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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
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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Developing [illegible]
[illegible] 1969

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PRODUCTION OF PETROCHEMICALS FROM PETROLEUM AND NATURAL GAS UNDER THE LOCAL CONDITIONS OF DEVELOPING COUNTRIES[1]

by

Max Gerhold
Austrian Petrochemical Consultants Ltd.
Vienna Austria

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[illegible].70-[illegible]

The rapid expansion of the fields of applications of petrochemical products, plastics and synthetic fibres in the last years had an important effect on the development of modern processes [illegible] hydrocarbon feedstocks for the production of intermediates. In this context, we want to draw special attention to the development [illegible] processes for the pyrolysis of hydrocarbons [illegible] aromatics by dehydrocyclisation [illegible]. Similar developments have been achieved in the field of [illegible] production of toluene, benzene and [illegible] in the [illegible] by [illegible] and in the catalytic oxidation of ethylene to acetaldehyde and ethylene oxide, as well as in the further transformation of these products to important intermediates and final products.

A considerable progress has equally been made in the field of catalytic oxidation [illegible] such as terephthalic acid, phthalic [illegible].

Similar efforts in development can be expected in the fields of stereo-specific polymerisation and copolymerization of olefines as well as in the copolymerisation of several monomers to polymerisates with special properties which will [illegible] field of application in the manufacture of [illegible] the production of synthetic fibres. The [illegible] of plastics and synthetic fibres [illegible] rapid increase of the [illegible] of application for new purposes.

In highly industrialized countries, this development leads to the construction of large plants for the production of petrochemical basic products, intermediates and monomers and to the installation of relatively large polymerisation [illegible] for the processing of polymerisates produced.

Considering the progress in the production of petrochemical products all over the world, it [illegible] that the production capacity in the period between [illegible] increased from [illegible] to 40 million tons and by [illegible] capacity is expected to increase to over 100 million tons/year.

[illegible] between 1955 and 1975

[illegible] the [illegible] plastic and synthetic [illegible] production of [illegible].

In 1960 the world production of plastics amounted to 6.7 million tons, for 1970 a production of 25 million tons is to be expected.

Graph. 2 Trend of the world plastic production between 1955 and 1975

In 1957 the world production of synthetic fibres amounted to only 400,000 tons. In 1962 the limit of 1 millions tons was exceeded, in 1968 the production went up to 4.3 million tons and for 1970 we can expect in a total fibre production of 25 million tons, a synthetic fibre rate of about [illegible] million tons.

Graph. 3 Trend of world fibres production up to 1975

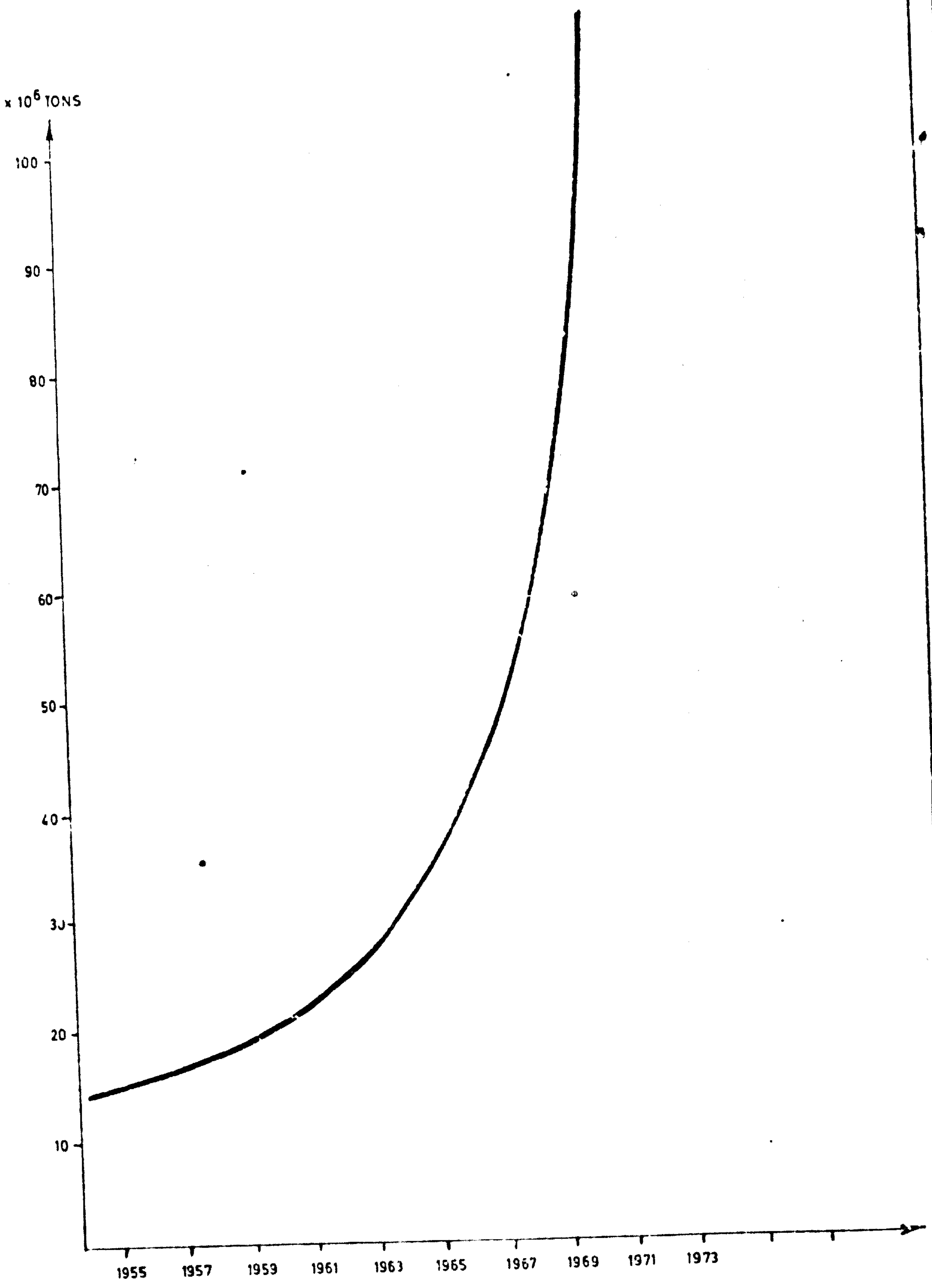
The same upward trend, as observed in the field of petrochemicals and plastics, is apparent in the field of fertilizers. In 1953 the nitrogen production in the world was 5 million tons, 1970 a production of 35 million tons can be expected.

Graph. 4 World trend of nitrogen fertilizers production

The increase capacity of the refineries of the world, which will double in the next 10 years from a present production of about 2,000 million tons (production of 1960: 1,000 million tons) is indicative of an increase in the production of intermediates and final products because they dispose of appropriate quantities as well as qualities of raw materials for the economic production of petrochemical goods. This production corresponds to about 80 - 90 million tons intermediates, e.g. 25 million tons ethylene, 13 million tons propylene, [illegible] million tons butadiene, 17 million tons gasoline.

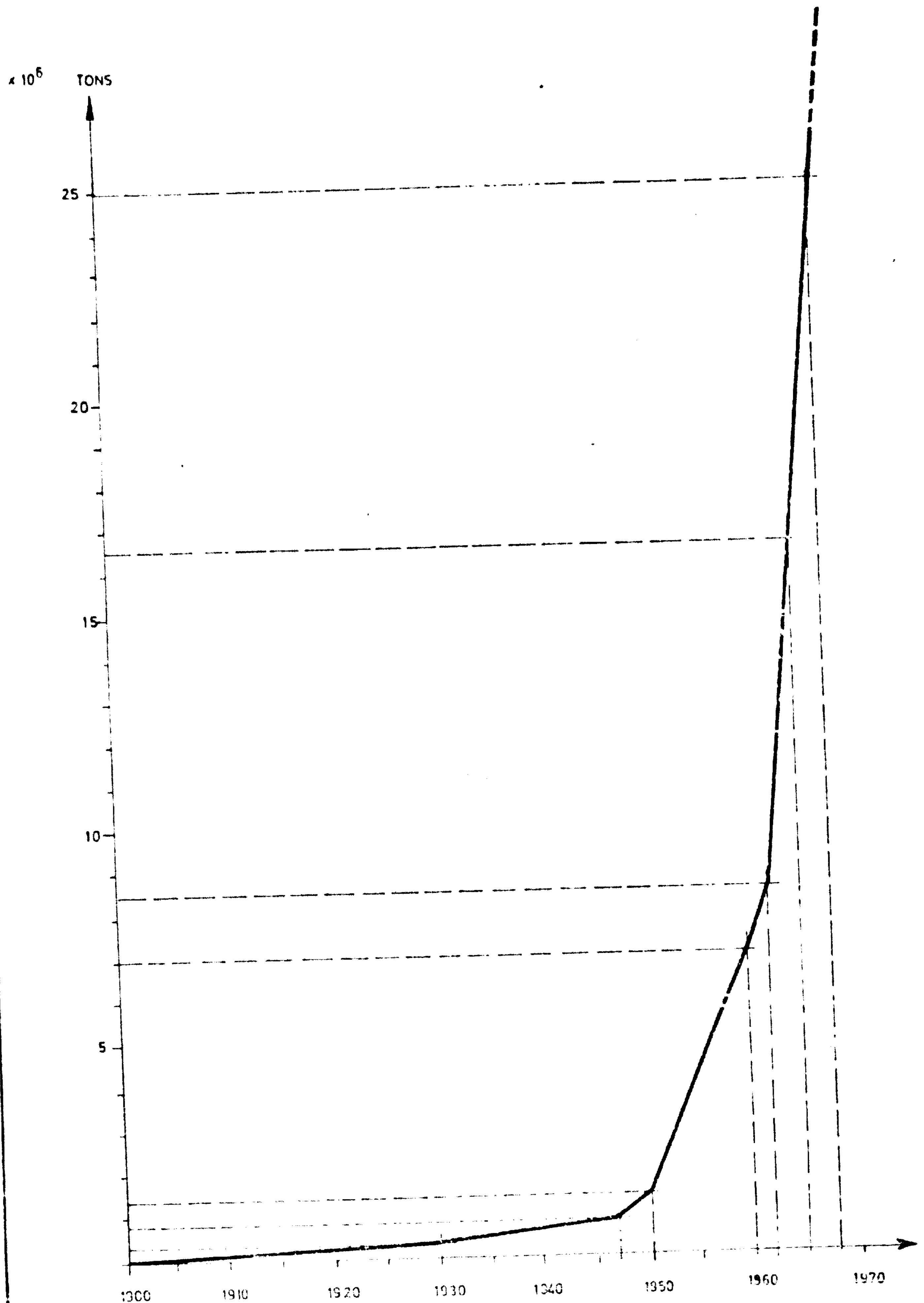
In industrialized countries the combined production of petroleum products and basic materials for the production of petrochemicals has been realized in several integrated plants. This kind of interconnection between crude oil refineries and petrochemical plants may vary from production plants which produce petrochemical raw materials and intermediates and exchange intermediates and by-products, as well as large, completely integrated refineries. This sort of consolidated refinery and petrochemical plant can also be realized in cases of relatively small refineries, if appropriate combinations of processes are selected and the intermediated products occurring in the combined plant, are

DEVELOPMENT OF WORLD PETROCHEMICALS PROD.



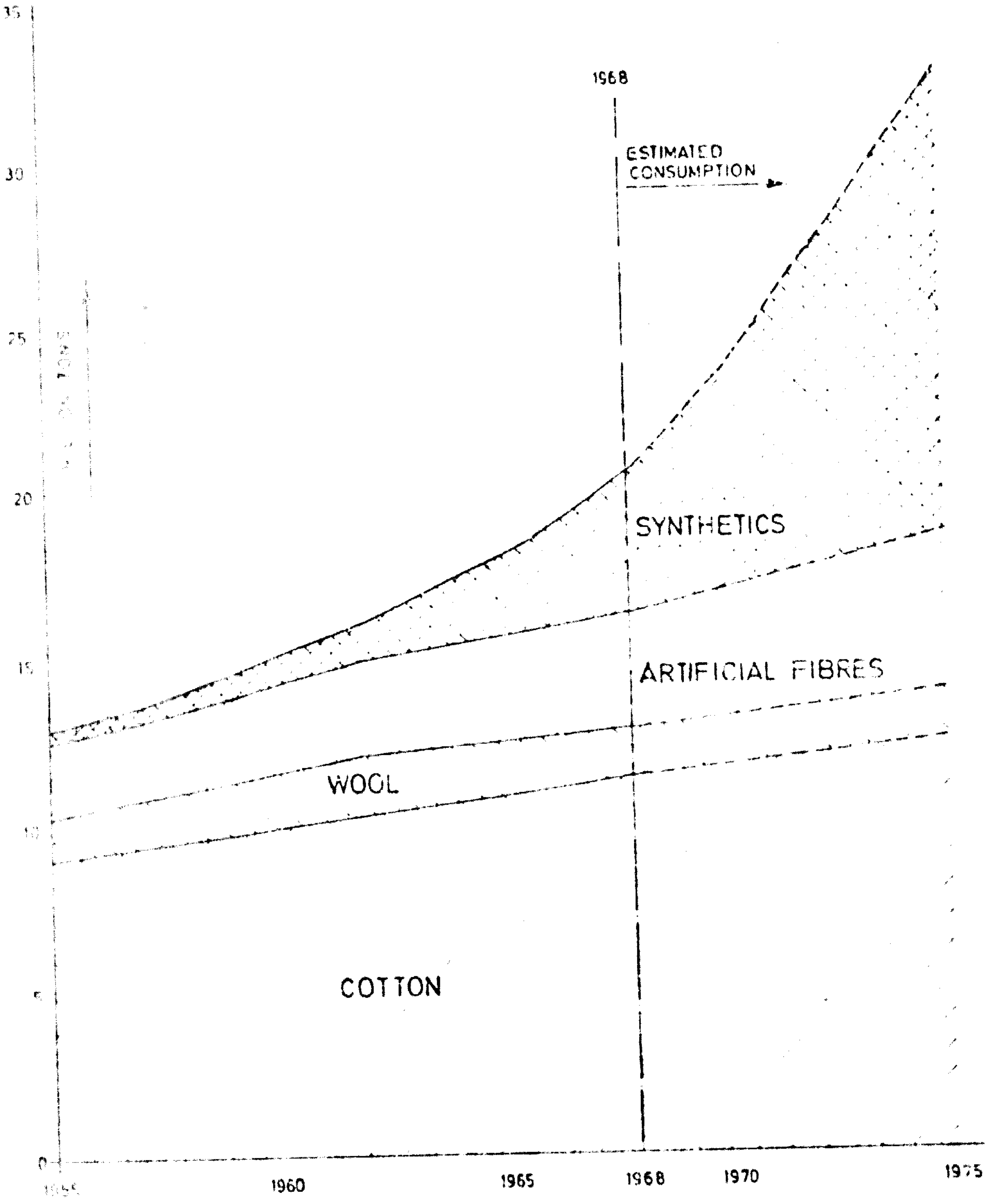
GRAPH 1

PLASTICS PRODUCTION IN THE WORLD 1900 - 1970



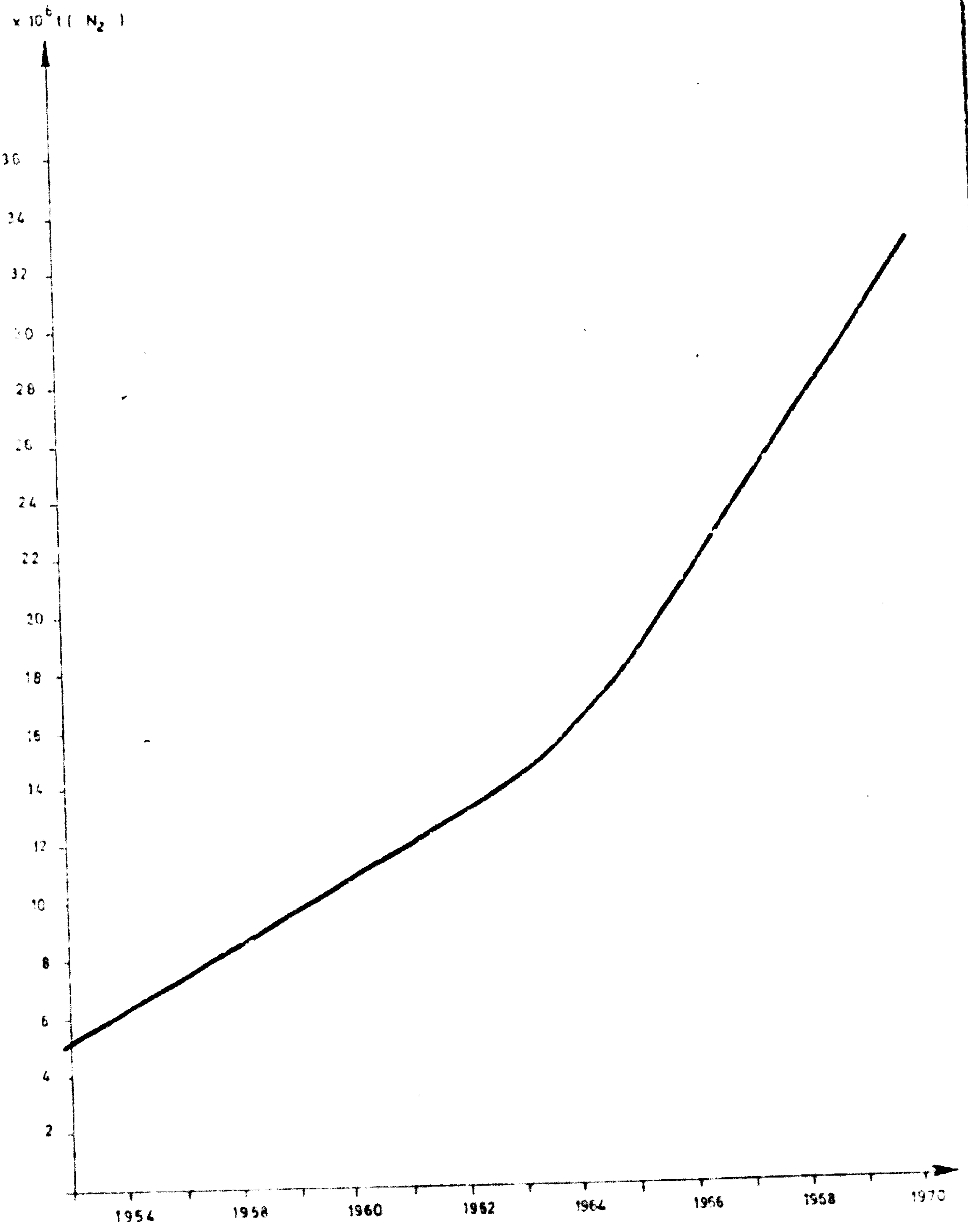
GRAPH 2

TREND OF WORLD FIBER PRODUCTION



GRAPH 3

DEVELOPMENT OF WORLD NITROGEN PRODUCTION



GRAPH 4

further processed in an economic way. These considerations are of special importance, if the design capacity of the diverse plants does not exceed the minimum economic size.

