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ELEMENTS OF RESEARCH AND DEVELOPMENT TO BE CONSIDERED IN THE PETROCHEMICAL INDUSTRY

Prepared by:

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CONCLUSIONS

The study, Elements of R and D to be Considered in the Petrochemical Industry issues the problems of R and D concerning the ways of it's establishing and management under specific conditions of developing countries. The work is representing an opinion of the author how the problems could be positively solved, especially for the economical environment of middle- and small-states.

The study covers the problems of R and D targets and the required ways of their accomplishment.

In some greater detail it points out at the necessity of economical backing, what in the case of smaller countries could be provided for by joint investments formed by regional partners.

Furthermore, it considers the importance of laboratory methods and equipment as well as pilot plants installations and training of the personnel.

Problems of evaluation of research projects and possible economical effects of realization dealt are with in detail.

I. INTRODUCTION

When analyzing nowadays world innovation potential it is possible to draw a conclusion that the well-known and common technologies are to a great extent ripe and the innovation possibilities exhausted.

Many of the basic processes of the chemical industry, production of plastic materials and crude oil refining are based on innovations brought up many years ago. Therefore a much discussed opinion has appeared that the contemporary shortage of high level innovations should be soon followed by another innovation wave with a due successive boost of technology.

The effort of all the developed industrial countries is therefore concentrated on formation of a potent research base and its maximal technological utilization with growing involvement of long-term goals.

Position of the petrochemical industry is nowadays characterized by evolutionary changes, it is marked by profoundness of interdisciplinary relations with the main innovation directions and the activity sphere of chemical production dominates from the point of view of the primary impulse as well as its consequent application in the field of new materials.

In this connection one cannot accept an opinion which regards the evolutionary changes based mainly on the improvement of the already established products and processes as an evidence of the fact, that the dominating period of development and innovative task of the chemistry is a pasttime reality.

Evaluating the phenomena of the recent period in the petrochemistry caused mainly by changes in cost and sales relations first of all in relation to man production leads to an opinion about the general maturity of the petrochemical industry.

The difficulty of foreseeing the revolutionary changes, brought about by the fact, besides other factors, that these changes are not caused directly through market requirements and are based on the knowledge and imagination of research and production, makes quantification of the influence of the petrochemistry upon the basic industrial structure more intricate.

It is evident, though that the petrochemical industry will continue in providing the developing industrial branches with new materials and though a new quality it will create impulses and conditions for the construction of new functional systems.

The significance of the petrochemistry will also grow in providing for new raw-materials, substitution of power resources as well as an important factor in elimination of industrialization impact on the environment.

Nevertheless the most important results will be derived from the knowledge and achievements of the basic research and development and from the point of view of their essence and application possibilities they will be unexpected.

I.1. Object and Aim of the Research and Development

In every innovation process we observe the succession of the following: stimulus, conception proposal, design. decision and realization, the stimulus (need) being the basic factor.

The essential problem in setting up of the research and development programme is the specification of the intention. Research under contemporary conditions is always associated with some long-term intentions. The research is either specifically known, or it is known only in very general terms and therefore to ensure its accomplishment it is necessary to devise a complete programme. Eventually there are cases when the aim is unknown and when it is inevitable to initiate the whole research by drawing up of the research conception. Out of this classification it can be further derived what kind of methods should be applied to ensure the best possible procedure in choosing of the tasks. There are many well-known methods of net-analysis, e.g. PERT, Critical Path Methods, value analysis etc.

This is directly connected with the elaboration of the research project as an instrument of research management.

Another group of problems of the research and development activities is formed by questions related to the preparations, choice and establishment of working teams in research and the duties of the managing staff.

The basic principle is a considerable flexibility in forming of the research teams as well as the competence of the organization to elect their most suitable structure in accordance with the specific nature of the individual tasks. Considering the decisive influence of the deliberate personnel choice upon the research efficiency, it seems inevitable to alternate the research staff structure in rather a flexible way in compliance with changes within the research profile of the working place.

This is directly connected with questions concerning the functions of the managing staff in research, their choice, qualifications and knowledge as well as their capabilities within the sphere of human relations, economy, finance and management principles.

Specifically an important role in the successful accomplishment of the research tasks is attributed to their material and financial backing at the given time in such a way as to eliminate any possible hindrance in attaining the set-up goal.

I.2. Terminology in Research and Development

The technical literature applies lot of terms from the sphere of research and development (R and D). Their definitions and interpretations are not always consistent and terms are grequently misused and their proper contents and sense is not clear.

The definitions of the basic concepts of R and D used in official documents in the U.S.A. are given below.

The concept of Research and Development in general relates to all kind of activities performed in governmental or private organizations financed by the government or other organizations. It comprises research and development in all spheres including education, social sciences, physical sciences, technical and exact sciences etc.

Research is a systematic, intensive study aimed at attaining the most possible complete scientific knowledge and clarification of the studied object.

Development is a systematic utilization of knowledge acquired through research aimed at production of necessary materials, equipment, systems or methods including the design and elaboration of prototypes and technological procedures.

The concepts of research and development do not comprise: common testing of products, quality inspection, technical description, collecting of general statistical data, experimental (pilot) production, common every-day operation programme evaluation and training of scientific and technical workers.

Basic research is a systematic, intensive study aimed at a deeper knowledge and clarification of the studied object.

Applied research is a systematic study aimed specifically at utilization of new knowledge to approach the identified needs.

The development of products is a systematic utilization of knowledge aimed at production of necessary materials, equipment, systems and methods, it includes design, development and improvement of prototyped and new technological procedures with the aim of fulfilment of specific requirements.

The above definitions serve to facilitate the distinguishing of individual categories though in practice they overlap one another to great extent.

II. HISTORICAL DEVELOPMENT OF PETROCHEMICAL INDUSTRY

The petrochemical industry dates back to the 1920s and 1930s, when companies began to turn their attention to the use of petroleum fractions to produce chemicals previously made from coal, mollasses and wood. Several pioneering chemical and oil companies started to produce alkohols, ketons, ethylene glycol, vinyl chloride, styrene and other organic chemicals from the olefins present in the overhead streams from refinery thermal cracking operations. The first production of amonia from natural gas and the commercialization of steam cracking technology for the production of ethylene, propylene and butadiene from petroleum-derivated hydrocarbons also occured during this period.

While these developments took place in the United States, where crude oil distillates and natural gas were available at very low cost, the petrochemical industry in Europe petrochemical processes were based on technological developments in Germany, the UK, USSR and France.

The tremendous growth in demand for the new materials that occured in the decades following World War II allowed the old-line chemical companies to move rapidly into the production of petrochemicals and also attracted a large number of new companies.

Most of these firms were not easily able to enter the new industry, since chemical technology was traditionally very closely held.

This combination of circumstances provided an exceptionally fertile situation for process development in the next decades.

New technology in almost every product area included under the heading of petrochemicals was developed during that period by:

- operating companies.
- independent research firms,
- engineering contractors and
- private inventors.

The commercialization of progressively more efficient processes and larger and larger plants provided greatly improved economics of manufacture. As a result, petrochemical, plastic, and synthetic fibre prices declined and the profitability of manufacture of bulk chemicals and plastics suffered accordingly.

However until the start of oil crises there was no abatement in the drive to develop still more efficient petrochemical process technology, either through the use of better catalysts, or through the substitution of alternate, lower cost raw materials in a different processing sequence.

By the 1970s, the uncertainties associated with the two "oil shocks" and a number of other factors brought to a close an era charakterized by:

a) broadscale successful process development activity,

b) construction of ever larger "single train" plants and,

c) advent of many new industry entrants.

Poor profitability, low demant growth and concerns involving enviromental and toxicity issues caused companies to make reappraisals of their petrochemical operations. The resulting steps taken by many of these firms, are often referred to as "industry restructuring".

One of the important results that affected the industry in these years was a serious cutback in process research and development activities.

Thus much of the research budget was switched to process improvement and product development work.

Another problem, associated with low demand growth, was the fact that companies recognized that, it was going to be far easier than before to keep existing plants on stream (with continued good maintenance practices) and that it would be more difficult for new process technology to force the shutdown of these existing units.

In effect, shutdown situations would probably only occur if the calculated selling price, including a sufficient investment return, for a product made via the new technology would be below the cash cost of a producer with a viable existing plant.

To meet these economic parameters, the calculated production cost of the new process would usually have to be 20 - 40% below that of the existing process.

II.1. The globale scene

The picture in the early 1980s was one of gross overcapacity and intense competition. The strong competitive pressures in the established producing regions of the United States. Western Europe and Japan are currently being intensified by exports from new plants built in other areas of the world, principally Saudi Arabia and Canada.

Although some 70 percent of the world's base chemical capacity is still located in the major consuming centres - the United States, Western Europe and Japan - the pattern over recent years has been changing with projects coming on-stream in a number of countries. (Appendix No. 1)

II.1.1. Export projects

Saudi Arabia is emerging as a major petrochemical producer with feedstock derived from huge resources of unutilised associated gas. As recently as 1980 around 40 milliard (10^9) cubic metres of this was flared.

Saudi Basic Industries Corporation (SABIC) embarked on a number of joint-venture projects at the end of the 1970s with major international oil companies and a Japanese consortium. Output from these projects is expected to include 1.6 million tonnes of ethylene equivalent by the end of 1985. These plants, based on the latest chemical technology, have been completed on or ahead of schedule, a considerable technical achievement.

In addition, other export projects have recently been commissioned in Qatar and Singapore and a further project is being brought on-stream in Libya.

II.1.2. Import substitution

A number of developing and newly industrialising countries have also built new petrochemical plants to replace imported products. During the past ten years combined ethylene capacity in Mexico, Brazil and Argentina increased by 2 million tonnes a year as a result of ambitious plans for self sufficiency. In Asia and the Far East a number of plants are on-stream, underconstruction or planned, for example in Thailand, Malaysia, India and China. A total increase of ethylene capacity in this region from 2.4 million tonnes in 1982 to 4.7 million tonnes in 1990 will go a long way to meeting future requirements in this high growth region.

By 1990, ethylene capacity outside the established producing areas of the United States, Japan and Western Europe is expected to be almost 8 million tonnes a year above the 1982 level. (Appendix No. 2)

III. RECENT ELEMENTS OF RESEARCH AND DEVELOPMENT TO BE CONSIDERED IN THE PETROCHEMICAL INDUSTRY

In the last two decades much of the effort in process development work was switched into evolutionary process improvements that would allow to achieve higher cash flows and therefore, better returns on existing assets.

