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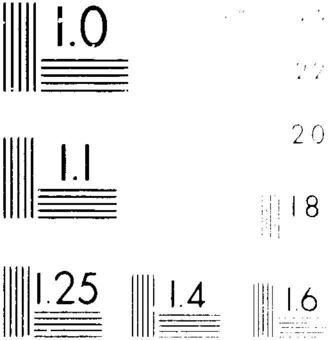
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Angola

ADVISORY SERVICES TO THE NATIONAL DIRECTORATE OF PETROLEUM.

SI/ANG/83/802

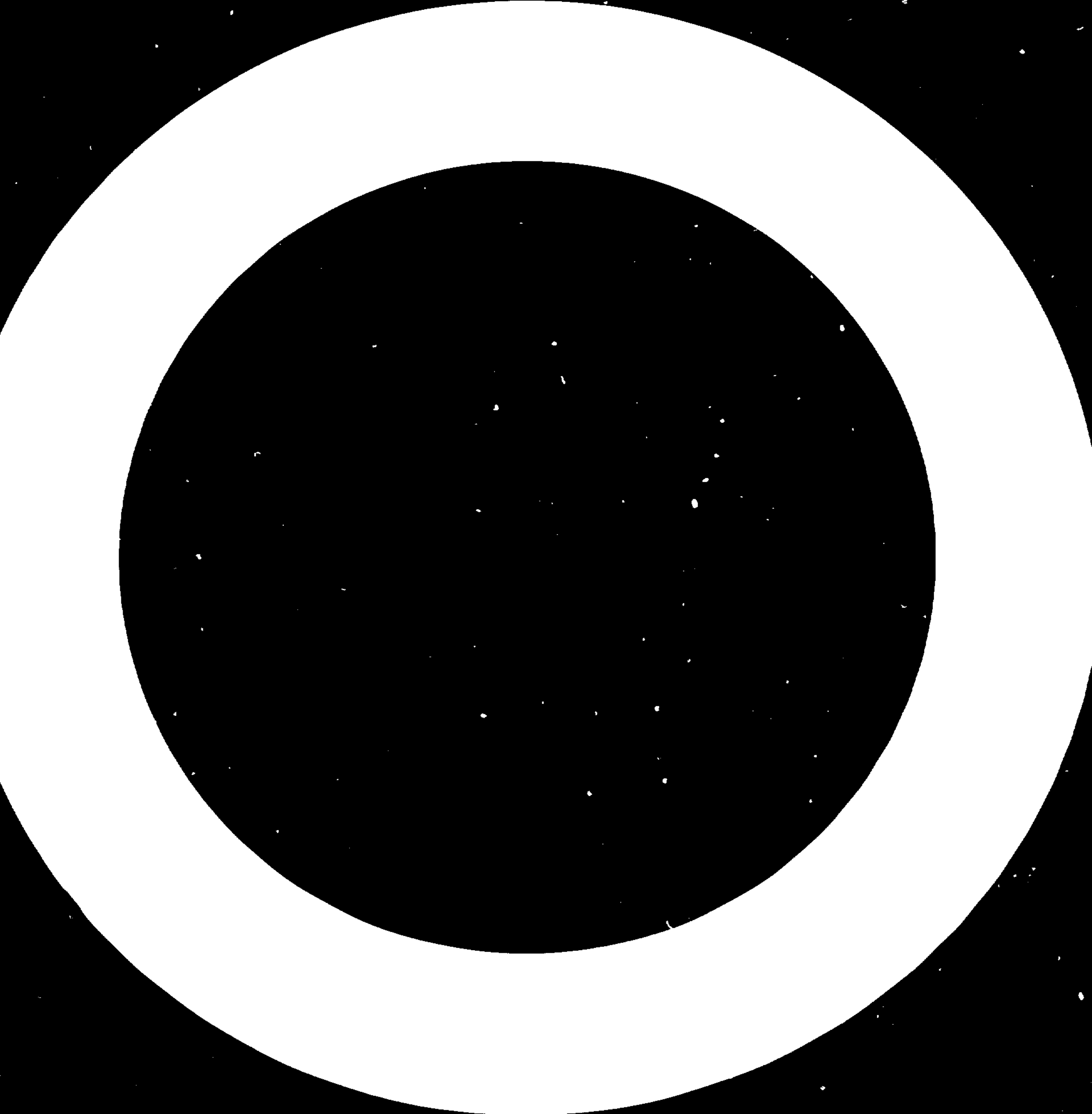
ANGOLA

Terminal report

Prepared for the Governement of Angola by the United Nations Industrial Development Organization, acting as executing agency for the United Nations Development Programme

Based on the work of M.Tatoiu,
adviser on crude oil processing and petrochemistry

United Nations Industrial Development Organization
Vienna



ABSTRACT

The project SI/ANG/83/802 named "Advisory Services to the National directorate of Petroleum" lasted for three months beginning in October 1983 until January 1984.

The objectives of the project were to study the possibilities of the implementations of a petrochemical industry, based on the existing raw materials.

It is also an ideological and economic objective of P.R.Angola to achieve self-sufficiency in as many of the products and commodities it consumes as are geographically practicable and to provide some quantities for export.

P.R.Angola is the single country, crude oil producer, in the region (S.A.D.C.C.) with the possibility to supply to the other members of the organisation energetic products and petrochemicals.

This situation opens the gates of cooperation at the implimentation of a petrochemical industry and the division of the financial efforts.

Since the Ministry of Petroleum is still considering the expansion of the existing refinery and underlining that without the expansion of the existing refinery and changing the present profile of the crude oil processing, any implimentation of petrochemical plants based on olefines and aromatics, is impossible.

On the body of the report it is also analised the possibility of the participation of the petrochemical industry at the food sufficiency of the country and the zone (S.A.D.C.C.) by producing petroproteins (Single Cell Proteins) from petroleum raw materials for animal feed (mainly for chicken) in order to increase the meat production.

It is advisable and recomended to impliment, taking into consideration the recomendations made further in the body of the report the objectives of the executive report conducted by the International Gas Development Corporation, taking into account that any delay is driving to sizable losses in money and products and also the waste of a precious raw material - the associated gases - which at present are flared.

Since the shortage of skilled manpower is very acute it is absolutely indispensable to take the most urgent coordinated steps to ensure the new industry with proper trained and experienced leading, operating and maintaining personnel.

Outstanding attention must be given to the formation of Angolan high level graduated people.

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INTRODUCTION

The expert worked for this project "Advisory Services to the National Directorate of Petroleum" SI/ANG/83/802 for a period of three months from October 1983 to January 1984.

The background of the project "Advisory Services" started with the activity of Mr.Frederik Sager,consultant of U.N.I.D.O.who worked for two months,during February - March 1979.Mr.Sager set up the foundation of the project whose purpose was to provide the Ministry of Petroleum with advice on the management of operations and the establishment of crude oil processing in P.R.Angola and specifically to recommend improvements in this field.

Mr.Sager's main activity was devoted to the realisation of "The Petroleum Development Centre" located in N'Gunza.He also gathered valuable datas about the petroleum industry in the P.R.Angola,datas which can give an introduction to anybody,interested in this project.

The next expert who worked on this project was Mr.Djordie Maletic technical councellor,who worked during July - October 1980.

His activity was centered mainly on the work of preparing the activity of investments for the expansion of the refinery,preparation of the pre-project activity,pre-feasability and feasability studies.

He was followed by the present expert Mr.Mircea Tatoiu who worked during his first stage from September 1982 to March 1983,having as objective to analyse the possibilities and to recommend the best way,from economic and technical point of vue,for the existing refinery.

The objective of the present job is to analyse the development of national petrochemical industry on the basis of existing refinery complex and natural gas resources,as a major step in economy development of the country.

To determine the technical and economic viability of establishing a complex for the production of fertilisers (in fact the production of amonia and urea) on the basis of the feasability study conducted by the International Gas Development Corporation,based on gas deposits in SOYO region.

At present there is no petrochemical industry in P.R.Angola,but the existance of a refining industry in the country and the availability of natural and associated gases (at present flared) are two important factors favoring the production of petrochemicals in the country.

During his activity the expert assumed also (as during his first assignement in P.R.Angola) the training of the graduates of "Faculdade da Engenharia Quimica" who prepared for final examination their diploma-work in engineering,on crude oil processes and equipments.

The counterpart of the expert assigned by the leadership of the Ministry of Petroleum to work with,was Mr.Pedro Gomes,head of the Processing Department.The whole activity of the expert was developed under the care and coordination of Mr.Desiderio Costa,National Director.The expert expresses his thanks to both of them for their best collaboration and support.

The expert also expresses his gratitude and thanks to the leaders of Petrangol Mr.Gerard Legrand,Mr.Gustav Mertens,Mr.Oscar Hostens and Mr.Luis Urbano,for the conditions created to fulfil the tasks of his assignment,for the valuable advice and the technical materials granted.

The expert makes a special remark and is thankful to Mr.Nikolai N.Krainov S.I.D.F.A.at U.N.I.D.O.office of Luanda,for his help and guidance during his assignement.

CONCLUSIONS AND RECOMMENDATIONS

People's Republic of Angola, with a production of 7.0 million tons/year of a very good quality crude oil and owning a petroleum refinery, is an importer of crude oil distillated products and an exporter of crude oil and residual fuel.

The installed capacity of the refinery of 1.5 million tons/year is not always used at its full extent.

This capacity and the fact that the refinery has a hydroskimming profile, which produces a high yield of residual fuel, does not satisfy the needs of the country and it is necessary to resort to imports.

Studies made on how to improve the situation provide, as a solution, to increase the throughput up to 4.0 million tons/year, in succesive steps and to change the profile from hydroskimming to a conversion refinery, adding a hydrocracking plant.

In order to improve more the efficiency of the refinery and to satisfy the needs of the country for synthetic materials the Government of P.R.Angola decided to implement the basis of a petrochemical industry in Angola; at present there is no petrochemical industry in the country.

There are also a number of facilities which either process or utilize petrochemicals as inputs for the manufacture of end products.

The country has attained a market of sufficient size as regards consumption of some petrochemicals including intermediates and plastics such as: P.V.C. Polyethylene, synthetic rubber, etc.

First of all, to start the implementation of petrochemical industry based on the existing refinery, the Ministry of Petroleum has to speed up the decision of the refinery expansion and the way of making it.

With the refinery at the present stage, any petrochemical start can not enter into consideration. After a concrete decision will be taken, the implementation of the petrochemical plants can have an orientation, in the absence of this decision the matter can be treated only by sup sitions and assumptions.

The first conclusion and at the same time a recommendation is that the Ministry of Petroleum has to settle the matter of the refinery expansion,as soon as possible.Any delay of this decision is producing large financial losses,from both points of view,crude oil processing (import of distilates) and petrochemical industry (import of petrochemical products).

Having in mind the possible expansion of the refinery,at a first stage,by increasing the crude oil throughput,the expert is analysing into details the possibility to produce in P.R.Angola Petroproteins (Single Cell Proteins).

Taking also into consideration the special efforts made by the Government of P.R.Angola to assure a self-sufficiency of the food in the country and the quality of Angolan crude oils the production of Petroproteins appears as feasible.

The Ministry of Petroleum has to contact the Ministry of Agriculture,the future user of the Petroproteins,eventually to ask for further assistance to U.N.I.D.O.and F.A.O.and to establish the way and concrete possibilities to implement a protein plant in P.R.Angola.

The cooperation with the other S.A.D.C.C.countries must be taken into consideration in the first place.

Regarding the turning into good account the associated gases -at present flared-in "SOYO"region,the expert recommends,first of all,a better cooperation of the Ministry of Petroleum with the Ministry of Industry,Ministry of Agriculture and the foreign trade organisations.

For instance the "Executive report"made by Industrial Gas Development Corporation,has as object the building up some nitrogenous fertilisers plants and for this matter U.N.I.D.O.granted technical assistance by an expert under the job No.SI/ANG/83/802,to the Ministry of Petroleum.

On the other hand the Ministry of Industry has requested "Advisory services in the field of fertilisers industry"and it was approved by U.N.I.D.O.with the job No.UF/ANG/83/194.

Since the industry of fertilisers has only one target,to help the growing up of the agricultural production,a close cooperation must be established among Ministry of Petroleum,Ministry of Industry and Ministry of Agriculture.It is necessary to form a joint committee,at least at the level of the Dy.National Directors from each Ministry,to analyse in common the needs of the agriculture and the possibilities to satisfy these needs,as soon as possible and in the most economic ways.

During the time this working group may become something like Kenia's "Government National Agricultural Chemicals and Fertilizers Company".With the assistance of U.N.I.D.O.this organisation will implement into P.R.Angola the new branch of the chemistry,"The Agrochemistry"looking for every item which cooperate to the optimum agriculture crops i.e.fertilizers,herbicides,insecticides, growth accelerators,etc.

At present very few farmers are using the optimum quantity of fertilizer and agro-chemicals at the right time.

If supplies were assured in terms of quantity,time and cost, farmers could grow more crops per acre of land.

This would virtually eliminate importation of food because it will be possible to grow almost all the varieties of fruits and vegetable consumed in the country.

At the same time,it would increase earnings from exports of such crops as for instance is coffee and the impact could be fantastic.

I. DEVELOPMENT OF THE PETROCHEMICAL INDUSTRY ON THE BASIS OF THE EXISTING REFINERY.

A. General aspects

The crude oil and the natural gases represented for the last three decades the basic raw material for the petrochemistry,top economic field of the chemical industry.

The petrochemical industry has favoured the development of mass production for plastic materials,synthetic fibres,elastomers,chemical fertilizers,basic products which have promoted the contemporary civilisation.

The petrochemical industry is characterized by its dynamism and rapidity of evolvement.Dynamism of demands and rapid evolution of its techniques,deep and quick transformation of industrial structure and implementations.

In the annex No.1 are shown schematically the main sources of raw materials for the petrochemical industry.As it can be seen the most important spring is the crude oil refining.

The annax No.2 shows the current world consumption of petrochemical materials by group of products,all of them obtained from the raw materials mentioned in the annex No.1.

The reasons which determined the use of more and more important quantities of crude oil and natural gas were (among others) the following:

1-Crude oil and natural gas provide products much more pure than those of carbochemical origin.

2-The crude oil processing produces materials which are difficult to be obtained from other sources (xylenes).

3-The crude oil and natural gas can supply some products which otherwise are not available in enough quantities (glycerine).

4-The crude oil and natural gas are ensuring raw materials and products at lower prices than the other sources (plastics).

5-The economic efficiency of producing and processing petrochemical products is very elevated,two examples are given below :for ethylene and for propylene both of them including al o partly the turning into good account of the benzol.

	Index
Ethylene.................	1x
Polyethilene.............	2,7x
Articles made from polyethilene.............	3,7x
Ethyleneoxyde............	2,5x
Ethyleneglycols..........	2,9x
Polystyrene..............	9,2x
Articles made from polystirene.............	21,1x
Propylene................	1x
Polypropylene............	6,5x
Phenol...................	9,5x
Acetone..................	11,5x
Synthetic fibres........	18,0x
Confections made from fibres...........	165,0x

At present it is very difficult,if not impossible to make a separation between petroleum processing and petrochemistry.

Having in mind that the crude oil is a raw material composed of many hydrocarbons and the reactions not always selective, particularly regarding the production of great intermediaries (i.e.olephines,aromatics),the petrochemistry leads always to a production of many components simultaneously.

This is the result that alongside the main product are obtained byproducts,which is very important to be well turned to good account like the main product,with the purpose to increase at maximum the rentability of the process.

This situation is leading to the implantation of integrated complexes,not separate fabrications.

That is why all the modern refineries are intimately combined with petrochemical plants.

As it is shown in the annex No.1 the petrochemistry can be developped starting from natural or associated gases or starting from crude oil.

In this chapter the expert analyses the crude oil branch only, natural and associated gases will be analysed further in a separate chapter.

Connected with Luanda refinery,at present,there are two principal ways to develop the petrochemistry,taking into account the possible lines of the expansion of the refinery:the catalytic reforming and the steam cracking.

The reforming can be operated on the way to favor the production of motor spirit,or as well as,to favor the production of aromatic hydrocarbons.

The steam cracking of naphta is leading to the production of olephines and dyolephines and also in lower quantities of benzene and other aromatics.

In the annex No.3 is shown the cracking yelds from various feedstocks.At present in Luanda refinery,the ethane is not available and the gas oil,due to its shortage as engine fuel,is also not available.The only remaining feedstock which is in excess at the refinery is naphta and the expert proposes that this raw material be taken into consideration for further developpment of petrochemistry.

On the other hand the ethane could be available in "SOYO" from the associated gases and according to the ethane and propane content to set up a cracking plant for these gases in order to produce ethylene for the use shown in the annex No.7 and 8.

Regarding the products obtained by steam cracking of naphta there are two groups of hydrocarbons of the most importance for the petrochemical industry:the olephines and the aromatics.Among the olephines of an outstanding importance are the ethylene and the propylene;of less importance,but only in this case,is the butadiene.

