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PETROCHEMICAL INDUSTRIES IN DEVELOPING COUNTRIES

Report of the Interregional Petrochemical Symposium on the Development of the Petrochemical Industries in Developing Countries

Baku, USSR, 21 - 31 October 1969

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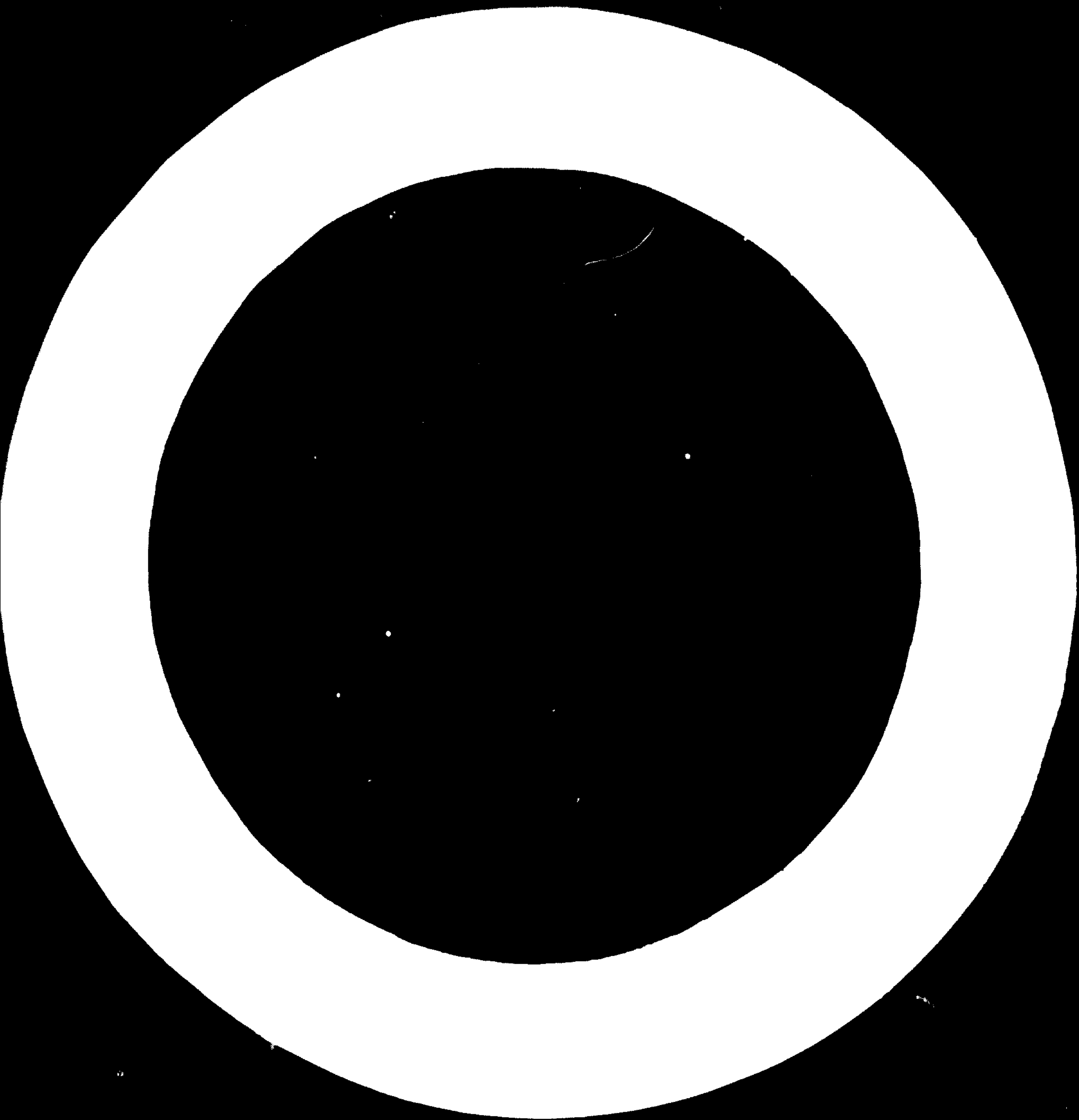

