF CATALYST: *ZINC ICI 32 SERIES*

Manufacturer	Characteristics	Operating conditions	Remarks
Imperial Chemical Industries Ltd.	CONTENT wt % Zinc oxide CARRIER: n.a. FORM: n.a. SIZE: Diameter (mm) 3—4.7 Length (mm) n.a. ABD (g/cm^3) 1.1	TEMPERATURE RANGE: up to 450°C PRESSURE RANGE: up to 50 atm SPACE VELOCITY: 200—2,000 h^{-1} up to 20,000 h^{-1} (as a guard)	It is recommended for the removal of hydrogen sulphide and reactive organic sulphur compounds. ICI 32-4 is recommended as a guard for low temperature CO shift catalyst in plants with very high sulphur levels, but normal chlorine levels. Available as ICI 32-4.

TYPE OF CATALYST: *LEAD MaP*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Lead CARRIER: special FORM: balls SIZE: n.a. ABD (g/cm^3) 0.7	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used at high and low temperature for elimination of a few ppm of H_2S from industrial waste gases.

DESULPHURIZATION OF NATURAL GAS

TYPE OF CATALYST: *METAL OXIDES ON ACTIVATED CARBON KATALKO 7—1; 7—2*

Manufacturer	Characteristics	Operating conditions	Remarks
Katalco Corporation	CONTENT wt % 7—1 iron oxide 5—7 7—2 metal oxide about 14 CARRIER: activated carbon FORM: granules SIZE (mm) 12×30; 4×10 ABD (g/cm^3) 0.5—0.56	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Desulphurization of natural gas streams at ambient temperature. 7—1 is suitable for removal of H_2S and other sulphur compounds, in low concentrations. 7—2 is suitable for removal of H_2S and other sulphur compounds, in higher concentrations up to about 50 ppm.

HYDRODESULPHURIZATION

TYPE OF CATALYST: *COBALT-MOLYBDENUM C-20—5*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % CoO 3.3—3.8 MoO_3 9.5—10.5 Na_2O 0.05 Fe_2O_3 0.2 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 1.5;3.2;5 ABD (g/cm^3) 0.7 SA (m^2/g) 175—225	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The catalyst is poisoned by arsenic. Principal uses: for pretreatment of feedstocks.

TYPE OF CATALYST: *COBALT-MOLYBDENUM C-20—6*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % CoO 3.3—3.8 MoO_3 13—15 Na_2O 0.05 Fe_2O_3 0.20 Chlorides 0.10 CARRIER: n.a. FORM: extrusions SIZE: Diameter (mm) 3.175; 2.1;1.6 ABD (g/cm^3) 0.48—0.64 SA (m^2/g) 175—225 PV (cm^3/g) 0.50—0.60 STRENGTH(kg/cm^2) (side crush) 9.06; 6.8; 4.53	TEMPERATURE RANGE: 280°—450°C PRESSURE RANGE: 7—105 atm SPACE VELOCITY (LHSV): 1—10 h^{-1}	Used for hydrotreating and stabilization of liquid petroleum fractions from light naphtha through heavy vacuum gas oils and lube stocks. Available also as C-20-6S. It is also used for hydrodenitrogenation.

TYPE OF CATALYST: *COBALT-MOLYBDENUM AGRO HDS-2; HDS-2A*

Manufacturer	Characteristics	Operating conditions	Remarks
Cyanamid International	CONTENT wt % CoO 3.0—4.0 MoO_3 14.15—16.0 SO_4 0.3 Na_2O 0.04 max. Fe_2O_3 0.05 max. Ignition loss 2.0 max. CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 1.5—3 Length (mm) n.a. ABD (g/cm^3)0.49—0.57 SA (m^2/g) 270 PV (cm^3/g) 0.7 STRENGTH (kg/cm^2) 6.4—8.2 TS (°C) up to 540	TEMPERATURE RANGE: 371°C PRESSURE RANGE: 21 atm. SPACE VELOCITY (LHSV): 5 h^{-1}	It is used to promote desulphurization, denitrogenation, deoxigenation and saturation reactions. Arsenic and lead are the worst poisons.

TYPE OF CATALYST: *CHROMIUM-ALUMINA G-41*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT n.a. CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 6;5 Length (mm) 6;5	TEMPERATURE RANGE: 290°—450°C PRESSURE RANGE: n.a.	It has special application for removal of carbonil sulphide and carbon disulphide from coke oven gas.

TYPE OF CATALYST: *COBALT-MOLYBDENUM G-39*

Manufacturer	Characteristics	Operating conditions	Remarks
Cirdler	CONTENT n.a. CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 4.5 Length (mm) 4.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.d.	It is also used for hydrodenitrification of petroleum stocks. Recommended for treatment of streams contamined with sulphur where conversion of the sulphur compounds to hydrogen sulphide and hydrogenation of the olefins can be accomplished simultanously.

HYDRODESULPHURIZATION OF HYDROCARBONS

TYPE OF CATALYST: *COBALT-MOLYBDENUM G-51*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % CoO 3.5 MoO_3 10 CARRIER: high purity alumina FORM: extrusions SIZE: Diameter (mm) 3;5 ABD (g/cm³) 0.65 STRENGTH (kg/cm²) 6 (DWL)	TEMPERATURE RANGE: 260°—400°C PRESSURE RANGE: 3.5—70 atm	Used principally for hydrodesulphurization of hydrocarbons where a material having maximum physical strength is not required and lower density is desirable with G-51, organic sulphur compounds can be reacted with hydrogen to produce H_2S and the corresponding hydrogenated hydrocarbon. H_2S can then be removed from the gas stream by reacting with G-72.

TYPE OF CATALYST: *COBALT-MOLYBDENUM G-35*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % $CoO + MoO_3$ 13.5 [CoO 3.5 MoO_3 10] CARRIER: high purity alumina FORM: tablets SIZE: Diameter (mm) 4.5 Length (mm) 4.5 ABD (g/cm^3) 1.0 STRENGTH (kg/cm^2) (DWL) 14	TEMPERATURE RANGE: 260°—430°C PRESSURE RANGE: 3.5—70 atm.	It is also used for hydrodenitrification of petroleum stocks.

TYPE OF CATALYST: *COBALT-MOLYBDENUM G-51.C*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % CoO 3.5 MoO_3 10 CARRIER: n.a. FORM: extrusion SIZE: Diameter (mm) 3—5 ABD (g/cm^3) 0.384 STRENGTH (kg/cm^2) 6.795	TEMPERATURE RANGE: 316°—400°C 600°—750°F PRESSURE RANGE: 21—70 atm.	It is also used for the denitrification of petroleum stocks. Used also for hydrogenation of olefins.

TYPE OF CATALYST: *COBALT-MOLYBDENUM G-76*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % CoO 3.5 MoO_3 10 It also contains Ni. CARRIER: n.a. FORM: extrusions or tablets SIZE: extrusions tablets Diameter (mm) 3 3—4.5 Length (mm) 15 3—4.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for pretreating refinery gases to make them suitable for steam hydrocarbon reforming. Its applications are similar to G-51. However, when nitrogen removal is required, this catalyst is preferred.

TYPE OF CATALYST: *MOLYBDENUM-NICKEL G-88*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT, wt % NiO 3.5 MoO_3 15 CARRIER: n.a. FORM: tablets; extrusions SIZE: tablets extrusions Diameter (mm) 3—4.5 3—4.5 Length (mm) 3—4.5 15 or 3	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used for nitrogen removal.

HYDRODESULPHURIZATION

TYPE OF CATALYST: *PALLADIUM GPH-7*

Manufacturer	Characteristics	Operating conditions	Remarks
Grande Paroisse	CONTENT n.a. CARRIER: alumina FORM: balls SIZE: Diameter (mm) 3 Length (mm) n.a. TS (°C) $\leqslant$550	TEMPERATURE RANGE: 200°—300°C PRESSURE RANGE: n.a. LIFE: over 2 years SPACE VELOCITY: up to 10,000 h^{-1}	It is used in natural gas hydrocarbons such as naphthas.

TYPE OF CATALYST: *COBALT-MOLYBDENUM CoMo-0401.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Cobalt oxide 3 Molybdenum oxide 9 CARRIER: alumina FORM: tablets SIZE: Diameter (mm) 3 ABD (g/cm^3) 0.96 SA (m^2/g) 160 PV (cm^3/g) 0.40 STRENGTH (kg/cm^2) 10	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for the desulphurization of hydrocarbons A silica promoted catalyst.

TYPE OF CATALYST: *COBALT-MOLYBDENUM CoMo-0402.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % CoO 3 MoO_3 15 CARRIER: alumina FORM: tablets SIZE: n.a. ABD (g/cm^3) 1.2 SA (m^2/g) 200 PV (cm^3/g) 0.4 STRENGTH (kg/cm^2) 10	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Also for denitrogenation by hydrotreating. A silica promoted catalyst.

TYPE OF CATALYST: *COBALT-MOLYBDENUM CoMo-0601.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % CoO 3 MoO_3 9 CARRIER: alumina FORM: tablets SIZE: Diameter (mm) 3 Length (mm) 3 ABD (g/cm^3) 1.1 SA (m^2/g) 160 PV (cm^3/g) 0.4 STRENGTH (kg/cm^2) 10	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	A non-silicated catalyst.

TYPE OF CATALYST: *COBALT-MOLYBDENUM H-9410*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % See Hydrogenation of olefins	TEMPERATURE RANGE: n.a. TEMPERATURE RANGE: n.a.	

TYPE OF CATALYST: *COBALT-MOLYBDENUM HR*$^{T.M.}$*-801*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT n.a. CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Low density catalyst; it is used to remove sulphur from naphthas, gas-oils, furnace oils and other similar refining operations.

TYPE OF CATALYST: *COBALT-MOLYBDENUM ICI 41—3; 41—4; 41—5; 41—6; 41—7*

Manufacturer	Characteristics	Operating conditions	Remarks
Imperial Chemical Industries	CONTENT wt % Cobalt oxide Molybdenum oxide CARRIER: alumina FORM: 41-5 pellets; 41-6/7 extrusions SIZE: pellets extrusions Diameter (mm) 5.4 3.2 Length (mm) 1.6 ABD (g/cm^3) 0.5—0.55	TEMPERATURE RANGE: 300°—400°C PRESSURE RANGE: up to 70 atm.	ICI 41-7 is a more active version of the catalyst 41-6. They are hydrotreating catalysts designed for use with the complete range of hydrocarbon fractions from natural gas to lube oils. They can also be used for the hydrogenolysis of oxygen, nitrogen and organometallic compounds. Under normal operation condition they do not saturate aromatic hydrocarbons.

TYPE OF CATALYST: *COBALT-MOLYBDENUM KATALCO 41—3; 41—4*

Manufacturer	Characteristics	Operating conditions	Remarks
Katalco Corporation	CONTENT wt % Cobalt oxide Molybdenum oxide CARRIER: alumina FORM: 41-3-tablets 41-4-extrusions SIZE: extrusions tablets Diameter (mm) 4 5.4 Length (mm) 3.6 ABD (g/cm^3) tablets: 0.96—1.02 extrusions: 0.8—0.88	TEMPERATURE RANGE: 570°—840°C PRESSURE RANGE: 1—70 atm. SPACE VELOCITY (LHSV): 0.2—5.0 h^{-1} (for petroleum fractions)	The main use is for the vapour phase; hydrodesulphurization of gases and petroleum fractions.

HYDRODESULPHURIZATION FOR BULK SULPHUR REMOVAL

TYPE OF CATALYST: *COBALT-MOLYBDENUM KATALCO 41-6*

Manufacturer	Characteristics	Operating conditions	Remarks
Katalco Corporation	CONTENT wt % MoO_3 12.5 CoO 3.5 Na_2O 0.05 Fe 0.03 SiO_2 0.3 Al_2O_3 balance CARRIER: alumina FORM: extrusions; spheres SIZE: Diameter (mm) 2—3 ABD (g/cm^3) 0.48—0.72 SA (m^2/g) 260 PV (cm^3/g) 0.46—0.65 STRENGTH (kg/cm^2)6	TEMPERATURE RANGE: 350°—370°C PRESSURE RANGE: 14—15 atm LIFE: 4—5 years SPACE VELOCITY (LHSV): 2.25 h^{-1}	It is a hydrotreating catalyst designed for use in units whose feedstock ranges from light petroleum gases through naphthas to lube oil. Hydrodesulphurization is the prime service, although the catalyst can be used for the hydrogenolysis of oxygen, nitrogen and organo-metallic compounds.

TYPE OF CATALYST: *COBALT-MOLYBDENUM KATALCO 41—7*

Manufacturer	Characteristics	Operating conditions	Remarks
Katalco Corporation	CONTENT wt % MoO_3 12.5 CoO 3.5 Na_2O 0.08 Fe 0.03 SiO_2 1.5 Al_2O_3 balance CARRIER: alumina FORM: extrusions; spheres SIZE: Diameter (mm) 2—3 ABD (g/cm^3) 0.48—0.72 SA (m^2/g) 270 PV (cm^3/g) 0.51—0.65 STRENGTH(kg/cm^2) 6	TEMPERATURE RANGE: 350°C PRESSURE RANGE: 14—15 atm LIFE: 4—5 years SPACE VELOCITY (LHSV): 2.25 h^{-1}	See Katalco 41—6.

TYPE OF CATALYST: *MOLYBDENUM-NICKEL KATALCO 50-2*

Manufacturer	Characteristics	Operating conditions	Remarks
Katalco Corporation	CONTENT wt % MoO_3 14.0 NiO 2.8—3.0 Na_2O 0.08 Fe 0.03 SiO_2 1.5 Al_2O_3 balance CARRIER: alumina FORM: extrusions; spheres SIZE: Diameter (mm) 2—3 ABD(g/cm^3) e:0.72; s:0.52 SA (m^2/g) e:270; s:260 PV (cm^3/g) e:0.51 s:0.57 STRENGTH (kg/cm^2) 6	TEMPERATURE RANGE: 300°—370°C PRESSURE RANGE: 30—35 atm LIFE: 5 years SPACE VELOCITY (LHSV): 3.0 h^{-1}	See Katalco 41—6 It is especially suitable for hydrotreating units where both desulphurization and denitrogenation are desired.

HYDRODESULPHURIZATION (HYDROTREATING)

TYPE OF CATALYST: *COBALT-MOLYBDENUM KETJENFINE*^{R} *124-1.5E*

Manufacturer	Characteristics	Operating conditions	Remarks
Akzo Chemie B.V. Dpt. Ketjen Catalysts	CONTENT wt % (dry base) CoO 4.0 MoO_3 12.0 SiO_2 1.0 Na_2O 0.06 Fe 0.06 SO_4 2.0 Ignition loss (1 hr at 650°C): 1.5 wet base CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 1.5 Length (mm) 4 ABD (g/cm^3) 0.55—0.70 SA (BET) (m^2/g) 250 PV (cm^3/g) 0.65—0.50 STRENGTH(kg/cm^2) 12	TEMPERATURE RANGE: 300°—360°C PRESSURE RANGE: 20—50 atm SPACE VELOCITY (VHSV): 2.5—5 h^{-1}	Abrasion: 1.0% See Ketjenfine 124-3.P Available as: 124-1.5E LD (low density) 124-1.5E HD (high density).

TYPE OF CATALYST: *COBALT- MOLYBDENUM KETJENFINE*^{R} *124-3E*

Manufacturer	Characteristics	Operating conditions	Remarks
Akzo Chemie B.V. Dpt. Ketjen Catalysts	CONTENT wt % (dry base) CoO 4.0 MoO_3 12.0 SiO_2 1.0 Na_2O 0.06 Fe 0.06 SO_4 2.0 Ignition loss (1 hr at 650°C) 1.5 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 2.5 Length (mm) 5.0 ABD(g/cm^3) 0.55—0.70 SA (BET) (m^2/g) 250 PV (cm^3/g) 0.65—0.50 STRENGTH (kg/cm^2) 11	TEMPERATURE RANGE: 300°—360°C PRESSURE RANGE: 20—50 atm SPACE VELOCITY (VSHV): 2.5—5 h^{-1}	Abrasion: 2% Estimated reactor density: 0.55—0.70 kg/l. See Ketjenfine 124-3.P Available as: 124-3E (LD-low density) 124-3E (HD-high density).

TYPE OF CATALYST: *COBALT-MOLYBDENUM KETJENFINE*^{R} *124-3.P*

Manufacturer	Characteristics	Operating conditions	Remarks
Akzo Chemie B.V. Dpt. Ketjen Catalysts	CONTENT wt % (dry base) CoO 4.0 MoO_3 12.0 SiO_2 1.0 Na_2O 0.06 Fe 0.06 SO_4 2.0 Ignition loss (1 hr at 650°C): 1.5 CARRIER: alumina FORM: cylinders SIZE: Diameter (mm) 3 Length (mm) 3 ABD (g/cm^3) 12 SA (BET) (m^2/g) 225 PV (cm^3/g) 0.50 STRENGTH (kg/cm^2) 5.889	TEMPERATURE RANGE: 300°—360°C PRESSURE RANGE: 20—50 atm SPACE VELOCITY (VHSV): 2.5—5 h^{-1}	Abrasion: 1.5%. Estimated reactor density: 0.60 kg/l. The Ketjenfine 124 series are applied in the petroleum industry for the treatment of naphthas, kerosines, light and heavy gas-oils. Special applications: (1) Desulphurization of naphtha in sandwich type reactor systems for gas reforming; (2) Gas purification; (3) The H-oil process — to reduce the sulphur content in atmospheric residues by hydrogenation.

TYPE OF CATALYST: *COBALT-MOLYBDENUM KETJENFINE*^{R} *124-5P*

Manufacturer	Characteristics	Operating conditions	Remarks
Akzo Chemie B.V. Dpt. Ketjen Catalysts	CONTENT wt % (dry base) CoO 4.0 MoO_3 12 SiO_2 1.0 Na_2O 0.06 Fe 0.06 SO_4 2.0 Ignition loss (1hr at 650°C): 1.5 wet base CARRIER: SiO_2 FORM: cylinders SIZE: Diameter (mm) 5 Length (mm) 5 ABD (g/cm³) 12 SA (m²/g) 225 PV (cm³/g) 0.50 STRENGTH (kg/cm²) 11,325	TEMPERATURE RANGE: 300°—360°C PRESSURE RANGE: 20—50 atm SPACE VELOCITY (VSHV): 2.5—5 h^{-1}	See Ketjenfine 124-3P Available also as 165-1.5E 16% Mo oxide and Co oxide, on 1.5 mm extrusions; density 0.70 g/cm³.

TYPE OF CATALYST: *MOLYBDENUM-NICKEL KETJENFINE*^{R} *153.E; 153—1.5E; 153—3E*

Manufacturer	Characteristics	Operating conditions	Remarks
Akzo Chemie B.V. Dpt. Ketjen Catalysts	CONTENT wt % (dry base) MoO_3 15.0 NiO 3.0 SiO_2 1.1 Na_2O 0.07 Fe 0.04 SO_4 2.0 Loss on heating (1 hr at 550°C) wet base 3.0 CARRIER: n.a. FORM: n.a. SIZE: Diameter (mm) 1.5;2.5 Length (mm)4—8;3—7 SA (BET) (m²/g) 180 PV (cm³/g) 0.5 STRENGTH (kg/cm²)11	TEMPERATURE RANGE: 300°—360°C PRESSURE RANGE: 20—50 atm SPACE VELOCITY: (VHSV) 2.5—5 h^{-1}	For removal of nitrogen and polyaromatic compounds from mineral oils. These catalysts are particularly suited for treatment of cracked feedstocks.

TYPE OF CATALYST: *COBALT-MOLYBDENUM-NICKEL KETJENFINE*^{R} *164-1.5R; 164—3E*

Manufacturer	Characteristics	Operating conditions	Remarks
Akzo Chemie B.V. Dpt. Ketjen Catalysts	CONTENT wt % (dry base) MoO_3 16.5 CoO 1.5 NiO 3.0 SiO_2 1.0 Na_2O 0.06 Fe 0.02 SO_4 2.0 Loss on heating (1 hr at 650°C): 2.0% CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 1.5;3 ABD (g/cm³) 0.7 SA (BET) (m²/g) 270 PV (cm³/g) 0.48 STRENGTH (kg/cm²) (side) 20	TEMPERATURE RANGE: 300°—360°C PRESSURE RANGE: 10—50 atm SPACE VELOCITY: (VSHV) 5.0 h^{-1}	It has an improved activity for sulphur removal, for denitrogenation, carbon-residue-reduction and colour improvement in any process for pretreating or treating gasolines, naphthas, middle distillates and/or distillate gas-oil. Also available as: 168—0.8;1.5E and 3E. 16% Mo oxide and 8% NiO + Co oxide on 1.5 and 3 mm extrusion form; density 0.69 g/cm³.

HYDRODESULPHURIZATION

TYPE OF CATALYST: *COBALT-MOLYBDENUM COMOX 204*

Manufacturer	Characteristics	Operating conditions	Remarks
Laporte Industries Limited, General Chemical Division, Spence Works	CONTENT wt % on basis of material heated to 550°C CoO 2.9 MoO_3 14.6 SO_3 1.2 SiO_2 1.4 Na_2O+K_2O 0.03 Loss on ignition (550°C) 0.6 CARRIER: alumina FORM: tablets SIZE: Diameter (mm) 2.96 Length (mm) 2.07 SA (m^2/g) 265 STRENGTH (kg/cm^2) 8.1	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Removal of sulphur and nitrogen from naphtha feeds to reforming plants. COMOX may be used as catalyst for the carbon monoxide — hydrogen shift conversion when the gas containing carbon monoxide has a high sulphur and tar content and conventional shift catalysts would be quickly poisoned. In such applications COMOX may be regenerated many times without the loss of activity. COMOX and NIMOX are also used in the production of town gas.

TYPE OF CATALYST: *COBALT -MOLYBDENUM COMOX 224*

Manufacturer	Characteristics	Operating conditions	Remarks
Laporte Industries Limited, General Chemical Division, Spence Works	CONTENT wt % on basis of material heated to 550°C CoO 2.8 NoO_3 15.2 SO_3 1.2 SiO_2 1.5 Na_2O+K_2O 0.05 Loss on ignition (550°C) 2.0 CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 2.96 Length (mm) 2.97 SA (m^2/g) 270 STRENGTH (kg/cm^2) (piece) 26.7	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See COMOX 204 It is used for the removal of sulphur and nitrogen from naphtha feeds to reforming plants.

TYPE OF CATALYST: *COBALT-MOLYBDENUM COMOX 451*

Manufacturer	Characteristics	Operating conditions	Remarks
Laporte Industries Limited, General Chemical Division, Spence Works	CONTENT wt % on basis of material heated to 550°C CoO 3.7 MoO_3 12.8 Na_2O+K_2O 0.06 SiO_2 1.4 SO_3 1.6 Fe 0.03 Loss on calcination (550°C): 2 CARRIER: n.a. FORM: extrusions SIZE: Diameter (mm) 2.5—1.5 Length (mm) 4.69—3.17 ABD (g/cm^3) 0.58—0.60 SA (m^2/g) 300 PV (cm^3/g) 0.66 STRENGTH (kg/cm^2) (piece) 1.50—1.00	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See COMOX 204 Used for the removal of sulphur and nitrogen from naphtha feeds to reforming plants.

TYPE OF CATALYST: *COBALT-MOLYBDENUM COMOX 454*

Manufacturer	Characteristics	Operating conditions	Remarks
Laporte Industries Limited, General Chemical Division, Spence Works	CONTENT wt % on basis of material heated to 550°C CoO 3.6 MoO_3 12.7 SO_3 0.5 SiO_2 1.0 Na_2O+K_2O 0.06 Loss on ignition (550°C): 1.5 CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 2.96 Length (mm) 2,97 ABD (g/cm^3) 0.61 SA (m^2/g) 290 STRENGTH (kg/cm^2) (piece) 5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for the removal of sulphur and nitrogen from naphtha feeds to reforming plants. See also COMOX 204.

TYPE OF CATALYST: *COBALT-MOLYBDENUM COMOX 471*

Manufacturer	Characteristics	Operating conditions	Remarks
Laporte Industries Limited, General Chemical Division, Spence Works	CONTENT wt % on basis of material heated to 550°C CoO 3.7 MoO_3 12.8 Na_2O+K_2O 0.06 SiO_2 1.4 SO_3 2.5 Fe 0.05 Loss on calcination (550°C): 2.0 CARRIER: n.a. FORM: extrusions SIZE: Diameter (mm) 2.5—1.5 Length (mm) 4.32—3.15 ABD (g/cm^3) 0.75 SA (m^2/g) 272 PV (cm^3/g) 0.45 STRENGTH(kg/cm^2) 2.05—1.35	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for the removal of sulphur and nitrogen from naphtha feeds to reforming plants. See COMOX 204. Other information for COMOX: Grade / % of CoO / % of MoO_3 / Form / Size (mm) 671 5.0 15.0 extrus. 1.5; 2.5 207 2.5 14.0 tabl. 5.0 210 2.5 14.0 tabl. 7.0 214 2.5 14.0 tabl. 10.0 304 3.5 10.0 tabl. 3.0 504 5.0 25.0 tabl. 3.0 604 5.0 15.0 tabl. 3.0 624 5.0 15.0 tabl. 3.0 724 4.5 11.0 tabl. 3.0

TYPE OF CATALYST: *COBALT-MOLYBDENUM COMOX 1661*

Manufacturer	Characteristics	Operating conditions	Remarks
Laporte Industries Limited, General Chemical Division, Spence Works	CONTENT wt % on basis of material heated to 550°C CoO 5.1 MoO_3 15.3 Na_2O+K_2O 0.06 SiO_2 1.4 SO_3 1.4 Fe 0.05 Loss on calcination (550°C): 2 CARRIER: n.a. FORM: extrusions SIZE: Diameter (mm) 2.5—1.5 Length (mm) 4.69—3.17 ABD (g/cm^3) 0.66 SA (m^2/g) 300 PV (cm^3/g) 0.6 STRENGTH (kg/cm^2) 2.0—1.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for the removal of sulphur and nitrogen from naphtha feeds to reforming plants. A catalyst based on Actal IV. For Actal IV, see „Carriers“.

TYPE OF CATALYST: *NICKEL-MOLYBDENUM NIMOX 304*

Manufacturer	Characteristics	Operating conditions	Remarks
Laporte Industries Limited, General Chemical Division, Spence Works	CONTENT wt % on basis of material heated to 550°C NiO 3.7 MoO_3 10.3 Na_2O+K_2O 0.03 SO_3 1.2 WO_2 0.42 Loss on calcination (550°C): 0.6 CARRIER: high activity alumina FORM: tablets SIZE: Diameter (mm) 2.96 Length (mm) 2.97 SA (m^2/g) 265 STRENGTH (kg/cm^2) (piece) 8.1	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Removal of sulphur and nitrogen from naphtha feeds to reforming plants.

TYPE OF CATALYST: *NICKEL-MOLYBDENUM NIMOX 351*

Manufacturer	Characteristics	Operating conditions	Remarks
Laporte Industries Limited, General Chemical Division, Spence Works	CONTENT wt % on basis of material heated to 550°C NiO 3.7 MoO_3 10.2 Na_2O+K_2O 0.06 SiO_2 0.4 SO_3 1.8 Fe 0.05 Loss on calcination (550°C) 2.0 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 2.5;1.5 Length (mm) 6.0;4.0 ABD (g/cm^3) 0.59 SA (m^2/g) 280 PV (cm^3/g) 0.70 STRENGTH (kg/cm^2) (piece) 4.30—1.00	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Removal of sulphur and nitrogen from naphtha feeds.

TYPE OF CATALYST: *NICKEL-MOLYBDENUM NIMOX 371*

Manufacturer	Characteristics	Operating conditions	Remarks
Laporte Industries Limited, General Chemical Division, Spence Works	CONTENT wt % on basis of material heated to 550°C NiO 3.7 MoO_3 10.2 Na_2O+K_2O 0.06 SiO_2 0.4 SO_3 3.0 Fe 0.05 Loss on calcination (550°C) 2.0 CARRIER: n.a. FORM: extrusions SIZE: Diameter (mm) 2.5—1.5 Length (mm) 4.32—3,15 ABD (g/cm^3) 0.75 SA (m^2g) 272 PV (cm^3g) 0.45 STRENGTH (kg/cm^2) 2.05—1.35	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The removal of sulphur and nitrogen from naphtha feeds to reforming plants.

TYPE OF CATALYST: *NICKEL-MOLYBDENUM NIMOX 651*

Manufacturer	Characteristics	Operating conditions	Remarks
Laporte Industries Limited, General Chemical Division, Spence Works	CONTENT wt % on basis of material heated to 550°C NiO 5.2 MoO_3 15.3 Na_2O+K_2O 0.06 SiO_2 0.6 SO_3 1.8 Fe 0.05 Loss on calcination: 2.0 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 2.5—1.5 Length (mm) 6.0—4.0 ABD (g/cm^3) 0.59 SA (m^2/g) 280 PV (cm^3/g) 0.70 STRENGTH (kg/cm^2) 1.30—1	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The removal of sulphur and nitrogen from naphtha feeds to reforming plants. See COMOX 204. Other information for NIMOX: Nimox NiO MoO_3 Physical form 307 3.5 10.0 tablets (5 mm) 310 3.5 10.0 tablets (5 mm) 671 5.0 15.0 extrusions (1.5—2.5 mm F)

TYPE OF CATALYST: *COBALT-NICKEL-MOLYBDENUM CONIMOX 651*

Manufacturer	Characteristics	Operating conditions	Remarks
Laporte Industries Limited, General Chemical Division, Spence Works	CONTENT wt % CoO 2.7 NiO 2.6 MoO_3 15.4 Na_2O+K_2O 0.06 SiO_2 0.4 SO_3 1.8 Fe 0.05 Loss on calcination (550°C): 2.0 CARRIER: high activity alumina FORM: extrusions SIZE: Diameter (mm) 2.5—1.5 Length (mm) 5.4—3.7 ABD (g/cm^3) 0.59—0.61 SA (m^2/g) 280 PV (cm^3/g) 0.43 STRENGTH (kg/cm^2) 1.25—1.00	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for the removal of sulphur and nitrogen from naphtha feeds to reforming plants.

TYPE OF CATALYST: *COBALT-NICKEL-MOLYBDENUM CONIMOX 671*

Manufacturer	Characteristics	Operating conditions	Remarks
Laporte Industries Limited, General Chemical Division, Spence Works	CONTENT wt % on basis of material heated to 550°C CoO 2.7 NiO 2.6 MoO_3 15.4 Na_2O+K_2O 0.06 SiO_2 0.4 SO_3 3.0 Fe 0.05 Loss on calcination (550°C): 2 CARRIER: high activity alumina FORM: extrusions SIZE: Diameter (mm) 2.5—1.5 Length (mm) 5.05—3.55 ABD (g/cm^3) 0.75 SA (m^2/g) 275 PV (cm^3/g) 0.55 STRENGTH (kg/cm^2) 2.05—1.35	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for the removal of sulphur and nitrogen from naphtha feeds to reforming plants. Pore volume: 300Å—0.42 cm^3/g.

TYPE OF CATALYST: *NICKEL-MOLYBDENUM KONTAKT 8198*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT wt % Nickel-molybdenum oxide CARRIER: alumina FORM: spheres SIZE: Diameter (mm) 3—4 ABD (g/cm^3) 0.78—0.92 STRENGTH (kg/particle) 12	TEMPERATURE RANGE: n. a. PRESSURE RANGE: n. a.	It is used at mid-pressure.

TYPE OF CATALYST: *COBALT-MOLYBDENUM SPHERICAT 474*

Manufacturer	Characteristics	Operating conditions	Remarks
Nalco	CONTENT n. a. CARRIER: n. a. FORM: spheres SIZE: n. a. ABD (g/cm^3) 0.48—0.6	TEMPERATURE RANGE: n. a. PRESSURE RANGE: n. a.	See Nalcomo 474.

TYPE OF CATALYST: *NICKEL-MOLYBDENUM SPHERICAT 502*

Manufacturer	Characteristics	Operating conditions	Remarks
Nalco	CONTENT n. a. CARRIER: n. a. FORM: spheres SIZE: n. a. ABD (g/cm^3) 0.4—0.6	TEMPERATURE RANGE: n. a. PRESSURE RANGE: n. a.	See Nalco NM-502. It is used for the hydrotreating (desulphurization and denitrification).

TYPE OF CATALYST: *NICKEL-TUNGSTEN SPHERICAT 550*

Manufacturer	Characteristics	Operating conditions	Remarks
Nalco	CONTENT n.a. CARRIER: n.a. FORM: spheres SIZE: n.a. ABD (g/cm^3) 0.4—0.6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See Nalco NT-500.

TYPE OF CATALYST: *NICKEL-MOLYBDENUM NALCO NM-502*

Manufacturer	Characteristics	Operating conditions	Remarks
Nalco	CONTENT wt % NiO 2.8 MoO$_3$ 14.0 CARRIER: alumina FORM: extrusions; spheres SIZE: Diameter (mm) n.a. Length (mm) 3.2—1.5 ABD (g/cm^3) 0.68—0.71 SA (m^2/g) 270 PV (cm^3/g) 0.55 STRENGTH (kg/cm^2) 6—8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	This catalyst is recommended for service in hydrotreating units where both desulphurization and denitrogenation are desired. It is also used when nitrogen content of the feedstock must be reduced to a minimum; for saturation of olefins and aromatics too.

TYPE OF CATALYST: *NICKEL-TUNGSTEN NALCO NT-550*

Manufacturer	Characteristics	Operating conditions	Remarks
Nalco	CONTENT wt % WO$_3$ 20.2 NiO 5.1 Alumina difference to 100% CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 2—3 ABD (g/cm^3) 0.78—0.80 SA (m^2/g) 250 PV (cm^3/g) 0.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	This is especially formulated material for difficult service on lube stocks, cycle oils and speciality distillates, with cracking and aromatic saturation capabilities.

TYPE OF CATALYST: *COBALT-MOLYBDENUM-ALUMINA NALCOMO 471*

Manufacturer	Characteristics	Operating conditions	Remarks
Nalco	CONTENT wt % CoO 3.5 MoO_3 12.5 Alumina: by difference to 100% CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) n.a. Length(mm) 3—1.5 ABD (g/cm^3) 0.66—0.68 SA (m^2/g) 295 PV (cm^3/g) 0.55 STRENGTH (kg/cm^2) 6.342—8.152	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is suitable for application in units where feedstocks range from fuel oil to lube oil. It is highly suitable for application in hydrotreating where desulphurization is the prime service.

TYPE OF CATALYST: *COBALT-MOLYBDENUM-ALUMINA NALCOMO 474*

Manufacturer	Characteristics	Operating conditions	Remarks
Nalco	CONTENT wt % CoO 3.5 MoO_3 12.5 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) n.a. Length (mm) 3.175—1.58 ABD (g/cm^3) 0.68—0.70 SA (m^2/g) 280 PV (cm^3/g) 0.58 STRENGTH (kg/cm^2) 6—8	TEMPERATURE RANGE n.a. PRESSURE RANGE: n.a.	This catalyst is outstanding in feedstocks requiring maximum desulphurization, in the presence of elevated nitrogen content.

TYPE OF CATALYST: *COBALT-MOLYBDENUM HR-101*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % MoO_3 13.5 CoO 2.4 Na_2O <0.09 Fe_2O_3 <0.05 Al_2O_3 by difference to 100% Loss on ignition (550°C): <0.5 CARRIER: alumina FORM: balls SIZE: Diameter (mm) 2—4 ABD (g/cm^3) 0.85±0.05 SA (m^2/g) 225±40 PV (cm^3/g) 0.45±0.05 STRENGTH (kg/cm^2) 30	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for the hydrodesulphurization of gasoline, naphthas and kerosenes. Used also for the hydrodenitrification of the same feedstocks.

TYPE OF CATALYST: *COBALT-MOLYBDENUM HR-103*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % MoO_3 13.5 CoO 2.4 Na_2O <0.09 Fe_2O_3 <0.05 Al_2O_3 by diff. to 100% Loss on ignition (550°C): <1 CARRIER: alumina FORM: balls SIZE: Diameter (mm) 2—4; 3—5 Length (mm) n.a. ABD (g/cm^3) 0.70±0.04 SA (m^2/g) 225 ± 25 PV (cm^3/g) 0.58±0.05 STRENGTH (kg/cm^2) 12	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Hydrodesulphurization of gasoline, naphthas, kerosenes, gas-oils. Used also for the hydrodenitrification of gasolines, naphthas, kerosenes, gas-oils.

TYPE OF CATALYST: *COBALT-MOLYBDENUM HR-304*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % MoO_3 12 CoO 2.2 Na_2O 700 ppm Fe_2O_3 400 ppm Al_2O_3 by diff. to 100% Loss on ignition (550°C): 1 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 3; 2 Length (mm) n.a. ABD (g/cm^3) 0.60±0.05 SA (m^2/g) 280±30 PV (cm^3/g) 0.70±0.05 STRENGTH (kg/cm^2) 8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Hydrodesulphurization of gasolines, kerosenes, gas-oils. Used also for the hydrodenitrification of gasolines, naphthas, kerosenes, gas-oils and for the hydrotreatment of heavy feedstocks.

TYPE OF CATALYST: *COBALT-MOLYBDENUM HRF-101*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % CoO 2.4 MoO_3 13.5 Fe_2O_3 <0.5 Al_2O_3 by difference to 100% Loss on ignition (550°C): <1 CARRIER: high purity alumina FORM: beads SIZE: Length (mm) 1.5—2.4 ABD (g/cm^3) 0.9 SA (m^2/g) >250 STRENGTH(kg/cm^2) >30	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used for the hydrodenitrification of gasoline and naphthas. It is recommended for the hydrodesulphurization of gasoline and naphthas.

TYPE OF CATALYST: Co-*Mo-Ni HRF-121*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % MoO_3 12 NiO 2 CoO 2 CARRIER: high purity alumina FORM: balls SIZE: Diameter (mm) 1.25—2.5 ABD (g/cm^3) 0.9 SA (m^2/g) 250 PV (cm^3/g) 0.40 STRENGTH (kg/cm^2) >4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used for hydrodenitrification.

TYPE OF CATALYST: *MOLYBDENUM-NICKEL HR-143*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % MoO_3 >12 NiO >2.2 Na_2O <0.09 Fe_2O_3 <0.05 Al_2O_3 by difference to 100% Loss on ignition (550°C): <1 CARRIER: n.a. FORM: n.a. SIZE n.a. ABD(g/cm^3) 0.74 ± 0.04 SA (m^2/g) 225 ± 25 STRENGTH (kg/cm^2) 10	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Also used for denitrification of benzols, naphthas, kerosenes. It is used for pretreatment of reforming feedstocks and also in steam reforming.

TYPE OF CATALYST: *NICKEL-TUNGSTEN HR-151*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % NiO $\geqslant 6.5$ WO_3 $\geqslant 12.5$ Additives 0 Al_2O_3 by difference to 100% CARRIER: high purity alumina FORM: balls SIZE: Diameter (mm) 2—4 ABD (g/cm^3) 0.8 SA (m^2/g) 225 STRENGTH (kg/cm^2) >5	TEMPERATURE RANGE: 180°—300°C PRESSURE RANGE: 40—60 atm approx. SPACE VELOCITY: 1—2 h^{-1}	Used for the hydrotreatment of average distillates, solvent dearomatisation and improvement of kerosenes smoke paint.

TYPE OF CATALYST: *NICKEL-TUNGSTEN HR-153*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % NiO $\geqslant 4$ WO_3 $\geqslant 16$ Additives 0 Al_2O_3 by difference to 100% CARRIER: high purity alumina FORM: balls SIZE: Diameter (mm) 2—4 ABD (g/cm³) 0.8 SA (m²/g) 225 PV (cm³/g) 0.50 STRENGTH (kg/cm²) >5	TEMPERATURE RANGE: 180°—300°C PRESSURE RANGE: 40—60 atm approx. SPACE VELOCITY: 1—2 h^{-1}	Used for hydrotreatment of average distillates.

TYPE OF CATALYST: *NICKEL-TUNGSTEN HR-155*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % NiO $\geqslant 6.5$ WO_3 $\geqslant 12.5$ Additives 6 Al_2O_3 by difference to 100% CARRIER: high purity alumina FORM: balls SIZE: Diameter (mm) 2—4 ABD (g/cm³) 0.8 SA (m²/g) 225 PV (cm³/g) 0.50 STRENGTH (kg/cm²) >5	TEMPERATURE RANGE: 180°—300°C PRESSURE RANGE: 40—60 atm approx. SPACE VELOCITY: 1—2 h^{-1}	Hydrotreatment of average distillates. Production of low aromatic compounds, fuels, solvents, special oils from light distillates.

TYPE OF CATALYST: *COBALT-MOLYBDENUM 27048*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Incorporated	CONTENT wt % CoO 3.5 MoO_3 10 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 4 SA (m²/g) approx. 244	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Other uses: Addition of H_2S to olefins to form mercaptans. Olefin disproportionation; Hydrogenation of naphthalene (sulphide form of the catalyst recommended).

TYPE OF CATALYST: *COBALT-MOLYBDENUM CMK-2*

Manufacturer	Characteristics	Operating conditions	Remarks
Haldor Topsøe	CONTENT wt % Cobalt oxide Molybdenum oxide CARRIER: alumina FORM: spheres SIZE: Diameter (mm) 2—5 Length (mm) n.a. ABD (g/cm³)0.80—0.85 SA (BET) (m²/g) 200	TEMPERATURE RANGE: 350°—400°C PRESSURE RANGE: 10—40 atm LIFE: more than 5 years	Hydrodesulphurization of naphtha or natural gas. See NMK-2.

HYDRODESULPHURIZATION OF NAPHTHA AND NATURAL GAS

TYPE OF CATALYST: *NICKEL-MOLYBDENUM NMK-2*

Manufacturer	Characteristics	Operating conditions	Remarks
Haldor Topsøe	CONTENT wt % Nickel oxide Molybdenum oxide CARRIER: alumina FORM: spheres SIZE: Diameter (mm) 2—5 ABD (g/cm³) 0.80—0.85 SA (BET) (m²/g) 200	TEMPERATURE RANGE: 350°—400°C PRESSURE RANGE: 10—40 atm LIFE: more than 5 years	It is used for hydrogenation of organic sulphur and nitrogen compounds. A special application is the use of the catalyst for hydrogenation of unsaturated hydrocarbons.

Guards for low temperature CO shift

GUARD FOR LOW TEMPERATURE CO SHIFT

TYPE OF CATALYST: *C-117*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Zinc oxide promoted CARRIER: none FORM: pellets SIZE: Diameter (mm) 4.762 ABD (g/cm^3) 1.12	TEMPERATURE RANGE: 120°—290°C PRESSURE RANGE: 1—40 atm SPACE VELOCITY: 20,000 v/h^{-1}	It is used to protect low temperature shift catalyst from poisoning. C-117-1 is composed of zinc and copper oxides plus a binder. It is used as a combination of sulphur and chloride guard adsorbent. They give protection against sulphur and also against chlorine.

TYPE OF CATALYST: *ZINC OXIDE CDZ-6.B*

Manufacturer	Characteristics	Operating conditions	Remarks
Fertilizer Corporation of India (F.C.I.)	CONTENT wt % CARRIER: n.a. FORM: cylindrical tablets; extrusions; spherical globules SIZE (*mm*): tablets: 6×6 extrusions: 5×10 globules: 2.5 ABD (g/cm^3) 1.1—1.4	TEMPERATURE RANGE: 190°—270°C PRESSURE RANGE: 35 atm	It is used as a guard catalyst against sulphide and chloride poisoning.

TYPE OF CATALYST :*COPPER-ZINC ICI 52-1.G*

Manufacturer	Characteristics	Operating conditions	Remarks
Imperial Chemical Industries Ltd	CONTENT wt % Copper oxide Zinc oxide CARRIER: alumina FORM: pellets SIZE: Diameter (mm) 5.4 Length (mm) 3.6 ABD (g/cm^3) 0.9	TEMPERATURE RANGE: 180°—250°C PRESSURE RANGE: up to 50 atm.	It is a modified version of the catalyst 52-1, ICI's low temperature shift catalyst. It is normally installed immediately on the top of the bed of catalyst 52-1.

TYPE OF CATALYST: *ICI 59-1*

Manufacturer	Characteristics	Operating conditions	Remarks
Imperial Chemical Industries Ltd.	CONTENT wt % Modified alumina CARRIER: n.a. FORM: pellets SIZE: Diameter (mm) 5.4 Length (mm) 3.6 ABD (g/cm^3) 1.1	TEMPERATURE RANGE: 150°—500°C PRESSURE RANGE: up to 50 atm SPACE VELOCITY: 5,000—20,000 h^{-1}	This is a new catalyst with a high chlorine absorption capacity. It has no activity for the shift reaction and is therefore not recommended for general use. It is recommended in plants with very high chlorine levels as a guard for the low temperature CO shift catalyst.

E. Halogenation (Dehalogenation)

Dehalogenation

Dehydrochlorination

HALOGENATION

TYPE OF CATALYST: *ALUMINA Al-1101. P*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Al_2O_3 90 (the balance being essentially moisture) CARRIER: n.a. FORM: powder SIZE: n.a. ABD (g/cm^3) 0.9	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *ALUMINIUM-FLUORIDE Al-1101. T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % AlF_3 85 FORM: tablets SIZE: Diameter (mm) 6.35 ABD (g/cm^3) 1.312 STRENGTH (kg/cm^2) 10	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	To add fluorine or HF to olefins.

TYPE OF CATALYST: *CHROMIUM Cr-0304. T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Cr_2O_3 33 CARRIER: silicated alumina FORM: tablets SIZE: Diameter (mm) 3.175 Length (mm) n.a. ABD (g/cm^3) 1.2 SA (m^2/g) 120 PV (cm^3/g) 0.26 STRENGTH (kg/cm^2) 18	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	To add fluorine or HF to olefins.

TYPE OF CATALYST: *SODIUM FLUORIDE Na 022-T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % NaF 99 CARRIER: n.a. FORM: porrous tablets SIZE: Diameter (mm) 3 Length (mm) n.a. ABD (g/cm^3) 1.040 SA (m^2/g) 1 PV (cm^3/g) 0.29 STRENGTH (kg/cm^2) 6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used to add fluorine or HF to olefins. It removes HF from gas streams by absorption.

CHLORINATION OF BENZENE TO PRODUCE CHLOROBENZENE

TYPE OF CATALYST: *COPPER Cu-0804. T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Cu 7.7 CARRIER: activated alumina FORM: tablets SIZE: Diameter (mm) 6.35 Length (mm) n.a. ABD (g/cm^3) 0.9 SA (m^2/g) 100 PV (cm^3/g) 0.36 STRENGTH (kg/cm^2) 8—8.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

CHLORINATION

TYPE OF CATALYST: *COPPER Cu-0905.P*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % $CuCl_2$ 10 CARRIER: activated alumina FORM: powder SIZE: n.a. ABD (g/cm^3) 0.960 SA (m^2/g) 80	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Copper chloride on various supports (Cu-0900 series) are also used to add Cl_2 or HCl to olefins.

TYPE OF CATALYST: *COPPER Cu-0905.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % $CuCl_2$ 10 CARRIER: activated alumina FORM: tablets SIZE: Diameter (mm) 3.175 Length (mm) n.a. ABD (g/cm^3) 0.960 SA (m^2/g) 59 PV (cm^3/g) 0.26 STRENGTH (kg/cm^2) 5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See Cu-0905.P.

TYPE OF CATALYST: *CUPRIC CHLORIDE ST-250*

Manufacturer	Characteristics	Operating conditions	Remarks
Sakaj Chemical Industry Co. Ltd.	CONTENT wt % $CuCl_2/Al_2O_3$ CARRIER: Al_2O_3 FORM: tablets SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Chlorination in vapour phase.

Dehalogenation

DEHALOGENATION

TYPE OF CATALYST: *BARIUM CHLORIDE Ba-0108.E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % $BaCl_2$ 27 CARRIER: carbon FORM: extrusions SIZE: Diameter (mm) 4 Length (mm) 6 ABD (g/cm³) 0.544	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used to remove hydrogen chloride from chlorine containing hydrocarbons.

DEHYDROHALOGENATION REACTIONS

TYPE OF CATALYST: *RHENIUM 75201; 75204*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Incorporated	CONTENT wt % 75201 Rhenium 0.5 75204 Rhenium 5 CARRIER: alumina FORM: 75201: pellets 75204: powder SIZE: n.a. SA (m²/g) high	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Also used for dehydrogenation of cyclohexanes to benzenes and reforming catalysts.

DEHYDROCHLORINATION

TYPE OF CATALYST: *BARIUM CHLORIDE* C-75—1			
Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT n.a. CARRIER: activated carbon FORM: irregular shapes 6—30 mesh SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for dehydrochlorination of linear chlorinated hydrocarbons.

F. Hydrogenation

Amonolysis
Hydrogenation of aromatic hydrocarbons
Hydrogenation of carbonyl compounds
Hydrogenation of carbon double bonds
Hydrogenation of esters and acids
Hydrogenation of functional groups (general)
Hydrogenation of nitriles
Hydrogenation of nitro-compounds
Hydrogenation reactions (general)
Selective hydrogenation
Hydrotreating reactions

Amonolysis

AMINATION OF ALCOHOLS

TYPE OF CATALYST: *COBALT G-61RS; G-62RS*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Cobalt on carrier G-61RS G-62RS Co 67±2 34.5±2 CARRIER: Kieselguhr; alumina (62RS) FORM: tablets(61RS); extrusions(62RS) SIZE: Diameter (mm) 5 Length (mm) 5 ABD (g/cm^3) 1.2±0.08 (tablets) 0.8±0.08 (extrusions) SA (m^2/g) 97;42 STRENGTH (kg/cm^2) 5.4;7	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Reduction of nitriles, carbonyls and aromatics. They are poisoned by CO, sulphur and halide compounds. It is designed for fixed bed operations using liquid, vapour or mixed phase feed. G-62RS is the prereduced and stabilized form of G-62. G-61RS is the prereduced and stabilized form of G-61.

TYPE OF CATALYST: *COBALT G-67; G-67RS*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Zirconium promoted cobalt G-67 G-67RS Co approx. 60 60±2 2.2±0.2 CARRIER: Kieselguhr FORM: tablets; extrusions SIZE: Diameter (mm) 5;5 ABD (g/cm^3) 1.2;1.0 SA (m^2/g) 65 STRENGTH (kg/cm^2) 7;4	TEMPERATURE RANGE: up to 400°C PRESSURE RANGE: n.a. LIFE: estimated to be in excess of one year	See G-61 and G-62. Available in oxide form and in prereduced and stabilized form, designated as G-67RS.

AMONOLYSIS OF ALCOHOLS WITH AMMONIA AND HYDROGEN TO AMINES

TYPE OF CATALYST: *NICKEL Ni-0107T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni 56 CARRIER: Kieselguhr FORM: tablets SIZE: Diameter (mm) 4 Length (mm) 3 ABD (g/cm^3) 1.44 SA (m^2/g) 130 PV (cm^3/g) 0.18 STRENGTH (kg/cm^2) 4.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Ratio of reduced nickel to total nickel: 0.5.

TYPE OF CATALYST: *NICKEL Ni-0707T*			
Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni 14 CARRIER: high activity alumina FORM: tablets SIZE: Diameter (mm) 3 Length (mm) 3 ABD (g/cm^3) 0.8 SA (m^2/g) 140 PV (cm^3/g) 0.38 STRENGTH (kg/cm^2) 10	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

AMONOLYSIS OF ALCOHOLS TO PRODUCE AMINES

TYPE OF CATALYST: *ALUMINIUM OXIDE — SILICIUM OXIDE KONTAKT 6067*			
Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT wt % Mixed aluminium oxide and silicium oxide FORM: extrusions SIZE: Diameter (mm) 14 Length (mm) 10—20	TEMPERATURE RANGE: 370°—440°C PRESSURE RANGE: 0—200 atm	

AMONOLYSIS OF THE ALDEHYDES AND KETONES

TYPE OF CATALYST: *COBALT RCH/45/20TS; 45/20HS; 45/20PYR*			
Manufacturer	Characteristics	Operating conditions	Remarks
Farbwerke Hoechst A.G.	CONTENT wt % RCH 45/20TS: Co 45 RCH 45/20HS: Co 43 RCH 45/20PYR :Co 46 CARRIER: Kieselguhr FORM: tablets; powder SIZE (mm): tablets: 6×5 ABD (g/cm^3) 0.5—1.0	TEMPERATURE RANGE: 100°—300°C PRESSURE RANGE: 40—250 atm	The reduction of nitriles to the respective amines.

Hydrogenation of aromatic hydrocarbons

HYDROGENATION OF BENZENE TO CYCLOHEXANE

TYPE OF CATALYST: *NICKEL CODE 235T*

Manufacturer	Characteristics	Operating conditions	Remarks
Calsicat Division	CONTENT wt % Ni 40 CARRIER: alumina FORM: tablets SIZE: Diameter (mm) 3;6;4 Length (mm) 3;6;4 ABD (g/cm³) 0.8 SA (m²/g) 220 STRENGTH (kg/cm²) 11 (individual particle)	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It can be used for the selective hydrogenation of aromatics to cycloparaffins.

SATURATION OF POLYAROMATICS

TYPE OF CATALYST: *NICKEL-MOLYBDENUM AERO HDS-3; AERO HDS-3A*

Manufacturer	Characteristics	Operating conditions	Remarks
Cyanamid International	CONTENT wt% NiO 3—5 MoO_3 14.5—16.0 Na_2O max. 0.04 Fe max. 0.05 CARRIER: n.a. FORM: cylindrical extrusions SIZE: Diameter (mm) 2.5—3.8 ABD (g/cm³) 0.72—0.8 SA (m²/g) 200 PV (cm³/g) 0.6 STRENGTH (kg/cm²) 5.4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Particularly used for pretreating cat-cracker feedstocks and lube oils. It has selectivity for polyaromatics, olefins and nitrogen removal.

SATURATION OF AROMATICS

TYPE OF CATALYST: *NICKEL-MOLYBDENUM AERO HDS-9*

Manufacturer	Characteristics	Operating conditions	Remarks
Cyanamid International	CONTENT wt% NiO 3.0—4.0 MoO_3 17.5—18.5 Na_2O 0.04 Fe 0.05 Loss on ignition: 2 CARRIER: n.a. FORM: cylindrical extrusions SIZE: Diameter (mm) 3.175 ABD (g/cm³) 0.72—0.8 STRENGTH (kg/cm²) 5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Recommended for processing stocks containing high percentages of nitrogen. For pretreatment of reformer feedstock when quality demands are stringent. For coker effluents. For cat-cracker feed preparation. For turbine fuel smokepoint improvement. For selected lube oil processing situations. For new ventures.

HYDROGENATION OF AROMATICS

TYPE OF CATALYST: *RANEY NICKEL GRADE 28*

Manufacturer	Characteristics	Operating conditions	Remarks
Davison Chemicals Division, W.R Grace and Co.	CONTENT wt% Ni 90 Al 9 Al_2O_3, Cu, Fe, Mg FORM: slurry in water 50% solid and 50% water SIZE: Diameter (mm) 70—40 microns SA (m^2/g) 80—100	TEMPERATURE RANGE: $<150°C$ PRESSURE RANGE: n.a.	Also grade 4200. Used for reductive amination, aromatic hydrogenation, *saturation* of olefinic bonds, reduction of aldehydes to alcohols. Grade 200 (highly active nickel fine).

HYDROGENATION OF AROMATIC HYDROCARBONS

TYPE OF CATALYST: *Ni—Al ALLOY B-013*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt% Ni 49.5—5 Al_2O_3 max. 1.5 Fe max. 0.75 Al remainder FORM: fine powder SIZE: Diameter (mm) $<75.10^{-3}$ ABD (g/cm^3) 1.8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Application: Hydrogenation of terpenes, phenol and naphthalene.

NUCLEAR HYDROGENATION OF AROMATICS AND HETEROCYCLES

TYPE OF CATALYST: *RHODIUM G-10 S*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt% Rhodium CARRIER: active charcoal FORM: powder	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Precious metal content usually of 0.1, 0.15, 1, 5 and 10 per cent.

HYDROGENATION OF BENZENE AND PHENOL

TYPE OF CATALYST: *NICKEL ACTIMET*^{R} *223*

Manufacturer	Characteristics	Operating conditions	Remarks
Doduco	CONTENT wt% Nickel CARRIER: silicic acid FORM: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *NICKEL ACTIMET*^{R} *225; ACTIMET*^{R} *229*

Manufacturer	Characteristics	Operating conditions	Remarks
Doduco	CONTENT wt% Nickel CARRIER: alumina FORM: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Sulphur resistant catalyst.

HYDROGENATION OF BENZENE TO CYCLOHEXANE OF HIGH PURITY

TYPE OF CATALYST: *PLATINUM SINCLAIR BAKER RD-260*

Manufacturer	Characteristics	Operating conditions	Remarks
Engelhard Minerals and Chemicals Corporation	CONTENT: wt% Pt 0.6 CARRIER: aluminium oxide FORM: extrusions SIZE: Diameter (mm) 1.5 Length (mm) 4.5 Density (g/cm^3) approx. 0.67	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Elaborated by Sinclair Research Inc. and by Baker Co., Newark

HYDROGENATION OF OLEFINS AND AROMATICS

TYPE OF CATALYST: *NICKEL G-87*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt% Ni 40 CARRIER: refractory oxide FORM: extrusions SIZE: Diameter (mm) 3 ABD (g/cm^3) 0.88 SA (m^2/g) 45 STRENGTH (kg/cm^2) 12 (dead weight load)	TEMPERATURE RANGE: 120°—260°C PRESSURE RANGE: 28—35 atm	It is also used for methanation and deoxygenation. It is available in both the oxidized state and the prereduced and stabilized form as G-87 RS.

HYDROGENATION OF BENZENE

TYPE OF CATALYST: *NICKEL Ni-0101.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt% Ni 44 present as hydrate CARRIER: Kieselguhr FORM: tablets SIZE (mm): 3×3×6 ABD (g/cm^3) 1.20—1.26 STRENGTH (kg/cm^2) 5—8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used for methanation.

TYPE OF CATALYST: *NICKEL Ni-0102.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt% Ni 55 (as NiO) CARRIER: Kieselguhr FORM: tablets SIZE: Diameter (mm) 3; 4; 6 Length (mm) 3; 4; 6 ABD (g/cm^3) 1.5—1.6 STRENGTH (kg/cm^2) 4.5—11.3	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for hydrogenation of naphthalene to tetraline or decaline.

TYPE OF CATALYST: *NICKEL Ni-0104.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt% Ni 58 CARRIER: Kieselguhr FORM: tablets SIZE: Diameter (mm) 3 Length (mm) 3 ABD (g/cm^3) 1.44 SA (m^2/g) 155—165 STRENGTH (kg/cm^2) 4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The tableted form of Ni-0104 P. Applications: hydrogenation of C = C and C=0 bonds; hydrogenation of nitrogen compounds; methanation.

TYPE OF CATALYST: *NICKEL Ni-0109.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt% Ni 60 CARRIER: Kieselguhr FORM: tablets SIZE: Diameter (mm) 6 Length (mm) 6 ABD (g/cm^3) 1.29—1.34 STRENGTH (kg/cm^2) 16	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Ratio of reduced nickel to total nickel: 0.75. Used for hydrogenation of naphthalene to tetraline or decaline.

HYDROGENATION OF AROMATIC HYDROCARBONS

TYPE OF CATALYST: *NICKEL Ni-0116.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt% Ni 60 CARRIER: Kieselguhr FORM: tablets SIZE (mm): 3×5×6 ABD (g/cm^3) 1.4—1.6 SA (m^2/g) 155—165 PV (m^3/g) 0.2 STRENGTH (kg/cm^2) 13	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for hydrogenation of naphthalene to tetraline or decaline and of benzene to cyclohexane.

TYPE OF CATALYST: *NICKEL Ni-1404.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt% Ni 68 CARRIER: proprietary FORM: tablets SIZE: Diameter (mm) 3 Length (mm) 3 ABD (g/cm^3) 1.2—1.3 SA (m^2/g) 132 PV (cm^3/g) 0.40 STRENGTH (kg/cm^2) 2—4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Other applications: Hydrogenation of olefins to *paraffins*; of carbonyl groups in aldehydes and ketones; Amonolysis of alcohols. It is used in fixed bed processes.

TYPE OF CATALYST: *NICKEL Ni-1406.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt% Ni 46 CARRIER: proprietary FORM: tablets SIZE: Diameter (mm) 4 Length (mm) 6 ABD (g/cm^3) 1.28 STRENGTH (kg/cm^2) 18	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for hydrogenation of naphthalene to tetraline or decaline.

SATURATION OF AROMATIC COMPOUNDS

TYPE OF CATALYST: *NICKEL-TUNGSTEN Ni-4301.E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt% Ni 6 W 19 CARRIER: silica-alumina FORM: extrusions SIZE: Diameter (mm) 2 Length (mm) 2 ABD (g/cm^3) 0.96 SA (m^2/g) 228 PV (cm^3/g) 0.37 STRENGTH (kg/cm^2) 6.3 (individual particle)	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The sulphided form of this catalyst is used for hydrogenation where a cracking function is desired. It is aslo used for denitrogenation and desulphurization. The sulphided form is Ni-4401.E.

SATURATION OF AROMATICS

TYPE OF CATALYST: *NICKEL-TUNGSTEN Ni-4303.E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni 6 W 19 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 2 Length (mm) 2 ABD (g/cm^3) 0.8 SA (m^2/g) 152 PV (cm^3/g) 0.54 STRENGTH (kg/cm^2) 8 (individual particle)	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The sulphided form of this catalyst is used for general hydrogenation. Used in the pretreatment of hydrocracker feedstock, saturation of mono and polycyclic aromatic compounds, denitrogenation and desulphurization. The sulphided form is Ni-4403.E.

TYPE OF CATALYST: *NICKEL-TUNGSTEN Ni-4305.E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni 4.5 W 9.5 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 3 Length (mm) 3 ABD (g/cm^3) 1.024 SA (m^2/g) 184 PV (cm^3/g) 0.53 STRENGTH (kg/cm^2) 7 (individual particle)	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The sulphided form of this catalyst (Ni-4405E) is used where a mildly acidic support is required. It is used for the hydrogenation of jet fuels, saturation of mono and polycyclic aromatic compounds, denitrogenation and desulphurization.

TYPE OF CATALYST: *NICKEL N-111; N-113; N-118*

Manufacturer	Characteristics	Operating conditions	Remarks
W.C.Heraeus GmbH	CONTENT wt % Nickel promotor CARRIER: Kieselguhr FORM: powder; tablets SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Also for methanation.

HYDROGENATION OF PHENOL TO CYCLOHEXANOL

TYPE OF CATALYST: *NICKEL H-1104*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Ni approx. 15 Cu 5 Cr 1 SiO_2 71 Loss on ignition (750°C): 2 CARRIER: SiO_2 FORM: irregular granules SIZE: Diameter (mm) 1—6 ABD (g/cm^3) 0.65 SA (m^2/g) (BET) 220 PV (cm^3/g) 0.7	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used also for the hydrogenation of olefinic and aromatic double bonds as well as of carbonyl groups of cyclic compounds. It may be used in gaseous as well as liquid phase reactions.

HYDROGENATION OF AROMATIC AND OLEFINIC HYDROCARBONS

TYPE OF CATALYST: *NICKEL H-1323*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Ni approx. 12 (as Nickel formate) SiO_2 approx. 65 Loss on drying approx. 3 CARRIER: SiO_2 FORM: extrusions SIZE: Diameter (mm) 4 Length (mm) 6—10 ABD (g/cm^3) 0.6 STRENGTH (kg/cm^2) 340	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The product to be hydrogenated should be free from chloride and sulphur.

HYDROGENATION OF AROMATICS

TYPE OF CATALYST: *NICKEL H-1321*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Ni 10 to 11% (as Ni formate) Cu approx. 3 Cr „ 0.2 SiO_2 „ 65 Loss on drying $\approx$ 1 CARRIER: SiO_2 FORM: extrusions SIZE: Diameter (mm) 4 Length (mm) 6—10 ABD (g/cm^3)approx. 0.6 STRENGTH(kg/cm^2) 190	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used in gas phase operations and it can be used for the hydrogenation of olefinic hydrocarbons.

TYPE OF CATALYST: *NICKEL LD 143*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % High purity alumina loaded with nickel CARRIER: alumina FORM: balls SIZE: Diameter (mm) 2—4 ABD (g/cm^3) 0.75 STRENGTH (kg/cm^2) 10 (individual particle)	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used for the hydrogenation of unsaturated hydrocarbons; of benzene to cyclohexane; for other hydrogenations like of diolefins and olefins.

HYDROGENATION OF AROMATIC HYDROCARBONS

TYPE OF CATALYST: *RANEY NICKEL 28189; 28192*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Incorporated	CONTENT wt % Raney nickel fine FORM: 50% slurry in water SA (m^2/g) high	TEMPERATURE RANGE: n.a. PRESSURE: RANGE: n.a.	Also used for the ring hydrogenation of anilines and phenols, hydrogenation of simple olefins, hydrogenation of olefins selectively when conjugated with aldehydes and ketones groups. Dehydrogenation (oxidation) of alcohols to aldehydes and ketones. Desulphurization catalyst. 28192 Raney nickel has a high activity.

TYPE OF CATALYST: *NICKEL - TUNGSTEN 28153*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Incorporated	CONTENT wt % NiO 6 WO_3 19 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 2 SA (m^2/g) approx. 150	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used also for hydrocracking of paraffins and cycloparaffins, denitrogenation and desulphurization.

Hydrogenation of carbonyl compounds

HYDROGENATION OF ALDEHYDES

TYPE OF CATALYST: *COPPER CHROMITE CODE 101*

Manufacturer	Characteristics	Operating conditions	Remarks
Calsicat Division	CONTENT wt % CuO 40 Cr_2O_3 41.5 Barium 7.2 (*as stabilizer*) CARRIER: n.a. FORM: powder SIZE: 90—100% through 325 mesh ABD (g/cm^3) 0.21 (Scott density) SA (m^2/g) 40—50	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Other applications: Hydrogenation of carbonyls, esters, imines. The addition of barium has been found to retard the reduction of the catalyst during use.

TYPE OF CATALYST: *COPPER CHROMITE CODE 102*

Manufacturer	Characteristics	Operating conditions	Remarks
Calsicat Division	CONTENT wt % CuO 44.6 Cr_2O_3 45.2 Barium 7.2 CARRIER: n.a. FORM: powder SIZE: 90—100% through 325 mesh ABD (g/cm^3) 0.21 (Scott density) SA (m^2/g) 20—30	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Other applications: Hydrogenation of carbonyls and esters.

TYPE OF CATALYST: *COPPER CHROMITE CODE 104*

Manufacturer	Characteristics	Operating conditions	Remarks
Calsicat Division	CONTENT wt % CuO: $CuCr_2O_4$ CuO 47 Cr_2O_3 47 CARRIER: n.a. FORM: n.a. SIZE: 90—100% through 325 mesh ABD (g/cm^3) 0.26—0.32 (Scott density) SA (m^2/g) 20—30	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used for the hydrogenation of carbonyls, esters and fatty acids.

HYDROGENATION OF ALDEHYDES AND KETONES

TYPE OF CATALYST: *NICKEL CODE 230 T*

Manufacturer	Characteristics	Operating conditions	Remarks
Calsicat Division	CONTENT wt % Ni 60 CARRIER: alumina FORM: tablets; cylinders SIZE: *tablets cylinders* Diameter (mm) 3;6 5 Length (mm) 3;6 5 ABD (g/cm^3) 1 SA (BET) (m^2/g) 150 PV (cm^3/g) 0.26	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It can be used for fixed bed applications.

HYDROGENATION OF CARBONYL GROUPS

TYPE OF CATALYST: *NICKEL CODE 237 T*

Manufacturer	Characteristics	Operating conditions	Remarks
Calsicat Division	CONTENT wt % Ni 60 CARRIER: proprietary FORM: tablets; cylinders SIZE: *tablets cylinders* Diameter (mm) 3;6 5 Length (mm) 3;6 5 SA (m^2/g) 150 STRENGTH (kg/cm^2) 8.1	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is recommended for fixed bed application, and for hydrogenation where resistance to sulphur contamination is important. It can be used for the hydrogenation of aromatics.

HYDROGENATION OF ALDEHYDES TO ALCOHOLS

TYPE OF CATALYST: *COPPER CHROMIUM C-47*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Copper and chromium oxides CARRIER: silica gel FORM: granules; extrusions SIZE: *granules extrusions* Diameter (mm) 5—9 3.1—4.7	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

HYDROGENATION OF ALDEHYDES (OXO PROCESS)

TYPE OF CATALYST: *COPPER-ZINC OXIDE C-61*			
Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Zinc to copper ratio 2.1 CARRIER: pumice FORM: tablets SIZE: Diameter (mm) 3 Length (mm) 6	TEMPERATURE RANGE: 204°—260°C PRESSURE RANGE: up to 100 atm LIFE: Hydrogenation 3—6 months; Dehydrogenation: 1 year	It is used also for dehydrogenation reactions at 371°—399°C (as C-61-1).

HYDROGENATION OF KETONES

TYPE OF CATALYST: *RUTHENIUM C-56 SERIES*			
Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Ruthenium 0.18—0.5 CARRIER: alumina FORM: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Other uses: hydrogenation of aniline from cyclohexylamine.

HYDROGENATION OF CARBONYL GROUPS

TYPE OF CATALYST: *COPPER CB*			
Manufacturer	Characteristics	Operating conditions	Remarks
CIECH Nitroplast	CONTENT wt % Copper CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 10 Length (mm) 4 ABD (g/cm³) 0.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Hydrogenation of butene-2-al to butanol; and of ethylhexane-2-al to 2 ethylhexanol.

TYPE OF CATALYST: *COPPER CH-1*			
Manufacturer	Characteristics	Operating conditions	Remarks
Combinatul Chimic Craiova	CONTENT wt % CuO 57 Fe_2O_3 0.2 MgO 0.4 SiO_2 42 CARRIER: diatomite FORM: pellets SIZE: Diameter (mm) 10 Length (mm) 6—10 STRENGTH (kg/cm^2) 4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The hydrogenation of crotonaldehyde to butanol.

HYDROGENATION OF d-GLUCOSE TO SORBITOL

TYPE OF CATALYST: *RANEY NICKEL NICAT S 52*			
Manufacturer	Characteristics	Operating conditions	Remarks
Crosfield Chemicals	CONTENT n.a. FORM: n.a.	TEMPERATURE RANGE: 130°C PRESSURE RANGE: 20 atm LIFE: more than 20 hours	

HYDROGENATION OF CARBONYL GROUPS

TYPE OF CATALYST: *RANEY COPPER B-136*			
Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt % Raney copper FORM: powder suspended in water SIZE: Diameter (mm) 50×10^{-3} ABD 0.6 kg Cu per kg of suspension	TEMPERATURE RANGE: 125°—150°C PRESSURE RANGE: n.a.	Other uses: Hydrogenation of nitriles, oximes and nitrocompounds and for the dehydrogenation of primary and secondary alcohols.

TYPE OF CATALYST: *RUTHENIUM H-10 H*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt % Ruthenium CARRIER: active charcoal FORM: powder SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Nuclear hydrogenation at high temperatures and pressures. Precious metal content usually 0.1%, 0.15%, 1%, 5% and 10%.

TYPE OF CATALYST: *PALLADIUM ACTIPAL*^{R}

Manufacturer	Characteristics	Operating conditions	Remarks
Doduco	CONTENT wt % Palladium black FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Hydrogenation of double bonds.

TYPE OF CATALYST: *NICKEL RCH: 52/35 TS; 50/35 TS*

Manufacturer	Characteristics	Operating conditions	Remarks
Farbwerke Hoechst AG	CONTENT wt % RCH 52/35 TS:Ni 52 RCH 50/35 TS:Ni 50 CARRIER: Kieselguhr FORM: powder; tablets SIZE: (mm) 6×5 ABD (g/cm^3) 0.5—1.0	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Other applications: Hydrogenation of the olefins to saturated hydrocarbons; Hydrogenation of phenol to cyclohexanol; Amonolysis of aldehydes and ketones; Hydrogenation of aromatic bonds. The catalysts can be used in gas or liquid phase.

REDUCTION OF OXO-ALDEHYDES TO ALCOHOLS

TYPE OF CATALYST: *COBALT G-103; G-103.R*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Co 40 FORM: G-103 (tablets) G-103.R (powder suspended in liquid) SIZE (mm): 6×6 (tablets)	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	In many respects similar to G-61. Used mainly for the reduction of oxo-aldehydes to the alcohols.

HYDROGENATION OF CARBONYL GROUPS

TYPE OF CATALYST: *COPPER CHROMITE Cu-0202.P*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % CuO 82 Cr_2O_3 17 FORM: powder ABD (g/cm^3) 0.88 SA (m^2/g) 10—13 PV (cm^3/g) 0.55	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used in selective hydrogenation of functional groups, without changing the unsaturation or saturation in aromatic rings or alkyl chains.

TYPE OF CATALYST: *COPPER CHROMITE Cu-0203.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % CuO 78 Cr_2O_3 20 FORM: tablets SIZE: Diameter (mm) 3 Length (mm) n.a. ABD (g/cm^3) 2.16 STRENGTH (kg/cm^2) 9	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	For fixed bed processes, for the hydrogenation of nitro-compounds to amines. Selective hydrogenation. Hydrogenation of functional groups. Catalyst for the second step in oxo processes. It is tableted form of Cu-0202.P.

TYPE OF CATALYST: *COPPER CHROMITE Cu-1107.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % CuO 33 Cr_2O_3 38 BaO 9 FORM: tablets SIZE: Diameter (mm) 3 Length (mm) 3 ABD (g/cm^3) 1.8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	For fixed bed processes in the hydrogenation of nitro compounds to amines. It is also used for the dehydrogenation of functional groups and for the hydrogenation of aldehydes (the second step) in oxo-processes.