In the annex No.4 is shown the present and the future of the ethylene,propylene and butadiene in the United States of America.

It can be observed that the ethylene and the propylene have a sharp growth and at the same time the butadiene is growing up almost imperceptible.

In the annex No.5 is shown the estimated use of ethylene in U.S.A.In the annex No.6 is reproduced the mass balance for a European naphta cracker,of course,the figures are not applicable to the case of Luanda refinery,but the conversions and the general outlook could be taken into consideration.

In the annexes No.7;8;9;10 and 11 are shown some of the possible uses of the ethylene,propylene,benzene,toluene and xylenes.

B. Factors which limit and restrict the petrochemical industry

The promoter of a petrochemical industry must take into consideration some factors which are very dangerous to be ignored.

1-The outlet of the products and the surface of the markets (local and export).

The size of the internal market is given by the needs of the country expressed in petrochemical products.

To establish the size of this market,quantitatively and qualitatively,the range of goods,the quantity of each sort,the priorities of implantation,etc.is the object of a close cooperation of the Ministry of Petroleum with the ministries of : industry,home trade,foreign trade,agriculture,armed forces,fisheries,etc.

It is strongly recommended that the decision be based on a very realistic and long term plan.

Such circumspection is very necessary,because once a decision is taken and the implimentation made,it will be impossible to change the option.For instance,if an option is given for plastics and after that,due to a possible fall of the market,the option is changed for synthetic fibres or rubber,it will be impossible from a technical point of view to change the plants and from economic point of view a total failure.

The size of local market,anyhow,is easier to establish having in mind that any measure to protect this market from an outside competition,can be taken.

The provisions for export must be very carefully examined having in mind the possible contradictions between the foresights and the reality of the market.

Anyhow there are two remarks to be made :

-The international market is not stable,the possibility of replacing a product with another is very high,therefore it is very risky to create an industry based mainly on export.

-The long term provisions must be very carefully considered and to avoid,at any cost,the excess of the optimism.

Regional or intercontinental competition must be taken into consideration,particularly that of the neighbouring countries, crude oil producers or not.

Anyhow P.R.Angola as an important producer of raw materials for the petrochemical industry,with the possibility to develop the crude oil processing must develop also the petrochemistry and it is very realistic to consider an export of petrochemical products,at least in the region.

2-The availability of raw materials,which determine the type of the plants and the profile of the complex.

In the case of Luanda refinery the basic assumption for developing the petrochemistry is to use as raw material,naphta,which is in excess.

3-Availability of power and its price.

About the price of power it is less to discuss.The availability of power is a matter to be taken very carefully into consideration

At the proper time was shown the negative influence of the very frequent power failures on the crude oil processing.

The expert underlines the fact that the petrochemical plants are very complex units working in a very narrow field of parameters and to build any petrochemical plant in the circumstances of power shortage will be a failure.

4-Availability of skilled manpower and its cost.

As it was written in the precedent paragraph the petrochemistry uses extremely complex plants with the last achievements of technique specially in the fields of:mechanics,metallurgy and most of all the automation.The staff operating such plants must be highly specialised with a great experience in the field.

The problem of personnel formation:engineers,foremen,operators, mechanicians,instrument maintenance and repair people has to be taken into consideration with a high sense of responsibility.

The history of petrochemistry is full of examples where mistakes were made due to the lack of conscientiousness or ignorance

This caused important material damages and the loss of numerous human lives.

5-The size of the plants.

In the case assumed for Luanda refinery the size of the plants is given by the quantity of raw material available.

In the case the Ministry of Petroleum intends to expand the refinery up to 4 or 5 million tons/year,other,proper arangements must be made.

6-Availability of hard currencies and the possibilities of financing the complex.

The cost of implantation of such a complex can go up to a large amount of money.For any company or government of a developping country could be a serious burden and proper means must be found to cover the investiments.

This can be covered by credits,loans,back-payment by the products of the complex,contribution of the neighbouring countries interested in the realisation of the complex,contribution of the foreign companies interested in a joint-venture.

The Ministry of Petroleum has to make an open investigation and to choose the most advantageous solution.

C. Possibilities to develop the petrochemistry at the Luanda Refinery.

Since the Ministry of Petroleum did not take any decision about the expansion of the expansion of the refinery,the implimentation of the petrochemical industry at the existing refinery can not be treated on a concrete basis,the matter may be touched only on suppositions and assumptions.

The basic assumption is that the Ministry of Petroleum will follow the most logical way to expand the refinery,by increasing the processing capacity by using at the maximum extent the existing equippment and in a second step with any additions of plants and equippments to expand further the capacity of the refinery to 2-2,5 million tons/year and by adding a hydrocracker to change also the profile of the refinery from hydroskimming to a conversion refinery (Petrofina study to expand the refinery step 1 and step 2).

The possibility to insert a petrochemical line which results from the above mentioned studies are :

1-To avoid the bottle neck at the reforming plant and also for future expansion, there is the proposal to build another reforming unit.

In this case one of the reformers can operate on a regime of aromatic yields and the other on high octane motor spirit.

2-Having in mind the change of the hydroskimming profile to the conversion type of refinery with the implantation of a hydrocracker, which needs hydrogen for its technological process.This hydrogen is supplied by a hydrogen plant which can be integrated in a naphta steam cracker.

This case is schematicaly represented in the annex No.12 where is shown the case of a refinery (or part of a refinery) of hydro-skimming profile processing 2.5 million tons/year,with a graft of petrochemistry,which could be the case of the Luanda refinery after the second step of the expansion,accordig to the above mentioned studies.

In this way are produced two of the most important categories of hydrocarbons for the petrochemistry:

-olephines,ethylene and propylene.

-aromatics,benzene,toluene,xylenes.(B.T.X.)

These plants will be completly integrated into the refinery.

The refinery will supply among others,naphta,the raw material for the petrochemical units and receive the byproducts from the petrochemical plants,which are used in the production of L.P.G. and motor spirit,mixed with other products of the refinery.

It is also necessary to point out that the petrochemical part of such complex requires-according to the European standards:

- 383 people,out of which
- 16 engineers
- 12 foremen
- 83 senior operators
- 180 operators
- 90 for auxiliary services

This proposal made on the assumptions made at the beginning of this chapter is one of the possibilities to implement the petrochemistry at the existing refinery.

There are also some other ways,and one of them is the participation of the petrochemical industry at the food sufficiency of the country,producing proteins from crude oil distilates.

This matter is treated separately in the following chapter.

II. PETROPROTEINS
SINGLE CELL PROTEINS PRODUCED FROM RAW MATERIALS OF PETROLEUM ORIGIN.

A. Definition

By single cell protein (S.C.P.) is meant micro-organisms of various kinds;bacteria,yeasts and fungi,which are cultivated for the specific purpose of being used as an ingredient in food or animal feeds.

They are made by fermentation processes using many different substrates,including methane,methanol,ethanol,n-alkanes,gasoil,etc.

In the dry state S.C.P.can contain from 50-80% of protein and up to 9% nucleic acids.

B. World food situation

1.General aspects. According to the statistical estimations yearly 3.5million human beings die due to the starvation,another 2.0 billion are suffering of famine and persistent malnutrition.

At present are living on our planet about 5.0 billion habitants and according to the anticipations during the year of 2000 the population level will reach 6-7 billion with a yearly medium growth of 2% but some regions and especially underdevelopped regions will reach 3% and even 3,5% growth.

Besides the great problems which the world is facing now,as the energy crisis and pollution,the shortage of proteins becomes more and more acute because their production is growing up slower than the population growth.

Below is given the deficit of proteins for 1980 and the estimations for the year of 2000,in million of tonns:

Year	Production	Needs	Deficit
1980	37	42.5	5.5
2000	47	65.0	18.0

At present the world can not remain dependent,in the problem of the proteins,only from conventional sources,as is the situation in the field of fibres;for covering the needs of clothing,since more than a decade,the natural fibres (cotton,wool,etc) gave yield to the synthetic fibres.

2.Human nutritional requirements. The human diet must provide a source of energy (fats and carbohydrates) and a source of proteins for tissue production and enzymes,also major minerals for skeletal structure and certain micronutrients such as vitamins and trace elements.

There has been considerable dispute in the past as to the quantity of protein required in the human diet.Current estimates put the figure at 1.9 grammes/Kg.of body weight per day of "average" protein for young children,decreasing to 0.9 gm/kg/day for a healthy adult.However,at times of stress,such as recovery from illness, pregnancy and lactation,these figures may increase considerably.

Since the energy intake regulates the total quantity of food eaten,the diet must have a sufficient proportion of protein in it

This is important because while protein can substitute as an energy source,carbohydrates and fats can not substitute the proteins.Root vegetables and cereals contain scarcely enough protein to meet the requirement and the diet,therefore,needs supplementing with richer sources such as legumes or meat and fish.

These latter materials have an added advantage for,as well as being high in protein,their quality is also better than most plant protein.

Among the 20 or so amino-acids that,in varying proportions go to make up every protein,10 are essential.That is to say they can not be made by the body and therefore have to be supplied in the food.

Also,if the amino-acids are to be used efficiently,the protein must be easily digestible.

From measures of the amino-acid composition and of the digestibility it is possible to construct a scale of the quality of food proteins.

The following table shows the relative protein quality of some important foods:

Source of protein	Biological value
Egg	0.99
Cows' milk	0.85
Fish	0.85
Beef	0.74
Rice	0.70
Wheat flour	0.64
Maize meal	0.54

5. Animal versus plant protein. Most vegetable proteins are deficient in one or more of the essential amino-acids and consequently are of a lower quality than animal proteins.

It is not true to say, however, that animal protein is a necessity since, in a varied diet, deficiencies in one vegetable protein are remedied by another. Thus, mixed cereals and, say, soyabean meal can form a very adequate diet.

Alternatively the deficiency can be remedied by the addition of synthetic amino-acids. These have been used by the animal feed industry and also in diets for humans on a limited scale.

On the other hand, high protein foods, usually based on animal protein, are generally regarded as very desirable dietary components

Because they are normally more expensive, the proportion of animal protein reflects the standard of living.

This can be seen from the following which is compiled from F.A.O. datas and also graphically in the annex No.13.

Region	Total protein	Animal protein	% of animal protein
	(gms/capita/day)		
Developing region	57.6	10.7	18.6
Far East	54.8	8.6	15.7
Near and M.East	71.6	14.0	19.5
Africa	58.5	10.9	18.6
Latin America	67.6	24.1	35.6
Developed region	89.1	48.3	54.3
Europe	87.6	42.8	48.8
N.America	93.1	65.3	70.1
Oceania	95.4	63.9	67.0
World	66.1	21.0	31.8

This preferance for meat protein is reflected in forecast figures for poultry and egg consumption made for 1985:

Region	Animal per capita consumption	
	Poultry (Kg)	Eggs (No)
Far East	2.3	46
Near and M.East	2.1	36
Africa	1.5	24
Latin America	4.0	112
Europe	12.5	280
N.America	29.0	350
World	5.1	108

4. Animal nutritional requirements. The principle behind the commercial feeding of livestock is quite simply:the achievement of maximum meat production at least cost to the producer.

Because of these economic considerations it is a fact that the nutritional requirements of animals are considerably better known than are those of humans.

The animal feed industry utilizes this knowledge to the best possible advantage,providing diets which meet the known requirements for all nutrients and supplying as little in excess as possible.Different species have different requirements for protein,and even within one species requirements change with age.Thus,cattle may only need 10-12% of protein,although high yielding cows will receive a protein supplement aswell as their usual ration,while some turkeys require up to 40% protein when they are very young.

The broiler chicken requires 23-25% of protein,but the laying hens need only 15-16%.

Because of the low protein concentration of cereals,these must be supplemented with high quality protein feeds.These include animal proteins (meat and bone meal,fish meal) and vegetable proteins (oil seed meals such as soya meal).Meat and bone meal contains some 50% protein,fish meal up to 72% and oilseed meals from 20 to 45%.

In general,if cereals are expensive,least cost considerations favour the inclusion of the highest quality proteins.

Also,in hot climates where the appetite is depressed,achievement of maximum growth is only possible with highly concentrated protein sources.

Ruminant animals such as sheep and cattle differ from single stomached creatures (poultry, man) in that they have in their rumen a population of micro-organisms capable of converting most sources of organic nitrogen into protein.For these animals, therefore,protein as such is not an important component of their diet and no amino-acids are essential.

5. Conventional protein sources. Fish meal is the highest feed fed to livestock,but can only be included in the diet to a limited extent before the meat takes on a "fishy" taint.

Estimates made by F.A.O.indicate that there will be little growth in the production of fish meal from present day levels and as a consequence demand will act to keep the price high.

Meat and bone meal is of variable quality,since it is made from waste materials,and has poor storage properties.

Soyabean meal gives the best performance in poultry diets.Most other meals,such as cottonseed or groundnut,although they contain only slightly less protein,are of poorer quality and require considerable supplementation with amino-acids.They may however,be used for feeding cattle and sheep without supplementation.

Many vegetable meals contain chemicals which are toxic to animals and humans.In most cases,however,these are removed either by treating the meal in some way or by growing varieties of the plant lacking the toxin.For example,cottonseeds contain a pigment gland which produces a substance known as gossypol,which is toxic to all non-ruminants.This may be removed by physically removing the gland, by extracting the meal with solvent,or by growing a variety of cotton which does not have the gland.

In total,of all meals produced,soya represents some 60% on a protein basis.This meal is even more important in the international trade which it dominates to the extent of over 80%.

Major,producing countries are the United States,Brazil and China,but only the first two supply the world market to any extent

It is estimated that soya meal will be produced in sufficient quantity to meet world economic demand for the remainder of this century.It will not,however,meet the nutritional needs of the world

Various estimates have been made of the future price of soya.

The price in constant 1975 U.S.Dollars has fluctuated between 3 U.S.D.and 12 U.S.D.per bushel (27.2Kg) over the last 30 years, but while it is at present over 5.5 U.S.D.per bushel it is generally felt that an average figure long term would be between 5 and 6 U.S.D.Much of this price will be carried by the meal component, since the price of soya oil will be held down by the plentiful supply of competitive materials,see annex No.14.

6. Single cell protein (S.C.P.) Single cell protein is made by growing microscopic unicellular organisms in an aqueous medium, using as source of nutrients and energy carbon,nitrogen and other elements,separating the organisms from the medium in which they are grown and drying them.

The difference that exists between alternative manufacturing processes for S.C.P.lie mainly in the choice of organism,the choice of carbon source (the substrate) and the process conditions.

Yeasts,a number of which have been used in foods for a considerable time,are being looked at as possible human food components.

Bacteria may be more advantageous as animal feeds-they grow faster,have higher protein and sulphur amino acids than other organisms.

The nutritional value and digestibility of S.C.P.sources are high;their flavour has been described as bland and those that have been used in human clinical trials can be consumed in amounts sufficient to meet the protein needs of adults.

At one time the presence of high nucleic acid concentration was regarded unfavourably since humans,unlike other animals,metabolise these compounds to form insoluble uric acid which can be deposited in tissues.However,suitable processing procedures,such as alkali washing,have been developed to reduce the nucleic acids to acceptable levels.

Nucleic acids are not a problem when using S.C.P.to feed domestic animals,since these metabolise such compounds to soluble products,such as allantoin,which are easily excreted.

In view of the considerable amount of testing that is required to ensure the safety of any novel material that may be used as a constituent of human foods,it is felt that S.C.P.will make little impact in this way for the medium term future.Its commercial importance will be as a source of high quality protein for inclusion in animal feedstuffs.

The attached table,annex No.15,sets out the amino acid composition of a number of S.C.P.materials and compares them with the conventional protein sources,soya meal and fish meal.

From these figures it is clear that S.C.P.has levels of the essential amino acids which compare well with fish meal and are considerably higher than those of soya meal.

In attempting to assess the relative commercial values of,say, soya meal and S.C.P.it is not strictly allowable to make direct comparisons on the basis of protein alone,since several other components which are nutritionally important should alsobtaken into account.Computer programmes which calculate the least cost rations for animals do this automatically.However it is clear that an S.C.P. with 75% protein can be priced considerably higher than soya meal (45% protein) and yet have equivalent value.

The higher quality of S.C.P.enhance its value yet further.Least cost calculations have shown that an S.C.P.with 75% protein may be of equal value to the animal grower if its price is twice than that of soya for an equal weight of material.

On the basis of the amino acid concentrations and the digestibility,it is possible to rank the quality of protein sources fed to animals as follows:

Source	Net protein utilisation*
Fish meal	65
S.C.P.	60-64
Soya meal	55
Wheat meals	35-50
Wheat/maize	36
Cottonseed	35
Groundnut	32
Feather meals	26

* A measure of nutritional value applied to animal feed proteins - figures are out of 100.

Much can be done to increase the yields of agricultural crops and there are additional areas which are not yet cultivated.