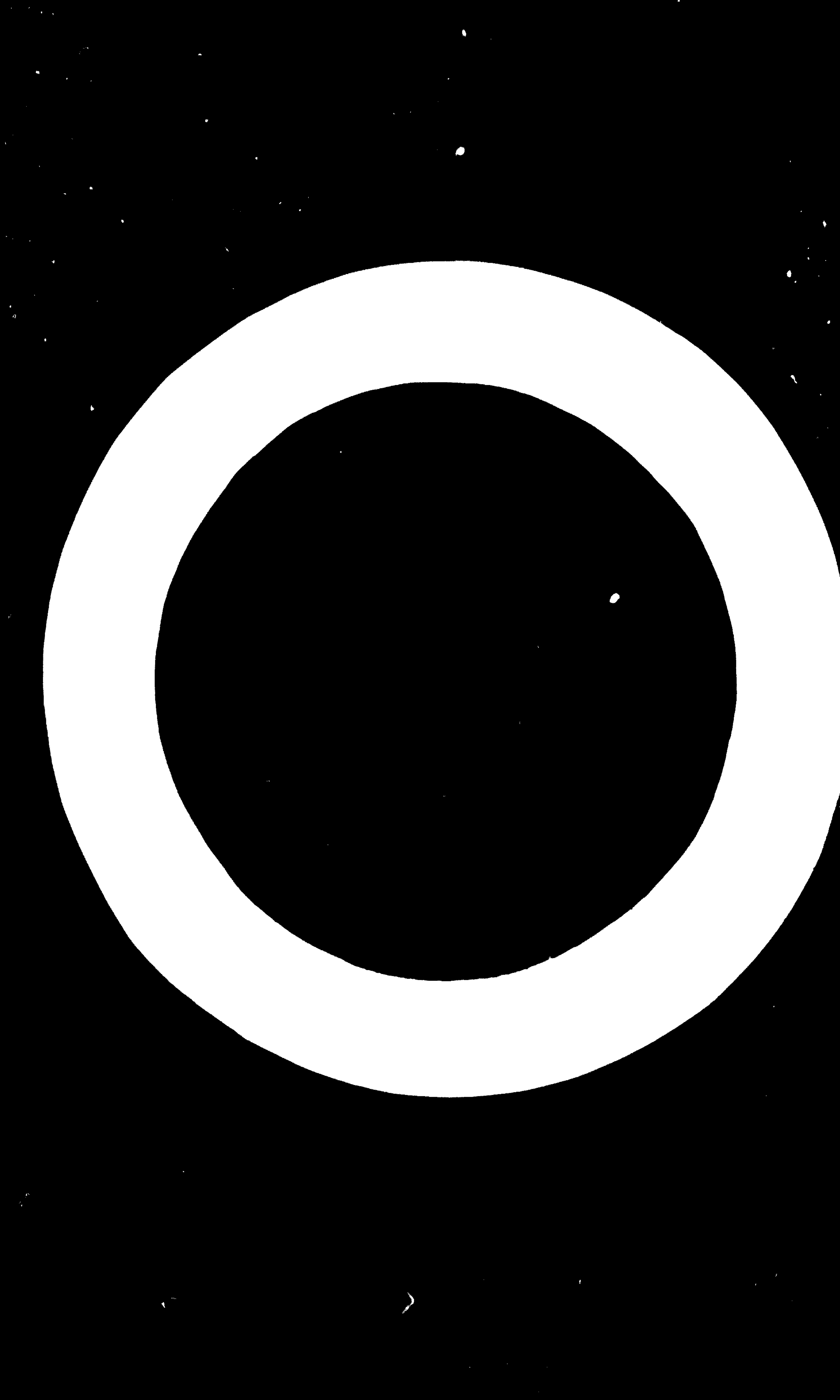

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION, VIENNA

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Explanatory notes

Reference to tons is to metric tons.

Reference to dollars ($) is to United States dollars.

Billion refers to thousand million.

A one-year period that is not a calendar year is indicated as follows: 1965/1966.

A period of two years or more is indicated as follows: 1965-1966, 1966-1968.

The following abbreviations have been used:

United Nations

ECA	Economic Commission for Africa
ECAFE	Economic Commission for Asia and the Far East
ECE	Economic Commission for Europe
ECLA	Economic Commission for Latin America
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Programme
UNESOB	United Nations Economic and Social Office in Beirut
UNIDO	United Nations Industrial Development Organization

Other organizations

CMEA, formerly COMECON	Council for Mutual Economic Assistance
EEC	European Economic Community
EFTA	European Free Trade Association
OECD	Organisation for Economic Co-operation and Development

Other abbreviations

ABS	acrylonitrile-butadiene-styrene
BR	butadiene rubber
BTX	benzene-toluene-xylenes
CBR	<u>cis</u>-butadiene rubber
DDT	dichloro-diphenyl-trichlorethane
DMAA	dimethyl acetamide
DMF	dimethyl formamide
DMSO	dimethyl sulphoxide
DMT	dimethyl terephthalate
FRP	fibre-reinforced polyesters
ft^3	cubic foot
HTP	high temperature and pressure
LPG	liquefied petroleum gas
m^3	cubic metre
NR	neoprene rubber
PVC	polyvinyl chloride
SBR	styrene-butadiene rubber
TPA	terephthalic acid
^{o}API	gravity in degrees as set by the American Petroleum Institute

Foreword

1. The First United Nations Interregional Conference on the Development of Petrochemical Industries in Developing Countries was held in Tehran in November 19[illegible]4. The report and the proceedings of this conference were published in 19[illegible] and 19[illegible], respectively.[1]

2. Since its inception in January 19[illegible], the United Nations Industrial Development Organization (UNIDO) has paid particular attention to the development of the petrochemical industries in developing countries. UNIDO assistance has been extended to developing countries in many ways, such as providing the services of experts to advise on improvement of quality control, productivity etc. in the plastics and the synthetic fibre industries; granting assistance in research and development and planning; and arranging for fellowships for the training abroad of nationals of developing countries. In the non-operational field, UNIDO has organized supporting activities such as studies, expert group meetings and symposia. The Symposium on Industrial Development, held in Athens in December 19[illegible], paid considerable attention to the petrochemical sector.[2]

3. The Interregional Petrochemical Symposium on the Development of the Petrochemical Industries in Developing Countries, organized by UNIDO in co-operation with the Government of the Union of Soviet Socialist Republics

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1/ *Report of the First United Nations Interregional Conference on the Development of Petrochemical Industries in Developing Countries* (United Nations publication, Sales No.: [illegible]); *Studies in Petrochemicals*, presented at the United Nations Interregional Conference on the Development of Petrochemical Industries in Developing Countries, Volumes I and II (United Nations publication, Sales No.: [illegible]).