Achievement of energy savings (fuels, feedstocks) were a priority in the new high energy cost environment. Investments of this nature offer a low-risk strategy for maintaining facilities that are already well depreciated in a competitive mode and at a good technology level. The best examples of this are situations where new, higher field or higher productivity catalysts could be loaded into an existing reactor. In other cases, improved productivity of polypropylene catalysts or continuing field increases in ethylene oxide production are examples of the former.

As other examples "retrofitting" could be used to allow a new reaction system to be employed in an existing plant, involving some new investment. The substitution of n-butane for benzene in a production of maleic anhydride is an example of this type of development.

During the 70s were introduced some notable advances in new process commercialization.

Some of these are mentioned below:

- Acetic acid via methanol carbonylation.
  This process was widely accepted, resulting in the shutdown of plants based on ethylene or n-butane.
- Acetic anhydrate from coal-based methanol.
- Xylene isomerization using zeolite catalyst.

The economic advantages of this low pressure nonnoble metal catalyst process are substantial.

- Alpha olefins from ethylene.
Oligomerization, isomerization and disproportionation reactions are used to produce a programmed mixture of alpha olefins, for conversion to alkohols using oxo technology.

The processes using reactive mixture of carbon monoxide and hydrogen (synthesis gas) are examples of so-called "C_1 Chemistry". This mixture can be produced from any carbon-containing feedstock (coal, methane etc.).

Synthesis gas (syngas), methane and methanol are the starting points for the manufacturing of number of primary and intermediate products. C_1 Chemistry could open the way for the use of methane and syngas from alternative sources for petrochemical purposes.

C_4-fraction containing saturated and unsaturated C_4 hydrocarbons is separated from liquid fractions of steam cracking unit. Most valuable components of this fraction are:

Isobutene more and more used for the preparation of methyl tert. butyl ether (MTBE). This product is used to rise octane level of lead free gasoline. For the same purpose also n-butan after isomerisation and dehydrogenation can be used. In industrial laboratories a series of new catalyst systems are developed for isomerization of n-butenes.

Other valuable product of C_4 fraction is butadiene used except of for syntetic butadiene-styrene rubber production also for chemical synthesis.

C_5 fraction serves increasingly for the production of isoprene as a monomer for polyisoprene rubber and for copolymerisation with styrene to thermoplastic copolymer rubber.

Cyclopentadiene separated from C_5 fraction has widely use as compound for copolymerisation, hydrogenation and chloration.

III.[illegible]. [illegible]

During the evolutionary period of the petrochemical industry increased output volume was accompanied by a widening in the range of products available. Numerous different chemicals became household names not so much as individual products, but rather in terms of general categories.

The largest of these categories, plastics and resins, became familiar to consumers because of their use in packaging, toys, building products, surface coatings, upholstery and other domestic goods as well as in a number of industrial applications. Synthetic rubbers, originally developed to replace disrupted supplies of natural rubber during World War II, currently account for approximately two-thirds (nearly 9 million tonnes annually) of the world's rubber requirements; the main outlets being tyres and footwear.

Synthetic fibres comprise over 35 per cent or 11 million tonnes of the world's annual fibre requirements, the most important being polyamides (nylons), polyesters and acrylics, which are used in a wide variety of domestic, commercial and industrial applications. In addition to continued growth in traditional plastics outlets, polypropylene is now also being used extensively as a textile fibre in carpets, sportswear and "absorbent" disposable nappies. Continuous filaments can be used to make, for example, nylon stockings and tights or alternatively they may be chopped up and then spun or woven in the same way as the traditional natural fibres.

Other major organic products originating from the petrochemical industry include: solvents, detergents and methanol.

Solvents have been used extensively in paint and other surface coatings, but the emphasis on this outlet has declined in recent years with their wider use in chemical processing, pharmaceuticals and engineering applications. Detergents have not only expanded the choice of cleaners available, they have also significantly improved cleaning efficiency compared to that achievable with natural products. Methanol is used primarily in the manufacture of resins, many chemical intermediates and more recently in conjunction with co-solvents as a valuable octane component in some motor gasolines. Anti-freeze, brake fluids and a host of organic precursors for the agrochemical, pharmaceutical and chemical industries are also produced by the petrochemical industry.

In addition to these organic chemicals, considerable tonnages of inorganic chemicals are also derived from oil and gas, though these are not normally classed as petrochemicals. The most important of these are ammonia, an invaluable source of nitrogen for many fertilisers, sulphur, which is used in the manufacture of sulphuric acid, and carbon-black, required by the tyre industry and for use in printing inks.

IV. BASIC RESEARCH

Basic research which has often called pure or fundamental research, studies mainly the nature of chemicals and their reactivity, the preparation of elements, chemical [illegible] and the hybrid compounds that can be induced.

This research is usually carried out in Universities and technical institutions or specialized research laboratories i.e. at Academia of Science, State Institutions, larger chemical or Oil Companies etc.

The chemical companies spend relatively small portions of their overall R and D fundings on basic research and often sponsor and cooperate with Academia and research State Institutions financed mostly by government. However recently it has become evident that the technologies used are in many instances outmoded, energy wasting, environmentally polluting and not sufficiently quality conscious. Principally, everything which was considered unalterable and inevitable in established technologies has become a candidate for major scruting and improvements, including equipment, utilities, catalysts conventional reactions, materials etc.

IV.1. Establishment of priorities

In such a way several hundred proceses, technologies and products could be considered as candidates for research as a part of a petrochemical industrialization program. Many were developed and are produced for many years and is not necessary to invent them. A listing of all possible reactions is a little value to the petrochemical research planer. Such a list represents a "forest" of alternatives, but we must take some basic elements which are adequate to existing conditions i.e.: If the country has universities, scientific and educational institutions, state research organizations and laboratories or significant petrochemical industry.

The adequate supposition for basic research have countries owning to rich hydrocarbon resources and with developed domestic market. This factors together with higher population and developed school educational system form prime priorities for research establishing.

Basic research does not promise early returns of invested capital and for many countries is a form of prestige more than economical necessity.

But at some economical and sociological level of developing is establishing of own research institutions absolutly needy.

Industrial research, cannot flourish without the necessary environment. It needs a local scientific, educational and industrial background. Close co-operation with universities and academic research organizations is as necessary as that with the every day industrial practice. Work has to be extended from bench scale to pilot plant. Contact with the international research and also the industrial community cannot be restricted to a well organized flow of information to the research workers, but close (personal) contacts with the leading world research organizations and industrial firms are vital elements.

The tempo of its technological advance paces the economic growth and financial rewards of an industrial company. Since basic research is the foundation on which all technological advance rests, it is of primary importance to industrial companies that basic research move forward at an everincreasing rate. Well-supported and effectively performed basic research in academic institutions is of vital importance to the immediate interest of the nation's industries, as well as to nation's cultural and technological progress and to education of its future scientists and engineers.

Research in petrochemicals is expensive. Results will come but one must be aware of what kind of results to expect and when to expect them. R and D in this field is a rather long process and only gradual results can be expected.

IV.2. Proposal for a Model Basic Research and Development Unit

The decission to establish research and developing centre in a developing country will mostly depend from the government policy. The joint venture with international oil company could be also the case, but due to concentration of science in developed countries is considered as very rear.

The personnel problem dominates: A professional staff of highest quality and deepest scientific training is the first in a priority list of the essentials. Since modern basic research so generally teams, and since unraveling the truths of nature in most areas that are of interest to industry requires participation by specialists in more than one of science's subdivisions, there is a minimum in size for an effective basic research group in an industrial laboratory. This minimum number of scientists is some four or five. If the number is less, all aspects of the problem may well not be covered at the required level of specialization.

The staff members must be deeply trained in science and mathematics. The doctorate level, as a minimum, gives insurance of adequate depth of training.

Within these depths of training, every effort should be made to obtain a high percentage of men of superior intelligence, unusual dedication, and creativity. They are not plentiful, but one of them will have values greater than several at the medium level.

IV.2.1. Facilities and Instrumentations

The attainment of new knowledge in a basic research and most certainly the amount of effort involved are dependent on quality of facilities and instrumentation. The needs of the basic research man should be promply and fully met. Since he is exploring new frontiers, often there do not exist standart facilities and instruments that can be purchased. In such situations, the support of appropriate design and engineering organizations should be made aviable.

The cost of facilities and instrumentation for research varies widely with the nature of the research. The annual charges to a research laboratory for rent, services, capital and depreciation are small in relation to solary, direct and indirect, expense supplies and other costs.

IV.2.2. Library and scientific and technical information Centre

For emphasis, library service is here given a coordinate heading with the major essentials, since in basic research, even more than in the succeeding operations of science and technology, library research is a most important part of the world there appear reports of new knowledge a very short time after it has been acquired. For the specific purpose of avoiding work to obtain knowledge that has already been acquired, it is most important that the basic scientist make library research an important part of his operations.

For these reasons a library with adequate professional staff is a most essential component of the facilities for basic research.

The size of the library must, of course be in economic balance with the size of the basic research effort of the company. Where a library sufficiently large to be comprehensive is economically impossible, arrangements can be made with larger libraries for supplementary service.

Research often results in new and useful inventions. Patents secure potentially valuable property rights in such inventions. The potential value of a patent is founded upon the invention it covers. This value is realized in terms of the ends sought when using the patent to protect the invention. The basic business policies of the company paying the research bill, and benefiting from the results of research, determine the manner of employing research-derived patents. Research management is concerned with the preservation and evaluation of valuable patent rights arising from inventions made in course of research.

IV.3. Instrumental Analytical Methods in Research and Petrochemical Industry

A quick and precise analytical inspection of chemical raw-materials and products is basic prerequisite of modern technologies as well as consequent ecological problems. In this connection the older and more simple methods providing certain general information about the analyzed object are substituted by advanced methods of the instrument analysis enabling specification of the chemical composition of different analyzed.

Modern analytical technology enables a ready checking of composition changes in analyzed samples even of minimal sizes. There are used analytical methods which are considered routine and those which are labeled as research type. When using the routine analyses the composition is essentially known and one cheeks mainly the quantity rativ of the analyzed samples. For the research analyses it is typical that there is only partial information about the sample composition and the chemical structure of the present components is often ascertained through a combination of different separation methods (distillation, liquid or preparative gas chromatography, thermo-difusion, gel chromatography, the use of molecular sieves etc.) and identification methodd, expecially spectral ones (mass spectrometry, nuclear magnetic resonance, infrared spectroscopy etc.), possibly gas chromatography or its combination with infrared and mass spectrometry. In compliance with these devices suitable for the routine analysis (mostly automated and cheaper) as well as for the research analysis (with higher parameters and more expensive) are available on the market.