There is,however,a need,particularly in countries where cropland is limited,for food which can be obtained without dependence on the land.Moreover there is a desire on the part of many people to increase the quality of their diet by a greater inclusion of animal proteins.

S.C.P.helps in the achievement of both these needs.Firstly,it is not dependent on large areas for its production - on a 10 hectares site an amount of S.C.P.can be produced equivalent to that from over 100,000 hectares of soya beans.

Also,S.C.P.is a new and high quality source of protein,particularly,suitable for feeding to livestock,such as poultry,which are grown intensively.

S.C.P.has an important role as a feedstuff for animals,eventually it may fulfil an equally important role as a new food for the mankind.

In the annex No.16 is shown the case of a S.C.P.plant producing 100,000 tonnes/year protein which uses 25 million cubic feet/day methane,or the equivalent,of other feedstuff (this amount can be associated with an oil production of between 30,000 and 70,000 barrels/day.

This amount of protein, when fed to poultry, can provide the animal requirements of chicken and eggs for 10 million people based on European food standards. To grow an equivalent amount of protein would need over 100,000 hectares of soyabeans at average U.S. production levels.

There are also a number of reasons why it might be attractive to produce S.C.P. in P.R. Angola.

1-S.C.P. can be produced more rapidly than any crop or animal form of protein because of the speed with which micro-organisms grow. Bellow is given a table showing the necessary time in hours for doubling the weight by growing up different organisms:

Organism	Hours
Bacteria and yeasts	0.3-2
Fungi, Chlorella	2.0-6
Plants (soya, corn, etc.)	144 - 288
Chicken	300 - 576
Pigs	672 -1008
Cattle	720 -1440

2-S.C.P. is a better quality protein and is more concentrated than conventional materials such as soya, cotton or groundnuts.

Only fish meal can compete with S.C.P. but this is already in short supply and it is forecast that there will in future not be enough at current prices to meet demand.

Groundnut and cottonseed meal are of too poor quality to be fed to poultry; these need very concentrated protein if they are to grow at the fastest rate particularly in hot climates. See also annex No.15.

3-S.C.P. production is not seasonal, the quantity produced and its price can be planned. Soya, the next best protein, has to be imported and, like the other protein crops, is subject to variations in weather, affecting volume, shipping delays and political decisions, which can cause wide fluctuations in price.

4-S.C.P. manufacturing units can be erected and brought on stream in a relatively short time - some three years, instead of up to 10 years required to build up the agricultural infrastructure to grow an equivalent amount of protein.

5-S.C.P.production makes better use of available capital,land and water resources.It is much less capital intensive,uses only the land occupied by any small manufacturing plant and consumes only a fraction of the amount of water that would be required to irrigate protein crops grown conventionally.The latter is a factor of special significance in Angolan conditions.

When planning the uses of such resources it might be considered that,since it is not possible to manufacture the carbohydrate part of the animal diet,priority should be given to growing the cereals which would then complement the protein-rich S.C.P.See annex No.17.

C. Major S.C.P. industrial processes.

Regardless of the process and technology used the very simplified principle of producing S.C.P.is shown in the annex No.18.

Four main processes have so far been developed for producing S.C.P.These are:

- The process in which the yeast is grown directly on the gas oil.
- The growth of a yeast on a substrate of normal paraffins (separated from gas oil by a molecular sieve process).
- The growth of a bacterium on a substrate of metanol.
- The growth of a mixed bacterial culture on a substrate of methane.

These four are described in more detail below.Work on a number of other processes has been carried out using high wax crude oils,sulphite liquors from paper mills,molasses,whey and other waste materials as substrates and also using algae as the organism to be grown.

While some of these have been brought to a comercial stage,it is unlikely that they will be of interest in P.R.Angola.

1-Gas oil process.This process,first developed by British Petroleum in France,utilized in its original form,a heavy gas oil containing some 10-30% of waxy paraffins (C_{15}-C_{30}).The organism grown was a yeast of a Candida species which grew on this fraction leaving a de-waxed gas oil to be recovered during the harvesting of the organism by centrifugation.

The dried S.C.P.was subsequantly cleaned by solvent extraction.

Careful control of physical conditions,particularly the pH of the aqueous culture medium,was used in an attempt to prevent contamination of the yeast by other micro-organisms.No feedstock sterilisation was considered necessary.

Although the optimum temperature for growth is 27° C,B.P.have operated at 30 °C and the fermentation was carried out in an air-lift fermenter.

2-Normal paraffin process.Difficulties in cleaning the residual gas oil from the S.C.P.and the development of the molecular sieve process led to a modification in which the paraffin fraction is separated from the gas oil before fermentation.The substrate,air and ammonia,and mineral nutrients,are all pre-sterilised and,in B.P's case,the fermentation is carried out with mechanical agitation.Air lift fermentation can also be used.The product stream is centrifugated to give a cell slurry containing some 15% solids which is then spray-dried.The final product contains aproximately 60% of crude protein.The productivity is about 3 Kg/cubic metre/hour.

In commercial terms,the n-paraffin process is the most developed, a number of countries and companies had built such plants with satisfactory results.

3-Methanol process. Developed by I.C.I.this process utilizes methanol as substrate and a Pseudomonas species of bacterium as the organism.The fermentation is carried out in a pressure cycle (air-lift) fermenter at 37-39°C.Substrate,air and other nutrients are sterilised and the product contains about 72% crude protein.

Apart from I.C.I.who have a 1,000 tons/annum pilot plant, research on methanol processes were undertaken by a number of groups in Japan (including Mitsubishi) by Hoechst-Uhde in Germany, by Institute of Microbiology in the U.S.S.R.Gulf,Sun Oil in USA,etc.

Shell researched a process in the early 1970's based on methanol and developed the concept of selected mixed cultures of organisms which was later used in the methane process.It is expected that I.C.I.is operating at a productivity of 3 Kg/cu metre/hour.

4-Methane process. The methane process,is the youngest of the four and has been developed by Shell.Methane,supplied in the form of natural gas,is the major substrate,although other hydrocarbons in the natural gas are converted to S.C.P.and this togather with air and essential nutrients,is added continuously to the fermenter.

Here the substrate is consumed by a carefully selected and controlled mixed culture of organisms which act symbiotically to achieve the highest yields of protein so far achieved.The temperature of operation is 45°C.A broth comprising some 2-3% suspension of bacterial cells is drawn off continuously.After floculation and separation,the process water is re-cycled and the cell paste is dried to a powder containing 75% protein.The productivity is claimed to be about 5 Kg/cu metre/hour.

D. Process economics.

Any S.C.P.process may be characterised as comprising new and complicated technology which utilizes microbiological growth on a scale never used before.

To have a general idea about the economics of the processes, calculations have been made with respect to all processes using certain base case assumption throughout.These were:

Plant size:	100,000 tonnes of S.C.P./annum.
Plant lifetime:	15 years.
Fiscal regime:	45% (7.1/2% straight line depreciation)
Profitability:	8% real earning power.

Standardised costs have been used for utilities, labour and overheads and nutrients-see annex No.19.Conditions such as cooling water temperature 35 °C are also taken as the same.

On this basis the relative process capital expenditure is as follows:

n-Paraffin process	U.S.D. 90 million.
Methanol process	U.S.D. 70 million.
Methane process	U.S.D. 80 million.

Note that no proportion of the methanol production plant,or the n-paraffin purification plant is included.However the extra refrigeration capital is included in the n-paraffin process.

Taking a range of substrate prices,the netbacks required by each process to achieve a real earning power of 8% are shown in the accompanying graphs-see annexes No.20;21;22-together with the contribution for the substrate.The two vertical scales on the graphs show respectively the netback required per ton of product and that required per ton of protein.

The cost of methanol relative to methane has been calculated on the basis of a 300,000 tonnes/annum methanol plant starting up at the same time.The relation between n-paraffin cost and gas oil is valid only in a European context.

It is tempting to superimpose the data on these graphs to study the relative economics of the processes.However,it should be remembered that such comparisons can only be made when the relative costs of the substrate are known.Also,a change in any of the basic assumptions (such as tax rate or required earning power) may have an impact on the relative economics.

E. Possibility to produce S.C.P.in P.R.Angola

The possible production of S.C.P.in P.R.Angola can start from the quality of Angolan crude oil.All these crude oils are characterized by low sulphur content and high content of paraffins.

An analysis of an average crude oil,realised by Petrangol, shows the following contentof paraffins determined on narrow distilated fractions:

T.B.P. °C	100-125	125-150	150-175	175-200	200-225
Aromatics %vol	2.6	5.8	8.6	12.3	15.5
Olephins %vol	0.5	1.0	0.8	1.0	6.3
Paraffins %vol	96.9	93.2	90.6	86.7	78.2

	225-250	250-275	275-300	300-325
	16.3	19.2	16.8	10.0
	5.4	6.1	4.2	2.0
	78.3	74.7	79.0	88.0

Taking into account the quality of the crude oil and also other existent and future factors in P.R.Angola the Ministry of Petroleum could analyse the possibility of implantation of a petroprotein plant.Of course this is a matter of comprehensive study,to choose carefully the process (the expert opinion at the moment is that the most suitable for P.R.Angola is the n-paraffin process),the organisms and mainly the supplier of the know-how and the plant.

A close cooperation is necessary with the Ministry of Agriculture,the future user of the petroproteins.

III. DEVELOPMENT OF THE PETROCHEMICAL INDUSTRY ON THE BASIS OF THE ASSOCIATED GASES.

A. General aspects.

Associated gas takes its name from the fact that it is produced in association with crude oil.

While still underground the associated form remains dissolved in the surrounding oil due to pressure.Released at the well-head when the pressure drops,it is flared there as a safety measure, failing any alternative use.

Flared gas was variously known to early civilisations as the "eternal flames",the"leaping fiery furnance"and the "burning springs"

Ignited by lightning and burning through the centuries,natural gas seepages were documented by the Greeks and Egyptians;in the Baku area of the U.S.S.R.gas flares existed from pre-Christian times.

As early as A.D.200 the Chinese transported natural gas through simple pipelines made of hollowed bamboo logs.

When oil reaches the surface,the dissolved gas released comprises a mixture of hydrocarbons ranging from methane (C_1) to butane (C_4) and heavier fractions together with impurities such as CO_2, SO_2,H_2S and N_2.

Usual oil field practice is to cool the gas to separate hydrocarbons heavier than C_4 as condensates;unless facilities are installed for recovering the other components,the remainder is either flared or reinjected.

The composition of associated gas differs significantly from that of non-associated gas in the higher level of heavier components ethane,propane and butane.Associated gas in the Middle East contains only 50 to 55 per cent volume methane compared to at least 80% and sometimes as much as 100% found in non-associated gas.On average,associated gas in the Middle East contains between 12 and 18% ethane,between 9 and 12%propane and about 5% butanes.In Mexico associated gas may contain about 82% methane and 10% ethane,while in Indonesia,both are lower:methane 72%,ethane 6%,due to high carbon dioxide levels.

Unfortunatelly no datas could be obtained about Angolan associated gas.

The significance of these differences is that whereas methane, the main component of non-associated gas,is confined to production of L.N.G.(Liquefied natural gas),for export use,fertilizers and methanol,for local use or export,and thermal uses,local use only, ethane is a potentially valuable raw material for local petrochemical production,and the propane/butane fractions can be sold locally or exported as L.P.G.(Liquefied petroleum gas).

The optimum use of associated gas therefore depends on finding economic local and export outlets for all the main components: methane,ethane,propane,butane and heavier fractions.

1-Methane,has so far mainly been used for fuel purposes,e.g. power stations and general industrial and domestic heating.Three large scale consumers of methane are:reinjection (after L.P.G.recovery) and export as pipeline gas or L.N.G.In the chemical industry methane serves mainly as feedstock for manufacturing ammonia and methanol.More attention is now being paid to technology for converting methane to synthesis gas (a mixture of carbon monoxide and hydrogen) as the basis of new routes to chemical products,gasoline and the middle distillates.Methanol is also attracting attention as a potential basic petrochemical block on a par with ethylene.

A plant to produce gasoline from methanol is under construction in New Zealand and work on processes for converting methane to ethylene is said to be well advanced.

2-Ethane,is most conveniently cracked to manufacture ethylene; the yields are high and this represents the most economical use.The range of petrochemical products that can be produced from ethylene is one of the largest.

3-Propane ,can be extracted along with butane in the form of L.P.G.and either exported or used locally.In developed countries, L.P.G's potential as a chemical feedstock is now more widely considered.Some crackers in the United States and Europe have been adapted to take L.P.G.in order to give feedstock flexibility.

When propane is cracked,it yields both ethylene and propylene, the percentage of propylene depending on the severity of cracking.

Propane can often be cracked together with ethane and the mixture produces mostly ethylene;only large crackers (producing 200,000 t/y ethylene or more) produce significant quantities of propylene.Thus if large quantities of propylene are required,it is better to crack propane alone,or a butane-propane mixture.

4-Butane,is mainly consumed as L.P.G.Chemically,it comprises a mixture of normal-butane and isomers,of which iso-butane is the more valuable because it can be converted to iso-butylene.

Iso-butylene is the precursor of a number of products including the alkylate required in large quantities for the gasoline pool.

A potentially important use for iso butane is to make M.T.B.E. (Methyl Tertiary Butyl Ether),a gasoline component needed to replace lead in high octane gasoline.

5-Pentane and heavier fractions,are generally separated in the field;the resulting liquid mixture,known as condensates,is either treated and sold as such or mixed with reformed motor gasoline, naphta or crude oil.

B. Treatment and processing.

Processing of crude gas depends ultimately on the way individual components are to be marketed,but there are two basic approaches-complete liquefaction to make L.N.G.and partial liquefaction to recover L.P.G.and possibly ethane.As noted,in either case pentane and heavier fractions are generally separated in the field.

Rising world gas prices and the developing countries' increasing control over their oil and gas resources lead to plans for increasing utilization of associated gas.

Five motives for industrialization can be identified:

-self sufficiency in petrochemicals;

-establishment of an export-oriented industry;

-oil conservation,boosting oil exports;

-diversification of income sources;

-elimination of political objections to flaring.

The world supply and demand outlook influencing gas-based petrochemical production indicates the need for the following plants to be built between 1984 and 1990:

- ethylene,18 units 500,000t/a each
- L.D.P.E. 32 units 200,000t/a
- H.D.P.E. 39 units 75,000t/a
- P.V.C. 26 units 250,000t/a

Nearly half these will have to be built to meet demand arising in the Third World itself.

Given their favourable feedstock position there is scope for many more to be built by the oil producing developing countries in order to supply developed regions.

Methanol is a special item because of its impending fuel and chemical uses,is conservatively forecast to move from a global surplus of 900,000 t/a in 1983 to a broadly balanced position in 1990 with demand in the region of 23 million t/a.

To achieve this capacity build-up two large production units, 2,500 t/d in Latin America,two in Asian developing countries,and three in Africa/Middle East could be based on associated gas.

If fuel uses for methanol grow rapidly,however,both demand and the number of plants required could be doubled.

In fertilizers,the demand analysis indicates a requirement for an additional 12 million tons N_2 capacity between 1984 and 1990.

Thus the expanding market alone is equivalent to 44 units with 1000 t/d capacity each.

Sponge iron demand is determined by the market for scrap steel, which in turn reflects the health of the steel industry in general and the growth rate in electric furnance steel in particular.

The long-term outlook is favoured by reduced availability of good quality steel scrap.In the mean time,developing countries are advised to gear both sponge iron and steel output to cover domestic or local regional demand.

Primary aluminium consumption is forecast to reach 19.9 million tons in 1985, 24.6 million tons in 1990 and 29.5 million tons in 1995.Between 1985 and 1995 some 60 to 70 smelters each with a capacity of 150,000 t/a would be needed to meet this demand assuming a G.N.P.(Gross National Product) growth of 3% annually.Given the general reapprisal of the industry's energy position,many of these plants could be built to use electric power from gas turbines fuelled with low-cost associated gas.

A comparison of net production cost for eleven products : ethylene;ethylene oxyde;ethylene glycol;H.D.P.E.;L.D.P.E.;ammonia; urea;sponge iron;steel;aluminium;based on associated gas in developing countries - and ethane,natural gas or naphtha in developec countries,showed all could be manufactured more cheaply in developing countries,than in the United States and the Federal Republic of Germany.

Inclusion of shipping costs to deliver these products to the

United States and North and South Europe indicate that developing countries production would be able to compete with broad margins against local products in the three developed country markets.

C. Fertilizers production.

The choice of products for industrial projects based on associated gas clearly reflects a combination of local needs and ease of international marketing.The Ministry of Petroleum choosed to give priority to the production of fertilizers and that is why the expert gave a larger attention to the position of these products in the internatinal market.

All gas-based production of fertilizers involves ammonia.The prospects for developing countries using associated gas to penetrate these markets are therefore determined by the supply and demand for ammonia and its nitrogen fertilizer derivates.