2/ *Report of the International Symposium on Industrial Development* (United Nations publication, Sales No. [illegible]).

was held in [illegible], USSR, from [illegible] to [illegible] October 196[illegible].[1] The purposes of the Symposium were:

(a) To review and bring up to date the various economic, technological and [illegible] conditions affecting the establishment or development of petrochemical industries in developing countries;

(b) [illegible] together [illegible] and operation of petrochemical [illegible] developing and developed countries for the [illegible] of experience [illegible] and related economic problems, as well as the present and future trends in [illegible];

(c) [illegible] with the development of new [illegible] and [illegible] technology [illegible] and [illegible] in the petrochemical field;

(d) [illegible] development during the United Nations Second Development Decade;

(e) To indicate [illegible] the areas in which UNIDO could provide technical assistance to the petrochemical industry, including planning and implementation [illegible], problems connected with existing plants and the [illegible] of small industrial plants.

[illegible]. The report is presented [illegible] the order of presentation and discussion of papers at the Symposium. Chapter [illegible] examines the present and future prospects of the petrochemical industry in developing countries and regions. Chapter [illegible] discusses [illegible] petrochemical products and raw materials. Chapter [illegible] deals with the development, technology of production and application of plastics in developing countries. Chapter [illegible] discusses the development and production of synthetic fibres. Chapter [illegible] discusses technologies and processes for the production of synthetic rubbers that should be of interest to developing countries. Chapter [illegible] proposes the development of the petrochemical industry during the Second Development Decade. Chapter [illegible] indicates possible ways in which UNIDO could assist the petrochemical industry in developing countries. The conclusions and recommendations of the Symposium are presented in chapter [illegible].

[illegible]. The Symposium emphasized particularly the present and future prospects of the petrochemical industry in developing countries. As part of the programme, the participants visited the [illegible] and Sumgait petroleum refineries and petrochemical complexes, the off-shore petroleum exploration in the

[1] The proceedings of this Symposium are being prepared for publication.

Caspian Sea, the Olefins Scientific Research Institute and the Astrophysics Observatory at Shemakha.

6. The Symposium held a total of 24 meetings at which 93 papers were presented.[4/] The presentation of the papers was followed by a discussion at each meeting or after each substantive item.

7. The Symposium was attended by 36 participants from 31 member states and three international organizations. Eight petrochemical consultants from eight countries participated in the work of the Symposium. In addition, 18 observers and experts from the petrochemical industries and scientific research institutes of the USSR and 51 observers and experts from 19 countries were present. A list of participants is given in annex 1.

8. The UNIDO secretariat and members of the Organizing Committee for the Organization of the Petrochemical Symposium of the USSR provided the supporting services for the Symposium. Leading petrochemical experts from both developing and developed countries served as sectional chairmen and technical rapporteurs. The draft report of the Symposium was prepared by a committee composed of the sectional chairmen, technical rapporteurs, participating members of UNIDO and specialists from both developing and developed countries, with Mr. A. Shah Nawaz as Chairman. The report was adopted by the Symposium at its concluding session.

9. The Symposium was opened by Mr. N. I. Sorokin, Chairman of the Organizing Committee, Deputy Minister of the Ministry for the Oil-Processing and Petrochemical Industries of the USSR. Mr. R. G. Ismailov, President of the Academy of Sciences, AzSSR, was unanimously elected Chairman, and Mr. M. Richards (Trinidad and Tobago) was elected Vice-Chairman. Mr. M. C. Verghese, Chief of Fertilizers, Pesticides and Petrochemicals Industry Section, UNIDO, was appointed Director of the Symposium for UNIDO and Mr. A. G. Litvinenko, Assistant Head of Division, Ministry for the Oil-Processing and Petrochemical Industries of the USSR as Director on behalf of the host Government. Sectional chairmen and technical rapporteurs were appointed in order to facilitate the discussions and the preparation of the report.

10. A selection of the messages and statements addressed to the Symposium is presented in annex 2. The Symposium was closed by Mr. Ismailov.

4/ The working papers circulated at the Symposium are listed in annex 3.

CHAPTER 1

PRESENT STATUS AND FUTURE PROSPECTS OF THE PETROCHEMICAL INDUSTRY IN DEVELOPING COUNTRIES AND REGIONS

The over-all picture

11. The Symposium began with a discussion of significant developments in petrochemical technology since the first Petrochemical Conference in Tehran in 1964. Papers prepared by the United Nations regional economic commissions, followed by individual country papers were presented describing:

(a) Progress made in petrochemical development in the region or country since the 1964 Tehran Conference;

(b) The present situation and future prospects for production, consumption and trade in petrochemicals projected to 1980;

(c) The factors affecting petrochemical development;

(d) The kind of external assistance required, including that from the United Nations and particularly from UNIDO.