In most of the developing countries the local production of crude oil is limited whereas natural gas resources are often quite abundant. At the moment, they are only used for heating purposes and for power production. By selecting appropriate processes and by fixing favourable capacities for the petrochemical plants, an economic combined production of petrochemicals, plastics, fertilizers and synthetic fibres is certainly possible in such countries.

In either case it is important not to consider such combined plants as an aggregation of several single plants but as an integrated combined production complex, with maximum use of intermediates and by-products.

When utilizing natural gas as raw material for the production of petrochemical products, acetylene is one of the basic materials. Today the improvement of the processes for the production of acetylene makes it possible to produce acetylene at comparatively low costs, provided that the remaining residual gas is used for the production of ammonia, methanol and their derivatives. Although the resulting products based on acetylene are relatively limited, an advantageous combination of processes offers the possibility of producing wide range of final products, which are needed in the developing countries. The economy of such projects depends on a maximum utilization of by-products and on the availability of cheap electrical power, which is most economic if it can be producted in the complex itself.

Many technicians hold the opinion that the processes using acetylene are less economical compared with newly developed processes. This comparison, however, is not always correct, as the published results on this type of new plant are based on plants with a relatively high capacity; in the case of smaller plants the advantages are likely to be less favourable. In many cases the necessary import of relatively expensive catalysts and chemicals, the higher cost of licenses and maintenance increase the production cost when compared with well developed standard processes.

Generally speaking, it can be recommended to select technically less complicated processes incourse of the implementation of local petrochemical industries in developing countries. In industrialized countries it will often be possible to utilise the main part of by-products obtained in the course of production, which could be difficult in developing countries. If this were not the case, the economy of such plants would decrease rapidly. Another important fact one must also consider is that the training of qualified personnel should start in less complicated types of plants. This was the natural way in all countries, even the highest industrialized ones. Based on well-trained personnel, a distinct improvement of standards and an extended degree of industrialization can be better effected step by step.

Proposal for an economic design for the production of petrochemical basic products from gaseous and liquid hydrocarbons

For the production of the most important basic materials such as olefines and aromatics on the basis of liquid hydrocarbons (B.P. 40 - 170°C) the processes which are principally used today differ in the quantitative proportion on olefines, aromatics etc. obtained.

1) Production of olefines by steam cracking with subsequent gas purification and separation, without further processing of the liquid by-products using light naphtha or crude oil as feedstock.
2) Acetylene and ethylene production by cracking or partial oxidation with subsequent gas purification and separation using light naphtha or crude oil as feedstock.
3) Olefines and aromatics production by steam cracking with subsequent gas purification and separation and further processing of the C_4- and gasoline fractions into C_4- hydrocarbons and pure aromatics.
4) Combined olefines and aromatics production from prefractionated petroleum feedstock (40 - 180°C) using full range naphtha feedstock. (Separate transformation of light naphtha and heavy naphtha into olefines and aromatics).

ad 1) For the production of olefines hydrocarbon fractions with a boiling range between 40 - 120°C are to be preferred. The cracking process is carried out at temperatures between 700 - 800°C using a surplus of steam. The resulting reaction mixture is quenched, the heat recovered is used for the production of steam. The quenched reaction mixture is further purified, compressed and separated in a multi-stage gas separation unit. Using light naphtha with the above given specifications, ethylene, propylene and C_4-olefines are obtained in a ratio of 1.0 : 0.8 : 0.5.

ad 2) For the simultaneous production of acetylene and ethylene gaseous hydrocarbons, light naphtha or crude oil are used as feedstock. The pre-heated feedstock is mixed with superheated steam and the reaction is carried out at a temperature of more than 1000°C. The resulting reaction mixture is rapidly cooled by quenching and after its purification acetylene is extracted using selective solvents.

From the remaining gas ethylene is isolated by fractionation. During this process carbon black is obtained as a by-product, which is burnt for the production of steam. Using light naphtha of normal specification, ethylene, acetylene and fuel gas are obtained in a ratio of 1.0 : 0.5 : 3.5.

ad 3) The combined aromatics and olefines production is mostly carried out in larger units. For these processes hydrocarbon fractions are preferred as feedstock which contain cyclic hydrocarbons which react under cracking conditions and form aromatics by dehydrogenation. The cracking process is carried out at a temperature between 750 and 850°C, in the presence of superheated steam. The reaction mixture is rapidly cooled by quenching and separated in a liquid and a gas phase. The gas phase is further processed by low temperature fractionation, whereby ethylene, propylene and C_4-fraction are separated.

The liquid part of the reaction mixture is further processed by catalytic hydrogenation. The hydrogenated gasoline is fractionated, yielding benzene, toluene and higher aromatics. Depending on the composition of the feedstock, the reaction product contains ethylene, propylene, C_4-olefines and aromatics in a ratio of 1.0 : 0.7 : 0.5 : 0.6.

(d 4) [illegible] of olefines and aromatics [illegible] to carry out the olefine and aromatics production in [illegible]. The feedstock full range naphtha fractions with a boiling range between 35 and 180 °C [illegible]. In the case of a [illegible] the feedstock is first fractionated, [illegible] the low-boiling fractions are cracked in [illegible], while the higher-boiling cuts of the feedstock [illegible] processed in a reforming unit.

The light hydrocarbons are cracked under the addition of steam at temperatures between 750 and 850 °C. The cracking product is [illegible] fractionated in a low-temperature fractionation unit. Butadiene, contained in the C_4-fraction, is separated by extraction [illegible]. Ethylene and propylene are obtained as top products in the low-temperature separation. For the production of aromatics the [illegible] heavy naphtha fraction is transformed in a reforming unit, in the presence of selective platinum catalysts by naphthene [illegible] dehydrogenation. The resulting reformate is processed together with the pyrolysis gasoline formed in the cracker unit after [illegible] hydrogenation. For the isolation of aromatics this reaction mixture is further treated by extraction with selective solvents. The paraffinic hydrocarbons resulting from the extraction are recycled to the steam cracker feedstock, while the aromatics fraction is further processed by fine fractionation, yielding benzene, toluene, C_8 and C_9 aromatics. If a higher yield of benzene is desired, the higher-boiling aromatics can be transformed by catalytical dealkylation.

Using naphtha feedstock derived from naphthene-base crude oil, the reaction mixture contains ethylene, propylene, C_4-olefines and aromatics in a ratio of 1.0 : 0.6 : 0.2 : 2.

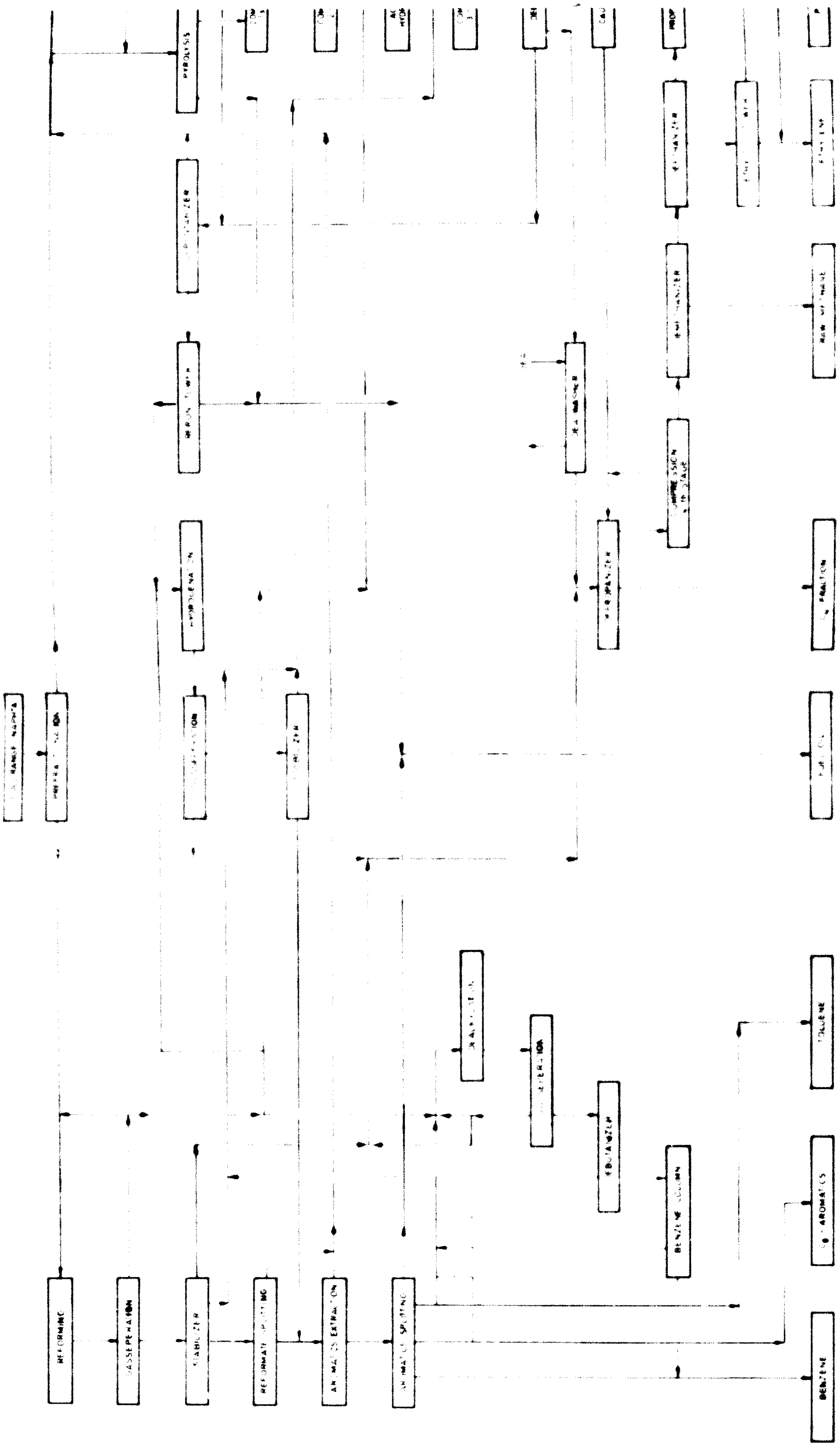
The selection of the most favourable process combination depends on the availability of appropriate feedstocks and the desirable ratio of olefines and aromatics for further processing.

Graph. 5 Different production possibilities for pure olefines and pure aromatics using crude oil and naphtha feedstock of common [illegible].

If natural gas is used as raw material for the production of petrochemicals, acetylene, hydrogen and synthesis gas are the main intermediate products for further transformation and processing. Acetylene is an important intermediate product for the production of a great number of monomers such as vinylchloride, vinylidenechloride, acrylonitrile, vinylacetate, vinylalcohol, etc.

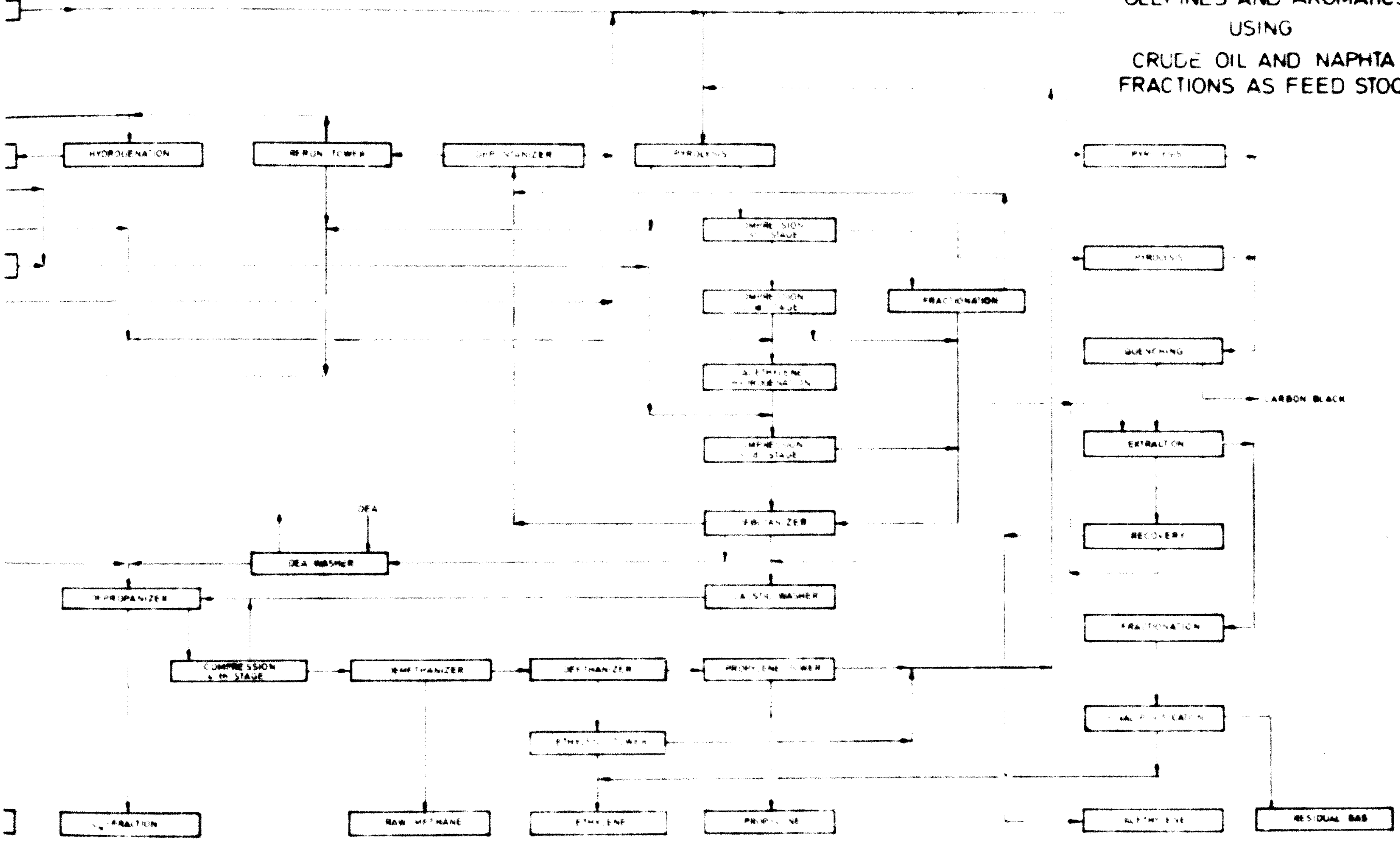
Vinylchloride can be produced by addition of hydrochloric acid to acetylene, using activated carbon impregnated with mercury salt as catalyst. Vinylchloride is one of the most important monomers for the production of plastics and synthetic fibres. Of a total plastic production estimated at 25 million tons in 1970, the production of vinylchloride will amount to about 44%, that is 11 million tons. The greatest market demand is expected to be for suspension polymers using further newly developed processes. By addition of hydrocyanic acid to acetylene in the presence of cuprous salt catalysts, at a temperature of 80°C acrylonitrile is produced. The purification of the reaction product obtained is quite simple and makes it possible to produce acrylonitrile of high purity.

Acrylonitrile and its derivatives such as acrylic esters are important monomers for the production of plastics and synthetic fibres. Further progress can be expected in the field of co-polymers. Vinylacetate, another important monomer, can be produced by reaction of acetylene and acetic acid at a temperature of 120°C in the presence of activated carbon catalysts. Vinylacetate can be further transformed into polymers by homopolymerisation or copolymerisation, with different degrees of polymerisation. These polymers are very important for the production of synthetic glues, paints, textile auxiliaries etc. Polyvinylacetate can also be converted to polyvinyl alcohol, which can be obtained at different degrees of polymerisation. Polyvinyl alcohol has a wide range of applications: as a basic product for the production of textile auxiliaries, impregnation agents, glues, protective colloids, and as basic material and copolymer for the production of synthetic fibres.