A preliminary separation of a sample to more simple fractions by means of separation procedures is usually necessary in case of mixtures with high number of components of different structures and higher molecular mass. A detail analysis, i.e. the specification of all the individual mixture components is usually curried out in case of hydrocarbons with boiling temperatures up to about 200 °C. For mixtures with higher boiling temperatures the detail analysis is only possible in special cases (n-alkenes, n-alkines, polycyclic aromatic hydrocarbons etc.). In this kind of samples usually the content of different functional groups (group analysis) is specified.

Modern instrument analytical methods can be divided to chromatographic, spectral and electrochemical. The most important in the given field are the chromatographic methods or combined chromatographic and spectral methods.

The most widely used chromatographic method is the gas chromatography which enables the detail analyses of volatile and stabile components with molecular mass up to about 1 000. In some cases the gas chromatography enables also the group analysis (mainly of aromatic hydrocarbons, cycloalkanes). Different advanced gas chromatographs from numerous firms are available (Hewlett-Packard, Varian, Pertin Elmer, Carbo Erba). Also the automated devices for the elementary analysis of carbon, hydrogen, nitrogen as well as oxygen and sulphur (Carlo Erba CHN + + O/S 1106, Perkin Elmer) operate on the principle of the gas chromatography.

For the detail analysis, partially also for the group analysis (alkanes, alkenes, aromates) of higher molecular materials as well as materials considered from the point view of gas chromatography as not stabile, a high efficiency liquid chromatography (Hewlett-Packard LC + diode array detector, LKB, Philips) appears suitable.

The shortage of positive identification of chromatographic methods is nowadays made up for by available combinations of chromatographic and spectral methods. The optimal one is mainly the newest combination of a capillary gas chromatography with infrared and mass detection (Hewlett-Packard GC-IRD-MSD). It enables from one sample dosing into the device to get chromatographic information about the identity of a component, IR-spectrum with information on functional groups and isomerism and MS-spectrum with information on molecular mass as well as the structure of analyzed components and at the same time the final information on the identity is processed automatically by a computer. There is also available a combination of the liquid chromatography with the mass detector (Hewlett-Packard LC-MS).

These new combined techniques to a certain degree diminished also the importance of the preparatory gas and liquid chromatography as means of preseparation when solving the problem of identification of mixture components.

The most frequently used spectral methods in the given field, mainly as methods of the group analysis, are the mass spectrometry, infrared spectroscopy, nuclear magnetic resonance, less frequently also ultraviolet spectroscopy and Raman spectroscopy. As perspective there appear also molecular fluorescent and phosphorescent spectroscopy.

The mass spectrometry (Finnigan, Jeol, Hewlett-Packard, Varian) is suitable for the group analysis of any fractions with the exception of heavy oil residues. Lighter fractions are analyzed without preseparation whereas for heavier fractions the preseparation is preferrable and for complex higher molecular fractions the preseparation is inevitable.

The defining of the molecular structure and geometry, checking of thermodynamic parameters of reactions, developing and control of new chemical productions as well as characterizing of polymer materials the NMR spectroscopy is suitable (Varian supplies routine instrumentation - Remini System as well as highly advanced research instrumentation - VXR Series.

Just as NMR the infrared spectroscopy enables specification of the components nature in the individual material groups (grade of side chaining, substitution etc.). It is used mainly for specification of some atomic groups in a molecule and in questions of structure of organic compounds (Pyl Unicam, Perkin Elmer). Nevertheless in case of more complex compounds the individuality of spectra of pure materials cannot be applied.

The ultraviolet spectroscopy is used mainly for the group analysis of aromates and alkenes with conjugated double bonds in low concentrations.

The Raman spectroscopy basically with the use of lasers, as well as the molecular fluorescent and phosphorescent spectroscopy enable specification of the structure.

To frequently used optical methods in chemical and petrochemical industry belong the atomic absorption spectrophotometry. It enables to specify more than 60 elements, first of all metals (Perkin Elmer 2 280 onebeam and 2 380 twobeam, Varian AA-875 twobeam and polyelement model AA-975, Pye Unicam PU 9 000). The more advanced and sensible is the atomic fluorescent spectrometry which is still being developed. As important methods in this field are considered to be the methods using lx-ray, electron and ion riadiation (ICP yobin Yvon 24 spectrometer).

To the electrochemical methods belong conductometry and dielectrimetry, potenciometry mainly with ion selective electrodes, voltometry and polarography, coulometry and electrogravimetry, electrophoresis including isotachophoresis. In the given field they are used less frequently in comparison to the above mentioned methods. Their application can be seen in specification of different impurities in raw materials and products, mainly in case of monomers.

The Price list of main laboratory instruments as offered by Producers is shown on a Appendix No. 5.

IV.4. Training of human resources for research and development institution

The various categories of manpower requirements for R and D in petrochemical industry are listed below:

- Highly qualified scientists and engineers, mostly with graduate or post-graduate degrees, for R and D.
- Graduate engineers and technical diploma holders with varying degrees of experience for pilot plant operation and maintenance.
- Experienced engineers, technicians and artisans for pilot plants construction.
- Experienced and highly qualified laboratory specialists and analysts.
- Marketing studies graduates or trained technical men for marketing.
- Lawyers for licensing and patents.
- Experienced perssonel for scientific and technical informations and library.
- Experienced administrative personnel.

The extent of training and experience needed for each category and each function within a category will vary. The basis for all is however education, starting with primary schools for lower skill and moving up to higher education for professionals.

Having made the best possible recruitment selection, it is common sense to capitalize on the basic qualities of new personnel and develop potential. In this way there will be higher morale, quicker production results, less defects, less material wastage and less need for close supervision in the case of workers; greater efficiency, on similar lines, with regard to research staff; and better chances of success on the part of managment. Training should start with induction and continue systematically throughout all subsequent service. Progressively, this should include apprenticeship if any, instruction in semi-skilled work, specialist training for technical and scientific work, training for supervisiors, and, finally, training for management.

IV.4.1. Induction Course

The primary objective of an induction course is to introduce a new employee to the background of the firm, its objectives, organisation, general policy, leading personalities, amenities, etc., and to describe the highlights of its achievements in providing goods or services, and consequent importance to the community. It is an attempt to make the recruit feel that he is now a part of a firm worth working for, to help him understand how his job fits into the general framework, and enable him to find his way about, and understand the rules and regulations that will affect his future. There are various ways of doing this in practice, including films, talks and conducted tours, coupled with frank answers to spontaneous questions raised in the process. A large enough firm could mount regular courses covering all the intake during a given period, where this is feasible in view of travelling and other constraints, but a smaller concern may have to content itself with something less ambitious.

IV.4.2. On-the-Job Training

Applicable in the case of operators mainly, it is based on the assumption that a great deal of instruction must inevitably take place on the laboratory or pilot plant floor.

Much depends on the ability of those operators selected to instruct trainees to provide the right type of training.

It is recognized that the support of senior management, defined as departmental heads and above, is essential and that the operators/instructors' own supervisors must also be kept in the picture. Hence an advance information session is usually organized for senior management; there is also an advance briefing for section supervisiors, defined as foremen, chargehands, etc. These are usually held some days before the course programme for the selected operators/instructors is carried out.

IV.4.3. Job Rotation

This can be instituted within a department, within a company, or within another company. The purpose is to improve a manager's understanding of jobs other than his own and provide a specific experience which will equip him for promotion. It is, of course, easier to arrange for lower levels of management. Short periods in different departments was at one time widely used for training of university graduates, but it was never fully satisfactory and led to a high labour turnover. As the period was so short, it did not enable the trainee to feel a sense of responsibility as he was not answerable for the result of his decisions.

IV.4.4. Formal Management Courses

These cannot teach anyone to manage, but can accelerate management development, if combined with the right experience. New management tools are occurring frequently and formal courses are efficient and exonomical. They can modify and widen perspectives and this is needed by functional managers who aspire to general management.

IV.4.5. Internal Courses

These courses may meet some training needs. Many management courses are residential and companies set up Staff Colleges where courses are held which are concerned with outlook and attitudes; the different atmosphere aids work.

Courses, whether of the formal or internal type can use one or more of the following training techniques:

a) Lectures. These are moderately efficient, and economical in giving information. They can relate new data to previous knowledge and ideally should be accompanied by visual aids.

b) Case Methods. The case is usually a written narrative of a phase of a company's operations (real or imaginary). They may pose problems or questions for discussion by trainees, who have to analyse the situation and offer a solution to the problem. It is important for a skilled instructor to lead the discussion. Many case studies present a mass of data in no apparent order and students meet in groups and try and analyse it logically, identifying problems and supporting their solution in the face of questioning by others.

c) Group Dynamics. This is also called sensitivity training or T. Groups, and is a method of helping people to understand their own feelings and motivations, their effect upon members of the working group and problems of interpersonal relations.

d) Management Games. Players form teams and act as imaginary firms allocating resources (e.g. to Advertising, Production), fixing prices, etc. Referees decode, often with the help of a computer, the results of competing firms, thus simulating, in a few hours a number of years' trading. They help participants to understand the interrelationship of buseness functions.

It will be most effective, wherever possible, to utilize existing operational plants for training of personnel. Co-operation between countries with such facilities and other developing countries will be of great help. This could be organized on the basis of a programme of exchange of experience and plants visits as well as elaboration of on-job plant training programmes. Similarly, on-the-job training or school training can be organized for the other categories of skills needed.

Organizing joint seminars to discuss common problems and experiences will be valuable as some problems could be particular to the developing countries and not always understable or solvable by industrialized countries. These seminars can cover the full spectrum of skills from the operators' level to the highest management level.

V. PROCESS AND PRODUCT RESEARCH AND DEVELOPMENT

These parts of R and D activity will be for developing countries most frequente and effective. Results of such a institute have the direct contact to the industry and could effect the economy of petrochemical plant in very short time.

This types of R and D are in the group of applied research and development.

Applied R and D (for cost reduction, product quality improvement, or broadening of the existing product line) has one principal objective: It is to maintain and strengthen the company's present sources of earnings in its present businesses which are probably well established and heavily invested.