1 - Present market size. The two most authoritative sources of information in this sector are F.A.O.for past and actual figures and the U.N.I.D.O/F.A.O.World Bank Working Group on Fertilizers, for yearly medium-term forecasts five and ten years ahead.F.A.O. is currently casting backwards its historical data base on China

The Working Group's five-year supply and demand forecast represents the harmonized result of commercial,lending and technical assistance authorities.The data and trends are crosschecked with the information supplied by individual members in a Delphi panel of experts.From 1978 onwards,the Group undertook a 10-year demand forecast using trend analysis judgements to reach panel consensus.

World consumption of nitrogen fertilizers reached 57.1 million tons of nitrogen in 1979/80 according to the figures from F.A.O.

Some 40% was consumed in developing and 60% in developed countries.Growth in over-all demand during 1970's averaged 6.1% annually,but it was both unevenly distributed and subject to considerable fluctuation.The 1978/79 growth of 6.5% meant a recovery of demand compared to previous years,but it was confined to the developed countries,mainly the United States.

Developing countries demand in contrast showed a market drop from the 12% annual growth throughout most of the 1970's to around

6% in 1978/79.Both markets recovered in the 1979/80 season.

On the supply side production rose 6.7% in 1978/79 to reach 59.6 million tons,out of which 57.3 million was available for agriculture.This increase was less than the 8.9%reported for the year before but it exceeded the 1970-77 average.

During 1978/79,the largest quantitative increases came from Western Europe and centrally planned Asia.The West European performance reflected better plant capacity utilization enhanced by idling or shutdown of capacity in the United States and Japan.An absolute decline in nitrogenous capacity in Japan was due to a rationalization programme for ammonia and urea induced by the rapidly risig cost of feedstocks.

During 1979/80,there was a substantial drop in production growth in most regions: Africa and Eastern Europe suffered absolute declines of 16.5% and 1.2% respectively.The U.S.S.R.suffered setbacks due to bad weather,shortcomings in feedstocks and other temporary technical and logistical difficulties.feedstock and power problems beset India,Turkey and the Philippines.Plant operation problems are still hindering the U.S.S.R,India and Mexico.The Republic of Korea is reducing production due to domestic and export market constraints brought on by the feedstock price squeeze.

Annex No.23 shows that the developed countries have a nitrogenous fertilizer supply capacity well in excess of their demand, whereas the developing countries remain in a deficit situation.

Comparison of total nitrogen production with ammonia capacity shows that the developing countries operate at 67.3% of ammonia capacity versus 79.5% for the developed countries.

However, in many countries there is an unusually large proportion of new ammonia capacity not matched by a corresponding dowwnstream conversion capacity to nitrogenous products,it is capacity that was primarily intended to supply ammonia export markets.This points to potential medium-term difficulties that may have to be resolved through improved operating rates for new downstream plants additional convertion capacity and price increases in finished fertilizers that would bring idling plants in the developed countries back on stream.

Annex No.24 shows inceases in ammonia capacity,the supply of nitrogenous products and the demand for such fertilizers up to 1990.

From this it is clear that in quantitative terms the developing countries are far outstripping the developed countries in adding new ammonia capacity.

In the period 1979-84, the developing countries have roughly doubled the new capacity increases in the developed countries.

The only significant developed country increases are in the Soviet Union, where the full impact of 41 plants recently built is evident.

Comparing firmly committed projects between 1976 and 1984 with actual ammonia plant implementation, it is evident that although developing countries planned to double ammonia capacity during the past four years, they could only achieve 65% of their aims; the lag on target dates was around two years.

The medium-term projects to 1984/85 show that the developing countries plan an even larger ammonia capacity increase than in the previous period, despite current learning curve problems in the Far East and Latin America.

On the demand side consumption of nitrogenous products in developing countries is growing twice as fast as that in developed countries through till 1990. This reflects their low per capita consumption. Nevertheless, the trend shows a steady decline through the decade. This situation may be exacerbated when the thorny problem of fertilizers subsidies and increased food production in developing countries is settled in the relatively near future.

D. Market structure and prices.

In the developing countries, which will account for the largest share of future sales, the nitrogenous industry is predominantly government owned, with minor participation of local private industry, co-operatives and joint-ventures with the large chemical/oil corporation. Eastern Europe apart, these same chemical/oil corporations dominate fertilizer production in developed countries, again with some minor participation by Western European Governments and some agricultural co-operatives.

The final market in all countries is composed of a large number of small consumers. Export deals are generally made, however, with either a relatively small number of importers in each country or with government organizations.Such contracts necessarily involve large quantities.The United States market is somewhat exceptional in having an established pipeline and ammonia distribution business, both are experienced in importing and redistributing ammonia in large quantities.Such deals have to be made on a long-term basis and would not,for example,be accessible via trading organizations.

Traders on the other hand could help build up spot sales to the United States market.

The bulk of all transactions is traded at contract prices.

These prices are generally not published but the trends in spot prices generally reflect similar trends in the contract market.

Despite large price fluctuation,extrapolating the longer-term trend in spot prices gives a urea price of 307 U.S.Dollars/ton in 1984 and 213 U.S.Dollars/ton for ammonia c.i.f.Western Europe.

The prices in early January 1981 were 235 and 175 respectively.

The United States Gulf Coast f.o.b.prices are about 20% lower than c.i.f.Western Europe ones.

Since traditional producers are suffering increases in production and distribution costs and are no longer able to absorb them through increases in efficiency,contract prices may undergo steeper growth rates than spot prices unless new producers with substantial production cost advantages make their presence felt in international markets.

E. Opportunities for new producers.

The difference between 1984 capacity and forecast demand in 1990 indicates a requirement for a net additional 12 million tons N_2 of capacity in this period.This is equivalent to 44 units of 1000 ton/day,many of which could be advantageously built to use developing countries' associated gas.

World exports of nitrogenous fertilizers reached 11.99 million tons of nitrogen in 1979/80,up 1.3% over the previous year.The ratio of international trade in nitrogen to world consumption increased from 18.8% in 1974/75 to 22.0% in 1978/79.A fall to 21.0% in 1979/80 reflected a deterioration of regional supply.

With the exception of the Near East,all of the developing regions stagnated due to production difficulties,thus reversing the past trend of increased regional self-sufficiency.The situation was such that even a high-cost fertilizer producer such as Japan could export more fertilizer than it consumed domestically;similarly,Western Europe, a high cost producing region,became the leading exporter.

It should be noted that practically all imports by the developed countries represent intra-trade in that macro-region.

The gap analysis for ammonia identifies North America and Western Europe as areas with both short and long term deficits of ammonia.In Western Europe developing country strategy should focus on pre-empting local investment.

The main competition for both these markets will come from the U.S.S.R.

The main opportunity for developing country producers remains, however,other developing countries.

These have continued to increase their imports of nitrogenous fertilizers over the years mainly from the developed countries.

As yet they do not appear to have reached a cost benefit ceiling on fertilizer prices in relation to prices for their exported agricultural commodities.

Their main constraints are foreign exchange restrictions and temporary shortages in domestic fertilizer production.

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As yet they do not appear to have a cost benefit ceiling on fertilizer prices in relation to prices for their exported agricultural commodities.Their main constraints are foreign exchange restrictions and temporary shortage in domestic fertilizer production.

Note.For everybody who looks for an extended analysis of medium and long term demand forecasts based on the Group's records since 1976,the expert recommend "Supplement to the Second World-Wide Study on the Fertilizer Industry 1975 - 2000" U.N.I.D.O.

F. Opportunity for producing fertilizers from associated gas in P.R.Angola.

Having as primary objective to eliminate the wasteful flaring of associated gas produced in conjunction with crude oil in "SOYO" in the northwest region of P.R.Angola,the Ministry of Petroleum has requested the "International Gas Development Corporation" to prepare an executive report,based on turning to good account the-at present flared gases in Soyo.

This work in a brief presentation,in English and Portuguese, is analysing the possibility of implantation of a fertilizer complex based on associated gas in Soyo region.

The study does not taken into consideration and is not analysing other variants of turning into good account the associated and non associated gas,through the production of other commodities.

In fact the whole study does not contain any analysis by components of the gases supposed to be processed.

The Executive Report evaluates two cases:

-one based on supplying only Angolan domestic fertilizer requirements

-the other,a larger project with a significant export component.

The following major bases were used in these evaluations:

-The primary objective of both project options is to eliminate the wasteful flaring of associated gas produced in conjunction with crude oil in the northwest region of Angola.

-Associated gas supplies will be supplemented as needed with existing,large reserves of non-associated gas in order to ensure consistent gas supply to the plant.

-Natural gas will be converted to solid urea in a plant sized solely to meet Angolan fertilizer needs in case I and for Angola plus export markets in a plant consuming 25 million cubic feet per day feed in case II.Domestic Angolan sales requirements are 35,000 tons/year in 1987,increasing by 10%per year throughout the life of the project.

-The Angolan government will have an interest in the plant,to ensure attainment of Angolan nationalobjectives,to protect Angolan interest,and to demonstrate Angolan commitment to the project.

-Foreign participation in the project,in the form of a joint-venture,will be sought in order to provide equity capital,access to financing,technical and operating expertise,training,and specialized marketing as well as distribution capability.

-Project life is assumed at fifteen years.

-Angolan income taxes are assumed at 50% of taxable income.

-The price of the natural gas sold to the plant will be such that it represents an acceptable return to the producers and provides sufficient incentive to develop and install producing and gathering facilities.Project economics are based on a gas sale price of 1.50 $ per million Btu.for gas delivered to the plant.

-The plant will be located in Soyo region in the vicinity of gas reserves.

-The plant will be entirely self-sufficient when supplied with natural gas feed and fresh water.

-Angolans will be trained to manage,operate and maintain the plant,to replace the expatriate personnel as early as possible.

-Effective distribution of fertilizer to local Angolan markets, including organization of all necessary facilities and personnel to carry out this important function,will be essential to the success of the project.

-Any liquid hydrocarbons (LPG's) in the associated gas are assumed not to be removed from the gas fed to the plant,but this option must remain available for future study and implementation.

-The capital investment to generate approximately 3,000 KW of electricity for local distribution and consumption in the Soyo area, is included in the estimated plant costs.

1 - Summary description of case I: Plant sized to meet only Angolan fertilizer requirements.

Capacity: 90,000 metric tons urea per year (275 tons/day)
Estimated plant costs for 1983 : $ 145 million
Amount of equity required (escalated) $ 49.7 million
Return on overall project(equity 100%,debt 0%) 4%.
Return on equity (equity 25%,debt 75%) 0.3%
Total revenue over life of project : $ 518 million
Total foreign exchange gain : $ 11.4 million.
Total Angolan taxes over the life of the project : $ 4 million.

Comment:Case I is an uneconomic project and will likely not attract foreign participation on an equitable basis.If implemented, this case must probably be considered a national project supported entirely by the government of Angola to stimulate development,improve agricultural productivity,avoid wasting a natural resource,and reduce foreign exchange payments for fertilizer imports.

2 - Summary description of case II : Plant sized to process approximately 25 million cubic feet of gas per day to produce fertilizer for domestic Angolan requirements and export markets.

Capacity : 390,000 metric tons urea per year (1,200 tonns/day)

Estimated 1983 plant cost : $ 195 million

Amount of equity required (escalated) : $ 67.5 million

Return on overall project (equity 100%,debt 0%) : 18.9%.

Return on equity (equity 25%,debt 75%) : 26.4%

Total revenue over life project : $ 2,244 million.

Total cash flow to equity participants over life of the project: $ 643 million.

Total foreign exchange gain : $ 1,088 million.

Total Angolan taxes over life of the project : $ 643 million.

Comment : Case II is an attractive venture and is recommended for future development.The anticipated economic returns will encourage foreign involvement,attract financing on acceptable terms and permit financing repayments to be made from export sales revenue.

3 - Factors favouring success of case II.

- Natural gas reserves are more than sufficient to support the project and are located in an area where oil producers are already active.

-Several attractive plant site locations exist in the Soyo area where infrastructure development has already begun and access to ocean shipping is available.

- The project will be developed in phases,with development expenditures minimized until the time that a firm commitment is made to proceed.

- Revenue from the sale of gas should be adequate to interest producers in developing the gas field,gathering and transport facilities.

- Future market opportunities - in Angola and nearby African countries are excellent.

- Prospects for securing the participation of a major international fertilizer company are excellent.Such participation will provide the necessary management,operations,and marketing know-how to successfully initiate the project while Angolan personnel are being trained in these skills.

- Direct participation of the Angolan government (through an appropriate agency) will give the project the necessary credibility and backing to attract other participants,to secure financing and to protect Angolan interests.

4 - Major benefits of case II to Angola.

Economic :

An attractive return on equity invested in the project.

Income from the utilization of presently wasted associated gas.

Tax revenue on the profits derived from the project.

Elimination of foreign exchange purchases for the import of nitrogen fertilizer.

Energy development :

Increased incentives for energy exploration and development in Angola

Attractive opportunities to increase recovery of natural gas liquids for use in Angola and for export.

Social development :

Industrialization and creation of skilled jobs in the Soyo area to be accomplished through long term training programs.

Additional port and infrastructure development in Northen Angola on the Rio Zaire.

Opportunity for training and improvements in fertilizer utilization and distribution in Angola.

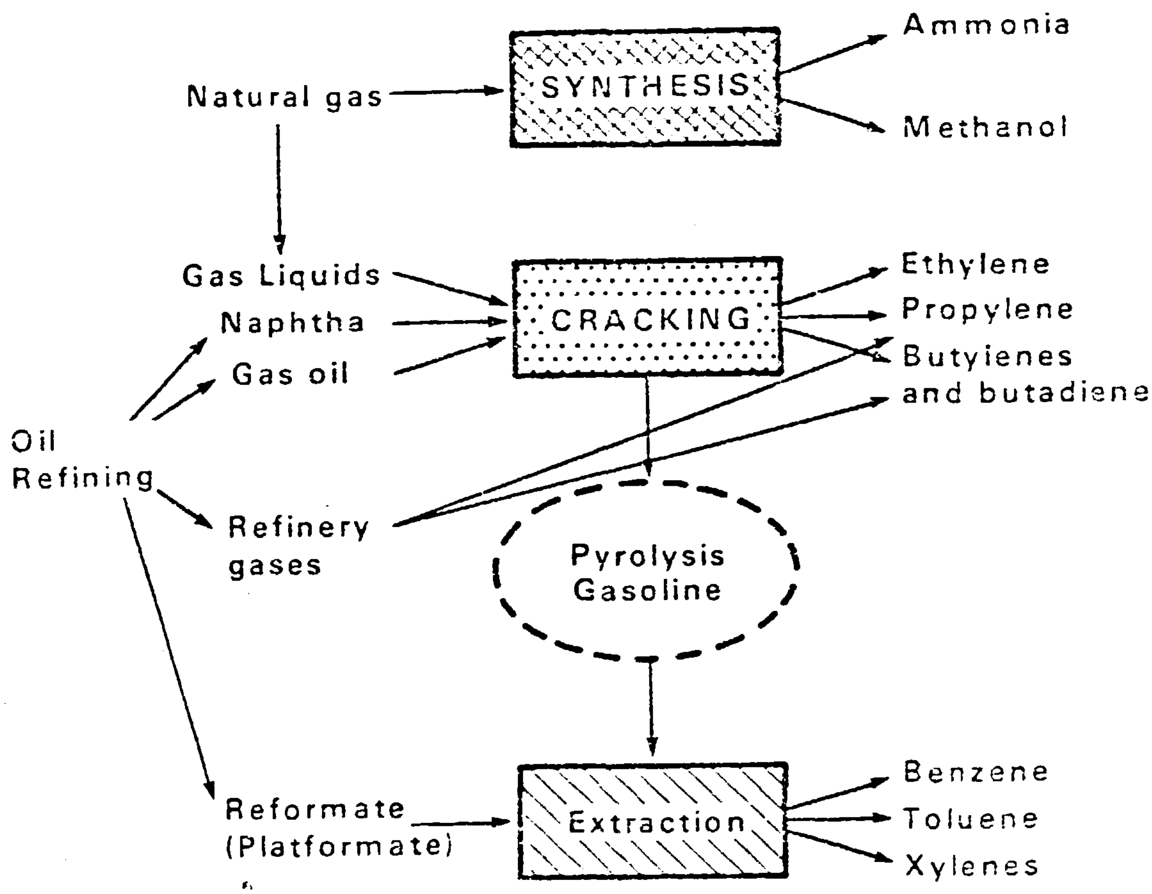
The possibility of a future complex fertilizer development program incorporating nearby phosphate in N'Zeto.

Note : This part III.F.must be read together with the "Executive Study" made by International Gas Development Corporation".

LUANDA 2nd OF JANUARY 1984.