REFORMING
GASSEPERATION
STABILIZER
REFORMATE SPLITTING
AROMATICS EXTRACTION
AROMATICS SPLITTING
BENZENE
C8 AROMATICS
TOLUENE
BENZENE COLUMN
DEBUTANIZER
FUEL OIL
C4 FRACTION
RAW METHANE
ETHYLENE
PYROLYSIS
RERUN TOWER
HYDROGENATION
PREFRACTIONATION
FULL RANGE NAPHTHA
DEMETHANIZER
DEPROPANIZER
COMPRESSION 4th STAGE

SECTION 1

DIFFERENT PRODUCTION POSSIBILITIES
OF
OLEFINES AND AROMATICS
USING
CRUDE OIL AND NAPHTA
FRACTIONS AS FEED STOCK



GRAPH 5

SECTION 2

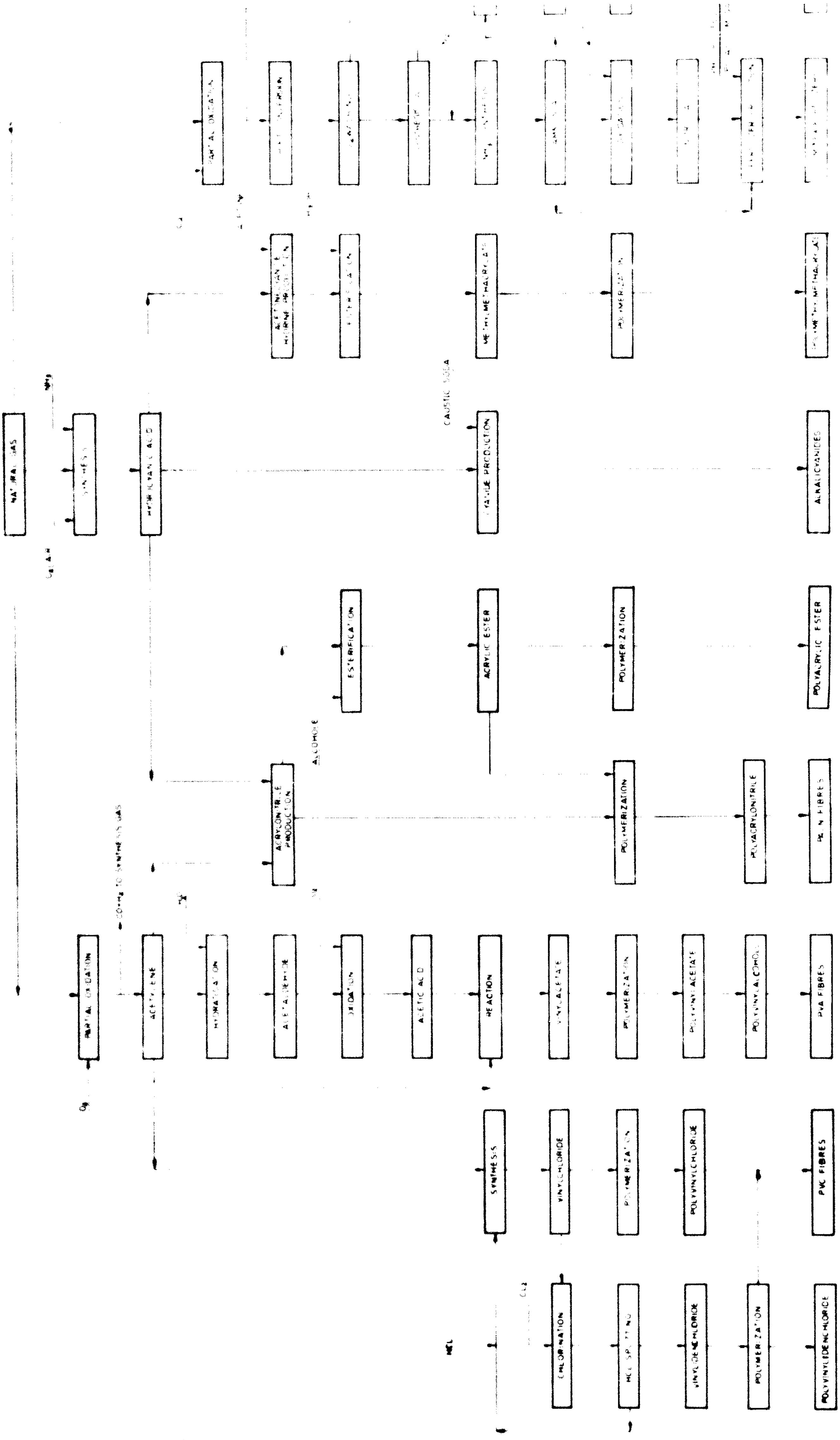
For the production of hydrogen [illegible] mixture [illegible] and oxygen are [illegible] presence of [illegible] production of [illegible] control for [illegible] important basic [illegible] use.

[illegible] suitable for the production of [illegible] important basic material for the production of formaldehyde, which [illegible] transformed with phenol, urea, [illegible] unsaturated pressure [illegible] lacquers, resins, glues etc. The remaining [illegible] used for the production of [illegible] transformation into ammonia [illegible] further [illegible] obtained in the [illegible] nitrogen, urea [illegible] material for the production of [illegible] melamine [illegible] resins.

Graph. 6 [illegible] the [illegible], [illegible] in [illegible].

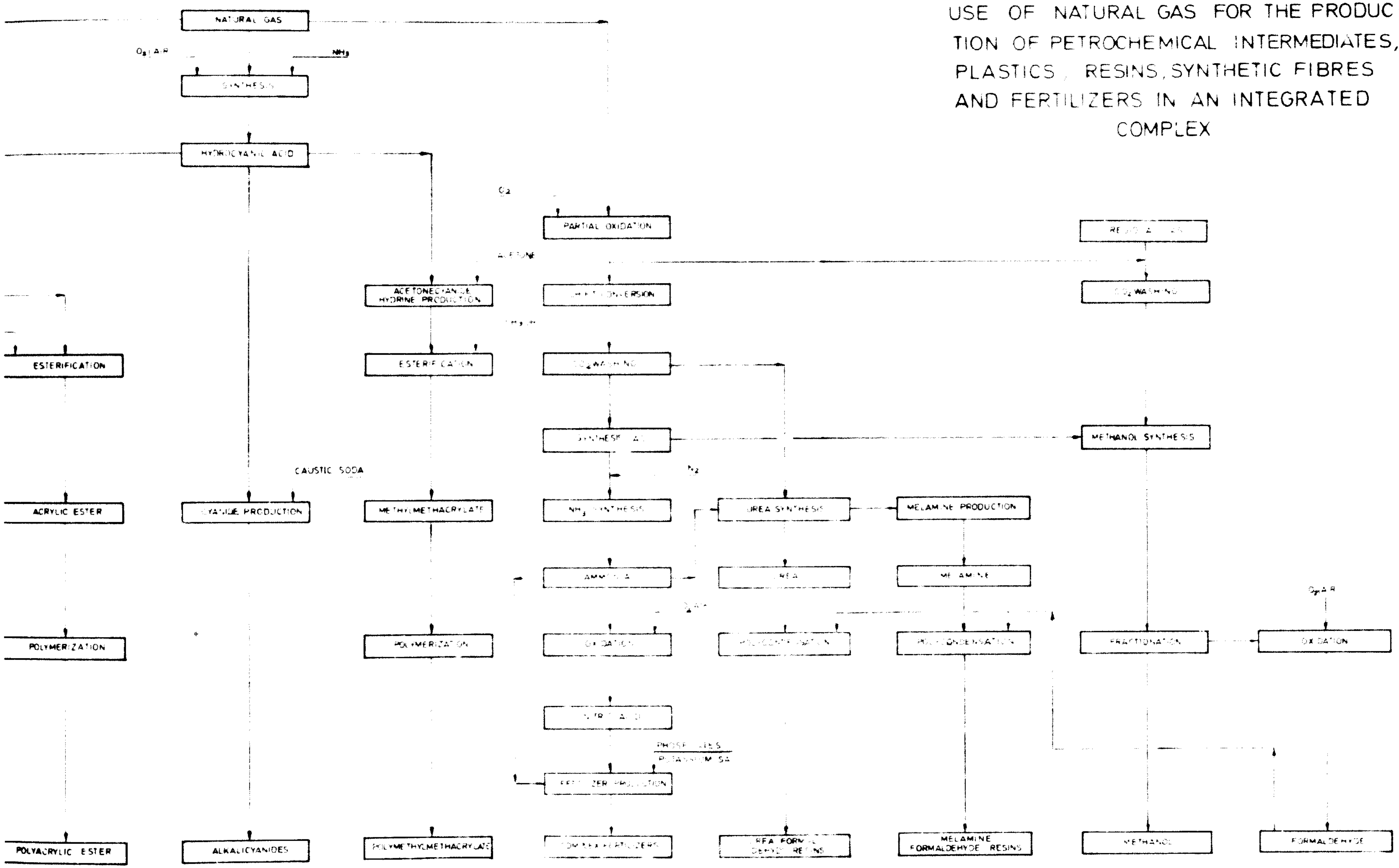
Overall profit [illegible] depends to a large extent [illegible] course of operation. [illegible] about 35 - [illegible] is transf[illegible] ation. Their [illegible] increased [illegible].

[illegible] production of acetylene of [illegible] and oxygen, about [illegible] - [illegible] raw material


NATURAL GAS
NH3
SYNTHESIS
HYDROCYANIC ACID
PARTIAL OXIDATION
ACETONE CYANOHYDRINE PRODUCTION
METHYLMETHACRYLATE
POLYMERIZATION
POLYMETHYLMETHACRYLATE
CAUSTIC SODA
CYANIDE PRODUCTION
ALKALICYANIDES
ESTERIFICATION
ACRYLIC ESTER
POLYMERIZATION
POLYACRYLIC ESTER
ALCOHOLE
ACRYLONITRILE PRODUCTION
POLYMERIZATION
POLYACRYLONITRILE
PAN FIBRES
CO+H2 TO SYNTHESIS GAS
PARTIAL OXIDATION
ACETYLENE
HYDRATATION
ACETALDEHYDE
OXIDATION
ACETIC ACID
REACTION
VINYLACETATE
POLYMERIZATION
POLYVINYLACETATE
POLYVINYLALCOHOL
PVA FIBRES
SYNTHESIS
VINYLCHLORIDE
POLYMERIZATION
POLYVINYLCHLORIDE
PVC FIBRES
HCl
Cl2
CHLORINATION
HCl SPLITTING
VINYLIDENECHLORIDE
POLYMERIZATION
POLYVINYLIDENECHLORIDE

SECTION 1

MOST IMPORTANT POSSIBILITIES FOR THE USE OF NATURAL GAS FOR THE PRODUCTION OF PETROCHEMICAL INTERMEDIATES, PLASTICS, RESINS, SYNTHETIC FIBRES AND FERTILIZERS IN AN INTEGRATED COMPLEX



GRAPH 6

SECTION 2

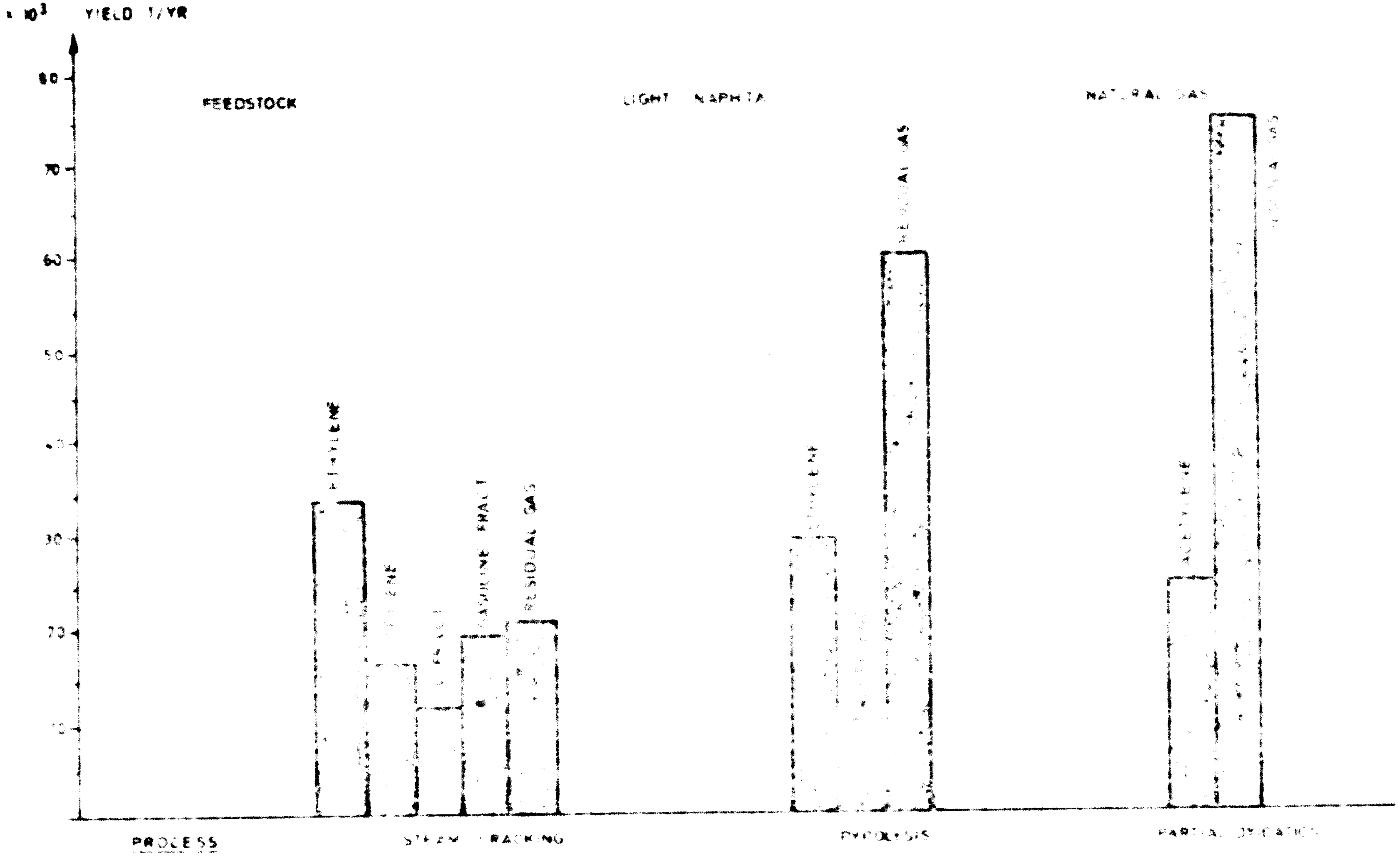
is transformed into residual gas, which should be transformed into fertilisers, methanol, formaldehyde and its derivates to secure a better viability for the whole complex.

Graph. 7 Average distribution of petrochemical intermediates obtained by steam cracking, pyrolysis and partial-oxidation processes based on 100,000 tons feedstock.

Intermediate and final products based on olefins

Ethylene constitutes the major part of pure olefins isolated in the course of their separation and purification and is an important basic material for the production of intermediate and final products.

By oxidation at selective silver catalysts it can be transformed into ethyleneoxide, which is an important raw material for the production of ethyleneglycol. By transformation of ethyleneoxide with alcohols glycolethers are obtained. Etherification products with low moleculer alcohols are important solvents, whereas the products with higher alcohols and phenols are used as detergents etc. By the transformation of ethyleneoxide with ammonia ethanolamines are obtained, which are mostly used for the production of textile auxiliaries. By homopolymerisation of ethyleneoxide in the presence of alkaline catalysts polyethyleneoxide with different degrees of polymerisation can be produced. By catalytic oxidation of ethylene in liquid phase and in the presence of palladiumchloride catalysts, acetaldehyde is produced, an important intermediate for the production of ethanol, acetic acid, vinylacetate etc. By catalytic hydratisation of ethylene in the gas phase using selective catalysts, ethylene can also be transformed directly into ethylalcohol. By chlorination or oxychlorination of ethylene vinylchloride is obtained as final product. It is one of the most important monomers for the production of plastics. By catalytic alkylation of benzene with ethylene different monomers can be produced. One of the most important products is styrene which is produced in large quantities by gasphase arylization at elevated temperatures and at elevated pressure. Similar products are obtained by alkylation of toluene which can be transformed into methylstyrene. Ethylene itself as well as the monomers mentioned above can be polymerized to important polymers, with a wide


x 10³ YIELD T/YR
80
70
60
50
40
30
20
10
FEEDSTOCK
LIGHT NAPHTA
NATURAL GAS
ETHYLENE
PROPYLENE
GASOLINE FRACT
RESIDUAL GAS
ETHYLENE
RESIDUAL GAS
ACETYLENE
RESIDUAL GAS
PROCESS
STEAM CRACKING
PYROLYSIS
PARTIAL OXIDATION

GRAPH 7

[illegible] Ethylene can be [illegible]

[illegible], fertilizers [illegible] can be produced by [illegible]

[illegible] to the improvements in the [illegible] ethyl chloride is mainly used for the production of [illegible]

[illegible] the production of [illegible] fibres.