Applied research and development pertaining to the development of new businesses (in the sense of altogether new product lines or new markets or both) serves a second additional corporate need. This is to provide new sources of corporate earnings and to capitalize on the available opportunities outside the present businesses. It is generally of a longer-term nature than the first. Cyclus of product development is shown in Appendix No. 6.

A typical and interesting example about the ratio of costs spend to different parts of research activity was published by Chemical News (31 July, 1985): The Du Pont Company spends 67% of its chemical R and D budget on product research, i.e. 35 per cent on new product development and 32 per cent on product improvement. The remainder is spend on process work (23 per cent of the total budget is devoted to process improvement, 7 per cent to new process development and 3 per cent to capacity increase).

The German chemical Companies spent in the year 1988 for R and D 9 000 millions DM.

From this amount Company BASF 1 600 millions DM and Company BAYER spent in the year 1987 about 2 300 millions DM.

Most of this costs are dedicated for new products developments (composite plastics, citric acid, polyuretanes etc.).

In the year 1988 the USA R and D costs have to reach 132 milliards USD, what is about 7% higher than in the year 1987. American Industry costs should make 62 milliards USD, what is about 47 per cent of total Budget. Federal costs should reach 68 milliards USD (about 49 per cent of total) and Academic Institutions and others not profit making Institutions should take about 3 per cent of total costs. (Chem.Eng.Progr. No 4/88.)

Very similar situation is in other companies and industrial states.

The material and technical needs for process and product research and development are generally the same as for basic research, except of more developed pilot plant and semi-commercial plant part. This technical background is formed by units of basic processes i.e.:

- distillation (atmospheric, vacuum, molecular distillation, azeotropic distillation etc.),
- extraction,
- crystalization,
- separation units using deep temperatures etc.

The separate part of experimental hall is used for multifunctional pilot plant which could be used for very different batch or continual processes and technologies. This unit could be dismantled and erected, due to prefabricated parts of multipurpose equipment, in short time.

For testing of catalysts usually the serie of more small continual testing units is in operation. This testing needs many thousands hours and different process conditions, so battery of such units must be in use.

Testing of products and their application capabilities and properties is done in laboratories and technical service departments.

Technical service to sales or manufacturing is to take immediate corrective action on urgent and pressing problems which have an immediate corrective action on urgent and pressing problems which have an immediate effect on corporate earnings.

Technical service department is furnished by sophisticated test machines. Products except of laboratory tests, have to pass special testing methods, where properties such as oxidation stability, life, elasticity and other properties simulating the application conditions, are measured.

Except of laboratories and pilot plant hall research institute have very strong and good equiped workshop furnished for maintenance and errection works as for the production of some parts of vessels, collums, separators etc. as other small capacity equipment.

The similar workshop for electronics and control instruments should be absolute necessary.

V.1. <u>Selection of Research Tasks</u>

It is not in the power of every research institute to solve the problems which usually are to be followed. The list of research tasks and problems which are "must", is longer than the reasonable capacity of research teams.

In those cases the screening or selection of tasks and problems must be done and after this selection step only those problems, which have suppositions to be solved and finalized in proper economical time and which solution is effective, could be written on a list of "urgency".

For selection of research tasks are many criterias developed.

V.2. Objectives and Basic Data

The evaluation that comes into play should be regarded as a tool not only for accepting or suspending or following, the research, but also to show economic importance of various aspects of the searched problem and possibilities to realized invented technology in the industrial measurement.

To fulfill these functions, the evaluation should examine the following five subjects:

1. The manufactured products.
2. The basic materials required raw-materials, reactans, solvents, catalysts and the forth.
3. The operating material balances, of the reaction section and the purification section.
4. The flow diagram and the technology.
5. Competitive processes.

V.2.1. The manufactured products

A distinction should be made between an established product from a new process and a new product.

V.2.1.1. Known Product from a New Process

Inovations of this type is characteristic for petrochemical industry with widely diffused products, such as bulk intermediate chemicals and polymers. The evaluation is often made for a well-defined market that has a predictable expansion. Since the technical characteristics of other manufacturing methods are relatively accessible, comparison studies are relatively easy to do.

V.2.1.2. New Product from New Technology

Since the product [illegible] new, it is not possible to make a direct comparison with an existing situation. Instead, evaluation consists of establishing a probable price for a product whose qualities have to be in demand during the course of a market study. The sales volume generally varies inversely to the selling price that can be assigned to such a product; and evaluation should lead to an analogous relation between the selling price and plant capacity. According to the respective positions of the two curves, an argument can be made for one of the four following cases (Appendix No. 7):

1. The manufactured price is always higher than the price defined by the market study; so the technology is incompatible with introducing the product on the market.

2. The manufactured price is always lower than the market price; so the project merits development.

3. The two curves cross each other so that the manufactured price becomes lower than the market price only at a certain capacity, so that commercialization requires a plant with a high capacity from the start.

4. The two curves cross each other such that the manufactured price is lower than the market price only at low capacity, so that product development is limited to applications of low tonnage.

V.2.2. Raw Materials

No matter whether a new product or a new process is being considered, the availability, quality, and price of the basic materials (feedstocks, reactants, etc.) constitute a primary consideration.

V.2.2.1. Availbility of the Basic Materials

There are two general cases in which restrictions faced by a raw material have pronounced effects on the planning for a new plant: either the material is produced in reduced amounts and is thus not generally available, or the material is by-produced in average to low quantities with another product.

In the first case, it may be necessary to include a manufacturing unit for the unavailable raw material along with the plant for the desired product. Examples of such combinations include oxygen units for the manufacture of etylene oxide, catalyst units for many processes, and purification units for recycling acetic acid in the manufacture of vinyl acetate.

In the second case, it may be necessary to locate the proposed manufacturing plant at a central location with respect to several sources of the desired product. Examples might be a butadiene extraction plant located centrally from several ethylene plants that by-produced the desired butadiene-rich C_4 stream, or an isoprene extraction plant similarly located to receive the C_5 stream by-produced in ethylene pyrolysis.

V.2.2.2. Quality of Raw Materials

There is usually a considerable cost advantage in using the commercial quality of raw materials, along with the implicit trace impurities or even several percentage

points of equal boilers that accrue from conventional manufacturing or refining technology. Consequently, any new process should be reviewed for the effects of such impurities; laboratory studies should be carried out first with the pure products, and then with synthetic mixtures.
One example:
The C_3 fraction coproduced with ethylene at ethylene unit generally contains 93% and 98% propylene. However, the presence of propane in certain reactions, particularly oxidation, can make the purification duty heavier and adversely affect the economics.

Depending on the importance of the effect of the impurities, it may be necessary to add pretreatment to the process; and such treatment must be accounted for under the economics of the process being evaluated, particularly in comparisons with technology that may or may not require the same kind of pretreatment.

V.2.2.3. Prices for Raw Materials

The effect of raw material costs on research projects is close to that on industrial projects; however, potential price changes need to be taken into account, particularly if commercialization is to take place at some far future date. Such forecasting is often difficult, for it must consider both the growth in productivity of existing manufacturing plants, as well as the increase in investment and operating costs as they affect prices.

A particularly difficult problem presents itself when the new process uses products that have no current use and therefore do not have a well-established price. Examples include petroleum fractions by-produced with gasoline, isobutyraldehyde prodeced from oxo syntheses, and the C_4 and C_5 fractions from steam cracking.

In theory, such a product has a base price depending on how its producer currently gets rid of it, e.g. fuel value for hydrocarbons and combustible products, or a price less than zero for products costing money for disposal. From the moment a demand makes itself known, however, the seller tries to charge a part of its manufacturing overhead against any by-product, and even to price that by-product so that it can yield a profit while also allowing the buyer to realize a profit.

V.2.3. Material Balances

Research projects, whether for a process or a product, are expressed through the design of one or more manufacturing stages, each with its own material balance, and each in turn often made up of a reaction section and a purification section. The purification section will usually consist of physical separation processes that can be studied in isolation.

V.2.4. Establishing the Flow Diagram

Determining the investment for a unit requires at least an elementary flow diagram showing the approximate primary equipment, as well as an idea of the materials of construction.

V.2.5. Competing Technology

The feasibility study for a research project does not in itself have any meaning unless it is compared to studies of the competition, whether that competition is a product or a process; and it is important that the comparison studies be made on the same basis and with the same methods.

V.2.5.1. Comparing Competitive Processes

A study of competitive technology may require modifying the research project's flow scheme with added operating steps such as those imposed by the use of a particular kind of feedstock or the need to make a by-product saleable. On the other hand, it may be necessary to add elements to the competitive technology for analogous reasons. Finally, it may be necessary to optimize the competitive process with respect to a particular set of conditions that put it on the same basis as the research project.

V.2.5.2. Comparing Competitive Products

The comparison can be carried out on the manufacturing system, when that is available, or on the cost of the product, when that is the only element of comparison. When comparing product costs, the following points should be verified:

Plant capacity should correspond to manufactured price.
Conditions of delivery should be the same.
The current uses should be the same.
The specifications should be the same.
Implications of the prices of coproducts or by-products should be allowed for.

V.3. Marketing of Developed Product

From the practical point of view, the evaluation of a research project logically proceeds through the successive stages of defining the market, the technology, and the economics for the project in question, and then of comparing it with the competition.

V.3.1. The Market Studies

The purpose of a market study is to determine six aspects of the research project:

1. The capacity for an eventual manufacturing plant
2. The location of the manufacturing site
3. Any necessary integration with existing industry
4. The impact of the competition
5. Any necessary provisions for assuring a supply of feed-stock
6. The expected price trends for raw materials, products, and by-products.

This study generally includes three different parts according to their emphasis on production volume, uses for the product, and prices. The production volume concerns not only the product but also the raw material and the principal countries or sites of production. This part is often basen on the literature: it considers prior developments, production trends, and if possible the actual production and consumption, including foreing trade.

The part emphasizing uses concerns the principal markets for the manufactured product, the apparent trends for the usual applications, and possibilities for new applications. The average annual growth rate is often the only data immediately accessible, but this appears to be sufficient for directing choices in the context of evaluating a research project.

The price study concerns price variations and tendencies. It takes on more importance when information about competitive production techniques is lacking or if the project is for manufacturing a new product.

V.4. Mastering of imported technology

Developed countries have reached such a high level in research and development activities that they dominate technological inovations. They further possess the major resources, such as scientists and technologists, laboratories as well as experience, all of which contribute to the efficient development of technology. It is therefore, likely to be more economical for developing countries to buy their technology from developed countries.