12. The recent technological progress in primary petrochemicals production has been centred on reducing manufacturing costs in the two basic processes, namely, steam cracking for olefins and aromatics and catalytic reforming for aromatics. Progress has been made in reducing capital cost and power consumption and in increasing yields of desirable end products. However, in most cases, the yield of desired products does not exceed 50 per cent. The idea of a "petrochemical refinery" designed to produce mainly basic petrochemicals rather than mainly fuels as in a normal refinery has recently been proposed. In fact, some new plants in Puerto Rico and in Italy (Priollo and Brindisi) are approaching the petrochemical refinery idea.

13. Recent progress in the production of oxygenated products, plastics, rubbers and fibres was reviewed. Some of the products are discussed in more detail in later chapters of this report.

Regional assessment and development prospects

14. Papers were presented to the Symposium containing details of regional consumption patterns and estimated production as well as the likely pattern of petrochemical development within each region. These are summarized below, followed by summaries for individual countries.

Africa

15. The situation in about forty African countries, grouped under four subregions (North, West, Central and East), was reviewed.

16. Because of the varied assumptions and approaches necessary owing to the lack of reliable information on the region as a whole, it was rather difficult to summarize the demand. However, attempts were made to project demand to [illegible] for plastics, synthetic fibres, synthetic rubbers and some other petrochemicals, although the definition of consumption of these products is unsatisfactory. Although it was not possible to state clearly the relative importance of petrochemicals by subregion, certain observations could be made. Polyethylene, nylon, dodecyl benzene and carbon black seem to be of major importance in North Africa, while polyvinyl chloride (PVC) and polyester fibres and adhesives predominate in West Africa. The insecticide [illegible] is of major importance in East Africa. Figures showing these trends indicate, to some extent, the relative significance and potential of the petrochemical industry in the subregions of Africa. For example, it is anticipated that, by [illegible], the overall demand for the principal plastics will reach [illegible] tons; for synthetic rubber, [illegible] tons; and for synthetic fibres, [illegible] tons, but much depends on how the industries using these materials develop.

17. In [illegible], world reserves of crude oil were estimated at about [illegible] billion barrels, or nearly eight times the estimated figures for [illegible]. World reserves of natural gas increased very substantially over the same period. Production of crude oil in [illegible] was 111 million tons, which is about six times the [illegible] figure. Exports of natural gas from the region are now significant, amounting to 800,000 tons to the countries of the Organisation for Economic Co-operation and Development (OECD) in 1966.

18. However, the distribution of oil and natural gas is uneven in the region; the North is well-endowed, the South relatively poor, and the East African subregion the least endowed. The producer countries are: Algeria, Angola, Congo (Brazzaville), Gabon, Libya, Morocco, Nigeria, Tunisia and the

United Arab Republic. Within the near future, Cameroon, Congo (Democratic Republic) and Dahomey are expected to join the ranks of producers.

19. At present, there is over-capacity in the established refineries in the region, and no major increases in capacity are foreseen in the period [illegible]. By the end of this period, however, the excess capacity is expected to have been absorbed. In contrast, a large capacity increase is expected in the period 1975-1980 to meet the requirements for petrochemical development in the region.

20. Although the availability of raw materials and fuel favour petrochemical development, there are many inhibiting factors. Among these are a shortage of electrical power, gaps in transport links, with resulting high transport costs, lack of trained manpower and limited markets. The Economic Commission for Africa (ECA) and some countries in the region are making efforts to overcome these difficulties. ECA has for some time adopted a multinational and subregional approach, and certain economic groupings are emerging.

21. Other remedies suggested include small plants based on simple and economical processes and techniques and small multipurpose plants adaptable to varying market conditions.

22. A trend towards diversification is evident in existing establishments in Africa, especially in the final stage of processing petrochemicals. It does not appear possible, however, to avoid importing certain end products for some time to come. Several production combinations and alternatives are possible in each subregion, depending on factors such as markets, availability of raw materials, utilities and infrastructure and the need for fair allocation of the production units among member countries. It was suggested that an inter-subregional approach would render the production of a number of petrochemicals practical. The fixed-investment implications of a number of proposed units were explored. The results indicated a possible investment of $400 million by 197[illegible] and an additional $[illegible] million between 1975 and 1980.

Asia and the Far East

23. The world position of the industry and the part played by the countries of the region covered by the Economic Commission for Asia and the Far East (ECAFE), and the demand for petrochemical products in the latter group of countries were discussed. Present consumption and future demand for plastics, synthetic resins, synthetic fibres and synthetic rubber and for detergents,

insecticides and carbon black were also discussed. The sources of raw material, namely, crude oil, naphtha, and natural gas, in each country of the region were considered.

24. Current production figures for plastics, synthetic fibres and synthetic rubber were given for those countries in the region that produce them, as well as the number and capacity of the plants in each country. Import and export figures for the more significant countries in the region were presented, followed by a detailed description of the plans for expansion in the countries.

25. The various factors affecting the development of petrochemicals were next examined, including the demand for end products and the processing industries necessary, disposal of co-products, availability of raw materials, financial resources, engineering design, know-how and training of personnel. The rate of expansion of consumption of end products expected in the decade 1970-1980 was then discussed, and the new plants necessary to meet this growth, together with the anticipated costs of production and investment necessary, were forecast. Whether developing countries would be able to match world prices for various petrochemical products was also discussed. The Symposium considered the possibility of grouping the production of primary products at central locations and examined estimates of the transport costs involved.