TYPE OF CATALYST: *COPPER CHROMITE N-201; N-202.D; N-203; N-208*

Manufacturer	Characteristics	Operating conditions	Remarks
W.C.Heraeus GmbH	CONTENT wt % Copper chromite CARRIER: Kieselguhr FORM: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	N-201 contains a promotor. They are used in vapour phase hydrogenation.

TYPE OF CATALYST: *COPPER H-1131*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Copper as active component modified with chromium. Cu (as carbonate) 11.5—12.5 Cr 0.5—0.6 Silica gel 70 Loss on drying: 1 FORM: irregular granules SIZE: Diameter (mm) 1—6 ABD (g/cm^3) 0.6 SA (m^2/g) 230 PV (cm^3/g) 0.7	TEMPERATURE RANGE: 220°C PRESSURE RANGE: n.a.	

HYDROGENATION OF ALDEHYDES TO ALCOHOLS

TYPE OF CATALYST: *COBALT 27042*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % Cobalt metal prereduced and stabilized Co 39 CARRIER: Kieselguhr FORM: pellets SIZE: Diameter (mm) 5 Length (mm) 5 SA (m^2/g) 140	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	For immediate use. Oxo reduction catalyst.

HYDROGENATION OF CARBONYL GROUPS

TYPE OF CATALYST: *COPPER 29065*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % Copper oxide Cu 10—12 CARRIER: alumina FORM: pellets SIZE: Diameter (mm) 5 Length (mm) 3 SA (m^2/g) approx. 187	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

HYDROGENATION OF ALDEHYDES

TYPE OF CATALYST: *COPPER U-5T*

Manufacturer	Characteristics	Operating conditions	Remarks
Unichema Chemie GmbH	CONTENT wt % Cu 35 CARRIER: n.a. FORM: tablets SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The hydrogenation of furfural to furfuryl-alcohol, reduction of aldehydes and ketones, O_2 removal of gases. It is also a low temperature shift catalyst. For the hydrogenation of furfural to furfuryl-alcohol it is also recommended U-5, available as powder and containing ca. 37% Cu.

TYPE OF CATALYST: *NICKEL S-52*

Manufacturer	Characteristics	Operating conditions	Remarks
Unichema Chemie GmbH	CONTENT wt % Ni 95 CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Raney type catalyst used for the hydrogenation of glucose to sorbitol, of dinitrotoluenes to toluene diamines, and the reduction of aldehydes and ketones.

Hydrogenation of carbon double bonds

HYDROGENATION OF UNSATURATED COMPOUNDS

TYPE OF CATALYST: *NICKEL BASF H-1—10*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % Nickel oxide CARRIER: silica FORM: extrusions SIZE: Diameter (mm) 4 ABD (g/cm^3) 0.65	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

HYDROGENATION OF OLEFINIC BONDS

TYPE OF CATALYST: *PALLADIUM CODE 140; 141*

Manufacturer	Characteristics	Operating conditions	Remarks
Calsicat Division	CONTENT wt % 140 141 Palladium 0.2 0.5 CARRIER: granular carbon FORM: powder SIZE: mesh size U. S. screen 4—10 SA (m^2/g) 1,200 ABD (g/cm^3) 0.45	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Other applications: Hydrogenation of complex aldehydes in fixed bed.

HYDROGENATION OF UNSATURATED HYDROCARBONS

TYPE OF CATALYST: *COBALT-MOLYBDENUM C-49*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Cobalt oxide Molybdenum oxide CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 15 or 3 ABD (g/cm^3) 0.64	TEMPERATURE RANGE: 260°—427°C PRESSURE RANGE: 7—42 atm.	Specific applications are pretreatment of light hydrocarbons prior to steam hydrocarbon reforming; saturation of olefins; and organic sulphur conversion.

HYDROGENATION OF DOUBLE BONDS

TYPE OF CATALYST: *MIXED OXIDES HYDRIER KONTAKT 1059*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Chemische Werke Buna	CONTENT wt % Ni min. 6.4 Cu min. 1.6 Cr min. 0.3 Loss on ignition: max. 2 CARRIER: ceramic FORM: balls; extrusions SIZE (mm): *balls* *extrusions* 2—5;5—8 10 ABD (g/cm^3) 0.9—1.1	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Applications: Hydrogenation of aldol to 1.3 butanediol; of acetone to isopropanol; and of toluene to methylcyclohexane. In oxo synthesis processes.

PRESSURE HYDROGENATION OF UNSATURATED COMBINATIONS

TYPE OF CATALYST: *NICKEL NB*

Manufacturer	Characteristics	Operating conditions	Remarks
CIECH Nitroplast	CONTENT wt % NiO 37±2 CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 10 Length (mm) 7 max. ABD (g/cm^3) 0.8—1.1	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	-

HYDROGENATION IN LIQUID PHASE OF ETHYLENIC BONDS

TYPE OF CATALYST: *NICKEL NICAT NP/AC-60*

Manufacturer	Characteristics	Operating conditions	Remarks
Crosfield Chemicals	CONTENT wt % Ni 62±4 S as (SO_4) less than 5 parts per million CARRIER: pure silica FORM: powder ABD (g/cm^3) 0.54 SA (m^2/g) 200±10 PV (cm^3/g) 0.30±0.05	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Uses: Hydrogenation of ethylenic bonds —C=C— which may be subdivided into: (i) bonds between unsubstituted carbon atoms; (ii) bonds between substituted carbon atoms; (iii) terminal double bonds; (iv) molecules containing several double bonds. Hydrogenation of aromatic and heterocyclic rings; Hydrogenation of acetylenic bonds; Hydrogenation of the groups: $> C = O$ to $> CHOH$; $—C \equiv N$ Hydrogenation of oximes: $CR_2 = N - OH \rightarrow CHR_2NH_2 + H_2O$. Hydrogenation of nitroso compounds to amines and of nitro compounds to amines.

HYDROGENATION OF UNSATURATED COMPOUNDS

TYPE OF CATALYST: *NICKEL NICAT NP/AC-60.P; NC/AC-60.PT*

Manufacturer	Characteristics	Operating conditions	Remarks
Crosfield Chemicals	CONTENT wt % Ni 55 CARRIER: silica FORM: powder; tablets	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	NP/AC—60.P is used for liquid phase hydrogenation of unsaturated organic compounds and also for the reduction of carbonyl, nitrile, nitroso and other functional groups. NP/AC—60.PT is the tableted form of NP/AC—60.P. It is used for gas phase hydrogenation of compounds similar to those described above.

TYPE OF CATALYST: *NICKEL NICAT NP/K-50.P; NICAT NP/K-50.PT*

Manufacturer	Characteristics	Operating conditions	Remarks
Crosfield Chemicals	CONTENT wt % Ni 50 CARRIER: Kieselguhr FORM: powder; tablets SIZE: Diameter (mm) 3	TEMPERATURE RANGE: 170°—180°C PRESSURE RANGE: 1—3 atm.	NICAT NP/K—50.P is used for the liquid phase hydrogenation of unsaturated organic compounds; powder. NICAT NP/K—50.PT is the tableted form of the first catalyst and it is recommended for gas phase hydrogenation of various unsaturated compounds and many functional groups.

HYDROGENATION OF ETHYLENIC BONDS

TYPE OF CATALYST: *NICKEL NICAT NP/T-502*

Manufacturer	Characteristics	Operating conditions	Remarks
Crosfield Chemicals	CONTENT wt % Ni 52±2 S as (SO_4) less than 5 parts per million CARRIER: pure silica FORM: black tablets SIZE: Diameter (mm) 4.7 Length (mm) 3.9 ABD (g/cm^3) 0.96 SA (BET) (m^2/g) 200±25	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a	Uses: Hydrogenation of single and multiethylenic bonds; Hydrogenation of aromatic and heterocyclic rings; Hydrogenation of acetylenic bonds; Hydrogenation of the groups $> C = O$ to $> CHOH$; Hydrogenation of the nitrile group: $—C \equiv N$; Hydrogenation of nitro groups to amines.

HYDROGENATION OF UNSATURATED BONDS

TYPE OF CATALYST: *RANEY NICKEL NICAT 101; NICAT 102*

Manufacturer	Characteristics	Operating conditions	Remarks
Crosfield Chemicals	CONTENT wt % Ni min. 85 pH supernated liquor 10.8 Na$_2$O content max. 0.3 FORM: suspension in water	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	NICAT 101 is recommended for hydrogenation of readily reducible groups such as ethylenic and acetylenic linkages as well as desulphurization and dehalogenation. NICAT 102 is recommended when a more specific catalyst is required such as in the hydrogenation of aldehydes, ketones, aromatic nuclei. The catalysts are pyrophoric in the dry state.

HYDROGENATION OF THE CARBON DOUBLE BOND

TYPE OF CATALYST: *RANEY COBALT B-133*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt % Cobalt FORM: powder suspended in water SIZE: Diameter (mm) max. 50×10^{-3} ABD 0.55 kg Co per kg of suspension	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Hydrogenation of benzene; reduction of dinitriles; hydrogenation of cyclohexenyl-acetonitrile; production of dibenzyl ether and toluene from benzyl alcohol; desulphurization of organic compounds. The catalyst also contains Al, Al$_2$O$_3$, Fe, traces of Ni. It is also a dehydrogenation catalyst.

HYDROGENATION OF MULTIPLE BONDS

TYPE OF CATALYST: *RANEY NICKEL B-113; B-114; B-115; B-213; B-313*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt % Raney nickel FORM: powder suspended in water SIZE: Diameter (mm) max. 50×10^{-3} ABD 0.5 kg Ni per kg of suspension	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Reduction of oxygen and nitrogen containing groups; hydrogenation of halogen and sulphur compounds; reductive amination; isomerization e.g. of allyl alcohol to propionic aldehyde; rearrangement e.g. from benzyl aldoxim to benzyl amide. The catalyst also contains Al, Al$_2$O$_3$, Fe and CO in traces. B-113 Z specially for sugar hydrogenations. B-113 CO selective hydrogenation of carbonyl compounds. B-113 Ni catalyst fine B-114 Ni catalyst medium B-115 Ni catalyst coarse B-113 Ni catalyst in tablets is used for reactions in gas and trickling stage.

HYDROGENATION OF MULTIPLE BONDS, AROMATIC AND HETEROCYCLIC SYSTEMS

TYPE OF CATALYST: *PALLADIUM E-10.N; E-10.R*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt % Palladium 5 CARRIER: activated charcoal FORM: powder SIZE: Diameter (mm) 4×10^{-2} ABD (g/cm^3) 0.3 SA (BET) (m^2/g) 700—800 PV (cm^3/g) 0.61	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Reduction of carbonyl compounds, nitro-derivatives and nitriles. Partial hydrogenations are possible in conjugated double bonds, triple bonds. Other palladium contents: 0.5%; 2.5%; 10%. E-10.R is used for the hydrogenation reactions in liquid phase. It is the reduced form of E-10.N.

TYPE OF CATALYST: *PALLADIUM E-20.R; E-22.P*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt % Metal content 0.1, 0.15, 1, 5, 10 CARRIER: gamma alumina FORM: powder; balls SIZE: Diameter (mm) 4—6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Reduction of carbonyl compounds, nitro-derivatives and nitriles. Partial hydrogenations are possible in conjugated double bonds, triple bonds and in many other cases. E-22.P is used for the hydrogenation in gas phase, catalytic combustion of organic substances at low temperatures for air purification (Decatox process).

TYPE OF CATALYST: *PLATINUM F-103.R*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt % Platinum CARRIER: active charcoal FORM: powder	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Reduction of carbonyl compounds, nitro-derivatives and nitriles.

HYDROGENATION OF CARBON MULTIPLE BOND

TYPE OF CATALYST: *NICKEL-ALUMINIUM ALLOY ACTIMET^R L*

Manufacturer	Characteristics	Operating conditions	Remarks
Doduco	CONTENT wt % Ni 50 Al 50 FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used in the reduction of the carbonyl group to primary or secondary alcohol, hydrogenation of nitriles, imines, oximes, and nitro compounds to amines. Hydrogenation of aromatic and heterocyclic systems.

HYDROGENATION OF CONJUGATED DOUBLE AND TRIPLE BONDS

TYPE OF CATALYST: *PALLADIUM ACTIPAL^R B*

Manufacturer	Characteristics	Operating conditions	Remarks
Doduco	CONTENT wt % Palladium CARRIER: barium sulphate FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

HYDROGENATION OF OLEFINS AND AROMATICS

TYPE OF CATALYST: *NICKEL G-33; G-52*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % G-33: Ni 32 G-52: Ni 36 Ni as nickel oxide CARRIER: silica-alumina FORM: tablets SIZE: G-33 G-52 Diameter (mm) 6 5 Length (mm) 6 5 ABD (g/cm^3) 0.96 SA (m^2/g) 70 STRENGTH (kg/cm^2) 11	TEMPERATURE RANGE: 120°—260°C PRESSURE RANGE: 24—35 atm.	G-33 is supplied in the oxidized form while G-52 is a prereduced and stabilized version of G-33. Since these Ni catalysts are easily poisoned, the feed stock must either be low in sulphur or desulphurized. They are widely used for production of cyclohexane from benzene, saturation of aromatics and olefins in solvent naphtha streams and for the hydrogenation of a variety of organic compounds. Also used as methanation and deoxygenation catalysts (oxygen removal).

TYPE OF CATALYST: *NICKEL G-49.A; G-49.B*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % G-49A G-49B Ni 60—64 54—60 CARRIER: Kieselguhr FORM: powder; tablets SIZE: Diameter (mm) 5 Length (mm) 3 ABD (g/cm^3) 0.4—0.9; 0.48—0.9 SA (m^2/g) 155; 244	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	G-80 is a modification of G-49.A. Both are recommended as economical replacement for sponge-nickel or noble-metal catalysts.

TYPE OF CATALYST: *NICKEL G-60*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Ni 35±2 Zr 1.5±0.3 Zirconium promoted nickel CARRIER: alumina FORM: tablets SIZE: Diameter (mm) 6 Length (mm) 6 ABD (g/cm^3) 0.96 SA (m^2/g) 60 STRENGTH (kg/cm^2) (DWL) 9	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	In prereduced and stabilized form the catalyst is designated as G-60.RS. Similar in composition and application to G-33. Zirconium promotor enhances the catalytic activity for some applications, particularly at lower temperatures.

TYPE OF CATALYST: *NICKEL G-69*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Zirconium promoted nickel Ni (powder) 52 Zr 2 Ni (tablets) 50 Zr 2 CARRIER: Kieselguhr FORM: powder; tablets SIZE: Diameter (mm) 5 Length (mm) 3 ABD (g/cm^3) 0.48—0.96 SA (m^2/g) 274 (tablets)	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Similar in composition and application to G-49. Available in reduced form G-69.R, with a nominal content of 55% Ni and 2% Zr. G-69.R is available as suspension of reduced powder or reduced tablets in the liquid of your choice. Zirconium improves low temperature activity for some applications.

HYDROGENATION OF METHYL-ACETYLENE AND PROPADIENE

TYPE OF CATALYST: *PALLADIUM G-55.A; G-55.B*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Promoted palladium CARRIER: alumina FORM: G-55.A G-55.B *tablets* *extrusions* SIZE: Diameter (mm) 5 5 Length (mm) 5 — ABD (g/cm^3) 0.88 0.72	TEMPERATURE RANGE: 54°—177°C PRESSURE RANGE: 3—25 atm.	It can be used for adiabatic or isothermal reactors.

HYDROGENATION OF UNSATURATED COMPOUNDS

TYPE OF CATALYST: *PALLADIUM G-63*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt% G-63.A: Pd 0.05 G-63.B: Pd 0.1 G-63.C: Pd 0.3 G-63.D: Pd 0.5 CARRIER: specially formulated refractory oxide FORM: tablets SIZE: Diameter (mm) 6 Length (mm) 6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for the hydrogenation of acetylene and olefins in gas streams, containing mixtures of carbon monoxide and hydrogen. Available as: G-63.A G-63.B G-63.C G-63.D

HYDROGENATION OF DIOLEFINS

TYPE OF CATALYST: *PALLADIUM G-68*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt% Pd 0.5 Cr 0.5 Chrome promoted palladium CARRIER: gamma alumina FORM: tablets SIZE: Diameter (mm) 5 Length (mm) 5 ABD (g/cm^3) 0.88; 0.96 STRENGTH (kg/cm^2) (DWL average) 9—11	TEMPERATURE RANGE: 80°—180°C PRESSURE RANGE: 15—70 atm.	For the first stage hydrogenation of diolefins, in the gasoline boiling range fraction of product distillate, resulting from the pyrolysis of hydrocarbons.

HYDROGENATION OF OLEFINIC BONDS

TYPE OF CATALYST: *PALLADIUM G-74*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt% G-74.A: Pd 0.15 G-74.C: Pd 0.3 G-74.D: Pd 0.5 CARRIER: gamma alumina FORM: tablets SIZE: Diameter (mm) 4.5 Length (mm) 4.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Available as: G-74.A; G-74.C and G-74.D. It is used for removal of small quantities of oxygen from hydrogen containing gas streams. Conversely, G-74 is also recommended for removing trace quantities of hydrogen from oxygen streams.

TYPE OF CATALYST: *PALLADIUM G-75*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt% G-75.A: Pd 0.1 G-75.C: Pd 0.3 G-75.E: Pd 0.5 CARRIER: granular activated carbon FORM: granules SIZE (mm) 4×8 mesh	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Available in the following forms: G-75.A; G-75.C and G-75.E. It is used to remove oxygen from hydrogen streams or oxygen from inert gas streams.

HYDROGENATION OF UNSATURATED COMPOUNDS

TYPE OF CATALYST: *PALLADIUM G-77*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt% G-77.A: Pd 0.05 G-77.B: Pd 0.10 G-77.C: Pd 0.30 G-77.D: Pd 0.50 CARRIER: silica-alumina FORM: extrusions SIZE: Diameter (mm) 5 ABD (g/cm^3) 0.72	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Available as: G-77.A; G-77.B; G-77.C and G-77.D. Suitable especially for hydrogenation of acetylene, diolefins and olefins, in hydrogen stream containing high concentration of CO. It will not promote the methanation reaction. At temperatures below 300°C it will not promote hydrocracking of C_2 and of higher hydrocarbons. It is used for the hydrogenation of acetylenes, diolefins and olefins.

HYDROGENATION OF OLEFINS TO PARAFFINS

TYPE OF CATALYST: *NICKEL Ni-3210.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt% Ni 35 CARRIER: proprietary FORM: tablets SIZE: Diameter (mm) 5 Length (mm) 6 ABD (g/cm^3) 0.88—1.0 SA (m^2/g) 175 PV (cm^3/g) 0.45 STRENGTH (kg/cm^2) 9—20	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Especially applicable for trickle phase beds and aqueous systems. Other applications: hydrogenation of aromatic hydrocarbons and of carbonyl group.

TYPE OF CATALYST: *NICKEL Ni-3250.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt% Ni 50 CARRIER: proprietary FORM: tablets SIZE (mm): 3×5×6 ABD (g/cm^3) 1.05 SA (m^2/g) 150 PV (cm^3/g) 0.34 STRENGTH (kg/cm^2) 8—11	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	A slightly alkaline catalyst. It is also used for the hydrogenation of aromatic hydrocarbons, i.e. benzene to cyclohexane, naphthalene to tetraline; carbonyl group.

HYDROGENATION OF OLEFINS

TYPE OF CATALYST: *NICKEL RCH-55/5.TS; RCH-55/5.HS; RCH-55/5.PYR*

Manufacturer	Characteristics	Operating conditions	Remarks
Farbwerke Hoechst AG	CONTENT wt% RCH-55/5.TS: Ni 55 RCH-55/5.HS: Ni 53 RCH-55/5.PYR: Ni 57 CARRIER: Kieselguhr FORM: tablets; powder SIZE: *tablets* Diameter (mm) 6 Length (mm) 5 ABD (g/cm^3) 0.5—1.0	TEMPERATURE RANGE: 100°—200°C PRESSURE RANGE: 5—50 atm.	Other applications: Amonolysis of alcohols, aldehydes and ketones; Reduction of nitro-groups to respective amines; Hydrogenation of aromatic bonds, in gas or liquid phase; Hydrogenation of fats.

TYPE OF CATALYST: *NICKEL RCH-55/5.FS; RCH-55/10.TS*

Manufacturer	Characteristics	Operating conditions	Remarks
Farbwerke Hoechst AG	CONTENT wt% RCH-55/5.FS: Ni 21 RCH-55/10.TS: Ni 55 CARRIER: Kieselguhr FORM: powder; tablets; extrusions SIZE: Diameter (mm) extrusions: 10 ABD (g/cm^3) powder: 0.4 tablets and extrusions: 0.9	TEMPERATURE RANGE: 50°—200°C PRESSURE RANGE: 1—50 atm.	Other applications: Reduction of nitrogroups to the amines; Partial hydrogenation of unsaturated fats and oils.

TYPE OF CATALYST: *COBALT-MOLYBDENUM H-9410*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt% CoO approx. 3 MoO_2 15 Al_2O_3 80 Loss on ignition (550°C): 2 FORM: extrusions SIZE: Diameter (mm) 2—4 Length (mm) 3—6 ABD (g/cm^3) 0.85 SA (BET) (m^2/g) 330 STRENGTH (kg/cm^2) 44	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used for the removal of sulphur, nitrogen and arsenic impurities from naphtha feedstocks; for the desulphurization of fuel oils and gas oils.

HYDROGENATION OF UNSATURATED ALDEHYDES

TYPE OF CATALYST: *COPPER H-1102*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt% Copper 12 CARRIER: silica gel FORM: granules SIZE: Diameter (mm) 2—5 ABD (g/cm^3) 0.6 SA (m^2/g) 270 PV (cm^3/g) 0.7	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Copper catalyst modified with nickel and chromium.

HYDROGENATION OF OLEFINIC AND AROMATIC HYDROCARBONS

TYPE OF CATALYST: *NICKEL H-1026*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt% Ni 32—33 Al_2O_3 20—21 ZnO 31—32 SiO_2 approx. 3.5 Graphite 2 FORM: tablets SIZE: Diameter (mm) 6 Length (mm) 6 ABD (g/cm^3) 1.05 SA (m^2/g) 120—130 PV (cm^3/g) 0.4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Available in a reduced and stabilized state, as H-1026 roused for the hydrogenation of olefinic and aromatic hydrocarbons especially benzene and phenol.

TYPE OF CATALYST: *NICKEL H-1031*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt% Ni 45 Al_2O_3 25 SiO_2 12 Graphite 3 Na_2O 0.2 FORM: tablets SIZE: Diameter (mm) 6 Length (mm) 6 ABD (g/cm^3) 1 SA (BET) (m^2/g) 200—230 PV (cm^3/g) 0.4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is suitable for gas phase as well as liquid phase (*trickle*) process at normal or high pressure.

TYPE OF CATALYST: *NICKEL H-1050.E; H-1050.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt% *H-1050.E* *H-1050.T* Ni approx. 46 approx. 46 SiO_2 approx. 35 approx. 36 Graphite — approx. 2 Loss on ignition (850°C) 6 7 FORM: extrusions; tablets SIZE: *extrusions* *tablets* Diameter (mm) 3 6 Length (mm) 3—6 6 ABD (g/cm^3) 1.24 1.05 SA (m^2/g) 250 240 PV (cm^3/g) 0.3 0.2	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Are suitable for gas phase, as well as liquid phase (trickle) processes at normal and increased pressures. They are used especially for the hydrogenation of benzenes.

HYDROGENATION OF UNSATURATED HYDROCARBONS

TYPE OF CATALYST: *NICKEL H-1057*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt% Ni 31 ZnO 32 SiO_2 27 Loss on ignition (850°C): 2 FORM: extrusions SIZE: Diameter (mm) 6 Length (mm) 4—10 ABD (g/cm^3) 0.85 SA (m^2/g) 110 PV (cm^3/g) 0.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It can be supplied, reduced and stabilized as H-1057.R or unreduced in the calcined state H-1057U. It is used for hydrogenation of halogen compounds containing olefinic and aromatic bonds.

HYDROGENATION OF α — METHYL-STYRENE TO CUMENE

TYPE OF CATALYST: *NICKEL H-1436*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt% Ni 10—11 Al_2O_3 15—86 Loss on ignition (750°C): 1 CARRIER: gamma alumina FORM: extrusions SIZE: Diameter (mm) 4 Length (mm) 3—6 ABD (g/cm^3) 1.0 SA (BET) (m^2/g) 60 PV (cm^3/g) 0.4—0.45	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Average pore diameter: 300Å

HYDROGENATION OF UNSATURATED ORGANIC CARBONYL COMPOUNDS

TYPE OF CATALYST: *PALLADIUM H-1423*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt% Pd 0.5 Al_2O_3 98 Na_2O 0.4 Loss on ignition: 1 FORM: extrusions SIZE: Diameter (mm) 3.2 or 4.0 ABD (g/cm^3) 0.85 SA (m^2/g) 80 PV (cm^3/g) 0.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used for the selective hydrogenation of carbon-carbon triple bond and a variety of hydrogenation processes.

HYDROGENATION OF CROTON ALDEHYDE

TYPE OF CATALYST: *PALLADIUM Pd-C*

Manufacturer	Characteristics	Operating conditions	Remarks
Kawaken Fine Chemicals Co. Ltd.	CONTENT wt% Pd 5 CARRIER: activated charcoal FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Also available for other palladium concentration such as 1%, 2%, 3%, 7% and 10%. Also recommendable for dehydrogenation of diethylamine to pyrolidine and for carbonyl removal of furfurol to furan.

HYDROGENATION OF THE UNSATURATED IMPURITIES IN THE PARAFFIN HYDROCARBONS

TYPE OF CATALYST: *NICKEL-TUNGSTEN KONTAKT 3076*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT wt% Mixed tungsten acid Nickel sulphide CARRIER: n.a. FORM: cylinders and extrusions SIZE: Diameter (mm) 10 Length (mm) 10 ABD (g/cm^3) 2.9±0.3 STRENGTH (kg/cm^2) 170±50	TEMPERATURE RANGE: 300°—320°C PRESSURE RANGE: approx. 200 atm.	

HYDROGENATION OF OLEFINS

TYPE OF CATALYST: *NICKEL 28139*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt% Ni 8 CARRIER: activated carbon FORM: granules SIZE: 4×8 mesh SA (m^2/g) high	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for ring hydrogenation of aromatic hydrocarbons, anilines and phenols. Air sensitive. Pre-reduced and stabilized for immediate use.

TYPE OF CATALYST: *NICKEL 28143*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt% Ni 60 CARRIER: Kieselguhr FORM: powder SA (m^2/g) approx. 100	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Air sensitive. Pre-reduced and stabilized for immediate use. It is also used for ring hydrogenation of aromatic hydrocarbons, anilines and phenols, of nitriles to amines. Dehydrogenation of cyclohexanes to benzenes.

TYPE OF CATALYST: *PALLADIUM 46190*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % Pd 10 CARRIER: activated carbon FORM: powder SA (m^2/g) approx. 1,150	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Also used for: Decarbonylation of formate esters to alcohols; Isomerization of olefins; Hydrogenation of aromatic nitro compounds to aromatic amines.

TYPE OF CATALYST: *PALLADIUM 46197; 46199; 46201; 46202; 46203*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt% 46197: Pd on Ba carbonate 46199: Pd on Ba sulphate 46201: Pd on Ca carbonate unpoisoned 46202: Pd on Ca carbonate, lead poisoned (Lindlar) 46203: Pd on Ca carbonate, lead and sulphur-poisoned (Lindlar cat.) FORM: powder SA (m^2/g) high	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Application: Isomerization of olefins; hydrogenation of aromatic ketones to aromatic hydrocarbons; hydrogenation of acetylenes to CIS-ethylenes.

HYDROGENATION OF DIENES TO MONOENES

TYPE OF CATALYST: ***PLATINUM 78142***

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt% Platinum black FORM: powder SA (m^2/g) approx. 24	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

HYDROGENATION OF SIMPLE OLEFINS

TYPE OF CATALYST: ***PLATINUM 78160; 78166***

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt% Platinum 5 CARRIER: 78160 78166 activated carbon alumina FORM: powder SA (m^2/g) 1,023; 80—100	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	There are used also for: Dehydrogenation of cyclohexenes and cyclohexanes to benzenes and of cyclohexanols to phenols. Hydrogenation of aldehydes to alcohols.

HYDROGENATION OF OLEFINS

TYPE OF CATALYST: ***RHODIUM 45181; 45183; 45186***

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % 1) 45181: Rhodium on alumina; 0.5 2) 45183: Rhodium on alumina; 5 3) 45186: Rhodium on carbon 5 FORM: 1) pellets; 2) powder 3) powder SIZE: pellets Diameter (mm) 3 Length (mm) 3 SA (m^2/g) 1) high 2) 80—100 3) aprox. 1,050	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used also for hydrogenation of the aromatic nucleus of aromatic hydrocarbons, aromatic acids and aromatic esters; and for hydrogenation of nitriles to amines, etc.

Hydrogenation of esters and acids

HYDROGENATION OF ESTERS TO ALCOHOLS

TYPE OF CATALYST: *CHROMITE CATALYSTS*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt% $\mathrm{Me} \| \mathrm{O.Me} \| \mathrm{Cr_2O_4}$ CARRIER: with or without Al_2O_3, SiO_2 or pumice FORM: powders or tablets SIZE: n.a. ABD (g/cm^3) 0.25—1.2	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The hydrogenation of carbon monoxide, of aldehydes and ketones, of unsaturated hydrocarbons, of heterocycles. Active metal (%) — Chrome content (%) Cu 33—34 29—30 Ni 30—31 27—28 Co 39—40 31—32 Cd 46—47 23—24 Ag 64—65 18—19 Zn 46—47 32—33

PRESSURE HYDROGENATION OF ESTERS

TYPE OF CATALYST: *COPPER CHROMITE ACTIMETR* ^{17}

Manufacturer	Characteristics	Operating conditions	Remarks
Doduco	CONTENT wt% CuO Cr_2O_3 CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used also in the pressure hydrogenation of acids, ketones and aldehydes to alcohols.

HYDROGENATION OF OILS, FATS, AND FATTY ACIDS

TYPE OF CATALYST: *NICKEL ACTIMET*^{R} „F“

Manufacturer	Characteristics	Operating conditions	Remarks
Doduco	CONTENT wt% Nickel CARRIER: hardened fat FORM: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *NICKEL G-15*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt% Nickel 25 Kieselguhr 10 Protective medium 65 CARRIER: Kieselguhr FORM: flakes	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is composed of electrolytically precipitated nickel, supported on Kieselguhr which has been dry reduced and suspended in a protective medium of hardened edible oil or tallow.

TYPE OF CATALYST: *NICKEL G-53*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt% Ni 23 Kieselguhr 13 Protective medium 60 CARRIER: Kieselguhr FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	A modified form of G-15. It is particularly suitable for difficult hydrogenation, such as of tallow, marine oils, fatty acids.

TYPE OF CATALYST: *NICKEL G-70*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt% Ni 25 Zr 1 Kieselguhr 14 Protective medium 60 CARRIER: Kieselguhr FORM: flakes	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Demonstrates selectivity for low as well as elevated temperature hydrogenations.

HYDROGENATION OF EDIBLE OILS AND OF FATTY ACIDS

TYPE OF CATALYST: *NICKEL G-111*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt% A nickel sub-sulphide on alumina suspended in a protective medium CARRIER: alumina FORM: suspension in edible oils	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is resistant to sulphur compounds.

TYPE OF CATALYST: *PALLADIUM G-109*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT, wt% Pd 1 Cr 1 CARRIER: alumina FORM: powder; tablets SIZE: *tablets* Diameter (mm) 4.5 Length (mm) 4.5 *powder*: free flowing	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

HYDROGENATION OF FATS: OILS AND FATTY ACIDS

TYPE OF CATALYST: *NICKEL Ni-0109F*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt% Ni 25—30 CARRIER: Kieselguhr FORM: flakes	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Protected by hardened oil.

HYDROGENATION OF FATTY OILS AND FATTY ACIDS

TYPE OF CATALYST: *NICKEL Ni-5000F RUFERT CATALYST*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt% Ni 25 CARRIER: hardened oil FORM: flakes	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also effective for hydrogenation of methyl esters, tall oils, fatty nitrogen compounds.

HYDROGENATION OF FATTY ESTERS TO ALCOHOLS

TYPE OF CATALYST: *COPPER H-1044*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt% Cu 22 $BaCrO_4$ 8 Cr_2O_3 2 Na_2O 0.5 SiO_2 61 Loss on ignition (750°C): 0.5 FORM: extrusions SIZE: Diameter (mm) 4 Length (mm) 4—7 ABD (g/cm^3) 0.6 SA (m^2/g) 180—240 PV (cm^3/g) 0.7 STRENGTH (kg/cm^2) 50	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used also for the dehydrogenation of alcohols at high temperature in the liquid phase. It is a copper catalyst modified by the addition of barium chromate.

HYDROGENATION OF ESTERS, ACIDS AND ALDEHYDES

TYPE OF CATALYST: *COPPER CHROMITE H-1001*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt% Cu 41 Cr 30 Ignition loss (750°C) 5—8 CARRIER: n.a. FORM: powder SIZE: Diameter (mm) 0.5—5 ABD (g/cm^3) 0.45—0.50	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used in the liquid phase under pressure.

HYDROGENATION OF FATTY ACIDS

TYPE OF CATALYST: *NICKEL KE/KTR*			
Manufacturer	Characteristics	Operating conditions	Remarks
Königswarter Ebell	CONTENT wt% Ni approx. 19 SiO_2 10—12 Remainder: hard fat FORM: flakes	TEMPERATURE RANGE: max. 200°C PRESSURE RANGE: 2 atm.	

HYDROGENATION OF VEGETABLE FATS

TYPE OF CATALYST: *NICKEL KE/NP*			
Manufacturer	Characteristics	Operating conditions	Remarks
Königswarter Ebell	CONTENT wt% Ni 25 (in hardened vegetable fat) FORM: flakes	TEMPERATURE RANGE: 140°—160°C PRESSURE RANGE: 0.5—1 atm.	The peroxide value should be close to zero.

HYDROGENATION OF OILS AND FATS

TYPE OF CATALYST: *NICKEL KE/NT*			
Manufacturer	Characteristics	Operating conditions	Remarks
Königswarter Ebell	CONTENT wt% Ni 25 (in hardened tallow fat) FORM: flakes	TEMPERATURE RANGE: 170°—290°C PRESSURE RANGE: <2 atm.	Hydrogenation of oils and fats of vegetable as well as of animal origin.

HYDROGENATION OF FATTY ACIDS

TYPE OF CATALYST: ***NICKEL KE/TR II***

Manufacturer	Characteristics	Operating conditions	Remarks
Königswarter Ebell	CONTENT wt% Ni about 27 (in hard fat) FORM: flakes	TEMPERATURE RANGE: 120°—200°C PRESSURE RANGE: 5—15 atm.	

TYPE OF CATALYST: ***COPPER CHROMITE KONTAKT 1968***

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT wt% It contains barium as promotor. The mol ratio of components is: copper : chrome : barium 0.9 1 0.1 CARRIER: n.a. FORM: powder or tablets SIZE: Diameter (mm) 1—10	TEMPERATURE RANGE: 150°—330°C PRESSURE RANGE: 250—350 atm.	

TYPE OF CATALYST: ***COPPER CHROMITE C-2***

Manufacturer	Characteristics	Operating conditions	Remarks
Sakaj Chemical Industry Co. Ltd	CONTENT wt% CuO approx. 50 Cr_2O_3 approx. 50 FORM: powder ABD (g/cm^3) 2.5±0.2	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Uses: Hydrogenation of fatty acids, their esters, aldehydes, ketones and furfurol; Manufacture of fatty alcohols; Dehydrogenation in liquid phase.

TYPE OF CATALYST: *COPPER CHROMITE C-3*

Manufacturer	Characteristics	Operating conditions	Remarks
Sakaj Chemical Industry Co. Ltd	CONTENT wt% CuO 46 Cr_2O_3 46 Ba 17 Other promotors FORM: powder ABD (g/cm^3) 2±0.2	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for: Hydrogenation of fatty acids, their esters, aldehydes, ketones, and furfurol; Manufacture of fatty alcohols; Dehydrogenation in liquid phase.

TYPE OF CATALYST: *COPPER CHROMITE C-5*

Manufacturer	Characteristics	Operating conditions	Remarks
Sakaj Chemical Industry Co. Ltd	CONTENT wt% CuO 46 Cr_2O_3 46 Mn 2.7 CARRIER: n.a. FORM: powder ABD (g/cm^3) 1.8±0.2	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Uses: Hydrogenation of fatty acids, their esters, aldehydes, ketones, and furfurol; Manufacture of fatty alcohols; Selective hydrogenation of fatty oils; Dehydrogenation in liquid phase.

HYDROGENATION OF OILS AND FATS

TYPE OF CATALYST: *FLAKE NICKEL CATALYSTS SO-100; SO-110*

Manufacturer	Characteristics	Operating conditions	Remarks
Sakaj Chemical Industry Co. Ltd	CONTENT wt% Ni approx. 18 CARRIER: Kieselguhr FORM: flakes	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	They are produced by dry process reduction of nickel salt mounted on refined Kieselguhr and dispersing in hardened oil and fats. Uses: Manufacture of general hardened oils; Hydrogenation of oil fats and fatty acids; Manufacture of edible hardened oils such as margine hase, shortening stock. It is good for the hydrogenation under normal pressure.

HYDROGENATION OF FATTY ACIDS

TYPE OF CATALYST: *NICKEL PA; NPA*			
Manufacturer	Characteristics	Operating conditions	Remarks
Unichema Chemie GmbH	CONTENT wt% PA: Ni 21 NPA: Ni 55 CARRIER: n.a. FORM: powder	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

HYDROGENATION OF EDIBLE OILS AND FATS

TYPE OF CATALYST: *NICKEL P, PS; COPPER U, U_4*			
Manufacturer	Characteristics	Operating conditions	Remarks
Unichema Chemie GmbH	CONTENT wt% Ni ~ 21 Cu ~ 37—42 CARRIER: n.a. FORM: flakes (P;PS) powder (U;U_4)	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

Hydrogenation of functional groups (general)

CATALYTIC REDUCTION OF FUNCTIONAL GROUPS

TYPE OF CATALYST: *PRECIOUS METALS — SUPPORTED CATALYSTS*

Manufacturer	Carrier	Precious metal	Concentration	Remarks
Engelhard Minerals and Chemicals Corp.	Alumina powder	Platinum	5% and 10%	Most powder catalysts are finer than 200 mesh in particle size. When advantageous, powder catalysts can be supplied wet (50% H_2O). The platinum metals may be applied to carriers other than those listed here. The platinum metals may be applied in concentration other than that listed here. Where advantageous, various combinations of platinum metals may be co-supported on certain carriers. Normally available from stock.
	Alumina powder	Palladium	5% and 10%	
	Alumina powder	Rhodium	5%	
	Alumina powder	Ruthenium	5%	
	Carbon powder	Platinum	5% and 10%	
	Carbon powder	Palladium	1%,3%,5%,10%	
	Carbon powder	Rhodium	5%	
	Carbon powder	Ruthenium	5%	
	Calcium carbonate	Palladium	5% and 10%	
	Zinc carbonate	Palladium	5% and 10%	
	Barium sulphate	Palladium	5% and 10%	
	3.17 Alumina pellets	Platinum	0.5%	
	3.17 Alumina pellets	Palladium	0.5%	
	3.17 Alumina pellets	Rhodium	0.5%	
	3.17 Alumina pellets	Ruthenium	0.5%	
	12.7 Mesh carbon	Platinum	0.5% and 1%	
	Asbestos fibre	Platinum	1%,2%,5%,10%	
	Asbestos fibre	Palladium	1%,2%,5%,10%	

REDUCTION OF FUNCTIONAL GROUPS

TYPE OF CATALYST: *PRECIOUS METALS—UNSUPPORTED CATALYSTS*

Manufacturer	Characteristics	Operating conditions	Remarks
Engelhard Minerals and Chemicals Corp.	CONTENT wt % Platinum oxide (Adam's) Palladium oxide Platinum black Palladium black Osmium tetroxide (osmic acid)	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	DB 750 catalyst is also used in catalytic oxidation of ammonia to produce nitric acid. Platinum-rhodium gauze is also used for the production of hydrocyanic acid, an important material in the manufacture of plstics and synthetic fibres.

Gauzes	Wire diameter (mm)	Mesh per cm²
Pure platinum	0.06	1,024
95% platinum, 5% rhodium	0.06	1,024
90% platinum, 10% rhodium (DB 750)	0.06	1,024
Fine silver	to various	specifications

HYDROGENATION OF FUNCTIONAL GROUPS

TYPE OF CATALYST: *NICKEL G-65*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Ni 27±2 (tablets) 18±2 (spheres) CARRIER: alumina FORM: tablets; spheres SIZE (mm) n.a. *tablets spheres* ABD (g/cm^3) 1.04 0.96 SA (m^2/g) 44 123 STRENGTH (kg/cm^2) (DWL) 11.3 TS (°C) 1,200	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Also used for methanation. Used for hydrogenation or hydrogenolysis of functional groups. Available in prereduced and stabilized form designed G-65 RS.

TYPE OF CATALYST: *NICKEL G-78*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Ni 57 CARRIER: special refractory oxide tablets SIZE: Diameter (mm) 6 Length (mm) 6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for hydrogenation or hydrogenolysis of functional groups. Similar to G-65. The prereduced and stabilized form is designated G-78 RS.

HYDROGENATION OF PHENOL TO CYCLOHEXANONE

TYPE OF CATALYST: *NICKEL KONTAKT 6524*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb. Leuna Werke „Walter Ulbricht“	CONTENT wt % Mixed nickel, nickel oxide Ni 45 CARRIER: aluminium oxide FORM: n.a. SIZE: n.a. ABD (g/cm^3) 0.650±0.06 STRENGTH (kg/cm^2) 150±50	TEMPERATURE RANGE: 140°—170°C PRESSURE RANGE: approx. 15 atm.	

HYDROGENATION OF NITRILES

TYPE OF CATALYST: *RANEY COBALT GRADE 27; 27S*			
Manufacturer	Characteristics	Operating conditions	Remarks
Davison Chemical Division, W.R. Grace and Co.	CONTENT n.a. FORM: slurry, 50% solid and 50% water	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used in the reduction of fatty nitriles to the corresponding primary amines.

HYDROGENATION OF UNSATURATED NITRILES TO UNSATURATED AMINES

TYPE OF CATALYST: *COPPER CHROMITE Cu-1800.P*			
Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % CuO 51 Cr_2O_3 47 FORM: powder ABD (g/cm^3) 0.65 SA (m^2/g) 37 PV (cm^3/g) 0.76	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Other applications: Reduction of nitro compounds to amines (batch process). Dehydrogenation of alcohols to aldehydes. The unstabilized copper chromite is sometimes preferred for dehydrogenation.

HYDROGENATION OF NITRILES TO AMINES

TYPE OF CATALYST: *COPPER CHROMITE Cu-2000.P*			
Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % CuO 54 Cr_2O_3 41 CARRIER: n.a. FORM: powder ABD (g/cm^3) 0.608 SA (m^2/g) 35 PV (cm^3/g) 1.13	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used for the hydrogenation (batch process) of nitro compounds.

HYDROGENATION OF NITRILES

TYPE OF CATALYST: *RANEY COBALT N-354*

Manufacturer	Characteristics	Operating conditions	Remarks
W.C.Heraeus GmbH	CONTENT wt % Raney Co FORM: powder	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

HYDROGENATION OF NITRILES TO AMINES

TYPE OF CATALYST: *COBALT H-1438*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Co 15 Mn } acti- 4.2 Ag } vators 0.23 CARRIER: Al_2O_3 FORM: spheres SIZE: Diameter (mm) 3—6 ABD (g/cm^3) 0.99	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is supplied in unreduced state as H-1438-U or reduced and stabilized as H-1438-R. The process is carried out in the presence of ammonia and under high pressure.

TYPE OF CATALYST: *COBALT H-1605*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Cobalt activated by manganese and silica Co approx. 27 Mn approx. 6—6.5 Ag approx. 0.33—0.35 Pumice 61—64 CARRIER: pumice FORM: irregular granules SIZE: Diameter (mm) 2—5 ABD (g/cm^3) 0.68—0.78 SA (BET) (m^2/g) approx. 10 PV (cm^3/g) 0.25—0.55	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is supplied either unreduced i.e. in the calcined state H-1605-U, or reduced and stabilized, H-1605-R. It is used by the trickle process carrying out the hydrogenation in the presence of ammonia and under high pressure.

TYPE OF CATALYST: *RANEY COBALT ODH; OF*

Manufacturer	Characteristics	Operating conditions	Remarks
Kawaken Fine Chemicals	CONTENT wt % ODH: Co 50 OF: Co 30 (and is further promoted by 3.5% manganese) FORM: powder SIZE (mm): 200—300 mesh	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	No secondary amine by-product. The activated types are ODHT and OFT.

TYPE OF CATALYST: *COBALT 27045*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % Cobalt metal 60 zirconium-promoted CARRIER: Kieselguhr FORM: powder SA (m^2/g) 65	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Prereduced and stabilized for immediate use. Air sensitive.

HYDROGENATION OF NITRILES

TYPE OF CATALYST: *NICKEL KONTAKT 6500*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb. Leuna Werke „Walter Ulbricht“	CONTENT wt % Nickel, nickel oxide and silicium oxide Ni 70 FORM: tablets SIZE: Diameter (mm) 5 Length (mm) 5 ABD (g/cm^3) 1.20±0.25 STRENGTH (kg/cm^2) 180±50	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used in gas or fluid phase processes.

HYDROGENATION OF NITRILES AND OXIMES TO AMINES

TYPE OF CATALYST: *RANEY COBALT 27185*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT n.a. FORM: 50% slurry in water SA (m^2/g) high	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Ring hydrogenation of aromatic amines.

HYDROGENATION OF FATTY NITRILES TO FATTY AMINES

TYPE OF CATALYST: *NICKEL NICAT 101; NICAT 102*

Manufacturer	Characteristics	Operating conditions	Remarks
Unichema Chemie GmbH	CONTENT wt % Ni ~ 95 FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Raney type catalysts.

TYPE OF CATALYST: *NICKEL NPN*

Manufacturer	Characteristics	Operating conditions	Remarks
Unichema Chemie GmbH	CONTENT wt % Ni ~ 55 FORM: powder SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

Hydrogenation of nitro-compounds

HYDROGENATION OF AROMATIC NITRO-COMPOUNDS TO AROMATIC AMINES

TYPE OF CATALYST: *COBALT C-51*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Cobalt oxide CARRIER: refractory FORM: extrusions; tablets SIZE (mm): extrusions 3—5 tablets 4—9	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Available as C-51-1 and C-51-2. Mild hydrogenation catalyst used also for reduction of aldehydes (oxo process). It is also used for hydrogenation of adiponitrile to hexamethylene diamine.

HYDROGENATION OF NITRO-COMPOUNDS

TYPE OF CATALYST: *COBALT C-59*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Co 5—30 CARRIER: pumice FORM: granules SIZE: 6×10 mesh	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for the conversion of aldehydes to alcohols. C-60 series contains 40—60% cobalt on Kieselguhr.

HYDROGENATION OF DINITROAROMATIC COMPOUNDS

TYPE OF CATALYST: *RANEY COPPER GRADE 29*

Manufacturer	Characteristics	Operating conditions	Remarks
Davison Chemical Division, W.R. Grace and Co.	CONTENT wt % Raney copper CARRIER: n.a. FORM: slurry — 50% solid, 50% water	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Extremely selective for the conversion of a dinitroaromatic compound into an aminonitro-derivate.

TYPE OF CATALYST: *RANEY CHROMIUM — PROMOTED NICKEL RANEY*^{R} *24*

Manufacturer	Characteristics	Operating conditions	Remarks
Davison Chemical Division, W.R. Grace and Co.	CONTENT n.a. FORM: powder SIZE: 70%; 0—40 microns	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is effective in the reduction of carbonyl groups to the corresponding alcohols.

TYPE OF CATALYST: *COBALT Co-1506.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Co 35 CARRIER: rugged proprietary alkaline SIZE: Diameter (mm) 3; 5; 6 Length (mm) 3; 5; 6 ABD (g/cm^3) 1.36—1.5 SA (m^2/g) 85 PV (cm^3/g) 0.24 STRENGTH (kg/cm^2) 8—14	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *COBALT Co-1606.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Co 85 CARRIER: rugged proprietary alkaline FORM: tablets SIZE: Diameter (mm) 5 Length (mm) 5 ABD (g/cm^3) 2.4 SA (m^2/g) 16 PV (cm^3/g) 0.13 STRENGTH(kg/cm^2)11	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

HYDROGENATION OF NITRO-COMPOUNDS TO AMINES

TYPE OF CATALYST: *COPPER CHROMITE Cu-0402.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % CuO 35 Cr_2O_3 38 BaO 10 CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 3 Length (mm) 3 ABD (g/cm^3) 1.6 STRENGTH (kg/cm^2) 4.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Other applications: Hydrogenation of carbonyl groups; Dehydrogenation of functional groups; Hydrogenation of aldehydes (second step reaction) in oxo process. The powdered form of 0402.T is Cu-0401.P.

TYPE OF CATALYST: *COPPER CHROMITE Cu-1808.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % CuO 42 Cr_2O_3 38 CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 3 Length (mm) 3 ABD (g/cm^3) 1.28 STRENGTH (kg/cm^2) 3.6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Other applications: Hydrogenation of carbonyl groups; Dehydrogenation of aldehydes and ketones; Oxo process catalyst for the second step reaction. It is the tableted form of Cu-1800.P.

HYDROGENATION OF NITRO-COMPOUNDS

TYPE OF CATALYST: *NICKEL Ni-0104.P*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni 58 Ratio of reduced nickel to total nickel: 0.60 : 0.65 CARRIER: Kieselguhr FORM: powder	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Applications: Hydrogenation of nitriles to primary amines; unsaturated alkyl nitriles to unsaturated amines; nitroso-compounds to the corresponding amines; nitro-compounds to monoamines (batch process); fat oils and fatty acids.

REDUCTION OF NITRO-GROUPS

TYPE OF CATALYST: *NICKEL RCH-25/10-HS; RCH-12/10-HS*

Manufacturer	Characteristics	Operating conditions	Remarks
Farbwerke Hoechst AG	CONTENT wt % RCH-25/10-HS Ni 25 RCH-12/10-HS Ni 12 CARRIER: Kieselguhr FORM: tablets; powder SIZE (mm): tablets 6×5 ABD (g/cm^3) 0.5—1.0	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The hydrogenation of aldehydes and ketones to the primary or secondary alcohols.

Hydrogenation reactions (general)

HYDROGENATION REACTIONS

TYPE OF CATALYST: *RANEY NICKEL BASF H-1—50*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % Ni 81.3 SiO_2 0.4 Al_2O_3 11.0 Fe 0.4 CaO 1.1 O_2 1.5 (Probably combinated with Ni and iron) FORM: aqueous suspension with a solid content of about 57% Specific gravity of the suspension: 1.7—1.8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *COPPER BASF H-3—10*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % Copper oxide CARRIER: silica FORM: grains of irregular shape SIZE: Diameter (mm) 3—6 ABD (g/cm^3) 0.650	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Other uses: Dehydrogenation of organic compounds.

TYPE OF CATALYST: *NICKEL 203.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Calsicat Division	CONTENT wt % Ni 58 Reduced and stabilized CARRIER: Kieselguhr FORM: tablets SIZE: Diameter (mm) 6; 3 Length (mm) 6; 3 ABD (g/cm^3) 1.36 SA (BET) (m^2/g) 200 PV (cm^3/g) 0.25 STRENGTH (kg/cm^2) 5 (individual particle)	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It can be used for fixed hydrogenation of aldehydes and ketones, and aromatic impurities from bulk organic streams. It can be supplied in unreduced form.

TYPE OF CATALYST: *NICKEL 210.P*

Manufacturer	Characteristics	Operating conditions	Remarks
Calsicat Division	CONTENT wt % Ni 53—58 Reduced and stabilized CARRIER: Kieselguhr FORM: powder SIZE: 90—100% through 325 mesh ABD (g/cm^3) 0.32 SA (m^2/g) 240	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Applications: Hydrogenation of fatty nitrogen compounds is one major area of commercial applications.

TYPE OF CATALYST: *NICKEL 215.F*

Manufacturer	Characteristics	Operating conditions	Remarks
Calsicat Division	CONTENT wt % Ni 25 Kieselguhr 15 Protective medium 60 CARRIER: Kieselguhr FORM: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The catalyst is suspended in a protective medium of hardened tallow or edible oil. Applications: Hydrogenation of inedible oils, fatty acids, nitriles, esters and other organic compounds.

TYPE OF CATALYST: *NICKEL 230.P*

Manufacturer	Characteristics	Operating conditions	Remarks
Calsicat Division	CONTENT wt % Ni 58—65 Pre-reduced and stabilized CARRIER: alumina FORM: powder SIZE: 90 × 100% through 325 mesh ABD (g/cm^3) 0.3 SA (m^2/g) 165	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is capable of selectivity in the hydrogenation of fats and oils.

A VARIETY OF SLURRY HYDROGENATION

TYPE OF CATALYST: *PALLADIUM CODES 154; 162; 163; 165; 167; 168; 169*

Manufacturer	Characteristics	Operating conditions	Remarks
Calsicat Division	CONTENT wt % Palladium 3—5 Loss on drying (3 hr at 150°C): 50% CARRIER: powdered carbon FORM: n.a. ABD (g/cm³) 0.4 SA (m²/g) 1,100—1,300	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for the hydrogenation of carbon-carbon bonds, nitrogen compounds.

TYPE OF CATALYST: *PLATINUM CODES 131; 132; 135; 137*

Manufacturer	Characteristics	Operating conditions	Remarks
Calsicat Division	CONTENT wt % Pt 1—5 Loss on drying (3 hr at 150°C): 60—70 CARRIER: powdered carbon FORM: n.a. ABD (g/cm³) 0.4 SA (m²/g) 1,000—1,100	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Application: Hydrogenation of carbon-carbon bonds, reductive alkylation.

HYDROGENATION OF SULPHUR FREE PETROLEUM STOCK (AROMATIC CONCENTRATE)

TYPE OF CATALYST: *NICKEL C-46*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Nickel oxide varying in amounts of: NiO 30—59; NiO 22—42 CARRIER: silica-alumina; Kieselguhr FORM: tablets; extrusions SIZE: *tablets extrusions* Diameter (mm) 9.5;6.35 4.753 Length (mm) 6.35; 4.789 ABD (g/cm³) 0.64—0.92	TEMPERATURE RANGE: 65°—230°C PRESSURE RANGE: 4—35 atm. LIFE: one year or more SPACE VELOCITY: (LHSV) 0.5 to 5	Hydrogenation of mesityl oxide to MIBK, aldehyde to alcohols. C-46-4, C-46-5, C-46-6 nickel supported on silica-alumina; C-46-7 nickel on Kieselguhr; C-46-8 nickel on silica; C-46-3 nickel on alumina.

HYDROGENATION REACTIONS

TYPE OF CATALYST: *NICKEL-PLATINUM C-53—1*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % A combination of nickel-platinum CARRIER: alumina FORM: tablets SIZE: Diameter (mm) 6 Length (mm) 6 ABD (g/cm^3) 0.96	TEMPERATURE RANGE: 340°—870°C PRESSURE RANGE: 1—70 atm.	It primarily is used for both nitrogen oxides removal from nitric acid tail gas streams to achieve decolorization and abatement.

TYPE OF CATALYST: *PLATINUM C-52 SERIES*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT n.a. CARRIER: carbon FORM: granules; powder SIZE (mm): granules 4×8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Synthesis of alcohols, amines and nitriles.

TYPE OF CATALYST: *PLATINUM C-53—3; 53—4; 53—5*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Pt 0.2—0.5 CARRIER: alumina FORM: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Operating conditions vary depending upon the individual application.

TYPE OF CATALYST: *COBALT CHEZA CATALYST 42—00*

Manufacturer	Characteristics	Operating conditions	Remarks
Chemical Works of CSF — CHEZA Catalysts	CONTENT A mixture of cobalt compounds with the addition of calcium and sodium compounds. CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 10; 6 Length (mm) 3—5; 4—6 ABD (g/cm^3) 1.5 STRENGTH (kg/cm^2) 150	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for hydrogenation reactions in the organic industry, ex. hydrogenation of aniline.

TYPE OF CATALYST: *Cu-CHROMIC OXIDE C-34/13*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt % Cu-chromic oxide CARRIER: without carrier or with Al_2O_3, SiO_2 or pumice FORM: powder; tablets SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Reduction of carboxylic acids (and derivatives), aldehydes and ketones to alcohols. Reduction of nitrobenzene to aniline. Hydrogenating cleavage of cyclic ethers. Oxidation of CO and hydrocarbons. Usually calls for increased pressures and temperatures.

TYPE OF CATALYST: *RANEY IRON B-139*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt % Raney iron FORM: powder suspended in water SIZE: Diameter (mm) 50×10^{-3} ABD 0.4 kg per kg of suspension	TEMPERATURE RANGE: 100°—133°C PRESSURE RANGE: 50—100 atm.	It can hydrogenate carbonyl, nitril, nitro-groups and acetylenic bonds.

ROSEMUND REACTION

TYPE OF CATALYST: *PALLADIUM E-50.F*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt % Palladium CARRIER: $BaSO_4$ FORM: powder	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Precious metal content usually 0.1%, 0.15%, 1%, 5% and 10%.

HYDROGENATION REACTIONS

TYPE OF CATALYST: *PALLADIUM BLACK*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt % Pd 96.5—98.5 O_2 1.6 H_2O 0.7 CARRIER: none FORM: powder ABD (g/cm^3) 5.6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The hydrogenations under pressure, or without pressure, in suspension. It is used for pharmaceutical synthesis and in analytical chemistry.

TYPE OF CATALYST: *PLATINUM OXIDE* $PtO_2.H_2O$

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt % Pt 80—82 CARRIER: n.a. FORM: powder ABD (g/cm^3) 6.8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for mild hydrogenation.

TYPE OF CATALYST: *RANEY NICKEL ACTIMET*^{R}

Manufacturer	Characteristics	Operating conditions	Remarks
Doduco	CONTENT FORM: aqueous suspension	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

HYDROGENATION OF ALIPHATIC COMPOUNDS

TYPE OF CATALYST: *PALLADIUM CARBONOR*^{R}

Manufacturer	Characteristics	Operating conditions	Remarks
Doduco	CONTENT wt % Palladium CARRIER: active carbon FORM: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	CARBONOR catalyst is also used for the hydrogenation of alicyclic double and triple compounds, aromatic nitro-compounds, aromatic carbonyl compounds, nitriles, etc.

HYDROGENATION REACTIONS

TYPE OF CATALYST: *PALLADIUM CONTACTOL*^{R}

Manufacturer	Characteristics	Operating conditions	Remarks
Doduco	CONTENT wt % $PdCl_2$ CARRIER: n.a. FORM: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

HYDROGENATION OF PHARMACEUTICAL PRODUCTS

TYPE OF CATALYST: *PLATINUM* *ACTIPLAT^{R}AG*

Manufacturer	Characteristics	Operating conditions	Remarks
Doduco	CONTENT wt % $PtO_2 \times H_2O$ (Adam's catalyst) FORM: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

HYDROGENATION REACTIONS

TYPE OF CATALYST: *PLATINUM* *ACTIPLAT^R M*

Manufacturer	Characteristics	Operating conditions	Remarks
Doduco	CONTENT wt % Platinum black FORM: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *PLATINUM* *SECOMET^R*

Manufacturer	Characteristics	Operating conditions	Remarks
Doduco	CONTENT wt % Platinum CARRIER: active carbon FORM: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

STEREOSPECIFIC HYDROGENATION

TYPE OF CATALYST: *RHODIUM RHODIOR*^{R}

Manufacturer	Characteristics	Operating conditions	Remarks
Doduco	CONTENT wt % Rhodium CARRIER: alumina FORM: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *RUTHENIUM RUTHENOR*^{R}

Manufacturer	Characteristics	Operating conditions	Remarks
Doduco	CONTENT wt % Ruthenium CARRIER: alumina FORM: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

HYDROGENATION REACTIONS

TYPE OF CATALYST: *COPPER CHROMITE G-13; G-22; G-22.C; G-89; G-79*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % G-13 G-22 G-22.C G-89 Cu 42 33.5 35 38 Cr 26.5 27.5 30 31 Ba — 11.5 8 — Mn — — — 3 FORM: powder; pellets; tablets SIZE (mm): pellets: 3×4 tablets: 4.5×4.5 powder: 95% passing through a 325 mesh screen.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	G-13 and G-22 are also used for the dehydrogenation. They are recommended for those applications requiring a mild hydrogenation catalyst. In powder form the catalysts are used for slurry operations. In tableted form they are used for fixed bed plants. G-79 is a barium promoted copper chromite catalyst available in powder and pellets form.

TYPE OF CATALYST: *NICKEL G-107*			
Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Ni 25 Kieselguhr 12 *Protective medium* 66.5 FORM: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is a wet reduced nickel catalyst. Its outstanding characteristics are the extreme selectivity and activity. It is used for all hydrogenation as of soybean, tallow, machine oils and fatty acids.

TYPE OF CATALYST: *RANEY NICKEL G-104*			
Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Nickel FORM: aqueous suspension containing 0.5 kg Ni/l suspension	TEMPERATURE RANGE: 20°—150 °C PRESSURE RANGE: n.a.	

SLURRY TYPE HYDROGENATION

TYPE OF CATALYST: *PALLADIUM G-71; G-81*			
Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % G-71A G-71B G-71C Pd 1 3 5 CARRIER: activated carbon FORM: powder; wet cake ABD (g/cm^3) 0.432	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Mesh size (approximate): % through 100 mesh screen: 95 % through 325 mesh screen: 70 G-81 is similar to G-71. It is used for the hydrogenation of olefinic bonds.

TYPE OF CATALYST: *COBALT Co-0502.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Cobalt 18 (as oxide) CARRIER: activated alumina FORM: tablets SIZE: Diameter (mm) 3 Length (mm) 3 ABD (g/cm³) 1.23 SA (m²/g) 49 PV (cm³/g) 0.38 STRENGTH(kg/cm²)11	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *COBALT Co-0901.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Co 5 Cu 5 (as oxides) CARRIER: activated alumina FORM: tablets SIZE: Diameter (mm) 3 Length (mm) 3 ABD (g/cm³) 1.07 SA (m²/g) 59 PV (cm³/g) 0.29 STRENGTH (kg/cm²) 6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for the hydrogenation or decomposition reactions.

TYPE OF CATALYST: *COPPER CHROMITE Cu-1106.P; Cu-1110.P*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Cu=1106.P Cu=1110.P CuO 39 41 Cr_2O^3 43.5 46 BaO 10 9 FORM: powder ABD (g/cm³) 0.48;0.65 SA (m²/g) 47; 1 PV (cm³/g) 0.76;0.92	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See Cu-1800.P and Cu-1402.P

TYPE OF CATALYST: *COPPER CHROMITE Cu-1402.P; Cu-1407.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Cu-1402.P Cu-1407.T CuO 40 37 Cr_2O_3 60 52 FORM: powder; tablets SIZE: Diameter (mm) 3 Length (mm) 3 ABD (g/cm^3) 1.16—1.68 SA (m^2/g) 10 PV (cm^3/g) 0.69	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See Cu-1800.P. Cu-1407.T is tableted form of Cu-1402.P. Copper chromite catalysts are capable of selectivity to hydrogenate or dehydrogenate functional groups in organic compounds without changing the unsaturation or saturation in aromatic rings or alkyl chains.

TYPE OF CATALYST: *IRON Fe-0303.P*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Fe_2O_3 20 CARRIER: high activity alumina FORM: powder ABD (g/cm^3) 1.1 SA (m^2/g) 105 PV (cm^3/g) 0.49	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	A fluid bed microspheroidal hydrogenation catalyst.

TYPE OF CATALYST: *NICKEL Ni-0104.G*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni 60 CARRIER: Kieselguhr FORM: granules ABD (g/cm^3) 1.04 SA (m^2/g) 110 PV (cm^3/g) 0.35	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	A hydrogenation catalyst particularly for trickle bed or liquid phase reactions.

TYPE OF CATALYST: *NICKEL Ni-0122.E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni 28 CARRIER: Kieselguhr FORM: extrusions SIZE: Diameter (mm) 1.6 Length (mm) 1.6 ABD (g/cm^3) 0.72 SA (m^2/g) 168 PV (cm^3/g) 0.53 STRENGTH (kg/cm^2) 4.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a	Ni-0123.F is recommended for the hydrogenation of fats, oils and fatty acids.

TYPE OF CATALYST: *NICKEL Ni-0302.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni 15 (in oxide form) CARRIER: activated alumina FORM: tablets SIZE: Diameter (mm) 3 Length (mm) 3 ABD (g/cm^3) 1.3 SA (m^2/g) 65 PV (cm^3/g) 0.20 STRENGTH (kg/cm^2)8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *NICKEL Ni–0502.F*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni 24 CARRIER: Kieselguhr FORM: flakes ABD (g/cm^3) 0.6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *NICKEL Ni-0704.E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % NiO 18 CARRIER: Kieselguhr FORM: extrusions SIZE: Diameter (mm) 4 Length (mm) 4 ABD (g/cm^3) 0.8 SA (m^2/g) 4 PV (cm^2/g) 0.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

BATCH PROCESS HYDROGENATION

TYPE OF CATALYST: *NICKEL Ni-1000.P*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni 50 Aluminium 50 FORM: powder ABD (g/cm^3) 2.2	TEMPERATURE RANGE: low to moderate PRESSURE RANGE: n.a.	Screen analysis: on 325 mesh 5% min. on 325 mesh 16% average through 325 mesh 84% average.

HYDROGENATION REACTIONS

TYPE OF CATALYST: *NICKEL Ni-1430.E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni 40 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 1.6 Length (mm) 1.6 ABD (g/cm^3) 0.64 SA (m^2/g) 160 PV (cm^3/g) 0.69 STRENGTH (kg/cm^2)4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *NICKEL Ni-1800.G-4-6*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % NiO 10 CuO 1 CARRIER: silica FORM: granules SIZE (mm): 4—6 mesh ABD (g/cm^3) 0.85 SA (m^2/g) 3	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *NICKEL Ni-3001.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni 49 Al 49 FORM: tablets SIZE: Diameter (mm) 5 Length (mm) 5 ABD (g/cm^3) 2.1 STRENGTH (kg/cm^2) 45.3	TEMPERATURE RANGE: low to moderate PRESSURE RANGE: n.a.	For fixed bed reactions.

TYPE OF CATALYST: *NICKEL Ni-3207.T; 3261.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % 3207.T: Ni 28 3261.T: Ni 58 CARRIER: proprietary FORM: tablets SIZE: Diameter (mm) 3 Length (mm) 5 ABD (g/cm^3) 1—1.3 STRENGTH (kg/cm^2) 5—14	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	They must be activated by reduction *in situ.*

TYPE OF CATALYST: *PALLADIUM Pd-0501; 0505.T; 0509.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Pd 0.3 CARRIER: high activity alumina FORM: tablets ABD (g/cm^3) 0.88 SA (m^2/g) 180—200 PV (cm^3/g) 0.38—0.40 STRENGTH (kg/cm^2) 11—15	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *NICKEL N-103; N-122. ARS*

Manufacturer	Characteristics	Operating conditions	Remarks
W.C. Heraeus GmbH	CONTENT wt % Nickel CARRIER: Kieselguhr FORM: powder	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Applications: Hydrogenation of oils, fats, aromatics.

TYPE OF CATALYST: *RANEY NICKEL N-154; N-155*

Manufacturer	Characteristics	Operating conditions	Remarks
W.C. Heraeus GmbH	CONTENT wt % Raney nickel FORM: powder	TEMPERATURE RANGE: n.a PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *SUPPORTED NOBLE METAL CATALYSTS*

Manufacturer	Carrier / Metal	Activated charcoal	Asbestos	Silica	Alumina	Silicate of alumina	Quartz wool	Sulphate of Ba	Black	Oxide	Colloid
W.C. Heraeus GmbH	Pt	×	×	×	×	×	×	×	×	×	×
	Pd	×	×	×	×	×	×	×	×	×	×
	PdO	×									
	Rh	×		×	×	×				×	
	Ru	×		×	×	×				×	

TYPE OF CATALYST: *UNSUPPORTED CATALYSTS*

Manufacturer	Catalysts		Content
W.C.Heraeus GmbH	2101	Platinum black (Pt)	Pt 98%
	S 2106	Platinum oxide (Adams'catalyst) ($PtO_2.H_2O$)	Pt 80%
		Colloidal Platinum	
		Spongeous Platinum	
	2201	Palladium black (Pd)	Pd 98%
	3204	Palladium (II) oxide ($PdO.H_2O$)	Pd 85—87%
	S 2202	Palladium (II) chloride ($PdCl_2$)	Pd 60%
		Colloidal Palladium	
		Spongeous Palladium	
	4406	Rhodium (III) oxide (Rh_2O_2)	Rh 81.1%
	6502	Osmium (VIII) oxide (OsO_4)	Os 74.8%
	4503	Kalium osmate (VI) ($K_2(OsO_4).2H_2O$)	Os 51.6%
	4604	Ruthenium (IV) oxide (RuO_2)	Ru 76%
	3605	Ruthenium (IV) oxihydrate ($RuO_2.H_2O$	Ru 64%

TYPE OF CATALYST: *NICKEL H-1207*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Ni 8 CARRIER: silica FORM: irregular granules SIZE: Diameter (mm) 4—7 ABD (g/cm^3) 1.0	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for *in situ* reduction.

TYPE OF CATALYST: *NICKEL H-1328*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Ni 8 Nickel catalyst modified by Cu and Cr CARRIER: silicic acid FORM: extrusions SIZE: Diameter (mm) 6 ABD (g/cm^3) 0.6 SA (m^2/g) 120 PV (cm^3/g) 0.8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Available also in a reduced and stabilized form as H-1328 R.

TYPE OF CATALYST: *NICKEL HSC$^{T.M.}$-102*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % NiO 42 CARRIER: alumina FORM: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *PALLADIUM H-1799*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Pd up to 10 CARRIER: activated charcoal FORM: powder; extrusions SIZE: *powder extrusions* Diameter (mm) 2 Length (mm) 5 ABD g/cm^3) 0.30 0.40—0.60 SA (m^2/g) 500—800 600—900	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Especially used in noble metal hydrogenation where a large internal surface area is desirable. For batch operations the catalyst is used as a powder, whereas in continuous gas phase or trickle processes extrusions are preferred.

TYPE OF CATALYST: *NICKEL ICI-18 SERIES*

Manufacturer	Characteristics	Operating conditions	Remarks
Imperial Chemical Industries Ltd	CONTENT wt % Nickel oxide CARRIER: Kieselguhr FORM: pellets; powder SIZE: *pellets* Diameter (mm) 5.4 Length (mm) 3.6 ABD (g/cm^3) 1.2	TEMPERATURE RANGE: 150°—400°C PRESSURE RANGE: n.a.	They are recommended for powerful hydrogenations. Available as: 18—4 pellets and 18—9 powder. They are originally developed for the vapour phase hydrogenation of di-isobutene to iso-octane. Now they are used in a variety of reactions where total hydrogenation is required including saturation of aromatic nuclei, alcohol purification and methanation of carbon oxides.

TYPE OF CATALYST: *COPPER OXIDE/ZINC OXIDE ICI-29 SERIES*

Manufacturer	Characteristics	Operating conditions	Remarks
Imperial Chemical Industries Ltd	CONTENT wt % Copper oxide Zinc oxide CARRIER: n.a. FORM: pellets; powder SIZE: *pellets* Diameter (mm) 5.4 Length (mm) 3.6 ABD (g/cm^3) 1.9	TEMPERATURE RANGE: 250°—400°C PRESSURE RANGE: 1—100 atm.	They are used for mild hydrogenation — dehydrogenation reactions. Available as: ICI-29-2 pellets; 29—9 powder. They can also be used for the purification of gases especially for the removal of traces of oxygen and/or hydrogen and sulphur.

TYPE OF CATALYST: *NICKEL ICI-42 SERIES*

Manufacturer	Characteristics	Operating conditions	Remarks
Imperial Chemical Industries Ltd	CONTENT wt % Promoted nickel oxide CARRIER: Kieselguhr. FORM: pellets; powder SIZE: *pellets* Diameter (mm) 3—5.4 Length (mm) 3—3,6 ABD (g/cm^3) 1.2	TEMPERATURE RANGE: 150°—200°C PRESSURE RANGE: n.a.	They are recommended for powerful hydrogenations. Available a. 42—1 pellets; 42—3 pellets; 42—9 powder. They are tolerant to traces of sulphur and CO but are slowly affected by both these poisons.