The intensive training and technical assistance of licensor and contractor can increase the efficiency of start-up and mastering of imported process.

But even the process is mastered proper way and the operation of the unit is safe and economical, it is necessary to follow up a progress of technology and using research to improve economical parameters of the unit.

Technology transfered from developed countries is not always appropriate to the various local conditions in developing countries. National technological capacity is necessary in order to adapt imported technology to national conditions so that it can be more efficiently used. On the other hand if this capacity is weak, imported technology tends to have a low productivity and results.

Research and Development institutes in developing countries have to provide the considerable amount of research which is required for adapting technology and for further increasing of process and technology efficiency.

Scientific and industrial knowledge enabling the institute to make well founded recommendation for the development policy to follow, for the right choice of products and processes to be purchased for implementation in the next project and to assist in the evaluation of bids.

The other duty is to recommende the proper product application and technical service for the customers.

VI. Economical effects of Research and Development

The company that has done the research and pilot-plant development and has carried a process or product through to commercial manufacture holds certain rights that it can sell to an eventual user. There are two types of payment or royalty for such rights: paid-up and running.

VI.1. Paid-up Royalties

A lump-sum royalty can be paid to the owner of a process, generally depending on the size and installed capacity of the manufacturing unit for which the rights are granted. The fee can vary according to the technology from a few dollars per installed ton of capacity for refinery processes to hundreds of dollars per installed ton of capacity for special products. Payments may be scheduled so as to be smaller as lant capacity is larger.

The actual payment is not generally made in one lump sum, but in parts determined by the contract (for example, 25% at the time of signing the contract, another 25% during construction of the plant, and the remaining 50% after the acceptance tests of the plant).

VI.2. Running Royalties

Sometimes royalties are paid as annuities for the duration of the depreciation of the plant or as long as the patents protecting the invention are in effect. Most often, these running royalties are related to the actual production and not to the installed capacity; and the payments are thus dependent on variations in the plant's production and subject to the hazards of the market.

As a first approximation, the following rule holds: a paid-up royalty is equivalent to the running royalty accumulated over 10 years.

Intermediary royalty arrangements include initial cash down payment followed by a continuing payment over a specified period and according to a calculation procedure defined by the contract.

VI.3. Process Data Book

During the period when engineering studies are being carried out to identify the best of the available technology, potential licensors will usually furnish technical and economica data for use in the analysis. When a given technology has been selected, however, and agreements made, the licensor of the selected process must give the licensee a document containing enough information about the process to allow the selected engineering company to undertake its own studies and work. Transmittal of this document, called the process data book, usually entails a payment fixed by contract.

Also, the licensor provides another document called the operating manual, which complements the process data book, but which is normally used at the time of start-up. Given to the engineering company, the operating manual permits verification of certain calculations. The cost of producing this manual is part of the payment tied to the delivery of the process data book.

New and planed production capacity of petrochemicals in Socialist Countries and Developing Countries (Since 1982)

(thousand tonnes)

	ethylene	propylene	ethylene Oxide ethylene Glycol	amonia	methanol
MIDDLE EAST	2 781	-	153/ 705	3 674	3 040
FAR EAST	7 738	728	55/ 370	13 926	414
SOUTH AMERICA	2 472	877	300/ -	4 660	2 808
SOCIALIST COUNTRIES	4 045	530	575/ 392	4 562	4 530
AFRICA	1 660	440	-/ 145	3 450	660
OTHERS	1 290	140	54/ 68	4 780	2 095
T o t a l	19 986	2 715	1 137/1 680	35 052	13 547
IN Operation	12 646	2 137	1 137/1 431	19 633	8 322
WEST EUROPE CAPACITY	13 660	8 200	1 800/1 400	14 800	2 600

	HDPE	LDPE	PP	PS	PVC	ABS
MIDDLE EAST	360	905	112	152	450	5
FAR EAST	605	850	744	73	222	85
SOUTH AMERICA	100	340	140	-	375	23
SOCIALIST COUNTRIES	1 265	1 105	1 380	118	668	-
AFRICA	555	700	311	-	360	-
OTHERS	40	175	85	-	160	-
T o t a l	2 925	4 075	2 772	343	2 235	113
IN Operation	1 990	2 620	2 095	275	1 304	23
WEST EUROPE CAPACITY	2 300	5 100	2 800	2 200	5 300	730

Eur. chem. News, No. 1242/86, p. 16.

Appendix No. 2

OUTLOOK FOR SELECTED CHEMICAL PRODUCTS

Production of aromatic hydrocarbons 1983 - 1985
and projections to 1989 (ECE/CHEM/64 (Vol. I)

Production of BENZENE a)

(Unit: Thousand tonnes)

REGION - COUNTRY	1983	1984	1985	Projections 1989
1	2	3	4	5
ECE - TOTAL	12 750	13 260	13 270	13 895
EUROPE - TOTAL	7 870	8 240	8 175	8 695
WESTERN EUROPE - TOTAL	4 815	5 050	4 945	5 120
EASTERN EUROPE - TOTAL	3 055	3 190	3 230	3 575
NORTH AMERICA - TOTAL	4 880	5 020	5 095	5 200
LATIN AMERICA - TOTAL	703	813	853	953
OCEANIA - TOTAL	65	50	50	65
AFRICA - TOTAL	33	70	70	90
ASIA MIDDLE EAST - TOTAL	20	25	80	250
ASIA FAR EAST - TOTAL	2 777	3 170	3 274	3 373
T O T A L WORLD	16 350	17 385	17 595	18 625

Production of TOLUENE a)

ECE - TOTAL	4 730	4 760	4 750	5 470
EUROPE - TOTAL	1 758	1 941	2 060	2 520
WESTERN EUROPE - TOTAL	874	1 046	1 050	1 085
EASTERN EUROPE - TOTAL	885	895	1 010	1 435
NORTH AMERICA - TOTAL	2 970	2 820	2 690	2 950
JAPAN	856	811	829	850
KOREA Republic of	140	155	160	200
BRASIL	130	150	150	150
MEXICO	225	220	225	225

Production of XYLENE a)

1	2	3	4	5
ECE - TOTAL	4 945	5 125	5 280	5 895
EUROPE - TOTAL	2 695	2 835	2 810	3 460
WESTERN EUROPE - TOTAL	1 505	1 640	1 575	1 765
EASTERN EUROPE - TOTAL	1 190	1 195	1 245	1 695
NORTH AMERICA - TOTAL	2 250	2 290	2 470	2 435
JAPAN	668	850	850	900
KOREA Republic of	150	160	160	220
BRASIL	150	160	170	200
MEXICO	180	200	200	220

Production of STYRENE

ECE - TOTAL	7 115	7 955	7 885	8 225
EUROPE - TOTAL	3 820	4 025	4 000	4 225
WESTERN EUROPE - TOTAL	2 795	2 995	2 930	3 025
EASTERN EUROPE - TOTAL (est.)	1 025	1 030	1 070	1 200
NORTH AMERICA - TOTAL	3 295	3 930	3 885	4 000
JAPAN a)	1 167	1 423	1 418	1 350
KOREA Republic of	80	80	80	125
BRASIL	210	230	240	260
MEXICO	24	30	30	30
SAUDI ARABIA	-	-	75	250
CHINA	50	50	50	150

Production of POLYSTYRENE a)

ECE - TOTAL	4 270	4 495	4 430	4 615
EUROPE - TOTAL	2 510	2 615	2 630	2 735
WESTERN EUROPE - TOTAL	1 950	1 995	1 990	2 050
EASTERN EUROPE - TOTAL	560	620	640	685
NORTH AMERICA - TOTAL	1 760	1 880	1 800	1 880
JAPAN (estimation)	858	983	1 068	1 000

Production of ETHYLBENZENE

1	2	3	4	5
ECE - TOTAL	8 360	8 880	8 800	9 255
EUROPE - TOTAL	3 340	4 500	4 375	4 685
WESTERN EUROPE - TOTAL	3 205	3 365	3 200	3 370
EASTERN EUROPE - TOTAL	1 135	1 135	1 175	1 315
NORTH AMERICA - TOTAL	4 020	4 380	4 425	4 570
JAPAN	1 300	1 580	1 570	1 500

Production of CYCLOHEXANE

ECE - TOTAL	2 060	2 305	2 150	2 270
EUROPE - TOTAL	1 220	1 250	1 270	1 280
WESTERN EUROPE - TOTAL	805	835	850	855
EASTERN EUROPE - TOTAL	415	420	420	425
NORTH AMERICA - TOTAL	840	1 055	880	990
JAPAN	454	492	530	550

Production of CUMENE

ECE - TOTAL	4 015	4 120	4 175	4 390
EUROPE - TOTAL	2 465	2 555	2 615	2 800
WESTERN EUROPE - TOTAL	1 580	1 620	1 675	1 680
EASTERN EUROPE - TOTAL	885	935	940	1 120
NORTH AMERICA - TOTAL	1 550	1 565	1 560	1 590
JAPAN	380	390	370	400

Production of PHENOL

ECE - TOTAL	3 030	3 340	3 285	3 435
EUROPE - TOTAL	1 800	2 010	1 990	2 100
NORTH AMERICA - TOTAL	1 230	1 330	1 295	1 335
JAPAN	271	272	262	270

Production of NAPHTALENE

1		2	3	4	5
ECE - TOTAL		630	640	650	680
EUROPE - TOTAL		445	450	460	480
WESTERN EUROPE - TOTAL		208	220	220	230
EASTERN EUROPE - TOTAL		237	230	240	250
NORTH AMERICA - TOTAL		125	190	190	200
LATIN AMERICA - TOTAL		10	10	10	10
OCEANIA - TOTAL		12	12	12	12
AFRICA - TOTAL		9	9	9	9
ASIA FAR EAST - TOTAL		248	275	292	330
CHINA	c)	73	80	80	100
INDIA		13	13	13	13
JAPAN		135	162	179	200
KOREA Republic of		20	20	20	20
T O T A L WORLD		910	945	975	1 045

Production of MALEIC ANHYDRIDE

ECE - TOTAL	375	420	425	440
EUROPE - TOTAL	235	250	250	265
WESTERN EUROPE - TOTAL	135	150	150	160
EASTERN EUROPE - TOTAL	100	100	100	105
NORTH AMERICA - TOTAL	140	170	175	175
JAPAN	70	70	70	70

Production of PHTALIC ANHYDRIDE

1		2	3	4	5
ECE - TOTAL		1 475	1 488	1 460	1 520
EUROPE - TOTAL		1 075	1 073	1 040	1 100
WESTERN EUROPE - TOTAL		690	662	620	675
EASTERN EUROPE - TOTAL		385	410	420	425
NORTH AMERICA - TOTAL		400	415	420	420
JAPAN	b)	161	156	165	170

Table of Footnotes

BENZENE: a) Pure plus technical grade 95-96 percent benzene.

e) (China) Source: World Chemical Industry Yearbook, 1984, China Chemical Industry, 1984.