26. The demand for petrochemicals in the ECAFE region is rising sharply. It is estimated that, in 1980, excluding the developed countries in the region, the demand for the basic plastics (polyethylene, PVC, polystyrene and polypropylene) will reach 2,110,000 tons; for synthetic fibres, 655,000 tons; for synthetic rubber, 335,000 tons; and for detergents, 518,000 tons. Growth rates are high in the region and average a cumulative 15 per cent for many countries. But here also, this depends on the growth of consumer industries.

27. Substantial additional production capacity must be developed in the region to meet demand. This amounts to 1,675,000 tons/year for the basic plastics; 460,000 tons/year for synthetic fibres; 240,000 tons/year for synthetic rubber; and 380,000 tons/year for synthetic detergents. In addition, substantial amounts of monomer production will be required. However, imports of both finished products and monomers from the developed countries of the region as well as from other countries will continue to be necessary.

28. Finally, tables were drawn up for each country in the region showing the estimated demand in 1980 for the principal plastics, fibres and synthetic rubbers, together with detergents and basic petrochemicals; the capacity

required by 1980; and number and size of plants. The possibility of joint ventures, for example, several countries investing in and/or sharing production from one plant, was examined in detail and recommendations made.

Latin America

29. The main features of production, foreign trade, apparent consumption, installed and/or projected capacity, and prices, in terms of both the region and the products, were discussed to the extent allowed by the data available, complemented by the series of studies made by the Economic Commission for Latin America (ECLA) on the chemical industry of this region.

30. In brief, the development of the petrochemical industry has been dynamic, with production in the region growing at a yearly average of 11 per cent over the period [illegible]; in [illegible], the industry had an installed capacity of over 1.3 million tons per year and produced almost [illegible] tons of basic petrochemicals, including ammonia. These figures indicate a process of import substitution, which reduced the share of imports from [illegible] to [illegible] per cent between [illegible] and [illegible]. They also show, on the one hand, considerable technological progress, together with heavy dependence on the external sector for want of a clear-cut regional development policy in this field and, on the other hand, a change in the structure of production, which is tending to become vertically integrated from the final product down to the basic materials. While this process has gone further in some countries, such as Argentina, Brazil and Mexico, the others intend to follow the same course.

31. Regional development has depended on the greater or lesser demand for specific groups of finished products in the domestic market. Thus the production of ammonia was developed, particularly in Mexico and Colombia, in response to the growth of demand for fertilizers; and the production of aromatic and olefin hydrocarbons, which ranked next in importance, expanded in response to the demand for plastics, textiles and paints. It should be noted, however, first, that installed capacity consists of a considerable number of small plants manufacturing the same products, often in the same country and, second, that intra-regional trade is a comparatively new departure, conducted on a small scale and generally involving marginal percentages of production.

32. The Symposium was of the opinion that development of the petrochemical industry has failed to reach the levels envisaged in the national industrial development plans, since it has not had the expected effect on the economy

(as it has had in Europe and the United States), in spite of Latin America's natural resources and the specially enacted legislation for promoting this branch of industry.

33. In the light of recent events, it may be assumed that Latin America's petrochemical industry has reached a rather critical stage in its development, inasmuch as it is continuing to be affected by national and regional circumstances connected with integration and competition. The industrial development policies adopted in each country with respect to the domestic, regional or world markets and the characteristics of the existing petrochemical industry will determine whether Latin America will be able to reach exceptionally high levels of petrochemical production. Organizations have already been set up for the integration of markets, at least at the [illegible] regional level, and for some products market integration has been going on for many years. The integration of production is indubitably a rational method of developing certain industries - particularly petrochemicals - since it makes possible production on a scale that is technologically and economically justified.

34. It is anticipated that the production capacity of basic petrochemicals, including ammonia, will reach 1.4 million tons/year in 19[illegible], of which about 1.[illegible] million tons/year will be ethylene and [illegible],000 tons/year, propylene.

The Middle East

35. The Middle East is one of the richest regions in the world as regards raw materials for petrochemicals, but as a market for petrochemicals it is of minor importance. The Symposium discussed the situation in each country in the region with respect to its petroleum and natural gas resources, its existing petrochemical production, if any, and its plans for the future.

36. The consumption of petrochemicals within the region can be expected to increase between 1975 and 1980. Consumption of plastics is expected to increase from a possible 110,000 tons in 1975 to 310,000 tons in 1980; that of synthetic rubber from 30,000 to 40,000 tons/year; and that of synthetic fibres from 100,000 to 300,000 tons/year. A scheme was drawn up showing the ethylene, methanol, benzene, polymers, synthetic fibres and rubbers and other chemicals the region could reasonably produce by 1975 and by 1980. The current and future markets for different plastics, rubbers and fibres were discussed in terms of each country and of the region. The rubber tire imports of the various countries were given as a guide to potential rubber production.

37. Suggestions were made for action on a national basis, such as tariff modifications, to allow exchange of products and standardization of quality by the various technical institutes. Action on a regional basis was then dealt with, including the setting up of a joint panel of scientists, joint planning, reduction of natural gas flaring. The regional production of chemicals could be increased fourfold by 1980, but an investment of $[illegible] million would be necessary.