Vinyl [illegible] with [illegible] of consumer [illegible]

[illegible] chloride, [illegible] or soda [illegible] industry [illegible] which may be [illegible]

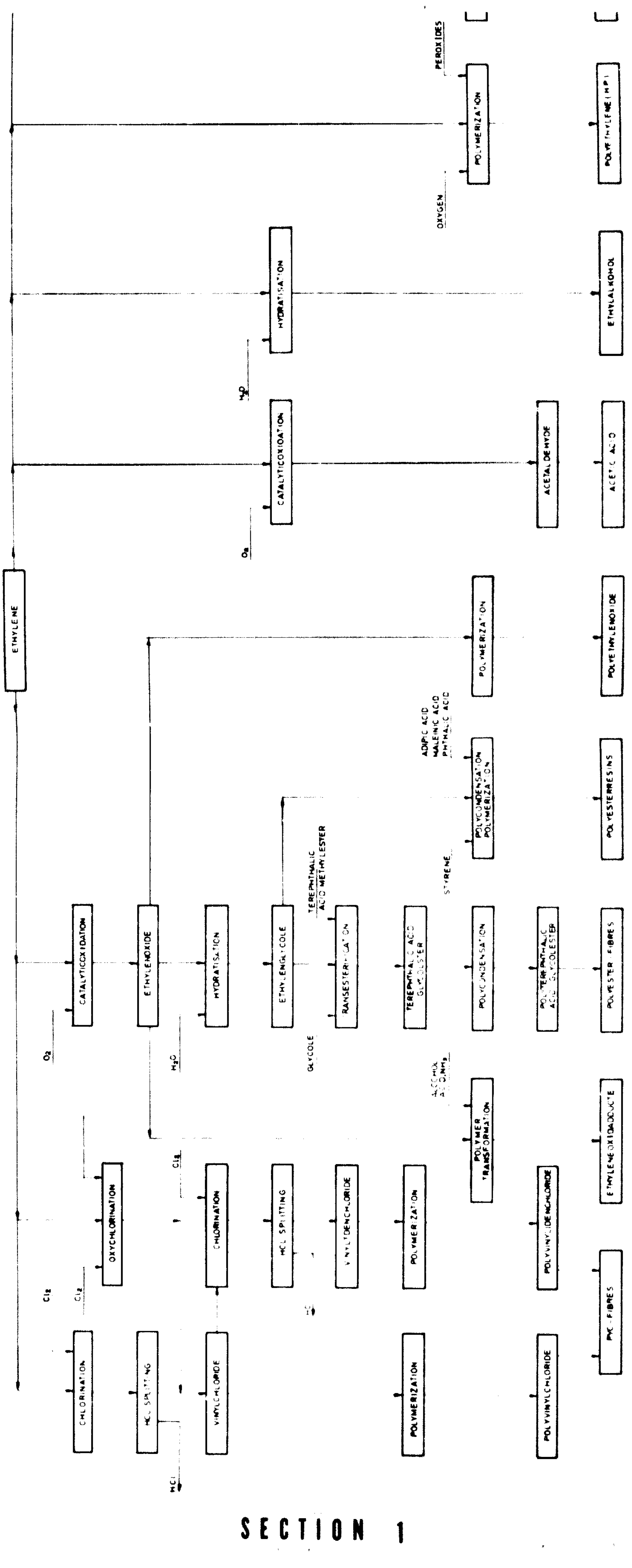
[illegible], the production of [illegible]. Its polymerization [illegible] are mainly produced by suspension polymerisation or [illegible] polymerisation, especially with butadiene and acrylonitrile. By copolymer- [illegible] high-grade types of synthetic [illegible]. Polystyrenes [illegible] and building materials [illegible] other goods. By co- [illegible] in appreciable quantities, butadiene- [illegible] types of [illegible]

[illegible] Different possibilities for the production of intermediates, petrochemicals, plastics and synthetic fibres on the basis of propylene

[illegible] olefines, [illegible] major component [illegible] especially under the conditions of developing [illegible] utilise [illegible] amount of the propylene [illegible]

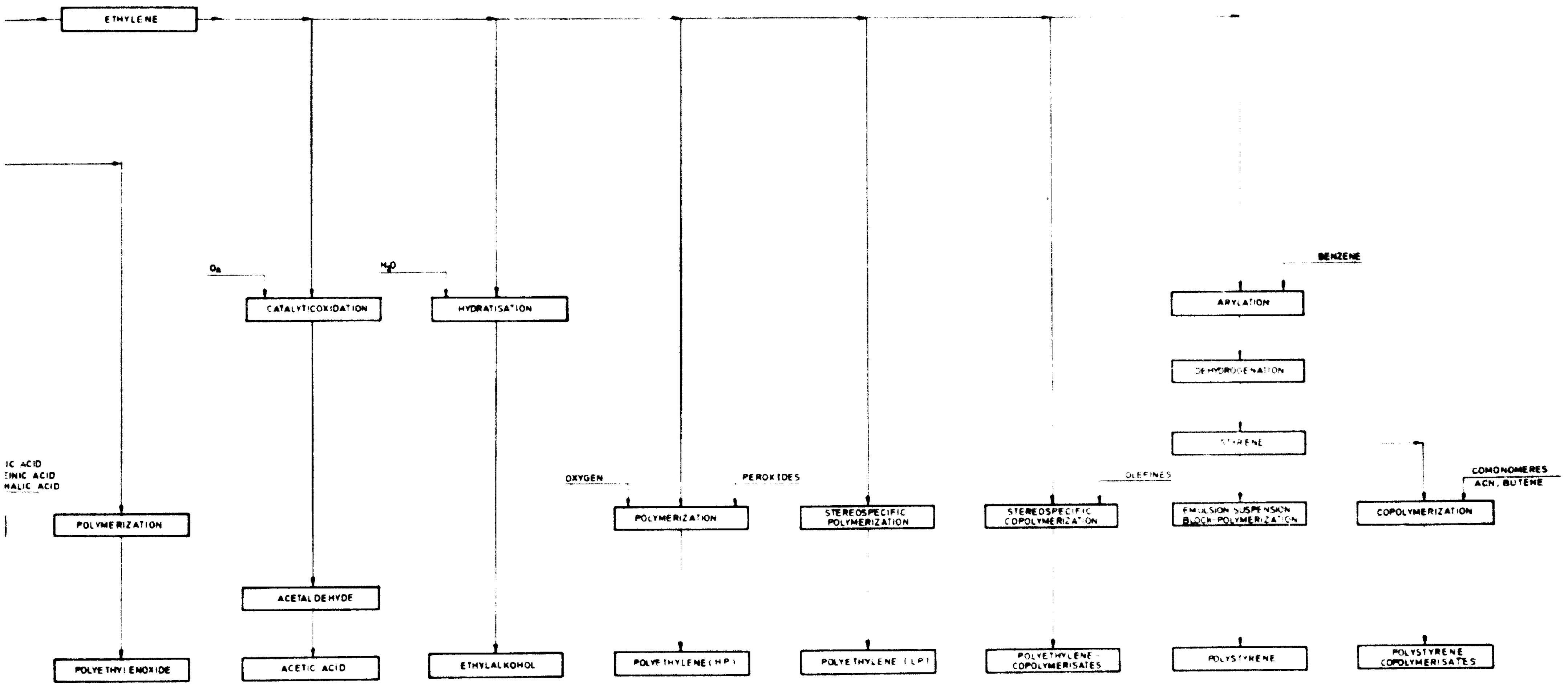
[illegible] produced, an [illegible] liquid phase [illegible] is obtained. Isopropyl- [illegible] propylene in the [illegible] catalysts [illegible]. It can be [illegible] alcohol are also im- portant products [illegible] synthetic glycerine [illegible] monomer for the production [illegible] of propylene in the [illegible] nitrile can be [illegible]. Acrylonitrile is an important monomer [illegible] for the production of copolymers [illegible] polyacrylonitrile fibres [illegible] fibres.

The chlorinated products of propylene [illegible] important basic materials [illegible] production of epichlorohydrine, [illegible] propylene-chlorohydrine,


ETHYLENE
CHLORINATION
HCL SPLITTING
HCl
VINYLCHLORIDE
Cl2
Cl2
OXYCHLORINATION
CHLORINATION
Cl2
HCL SPLITTING
VINYLIDENCHLORIDE
POLYMERIZATION
POLYMERIZATION
POLYVINYLCHLORIDE
POLYVINYLIDENCHLORIDE
PVC-FIBRES
ETHYLENEOXIDADDUCTE
ALCOHOL ACID NH3
POLYMER TRANSFORMATION
O2
CATALYTICOXIDATION
ETHYLENOXIDE
H2O
HYDRATISATION
ETHYLENGLYCOLE
GLYCOLE
TEREPHTHALIC ACID METHYLESTER
TRANSESTERIFICATION
TEREPHTHALIC ACID GLYCOLESTER
POLYCONDENSATION
POLYTEREPHTHALIC ACID GLYCOLESTER
POLYESTER FIBRES
STYRENE
POLYCONDENSATION POLYMERIZATION
ADIPIC ACID
MALEINIC ACID
PHTHALIC ACID
POLYESTERRESINS
POLYMERIZATION
POLYETHYLENOXIDE
O2
CATALYTICOXIDATION
ACETALDEHYDE
ACETIC ACID
H2O
HYDRATISATION
ETHYLALKOHOL
OXYGEN
POLYMERIZATION
PEROXIDES
POLYETHYLENE (HP)

SECTION 1

DIFFERENT POSSIBILITIES FOR THE PRODUCTION OF INTERMEDIATES PETRO-CHEMICALS PLASTICS AND SYNTHETIC FIBRES ON THE BASIS OF ETHYLENE



GRAPH 8

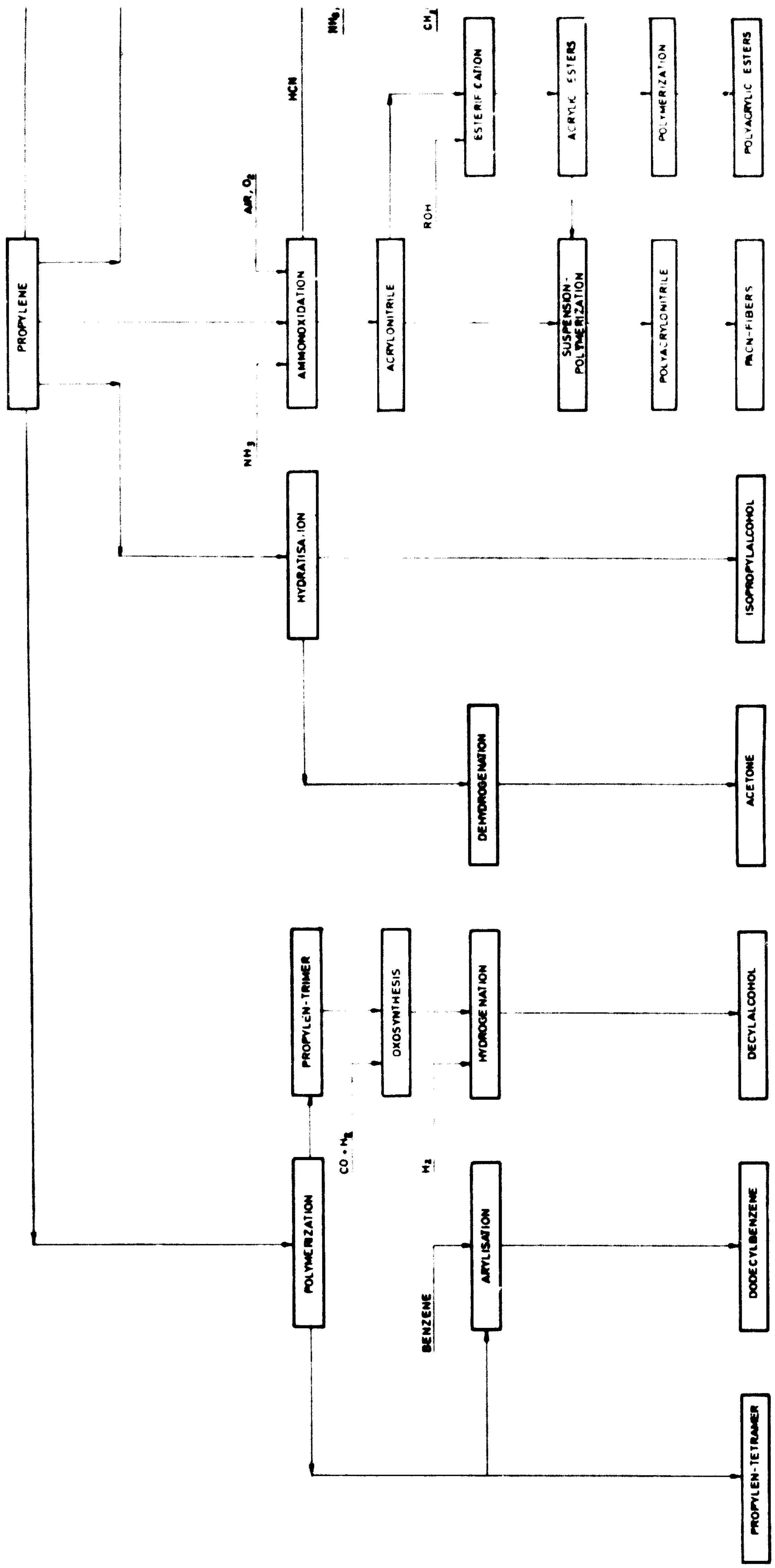
SECTION 2

as basic materials for the production of moulding resins and propylene-glycols.

By alkylation of benzene with propylene in the gas phase, using selective catalysts, cumene is produced which can be split into phenol and acetone, both being important basic materials. In addition to the production of acrylonitrile fibres via propylene the stereospecific polymerisation of propylene to isotactic polymers may get considerable importance for developing countries. The latest developments of processes using polypropylene as raw material for the production of synthetic fibres indicate that polypropylene fibres can be processed to suitable fabrics or mixed fabrics of low weight. The cost for the production of this fibre can be lowered in case that polypropylene is produced in a plant of larger capacity and that the balance is used for the production of plastics. Especially in developing countries the combined production of fibres and processed consumer goods based on polypropylene can be expected to be profitable. By a reproducable polymerisation of propylene, in the presence of phosphoric acid catalysts, trimeric and tetrameric propylene is obtained. Trimeric propylene can be further processed by oxo-synthesis to decylaldehyde and decylalcohol, which is an important softener and a basic product for the detergent and plasticizers industries Tetrameric propylene is the basic material for the production of dodecylbenzenesulphonate. By copolymerisation of ethylene with propylene or other olefines, rubber-like polymerisates can be obtained. These will become more and more important in future years. From the products mentioned above polyacrylonitrile, polypropylene and their copolymers are the most important products in regard to the situation in developing countries, especially for the economic utilisation of this by-product.

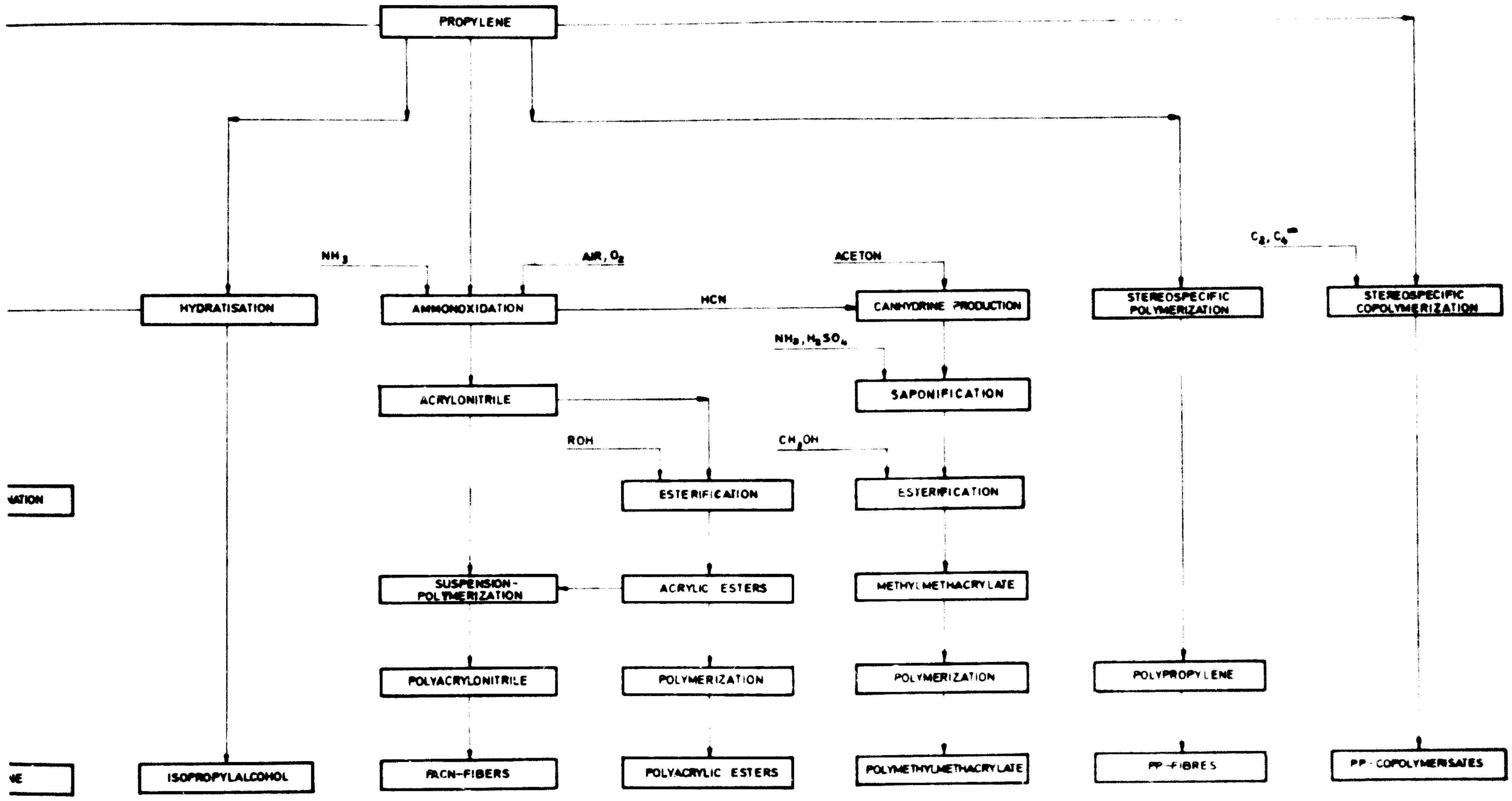
Graph. 9 Different possibilities for the production of intermediates, petrochemicals, plastics and synthetic fibres on the basis of propylene