TOLUENE: a) Toluene abtained as a hydrodealkylation process should not be included.

XYLENE: a) Only as octho- and para-xylenes. Mictures of xylenes used as solvent is excluded.

c) (Ch[illegible]a) Source as under Benzene, Nov. 1984.

STYRENE: a) Source: Yearbook of Industrial Statistics, Vol. 2 (United Nations, New York).

POLYSTYRENE: a) ABS and SAN are excluded.

NAPHTALENE: c) Source as previously.

PHTALIC ANHYDRIDE: b) Chemical Engineering News, Vol. 63, No. 23, June 10, 1985.

Production of olefines 1983 - 1985 and projections to 1989 (ECE/CHEM/64 (Vol.I)

Production of ETHYLENE

1	2	3	4	5
ECE - TOTAL	30 515	32 960	32 875	34 715
EUROPE - TOTAL	16 310	17 260	17 270	18 365
WESTERN EUROPE - TOTAL	12 000	12 570	12 490	13 055
EASTERN EUROPE - TOTAL	4 310	4 690	4 780	5 310
NORTH AMERICA - TOTAL	14 205	15 699	15 605	16 350
LATIN AMERICA - TOTAL	1 830	2 020	2 000	2 330
OCEANIA - TOTAL	270	270	270	320
AFRICA - TOTAL	248	250	250	450
ASIA - MIDDLE EAST - TOTAL	220	230	740	1 560
ASIA - FAR EAST - TOTAL	5 515	6 470	6 570	7 240
CHINA	e) 654	e) 648	650	1 200
JAPAN	e) 3 684	e) 4 385	4 224	4 000
KOREA Republic of	e) 489	e) 526	525	650
T O T A L WORLD	38 600	42 200	42 750	46 620

Production of PROPYLENE

ECE - TOTAL	15 650	17 020	16 680	18 395
EUROPE - TOTAL	8 605	9 305	9 260	10 095
WESTERN EUROPE - TOTAL	6 470	7 090	6 950	7 345
EASTERN EUROPE - TOTAL	2 135	2 220	2 310	2 750
NORTH AMERICA - TOTAL	7 046	7 713	7 420	8 300
LATIN AMERICA - TOTAL	740	788	820	925
OCEANIA - TOTAL	135	135	150	160
AFRICA - TOTAL	26	26	26	101
ASIA MIDDLE EAST - TOTAL	48	50	50	50
ASIA FAR EAST - TOTAL	3 630	4 105	4 195	4 385
JAPAN	e) 2 632	e) 2 981	2 930	2 800
CHINA	e) 373	e) 370	380	600
KOREA Republic of	268	275	275	310
T O T A L WORLD	20 230	22 125	21 925	24 020

NOTE: All figures are estimates, except where footnotes are shown

Production of BUTADIENE

1	2	3	4	5
ECE - TOTAL	4 165	4 360	4 305	4 885
EUROPE - TOTAL	2 965	3 070	3 030	3 285
WESTERN EUROPE - TOTAL	1 705	1 750	1 695	1 745
EASTERN EUROPE - TOTAL	1 260	1 315	1 335	1 540
NORTH AMERICA - TOTAL	1 200	1 295	1 275	1 600
ASIA FAR EAST - TOTAL	845	960	985	1 105
CHINA	b) 137	135	135	250
JAPAN	555	627	620	600
KOREA Republic of	77	85	85	90

Production of VINIL CHLORIDE MONOMER

ECE - TOTAL	9 340	9 955	11 140	11 595
EUROPE - TOTAL	5 775	5 995	6 540	6 845
WESTERN EUROPE - TOTAL	4 655	4 840	4 910	4 935
EASTERN EUROPE - TOTAL	1 115	1 155	1 630	1 910
NORTH AMERICA - TOTAL	3 570	3 960	4 600	4 750
JAPAN	1 573	1 693	1 733	1 800

Production of ETHYLENE OXIDE

ECE - TOTAL	4 755	5 085	5 145	5 165
EUROPE - TOTAL	1 975	2 180	2 160	2 065
WESTERN EUROPE - TOTAL	1 395	1 490	1 405	1 340
EASTERN EUROPE - TOTAL	580	690	695	725
NORTH AMERICA - TOTAL	2 779	2 905	3 045	400
JAPAN	d) 468	d) 533	555	450

Production of POLYETHYLENE (LDPE + LLDPE + HDPE)

1	2	3	4	5
ECE - TOTAL	15 245	16 045	16 840	18 135
EUROPE - TOTAL	8 350	8 710	8 815	9 985
WESTERN EUROPE - TOTAL	6 596	6 815	6 840	7 340
EASTERN EUROPE - TOTAL	1 755	1 895	1 975	2 645
NORTH AMERICA - TOTAL	6 900	7 335	8 025	8 150
ASIA MIDDLE EAST - TOTAL	175	195	440	770
ASIA FAR EAST - TOTAL	2 755	3 220	3 150	3 530
CHINA	373	375	380	565
INDIA	138	137	140	150
JAPAN	1 766	2 098	1 904	1 950
KOREA Republic of	269	271	295	310

Production of LOW DENSITY POLYETHYLENE (including linear LDPE)

ECE - TOTAL	10 180	10 485	10 940	11 705
EUROPE - TOTAL	6 065	6 140	6 175	7 005
WESTERN EUROPE - TOTAL	4 695	4 755	4 725	5 045
EASTERN EUROPE - TOTAL	1 370	1 385	1 450	1 960
NORTH AMERICA - TOTAL	4 117	4 345	4 765	4 700
ASIA - MIDDLE EAST - TOTAL	175	195	400	570
ISRAEL	40	40	40	40
QATAR	135	135	140	150
SAUDI ARABIA	-	20	220	380
ASIA FAR EAST - TOTAL	1 815	2 035	1 975	2 155
CHINA	310	310	310	365
INDIA	107	107	110	120
JAPAN	1 080	1 257	1 119	1 150
KOREA Republic of	141	141	165	180

Production of HIGH DENSITY POLYETHYLENE

1	2	3	4	5
ECE - TOTAL	5 065	5 560	5 900	6 430
EUROPE - TOTAL	2 285	2 570	2 640	2 780
WESTERN EUROPE - TOTAL	1 900	2 060	2 115	2 295
EASTERN EUROPE - TOTAL	385	510	525	685
NORTH AMERICA - TOTAL	2 782	2 990	3 260	3 450
ASIA - MIDDLE EAST - TOTAL	-	-	40	200
SAUDI ARABIA	-	-	40	200
ASIA - FAR EAST - TOTAL	940	1 185	1 175	1 375
CHINA	63	65	70	200
INDIA	31	30	30	30
JAPAN	686	841	785	800

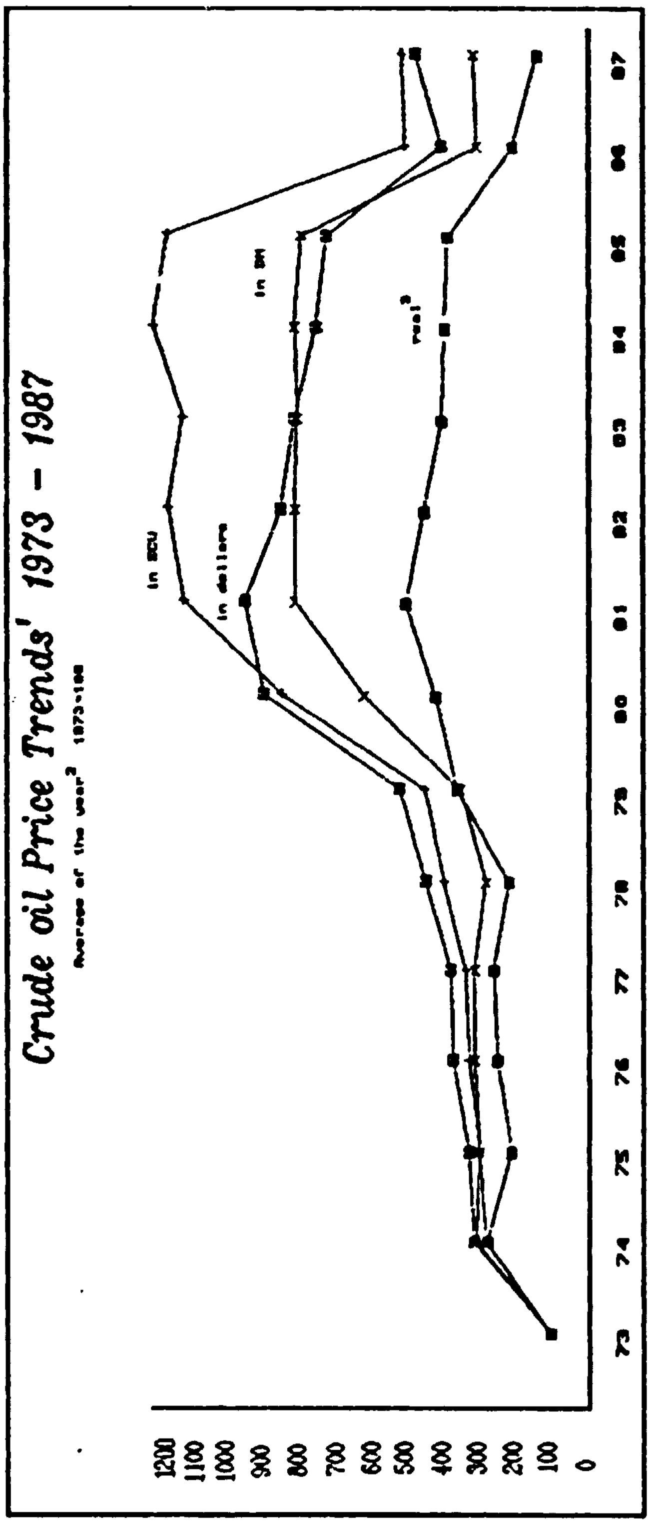
Production of POLYPROPYLENE

ECE - TOTAL	4 680	5 255	5 320	6 135
EUROPE - TOTAL	2 525	2 875	2 975	3 485
WESTERN EUROPE - TOTAL	2 050	2 325	2 400	2 750
EASTERN EUROPE - TOTAL	475	550	575	735
NORTH AMERICA - TOTAL	2 155	2 380	2 345	2 650
ASIA FAR EAST - TOTAL	1 515	1 795	1 945	2 155
CHINA	120	130	130	240
INDIA	25	28	28	40
JAPAN	c) 1 062	c) 1 271	1 304	1 300
KOREA Republic of	199	205	210	250
INDONESIA	7	7	7	7