ALL KINDS OF HYDROGENATION REACTIONS

TYPE OF CATALYST: *JMC UNSUPPORTED CATALYSTS*

Manufacturer	Catalyst	Remarks
Johnson Matthey Chemicals Ltd	Adams' platinum oxide $PtO_2.H_2O$	Of all chemical reactions, hydrogenation is most commonly catalysed by platinum metal catalysts. Pd, Pt and Rh are extremely efficient catalysts for the hydrogenation of olefinic and acetylenic groups, but Ru and Ir catalysts are less active. Pt, Rh and Pd are good catalysts for certain oxidation reactions, dehydrogenation and hydrogen transfer reactions. Mixed oxides on reduction are often more active than either component oxide by itself.
	Palladium oxide catalyst $PdO.H_2O$	
	Ruthenium oxide catalyst	
	Iridium oxide catalyst	
	Rhodium oxide catalyst	
	Ruthenium-platinum mixed oxide	
	Ruthenium-palladium mixed oxide	
	Rhodium-palladium mixed oxide	
	Platinum black	
	Palladium black	

TYPE OF CATALYST: I. *JMC SUPPORTED CATALYSTS*
JMC STANDARD GRANULAR PELLETED AND RELATED CATALYSTS

Manufacturer	Metal	Carrier	Form	Size	Remarks
Johnson Matthey Chemicals Ltd	Platinum	alumina	pellets	3.2 mm	Of all chemical reactions hydrogenation is most commonly catalysed by platinum metal catalysts. Pd, Pt and Rh are extremely efficient catalysts for the hydrogenation of olefinic and acetylenic groups, but Ru and Ir catalysts are less active. Pt, Rh and Pd are good catalysts for certain oxidation reactions, dehydrogenation and hydrogen transfer reactions. Mixed oxides on reduction are often more active than either component oxide by itself.
	Palladium	alumina	pellets	4.7 mm	
	Rhodium	alumina	pellets	6.4 mm	
	Ruthenium	alumina	granules	8—16 mesh	
	Ruthenium-palladium	alumina	—	—	
	Platinum	charcoal	granules	1—3 mm	
	Palladium	charcoal	granules	3—5 mm	
	Ruthenium	charcoal	granules	4—8 mesh	
	Platinum	asbestos	—	—	
	Palladium	asbestos	—	—	

TYPE OF CATALYST: II. *JMC SUPPORTED CATALYSTS*
JMC STANDARD POWDERED CATALYSTS

Manufacturer	Metal	Carrier	Remarks
Johnson Matthey Chemicals Ltd	Palladium[a,c]	charcoal	See JMC (I)
	Platinum[a]	charcoal	
	Ruthenium[a,b]	charcoal	
	Rhodium	charcoal	
	Palladium[b]	alumina	
	Platinum[b]	alumina	
	Ruthenium[b]	alumina	
	Rhodium[b]	alumina	
	Iridium[b]	alumina	
	Palladium	calcium carbonate	
	Iridium	calcium carbonate	
	Palladium	barium sulphate	

[a] Available as dry powder or as a paste containing about 55% by weight of water.
[b] Supplied in oxide form.
[c] Also available unreduced.

TYPE OF CATALYST: *RANEY NICKEL A 40*

Manufacturer	Characteristics	Operating conditions	Remarks
Kawaken Fine Chemicals Co. Ltd	CONTENT wt % Activated and packed in oil or wax. It is a porous catalyst having the same composition as ND. FORM: granules or flakes	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is suitable for difficult hydrogenations such as of tallows, marine oil, fatty acids. It is supplied in the state of oil or wax packed form.

TYPE OF CATALYST: *RANEY NICKEL ND*

Manufacturer	Characteristics	Operating conditions	Remarks
Kawaken Fine Chemicals Co. Ltd	CONTENT wt % Ni 40 Al 60 FORM: powder SIZE: 200—300 mesh	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for a wide range of hydrogenation: e.g. glucose to sorbitol, phenol to cyclohexanol, butylaldehyde to octanol, acetone to methylisobutyl-ketone. Activated type: NDT.

TYPE OF CATALYST: *RANEY NICKEL NDH*

Manufacturer	Characteristics	Operating conditions	Remarks
Kawaken Fine Chemicals Co. Ltd	CONTENT wt % Ni 50 Al 50 FORM: powder SIZE: 200—300 mesh	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The activated type is NDHT. It shows an anti-poisonous effect.

TYPE OF CATALYST: *RANEY NICKEL NP*

Manufacturer	Characteristics	Operating conditions	Remarks
Kawaken Fine Chemicals Co. Ltd	CONTENT A bit of poisonous lead metal besides 45% nickel FORM: powder SIZE: 200—300 mesh	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used for dehalogenized hydrogenation. The activated type is NPT.

TYPE OF CATALYST: *RANEY NICKEL PL*

Manufacturer	Characteristics	Operating conditions	Remarks
Kawaken Fine Chemicals Co. Ltd	CONTENT wt % Ni 30 Fe 4 (as promotor) FORM: powder SIZE: 200—300 mesh	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The activated type is PLT. Rather recommendable in some cases such as for ketone acid to aminoacid, malonate to succinate and l-menthon to l-menthol reduction. Its uses are almost similar to ND catalyst.

TYPE OF CATALYST: *ADAMS' PLATINUM CATALYST*

Manufacturer	Characteristics	Operating conditions	Remarks
Kawaken Fine Chemicals Co. Ltd	CONTENT wt % PtO_2 FORM: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	For complex organic synthesis. Hydrogenation of all pyridine salts, streptomycine sulphate, succinic anhydride derivatives. Hydroisomerization of cis-stylbenes. Hydrogenolysis of unsaturated alcohols.

TYPE OF CATALYST: *NICKEL-ALUMINIUM PX*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Raney alloy CARRIER: special FORM: powder SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *NICKEL CHX-3*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT n.a. CARRIER: activated charcoal FORM: extrusions SIZE: Diameter (mm) 3	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used in gaseous phase and fixed bed.

TYPE OF CATALYST: *NICKEL LD-742*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Nickel CARRIER: SiO_2 FORM: extrusions SIZE: Diameter (mm) 4—6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for the hydrogenation of benzene to cyclohexane and general hydrogenation reactions in liquid phase.

SPECIFIC HYDROGENATION IN THE LIQUID PHASE

TYPE OF CATALYST: *NICKEL Ni—PS-2*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Ni >65 Loss on ignition: 5 CARRIER: special FORM: powder ABD (g/cm^3) 2.4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a. LIFE: several months	Average particle size: microns % <20 5—20 20—100 50—65 100—315 25—35 >315 0—5 It can be used for hydrogenations generally done with Raney nickel, in hydrogenation of benzene into cyclohexane. Make up gas should not contain any H_2S or CO.

HYDROGENATION REACTIONS

TYPE OF CATALYST: *COPPER CHROMITE ST-202; ST-203; ST-205*

Manufacturer	Characteristics	Operating conditions	Remarks
Sakaj Chemical Industry Co. Ltd	CONTENT wt% Copper chromite Promotors: barium or manganese FORM: tablets SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Other uses: Dehydrogenation in vapour phase. Oxidation in vapour phase.

TYPE OF CATALYST: *NICKEL SN-100; SN-110*

Manufacturer	Characteristics	Operating conditions	Remarks
Sakaj Chemical Industry Co. Ltd	CONTENT wt % Ni 50 SN-100 contains a small amount of metal oxides (Cu, Al, Cr) as promotors. CARRIER: Kieselguhr FORM: powder SIZE: All through 150 mm mesh ABD (g/cm^3)2.7±0.2	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Uses in liquid phase: Hydrogenation of carbon to carbon double bonds. Full hardening and partial hydrogenation of oil and fats. Reduction of aldehydes and ketones. Hydrogenation of other organic compounds in liquid phase.

TYPE OF CATALYST: *NICKEL ST-101; ST-111*			
Manufacturer	Characteristics	Operating conditions	Remarks
Sakaj Chemical Industry Co. Ltd	CONTENT wt % Ni 50 ST-101 contains a small amount of metal oxides (Cu, Al, Cr) as promotors. CARRIER: Kieselguhr FORM: tablets	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Uses in vapour phase. Full hardening and partial hydrogenation of oil and fats. Hydrogenation of aromatic rings. Hydrogenation of carbon to carbon double bonds. Reduction of aldehydes and ketones. Hydrogenation of other organic compounds in liquid phase.

TYPE OF CATALYST: *RANEY IRON 26375*			
Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % Fe 50 Al 50 FORM: powder SA (m^2/g) high	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used as an alternative to Raney nickel and Raney cobalt.

HYDROGENATION — DEHYDROGENATION REACTIONS

TYPE OF CATALYST: *PLATINUM 78161; 78164; 78177*			
Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT 78161: Pt 10% on activated carbon; 78164: Pt 0.5% on alumina; 78177: Pt 0.3% on gamma alumina coated on Dupont Torvex ceramic honeycomb. FORM: powder; pellets; discs SIZE: *pellets* Diameter (mm) 3 Length (mm) 3 SA (m^2/g) 78161: 2 78164: high 78177: 240	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Hydrochlorination catalyst. Hydrogenation of aliphatic aldehydes to alcohols.

TYPE OF CATALYST: *RUTHENIUM 44388; 44391; 44400; 44404*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % 44388: Ru 0.5% on alumina; 44391: Ru 5% on alumina; 44400: Ru 0.5% on carbon; 44404: Ru 5% on carbon FORM: pellets; powder; granules; powder SA (m^2/g) 44391: 80—100 44404: 1,150	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Hydrogenation of aliphatic aldehydes and ketones to alcohols in aqueous solution. Selective hydrogenation reactions. Oxidation reactions. Ring hydrogenation of aromatic esters, phenols and anilines. Hydrogenation of aromatic nucleus of aromatic amines.

TYPE OF CATALYST: *NICKEL NP; NPN; NPNT*

Manufacturer	Characteristics	Operating conditions	Remarks
Unichema Chemie GmbH	CONTENT wt % Ni 53—55	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	NP, NPN are available as powders; NPNT as tablets. NP and NPN are also used for hydrogenation of dinitrotoluenes to toluenediamines and of nitrobenzene to aniline. NPNT is also used for the hydrogenation of nitrobenzene to aniline, for the reduction of aldehydes and ketones and for methanation.

TYPE OF CATALYST: *PALLADIUM SK-300*

Manufacturer	Characteristics	Operating conditions	Remarks
Union Carbide Corp. Linde Molecular Sieve Catalysts	CONTENT wt % (anhydrous base) SiO_2 64.4±0.5 Al_2O_3 21.8±0.5 Na_2O 13.3±0.5 Cl^- <0.05 Fe^- <0.05 Pd 0.5±0.2 FORM: tablets SIZE: Diameter (mm) 4 Length (mm) 4 ABD (g/cm^3) 0.65 SA (m^2/g) >500	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is a molecular sieve type Y.

TYPE OF CATALYST: ***PALLADIUM SK-310***

Manufacturer	Characteristics	Operating conditions	Remarks
Union Carbide Corp. Linde Molecular Sieve Catalysts	CONTENT wt % (anhydrous base) SiO_2 56.6±0.5 Al_2O_3 22.2±0.5 Na_2O 1.8±0.2 CaO 10.3±0.3 Cl^- <0.05 Fe^- <0.05 Pd 0.5±0.02 FORM: tablets SIZE: Diameter (mm) 4 Length (mm) 4 ABD (g/cm³) 0.65 SA (m²/g) >500	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is a calcium exchanged type Y.

Selective hydrogenation

SELECTIVE HYDROGENATION OF UNSATURATED COMPOUNDS

TYPE OF CATALYST: *PALLADIUM BASF H-0—10*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % Palladium CARRIER: special FORM: grains SIZE: Diameter (mm) 4 Length (mm) 5 ABD (g/cm^3) 0.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for selective hydrogenation of unsaturated compounds, e.g. acetylene in ethylene streams.

SELECTIVE HYDROGENATION

TYPE OF CATALYST: *NICKEL CODE 232.F*

Manufacturer	Characteristics	Operating conditions	Remarks
Calsicat Division	CONTENT wt % Ni 25 Support 15 Protective medium 60 CARRIER: proprietary FORM: flakes	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The protective medium is an edible oil. Selectivity in the hydrogenation of edible oils, fatty acids, nitriles, esters.

TYPE OF CATALYST: *PLATINUM CODE 138*

Manufacturer	Characteristics	Operating conditions	Remarks
Calsicat Division	CONTENT wt % Pt 0.3 CARRIER: alumina FORM: tablets SIZE: Diameter (mm) 3 Length (mm) 3 ABD (g/cm^3) 0.7 SA (m^2/g) 156 STRENGTH (kg/cm^2) 8.6 (individual particle)	TEMPERATURE RANGE: n.a PRESSURE RANGE: n.a.	Applications: Liquid phase hydrogenation. Oxidation of organic pollutants in effluent gases.

TYPE OF CATALYST: *COBALT C-37*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Cobalt oxide CARRIER: refractory FORM: spheres SIZE: Diameter (mm) 4; 9	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Selective hydrogenation of acetylenes and dienes in sulphur-containing olefins streams.

TYPE OF CATALYST: *COPPER CHROMITE C-43-1; C-44-1; C-45-1*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Copper chromite C45-1 contains barium as stabilizer CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Applications: Hydrogenation and dehydrogenation of functional groups in preference to carbon-carbon bonds in aldehydes and ketones. Typical applications: Hydrogenation of nitrobenzene to aniline, crotonaldehyde to butyraldehyde and the production of high molecular weight alcohols from the corresponding fatty acids or esters.

SELECTIVE HYDROGENATION OF ACETYLENES FROM OLEFIN STREAMS

TYPE OF CATALYST: *NICKEL-COBALT-CHROMIUM C-36*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Nickel Cobalt Chromium CARRIER: alumina-silica FORM: spheres SIZE: Diameter (mm) 8—9 ABD (g/cm^3) 0.8	TEMPERATURE RANGE: 120°—320°C PRESSURE RANGE: 1—23 atm. LIFE: more than 5 years SPACE VELOCITY: 1,500—5,000 h^{-1}	It is used for the purification of ethylene to produce a grade suitable for the production of polyethylene. It may be used for the selective hydrogenation of acetylenic compounds in gas streams. The raw gas stream may contain CO, sulphur compounds, oxygen and a large excess of hydrogen.

SELECTIVE HYDROGENATION

TYPE OF CATALYST: *NICKEL OXIDE C-38-1*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Nickel oxide CARRIER: n.a. FORM: spheres SIZE: 3—8 mesh ABD (g/cm^3) 0.8	TEMPERATURE RANGE: 177°—288°C PRESSURE RANGE: 7 atm	Used for removal of olefins by hydrogenation. Used also for promoting the selective hydrogenation of butadiene and acetylene from sulphur-bearing butylene streams.

TYPE OF CATALYST: *PALLADIUM C-31-3; C-31-4; C-31-5; C-31-6; C-31-7; C-31-8*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Pd 0.07—0.41 CARRIER: alumina FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

SELECTIVE HYDROGENATION OF DIENES

TYPE OF CATALYST: *PALLADIUM C-31; C-31-1; C-31-1.A*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Pd 0.045—0.055 CARRIER: alumina FORM: extrusions; spheres SIZE: *spheres* Diameter (mm) 2.5—3.6 ABD (g/cm^3) 0.72—0.85	TEMPERATURE RANGE: 25°—250°C PRESSURE RANGE: 7—25 atm SPACE VELOCITY: 1000—3500 h^{-1}	Used for selective hydrogenation of propadiene from concentrated propylene streams. Used for propylene purification.

SELECTIVE HYDROGENATION

TYPE OF CATALYST: *PALLADIUM C-32*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Palladium CARRIER: low surface area refractory FORM: spheres SIZE: Diameter (mm) 9	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for hydrogenation of acetylenes and dienes from concentrated olefin streams.

SELECTIVE HYDROGENATION OF ACETYLENES AND DIENES

TYPE OF CATALYST: *PALLADIUM C-35*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Palladium CARRIER: alumina FORM: extrusions; tablets SIZE: Diameter (mm) 6.4×3.2 ABD (g/cm^3) 0.72	TEMPERATURE RANGE: 40°—95°C PRESSURE RANGE: 3—35 atm. SPACE VELOCITY: 4000—7000 h^{-1}	Used for selective hydrogenation of acetylene from cracked gas stream. Composition: palladium mounted on an especially prepared carrier. Available as C-35-1, C-35-2, C-35-3.

SELECTIVE HYDROGENATION OF NITRILES AND CARBOXYLIC ACID

TYPE OF CATALYST: *RHODIUM C-55-1*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Rh 0.5 CARRIER: alumina FORM: spheres; extrusions; tablets SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The reduction of aldehydes at low temperature and pressure.

SELECTIVE HYDROGENATION

TYPE OF CATALYST: *RANEY COPPER RCU-5*

Manufacturer	Characteristics	Operating conditions	Remarks
Crossfield Chemicals	CONTENT wt % Cu 95—97 typical Na_2O 0.1 max. FORM: suspension in water	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Pyrophoric in the dry state. Dienes and trienes can be hydrogenated to monoenes. Carbonyl compounds can be hydrogenated to alcohols. Conversely, alcohols can be dehydrogenated to carbonyl compounds without hydrogenolysis.

TYPE OF CATALYST: *PALLADIUM ON RASCHIG RINGS*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt % Pd 5—10 CARRIER: Raschig rings FORM: rings SIZE: n.a. ABD (g/cm^3) 0.52	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for the hydrogenation reactions in the gas phase.

SELECTIVE HYDROGENATION OF OLEFINS

TYPE OF CATALYST: *NICKEL - CHROME C-00/07*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt % Nickel chromic oxide CARRIER: without carrier or with Al_2O_3, SiO_2 or pumice FORM: powder; tablets SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Selective hydrogenation of olefins (fatty acids) preserving the carbonyl and carboxyl groups; conversion of butane and NH_3 to butylamine.

SELECTIVE HYDROGENATION OF ACETYLENE

TYPE OF CATALYST: *PALLADIUM G-58.A; G-58.B*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Palladium CARRIER: alumina FORM: tablets (G.58.A); extrusions (G.58.B) SIZE: Diameter (mm) 5 Length (mm) 5 ABD (g/cm^3) 0.72—1.28	TEMPERATURE RANGE: 20°—180°C PRESSURE RANGE: 3.5—35 atm.	Selective hydrogenation of acetylene impurified and partially purified ethylene streams. Depending on the acetylene concentration it is used in adiabatic fixed bed or isothermal tube reactors.

SELECTIVE HYDROGENATION OF ACETYLENE IN RAW OLEFIN STREAMS

TYPE OF CATALYST: *PALLADIUM G-83*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Promoted palladium CARRIER: alumina FORM: tablets SIZE: Diameter (mm) 4 Length (mm) 4	TEMPERATURE RANGE: 60°—110°C PRESSURE RANGE: n.a. SPACE VELOCITY: up to 10000 h^{-1}	Especially suitable for isothermal tube reactors, in the range of 90°C.

SELECTIVE HYDROGENATION OF ACETYLENE

TYPE OF CATALYST: *PALLADIUM GPH-5*

Manufacturer	Characteristics	Operating conditions	Remarks
Grande Paroisse	CONTENT wt % Palladium CARRIER: alumina FORM: balls SIZE: Diameter (mm) 3 TS (°C) $\leqslant$ 550	TEMPERATURE RANGE: 100°—200°C PRESSURE RANGE: n.a. LIFE: 2 years SPACE VELOCITY (VHSV): up to 10000 h^{-1}	Other application: For hydrogenation of ethylene mixtures, eventually in presence of sulphur.

SELECTIVE HYDROGENATION

TYPE OF CATALYST: *NICKEL Ni-0301.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni 11 present as oxide CARRIER: activated alumina FORM: tablets SIZE: Diameter (mm) 3 Length mm) 3 ABD (g/cm^3) 1.1 SA (m^2/g) 64 PV (cm^3/g) 0.32 STRENGTH (kg/cm^2) 6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The sulphided form of this catalyst is used for the selective hydrogenation of diolefins to monolefins.

TYPE OF CATALYST: *NICKEL Ni-0304.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % NiO 32 CARRIER: active alumina FORM: tablets SIZE: Diameter (mm) 4 Length (mm) 4 ABD (g/cm^3) 1.4 SA (m^2/g) 52 PV (cm^3/g) 0.23 STRENGTH (kg/cm^2) 10 (individual particle)	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *NICKEL Ni-3201.F (NYSEL)*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % 25 or 30 fully active nickel protected by 60% stearine CARRIER: proprietary FORM: flakes	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Selectivity in the hydrogenation of edible oils, fatty acids, nitriles, esters and other organic compounds.

TYPE OF CATALYST: *COPPER RCH-20/35; RCH-60/35*

Manufacturer	Characteristics	Operating conditions	Remarks
Farbwerke Hoechst A.G.	CONTENT wt % RCH-20/35 Cu 21 RCH-60/35 Cu 60 CARRIER: SiO_2 FORM: tablets; powder SIZE: n.a. ABD (g/cm³) 0.4—0.9	TEMPERATURE RANGE: 100°—200°C PRESSURE RANGE: 4—50 atm.	Other applications: Hydrogenation of the olefins; of the carbonyl groups; selective hydrogenation of the unsaturated oils.

SELECTIVE HYDROGENATION OF UNSATURATED HYDROCARBONS

TYPE OF CATALYST: *COPPER H-1175*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Cu 11 Copper modified with chromium and MgO CARRIER: silica gel FORM: granules SIZE: Diameter (mm) 2—6 ABD (g/cm³) (packed) 0.7 PV (cm³/g) 0.6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

SELECTIVE HYDROGENATION OF ACETYLENE IN CRUDE ETHYLENE AND CRUDE PROPYLENE STREAMS

TYPE OF CATALYST: *PALLADIUM H-1100*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt% Pd 0.03 SiO_2 97 Loss on drying (120°C): 0.1 Loss on ignition (750°C): 2—3 CARRIER: silica FORM: irregular granules SIZE: Diameter (mm) 3—6 ABD (g/cm³) 0.47 SA (m²/g) 260 PV (cm³/g) 0.9	TEMPERATURE RANGE: 100°—250°C PRESSURE RANGE: n.a.	It may be used at normal, as well as at increased pressure.

SELECTIVE HYDROGENATION OF ALKINES

TYPE OF CATALYST: *PALLADIUM H-1424*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt% Pd 0.05 Al_2O_3 98.5 Na_2O 0.4 Loss on ignition: 0.9 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 3.2 Length (mm) 4—6 ABD (g/cm^3) 0.84 SA (m^2/g) 80 PV (cm^3/g) 0.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for the hydrogenation of acetylene, propene and vinyl acetylene in crude ethylene.

SELECTIVE HYDROGENATION OF ACETYLENE IN OLEFIN STREAMS

TYPE OF CATALYST: *PALLADIUM ICI-38 SERIES*

Manufacturer	Characteristics	Operating conditions	Remarks
Imperial Chemical Industries Ltd	CONTENT wt% Palladium CARRIER: alumina FORM: pellets SIZE: Diameter (mm) 5.4 Length (mm) 3.6 ABD (g/cm^3) 1.05	TEMPERATURE RANGE: 35°—100°C PRESSURE RANGE: up to 35 atm. (ICI-38—1) SPACE VELOCITY (VHSV): 2000—8000 h^{-1}	Available as ICI-38—1 and 38—3. It is used to remove acetylenes and dienes from separated C_2 and C_3 streams produced by steam cracking of hydrocarbons.

SELECTIVE HYDROGENATION OF PHENOL TO CYCLOHEXANE

TYPE OF CATALYST: *PALLADIUM KONTAKT 7720*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb. Leuna Werke „Walter Ulbricht"	CONTENT wt% Palladium CARRIER: a special aluminium oxide FORM: tablets SIZE: Diameter (mm) 5 ABD (g/cm^3) 1.0±0.15 STRENGTH (kg/cm^2) $\geqslant$ 800	TEMPERATURE RANGE: 130°—165°C PRESSURE RANGE: 1 atm.	

TYPE OF CATALYST: *PALLADIUM KONTAKT 7720/S*			
Manufacturer	Characteristics	Operating conditions	Remarks
Veb. Leuna Werke „Walter Ulbricht“	CONTENT wt% Palladium CARRIER: especially aluminium oxide FORM: extrusions SIZE: Diameter (mm) 3 Length (mm) 2—6 ABD (g/cm^3) 1.0±0.15	TEMPERATURE RANGE: 130°—165°C PRESSURE RANGE: 1 atm.	

SELECTIVE HYDROGENATION

TYPE OF CATALYST: *PALLADIUM KONTAKT 7746*			
Manufacturer	Characteristics	Operating conditions	Remarks
Veb. Leuna Werke „Walter Ulbricht“	CONTENT wt% Palladium and iron oxide CARRIER: alpha alumina FORM: tablets SIZE: Diameter (mm) 5 or 10 ABD (g/cm^3) 0.80—1.1 STRENGTH (kg/cm^2) 150	TEMPERATURE RANGE: 80°—200°C PRESSURE RANGE: 25—30 atm.	

SELECTIVE HYDROGENATION OF ACETYLENE TO ETHYLENE

TYPE OF CATALYST: *PALLADIUM KONTAKT 7747*			
Manufacturer	Characteristics	Operating conditions	Remarks
Veb. Leuna Werke „Walter Ulbricht“	CONTENT wt% Palladium CARRIER: alpha alumina FORM: cylinders SIZE: Diameter (mm) 10—15 Length (mm) 10—15 ABD (g/cm^3) 0.7—1.0 STRENGTH (kg/cm^2) 50—100	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

SELECTIVE HYDROGENATION OF C_3 AND C_4 HYDROCARBONS

TYPE OF CATALYST: *PALLADIUM KONTAKT 7751*			
Manufacturer	Characteristics	Operating conditions	Remarks
Veb. Leuna Werke „Walter Ulbricht"	CONTENT wt% Promoted palladium CARRIER: alumina FORM: spheres; extrusions SIZE: Diameter (mm) 2—4 (spheres) 3 (extrusions) ABD (g/cm³) 1.0±0.15	TEMPERATURE RANGE: 10°—20°C PRESSURE RANGE: 5—15 atm.	It is used in fluid phase.

SELECTIVE HYDROGENATION

TYPE OF CATALYST: *PALLADIUM KONTAKT 7761*			
Manufacturer	Characteristics	Operating conditions	Remarks
Veb. Leuna Werke „Walter Ulbricht"	CONTENT wt% Palladium CARRIER: aluminium oxide FORM: extrusions SIZE: Diameter (mm) 3 Length (mm) 2—6	TEMPERATURE RANGE: 80°—250°C PRESSURE RANGE: 20—50 atm.	

TYPE OF CATALYST: *NICKEL SNX; ST-130*			
Manufacturer	Characteristics	Operating conditions	Remarks
Sakaj Chemical Industry Co Ltd	CONTENT wt% Nickel sulphide CARRIER: Kieselguhr FORM: powder; tablets	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Selective hydrogenation in vapour phase.

TYPE OF CATALYST: *COPPER 29041*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt% Copper chromite, barium promoted CuO 39.6 Cr_2O_3 41.7 BaO 8.6 CARRIER: n.a. FORM: powder SA (m^2/g) high	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Barium inhibits reduction of the catalyst thereby stabilizing it for use as hydrogenation catalyst. This catalyst selectively hydrogenates aromatic nitrocompounds to aromatic amines and carbonyl groups attached to an aromatic nucleus to either the carbonyl or methylene function. Olefinic groups attached to an aromatic nucleus are selectively hydrogenated. Unsaturated nitriles are selectively hydrogenated to unsaturated amines.

SELECTIVE HYDROGENATION OF AROMATIC NITRO-COMPOUNDS

TYPE OF CATALYST: *RANEY COPPER 29275*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT n.a. FORM: 50% slurry in water SA (m^2/g) high	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

SELECTIVE HYDROGENATION OF SIMPLE OLEFINS

TYPE OF CATALYST: *PALLADIUM 46-183*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt% Palladium black FORM: powder SA (m^2/g) approx. 23	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used also for the hydrogenation of aromatic ketones to aromatic hydrocarbons.

SELECTIVE HYDROGENATION

TYPE OF CATALYST: *PALLADIUM 46189*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt% Palladium 5 CARRIER: activated carbon FORM: powder SA (m^2/g) approx. 1050	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Also used for: Dehydrogenation reactions. Decarbonylation of aldehydes and acid chlorides to alkanes and alkyl halides respectively. Hydrogenation of aromatic nitro compounds to aromatic amines. Dehalogenation reactions.

TYPE OF CATALYST: *PALLADIUM 46-192; 46-195*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt% 46-192: Pd 0.5 46-195: Pd 5 CARRIER: alumina FORM: pellets (46—192); powder (46—195) SIZE (mm): pellets: 3×3 SA (m^2/g) 46-192: high 46-195: 80—100	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Applications: Isomerization of olefins. Oxidation of ethylene to vinyl acetate.

TYPE OF CATALYST: *PALLADIUM 46-205*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt% Pd 0.3—0.5 CARRIER: gamma alumina coated on Dupont Torvex ceramic honeycomb FORM: discs SIZE: Diameter (mm) 50 Thickness (mm) 25 SA (m^2/g) approx. 240	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See 46-189 and 46-192

TYPE OF CATALYST: *PALLADIUM 46-207*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt% Pd 0.5 CARRIER: Kaolin (natural silica-alumina) FORM: pellets SIZE: n.a. SA (m^2/g) 90—100	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See 46-189

SELECTIVE HYDROGENATION OF SIMPLE OLEFINS

TYPE OF CATALYST: *PALLADIUM 46-211*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt% Palladium oxide CARRIER: n.a. FORM: powder SA (m^2/g) 225	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Also used for: Hydrogenation of aromatic ketones to aromatic hydrocarbons.

HYDROTREATING REACTIONS

TYPE OF CATALYST: *COBALT-MOLYBDENUM C-20-5; C-20-6*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt% CoO 3.3—3.8 MoO_3 13.5—15.5 Na_2O 0.05 Fe_2O_3 0.20 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 1.6; 3.2; 5 ABD (g/cm^3) 0.7 SA (m^2/g) 175—225 PV (cm^3/g) 0.5—0.6	TEMPERATURE RANGE: 288°—454°C PRESSURE RANGE: 7—105 atm.	Used for denitrification of hydrocarbons, the hydrogenation of petroleum fractions. Also for converting organic nitrogen and sulphur compounds to ammonia and H_2S. Stabilization of petroleum fractions.

TYPE OF CATALYST: *MOLYBDENUM CHEZA CATALYST 36—00; 36—01*

Manufacturer	Characteristics	Operating conditions	Remarks
Chemical Works of CSF	CONTENT wt% MoO_3 12 CoO 3 Na_2O max. 0.1 CARRIER: alumina FORM: 36—00 36—01 *tablets balls* SIZE: (mm) 10×8; 3 6×6 ABD (g/cm^3) 0.85 STRENGTH (kg/cm^2) 150; 2.5 per ball	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used also for hydrodesulphurization of crude oil fractions from petroleum. For hydrotreating of crude coal tar benzol, lubricating oils, paraffin waxes and similar products.

TYPE OF CATALYST: *COBALT-MOLYBDENUM AERO HDS-2*

Manufacturer	Characteristics	Operating conditions	Remarks
Cyanamid International	CONTENT wt% CoO 3—4 MoO_3 14.5—16.0 Na_2O max. 0.04 Fe max. 0.05 Loss on ignition: 2.0 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 3 Length (mm) 6 ABD (g/cm^3) 0.42 SA (m^2/g) 270 PV (cm^3/g) 0.7 STRENGTH (kg/cm^2) 7.2 TS (°C) 540	TEMPERATURE RANGE: 300°—370°C PRESSURE RANGE: 42 atm. SPACE VELOCITY (LHSV): $5\ h^{-1}$	It is used to promote desulphurization, denitrogenation, deoxygenation and saturation reactions.

TYPE OF CATALYST: *NICKEL-MOLYBDENUM AERO HDS-3*

Manufacturer	Characteristics	Operating conditions	Remarks
Cyanamid International	CONTENT wt% NiO 3.1 MoO_3 15 Na_2O 0.02 Fe 0.04 SO_4 0.3 SiO_2 0.1 Loss on ignition: 1.4 CARRIER: alumina FORM: extrusions Diameter (mm) 1.5; 3 Length (mm) 6 ABD (g/cm^3) 0.56 SA (m^2/g) 200 PV (cm^3/g) 0.6 STRENGTH (kg/cm^2) 7.7	TEMPERATURE RANGE: 300°—370°C PRESSURE RANGE: 42 atm. SPACE VELOCITY (LHSV): 5 h^{-1}	The catalyst is designed for use on feedstocks containing high percentages of nitrogen and polyaromatics compounds. It is adapted for the treatment of nitrogen containing naphthas, hydrogenation of cat-cracker feed and middle distillates and for giving improved colour in waxes.

HYDROTREATING OF COKER NAPHTHAS

TYPE OF CATALYST: *NICKEL-MOLYBDENUM KETJENFINE^R 153—1.5E*

Manufacturer	Characteristics	Operating conditions	Remarks
Akzo Chemie B.V. Dpt. Ketjen Catalysts	CONTENT wt% (dry base) NiO 3.0 MoO_3 15 SiO_2 1.0 Na_2O 0.06 Fe 0.06 SO_4 1.5 Loss on ignition (650°C) wet base: 3.0 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 1.5 Length (mm) 4.0 SA (m^2/g) 180 (1 hr at 600°C) PV (H_2O) (cm^3/g) 0.50 STRENGTH (kg/cm^2) 11	TEMPERATURE RANGE: 300°—380°C PRESSURE RANGE: 1—40 atm.	See Ketjenfine 153-3E

TYPE OF CATALYST: *NICKEL-MOLYBDENUM KETJENFINE^R 153—3E*

Manufacturer	Characteristics	Operating conditions	Remarks
Akzo Chemie B.V. Dpt. Ketjen Catalysts	CONTENT wt% (dry base) NiO 3 MoO_3 15 SiO_2 1 Na_2O 0.06 Fe 0.06 SO_4 1.5 Loss on ignition (650°C) wet base: 3 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 2.5 Length (mm) 5.0 ABD (g/cm^3) n.a. SA (m^2/g) 180 (1hr at 600°C) PV (H_2O)(cm^3/g) 0.50 STRENGTH(kg/cm^2) 11	TEMPERATURE RANGE: 300°—380°C PRESSURE RANGE: 1—40 atm.	The Ketjenfine 153 have been especially developed for removal of nitrogen and polyaromatic compounds from mineral oils. They are suited for treatment of cracked feedstocks such as coker naphthas and gas oils, catalytic cracker feedstocks and lube-oil basestocks.

MILD HYDROTREATING OF OILS

TYPE OF CATALYST: *NICKEL-MOLYBDENUM HR 344*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt% MoO_3 13 NiO 2.5 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 1.5; 2; 3 STRENGTH (kg/cm^2) $\geqslant 12$	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Standard hydrofinishing charges with nitrogen compounds.

HYDROTREATMENT OF DISTILLATES

TYPE OF CATALYST: *NICKEL-TUNGSTEN HR 151—155*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT FORM: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See section on hydrodesulphurization.

TYPE OF CATALYST: *NICKEL-TUNGSTEN HR 356*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 1.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *COBALT-MOLYBDENUM SHELL 244*

Manufacturer	Characteristics	Operating conditions	Remarks
Shell Chemical Co.	CONTENT wt% Co 2.0—2.4 Mo 8.4—9.2 Na 0.1 Loss on ignition: max. 1.5 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 1.8—3 (average) ABD (g/cm^3) 0.61—0.74 SA (m^2/g) 180 PV (cm^3/g) 0.4 Side Plate Crush (kg) 11—12	TEMPERATURE RANGE: approx. 290°C PRESSURE RANGE: 35 atm. SPACE VELOCITY (LHSV): 2.3—4.2 h^{-1}	It is recommended for desulphurization of: straight run naphtha, kerosene, heating oil and diesel fuel, and heavy fuel oil. It is designed for the increased desulphurization requirements of naphthas and fuel oils called for by use of bimetallic reformer catalysts.

TYPE OF CATALYST: *NICKEL-MOLYBDENUM SHELL 214*

Manufacturer	Characteristics	Operating conditions	Remarks
Shell Chemical Co.	CONTENT wt% Ni 2.0—2.4 Mo 8.5—9.5 Na 0.1 Loss on ignition: max. 1.5 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 1.8—3 (average) ABD (g/cm^3) 0.64—0.77 SA (m^2/g) 180 PV (cm^3/g) 0.4 Side Plate Crush (kg) 11—12	TEMPERATURE RANGE: 300°—350°C PRESSURE RANGE: 20—100 atm. SPACE VELOCITY (LHSV): 0.9—5 h^{-1}	It is recommended for processing: Cocker products High nitrogen content naphthas High nitrogen content kerosene, heating oil and diesel fuel Lube oils, waxes and solvents. It is designed for multipurpose hydrotreating where maximum desulphurization, denitrogenation and polyaromatic saturation are not needed.

TYPE OF CATALYST: *NICKEL-MOLYBDENUM SHELL 324*

Manufacturer	Characteristics	Operating conditions	Remarks
Shell Chemical Co.	CONTENT wt% Ni 2.9 Mo 12.0 Na 0.1 CARRIER: high density alumina FORM: extrusions SIZE: Diameter (mm) 1.8—3 (average) ABD (g/cm^3) 0.8—0.95 SA (m^2/g) 180 PV (cm^3/g) 0.4 Side Plate Crush (kg) 4	TEMPERATURE RANGE: 320°—370°C PRESSURE RANGE: 38—70 atm. SPACE VELOCITY (LHSV): 1.2—4.8 h^{-1}	It is recommended for: Processing unsaturated and unstable streams such as cocker products, cracker products and pyrolysis gasolines; Catalytic cracker feed preparation; Heavy fuel oil desulphurization; Stocks with high nitrogen content; Smoke point improvement of turbine fuels; Pretreating naphthas for reformers using bimetallic catalysts; Lube oil treating.

G. Isomerization

ISOMERIZATION

TYPE OF CATALYST: *ANHYDROUS ALUMINIUM CHLORIDE*

Manufacturer	Characteristics	Operating conditions	Remarks
Allied Chemical	CONTENT Aluminium chloride is used alone, with mixtures of other catalytic materials, or in complex with hydrocarbon solvents	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	There are a wide variety of chemical reactions in the petroleum industry which can use aluminium chloride as a catalyst. The more important of these are polymerization, alkylation, acylation and isomerization.

TYPE OF CATALYST: *ALUMINA BASF D-10—10*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt% Al_2O_3 main constituent Na + K <0.1 Fe <0.1 Loss on ignition expressed in terms of dry catalyst 5 FORM: extrusions SIZE: Diameter (mm) 4 ABD (g/cm³) 0.650 TS (°C) up to 500	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for diverse chemical reactions such as dehydration, isomerization.

SOMERIZATION OF n-BUTANE AND n-PENTANE TO ISOBUTANE AND ISOPENTANE

TYPE OF CATALYST: *ANHYDROUS ALUMINIUM CHLORIDE*

Manufacturer	Characteristics	Operating conditions	Remarks
Davison Chemical Division, W.R. and Grace Co.	CONTENT wt% Anhydrous aluminium chloride FORM: crystalline solid or granular form	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The catalyst is used for production of C_{12} to C_{16} alkyl benzenes.

CONVERSION OF NORMAL BUTANE TO ISOBUTANE

TYPE OF CATALYST: *MOLYBDENUM ALUMINA Mo-1201.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt% MoO$_3$ 10 CARRIER: high activity alumina FORM: tablets SIZE: Diameter (mm) 3.175 Length (mm) n.a. ABD (g/cm^3) 0.848 SA (m^2/g) 160 PV (cm^3/g) 0.36 STRENGTH (kg/cm^2) 8.607	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used also for hydrogenation, dehydrogenation and hydroforming.

TYPE OF CATALYST: *NICKEL TUNGSTEN Ni-4301.E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt% Nickel 6 Tungsten 19 CARRIER: silica-alumina FORM: tablets SIZE: Diameter (mm) 0.21 Length (mm) n.a. ABD (g/cm^3) 0.96 SA (m^2/g) 228 PV (cm^3/g) 0.37 STRENGTH (kg/cm^2) 6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The sulphide form of this catalyst is used for hydrogenation where a cracking function is desired. The catalyst is also used for saturation of mono-and polycyclic aromatic compounds, denitrogenation and desulphurization.

ISOMERIZATION

TYPE OF CATALYST: *SELENIUM POWDER*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt% Se min. 99 FORM: powder SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used also for oxidation, hydrogenation and polymer treatment.

CONVERSION OF NORMAL BUTANE TO ISOBUTANE

TYPE OF CATALYST: *TITANUM Ti-0102-T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt% TiO_2 86 CARRIER: alumina FORM: tablets SIZE: Diameter (mm) 3.175 Length (mm) n.a. ABD (g/cm^3) 1.392 SA (m^2/g) 70 PV (cm^3/g) 0.25 STRENGTH (kg/cm^2)6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

ISOMERIZATION

TYPE OF CATALYST: *VANADIA V-0601.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt% V_2O_5 10 CARRIER: high activity alumina FORM: tablets SIZE: n.a. ABD (g/cm^3) 0.96 SA (m^2/g) 115 PV (cm^3/g) 0.28 STRENGTH (kg/cm^2) 9.06	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used also for oxidation.

TYPE OF CATALYST: *PHOSPHORIC ACID H-3301*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt% Phosphoric acid as active component CARRIER: silicic acid FORM: extrusions SIZE: Diameter (mm) 4 or 6 Length (mm) 3—8 or 6—15 ABD (g/cm^3) 0.5—0.9	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The catalyst dried at 110°C (H-3301-t) contains orthophosphoric acid whereas by calcinating at approx. 230°C (H-3301-c) condensed phosphoric acid is formed. It is also applied in hydration and polymerization reactions. *Content* *H-3301-t* (*wt*%) H_3PO_4 18 35 50 P_2O_5 13 25 36 SiO_2 81 64 49 H_2O 5 10 14 *Content* *H-3301-c* (*wt* %) H_3PO_4 18 35 50 P_2O_5 13 27 40 SiO_2 85 70 55 H_2O 2 3 5

ISOMERIZATION OF C_5 AND C_6 HYDROCARBONS

TYPE OF CATALYST: *PLATINUM SINCLAIR BAKER RD-290*

Manufacturer	Characteristics	Operating conditions	Remarks
Kali Chemie Engelhard Katalysatoren GmbH	CONTENT wt% Pt 0.6 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 1.5 Length (mm) 4.5 ABD (g/cm^3) 0.67	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Similar to Sinclair Baker RD-150

ISOMERIZATION OF C_8 HYDROCARBONS TO PRODUCE XYLENES

TYPE OF CATALYST: *PLATINUM ALUMINA ATLANTIC-ENGELHARD OCTAFINING*

Manufacturer	Characteristics	Operating conditions	Remarks
Kali Chemie Engelhard Katalysatoren GmbH	CONTENT wt% Pt 0.4 CARRIER: Al_2O_3 and alumina silicate FORM: extrusions SIZE: Diameter (mm) 1.5 Length (mm) 4.5 ABD (g/cm^3) 0.60	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Elaborated by the Atlantic Refining Co. and Engelhard Industries Inc.

ISOMERIZATION OF XYLENE

TYPE OF CATALYST: *PROMOTED ALUMINA SILICAT KONTAKT 9063*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb. Leuna Werke „Walter Ulbricht“	CONTENT wt% *Promotors:* MO_3 and WoO_3 CARRIER: alumina silicate FORM: tablets SIZE: Diameter (mm) 10 ABD (g/cm^3) 0.9±0.1 STRENGTH (kg/cm^2) 400±75	TEMPERATURE RANGE: 380°—420°C PRESSURE RANGE: 40 atm.	

TYPE OF CATALYST: *PALLADIUM SK-100*

Manufacturer	Characteristics	Operating conditions	Remarks
Union Carbide Corporation, Linde Molecular Sieve Catalysts	CONTENT wt % (anhydrous base) SiO_2 74.0±0.5 Al_2O_3 25.0±0.5 Cl^- $\leqslant$ 0.05 F^- $\leqslant$ 0.05 Pd 0.5±0.02 Na_2O 1.5±0.5 FORM: tablets SIZE: Diameter (mm) 4 Length (mm) 4 ABD (g/cm^3) 0.70 SA (m^2/g) $>$ 500	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for the pentane-hexane isomerization. It is a decationized molecular sieve of Y type.

TYPE OF CATALYST: *PALLADIUM SK-110*

Manufacturer	Characteristics	Operating conditions	Remarks
Union Carbide Corporation, Linde Molecular Sieve Catalysts	CONTENT wt % (anhydrous base) SiO_2 69.0±0.5 Al_2O_3 23.3±0.5 Na_2O 2.4±0.2 Cl^- $\leqslant$0.05 F^- $\leqslant$0.05 Mn 5.2±0.2 Pd 0.5±0.02 FORM: tablets SIZE: Diameter (mm) 4 Length (mm) 4 ABD (g/cm^3) 0.6 SA (m^2/g) $>$500	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is a partially decationized, partially magnese exchanged type Y, used for the pentane-hexane isomerization.

H. Oxidation

CATALYTIC ALUMINA

TYPE OF CATALYST: *ALUMINA TABULAR ALUMINA T-61*

Manufacturer	Characteristics	Operating conditions	Remarks
Aluminium Company of America (ALCOA)	CONTENT wt % Al_2O_3 99.5 Na_2O 0.02 Fe_2O_3 0.06 SO_3 0.09 CaO 0.06 Loss on ignition (1,100°C): 0.0 FORM: granular SIZE:* 4—48 mesh (0.004—0.2 mm) Diameter (mm) 6—12 Length (mm) n.a. ABD (g/cm^3) 1.9—2.2 SA (m^2/g) 0.04 PV (cm^3/g) 0.015	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Tabular alumina is suited for catalytic applications such as oxidation reactions. Fixed bed operations use granular tabular alumina T-61. Powder forms are available for fluid processes. If balled forms are desired, then tabular alumina T-164 would be the product indicated.

* Tyler standard screen scale sieves.

OXIDATION REACTIONS

TYPE OF CATALYST: *COPPER-CHROMIUM C-43*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Copper and chromium co-precipitaded as „copper chromite“ FORM: powder SIZE: passing 325 mesh screen	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for hydrogenation of esters and acids, oxidation and dehydrogenation of organic materials.

OXIDATION OF ETHYLENE TO ETHYLENE OXIDE

TYPE OF CATALYST: *SILVER SYN DOX*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalyst Development Corporation (C.D.C.)	CONTENT wt % Silver CARRIER: refractory oxides FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Oxidation of ethylene using either air or oxygen. It is employed in a recycle process.

OXIDATION OF HYDROCARBONS

TYPE OF CATALYST: *COPPER CHROMITE*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt % Cu 33—34 Cr 29—30 FORM: powder or tablets SIZE: n.a. ABD (g/cm³) 0.35	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Also pellets on Al_2O_3, SiO_3 and pumice stone as carriers.

TYPE OF CATALYST: *NICKEL CHROMITE*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt % Ni 33—34 Cr 27—28 CARRIER: without Al_2O_3, SiO_2 or pumice FORM: powder SIZE: n.a. ABD (g/cm³) 0.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Available also as tablets.

OXIDATION REACTIONS

TYPE OF CATALYST: *MANGANESE Mn-0201.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % MnO_2 12 CARRIER: activated alumina FORM: tablets SIZE: Diameter (mm) 3 Length (mm) n.a. ABD (g/cm³) 1.12 SA (m²/g) 69 PV (cm³/g) 0.23 STRENGTH, (kg/cm²) 15.8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *MANGANESE Mn-0501.G6-10*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Manganese 2 (present in oxide form) CARRIER: silica FORM: granules SIZE: Diameter (mm) 6—10 ABD (g/cm³) 0.48 SA (m²/g) 258 PV (cm³/g) 0.97	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *SELENIUM POWDER*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Se min. 99	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See chapter on isomerization.

TYPE OF CATALYST: *SILVER Ag-0103.E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Reduced silver 4 CARRIER: inert alumina FORM: extrusions SIZE: Diameter (mm) 3 Length (mm) n.a. ABD (g/cm³) 1.13 SA (m²/g) 0.5 PV (cm³/g) 0.03	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *SILVER Ag-0105.E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Reduced silver 8 CARRIER: inert alumina FORM: extrusions SIZE: Diameter (mm) 3 Length (mm) n.a. ABD (g/cm^3) 1.36 SA (m^2/g) 1.5 PV (cm^3/g) 0.07	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *SILVER Ag-0107.E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Reduced silver 11 CARRIER: inert support FORM: extrusions SIZE: Diameter (mm) 3 Length (mm) n.a. ABD (g/cm^3) 1.4 SA (m^2/g) 0.5 PV (cm^3/g) 0.01	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *VANADIUM V-0301.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % V_2O_5 10 CARRIER: activated alumina FORM: tablets SIZE: Diameter (mm) 3 Length (mm) n.a. ABD (g/cm^3) 0.95 SA (m^2/g) 78 PV (cm^3/g) 0.33 STRENGTH (kg/cm^2) 4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *VANADIUM V-0501.S*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % V_2O_5 10 CARRIER: inert alumina FORM: spheres SIZE: Diameter (mm) 6 Length (mm) n.a. ABD (g/cm^3) 1.28 SA (m^2/g) 1	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *VANADIUM V-0601.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % V_2O_5 10 CARRIER: high activity alumina FORM: tablets SIZE: Diameter (mm) 3 Length (mm) n.a. ABD (g/cm^3) 0.9 SA (m^2/g) 115 PV (cm^3/g) 0.28 STRENTGH (kg/cm^2) 12	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *VANADIUM V-0701.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % V_2O_5 10 CARRIER: silica alumina FORM: tablets SIZE: Diameter (mm) 3.1 Length (mm) n.a. ABD (g/cm^3) 0.9 SA (m^2/g) 139 PV (cm^3/g) 0.45 STRENGTH (kg/cm^2) 10.4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *VANADIUM V-0802.S*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % V_2O_5 10 CARRIER: alumina FORM: spheres SIZE: Diameter (mm) 3.2 Length (mm) n.a. ABD (g/cm^3) 0.98 SA (m^2/g) 214 PV (cm^3/g) 0.34 STRENGTH (kg/cm^2) 12.23	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *VANADIUM V-1001.E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % V_2O_5 6 MoO_3 3 CARRIER: inert alpha alumina FORM: extrusions SIZE: Diameter (mm) 5 Length (mm) n.a. ABD (g/cm^3) 1.13 SA (m^2/g) 1	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *VANADIUM V-1002.E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % V_2O_5 6 MoO_3 3 CARRIER: inert alpha alumina FORM: extrusions SIZE: Diameter (mm) 5 Length (mm) n.a. ABD (g/cm^3) 1.13 SA (m^2/g) 1	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

PARTIAL OXIDATION OF HYDROCARBONS

TYPE OF CATALYST: *NICKEL N-174*

Manufacturer	Characteristics	Operating conditions	Remarks
W.C.Heraeus GmbH	CONTENT wt % Nickel CARRIER: special FORM: cylindrical rings SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

SULPHUR RECOVERY (CLAUS PROCESS)

TYPE OF CATALYST: *CHROMIUM KONTAKT 6301*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT n.a. CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 8 Length (mm) 8—12	TEMPERATURE RANGE: 280°—360°C PRESSURE RANGE: n.a.	Chrome is present as chrome oxide III and VI.

TYPE OF CATALYST: *ALUMINA-POROCEL SULPHUR RECOVERY CATALYST*

Manufacturer	Characteristics	Operating conditions	Remarks
Porocel Corporation, Engelhard Minerals and Chemicals Corp.	CONTENT wt % Alumina 88—92 CARRIER: high alumina, activable bauxite FORM: n.a. SIZE: (mesh grade) 2/4 and 4/8 ABD (g/cm^3) 0.82—0.86 SA (m^2/g) 220—240 STRENGTH (kg/cm^2) 0.82—0.86	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *ALUMINA CR*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Al_2O_5 >95 Na_2O <0.1 Loss on ignition (1000°C): 4 CARRIER: high purity alumina FORM: balls SIZE: Diameter (mm) 5—10 Length (mm) n.a. ABD (g/cm^3) 0.75 SA (m^2/g) 300 STRENGTH (kg/cm^2) 15	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for sulphur recovery from H_2S. Available as: CRS-21 and CRS-32

TYPE OF CATALYST: *ALUMINA DR*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Al_2O_3 >95 Total Na_2O content <0.5 Loss on ignition (1000°C): 4 CARRIER: highly pure alumina FORM: balls SIZE: Diameter (mm) 5—10 ABD (g/cm^3) 0.75 SA (m^2/g) 300 STRENGTH (kg/cm^2) 15	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a. LIFE: longer than 6 years	Used for sulphur recovery from H_2S.

OXIDATION IN LIQUID PHASE

TYPE OF CATALYST: *PALLADIUM ST-800*

Manufacturer	Characteristics	Operating conditions	Remarks
Sakaj Chemical Industry Co. Ltd	CONTENT wt % Palladium CARRIER: n.a. FORM: tablets SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

ETHYLENE OXIDE PRODUCTION

TYPE OF CATALYST: *SHELL 809/829*

Manufacturer	Characteristics	Operating conditions	Remarks
Shell Chemical Co.	CONTENT n.a. CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

OXIDATION OF ALCOHOLS TO ALDEHYDES

TYPE OF CATALYST: *COPPER 29028*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % Copper carbonate 6 CARRIER: silica FORM: granules SIZE (mm) 4—10 mesh SA (m^2/g) 4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used for selective hydrogenation of aromatic nitro compounds to aromatic amines.

OXIDATION REACTIONS

TYPE OF CATALYST: *MANGANESE 25139*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % MnO_2 19 CARRIER: alumina FORM: pellets SIZE: Diameter (mm) 3 Length (mm) 3 SA (m^2/g) approx. 70	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

OXIDATION OF PRIMARY ALCOHOLS TO ALDEHYDES

TYPE OF CATALYST: *MANGANESE 35136*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % Manganese dioxide activated CARRIER: n.a. FORM: powder SIZE: n.a. SA (m^2/g) high	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Applications: Oxidation of secondary alcohols to ketones.

OXIDATION REACTIONS

TYPE OF CATALYST: *SILVER 47250; 47700*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % Ag 4 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 3 SA (m^2/g) approx. 1	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Applications: Vapour phase oxidation of alcohols to aldehydes. Hydration of ethylene oxide. 47700 is a Raney silver catalyst, available as 50% slurry in water.

VAPOUR PHASE OXIDATION OF HYDROCARBONS

TYPE OF CATALYST: *VANADIUM 23.400; 23.409; 23.411*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % V_2O_5 (a) 23.400 10 (b) 23.409 2—3 (c) 23.411 4 CARRIER: (a) alumina (b) silica fibres (c) silica gel FORM: (a) pellets; (b) long fibres; (c) fluidized powder SIZE: n.a. SA (m^2/g) (a) 78; (b) 62; (c) high	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

I. Polymerization

POLYMERIZATION

TYPE OF CATALYST: *ANHYDROUS ALUMINIUM CHLORIDE*

Manufacturer	Characteristics	Operating conditions	Remarks
Allied Chemicals	CONTENT See chapter on alkylation	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Low boiling hydrocarbons gases are converted into lubricants and motor oils.

POLYMERIZATION OF ISOBUTYLENE

TYPE OF CATALYST: *PHOSPHORIC ACID C-82*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Phosphoric acid CARRIER: activated carbon FORM: granules SIZE (mm): 4—12 mesh	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

POLYMERIZATION OF OLEFINS (PROPYLENES AND BUTYLENES)

TYPE OF CATALYST: *PHOSPHORIC ACID C-84*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Acid content (as H_3PO_4 100%): available 19—26 total 67—75 CARRIER: Kieselguhr FORM: spheres SIZE: Diameter (mm) 5—6; 6—8 Length (mm) n.a. ABD (g/cm^3) 0.88 STRENGTH (kg/cm^2) 13.6; 15.86	TEMPERATURE RANGE: 149°—232°C PRESSURE RANGE: 28—84 atm.	Another large and increasing application is in the alkylation of benzene and propylene to produce cumene. In addition, there is a sizeable use of this catalyst for selectively producing linear olefins. The catalysts operate excellently in either isothermal, tubular reactors or adiabatic multibed chamber units (C-84-1) and (C-84-2). Certain compounds that may be present in the feed can have a deleterious effect on catalyst performance: nitrogen, sulphur, caustic dienes and acetylenes.

MANUFACTURE OF LIQUID POLYBUTENE

TYPE OF CATALYST: *ANHYDROUS ALUMINIUM CHLORIDE*

Manufacturer	Characteristics	Operating conditions	Remarks
Davison Chemical Division, W.R. Grace and Co.	CONTENT wt % See chapter on alkylation	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Copolymerization of isobutylene and isoprene to produce butyl rubber. Low molecular weight thermoplastic resins. From petroleum refinery C_4 hydrocarbon steams containing isobutylene.

POLYMERIZATION REACTIONS

TYPE OF CATALYST: *H_3PO_4 ACTIMET 291*

Manufacturer	Characteristics	Operating conditions	Remarks
Doduco	CONTENT wt % Phosphoric acid CARRIER: SiO_2 FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used also for hydration and isomerization.

CROSSLINKING AGENT FOR POLYMERS

TYPE OF CATALYST: *CHROMIUM CHLORIDE*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Chromium chloride CARRIER: n.a. FORM: crystals SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used as crosslinking agent for polymers in oil drilling muds.

POLYMERIZATION REACTIONS

TYPE OF CATALYST: *PHOSPHORIC ACID CATALYST H-330t*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % See chapter on isomerization	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

POLYMERIZATION OF C_3 AND C_4 FOR THE PRODUCTION OF HEPTENES

TYPE OF CATALYST: *P_2O_5 AP-792; AP-794*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % P_2O_5 CARRIER: SiO_2 FORM: extrusions SIZE: Diameter (mm) 4 Length (mm) n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	AP-792 is used for the alkylation of benzene by propylene. AP-794 is used for the polymerization of C_3 and C_4 cuts for the production of nonenes, dodecenes, gasolines.

POLYMERIZATION REACTIONS

TYPE OF CATALYST: *ANTIMONY TRICHLORIDE*

Manufacturer	Characteristics	Operating conditions	Remarks
Stauffer Chemical Company	CONTENT wt % Antimony trichloride FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used in the manufacture of antimony compounds, match heads and pyrotechnics; as a catalyst in fluorocarbon preparation, rubber polymerization, izomerization, alkylation and cracking; as a mordant and fireproofing for textile and for bronzing of iron and blackening of zinc.

POLYMERIZATION OF OLEFINS

TYPE OF CATALYST: *VANADIUM TRICHLORIDE*

Manufacturer	Characteristics	Operating conditions	Remarks
Stauffer Chemical Company	CONTENT wt % Vanadium trichloride CARRIER: n.a. FORM: powder SIZE: n.a. DENSITY (g/cm^3) 0.72—0.96	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used as an olefin polymerization catalyst in combination with an aluminium alkyl and in the preparation of vanadium dichloride and organovanadium compounds.

POLYMERIZATION

TYPE OF CATALYST: *TITANIUM TRICHLORIDE TAC*

Manufacturer	Characteristics	Operating conditions	Remarks
Toho Titanium Co. Ltd.	CONTENT Molecular ratio $TiCl_3$: $AlCl_3$ 3:1 FORM: powder SIZE: n.a. ABD (g/cm^3) 0.7—1.1 TS (°C) 150 (in an inert atmosphere)	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Types of TAC: TAC 100 TAC 101 (standard TAC 121 type) TAC 131 TAC 141 TAC 191 Used for the production of polypropylene. The catalyst is obtained by a special treatment, given to raw product, obtained by reduction of titanium tetrachloride with metallic aluminium. True specific gravity: 2.6 g/cm^3.

PRODUCTION OF POLYETHYLENE TEREPHTHALATE

TYPE OF CATALYST: *ANTIMONY M&T CATALYST S21*

Manufacturer	Characteristics	Operating conditions	Remarks
M&T International N.V.	CONTENT wt % Antimony $\geqslant$ 38 Iron max $\leqslant$ 100 ppm Sulphate max. $\leqslant$ 100 ppm Chloride max. 100 ppm FORM: white to off-white moist crystalyne solid ABD (g/cm^3) 0.1	TEMPERATURE RANGE: 124°—147°C PRESSURE RANGE: n.a. PURITY: $\geqslant$ 95% STABILITY: hydrolytically unstable	It is a polycondensation catalyst for batch and continuous operations, for fast generation of high intrinsic viscosity polymer.

J. Purification

Purification of gases
Purification by combustion
Purification by hydrotreating
Denitrogenation
Desoxygenation

Purification of gases

CATALYTIC ALUMINA

TYPE OF CATALYST: *ACTIVATED ALUMINA F-7*

Manufacturer	Characteristics	Operating conditions	Remarks
Aluminium Company of America (ALCOA)	CONTENT wt % Al_2O_3 84.0 Na_2O 0.90 Fe_2O_3 0.08 SiO_2 0.09 Nickel formate 2.5 FORM: granular SIZE: Diameter (mm) 12.7—25.4 25.4—50.8 ABD (g/cm^3) 0.83—0.82	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	F-7 is made by impregnating F-1 with approx. 2.5% nickel formate. It is used as a catalyst for production of controlled atmospheres in heat treating furnaces.

PURIFICATION

TYPE OF CATALYST: *COBALT MOLYBDENUM BASF M-8—10*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % MoO_3 13.5 CoO 5 SiO_2 2 SO_4 3 Na_2O 0.7 Remainders: carriers CARRIER: Al_2O_3 FORM: extrusions; pellets SIZE: Diameter (mm) 1.5 and 3; 3 and 5 Length (mm) 3; 5 ABD (g/cm^3) 0.65; 0.68 SA (BET) (m^2/g) 220 PV (cm^3/g) 0.5 (titration method) STRENGTH: Extrusions: at right angles to direction of extrusions: 1.6 kg/cm^2 Pellets: bursting pressure at the faces: 300 kg/cm^2 TS (°C) up to 500	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Pressure hydrogen refining of petroleum derivatives of all types and boiling ranges, for reduction of sulphur, nitrogen and oxygen compounds, to remove metallic impurities and for hydrogenation of unsaturated compounds.

TYPE OF CATALYST: *MOLYBDENUM BASF M-8—30*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % MoO_3 15 SO_4 3 Na_2O 0.7 Remainder: Al_2O_3 Loss on ignition: 2 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 5 ABD (g/cm^3) 0.66 SA (BET) (m^2/g) 200 PV (cm^3/g) 0.5 TS (°C) up to about 500	TEMPERATURE RANGE: 300°—400°C PRESSURE RANGE: n.a.	Pressure refining of crude benzene.

TYPE OF CATALYST: *NICKEL-MOLYBDENUM C 20—7*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT n.a. CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 3.175; 1.6 Length (mm) n.a. ABD (g/cm^3) 0.8	TEMPERATURE RANGE: 288°—399°C PRESSURE RANGE: 7—105 atm.	Used for hydrotreating, hydrodenitrification, stabilization and saturation of polyaromatics in petroleum fractions. Available also as C 20-8.

GAS PURIFICATION

TYPE OF CATALYST: *COPPER CHEZA 43—00*

Manufacturer	Characteristics	Operating conditions	Remarks
Chemical Works of CSF	CONTENT wt % Cu 15 Na_2O max. 0.1 Loss on ignition (650°C): max. 10 CARRIER: Al_2O_3 FORM: tablets SIZE: Diameter (mm) 10 Length (mm) 6—10 ABD (g/cm^3) 0.7 STRENGTH (kg/cm^2) 150	TEMPERATURE RANGE: 300°—600°C PRESSURE RANGE: n.a. SPACE VELOCITY (VHSV): 500 — 1,000 h^{-1}	It is used for catalytic burning flammable gases in inert gases by the addition of oxygen at least a minimum stoichiometric ratio to the present flammable gases.

TYPE OF CATALYST: *NICKEL-TUNGSTEN CHEZA 34—00*

Manufacturer	Characteristics	Operating conditions	Remarks
Chemical Works of CSF	CONTENT wt % WO_3 25—30 NiO 5—7 Na_2O 0.1 CARRIER: Al_2O_3 FORM: tablets SIZE: Diameter (mm) 10 Length (mm) 0—20 ABD (g/cm^3) 0.9 STRENGTH (kg/cm^2) 200	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	For the refining of hydrocarbons from oxygen, nitrogen, sulphur, arsen compounds.

CATALYTIC AIR PURIFICATION

TYPE OF CATALYST: *DOPED Cu-CHROMIC OXIDE A-38.MK*			
Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT n.a. CARRIER: γ Al_2O_3 FORM: balls SIZE: Diameter (mm) 4—6 Length (mm) n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The other use is combustion of gases.

GAS PURIFICATION, e.g. OF H_2, N_2 AND NOBLE GASES

TYPE OF CATALYST: *PALLADIUM E-56.H PURICAT*			
Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt% Palladium CARRIER: aluminium silicate FORM: tablets SIZE: Diameter (mm) 5 Length (mm) 3 ABD (g/cm^3) 0.7 STRENGTH (kg/cm^2) 50	TEMPERATURE RANGE: room temperature to 400°C PRESSURE RANGE: n.a. LIFE: 10,000 hours	Detonating gas reaction at room temperature (production of protective gas); H_2O_2 recombination in boiling water-reactors. Precious metal content usually 0.1%, 0.15%, 1%, 5% and 10%.

AIR PURIFICATION

TYPE OF CATALYST: *PALLADIUM E-293.P*			
Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt% Palladium CARRIER: Al_2O_3 FORM: bodies SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	For purification of air (Decatox^R process). Precious metal content usually 0.1%, 0.15%, 1%, 5% and 10%.

PURIFICATION OF ORGANIC GASES AND VAPOURS

TYPE OF CATALYST: *PLATINUM PLATINUM ASBESTOS*

Manufacturer	Characteristics	Operating conditions	Remarks
Doduco	CONTENT wt% Platinum CARRIER: asbestos FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

PURIFICATION OF GAS STREAM

TYPE OF CATALYST: *PALLADIUM G-75*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt% Palladium CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See chapter on hydrogenation of olefinic bonds.

TYPE OF CATALYST: *PALLADIUM G-77*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt% Palladium CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See chapter on hydrogenation of acetylene, diolefins.

TYPE OF CATALYST: *PLATINUM G-43*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Pt 0.1 Ni 3 CARRIER: alumina FORM: tablets SIZE: Diameter (mm) 5 Length (mm) 5 ABD (g/cm^3) 1 SA (m^2/g) 212 STRENGTH (kg/cm^2) (DWL) no less than 15	TEMPERATURE RANGE: 860°C PRESSURE RANGE: n.a. LIFE: more than 8 years	Suitable for removal of higher concentrations of oxygen, hydrogen and nitrogen oxide.

GAS PURIFICATION

TYPE OF CATALYST: *MOLECULAR SIEVES ALITE 150; 180*

Manufacturer	Characteristics	Operating conditions	Remarks
Grande Paroisse	CONTENT n.a. CARRIER: n.a. FORM: powder; granules SIZE: Diameter (mm) (granules) 1.8—3 ABD (g/cm^3) 0.850 SA (m^2/g) (powder) 500 Pore diameter: 6 Å	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See Alite 1030. They possess a structure similar to a natural zeolite-mordenite (Alite 150). Alite 180 is the acid form of the Alite 150.

TYPE OF CATALYST: *MOLECULAR SIEVES ALITE 1030, 1040, 1050*

Manufacturer	Characteristics	Operating conditions	Remarks
Grande Paroisse	CONTENT wt % Molar ratio Si/Al: 2 SiO_2 41—43 Al_2O_3 34—35.5 Na_2O 3.5—17 CaO 15—1.5 CARRIER: n.a. FORM: extrusions SIZE: Diameter (mm) 1.6—3 Length (mm) n.a. STRENGTH (kg/cm^2) 8—12 Pore diameter: 3—5 Å	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	They are molecular sieves, a synthetic zeolite type A. They are used in fluid bed or fixed bed processes. Applications: air purification; as catalyst carrier; for the reforming, hydrocracking and cracking processes.

PURIFICATION OF GAS STREAM

TYPE OF CATALYST: *COPPER Cu-1900.S*			
Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt% CuO 5 CARRIER: high fired inert alumina FORM: spheres SIZE: Diameter (mm) 1.2 SA (m^2/g) 1 PV (cm^3/g) 0.07	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Removal of oxygen, carbon monoxide or hydrogen from gas streams.

PURIFICATION

TYPE OF CATALYST: *NICKEL Ni-4303.E*			
Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt% Nickel 6 Tungsten 19 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 2.1 Length (mm) n.a. ABD (g/cm^3) 0.8 SA (m^2/g) 152 PV (cm^3/g) 0.54	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for the pretreatment of hydrocracker feedstocks, denitrification and desulphurization.

TYPE OF CATALYST: *NICKEL TUNGSTEN Ni-4301.E*			
Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt% Nickel 6 Tungsten 19 CARRIER: silica-alumina FORM: extrusions SIZE: Diameter (mm) 2.1 Length (mm) n.a. ABD (g/cm^3) 0.96 SA (m^2/g) 228 PV (cm^3/g) 0.37	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for the pretreatment of hydrocracker feedstocks, saturation of cyclic aromatic compounds, denitrogenation and desulphurization.

TYPE OF CATALYST: *NICKEL TUNGSTEN Ni-4309.E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt% Nickel 5 Tungsten 10 Boron 3 (promotor) CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 1.6; 2.1; 3.2 ABD (g/cm^3) 0.9 SA (m^2/g) 150 PV (cm^3/g) 0.3	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Pressure hydrogen refining of petroleum derivatives of all types and boiling ranges; for reduction of sulphur, nitrogen and oxygen compounds; for removal of metallic impurities; for hydrogenation of unsaturated compounds. Used for high pressure catcracker pretreatment.

GAS PURIFICATION (THE DEOXO PRINCIPLE)

TYPE OF CATALYST: *DEOXO D; DN; DS; M*

Manufacturer	Characteristics	Operating conditions	Remarks
W.C.Heraeus GmbH	CONTENT n.a. CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	D, DN — for removal of oxygen from hydrogen or from gases containing hydrogen. DS — same as D, DN, but for wet gases. M — for removal of hydrogen, from oxygen or from gases containing oxygen.

GAS PURIFICATION

TYPE OF CATALYST: *L; D; R; P; T; S*

Manufacturer	Characteristics	Operating conditions	Remarks
W.C. Heraeus GmbH	CONTENT Noble metals, noble metals mixture or non-noble metals CARRIER: ceramic FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Application: L is used in lacquer plants; D is used as purifier of Diesel exhaust gases; R is used for gas purification; P is used in impregnating plants; T is used as a dryer; S has diverse applications.

EXHAUST GAS PURIFICATION

TYPE OF CATALYST: *NEW HONEYCOMB-SHAPED CATALYST*

Manufacturer	Characteristics	Operating conditions	Remarks
W.C. Heraeus GmbH	CONTENT n.a. CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: 600°—750°C PRESSURE RANGE: n.a.	

PURIFICATION

TYPE OF CATALYST: *NICKEL RCH-52/35.TS*

Manufacturer	Characteristics	Operating conditions	Remarks
Farbwerke Hoechst AG	CONTENT wt % Ni 52 CARRIER: Kieselguhr FORM: powder; tablets SIZE: Diameter (mm) 6 Length (mm) 5 ABD (g/cm^3) 0.5; 1	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Refining of feedstocks which contain poisons in big quantities. See also RCH-50/35.TS.

CHLORINE REMOVAL

TYPE OF CATALYST: *ICI-59—1; 59—3*

Manufacturer	Characteristics	Operating conditions	Remarks
Imperial Chemical Industries Ltd	CONTENT n.a. CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See chapter on desulphurization. Guards for low temperature CO shift.

TYPE OF CATALYST: *PLATINUM KCE-3010.A*

Manufacturer	Characteristics	Operating conditions	Remarks
Kali Chemie Engelhard	CONTENT wt % Platinum CARRIER: n.a. FORM: extrusions SIZE: Diameter (mm) 4 Length (mm) 10 ABD (g/cm^3) 1	TEMPERATURE RANGE: 400°—800°C PRESSURE RANGE: n.a.	See KCE-3795.A

TYPE OF CATALYST: *PLATINUM KCE-3366*

Manufacturer	Characteristics	Operating conditions	Remarks
Kali Chemie Engelhard	CONTENT wt % Pt 0.1 CARRIER: special FORM: extrusions SIZE: Diameter (mm) 2.5 Length (mm) 2.5 ABD (g/cm^3) 0.9	TEMPERATURE RANGE: 400°—800°C PRESSURE RANGE: n.a.	See KCE-3795.A

TYPE OF CATALYST: *PLATINUM KCE-3778; KCE-3778.A*

Manufacturer	Characteristics	Operating conditions	Remarks
Kali Chemie Engelhard	CONTENT wt % Pt 0.05 CARRIER: clay/alumina FORM: extrusions SIZE: Diameter (mm) 4 Length (mm) 4—10 ABD (g/cm^3) 1—1.07	TEMPERATURE RANGE: 400°—800°C PRESSURE RANGE: n.a.	See KCE-3795.A

TYPE OF CATALYST: *PLATINUM KCE-3795; KCE-3795A*

Manufacturer	Characteristics	Operating conditions	Remarks
Kali Chemie Engelhard	CONTENT wt % Pt 0.1 CARRIER: clay/alumina FORM: extrusions SIZE: Diameter (mm) 4 Length (mm) 4—10 ABD (g/cm^3) 1	TEMPERATURE RANGE: 400°—800°C PRESSURE RANGE: n.a.	The KCE catalysts are used for catalytic removal of CO_2, CO, H_2, H_2S (burning to SO_2), organic sulphur, ammonia, amines, cyanhydric acid.

EXHAUST GAS PURIFICATION

TYPE OF CATALYST: *PLATINUM PTX*

Manufacturer	Characteristics	Operating conditions	Remarks
Kali Chemie Engelhard	CONTENT wt % Pt CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Also PTX.4 PTX.5 PTX.6

PURIFICATION OF GASES

TYPE OF CATALYST: *COPPER KONTAKT 4492*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT wt % Copper oxide CARRIER: magnesium silicate FORM: tablets SIZE: Diameter (mm) 5 Length (mm) n.a. ABD (g/cm^3) 0.95 STRENGTH (kg/cm^2) 450±50	TEMPERATURE RANGE: <120°C PRESSURE RANGE: n.a.	Removal of traces of O_2 and CO. It can also be used in hydrogenation and desulphurization process.

TYPE OF CATALYST: *NICKEL KONTAKT 6525*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT wt % Nickel oxide CARRIER: alumina FORM: tablets SIZE: Diameter (mm) 5 Length (mm) n.a. ABD (g/cm^3) 0.7—1.1 STRENGTH (kg/cm^2) 80—100	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Removal of traces of O_2 and CO from Ar, N_2, CO_2.