38. At this time, petrochemical conversion of natural resources other than fertilizer production hardly exists in the countries of the Middle East, which have the largest crude oil reserves in the world. Furthermore, more than 70 per cent of the natural gas produced is merely flared away. However, petrochemical products, many of them based on Middle Eastern crude oil, are imported from all over the world. On the basis of import figures of raw materials for plastics, synthetic rubber and synthetic fibres in the last years, an actual *per capita* consumption of 2 to 3 kg has been found. (This does not include consumption of processed plastics, rubbers and fibres.) The erection of a petrochemical complex based on natural resources was suggested. Following a given model, the main petrochemical products and their derivatives could be produced in the Middle East to meet domestic demand during the Second Development Decade. Consumption is expected to attain the range of 8 to 10 kg of petrochemicals *per capita* by 1980. Thus, production in the Middle East will rise to [illegible] tons/year of plastics; 60,000 tons/year of synthetic rubber; and [illegible] tons/year of synthetic fibres by 1980.

Eastern Europe

39. The rapid growth in the plastics and synthetic resins industry in Eastern Europe was stressed. In the member countries of the Council for Mutual Economic Assistance (CMEA), thermosetting compositions have had, up to now, a great share in the total production, while the production of thermoplastics, mainly polyolefins, is to develop in the near future. Because of the shortage of crude oil in the CMEA countries, other than the USSR and Romania, substantial imports are necessary. The position of each country in this respect was described. Next, the stage reached in each CMEA country in the production of plastics and synthetic resins and particularly thermoplastics from petrochemical sources was considered. The exports and imports of plastics and synthetic resins of these countries, are not very significant, although consumption now exceeds production. However, the production of petrochemicals

in the CMEA countries and Yugoslavia will have reached a substantial volume by 1970, amounting to 1,673,000 tons of plastics and synthetic resins, of which 636,000 tons will be of PVC and 494,000 tons will be of polyethylene.

Western Europe

40. The growth in production and consumption of, and trade in, the principal petrochemical basic materials in Europe over the years 1964 through 1967 and forecasts of the demand in 1970 and 1975 were discussed. Countries were grouped under three headings: European Economic Community (EEC), European Free Trade Association (EFTA) and others. The following basic materials were considered:

(a) Ethylene, and the various products made from it - polyethylene, ethylene oxide, ethylbenzene, vinyl chloride, ethyl alcohol, acetaldehyde, and others (linear alcohols and olefins, ethylene-propylene rubbers, ethyl chloride) and so on;

(b) Propylene, and the various products made from it - acrylonitrile, polypropylene, cumene, propylene oxide, oxo-alcohols, isopropyl alcohol and others (propylene trimer and tetramer and synthetic glycerine);

(c) Butadiene, and the various products made from it - styrene butadiene rubber (SBR), polybutadiene, nitrile rubber, acrylonitrile-butadiene-styrene (ABS) resins and others (butadiene trimer and tetrahydrophthalic anhydride);

(d) Benzene, and the various products made from it - cumene, ethyl-benzene, cyclohexane, dodecyl benzene, chlorobenzene, maleic anhydride and others (nitrobenzene, diphenyl and so on);

(e) Para-xylene, with some discussion on the future of polyester fibres.

Present indications are that there should be an increase of [illegible] per cent per year over the 1967-1970 period, but a reduction to 13 to 14 per cent per year between 1970 and 1975 may become inevitable. Such a slackening-off period is not unusual after a few years of rapid expansion. According to data from the Economic Commission for Europe (ECE), the production of ethylene derivatives will reach 12 million tons in 1975; propylene derivatives, 5.75 million tons; and butadiene derivatives, 1.16 million tons.

North America

41. The North American synthetic organic chemical industry was originally based on coal tar, distillates for aromatics, wood distillates and fermentation for aliphatic compounds. Acetylene was available from calcium carbide, and the advent of cracking in the oil-refining industry made olefins available so that in the years before the Second World War there was a shift to these

materials as the starting point for aliphatic chemicals. Immediately after the war, supplies from refineries began to be supplemented by the cracking of natural gas and, as the gas-refining industry grew up alongside the oil-refining industry, the chemical and oil companies began to integrate their operations to make the most efficient use of the gas and liquid streams available.

42. The Symposium examined the growth of the North American petrochemical industry and discussed the changes likely to take place up to 1980. The industry consists mainly of the United States industry, since the Canadian and Mexican facilities represent only a small part of the total. The survey was confined to existing products of major importance, since there does not appear to be anything in the laboratory stage that can become a million-tons-per-year product by 1980. The emphasis is likely to be on larger plants and process improvements in a continuing effort to keep costs down.

43. At present, North America has about 7 per cent of world population and about 40 per cent of world petrochemical production. Although growth rates are expected to remain high (in the 7 to 9 per cent range), the North American share of the total is expected to fall as other countries expand existing facilities and install new ones. Growth rates will be somewhat variable, with the highest figures in the polymers field, but virtually no petrochemical will actually decrease in output tonnage during the period under review.

Country papers

Algeria

44. Algeria possesses major resources of liquid and gaseous hydrocarbons, and it has been decided to base industrialization on these resources. About a dozen projects have been studied, and most of them are being implemented. All of these projects are major ones and should absorb much of the Algerian market. As a result, Algeria may be able to trade in petrochemicals with both developed and developing countries.