TABLE OF FOOTNOTES

ETHYLENE e) Chemical a. Entineering News, May 6, June 10, Dec. 16, 23, 1985
PROPYLENE e) - " - - " -
BUTADIENE b) WORLD Chemical Industry 1984, CHINA CHEMIC. Ind. Nov. 1984
VINYL CHLORIDE MONOMER / - " - - " -
ETHYLENE OXIDE d) Chemical a. Engineering News, May 6, June 10, Dec. 16, 23, 1985
POLYPROPYLENE c) - " - - " -

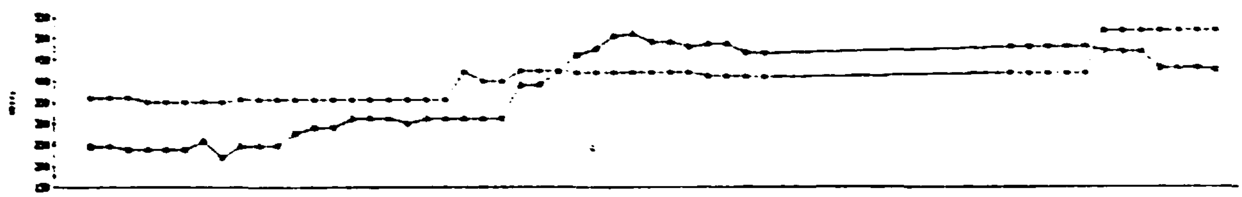
Appendix No. 3



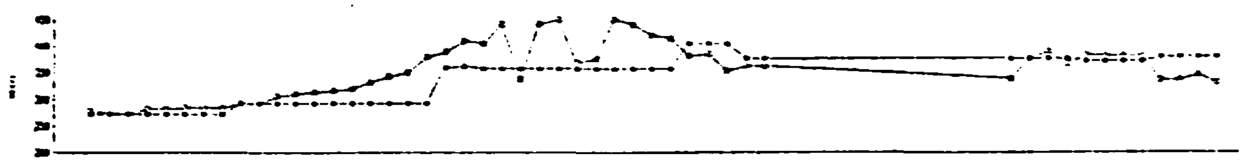
1 Import price of OECD
2 First half of the 1987
3 Compensated for the price of industrial goods

Price Trend Of Basic Chemical Products

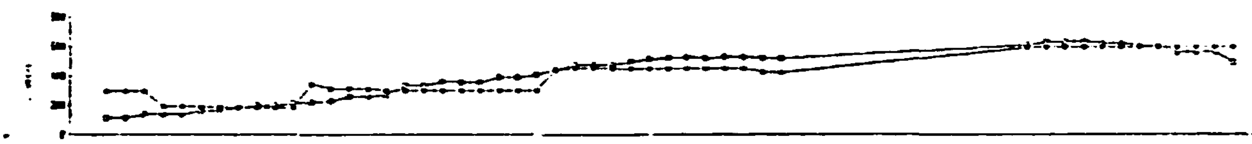
Ethylene



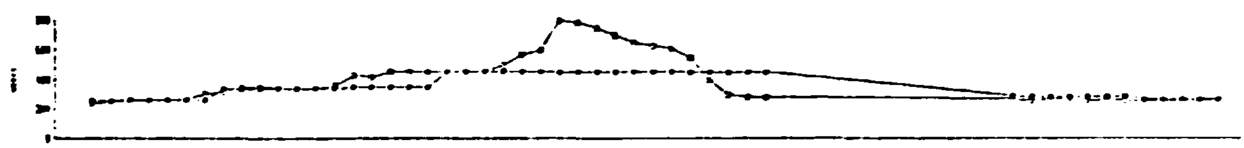
Propylene



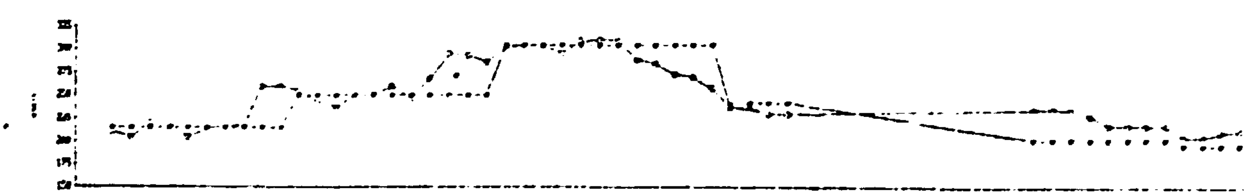
Butadiene



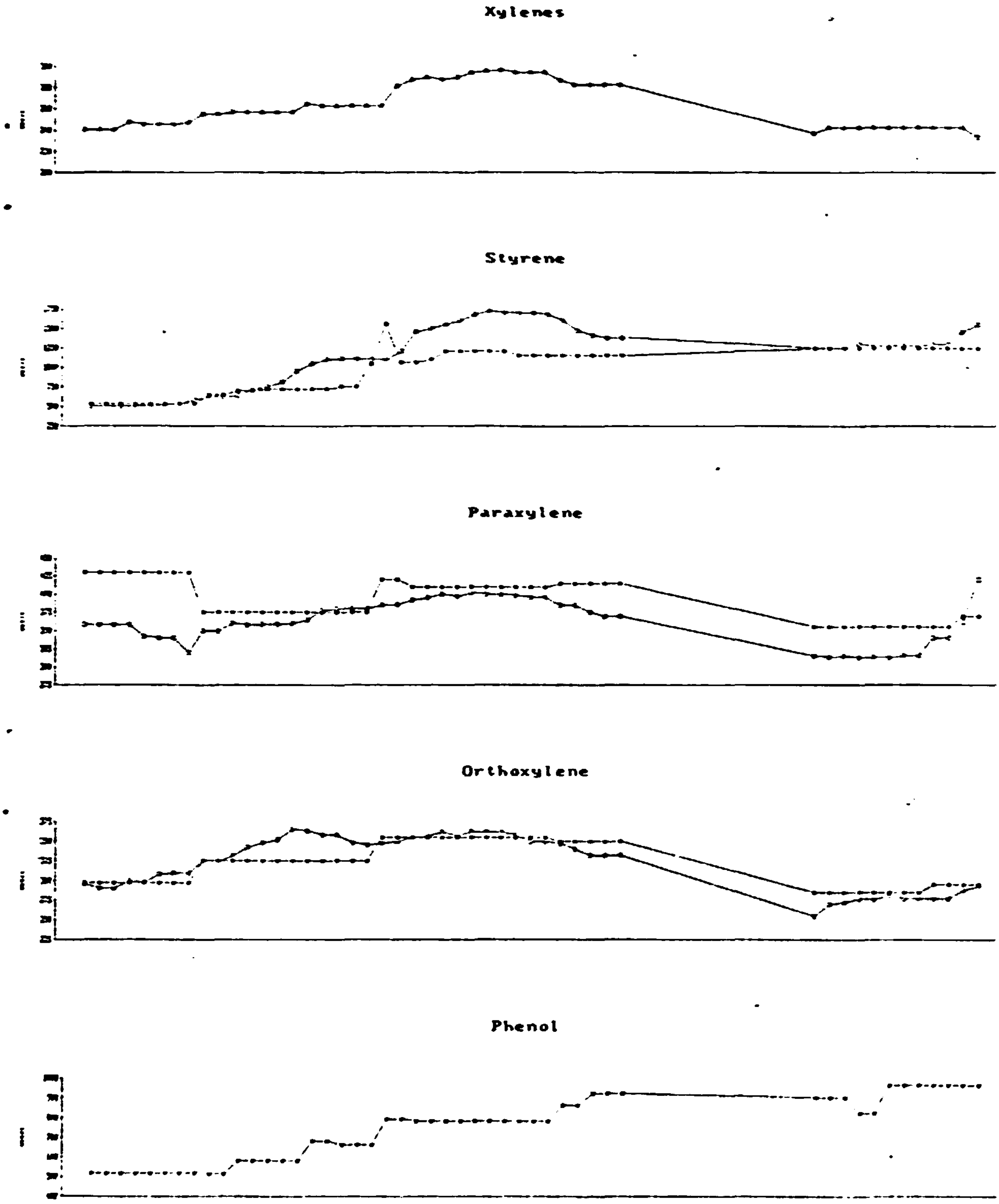
Benzene



Toluene

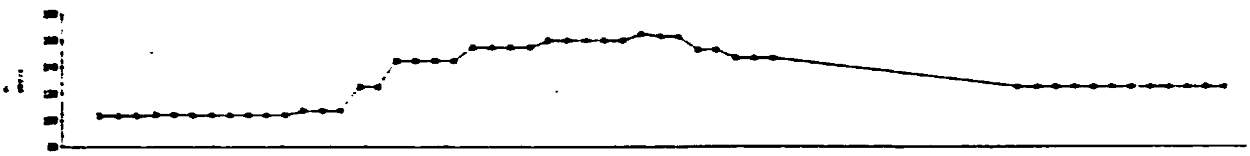


West European ☐ Spot and ▣ Contract prices in US$/t.
Scale is from November 1986 till January 1988.

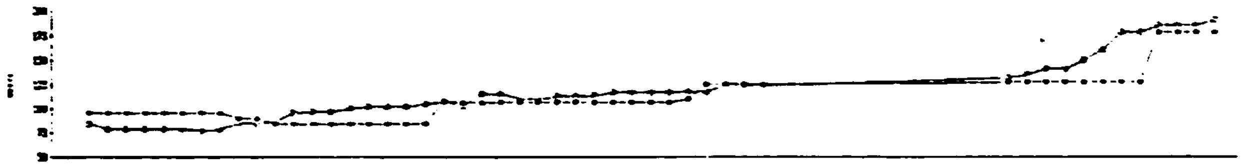


West European ❑ Spot and ▤ Contract prices in US$/t.
Scale is from November 1986 till January 1988.