PURIFICATION OF EXHAUST GASES

TYPE OF CATALYST: *PLATINUM KONTAKT 7713*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT wt % Platinum CARRIER: γ alumina FORM: spheres SIZE: Diameter (mm) 4—6 Length (mm) n.a. ABD (g/cm^3) 0.75—0.85 SA (m^2/g) 170—200 PV (cm^3/g) 0.3—0.5 STRENGTH (kg/cm^2) 7	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Also Kontakt 7713/TK. Spheres of 2—4 mm diameter: ABD (g/cm^3) 0.58—0.65 SA (m^2/g) 170—200 PV (cm^3/g) 0.3—0.5 STRENGTH (kg/cm^2) 12.

PURIFICATION OF GASES

TYPE OF CATALYST: *ADSORBENT MASS MIP-2*

Manufacturer	Characteristics	Operating conditions	Remarks
Montedison S.p.A.	CONTENT wt % Sulphur 10 Activated carbon 90 CARRIER: activated carbon FORM: pellets SIZE: (mm) 2×4 ABD (g/cm^3) 0.56 SA (m^2/g) 750	TEMPERATURE RANGE: 0°—100°C PRESSURE RANGE: 1—30 atm. SPACE VELOCITY: (VHSV) 1000 — 10000 h^{-1}	Adsorbent for the mercury removal from gases.

TYPE OF CATALYST: *ADSORBENT MASS MIS-2*

Manufacturer	Characteristics	Operating conditions	Remarks
Montedison S.p.A.	CONTENT wt % Sulphur 10 Activated carbon 90 CARRIER: activated carbon FORM: extrusions SIZE: Diameter (mm) 4 Length (mm) 6—9 ABD (g/cm^3) 0.40 SA (m^2/g) 1,100	TEMPERATURE RANGE: 0°—100°C PRESSURE RANGE: 1—30 atm. SPACE VELOCITY (VHSV): 1,000—10,000 h^{-1}	Adsorbent for the mercury removal from gases.

PURIFICATION OF WASTE GASES

TYPE OF CATALYST: *COPPER DO-3*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Copper oxide CARRIER: alumina FORM: balls SIZE: Diameter (mm) 2—4; 4—6 Length (mm) n.a. ABD (g/cm^3) 0.9 SA (m^2/g) 130 PV (cm^3/g) 0.5 STRENGTH (kg/cm^2) > 10	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Elimination of O_2 and/or CO in a gas containing H_2. Methanation.

PURIFICATION OF INDUSTRIAL WASTE GASES

TYPE OF CATALYST: *COPPER PC-183 PROTOXAL*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Copper oxide CARRIER: alumina FORM: balls SIZE: Diameter (mm) 2—4; 4—6 Length (mm) n.a. ABD (g/cm^3) 0.7 SA (m^2/g) 130 PV (cm^3/g) 0.6 STRENGTH (kg/cm^2) >5	TEMPERATURE RANGE: 100°—450°C PRESSURE RANGE: n.a.	It is also used for the elimination of solvents and for methanation.

PURIFICATION OF WASTE GASES

TYPE OF CATALYST: *COPPER-PALLADIUM DO-4*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Palladium Copper oxide CARRIER: alumina FORM: balls SIZE: Diameter (mm) 2—4; 4—6 Length (mm) n.a. ABD (g/cm^3) 0.7 SA (m^2/g) 250 PV (cm^3/g) 0.6 STRENGTH (kg/cm^2) >10	TEMPERATURE RANGE: 70°—225°C PRESSURE RANGE: n.a.	DO-5 has the same use. Elimination of CO and H_2 in a gas with injection of O_2. Methanation.

PURIFICATION OF INDUSTRIAL WASTE GASES

TYPE OF CATALYST: *CHROMIUM PC-173 PROTOXAL*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Cr_2O_3 CARRIER: alumina FORM: balls SIZE: Diameter (mm) 2—4; 4—6 Length (mm) n.a. ABD (g/cm^3) 0.7 SA (m^2/g) 260 PV (cm^3/g) 0.6 STRENGTH (kg/cm^2) >5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Uses: Elimination of hydrocarbons-post combustion of engine gases. Methanation.

TYPE OF CATALYST: *MANGANESE PC-193 PROTOXAL*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Mn_2O_3 CARRIER: alumina FORM: balls SIZE: Diameter (mm) 2—4; 4—6 Length (mm) n.a. ABD (g/cm^3) 0.7 SA (m^2/g) 130 PV (cm^3/g) 0.6 STRENGTH (kg/cm^2) > 5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Elimination of hydrocarbons.

PURIFICATION OF WASTE GASES

TYPE OF CATALYST: *NICKEL PALLADIUM PC-247*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Nickel oxide Palladium CARRIER: alumina FORM: balls SIZE: Diameter (mm) 6—10 Length (mm) n.a. ABD (g/cm^3) 0.75 SA (m^2/g) 30 PV (cm^3/g) 0.5 STRENGTH (kg/cm^2) >15	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Special for aluminium plant waste gases methanation.

TYPE OF CATALYST: *PALLADIUM DO-2*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Palladium CARRIER: alumina FORM: balls SIZE: Diameter (mm) 2—5; 5—8 Length (mm) n.a. ABD (g/cm^3) 0.75 SA (m^2/g) 300 PV (cm^3/g) 0.5 STRENGTH (kg/cm^2) >10	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Elimination of O_2 and/or H_2 in a gas with less than 5000 ppm CO. Methanation.

DEODORIZATION

TYPE OF CATALYST: *BASE METALS ST-500*

Manufacturer	Characteristics	Operating conditions	Remarks
Sakaj Chemical Industry Co. Ltd.	CONTENT Base metals, carrier and occasionally noble metals CARRIER: n.a FORM: tablets SIZE: n.a.	TEMPERATURE RANGE: 150°—400°C PRESSURE RANGE: n.a.	Use for deodorizing of exhausting solvent vapour from baking finish, printing baking enamel wire, adhesive process; deodorizing of odorous gas from sewerage, oil and fats, plant, craft pulp plant.

FOR CATALYTIC ODOUR CONTROL INSTALLATIONS

TYPE OF CATALYST: *PLATINUM FAMILY ALL METAL CATALYSTS*

Manufacturer	Characteristics	Operating conditions	Remarks
UOP, Air Correction Division	CONTENT Metals of the platinum family firmly bonded on the support ribbon CARRIER: thin alloy ribbon which is crimped FORM: mat form SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a. LIFE: 3—5 years	All metal catalysts elements destroy odours by converting oven exhaust fumes to clean, odourless gases in a single-step combustion reaction.

PURIFICATION OF GASES

TYPE OF CATALYST: *ZEOSORB 3A; 4A; 5A; 10X; 13X; 51M*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Farbenfabrik Wolfen	CONTENT Synthetic zeolites (molecular sieves) Metal alumo-silicates CARRIER: n.a. FORM: extrusions, powders, balls SIZE (mm): powder: 10^{-3} balls: 1.6—2.2; 2.2—2.5; extrusions: 2, 3, 4, 5, 6 Length (mm) 5—15 ABD (g/cm^3) 0.5—0.8 STRENGTH (kg/cm^2) 20—263	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Drying agents, adsorbents, gas separation by selective adsorption, purification of gaseous hydrocarbons and inert gases. Selective separation of normal paraffins C_5—C_8 from benzene fractions. Desulphurization agents.

Purification by combustion

FLAMELESS GAS COMBUSTION (INFRARED LAMP)

TYPE OF CATALYST: *Pd E-71.P*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT n.a. CARRIER: asbestos FORM: fibre SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Precious metal content usually 0.1%, 0.15%, 1%, 5% and 10%.

TYPE OF CATALYST: *Pt F-71.P*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT n.a. CARRIER: asbestos FORM: fibre SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Precious metal content usually 0.1%, 0.15%, 1%, 5% and 10%.

COMBUSTION OF GASES AND VAPOURS AT HIGH TEMPERATURE

TYPE OF CATALYST: *PALLADIUM ACTIPAL*^{R}

Manufacturer	Characteristics	Operating conditions	Remarks
Doduco	CONTENT n.a. CARRIER: n.a. FORM: Raschig rings SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

COMBUSTION AT HIGH TEMPERATURE

TYPE OF CATALYST: *PALLADIUM PALLADIUM-ASBESTOS*

Manufacturer	Characteristics	Operating conditions	Remarks
Doduco	CONTENT n.a. CARRIER: asbestos FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

Purification by hydrotreating

PURIFICATION BY HYDROTREATING

TYPE OF CATALYST: *NICKEL MOLYBDENUM HDS-3; HDS-3A*

Manufacturer	Characteristics	Operating conditions	Remarks
Cyanamid International	CONTENT wt % NiO 3.0—4.0 MoO_3 14.5—16.0 Na_2O max. 0.04 Loss on ignition: max. 2.0 CARRIER: n.a. FORM: extrusions SIZE: Diameter (mm) 1.5—3 ABD (g/cm^3) 0.6—0.7 SA (m^2/g) 180 PV (cm^3/g) 0.6 STRENGTH (kg/cm^2) 6.7—7.7	TEMPERATURE RANGE: 200°—400°C PRESSURE RANGE: 10—60 atm. SPACE VELOCITY (LHSV): 5 h^{-1}	Used for removal of nitrogen and polyaromatics saturation. It is particularly adapted for hydrotreating of naphthas containing nitrogen. Selective for polyaromatics, olefins and nitrogen removal.

TYPE OF CATALYST: *NICKEL MOLYBDENUM AERO HDS-9; HDS-9A*

Manufacturer	Characteristics	Operating conditions	Remarks
Cyanamid International	CONTENT wt % NiO 3.0—4.0 MoO_3 17.5—18.5 Na_2O max. 0.04 Fe max. 0.05 Loss on ignition: max. 2.0 CARRIER: n.a. FORM: extrusions SIZE: Diameter (mm) 1.2—2.5 Length (mm) n.a. ABD (g/cm^3) 0.7—0.8 STRENGTH (kg/cm^2) min. 5.5	TEMPERATURE RANGE: 300°—370°C PRESSURE RANGE: 50 atm.	Applications: Recommended for: (a) Processing stocks containing high percentages of nitrogen; (b) Pretreatment of reformer feedstock when quality demands are stringent; (c) Cocker effluents; (d) Cat-Cracker feed preparation; (e) Turbine fuel smoke point improvement; (f) Selected lube oil processing situations; (g) New ventures.

DECOMPOSITION OF HYDROCARBONS

TYPE OF CATALYST: *ZIRCONIUM GPE-5*

Manufacturer	Characteristics	Operating conditions	Remarks
Grande Paroisse	CONTENT wt % ZrO_2—MgO and additives CARRIER: alumina FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for the decomposition of hydrocarbons of which propane, butane refinery gas and naphtha rich in ethylene.

PURIFICATION BY HYDROTREATING

TYPE OF CATALYST: *NICKEL MOLYBDENUM HT-100.E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % NiO 3.8 MoO_3 16.8 CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 1.6; 3 ABD (g/cm³) 0.608 SA (m²/g) 190 PV (cm³/g) 0.54 STRENGTH (kg/cm²) 6.3—9	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The sulphided form of this catalyst is used in hydrotreating naphtha for reforming, lube oil for purification, gas oil for catalytic cracking furnace oil, diesel fuel, for sulphur and metals removal. Silica promoted.

PURIFICATION OF HYDROCARBONS

TYPE OF CATALYST: *NICKEL TUNGSTEN KONTAKT 8378*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht"	CONTENT wt % NiO, WO_3 CARRIER: aluminium silicate FORM: cylinders SIZE: Diameter (mm) 10 Length (mm) 10 ABD (g/cm³) 0.8 STRENGTH (kg/cm²) 480	TEMPERATURE RANGE: 360°—420°C PRESSURE RANGE: 70—150 atm.	

Denitrogenation

PURIFICATION

TYPE OF CATALYST: *NICKEL MOLYBDENUM BASF M-8—20*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % MoO_3 10 NiO 4 CARRIER: activated alumina FORM: extrusions; pellets SIZE: Diameter (mm) 1.5; 3 Length (mm) 3; 5 ABD (g/cm^3) 0.6; 0.76 SA (BET) (m^2/g) 200 PV (cm^3/g) 0.5 STRENGTH (kg/cm^2): *extrusions*: at right angles to direction of extrusion: 1.3 *pellets*: bursting pressure at the faces: 300 TS (°C) up to about 500	TEMPERATURE RANGE: 280°—400°C PRESSURE RANGE: n.a.	Used for deoxidation, desulphurization, denitrification.

NITROGEN OXIDE REMOVAL

TYPE OF CATALYST: *PLATINUM-NICKEL C-53—1*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Platinum and nickel CARRIER: alumina FORM: tablets SIZE: Diameter (mm) 6 Length (mm) 6 ABD (g/cm^3) 0.96	TEMPERATURE RANGE: 340°—870°C PRESSURE RANGE: 1—10 atm.	Used in the processes for nitrogen oxide removal and power recovery from nitric acid tail gas streams.

REMOVAL OF NITRIC OXIDE

TYPE OF CATALYST: *PALLADIUM-RUTHENIUM EH-22.P*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT n.a. CARRIER: γ Al_2O_3 FORM: balls SIZE: Diameter (mm) 4—6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Precious metal content usually 0.1%, 0.15%, 1%, 5% and 10%. It is used for the purification of synthesis gas.

DENITROGENATION OF HYDROCARBONS BY HYDROTREATING

TYPE OF CATALYST: *COBALT-MOLYBDENUM CoMo-0603.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % CoO 3 MoO_3 9 CARRIER: alumina FORM: tablets SIZE: Diameter (mm) 3 Length (mm) 3 ABD (g/cm^3) 1.2 SA (m^2/g) 166 PV (cm^3/g) 0.40 STRENGTH (kg/cm^2) 10	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used for desulphurization. A non-silicated catalyst.

AIR POLLUTION CONTROL

TYPE OF CATALYST: *PLATINUM HONEY CATALYST*

Manufacturer	Characteristics	Operating conditions	Remarks
Johnson Matthey Chemicals Ltd	CONTENT wt % Platinised ceramic honey combination CARRIER: ceramic FORM: blocks SIZE (mm) 30×30	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Reduces the effluent nitrogen oxide gases in nitric acid plants.

HYDRODENITRIFICATION

TYPE OF CATALYST: *COBALT-MOLYBDENUM HR-304*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % CoO 5 MoO_3 13 SiO_2 1 SO_4 1 Na_2O <0.6 Al_2O_3 balance to 100 Loss on ignition (550°C): $<1\%$ CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 1.5—2.5 ABD (g/cm^3) 0.65 SA (m^2/g) 300 PV (cm^3/g) 0.5 STRENGTH (kg/cm^2) 13	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for hydrodesulphurization and hydrodenitrification of gasolines, naphthas, kerosenes, gasoils and heavy cuts.

HYDRODENITRIFICATION OF KEROSENE, GAS-OILS, HEAVY CUTS

TYPE OF CATALYST: *COBALT-MOLYBDENUM HR-306*			
Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT n.a. CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 1.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

HYDRODENITRIFICATION

TYPE OF CATALYST: *NICKEL-COBALT-MOLYBDENUM HRF-121*			
Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See chapter on hydrodesulphurization.

HYDRODENITRIFICATION OF HEAVY CUTS (ATMOSPHERIC RESIDUES)

TYPE OF CATALYST: *NICKEL-MOLYBDENUM HRF-141*			
Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % MoO_3 12 NiO 3.5 CARRIER: alumina FORM: balls SIZE: Diameter (mm) 1.25—2.5 ABD (g/cm^3) 0.9 SA (m^2/g) 250 PV (cm^3/g) 0.40 STRENGTH (kg/ball) >4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

HYDRODENITRIFICATION

TYPE OF CATALYST: *NICKEL-MOLYBDENUM HR-143*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See chapter on hydrodesulphurization.

TYPE OF CATALYST: *NICKEL-MOLYBDENUM HR-346*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT n.a. CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 1.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

Desoxygenation

REMOVAL OF OXYGEN FROM HYDROGEN, NITROGEN, ARGON

TYPE OF CATALYST: *PALLADIUM CHEZA 40—00*

Manufacturer	Characteristics	Operating conditions	Remarks
Chemical Works of CSF	CONTENT wt % Palladium CARRIER: Al_2O_3 FORM: balls SIZE: Diameter (mm) 2—4 ABD (g/cm^3) 0.7	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

DESOXYGENATION OF INERT GAS STREAM BY HYDROGENATION OF O_2

TYPE OF CATALYST: *PALLADIUM C-54—1; C-54—7*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Palladium CARRIER: alumina FORM: spheres SIZE: n.a. ABD (g/cm^3) 0.7	TEMPERATURE RANGE: 20°—400°C PRESSURE RANGE: 1—50 atm.	

REMOVAL OF O_2, H_2 OR CO_2 FROM VARIOUS GASES

TYPE OF CATALYST: *COPPER ACTIMET 13*

Manufacturer	Characteristics	Operating conditions	Remarks
Doduco	CONTENT n.a. CARRIER: alumina FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used for dissociation of methanol (production of inert gas).

REMOVAL OF OXYGEN FROM N_2

TYPE OF CATALYST: *PALLADIUM DEDUX*			
Manufacturer	Characteristics	Operating conditions	Remarks
Döduco	CONTENT n.a. CARRIER: alumina FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used also for the removal of oxygen from H_2 and other gases.

ELIMINATION OF OXYGEN

TYPE OF CATALYST: *PLATINUM COEX*			
Manufacturer	Characteristics	Operating conditions	Remarks
Doduco	CONTENT n.a. CARRIER: alumina FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used also for the oxidation of hydrocarbons, carbon monoxide etc.

PURIFICATION

TYPE OF CATALYST: *PLATINISED QUARTZWOOL*			
Manufacturer	Characteristics	Operating conditions	Remarks
Doduco	CONTENT n.a. CARRIER: quartzwool FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Oxidizing catalyst, for instance flameless propane condensation.

REMOVAL OF OXYGEN

TYPE OF CATALYST: *COPPER G-108.A; G-108.B*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % G—108.A: Cu 16 G—108.B: Cu 30 CARRIER: special silica FORM: spheres SIZE: Diameter (mm) 5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	These catalysts are used for removing traces of oxygen from reducing gases or viceversa, in cyclic or continuous systems.

REMOVAL OF HYDROGEN AND OXYGEN

TYPE OF CATALYST: *PALLADIUM G-74*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT n.a. CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See chapter on hydrogenation of olefinic bonds.

GAS PURIFICATION (DESOXYGENATION)

TYPE OF CATALYST: *COPPER-MAGNESIUM GPD-5*

Manufacturer	Characteristics	Operating conditions	Remarks
Grande Paroisse	CONTENT wt % CuO, MgO, Al_2O_3, ZrO_2 CARRIER: n.a. FORM: pellets SIZE: Diameter (mm) 12—14	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	For action of hydrogen on oxygen of fumes to render them inert.

REMOVAL OF OXYGEN OR HYDROGEN FROM GAS STREAM

TYPE OF CATALYST: *COPPER Cu-0307.T*			
Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % CuO 99 CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 3 Length (mm) 3 ABD (g/cm^3) 1.4 SA (m^2/g) 5 PV (cm^3/g) 0.26 STRENGTH (kg/cm^2) approx. 10	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

REMOVAL OF OXYGEN FROM GAS STREAM

TYPE OF CATALYST: *COPPER Cu-0803.T*			
Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % CuO 10 CARRIER: high activity alumina FORM: tablets SIZE: Diameter (mm) 3 Length (mm) 3 ABD (g/cm^3) 0.85 SA (m^2/g) 137 PV (cm^3/g) 0.42 STRENGTH (kg/cm^2) 12	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It removes trace amounts of oxygen.

DESOXYGENATION

TYPE OF CATALYST: *NICKEL RCH-50/35.TS*			
Manufacturer	Characteristics	Operating conditions	Remarks
Farbwerke Hoechst AG	CONTENT wt % Nickel 50 CARRIER: Kieselguhr FORM: powder; tablets SIZE: Diameter (mm) 6 Length (mm) 5 ABD (g/cm^3) 0.5 (powder) 1 (tablets)	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It can also be used for hydrogenation of olefins to saturated hydrocarbons; of aromatic hydrocarbons; of phenol.

TYPE OF CATALYST: *NICKEL RCH-55/5.PYR*

Manufacturer	Characteristics	Operating conditions	Remarks
Farbwerke Hoechst AG	CONTENT wt % Ni 57 CARRIER: Kieselguhr FORM: tablets SIZE: Diameter (mm) 6 Length (mm) 5 ABD (g/cm^3) 0.8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for desoxygenation of hydrocarbons; for the refining of paraffins by hydrogenation; to remove oxygen from various gases.

OXIDATIVE PURIFICATION OF WASTE GASES

TYPE OF CATALYST: *PALLADIUM KONTAKT 7791*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT wt % Palladium CARRIER: metallic FORM: cuttings SIZE: Diameter (mm) 0.1—0.3 Length (mm) 2—5 ABD (g/cm^3) 0.2±0.03	TEMPERATURE RANGE: 300°—500°C PRESSURE RANGE: n.a.	It is used for the purification of waste gases, by combustion.

TYPE OF CATALYST: *PLATINUM KONTAKT 7790*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT wt % Platinum CARRIER: n.a. FORM: cuttings SIZE: Diameter (mm) 0.1—0.3 Length (mm) n.a. ABD (g/cm^3) 0.2	TEMPERATURE RANGE: 600°—800°C PRESSURE RANGE: n.a.	Purification of waste gases containing solvents from varnishing shops.

K. Reforming

Steam reforming
Petroleum refining
Naphtha reforming

Steam reforming

CYCLIC STEAM REFORMING OF LIGHT HYDROCARBONS

TYPE OF CATALYST: *NICKEL DaN and DN*			
Manufacturer	Characteristics	Operating conditions	Remarks
Azote et produits chimiques S.A.	CONTENT wt % Nickel CARRIER: alumina FORM: rings; cylinders SIZE Diameter (mm) 15; 6 Length (mm) 15 ABD (g/cm^3) 1.3—1.4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	DaN catalyst enables the processing of either naphthas or natural gas. DN is used in many town gas plants.

CYCLIC STEAM REFORMING OF FUEL OILS AND NAPHTHAS

TYPE OF CATALYST: *NICKEL SIN*			
Manufacturer	Characteristics	Operating conditions	Remarks
Azote et produits chimiques S.A.	CONTENT wt % Nickel CARRIER: silica-alumina FORM: cylinders SIZE: Diameter (mm) 15 Length (mm) 15 ABD (g/cm^3) 1.45	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See Nickel YN.

CYCLIC STEAM REFORMING OF GASEOUS HYDROCARBONS

TYPE OF CATALYST: *NICKEL XN*			
Manufacturer	Characteristics	Operating conditions	Remarks
Azote et produits chimiques S.A.	CONTENT wt % Nickel CARRIER: silica-alumina FORM: cylinders SIZE: Diameter (mm) 15 Length (mm) 15 ABD (g/cm^3) 1.25	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	XN is highly suitable for cyclic cracking of natural gases from various sources and of methane rich industrial gases.

CYCLIC REFORMING OF LOW SULPHUR NAPHTHAS

TYPE OF CATALYST: *NICKEL YCN*			
Manufacturer	Characteristics	Operating conditions	Remarks
Azote et produits chimiques S.A.	CONTENT wt % Nickel CARRIER: magnesia FORM: cylinders SIZE: Diameter (mm) 15 Length (mm) 15 ABD (g/cm^3) 1.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The support for YCN has been specially developed to avoid any combination of nickel.

CYCLIC STEAM REFORMING OF FUEL OILS AND NAPHTHAS

TYPE OF CATALYST: *NICKEL YN*			
Manufacturer	Characteristics	Operating conditions	Remarks
Azote et produits chimiques S.A.	CONTENT wt % Nickel CARRIER: magnesia FORM: nodules SIZE: Diameter (mm) 10—20 Length (mm) n.a. ABD (g/cm^3) 1.85	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used in the cyclic operation of town gas plants for direct production of gas of gross heating value.

AUTOTHERMIC STEAM REFORMING OF HYDROCARBONS

TYPE OF CATALYST: *PLATINUM-NICKEL DaNS*			
Manufacturer	Characteristics	Operating conditions	Remarks
Azote et produits chimiques S.A.	CONTENT wt % Platinum-nickel active elements CARRIER: n.a. FORM: rings SIZE: Diameter (mm) 15.6 Length (mm) 15 ABD (g/cm^3) 1.3	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	DaNS catalyst is a dual purpose catalyst used as a „shock bed“ associated with XN catalyst in autothermic reforming plants. It carries out both the exothermic oxidation of a portion of the hydrocarbon and allows the simultaneous initiation of the endothermic reforming reaction which is going on, in the presence of XN catalyst placed just above.

REFORMING OF HYDROCARBONS

TYPE OF CATALYST: *NICKEL BASF G-1—12*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % Ni 3 CARRIER: high mechanical and thermal stability FORM: spheres SIZE: Diameter (mm) 18 Length (mm) n.a. ABD (g/cm^3) 1.8 TS (°C) up to 1,400	TEMPERATURE RANGE: 700°—1,200°C PRESSURE RANGE: n.a.	The catalyst is employed in continuous and cyclic reforming processes for the production of town gas and synthesis gas. It is used at atmospheric or elevated pressure. It is used for the reforming of hydrocarbons such as methane, LPG and LPF with steam and oxygen or air.

STEAM REFORMING OF HYDROCARBONS

TYPE OF CATALYST: *NICKEL C-11—6.A*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % NiO 5±0.2 CARRIER: alumina FORM: Raschig rings SIZE (mm) 15×15×16 ABD (g/cm^3) 1.296 STRENGTH (kg/cm^2) 1,500	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It has been developed for the cyclic reforming of liquid or gaseous hydrocarbons, which may contain sulphur to produce gas of gross heating value. The catalyst is poisoned by Bi, lead, arsenic, alkaline metals, H_2SO_4.

TYPE OF CATALYST: *NICKEL C-11—6.B*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Ni 3 CARRIER: magnesia FORM: nodules SIZE: Diameter (mm) 10—20 ABD (g/cm^3) 1.840 SA (m^2/g) 0.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	A cyclic reforming catalyst for the cyclic reforming of fuel oils and sulphur containing naphthas. The catalyst poisons are lead, arsenic ,vanadium and alkaline metals.

STEAM REFORMING OF NAPHTHA

TYPE OF CATALYST: *NICKEL C-11—7*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International (from 1964); Grande Paroisse (from 1955)	CONTENT wt % NiO CARRIER: alumino-silica FORM: Raschig rings SIZE: Diameter (mm) 16; 16 Length (mm) 16; 10 ABD (g/cm^3) 1.6	TEMPERATURE RANGE: below 1,000°C PRESSURE RANGE: 1—40 atm. LIFE: 5 years SPACE VELOCITY: 0.5—3 h^{-1}	Used in externally fired tubes packed with catalyst for production of rich gases. The catalyst loading composes C-11 — 7 at the inlet and C-11—9 at the outlet.

PRIMARY REFORMING OF NAPHTHA

TYPE OF CATALYST: *NICKEL CD—RN-33.B*

Manufacturer	Characteristics	Operating conditions	Remarks
Fertilizer Corporation of India (FCI)	CONTENT wt % Nickel CARRIER: rugged alumina FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: 800°—900°C PRESSURE RANGE: up to 35 atm. SPACE VELOCITY: 0.5—0.9 h^{-1}	It is recommended for steam reforming naphtha for production of methanol synthesis gas, or hydrogen where very low residual methane content is desired.

STEAM REFORMING OF HYDROCARBONS

TYPE OF CATALYST: *NICKEL G-56.H*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % 1 2 T Ni 17—20 13—15 15 Alkali 0.5 — — SiO_2 <0.2 <0.2 <0.2 CARRIER: high pure calcinated alumina FORM: rings SIZE (mm): 15.8×15.8×6.35 ABD (g/cm^3) 0.9 STRENGTH (kg/cm^2) (DWL) 40—50	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	G-56.H is used in the high pressure reforming of refinery off-gas, or LPG and light naphtha. It is a high bulk density version of G-56.HT.

STEAM REFORMING OF HYDROCARBONS

TYPE OF CATALYST: *NICKEL G-90*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % G-90.A G-90.B G-90.C Ni 7 11 15 S max. 0.02 0.02 0.02 SiO_2max.0.2 0.2 0.2 CARRIER: n.a. FORM: rings, cylindrical tablets, extruded pellets SIZE (mm): 19.05×19.05 15.85×15.85 15.85×9.51	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The Girdler G-90 series has been developed for those steam reforming of hydrocarbons whose application require an extremely rugged catalyst.

TYPE OF CATALYST: *NICKEL G-131*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT wt % Ni 15 U (as promotor) 9 CARRIER: rugged alumina FORM: rings SIZE (mm): 15×15×6 15×10×6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used in the most severe cases, for example in units using butane feed or with feed containing olefins or sulphur traces.

STEAM REFORMING OF C_6 HYDROCARBONS

TYPE OF CATALYST: *NICKEL GPR-7*

Manufacturer	Characteristics	Operating conditions	Remarks
Grande Paroisse	CONTENT wt % NiO on special support and additives CARRIER: n.a. FORM: pellets SIZE: Diameter (mm) 1.5 Length (mm) n.a. TS (°C) up to 1,200	TEMPERATURE RANGE: higher than 1,000°C PRESSURE RANGE: 1—60 atm.	

GAS REFORMING

TYPE OF CATALYST: *NICKEL Ni-0901.S*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % NiO 5 CARRIER: inert alumina-silica FORM: spheres SIZE: Diameter (mm) 10; 12; 19; 25.4 ABD (g/cm³) 1.2 SA (m²/g) 1	TEMPERATURE RANGE: 980°C PRESSURE RANGE: n.a.	Endothermic generators. The quantitive relationship of these various gases is directly related to the ratio of the original air-gas mixture. This catalyst is used to reform low molecular weight hydrocarbons.

TYPE OF CATALYST: *NICKEL Ni-0910.S*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % NiO 10 CARRIER: alumino-silica FORM: spheres SIZE: Diameter (mm) 25.4 ABD (g/cm³) 1.264 SA (m²/g) 1	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used to reform low molecular weight hydrocarbons.

TYPE OF CATALYST: *NICKEL Ni-0912.S*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni oxide 5 Mg (as promotor) 1.2 CARRIER: inert alumina FORM: spheres SIZE: Diameter (mm) 25.4 Length (mm) n.a. ABD (g/cm³) 1.248 SA (m²/g) 1	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *NICKEL Ni-0914.R*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % NiO 1.5 CARRIER: inert alumina-silica FORM: rings SIZE: Diameter (mm) 19.05 ABD (g/cm^3) 1.088 SA (m^2/g) 1	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *NICKEL Ni-1901.G-2—1*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % NiO 3 CARRIER: activated alumina FORM: granules SIZE: n.a. ABD (g/cm^3) 0.848	TEMPERATURE RANGE: 1,000°—1,200°C PRESSURE RANGE: n.a.	Used for exothermic generators. The catalyst is used to aid in the reforming of hydrocarbons at about 1,200°C operating temperature for lean gas as low as 1,050°C for rich gas. The quantitative relationship of the various gases is directly related to the ratio of the original air-gas mixture.

TYPE OF CATALYST: *NICKEL Ni-2002.C Spec. 103*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % NiO 5 CARRIER: inert alumina FORM: cubes SIZE: Length (mm) 25.4 ABD (g/cm^3) 0.608	TEMPERATURE RANGE: approx. 980°C PRESSURE RANGE: n.a.	Endothermic generators.

TYPE OF CATALYST: *NICKEL ICI-57—1; 57—3; 57—4*

Manufacturer	Characteristics	Operating conditions	Remarks
Imperial Chemical Industries Ltd (ICI)	CONTENT wt % Supported nickel oxide CARRIER: n.a. FORM: rings, pellets SIZE: Diameter (mm) 17 Length (mm) 11—17 ABD (g/cm³) 1.1	TEMPERATURE RANGE: up to 850°C PRESSURE RANGE: up to 35 atm.	Used for primary reforming of methane and other light hydrocarbons on tubular reformers. See also ammonia synthesis.

TYPE OF CATALYST: *NICKEL KATALCO 22.625; 22.635*

Manufacturer	Characteristics	Operating conditions	Remarks
Katalco Corporation	CONTENT wt % Supported nickel oxide (a) 22.625: NiO 24—27 (b) 22.635: NiO 34—37 CARRIER: n.a. FORM: Raschig rings SIZE (mm): (a): 18×18×6 15×15×6 (b): 15×15×6 15×10×6 18×18×6 ABD (g/cm³) 1.04—1.12	TEMPERATURE RANGE: 700°—850°C PRESSURE RANGE: 1—25 atm. SPACE VELOCITY (VSHV): 1,500—5,000 h⁻¹	Steam reforming of light hydrocarbons. It is available in several sizes and concentration levels of active nickel.

TYPE OF CATALYST: *NICKEL CRG-7; MSC-7*

Manufacturer	Characteristics	Operating conditions	Remarks
Laporte Industries Ltd, General Chemical Division, Spence Works	CONTENT wt % CRG-7 nickel on alumina MSC-7 nickel on established magnesia CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	For catalytic rich gas process, for the manufacture of rich gas from naphtha. CRG-7 was developed in cooperation with the Gas Council. MSC-7 was developed in collaboration with Stazione Sperimentale per i Combustibili, Milano.

GAS REFORMING

TYPE OF CATALYST: *NICKEL KONTAKT 9024*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT wt % NiO 1.2 CARRIER: ceramic, magnesium oxide FORM: grains SIZE: Diameter (mm) 10—20 ABD (g/cm³) 1.55± 0.15	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used to produce town gas.

TYPE OF CATALYST: *PLATINUM — ALUMINA KONTAKT 8813*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT wt % F 0.55 Kontakt 8813—6: Pt 0.57 Kontakt 8813—4: Pt 0.4 CARRIER: high activity γ alumina FORM: spheres SIZE: Diameter (mm) 2—4 SA (m²/g) 170—200 PV (cm³/g) 0.5—0.6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Available as: Kontakt 8813-4 Kontakt 8813-6

TYPE OF CATALYST: *PLATINUM KONTAKT 8815*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT wt % Platinum CARRIER: high activity alumina FORM: extrusions SIZE: Diameter (mm) 2 Length (mm) n.a. ABD (g/cm³) 0.7± 0.07	TEMPERATURE RANGE: 490°—515°C PRESSURE RANGE: 25—45 atm	It is used for production of fuels with high octane number and aromatic hydrocarbons.

TYPE OF CATALYST: *PLATINUM-RHENIUM KONTAKT 8816*			
Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT wt % Bimetallic catalyst CARRIER: high activity alumina FORM: extrusions SIZE: Diameter (mm) 2 Length (mm) n.a. ABD (g/cm^3) 0.7± 0.07 SA (m^2/g) 300	TEMPERATURE RANGE: 490°—520°C PRESSURE RANGE: 20—45 atm.	

STEAM REFORMING OF HYDROCARBONS

TYPE OF CATALYST: *NICKEL MRH-3*			
Manufacturer	Characteristics	Operating conditions	Remarks
Montedison S.p.A.	CONTENT wt % NiO 3—5—10 CARRIER: high alumina content FORM: cylindrical extrusions SIZE: Diameter (mm) 5 Length (mm) 10 ABD (g/cm^3) 0.82—0.85 PV (cm^3/g) 0.35—0.38 STRENGTH (kg/cm^2) 30 (axial); 15 (radial) TS (°C) $\leqslant$ 1150	TEMPERATURE RANGE: 400°—1,100°C PRESSURE RANGE: $\leqslant$3 atm. LIFE: 5 years SPACE VELOCITY (VHSV): 800—3,500 h^{-1}	Steam oxygen methane reforming.

TYPE OF CATALYST: *NICKEL M*			
Manufacturer	Characteristics	Operating conditions	Remarks
Chemie Linz A.G.	CONTENT wt % Nickel CARRIER: Al_2O_3; SiO_2 FORM: spheres SIZE: Diameter (mm) 15—20 Length (mm) n.a. ABD (g/cm^3) 1.6—1.8 TS (°C) max. 1,400	TEMPERATURE RANGE: 800°—900°C PRESSURE RANGE: 5 atm. LIFE: 1 year SPACE VELOCITY: 450—900 h^{-1}	It is used for the reforming of hydrocarbons in the presence of water vapour, carbon dioxide, air and oxygen (either individual or in mixtures).

STEAM HYDROCARBONS REFORMING

TYPE OF CATALYST: *NICKEL S*

Manufacturer	Characteristics	Operating conditions	Remarks
Chemie Linz A.G.	CONTENT wt % Nickel CARRIER: Al_2O_3; SiO_2 FORM: spherical SIZE: Diameter (mm) 15—20 Length (mm) n.a. ABD (g/cm^3) 1.4—1.6 TS (°C) up to 1,100	TEMPERATURE RANGE: 750°C PRESSURE RANGE: up to 5 atm. LIFE: 1 year SPACE VELOCITY: 550—1,000 h^{-1}	This catalyst is also suitable for reforming substances of low sulphur content. It can be used for both continuous and cyclic processes. See also „M".

CYCLIC LOW PRESSURE REFORMING

TYPE OF CATALYST: *NICKEL NA-50*

Manufacturer	Characteristics	Operating conditions	Remarks
Price Pearson Refractories Limited, Catalyst Division	CONTENT wt % Ni 5 SiO_2 2 CARRIER: alpha alumina FORM: Raschig rings SIZE: Diameter (mm) 32 Length (mm) 32 ABD (g/cm^3) 1.23	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is suitable for all types of cyclic plant reforming distillate or natural gas.

TYPE OF CATALYST: *NICKEL-URANIUM NUA-52*

Manufacturer	Characteristics	Operating conditions	Remarks
Price Pearson Refractories Limited, Catalyst Division	CONTENT wt % Ni 5 U 2 SiO 2 CARRIER: alpha alumina FORM: Raschig rings SIZE: Diameter (mm) 32 (ID: 12) Length (mm) 32 ABD (g/cm^3) 1.23	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See NA 50.

STEAM REFORMING OF HYDROCARBONS

TYPE OF CATALYST: *NICKEL G-1; G-2*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Nickel CARRIER: alumina FORM: balls SIZE: Diameter (mm) 5—10; 10—15 Length (mm) n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: usual	It is recommended for cyclic and autothermic processes.

STEAM REFORMING

TYPE OF CATALYST: *NICKEL G-3; GV-3*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Al_2O_3 ~97 Ni ~3 Fe <0.03 Na_2O <0.05 CARRIER: high purity alumina FORM: balls SIZE: Diameter (mm) 5—10;10—15 15—20;20—25 Length (mm) n.a. ABD (g/cm^3) 1.6±0.1 SA (m^2/g) <5 PV (cm^3/g) 0.08—0.15 STRENGTH (kg/cm^2) 100—300	TEMPERATURE RANGE: 650°—850°C PRESSURE RANGE: n.a. LIFE: 16,000—32,000 hours SPACE VELOCITY: 1,000 h^{-1}	It is recommended for the production of gas with a calorific value of 3,000 to 4,500 kcal/m^3 in autothermic and cyclic processes.

STEAM REFORMING OF NAPHTHA OR NATURAL GAS

TYPE OF CATALYST: *NICKEL GV-6*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Al_2O_3 ~94 Ni ~6 Fe <0.03 Na_2O <0.05 Loss on ignition (1,000°C): <0.5 CARRIER: high purity alumina FORM: balls SIZE: Diameter (mm) 5—10;10—15; 15—20;20—25 Length (mm) n.a. ABD (g/cm^3) 1.35±0.1 SA (m^2/g) 5 PV (cm^3/g) 0.15—0.20 STRENGTH (kg/cm^2) 100—200	TEMPERATURE RANGE: 650°—850°C PRESSURE RANGE: n.a. LIFE: 16,000—32,000 hrs. SPACE VELOCITY: 1,250 h^{-1}	Cyclic and autothermic processes.

PETROLEUM REFINING

TYPE OF CATALYST: *PLATINUM NAPH-TANE 135-E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Platinum monometallic reforming catalyst Pt 0.35 CARRIER: n.a. FORM: extrusions SIZE: Diameter (mm) 1.5 Length (mm) n.a. ABD (g/cm³) 0.64 SA (m²/g) 200 PV (cm³/g) 0.6 STRENGTH (kg/cm²) 7	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	This catalyst is used in conventional catalytic reforming units to convert naphtha to motor fuel and/or aromatics. Harshaw is associated with the Institute français du pétrole (IFP) as North American marketing and manufacturing agent for their subsidiary companies offering the Naph-Tane family of mono- and bimetallic catalyst.

TYPE OF CATALYST: *PLATINUM NAPH-TANE 160-E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT Same as Naph-Tane 135 except that this catalyst contains 0.6%. Pt CARRIER: n.a. FORM: n.a. SIZE: Diameter (mm) 1.5 Length (mm) n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See Naph-Tane 135-E.

TYPE OF CATALYST: *PLATINUM NAPH-TANE 220-E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Platinum bimetallic catalyst Pt 0.20 A proprietary promotor CARRIER: n.a. FORM: extrusions SIZE: Diameter (mm) 1.5 Length (mm) n.a. ABD (g/cm³) 0.656 SA (m²/g) 200 PV(cm³/g) 0.6 STRENGTH (kg/cm²) 7	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used in the catalytic reforming of hydrocarbons where high octane product is desired in conjunction with low pressure operation.

TYPE OF CATALYST: *PLATINUM NAPH-TANE 235-E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT Same as Naph-Tane 220 except that this catalyst contains 0.35% Pt CARRIER: n.a. FORM: n.a. SIZE: Diameter (mm) 1.5 Length (mm) n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *PLATINUM NAPH-TANE 260-E*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT Same as Naph-Tane 220, except that this catalyst contains 0.60% Pt and a greater concentration of proprietary promotor CARRIER: n.a. FORM: n.a. SIZE: Diameter (mm) 1.5 Length (mm) n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

REFINING OF PETROLEUM DERIVATIVES

TYPE OF CATALYST: *NICKEL-MOLYBDENUM KONTAKT 8197*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT wt % NiO MoO_3 CARRIER: n.a. FORM: cylinders SIZE: Diameter (mm) 10 Length (mm) 10 ABD (g/cm³) 0.9—1.2 STRENGTH (kg/cm²) 350—375	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Also KONTAKT 8197/S in the form of extrusions 7 mm diameter and ABD of 0.75 g/cm³. By means of this catalytic treatment, sulphur, nitrogen and oxygen compounds are reduced.

TYPE OF CATALYST: *NICKEL-MOLYBDENUM KONTAKT 8199.K*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT wt % NiO. MoO_3 CARRIER: aluminium oxide FORM: spheres SIZE: Diameter (mm) 3—4 ABD (g/cm^3) 0.8	TEMPERATURE RANGE: 300°—400°C PRESSURE RANGE: 20—50 atm.	KONTAKT 8199/S: Also extrusions of 3—4 mm diameter, 4—6 mm length, and ABD of 0.9 g/cm^3.

Naphtha reforming

REFORMING

TYPE OF CATALYST: *PLATINUM CYANAMID KETJEN CK-300; CK-303; CK-304; CK-306*

Manufacturer	Characteristics	Operating conditions	Remarks
Cyanamid International	CONTENT wt % Pt 0.3—0.4—0.6 Cu 0.002 Fe 0.012 Na, K 0.002 Si 0.006 As 0.0001 Cl 0.6 N 0.0065 CARRIER: n.a. FORM: n.a. SIZE: Diameter (mm) 1.2 Length (mm) 4 ABD (g/cm^3) 0.67 SA (m^2/g) 180 PV (cm^3/g) 0.5 STRENGTH (kg/cm^2) 3.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It also contains Ag, Cr, Mg, Sn, Co, Au in a proportion of 0.002 wt %.

PETROLEUM REFORMING

TYPE OF CATALYST: *PLATINUM ALUMINA 182-CP*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Series 182-CP A B Metal content 0.5 1 Ignition loss (760°C) max. 2.5 CARRIER: alumina FORM: pellets SIZE: Diameter (mm) 6.1; 10.1; 16.1 Length average 1—1.5 times the diameter of pellet ABD (g/cm^3) 0.75—0.78 SA (m^2/g) 225	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Platinum catalyst is used for reforming, dehydrogenation, isomerization. The early large sacle industrial applications of platinum catalyst were in the field of petroleum refining for the conversion of naphtha cuts into motor gasoline and aromatics.

TYPE OF CATALYST: *PLATINUM-ALUMINA 183-CP*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Series 183-CP A B Metal content 0.5 1 Ignition loss (760°C): max. 2.5 CARRIER: alumina FORM: pellets SIZE: Diameter (mm) 6.1; 10.1;16.1 Length 1—1.5 times the diameter of pellet ABD (g/cm^3) 0.8 SA (m^2/g) 80	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See 182—CP.

TYPE OF CATALYST: *PLATINUM-ALUMINA 538-CP*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Series 538-CP A B Metal content 0.5 1 Ignition loss (760°C): max. 2.5 CARRIER: alumina FORM: pellets SIZE: Diameter (mm) 6.1; 10.1; 16.1 Length 1—1.5 times the diameter of pellet ABD (g/cm^3) 0.8 SA (m^2/g) 165	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See 182-CP.

NAPHTHA REFORMING

TYPE OF CATALYST: *PLATINUM HOUDRY$^{T.M.}$ TYPE 3-G*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Pt 0.3—0.75 Ignition loss (760°C): 1.7 CARRIER: alumina FORM: pellets SIZE: Diameter (mm) 2.4 Length (mm) n.a. ABD (g/cm^3) 0.85 SA (m^2/g) 225 STRENGTH (kg/cm^2) 6.3	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	In naphtha reforming processes both for gasoline and aromatic production. It has also found applications in other hydrogenation type reactions.

TYPE OF CATALYST: *PLATINUM TYPE 3-H*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Pt 0.3—0.75 Ignition loss (760°C): 1.9 CARRIER: alumina FORM: pellets SIZE: Diameter (mm) 2.4 Length (mm) n.a. ABD (g/cm^3) 0.84 SA (m^2/g) 215 STRENGTH (kg/cm^2) 5.4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See Houdry 3-G.

TYPE OF CATALYST: *BIMETALLIC HOUDRY*$^{T.M.}$ *HR-71*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Ignition loss (760°C): 2.5 CARRIER: n.a. FORM: pellets SIZE: Diameter (mm) 1.5 Length (mm) n.a. ABD (g/cm^3) 0.45—0.48 SA (m^2/g) 240 STRENGTH (kg/cm^2) 4.53	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is resistant to modest amount of sulphur on the feed. For high octanes.

TYPE OF CATALYST: *PLATINUM HOUDRY*$^{T.M.}$ *TYPE 3-K*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Pt 0.3—0.75 Ignition loss (760°C): 1.9 CARRIER: alumina FORM: pellets SIZE: Diameter (mm) 1.5 Length (mm) n.a. ABD (g/cm^3) 0.69 SA (m^2/g) 250 STRENGTH (kg/cm^2) 2.2	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See Houdry 3-G.

TYPE OF CATALYST: *PLATINUM HOUDRY TYPE 3-L*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Pt 0.3—0.75 Ignition loss (760°C): 2.0 CARRIER: alumina FORM: pellets SIZE: Diameter (mm) 1.5 Length (mm) n.a. ABD (g/cm^3) 0.85 SA (m^2/g) 200 STRENGTH (kg/cm^2) 5.4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See Houdry 3-G.

FUEL OILS REFORMING

TYPE OF CATALYST: *PLATINUM ATLANTIC 16*

Manufacturer	Characteristics	Operating conditions	Remarks
Kali-Chemie Engelhard	CONTENT wt % Pt 0.55 CARRIER: silica-alumina FORM: extrusions SIZE: Diameter (mm) 1.5 Length (mm) 4.5 ABD (g/cm^3) 0.61	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Elaborated by The Atlantic Refining Co. and Engelhard Industries Inc.

TYPE OF CATALYST: *PLATINUM E-301; E-302*

Manufacturer	Characteristics	Operating conditions	Remarks
Kali-Chemie Engelhard	CONTENT wt % E 301 E 302 Pt 0.6 0.35 CARRIER: aluminium oxide FORM: extrusions SIZE: Diameter (mm) 1.5 Length (mm) 4.5 ABD (g/cm^3) 0.67	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The catalyst was elaborated by Sinclair Research Laboratories Inc., New-York and Baker and Co., Newmark.

NAPHTHA REFORMING

TYPE OF CATALYST: *PLATINUM RG-101*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Pt 0.6±0.02 Cl approx. 0.5 Heating loss (550°C) 0.5 F approx. 0.4 B 500 ppm; Al_2O_3 diff. to 100% Fe_2O_3 500 ppm Na_2O 300 ppm Pb 10 ppm Cu 120 ppm As 5 ppm Si 200 ppm CARRIER: alumina FORM: balls SIZE: Diameter (mm) 1.25—2.5 ABD (g/cm^3) 0.75±0.05 SA (m^2/g) 320±40 PV (cm^3/g) 0.52±0.05	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used in various processes for raising the octane number of naphthas and production of aromatics.

TYPE OF CATALYST: *PLATINUM RG-402; RG-404*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Pt 0.6 Loss on ignition (1,100°C): <5% CARRIER: high purity alumina FORM: extrusions SIZE: Diameter (mm) 1.2—2.2 ABD (g/cm³) 0.6 SA (m²/g) 200 PV (cm³/g) 0.60 STRENGTH (kg/cm²) >4	TEMPERATURE RANGE: 480°—530°C PRESSURE RANGE: usual	Used for the production of aromatics.

TYPE OF CATALYST: *PLATINUM RG-422; RG-432; RG-442*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Promoted platinum CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 1.2 Length (mm) n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Are recommended as well for the increase of the octane number and for the production of the aromatics.

TYPE OF CATALYST: *PLATINUM RG-412; RG-414*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Pt 0.35 Loss on ingnition (1,100°C): <5% CARRIER: high purity alumina FORM: extrusions SIZE: Diameter (mm) 1.2—2.2 ABD (g/cm³) 0.6 SA (m²/g) 200 PV (cm³/g) 0.60 STRENGTH (kg/cm²) >4	TEMPERATURE RANGE: 480°—530°C PRESSURE RANGE: usual	Used for the production of aromatics.

TYPE OF CATALYST: *PLATINUM RG-452; RG-454*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Promoted platinum CARRIER: alumina FORM: extrusions SIZE: Diameter (mm) 1.2—2 Length (mm) n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Are recommended as well for increase of the octane number and for production of aromatics.

TYPE OF CATALYST: *PLATINUM RG-451; RG-461*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % Promoted platinum CARRIER: alumina FORM: balls SIZE: Diameter (mm) 1.8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	They are recommended as well for the increase of the octane number and for the production of aromatics.

TYPE OF CATALYST: *PLATINUM SK-200*

Manufacturer	Characteristics	Operating conditions	Remarks
Union Carbide Corporation, Linde Molecular Sieve Catalysts	CONTENT wt % (anhydrous base) SiO_2 65.6±0.5 Al_2O_3 22.3±0.5 Na_2O 1.8±0.2 CaO 10.3±0.3 Cl^- <0.05 F^- <0.05 Pt 0.5±0.02 FORM: tablets SIZE: Diameter (mm) 4 Length (mm) 4 ABD (g/cm^3) 0.65 SA (m^2/g) >500	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is a calcium exchanged molecular sieve type Y.

L. Catalysts for various chemical reactions

Ammonium dissociation
Cyclization — dehydrocyclization
Esterification — interesterification
Hydration — dehydration

Ammonium dissociation

AMMONIA DISSOCIATION

TYPE OF CATALYST: *NICKEL BASF G-1—22*

Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % Nickel CARRIER: ceramic FORM: cylindrical rings SIZE: Diameter (mm) 16 Length (mm) n.a. ABD (g/cm^3) 1 STRENGTH (kg/cm^2) 300 (measured at the faces) TS (°C) up to 900	TEMPERATURE RANGE: 650°—850C° PRESSURE RANGE: n.a.	Splitting ammonia to produce inert gas, e.g. in the electrical industry (production of electronic valves) and in the metalworking industry (production of sheet metal for transformers and galvanizing metal).

TYPE OF CATALYST: *IRON C-17—1*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Iron oxide CARRIER: refractory alumina FORM: spheres SIZE: Diameter (mm) 19 Length (mm) n.a. ABD (g/cm^3) 1.22	TEMPERATURE RANGE: 700—1,040°C PRESSURE RANGE: 1—35 atm. SPACE VELOCITY (VHSV): 1,500—2,000 h^{-1}	Catalytic dissociation of NH_3 for production of H_2 gas suitable for variety of uses. C-17-1-01 uses iron as active ingredient; C-17-1-02 uses nickel as *active ingredient.*

TYPE OF CATALYST: *NICKEL C-17—2*

Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Nickel oxide CARRIER: refractory alumina FORM: spheres SIZE: Diameter (mm) 19 Length (mm) n.a. ABD (g/cm^3) 1.22	TEMPERATURE RANGE: 700°—1,040°C PRESSURE RANGE: n.a. SPACE VELOCITY (VHSV): 1,500—2,000 h^{-1}	Lower pressures favour more complete dissociation at lower temperatures. The rugged carrier of the C-17 catalyst contributes to long useful life.

TYPE OF CATALYST: *NICKEL ACTIMET^R 41*

Manufacturer	Characteristics	Operating conditions	Remarks
Doduco	CONTENT wt % Nickel on carrier CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used for the production of inert gas.

TYPE OF CATALYST: *NICKEL CDA-9*

Manufacturer	Characteristics	Operating conditions	Remarks
FCI Catalysts	CONTENT wt % Nickel CARRIER: alumina FORM: cylindrical tablets SIZE: Diameter (mm) 6 Length (mm) 6 ABD (g/cm^3) 1.1—1.2	TEMPERATURE RANGE: 600°—1,000°C PRESSURE RANGE: n.a. SPACE VELOCITY: up to 1,000 h^{-1}	The catalyst is highly active (with close approach to equilibrium and resistant to thermal sintering).

TYPE OF CATALYST: *IRON G-47*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT An iron oxide catalyst, containing 2.5% Fe CARRIER: rugged FORM: spheres SIZE: Diameter (mm) 6—25 Length (mm) n.a. ABD (g/cm^3) 1.21—1.28	TEMPERATURE RANGE: 870°—980°C PRESSURE RANGE: near atmospheric SPACE VELOCITY (VHSV): 2,000 h^{-1}	

TYPE OF CATALYST: *NICKEL G-29*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT n.a. CARRIER: n.a. FORM: cylinders; Raschig rings SIZE: Diameter (mm) 12;19; 15×15	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See chapter on Reforming.

TYPE OF CATALYST: *NICKEL G-56*

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT n.a. CARRIER n.a. FORM: Raschig rings; tablets SIZE (mm): *Rings* *Tablets* 17×17×6 6×6 16×16×6 9×9 17×10×6 12×12	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See chapter on Reforming. Available as G-56 B and G-56 H cylinders with diameters of 12.7 mm and 19 mm.

TYPE OF CATALYST: *IRON Fe-1401.S*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Fe_2O_3 5 CARRIER: high fixed inert alumina FORM: spheres SIZE: Diameter (mm) 10 Length (mm) n.a. ABD (g/cm^3) 1.2 SA (m^2/g) 1 PV (cm^3/g) 0.06 STRENGTH (kg/cm^2) 2.7	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a	Used also to reform low molecular weight hydrocarbons.

TYPE OF CATALYST: *NICKEL Ni-0901.S*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni 5 (present as oxide) CARRIER: alumina-silica FORM: spheres SIZE: Diameter (mm) 9.6; 12.7; 18.6; 25.4 ABD (g/cm^3) 1.2 SA (m^2/g) 1	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Ammonia is dissociated yielding a gas consisting of 75% hydrogen and 25% nitrogen by volume and usually less than 0.1% residual free ammonia. The cracking occurs at about 1,000°C.

TYPE OF CATALYST: *NICKEL Ni-0910.S*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Ni 10 (present as nickel oxide) CARRIER: alumina-silica FORM: spheres SIZE: Diameter (mm) 25.4 Length (mm) n.a. ABD (g/cm^3) 1.2 SA (m^2/g) 1	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used also to reform low molecular weight hydrocarbons.

TYPE OF CATALYST: *NICKEL ICI-27—1; ICI-47—1*

Manufacturer	Characteristics	Operating conditions	Remarks
Imperial Chemical Industries Ltd	CONTENT wt % Nickel oxide CARRIER: alumina FORM: 27-1 *irregular granules*; 47-1 *pellets* SIZE: Diameter (mm) 4.8—9.5 5.4 ABD (g/cm^3) 1.1	TEMPERATURE RANGE: ICI 27—1: 850°C ICI 47—1: 450°C PRESSURE RANGE: n.a.	Both types are most active when the nickel oxide is reduced to nickel.

TYPE OF CATALYST: *NICKEL G-4*

Manufacturer	Characteristics	Operating conditions	Remarks
Pro Catalyse	CONTENT wt % NiO 4 CARRIER: alumina FORM: balls SIZE: n.a. ABD (g/cm³) 1.6 PV (cm³/g) 0.08 TS (°C) 100—300	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *PELLETED IRON DNK*

Manufacturer	Characteristics	Operating conditions	Remarks
Haldor Topsøe	CONTENT n.a. CARRIER: ceramic FORM: cylinders; rings SIZE: *cylindres* *rings* Diameter (mm) 6 10/4 Length (mm) 6 7 ABD (g/cm³) 1.6 1.35	TEMPERATURE RANGE: 550°—800°C PRESSURE RANGE: n.a.	

Cyclization-dehydrocyclization

DEHYDROCYCLIZATION

TYPE OF CATALYST: *CHROME ALUMINA Cr-0205.T, spec. 102*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Cr_2O_3 19 CARRIER: activated alumina FORM: tablets SIZE: Diameter (mm) 4 Length (mm) n.a. ABD (g/cm^3) 0.96 SA (m^2/g) 60 PV (cm^3/g) 0.29 STRENGTH (kg/cm^2) 8.6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used in dehydrogenation of butane to butadiene.

TYPE OF CATALYST: *CHROME ALUMINA Cr-0211.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Cr_2O_3 19 CARRIER: activated alumina SIZE: Diameter (mm) 4 Length (mm) n.a. ABD (g/cm^3) 1.15 SA (m^2/g) 0.3 STRENGTH (kg/cm^2) 9.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See chapter on dehydrogenation. Capable of selectivity for the dehydrogenation of butane to butene.

TYPE OF CATALYST: *MOLYBDENUM ALUMINA Mo-1201.T; Mo-1201.TV*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT n.a. CARRIER: n.a. FORM: n.a. SIZE: Diameter (mm) 3.2 Length (mm) n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See chapter on dehydrogenation.

DEHYDROCYCLIZATION OF n-PARAFFINS

TYPE OF CATALYST: *CHROMIUM KONTAKT 6450*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT wt % Cr_2O_3 CARRIER: alumina FORM: spheres SIZE: Diameter (mm) 3—5 Length (mm) n.a. ABD (g/cm^3) 0.85±0.1	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used also for dehydrogenation of butane to butadiene.

Esterification-interesterification

ESTERIFICATION REACTIONS

TYPE OF CATALYST: *ALUMINA Al-0104.T*			
Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Al_2O_3 99 FORM: tablets SIZE: Diameter (mm) 3; 4; 5; 6.35 ABD (g/cm^3) 0.604—0.928 SA (m^2/g) 80—100 PV (cm^3/g) 0.28—0.33 STRENGTH (kg/tablet) 4—11	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used commercially as a catalyst support drying agent and for dehydration reactions.

TRANSESTERIFICATION OF ESTERS

TYPE OF CATALYST: *BORON TRIFLUORIDE DIHYDRATE*			
Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT See chapter on isomerization CARRIER: n.a. FORM: fuming hygroscopic liquid SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Catalyst for polymerization, resin curing. For the production of high price esters.

INTERESTERIFICATION OF TRI-GLYCERIDE FATS

TYPE OF CATALYST: *SODIUM METHYLATE*			
Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Sodium methylate 87 CARRIER: n.a. FORM: powder SIZE: 150 mesh	TEMPERATURE RANGE: 50°—100°C PRESSURE RANGE: n.a.	The catalyst is inactivated by the adition of water or acid.

ACRYLIC ESTER ALCOLYSIS

TYPE OF CATALYST: *ORGANIC TITANIUM COMPOUNDS TIL*

Manufacturer	Characteristics	Operating conditions	Remarks
Titanium Intermediates Ltd	CONTENT n.a. CARRIER: n.a. FORM: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Catalytic applications of organic titanium compounds: (a) polyester manufacture; (b) ester and plasticizer manufacture (by direct route); (c) ester manufacture (by ester interchange); (d) silicone manufacture and applications (particularly for textile water proofing); (e) curing of epoxy resins.

Hydration-dehydration

DEHYDRATION REACTIONS

TYPE OF CATALYST: *BASF D-10—10*			
Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT See chapter on isomerization	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	For dehydration, isomerization and diverse chemical reactions.

TYPE OF CATALYST: *ALUMINA, C-1*			
Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Al_2O_3 Na_2O less than 0.05 CARRIER: n.a. FORM: tablets; extrusions SIZE: Diameter (mm) 3—12 Length (mm) n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for hydration, dehydration and catalyst support.

TYPE OF CATALYST: *ALUMINA C-2*			
Manufacturer	Characteristics	Operating conditions	Remarks
Catalysts and Chemicals International	CONTENT wt % Al_2O_3 Na_2O 0.3 CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 5—12 Length (mm) n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for hydration, dehydration and as catalyst support.

HYDRATION — DEHYDRATION REACTIONS

TYPE OF CATALYST: *ALUMINIUM OXIDE CHEZA 33—00*

Manufacturer	Characteristics	Operating conditions	Remarks
Chemical Works of CSF	CONTENT wt % $Na_2O + K_2O$ 0.1 Fe_2O_3 0.1 SiO_2 0.9 SO_3 0.5 NO_3 1.5 Al_2O_3 the remainder Loss by heating (1,200°C) 10 CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 10; 6 Length (mm) 6—8; 6 ABD (g/cm^3) 0.75 STRENGTH (kg/cm^2) 200	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used also in dehydrogenation reactions. It may be used as a carrier for the preparation of different impregnated catalysts. Under certain circumstances it may be used as a drying, adsorption agent for gases, eventually liquids.

HYDRATION

TYPE OF CATALYST: *ALUMINIUM CHEZA 33—01*

Manufacturer	Characteristics	Operating conditions	Remarks
Chemical Works of CSF	CONTENT wt % $Na_2O + K_2O$ 0.05 Fe_2O_3 0.05 SiO_2 0.3 SO_3 0.5 NO_3 0.5 Al_2O_3 the remainder Loss by heating (1,200°C): 5 CARRIER: n.a. FORM: balls SIZE: Diameter (mm) 2—4 Length (mm) n.a. ABD (g/cm^3) 0.7 STRENGTH (kg/cm^2) 2 (tested by the edge of a knife)	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See CHEZA 33—00

DENYDRATION

TYPE OF CATALYST: *ACTIVATED ALUMINA F-1*

Manufacturer	Characteristics	Operating conditions	Remarks
Aluminium Company of America (ALCOA)	CONTENT wt % Al_2O_3 92 Na_2O 0.90 Fe_2O_3 0.08 SiO_2 0.09 CARRIER: n.a. FORM: granular SIZE: 6—100 mesh (3.3—1.27 mm) Diameter (mm) 6—12 Length (mm) n.a. ABD (g/cm^3) 0.83—0.88 SA (m^2/g) 210 STRENGTH (kg/cm^2) 25	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Although primarily used as a desicant, activated alumina F-1 finds applications as a catalyst in such reactions as the destructive dehydration of alcohols in which a typical soda content of 0.9% is not harmful.

TYPE OF CATALYST: *SILICA-ALUMINA GRADE 970; 980*

Manufacturer	Characteristics	Operating conditions	Remarks
Davison Chemical Division W.R. Grace and Co.	CONTENT Modified silica-alumina. 13% alumina or 25% alumina with the balance silica FORM: pellets SIZE: Diameter (mm) 3; 4 Length (mm) n.a. SA (m^2/g) 970—980 100—500	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	They are also used as catalyst supports.

TYPE OF CATALYST: *ALUMINA Al-0104.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT Activated alumina containing 99% Al_2O_3 CARRIER: n.a. FORM: tablets SIZE: Diameter (mm) 3.175; 3.96; 4.762; 6.35; 9.525 ABD (g/cm^3) 0.6—0.9 (depending on size) SA (m^2/g) 80—100 PV (cm^3/g) 0.28—0.33 STRENGTH (kg/cm^2) 4—11	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used commercially as a catalyst support, drying agent for dehydration reactions.

TYPE OF CATALYST: *ALUMINA Al-1404.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % High activity alumina containing 97% Al_2O_3 CARRIER: n.a. FORM: tablets SIZE: n.a. ABD (g/cm^3) 0.064—0.880 SA (m^2/g) 180—200 PV (cm^3/g) 0.42—5.1 STRENGTH (kg/cm^2) 11—28	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used as a catalyst support, drying agent and for dehydration reactions.

TYPE OF CATALYST: *TUNGSTEN W-0101.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % WO_3 10 CARRIER: activated alumina FORM: tablets SIZE: Diameter (mm) 3 Length (mm) n.a. ABD (g/cm^3) 0.944 SA (m^2/g) 75 PV (cm^3/g) 0.37 STRENGTH (kg/cm^2) 5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *TUNGSTEN W-0602.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % WO_3 95 FORM: tablets SIZE: Diameter (mm) 3 Length (mm) n.a. ABD (g/cm^3) 1.728 SA (m^2/g) 17 PV (cm^3/g) 0.19 STRENGTH (kg/cm^2) 4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *TUNGSTEN W-0801.T*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % WO_3 10 CARRIER: high activity alumina FORM: tablets SIZE: Diameter (mm) 3 Length (mm) n.a. ABD (g/cm^3) 1.008 SA (m^2/g) 145 PV (cm^3/g) 0.36 STRENGTH (kg/cm^2) 9.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

DEHYDRATION REACTIONS (ESTERIFICATION)

TYPE OF CATALYST: *ALUMINA H-0423*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Al_2O_3 90 Loss on ignition (850°C): 10 CARRIER: n.a. FORM: tablets; extrusions SIZE: Diameter (mm) 4 Length (mm) n.a. ABD (g/cm^3) 0.95—0.80 SA (BET) (m^2/g) 190—200 PV (cm^3/g) 0.42—0.48	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It can also be used as carrier in the manufacturing of catalysts for various purposes.

HYDRATION REACTIONS

TYPE OF CATALYST: *PHOSPHORIC ACID H-3301*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT See chapter on isomerization	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a	See chapter on isomerization.

TYPE OF CATALYST: *ALUMINIUM KONTAKT 5780/S*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT wt % Al_2O_3 94—98 Na_2O 0.1 max. FORM: extrusions SIZE: Diameter (mm) 5 Length (mm) 5—10 ABD (g/cm^3) 0.65±0.10	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used as a carrier and a drying agent, and also for the dehydration of alcohols.

DEHYDRATION REACTIONS

TYPE OF CATALYST: *TUNGSTEN 74300; 74311*			
Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % Tungsten oxide (a) 74300: WO_3 95 (b) 74311: WO_3 10 CARRIER: n.a. FORM: pellets SIZE: Diameter (mm) 3 Length (mm) 3 SA (m^2/g) (a) 17 (b) 145	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	They are used for dehydration of alcohols, denitrogenation, hydrocracking and hydrotreating.

Annex III

Homogeneous catalysts

A. Disproportionation reactions
B. General reactions
C. Hydroformylation
D. Isomerization
E. Oxidation reactions
F. Polymerization

A. Disproportionation reactions

DISPROPORTIONATION PROCESS OF ABIETIC ACID

TYPE OF CATALYST: *PALLADIUM PK-11*

Manufacturer	Characteristics	Operating conditions	Remarks
CIECH Nitroplast	CONTENT wt % Pd 2.3—2.5 CARRIER: n.a. FORM: grains SIZE: Diameter (mm) 0.4—0.6 Length (mm) n.a. ABD (g/cm^3) 0.4—0.6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is applied in fluid phase of the disproportion process of abietic acid contained in the resin of coniferous trees, which is used for production of resin soaps being the emulsifier of polymerization of butadiene from styrene.

DISPROPORTIONATION OF OLEFINS

TYPE OF CATALYST: *METAL CARBONYLS*

Manufacturer	Characteristics	Operating conditions	Remarks
Pressure Chemical Co.	CONTENT (a) Ruthenium carbonyl $Ru_3(CO)_{12}$ (b) Tungsten hexacarbonyl $W(CO)_6$ CARRIER: n.a. SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	(a) Orange solid: M.p. 150°C (dec) Air stable (b) White solid: M.p. 175°C (dec) Air stable

TYPE OF CATALYST: *TUNGSTEN 74-220*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % Tungsten carbonyl $W(CO)_6$ FORM: white solid SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Stability: air stable.

HYDROGENATION OF NITROBENZENE TO ANILINE

TYPE OF CATALYST: *RUTHENIUM 44-180; 44-185; 44-588*			
Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % (a) 44—180 Ruthenium (II) acetylacetonate $Ru(C_5H_7O_2)_3$ (b) Ruthenium carbonyl $Ru_3(CO)_{12}$ (c) Ruthenium (III) trichloride hydrate FORM: (a) red-brown solid; (b) orange solid; (c) black solid SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Other applications: Hydrogenation of nitrobenzene to aniline in the presence of carbon monoxide and hydrogen; Hydrogenation of activated olefins; Linear oligomerization and co-oligomerization of olefins; Stability: all air stable.

B. General reactions

TYPE OF CATALYST: KA

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT n.a. CARRIER: n.a. FORM: powder; spheres SIZE: n.a. ABD (g/cm^3) 0.8—0.9 (spheres) 0.48—0.50 (powder) SA (BET) (m^2/g) 195 PV (cm^3/g) 0.6—0.7 STRENGTH (kg/cm^2) 4—5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Based on SiO_2. It is also most suitable as a catalyst carrier. Moisture: 1—3%. Average pore diameter: 100 Å Hardness: 6—10%. Read density: 2.2 g/cm^3.

TYPE OF CATALYST: ***K SERIES***

Manufacturer	Characteristics	Operating conditions	Remarks
Girdler	CONTENT The catalyst is produced from the mineral Montmorillonite CARRIER: n.a. FORM: powder SIZE: n.a. ABD (g/cm^3) 0.3—0.6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	The K-series are activated montmorillonite clays. They are ideal for many reactions catalyzed by hydrogen acids or Lewis acid salts. The following catalysts are produced: KSF, KSF/G, K_{10}, K_{10}/SF, K20, K306, KA. K306 and KA can also be supplied as spheres, with a bulk density of 0.4—0.8 g/cm^3.

C. Hydroformylation

HYDROFORMYLATION (FIRST STEP OF THE OXOPROCESS)

TYPE OF CATALYST: *COBALT ACETATE*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Co 23 FORM: hydrated granular crystal ABD (g/cm³) 0.88	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *COBALT NAPHTHENATE*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Co 6 (in any compatible petroleum solvent) FORM: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *COBALT OCTASOL — COBALT 2 ETHYL HEXOAT*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Co 6 or 12 (in any compatible petroleum solvent specified by customer) FORM: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *COBALT SULPHATE*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Co 21 FORM: hydrated red crystal ABD (g/cm^3) 1.3	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *COBALT THALLATE*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Co 6 (in any compatible petroleum solvent specified by customer) FORM: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *METAL CARBONYLS*

Manufacturer	Characteristics	Operating conditions	Remarks
Pressure Chemical Co.	CONTENT wt % (a) Cobalt carbonyl $Co_2(CO)_8$ (b) Manganese carbonyl $Mn_2(CO)_{10}$	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	(a) Dark orange solid: M.p. 51°—52°C (dec) Heat and air sensitive (b) Yellow solid: M.p. 153°—155°C Heat and air sensitive Volatile in steam Soluble in most organic solvents.

HYDROFORMYLATION OF OLEFINS (OXO PROCESS)

TYPE OF CATALYST: *COBALT 27040*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % Cobalt carbonyl $Co_2(CO)_8$ FORM: dark orange solid	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Other applications: Carboxylation of olefins; Hydrogenation of aldehydes to alcohols; Isomerization of olefins, hydrogenation of olefins; Cyclic oligomerization of acetylenes to benzenes etc.; Stability: air sensitive, heat sensitive.

HYDROFORMYLATION OF OLEFINS TO ALDEHYDES

TYPE OF CATALYST: *RHODIUM 45—188; 45—225*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % (a) 45-188 Rhodium (III) trichloride hydrate $RhCl_3 \times H_2O$ (b) 45-225 Trichlorotris (pyridine) rhodium (III) $RhCl_3(C_5H_5N)_3$ FORM: (a) dark red solid (b) orange-yellow solid	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Other applications: Low pressure carbonylation of methanol to acetic acid; Isomerization of olefins; Co-oligomerization of ethylene and butadiene to hexadiene; Stability: both air stable.

D. Isomerization

ISOMERIZATION

TYPE OF CATALYST: *BORON TRIFLUORIDE*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT wt % Compressed gas BF_3 99.55 Boron trifluoride dihydrate: fuming hygroscopic liquid CARRIER: n.a. FORM: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Catalyst for organic condensation (compressed gas). Dihydrate-catalyst used also for polymerization, resin curing.

ISOMERIZATION OF OLEFINS

TYPE OF CATALYST: *METAL CARBONYL*

Manufacturer	Characteristics	Operating conditions	Remarks
Pressure Chemical Co.	CONTENT wt % (a) Iron pentacarbonyl $Fe(CO)_5$ (b) Di-iron nonacarbonyl $Fe_2(CO)_9$ (c) Tri-iron dodecacarbonyl $Fe_3(CO)_{12}$ (d) Molybdenum hexacarbonyl $Mo(CO)_6$	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	(a) Redish-brown liquid: B.p. 103°C/760 mm Heat and air sensitive (b) Golden-orange solid: M.p. 100°C (dec) Heat and air sensitive (c) Greenish-black solid: M.p. 140°C (dec) Heat and air senitive (d) White solid: M.p. volat 150°C (dec) Air stable.