In the course of the production of olefins appreciable quantities of C_4-olefines are obtained. The most important among them is butadiene. The butadiene content depends on the cracking conditions selected. Using


PROPYLENE
AIR, O2
HCN
NH3
CH4
NH3
AMMONOXIDATION
ACRYLONITRILE
ROH
ESTERIFICATION
ACRYLIC ESTERS
POLYMERIZATION
POLYACRYLIC ESTERS
SUSPENSION-POLYMERIZATION
POLYACRYLONITRILE
PACN-FIBERS
HYDRATISATION
ISOPROPYLALCOHOL
DEHYDROGENATION
ACETONE
POLYMERIZATION
PROPYLEN-TRIMER
CO + H2
OXOSYNTHESIS
H2
HYDROGENATION
DECYLALCOHOL
BENZENE
ARYLISATION
DODECYLBENZENE
PROPYLEN-TETRAMER

SECTION 1

PRODUCTION OF PETROCHEMICAL PRODUCTS
BASED ON
PROPYLENE



GRAPH 9

SECTION 2

light naphtha of normal specification, by mild cracking about 11 - 14% C_4 fraction can be obtained. This fraction contains 30 - 40% butadiene. For the separation of butadiene selective solvents are usually applied, such as acetonitrile, [illegible] made etc. In the course of its purification, higher acetylenes have first to be removed, and mostly using the same solvent. Butadiene is one of the most important monomers for the production of synthetic rubber, either by stereo-specific polymerisation or by copolymerisation with styrene and/or acrylonitrile. These products possess a wide range of application for the production of synthetic rubber and plastics.

Whereas, a few years ago, the largest part of butadiene was produced by catalytic dehydrogenation of n-butene, the selective extraction has more and more prevailed in recent years; because of the bringing on stream of large cracking units, the output of butadiene-containing fractions has thus been considerably increased. In developing countries the dehydrogenation of n-butene in order to increase the production of butadiene should be considered in the planning of producing the usual types of rubber. The development in the field of copolymerisates should be considered, especially so as to obtain the maximum utilization of products contained in the C_4-fraction (i-butene, n-butane).

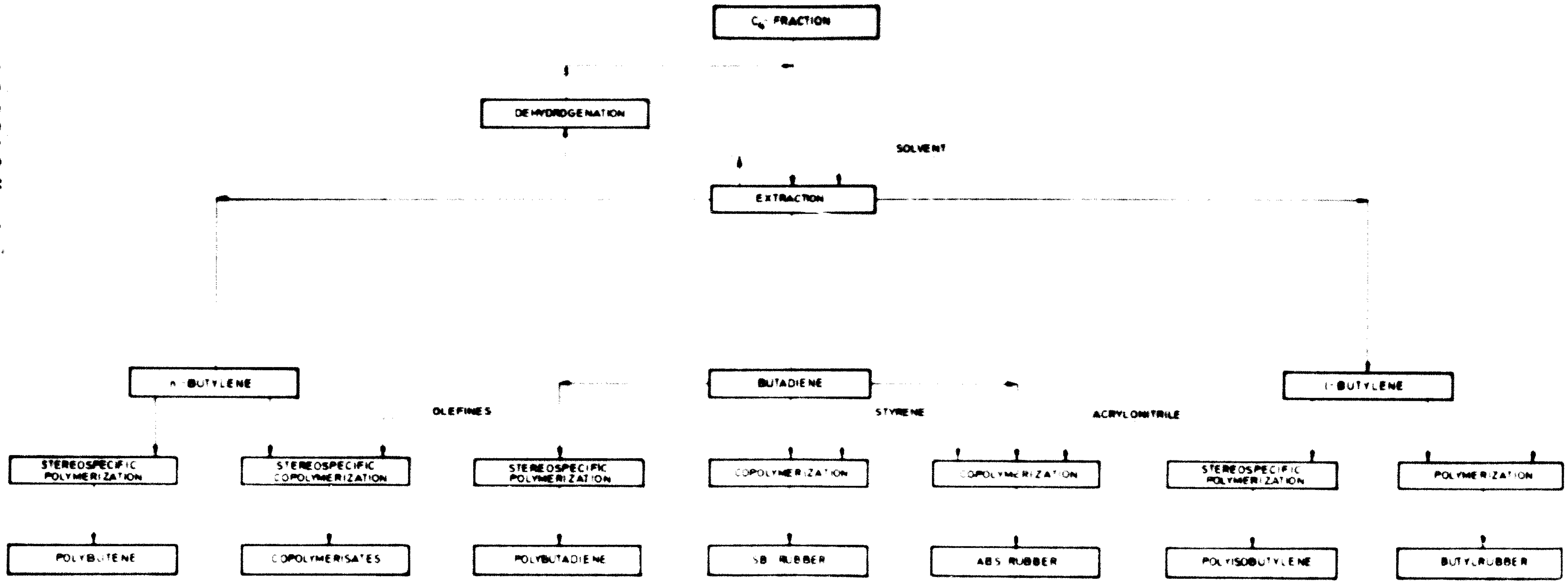
On one hand the local production of synthetic rubber is of great importance for many countries. On the other hand, from the point of view of a maximum utilization of the coproducts obtained during the cracking of light naphtha, these considerations are also important for the whole economy of integrated plants in developing countries.

Graph. 10 Processing possibilities of C_4-hydrocarbons to different rubber types.

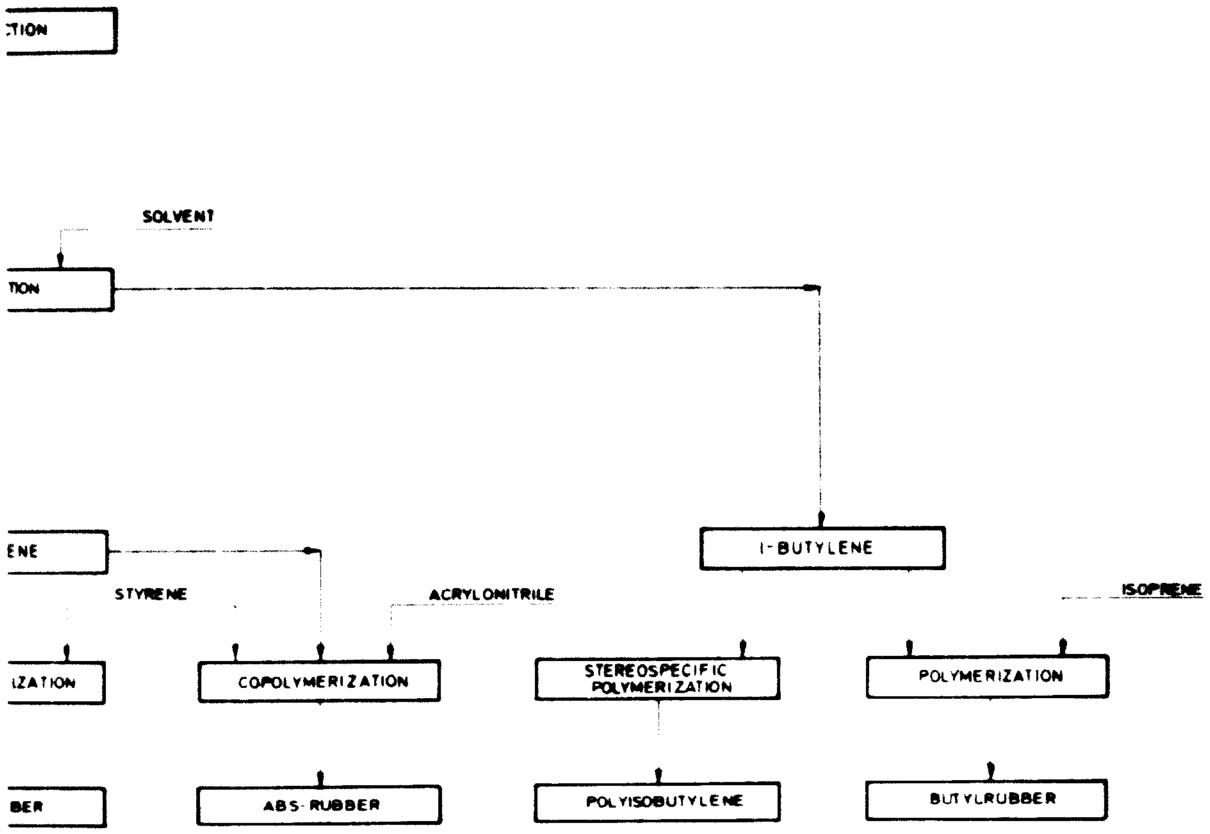
Intermediate and final products based on aromatics

By cracking of hydrocarbons, and in case of combined aromatics and olefines production in a petrochemical combined plant aromatic fractions are obtained which contain aromatics at different concentrations. The content of aromatics depends on the composition of the hydrocarbon feedstock,

SECTION 1


C_4 FRACTION
DEHYDROGENATION
SOLVENT
EXTRACTION
n-BUTYLENE
BUTADIENE
i-BUTYLENE
OLEFINES
STYRENE
ACRYLONITRILE
STEREOSPECIFIC POLYMERIZATION
STEREOSPECIFIC COPOLYMERIZATION
STEREOSPECIFIC POLYMERIZATION
COPOLYMERIZATION
COPOLYMERIZATION
STEREOSPECIFIC POLYMERIZATION
POLYMERIZATION
POLYBUTENE
COPOLYMERISATES
POLYBUTADIENE
SB RUBBER
ABS RUBBER
POLYISOBUTYLENE
BUTYLRUBBER

PROCESSING POSSIBILITIES OF
C_4 - HYDROCARBONS
TO
DIFFERENT RUBBER TYPES



GRAPH 10

SECTION 2

the cracking conditions selected and finally on the reforming process used. Gasoline fractions from steam cracking processes which occur in a yield of 15 - 20 % contains about 30 - 35 % benzene. The balance consists of toluenes and xylenes. Reformates or platformates contain less benzene and a larger quantity of higher aromatics. As benzene is the most important of the aromatics contained in aromatic fractions the output of benzene can be increased by dealkylation. From the higher aromatics p-xylene and o-xylene are mostly used for further processing to intermediates. (Phtalic acid, therephtalic acid, DMT etc.)

Benzene is the most important basic material for the production of nylon-6 and nylon-66 via cyclohexane and cyclohexanol, from the catalytic oxidation of cyclohexene in the liquid phase are caprolactam and adipic acid, the monomers for the production of polyamides, nylon-6 and nylon-66 which are highly important basic materials for the production of synthetic fibres. Polymides are also used for manufacturing of abrasion resistant parts of machinery and equipment.

By the oxidation of benzene in the presence of vanadium catalysts maleicacid anhydride can be produced. This is an important basic material for the production of alkyd resins. By alkylation of benzene with ethylene styrene via ethylbenzene is obtained and by alkylation with propylene, phenol and acetone via cumene as intermediate. Styrene is an important raw material for the production of plastic goods and films with the widest range of application in the field of packing, the building industry and the production of consumer goods. Phenol and acetone are basic materials for the production of resins and artificial glass (cfg). By catalytic oxidation of o-xylene in the gas phase phthalic anhydride can be produced. After esterification with higher alcohols it is an important basic material for the production of softeners and plasticizers. By catalytic oxidation of p-xylene in the liquid phase using selective catalysts tere-phthalic acid can be produced. The esterification product of terephthalic acid with methanol (di-methyltherephthalte) as well as the acid itself are important basic materials for the production of polyester products, after their transesterification or esterification with ethylene glycol. By polycondensation terephthalicacidglycolesters with different degrees of polymerisation are obtained. These are important raw materials for the production of films, plastic goods and for the production of polyester fibres. Polyester fibre is one of the most important synthetic fibres for the [illegible] of [illegible] in [illegible] with wool, cotton or other synthetic fibres. In developing countries, which possess local resources of crude oil and which are going to establish a petrochemical industry in line with local refineries. Under these circumstances, the combined production of [illegible] polyolefin fibres or polyprolylene fibres can also be of interest.

Graph. 11 [illegible] most important petrochemical [illegible]

The implementation of combined plants for the production of petrochemicals in developing countries depends to a large extent on the raw material resources in the countries.

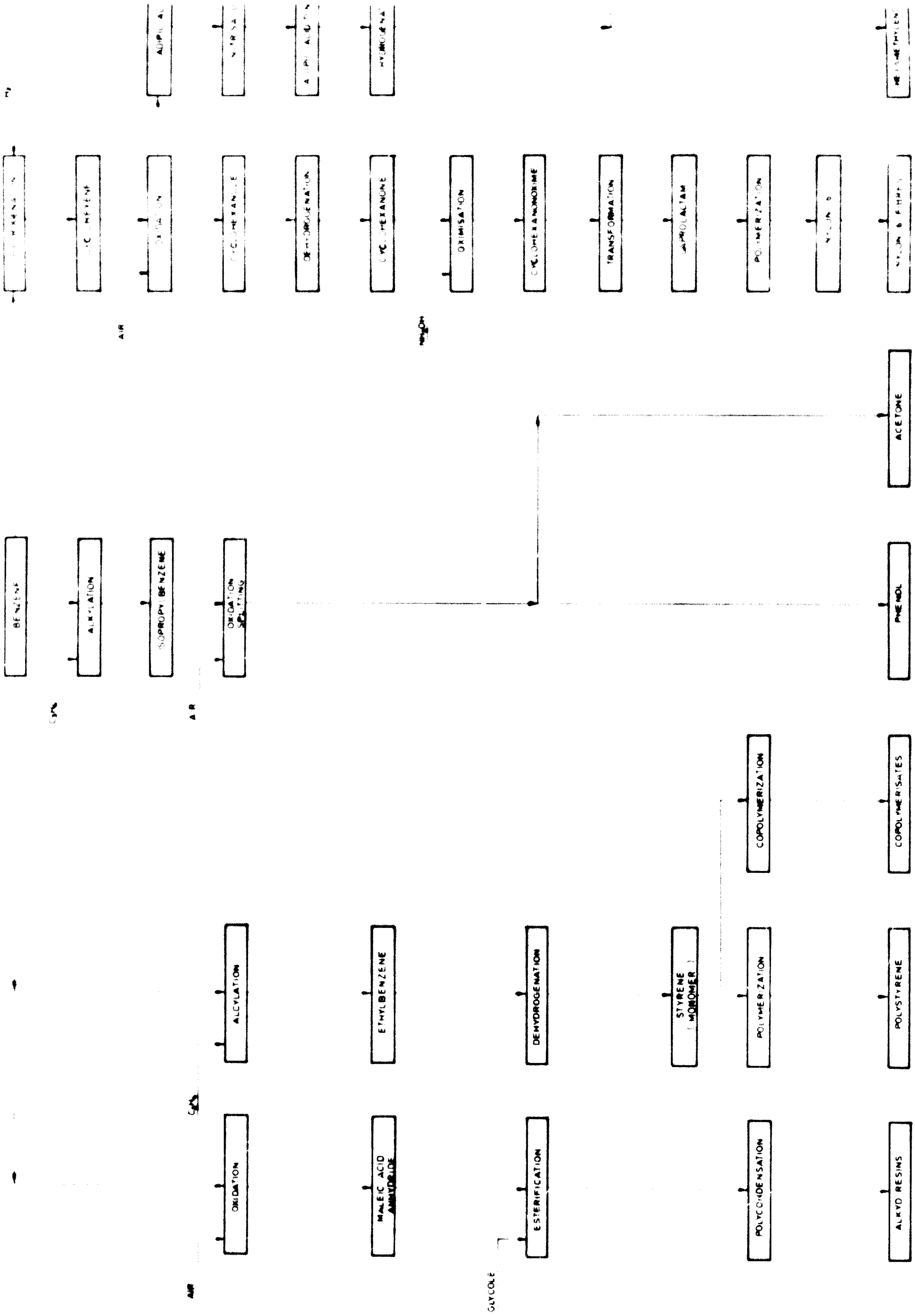
In regard to the availability of raw materials developing countries generally speaking, can be divided into three groups:

1) Developing countries which possess crude oil and natural gas but limited resources of minerals, iron, coal and wood.
2) Developing countries which possess only natural gas as basic material for petrochemical industries, but sufficient resources of minerals and wood.
3) Developing countries which possess only substantial resources of natural gas as basic material and limited amounts of minerals and wood.

This enumeration is, of course, not comprehensive.