ANNEX No.1

MAIN SOURCES OF PETROCHEMICALS

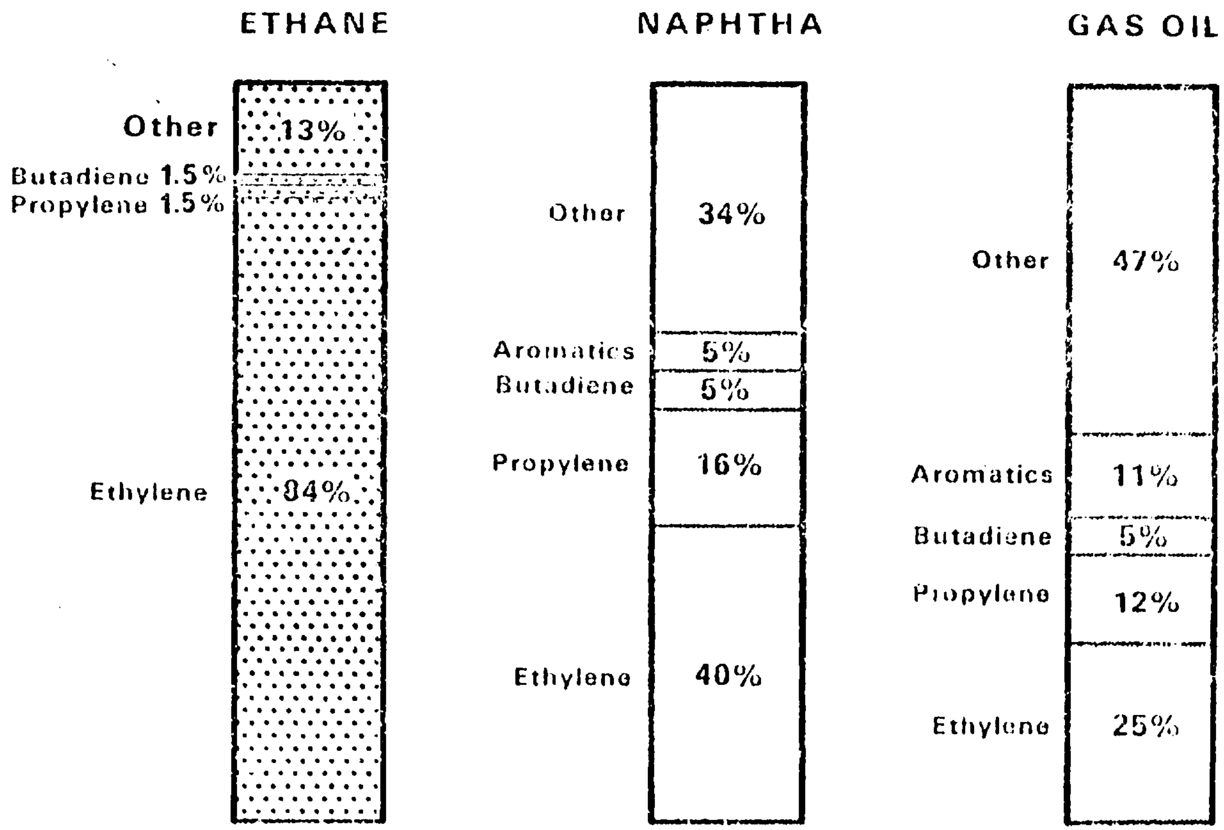


ANNEX No.2

MAIN ORGANIC END PRODUCTS

PRODUCT GROUP	CURRENT WORLD CONSUMPTION (million tonnes)
Plastics and resins	25-30
Synthetic rubbers	5- 6
Synthetic fibres	7- 8
Synthetic detergents	13-15
(active matter content	3- 4)
Chemical solvents	7- 8

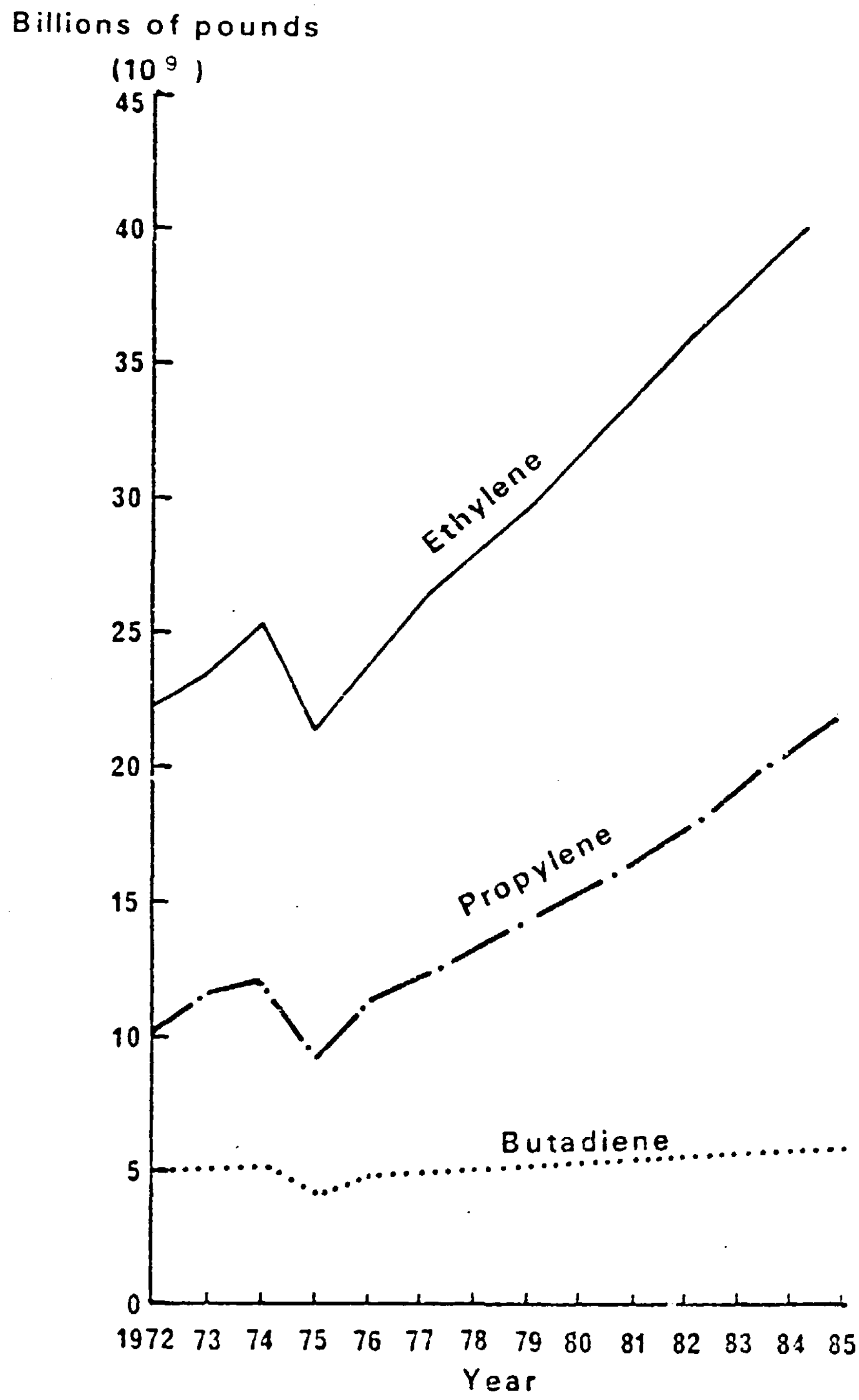
CRACKING YIELDS FROM VARIOUS FEEDSTOCKS



ANNEX No. 3

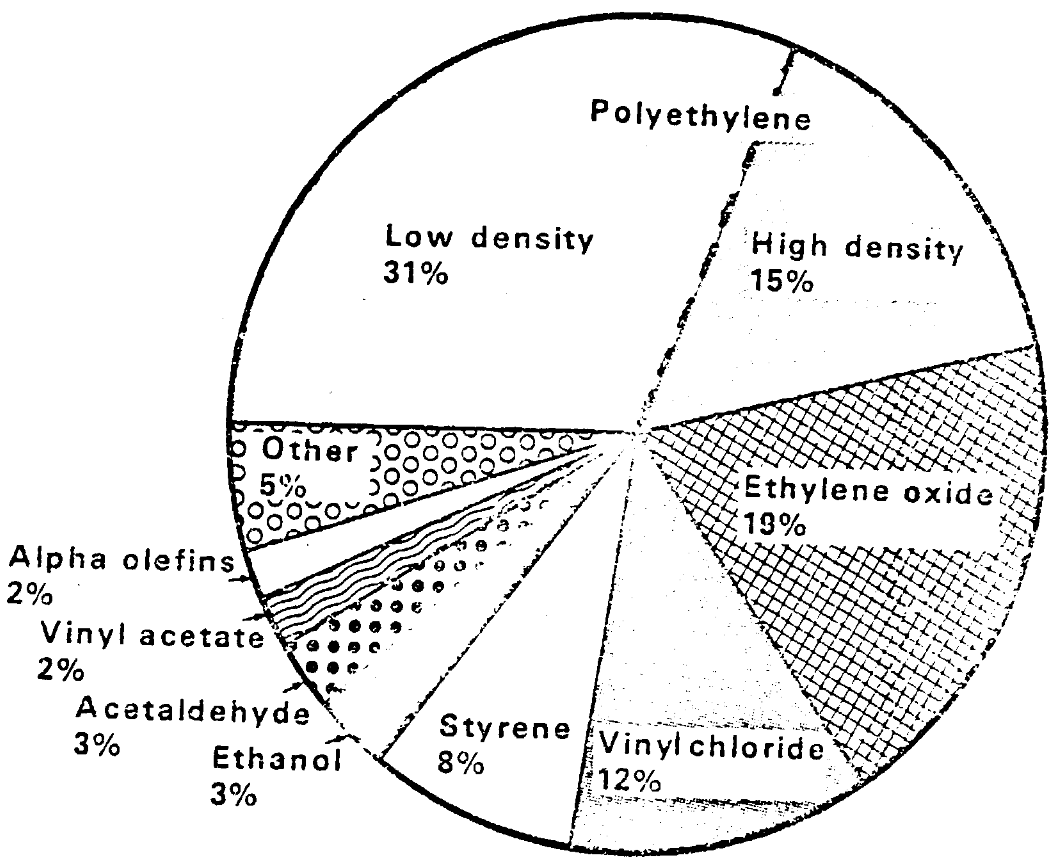
ANNEX No.4

THE PAST, PRESENT AND FUTURE PRODUCTION OF ETHYLENE, PROPYLENE AND BUTADIENE IN THE U.S.