TYPE OF CATALYST: *IRON* (a) *26250*; (*b*) *25264*; (*c*) *26280*; (*d*) *26090*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % (a) Iron dodecacarbonyl $Fe_3(CO)_{12}$ (b) Iron nonacarbonyl $Fe_2(CO)_9$ (c) Iron pentacarbonyl $Fe(CO)_5$ (d) Cyclopentadienyl-iron dicarbonyl-dimer $[C_5H_5Fe(CO)_2]_2$ FORM: (a) black solid; (b) orange-yellow solid; (c) orange liquid; (d) purple red solid.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Other applications: Cyclic oligomerization of acetylenes to benzenes; Dimerization of norbornadiene; Carbonylation of olefins to alcohols in the presence of H_2O; For the addition of carbon tetrachloride and CO to olefins. Stability: (a) Air sensitive; (b) Air sensitive, heat sensitive (store cold); (c) Air sensitive, heat sensitive (store cold); (d) Air stable.

TYPE OF CATALYST: *MOLYBDENUM 42040; 42135*			
Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % (a) Cyclopentadienyl molybdenum tricarbonyl dimer: $[C_5H_5Mo(CO)_3]_2$ C = 39.7 (b) Molybdenum carbonyl: $Mo(CO)_6$ C=27.2 FORM: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Applications: (a) Addition of carbon tetrachloride to olefins; (b) Isomerization of olefins, disproportionation of olefins. Epoxidation of olefins with organic hydroperoxides. Stability: (a) Air-sensitive; (b) Air-stable.

TYPE OF CATALYST: *RHODIUM 45027; 45045*			
Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % (a) Chlorobis (ethylene) rhodium (I) dimer (b) Chlorodicarbonyl rhodium (I) dimer FORM: (a) rust coloured solid; (b) red solid.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Other applications: Dimerization of ethylene to butenes; Hydroformylation of olefins; Hydrogenation of aldehydes to alcohols; Low pressure carbonylation of methanol to acetic acid. Stability: both, air sensitive (store cold).

ISOMERIZATION OF NON-CONJUGATED OLEFINS TO CONJUGATED ONES

TYPE OF CATALYST: *PLATINUM 78148*			
Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % Platinum (II) chloride $PtCl_2$ Pt 72.7 FORM: brown solid	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used for the hydrogenation of olefins.

E. Oxidation reactions

OXIDATION REACTIONS

TYPE OF CATALYST: *MANGANESE CATRON MB-11*

Manufacturer	Characteristics	Operating conditions	Remarks
Anderson Development Co.	CONTENT wt % Mn 10—11 P 12—14 CARRIER: n.a. FORM: waxy solid melting in the range of 100°—120°C SIZE: n.a. TS (°C) 200	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It contains manganese in the form of an organometallic polymer with phosphorus. Aliphatic hydrocarbons may be converted into aldehydes and acids, alcohols into aldehydes, acids into ketones and aldehydes and esters into unsaturates and ethers. Chlorination and nitration of aromatics and carbohydrates may be enhanced by traces of CATRON MB-11. It serves as an effective oil soluble drying agent for air-cured coatings.

OXIDATION OF ETHYLENE TO ACETALDEHYDE

TYPE OF CATALYST: *PALLADIUM CHLORIDE*

Manufacturer	Characteristics	Operating conditions	Remarks
Degussa	CONTENT wt % $PdCl_2$ 15—20 FORM: solution in water	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used for the oxidation of propylene to acetone.

OXIDATION OF OLEFINS

TYPE OF CATALYST: *PALLADIUM 46178; 46185*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % (a) Palladium (II) acetate $Pd(O_2CH_3)_2$ (b) Palladium (II) chloride Pd Cl_2 FORM: (a) brown solid; (b) rust coloured solid	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Other applications: Oxidation of ethylene to vinyl acetate; Carbonylation of olefins; Carbonylation of amines to isocyanates; Synthesis of allylic esters from allylic chlorides in the presence of acetate ion. Stability: both, air stable.

F. Polymerization

POLYMERIZATION OF OLEFINS

TYPE OF CATALYST: *FERROCENE (DICYCLOPENTADIENYL IRON)*

Manufacturer	Characteristics	Operating conditions	Remarks
Anderson Development Co.	CONTENT wt % *powder crystals* Benzene insoluble (max., %) 2 0.2 Non-volatile matter (max. %) 5 0.4 FORM: crude powder; purified crystals Melting point (°C): 170 (powder); 171—172 (crystals) ABD (g/cm³) 1.49	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It has been used: To promote oxidation performance of fuels; As a stabilizer fcr organosilicon polymers; To provide an inexpensive source of organometallic substance for building new special purpose derivatives and polymers.

POLYMERIZATION

Manufacturer: Ethyl Corporation	TYPE OF CATALYST						
	Trimethyl aluminium TMA	Triethyl aluminium TEA	Diisobutyl aluminium hydride DIBAH	Triisobutyl aluminium TIBA	Diethyl aluminium chloride DEAC	Diisobutyl aluminium chloride DIBAC	Remarks
Formula	$(CH_3)_3Al$	$(C_2H_5)_3Al$	$(i\text{-}C_4H_9)_2AlH$	$(i\text{-}C_4H_9)_3Al$	$(C_2H_5)_2AlCl$	$(i\text{-}C_4H_9)_2AlCl$	Aluminium alkyls, catalyst components for polymerization of olefins in the manufacture of synthetic rubber and plastics and for specific olefin syntheses. Alkylation and reducing agents
Formula weight	72.09	114.17	142.22	198.33	120.56	176.67	
Theoretical composition:							
Al wt %	37.4	23.6	19.0	13.6	22.4	15.3	
Chlorine wt %	—	—	—	—	29.4	20.1	
Density (g/ml at 25°C)	0.7478	0.8324	0.7990	0.7823	0.9709	0.9118	
Freezing point (°C)	15.3	ca —46	—80	1	—74	—40	
Boiling point (°C)	127	187	275	212	214	289	
Vapour pressure, (mm Hg) at:							
25°C	12	—	—	—	—	—	
60°C	69	0.8	0.01	1.8	1.9	0.03	
100°C	323	13	0.3	16	17	0.6	

POLYMERIZATION REACTIONS

TYPE OF CATALYST: *BORON TRIFLUORIDE.DIHYDRATE*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT n.a. FORM: fuming hygroscopic liquid	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for resin curing.

TYPE OF CATALYST: *BORON TRIFLUORIDE PHOSPHORIC ACID*

Manufacturer	Characteristics	Operating conditions	Remarks
Harshaw	CONTENT n.a. FORM: fuming liquid	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used for alkylation and polymerization reactions. Boron trifluoride complexes catalysts for polymerization and condensation modifying reactivity of BF_3.

PRODUCTION OF POLYETHYLENE TEREPHTHALATE

TYPE OF CATALYST: *ANTIMONY-BASED M&T CATALYST S-24*

Manufacturer	Characteristics	Operating conditions	Remarks
M&T International NV	CONTENT wt % Antimony min. 56 Chloride max. 100 ppm Iron max. 100 ppm Sulphate max. 100 ppm FORM: white crystalline solid	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a. PURITY: $\geqslant$95%	Polycondensation catalyst for polyester manufacture.

TYPE OF CATALYST: *ANTIMONY M&T CATALYST S-22*

Manufacturer	Characteristics	Operating conditions	Remarks
M&T International NV	CONTENT wt % Antimony $\geqslant$11.5 Iron $\leqslant$100 ppm Sulphate $\leqslant$100 ppm FORM: amber liquid VISCOSITY at 25°C: 105 cs Specific gravity at 25°C: 1.02—1.04 Flash point: 232°C Freezing point: —2°C (max.)	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a. PURITY: $\geqslant$95%	Catalyst S-22 is a nonvolatile liquid, may be used for continuous polyester production.

TYPE OF CATALYST: *TRIBUTYL ANTIMONITE M& T CATALYST S-23*

Manufacturer	Characteristics	Operating conditions	Remarks
M& T International N V	CONTENT wt % Tributyl antimonite min. 95 Antimony min. 33.9 Chloride 100 ppm Sulphate 100 ppm Iron 100 ppm FORM: water white liquid VISCOSITY at 25°C: 7.67 cs Specific gravity at 25°C: 1.26 Flash point: 102°C Freezing point: —60°C	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a. PURITY: $\geqslant$95 %	Catalyst S-23, with a low viscosity, low freezing point liquid, is suitable for batch or continuous processes, for polyethylene terephthalate manufacture.

POLYMERIZATION OF OLEFINS

TYPE OF CATALYST· *METALOCENES*

Manufacturer	Characteristics	Operating conditions	Remarks
Pressure Chemical Co.	CONTENT wt % (a) Ferrocene $(C_5H_5)_2Fe$ (b) Nickelocene $(C_5H_5)_2Ni$ (c) Biscyclopentadienyltitanium dichloride $(C_5H_5)_2TiCl_2$ (d) Biscyclopentadienylvanadium dichloride $(C_5H_5)_2VCl_2$	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	(a) Orange solid: M.p. 173°C Air stable (b) Dark green solid: M.p. 173—174°C Air sensitive (c) Red solid: M.p. 289—291°C Air stable (d) Green solid M.p. 250°C Air sensitive

TYPE OF CATALYST: *NICKEL CARBONYL*

Manufacturer	Characteristics	Operating conditions	Remarks
Pressure Chemical Co.	CONTENT wt % $Ni(CO)_4$ 34.37 Ni Critical temperature: 200°C Melting point: —25°C Boiling point: 42.6°C Critical pressure: 30atm.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is exceedingly toxic. Other applications: Carboxylation of acetylenes to acrylates; Carbonylation of alkyl halides; Cyclic oligomerization of acetylenes.

POLYMERIZATION REACTIONS

TYPE OF CATALYST: *TRI N-BUTYL ANTIMONITE*

Manufacturer	Characteristics	Operating conditions	Remarks
Stauffer Chemical Co.	CONTENT wt % $(C_4H_9O)_3Sb$ FORM: colourless liquid DENSITY(g/cm^3) 2.99	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used as a flame retardant, a cross linking agent for other antimony compounds and a catalyst for the production of polyesters.

TYPE OF CATALYST: *TRI n-BUTYL VANADATE*

Manufacturer	Characteristics	Operating conditions	Remarks
Stauffer Chemical Co.	CONTENT wt % $V(O)\ (C_4H_9O)_3$ FORM: clear yellow-brown liquid DENSITY (g/cm^3) 0.97	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used as an EPDM polymerization catalyst in combination with an aluminium alkyl halide.

TYPE OF CATALYST: *TRI ETHYL VANADATE*

Manufacturer	Characteristics	Operating conditions	Remarks
Stauffer Chemical Co.	CONTENT wt % $V(O)\ (C_2H_5O)_3$ FORM: clear yellow-brown liquid DENSITY (g/cm^3) 1.06	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used as an EPDM polymerizaticn catalyst in combination with an aluminium alkyl halide.

TYPE OF CATALYST: *TETRAALKYL TITANATES*

Manufacturer	Characteristics	Operating conditions	Remarks
Stauffer Chemical Co.	CONTENT wt % (a) $(C_3H_7O)_4Ti$ (b) $(C_4H_9O)_4Ti$ (c) $(C_8H_{17}O)_4Ti$ (d) $(C_7H_7O)_4Ti$ FORM: liquid DENSITY (g/cm^3) (a) 0.94 (b) 0.99 (c) 0.89 (d) —	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used as a polymerization catalyst in combination with an aluminium alkyl, a transesterification and esterification catalyst, an adhesion promotor, a resin modifier, and in the preparation of heat resistant coatings and water repellent finishes.

TYPE OF CATALYST: *TITANIUM TETRACHLORIDE*

Manufacturer	Characteristics	Operating conditions	Remarks
Stauffer Chemical Co.	CONTENT wt % $TiCl_4$ FORM: colourless liquid DENSITY (g/cm^3) 1.7	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used as a polymerization catalyst in combination with an aluminium alkyl, as an intermediate in the production of titanium dioxide, in the textile industry.

TYPE OF CATALYST: *TITANIUM TRICHLORIDES*

Manufacturer	Characteristics	Operating conditions	Remarks
Stauffer Chemical Co.	CONTENT wt % Titan. trichl. H $TiCl_3$ Titan. trichl. 1.1 $(TiCl_3)_3AlCl_3$ Titan. trichl. 1.2 $(TiCl_3)_3AlCl_3$ Titan. trichl. 2.1 $(TiCl_3)_3AlCl_3$ FORM: powder SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Grade H is used in systems in which stereospecificity is not important; Grade 1.1 is used to produce stereospecific polymers with a broad particle size distribution; Grade 1.2 produces stereospecific polymers with narrower particle size distribution; Grade 2.1 produces polymer in high yield with small particle size. Normally used in combination with an aluminium alkyl (Ziegler-Natta system) to produce polymers.

POLYMERIZATION OF OLEFINS

TYPE OF CATALYST: *VANADIUM OXYCHLORIDE*

Manufacturer	Characteristics	Operating conditions	Remarks
Stauffer Chemical Co.	CONTENT wt % $VOCl_3$ FORM: light yellow liquid DENSITY (g/cm^3) 1.8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used as an olefin polymerization catalyst in combination with an aluminium alkyl and in the synthesis of trialkoxy and alkoxy chloro vanadates.

TYPE OF CATALYST: *VANADIUM TETRACHLORIDE*

Manufacturer	Characteristics	Operating conditions	Remarks
Stauffer Chemical Co.	CONTENT wt % VCl_4 FORM: red-brown liquid DENSITY (g/cm^3) 1.8	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used as an olefin polymerization catalyst in combination with an aluminium alkyl, a source of high purity vanadium metal, a chlorinating agent and an intermediate in the preparation of organovanadium compounds.

TYPE OF CATALYST: *VANADIUM TRISACETYLACETONATE*

Manufacturer	Characteristics	Operating conditions	Remarks
Stauffer Chemical Co.	CONTENT wt % $V(C_5H_7O)_3$ FORM: brown solid DENSITY (g/cm^3) 0.48	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used as an olefin polymerization catalyst in combination with an aluminium alkyl and as an additive to Ziegler catalyst system for production of polypropylene and ethylene propylene elastomers.

CYCLIC OLIGOMERIZATION OF ACETYLENES TO BENZENES

TYPE OF CATALYST: *CHROMIUM 24012*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % Benzene chromium tricarbonyl $C_6H_6Cr(CO)_3$ FORM: yelow solid	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Application: Stereoselective hydrogenation of 1.4 and 1.3—dienes by 1.4—addition to form cis-monoenes; Air-stable.

CYCLYC OLIGOMERIZATION OF ACETYLENE

TYPE OF CATALYST: *NICKEL 28115; 28130*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % (a) Nickel carbonyl $Ni(CO)_4$ (b) Nickelocene bis (cyclopentadienyl) Nickel $(C_5H_5)_2Ni$ FORM: (a) colourless liquid; (b) dark-green solid	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Other applications: Carboxylation of acetylenes to acrylates; Carbonylation of allyl halides; Dimerization of ethylene. Stability: (a) Air sensitive, heat sensitive; (b) Air sensitive. Toxicity: (a) high

POLYMERIZATION OF OLEFINS

TYPE OF CATALYST: *TITANIUM 22115; 22118; 22020*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % (a) Titanium (IV) tetrachloride $TiCl_4$ (b) Titanium (III) trichloride $TiCl_3$ (c) Titanocene dichloride $(C_5H_5)_2TiCl_2$ FORM: (a) colourless liquid; (b) purple solid; (c) red solid	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Other applications: Hydrogenation of conjugated dienes to alkanes; Linear oligomerization and polymerization of olefins. Stability: (a) and (b): air senstive; (c): air stable.

TYPE OF CATALYST: *VANADIUM 23225; 23020*			
Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % (a) Vanadium (III) acetylacetonate $V(C_5H_7O_2)_3$ (b) Vanadocene dichloride $(C_5H_5)_2VCl_2$ FORM: (a) brown solid; (b) green solid	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Other applications: Epoxidation of olefins; Selective hydrogenation of conjugated dienes to monoenes. Stability: both air sensitive.

POLYMERIZATION REACTIONS

TYPE OF CATALYST: *ALUMINIUM ALKYLS*			
Manufacturer	Characteristics	Operating conditions	Remarks
Texas Alkyls Inc.	CONTENT wt % DEAC — Diethylaluminium chloride; DEAL-E— Diethylaluminium ethoxide; DEAL-I — Diethylaluminium iodide; DIBAC — Diisobutylaluminium chloride	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Others: DIBAL-H — Diisobutylaluminium hydride; EADC — Ethylaluminium dichloride; MONIBAC — Monoisobutylaluminium dichloride; ISOPRENYL — Isoprenylaluminium; TEAL — Triethylaluminium; TIBAR — Triisobutylaluminium; TEB — Triethyl borane. Catalyst components for olefin and diene polymers, including polypropylene, polyethylene, polybutadiene, polyisoprene, ethylene-propylene copolymers and terpolymers.

Annex IV

Carriers

CATALYTIC ALUMINA

TYPE OF CATALYST: *ALUMINA TABULAR ALUMINA T-71*

Manufacturer	Characteristics	Operating conditions	Remarks
Aluminium Company of America (ALCOA)	CONTENT wt % Al_2O_3 99.5 Na_2O 0.01 Fe_2O_3 0.06 SiO_2 0.04 SO_3 0.09 CaO 0.06 Loss on ignition (1,100°C): 0.0 FORM: granular SIZE: 4—8 mesh (4—1.3 mm) Diameter (mm) 12.5—25.3 Length (mm) n.a. ABD (g/cm^3) 1.2—1.3 SA (m^2/g) 0.5 PV (cm^3/g) 0.15—0.20	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is a porous alumina having 35—50% porosity. It is used primarily as a low surface area catalyst or catalyst support. It may be used as an aggregate in insulating castable refractories.

CARRIER

TYPE OF CATALYST: *THERMA COMB^R BRAND ALSIMAG 795; ALSIMAG 843*

Manufacturer	Characteristics	Operating conditions	Remarks
American Lava 3M Company, Technical Ceramic Products Division	CONTENT wt % ALSIMAG 795: cordierite ($2MgO2Al_2O_3$ $5SiO_2$) ALSIMAG 843: lithia-alumina-silica FORM: n.a. SA (m^2/g) 0.07—0.1 STRENGTH(kg/cm^2) 141—195 (parallel to passages); 6.3 5 (perpendicular to passages)	TEMPERATURE RANGE: 1,200°C PRESSURE RANGE: n.a.	See ALSIMAG 614.

TYPE OF CATALYST: *ALPHA ALUMINA THERMA COMB^R BRAND ALSIMAG 614; ALSIMAG 776*

Manufacturer	Characteristics	Operating conditions	Remarks
American Lava 3M Company, Technical Ceramic Products Division	CONTENT wt % Alpha alumina FORM: corrugated ceramics	TEMPERATURE RANGE: 1,200°—1,538°C PRESSURE RANGE: n.a.	Catalyst supports in air pollution control, equipment for odour control, nitric acid tail gas, fume abatement, heat exchangers, flame arrestors, laminar flow gas mixers. Basic structure: A.H.C. Honey comb B. SC. Split Cell.

TYPE OF CATALYST: *SILICA BASF D-11—10*			
Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % SiO_2 main constituent Na + K approx. 0.6 Fe 0.15 Loss on ignition (dry base): 2—4 FORM: extrusions SIZE: Diameter (mm) 4—6 ABD (g/cm^3) 0.43 TS (°C) 550	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used for diverse chemical reactions.

TYPE OF CATALYST: *SILICA BASF D-11—11*			
Manufacturer	Characteristics	Operating conditions	Remarks
BASF	CONTENT wt % SiO_2 main constituent Na + K <0.05 Fe <0.06 Loss on ignition (dry base): 1—2 FORM: extrusions SIZE: Diameter (mm) 4—6 Length (mm) n.a. ABD (g/cm^3) 0.43 TS (°C) 700	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used for diverse chemical reactions.

CALSICAT DIVISION

ALUMINA SUPPORTS FOR EXPERIMENTAL USES

TYPICAL PROPERTIES

Calsicat 1/8″ tableted alumina supports

Type	SA m^2/g(1)	ABD g/cm^3(2)	PV cm^3/g (3)	CS lbs. (4)	% of pores			
					>1μ	.1μ to 1μ	.01μ to.1 μ	<.01μ
A	200	.80	.50	20	2	10	5	83
B	160	.80	.50	15	3	13	6	78
C	50	.95	.44	15	3	20	57	20
D	5	1.25	.23	32	4	66	30	0
AA	215	.63	.70	25	2	1	35	62
BB	170	.65	.64	22	2	2	45	51
BC	150	.70	.63	20	1	4	68	26
CC	30	.93	.40	25	1	61	30	8
DD	9	1.00	.35	38	1	79	20	0

%SiO_2 A — D .01 AA — DD .12
%Na_2O A — D .005 AA — DD .07

(1) Surface area by BET
(2) Bulk density, loose packing
(3) Pore volume by H_2O absorption
(4) Crush strength

CATALYST CARRIERS

Manufacturer: Catalysts and Chemicals International

Remarks: The catalyst carriers and supports described find a host of industrial catalytic applications when various active metals are added normally by impregnation

Designation	Principal components	Form	Size (in)	Surface area (m^2/g)	Pore volume (cm^3/g)	Density (lb/ft^3)
CS-201	Silica alumina	tablets	1/4×1/4	500—600	0.80	32±3
CS-201-4	Alumina	Raschig rings	1/2×3/8× ×3/16	300	0.70	30±3
CS-300	Calcium aluminate	rings	1×0.6 and 3/4×3/4	100	0.30	45±5
CS-301	Alumina	spheres	1/4×3/4	1—2	0.10	130±10
CS-303	Alumina	Raschig rings	5/8×1/4 3/8 and5/8	5—10	0.20	65±5
CS-330	Alumina	extrusions	1/8 and 1/16	150±25	0.4—0.5	45±5
CS-330-2	Alumina	tablets	1/4×1/4	150±25	0.30	65±5
CS-331	Alumina	extrusions	1/8 and 1/16	300	0.80	30±3
CS 331-3	Alumina	extrusions	1/8 and 1/16	∼360	∼0.76	∼38
CS-331-4	Alumina	extrusions	1/8 and 1/16	∼350	∼1.09	∼43
CS-331-5	Alumina	extrusions	1/8 and 1/16	∼320	∼1.10	∼26
CS-360	Silica alumina	spheres	1/3	∼2	∼0.20	∼48

CARRIER

TYPE OF CATALYST: *ALUMOGEL 44—00*

Manufacturer	Characteristics	Operating conditions	Remarks
Chemical Works of CSF	CONTENT wt % Activated alumina Na_2O max. 0.8 SiO_2 max. 0.9 Fe_2O_3 max. 0.1 Loss by heating to 1,100°C: max. 7 FORM: balls SIZE: Diameter (mm) 3—5; 5—8 Length (mm) n.a. ABD (g/cm^3) 0.9—0.9 STRENGTH (kg/cm^2) 3	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used as dryer for gases and liquids.

TYPE : Activated carbon[a]	Content	SA (m²/g)	Applications	Remarks
Chemiviron S6L	Bituminous coal	1,000—12,000	Liquid phase applications	Granules 8× 30 mesh
Chemiviron Filtrasorb 200	Bituminous coal	1,000—12,000		
Chemiviron BPL & VCL	Bitumnious coal	1,200—1,400	Vapor phase applications: solvent recovery; carrier	
Chemiviron PAC & RB	Bituminous coal	800—1,000		
Chemiviron SC II	Coconut shell	1,150—1,250	Vapor phase applications: removal of organic sulphur compounds in fixed bed, selective adsorption of hydrocarbon fractions; removal of aromatics, purification of CO_2, acetylene, H_2, compressed air	
Chemiviron SC XII	Coconut shell	900—1,100		
Darco S 51	Lignite	500—550		
Darco S 60	Lignite	750—800		
Darco XB	Wood	950—1,000		
Hydro Darco	Lignite	550—650		
Nuchar Aqua	Pulp mill residue	550—650		
Nuchar C	Pulp mill residue	1,050—1,100		
Nuchar (various)	Pulp mill residue	300—1,400		
Norit (various)	Wood	700—1,400		
Type CA-1	Coal		Liquid phase applications-decolorization	Granules of 12×40 mesh
Type CP-6	Coal		Liquid phase applications-purification of vitamin solutions	Granules of 14×40 mesh
Type BPL & BPX	Coal		Vapor phase applications	

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a) Chemiviron's granular activated carbons were developed by the Pittsburgh Activated Carbon Division of Calgon Corporation

TYPE OF CATALYST: ***INERT CATALYST BED SUPPORT***

Manufacturer	Characteristics	Operating conditions	Remarks
Fertilizer Corporation of India (F.C.I.)	CONTENT wt % Al_2O_3 main constituent 95—99.5 Na+K Fe FORM: spherical balls; extrusions SIZE: *balls extrusions* Diameter (mm) 3—38; 6—25 ABD (g/cm³) 1.2—1.5 TS (°C) 1,600	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used to protect catalyst beds.

TYPE OF CATALYST: ***DAVISON MULLITE***

Manufacturer	Characteristics	Operating conditions	Remarks
Grace Davison Chemicals	CONTENT Thermally fused spheres of combined alumina and silica FORM: pellets	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used in the hydrocarbon processing industry. It is chemically inert.

TYPE OF CATALYST: ***N-608; N-611; N-631***

Manufacturer	Characteristics	Operating conditions	Remarks
W.C. Heraeus GmbH	CONTENT wt % N-608: SiO_2 N-611: Al_3O_3 N-631: SiO_2/Al_2O_3 FORM: N-608: extrusions N-611 and N-631: tablets SIZE: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: ***H-0401***

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Al_2O_3 90 SiO_2 0.05 Na_2O 0.4 Loss on ignition (at 750°C) : 9 FORM: extrusions SIZE: Diameter (mm) 4 Length (mm) 2—10 ABD (g/cm^3) 0.9 SA (m^2/g) 200 PV (cm^3/g) 0.42	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Mean pore diameter 85Å.

TYPE OF CATALYST: *H-0403*			
Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Al_2O_3 94—97 SiO_2 0.05 Na_2O 0.4—0.6 Loss on ignition (at 750°C): 6 FORM: extrusions SIZE: Diameter (mm) 2.4; 3.2; 4.0 Length (mm) 3—7 DENSITY (g/cm³) 0.81—0.84 SA (m²/g) 320—350 PV (cm³/g) 0.52—0.56	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used as dryer for gases and fluids.

TYPE OF CATALYST: *H-0407*			
Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Al_2O_3 98—99 SiO_2 0.05 Na_2O 0.4 Loss on ignition (at 750°C): 0.5 FORM: extrusions Diameter (mm) 4.0 Length (mm) 2—10 ABD (g/cm³) 0.8 SA (m²/g) 0.49	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Mean pore diameter 250Å. H-0407 contains about 10—15% γ and little η Al_2O_3.

TYPE OF CATALYST: *H-0408*			
Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Al_2O_3 99 SiO_2 0.05 Na_2O 0.4 Loss on ignition (at 750°C): 0.5 FORM: extrusions SIZE: Diameter (mm) 4 Length (mm) 2—10 ABD (g/cm³) 0.8 SA (m²/g) 170 PV (cm³/g) 0.5	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Mean pore diameter 120Å. H-0408 consists essentially of γ Al_2O_3.

TYPE OF CATALYST: *H-0418*

Manufacturer	Characteristics	Operating conditions	Remarks
Houdry	CONTENT wt % Al_2O_3 94—97 SiO_2 0.05 Na_2O 0.4—0.6 Loss on ignition (at 750°C): 2—6 CARRIER: n.a. FORM: extrusions SIZE: Diameter (mm) 2.4; 3.2; 4.0 Length (mm) 3—8 DENSITY (g/cm^3) 0.81—0.84 SA (m^2/g) 410—450 PV (cm^3/g) 0.52—0.54	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is also used as dryer for gases and fluids.

TYPE OF CATALYST: *ALUMINA ICI-12—1; ICI-12—2; ICI-13—1*

Manufacturer	Characteristics	Operating conditions	Remarks
Imperial Chemical Industries Ltd	CONTENT wt % Alumina FORM: powder; pellets SIZE: *pellets* Diameter (mm) 4—5.4 Length (mm) 3—3.6	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	ICI-12—1 and 12—2: pellets; ICI-13—1: powder. They are medium area alumina catalysts largely used as supports in the production of noble metal catalysts. 12—1 and 12—2 are robust pellets and retain their strength during impregnation steps.

TYPE OF CATALYST: *ALUMINA ICI-13*

Manufacturer	Characteristics	Operating conditions	Remarks
Imperial Chemical Industries Ltd	CONTENT wt % Alumina FORM: n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	

TYPE OF CATALYST: *ACTIVATED ALUMINA ACTAL*

Manufacturer	Characteristics	Operating conditions	Remarks
Laporte Industries Limited (Peter Spence)	CONTENT wt % Al_2O_3 85 residual H_2O 12 SO_3 3 Traces only of Na_2O, SiO_2, Fe_2O_3 and NH_3 FORM: granules; pellets SIZE (mm): *granules* *pellets* 12—6 11.1 6—3 7.9 3—1.5 5.6 1.5—0.7 3.2 ABD (g/cm^3) 0.61—0.66 0.875—0.925 SA (BET) (m^2/g) 275 n.a. PV(cm^3/g) 0.37 n.a.	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	In particular it is used for dehydration of ethanol to ethylene and also in the recovery of sulphur from refinery gases using the Claus reaction. Pelleted ACTAL is specially suitable for drying under high pressure and under conditions where rapid changes in pressure are likely to take place. Its use virtually eliminates the formation of dust.

TYPE OF CATALYST: *ALUMINIUM OXIDE CATALYST KONTAKT 5780*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT wt % Al_2O_3 93—99 SiO_2 <0.1 Fe_2O_3 <0.1 Na_2O <0.1 Halogen free FORM: n.a. ABD (g/cm^3) 0.5—1 SA (BET) (m^2/g) 200—300 PV (cm^3/g) 0.4—0.1	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Used as carrier in γ and η active form and in inactive form α. As catalyst in dehydration of alcohols and as adsorbent.

TYPE OF CATALYST: *ALUMINIUM OXIDE CATALYST KONTAKT 5704*

Manufacturer	Characteristics	Operating conditions	Remarks
Veb Leuna Werke „Walter Ulbricht“	CONTENT n.a. FORM: spheres SIZE: Diameter (mm) 3—5 ABD (g/cm^3) 0.95± 0.15 SA (m^2/g) 250	TEMPERATURE RANGE: 180°—250°C PRESSURE RANGE: n.a.	It is also used as dryer for gases.

TYPE OF CATALYST: ***CERAMIC HONEYCOMB TORVEX***

Manufacturer	Characteristics	Operating conditions	Remarks
E.I. Du Pont de Nemours and Co. (Inc.)	CONTENT wt % ceramic	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Typical catalytic abatement system application with Torvex are in fume abatement equipment for the oxidation of hydrocarbon fumes or the reduction of nitrogen oxide fumes.

TYPE OF CATALYST: ***COLLOIDAL SILICA LUDOX^R AS AND HS***

Manufacturer	Characteristics	Operating conditions	Remarks
E.I. Du Pont de Nemours and Co. (Inc.)	CONTENT wt % Stabilizing ammonium counter ion SiO_2 30 SiO_2/Na_2O 120 NaCl 0.002 Na_2SO_4 0.003 SIZE: 13—14.10^{-6} SA (m^2/g) 210—230	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used in petroleum refining as catalyst binder or support.

TYPE OF CATALYST: ***ALPHA ALUMINA 13—075; 13—081***

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % Al_2O_3 99.5 FORM: granules SIZE (mm): 6 — 8 mesh (13—081); 28 — 48 mesh(13—075)	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	Low surface area alumina which are highly inert materials. They are also used for diluting catalyst beds, and packing inlet and outlet sections of tubular reactors.

TYPE OF CATALYST: *CARBON 06-005; 06-010; 06-014*			
Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % (a) activated carbon (b) activated carbon (c) carbon fibers FORM: (a) granules; (b) powder; (c) 3.6 mm fibers SA (m^2/g) (a) and (b): high; (c): 300 PV (cm^3/g) (c): 0.4	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It should be used in a non-oxidizing medium.

CARRIER (HIGH SURFACE AREA)

TYPE OF CATALYST: *ALPHA ALUMINA TRIHYDRATE 13—100*			
Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % Al_2O_3 64.9 Combined-H_2O 34.7 Na_2O 0.35 FORM: powder	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	In addition is used as drying agent and dehydration catalyst.

TYPE OF CATALYST: *GAMMA ALUMINA 13—250*			
Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % Al_2O_3 98 H_2O 2 FORM: powder SA (m^2/g) approx. 105	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	It is used as drying agent and dehydration catalyst.

TYPE OF CATALYST: *GAMMA ALUMINA 13—255*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Iuc.	CONTENT wt % Al_2O_3 98 FORM: pellets SIZE: Diameter (mm) 3 Length (mm) 3 SA (m^2/g) approx. 100	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See 13—250.

TYPE OF CATALYST: *GAMMA ALUMINA HIGH ACTIVITY 13—261*

Manufacturer	Characteristics	Operating conditions	Remarks
Strem Chemicals Inc.	CONTENT wt % Al_2O_3 96 FORM: pellets SIZE: Diameter (mm) 3 Length (mm) 3 SA (m^2/g) approx. 200	TEMPERATURE RANGE: n.a. PRESSURE RANGE: n.a.	See 13-250.

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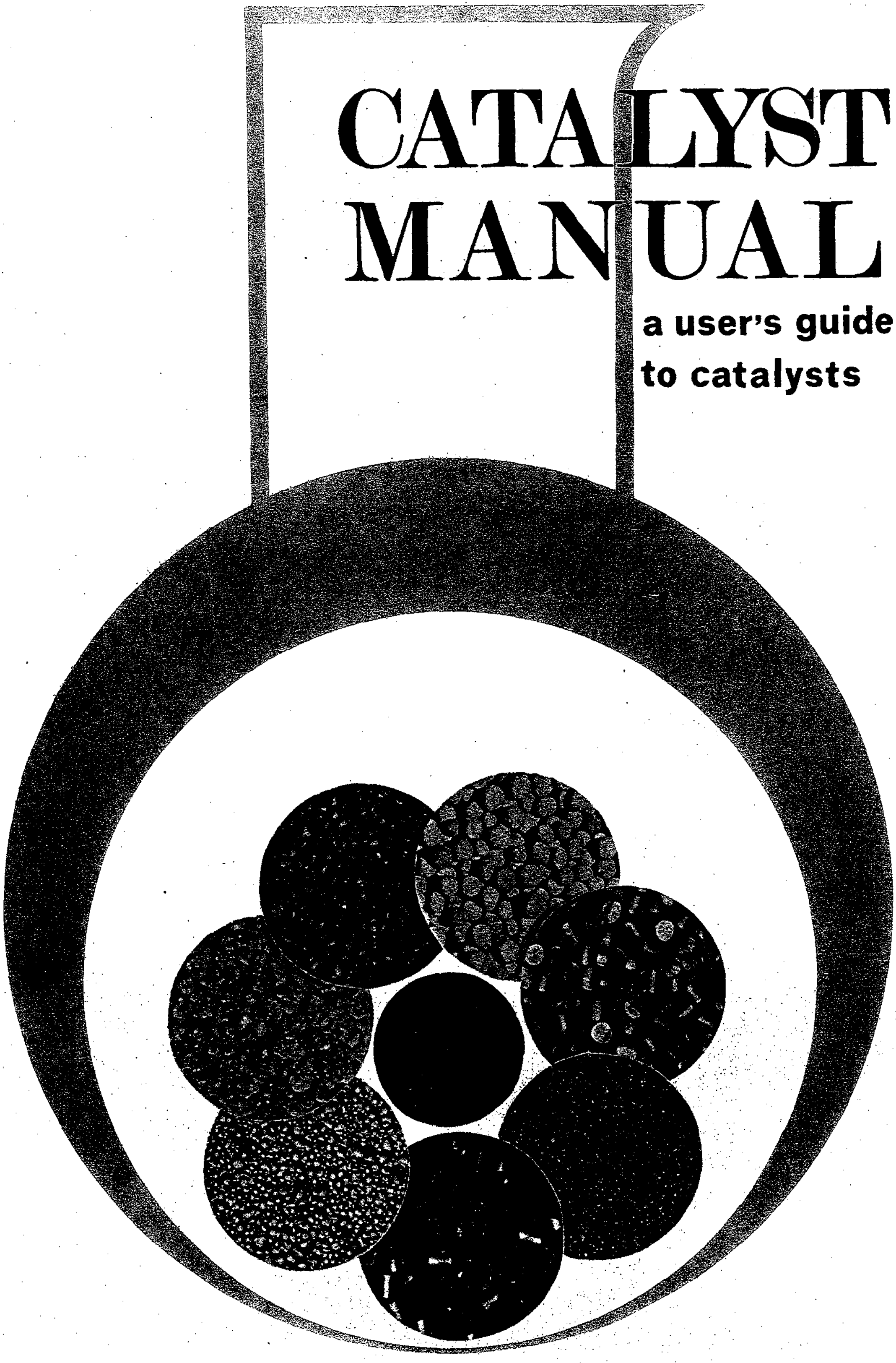
CATALYST MANUAL

a user's guide to catalysts



for the petrochemical and fertilizer industries

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CATALYST MANUAL

A USER'S GUIDE TO CATALYSTS FOR THE PETROCHEMICAL AND FERTILIZER INDUSTRIES

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Compiled by the
JOINT UNIDO-ROMANIA CENTRE
Bucharest

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EXPLANATORY NOTES

Use of a hyphen (–) between dates representing years signifies the full period involved, including the beginning and end years, e.g. 1971–1973.

Reference to "tons" indicates metric tons, unless otherwise stated.

The following forms are used in tables:

A dash (–) indicates that the amount is nil or negligible.

A blank indicates that the item is not applicable.

The following abbreviations are used:

Å	ångström
ABD	apparent bulk density
ID	inner diameter
n.a.	not available
LHSV	liquid hourly space velocity
PV	pore volume
PVC	polyvinyl chloride
SA	surface area – specific surface
STRENGTH	crushing strength
TS	thermal stability
VHSV	volume hourly space velocity
WHSV	weight hourly space velocity

Te following terms are used in this manual:

Apparent bulk density (ABD). Two values may be calculated: packed and loose. Packed density is calculated from the weight obtained by filling a graduated cylinder in small increments, tapping the cylinder on a soft surface after each addition until a constant volume results. Loose density is calculated from the weight obtained by gently filling a graduated cylinder from a funnel without shock or tapping. In large-diameter reactors (low ratio of wall area to volume) the filling weight would be closely equivalent to the packed ABD. In small-diameter multi-tube reactors (high ratio of wall area to volume) the filling weight would be about median between packed and loose ABD. The data shown in this manual generally refer to packed ABD.

Carrier. A physical support for a catalyst deposited in or on it. A carrier may be catalytically active or inert. Support, mount, base are synonyms for carrier.

Life. The most important characteristic of a catalyst is its "life"; this represents the length of time it will function economically for the purpose intended. Naturally, this will depend also on the installation in which it (the catalyst) is used and on the manner of operation.

Micro-mesh sieve analysis. Method of determining partial size distribution of powders, finer than 100 microns in diameter; this method is the one generally recommended in the technical cards. A series of micro-mesh sieves are employed with screen openings of 20, 45, 60 and 80 microns. The dry method is used whenever possible but in some instances it may be necessary to use a compatible liquid for complete separation on the finer screens. At times, full wet screening is necessary.

Pore volume (PV). Includes all pore volumes larger than about 10 Å diameter; it usually is expressed as cubic centimetres per gram. The simplest procedure is to calculate from the porosity the volume of water absorbed per unit weight of dry sample. Immersion liquids other than water may also be used, applying to the calculations the specific gravity of the particular liquid. A more accurate procedure is the mercury-helium method. Crushing strength is an arbitrary measurement of the force needed to collapse a single tablet. The force can be applied either to the side or the end of the tablets. It is expressed in kg/cm^2 or in g/cm^2.

Space velocity. Volume of gas or liquid measured under specific conditions passing through unit volume of catalyst bed per unit time. It may be expressed as:

a) *volume hourly space velocity* (VHSV), representing the volume of reactant under standard temperature and pressure passing through a catalyst bed per hour and per volume, of catalyst bed;

b) *liquid hourly space velocity* (LHSV), representing the volume of liquid reactant under standard conditions of temperature and pressure, passing through a catalyst bed per hour and per volume of catalyst bed;

c) *weight hourly space velocity* (WHSV) representing weight of reactant under standard conditions of pressure and temperature passing through a catalyst bed per hour and per weight of catalyst bed.

Space velocity is expressed as h^{-1}.

Surface area (SA). The surface area per unit weight of a carrier or catalyst as measured by gas absorption, expressed in square metres per gram. A method of estimating surface area is the BET method, a procedure developed by Bunauer, Emmet and Teller from physical absorption isotherms.

Thermal stability (TS). The highest temperature to which the catalyst may be exposed and retain its catalytic activity.

Preface

The preparation of a manual listing world catalyst manufacturers for the use of fertilizer and petrochemical industries was seen as necessary in the recommendations of the "Expert Group Meeting on the Transfer of Know-How in the Production and Use of Catalysts", held at Bucharest, Romania, 26—30 June 1972 under the auspices of the United Nations Industrial Development Organization (UNIDO). At this meeting, it was noted that no single compilation existed, giving comprehensively the names and addresses of these manufacturers together with the types of catalysts produced for each of the petrochemical and fertilizer processes.

The task of compilation was undertaken by the Joint UNIDO-Romania Centre, Bucharest. In order to obtain the catalogues, pamphlets, leaflets and other kinds of documentary material needed to compile a manual of catalyst producers that would particularly benefit developing countries, a circular letter was dispatched to chambers of commerce and to industrial and national associations in 116 countries. Sixty per cent of these responded to the circular, recommending catalyst manufacturers in their respective countries.

A new series of circular letters was then sent to 300 companies. About 250 companies replied and 100 companies sent pamphlets and technical leaflets regarding their products. Of these companies, however, only 71 were producers of catalysts used in the fertilizer and petrochemical industries. An alphabetic index of these manufacturers, with their addresses, is given in chapter XXIV of this manual.

The documentation elicited by the enquiry was analysed and summarized, and for each type of catalyst a technical card was filled in. By pursuing correspondence with the various companies, every attempt was made to make the information as complete as possible, wherever it was found to be not comprehensive. The cards, however were filled in only with indications given by the manufacturers. The information given in the cards is presented in the annexes to this manual.

In the column showing the type of catalyst, the basic chemical component is given along with the code number, as mentioned in the catalogue of the manufacturing company. In characterization of the catalyst, only the indications given by the manufacturing company are stated, for the most part of general informative nature. The numerical values given for the respective parameters are to a large extent dependent on the determination method applied. At present, no standard methods exist; where companies have supplied the method, it is given in parentheses.

No technical cards were drawn up for the catalysts produced and delivered by companies on a licence basis. Peroxides, initiators, inhibitors and other types of chemical substances which might be improperly considered catalysts are not discussed in this manual, nor are the names of the companies producing such substances.

The manual comprises catalysts recommended by companies to be used in heterogeneous and homogeneous catalysis, classified according to the chemical process for which they were manufactured. Within a process there are sub-processes, and the types of catalyst, for example, copper or nickel, as well as the manufacturing company, are indicated in alphabetical order in chapter XXVI.

Each process is preceded by a short introduction regarding the process in itself, with data on the technical conditions of the recommended catalysts.

The introduction to this publication discusses the catalysts recommended by companies to be applied in ammonia, sulphuric and nitric acids plants, which are the main factors for the fertilizer industry. For ammonia production, the sequence of processes used in gas synthesis was taken into account: reforming, shift conversion, methanation and ammonia synthesis.

Desulphurization of the gases going to reforming is an important and necessary operation. Catalysts that might be used in this operation are indicated in chapter VII ("Desulphurization") *since it is impossible to recommend catalysts used in gas desulphurization for ammonia synthesis only. Thus, in order to choose the catalysts used for desulphurization, chapter VII should be consulted.*

Catalysts recommended by the respective companies for petrochemical processes are examined in chapter II. Only those catalysts were selected for these processes where express recommendations were given. It is possible that other catalysts indicated for the general processes, such as halogenation, oxidation and reforming, may be used for these special processes, but conclusions in this regard are not included in this study.

Homogeneous catalysis is discussed in chapter XVI. This classification of catalysts by main processes has been used because of the difficulty of examining and recommending catalysts for each chemical reaction, especially where the catalysts have a multipurpose application. By "main process" is understood any process that is a large consumer of catalyst in the chemical industry.

In the case of multipurpose catalysts, the characteristics given by the manufacturing company were included in only one technical card within a chemical process: for example in the case of a catalyst recommended for alkylation and isomerization, the characteristics were given in the technical card of the alkylation process, with an appropriate cross reference on the card given for the isomerization process.

Users should carry on extensive discussions with the catalyst manufacturer to obtain as precise information as possible as to the best correlation between the particle size of the catalyst and the diameter of the reactor, the most efficient quantity of the loaded catalyst, and other indications. Such discussions are advisable, since all catalogues state that the indications given are approximate and that they can be detailed with greater exactitude only when the company knows exactly the technological conditions of operation.

It must be mentioned that in this manual attention is focused on catalysts according to the type of reaction being catalyzed and not on the engineering or economic characteristics of the processes. It should be noted too, that the present work does not include the biochemical catalysts, the enzymes, that are essential to life itself.

Introduction

THE NATURE OF CATALYTIC REACTIONS

As kinetic information began to accumulate during the last century, it appeared that the rates of certain reactions were influenced by the presence of a material which itself was unchanged during the process. In 1838, J. J. Berzelius thoroughly reviewed these reactions and came to the conclusion that a "catalytic" force was in operation.

Among the reactions studied by Berzelius were the conversion of starch into sugar in the presence of acids, the decomposition of hydrogen peroxide in alkaline solutions, and the combination of hydrogen and oxygen on the surface of spongy platinum. In these examples, the acids, alkaline ions and spongy platinum were the materials which increased the rate, and yet were unchanged as the result of the reaction.

Although the concept of a catalytic force proposed by Berzelius has now been discarded, the term "catalysis" is retained to describe all processes in which the rate of a reaction is influenced by a substance that remains chemically unaffected.

Although the catalyst is unchanged at the end of the process, there is no requirement that excludes its participation in the reaction. Indeed, present theories attempting to explain the activity of catalysts postulate that they do take part in the reaction.

From the concept of the energy of activation, the mechanism of catalysis would have to be such that the free energy of activation is lowered by the presence of the catalyst. In other words, a catalyst is effective in increasing the rate of a reaction because it makes possible an alternative mechanism, each step of which has a lower free energy of activation than that for the uncatalyzed process. For example, in the reaction between hydrogen and oxygen in the presence of spongy platinum, hydrogen combines with the spongy platinum to form an intermediate substance, which reacts with oxygen to provide the final product and reproduce the catalyst. It is required that the mechanism involving the platinum surface should occur at a faster rate than the reaction between the hydrogen and oxygen alone. The energies of activation for forming the intermediate compounds and fot their decomposition into the products are lower than that for the homogeneous combination of hydrogen and oxygen.

One other important characteristic of catalytic reactions is that a relatively small quantity of catalyst can cause conversion of a large quantity of reactants. The idea, however, that a small quantity of the catalyst can cause a large reaction does not mean that the catalyst concentration is unimportant. In fact, when the reaction does not involve a chain mechanism, it is generally true that the rate of the reaction is proportional to the concentration of the catalyst. This is perhaps most readily understood by considering the case of surface catalytic reactions.

A further property of catalytic reactions is that the position of equilibrium in a reversible reaction is not changed by the presence of the catalyst. If the equilibrium constant is unchanged by the presence of the catalyst, it is apparent that the ratio of the reaction-velocity constants for the forward and reverse reactions must be the same. Therefore, the catalyst for promoting the forward reaction must also be a catalyst for the reverse process. This has been verified in the study of the oxidation of sulphur dioxide. Thus platinum, which is an effective catalyst for the forward reaction, also has been found to accelerate the decomposition of sulphur trioxide.

Examples have been observed of so-called negative catalysis where the rate is decreased by the catalyst. Indeed, the definition of catalysis in its general form suggests only that the material has an influence on the rate of reaction.

Perhaps, the most reasonable theory of negative catalysis has been developed for chain reactions. It is postulated that the catalyst breaks the reaction chains or sequence of steps in the mechanism of the process. For example, nitric oxide reduces the rate of decomposition of acetaldehyde and ethyl ether. Apparently nitric oxide has the characteristic of combining with the free radicals involved in the reaction mechanism.

CLASSIFICATION OF CATALYTIC REACTIONS

Catalytic reactions are homogeneous or heterogeneous in nature depending upon the relations between the catalyst and the reactants.

The hydrolysis of an ester in an aqueous solution containing hydrogen ions is an example of homogeneous catalysis. The combination of hydrogen and oxygen to form water vapour in the presence of spongy platinum is heterogeneous since the platinum catalyst forms a separate phase from the reaction mixture. Heterogeneous catalysis need not involve only gas and solid phases. In emulsion polymerization, the reactants can be in the liquid phase and the catalyst in a solid phase or separate liquid phase.

Homogeneous catalytic reactions are subdivided into gaseous and liquid reactions.

The chamber process for the manufacture of sulphuric acid is an example of the former. Homogeneous liquid catalytic reactions are numerous and are widely used in industry. Most applications of this type are carried out in batch or continuous-tank reactors, such as the hydrolysis of organic esters in acid solutions and the nitration of aromatic liquids with nitric acid in the presence of sulphuric acid.

Heterogeneous reactions are of considerable significance to engineers. A few industrial applications of current importance are the oxidation of sulphur dioxide on vanadium pentoxide catalysts, the catalytic cracking of petroleum stocks using fixed or fluidized beds of solid catalysts, the oxidation of naphthalene to phthalic anhydride using vandium pentoxide catalyst and the manufacture of vinyl chloride by the reaction of acetylene and hydrogen chloride gas on a catalyst of mercuric chloride. In all these examples, the reaction mixture is in the gas phase. There are other cases where the reaction mixture is either in both the gas and the liquid phase or in the latter alone. For example, a desulphurization process for the removal of mercaptans and sulphides from petroleum stocks involves the flow of a liquid-phase reaction mixture over a solid catalyst.

The study of catalysis in such heterogeneous cases is closely being connected with the subject of surface chemistry, since surface processes play a dominant part in determining the kinetics of the reactions.

PHYSICAL PROPERTIES OF SOLID CATALYSTS

SURFACE AREA

The surface area is the sum of the external, or outer surface, plus the internal surface formed by walls of pores, cracks and crevices in the porous material. Usually, the inner part is of an order of magnitude greater than the outer surface. It is well known that increasing the surface area of a solid has a pronounced effect on its ability to adsorb gases and hence on its activity as a catalyst.

When carriers are used, in some instances the catalytic material does not impregnate all the interior surface of a porous catalyst carrier. In this case, the catalyst surface will consist of the external area plus the part of the inner surface covered with catalytic material. The surface area is determined by the BET method.

PORE SIZE

While a large surface area indicates a high activity, it is not safe to compare catalysts entirely on the basis of surface areas per unit mass because the interior surface of a porous catalyst may not be readily available for reaction.

There are many possible reasons for this. One of the most important is that the size of the openings or pores into the interior of a catalyst particle may be too small to allow easy access of the reactants to the inner surface. Hence it is not sufficient to know the surface area of the catalyst. In order to understand fully how reactions occur in pores, the following data must also be known: the average pore radius, the pore size distribution and the nature of the connexions between pores.

ACTIVITY

A large surface area is very desirable for the activity of catalytic material. If the activity of a catalyst for a specific reaction is defined as the amount of product produced per unit time per unit mass of catalyst, the activity will increase as surface area increases. However, the activity is frequently not directly proportional to the surface area. One reason is the inaccessibility of the interior due to small pore size. A direct proportionality is more likely to exist in comparing different batches of the same catalyst with the same reaction. Under these constant conditions, surface area is likely to be only variable. When different catalysts are compared for the same reaction, surface area is not as good a measurement of activity. One of the main reasons is based upon the concept that reaction occurs only on certain parts, i.e. active centres of the surface. If the fractions of the total surface that contain active centres are different for different catalysts, then activity will not be proportional to the surface.

CATALYST LIFE: CATALYST POISONS

In some reaction systems, the catalyst activity decreases so slowly that exchange for new material or regeneration is required only at long intervals. Examples are synthetic ammonia catalysts. On the other hand, cracking catalysts require frequent regeneration. The decrease in activity is due to poisons, deposited on the surface of the catalyst.

Poisons are substances existing in the reactant stream or produced by the reaction which lower the activity of the catalyst by deposition on the surface.

DEPOSITED POISONS

One example is the deposition of carbon on catalysts used in the petroleum industry. The carbon covers the active surface and partially plugs the pore entrances. It results in a less active surface and a decreased activity. This type of poisoning is partially reversible. Regeneration can be accomplished by burning off the carbon with air. If the poison is deposited as high-boiling hydrocarbon, the catalyst can be regenerated with steam.

CHEMISORBED POISONS

Compounds of sulphur and other materials are frequently chemisorbed on nickel, copper and platinum catalysts, thereby covering the active sites, which could adsorb reactant molecules.

CATALYST PREPARATION

The chemical composition of a catalyst does not alone determine activity. The physical properties of surface area, pore size and particle size greatly affect it. These properties are determined by the preparation procedure. A distinction must be made between preparations in which the entire material constitutes the catalyst and those in which the active agent is mounted on an inert material, i.e. the carrier. A catalyst corresponding to the first case is prepared by precipitation, gel formation or simple mixing of the components.

PRECIPITATION

Precipitation is a method for obtaining the solid material in porous form. The concentration of the aqueous solution, temperature, time of drying and calcining steps can influence the surface area and pore structure of the catalyst. Traces of impurities remaining from the washing may act as poisons.

GEL FORMATION

A special precipitation method is gel formation. A colloidal precipitate can be obtained from gels. The steps in the process are the same as for the precipitation method. Catalysts containing silica and alumina are especially suitable for preparation by gel formation, because their precipitates are colloids.

MIXING OF CATALYST COMPONENTS

The components of the catalyst are mixed with water, moulded to the desired grain size, dried and calcined. The proper particle size is finally obtained by grinding and sieving.

SELECTIVITY POISONS

It is known that some materials in the reactant stream will adsorb on the surface and then catalyze other undesirable reactions, thereby lowering the selectivity. The very small quantities of nickel, copper and iron in petroleum stocks can act as poisons in this way. The metal deposits on the catalyst act as a dehydrogenation catalyst, resulting in increased yields of hydrogen and coke and lower yields of gasoline.

STABILITY POISONS

These poisons are caused by the effect of water on the structure of the catalyst carrier. The temperature also has a pronounced effect on stability poisoning. Sintering and localized melting can occur as the temperature is increased. This changes the catalyst structure.

DIFFUSION POISONS

Entrained solids or fluids in the reactants form a solid residue on the catalyst and can cause this type of poisoning.

PROMOTERS AND INHIBITORS

A promoter is a substance added to the catalyst during its preparation which gives improved activity, selectivity and stability for a desired reaction. The promoter is present in small quantities and by itself has little activity.

An inhibitor has the opposite effect of a promoter when added in small quantities during catalyst manufacture. It causes poorer activity, stability or selectivity. Theoretically, inhibitors can be useful for reducing the activity of a catalyst in an undesirable side reaction.

Materials that are added to a reactant stream to improve the performance of a catalyst are called accelerators. They are the opposites of poisons. For example, steam added to the butene feed of a dehydrogenation reactor appears to reduce the amount of coke formed and increase the yield of butadiene.

PREPARATION OF CATALYSTS ON CARRIERS

Silica gel and alumina have very large surface areas. Hence they serve as carriers for those catalytic materials which are difficult to produce in a highly porous form. Carriers are also of value for obtaining a large surface area with a small quantity of an expensive active metal such as platinum, nickel or silver. The optimum amount of the active agent that should be impregnated on a carrier should be only a fraction or 1 per cent, or at most a few per cent of the mass of the carrier.

MISCELLANEOUS PROCEDURES

For preparing proprietary catalysts there are numerous special methods, such as the Raney-type catalysts, obtained by dissolving the aluminium out of an alloy of nickel, cobalt, or copper and aluminium, with an alkaline solution.

EVOLUTION OF CATALYSIS IN INDUSTRY

Catalysis holds an important part in the manufacture of many products of the petroleum and chemical industries such as refined gasolines, chemical fertilizers, synthetic fibres, synthetic rubber and synthetic polymers. From the three large subdivisions of catalysis — heterogeneous, homogeneous and enzymatic — the first plays the most important role. At present 70% of the catalytic processes applied in industry are heterogeneous. The development of the catalytic cracking process brought forth polypropylene, cis-polybutadiene, stereo-specific macromolecular products (according to Ziegler-Natta process). Other products include iso-paraffins, acrylonitrile, phthalic and maleic anhydride, and ethylene oxide. Ethylene oxide production reached about 800,000 tons in 1957 as compared to approximately 10 tons in 1930.

Catalysis in industry has been developed in three stages. During the first stage (1868—1913), most of the applications were in the inorganic chemical industry. The following processes were developed during this period: the catalytic process (Deacon) for chlorine production, the catalytic oxidation of ammonia to nitric acid (Oswald), ammonia synthesis from elements (Haber) and the oxidation of sulphur dioxide to trioxide for the manufacture of sulphuric acid.

During the second stage (1890—1940), the organic chemical industry used catalytic processes for the hydrogenation of edible oils, and methanol synthesis was developed. After 1920, petrochemistry appeared in the synthetic manufacture of alcohols and acetones. Ammonia synthesis was developed from methane gas.

In the third stage (1940 to the present), use of catalysts was extended to the petroleum industry and especially to the production of synthetic fuels. The *increasing demand for high-quality petroleum products has played a prime role in the development of cracking and reforming processes for the production of high-quality gasoline.*

Catalytic reforming was developed in 1950. It is now important and assures the production of aromatics, high-octane gasoline and inexpensive hydrogen for ammonia manufacture of hydrofining. The catalytic reforming process assures the simultaneous hydrogenation of naphthene to aromatics and isomerization of linear paraffins to iso-paraffins, avoiding as far as possible the cracking reactions, which diminish not only the gasoline yield but also the hydrogen one.

The catalysts used in this process have a multipurpose activity. They must react simultaneously with several raw materials containing a great number of hydrocarbons with a diversified chemical composition and different molecular structures and weight. Secondary reactions should be avoided as they lead to coke deposits on the catalyst, and to the partial or total loss of the catalyst activity.

In the countries of North and South America, Africa, Western Europe, the Middle East, Asia and the Pacific area there existed in 1970 a capacity of 304 million m^3 catalytic reforming using platinum catalyst on an aluminium carrier having a capacity of 8,400 tons.

For 1975, the capacity is expected to increase to 400 million m^3, and catalyst requirements will reach 11,900 tons.

The cracking process was developed similarly. In 1936, thermal cracking was important, and the gasoline produced had octane number 68. After 1936, the first catalytic cracking unit was set up.

CATALYST MANUFACTURING

Initially the catalysts were produced in the unit in which the catalytic processes were applied. The increasing demand for catalysts resulted in the development of catalyst manufacture plants within these units or in special catalyst plants.

Catalyst manufacture is complex because of the close relationship between the catalytic process and the catalyst applied. The catalyst represents the basic element of the catalytic process and it conveys to the process its peculiarity. The catalyst is a complex substance whose characteristics vary in importance depending on the user, manufacturer and researcher.

The user grants a high importance to the functional qualities of the catalyst, namely: activity, selectivity, stability, good mechanical and thermal strength, good regeneration, perfect reproductibility during manufacture and a reasonable price, which should not influence the economic efficiency of the applied catalytic process.

The manufacturer considers the catalyst as chemical material that must be produced and characterizes the catalyst by its composition and method of manufacturing namely: the nature of raw materials, the precipitation conditions, maturing, washing, drying, impregnation, calcination and activation, which are carefully controlled during the manufacturing process so that the final product meets the conditions requested by the user. The process must be perfectly reproducible.

The researcher is interested in all the characteristics wanted by the user and in those the manufacturer requires. He defines the catalyst by its texture, pore distribution, specific surface, structural density and gram density. He also examines certain electronic properties such as the energetic levels of electrons, and the superficial properties of the catalyst, especially in the reaction medium in which it will be used, namely the superficial state of oxido-reduction, the surface acidity or basicity, and the chemosorption properties by studying the nature of the relationships in the adsorbed phase, by determining the adsorption heat. All these aspects of the catalyst are not independent but, on the contrary, are complementary.

CATALYST CONSUMPTION

It is expected that the catalysts used in the heterogeneous catalytic processes of the crude-oil processing industry in the world, namely catalytic cracking, catalytic reforming and hydrofinishing, will record a total growth of about 70% in 1980 as compared to 1970 (from about 290,000 tons to about 490,000 tons). The distribution of this growth of catalyst consumption between the processes will be about: 40% for catalytic cracking catalysts; 110% for catalytic reforming catalysts; and 200% for hydrotreating catalysts.

For the fertilizer industry, the total consumption of catalysts for the production of ammonia and nitric and sulphuric acids will grow by about 146% in 1980 as compared to 1969 (from approximately 30,000 tons to 75,000 tons). If on the world scale during 1969—1980, the same consumption of ammonia, and nitric and sulphuric acids will be maintained as in 1969; the fertilizer industry will make use of about 74% of the entire quantity of catalysts necessary for the manufacture of these products in 1980.

The value of the total catalyst consumption for the production of ammonia, and nitric and sulphuric acids will increase to about 130 million United States dollars ($US) in 1980 as compared to about $US 59 million in 1969.

Part one

Heterogeneous catalysts for main industrial processes

I. AMMONIA PRODUCTION

The process of the production of ammonia consists essentially in reacting nitrogen and hydrogen under high pressure and temperature as per the following equation:

$$N_2 + 3H_2 \rightleftarrows 2NH_3$$

The nitrogen for ammonia synthesis is derived from the air. A wide variety of sources are used to supply the hydrogen. The biggest research and development effort in the ammonia industry is to obtain hydrogen at the lowest possible price. Today practically all new ammonia facilities obtain hydrogen from natural gas or petroleum.

There are exceptions — in isolated cases — where ammonia plants based on coke oven gas are still being considered, and a few plants are being built based on gasification of coal and other solid fuels. Generally, natural gas or petroleum fractions are preferred for hydrogen preparation. Selection of the particular process or feedstocks depends upon feedstock availability and the economics of the area in which the plants is to be built. However, when producing hydrogen from basic raw material such as natural gas, petroleum or coal, a complex plant is needed. In this process the following steps are required:

(a) *Sulphur removal.* Normally, sulphur is removed from the natural gas feedstock by activated carbon. In the case of naphtha, acid treating is used for bulk sulphur removal;

(b) *Hydrodesulphurization.* The vapourized naphtha in natural gas is mixed with a stream of gas which contains hydrogen. This gas may be obtained by recycle from the outlet of the reformer or it can be obtained, in the case of an ammonia synthesis plant, from the ammonia synthesis loop. The mixture is passed at a temperature of 350°—400°C over a combination of catalysts and the H_2S produced is absorbed in zinc oxide. For the catalysts recommended see chapter VII ("Desulphurization").

(c) *Conversion of hydrocarbons to synthesis gas.* Primary steam reforming and secondary reforming are processes used in converting hydrocarbons to synthesis gas (CO and H_2).

REFORMING

PRIMARY STEAM REFORMING

The sulphur-free naphtha vapour, mixed with steam is reformed in a tubular furnace. The basic reaction is:

$$C_nH_m + nH_2O \rightarrow nCO + \frac{2n+m}{2}H_2$$

When using methane as feedstock, the reaction is simplified to:

$$CH_4 + H_2O \rightarrow CO + 3H_2$$

The outlet temperature is in the range 750°—830°C. The higher temperatures are needed only when producing nitrogen-free hydrogen for methanol synthesis and hydrogenation purposes. For other purposes, such as town gas and ammonia synthesis gas, temperature is low.

CONVENTIONAL SECONDARY REFORMING

This is in effect a catalytic partial oxidation process using air and not oxygen. Air is added to the mixture leaving the primary reformer and burns with it, raising its temperature to about 1,250°C. The heated mixture then flows over a single bed catalyst. The methane present in the gas from the primary reformer is thus caused to react with the excess steam that is present. Because of the endothermic nature of the reaction, the temperature of the gas falls as it passes through the secondary reformer. The amount of air added is exactly that required to introduce the amount of nitrogen needed for ammonia synthesis (all the reactions that take place during reforming are listed in chapter XIV ("Reforming")).

Because of certain problems, such as carbon deposition, associated with earlier catalytic steam reforming, a number of processes have been developed to introduce oxygen into the reaction vessel to produce synthesis gas:

$$C_nH_m + \left(\frac{n}{2}\right) O_2 \rightarrow nCO + \left(\frac{m}{2}\right) H_2O$$

For methane:

$$CH_4 + \frac{1}{2} O_2 \rightarrow CO + 2H_2$$

In general, where natural gas or naphtha is available at a reasonable price, steam reforming is used. Partial oxidation processes are more suitable for countries that have fuel oil surpluses, a lack of low-priced natural gas and a higher relative requirement for naphtha in gasoline production.

The catalyst used in steam reforming usually contains 20—35% NiO, on a refractory support. Reformer catalyst's life is generally about five years.

SHIFT CONVERSION

CONVERSION OF CO TO CO_2 AND H_2

The gases from the reforming or partial oxidation units are sent to what is known as a shift converter, to convert the CO content of gas to CO_2 and H_2:

$$CO + H_2O \rightleftarrows CO_2 + H_2$$

The reaction is mildly exothermic, lower temperatures favouring more complete conversion of CO.

HIGH-TEMPERATURE CATALYST SYSTEM

The catalyst in general use is chromium promoted iron, formed by the co-precipitation of the oxides of the two metals. These catalysts normally operate in the range of 340°—550°C. The content of the catalyst is Fe_2O_3, but this is reduced to Fe_3O_4 in the plant convertors by the steam and H_2 mixture from the reformers. It usually contains a percentage of Cr_2O_3 to retard the sintering of the Fe_3O_4. In the past, the high-temperature CO-shift conversion system has normally been operated in two stages to obtain more complete conversion. In the high-temperature stage, carbon monoxide concentration can be dropped to 3 per cent.

LOW-TEMPERATURE SHIFT CONVERSION

Recent developments in catalyst technology have made fundamental changes in shift conversion design. Low-temperature catalysts with high activity have been developed. These catalysts are a mixture of the oxides of zinc, chromium and copper. They permit operation of the shift conversion unit at temperatures of 170°—290°C. In the low-temperature stage, the carbon monoxide concentration is brought down to 0.2%.

CARBON DIOXIDE REMOVAL

Before being sent to the ammonia synthesis unit, the carbon dioxide content of the gas stream must be removed. All processes for CO_2 removal are based upon the scrubbing of the gas with various solvents. The solvents can be reactive or non-reactive. The choice of the process depends on economics, the amount of CO_2 to be removed, and the final CO_2 content desired. Sulphur compounds not removed in an earlier stage are also removed by the CO_2 removal process.

FINAL PURIFICATION—METHANATION

In this process, both CO and CO_2 are hydrogenated to methane to less than 10 ppm by reaction with hydrogen over a nickel catalyst as per the following equations:

$$3H_2 + CO \rightarrow CH_4 + H_2O \quad \Delta H = -49.2 \text{ kcal}$$

$$4H_2 + CO_2 \rightarrow CH_4 + 2H_2O \quad \Delta H = -39.4 \text{ kcal}$$

Methanation is a highly exothermic process and where gases containing more than 1% of CO + CO_2 are being treated, it is usually necessary to recycle some of the cooled exit gas to dissipate the heat of reaction and maintain the catalyst below the normal operating temperature limit. The reaction is carried out at 1 to 50 atm, about 20,000 space velocity and about 400°C. Problems encountered in this process are S poisoning, carbon lay-down (450°—600°C), C_4 hydrocarbon formation, and loss in activity resulting from poor temperature control because of the high heat of reaction. The catalysts used are nickel catalysts promoted with alumina and iron catalysts. Methanation has replaced the copper liquor process in most new installations. Methanation is less expensive than copper liquor scrubbing, requires less equipment, is a cleaner plant and has a low operation cost.

Methanation is particularly suitable in plants using the new low-temperature shift conversion catalysts, or where the CO content has been reduced to a low level. For methanation a high-activity catalyst is required, metallic nickel being a usual active component produced in the converter by reduction of nickel oxide by hydrogen. The catalyst is used at pressures up to 30 atm and at temperatures of 250°—350°C.

Some catalysts used are alumina based and can be in the form of pellets, granules or extrusions; some also contain a cement binder. The lower concentrations of nickel (5—10%) can be obtained by impregnating alumina, but for higher concentrations (30%) which can be more active, the metal has to be introduced in other ways. Some containing chromia instead of alumina are particularly active for methanation.

AMMONIA SYNTHESIS

Ammonia is produced by the catalytic reaction of hydrogen and nitrogen at elevated temperatures and pressures. The principal variable distinguishing the different processes is the pressure. The catalyst used for ammonia synthesis is iron oxide promoted by one or four other acidic or alkaline oxides.

The iron oxide is magnetite (Fe_3O_4) although some catalysts have a portion of their iron oxide content as FeO. Promoted catalysts have the following oxides added at the time of manufacture:

Singly promoted: Al_2O_3

Doubly promoted: Al_2O_3, K_2O

Triply promoted: Al_2O_3, K_2O, CaO

Quadruply promoted: Al_2O_3, K_2O, CaO, MgO

Particle size of catalysts varies from 3 mm up to 23 mm but standard size is about 3—9 mm. Catalysts are supplied in two forms: oxidized and reduced. A catalyst's life is affected by a number of factors. One of the most significant is temperature; slow deactivation occurs above 530°C. Careful temperature control is important.

Another factor affecting the life of a catalyst is the impurities contained in the feed gas. Sulphur and chlorine cause permanent poisoning of catalyst, while carbon oxides and water cause semipermanent poisoning that can be partially reversed by reduction.

Methane and argon accumulating in the circulating gas do not poison the catalyst but reduce conversion by lowering the partial pressures of the reactants.

The life of the catalyst depends on the operating conditions and is generally from two to five years.

Work has been conducted to develop catalysts for conversion at room temperatures and atmospheric pressures. Dicyclopentadienyltitanum dichloride, promoted with ethylmagnesium halide, is being investigated. Rhodium and iridium complexes are being investigated that would break the durable triple linkage between two nitrogen atoms in gaseous form.

II. PETROCHEMICAL INDUSTRY

ACRYLONITRILE SYNTHESIS

Acrylonitrile ($H_2C = CH - CN$) is the most important representative of the acryl monomers, having multiple applications in the field of macromolecules. It enters into the composition of acryl synthetic fibres as a wool substitute.

The elastomers containing acrylonitrile present remarkable resistance to the action of chemical agents and good behaviour in the range of low temperatures. The technologies for acrylonitrile production having industrial importance are:

(a) From acetylene and hydrocyanic acid:

$$HC \equiv CH + HCN \xrightarrow{Cu_2Cl_2} H_2C = CH - CN \quad \Delta H = -41.15 \text{ kcal/mol}$$

The reaction takes place in a liquid phase in the presence of a Nieuwland catalyst (aqueous solution of $Cu_2Cl_2 + NH_4Cl$);

(b) From propylene and nitrogen oxide:

$$4H_2C = CH - CH_3 + 6NO \rightarrow 4H_2C = CH - CN + 6H_2O + 3N_2$$

The gases of ammonia oxidation containing 15% NO and 83—84% N_2 react with an excess of propylene at 400° — 700°C in the presence of lead-containing catalysts (in the form of titanate, zirconate, stanate).

(c) From propylene, ammonia and oxygen. The reaction on which several important industrial processes are based and which differ among themselves on the catalyst need, is the following:

$$H_2C = CH - CH_3 + NH_3 + \frac{3}{2} O_2 \rightarrow H_2C = CH - CN + 3H_2O$$

$$\Delta H = -123 \text{ kcal/mol}$$

In view of the importance of the process, numerous variants were elaborated, but they differed among themselves, especially with regard to the nature of the catalyst. Some information regarding these variants were selected from the patents literature:

(a) Bi, Sn, Sb molybdates and phosphomolybdates, phosphotungstates, Sb and U oxides on SiO_2 with activators — Sohio process, United States of America;

(b) Ti, Mn, Co, Bi, etc., phosphates or phosphoborates — Bayer process, Federal Republic of Germany;

(c) Fe, Bi phosphates — Shell process, the Netherlands;

(d) Sn molybdates — BASF process, Federal Republic of Germany.

FORMALDEHYDE SYNTHESIS

World production of formaldehyde currently amounts to some 5 million tons per year. Thus, formaldehyde has become an important raw material for the chemical industry.

Formaldehyde derivatives include mainly resins and glues for the wood, paper and textile processing industries, the major proportion being glues for manufacturing chip board and plywood.

More than 90% of the world formaldehyde output is produced by the catalytic oxidation of methanol in the presence of atmospheric oxygen. Two major processes are available for the catalytic conversion of methanol to formaldehyde: using silver catalyst; and using metal oxide catalyst (e.g. iron/molybdenum oxide).

In the process using silver catalyst, vaporized methanol and air are passed over silver crystals or silver gauze, the methanol concentration being above the explosion limit of methanol in air, i.e. above 36 vol. %. Formaldehyde is formed by combined dehydrogenation and oxidation of methanol.

OXIDATION/DEHYDROGENATION PROCESS (SILVER CATALYST)

Main reactions:

(1) $CH_3OH + \frac{1}{2} O_2 \rightarrow CH_2O + H_2O$ $+ 36.8$ kcal/mol

(2) $CH_3OH \rightleftarrows CH_2O + H_2$ $- 28.8$ kcal/mol

(3) $H_2 + \frac{1}{2} O_2 \rightarrow H_2O$ $+ 5.8$ kcal/mol

Secondary reactions:

(4) $CH_3OH + 3/2\ O_2 \rightarrow CO_2 + 2H_2O$ $+ 72$ kcal/mol

(5) $CH_2O + O_2 \longrightarrow CO_2 + H_2O$ $+ 123$ kcal/mol

(6) $CH_2O \rightleftarrows CO + H_2$ $- 2$ kcal/mol

Apart from the main reactions according to equations (1) to (3), a number of undesired secondary reactions (equations (4) to (6)) take place which reduce the formaldehyde yield related to the methanol input. These losses are due in particular to the formation of carbon monoxide and carbon dioxide.