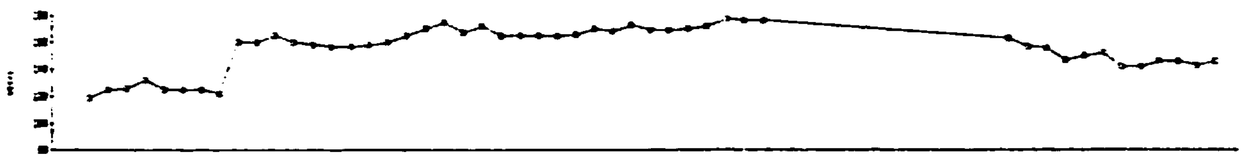
Ammonia



Methanol



Virgin naphtha



West European ☐ Spot and ▤ Contract prices in US$/t.
Scale is from November 1986 till January 1988.

Plastics price report (DM/kg)

Product	Manufacturers' (list) price	Market price
High density polyethylene (hdPE)		
Injection moulding	2.20	1.20-1.25
Film (extrusion) grade	2.55	1.40-1.50
Blow moulding	2.35	1.30-1.40
Linear low density polyethylene (lldPE)		
Film grade (butene-based)	2.30	[illegible]
Low density polyethylene (ldPE)		
Film grade	2.25	1.30-1.35
Polypropylene (PP)		
Raffia grade	2.25	1.40-1.50
Injection moulding	2.35	1.50-1.55
Copolymer	2.80	1.85-2.2[illegible]
Polystyrene (PS)		
Crystal	2.55	1.80-1.90
High impact	2.65	1.95-2.05
Polyvinyl chloride (PVC)		
Pipe grade	1.70	1.40-1.45
Paste grade	2.40	1.95-2.10

Eur.Chem. News 22/29 12 86, p. 11

Product	Manufacturers' (list) price	Market price
High density polyethylene (hdPE)		
Injection moulding	2.20	1.25-1.30
Film (extrusion) grade	2.55	1.45-1.50
Blow moulding	2.35	1.35-1.40
Linear low density polyethylene (lldPE)		
Film grade (butene-based)	2.30	1.30-1.35
Low density polyethylene (ldPE)		
Film grade	2.25	1.35-1.40
Polypropylene (PP)		
Raffia grade	2.25	1.45-1.50
Injection moulding	2.35	1.55-1.60
Copolymer	2.80	1.85-2.20
Polystyrene (PS)		
Crystal	2.55	2.00-2.10
High impact	2.65	2.10-2.20
Polyvinyl chloride (PVC)		
Pipe grade	1.70	1.35-1.45
Paste grade	2.40	1.95-2.10

Eur.Chem. News 2.2.87. p. 11

The manufacturers' (list) price column indicates price levels or targets set by producers. Market price column gives a guide to price levels for large-to-medium size buyers and for the general purpose grades.

Plastics price report (DM/kg)

Product	Manufacturers' (list) price	Market price
High density polyethylene (hdPE)		
Injection moulding	2.20	1.25-1.30
Film (extrusion) grade	2.55	1.45-1.50
Blow moulding	2.35	1.40-1.45
Linear low density polyethylene (lldPE)		
Film grade (butene-based)	2.30	1.30-1.35
Low density polyethylene (ldPE)		
Film grade	2.25	1.35-1.40
Polypropylene (PP)		
Raffia grade	2.25	1.45-1.50
Injection moulding	2.35	1.55-1.60
Copolymer	2.80	1.90-2.20
Polystyrene (PS)		
Crystal	2.55	2.00-2.10
High impact	2.65	2.10-2.20
Polyvinyl chloride (PVC)		
Pipe grade	1.70	1.35-1.45
Paste grade	2.40	1.95-2.10

Eur.Chem. News, 23.2.87, p. 8

Plastics price report (DM/kg)

Product	Manufacturers' (list) price	Market price
High density polyethylene (hdPE)		
Injection moulding	2.20	1.25-1.30
Film (extrusion) grade	2.55	1.40-1.50
Blow moulding	2.35	1.40-1.45
Linear low density polyethylene (lldPE)		
Film grade (butene-based)	2.30	1.40-1.45
Low density polyethylene (ldPE)		
Film grade	2.25	1.35-1.40
Polypropylene (PP)		
Raffia grade	2.25	1.45-1.50
Injection moulding	2.35	1.55-1.60
Copolymer	2.80	1.90-2.20
Polystyrene (PS)		
Crystal	2.55	2.00-2.10
High impact	2.65	2.10-2.20
Polyvinyl chloride (PVC)		
Pipe grade	1.70	1.38-1.45
Paste grade	2.40	1.95-2.10

Eur.Chem. News, 30.3.87, p. 9

Plastics price report (DM/kg)

Product	Manufacturers' (list) price	Market price
High density polyethylene (hdPE)		
Injection moulding	2.20	1.35-1.40
Film (extrusion) grade	2.55	1.50-1.55
Blow moulding	2.35	1.50-1.55
Linear low density polyethylene (lldPE)		
Film grade (butene-based)	2.30	1.45-1.50
Low density polyethylene (ldPE)		
Film grade	2.25	1.40-1.45
Polypropylene (PP)		
Raffia grade	2.25	1.60-1.65
Injection moulding	2.35	1.65-1.75
Copolymer	2.80	1.90-2.10
Polystyrene (PS)		
Crystal	2.55	2.15-2.25
High impact	2.65	2.25-2.40
Polyvinyl chloride (PVC)		
Pipe grade	1.70	1.45-1.50
Paste grade	2.40	1.95-2.10

Eur.Chem. News, 25.5.1987, p. 10

Plastics price report (DM/kg)

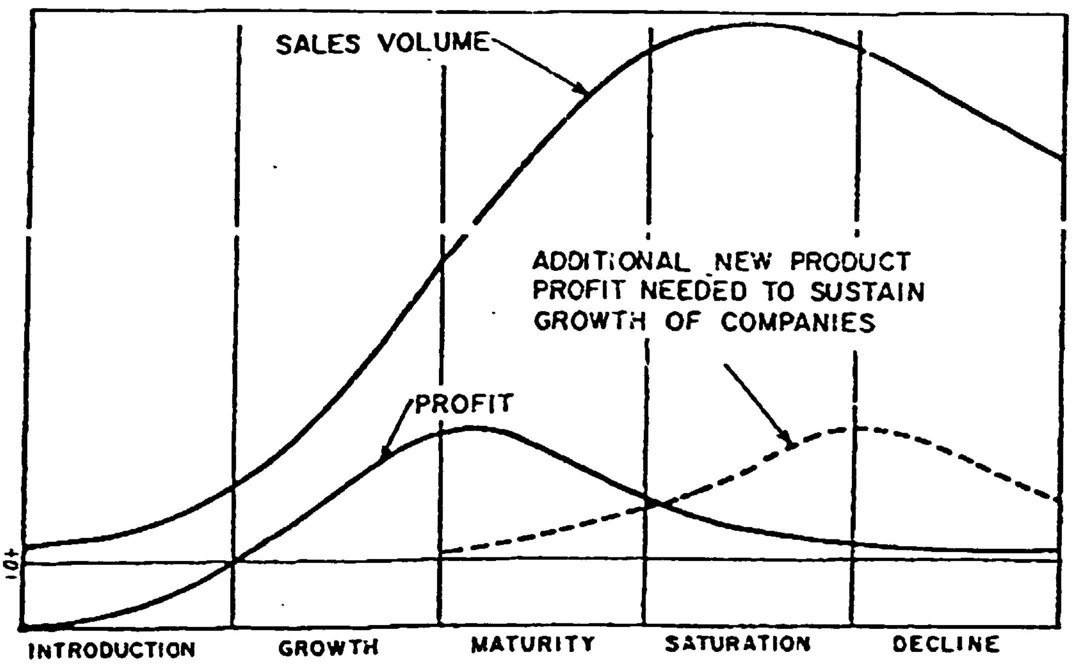
Product	Manufacturers' (list) price	Market price
High density polyethylene (hdPE)		
Injection moulding	2.20	1.45-1.50
Film (extrusion) grade	2.55	1.60-1.65
Blow moulding	2.35	1.55-1.60
Linear low density polyethylene (lldPE)		
Film grade (butene-based)	2.30	1.50-1.60
Low density polyethylene (ldPE)		
Film grade	2.25	1.45-1.50
Polypropylene (PP)		
Raffia grade	2.25	1.65-1.75
Injection moulding	2.35	1.75-1.85
Copolymer	2.80	1.92-2.10
Polystyrene (PS)		
Crystal	2.55	2.30-2.40
High impact	2.65	2.40-2.45
Polyvinyl chloride (PVC)		
Pipe grade	1.70	1.45-1.50
Paste grade	2.40	2.00-2.20

Eur.Chem. News, 20.7.1987, p. 8

Price of main laboratory instruments for R and D laboratory (valid for 1988 as offered by Producers)

ITEM	AVAILABILITY	UNIT-PRICE US $
ANALYTIC BALANCE	4 weeks	1 850
POUR POINT AUTOMATIC	3 month	17 060
ACCESSORIES and SPARE PARTS	3 month	12 100
TITRATION AUTOMAT	6 weeks	3 500
ANILIN POINT (ASTM D 611)	4 weeks	1 541
DOUBLE BEAM UV-VISIBLE SPRECTROPHOTOMETER	3 month	19 354
LAMBDA 15 UV-VISIBLE SPECTROPHOTOMETER with PC and SOFTWARE	3 month	32 151
C H N ELEMENTARY ANALYSATOR	2-3 month	58 000
ACCESSORIES and SOFTWEAR		5 800
HP 5880 A GAS CHROMATOGRAPH	14 weeks	13 676
ACCESSORIES and SPARE PARTS	14 weeks	38 824
HP 5890 A GAS CHROMATOGRAPH	12 weeks	7 411
ACCESSORIES and SPARE PARTS	12 weeks	37 489
VEGA GAS CHROMATOGRAPHY SYSTEM	12 weeks	10 816
ACCESSORIES and SPARE PARTS	12 weeks	22 990
DEDICATED SYSTEM FOR OXYGENATED COMPOUNDS SELECTIVE GAS CHROMATOGRAPHY	12 weeks	31 670
ACCESSORIES and SPARE PARTS	12 weeks	8 670

Basic life cycle of new products



Comparing manufactured and market prices as a function of capacity