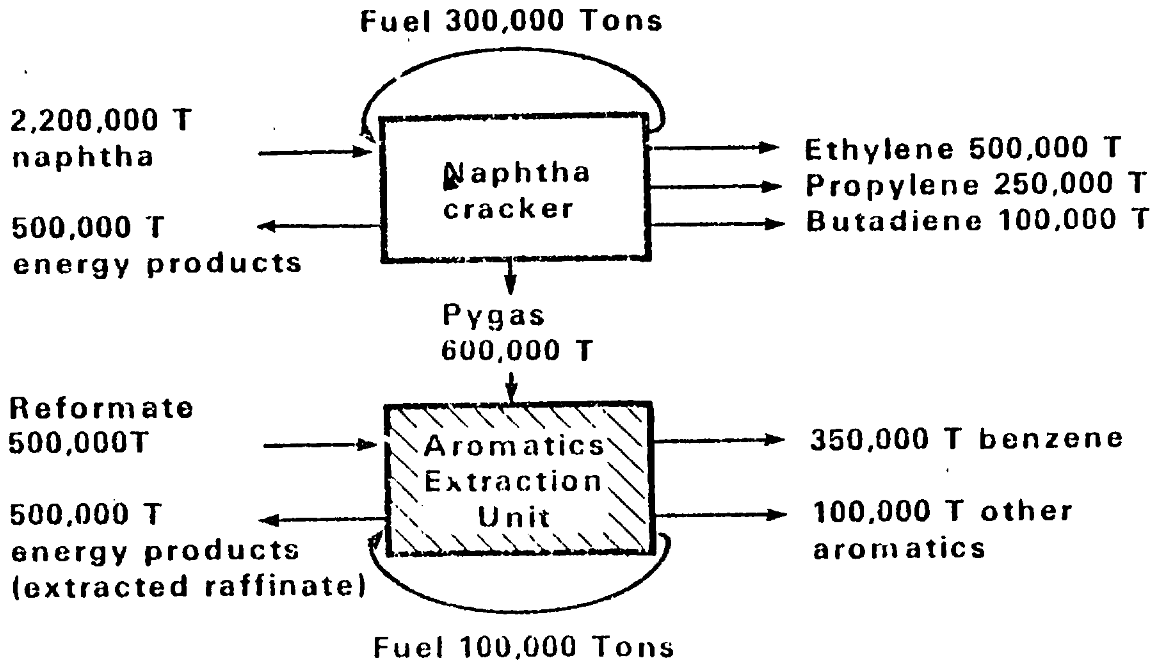


ANNEX No.5

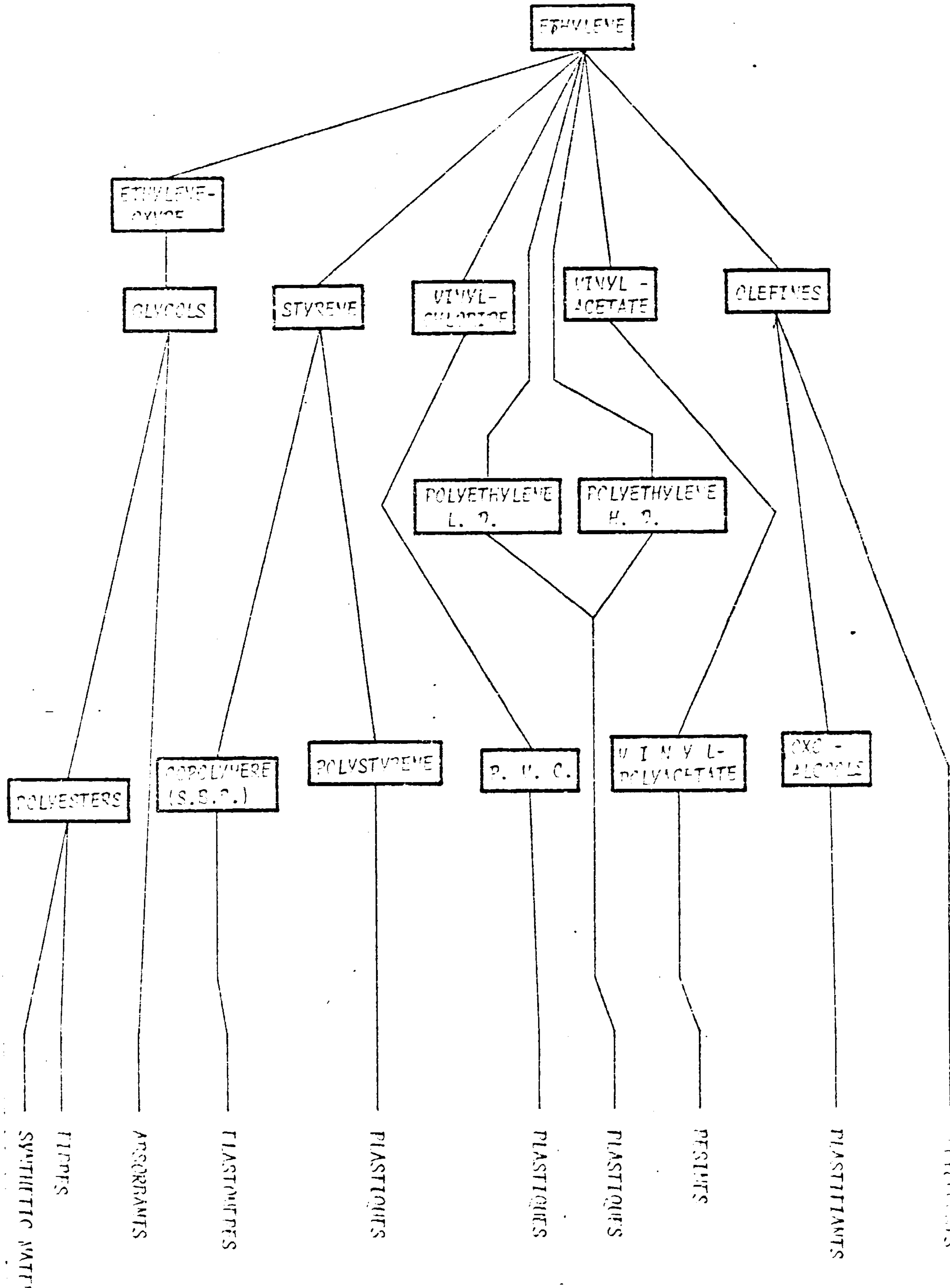
ESTIMATED USE OF ETHYLENE IN USA



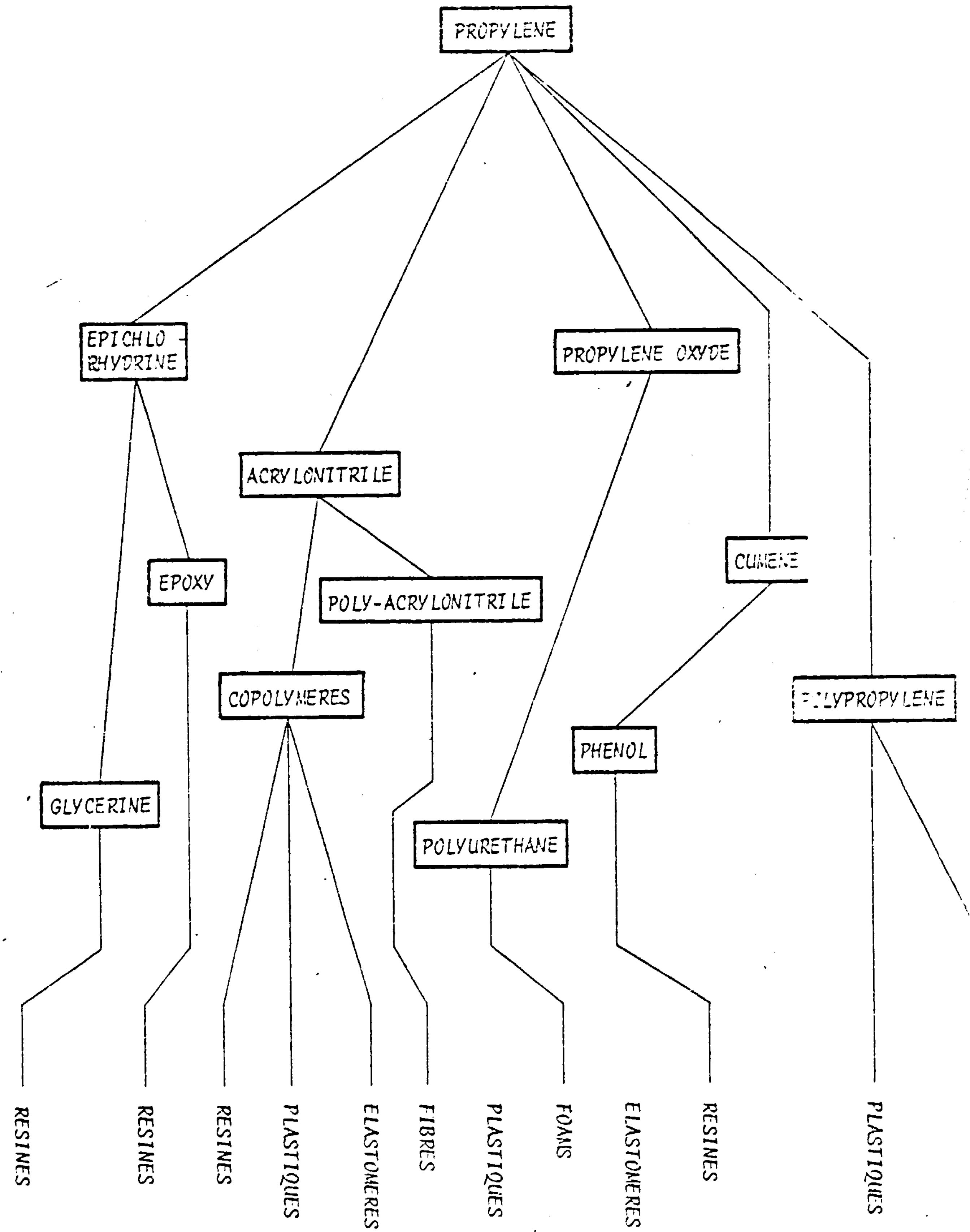
MASS BALANCE FOR A EUROPEAN NAPHTHA CRACKER



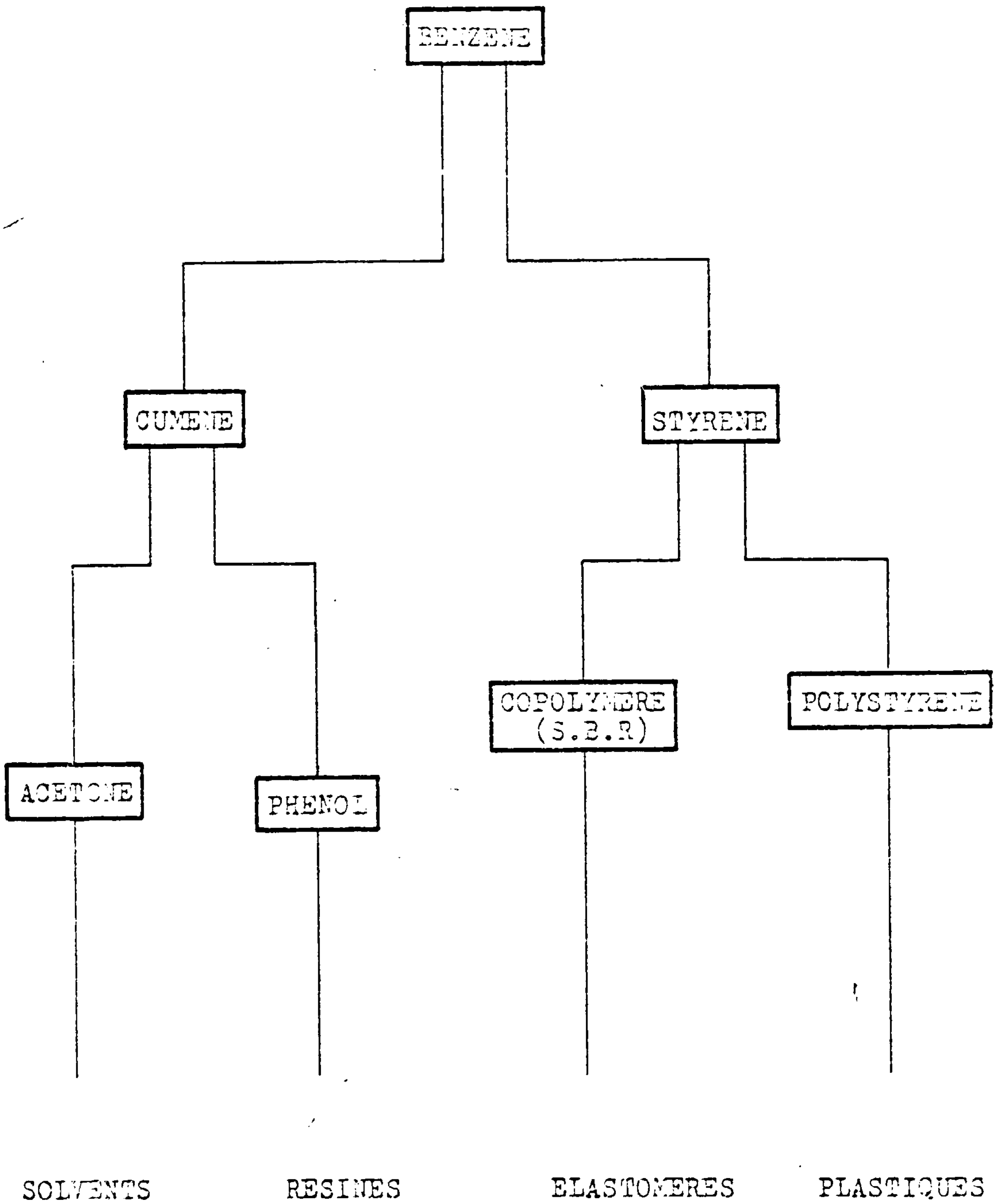
ANNEX No.6


ETHYLENE
ETHYLENE-OXYDE
GLYCOLS
STYRENE
VINYL-CHLORIDE
VINYL-ACETATE
OLEFINES
POLYETHYLENE L. D.
POLYETHYLENE H. D.
POLYESTERS
COPOLYMERE (S.B.R.)
POLYSTYRENE
P. V. C.
VINYL-POLYACETATE
OXO-ALCOOLS
SYNTHETIC MATERIALS
FIBRES
ABSORBANTS
ELASTOMERES
PLASTIQUES
PLASTIQUES
PLASTIQUES
RESINES
PLASTIFIANTS

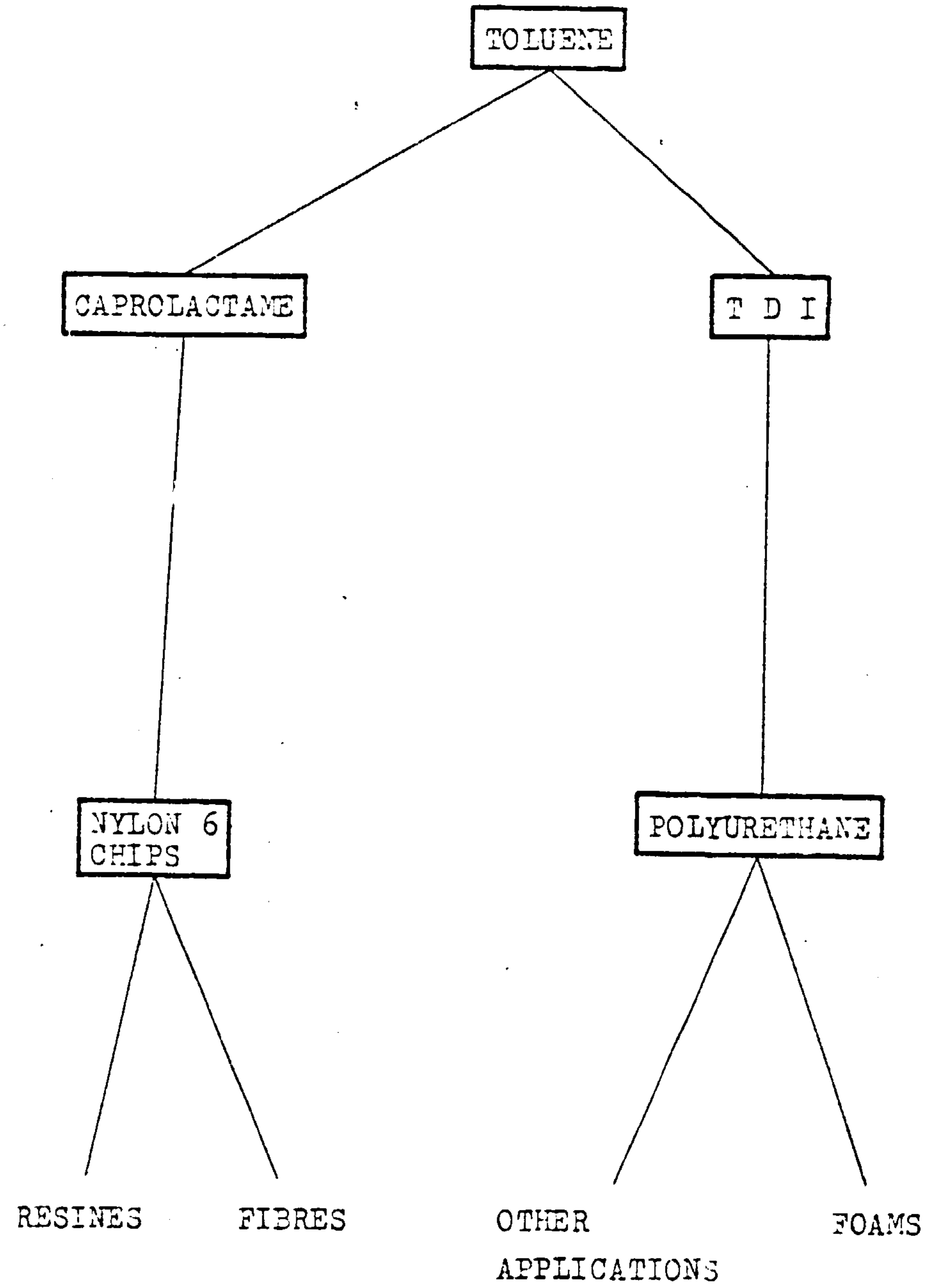
ANNEX NO.8


PROPYLENE
EPICHLO-
RHYDRINE
PROPYLENE OXYDE
ACRYLONITRILE
CUMENE
EPOXY
POLY-ACRYLONITRILE
COPOLYMERES
POLYPROPYLENE
PHENOL
GLYCERINE
POLYURETHANE
RESINES
RESINES
RESINES
PLASTIQUES
ELASTOMERES
FIBRES
PLASTIQUES
FOAMS
ELASTOMERES
RESINES
PLASTIQUES