In most processes using silver catalysts, the methanol charged together with the process air is converted to formaldehyde only in part so that the product obtained must be freed of surplus methanol by distillation.

OXIDATION PROCESS (METAL OXIDE CATALYST)

$$CH_3OH + \frac{1}{2} O_2 \rightarrow CH_2O + H_2O \quad + 36.8 \text{ kcal/mol}$$

In formaldehyde processes using metal oxide catalysts, the formation of formaldehyde proceeds according to the equation, i.e. by oxidation of methanol as the highly selective catalysts largely suppress secondary reactions. Therefore, the yield is higher compared to silver catalyst processes. The methanol concentration in the methanol-air feed mixture is below the explosion limit, i.e. below 7—8 vol.%. The methanol is converted to formaldehyde, making distillation of the product unnecessary.

Processes using metal oxide catalysts are particularly suitable for small and medium-size production capacities of between 10,000 and 100,000 tons per year of formaldehyde. For larger capacities, processes using silver catalysts are employed. The choice of the process, however, is not only dependent on the plant capacity but on the specific conditions at the plant site.

COMBINED DEHYDROGENATION AND OXIDATION PROCESS OF METHANOL TO FORMALDEHYDE

The combined dehydrogenation and oxidation of methanol is shown in the following equations:

$$(1)\ CH_3OH + \frac{1}{2}O_2 \rightarrow HCHO + H_2O \quad \Delta R_H = +38\ \text{kcal/mol}$$

$$(2)\ CH_3OH \xrightarrow{\qquad} HCHO + H_2 \quad \Delta R_H = -20\ \text{kcal/mol}$$

The first reaction is highly exothermic. Air is therefore added in such a quantity that about 60% of the methanol reacts according to equation (1), and the remainder according to equation (2).

The methanol charge is vaporized in a steam-heated evaporator by adding purified air. The methanol-air mixture is indirectly vaporized and is heated with steam up to 100°C in a connected heater. The conversion into formaldehyde takes place at a fixed silver bed catalyst at temperatures between 600° and 650°C.

To prevent any undesired secondary reactions, the hot reaction gases are quickly cooled in a waste-heat boiler arranged just below the catalyst. The greater portion of the condensable reaction mixture is condensed to formaldehyde solution in a subsequent heat exchanger.

The mixture with the non-condensed formaldehyde passes to a Raschig ring packed absorption column, and here the formaldehyde is first cooled by means of circulating cooled formaldehyde and then washed out by process water fed into the upper part of the column. The non-condensable and formaldehyde-free reaction gases (N_2, CO_2, CO etc.) are discharged into the atmosphere through exhaust gas pipes.

With a concentration of up to 42%, the formaldehyde solution can be drawn from the circulation system at the absorption column. With higher concentrations (up to 50%) a strip column is connected.

The instrumentation used in the plant permits supervision and control of the continuous process flow.

METHANOL OXIDATION PROCESS TO FORMALDEHYDE USING A SURPLUS OF AIR

The process air is compressed to about 1.2 atm abs by a radial blower and mixed with vaporized methanol. This mixture has about the following composition:

	Vol. %
N_2	73.1
O_2	19.3
CH_3OH	6.8
H_2O	0.8

The methanol-air mixture is heated to about 200°C in a heat exchanger with hot reactor effluent before it enters the reactor containing a multitude of tubes to hold the catalyst.

The methanol contained in the feed mixture is almost completely converted to formaldehyde in the presence of the catalyst or about 350°C. The heat developed during reaction is transferred to a heat carrier oil flowing around the catalyst tubes. The heat carrier oil is constantly circulated by a pump. The heat picked up by the oil is utilized in the oil cooler for generating steam. Part of this steam is used for vaporizing the feed methanol, while the balance is discharged as surplus steam. The rate of surplus steam is 350 kg per ton of 37% formaldehyde solution.

The reactor effluent is cooled to about 120°C in the heat exchanger before entering the absorber where the formaldehyde vapours are absorbed by water.

The absorber has two stages, the lower stage being packed with Pall rings and the upper stage provided with sieve trays. In the lower stage the aqueous formaldehyde solution is circulated and the absorption heat transferred to cooling water. The sieve trays in the upper stage of the absorber are also cooled with cooling water.

The process water required for absorbing the formaldehyde vapours is charged to the absorber top.

The finished formaldehyde solution is withdrawn downstream of the cooler and pumped to the storage tank.

By simple metering of the process water, formaldehyde solutions can be produced in concentrations of from 37 to 55 wt%. Distillation of this solution is not necessary.

With the installation of a few additional items of equipment it is possible to produce urea formaldehyde solutions instead of aqueous formaldehyde solutions. In this case, aqueous urea solution instead of process water is charged to the absorber top.

The production of urea formaldehyde solutions would be practicable, for instance, to increase the output of existing glue manufacturing plants.

MALEIC ANHYDRIDE SYNTHESIS

The use of maleic anhydride for the production of different types of polyester resins, alkyd resins, maleinized drying oils and various copolymers, for example with styrene, fumaric acid, tetrahydrophthalic anhydride amongst many, is well known. Pentaerythritol-maleic anhydride resins, too, may increase in use. On the other hand, the possibilities offered by the Diels-Alder synthesis foreshadow considerable further demand for maleic anhydride.

Due to its double function, the maleic anhydride molecule is ideally suited for chemical synthesis, because any atom in the molecule can be induced to react under specific conditions. Additionally, the double bond adjacent to two carboxylic groups shows almost the properties characteristic of unsaturated compounds.

In the hydrogenation of maleic anhydride, new technical implementations have been found. Succine acid, Butyrolactone and Tetrahydrofuran (THF) are three examples. Pyrrolidone, produced either from Butyrolactone or direct from maleic anhydride, represents the raw materials for polyamides (Nylon-4). This fibre has recently been introduced into the United States and has aroused much interest.

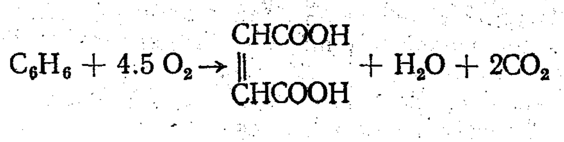
Polyester resins, which account for approximately 40—50% of maleic anhydride consumption, show excellent growth rates in the construction industry, for tanks and tubes, also in the transportation and electrical industry.

Benzene is catalytically oxidized to yield maleic anhydride in a manner similar to the production of phthalic anhydride by naphthalene or o-xylene oxidation.

Benzene presents a very stable configuration towards both thermal dissociation and oxidation. The primary effect of exposure of benzene to elevated temperature is the dissociation of the hydrogen atom accompanied by the joining of the residues to form a diphenyl, a more stable substance which may be recovered in good yield. Vapour-phase oxidation to phenol is possible and has been attained with comparatively low yields and conversions.

Phenol, however, does not present any great stability towards oxidation, and its commercial production by this method is somewhat limited at the present stage of development. Continued oxidation results in the formation of quinol and quinone, both of which have been identified in the vapour-phase oxidation products of benzene. High yields have not been attained, however, owing, no doubt, to the comparative instability of the ring at this stage of oxidation. Continued oxidation results in the rupture of the ring and leads to the formation of maleic acid, which may be obtained in good yields. The complete combustion of benzene thus probably involves the formation of quinone and maleic acid as the main points of stability before complete combustion products are reached.

The commercial production of maleic acid by oxidation of benzene has, in large measure, been due to the early work of Weiss and Downs on this particular reaction and of Gibbs and his associates at the Bureau of Chemistry in Washington on aromatic hydrocarbons in general.



$$C_6H_6 + 4.5\,O_2 \rightarrow \begin{array}{c}\mathrm{CHCOOH}\\ \| \\ \mathrm{CHCOOH}\end{array} + H_2O + 2CO_2$$

The stability of benzene and the fact that nine atoms of oxygen are required for the oxidation of a molecule of benzene to maleic anhydride necessitate the use of high air-to-hydrocarbon ratios in the oxidation. Thus, the theoretical requirement would be about 106 ft^3 of dry air at room temperature per pound of benzene oxidized to maleic anhydride. In practice, higher ratios than this are used (two to five times).

The heat theoretically liberated in the oxidation of benzene to maleic acid is about 10,500 Btu per lb of benzene reacting, and the heat released in the complete combustion of benzene is approximately 18,000 Btu per lb. In practice, where a certain quantity of the benzene may undergo complete combustion during the reaction, the heat released would be approximately 12,000 to 13,000 Btu per lb of benzene reacted. It is imperative that this reaction heat be removed from the catalyst zone and that the catalyst temperature be maintained at the proper operating level. Special means have been provided at the industrial scale plants to achieve an efficient heat removal.

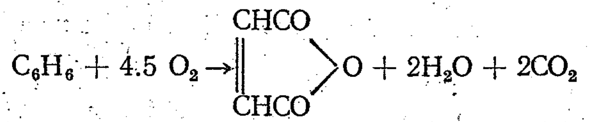
A variety of catalysts have been developed for this oxidation, and the oxides of the metals of the fifth and sixth groups of the periodic system have been particularly stressed. Of these, vanadium pentoxide has been shown to be one of the best when used in a single-component catalyst supported on an inert carrier. Vanadium pentoxide becomes active in promoting the oxidation reaction at a temperature of about 300°C, and reaches its maximum usefulness in the range of 400° to 500°C.

For years benzene has been the preferred raw material for maleic anhydride manufacture, although one manufacturer uses a mixture of butylenes and butadiene as feedstock. Actually, almost any four- or five-carbon organic chemical, except the paraffin hydrocarbons, yields maleic anhydride by vapour-phase oxidation over vanadium catalysts. Furfural, crotonaldehyde, and olefins are particularly satisfactory, but price still favours benzene.

Vapour-phase oxidation of olefins in the presence of vanadium pentoxide catalysts results in substantial yields of maleic anhydride which increase with the increase in molecular weight of the olefin. Thus, from pentene-2, trimethylene, technical amylene, methyl pentane, heptane, and octane, approximative relative conversions of 10, 25, 27 and 30%, respectively, were obtained from 5, 6, 7 and 8 C-atom olefins. Optimum temperatures of about 425°C were found for amylene oxidation.

Catalytic vapour-phase oxidation of m-xylene results in formation of maleic anhydride in yields comparable to those obtained from benzene. Relative to benzene, m-xylene requires more oxidation to convert it to maleic anhydride and, under the present circumstances, is a relatively more expensive raw material. Another potential source for the production of maleic acid is cyclohexane.

Benzene is catalytically oxidized to yield maleic anhydride in a manner similar to the production of phthalic anhydride



$$C_6H_6 + 4.5\ O_2 \rightarrow \begin{array}{l} CHCO \\ \| \qquad \rangle O \\ CHCO \end{array} + 2H_2O + 2CO_2$$

Compressed air is fed to a mixer where a measured stream of benzene is added under such conditions that the benzene is vaporized and the correct benzene-air ratio is obtained. The vapour mixture is blown through a multitubular reactor, containing a catalyst supported on an inert carrier (fixed bed catalyst). The reaction is highly exothermic, and, once initiated, it is self-supporting. A temperature of 450°—500°C is maintained by efficient heat removal by circulating fused salts across the tube banks in the oxidation reactor. The contact time is approximately 0.1 sec at about 1 atm pressure and the temperature is between 450° and 500°C. The reaction gases, consisting mostly of a maleic anhydride—maleic acid mixture, carbon dioxide, water, and some unreacted benzene, pass through a vapour cooler. This cooler acts as a heat exchanger and provides for the preheating of the air, benzene and the heating of the reactants and reaction products lines.

The plant design and layout for the oxidation stage is the same as for a phthalic anhydride plant.

The recovery apparatus differs from plant to plant and depends on the nature of the product desired. If maleic acid is to be the sole product, the cooled gases are adsorbed in water to yield about 40% maleic acid solution. After a purifying treatment using decolourizing carbon, the solution may be partially evaporated and crystallized to yield crystalline maleic acid. If fumaric acid is to be the final product, the maleic acid is isomerized to crystalline fumaric acid in an additional operation.

If maleic anhydride is to be the sole product, the cooled gases are passed through a partial condenser maintained at a temperature slightly above the melting point of maleic anhydride (60°C). Most of the maleic anhydride and maleic acid are condensed, and the remaining vapours pass to an absorber. Here the gases are absorbed in either aqueous or nonaqueous solvents. Hydrocarbons such as benzene or high-boiling esters may be used to absorb the anhydride, which may then be recovered by dehydration and distillation.

The bulk of maleic anhydride is recovered from the partial condensers and contains varying amounts of maleic acid. This is converted to anhydride by removing the water by vacuum or azeotropic distillation (using hydrocarbons, i.e. xylene). The removal of the water by direct heat is neither desirable nor practicable, since maleic acid gradually changes to fumaric acid when heated above its melting point. The crude maleic anhydride may be stored or packaged or first purified by vacuum distillation or sublimation. When using a vacuum distillation for purification, the distillate is passed on a flaking machine or pelletizer and the final product, in the form of flakes or pellets, is passed to a weighing and bagging machine.

It is also possible to recover fumaric acid directly from benzene oxidation gases, if the converter (oxidation reactor) exit gases are scrubbed with hydrochloric acid solution.

METHANOL SYNTHESIS

The synthesis of methanol from carbon monoxide and hydrogen is a reversible reaction:

$$CO + 2H_2 \rightleftarrows CH_3OH$$

The physical aspects of this problem are many and varied, but the combined application of physical and chemical principles has rapidly developed a variety of synthesis from water gas. The methanol, carbon monoxide and hydrogen equilibrium has been the subject of several investigations. The data obtained from these investigations show that the equilibrium constant is small, and that it decreases rapidly with temperature. Consequently, the temperature interval over which the synthesis is operative from a practical viewpoint, is not very large. At temperatures much below 300°C the rate of reaction is slow, so the capacity of the apparatus is small. Above 400°C, the equilibrium becomes too unfavourable. Despite the small values of the equilibrium constant, very satisfactory conversions are obtained. This is because of the decrease in volume attending the reaction, so that by the application of pressure, the reaction is driven to the right, or to higher conversion. Thus, at 350°C and 245 atm using the theoretical mixture, one vol. of carbon monoxide and two of hydrogen, the equilibrium yield is above 60%, whereas under exactly the same conditions, but working at 10 atm, the yield is less than 2%. The pressures used in the synthesis are usually from 200 to 300 atm.

Along with the synthesis of methanol, other side reactions are possible. Some of these are:

$$CO + 3H_2 \rightarrow CH_4 + H_2O$$

$$2CO + 2H_2 \rightarrow CH_4 + CO_2$$

$$2CO \rightarrow C + CO_2$$

Not only do these reactions consume carbon monoxide and hydrogen, they also make control more difficult, as they are more exothermic than the methanol reaction. In this synthesis a catalyst is selected that causes reduction principally to methanol. For the production of hydrogen, the operations are similar as those for the ammonia synthesis.

For the methanol synthesis the catalysts usually consist of metal and metallic oxide mixtures, the most common constituents being copper with oxides of zinc, chromium, manganese and aluminium. Zinc chromate is typical of the catalysts used.

For the synthesis of methanol alone, contact of the hot gases with iron should be avoided. In this case the reactors are lined, usually with copper or some other material not affecting the catalyst. The catalysts for pure methanol are usually susceptible to iron carbonyl, formed when carbon monoxide is in contact with iron. This impairs the catalyst's activity or else induces undesirable side reactions.

With the proper catalyst and the exclusion of sulphur and iron, methanol of a purity of 99% or better can be produced. The CO and H_2 necessary for methanol synthesis are obtained by steam reforming of methane or by steam reforming of hydrocarbons. The process sequence used to make methanol is about the same as for ammonia synthesis.

The greatest use of methanol is for the production of formaldehyde. It is also used for the manufacture of dimethylaniline, dimethylamine, methacrylates and miscellaneous solvents.

HYDROFORMYLATION (OXO REACTION)

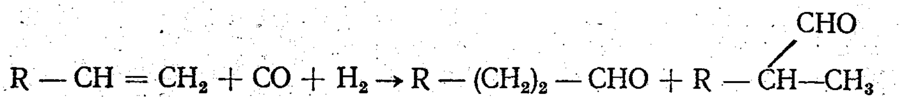
Oxo reaction was developed in the course of research on the Fischer-Tropsch synthesis for the production of liquid fuels and chemicals from coal. The reaction originally consisted of the treatment of an olefin with water gas ($H_2 + CO$) in the presence of a cobalt catalyst to produce aldehydes containing one carbon atom more than the starting compounds.

The reaction results in the addition of the units of formaldehyde H-CHO across the double bond. The synthesis was first carried out with ethylene. Diethyl ketone and propionaldehyde were obtained, and because both products contained a carbonyl or "oxo" group, the reaction was called the oxo-synthesis.

Later it was found that ketone production was relatively unimportant; aldehydes were almost always the principal product. Although the reaction was recognized as being an aldehyde synthesis, the name oxo was retained, probably for the sake of convenience and brevity.

Because the reaction consists of the addition of H and CHO, it is perhaps more accurate to call it formylation or better hydroformylation.

The oxo reaction is a special case of the introduction of carbon monoxide into an organic molecule, which produces aldehydes:



$$R-CH=CH_2+CO+H_2\rightarrow R-(CH_2)_2-CHO+R-\overset{\displaystyle CHO}{CH}-CH_3$$

Hydroformylation may employ either a slurry process or a fixed bed.

Typical operating conditions for a slurry process are: 150°—200°C, at a 150—200 atm, with a synthesis gas (1 to 1 ratio of carbon monoxide to hydrogen) in contact with an olefin containing 3—5% catalyst.

The catalysts used are cobalt, iron and nickel carbonyls. Other patents indicate that calcium, magnesium and zinc are also catalysts for the oxo reactions.

Exothermic reaction is controlled by cooling and recycling, with perhaps 70% conversion in primary reactors supplemented by further conversion in secondary reactors.

Fixed bed processes under similar operating conditions eliminate the problem of catalyst separation from product, but require special cooling facilities to remove heat of reaction.

Partial hydrogenation of the aldehydes to alcohols may occur during hydroformylation, particularly at higher temperatures and with hydrogen-rich ratios in the synthesis gas. Complete reduction to alcohols is usually accomplished in a separate stage, using pure hydrogen. The catalyst (cobalt) used in the first stage, or other available hydrogenation catalysts, may be used. In either case it is considered necessary to remove all carbon monoxide and cobalt carbonyl prior to the hydrogenation.

The alcohols secured by the reduction are converted into detergents, plasticizers and other products.

PHTHALIC ANHYDRIDE SYNTHESIS

In the initial stage of industrial development, phthalic anhydride serves as a valuable raw material and intermediate product for local industrial enterprises, mainly in the field of plasticizers, paints and colourants, PVC products and plastic materials in general.

Phthalic anhydride is produced from naphthalene or o-xylene, or from mixtures of both products by air oxidation in vapour phase at elevated temperature with the aid of a catalyst. Mainly fixed bed catalysts are used, although some plants use a fluid catalyst bed process.

Main reactions take place in accordance with the following equations:

$$C_{10}H_8 + 4.5O_2 \rightarrow C_8H_4O_3 + 2CO_2 + 2H_2O$$

$$C_8H_{10} + 3O_2 \longrightarrow C_8H_4O_3 + 3H_2O$$

Several side reactions occur at elevated temperature and these side reactions lead to the formation of small quantities of naphthoquinone, maleic anhydride and CO_2 when naphthalene is used as feedstock, and of maleic anhydride when o-xylene is used as feedstock.

Considerable excess of air is used, up to three times that theoretically required. Thus, from 20 to 60 moles of air must be used per mole of naphthalene oxidized.

The reaction is very exothermic and specially designed catalytic reactors must be used to remove this heat efficiently and without disturbing the temperature equilibrium of the catalyst mass.

Approximately 5,000 calories per kilo of oxidized naphthalene and approximately 5,600 calories per kilo of oxidized o-xylene are released. This heat is continuously removed and utilized for the production of steam. The application of special catalyst carriers and the particular composition of the catalyst active mass allows speeds of 350—450 g of feedstock per litre of catalyst per hour resulting in effective yields of about 80% of the theoretical.

Catalysts similar to those mentioned for benzene oxidation to maleic anhydride are applicable to the naphthalene or o-xylene reaction. The published results have shown that vanadium and molybdenum oxides are efficient and active catalysts.

Vanadium pentoxide catalysts become active for the oxidation of naphthalene or o-xylene at temperatures of 360°—480°C, the optimum temperature being about 420°—480°C.

Another carrier recommended for vanadium catalyst is silica gel, prepared from potassium silicate and sulphuric acid. The catalyst contains 10% V_2O_5 and can be used in a fluidized bed reactor.

It has been claimed that mixtures of metal oxides form better catalysts than the oxides alone. For instance, a mixture of 85% vanadium pentoxide with 15% molybdenum oxide is claimed to be better than the vanadium oxide alone; and a mixture of 65% molybdenum oxide and 5% either manganese or calcium oxide still better.

Porous, granular, intimate mixtures of the trioxides of tungsten and molybdenum in molecular ratios between 10:1 and 1:10 have been described as effective oxidation catalysts.

The catalyst is of particular importance in the efficient operation of the reaction and, while an essential component is vanadium pentoxide on a special carrier, there are also certain additions and modifications which differentiate the various catalysts available and which have an appreciable effect on the over-all efficiency.

Of particular importance also is reactor engineering and reactor design.

STYRENE SYNTHESIS

Styrene (vinyl benzene) is commercially produced in large quantities by the dehydrogenation of ethylbenzene, which is obtained by the Friedel-Crafts reaction of ethylene and benzene in the presence of hydrogen chloride and $AlCl_3$ as a catalyst.

THE ALKYLATION OF BENZENE WITH ETHYLENE

$$C_6H_6 + CH_2 = CH_2 \rightleftarrows C_6H_5 - CH_2 - CH_3$$

(a) In the presence of $AlCl_3$ as a catalyst. The reaction is carried out at atmospheric pressure, at 90°—95°C. The presence of oxygen, carbon monoxide, acetylene, increases the consumed quantity of $AlCl_3$. The benzene must be of high purity, with a sulphur content $< 0.1\%$ and water content <30 ppm. The ethylene must not contain other olefins.

(b) The alkylation catalysed by phosphoric acid on solid support. The reaction is carried out in gaseous phase in the presence of phosphoric acid on Kieselguhr. In this process the conditions concerning the purity of ethylene are less severe.

THE OXIDATIVE DEHYDROGENATION OF ETHYLENE TO STYRENE

$$C_6H_5-CH_2-CH_3 \rightarrow C_6H_5-CH=CH_2+H_2 \quad \Delta H=+28.7 \text{ kcal/mol}$$

The reaction is carried out in the temperature range of 600°—630°C in adiabatic or isothermal reactors. The catalysts used are a mixture of metallic oxides (ZnO, Al_2O_3, CaO). The alumina in these catalysts acts as activator, the CaO catalyses the oxidation of carbon deposited on the catalyst.

The absence, or too small quantities, of aluminium oxide determine high reaction temperatures whereas too big quantities favour secondary reactions.

A higher basicity of catalyst is advantageous and it is obtained by addition of potassium salts (K_2SO_4 and K_2CrO_4). Under the reaction conditions these salts decompose into K_2O and Cr_2O_3 — a fact which implies an increase of the catalyst basicity and its activation. The catalysts applied in butylene dehydrogenation may also be used. For ethyl-benzene dehydrogenation, iron oxide with a carrier having K_2CO_3 as promotor can be used.

VINYL ACETATE MONOMER SYNTHESIS

Vinyl acetate is obtained by the addition of acetylene to acetic acid in the presence of a suitable catalyst:

$$CH\equiv CH+HOOC-CH_3 \rightarrow CH_3COOCH=CH_2$$

The reaction can take place in a liquid or vapour phase. A more recent procedure consists of treating the ethylene with acetic acid in the presence of an alkaline acetate, palladium chloride and of a redox system for the conversion of Pd in palladium chloride again. This procedure is in principle similar to the production of acetaldehyde from ethylene in the presence of palladium salts:

$$H_2C=CH_2+PdCl_2+2CH_3COONa \rightarrow H_2C=CNOOCCH_3+2NaCl+$$
$$+Pd+CH_3COOH$$

The presence of a redox system that will oxidize the metallic palladium again to palladium chloride is necessary to assure a continuous process.

Similar to the production of acetaldehyde from ethylene, the redox system is a cupric-cuprous chloride couple.

$$Pd+2Cu^{2+}+4Cl^- \longrightarrow PdCl_2+2CuCl$$

$$2CuCl+\frac{1}{2}O_2+2HCl \rightarrow 2CuCl_2+H_2O$$

The process for the production of vinyl acetate by acetylene addition to acetic acid, as has been mentioned, can be carried out in either a liquid or a gaseous phase.

For industry, the vapour phase process is of importance. High yields of 90—95% are obtained as compared to acetylene and of 93—99% as compared to acetic acid. Similarly, low percentages of secondary products and reduced corrosion are obtained.

The normally used catalyst is obtained by impregnating the active coal with zinc or cadmium acetate to a concentration of 20—50 parts of acetate to 100 parts of coal. Pumice, silica gel, active aluminium oxide and other substances with big specific surfaces are recommended as carriers.

The metallic salts are: zinc chloride (which gives the best results), mercury, magnesium, barium, copper, silver chlorides or acetates, mercury, silver or zinc phosphate, zinc or cadmium silicate. It is recommended impregnating the zinc catalysts with small quantities of $BiOI$ or BiI_3 and a little copper in order to enhance their activity. The presence of the catalyst is debatable due to the secondary reactions of the acetylene.

The rol̃e of zinc acetate is that of a co-catalyst towards coal. The catalyst activity is proportional to the specific surface and to the content of zinc acetate.

Trends towards improving catalyst life, yield and conversion are inclined to the use of metal chromates, silicates and the zinc salts of dicarboxylic acids. Silica, alumina or silica-alumina catalysts are proving to be superior.

The industrial synthesis of vinyl acetate from acetylene and acetic acid in gaseous phase consists of the following main stages:

(a) Acetylene drying and acetic acid evaporation;

(b) $C_2H_2 + CH_3COOH$ mixture and its heating up to the reaction temperature;

(c) Acetylene and acetic acid reaction;

(d) Condensation of the reaction products (unreacted acetylene) — recirculation is included;

(e) Separation of vinyl acetate and acetic acid from the reaction products.

To ensure longer catalyst life, it is necessary to use pure raw materials, to isothermally remove the reaction heat and to avoid superheating. As it was difficult to get an efficient lateral thermal transfer in the fixed bed catalyst reactor, the fluidized bed reaction was studied too.

In such a case it is recommended that an active coal catalyst with a granulation of 100—250 μ impregnated with zinc acetate 33% weight be used. The coal should have good mechanical properties in order to avoid the modification of its granulation by erosion.

VINYL CHLORIDE SYNTHESIS

Vinyl chloride ($H_2C{=}CHCl$) is processed to obtain polymers and copolymers (vinyl acetate, styrene, aryl esters, maleic esters).

The molecule of vinyl chloride consists of a hydrocarbonate rest and chlorine. In the industrial production of the vinyl chloride, the hydrocarbon rest comes from ethylene or from acetylene while the chlorine is introduced by the direct chlorination or by means of hydrochloric acid.

Vinyl chloride production usually comprises the following phases in a single industrial complex:

(a) Obtaining the raw material at the degree of purity imposed by the selected process;

(b) Vinyl chloride synthesis;

(c) Vinyl chloride separation and purification, generally followed by polymerization.

(a) The gases resulting from cracking go to a preliminary purification system, then to a separation and concentration of ethylene unit, and then to the final purification (removal of acetylene, water, carbon dioxide). For the acetylene removal (selective hydrogenation), catalysts like molybdenum sulphide (on activated aluminium oxide), cobalt molybdate, nickel derivatives and nickel-cobalt, and chromium are used.

Palladium and palladium-promoted catalysts are used for the hydrogenation of small amounts of acetylene present in the purified olefins. These catalysts are sensitive to sulphur poisoning and therefore the sulphur compounds have to be removed before hydrogenation;

(b) The main processes for vinyl choride synthesis are:

(i) Dehydrochlorination of the dichloroethane in a liquid or gaseous phase:

$$CH_2Cl - CH_2Cl \xrightarrow[550^\circ C]{\text{activated charcoal}} CH_2 = CHCl + HCl$$

$$CH_2Cl - CH_2Cl \xrightarrow[280^\circ C,\ 1\ \text{atm}]{BaCl_2\ \text{on activated charcoal}} CH_2 = CHCl + HCl$$

(ii) Addition of hydrogen chloride to acetylene in a liquid or gaseous phase:

$$C_2H_2 + HCl \xrightarrow[\text{activated charcoal}]{HgCl_2 \text{ on}} CH_2 = CHCl$$

(iii) Ethane chlorination or substitutive chlorination of ethylene.

Vinyl chloride can be obtained from dilute mixture of acetylene-ethylene.

The catalysts used in the dichloroethane dehydrochlorination process are metal chlorides and active coal. The conversion obtained depends on the nature of the catalyst and on temperature. Maximum efficiency is obtained by using active coal impregnated with 30% $BaCl_2$ at 350°C in the presence of 0.5% chlorine.

In the case of hydrogen chloride addition to acetylene, the catalysts used are charcoal, coke and pumice impregnated with the chlorides or oxides of some metals.

The catalyst with the most selective action is the mercury chloride deposited on the active coal, especially on coal having a high affinity towards the halogenating agent.

The life of a mercury chloride catalyst is determined to a great extent by the reactants' purity and especially their humidity, and by carrying the reaction in an isothermal regime.

The mercury chloride catalyst is activated by adding $CuCl_2$, $CeCl_2$, $ThCl_4$, ammonium metavanadate, phosphoric, sulphuric or chloric acids.

For the production of vinyl chloride by ethylene chlorination, the technical process is complicated due to the secondary reactions of addition and substitution. In some variants, the use of active coal catalysts impregnated with 10—25% $CaCl_2$ or $SrCl_2$ is indicated.

The production of vinyl chloride from a dilute mixture of acetylene-ethylene starts from a mixture of acetylene-ethylene obtained from the oxidative pyrolysis of petroleum cuts containing acetylene and ethylene in an almost equimolecular ratio.

The thermal cracking of the petroleum cuts takes place in the absence of catalysts. The acetylene reaction follows the addition scheme of hydrogen chloride on a mercury chloride catalyst.

The chlorination of ethylene is carried out in a dichloroethane solution with iron chloride as catalyst;

(c) The separation and purification of vinyl chloride take place according to similar procedures irrespective of the technology used for the production of vinyl chloride.

The sequence of operations is the following:

reaction gases → preliminary purification,
(drying, HCl removal)
↙ ↘
heavy cuts separation — light cuts separation, C_2H_2, etc.
→ fine purification → pure vinyl chloride.

In selecting one of the above processes all elements contributing to the price should be considered; it has been noticed, however, that the decisive factor is usually represented by the ethylene/acetylene ratio.

III. PRODUCTION OF ACIDS

NITRIC ACID

The manufacturing process for nitric acid is based on the catalytic oxidation of ammonia. It consists of nitrogen oxide production, its oxidation into superior oxides and their absorption into water; these partial processes can be expressed by the following reactions:

$$4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O \qquad \Delta H = -216.7 \text{ kcal}$$

$$2NO + O_2 \longrightarrow 2NO_2$$

$$3NO_2 + H_2O \rightarrow 2HNO_3 + NO$$

The short equation of the transformation process of ammonia into nitric acid can be expressed as:

$$NH_3 + 2O_2 \rightleftarrows HNO_3 + H_2O \quad \Delta H = -100.6 \text{ kcal}$$

By the catalytic oxidation of ammonia with oxygen the following main reactions are possible:

$$4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O \qquad \Delta H = -216.7 \text{ kcal (l)}$$

$$4NH_3 + 4O_2 \rightarrow 2N_2O + 6H_2O \qquad \Delta H = -263.9 \text{ kcal}$$

$$4NH_3 + 3O_2 \rightarrow 2N_2 + 6H_2O \qquad \Delta H = -303.1 \text{ kcal}$$

Secondary reactions can also take place without catalyst participation:

$$2NH_3 \longrightarrow N_2 + 3H_2 \qquad \Delta H = + 21.96 \text{ kcal}$$

$$2NO \longrightarrow N_2 + O_2 \qquad \Delta H = - 43.14 \text{ kcal}$$

$$4NH_3 + 6NO \rightarrow 5N_2 + 6H_2O \qquad \Delta H = -431.60 \text{ kcal}$$

Decomposition of ammonia into nitrogen and hydrogen can take place at high temperatures in the oxidation installation before passing over the catalyst.

Dilute nitric acid is obtained according to the reaction of the ammonia oxidation. In this respect, research has been undertaken to find selective action catalysts that will intensify only this reaction.

The research has established that the catalysts that give a high yield of transformation of ammonia into oxides in the 600°—1,000°C temperature range are platinum, its alloys and certain metal oxides.

Platinum and its alloys are considered the best catalysts for the selective oxidation of ammonia to nitrogen oxide. The catalytic oxidation process of ammonia starts with the activated adsorption of oxygen on the catalyst surface. It follows the activated adsorption of ammonia, the formation of unstable intermediate products, their decomposition, the formation of final products, and their denuding. The platinum adsorbs the oxygen very well, but it hardly adsorbs any of the nitrogen. For the oxidation of ammonia an excess of oxygen is necessary as this accelerates the reaction and favours an increased yield of nitrogen oxide. In the presence of a good quantity of excess oxygen, the adsorption capacity of nitrogen oxide and of water vapours by platinum is very low; thus the denuding of the reaction final products is facilitated.

Platinum catalysts or their alloys are used as sieves having 1,024—3,600 mesh/cm^2 and wire diameter of 0.045—0.09 mm. Good yields of transformation are obtained with platinum alloys-rhodium or platinum-palladium.

In order to replace expensive platinum catalysts with cheap non-platinum ones, almost all metal oxides were tested and the conclusion was that the most active were the iron, cobalt and silver oxides that have small additions (3—10%) of other metal oxides as activators (bismuth oxides, manganese bioxide). These catalysts were used under the form of rings with diameters of 6—8 mm. Sometimes catalysts consisting of a platinum sieve and a non-platinum catalyst layer are used. The processes carried out at atmospheric pressure take place at about 800°C while those carried out at high pressure take place at a temperature of 870°—900°C.

Poisons for catalytic sieves are: H_2S, H_3P, CO. Water vapours, H_2 and O_2 increase the degree of corrosion.

SULPHURIC ACID

Sulphuric acid is essential for all production branches; its manufacture is an indication of the industrial level of a country.

In the chemical industry, the biggest consumer is the fertilizer sector, the rapid growth of which represents the main reason for the steady rhythm of growth of sulphuric acid production.

Parallel with the production of fertilizers in the chemical industry, sulphuric acid is applied in organic synthesis (nitration, sulphonation, dyestuff production, medicaments, detergents, explosives, synthetic fibres), in the production of inorganic salts (sulphates, bichromates), pigments (titanium white) and insecticides, and in gas drying. Important quantities of sulphuric acid are also used in crude-oil refining, in the textile industry and in the extraction industry.

Initially, sulphur was the raw material used in sulphuric acid manufacture; later on pyrites were used, and more recently other sulphur-content raw materials and a series of sulphur secondary products resulting from various processes have been used.

The main technological processes for sulphuric acid production are: contact and chamber.

CONTACT PROCESS

The sulphurous or sulphur-content gases containing SO_2 are purified by the dry and wet method. The purified gases are then air-diluted, dried with concentrated sulphuric acid in a spraying tower, circulated by means of blowers, preheated and introduced in the contact oven where the catalytic oxidation takes place according to the reaction:

$$SO_2 + \frac{1}{2}O_2 \rightleftarrows SO_3 + 22.980 \text{ kcal}$$

The SO_3 gases are cooled down and absorbed in the concentrated sulphuric acid. Then oleum sulphuric acid or monohydrate is obtained, according to the reaction:

$$SO_3 + H_2O \rightarrow H_2SO_4$$

CHAMBER PROCESS

The sulphur-content gases and their dry purification have the same technological treatment as the contact method. The SO_2-content gases are sent to a filling tower where they are counter-currently washed (sulphuric acid and nitrogen oxides). The gases leaving the tower entrain the nitrogen oxides with which they enter the oxidation chamber where the formation of the sulphuric acid takes place according to reactions:

$$SO_2 + NO_2 + H_2O \rightarrow H_2SO_4 + NO$$

$$2NO + O_2 \rightarrow 2NO_2$$

$$NO_2 + NO \rightarrow N_2O_3$$

At the present stage of development, the contact process tends to replace more and more the chamber process.

In the contact process, the vanadium catalyst can oxidize the sulphur dioxide in industrial reactors without changing its quality at temperature ranges between 400° and 600°C. This corresponds to a large extent to the behaviour of the oxidation reaction, which is a reversible one. For this reason, the influence of temperature on the velocity of sulphur trioxide formation is characterized by the existence of an optimum temperature which is modified during the reaction and which assures its maximum speed.

The chemical composition of the catalyst is the main factor in determining its properties and especially its catalytic activity. The main transformation in the manufacture of sulphuric acid by the contact process, the catalytic oxidation of the sulphur dioxide, takes place in the adsorbed phase on the catalyst surface as a heterogeneous gas-solid catalytic reaction.

The interaction of the two phases takes place in a fixed and fluidized bed.

In present-day sulphuric acid manufacture, the old platinum catalyst is being replaced by the vanadium-base catalyst. This type of catalyst can be represented by the $V_2O_5 — (Na_2SO_4)K_2SO_4$ system on a SiO_2 base porous carrier. Vanadium compounds with a high activity can pass into inactive compounds (vanadyl sulphate) by decreasing the reaction temperature and into vanadyl vanadates by increasing the reaction temperature.

The alkaline salts and the carrier increase the stability period of the active compounds. The stabilizing action of the alkaline salts increases in the order Na, K, Rb, Cs.

At present, it is considered that in the $V_2O_5 — K_2SO_4$ system, the active components are mono-sulpho potassium vanadate ($K_2OSO_3V_2O_5$) or disulpho-potassium vanadate ($K_2O\ 2SO_3V_2O_5$).

Experimental research has shown that a similar action to that of the alkaline salts is undertaken by the Ba, Sn, Ag, Pb, Mn salts. The water vapours play the role of an activator up to the concentration that determines the condensation under the reaction conditions.

On the other hand, the As impurities and, to a lesser extend those of selenium, have a poisonous action. The dust and the sulphates that can be deposited from gases, covering the pores of the catalytic mass, have a noxious effect.

Part two

Heterogeneous catalysts for unit operations

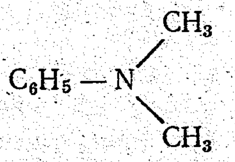
IV. ALKYLATION

Alkylation may be defined as the introduction of an alkyl or aralkyl radical, by substitution or addition, into an organic compound. Alkylation is of six general types, depending on the linkage effected:

(a) Substitution for hydrogen, in the hydroxyl group of an alcohol or a phenol. Here the alkyl is bound to oxygen:

$$C_2H_5 - O - C_2H_5; \quad C_6H_5 - O - CH_3$$

(b) Substitution for hydrogen attached to nitrogen. Here the alkyl is bound to trivalent nitrogen:

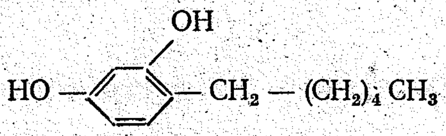


$$C_6H_5 - N\begin{matrix} CH_3 \\ CH_3 \end{matrix}$$

(c) Addition of an alkyl halide or an alkyl ester to a tertiary nitrogen:

$$C_6H_5 - \overset{+}{N}(CH_3)_3Cl^- \quad \text{(an electrostatic bond)}$$

(d) Substitution for hydrogen in carbon compounds. The carbon of the alkyl is bound to carbon of either aliphatic or aromatic compounds. This is carbon-to-carbon alkylation:



(e) Alkyl metallic compounds. Here the alkyl is bound to the metal:

$$Pb(C_2H_5)_4$$

(f) Miscellaneous alkylations. In mercaptan, the alkyl group is bound to sulphur; in the alkyl silanes, it is bound to silicon:

$$nC_{12}H_{25}SH; \quad C_2H_5SiCl_3$$

An examination of the products obtained as a result of alkylation shows that this unit process is used in the manufacture of anesthetics, antipyretics, alkaloids, antiseptics, detergents, dyes, explosives, flavours, hypnotics, intermediate compounds, lubricants, medicinal products, perfumes, photographic chemicals, plasticizers, plastics, resins, synthetic rubber, rubber chemicals (accelerators, antioxidants, modifiers and stabilizers), solvents, saporifics and synthetic gasoline.

An apparent characteristic of many alkylation and dealkylation reactions is their initial slowness. It is necessary to resort to catalysis for the reaction to proceed at a rate that will be commercially feasible. Mineral acids, such as sulphuric, phosphoric, hydrochloric and hydrofluoric, are widely employed, as are aluminium chloride, ferric chloride and boron fluoride.

The choice of a catalyst and alkylating agent for any commercial reaction from the large variety of available catalysts and alkylating agents depends upon the relative cost, as well as upon the equilibrium of the reaction; and the reaction rate which results from their use.

Alkylations are equilibrium reactions that are often characterized by position and structural isomerization. Alkylation reactions can be carried with $AlCl_3$ (Friedel—Crafts synthesis) and can be effected with alkyl, aralkyl and cycloparaffinic halides, olefins, alcohols and esters. In practically all instances, hydrogen chloride is a product of the reaction and it may reasonably be presumed that olefins, esters and, in many instances, alcohols are first transformed into alkyl halide complexes with $AlCl_3$ before entering into the alkylation reaction.

In dealkylation-realkylation, certain catalysts, especially aluminium and ferric chlorides, facilitate the removal of an alkyl group from a polyalkylated product. This happens particularly with ring systems; an industrial example is the reforming of the polyalkylated derivatives separated as the high-boiling fractions in the isopropylation of benzene to cumene.

V. CRACKING

The term "cracking" has attained rather broad usage: it encompasses the fission or splitting of any hydrocarbon in such a way that a carbon-carbon bond is ruptured. In the most common reaction, the craking of paraffins, the main reaction is one of dealkylation according to the general equation;

$$R_1CH_2 - CH_2 - R_2 \rightleftarrows R_1CH = CH_2 + R_2H$$

leading to the formation of an olefin and a lower paraffin.

Cracking generally leads to a variety of products since primary products may in turn undergo further splitting and various carbon-carbon bonds may be involved.

Catalysts active for splitting carbon-carbon bonds also appear to have activity for splitting carbon-hydrogen bonds.

Because of subsequent reactions such as polymerization and hydrogenation, the net heat effect in the cracking of gas oil is small. At low conversion it is endothermic, while at high conversion it is exothermic.

The cracking of gas oil or even higher-boiling petroleum fractions has assumed such a great economic importance in the past decade that it overshadows other catalytic processes in production capacity. Further evidence of the importance of cracking is the large volume of recent literature regarding the catalyst types.

SYNTHETIC SILICA-ALUMINA CATALYSTS

These catalysts can be regarded as the reaction product of silica gel and alumina. They are generally adopted for the first cracking units. They are manufactured in powder form for fluid cracking units or in bead or pellet form. There is much evidence that the active component is a surface compound or complex resulting from the reaction of surface silicic acid and alumina. Increased porosity appears to lead to increased catalyst stability and decreased attrition resistance.

SYNTHETIC SILICA-MAGNESIA CATALYSTS

These catalysts can be regarded as the surface reaction products of silica gel and magnesia. Unlike silica-alumina catalysts, silica-magnesia catalysts do not develop an appreciably increased pore diameter during usage. The resultant fine pore structure may account for the poor regeneration properties.

NATURAL CRACKING CATALYSTS

Along with synthetic silica-alumina cracking catalysts, natural cracking catalysts of similar composition find wide commercial use. These catalysts are mainly derived from montmorillonite and are acid treated to activate them (exchange other surface actions for hydrogen ions).

OTHER CATALYSTS

Other materials that show activity for cracking include silica-zirconia, silica-titania and fluorides or fluoborates on silica-alumina or alumina carriers.

CRACKING OF PURE HYDROCARBONS

The following generalizations are valid for the cracking of many paraffins, olefins, naphthenes and aromatics over silica-alumina and silica-zirconia-alumina catalysts:

(a) Carbon-carbon bond cracking is selective so that cracked products seldom have fewer than three carbon atoms;

(b) Comparison of catalytic cracking of paraffins with thermal cracking indicates the former to be 5 to 60 times as rapid, the ratio increasing with molecular weight;

(c) Lower saturated hydrocarbons are not appreciably isomerized or cracked under usual cracking conditions;

(d) Olefins are much more easily cracked than paraffins and also readily undergo isomerization and coke formation under cracking conditions. Diolefins and aromatic olefins are even more readily cracked, saturated, polymerized and converted to coke;

(e) Naphthenes are quite susceptible to catalytic cracking. The rate increases with molecular weight and is about 1,000 times that of thermal cracking. Final products are largely determined by secondary reactions;

(f) Wholly aromatic compounds such as benzene, diphenyl and naphthalene are practically inert under cracking conditions, whereas alkyl aromatics are readily cracked next to the ring to produce benzene etc., the ease of cracking increasing with size of the alkyl group.

VI. DEHYDROGENATION

This class of reactions includes all reaction in which hydrogen is a product, in which a hydrogen-hydrogen bond is broken or formed, with the exception of reactions in which both H_2 and H_2O are products (for example the synthesis of butadiene from ethyl alcohol).

The different reactions are:

(a) Dehydrogenation of paraffins to olefins and diolefins (butanes and butenes to butadiene);

(b) Dehydrogenation of ethylbenzene to styrene, of cumene to α-methyl styrene;

(c) Dehydrogenation of oxyorganic compounds (of alcohols to aldehydes and ketones).

Dehydrogenation of straight chain hydrocarbons is only favoured at temperatures higher than 600°C.

An important reaction of this class is butadiene synthesis from butenes, which are usually obtained by butane dehydrogenation. The most generally used catalysts for this purpose have a Fe_2O_3—MgO—K_2O composition. The reaction is carried out at 650°C or higher, in the presence of steam to prevent carbon deposition. Iron might be considered as the active agent, magnesia the bonder and carrier, while the function of the potassia is to catalyse the reaction of steam with incipient coke.

Chromia-alumina catalysts are generally used for conversion of butanes to butenes.

For the dehydrogenation of ethylbenzene to styrene, the ZnO — Cr_2O_3 — Al_2O_3 catalysts are used.

For another dehydrogenation reaction, the calcium-nickel catalysts are recommended.

VII. DESULPHURIZATION

In a typical desulphurization process, naphthas containing 80—300 ppm sulphur are purified to contents of 0.2 — 0.5 ppm maximum.

$$H_2S + ZnO \rightarrow ZnS + H_2O$$
$$COS + ZnO \rightarrow ZnS + CO_2$$
$$CS_2 + 2ZnO \rightarrow 2ZnS + CO_2$$
$$RS + 2H_2 \rightarrow RH_2 + H_2S$$

Reactions of this type, such as

$$C_2H_5SH + H_2 \rightarrow C_2H_6 + H_2S + 18 \text{ kcal},$$

find considerable application in converting the sulphur compounds in crude (sour) petroleum stocks to easily removable H_2S. Sulphur compounds decrease the octane rating of leaded gasoline and are also corrosive.

Many catalysts are severely poisoned by sulphur compounds and, hence, hydrodesulphurization and H_2S removal often carried out prior to the main catalytic process (for example, the reaction of natural gas with steam on Ni catalysts or naphtha reforming on Pt catalysts).

The desulphurization process is used in conjunction with many modern high-pressure reformers, in the naphtha pre-treaters in recently built town gas, lean gas and rich gas plants, as well as in a number of ammonia plants.

The contact of straight run or catalytically cracked naphthas with hydrogen over desulphurizing catalysts removes sulphur and oxygen and also reduces appreciably the concentration of nitrogen compounds and metal impurities. Such pre-treatment of feeds improves the octane rating and stability of the reformed product.

In hydrocracking, the removal of nitrogen and oxygen compounds from the feedstocks is an important function of desulphurizing catalysts. By reducing the sulphur content, hydrogen treatment over the desulphurizing catalysts improves colour, odour and stability of kerosene, tractor and diesel fuels, lubricating oils and other distillates. Gas oil feeds in catalytic cracking units can also be treated with hydrogen over such catalysts. It is claimed that the cracking stage coke deposits can be reduced by 50% and naphtha yields increased up to 20%.

In this chapter there have been also introduced the guard catalysts for low-temperature CO shift catalysts, because of their capacity for sulphur absorption. These guard catalysts are used before low-temperature CO shift catalysts and are normally installed immediately on the top of the bed of CO shift catalyst. The size of the guard beds will depend on the plant design and on the particular low-temperature shift duty. They require reduction of metal oxide before they are fully effective.

VIII. HALOGENATION AND DEHALOGENATION

All reactions involving gain or loss of halogens are classified in this group.

Halogenation is defined as the process whereby one or more halogen atoms are introduced into an organic compound. The fabrication of organic compounds containing fluorine. chlorine, bromine and iodine can be accomplished by a variety of methods. The conditions and procedures differ not only for each halogen, but also with the type and structure of the compound undergoing treatment.

The chlorine derivatives are by far the most important technical halogen compounds because of the greater economy in effecting their preparation. The bromine derivatives, however, sometimes have certain advantages because of the greater ease in effecting the replacement of this halogen in subsequent reactions or because it possesses certain desirable properties for pharmaceuticals or dyes.

The following examples show that halogenation may involve reactions of addition (1), substitution (2), or replacement (3) (e.g. of groups). The hydroxyl or sulphonic group:

$$(1)\quad HC \equiv CH + 2Cl_2 \xrightarrow{FeCl_3} Cl_2HC-CHCl_2$$

$$(2)\quad CH_3-COOH + Cl_2 \xrightarrow{P(red)} CH_2Cl-COOH + HCl$$

$$(3)\quad C_2H_5OH + HCl \xrightarrow{ZnCl_2} C_2H_5Cl + H_2O$$

From the preceding formulae, it becomes clear that each type of reaction may involve not only a specific halogenation agent but also a suitable catalyst. The catalysts, with the exception of carbon, are halogen carriers. Thus, iron, antimony and phosphorus, which are able to exist in two valences as halogen compounds, are used to a large extent, for they are less stable at the higher valence and give up part of their chlorine during the process.

In the presence of free chlorine, such compounds alternately add and give halogen to carry on the reaction.

Iodine and bromide, which are capable of forming mixed halogens with chlorine, are also frequently employed as catalysts in chlorination processes.

The halogenation agent may be the halogen, as in the addition of chlorine to benzene to form chlorobenzene, or the anhydrous acid as in the formation of vinyl chloride monomer, by reacting HCl and acetylene.

In the dechlorination process, chlorine is removed in the form of HCl followed by condensation and/or polymerization. The product could also be unsaturated compounds.

Examples of the principal reaction types are:

DIRECT HALOGENATION OF PARAFFINS

$$CH_4 + Cl_2 \rightarrow CH_3Cl + HCl + 33\ kcal$$

$$CH_4 + 2Cl_2 \rightarrow CH_2Cl_2 + 2HCl + 60\ kcal$$

$$CH_4 + 4Cl_2 \rightarrow CCl_4 + 4HCl + 127\ kcal$$

$$CH_4 + 4F_2 \rightarrow CF_4 + 4HF + 403\ kcal$$

CHLORINATION OF PARAFFINS WITH O_2 AND HCl

$$C_2H_6 + HCl + \frac{1}{2}O_2 \rightarrow C_2H_5Cl + H_2O + 41 \text{ kcal}$$

DEACON PROCESS

$$4HCl + O_2 \rightarrow 2Cl_2 + 2H_2O + 28 \text{ kcal}$$

FRIEDEL-CRAFTS REACTION

$$C_6H_6 + C_2H_5Cl \rightarrow C_6H_5C_2H_5 + HCl + 9 \text{ kcal}$$

IX. HYDROGENATION

Reduction is the term usually applied to a reaction in which oxygen is withdrawn from or hydrogen is added to a compound. In addition, other elements besides oxygen may be eliminated from a molecule by the action of hydrogen, the most common being nitrogen, sulphur, carbon and halogens.

Reduction may be performed in a variety of ways; the most important commercial method is the catalytic reduction by hydrogen.

In order to correlate and condense the innumerable and diversified examples of catalytic hydrogenation, the following arbitrary classification has been made that includes only four types of reactions:

(a) Reduction of an ethylenic linkage:

$$RCH = CHR' + H_2 \rightarrow RCH_2{\cdot}CH_2R'$$

where R and R' are aliphatic or aromatic groups;

b) Reduction of a carbonyl to an alcohol group, or to a hydrocarbon:

$$CO + 2H_2 \rightarrow CH_3OH$$

$$xCO + yH_2 \rightarrow \text{hydrocarbons} + \text{water}$$
$$(\text{or } CO_2)$$

(c) Reduction of a carboxyl to an alcohol group:

$$RCOOR' + 2H_2 \rightarrow RCH_2 - OH + R' - OH$$

where R is preferably an aliphatic or hydroaromatic group, and R' is the same or a hydrogen atom;

(d) Hydrogenolysis or reactions involving molecular cleavage on the addition of hydrogen.

The hydrogenation of an ethylenic to a paraffinic linkage, can be accomplished usually in the presence of a nickel or nickel-containing catalyst and sometimes with platinum or palladium catalysts.

The hydrogenation of the carbonyl group in aldehydes, ketones, esters and acids can be reduced by hydrogen with catalysts either partially to give a hydroxyl group or entirely to give a hydrocarbon group. The partial reduction is characterized as mild hydrogenation. Ferric oxide, vanadium pentoxide and cerium oxide are promoters for the nickel-charcoal catalysts.

For the hydrogenation leading to hydrocarbon groups, the catalysts contain iron, nickel, copper and cobalt along with metallic oxides. Cobalt seems to be the best of the metals and the oxides of chromium, zinc, rare earths, aluminium, magnesium and manganese are used.

Formaldehyde, acetaldehyde as well as propionic, butyric and valeric aldehydes are reduced to the corresponding alcohols at about 100° to 150°C in the presence of a nickel catalyst.

The carboxyl group of esters and acids can be reduced to the corresponding hydroxyl group by the use of mild hydrogenating catalysts and hydrogen pressure generally of 100 atm or more. In general, the catalysts are of the type used in synthesizing methanol and higher alcohols. The reduction of the carboxyl group is most satisfactory in aliphatic or hydroaromatic compounds.

Hydrogenolysis involving cleavages of carbon-to-carbon bonds, refers particularly to cleavages in a molecule associated with the addition of hydrogen to the molecule. Hydrogenolysis is a term analogous to hydrolysis, alcoholysis, in which a double decomposition is accomplished:

$$C_2H_5 - O - H_5C_2 + H_2O \rightarrow 2\,C_2H_5OH \text{ (hydrolysis)}$$

$$C_2H_5O - H_5C_2 + H_2 \rightarrow C_2H_6 + C_2H_5OH \text{ (hydrogenolysis)}$$

This type of hydrogenation has certain applications in petroleum refining. In the hydrogenation of petroleum, coals and tars, the application pertains to the elimination of sulphur, nitrogen or oxygen and to the conversion of heavy, tarry or asphaltic substances to more desirable hydrocarbon products, usually of a more paraffinic or saturated type. In general, hydrogenolysis is favoured by increased temperature, higher hydrogen pressures ant the more vigorous type of hydrogenating catalysts. Frequently, in cases of carbon-to-oxygen cleavage, it may be desirable to incorporate a dehydrating catalyst with the hydrogenating catalyst. Examples of this type of catalysts are nickel-alumina and nickel-thoria.

Phenols and cresols can be reduced to the corresponding hydroaromatic or aromatic hydrocarbons, depending on the temperature, the pressure of hydrogen and the type of catalyst. Hydrocarbons, depending on the length of the chain or branching in the chain or the ring structure, under the combined action of hydrogen, catalysts and heat, undergo certain cleavages that involve the splitting off of groups or molecular fragments or the opening of ring structures.

These reactions are also of great technical importance, for they are probably the type of reaction occurring in the hydrogenation of heavy petroleum residues or asphaltic or aromatic base oils, whereby conversion takes place in high yields to stable, more volatile petroleum products such as gasoline and kerosene. Catalysts are essential to most hydrogenation reactions. The large bulk of hydrogenation reactions use hydrogen gas as the source of hydrogen. The function of the catalyst is to effect the over-all result of chemically combining the gaseous hydrogen with the substance capable of adding hydrogen to its molecular structure. It is the purpose of the catalyst to effect this combination along the desired path as quickly as possible.

Most hydrogenation catalysts are solid metals and metal oxides. The hydrogenation is effected at the surface of the catalyst, so a highly extended surface is essential.

Because an apparently small amount of substance such as halogens, sulphur, arsenic and sometimes metals of low melting point such as mercury, lead and tin, might poison the activity of a catalyst, it is necessary to use mixed-metal catalysts or promoted catalysts. More common mixtures with the well known types of catalysts are nickel-copper, nickel-alumina, copper-zinc oxide, copper chromium oxide, and, zinc oxide — chromium oxide. The use of combinations of almost all metals and metal oxides in the periodic system is described in the recent chemical and patent literature.

Hydrogenation catalysts are classified as vigorous hydrogenation catalysts and mild hydrogenation catalysts. Common vigorous hydrogenation catalysts are the nickel, cobalt, or iron types as well as molybdenum and tungsten oxides or sulphides and Raney nickel. Mild hydrogenation catalysts are able to carry out only one step at a time in a hydrogenation, or at least they do not permit the reaction to proceed to the hydrocarbon stage. They usually contain copper, zinc oxide, chromium oxide and manganese oxide, and may include some of the rarer elements as promoters. In addition, the noble metal catalysts such as platinum or palladium or their oxides belong to this class.

The synthesis of higher alcohols from water gas involves a condensation as well as a hydrogenation reaction. These so-called higher alcohol catalysts are usually of the mild hydrogenation type but contain some more alkaline materials, such as sodium, calcium or barium carbonates, or aluminium or magnesium oxides.

Other types of catalysts are capable of splitting out water from a molecule along with the hydrogenation but do not possess any appreciable cracking tendencies such as alumina, thoria, tungstic oxide or chromium oxide.

Molybdenum sulphide and especially tungsten disulphide are active catalysts for hydrogenating sulphur, oxygen and nitrogen-containing compounds at pressures of about 200 atm.

Hydrodesulphurization (chapter VII) and methanation (chapter II) are also hydrogenation reactions that are treated separately in this manual.

HYDROTREATING

Hydrotreating or hydrogen treating is a process applied generally to petroleum or coal products, to improve existing petroleum products or develop new uses and products, to convert inferior or low-grade materials such as heavy oils and tars into valuable petroleum products and to transform solid fuels such as lignites and coals into liquid fuels. Hydrotreating is also for the elimination of sulphur, nitrogen, oxygen, halides and trace metals from petroleum and coal products.

The treatment may be applied to stocks ranging from light naphthas to lubricating oils.

The hydrogen treating is also used as a pre-treatment to catalytic cracking to reduce coking by as much as 25%.

The distinguishing feature of these operations is that both the raw materials and finished products are very complex mixtures of relatively unknown compositions. All types and sizes of molecules are present along, with a variety of contaminating impurities. In the hydrogenation process. a variety of reactions may be occurring simultaneously and to varying degrees. Yet the final product may be satisfactory and meet all the required specifications.

These complicated mixtures are identified and recognized by certain properties, sometimes more physical than chemical in character. Hydrogenation may result in an upgrading of one or all of the properties of the material.

Catalysts not only must accelerate these hydrogenations but also must guide and direct the desired reactions and effect a balancing and harmonizing of many factors so that the correct over-all result is attained. They must also be able to operate on liquid, solid or gaseous materials, and, in addition, cause impurities that are common catalytic poisons, such as sulphur, oxygen and nitrogen, to be detached from their molecular linkages and removed as H_2S, H_2O or NH_3.

The elements of group 6 of the periodic system are very suitable, particularly molybdenum, tungsten and chromium, as oxides, suphides or more complicated mixtures with one another.

Hydrogenations involving petroleum, tar or coal are usually exothermic. The hydrogen consumed in the process depends on the difference in hydrogen content of the raw material and finished product and on the extent to which gases containing methane and other low-boiling hydrocarbons are formed.

AMMONOLYSIS

Amination by ammonolysis is the process of forming amines by the action of ammonia. By extension, the use of primary and secondary amines as aminating agents (aminolysis) is also included. Considering the behaviour of ammonia, the ammonolytic reactions may involve:

(a) Double decomposition, in which the NH_3 molecule is split into NH_2 and H fragments, the former becoming part of the newly formed amine, while the latter unites with the radical — Cl, —SO_3H, — NO_2 that is substituted;

(b) Dehydration, in which NH_3 serves as a dehydrant, and water and amines result from the ammonolysis of alcohols and from the hydroammonolysis of carbonyl compounds;

(c) Simple addition, in which both fragments of the NH_3 molecules enter the new compound as in the preparation of alkanolamines from alkylene oxides;

(d) Multiple activity, in which nascent or recycled amines compete with ammonia as a co-reactant resulting in the formation of secondary and tertiary amines by aminolysis.

Among the factors that accelerate or retard the replacement of atoms or radicals by the amino group are: solubility, agitation, the halogen derivative treated, the presence of nitro group, the temperature of amination and NH_3 concentration.

Compounds of metals following hydrogen in the electrochemical series, e.g. arsenic, copper and silver can advantageously be employed in the conversion of certain halogen compounds to amino derivatives.

Ammonolysis and aminolysis in the gas phase are generally exothermic except in the case of hydrocarbons. The ammonolysis of unsaturated carbonyl compounds in the presence of hydrogen is the most exothermic type. Reaction of phenols, alcohols and haloids with ammonia is only slightly exothermic. Aminolysis of alcohols is much more exothermic than the ammonolysis. Reactions of hydrocarbons with ammonia to form nitriles seem to be special cases in that they are extremely endothermic in nature.

Ammonolysis of aromatic hydrocarbons requires temperatures higher than 400°C. Ammonolysis can be carried out either in high-pressure autoclaves or in tubular reactors.

HYDROGENATION OF AROMATIC HYDROCARBONS

Reactions for the hydrogenation of aromatics are fairly exothermic. The reaction converting benzene to cyclohexane proceeds even at ambient temperature and moderate pressure in liquid phase. The speed of hydrogenation is tripled by an increase from 20° to 50°C.

Vapour-phase hydrogenation takes place at temperatures of about 200° to 250°C, and 1—10 atm to produce a product containing 0.1% benzene. Heat released at 250°C is 54 kcal/mol.

Other aromatics such as toluene and xylenes as well as ethyl-, propyl-, butyl- and other substituted benzenes can be hydrogenated to the corresponding hexahydrobenzenes when their vapours are passed with hydrogen over nickel catalysts maintained at temperatures from 150° to 200°C. In the case of napthalene or substituted naphthalenes, the product may be the tetra or decahydronaphthalene derivative.

Atmospheric pressures are usually employed in these vapour-phase hydrogenations, although higher hydrogen partial pressures are also suitable. With more substituent groups or with chains longer than butyl or amyl, secondary decomposition products resulting from cracking or the breaking of carbon-to-carbon linkages in the chain appear. In these cases, hydrogenating at lower temperatures but with higher hydrogen pressures and using platinum or nickel catalysts is more practical.

HYDROGENATION OF CARBON DOUBLE BONDS

General reaction: $R-CH=CH-R+H_2 \longrightarrow R-CH_2-CH_2-R'$ where R and R′ are aliphatic or aromatic groups.

In general, the hydrogen pressure need not be high, except when the hydrogenation is slow; then, increased pressure usually accelerates the reaction.

Since hydrocarbons are generally more volatile than the ester or acid of the same number of carbon atoms, a considerable number of these hydrogenations take place in the vapour phase simply by the vapourized compound and hydrogen being passed over the catalyst at a suitable temperature.

The lower-molecular-weight olefins, such as ethylene, propylene, butenes pentenes, hexenes and heptenes, are readily hydrogenated to the corresponding paraffin hydrocarbon in the vapour phase by passing the olefin and hydrogen over nickel at atmospheric pressure and temperatures of 100° to 200°C. At higher temperatures, side reactions involving cleavages in the hydrocarbon chain will occur.

It is advisable to use a considerable excess of hydrogen. Higher-molecular-weight olefins can also be hydrogenated in the vapour-phase in the presence of a nickel catalyst if they have sufficient volatility at the temperature for hydrogenation (150°—200°C). Otherwise the reduction is accomplished in a shaking or stirred autoclave in the liquid phase and hydrogen pressure (1—100 atm). Nickel catalysts are used and also platium or palladium black or their oxides, suspended in the liquid by the mechanical agitation. Aromatic hydrocarbons such as benzene, toluene, and xylenes as well as ethyl-, propyl-, butyl- and other substituted benzenes, can be reduced to the corresponding hexahydrobenzenes when their vapours are passed with hydrogen over nickel catalysts at temperatures of 150° to 200°C.

Atmospheric pressures are usually employed in these vapour-phase hydrogenations, although higher hydrogen partial pressures are also suitable.

With more substituent groups or with chains longer than butyl or amyl, secondary decomposition products appear resulting from cracking or the braking of carbon-to-carbon linkages in the chain. In these cases, platinum or nickel catalysts are recommended.

Cyclic hydrocarbons, other than five or six carbon rings, are hydrogenated with the opening of the ring or with the formation of five- or six-membered rings.

Thus, cyclopropane or trimethylene is readily reduced to propane when passed with hydrogen over nickel at 80° to 180°C.

Cyclobutane is hydrogenated at 180°C to butane in a similar manner, while cyclopentane and cyclohexane are not changed. These five- and six-membered rings are very stable and do not undergo any change except the usual degradative decompositions at higher temperatures. However, isomerization of six- to five-membered rings and vice versa can occur.

The hydrogenation of unsaturated acids and esters is not particularly adapted to vapour-phase reaction because of their low volatility. Most of these reductions are carried out in the liquid phase and at somewhat elevated hydrogen pressures. The types of catalysts employed are very similar to those used in saturating ethylenic linkages.

HYDROGENATION OF ESTERS AND ACIDS

General reaction $RCOO\ R' + 2H_2 \rightarrow RCH_2OH + R'OH$ where R is usually an aliphatic group, and R′ is the same or a hydrogen atom.

The carboxyl group in esters and acids can be reduced to the corresponding hydroxyl group by the use of mild hydrogenating catalysts and hydrogen pressures of 100 atm or more. It is necessary that the hydrogenation conditions be controlled carefully in order to avoid dehydration of the alcohol — resulting in an olefin — or if the latter is further reduced by hydrogen, a paraffin hydrocarbon is formed. In general, the catalysts are of the type used in synthesizing methanol and higher alcohols. The reduction of the carboxyl groups is most satisfactory in aliphatic or hydroaromatic compounds. In the aromatic series, the reduction to alcohols also occurs, the best results being obtained when the carboxyl group is in an aliphatic chain. If the group is directly attached or near to an aromatic ring, side reactions usually accompany the reduction. These generally involve the reduction of the alcohol group to a hydrocarbon group. These side reaction are usually cases of hydrogenolysis. This type of hydrogenation has certain applications to problems of petroleum refining and to synthetic organic chemistry.

The process may be carried out in a batch system or in a flow system, the latter being preferable.

The acid or ester, if solid, may be melted or may be dissolved in a solvent such as normal butyl alcohol or ethyl alcohol, and is then pumped into the reactor and over the catalyst. The catalyst in granular form is held in place in a heated tube capable of withstanding the pressure and temperature.

HYDROGENATION OF CARBONYL COMPOUNDS

General reaction $R\,CO\,R' + H_2 \rightarrow R\,CH\,OH\,R'$ where R is an aliphatic aromatic group and R' may be the same or a hydrogen atom.

Carbon monoxide may be considered the simplest compound containing this group. Its hydrogenation leads to the synthesis of alcohols, ketones, acids and hydrocarbons, the last containing as many as several hundred carbon atoms. This is because carbon monoxide, in partial reduction,can yield compounds or molecular fragments, e.g. CH_2 which are capable of undergoing extensive condensation on the same catalysts that effect the initial hydrogenation.

Thus, from the simple substances carbon monoxide (and, in some cases, carbon dioxide) and hydrogen, practically unlimited synthesis are possible; the greatest problem associated with these reactions is the separation of individual compounds. Methane results when carbon monoxide and hydrogen in the proportion of 2 : 3 are passed over a nickel catalyst at ordinary pressure and temperatures of 200° to 250°C.

Higher hydrocarbons result from the reduction of carbon monoxide by hydrogen at atmospheric or low pressure with cobalt-containing catalysts. Fischer and Tropsch initiated this work in 1926. It may be considered a synthetic petroleum.

Aldehydes are reduced to the corresponding alcohols at about 100° to 150°C in the presence of a nickel catalyst. Methane and water are formed by, however, side reactions.

The reduction of ketones by hydrogen at elevated temperatures is also a reversible reaction. Thus in the case of acetone, at 218°C and atmospheric pressure, the hydrogenation is about only 30% complete.

The reduction of aldehydes is carried out in the presence of the catalysts as: nickel, platinum oxide, copper chromite, platinum with ferric chloride as promoter, at 1--200 in liquid phase.

HYDROGENATION OF NITRILES

Nitrile reduction is obtained by metallic sodium and alcohol and it leads to primary amines.

By the catalytic reduction of nitrile at heat with nickel or at cold with palladium next to the primary amines, the secondary amines are obtained. This is because hydrogen addition to the triple bond occurs in two stages:

$$RC \equiv N + 2[H] \rightarrow R{-}CH = NH + 2[H] \rightarrow R{-}CH_2{-}NH_2$$

The amines formed in the first stage are derivatives of aldehydes and they react with the primary amines to give condensation products (Shiff bases). In turn, these products are hydrogenated to secondary amines:

$$R-CH=NH+H_2NCH_2R\xrightarrow{-NH_3}RCH=NCH_2R\xrightarrow{+2(H)}RCH_2-NH-CH_2R$$

HYDROGENATION OF NITRO COMPOUNDS
(Hydrogenolysis of nitrogen-oxygen bonds)

Reactions of this type are usually very exothermic and equilibrium is generally favourable in the forward direction at all temperatures.

Liquid-phase processes are almost always used for the hydrogenolysis of nitroparaffins although there are a few exceptions. Considerable work has appeared on vapour-phase hydrogenolysis of nitroaromatics. Important applications of this reaction are the use of aniline for aniline dyes and xylidines for blending with aviation gasoline (for improved supercharged engine performance).

Fluid operation helps to solve one of the major problems of hydrogenolysis reactions — temperature control. Copper, nickel and oxides or sulphides of Mo, W, Ni and V are favourable for reactions of this type.

Since Ni is such an active catalyst for this purpose, reduction of the aniline to cyclohexane and ammonia is known to take place.

When a copper catalyst is used, the reaction is more moderate and the yields under optimum conditions are uniformly good.

HYDROGENATION REACTIONS (GENERAL)

Hydrogenation processes have been steadily increasing in size, variety and importance. The unit process of hydrogenation is becoming one of the most useful and widely used methods in organic synthesis.

It is possible to convert liquid fats into solid fats or as it is often called, fat hardening. Both edible and non-edible fats are obtained from the hardening of fish oil or vegetable oils such as linseed, soybean and cottonseed oil by the addition of hydrogen under pressure.

The edible fats are used as lards and butter substitutes.

The soap industry is the largest consumer of non-edible hardened oils. Minor used are in leather dressings, electrical insulations and the manufacture of paints and pharmaceutical ointments.

Another development of importance to the soap industry is the manufacture of detergents. These products are sulphuric acid esters of long-chain aliphatic alcohols such as lauryl, cetyl and stearyl alcohols.

Instead of making the sodium salt of palmitic or stearic acid, as in ordinary soap manufacture, these acids are first reduced to the corresponding alcohols by hydrogenation at high pressure, and the alcohols then esterified with sulphuric acid.

A large number of organic chemicals, higher alcohols and aldehydes can be made from water gas or high-pressure hydrogenation of carbon monoxide.

This chapter comprises all the reactions that are not included in other specific hydrogenation processes.

SELECTIVE HYDROGENATION

Since many organic compounds can be hydrogenated to more than one product, it is often necessary not only that no other classes of reactions occur, but also that only the desired hydrogenation or dehydrogenation reactions take place.

The selective action may involve:

(a) Hydrogenation of one functional group but not another;

(b) Hydrogenation or dehydrogenation to the desired product but not further reaction to undesired products. Selective action may be obtained by several approaches.

USE OF OPTIMUM CONTACT TIME

In cases in which the desired product is capable of undergoing further reaction, such as the partial hydrogenation of acetylene to ethylene, contact time is of extreme importance. The shorter the time of contact, the less chance for further hydrogenation. Hence, it is important to have a catalyst which gives a narrow contact time distribution so that at optimum space velocity almost all molecules will have time enough to be converted but few will have time enough to react further.

ADJUSTMENT OF CONDITIONS FOR THERMODYNAMIC SELECTIVITY

By use of suitable temperature and pressure, it is sometimes possible to make the undesired reaction thermodynamically impossible while the desired reaction is favoured. The most commonly used approach is to find a catalyst which under some conditions will favour one reaction over the other. The Ni and Cu-Cr_2O_3 catalysts have selective action for hydrogenating various functional groups. Seldom is the nature of selective action clear, but certainly differences in catalyst and functional group geometry play an important role.

It has attributed the preferential activity of Cu-Cr_2O_3 for the hydrogenation of groups containing oxygen and the preferential activity of Ni for carbon-carbon unsaturation to selective absorption.