45. Algeria is seriously examining all schemes of co-operation which would be of mutual benefit and is ready to place its modest expertise at the disposal of developing countries. Special institutes have already been created to solve production problems. Algeria appreciates the technical assistance UNIDO provides and its aid in solving marketing problems.

Gabon

46. No petrochemical industry exists in this country at present, but numerous studies have been made of the relatively abundant raw materials (crude petroleum, natural gas and a heavy residue from an oil refinery). The materials concerned are:

(a) Crude petroleum - production of 4.[illegible] million tons in 196[illegible]; [illegible] million tons in 1969; reserves estimated at 1[illegible] million tons (enough for about [illegible] years at the present rate of consumption);

(b) Heavy residues - production of 100,000 tons/year; in two or three years the capacity will certainly be doubled, perhaps increased fivefold;

(c) Reserves of natural gas - [illegible],500 million m³ taking into account only gas associated with oil. However, gas obtained by drilling fields unconnected with oil must also be taken into account. The present total output is 448 million m³, but only [illegible] million m³ are being used commercially.

47. Among the projects envisaged are the production of 600 tons/day of ammonia and the production of 700 tons/day of urea using the Stamicarbon process (Netherlands). An investment of 11 billion CFA francs 5/ would be required. Another project is a mill for the production of synthetic fibre for weaving, with an output of 5.[illegible] to 6.5 tons/day, with a market oriented towards the Tariff Union of Central Africa. This would require an investment on the order of 1.5 billion CFA francs.

48. Studies for other projects are being undertaken. One is directed towards the use of the crude kerosene fraction to produce solvents in the small units associated with a refinery. Another is the use of refinery residues to produce synthetic detergents and petroleum coke. (The ALUCAN plant for the electrolysis of alumina at Edéa in Cameroon consumes 30,000 tons/year of petroleum coke.)

49. The primary problems Gabon faces are the smallness of the market and the lack of capital and national technicians.

Morocco

50. Although petrochemical industries are nonexistent in Morocco, the consumption of petrochemical products is increasing rapidly (200 per cent between 1951 and 1968). In this same period the import of petrochemicals (excluding finished products) amounted to $30 million. A project

5/ In early 1970 the rate of exchange of the CFA (central franc area) franc was 2.78 to the dollar.

for producing synthetic fibres (polyamide 6 and polyesters) is under consideration.

51. Two of the main difficulties encountered in the rapid installation of petrochemical industries are a shortage of technicians and the absence of research for developing new petrochemical materials adapted to local conditions. It was recommended that UNIDO help Morocco to overcome these difficulties by studying the possibility of creating an institute for training the needed technicians and a centre for research on the use of plastics in agriculture and in the construction industry.

Nigeria

52. Since no petrochemical industry yet exists in Nigeria, present emphasis is on the great abundance of resources from which chemicals, fertilizers and pharmaceuticals can be derived. Statistics based on past performance and projections from them were provided on the production, local consumption, qualities and specifications of crude oil and natural gas; import of PVC compounds and resins, polyethylene, calcium carbide, caustic soda and liquefied petroleum gas (LPG), and phosphate and nitrogen fertilizers. Future prospects were considered, with indications of possible dates when such projects might be established. The problems encountered were analysed and the assistance required of UNIDO was defined. Among these needs are staff training, evaluation and integration of varieties of products, and capital requirements. The policy and incentives the Government offers to encourage the rapid establishment of such a complex were described.

Burma

53. A urea plant with a capacity of [illegible] tons/day, using natural gas, will come into production in [illegible], and a similar one will come on stream in the following year. An intensive search for oil and gas within the country is continuing.

54. Existing petrochemical refining capacity totals 1 million tons, with a naphtha surplus of [illegible] tons/year. Crude oil production is increasing at a rate of about [illegible] per cent yearly, and another 1 million tons of refining capacity is scheduled to come into production in [illegible]. The naphtha surplus will then be about 100,000 tons/year. This naphtha is to be used to supply a plant that will produce [illegible] tons of ethylene (including [illegible] tons of polyethylene

and 10,000 tons of PVC) yearly. Facilities for the production of chlorine and caustic soda can be incorporated.

55. Present fertilizer requirements are 700,000 tons/year, and more fertilizer plants are needed to close the export gap. During the five years 1970 to 1975, a fertilizer plant with an output of 400 tons/day is to be completed.

Ceylon

56. No serious thought has been given to the development of chemical industries. In view of the lack of demand, it would be uneconomic to enter this segment of industry, and especially to begin to produce synthetic fibres and plastics.

57. However, two major steps towards the creation of a petroleum industry were mentioned. The first government-owned petroleum refinery, which is expected to meet the country's entire domestic demand for petroleum products, has been established. It is proposed to set up an ammonia plant for the manufacture of urea from chemical naphtha from the refinery. This plant is expected to go into production by 1972 and to meet the country's total requirements for nitrogen fertilizers.