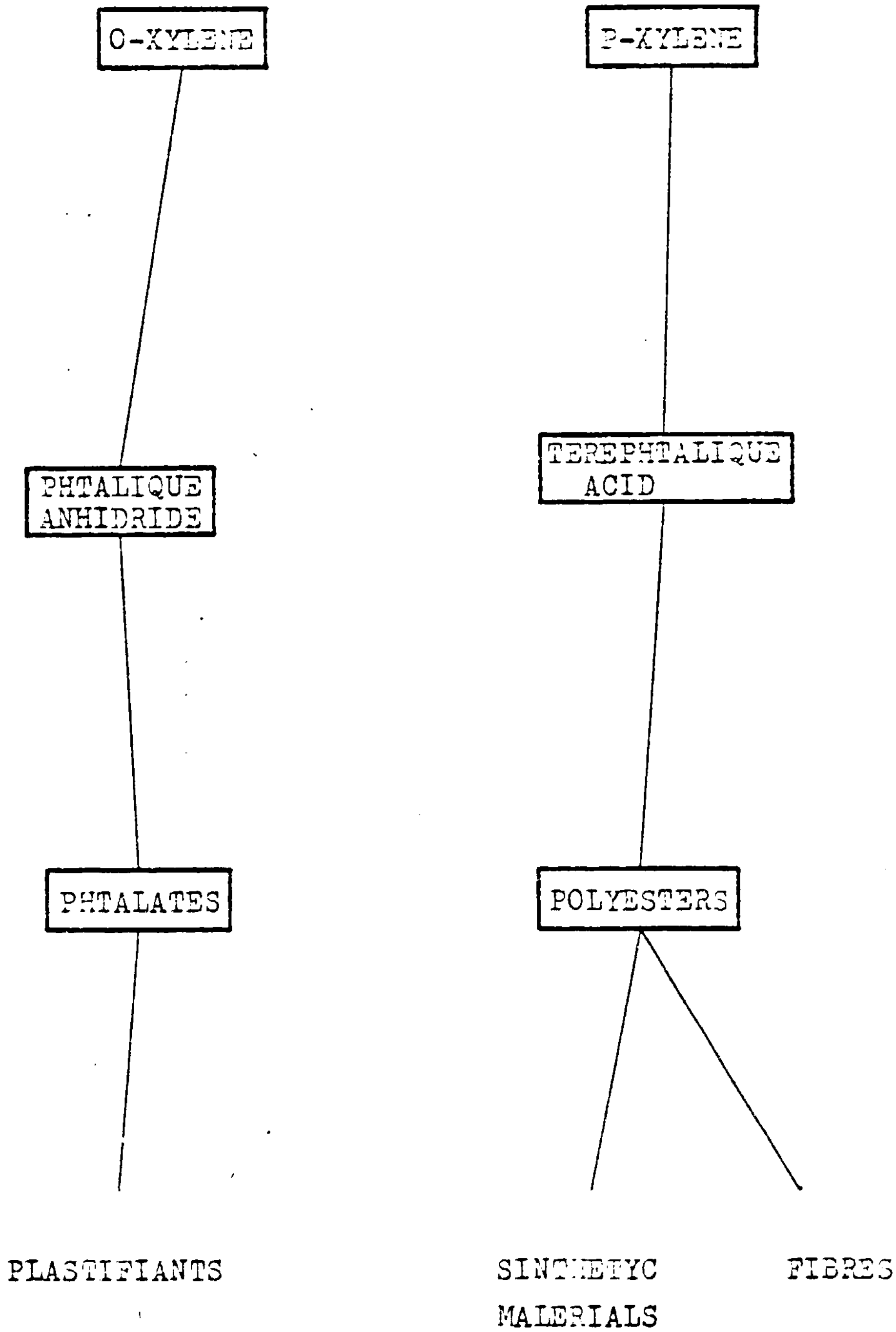
ANNEX No.9


BENZENE
CUMENE
STYRENE
ACETONE
PHENOL
COPOLYMERE (S.B.R)
POLYSTYRENE
SOLVENTS
RESINES
ELASTOMERES
PLASTIQUES

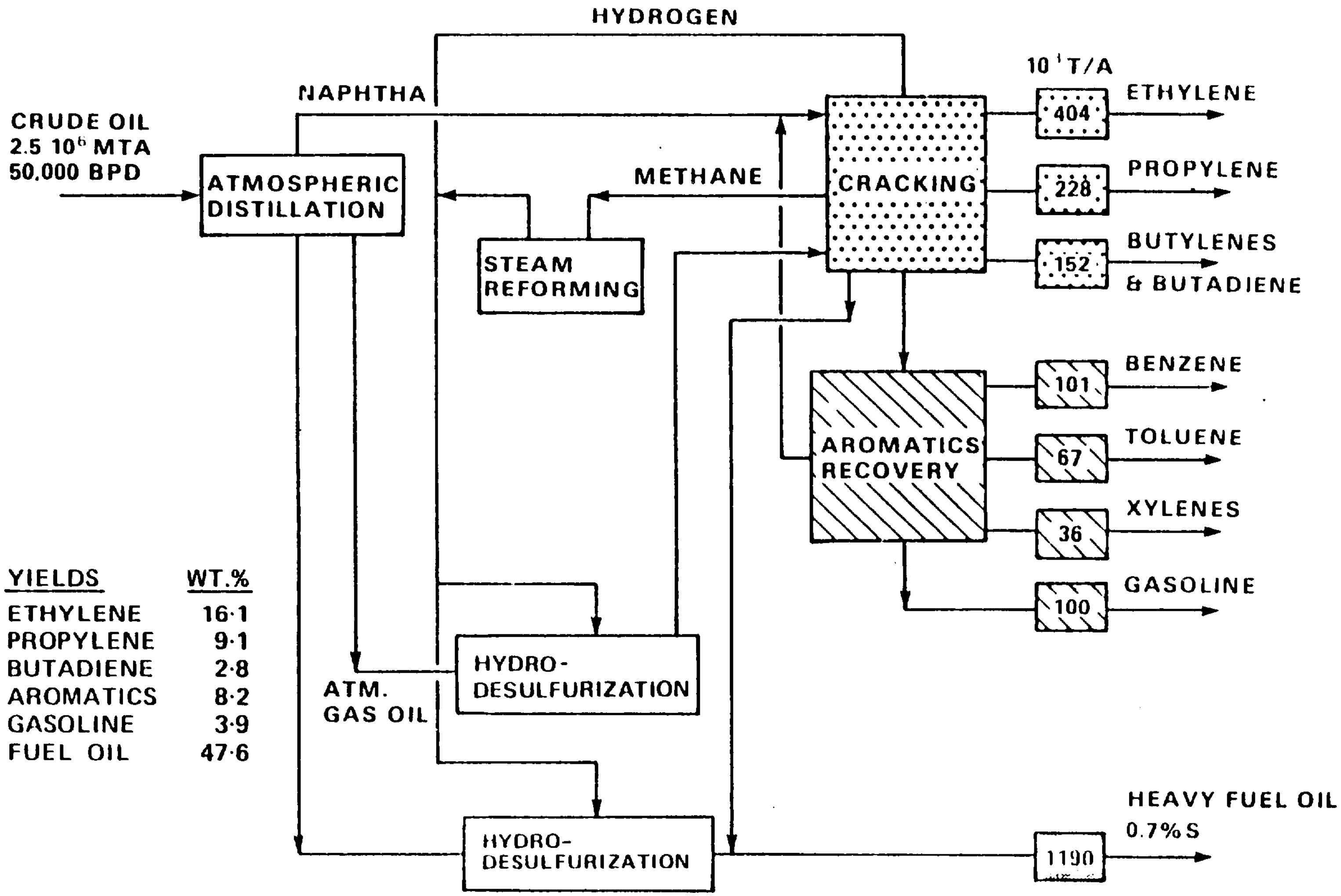
ANNEX No.10.


TOLUENE
CAPROLACTAME
T D I
NYLON 6 CHIPS
POLYURETHANE
RESINES
FIBRES
OTHER APPLICATIONS
FOAMS

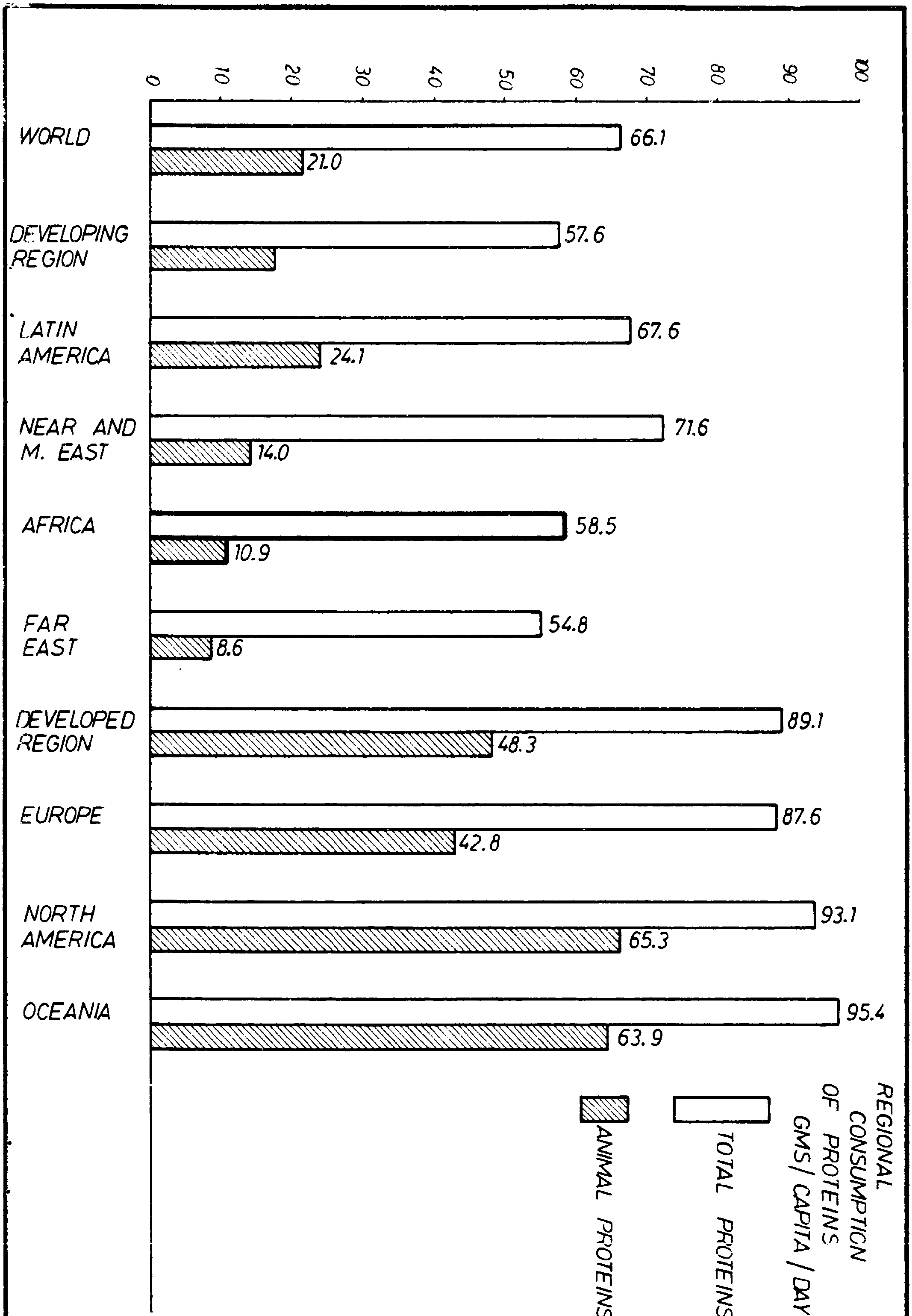
ANNEX No.11


O-XYLENE
P-XYLENE
PHTALIQUE ANHIDRIDE
TEREPHTALIQUE ACID
PHTALATES
POLYESTERS
PLASTIFIANTS
SINTHETYC MALERIALS
FIBRES

DISTILLATION AND CRACKING OF DISTILLATES FOR FUELS AND PETROCHEMICALS

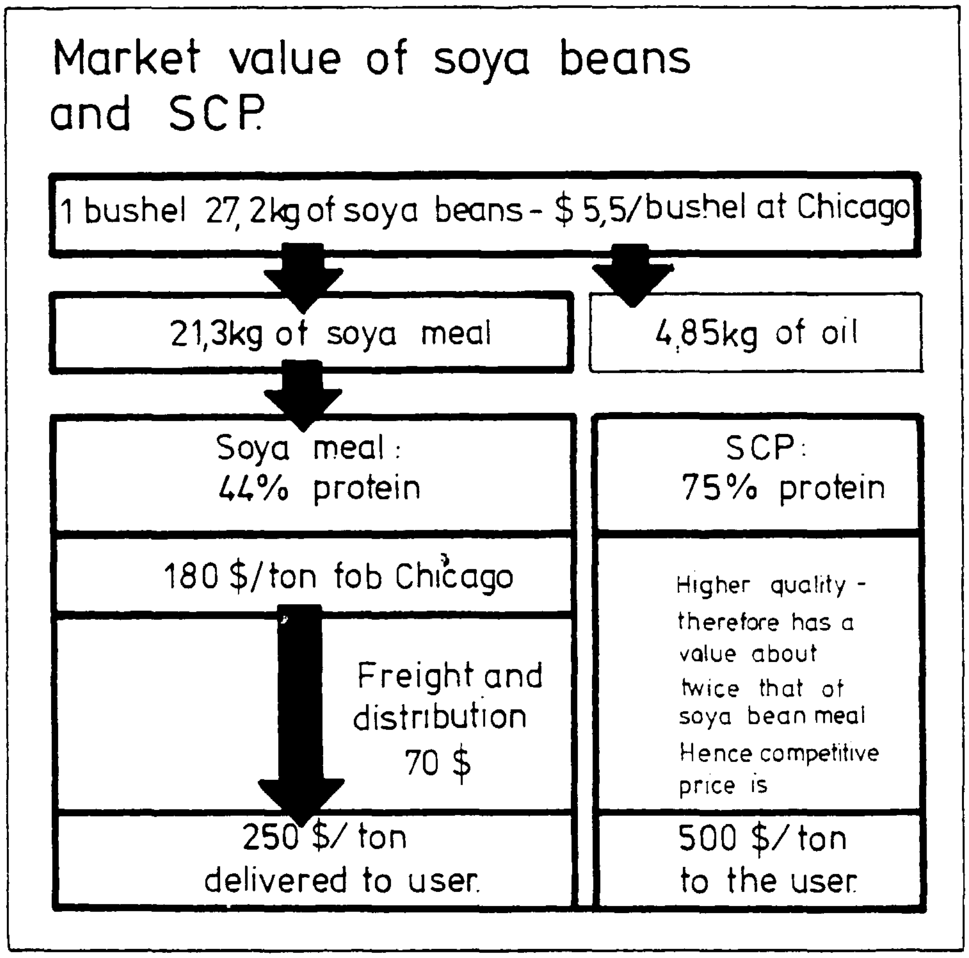


YIELDS	WT.%
ETHYLENE	16·1
PROPYLENE	9·1
BUTADIENE	2·8
AROMATICS	8·2
GASOLINE	3·9
FUEL OIL	47·6


REGIONAL CONSUMPTION OF PROTEINS GMS / CAPITA / DAY
TOTAL PROTEINS
ANIMAL PROTEINS
0
10
20
30
40
50
60
70
80
90
100
WORLD
66.1
21.0
DEVELOPING REGION
57.6
LATIN AMERICA
67.6
24.1
NEAR AND M. EAST
71.6
14.0
AFRICA
58.5
10.9
FAR EAST
54.8
8.6
DEVELOPED REGION
89.1
48.3
EUROPE
87.6
42.8
NORTH AMERICA
93.1
65.3
OCEANIA
95.4
63.9

ANNEX NO.13.

ANNEX No.14.


Market value of soya beans and SCP
1 bushel 27,2kg of soya beans - $ 5,5/bushel at Chicago
21,3kg of soya meal
4,85kg of oil
Soya meal: 44% protein
SCP: 75% protein
180 $/ton fob Chicago
Freight and distribution 70 $
Higher quality - therefore has a value about twice that of soya bean meal Hence competitive price is
250 $/ton delivered to user.
500 $/ton to the user.

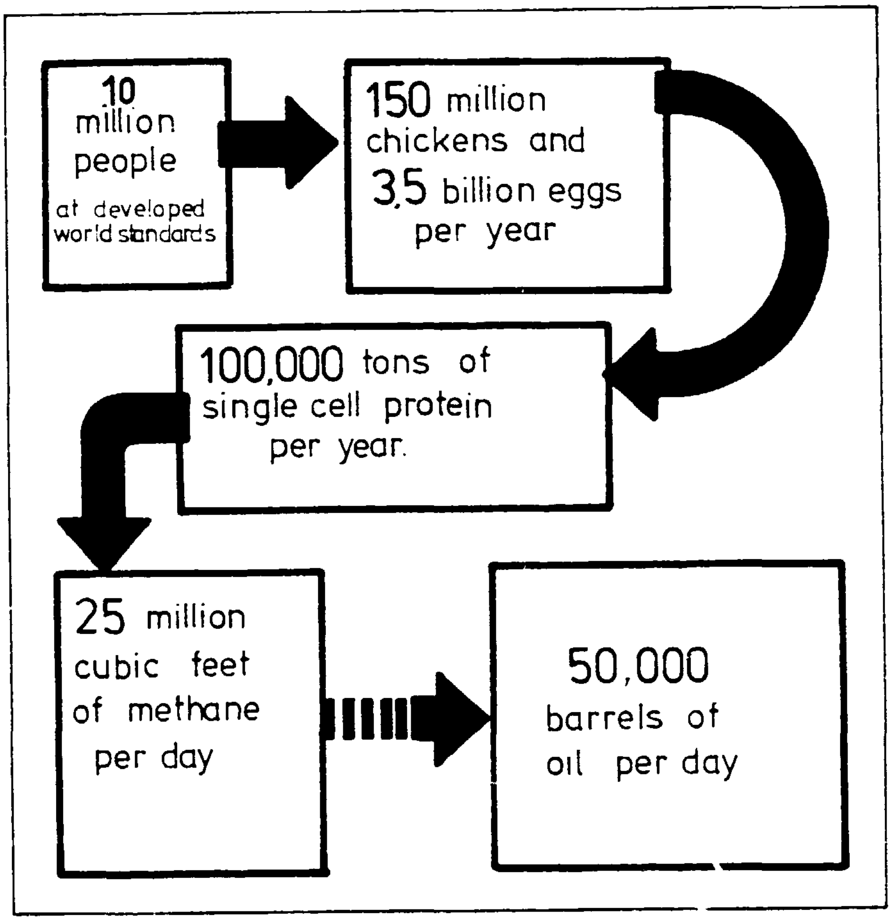
ANNEX No.15.

AMINO ACID COMPOSITION
OF SCP AND CONVENTIONAL PROTEINS

(Figures are in g/100g of material)

Amino Acid	Soya Meal	Fish Meal	Toprina G	Pruteen	Shell SCP	I.F.P. S.C.P.
LYSINE	2.8	4.9	4.3	4.9	5.5	10.7
CYSTINE	0.6	0.7	0.8	0.5	0.8	0.6
METHIONINE	0.6	1.9	1.0	1.8	1.8	3.2
ARGININE	3.4	3.6	3.2	3.6	5.8	5.4
ISOLEUCINE	2.2	3.2	3.0	3.4	3.1	4.8
LEUCINE	3.3	5.0	4.4	5.2	6.1	8.2
PHENYLALANINE	2.2	2.9	2.7	2.6	3.7	4.3
THREONINE	1.9	3.0	3.1	3.3	3.4	3.9
TRYPTOPHAN	0.6	0.9	0.7	0.7	1.5	1.7
TYROSINE	1.6	2.3	2.4	2.3	3.4	3.5
VALINE	2.3	3.7	3.7	4.1	4.5	6.3
CRUDE PROTEIN	45	65	61	72	72	80

ANNEX No.16.

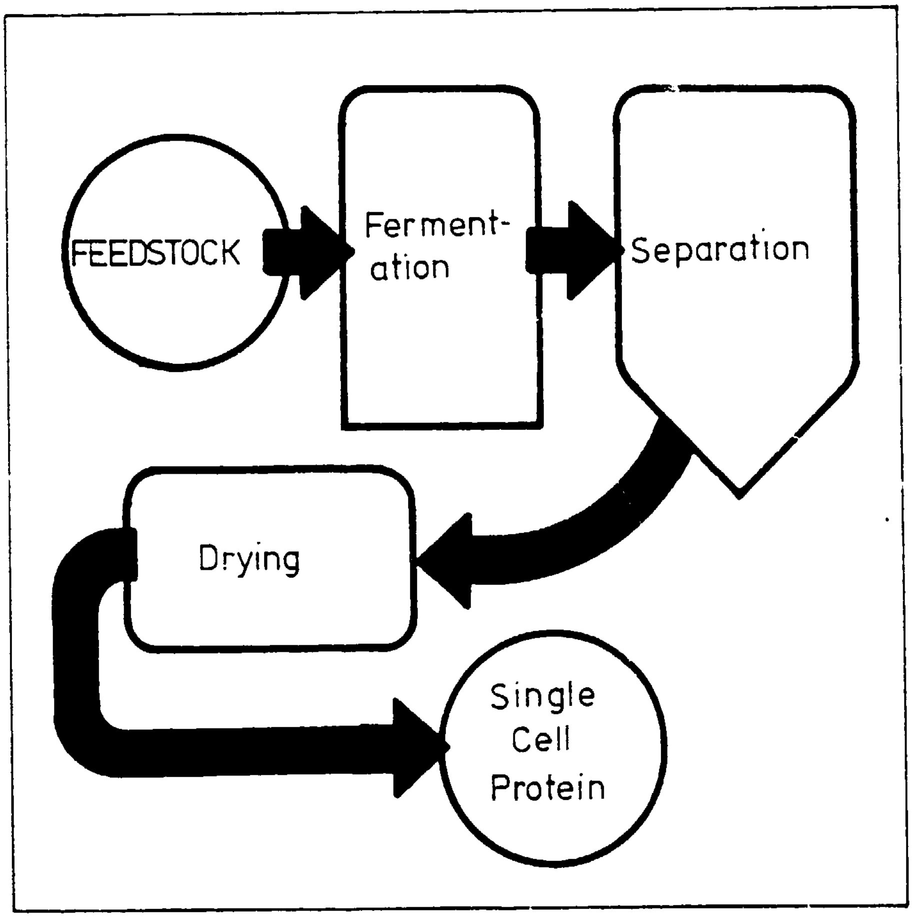

10 million people at developed world standards
150 million chickens and 3.5 billion eggs per year
100,000 tons of single cell protein per year.
25 million cubic feet of methane per day
50,000 barrels of oil per day

ANNEX No.17.