It must be realized however, that promoters such as alkalis and physical factors such as surface area and pore structure also play an important role in selective action.

X. ISOMERIZATION

Isomerization converts hydrocarbons or other organic compounds into products whose molecules have a different arrangement of atoms but the same number and kind of atoms.

There are many isomeric compounds and, therefore, many isomerization reactions. Some of the more important types are:

(a) *n*-butane $\rightleftarrows$ isobutane	$\Delta H = -2.0$ kcal
(b) 1-butene $\rightleftarrows$ cis-2-butene	$\Delta H = +1.7$ kcal
(c) *n*-butene $\rightleftarrows$ isobutene	$\Delta H = +3.6$ kcal
(d) ethylbenzene $\rightleftarrows$ *o*-xylene	$\Delta H = -2.6$ kcal
(e) ethylene oxide $\rightleftarrows$ acetaldehyde	$\Delta H = +24$ kcal
(f) methylcyclopentane $\rightleftarrows$ cyclohexane	$\Delta H = +3.9$ kcal

The conversion of straight chain to branched chain hydrocarbons is by far the most important type of isomerization reaction because of the much higher octane number of the latter. This reaction occurs during catalytic cracking of gas oil and naphtha reforming, in addition to the primary dehydrogenation and dealkylation reactions, and accounts to a major extent for the high octane number of the product.

Although this reaction, like alkylation, is usually carried out in the liquid phase, the vapour-phase process has not been entirely neglected. Low temperature (80°—150°C), moderate pressure (10—20 atm), with a supported acid-promoted aluminium chloride are commonly used. Equilibrium is generally less favourable at high temperature, though the temperature coefficient and heats of reaction are low.

Although acid-type catalysts are generally used for isomerization, even better conversion of normal paraffins to isoparaffins are obtained when both hydrogenation and acidic sites are present. Due to the technical importance of isobutane and the higher branched-chain paraffins in the production of high-octane motor fuels, the isomerization of normal paraffins has received intensive study, especially concerning diverse metal halides and combinations, continuous operating conditions and the use of fluid or molten catalysts.

XI. OXIDATION

In the organic chemical industry, oxidation constitutes one of the most powerful tools used in the synthesis of chemical compounds.

The oxidation processes are many and varied and are manifested in a variety of net effects. The principal types of oxidative reactions may be set forth as follows:

(a) Dehydrogenation as illustrated in the transformation of a primary alcohol to an aldehyde:

$$C_2H_5OH + \frac{1}{2}O_2 \rightarrow CH_3CHO + H_2O$$

or a secondary alcohol to a ketone:

$$CH_3 - CHOH - CH_3 + \frac{1}{2}O_2 \rightarrow CH_3 - CO - CH_3 + H_2O$$

(b) An atom of oxygen may be introduced into a molecule as illustrated by the oxidation of an aldehyde to an acid:

$$CH_3 - CHO + \frac{1}{2}O_2 \rightarrow CH_3 - COOH$$

or of hydrocarbon to an alcohol:

$$(C_6H_5)_3\ CH + \frac{1}{2}O_2 \rightarrow (C_6H_5)_3C - OH$$

(c) A combination of dehydrogenation and introduction of oxygen may occur, as in the preparation of an aldehyde from hydrocarbons:

$$CH_4 + O_2 \rightarrow CH_2O + H_2O$$

or the preparation of benzoic acid from benzyl alcohol:

$$C_6H_5 - CH_2OH + O_2 \rightarrow C_6H_5 - COOH + H_2O$$

(d) Dehydrogenation may also be accompanied by molecular condensation as in the case when two molecules of benzene form diphenyl or two molecules of toluene form stilbene:

$$2C_6H_6 + \frac{1}{2}O_2 \rightarrow C_6H_5 - C_6H_5 + H_2O$$

$$2C_6H_5CH_3 + O_2 \rightarrow C_6H_5 - CH = CH - C_6H_5 + 2H_2O$$

(e) Dehydrogenation, oxygen introduction and destruction of carbon linkages may all occur in the same process of oxidation, e.g. in the oxidation of naphthalene to phthalic anhydride:

$$C_{10}H_8 + 4.5O_2 \rightarrow C_8H_4O_3 + 2H_2O + 2CO_2$$

(f) Oxidation may be accomplished indirectly through the use of intermediate reactions:

$$C_6H_5 - CH_3 \rightarrow C_6H_5CCl_3 \xrightarrow{H_2O} C_6H_5 - COOH$$

$$CH_3 - OH + CO \rightarrow CH_3 - COOH$$

(g) Olefins may be oxidized under mild conditions to hydroxy derivatives and may be converted to aldehydes and carboxylic acids of lower molecular weight when stronger oxidizers are employed;

(h) Peroxidation occurs readily under certain conditions. Thus some reactions occur directly with air when catalyzed by ultra-violet irradiation;

(i) Amino compounds may be oxidized to azobenzene, *p*-amino phenol or nitrobenzene under moderate conditions, or the N-containing radical may be completely removed under drastic conditions. In this way, quinone is derived from aniline;

(j) Sulphur compounds may be oxidized by acid permanganate (the sulphide sulphur is oxidized to sulphonic groups).

In inorganic chemistry, two examples are the oxidation of ammonia for nitric acid production (chapter III) and the oxidation of SO_2 for the sulphuric acid production (chapter III).

The oxidation may be carried in liquid or vapour phase.

XII. POLYMERIZATION

The reaction that produces polymers is generally named polymerization. The polymers are substances consisting of molecules having a very high molecular weight which ranges from about 5,000 to many millions. High polymers consist of large molecules built up by chemical bonds. The macromolecules themselves consist of repeated low-molecular weight units. Each single unit is called a monomer, and a macromolecule composed of many monomers is called a polymer.

Many high molecular weight substances, such as rubber, cellulose, silk, wool, starch, natural resins and gums, exist in nature. Others can be produced synthetically and because of their industrially important properties are at present manufactured in large and every increasing quantities.

The conception of ordinary organic molecules linking up to give a polymer molecule poses the question of the nature of the reaction that produces such polymers and the types of molecules that are capable of undergoing these reactions.

In later investigations it was shown that one particular structural characteristic is common to all molecules able to participate in the formation of a polymer; the molecule must be bifunctional or polyfunctional, and essentially two types of reactions lead to the formation of very large molecules — polycondensation and addition polymerization.

A molecule is called bifunctional or polyfunctional if two or more reactive or functional groups either are present at the beginning of the reaction or appear in the course of it. Simple examples of polyfunctional molecules are hydroxy or amino acids, dialcohols or polyalcohols, diamines or polyamines, diacids or polyacids. These molecules interact with each other through their chemically active groups; but since two or more of them are located on each molecule, the reaction continues in two or three directions and linear or tridimensional molecules are formed.

Another type of bifunctionality is exhibited by a large group of molecules containing double or triple bonds.

The reactions leading to the formation of polymer molecules are polycondensation and addition polymerization.

In polycondensations, bifunctional or polyfunctional molecules condense with one another by repeatedly splitting off H_2O, NH_3, CH_2O, NaCl or other small molecules, as the reaction proceeds. Polycondensation proceeds fundamentally in the same manner as low-molecular condensation.

Addition polymerization, on the other hand, occurs among molecules containing double or triple bond, or bifunctional molecules resulting from the breaking of ring structures. No small molecules are liberated during this process. Polycondensations are typical step reactions, whereas the most important addition polymerizations are chain reactions.

In the large molecules resulting from an addition polymerization, either the recurring low-molecular units are the monomers themselves or two or more different monomers may copolymerize. Examples of industrial polycondensations are phenol-formaldehyde condensation producing phenolic resins, polycondensation between bifunctional alcohols and acids leading to alkyl resins and polyesters, polycondensation of diamines and dibasic acids leading to polyamides and the polycondensation leading to silicones.

The four possible methods of polymerization are in bulk (mass or block polymerization); in solution; in emulsion; and in suspension (pearl).

XIII. PURIFICATION

Generally, purification means nitrogen removal (denitrogenation), oxygen and traces of unsaturated hydrocarbons removal and sulphur removal (desulphurization).

For desulphurization see chapter VII. For unsaturated removal see chapter IX ("Hydrogenation"). This chapter also includes denitrogenation; desoxygenation reactions; the removal of CO_2, CO, ammonia and amines; and the purification by absorption, by combustion and by using molecular sieves.

Typical reactions of the reactive constituents with hydrogen and methane are:

$$2NO_2 + 4H_2 \rightarrow N_2 + 4H_2O$$

$$2NO + 2H_2 \rightarrow N_2 + 2H_2O$$

$$O_2 + 2H_2 \rightarrow 2H_2O$$

$$2NO_2 + CH_4 \rightarrow N_2 + CO_2 + 2H_2O$$

$$4NO + CH_4 \rightarrow 2N_2 + CO_2 + 2H_2O$$

$$2O_2 + CH_4 \rightarrow CO_2 + 2H_2O$$

Some of these reactions are hydrogenation reactions that take place in the presence of typical catalysts.

XIV. CATALYTIC REFORMING OF GASOLINE

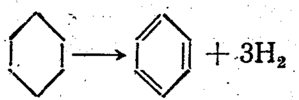
Catalytic reforming as applied to the petroleum refining industry is defined as the conversion of either straight chain or cyclic hydrocarbons, boiling substantially within the gasoline range, in the presence of hydrogen and a precious metal catalyst, to produce motor fuels or aromatic hydrocarbons.

Motor fuel production via catalytic reforming usually involves the transformation of low octane naphthas to high octane hydrocarbons.

Aromatic hydrocarbon manufacture by catalytic reforming commonly converts paraffinic hydrocarbons to benzene, toluene and xylenes.

The catalytic reforming process for both motor fuels and aromatics incorporates the following simultaneous reactions:

Dehydrogenation of cyclohexane:



Isomerization of other naphthenes and their dehydrogenation to aromatics (pentane to isopentane)

Dehydrocyclization of paraffins

Hydrocracking

Isomerization of paraffins

Hydrogenation

aromatics ⟶ naphthenes
olefins ⟶ paraffins
aldehydes
ketones ⟶ alcohols

Of much greater and of fast growing industrial importance for the production of hydrogen for the methanol or ammonia synthesis is the reaction in which C_1 to C_4 hydrocarbons are reformed with steam to produce hydrogen and carbon oxides (primary and secondary). At present, more hydrogen is made by this process.

Propane or other low-molecular weight hydrocarbons are reformed to give a mixture which is a good substitute for that normally supplied by the gas utility.

The reaction

$$C_nH_{2n+2} + nH_2O \rightarrow nCO + 2n + 1H_2$$

is endothermic, i.e., it is necessary to supply large amounts of heat to the reactor. Reforming operations are generally carried out with the aid of nickel catalysts at 550° to 850°C and 1—35 atm steam/gas ratio 2—10 and a hydrocarbon space velocity of 200 to 2,000.

The reforming of CH_4 with air according to the equation

$$CH_4 + \frac{1}{2} O_2 \rightarrow CO + 2H_2$$

is an autothermic reaction.

Catalyst problems are similar to those encountered in synthesis. Overheating of catalysts can readily occur if inlet feed is reduced too much without a corresponding reduction in heat input. This permanently deactivates commercial nickel catalysts when the temperature reaches about 1,050°C, probably owing to a loss in surface area. Nickel catalysts are also poisoned by very small amounts of sulphur gases (over about 4 ppm).

Aside from increasing methane equilibrium conversion and conversion rate, higher temperatures also increase the CO/CO_2 equilibrium ratio. In synthesis employing both CO and H_2 such as alcohol and hydrocarbon synthesis, high temperatures (800°—850°C) are used for the methane steam reaction to obtain the desired ratio of H_2/CO, while low temperature operation (700°—750°C) is favoured where only hydrogen and no carbon monoxide is, such as for ammonia synthesis. The recent literature indicates that ethane, propane and butane can be reformed as readily as methane over Ni catalysts though the steam/hydrocarbon ratio should be increased to prevent coke formation.

Reactions that take place during reforming are:

$CH_4 + H_2O \rightarrow CO + 3H_2$ (endothermic)

$CO + H_2O \rightarrow CO_2 + H_2$ (exothermic)

$CH_4 + 2H_2O \rightarrow CO_2 + 4H_2$ (endothermic)

$CO + 3H_2 \rightarrow CH_4 + H_2O$ (exothermic)

$CH_4 + CO_2 \rightarrow 2CO + 2H_2$ (endothermic)

$CH_4 + CO_2 \rightarrow CO + H_2 + H_2O + C$ (endothermic)

$2CH_4 \rightarrow C_2H_4 + 2H_2$ (endothermic)

XV. CATALYSTS FOR VARIOUS CHEMICAL REACTIONS

AMMONIA DISSOCIATION

Ammonia is dissociated like methanol for the production of inert gas. It is dissociated yielding a gas consisting of 75% hydrogen and 25% nitrogen by volume, and usually less than 0.1% residual free ammonia. Cracking occurs at about 1,000°C. The catalysts used must be resistant to sintering. The metals recommended as catalysts are nickel and iron. Generally, the catalysts used for the reforming of low molecular weight hydrocarbons can be recommended for ammonia dissociation.

CYCLIZATION (DEHYDROCYCLIZATION)

The conversion of aliphatic hydrocarbons containing six or more carbon atoms in a chain to the corresponding aromatic hydrocarbons is known as dehydrocyclization. The reaction sequence is believed to involve dehydrogenation of a paraffin to an olefin followed by ring closure and subsequent dehydrogenation of the ring compound to an aromatic. In many cases, isomerization reactions also take place.

Cyclizations not requiring isomerization proceed rapidly around 450°C. If isomerization is involved, temperatures above 500°C are usually required. Reaction under hydrogen pressure reduces the rate of formation of polymeric tars, thus extending the catalyst's life.

ESTERIFICATION

Esterification is a reversible reaction used to obtain esters. The reactions by which esters are produced may be divided into two groups: those in which two compounds react to give an ester a second compound, as is the case when an acid reacts with an alcohol (direct esterification), and those in which an ester is formed by the addition of one compound to another, as when ethylene is taken up by sulphuric acid.

In direct esterification, an alcohol reacts with an acid, either organic or inorganic:

$$CH_3COOH + HOC_2H_5 \rightleftarrows CH_3COOC_2H_5 + H_2O$$

$$C_2H_5OH + HNO_3 \rightleftarrows C_2H_5ONO_2 + H_2O$$

In all these cases, water, hydrogen chloride or sodium chloride appear as by-products.

In the second group are placed reactions in which esters are formed by the addition of two compounds.

Generally, these are:

(a) Esterification with inorganic acids:

$$C_2H_5OH + HNO_3 \rightarrow C_2H_5ONO_2 + H_2O$$

(b) Esterification with organic acids:

$$C_2H_5OH + HOCOCH_3 \rightleftarrows C_2H_5OCOCH_3 + H_2O$$

(c) Esterification of an ester:

$$CH_3COOC_2H_5 + HOCH_3 \rightleftarrows CH_3—COOCH_3 + HOC_2H_5$$

in which an alcohol displaces another alcohol; it is called alcoholysis, ester interchange or re-esterification. Alcoholysis is only a special case of esterification.

The most commonly used catalysts are sodium alcoholates and the strong acids.

(d) Alcoholysis:

$$CH_3COOC_2H_5 + C_5H_{11}COOH \rightleftarrows C_5H_{11}COOC_2H_5 + CH_3 — COOH$$

The counterpart of alcoholysis is acidolysis, in which one acid displaces another from its ester to form another ester.

Effective catalysts are: brom fluoride and mercury salts (are recommended for vinyl esters).

(e) Esters from acetylene (see vinyl acetate synthesis and vinyl chloride synthesis, chapter II).

(f) Esterification with ethylene oxide.

Ethylene oxide reacts with water to form glycol, with an alcohol to form a glycol ether, and with acetic acid to form glycol acetates. This reaction takes place in the presence of sulphuric acid or a similar catalyst. Aluminium above 150°C, under pressure and in the presence of catalysts, ethylene oxide and carbon dioxide combines to give ethylene carbonate.

(g) Esters from carbon monoxide:

$$CH_3 — OH + CO \rightarrow HCOOCH_3$$

In the presence of acids or of brom fluoride and at somewhat higher temperatures and under high pressure the product is an acid:

$$CH_3 — OH + CO \rightarrow CH_3 — COOH$$

Other important esters are cellulose-acetate, glycerine trinitrate (nitroglycerine), cellulose nitrate (commonly called nitrocellulose).

HYDRATION (DEHYDRATION)

This class of reactions is limited herein to those in which water is tranferred, added or abstracted, in which gaseous hydrogen is not involved.

Dehydration may be either intramolecular (e.g. dehydration of an alcohol) or intermolecular (e.g. ester formation). Addition or removal of water from a compound may be accomplished by a catalyst.

A complicating factor in nearly all reactions of this class is the occurrence of competitive, secondary and side reactions. In the hydration of an olefin to an alcohol, for example, the olefin may also undergo polymerization and the alcohol may undergo dehydration to an ether or dehydrogenation to an aldehyde.

Substantially all hydration-dehydration catalysts have in common a strong affinity for water.

The prime example is alumina which has a water content of several percentage even at 600°C which can be attributed to chemisorption.

Next to alumina in point of usage for reactions in this class comes phosphoric acid or acid salts on various inert carriers. They also have a strong affinity for water. Other active catalysts include silica-alumina gel, various metal combinations with alumina and clays. Combining silica gel with tantalum, zirconium or hafnium proved most suitable for butadiene synthesis.

The hydration reactions are governed by pressures, temperature and mol ratio of reactants.

Sometimes high pressure is necessary to counteract dehydration tendency and promote hydration.

Among the reaction types in this class are the following:

(a) Alcohol synthesis:

$$CH_2 = CH_2 + H_2O \leftrightarrow CH_3 - CH_2OH \qquad \Delta H = -11 \text{ kcal/mol}$$

(b) Aldehyde synthesis:

$$HC \equiv CH + H_2O \leftrightarrow CH_3 - CHO \qquad \Delta H = -40 \text{ kcal/mol}$$

(c) Ketone synthesis:

$$2HC \equiv CH + 2H_2O \leftrightarrow CH_3 - CO - CH_3 + CO \qquad \Delta H = -85 \text{ kcal/mol}$$

(d) Ester synthesis:

$$CH_3—OH + HCOCOH \leftrightarrow HCOOCH_3 + H_2O \qquad \Delta H = -5.6 \text{ kcal/mol}$$

(e) Alkyl aryl synthesis: $ROH + H_2 \leftrightarrow RH + H_2O$

(f) Amine synthesis:

$$CH_3 - OH + NH_3 \leftrightarrow CH_3 - NH_2 + H_2O \qquad \Delta H = -5.7 \text{ kcal/mol}$$

(g) Amide synthesis:

$$CH_3 - COOH + NH_3 \leftrightarrow CH_3CONH_2 + H_2O \quad \Delta H = -4 \text{ kcal/mol}$$

(h) Diene synthesis:

$$CH_3CHO + C_2H_5OH \rightarrow CH_2 = CH - CH = CH_2 + 2H_2O \quad \Delta H = -13 \text{ kcal/mol}$$

In general, intramolecular dehydrations are endothermic and high equilibrium conversion is obtained only at high temperatures and low pressures. Intermolecular dehydration equilibrium is not in general markedly affected by temperature or pressure.

Part three

Homogeneous catalysts

XVI. HOMOGENEOUS CATALYSIS

Two broad classes of catalytic reactions are recognized: homogeneous and heterogeneous.

Known homogeneous catalytic reactions are either gas or liquid phase, preponderantly the latter; existence of solid phase reactions of this type is considered doubtful.

Homogeneous catalysis in the gas phase is comparatively rare, but a few exceptions may be noted:

(a) Nitric oxide is an industrial catalyst for the oxidation of sulphur dioxide. It has been shown that the reaction proceeds much more rapidly by the sequence:

$$2NO + O_2 \rightarrow 2NO_2$$

$$NO_2 + SO_2 \rightarrow NO + SO_3$$

(b) Decomposition of acetaldehyde, various ethers and nitrous oxide are strongly catalysed by iodine in the gas phase;

(c) Formation of hydrogen chloride from its elements is catalysed by sodium or potassium vapour. Several thousand molecules of HCl result from the reaction of a single metallic atom.

Liquid-phase homogeneous catalysis is common. Most widely investigated has been catalysis by ions, of which the most important type is acid and base catalysis. Processes catalysed by acids and bases include esterification, saponification, inversion, mutarotation, enolization and many oxidations and reductions. Rates of such reactions are expressed in terms of the generalized concept of acid and base. According to this definition, molecules able to furnish a proton are called acids, and those able to combine with the proton are called bases; these molecules may be ions or neutral. Thus acids and bases are related by the equation¹):

$$\text{acid} \rightleftarrows \text{base} + H^+$$

Neutral salts in solution influence reactivity. It is to be expected that collisions of ions will be influenced by the ionic atmospheres, which are in turn affected by the presence of salts. Collisions between oppositely charged ions are increased by salts which favour electrostatic attraction and decreased by salts which modify the ionic atmosphere so that electrostatic attraction is decreased. This effect is correlated in terms of the ionic strength of the solution; its order of magnitude is rather less than that of most catalytic effects.

Nature of the solvent sometimes may affect the kinetics of a process. This may possibly be regarded as an example of catalysis. In some cases this effect is due to the influence of the solvent on the thermodynamic activity of the reactants. Solvating power, acid dielectric constant are pertinent properties. Where important molecules are concerned, reactions yielding products more polar than the reactants proceed better in polar solvents, while those with products less polar than the reactants proceed better in non-polar solvents.

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1) A catalyst in a homogeneous system is a substance that appears in the speed equation without appearing in the stoichiometric equation of the reaction. A more general definition of the catalyst in a homogeneous reaction would be a substance whose concentration appears in the speed equation at a higher power than in the stoichiometric equation. This definition includes also the more rare cases of self catalysis.

Part four

Catalyst carriers

XVII. CARRIERS

Only very rarely do commercial catalysts consist of a single component. The term "catalyst carrier" as used herein refers to a major catalyst constituent that serves as a base, support, carrier or binder for the active constituent but which by itself has little, if any, catalytic activity for the reaction in question.

The mechanical function of a carrier is to act as a base or framework for the catalytic component. It may serve to reduce shrinkage and lend physical strength.

Aside from its purely mechanical function, other possible desirable effects of a carrier include:

(a) Giving a larger exposed surface of active agent and thereby greater catalytic activity in cases in which this agent by itself has low surface area, or giving an equal surface area and activity with much less active material;

(b) Increasing catalyst stability by keeping fine crystals of the active constituent too far apart for sintering to occur;

(c) Favourably modifying the catalytic activity or selectivity, poison resistance etc. of the active constituent. In some cases surface compound or complex formation may take place between the carrier and the supported material giving a complex which has better catalytic properties per unit area than the latter. Silica-alumina and silica-magnesia cracking catalysts are in this category;

(d) Improving activity by increasing the accessibility of the active surface. This is important in many industrial catalytic processes in which the catalyst is used in the form of large granules, pellets or rings. Supports with large pores, such as diatomaceous earth would be expected to act in this manner. Physical structure has also been found to have an important effect on selectivity;

(e) The increase of active surface resulting from use of a carrier may result in a decrease in sensitivity to poisons;

(f) Catalysing one of the steps where there is a dual action mechanism; this is similar to the function of a dual action promoter except that the carrier acts also as a mechanical support for the other constituent;

(g) Helping to dissipate heat and prevent local over-heating which would cause sintering with resultant loss in active surface. High heat conductivity carriers are favoured for such purposes. In the catalytic oxidation of ethylene, metallic silver carriers are commonly used.

Because of pressure drops considerations, industrial vapour-phase catalysts are almost entirely of two types: powders, 20—300 microns, for fluid bed operations and granules, rings or pellets for fixed bed processes.

Among the factors to be considered in the selection of a carrier are:

Possible catalytic activity of the carrier component
Modification of the properties of the supported component by the carrier
Surface area
Porosity
Structure
Specific heat
Heat conductivity

Particle size
Density
Attrition resistance, hardness and compressive strength
Stability under reaction conditions

Although it is not easy to classify carrier materials, and some carriers can be "tailor-made" to have widely varying properties (e.g. silica gel), the best way to classify them seems to be on the basis of structure. The main classes of structure are: low-area carriers, high-area carriers, miscellaneous carriers and fibrous materials.

During the last few years the importance of the role of the catalyst carrier in heterogeneous catalyst systems has been more fully appreciated, if not completely understood. A very comprehensive range of catalyst carriers is now available from industry. The fact that there is now such a wide variety of catalyst carriers available to the research chemist gives rise to problems of catalyst carrier selection.

In the field of catalyst carriers it is convenient to classify them on the basis of their internal surface area as follows:

Low surface area (LSA):	less than 1.0 m^2/g
Intermediate surface area (ISA):	less than 1—100 m^2/g
High surface area (HSA):	greater than 100 m^2/g

LOW SURFACE AREA CATALYST CARRIERS

Under this classification a number of products are available which vary in both chemical and physical properties.

CHEMICAL PROPERTIES

Materials available include:

Pure alumina:	99 + % Al_2O_3
Alumina silica:	greater than 50% Al_2O_3
Silica alumina:	greater than 50% SiO_2
Pure silica:	99% SiO_2
True mullite:	stable alumina silica compound $3Al_2O_3.2SiO_2$
Silicon carbide:	80%—96% SiC
Titania:	90% TiO_2

SURFACE AREA (SA)

Even within this classification there is some scope for variation in surface area between 0.01 and 1.0 m^2/g. This property is dependent on the pore diameter and volume of pores present.

PORE SIZE DISTRIBUTION (PSD)

Products are available with pores in the range 1—1,500 microns.

OTHER PROPERTIES

Whilst porosity, water absorption and strength are important properties, they become to some extent fixed by the properties of surface area and pore size distribution. They are usually more than adequate for the catalyst manufacturer's production techniques.

SELECTION

When faced with the selection of a suitable catalyst carrier, the research chemist is to some extent spoilt for choice. By plotting catalyst performance (activity, conversion, yield, life) against average pore diameter and against surface area the research chemist will be able to optimize the catalysts carrier required.

APPLICATIONS

LSA catalyst carriers are used for reactions where controlled low activity is desired to produce an intermediate product. Typical reactions include:

Oxidation of ethylene to ethylene oxide
Oxidation of benzene to maleic anhydride
Oxidation of naphthalene/ortho-xylene to phthalic anhydride
Production of lean town gas
Steam reforming of hydrocarbons

INTERMEDIATE SURFACE AREA CATALYST-CARRIERS

This product classification is probably the least used and least known. This is mainly due to the lack of commercially available products. Recent new ceramic technology makes available new products in this range for evaluation by the research chemist.

CHEMICAL PROPERTIES

Materials available include:

Pure alumina:	98% Al_2O_3 in various crystal forms
Alumina silica:	85% Al_2O_3
Titania:	92% TiO_2

PURE ALUMINA

These products are derived from the dehydration sequence of alumina hydrate. Alpha alumina trihydrate gives kappa and alpha alumina products within this surface area classification, but the surface area *versus* temperature characteristics of these raw materials make it difficult to control the surface area in the range 10—100 m^2/g. Alpha alumina monohydrate dehydration gives theta and alpha products in this surface area range and the surface area *versus* temperature characteristics allow much improved surface area control in the region 10—100 m^2/g.

PORE SIZE DISTRIBUTION

The average pore diameter of products increases with decrease in surface area.

SELECTION

When selecting carriers in this product range, it is obvious that one should choose at least two surface area ranges, e.g. 20—30 (alpha), 60—80 (alpha + theta). Further optimization may be possible by selection on the basis of surface area and average pore diameter particularly when pore diffusion limitation is expected.

HIGH SURFACE AREA CATALYST CARRIERS

This classification covers the largest volume of all catalyst carriers used in heterogeneous catalysts.

TABLE 1

LOW SURFACE AREA CATALYST CARRIERS: TYPICAL CHEMICAL ANALYSIS a/

Al_2O_3	SiO_2	Fe_2O_3	TiO_2	CaO	MgO	Na_2O	K_2O	ZrO_2+HfO_2	SiC
Aluminium oxide									
90.40	8.46	0.26	0.28	0.04	0.07	0.33	0.09	0.05	—
86.96	11.65	0.30	0.42	0.05	0.11	0.32	0.17	0.02	—
76.60	16.80	1.20	2.5	0.80	0.60	0.40	1.00	—	—
92.67	6.03	0.22	0.22	0.11	0.16	0.43	0.11	—	—
86.96	11.65	0.30	0.42	0.05	0.11	0.32	0.17	0.02	—
99.3	0.4	0.10	—	0.10	—	0.10	—	—	—
95.9	3.5	Tr.	Tr.	Tr.	Tr.	0.20	0.40	—	—
Silicon carbide									
4.73	28.48	0.34	Tr.	0.24	0.06	0.23		—	65.8
Silica									
3.1	96.0	0.26	0.26	0.04	0.11	0.16	0.07	—	—
0.8	96.9	0.10	—	—	0.10	0.50	(B_2O_3) 1.6%		—
									—
Zirconium silicate									
2.97	32.33	0.17	0.20	0.16	0.25	0.01	0.06	63.84	—
2.97	32.33	0.17	0.20	0.16	0.25	0.01	0.06	63.84	—
Mullite									
70.02	28.90	0.29	0.36	0.13	0.15	0.10	0.05	—	—
Zirconia									
0.38	1.57	0.16	0.25	3.50	—	—	—	94.14	—

a/ All elements reported as metal oxides. Actual presence of the metals in the form of complex silicates and/or aluminates.

TABLE 2

LOW SURFACE AREA CATALYST CARRIERS: PHYSICAL PROPERTIES

Apparent porosity (%)	Water absorption (%)	Bulk density $(\mathrm{g/cm^3})$	Apparent specific gravity	Packing density $(\mathrm{lb/ft^3})$	Maximum attrition loss per hour (%)	Pores		Surface area $(\mathrm{m^2/g})$
						Diameter range (μm)	Percentage of pore volume in the range	
				Aluminium oxide				
38–47	17–24	1.9–2.1	3.5–3.7	58–78	15	2–40	90	<1
43–52	21–30	1.7–1.9	3.5–3.7	55.73	15	3–60	90	<1
39–45	18–24	2.0–2.3	3.5–3.7	75–80	10	3–30	90	<1
42–48	20–26	1.7–1.9	3.5–3.7	64.71	15	3–60	90	<1
39–44	16–22	1.7–1.9	3.5–3.7	72–78	10	3–30	90	<1
36–42	15–20	2.0–2.2	3.4–3.6	63–83	10	2.30	80	<1
40–46	19–24	1.8–2.0	3.2–3.4	71–75	15	2–40	90	<1
35–40	15–19	2.1–2.3	3.4–3.7	72–80	12	2–40	85	<1
40–45	19–23	1.9–2.1	3.4–3.6	69–74	15	2–60	90	<1
36–44	15–21	2.0–2.4	3.5–3.8	77–84	10	2–40	85	<1
32–40	12–18	1.9–2.1	3.3–3.5	71–83	15	2–30	80	<1
31–36	12–16	2.0–2.2	3.3–3.5	78–84	5	2–30	80	<1
6–14	1–5	3.0–3.2	3.5–3.7	110–120	1	1–3	95	<1
48–54	25–31	2.0–2.4	3.5–3.8	58–65	15	4–70	95	<1
48–54	25–31	1.7–2.0	3.5–3.8	58–65	15	4–70	95	<1
40–44	16–20	2.2–2.4	3.9–4.0	85–89	12	1–20	95	<1
30–34	10–14	2.6–2.8	3.9–4.0	97–102	5	1–10	95	<1
				Silicon carbide				
39–43	22–25	1.6–1.8	2.8–3.0	60–64	10	10–40	95	<1
42–48	26–30	1.5–1.8	2.8–3.0	54–62	10	10–40	95	<1
				Silica				
35–39	22–26	1.3–1.5	2.3–2.4	59–63	5	1–5	90	<1
32–38	19–25	1.5–1.7	2.3–2.4	55–59	6	1–5	90	<1
48–52	44–48	1.0–1.2	2.1–2.3	42–46	—	—	—	<1
				Zirconium silicate				
3–8	1–3	3.8–4.0	4.1–4.3	141–147	2	2–10	85	<1
24–32	7–12	3.0–3.4	4.4–4.6	112–121	5	—	—	<1
				Mullite				
34–40	16–22	1.9–2.1	3.1–3.3	67–73	5	—	—	<1
34–40	16–22	1.9–2.1	3.1–3.3	64–70	5	—	—	<1
				Zirconia				
42–47	12–16	3.0–3.3	5.5–5.8	103–110	22	—	—	<1

TABLE 3

LOW SURFACE AREA "MACROPORE" CATALYST CARRIERS: TYPICAL CHEMICAL ANALYSIS [a]

Al_2O_3	SiO_2	Fe_2O_3	TiO_2	CaO	MgO	Na_2O	K_2O	$ArO_2 + HfO_2$	SiC
Aluminium oxide									
84.7	13.4	0.20	0.30	0.02	0.04	0.60	0.70	—	—
83.0	14.0	0.40	0.30	0.50	0.50	0.60	0.70	—	—
85.5	12.4	0.20	0.10	0.60	0.40	0.30	0.50	—	—
Silicon carbide									
2.6	6.5	0.20	0.10	0.10	0.10	0.10	0.20	—	90.0
Zirconium silicate									
4.8	39.9	0.3	0.5	0.1	—	0.2	0.8	53.4	—
Mullite									
69.91	28.38	0.21	0.17	0.59	0.39	0.14	0.21	—	—
69.91	28.38	0.21	0.17	0.59	0.39	0.14	0.21	—	—

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[a] All elements reported as metal oxides. Actual presence of the metals in the form of complex silicates and/or aluminates.

TABLE 4

LOW SURFACE AREA "MACROPORE" CATALYST CARRIERS: PHYSICAL PROPERTIES

Apparent porosity (%)	Water absorption (%)	Bulk density (g/cm^3)	Apparent specific gravity	Packing density (lb/ft^3)	Maximum attrition loss per hour (%)	Pores		Surface area (m^2/g)
						Diameter range (μm)	Percentage of pore volume in the range	
Aluminium oxide								
53—59	33—39	1.5—1.7	3.3—3.6	53—59	6	100—1500	95	<1
55—61	37—43	1.4—1.6	3.3—3.6	50—56	8	100—1500	95	<1
55—61	37—43	1.4—1.6	3.3—3.6	44—48	10	100—1500	100	<1
43—47	20—24	1.8—2.0	3.5—3.8	63—67	15	20—180	100	<1
36—42	15—21	2.0—2.4	3.4—3.8	66—74	10	20—180	100	<1
Silicon carbide								
43—48	24—30	1.6—1.8	3.0—3.2	53—57	15	3—100	100	<1
Zirconium silicate								
44—48	19—23	2.0—2.3	3.9—4.1	63—67	5	—	—	<1
Mullite								
41—45	23—27	1.9—2.1	3.1—3.3	55—59	6	—	—	<1
41—45	23—27	1.6—1.9	3.0—3.2	55—59	6	—	—	<1

TABLE 5

INTERMEDIATE SURFACE AREA CATALYST CARRIERS: PHYSICAL PROPERTIES

Apparent porosity (%)	Water absorption (%)	Bulk density (g/cm³)	Apparent specific gravity	Packing density (lb/ft³)	Maximum attrition loss per hour (%)	Pores		Surface area (m²/g)
						Diameter range (μm)	Percentage of pore volume in the range	
Aluminium oxide								
62–66	53–57	1.1–1.3	3.1–3.3	42–46	–	–	–	10–20
62–66	52–56	1.1–1.3	3.2–3.4	40–44	–	–	–	10–20
62–66	54–58	1.1–1.3	3.1–3.3	40–44	–	–	–	35–45
62–66	55–59	1.1–1.3	3.1–3.3	37–44	–	–	–	35–45

TABLE 6

INTERMEDIATE SURFACE AREA CATALYST CARRIERS: TYPICAL CHEMICAL ANALYSIS [a]

Al_2O_3	SiO_2	Fe_2O_3	TiO_2	CaO	MgO	Na_2O	K_2O	$ZrO_2 + HfO_2$	SiC
Aluminium oxide									
83.0	15.3	0.44	0.50	0.09	0.07	0.34	0.16	–	–

a/ All elements reported as metal oxides. Actual presence of the metals in the form of complex ilicates and/or aluminates.

XVIII. CRYSTALLINE MATERIALS

Crystalline materials are produced in high temperature electric furnaces and further processed to meet demands of industry for purity, density, shape and size. These high temperature crystalline materials are available in granular and powdered form.

REGULAR FUSED ALUMINA (Al_2O_3)

Regular fused alumina is a hard brown grain, produced by fusing a mixture of calcined bauxite, coke, and iron filings in the Higgins electric arc furnace at a temperature above 3,630°F (2,000°C). During the process purification and crystallization of the grain takes place.

A typical chemical analysis is:

	Per cent (by difference)
Al_2O_3:	94.47
SiO_2:	1.70
Fe_2O_3:	0.20
TiO_2:	3.10
ZrO_2:	0.15
CaO:	0.08
MnO:	0.10
MgO:	0.20

The characteristics are:

Crystal form:	alpha alumina
Maximum usable temperature:	about 3,450°F(1,900°C)
Chemical nature:	amphoteric
Reaction with acids:	subject to mild attack by aqua regia and/or hydrofluoric acid
Reaction with alkalies:	very slight with strong hot solutions only
Oxidation-reduction effects:	none
True specific gravity:	3.95
Packing density:	110–128 lb/ft^3 depending on grain size and shape
Hardness (Knoop):	2,000
(Mohs):	9.0
Electrical resistivity:	10^{16} at 80°F (30°C) 10^5 at 1,650°F (900°C)

Two shapes are available. These grain shapes are determined by the degree of crushing and milling. The two shapes are: strong — a strong, block-shaped grain; and intermediate — a wedge-shaped grain intermediate between a stronger block shape and a weaker sliver shape.

The grain sizes are: crude — lumps 1 1/2" and finer; and grit sizes — in either strong or intermediate shape.

Coarse		to		Fine
4				
6	20		70	120
8	24	46	80	
10		54		150
12	30	60	90	
14				180
16	36		100	220

WHITE FUSED ALUMINA (Al_2O_3)

There are many applications that demand high-purity white grain. White in colour, it is somewhat more refractory than regular fused alumina. This white grain is electrically fused from Bayer process alumina. Although considerably purer, its physical properties are comparable to regular grain.

A typical chemical analysis is:

	Per cent (by difference)
Al_2O_3:	99.28
SiO_2:	0.05
Fe_2O_3:	0.15
TiO_2:	0.02
Na_2O:	0.50

The characteristics are:

Crystal form:	alpha alumina
Maximum usable temperature:	3,630°F (2,000°C)
Chemical nature:	amphoteric
Reaction with acids:	less attack than regular grain
Reaction with alkalis:	very slight with strong hot solutions
Oxidation-reduction effects:	none
True specific gravity:	3.97
Packing density:	approx. 107–119 lb/ft³ depending on grain size.
Hardness (Knoop):	2,000
(Mohs):	9.0
Electrical resistivity:	10^{16} at 80°F (30°C) 10^6 at 1,650°F (900°C)

The grain shape is wedge, intermediate between a strong or block shape and a weak or sliver one. The sizes are: crude — lumps 1 1/2" and finer; and grit sizes.

Coarse		to		Fine
6	16		70	120
8	20	46	80	150
10	24	54		
12	30	60	90	180
14	36		100	220

FUSED MULLITE ($3Al_2O_3 \cdot 2SiO_2$)

Refractory products using mullite grain have good high temperature strength and thermal shock resistance. Mullite grain is an aluminium silicate ($3\,Al_2O_3 \cdot 2\,SiO_2$) fused in an electric furnace to insure complete reaction of

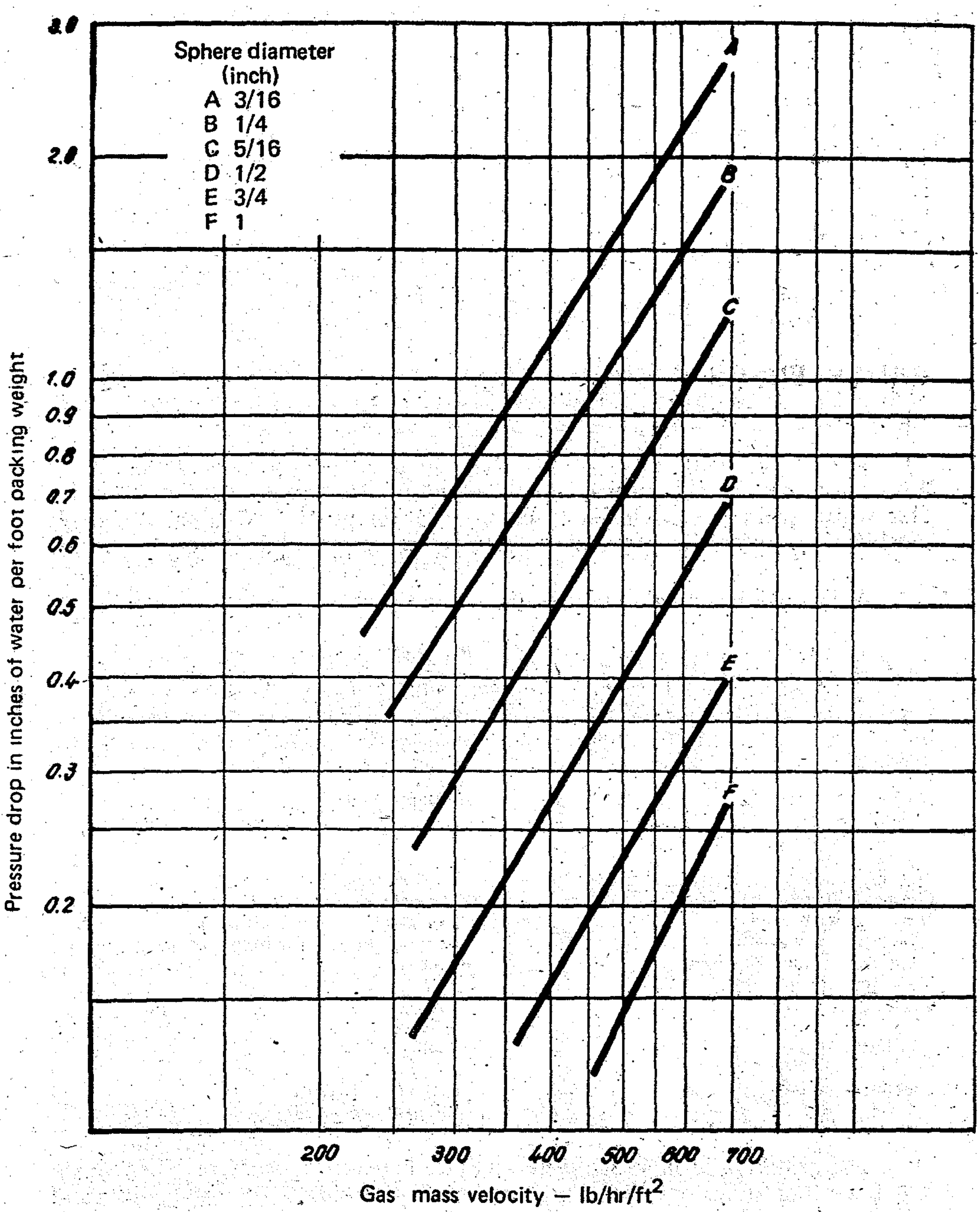

Figure I. Pressure drop through fixed beds of spherical catalyst

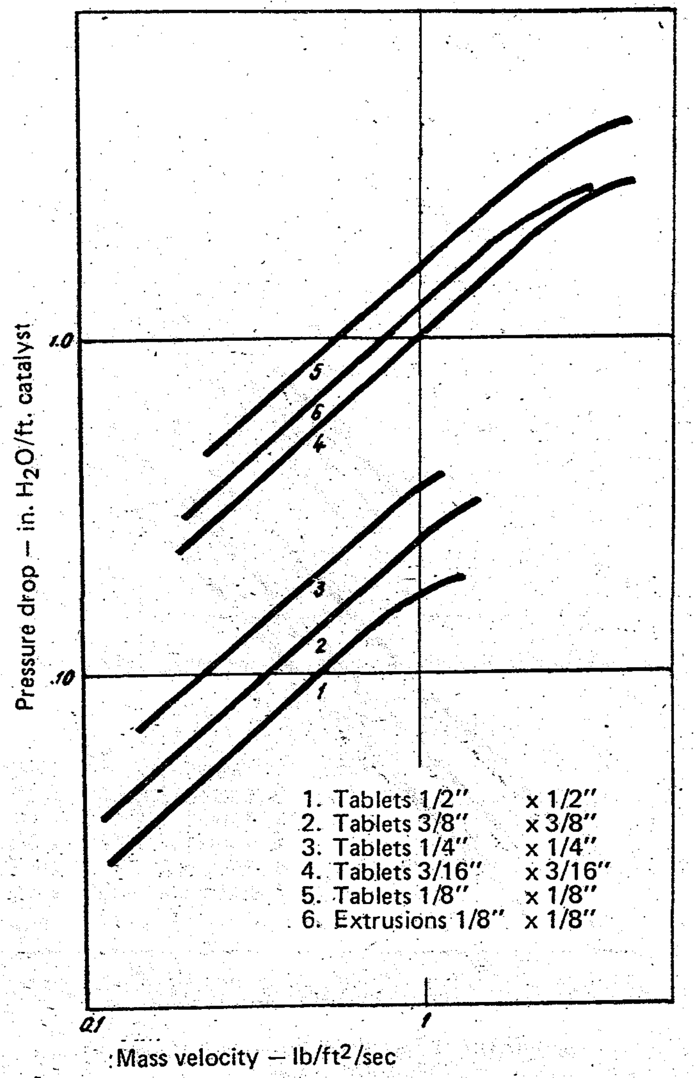

Figure 11. **Pressure drop per foot of catalyst tablets vs. mass velocity**

the raw materials. An excess of alumina is used in the fusion, causing the resultant composition to be on the high alumina side of theoretical mullite, that is, 72% Al_2O_3. Petrographic examination reveals about 2% free alumina and 1% glass. These factors enable mullite grain to remain in the crystalline form (i.e., no liquids are formed) up to the eutectic melting point 3,340°F (1,840°C) between mullite and alumina.

A typical chemical analysis is:

	Per cent (by difference)
Al_2O_3	75.10
SiO_2	24.35
Fe_2O_3	0.12
TiO_2	0.03
Na_2O	0.35
C	0.05

The characteristics are:

Crystal form:	orthorhombic (excess alumina-present as corundum)
Melting point:	congruently at 3,340°F (1,840°C)
Chemical nature:	slightly acid

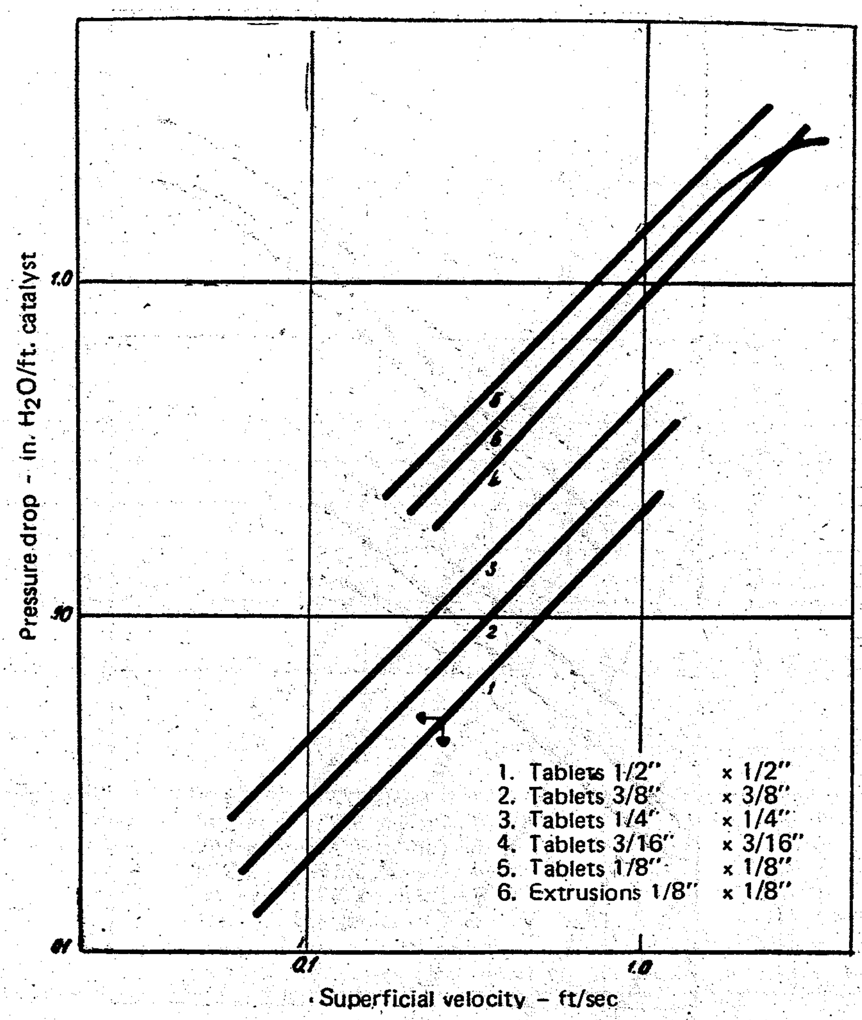

Figure III. **Average superficial velocity of air at 65°F vs. pressure drop per foot of catalyst tablets**

Reaction with acids, alkalis and general:	Insoluble in most acids attacked by molten alkalis and many basic slags
Maximum usable temperature:	3.340°F (1,840°C)
True specific gravity:	3.23
Packing density:	85 to 103 lb/ft³ depending on grain size
Hardness (Knoop):	820
(Mohs):	7

TESTING PROCEDURES

PROCEDURE FOR DETERMINING APPARENT POROSITY, WATER ABSORPTION, APPARENT SPECIFIC GRAVITY AND SOLID BULK DENSITY

The equipment used is:

A rectangular stainless steel wire mesh basket (2 1/2" × 2" × 1" deep with wire handle) for holding sample
A balance weighing to nearest 0.1 g

A deep porcelain dish
A damp cloth
A small aluminium or plastic container

The testing procedure is as follows:

(1) Weigh dry wire mesh basket in air to nearest 0.1 g;

(2) Place about 80—100 g of dry carriers in basket and reweigh in air;

Note: This weight suggested for $\frac{1}{2}''$ size and smaller. weight per cubic foot 40—80 lb. For sizes larger than $\frac{1}{2}''$ or dense materials, sample weight 250 g;

(3) Subtract (1) from (2). This is dry weight of carriers in air. Call this weight "D";

(4) Fill porcelain dish with water and heat to boiling;

(5) Immerse wire basket containing carriers in the boiling water. Boil gently for 30 minutes;

Note: Keep carriers covered with water at all times during boiling. Do not let basket rest on bottom of porcelain dish.

(6) Remove porcelain dish from heat, place under cold water faucet and run in cold water until mass has cooled to room temperature;

(7) Remove wire mesh basket containing carriers from cold water and weigh entire mass suspended in water at room temperature;

(8) Weigh dry aluminium or plastic container in air;

(9) Soak a piece of cloth towel in water and wring out thoroughly by hand;

(10) Transfer sample from basket to damp cloth towel and blot lightly to remove all drops of surface water;

(11) Transfer sample to weighed aluminium or plastic container and weigh entire mass in air;

(12) Subtract weight (8) from weight (11) to get weight of saturated carriers. Call this weight "W";

(13) Weigh wire mesh basket submerged in water;

(14) Subtract weight (13) from weight (7) to get suspended weight of carriers. Call this weight "S".

The exterior volume (V) in cubic cm of the carriers is obtained by subtracting the suspended weight from saturated weight, thus:

$$V = W - S$$

The apparent porosity (P) expresses as a percentage the relationship of the volume of the open pores of the carrier to its exterior volume and it is calculated as follows:

$$P = \frac{W-D}{V} \times 100$$

The water absorption (A) expresses as a percentage the relationship of the weight of water absorbed to the weight of dry carriers. It is calculated as follows:

$$A = \frac{W-D}{D} \times 100$$

The apparent specific gravity (T) is that portion which is impervious to boiling water. It is calculated as follows:

$$T = \frac{D}{D-S}$$

The bulk density (B) in grams per cubic cm is the quotient of its dry weight divided by its exterior volume including pores. It is calculated as follows:

$$B = \frac{D}{V}$$

PROCEDURE FOR DETERMINING PACKING DENSITY (VOLUMETRIC BULK DENSITY)

The equipment used is:
A metal cone of the following dimensions:

90° angle at vertex
12 3/4″ diameter at top
$1\frac{1''}{2}$ diameter hole at bottom
1″ height from bottom of cone to top of weighing cylinder facilitated by three legs on outer surface of cone;
A metal base plate (10″ × 10″ × 1″ thick);
A standard 1/8 cubic foot grain density cam with following dimensions:
3 7/8″ ID at bottom
3 7/8″ ID at top
17 15/32″ inside height

(A multiplication factor should be applied to the results — as the grain density cam is slightly under 1/8 ft^3. This factor must be obtained for each container.)

The testing procedure is as follows:

(1) Weigh out 3—5 lb of carriers. This weight dependent on density of material to be tested. (Amount to weigh out should fill container half full.);

(2) Place grain density cam on 10″ × 10″ × 1″ thick steel plate. Steel plate must be placed on solid rigid surface. A concrete floor is advisable;

(3) Place metal cone on grain density cam;

(4) With one hand under $1\frac{1}{2}''$ cone opening pour the sample to be tested into cone;

(5) Release hand under cone opening allowing constant flow of carriers through $1\frac{1}{2}''$ cone opening into cylinder;

(6) Raise container $\frac{1}{2}''$ until it touches a bar clamped to a laboratory clamp stand. Allow to fall freely onto the steel plate. Repeat to a total of 10 drops;

(7) Repeat steps (1) through (5);

(8) Level overflowing cylinder with metal straight edge;

(9) Repeat step (6);

(10) Add additional carriers to fill grain density cam to overflow;

(11) Level overflowing cylinder with metal straight edge;

(12) Weigh contents of grain density cam and convert to weight per cubic foot using proper factor for cylinder.

PROCEDURE FOR DETERMINATION OF ABRASION RESISTANCE

This test is designed to measure how well catalyst carriers will resist abrasion. The abrasion loss is determined in terms of material finer than 10 mesh (0.07″ ± 0.1″ screen openings ten per inch) which is removed from the carriers by tumbling under controlled conditions.

The equipment used is:

A fibre drum with lid (Continental Can Company No T-158-2 X) with the following dimensions: outside diameter, 8 5/16″; inside diameter, 8″; inside length, 7″.

The inside surfaces of the bottom of the drum and the lid should be covered by discs of smooth wear resistant rubber 1/64″ thick, cemented to the respective surfaces by rubber cement (Goodyear Pliobond).

After attaching the rubber disc to the inside of the bottom of the drum, the entire inside wall of the container should be covered by one piece of ribbed rubber cemented to the walls by rubber cement. This rubber shall be attached so that the ribs are parallel to the length of the drum;

A laboratory ball mill rollers capable of rotating corrugated rubber lined drum charged with sample at 60 ± 1 rpm;

A 10 mesh wire screen (0.07″ ± .01″ screen openings 10 per inch);

A scale capable of weighing up to at least 10 lb to two decimal places.

The testing procedure is as follows:

(1) Weigh out sample of screened material and place this weighed sample in container. (Sample weight depends on size, shape and density. Sample weight is generally 5 lb, however, for "Macropore" series sample weight is $3\frac{1}{2}$ lb);

(2) Place lid on container and seal lid joint with 2″ wide rubber band;

(3) Place container and contents on rollers and rotate for 15 minutes at 60 rpm;

(4) After 15 minutes remove the container and empty all contents onto the 10 mesh wire screen;

(5) Shake screen by hand to remove all fines;

(6) Weigh material remaining on screen;

(7) Calculate per cent of loss for a total of 15 minutes;

(8) Replace pellets in corrugated rubber lined drum;

(9) Repeat steps (2), (3), (4), (5) and (6);

(10) Calculate per cent of cumulative loss of a total of 30 minutes;

(11) Repeat step (8);

(12) Repeat step (2);

(13) Replace container on rollers and rotate for 30 minutes at 60 rpm;

(14) Empty all the contents onto the 10 mesh wire screen;

(15) Repeat steps (5) and (6);

(16) Calculate per cent of cumulative loss for a total of 60 minutes.

XIX. CATALYST CARRIERS — PRESSURE DROP

EXPERIMENTAL TEST METHOD

All materials were loose filled in a 4.02 ID tube 2′ in length. The outer walls were pounded with a hammer until no more settling was observed. Additional make-up was added to top off the bed and the pounding repeated. Thus, all materials were tested at maximum packing density and minimum bed voidage for the imposed particle to tube geometry.

Pressure taps were installed in the column just above and below the bed. The pressure differential was observed by sighting through a cathetometer, a water filled manometer. The empty tower provided a negligible pressure drop of less than 0.01″ of water at a G equalling 1,000 pounds of air per hour per square foot. Use of the cathetometer allowed detection of a pressure drop of less than 0.04″ of water with excellent accuracy and reproducibility.

Pressure regulated plant compressed air was fed to two needle valves in parallel. These needle valves acted as critical flow orifices above a 25 psig supply pressure at the maximum back pressure created by the air line, column bed and gas meter. The open area of each needle valve was set at positions which would provide coverage of the flow regime desired. Both needle valves were calibrated individually and together to provide a straight line plot of superficial mass velocity as inlet pressure to the needle valve. Air was directed down through the bed. Air flow was measured using a standard 60 light gas meter.

All data were obtained by measuring the pressure differential over the bed data minimum of 15 values of superficial mass velocity. A disproportionately greater number of points were obtained at low superficial mass velocities for large particle sizes to average out any errors in reading the manometer at small pressure differentials.

A study was completed on pressure drop data for air flowing through packed beds of catalyst carriers. In this study all products tested were in dense packed beds 4″ in diameter and 2′ length. All materials were loose filled and the outer columns were pounded with a hammer until no more settling was observed. Additional make-up was added to top off the bed and the pounding repeated. Thus, all materials were tested at maximum packing density and minimum bed voidage for the imposed particle to tube geometry.

Table 7 shows pressure drop data for spheres, pellets, grooved pellets, rings, grooved rings and aggregate. Table 8 gives the properties of certain kinds of spheres. Spheres — pellets or granulates (grain) showing distinct properties can be composed to specification. The recommended packing for transportation by railway is jute or plastic bags; for transportation by sea, iron drums.

TABLE 7

PRESSURE DROP DATA FOR SPHERES, PELLETS, GROOVED PELLETS, RINGS, GROOVED RINGS AND AGGREGATE ΔP/L (INCHES OF WATER PER FOOT OF PACKED DEPTH)

Spheres	Gas mass velocity (Air) lb/hr/ft²									
	100	200	300	400	500	600	700	800	900	1000
1/8	0.31	0.84	1.6	2.4	3.5	4.7	6,1	7.4	9.2	11.0
3/16	0.17	0.46	0.88	1.4	2.0	2.8	3.6	4.4	5.5	6.7
1/4	0.097	0.27	0.54	0.84	1.3	1.7	2.2	2.7	3.4	4.1
5/16	0.075	0.22	0.43	0.68	0.99	1.4	1.9	2.3	2.9	3.5
3/8	0.059	0.19	0.38	0.61	0.90	1.3	1.7	2.1	2.6	3.1
1/2	0.042	0.13	0.25	0.40	0.59	0.82	1.1	1.4	1.8	2.1
1	0.011	0.036	0.075	0.13	0.19	0.27	0.35	0.44	0.55	0.68
Pellets										
1/8×1/8	0.39	1.0	1.9	2.9	4.2	5.6	7.4	9.1	11.0	14.0
3/16×3/16	0.21	0.59	1.13	1.79	2.6	3.4	4.5	5.5	6.9	8.3
1/4×1/4	0.15	0.46	0.82	1.3	1.9	2.6	3.4	4.2	5.2	6.5
3/8×3/8	0.088	0.26	0.51	0.81	1.2	1.7	2.2	2.7	3.4	4.1
Grooved pellets										
5/32×5/32	0.19	0.53	0.99	1.6	2.3	3.1	4.0	5.0	6.2	7.6
7/32×7/32	0.12	0.33	0.63	1.0	1.5	2.0	2.6	3.2	4.0	4.8
Rings										
1/8×5/16×5/16	0.089	0.26	0.49	0.78	1.2	1.6	2.1	2.7	3.4	4.2
3/16×3/8×7/16	0.052	0.16	0.31	0.51	0.78	1.1	1.5	1.9	2.4	3.0
1/4×1/2×1/2	0.040	0.12	0.24	0.39	0.59	0.84	1.1	1.4	1.8	2.2
Grooved rings										
1/8×5/16×5/16	0.069	0.16	0.32	0.52	0.78	1.1	1.4	1.8	2.3	2.8
Aggregate										
3/5 mesh	0.10	0.28	0.51	0.83	1.2	1.7	2.3	2.7	3.4	4.1

Note: All materials were tested at maximum packing density and minimum bed voidage for the imposed particle to tube geometry.

Gas temperature 77°F	Bed diameter 4.03″
Gas pressure 14.7 psi	Bed height 2′

TABLE 8

SPHERES: CHEMICAL AND PHYSICAL MATERIAL PROPERTIES (APPROXIMATE AVERAGE VALUES)

	Ceramic	Synthetic mullite	Aluminium oxide
Chemical analysis:			
Al_2O_3	23–26	75–77	95–97
SiO_2	69–72	20–22	2.5–3.5
Na_2O+K_2O	2.2–3.2	—	—
Na_2O	—	0.4	0.4
K_2O	—	2.4	0.2
MgO+CaO	0.06–0.68	—	—
MgO	—	0.5	0.4
CaO	—	0.5	0.4
Fe_2O_3	0.7–1.6	0.7	
No trace of other substances found			
Specific gravity	2.43	3.0	3.6
Bulk weight kg/l	1.4–1.25	1.75	2–2.1
Water absorption (percentage of weight)	0.053	2.0	2.0
Open porosity (percentage of volume)	0.127	3–7	3–7
Fire-resistive quality under pressure according to DIN 1064	ta 1330°C te 1510°C	— —	— —
Temperature resistance up to	1300°C	1300°C	1650°C
Free space in the filling-bed (per cent, approx.)	30	30	30
Catalytic neutrality	complete		
Resistance to thermal shock	sufficient in all qualities		
Resistance to temperature changes	excellent in all qualities		
Sphere pressure resistance 6 mm diam. 111 kp/sphere	12 mm diam. 114 kp/sphere	20 mm diam. 331 kp/sphere	25 mm diam. 450 kp/sphere

XX. WHITE CORUNDUM CATALYST CARRIERS

As a carrier for catalysts, fused alumina, and here particularly high-purity white corundum, is becoming increasingly important owing to its outstanding quality and regularity of supplies.

The general requirements of the properties of a suitable catalyst carrier, namely abrasion resistance, crushing strength, chemical inertness, thermal stability and good heat conductivity are largely fulfilled in the corundum catalyst carriers, which are therefore particularly suitable for many industrial catalytic processes using fixed bed or fluidized catalysts.

High-purity white corundum is an electrically fused, crushed and sieved alpha-alumina of the highest available purity. It is produced in an electric furnace by a special procedure from selected Bayer process calcined alumina (which itself is largely artificial corundum). The lump ingot is crushed and ground, followed by removal of residual magnetic material by magnetic separators and followed by grading into a great variety of size fractions, from 4 mesh per inch to micron sizes. It is pure white in colour and practically free from objectionable impurities, such as iron or silica. The absence of iron proves beneficial in the preparation of various oxidation catalysts where small amounts of iron cause a detrimental effect as poison to the catalyst activity. The silica-free catalyst carrier is especially suitable for secondary steam reforming where a silica-free type, or a type with a very low silica content, is required to prevent silica transport and contamination of subsequent equipment.

The excellent abrasion resistance, high crushing strength and the non-powdering structure of the corundum catalyst carriers prevents the plugging of the catalyst bed and the contamination of the catalyst and decreases the pressure drop, thus ensuring a longer life for the catalyst. They are capable of withstanding high process temperatures and severe thermal shock. Their high heat conductivity eliminates or greatly reduces the development of "hot spots".

The excellent chemical resistance against attacks by acids or alkalis and chemical inertness and absence of catalyst poisons characterizes the outstanding qualities of the corundum catalyst carriers. Consequently, high-purity white corundum (fused alumina Al_2O_3) can be strongly recommended as an ideal carrier for catalysts.

A further development in this field is the pre-impregnation or pre-coating of the catalyst carrier. For certain requirements, a catalyst carrier can be supplied in a selected grain size provided with pre-impregnation or pre-coating by various metal oxides thus forming a semi-finished product which can then be completed by the user. An example for such a pre-impregnated or pre-coated catalyst carrier is high-purity white corundum coated with vanadium, molybdenum or titanium.

ALUMINA

Alumina, the oxide of aluminium, occurs as corundum which is a hard crystalline mineral. The dark variety of corundum contains magnetite and is known as emery; clear transparent crystals tinted by other metallic oxides are gem stones such as ruby or sapphire. Alumina may be prepared by the ignition of aluminium hydroxide, ammonium alum etc., and from the various natural hydrated oxides of aluminium which occur in the minerals bauxite and gibbsite. Alumina is used in the manufacture of metallic alluminium and synthetic gems, as an abrasive, and in the manufacture of refractory materials. It is polymorphous, existing in a number of crystalline forms, close to the diamond in hardness and has the chemical formula Al_2O_3.

CORUNDUM

Corundum is a mineral composed of aluminium oxide, Al_2O_3, and in its finer varieties forms valuable gems such as ruby and sapphire. The massive form in combination with iron oxides and spinel is called emery. The name corundum is believed to be derived from Hindi (Korund), the mineral first being identified from India.

Next to diamond, corundum is the hardest known mineral (9 on Mohs scale), this being sufficient to separate it from all other minerals. The pure mineral is colourless, small amounts of impurities explaining the wide range of colours in nature. Ruby contains chromium, sapphire presumably iron or titanium; most corundum contains nearly 1% iron oxide. Silimanite, kyanite margarite, damourite and hydrated alumina minerals are common alteration products.

Artificial corundum has similar properties and has become the source of most pure abrasives.

Corundum crystallizes in the hexagonal system (rhombohedral class) showing considerable variety of habit, the commonest being acute hexagonal bipyramids, sometimes in barrel-shaped forms, or tabular owing to predominance of the basal form. Corundum has no true cleavage but a parting parallel, to the base and the rhombohedron, the latter a plane of lamellar twinning sometimes secondarily produced through pressure. Density is 3.95—4.0 g/cm^3, refringence (refraction) as high as 1.7686 (sodium light), melting point 2,040°C, dielectric (nonconductive) constant about 10. Corundum resists attack by acids or alkalis. Alumina-rich melts have great power of crystallization, making it difficult to preserve glasses of such composition. Single crystal alumina bodies can be formed into rods and bent at high temperatures, yet retain noncrystallinity. No other natural Al_2O_3 mineral is known but essentially anhydrous oxides are encountered in laboratory studies, differing distinctly from the alpha-Al_2O_3 or corundum phase into which they transform on heating to about 1,200°C the so-called beta-Al_2O_3 is actually $Na_2O \cdot 11Al_2O_3$ and is not a dimorph of corundum as long was thought.

ARTIFICIAL CORUNDUM[2]

Artificial corundum has the same properties as natural corundum or alpha alumina. The development of techniques around 1900 permitted the large-scale production of artificial corundum. In addition to being very hard

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[2] A. W. Wilkinson, "The production of synthetic abrasives", *Canadian Chemical Processing*, vol. 38, September 1954; A.L. Ball and A.A. Kline, "Application of abrasives", *ASTM Stand.*, bulletin 191 (July 1953).

(9 on Mohs' scale), artificial corundum is very strong. It fractures in such a way that new, sharp cutting points are continuously formed. It has low specific heat and thermal expansion.

Artificial corundum is sometimes known as fused bauxite, or fused alumina, and by trade names such as Alodur, Alundum, Borolon, Aloxite, Lionite and Oxaluma. Fused bauxite is made by melting calcined bauxite (composition approximately 86% Al_2O_3, 7% SiO_2, 3% Fe_2O_3, 3% TiO_2 and 1% water) with coke and metallic iron in electric arc furnaces of several tons capacity, at a temperature of about 2,200°C. Hanging graphite electrodes carry alternating current to the melt. Furnaces are of two types: batch — a removable conical shell on a flat, carbon-lined, wheeled base; and continuous — tilting furnaces from which small pigs can be poured. Furnace shells are water cooled. Large continuous furnaces may operate at several thousand kilowatts.

In batch furnaces, the coke reduces oxide impurities to elements, which unite the added iron to form magnetic ferro-silicon; this settles to the bottom, leaving the alumina in a much purified state. Carbon is eliminated as carbon monoxide (CO) which burns to the dioxide (CO_2) on leaving the furnace. When the furnace is fully charged, the electrodes are withdrawn, and before long the shell can be lifted off to allow the several tons ingot to cool. As it solidifies, the alumina crystallizes into a solid mass of large irregular crystals. Both batch and continuous procedures can be controlled to yield a product containing roughly 95% alumina, 1.5% silica, 0.5% ferric oxide and 3% titania.

The lump ingot is crushed and ground in jaw crushers, rolls and ball mills, followed by removal of residual magnetic material by magnetic separators. Grading into a large variety of size fractions, from 6 mesh per inch to micron sizes, is carried out by vibrating screens, hydroclassifiers and air separators. Fused bauxite is commonly deep reddish-brown in colour and translucent.

The production of white artificial corundum from Bayer process calcined alumina (which itself is largely artificial corundum) has continuously expanded. This employs essentially the same process as for calcined bauxite as described previously, but the starting purity of the alumina (99%) obviates the need of separtion of silicon and iron. Bayer alumina contains some soda, part of which combines with alumina to form so-called beta-alumina, actually $Na_2O.11Al_2O_3$, which is brittle and objectionable in the final product. It may be removed from the cooled batch pig by cooling the central and upper zones where it tends to segregate during crystallization. Other impurities imparting colour to the product are also objectionable. White fused alumina is crushed and sized as fused bauxite is. A special process involving fusion and crystallization in a water-decomposable matrix allows the development of small, sharp, separate crystals that can be recovered as such, avoiding the need of heavy crushing and sizing. Artificial corundum is also produced as a specialty product by slow accretion and controlled growth on a boule in an oxyhydrogen flame.

WHITE CORUNDUM (Al_2O_3)

White corundum is of high purity (fused alpha-alumina Al_2O_3), pure white, meticulously de-ironed, and produced from a selected Bayer process using highly calcined alumina. It is free of objectionable impurities which might prove to be poisonous to many types of catalysts. The sizes of the grains are controlled according to the most advanced techniques in this field and particular methods and criteria have been developed to ensure an excellent and continuously regular quality of the product.

A typical chemical analysis is:

	Per cent
Al_2O_3 (calculated)	99.68
Fe_2O_3	0.03
Na_2O	0.28
TiO_2	under 0.01

The available sizes (mesh) are:

4, 6, 8, 10, 12, 14, 16, 20, 24, 30, 36, 46, 54, 60, 70, 80, 90, 100, 120, 150, 180, 220, 240.

HIGH-PURITY WHITE CORUNDUM

The physical properties are:

Specific gravity	3.97
Hardness (Mohs scale)	9.0
Hardness (Knoop) K 100	2.050
Linear thermal expansion	0.55% (0°–600°C)
Maximal usable temperature	2,000°C(3,632°F)
Colour	pure white
Crystal form	alpha alumina

A typical chemical analysis is:

	Per cent (by difference)
Al_2O_3	99.63
SiO_2	0.04
Fe_2O_3	0.03
TiO_2	0.01
$CaO + MgO$	0.01
Na_2O	0.28
Magnetic iron	traces

Tables 9 and 10 show the number, weight, surface and pressure drop in example contact tubes of 20 and 24 mm diameter with a bed depth of 1 000 mm containing grain sizes 4, 6, 8 and 10[3].

TABLE 9

CONTACT TUBE, 20 mm DIAMETER, DEPTH OF BED 1,000 mm

	Grain size			
	4	6	8	10
Weight (kg)	0.515	0.540	0.565	0.590
Volume (m^3)	3.14×10^{-4}	3.14×10^{-4}	3.14×10^{-4}	3.14×10^{-4}
Number of grains	2 163	5 346	23 268	28 615
Surface (m^2)	0.35	0.507	0.888	1.131
Pressure drop m WC (at 0.5 kg/cm^2)	4.970	4.985	4.990	4.993

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[3] See "A survey of developments in reactor technology (Reactors for catalytic gas phase processes)", paper prepared by O.F. Joklik (ID/WG.123/21).

TABLE 10

CONTACT TUBE, 24 mm DIAMETER, DEPTH OF BED 1,000 mm

	Grain size			
	4	6	8	10
Weight (kg)	0.855	0.880	0.910	0.940
Volume (m^3)	4.91×10^{-4}	4.91×10^{-4}	4.91×10^{-4}	4.91×10^{-4}
Number of grains	3 591	8 653	35 269	45 950
Surface (m^2)	0.58	0.796	1.345	1.810
Pressure drop m WC (at 0.5 kg/cm^2)	4.950	4.970	4.979	4.986

XXI. CATALYST CARRIERS DOPED WITH LANTHANIDES

Catalyst carriers doped with lanthanides are a further development in catalyst technology.

Regular catalyst carriers—high-purity white corundum (fused alumina Al_2O_3)—are widely used as catalyst carriers of outstanding quality. The doping of these carriers with lanthanides (the rare earths La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu) and, in some cases, with Y, to the extent of approximately 0.5 to 1.5% by weight is effectuated by adding the proper quantities of lanthanides to alumina and thus a very uniform and regular distribution of the lanthanides within the crystal structure is ensured.