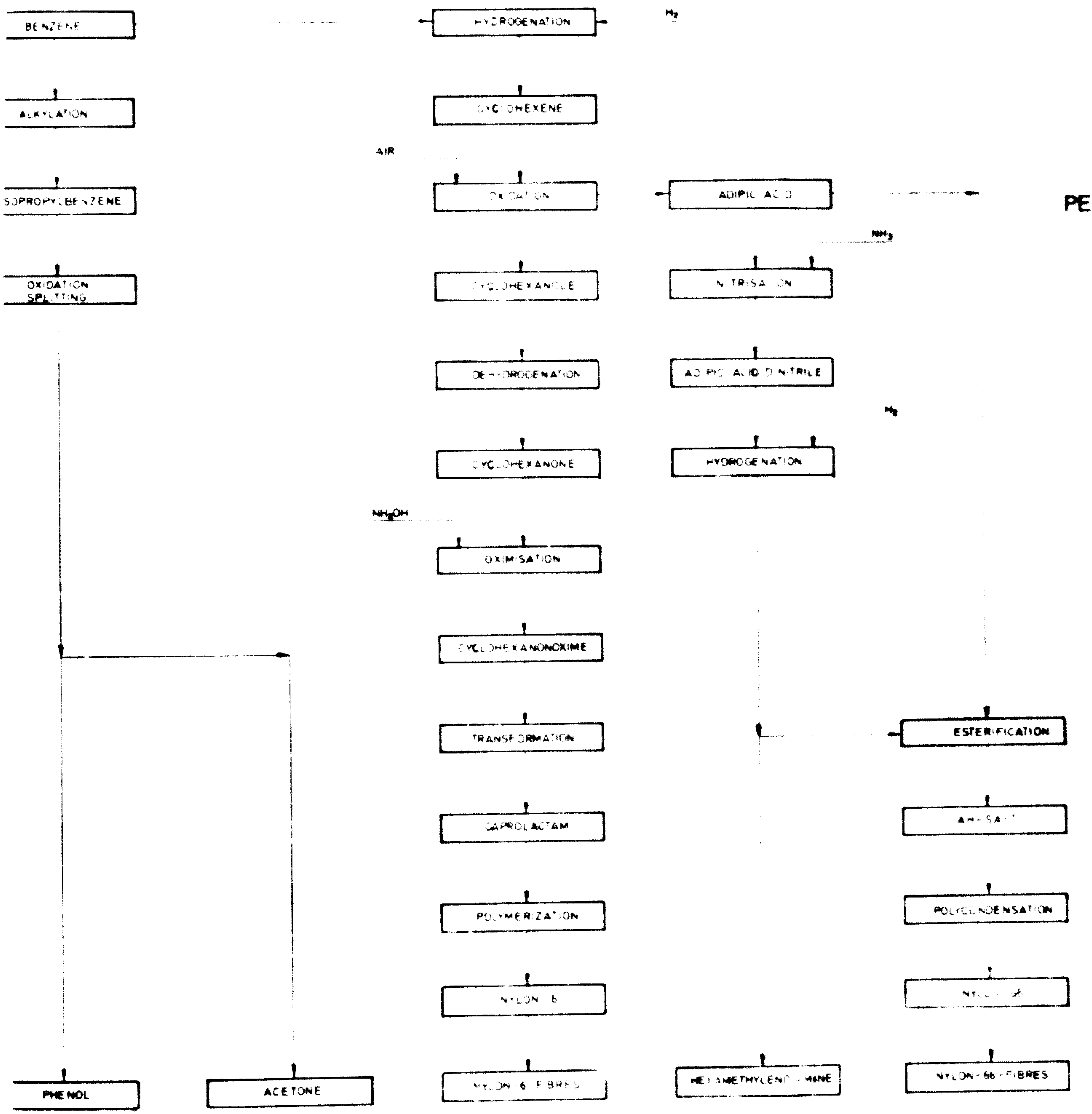
There are many alternatives and these are only examples for cases of extreme conditions.

Careful planning of petrochemical combined plants, considering all local aspects, will make it possible to establish local petrochemical industry which can provide basic materials for a large processing industry, for the manufacture of technical goods replacing iron, steel or concrete in combination with locally available wood or other locally available cheap raw materials. The modern processing industry offers numerous opportunities


BENZENE
ALKYLATION
ISOPROPYLBENZENE
OXIDATION SPLITTING
AIR
ACETONE
PHENOL
DEHYDROGENATION
CYCLOHEXANONE
OXIMISATION
NH2OH
CYCLOHEXANONOXIME
TRANSFORMATION
CAPROLACTAM
POLYMERIZATION
AIR
ADIPIC AC
HYDROGENA
COPOLYMERIZATION
COPOLYMERISATES
ALCYLATION
ETHYLBENZENE
DEHYDROGENATION
STYRENE (MONOMER)
POLYMERIZATION
POLYSTYRENE
AIR
OXIDATION
MALEIC ACID ANHYDRIDE
ESTERIFICATION
GLYCOLE
POLYCONDENSATION
ALKYD RESINS