Use of resources

	SCP	Soya bean
Land	10 ha	116,000 ha
Capital costs	$ 80 million	$ 2.4 billion in irrigation, roads, land preparation.
Water	600,000 cu m of fresh water and 250 million cu m of salt water.	928 million cu m of fresh water for irrigation.
per 75.000 tonnes of 100% protein		

ANNEX No.18.


FEEDSTOCK
Ferment-
ation
Separation
Drying
Single
Cell
Protein

SCP CONSUMPTION DATA (per ton of SCP)

(Basis for netback calculations)

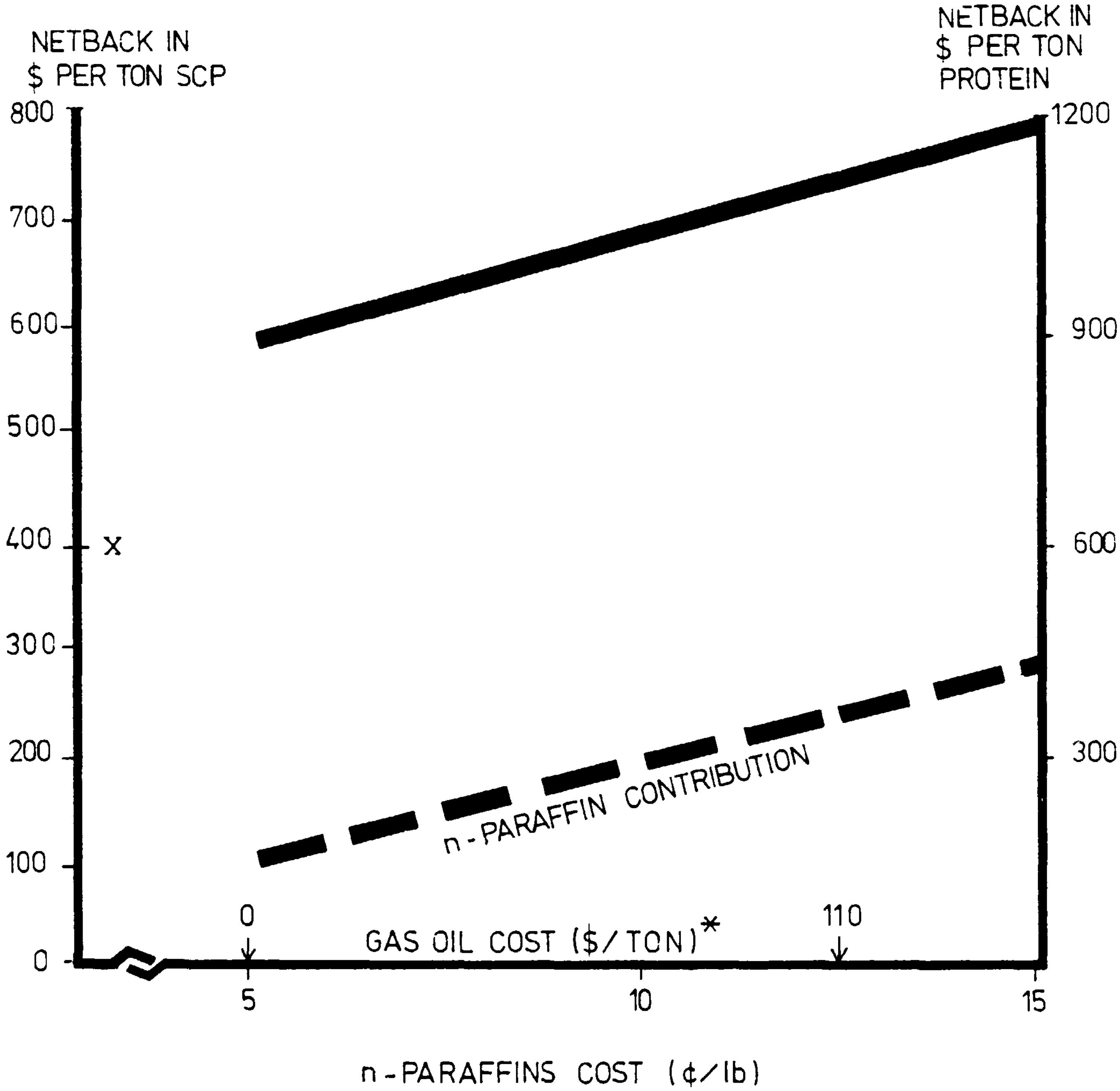
	N-PARAFFIN PROCESS	METHANOL PROCESS	METHANE PROCESS
Raw materials (tons)			
Methanol	-	1.80	-
N-Paraffin	0.87	-	-
Methane	-	-	1.17 (6.7×10^4 $ft.^3$ (sd)).
Ammonia	0.15	0.15	0.151
Phosphoric acid (75%)	0.125	0.125	0.125
Utilities			
Electricity (Mwh)	3.30	1.065	2.11
Cooling water (Kt)	1.121	2.013	2.27
Process water (tons)	5.66	5.66	5.66
Natural gas (tons)	0.25	0.25	0.23 (1.3×10^4 $ft.^3$ (sd)

Fixed costs

Operating	35 man years
Maitenance	3% of capital
Overheads	110% of Operating + Maintenance

Production of SCP from n - Paraffins

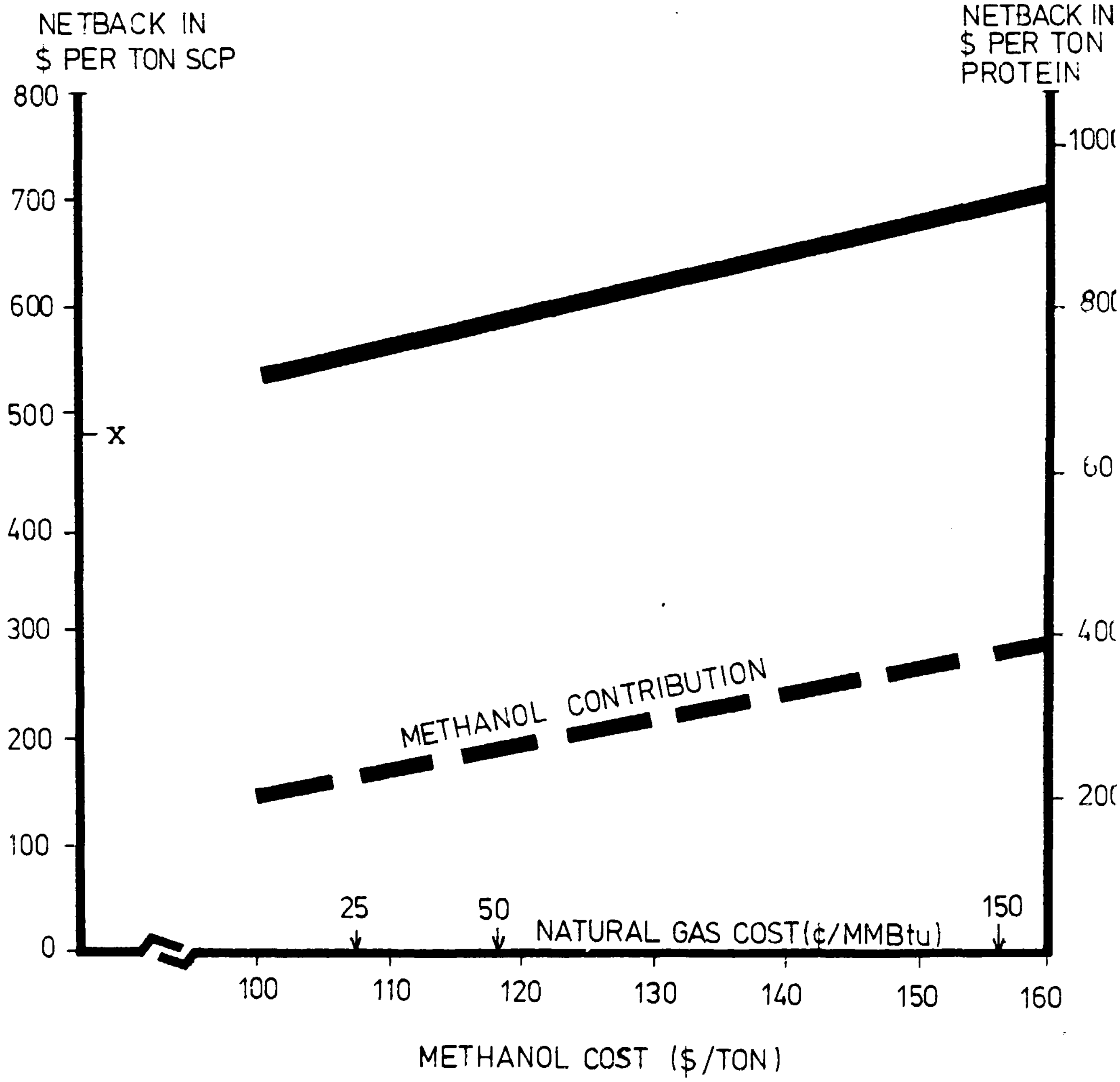
Effect of n - Paraffin cost on netback required for 8% earning power



* VALID ONLY UNDER EUROPEAN CONDITIONS

Production of SCP from Methanol

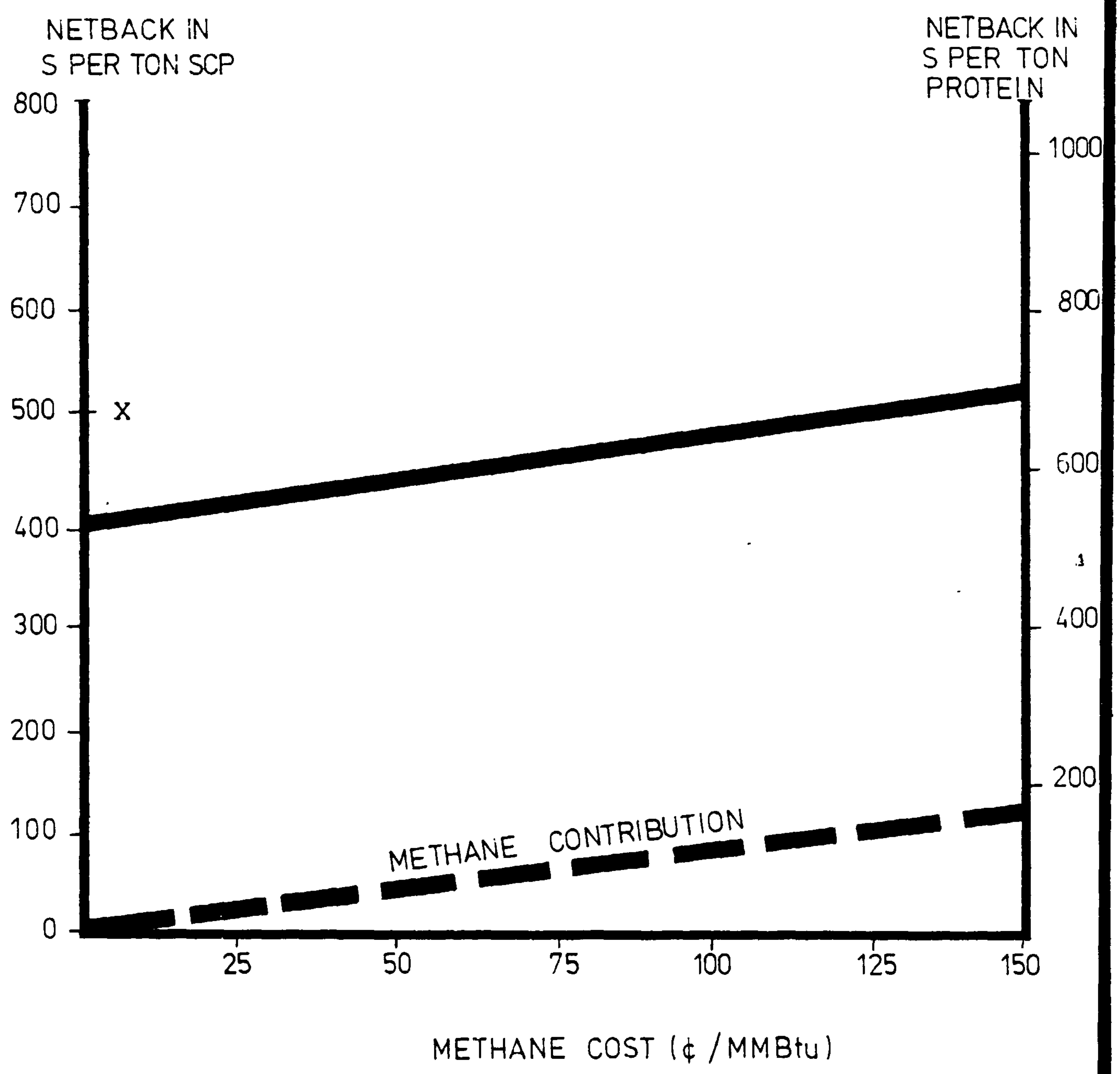
Effect of Methanol cost on netback required for 8% earning power



* VALID ONLY FOR A 300 000 TON/YEAR METHANOL PLANT UNDER BASE CASE ASSUMPTIONS

Production of SCP from Methane

Effect of Methane cost on netback required for 8% earning power



Forecast capacity, supply and demand for
ammonia and nitrogenous fertilizers (1984 and 199o)

Region	Ammonia capacity 1984 million tons N	Fertilizer production 1984 million tons N	Fertilizer demand 1984 million tons N	Surplus/ deficit (-) 1984 million tons N	Fertilizer demand 199o million tons N
North America	19.22	13.85	13.18	.72	15.oo
Western Europe	16.86	12.57	1o.87	1.7o	12.3o
Eastern Europe	35.91	18.o2	14.88	3.14	18.oo
Other developed countries	4.12	2.32	1.66	.66	1.87
Total developed countries	76.11	46.76	4o.59	6.17	47.17
Africa	1.31	o.68	o.79	-.11	1.o5
Latin America	6.58	2.79	3.81	-1.o2	4.84
Near East	6.24	3.o7	2.65	.42	3.6o
Far East	11.89	7.2o	8.62	-1.42	11.25
Centrally planned Asia	8.37	12.43	14.o4	-1.61	17.oo
Total developing countries	34.39	26.17	29.91	-3.74	37.74
World total	11o.5o	72.93	7o.5o	2.43	84.91
Share developing countries, per cent	31.1	35.9	42.4		44.4

Capacity, supply and demand for
ammonia and nitrogenous fertilizers

Region	Ammonia capacity million tons N	Production nitrogenous products: Fertilizers million tons N	Production nitrogenous products: % technical	Demand nitrogenous products: Fertilizers million tons N	Demand nitrogenous products: % technical
North America	18.9	12.9	28.0	11.1	27.6
Western Europe	15.7	11.7	26.0	10.0	26.8
Eastern Europe	30.4	15.1	11.6	12.0	14.6
Other developed countries	4.0	2.2	52.4	1.5	113.1
Total developed countries	69.0	41.8		34.6	
Africa	0.7	0.1	6.7	0.5	8.4
Latin America	4.0	1.5	4.1	2.7	4.0
Near East	4.2	1.5	1.6	1.8	2.6
Far East	7.9	4.6	2.9	6.3	2.8
Centrally planned Asia	5.7 a/	9.6	5.3	11.2	4.5
Total developing countries	22.5	17.8		22.5	
World total	91.5	59.6		57.1	
Share developing countries per cent	24.5	29.8		39.4	

Source : FAO

a/ Excludes ammonium bicarbonate capacity