Besides the high-purity white corundum doped with lanthanides, a wide range of catalyst carriers in well-defined, mathematic forms (spheres, pellets, rings, saddles etc.) made of ceramic or pure Al_2O_3, also doped with lanthanides to the extent of approximately 0.5 to 1.5% by weight is available. A percentage up to 5% by weight is possible for certain special carrier formulations. It is also possible to incorporate both alpha- and gamma-phases of alumina in the carrier in suitable and precisely defined proportions.

Alkylation
Catalytic conversion
Catalytic cracking
Catalytic oxidation
Catalytic reforming
Condensation
Dehydrogenation
Desulphurization

Hydrocracking
Hydrodealkylation
Hydrofining
Hydrogenation
Isomerization
Methanation
Shift conversion
Thermal cracking

Alumina in alpha-phase is considered to be a better carrier for certain types of catalyst (i.e. for reforming catalysts) than the alumina in gamma phase due to much higher structural stability and less acidic character of the former[4]. But alumina in gamma-phase is considered to be more active as catalyst carrier, most likely due to its much higher specific surface area[5].

Alumina in gamma-phase is believed to have a large number of acid sites (Lewis), measured by many workers[6]. The presence of acid sites is responsible for carbon deposition according to the mechanism discussed by Applebey and others[7].

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[4] T. Nicklin and R. Whittaker, Inst. Gas. Eng. Jour. **8**:15 (1968).

[5] Tatsuo Yamanaka, Jour. Sci. Research Inst. (Tokyo) **49**:243 (1955); A. Sedzimir, Rocz. Chem. **41**:655 (1967); M. Popowicz, W. Celler, E. Treszczanowicz and W. Romanowski, Przemysl. Chem. **42**:563 (1968); N. S. Repina and N.F. Ermolenko, Zh. Fiz. Khim. **42**:477 (1968); BASF, British patent No. 803,261 of 22 October 1958; J. Misra, D. K. Mukherjee and S. P. Sen, Technol. **7**: 231 (1970); D. K. Mukherjee, J. Misra, S. P. Sen and K. R. Chakravorthy, Technol. **8**:201 (1971).

[6] E. P. Parry, Jour Catalysis **2**:371 (1963); J. E. Mapes and R. P. Eischens, Jour. Phys. Chem. **58**:1059 (1954).

[7] W. G. Applebey, J. W. Gibson and J. M. Good, I. and E. C. Process Design and Development **1**:102 (1962).

Attempts were made to neutralize acid sites of such a catalyst by incorporating some basic components like alkali metal oxides[8]. Although the problem of carbon liberation at an economic steam/carbon ratio with such a catalyst could be avoided to some extent yet the activity is reported to be less with an alkalyzed catalyst[9]. In addition, the problem of loss of alkali from the catalyst during run is also reported[10].

It is also observed that presence of the major amount of alumina in gamma-phase in catalysts makes the structure of the catalyst unstable due to phase transformation from gamma- to alpha-form, which is accompanied by shrinkage of pores and surface area.

Because of all these problems with alumina in gamma-phase, alumina in alpha-phase which is stable up to 1,500°C and possesses much less acid sites is preferred as a carrier material for certain types of catalysts (i.e. reforming catalysts). Such catalysts are believed to have a better stability.

The structures of both gamma- and alpha-forms of alumina have been discussed in detail by wells from which it is observed that while alumina in alpha-phase has a crystalline structure with hexagonal close-packed lattice, alumina in gamma-phase possesses defect spinel structure with cubic lattice having some vacant metal holes in it[11]. It is probably due to its defect structure that is responsible for a higher surface activity of alumina in gamma-phase than that of alumina in alpha-phase.

So it is probable to achieve a compromise between activity and stability by incorporating both aluminas in alpha- and gamma-phase in the carrier in suitable proportions. With this end view, investigations have been taken up by Misra, Mukherjee and Sen to study the effects of the presence of both alpha-and gamma-phases of alumina in the carrier of steam-naphtha reforming catalyst [12]. The results obtained show that the structural parameters, like crushing strength, pore volume and surface area, increase consistently with increasing concentration of alumina in gamma-phase in the carrier. Higher crushing strength, porosity and surface area of alumina in gamma-phase have also been reported by other authors [13].

Again, it is observed that compressive strength, specific pore volume and specific surface area of the corresponding catalyst samples also increase steadily with increasing concentrations of alumina in gamma-phase. The percentage of pores in the smallest range, viz. between 4 and 175 Å, increases with the concentration of alumina in the gamma-phase while the same in the higher range, viz. between 500 and 75,000 Å decreases in the same direction.

All these changes in the structural parameters with increasing proportion of alumina in the gamma-phase are favourable for a catalyst.

The weak points of the carrier, i.e. of alumina in the gamma-phase with its defect spinel structure with cubic lattice having some vacant metal holes in it, may be overcome by incroporating rare earths — lanthanides — in the range of some 0.5 to 1.5% by weight. These incorporated rare earths, particularly Sm, Nd, La, and in certain cases Y, function to neutralize the acid sites thus contributing essentially to the prolonged life of the carrier and the catalyst and to its increase of mechanic and thermal stability and resistance.

Besides the merely internal function of the lanthanides in the crystal structure of the carrier, there is observed an increased catalytic activity of the ready-for-use catalyst, as very often and contrary to the general opinion

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[8] Imperial Chemical Industries, Belgian patent No. 634,920 of 13 January 1964.

[9] T. Ogura and T. Huzimura, Jour. Chem. Soc. Japan 60:139 (1939); Sydney P. S. Andrews, Ind. and Eng. Chem., Product and Research Development 8(3):321 (1969).

[10] Sydney P. S. Andrews, *ibid.*

[11] G. Hagg and G. Soderholm, Z. Physik. Chem. 29B:88 (1935); M. H. Jellinek and I. Fankuchen, Ind. Eng. Chem. 37:158 (1945).

[12] J. Misra, D. K. Mukherjee and S. P. Sen, Technol. 7:231 (1970).

[13] BASF, British patent No. 803,261 of 22 October 1958; H. M. Brennah, H. S. Seelig and R. W. Vander Haar, United States patent No. 2,892,799 of 30 June 1959; N. S. Repina and N. F. Ermolenko, Zh. Fiz. Khim. 42:477 (1968).

in this particular field the catalyst carrier has a catalytic effect by itself which increases the importance of a proper choice of the catalyst carrier for all catalytic reactions.

The increased catalytic activity of a catalyst using a carrier doped with lanthanides, the full mechanism being as yet unknown, may be explained by their ready acceptance and rejection of electrons because of their range of valences and consequently by their ability to form complex molecules. Another theory explains the phenomena by considering the catalyst as being and acting as a semi-conductor. Further experimental and analytical work is required to explain the inherent problems.

XXII. TOWER PACKINGS AS CATALYST CARRIERS

INTRODUCTORY REMARKS

In 1873 Robert Ilges built the first industrial packed tower, using a primitive type of packing[14]). Tower packings evolved naturally, from the knowledge that the best conditions for material or heat transfer between materials in the gas or vapour phase gravity could be provided: "By direct contact of the materials involved, on the largest possible surface (inter-face) in very fine sub-division"[14]).

Wherever a purely chemical reaction takes place in these mass-transfer processes, the time of contact between the reagents involved is of great, or even critical importance and has usually to be as long as possible.

In the course of development the fundamental principle became evident, that the results obtained, with economic running—and initial costs would approach the ideal: "In proportion to the extent to which the mathematical form of the packing element, the method of packing, the diameter and height of the column, the intensity and distribution of the gas stream were suited to the particular problem"[14]).

Tower packings of good, averge characteristics should meet, in general, the following conditions:

(a) Vapour must be distributed evenly, and with the maximum dispersion over the whole cross-section, throughout the height of the column;

(b) Vapours should be diverted, redistributed, thoroughly spread into the thinnest possible film and brought into the closest contact on the surface of the tower packings. The path of vapour, as compared with the empty column, must be increased a thousandfold by radial currents and centrifugal action, and by edging. Even when working with relatively high velocities, no entrainment must occur. The frictional resistance must be as low as possible, and the displacement of the packing, small (meaning the free area must be large);

(c) The tower packings must be resistant to attack; resistant to elevated temperatures and thermal shock; of considerable mechanical strength and resistance to abrasion; also of low bulk density.

It is evident that this multiplicity of requirements cannot be met by any one shape or constructional material of the packing. In practice, the chemical engineer or manufacturer has to compromise in choosing packings which will fulfill the majority of requirements, and which are economical at the same time.

Just as optimum conditions for most chemical and physical processes have been determined and are still being developed and brought to perfection, so have the forms of packing been improved and often developed to offer special properties. Here, as everywhere in industry, no finality has been reached, but new ideas and possibilites are being exploited by the invention, of new forms. The progress achieved is evident from a comparison of bulk volumes and surface obtained in various types of packings, as shown below.

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[14]) F. Stage, *Angewandte Chemie*, B (7): 178, (1947).

Packing body	Calculated surface referred to (approx. ft^2/ft^3)
Three-sided prism	194
Coke, pieces 1"–2"	409
Slats	646
Rectangular prisms	720
Quartz lumps about 1"	1,076
Raschig rings 1"×1"	2,370
Berl saddles 1"	2,800
Super Berl saddles 1"	3,320

Catalytic processes are characterized by changes of reaction velocity brought about by the presence of specific materials which neither appear in the end product nor participate in the reaction itself. Many theories have been developed on the cause of these contact or catalytic phenomena and the literature should be consulted on the subject. Fundamentally they can be explained by chemical and physical forces at the contact surface.

Scientific and experimental research have proved that the contact activity of a material increases in proportion to its accessibility to the reacting molecules. This can be achieved, as in the case of mass transfer processes taking place on packings, by the creation of a very large surface upon which the catalyst is distributed in a thin film. Therefore the carrier has to have a surface which will increase the contact surface of the catalyst.

Apart from highly porous mineral or carbonaceous catalyst carriers in the form of grain or powder (kieselguhr-gel-bauxite-clays, activated carbon) great success has been achieved in certain catalytic processes by the use of ceramic catalyst carriers (porcelain and earthenware) with well-defined geometric forms and with close control of mechanical properties and physical structure, for instance, size of pores, volume of pores, temperature resistance and mechanical strength. It is a further advantage for the granules to be made with a hydrodynamically suitable shape presenting maximum surface with good flow characteristics for contact with the materials to be catalysed. These carriers reduce resistance to the passage of gases through the catalyst layer and also help to promote the even distribution of gases.

For instance Berl saddles with their geometrically ideal form represent an ideal carrier for catalyst, if made in a suitably porous body. They not only provide the largest possible active surface for the finely dispersed catalyst, but are also very suitable for the catalyst, due to the particular shape of the rims.

ACIDUR[15] SPECIAL STONEWARE

This is the most extensively used construction material, possessing almost universal chemical resistance, particularly against all acids (with the exception of hydrofluoric and phosphoric acids and their compounds), in diluted or concentrated form at all chemical compositions. It also possesses very good physical properties as far as strength is concerned; also resistance to high temperature and thermal shock; excellent abrasion resistance against friction, and high tensile and compressive strength.

Resistence to alkalis is only limited. For instance, sodium and potassium hydroxide do not attack in concentrations of, for example, up to 10% at a temperature of 30°C. However, at increasing temperatures and concentrations attack takes place readily.

The raw materials are plastic clays of very high softening point and relatively low sintering point, consisting largely of silica and alumina, with only traces of iron oxide.

The basis for the excellent properties of this stoneware is the highly suitable composition of clays of definite chemical and physical resistance

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[15] Registered trade mark.

combined with a preparation suited to the requirements, comprising firing at 1,200°—1,300°C, thus producing a structure similar to that of glass and of a metallic hardness.

The stoneware has, naturally, a somewhat rough, reticulated surface, which is an important factor in the activation of the surface.

In special cases a smooth, glass-like surface glaze can be provided for the stoneware — so-called salt glaze. This is a sodium silicate glaze produced by the addition of sodium chloride during the burning process. It forms a chemical compound with the alumina and has the same chemical and physical resistance as the stoneware material itself.

It is equally possible to produce a stoneware which, by suitable combination of raw materials, possess a special resistance to high temperature, sudden thermal shock, or any other special property. Porous stoneware can be produced with virtually any degree of porosity up to an absorption of 50% by volume of water. Beyond that, it is possible to formulate materials, consisting almost entirely of pure silica or alumina. These variations are quite easily carried out and permit the optimum material specification for special requirements.

CHEMICAL RESISTANCE

The following determination is made with comminuted material according to the Seger method [16]:

The comminuted stoneware is sifted through standard sieves having 15 and 25 meshes per linear inch respectively. For the purpose of the examination, only grains that are passed by the coarser, and retained by the finer sieve are taken. These grains are freed from adhering dust particles by washing and dried till constant weight is reached. A sample of 100 g of the grains thus obtained is covered in a dish with 200 cm^3 of an acid mixture consisting of 25% sulphuric acid (sp. gr. 1.84); 10% nitric acid (sp. gr. 1.40); and 65% water.

The contents of the dish are boiled until water and nitric acid have completely evaporated. The remaining sulphuric acid is then kept for a further 15 minutes at a constant temperature of 250°C. After cooling, the contents of the dish are diluted, while stirring, with about 800 cc of water, to which 10 cc of nitric acid have been added. The contents of the dish are then brought to boiling once more, the acid liquor poured off, and the grains washed with water, until no more acid can be detected.

After drying, the loss of weight suffered by the grains is determined. On examination, the material showed a loss of weight of 0.0919%. The acid mixture after treatment, was practically clear, so that virtually no loss of material had been suffered by the grains and therefore the loss in weight can be ignored.

The analysis of the comminuted stoneware, after drying, was kept for 72 hours in hydrochloric acid of 22°Bé at 15—20°C, then washed and dried; it showed a loss of weight of 0.15%.

For practical purposes it can be said that the effect of acids on pulverised materials is negligible. This stoneware, therefore, is fully resistant against most acids and acid compounds; also against acid gases and vapours at all temperatures occurring in practice. The sole exception are hydrofluoric and phosphoric acids and their compounds.

ALKALI-RESISTANCE

As already said, the stoneware is only resistant against alkaline reagents at relatively low temperatures and concentrations.

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[16] Method of the Ceramics Laboratory, Berlin.

TESTS WITH WHOLE PIECES[17] (NON-COMMINUTED MATERIAL)

After immersing samples for 20 days in 10% caustic soda at room temperature, no loss of weight could be seen. After storage for the same period in similar concentrations of caustic soda, with the alkaline bath at constant temperature of 30°C, the lowest loss was 138% by weight; the highest loss was 187%. After storage for the same duration in the same concentration of caustic soda at a constant temperature of the liquid of 55°C, the loss amounted to 10.24%.

Further test of whole rings gave the following results:

Initial concentration of lye (percentages)	**Concentration of lye after 23 days' immersion at room temperature** (percentages)	**Loss in weight of ring after refluxing for 8 hours following 23 days' immersion** (loss in weight)
5 NaOH	0.026	1.48
10 NaOH	0.021	3.09
20 NaOH	0.020	5.99
10 soda solution	0.004	

The good resistance of stoneware packing rings was apparent after exposing them for 311 days at 35°C in a stream of gas in which chlorinated compounds were prevalent, while at the same time continuously scrubbing with 5% caustic soda solution.

The physical properties are:

Bulk density:	2.44
Water absorption:	0.11% by weight
Apparent porosity:	0.26% by volume
True density:	2.57
Compressive strength, tested according to German Standard DIN 1604, average value:	43,000 lb/in²
Maximum pressure exerted upon the ring in horizontal position, on the upper most line, only, according to German Standard DIN 1604 average value:	432 lb/in²
Tensile strength:	185—285 lb/in²
Hardness, according to Mohs'scale:	7—8 (quartz hardness)
Refractoriness according to DIN 1063:	Seger Cone 29/30 = = 1,500°C

To ascertain resistance to alternating thermal shock (more than 20 cycles — conditions of the experiment) the material of the test was heated to 200°C; kept there for 1 hour; cooled rapidly in water at room temperature for 5 minutes; and repeated 20 times, after which the material under test was entirely unharmed and free from cracks.

As an example of the resistance to change in temperature which stoneware can withstand, the following case should be mentioned:

In a special travelling furnace called the Wander-Oven, the metal parts traversing the oven are supported on rings of 1" × 1" × 1/8".

These rings are heated fairly rapidly to 1,100°C and cooled equally rapidly, without experiencing the least damage. This is continuously repeated under normal working conditions.

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[17] The solubility in 10% soda solution was a fraction lower than in the case of caustic soda. The loss in weight of non-comminuted material in 15% caustic soda, after 40 hours immersion at a constant temperature of plus 80° was 5%.

STRESS CONDITIONS FOR RANDOM PACKED STONEWARE RINGS

The compressive strength of individual rings is so large that in the heights of packing occurring in practice it is not even approached, even on the theoretical assumption that one single ring is carrying the whole load of all rings vertically above it. The initial crushing of rings was found experimentally, according to the requirements of the German Standard DIN 1604 with the following loads:

Stoneware rings (inches)	Load (lb)
1 3/8×1 3/8×5/32	154
2×2×3/16	123
2 3/8×2 3/8×1/4	247
3 3/16×3 3/16×5/16	247

From this the following height of unsupported layers can be found as stated in the original:

Stoneware rings (inches)	Height (ft)
1 3/8×1 3/8×5/32	259
2×2×3/16	92
2 3/8×2 3/8×1/4	144
3 3/16×3 3/16×5/16	85

Under actual conditions the permissible height of packing is much higher than calculated, due to the fact that random packed rings, dependin, on their angle of repose, lose a considerable part of their own vertical thrus sideways to the wall of the column and due to the fact that in random packing some of the rings are lying parallel to the axis, so that the theoretical maximum pressure exerted on the lowest ring, can never really apply.

In those cases where the stoneware packing is stacked, the full specific compressive strength (43,000 lb/in^2) is effective, so that in this case there is virtually no upper limit at all.

In the case of packing rings with perforated walls, which, therefore, have only about 60% of the normal solid surface, the first fractures under the weight of the packing itself, in cases of packings of 2″ × 2″ × 3/16″ occurred as a height of 42 ft.

ANGLE OF REPOSE OF RANDOM PACKED RINGS

In connexion with the angle of repose for rings, the following data are of interest:

Inches	
1 3/8 × 1 3/8	36°
2 × 2	35°
2 3/8 × 2 3/8	40°

DURANIT[18] HARD PORCELAIN

In special cases, for instance when there is alternate exposure to acid and alkalis in low or medium concentration or when it is necessary to have raw material practically free from iron and chemically pure, hard porcelain is indicated.

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[18] Registered trade mark.

It is a material which is most suitable for the processing of highly sensitive materials or alkaline liquors (with a pH higher than 7) at their boiling points and in a number of similar cases, which cannot all be referred to here.

Equally useful is the white, glazed hard porcelain in cases where an absolutely smooth glasslike surface, free from porosity, is required. Chemically the composition of hard porcelain is as follows (partial chemical analysis):

	Approx. per cent
SiO_2	69
Al_2O_3	27
Fe_2O_3	0.32

CHEMICAL RESISTANCE AGAINST ACIDS

Determination with comminuted material according to the Seger method has been described above under "stoneware". The results:

After first test:	0.0146% loss in weight
After second test of the same material:	0.065% loss in weight

ALKALI RESISTANCE

The resuts of determination on comminuted material according to Seger method were:

With 27% caustic soda: 0.462% loss in weight
With 31% caustic potash: 0.5201% loss in weight

The results of determination on whole pieces (non-comminuted material) were:

Packing rings boiled 3 times in 8 hours in 5% caustic soda showed no evidence of any external change in the rings or any changes of the lye.

In another test, six rings, 1″ × 1″ × 1/8″, were dried at 110°C to constant weight. After this, exact measurements and weights of the individual rings were taken, and they were boiled for 8 hours in caustic soda of 15%. The result:

Ring	Loss in weight (gram)	Weight before analysis (percentage)
1	0.3392	2.44
2	0.2489	1.80
3	0.3153	2.22
4	0.2634	1.15
5	0.2514	1.86
6	0.2831	2.00
	1.7013	11.47
Average	0.283	1,91

After treatment with caustic soda as described, no changes in the dimensions of the rings were found. No wasting of the edges of the individual rings was evident. The surface of the rings was found to be merely somewhat dull. Microscopic examination also showed no substantial change in the nature of the surface or of the structure.

In yet another test, hard porcelain rings, 1″×1″×1/8″, were boiled once in 27% and once in 13.5% caustic soda under reflux. The result:

Concentration of lye by weight (percentage)	**Loss in weight (percentage) after 3 hrs**	**9 hrs**	**11 hrs**
27	2.71	12.06	17.08
27	2.10	11.65	16.04
13.5	1.11	5.38	7.39
13.5	1.03	5.26	7.18

Finally, when hard procelain rings, 1″×1″×1/8″, were immersed for 20 days in a caustic soda solution of 10% concentration, kept at a constant temperature of 55°C, the average loss in weight was 0.627%, by weight.

PHYSICAL CONSTANTS

The physical constants of hard porcelain are:

Bulk density:	2.48
Water absorption:	0.00%
Apparent porosity:	0.00%
Compressive strength:	64.000 lb/in^2
Softening temperature:	1,500°C
Tensile strength:	3,420—4,550 lb/in^2
Transverse strength:	4.265—8,530 lb/in^2
Impact strength:	1.3—1.6 cm/kg/cm^2
Hardness (Mohs):	7—8
Water absorption under 50 atm for one hour:	0.0—0.5% by weight

CRUSHING RESISTANCE OF RANDOM PACKED HARD-PORCELAIN RINGS

The diametric compressive strength is 240 lb/in^2 in rings of 1″×1″×1/8″, as an average value (i.e. an actual load of 240 lb for the 1″ ring).

From this follows a strength equivalent to 105 ft height of column even on the assumption, which cannot arise in practice, that a single ring has to carry the whole load of superimposed rings. The actual compressive strength is very much higher.

Resistance to alternating thermal shock is in excess of 20 cycles between the limits of 0°—800°C.

XXIII. APPROXIMATE DATA FOR CATALYST CARRIERS

The pressure drop for stacked rings, which almost exclusively applies to the larger sizes for the larger towers, is generally of no importance. The total pressure drop is small and has no influence upon the total quantity of gas passed. An estimate is very difficult to give, even in cases of normal low gas velocities in larger towers, because the bouyancy and natural draught of hot gases is comparable with the relatively low resistance.

Considerable progress in reducing the necessary resistance has been made by the introduction of Berl saddles. This is shown by the comparison of pressure drop in a dry column of 3.28 ft packed height, through which air is passed at a velocity of 3.28 ft per second, calculated upon the free area of the column.

Size of tower packing (inches)	Pressure drop in inches W.G. Berl saddles, porcelain	Pressure drop in inches W.G. Raschig rings, porcelain
3/8	3.1	
5/16		5.6
5/8	1.65	2.64
1	0.87	1.30

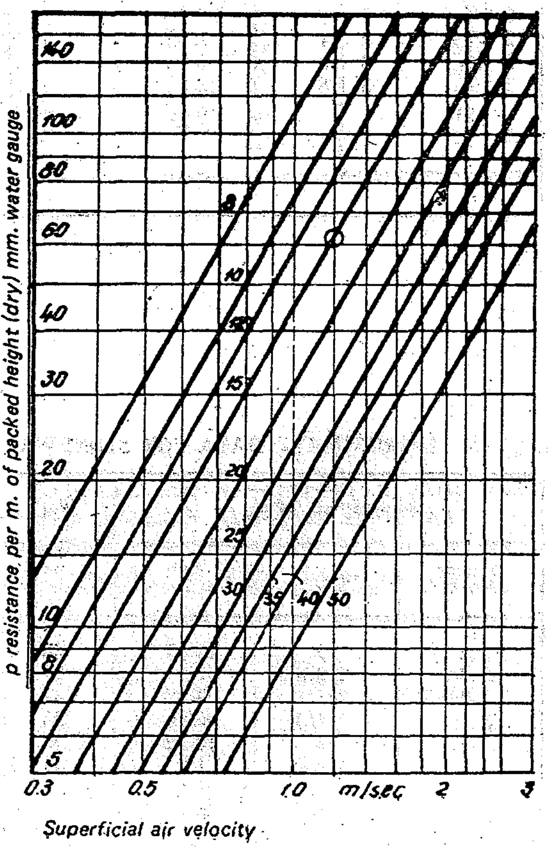

Figure IV: Resistance properties of dry packing body

Under conditions of equal resistance, Berl saddles provide a surface which is approximately 80% larger than that of Raschig rings. Similar differences in pressure drop is more evident in other sizes, and in wetted packed columns, in favour of Berl saddles. The reason lies in the better aero-dynamic, or streamlined form of Berl saddles. The difference in pressure drop is more evident with increase in gas velocity, that is taking into account the gas loading of a packed column. Berl saddles remain the shapes of lowest resistance.

Figure IV shows the resistance properties of a dry, packing body. The pressure drop refers to air of a density of 1.2 kg/m^3. When the gas density (γL) varies, the pressure drop $>$p also varies, at the rate of $\gamma 0.83$. The pressure drop is directly proportional to the height of packing. The total values of pressure drop for packings of stoneware or hard porcelain.

TABLE 11

APPROXIMATE DATA FOR STONEWARE RINGS (RASCHIG TYPE)

Dimensions (inch)			Weight (lb/ft^3)		Total surface (approximately ft^2/ft^3)	
Outside diameter	Height	.Wall thickness	Random packed	Stacked	Random packed	Stacked
3/16	3/16	3/64	56	—	305	—
5/16	5/16	1/16	53	—	167	—
3/8	3/8	5/64	50	—	134	—
1/2	1/2	5/64	45	—	110	—
5/8	5/8	5/64	44	—	101	—
3/4	3/4	3/32	40	—	85	—
1	1	1/8	38	—	59	—
1 3/16	1. 3/16	5/32	37	—	52	—
1 3/8	1 3/8	5/32	34	52	43	64
1 5/8	1 5/8	5/32	32	49	38	58
2	2	13/64	32	42	33 1/2	46
2 3/8	2 3/8	1/4	33	42	24	32
2 3/8	2 3/8	5/16	39	45	24	32
2 3/4	2 3/4	9/32	33	42	22	29 1/2
3 1/8	3 1/8	5/16	34	49	18 1/2	24 1/2
3 1/8	3 1/8	13/32	36	51	18 1/2	24 1/2
4	4	13/32	28	39	13 1/2	20
4 3/4	4 3/4	1/2	26	36	10 1/2	14 1/2
6	6	5/8	—	37	—	13 1/2
8	8	5/8	—	28	—	10

TABLE 12

APPROXIMATE DATA FOR STONEWARE RINGS WITH PARTITION

Dimensions (inch)			Weight (lb/ft^3)		Total surface (approximately ft^2/ft^3)	
Outside diameter	Height	Wall thickness	Random packed	Stacked	Random packed	Stacked
2	2	13/64	36	53	36 1/2	53
2 3/8	2 3/8	1/4	37	56	27 1/2	40
2 3/4	2 3/4	9/32	36	54	26	36 1/2
3 1/8	3 1/8	5/16	35	50	24	33 1/2
4	4	13/32	33	45	20	27 1/2
4 3/4	4 3/4	1/2	31	42	14 1/2	27 1/2
6	6	5/8	—	49	—	20
8	8	5/8	—	37	—	13 1/2

TABLE 13

APPROXIMATE DATA FOR SOLID SPHERES IN STONEWARE

Diameter of spheres (inch)	Number of spheres (per ft³)	Approximate weight (lb/ft³)	Total surface (ft²/ft³)
13/64	225,000	74	191
5/16	55,300	75	119
13/32	28,300	76	96
1/2	14,500	66	70
5/8	8,380	74	64
3/4	3,540	75	48
1	1,810	75	38
1 3/16	1,050	75	32
1 3/8	625	71	251/2
2	225	75	19

TABLE 14

APPROXIMATE DATA FOR HARD PORCELAIN RINGS (RASCHIG TYPE)

Approximate size (inch)	Weight random packed (lb/ft³)	Number of pieces per ft³ random pieces	Total surface random packed (ft²/ft³)
1/4×3/64	57	113,000	274
5/16×3/64	49	38,500	183
13/32×1/16	47	20,000	134
1/2×5/64	46	11,600	122
5/8×5/64	42	6,200	94
3/4×5/64	40	2,800	91
1×1/8	37	1,400	67
1 3/16×1/8	35	850	58
1 3/8×5/32	34	525	43
2×13/64	32	170	33 1/2

TABLE 15

APPROXIMATE DATA FOR BERL SADDLES (WITH REINFORCED RIM) MADE OF STONEWARE AND HARD PORCELAIN ABRASION RESISTANT

Size (inch)	Active surface (ft²/ft³) random packed	Weight (lb/ft³)	Number of pieces per ft³ random packed	Packing factor
5/32×5/32	610	69	623,000	1.20
1/4×1/4	351	56	146,000	1.11
5/16×5/16	299	53	62,000	1.10
3/8×3/8	220	50	29,000	1.20
5/8×5/8	137	47	7,900	1.15
1×1	79	44	2,120	1.23
1 3/8×1 3/8	54	41	710	1.24
2×2	37	37	225	1.23

CARRIERS FOR CATALYSTS: TYPICAL PROPERTIES OF ALUMINAS AND SILICA-ALUMINAS

TABLE 16

	Fluid powders			Tablets			Extrudates			Beads[b] 1—2 mm	Tablets		Extrudates	
	Alumina grade A	High purity fluid[a] alumina	Alumina grade B	000-5P	000-3P	High purity CK-200	High purity CK-300	000-1.5E	000-3E		Silica-alumina			
											HA-3P	LA-3P	HA-1.5E	85/15 000-3E'
Chemical properties														
Loss on heating 1 hr 1000°C wt%wb	23.5	29.7	33.2	3.2	6.1	1.2	1.5	7.3	2.5	1.6	2.6	3.6	4.6	1.16
SiO_2 wt% db	2.58	0.012	0.85	1.25	0.84	0.0050	0.0060	1.18	1.02	0.2	balance	balance	balance	18.1
Al_2O_3 wt%db	balance	balance	balance	balance	balance	balance	balance	balance	balance	balance	24.9	15.4	25.3	balance
Na_2O wt% db	0.028	0.0010	0.045	0.087	0.10	0.0004	0.0010	0.019	0.059	0.09	0.010	0.007	0.015	0.055
SO_4 wt% db	1.01	0.00	1.84	2.40	1.05	0.09	0.00	1.70	0.79	1.7	0.67	0.13	0.88	0.68
Fe wt% db	0.23	0.0074	0.019	0.020	0.024	0.0131	0.0100	0.023	0.046	0.05	0.017	0.016	0.028	0.47
Total other metals wt% db	—	0.0100	—	—	—	0.0100	0.100	—	—	—	—	—	—	—
Physical properties														
Particle diameter mm	—	—	—	4.6	3.2	3.0	1.5	1.5	2.5	1.5	3.0	3.1	1.6	2.5
Particle size bistridution														
— 140 micron wt%	94.4	100	98.2	—	—	—	—	—	—	—	—	—	—	—
— 105 micron wt%	75.9	—	69.6	—	—	—	—	—	—	—	—	—	—	—
— 74 micron wt%	50.0	99.8	40.9	—	—	—	—	—	—	—	—	—	—	—
— 40 micron wt%	25.5	96	5.9	—	—	—	—	—	—	—	—	—	—	—
Surface area m^2/g	303	336	327	265	266	145	180	276	252	240	428	485	407	334
Pore volume ml/g	0.51	0.55	1.55	0.90	0.81	0.40	0.45	0.53	0.58	0.95	0.60	0.55	0.67	0.59
Apparent bulk density g/ml	0.86	—	0.35	—	—	—	—	—	—	0.50	—	—	—	0.58
Estimated reactor density g/ml	—	—	—	0.48	0.54	0.50	0.60	0.64	0.58	0.52	0.58	0.57	0.47	0.50
Abrasion wt%	—	—	—	0.9	0.7	0.7	0.5-1.0	0.6	0.6	1.3	1.7	4.2	0.1	1.2
Attrition wt%	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Bulk crushing strength kg/cm^2	—	—	—	11.4	13.5	—	—	0.7	—	20.1	13.1	10.5	8.1	12
Average crushing strength lb	—	—	—	32.3	11.7	29	18	20.8	—	3.8	14.2	9.3	14.1	10
Average length mm	—	—	—	5	3	3.0	6	3.3	2.9	—	3	3	5.6	6

[a] Also available in average part size of 70 micron.

[b] Sizes available (mm): 0.4—0.7
0.7—1.0
1.0—2.0
2—3
3

Part five

Catalyst manufacturers

XXIV. ALPHABETICAL INDEX OF CATALYST MANUFACTURERS

AIR PRODUCTS AND CHEMICALS INC. (Houdry)
Five Executive Mall, Swedesford
Wayne, Pa. 19087, United States

AKZO CHEMIE B. V. Dpt. Ketjen Catalysts
(KETJEN)
P.O. Box 15, 1–3 Nieuwendammerkade
Amsterdam, Netherlands

ALLIED CHEMICAL CORPORATION
Speciality Chemicals Division
P.O. Box 70, Morristown
New Jersey 07960, United States

ALUMINIUM COMPANY OF AMERICA (ALCOA)
1501 Alcoa Building, Pittsburgh
Pennsylvania 15219, United States

AMERICAN CYANAMID COMPANY
Refinery Chemicals Dept.
Bound Brook, New Jersey 08805
United States

AMERICAN LAVA, 3 M Company
Technical Ceramic Products Division
and Manufacture
Cherokee Boulevard, Road Chattanooga
Tennessee, United States

ANDERSON DEVELOPMENT COMPANY
1415 East Michigan Street
Adrian, Michigan 49222, United States

AZOTE ET PRODUITS CHIMIQUES S.A. (APC)
Division produits chimiques-catalyseurs
62–68, rue Jeanne d'Arc,
75646 Paris, Cedex 13, France

BADISCHE ANILIN UND SODA FABRIK A.G. (BASF)
D 6700 Ludwigshafen
Federal Republic of Germany

BAYER A.G.
D 509 Leverkusen
Federal Republic of Germany

CALSICAT DIVISION, MALLINGRODT CHEMICAL WORKS
1707 Gaskell Avenue, Erie
Pennsylvania 16503, United States

CATALYSTS AND CHEMICALS INC. (CCI)
1227 So. Twelfth Street, P.O. Box 86
Louisville, Kentucky 40201
United States

CATALYSTS AND CHEMICALS INC: FAR EAST (CCIFE)
Sankaido Building 9–13, 1-chome
Akasaka, Minato-ku, Tokyo, Japan

CATALYSTS AND CHEMICALS EUROPE (CCE)
Place du Champ Mars 2
B 1050 Brussels, Belgium

CATALYSTS AND CHEMICALS INDIA (WEST ASIA) (CCIWA)
240 D, Naoroji Road
Bombay 1, India

CATALYSTS AND CHEMICALS INDUSTRIES CO. LTD (CCIC)
6–2, 2-chome, Otemachi
Chiyoda-ku, Tokyo, Japan

CATALYST DEVELOPMENT CORPORATION
59 Industrial Avenue, Little Ferry
New Jersey, United States

CHEMETRON CHEMICALS, Girdler
Catalysts Department
4900 Crittenden Drive, P.O. Box 337
Lousiville, Kentucky 40201
United States

CHEMICAL WORKS OF CZECHOSLOVAK-SOVIET FRIENDSHIP (CSF)
(CHEZA CATALYSTS)
Zaluzi v Krusnych, Czechoslovakia

CHEMIE LINZ A. G.
St. Peter 224, P. O. Box 296
A 4021 Linz, Austria

CHEMVIRON S. A. (Subsidiary of Calgon Corporation, USA)
P.O. Box 17, Ixelles 1-B
1050 Brussels, Belgium

CIECH-NITRO PLAST
Ul. Jasna 12, Warsaw, Poland

COMBINATUL CHIMIC CRAIOVA
Craiova, Romania

COMPTOIR LYON ALLEMAND, LOUYOT ET CO.
13, rue de Montmorency
75003 Paris, France

JOSEPH CROSFIELD AND SONS LTD (CROSSFIELD CHEMICALS)
Bank Quay, Warrington, England

CYANAMID INTERNATIONAL, Division of American Cyanamid Co.
Wayne, New Jersey 07470, United States

DEGUSSA A.G., Catalysts Division
Zweigniederlassung Hanau, P.O. Box 622
D 6450 Hanau, Federal Republic of Germany

E. I. DU PONT DE NEMOURS AND CO.
Wilmington, Delaware 19898
United States

DR. E. DÜRRWÄCHTER DODUCO K.G. (DODUCO)
P.O. Box 245
D 6920 Sinsheim/Elsenz
Federal Republic of Germany

ENGELHARD SALES LTD, Chemical Division
Valley Road, Cinderford
Gloucester, England

ENGELHARD MINERALS AND CHEMICALS CORP.
113 Astor Street, Newark
New Jersey 07114, United States

FARBWERKE HOECHST A.G.
D 6230 Frankfurt/Main 80
Federal Republic of Germany

FERTILIZER CORPORATION OF INDIA (FCI)
Planning and Development Division
Sindri, Dhanbad, Bihar, India

GIRDLER-SÜDCHEMIE KATALYSATOR GmbH
Lenbachplatz 6, P.O.Box 201003
D 8 Munich, Federal Republic of Germany

GRACE DAVISON CHEMICAL, W. R. GRACE and CO
Davison Chemical Division
Baltimore, Maryland 21203, United States

GRILLO-WERKE A.G.
Duisburg, Hamborn
Federal Republic of Germany

THE HARSHAW CHEMICAL COMPANY
1945 East 97th Street
Cleveland, Ohio 44106, United States

HARSHAW CHEMIE B. V.
Strijkviertel 95, P. O. Box 19
De Meern, Netherlands

W.C. HERAEUS GmbH, Werksgruppe Metalle
D 645 Hanau, Federal Republic of Germany

HYDRONYL-NORTON LTD
King Street, Fenton,
Stoke-on-Trent ST4 2LT, England

IMPERIAL CHEMICAL INDUSTRIES LTD (ICI)
P.O. Box 1, Billingham
Teesside, England

ISC CHEMICALS LTD
St. Andrews Road, Avenmouth
Bristol BS11 9HP, England

KALI-CHEMIE ENGELHARD KATALYSATOREN GmbH
D 3000 Hannover, Federal Republic of Germany

KATALCO CORPORATION
180 North Michigan Avenue
Chicago, Illinois 60601, United States

KATALYSATORENWERKE HOUDRY-HÜLS GmbH
D 4370 Marl, Federal Republic of Germany

KAWAKEN FINE CHEMICALS CO. LTD
Ogura Bldg. 1—2—chome, Kofune-cho
Nihonbashi, Chuo-ku, Tokyo, Japan

KEMIRA OY
P.O. Box 330
SF 00101 Helsinki 10, Finland

KOCH LIGHT LABORATORIES LTD
Colnbrook, Bucks SL3 OBZ, England

KÖNIGSWARTER UND EBELL CHEMISCHE FABRIK GmbH
D 58 Hagen, Dieckstrasse 42
Federal Republic of Germany

LAPORTE INDUSTRIES LIMITED, General Chemical Division, Spence Works
Morrfield Road, Widness
Lancashire, England

VEB LEUNA WERKE „WALTER ULBRICHT“
422 Leuna 3, German Democratic Republic

M and T CHEMICALS INC.
American Lane, Greenwich
Connecticut 06830, United States

MINERALS AND CHEMICALS CORPORATION OF AMERICA
Menlo Park, New Jersey, United States

MONSANTO COMPANY
800 N. Lindbergh Blvd.
St. Louis Missouri 63166, United States

MONTEDISON S.P.A.
Piazza della Repubblica, 14/16
20124 Milan, Italy

NALCO CHEMICAL COMPANY, Petroleum Division, Refinery Chemicals
1800 Esperson Building
Houston, Texas 77002, United States and
4001 W. 71st St., Chicago,
Illinois 60629, United States

NISSAN CHEMETRON CATALYST LTD
2 fl. Shinjo Bldg., No. 9, 2-chome
Ta-cho, Kanda, Chiyod-ku, Tokyo, Japan

NORTON INC., Chemical Process
Products Division
P.O. Box 350
Akron, Ohio 44309, United States

ÖSTERREICHISCHE HIAG
WERKE A.G.
Glückgasse 2
A 1015 Vienna, Austria

POROCEL CORPORATION (Subsidiary of
Engelhard Minerals and Chemicals Corp.)
Menlo Park, Edison, New Jersey
United States

PRESSURE CHEMICALS CO.
3419 Smalman St., Pittsburgh
Pennsylvania 15201, United States

PRICE PEARSON REFRACTORIES LIMITED
P.O. Box 9, Moor Street, Brierley Hill
Staffordshire DY5 3SY, England

RIKKIHAPPO OY
P.O. Box 10330, Helsinki 10, Finland

SAKAI CHEMICAL INDUSTRY CO. LTD
Ebisujima-cho,
Sakai City, Osaka, Japan

SHELL CHEMICAL COMPANY
One, Shell Plaza, P.O. Box 2463
Houston, Texas 77001, United States

SOCIÉTÉ CHIMIQUE DE LA GRANDE PAROISSE
(AZOTE ET PRODUITS CHIMIQUES)
8, rue Cognac-Jay
75007 Paris, France

SOCIÉTÉ FRANÇAISE DES PRODUITS POUR CATALYSE (PRO CATALYSE),
Subsidiary of Rhone-Progil S.A., Institut
Français du Petrole
6, rue Piccini, 75016 Paris, France

SOCIÉTÉ FRANÇAISE D'OXYCATALYSE OXY-FRANCE
(145, rue Pierre de Montreuil-sous-Bois
Seine), Paris, France

SOJUZCHIMEXPORT
Smolenskaja Sennaia 32—34, Moscow,
USSR

STAUFFER CHEMICAL COMPANY,
Speciality Chemical Division
Westport, Connecticut 06880, United States

STAUFFER CHEMICAL EUROPE A.A.
25, rue des Caroubiers
CH-1227 Geneva, Switzerland

STREM CHEMICALS INCORPORATED
150 Andover Street
Danvers, Massachusetts 01923, United
States

TITANIUM INTERMEDIATES LIMITED
10 Stratton Street
London W1, England

TOHO TITANIUM CO. LTD
3 Aoi-cho, Akasaka, Namato-ku
Tokyo, Japan

HALDOR TOPSØE A/S
Telefonvej 6, Søborg, Denmark

TREIBACHER CHEMISCHE WERKE
A. G. (TCW)
P.O. Box 31
A 9330 Treibach/Kärnten, Austria

UEB INDUSTRIES LTD
7—2, Kasumigaseki, 3-chome
Chiyoda-ku, Tokyo, Japan

UNICHEMA CHEMIE GmbH
P.O. Box 1280, D 4240 Emmerich/Rhein
Federal Republic of Germany

UNION CARBIDE CORPORATION,
LINDE DIVISION
Molecular Sieves Products
270 Park Avenue
New York, New York 10017, United States

UNIVERSAL OIL PRODUCTS COMPANY
(UOP)
Tokeneke Road
Darien, Connecticut 06820, United States

VEB CHEMISCHE WERKE BUNA
4212 Schkopau über Merseburg
German Democratic Republic

VEB FARBENFABRIK WOLFEN
444 Wolfen 1, German Democratic Republic

VEREINIGTE FÜLLPER-FABRIKEN
GmbH UND CO (VFF)
Ransbach-Baumbach/Westerwald
Federal Republic of Germany

WAKO PURE CHEMICAL INDUSTRIES
LTD
10 Doshomachi, 3-chome, Higashi-ku
Osaka, Japan

XXV. INDEX OF CATALYST MANUFACTURERS BY MAIN INDUSTRIAL PROCESSES

Steam reforming

APC
BASF
CCI
Craiova
FCI
Girdler
Grande Paroisse
Heraeus
ICI
Katalco
Leuna
Pro-catalyse
Topsøe

Low temperature shift

CCI
FCI
Girdler
ICI
Leuna
Topsøe

High temperature shift

APC
BASF
CCI
CSF
Craiova
FCI
Girdler
Grande Paroisse
ICI
Katalco
Leuna
Montedison
Topsøe
Ube

Methanation

BASF
CCI
Degussa
FCI
Girdler
Grande Paroisse
Harshaw
Hoechst
ICI
Katalco
Leuna
Pro-catalyse
Topsøe

Ammonia synthesis

APC
BASF
CCI
CSF
Craiova
Girdler
Grande Paroisse
ICI
Katalco
Montedison
Sojuzchimexport
Topsøe
Chemie Linz

Acrylonitrile

Akzo
Leuna

Formaldehyde

Degussa
Doduco
Girdler
Johnson Matthey
Leuna
Montedison
Topsøe
Hiag

Maleic anhydride

CDC
Montedison

Methanol

BASF
CCI
Degussa
Harshaw
ICI
Leuna
Montedison
Pro-catalyse
Topsøe

Oxo-synthesis

CCI
Girdler
Harshaw
Leuna

Phthalic anhydride

BASF
Cyanamid
Davison
TCW

Styrene

BASF
Buna
CCI
CSF
Girdler
Shell
Strem

Vinyl acetate

Bayer
Buna
CCI
Calsicat
Ciech
Craiova
Harshaw
Montedison
Strem

Vinyl chloride

BASF
Buna
Calsicat
CCI
Harshaw
Houdry
Montedison
Strem

Nitric acid

CCI
Comptoir Lyon
Engelhard
Johnson Matthey

Sulphuric acid

BASF
CCI
Cyanamid
Girdler
Grillo
ISC
Monsanto
Montedison
Rikkihappo
Topsøe
Wolfen

Alkylation

CCI
Allied Chemical
Davison
Girdler
Harshaw
Heraeus
Pro-catalyse
Strem
UCC/Linde

Fluid cracking

CCI
Cyanamid
Davison
Houdry
Minerals and Chemicals
Akzo

Hydrocracking

Harshaw
Nalco
Strem

Cat-cracking

Allied Chemical
CSF
Pro-catalyse
Strem

Fixed bed cat-cracking

Houdry

Dehydrogenation

BASF
CCI
CSF
Davison
Degussa
Doduco
Girdler
Harshaw
Houdry
Kawaken
Leuna
Pro-catalyse
Sakai
Strem

Sulphur removal

APG
CCI
FCI
Girdler
Grande Paroisse
Harshaw
Houdry
Katalco
Laporte
Leuna
Sakai
Topsøe

Desulphurization

CCI
Girdler
Grande Paroisse
Harshaw
Houdry
ICI
Katalco
Pro-catalyse

Hydrodesulphurization

Akzo
CCI
Cyanamid
Girdler
Grande Paroisse
Harshaw
Houdry
ICI
Katalco
Laporte
Leuna
Nalco
Pro-catalyse
Strem
Topsøe

Guards for LTS

CCI
FCI
ICI

Halogenation

Harshaw
Sakai

Dehalogenation

Harshaw

Dehydrochlorination

CCI
Strem

Hydrotreating

Akzo
CCI
CSF
Cyanamid
Pro-catalyse
Shell

Ammonolysis

Girdler
Harshaw
Hoechst
Leuna

Hydrogenation of aromatic hydrocarbons

Calsicat
Cyanamid
Davison
Degussa
Doduco
Engelhard
Girdler
Harshaw
Heraeus
Houdry
Pro-catalyse
Strem

Hydrogenation of carbonyl compounds

Calsicat
CCI
Ciech
Craiova
Crosfield
Degussa
Doduco
Hoechst
Girdler
Harshaw
Heraeus
Houdry
Strem
Unichema

Hydrogenation of carbon double bonds

BASF
Buna
Calsicat
Ciech
Crosfield
Degussa
Doduco
Girdler
Harshaw
Hoechst
Houdry
Kawaken
Leuna
Strem

Hydrogenation of esters and acids

Degussa
Doduco
Girdler
Harshaw
Houdry
Königswarter
Leuna
Sakai
Unichema

Hydrogenation of functional groups

Engelhard
Girdler
Leuna

Hydrogenation of nitriles

Davison
Harshaw

Heraeus
Houdry
Kawaken
Leuna
Strem
Unichema

Hydrogenation of nitro-compounds

CCI
Davison
Harshaw
Hoechst

Hydrogenation (general)

BASF
Bayer
Calsicat
CCI
CSF
Degussa
Doduco
Girdler
Harshaw
Heraeus
Houdry
ICI
Johnson Matthey
Kawaken
Pro-catalyse
Sakai
Strem
Unichema
UCC/Linde

Selective hydrogenation

BASF
Calsicat
CCI
Crosfield
Degussa
Girdler
Grande Paroisse
Harshaw
Hoechst
Houdry
ICI
Leuna
Strem
Sakai

Isomerization

Allied Chemical
BASF
Davison
Harshaw
Houdry
Kali-Engelhard
Leuna
Pressure Chemicals
Strem
UCC/Linde

Oxidation

Alcoa
Anderson
BASF
CCI
CDC
Degussa
Harshaw
Heraeus

Montedison
Leuna
Porocel
Pro-catalyse
Sakai
Shell
Strem
TCW

Polymerization

Allied Chemical
Anderson
CCI
Davison
Doduco
Harshaw
Houdry
M and T chemicals
Pressure Chemicals
Pro-catalyse
Stauffer
Strem
Toho Titanium
Texas Alkyls

Dimerization

Pressure Chemicals

Cyclic oligomerization

Strem

Purification by combustion

Alcoa
Degussa
Doduco

Purification of gases

CSF
Degussa
Doduco
Girdler
Grande Paroisse
Harshaw
Heraeus
ICI
Johnson Matthey
Kali-Engelhard
Leuna
Montedison
Pro-catalyse
Sakai
UOP
Wolfen

Purification by hydrotreating

BASF
CCI
Cyanamid
Grande Paroisse
Harshaw
Hoechst
Leuna

Denitrogenation

CCI
Degussa

Harshaw
Pro-catalyse

Desoxygenation

BASF
CCI
CSF
Doduco
Girdler
Grande Paroisse
Harshaw
Hoechst
Leuna

Steam reforming

APC
BASF
CCI
Cyanamid
FCI
Girdler
Grande Paroisse
Harshaw
Houdry
ICI
Kali-Engelhard
Katalco
Laporte
Leuna
Montedison
Price Pearson
Pro-catalyse
UCC/Linde

Petroleum refining

Harshaw

Ammonia dissociation

BASF
CCI
Doduco
FCI
Girdler
Harshaw
ICI
Pro-catalyse
Topsøe

Cyclization — dehydrocyclization

Harshaw
Leuna

Esterification-interesterification

CSF
Ciech
Girdler
Harshaw
Titanium Intermed.

Hydration — dehydration

Alcoa
BASF
CCI

CSF
Davison
Harshaw
Houdry
Leuna
Strem

Acid catalysed reactions

Girdler

Catalytic alumina

Alcoa

Hydroformylation (1st step Oxo-reaction)

Harshaw

Pressure Chemicals
Strem

Disproportionation

CSF
Ciech
Pressure Chemicals
Strem

Homogeneous catalysts

Anderson
Degussa
Harshaw
M + T Chemicals
Pressure Chemicals
Stauffer
Strem
Texas Alkyls

Carriers

Akzo
American Lava
Alcoa
BASF
Calsicat
CCI
CSF
Chemetron
DuPont
FCI
Grace
Heraeus
Houdry
Hydronyl-Norton
ICI
Laporte (Spence)
Leuna
Norton
TCW
VFF
Strem

XXVI. INDEX OF CATALYST MANUFACTURERS, INDICATING MAIN CATALYSTS PRODUCED BY COUNTRY

Austria

Chemie Linz A. G.
St. Peter 224
4020 Linz
Ammonia synthesis catalyst
Cracking catalysts

Österreichische Hiag Werke A.G.
Gluckgasse 2
1010 Vienna
Fox-Hiag Formaldehyde synthesis catalyst

Treibacher Chemische Werke A. G. (TCW)
P.O. Box 31
9330 Treibach
Oxidation catalysts (Phthalic anhydride catalyst)
Corundum catalyst carriers
Catalyst chemicals

Belgium

Catalysts and Chemicals Europe S.A. (CCE)
Place du Champs de Mars 2
1050 Brussels

Chemviron S. A.
Ixelles 1-B, P.O. Box 17
1050 Bruxelles

Bulgaria

Naftochim
11 August Street
Sofia, No. 6

Canada

Nalco Catalyst Co. Ltd
Edmonton, Alberta
Vistron Canada Ltd

Czechoslovakia

Chemical Works of Czechoslovak-Soviet Friendship (CSF)
Zaluzi v Krusnych Harach

Denmark

Haldor Topsøe A/S
Telefonvej 6, P.O. Box 49
2860 Søborg

Finland

Kemira Oy
P.O. Box 330
00101 Helsinki 10

Rikkihappo Oy
P.O. Box 10330
Helsinki 10
Sulphuric acid catalyst

France

Azote et produits chimiques S.A. (APC)
11, Avenue de Friedland
75008 Paris

Division produits chimiques — catalyseurs
62—68, rue Jeanne d'Arc
75646 Paris, Cedex 13
Catalysts for reforming, shift, ammonia synthesis, sulphur removal

Comptoir Lyon allemand, Louyot et Co.
13, rue de Montmorency 75003 Paris
Nitric acid catalyst

Pechiney
23, rue Balzac
75008 Paris

Pechiney-Saint Gobain
63, rue de Villiers
97 Neuilly-sur-Seine

Rhone-Poulenc (Ste. des usines chimiques)
22, avenue Montaigne
75008 Paris

Rhone-Progil
47, rue de Villiers
97 Neuilly-sur-Seine

Société chimique de la Grande Paroisse
(Azote et produits chimiques)
8, rue Cognacq-Jay
75007 Paris
Catalysts for reforming, shift, methanation, ammonia synthesis, sulphur removal, desulphurization, hydrodesulphurization, selective hydrogenation, purification of gases, purification by hydrotreating, desoxygenation

Société française des produits pour catalyse
(pro catalyse)
Subsidiary of Rhone-Progil S.A. — Institut français de pétrole
6, rue Piccini
75016 Paris
Catalysts for reforming, methanation, methanol synthesis, alkylation, cat-cracking, dehydrogenation, desulphurization, hydrodesulphurization, hydrotreating, hydrogenation, oxidation, polymerization, purification of gases, denitrogenation, ammonia dissociation

Société française d'oxycatalyse oxy-france
145, rue Pierre de Montreuil
93 Montreuil-sous-Bois

German Democratic Republic

Veb Chemische Werke Buna
4212 Schkopau, Merseburg 49
Catalysts for styrene, vinyl chloride, hydrogenation

Veb Farbenfabrik Wolfen
444 Wolfen 1
Sulphuric acid catalyst

Veb Leuna Werke "Walter Ulbricht"
422 Leuna 3, Merseburg 430
Catalysts for reforming, shift, methanation, acrylonitrile, formaldehyde, methanol, oxo-synthesis, dehydrogenation, desulphurization, hydrogenation, isomerization, oxidation, purification of gases, hydration, catalyst carriers

Germany, Federal Republic of

Badische Anilin und Soda Fabrik A.G. (BASF)
6700 Ludwigshafen
Catalysts for reforming, shift, methanation, ammonia synthesis, methanol, phthalic anhydride, maleic anhydride, styrene, vinyl chloride, sulphuric acid, dehydrogenation, hydrogenation, isomerization, oxidation, purification by hydrotreating, desoxygenation, ammonia dissociation, hydration, catalyst carriers

Degussa, Deutsche Gold- und Silber-Scheideanstalt
Weissfrauenstrasse 9
6 Frankfurt
Catalysts for methanation, formaldehyde, methanol dehydrogenation, hydrogenation, oxidation, purification of gases, homogeneous catalysts

Dr. E. Dürrwächter Doduco K. G. (Doduco)
Doduco-Chemiewerk
P.O. Box 245
6920 Sinsheim/Elsenz
Catalysts for hydrogenation and purification of gases

Elektrochemische Werke
Höllriegelskreuth
8023 Munich

Farbenfabriken Bayer A.G.
509 Leverkusen
Catalysts for vinyl acetate, hydrogenation

Farbwerke Hoechst A.G.
6230 Frankfurt/Main — Hoechst

Girdler-Südchemie Katalysator GmbH
Lenbachplatz 6, P.O.Box 201003
8 Munich 2
Catalysts for hydrogen and synthesis gas manufacture, purification of gases, hydrogenation, dehydrogenation, sulphuric acid, formaldehyde, ammonia dissociation, alkylation dehydration and acid-catalyzed reactions

Grillo-Werke A.G.
Duisburg — Hamborn
Sulphuric acid catalyst

W. C. Heraeus GmbH
Heraeusstrasse 12—14
6450 Hanau
Catalysts for alkylation, hydrogenation, oxidation, purification of gases. Catalyst carriers.

Kali-Chemie A.G.
3 Hannover
Catalysts for the production of high-grade anti-knock-gasoline and for special processes in the chemical industry. Catalytic cracking catalysts

Kali-Chemie Engelhard Katalysatoren GmbH
Hans Böckler Allee 20
3 Hannover
Catalysts for reforming, hydrogenation and isomerization. Precious metal catalysts for catalytic reduction of functional groups and for gas purification

Katalysatorenwerke Houdry-Hüls GmbH
4370 Marl
Catalysts for hydrogenation, dehydrogenation, hydrochlorination, reforming, hydration, dehydration, isomerization and polymerization

Königswarter und Ebell Chemische Fabrik GmbH
Dieckstrasse 42
5800 Hagen
Nickel catalysts for hydrogenation, especially for oil and fat hardening

Peroxid-Chemie GmbH
Dr. Gustav Adolf Strasse 3
8023 Höllriegelskreuth

Ruhrchemie A. G.
Bruchstrasse, P.O. Box 35
4200 Oberhausen 13 — Holten
Co-catalysts for hydrogenation and amination by hydrogenation

Süd-Chemie A.G.
Lenbachplatz 6
8 Munich

Taunus-Quarzit-Werke GmbH
Promenade 90
6380 Bad Homburg

Unichema Chemie GmbH
P.O. Box 1280
4240 Emmerich/Rhein

Vereinigte Füllkörper-Fabriken GmbH und Co. (VFF)
5412 Ransbach-Baumbach
Ceramic catalyst carriers
Wallace und Tiernan Chemie GmbH
8870 Günzburg

India
Catalysts and Chemicals India (West Asia), *(CCIWA)*
240 D, Naoroji Road
Bombay 1

Fertilizer Corporation of India Ltd (FCI)
Planning and Development Division
Sindri, Dhanbad, Bihar
Catalysts for reforming, shift, methanation, ammonia dissociation and desulphurization. Catalyst carriers

Italy
Montedison S.P.A.
Piazza della Republica 14/16
20125 Milan
Catalysts for shift, ammonia synthesis, formaldehyde, methanol, vinyl acetate, vinyl chloride, sulphuric acid, maleic anhydride, oxidation, purification of gases, steam reforming

Japan
Catalysts and Chemicals Inc. Far East

(*CCIFE*)
Sankaido Building 9—13, 1-chome,
Akasaka Minato-ku, Tokyo
Catalysts for petroleum refining, for manufacture of petrochemical products and for manufacture of gases

Catalysts and Chemicals Industries Co. Ltd (*CCIC*)
6—2, 2-chome, Otemachi,
Chiyoda-ku, Tokyo.
Catalysts for petroleum refining, for manufacture of petrochemical products and for manufacture of inorganic chemicals

Hakko Kagaku Kogyo K.K.
Mitsui Bldg. no. 2, 4-chome
Nihonhashi, Hongoku-Cho
Chuo-Ku, Tokyo
Catalysts for manufacture of inorganic chemicals

Hashimoto Chemical Industries Co.
41, Nishi 4-Cho Shorinjimachi
Sakai-shi, Osaka
Catalysts for manufacture of inorganic chemicals

Kansai Catalyst Co.
5, 3-chome, Nakanoshima
Kita-Ku, Osaka
Catalysts for oils and fats processing, for manufacture of pharmaceuticals and foodstuffs and other catalysts

Kawaken Fine Chemicals Co.
1, 2-chome, Nihombashi Kozune-Cho
Chuo-Ku, Tokyo
Catalysts for manufacture of petrochemical products, for oils and fats processing and for manufacture of pharmaceuticals and foodstuffs

Kyushu Refractories Co.
Catalysts for manufacture of gases

Lederle Japan Ltd
Catalysts for fuel oil desulphurization

Mitsui Toatsu Chemicals Inc.
2-5, Kasusnigasaki 3-chome
Chyoda-Ku, Tokyo
Catalysts for manufacture of inorganic chemicals

Nihon Tokushu Kasei K.K.
8, 2-chome, Nihombashi Muro-machi
Chuo-Ku, Tokyo
Catalysts for the manufacture of inorganic chemicals

Nikki Chemical Co.
Shin Ohtemachi Bldg. 4, 2-chome
Ohic-Machi, Chiyoda-Ku, Tokyo
Catalysts for heavy crude oil desulphurization, for manufacture of petrochemical products, for manufacture of inorganic chemicals, for manufacture of gases, for oils and fats processing, for manufacture of pharmaceuticals and foodstuffs

Nikko Scientific and Chemical Industries Ltd
Catalysts for the manufacture of petrochemical products, for oils and fats processing, for the manufacture of pharmaceuticals and foodstuffs

Nikon Kagaku Sangyo Co.
20—5, 2-chome, Shitaya Daito-Ku, Tokyo
Catalysts for the manufacture of petrochemical products

Nippon Aluminium Alkils Ltd
70, 3-chome, Nisihimiyahuracho
Higashiyodagawa-Ku, Osaka
High-polymerization catalysts

Nippon Engelhard Ltd
Catalysts for the manufacture of petrochemical products, for the manufacture of inorganic chemicals and for the manufacture of pharmaceuticals and foodstuffs

Nippon Inorganic Colour and Chemical Co.
2—2, 1-chome Uchisaiwaicho
Chyoda-Ku, Tokyo
Catalysts for the manufacture of petrochemical products

Nippon Ketjen Co.
Niihama, Ehime Pref.
Catalysts for hydrodesulphurization, hydrogenation and hydrocracking

Nippon Shokubai Kagaku Kogyo Co.
Catalysts for manufacture of petrochemical products, for manufacture of inorganic chemicals

Nissan Chemetron Catalysts Ltd
2 fl. Shinjo Bldg., no. 9, 2-chome
Ta-cho, Kanda, Chiyoda-Ku, Tokyo
2, 1-chome, Nihombashi, Hon-cho
Chuo-Ku Tokyo
Catalysts for petroleum refining, for heavy crude oil desulphurization, for the manufacture of petrochemical products, high-polymerization catalysts, for the manufacture of inorganic chemicals, for the manufacture of gases, for oils and fats processing, for the manufacture of pharmaceuticals and foodstuffs and other catalysts

Owa Chemical Industry Co.
Catalysts for oils and fats processing

Sakai Chemical Industry Co.
1—26, 3-chome, Oike-cho, Suma-Ku, Kohe
Ebisuhima-cho, Sakai City, Osaka
Catalysts for oils and fats processing

Toho Titanium Co. Ltd
3 Aoi-cho, Akasaka, Minato-Ku, Tokyo

Toyo Stauffer Chemical Co.
High-polymerization catalysts, alkyl aluminium catalysts

Ube Industries Ltd
7—2, 3-chome, Kasumigaseki
Chiyoda-Ku, Tokyo
Catalysts for manufacture of inorganic chemicals

Wako Pure Chemical Industries Ltd
10, 3-chome, Dosha-machi
Higashi-Ku, Osaka
High-polymerization catalysts

Netherlands

Akzo Chemie B.V., Ketjen Catalysts
Nieuwendammerkade 1—3, P.O.Box 15
Amsterdam — N.
Catalysts for fluid cracking, hydrotreating catalysts for desulphurization and hydrogenation; fluid hydroforming catalysts; acrylonitrile catalysts for the Sohio process

Harshaw Chemie B. V.
P.O. Box 19
De Meern
Catalysts for hydrogenation, dehydrogenation, dehydration, hydrotreating, halogenation and dehalogenation, organic syntheses, oxo-process, oxidation and gas purification

Poland

Ciech-Nitroplast
Ul. Jasna 12
Warsaw
Catalysts for vinyl acetate, hydrogenation of carbonyl compounds, hydrogenation of carbon double bonds, esterification and disproportionation

Romania

Combinatul Chimic Craiova
Craiova
Catalysts for reforming, shift, ammonia synthesis, vinyl acetate, hydrogenation of carbonyl compounds

Spain

Energia e Industrias Aragonesas S.A.
Avenida Calvo Sotelo 27
Madrid 4

Sweden

Kema Nord A. B.
P.O. Box 5042
10242 Stockholm

Switzerland

Linde Company, Union Carbide Europe S.A.
40, rue du Rhône
Geneva 3
Molecular sieves

Stauffer Chemical Europe S.A.
25, rue des Caroubiers
1227 Geneva

Union of Soviet Socialist Republics

Sojuzchimexport
Smolenskaja Sennaja 32—34
Moscow
Ammonia synthesis catalyst

United Kingdom of Great Britain and Northern Ireland

Anglo-Continental Fullers Earth Co. Ltd
1 Lloyds Avenue
London EC3

Crosfield Joseph and Sons Ltd
P.O. Box 26, Bank Quay
Warrington, Lancs.
Catalysts for hydrogenation of carbonil compounds and for hydrogenation of carbon double bonds. Catalysts for selective hydrogenation

Cyanamid of Great Britain
North West Wing, Bush House
Aldwych,London WC2

Engelhard Industries Ltd
St. Nicholas House, St. Nicholas Road
Sutton, Surrey

Chemical Division:
Valley Road
Cinderford, Glos.
Precious metals catalysts

Hydronyl-Norton Ltd
King Street, Fenton
Stoke-on-Trent
Catalyst carriers

Imperial Chemical Industries Ltd (ICI)
Imperial Chemical House, Milbank
London SW1
Agricultural Division — Catalysts:
P.O. Box 1
Billingham, Teesside
Catalysts for reforming, shift, methanation, ammonia synthesis, methanol, formaldehyde, desulphurization, hydrodesulphurization, guards for LTS, hydrogenation, purification of gases, ammonia dissociation, catalyst carriers

Imperial Smelting Corp. (N.S.C.) Ltd (ISC)
St. Andrew's Road
Avonmouth, Bristol
Sulphuric acid catalyst

Johnson Matthey Chemicals Ltd
74 Hatton Garden
London EC1

Koch Light Laboratories Ltd
Colnbrook, Bucks

Laporte Industries Ltd
Moorfield Road
Widnes, Lancs.
Catalysts for British Gas Council's catalystic rich gas process (CRG).
Catalysts for sulphur removal, hydrodesulphurization, steam reforming. Catalyst carriers

Monsanto Chemicals Ltd
Monsanto House, 10—18 Victoria Street
London SW1

Price Pearson Refractories Ltd
Moor Street, P.O. Box 9
Brierley Hill, Staffordshire
Catalysts for steam reforming

Titanium Intermediates Ltd
10 Stratton Street
London
Esterification catalysts

Universal Matthey Products Ltd
Underbridge Way, Brinesdown
Enfield, Middx.

United States of America

Activated Metals and Chemicals Inc.
P.O. Box 32
Sevierville, Tennessee 37862

Air Products and Chemicals Inc.
5 Executive Mall Bldg. 656 E Swedesford Rd., Wayne, Pennsylvania 19087
Fluid bed and moving bed cracking catalysts, kaolin cracking catalysts.
Catalysts for hydrogenation, dehydrogenation, hydrochlorination, reforming of naphtha, hydration, dehydration, isomerization and polymerization

Allied Chemical Corp., Industrial Chemicals Division
P.O. Box 1139 R, Morristown, New York 07960 Catalysts for isomerization and polymerization. Alkylation, cat-cracking

Aluminium Company of America (ALCOA)
1501 Alcoa Building,
Pittsburgh, Pennsylvania 15219
Catalysts for oxidation, hydration, dehydration. Catalytic alumina

American Cyanamid Company, Refinery Chemicals Dept.
Bound Brook, New Jersey 08805
Catalysts for phthalic anhydride, sulphuric acid, fluid cracking, hydrodesulphurization, hydrotreating, hydrogenation, steam reforming

American Lava (3M Company),
Technical Ceramic Products Division
Cherokee Boulevard, Road Chattanooga
Tennessee

Anderson Development Company
1415 East Michigan Street
Adrian, Michigan 49222
Catalysts for oxidation, polymerization and homogeneous catalysts

Calsicat Division, Mallinckrodt Chemical Works
1707 Gaskell Avenue, Erie,
Pennsylvania 16503
Catalysts for vinyl acetate, vinyl chloride, hydrogenation. Catalyst carriers

Catalyst Development Corporation (CDC)
59 Industrial Avenue, New Jersey
Catalysts for maleic anhydride, ethylene oxide

Catalysts and Chemicals Inc. (CCI)
1227 So. Twelfth Street, P.O. Box 86
Louisville, Kentucky 40201
Catalysts for reforming, shift, methanation, ammonia synthesis, methanol, oxo-synthesis, styrene, vinyl acetate, vinyl chloride, nitric acid, sulphuric acid, alkylation, fluid cracking, dehydrogenation, sulphur removal, desulphurization, hydrodesulphurization, guards for LTS, dehydrochlorination, hydrotreating, hydrogenation, oxidation, polymerization, denitrogenation, desoxygenation, steam reforming, ammonia dissociation, hydration. Catalyst carriers

Chemetron Corporation, Catalyst Division Girdler Catalysts Department
4900 Crittenden Drive, P.O. Box 337
Louisville, Kentucky 40201
Catalysts for reforming, shift, methanation, ammonia synthesis, formaldehyde, oxo-synthesis, styrene, sulphuric acid, alkylation, dehydrogenation, sulphur removal, desulphurization, hydrodesulphurization, ammonolysis, hydrogenation, purification of gases, desoxygenation, steam reforming, ammonia dissociation, esterification, acid catalyzed reactions

Cyanamid International
Wayne, New Jersey 07470

Cyanamid – Ketjen
Catalysts for steam-reforming

Grace Davison Chemical, Davison Chemical Division
Baltimore, Maryland 21203
Catalysts for fluid cracking, phthalic anhydride, dehydrogenation, hydrogenation, isomerization, polymerization, hydration, dehydration

Dow Chemical Company
2030 Abbott Road
Midland, Michigan 48640

E.I. Du Pont de Nemours and Co.
Wilmington, Delaware 19898

W. R. Grace and Company
6 Hannover Square
New York, New York 10006

Engelhard Minerals and Chemicals Corp.
113 Astor Street
Newark, New Jersey 07114
Precious metal catalysts for catalytic reduction of functional groups and for gas purification.
Catalysts for reforming, isomerization and hydrogenation

Engelhard Industries Division
429 Delaney Street
Newark, New Jersey 07114

Esso Research and Engineering Corp.
Multimetallic reforming catalyst

Harshaw Chemical Company
1945 East 97th Street
Cleveland, Ohio 44106
Catalysts for hydrogenation, dehydrogenation, dehydration, hydrotreating, halogenation and dehalogenation, organic syntheses, oxo-process, oxidation and gas purification

Houdry Division
5 Executive Mall, Swedesford Rd.
Wayne, Pennsylvania 19087

Houdry-Topsøe Co.
Bayport, Texas
Catalysts for ammonia synthesis, methanol, sulphuric acid and formaldehyde. Catalysts for desulphurization, shift and methanation

Jefferson Chemical Co. Inc.
P.O. Box 53300
Houston, Texas

Katalco Corporation
180 North Michigan Avenue
Chicago, Illinois 60601
Catalyst for SNG substitute natural gas (with British Gas Council).
Catalysts for reforming, shift, methanation, ammonia synthesis, sulphur removal, desulphurization, hydrodesulphurization, steam reforming

Laporte and Grace Co.
Catalysts for hydrodesulphurization. SNG catalyst

M and T Chemicals Inc.
Rahway, New York 07065
Catalysts for polymerization.
Homogeneous catalysts

Mallinckrodt Chemical Works
P.O. Box 5439
St. Louis, Missouri 63160

Mooney Chemicals Inc.
2301 Scranton Road
Cleveland, Ohio 44113
Catalysts for core binders

Monsanto Company
800 N. Lindbergh Boulevard
St. Louis, Missouri 63166

Minerals and Chemicals Corporation of America
Menlo Park, New Jersey

Nalco Chemical Company,
Petroleum Division, Refinery Chemicals
1800 Esperson Building
Houston, Texas 77002
4001 West 71st Street
Chicago, Illinois 60629
Hydrotreating catalysts. Catalysts for hydrodesulphurization.

Norton Inc., Norton Chemical Process Products Division
P.O. Box 350, Akron, Ohio 44309
Catalyst carriers

Noury Chemical Corporation
Burt, New York

Pressure Chemicals Co.
3419 Smalman St.
Pittsburgh, Pennsylvania 15201
Catalysts for isomerization, polymerization, disproportionation. Homogeneous catalysts

Shell Chemical Company
1 Shell Plaza, P.O. Box 2463
Houston, Texas 77001

Stauffer Chemical Company, Speciality Chemicals Division
Westport, Connecticut 06880

Industrial Chemical Division
299 Park Avenue
New York, New York 10017

Strem Chemicals Inc.
150 Andover Street, Danvers, Mass. 01923
Catalysts for styrene, vinyl acetate, vinyl chloride, hydrocracking, cat-cracking, dehydrogenation, dehydrochlorination, hydrogenation, cyclic oligomerization, hydration, hydroformylation, catalyst carriers

Union Carbide Corporation, Linde Division, Molecular Sieves Dept.
Old Saw Mill River Road
Tarrytown, New York 10591
Molecular, non-molecular sieve catalysts. Noble and non-noble metal catalysts

Universal Oil Products
Company (UOP), Air Corporation Division
Tokeneke Road, Darien, Connecticut 06820
Vehicle exhaust emission control catalysts. Purification of gases catalysts

Vistron Corporation (Standard Oil)
Ohio Catalyst for acrylonitrile synthesis

Witco Chemical Corporation, Balab Products
P.O. Box 1068
Burlingame, California 94010

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