SECTION 1

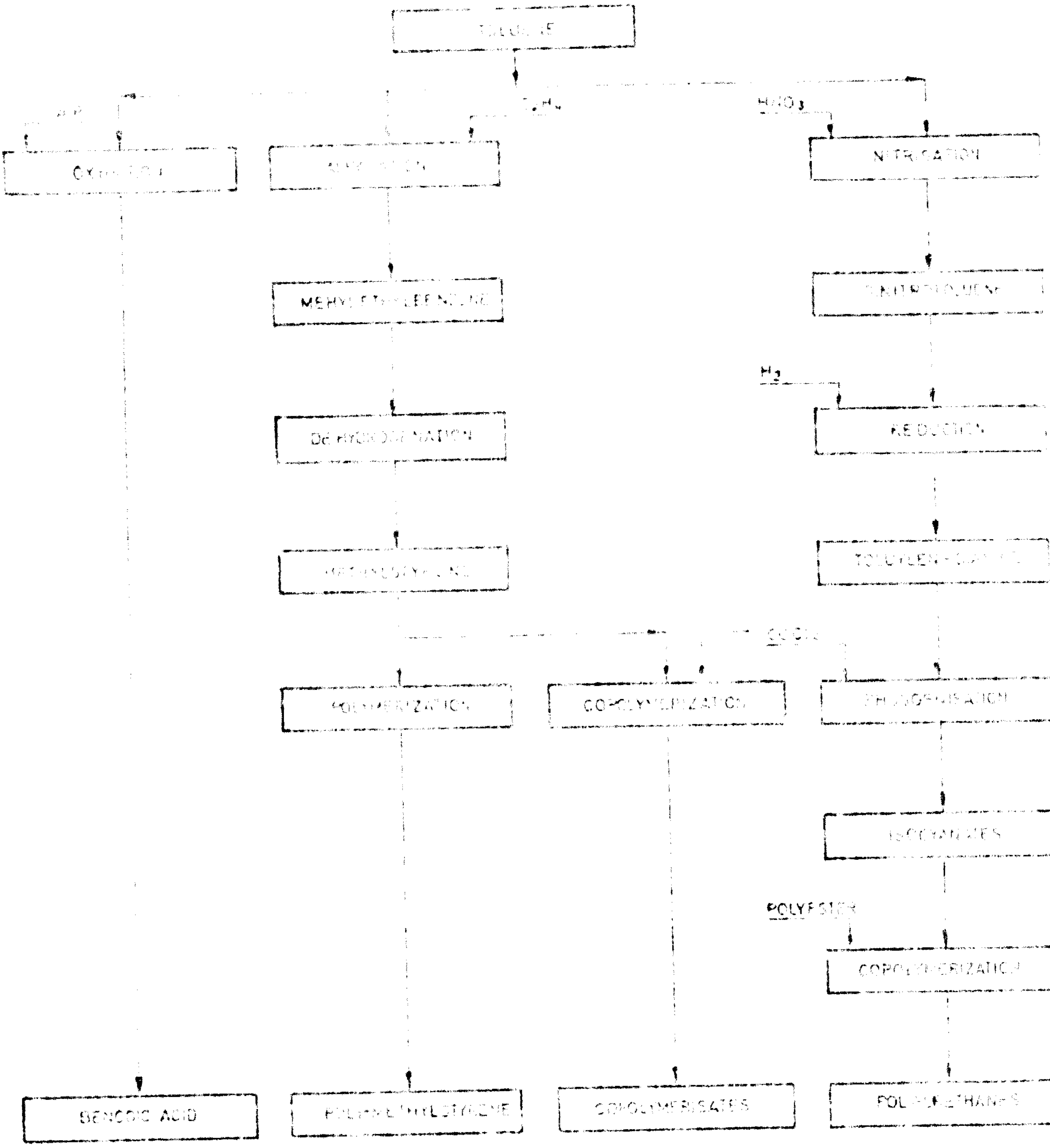
PETROCHEMICAL PRODUCTS BASED ON BENZENE



GRAPH 11 a

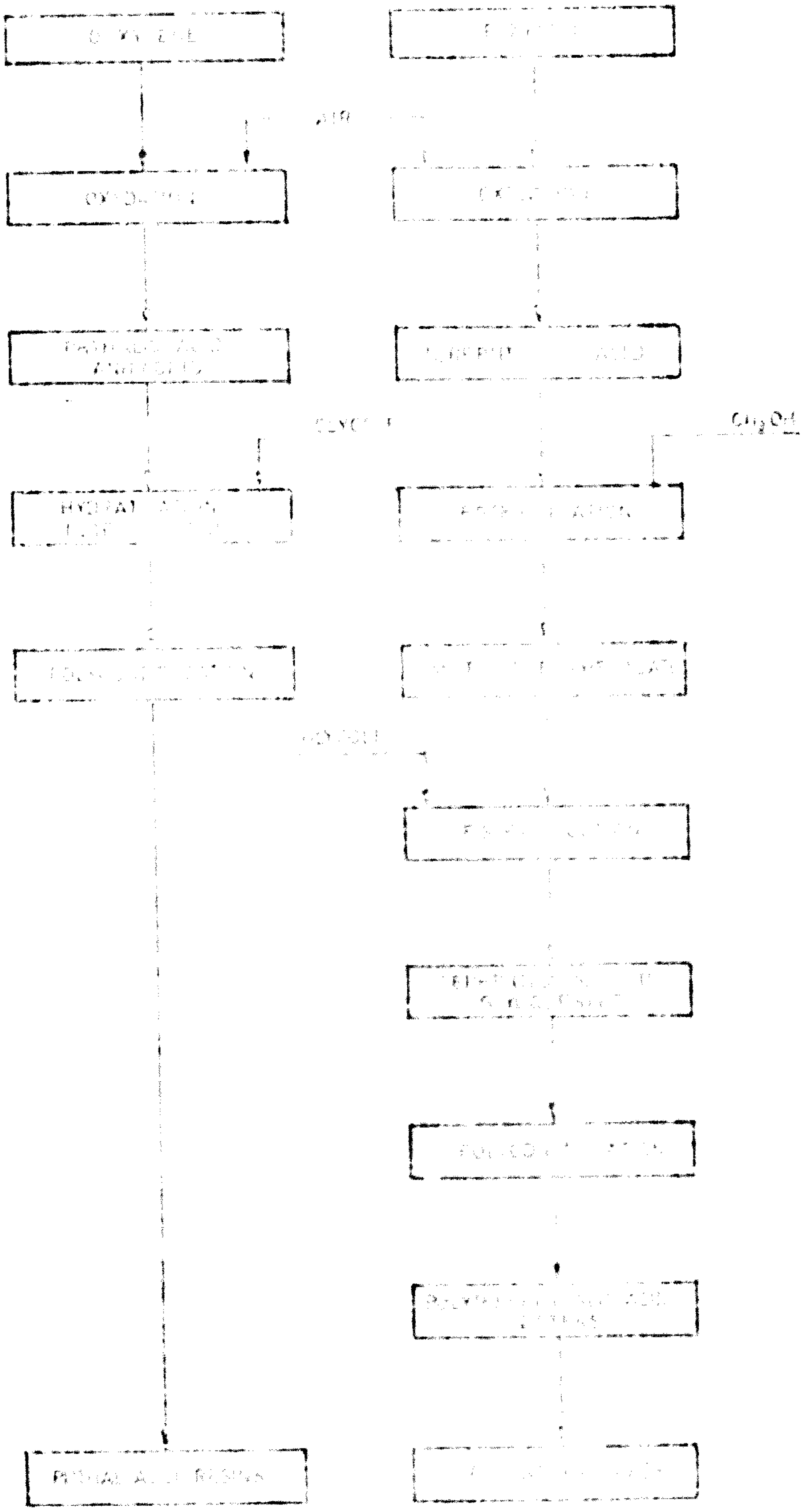
SECTION 2

PETROCHEMICAL PRODUCTS BASED ON TOLUENE

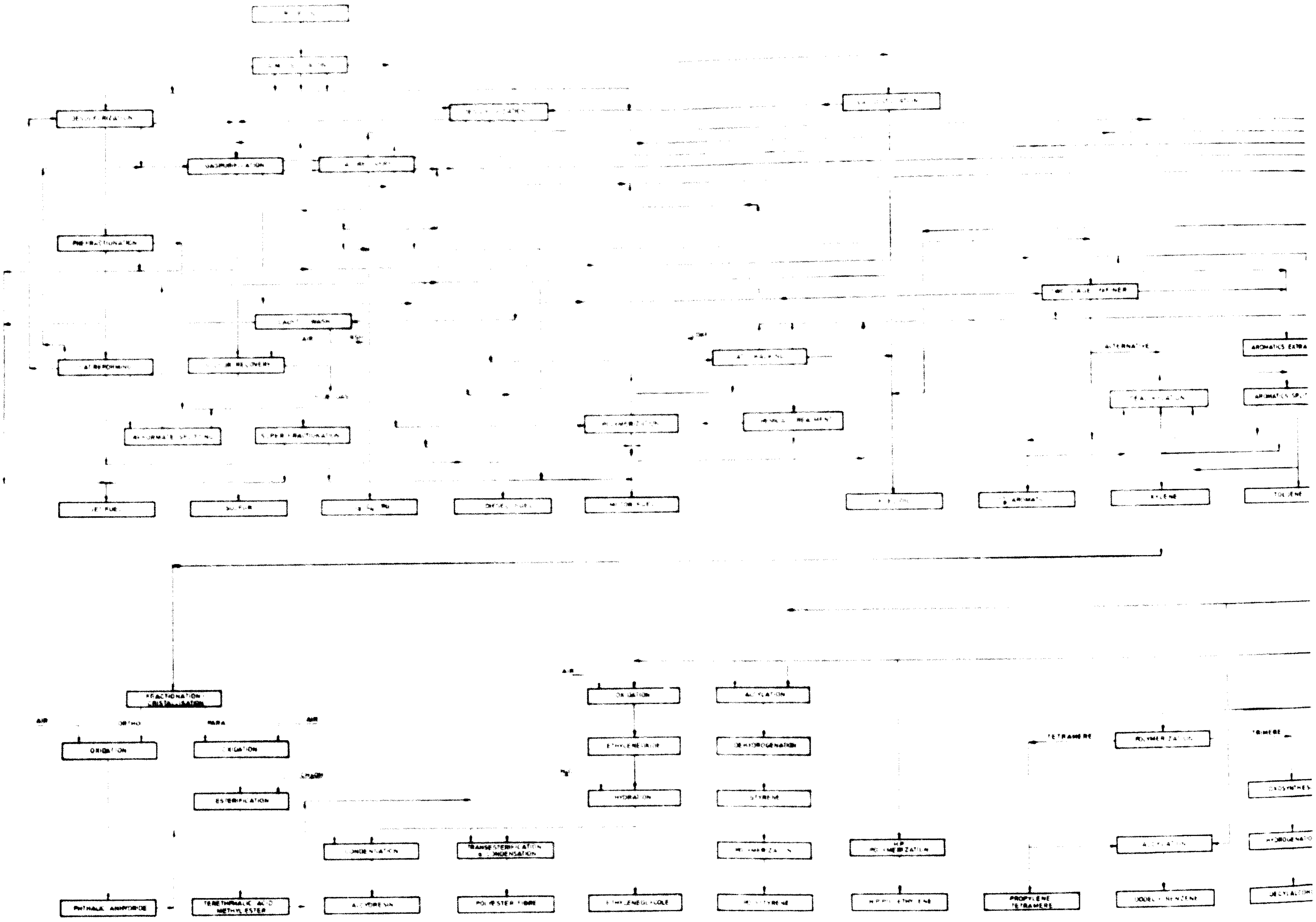


GRAPH. 11b

PETROCHEMICAL PRODUCTS BASED ON XYLENES

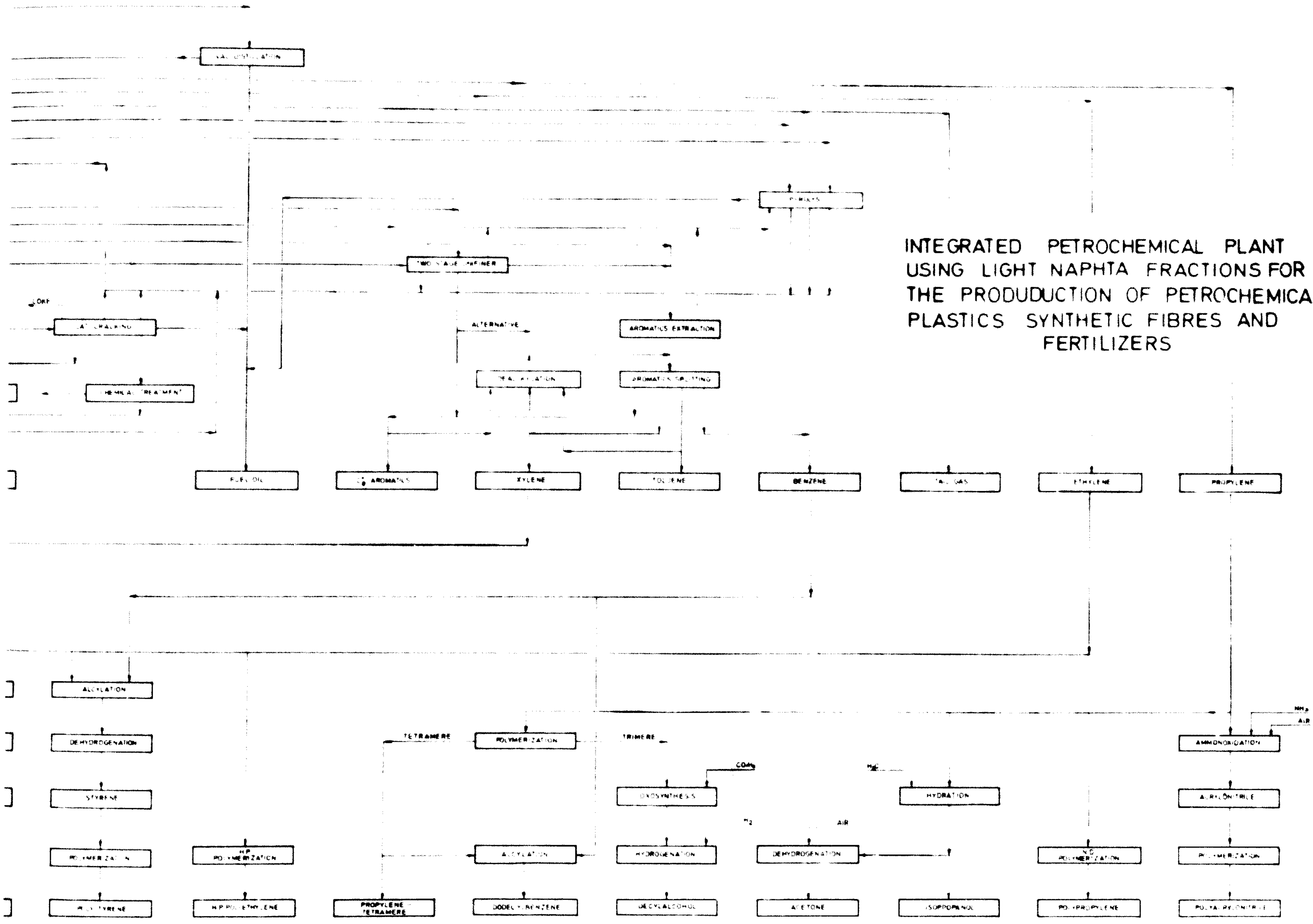


GRAPH 11 c


DESULFURIZATION
GAS PURIFICATION
PREFRACTIONATION
CAUSTIC WASH
AIR
REFORMING
SULFUR RECOVERY
REFORMATE SPLITTING
SUPERFRACTIONATION
JET FUEL
SULFUR
DIESEL FUEL
MOTOR FUEL
POLYMERIZATION
CHEMICAL TREATMENT
ALTERNATIVE
DEALKYLATION
AROMATICS EXTRA
AROMATICS SPLI
AROMATICS
XYLENE
TOLUENE
FRACTIONATION CRYSTALLIZATION
AIR
ORTHO
PARA
AIR
OXIDATION
OXIDATION
ESTERIFICATION
PHTHALIC ANHYDRIDE
TEREPHTHALIC ACID METHYL ESTER
CONDENSATION
TRANSESTERIFICATION & CONDENSATION
ALKYDRESIN
POLYESTER FIBRE
AIR
OXIDATION
ETHYLENEOXIDE
HYDRATION
ETHYLENEGLYCOLE
ALKYLATION
DEHYDROGENATION
STYRENE
POLYMERIZATION
POLYSTYRENE
H.P. POLYMERIZATION
H.P. POLYETHYLENE
TETRAMERE
PROPYLENE TETRAMERE
POLYMERIZATION
ALKYLATION
DODECYLBENZENE
TRIMERE
OXOSYNTHES
HYDROGENATIO
DECYLALCOH

SECTION 1

INTEGRATED PETROCHEMICAL PLANT USING LIGHT NAPHTA FRACTIONS FOR THE PRODUDUCTION OF PETROCHEMICALS PLASTICS SYNTHETIC FIBRES AND FERTILIZERS



GRAPH. 12

SECTION 2

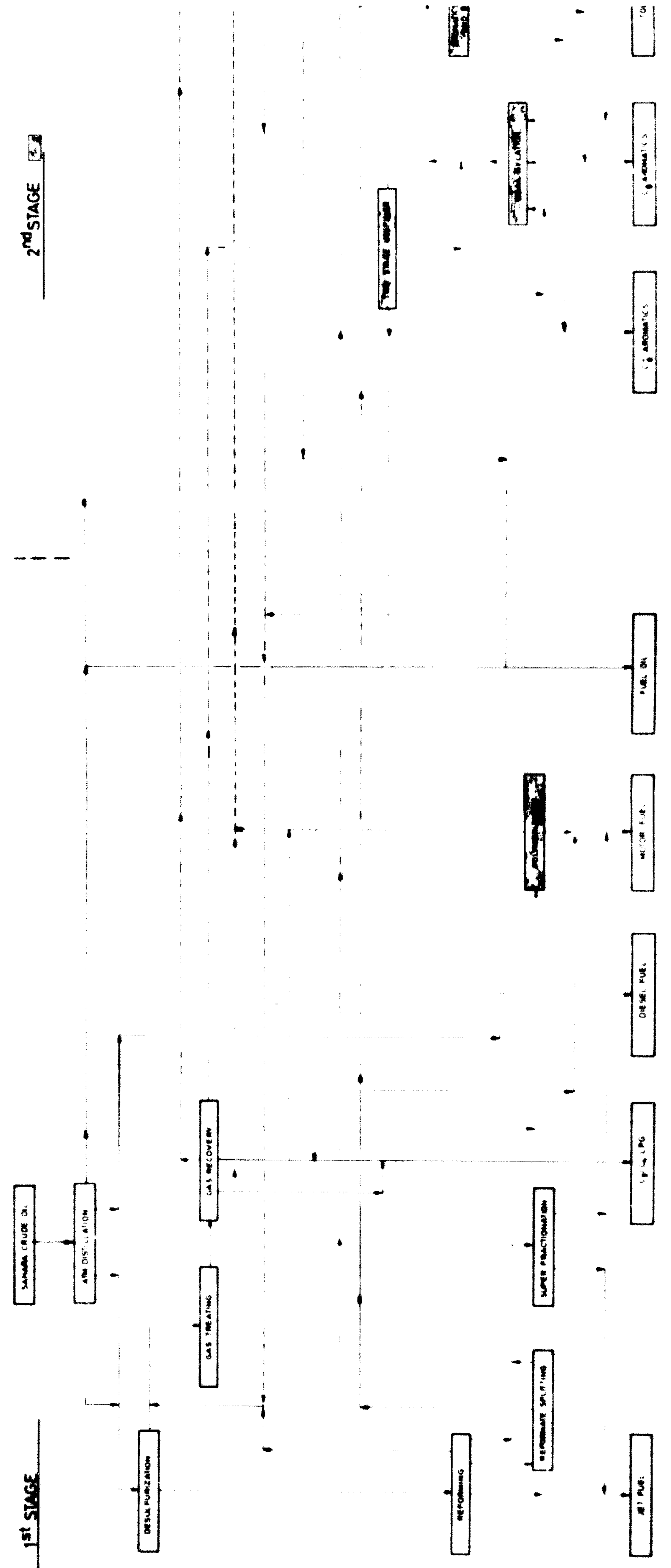
the economic production of petrochemical intermediates.

Refineries with a crude oil throughput of 2,000,000 tons/year using Sahara Crude [illegible] considering the maximum [illegible] of [illegible], aromatics and C_4-hydrocarbons with full exchange and use of all by-products [illegible] in course of operation.

Graph 17: Overall [illegible] of [illegible] refinery for the [illegible] production of petrochemical intermediates from Sahara Crude [illegible]

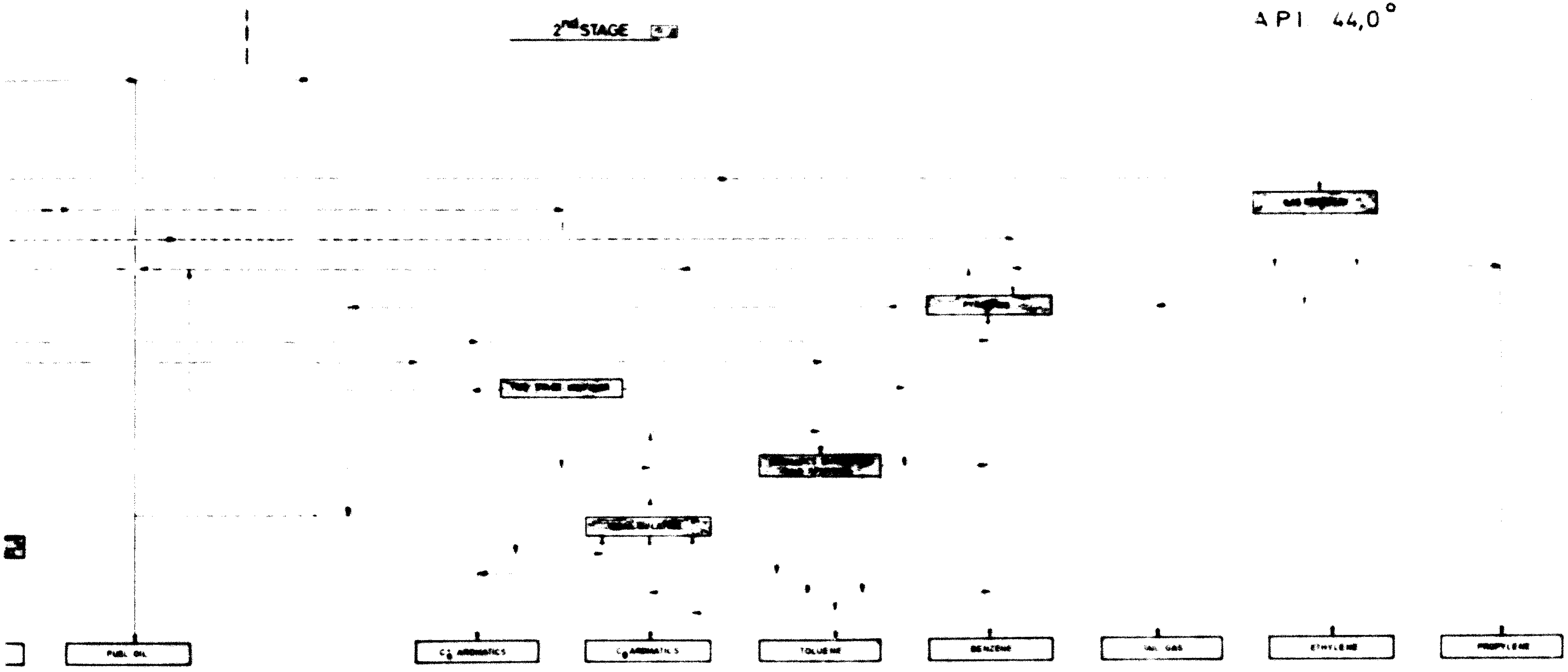
Table 18: Overall [illegible] Material Balance in Processing of 2 Million tons Sahara Crude [illegible]

Products	1st Stage (t/year)		2nd Stage (t/year)
Ethylene			[illegible]
Propylene			[illegible]
C_3C_4 LPG	133,000	C_4	[illegible]
Motor fuel	346,000		[illegible]
Jet fuel	272,000		249,000
Diesel fuel	534,000		530,000
No.5 No.6 fuel	460,000		[illegible]40,000
Benzene			30,000
Toluene			35,000
C_8-aromatics			28,000
C_9-aromatics			26.000
Refinery fuel and losses	255,000		21[illegible],000
Grand Total	2,000,000 t/year		2,000,000 t/year


1st STAGE
2nd STAGE
SAHARA CRUDE OIL
ATM DISTILLATION
DESULFURIZATION
GAS TREATING
GAS RECOVERY
REFORMING
REFORMATE SPLITTING
SUPER FRACTIONATION
JET FUEL
LPG
DIESEL FUEL
MOTOR FUEL
FUEL OIL
AROMATICS
AROMATICS

SECTION 1

PROPOSAL FOR THE IMPLEMENTATION OF A CRUDE OIL REFINERY FOR THE COMBINED PRODUCTION OF PETROCHEMICAL INTERMEDIATES FROM SAHARA CRUDE OIL API 44,0°



GRAPH 13

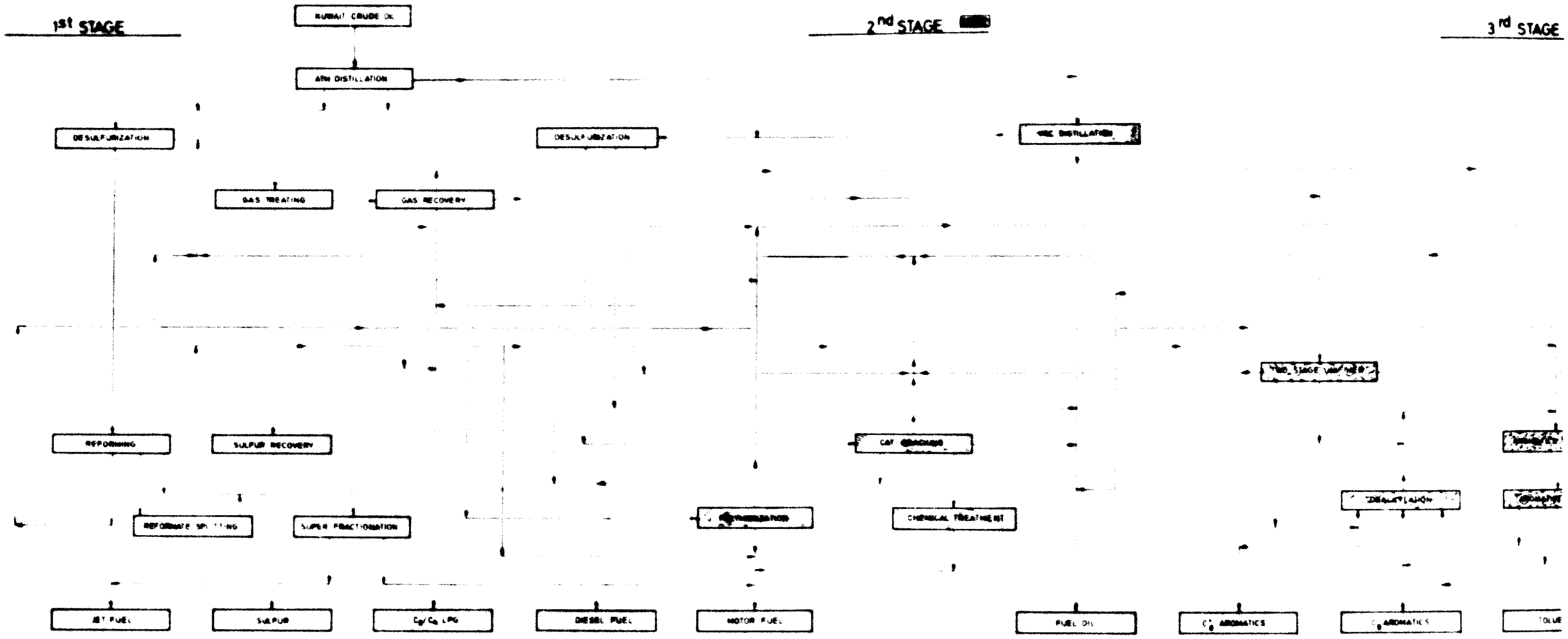
SECTION 2

Graph. 15 Proposal for the implementation of a crude oil refinery [illegible] of petrochemical [illegible]

Table [illegible]: Overall [illegible] Refinery with [illegible]

Overall [illegible] for Processing of [illegible] Crude [illegible] API

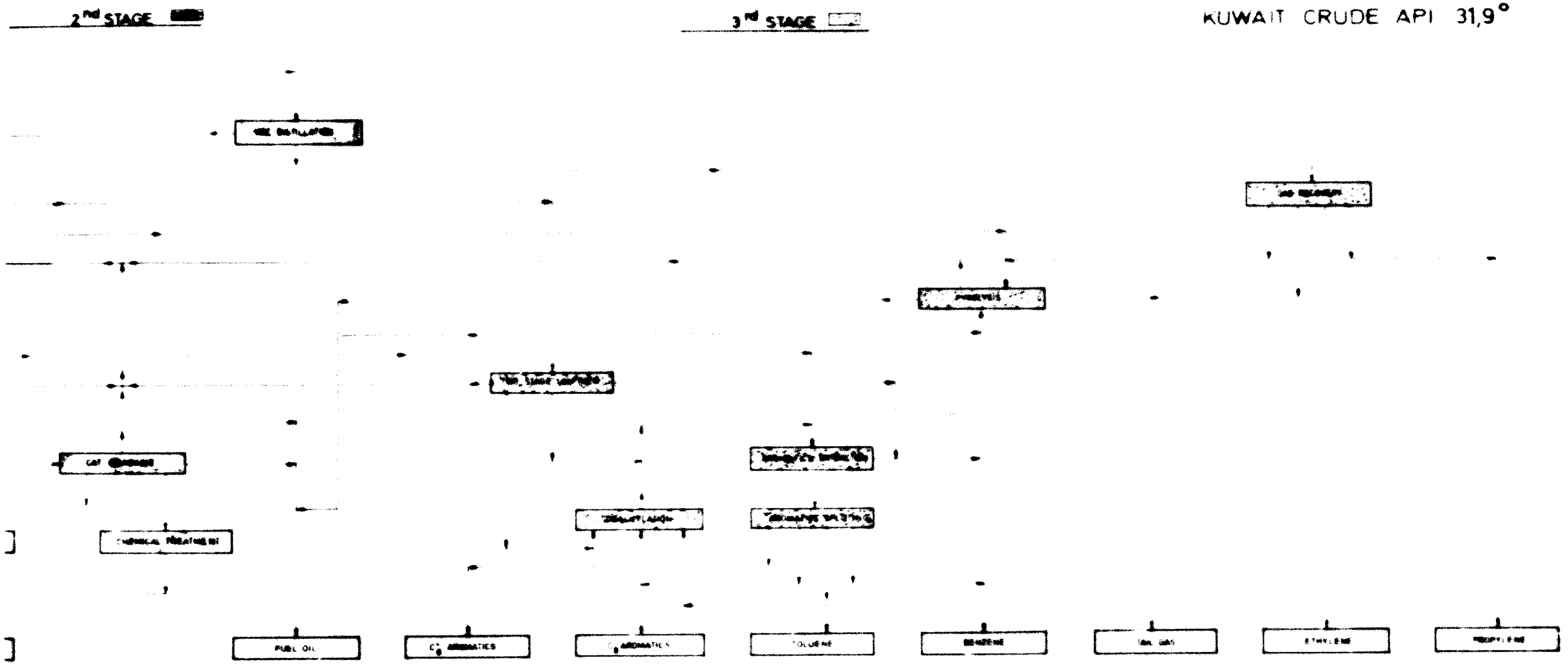
Products	1st stage t/year	[illegible] stage t/year	[illegible] t/year
Ethylene			70,000
Propylene			35,000
C_3C_4 LPG	73,000	[illegible]	[illegible]
Motor fuel	[illegible]	353,000	[illegible]
Jet fuel	240,000	250,000	137,000
Diesel fuel	325,000	365,000	[illegible]
No.5 No.6 fuel oil	927,000	755,000	[illegible]
Benzene			30,000
Toluene			34,000
C_8-aromatics			23,000
C_9-aromatics			19,000
Sulfur	4,000	4,000	[illegible]
Refinery fuel and losses	[illegible]	[illegible]	[illegible]
Grand total	[illegible] tons	[illegible] tons	[illegible] tons


1st STAGE
2nd STAGE
3rd STAGE
KUWAIT CRUDE OIL
ATM DISTILLATION
DESULFURIZATION
GAS TREATING
GAS RECOVERY
DESULFURIZATION
VAC DISTILLATION
REFORMING
SULFUR RECOVERY
REFORMATE SPLITTING
SUPER FRACTIONATION
CAT
CHEMICAL TREATMENT
TWO STAGE
DEALKYLATION
JET FUEL
SULFUR
C_3/C_4 LPG
DIESEL FUEL
MOTOR FUEL
FUEL OIL
C_8 AROMATICS
C_6 AROMATICS
TOLUE

SECTION 1

PROPOSAL FOR THE IMPLEMENTATION OF A CRUDE OIL REFINERY CONSIDERING THE COMBINED PRODUCTION OF PETROCHEMICAL INTERMEDIATES FROM

KUWAIT CRUDE API 31,9°



GRAPH 15

In case where developing countries possess only natural gas, the distribution of final products is limited. But even in this case a comparatively wide range of intermediate and final products can be obtained, which allows the establishment of a local industry producing important materials for subsequent processing to technical and consumer goods. It is extremely important for the economy of a complex based on natural gas to consider the combined production of petrochemicals and fertilizers. As the demand for fertilizers is constantly growing this development is very favourable.

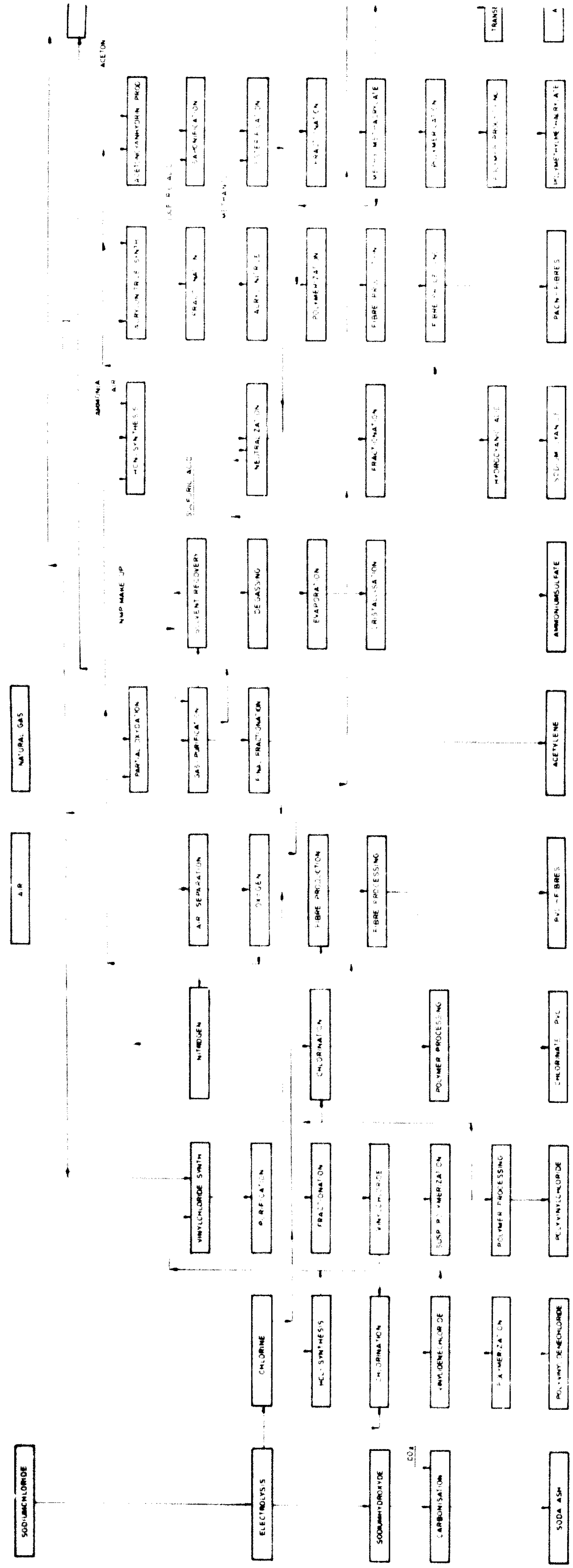
A petrochemical complex based on natural gas of about 200,000 t/year can produce about 500,000 t/year of final products with a sales value of approximately \$100 million for the processing plants, i.e. \$124 million on the whole. As a result the amortization period will be about 3-4 years, by a turnover ratio of about 70% (price base for natural gas \$4 - \$5/t.)

Graph. 17 Proposal for the establishment of a petrochemical plant based on natural gas considering the local situation in developing countries

In all countries which aim to achieve an increase in industrialization in order to generally rise the standard of living, and which possess only limited raw material resources, intelligently designed petrochemical combined plants offer the opportunity to solve the most complex problems occuring in the field of the production of energy, chemicals, plastics, resins and synthetic fibres as well as the production of fertilizers and proteins.

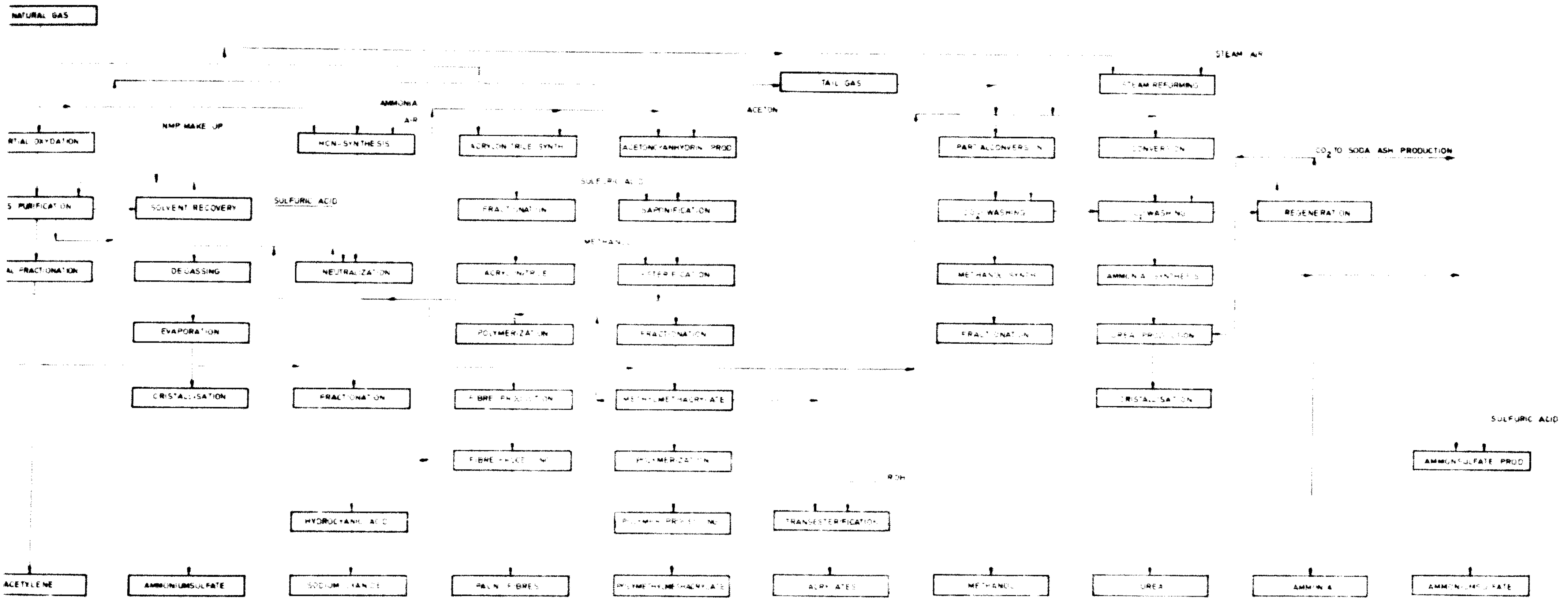
Considering that by the year 2,000 the world population will, with all probability, rise up to 5 thousand million this means that in the next 30 years, 2 thousand million more people than today will have to be fed, clothed and provided with consumer goods. Food provision corresponding in quality to present standards will only be possible by intense cultivation of the land available and by the production of a larger amount of proteins by synthetic processes. Natural gas and hydrocarbons are raw materials which are available in sufficient quantities for this purpose.

In a similar way, the production of petrochemical products, plastics, resins and synthetic fibres from natural gas or hydrocarbons feedstocks helps to increase considerably the standard of living by manufacturing cheap


SODIUMCHLORIDE
ELECTROLYSIS
SODIUMHYDROXYDE
CO2
CARBONISATION
SODA ASH
CHLORINE
HCl SYNTHESIS
CHLORINATION
VINYLIDENECHLORIDE
POLYMERIZATION
POLYVINYLIDENECHLORIDE
VINYLCHLORIDE SYNTH.
PURIFICATION
FRACTIONATION
VINYLCHLORIDE
SUSP. POLYMERIZATION
POLYMER PROCESSING
POLYVINYLCHLORIDE
NITROGEN
CHLORINATION
POLYMER PROCESSING
CHLORINATED PVC
AIR
AIR SEPARATION
OXYGEN
FIBRE PRODUCTION
FIBRE PROCESSING
PVC-FIBRES
NATURAL GAS
PARTIAL OXIDATION
GAS PURIFICATION
FINAL FRACTIONATION
ACETYLENE
NMP MAKE UP
SOLVENT RECOVERY
DEGASSING
EVAPORATION
CRYSTALLISATION
AMMONIUMSULFATE
SULFURIC ACID
AMMONIA
AIR
HCN SYNTHESIS
NEUTRALIZATION
FRACTIONATION
HYDROCYANIC ACID
SODIUM CYANIDE
ACRYLONITRILE SYNTH.
FRACTIONATION
ACRYLONITRILE
POLYMERIZATION
FIBRE PRODUCTION
FIBRE FINISHING
PAN-FIBRES
SULFURIC ACID
METHANOL
ACETONCYANHYDRIN PROC.
SAPONIFICATION
ESTERIFICATION
FRACTIONATION
METHYL METHACRYLATE
POLYMERIZATION
POLYMER PROCESSING
POLYMETHYLMETHACRYLATE
ACETON
TRANSF

SECTION 1

PROPOSAL FOR THE ESTABLISHMENT OF A PETROCHEMICAL PLANT BASED ON NATURAL GAS

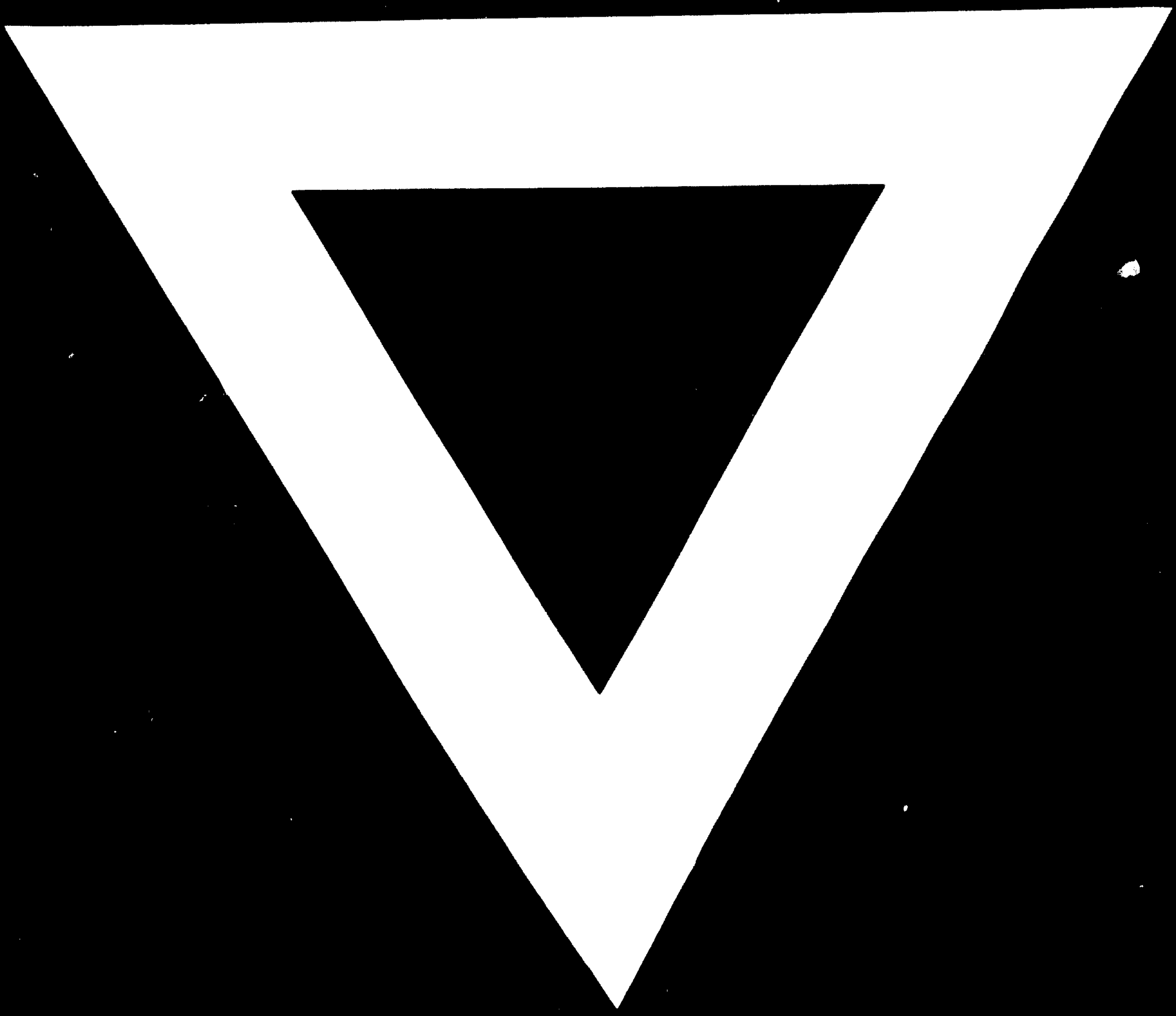


SECTION 2

consumer goods and fabrics. The expansion of such an industry gives rise to many problems as to the design and engineering of this kind of integrated plants. At the same time, economic considerations are necessary to find the most suitable solutions to all these interconnected problems. This can only be realized by close co-operation between developing and industrialized countries.

This report was meant to contribute to the solution of this tremendous task by giving a short summary of the different considerations of present trends, expected development and expansion in this industry.

We sincerely hope that this will help to build up a peaceful world.



12. 7. 74