58. It is also planned to install a 10,000-ton LPG plant and a 10,000-ton sulphur-extraction plant by the end of 1970. The problem for a country like Ceylon is not to catch up with industrialized countries in the development and generation of new technology but rather to utilise effectively the best technology available. In a small country like Ceylon, lacking natural gas and oil, the petroleum refinery should be made to yield the maximum value for both primary and secondary products. As a first step, the establishment of finishing plants is anticipated, for example, for polymerization of imported caprolactam to yield nylon, which is used increasingly in the textile industry. In Ceylon, lack of capital, a limited local market, low-priced competition from highly industrialized countries and a lack of technical know-how and trained personnel are among the many obstacles that must be overcome if a petrochemical industry is to be established.

India

59. The details of the first petrochemical complex based on two refineries in the Bombay area that are already in operation were provided. This complex includes: two crackers; and down-stream plants for polyethylene, polystyrene,

PVC, polyester fibre, solvents (acetone, benzene, butanol etc.), plasticizers, chemical intermediates, such as phthalic anhydride, phenol and 2-ethyl hexanol; and a fertilizer plant along with a methanol unit and a carbon black unit.

60. A consolidated chart was presented giving details of petrochemicals and the intermediates from which they are produced, including those from non-hydrocarbon sources. Some of the future plans for the development of this industry were indicated, along with estimated demand patterns for 1973/1974 and 1978/1979.

61. The status of the second petrochemical complex in the Gujarat area, which is developing around a government refinery, was described in detail. A few of the units in this complex, including some for fertilizers, a Udex plant producing benzene, toluene and xylenes (BTX), and a phthalic anhydride plant based on ortho-xylene, have already been on stream. Several other projects, including plants to produce caprolactam, polyester, dimethyl terephthalate (DMT), ortho- and para-xylene, are under construction and the rest, based on ethylene production, are scheduled for completion within the next five years. This complex was planned in such a way that the import bills for maintenance of the units already established or under implementation could be reduced to a minimum through the use of basic chemicals from this project. The complex is expected to provide the vital intermediates for synthetic fibre units already in operation in different parts of the country, in addition to expanding the capacity of plastic polymers and providing basic intermediates for the pharmaceutical and pesticide industries. Mention was made of future plans for other complexes in different parts of India, such as those in Barauni, Haldia and Madras. These are not likely to come on stream before 1975.

62. A picture of the present and future production of nitrogen fertilizers based on naphtha/natural gas was presented. The special features of petrochemical industries and the general constraints encountered in their development and the solutions found were stressed and elaborated. The capital-intensive nature, the sophisticated technology, the comparatively large-sized economic units and the need for a complex because of the interdependent nature of downstream units vis-à-vis the main olefin plant were made clear.

63. The problems associated with the growth of the petrochemical industry in developing countries such as India, and their probable recurrence in other developing countries were considered. The assistance, based on acquired experience, that India can offer UNIDO was described, and the type of assistance required from UNIDO was indicated.

Iran

64. Vast resources of petrochemical feedstocks are available in Iran at very low prices. The aim is to utilize these valuable natural resources in plants of economic size, first, to meet local demand and, second, to market the surplus abroad at competitive prices. To achieve this, a policy of encouraging the formation of joint ventures with foreign partners having the necessary technical and financial qualifications and access to various markets of the region or the world has been adopted. Iran's local market potential and favourable geographical proximity to potential foreign markets east of Suez and the availability of skilled personnel, infrastructure, suitable feedstocks, economic and financial stability etc. are the main reasons for adopting this policy.

65. The granting of many advantages and benefits to potential foreign investors has accelerated the implementation of this policy. Among the measures adopted to provide these benefits are the following:

(a) The Law for the Attraction and Protection of Foreign Capital;

(b) The Act Concerning the Development of Petrochemical Industries in Iran;

(c) The Direct Taxation Act;

(d) Exemption from all customs duties, taxes and other charges and payments on all imports required for the construction and operation of a petrochemical complex;

(e) Free convertibility and transfer of local currency and foreign exchange of a joint venture and free establishment of bank accounts in Iran and abroad;

(f) Assurance of the supply of the necessary raw materials to a joint venture;

(g) Special provisions giving a joint venture the right to conduct and manage all production, transportation and other operations of a complex;

(h) Financing of the projects with the help of the Iranian Government through its agency called Plan Organization.

Iran has successfully established three petrochemical complexes within a span of three years, following the policy described above. The total cost of these three complexes exceeded $3[illegible]0 million.

66. Iran would welcome the participation of any foreign investor with the necessary qualifications in implementing projects jointly with the National Petrochemical Company of Iran. Iran would also appreciate UNIDO's assistance in identifying potential investors.

Indonesia

67. The First Five-Year National Development Plan, 1969/1970 through 1973/1974, stresses agricultural development, particularly the increase of rice production. The development of agro-oriented industries, such as the fertilizer and pesticide industries, is being given high priority. Preparations are also under way for a country-wide survey on the petrochemical industry to identify and evaluate potential petrochemical projects in order to draw up a master plan for future development of the industry.

68. Shortage of capital, a relatively small market for petrochemical products, lack of infrastructure and public utilities are problems the Government faces. The promulgation in 1967 of the Foreign Investment Law, with its incentives, has been successful in attracting foreign capital to Indonesia. Improvement in infrastructure and public utilities is continuously being carried out because of their importance in initiating successful development. The creation of a capital market is in the final stages of preparation, and this will no doubt enhance future economic development.

69. From the point of view of raw materials and the potential market, the petrochemical industry has a promising future, especially if the expected increase in the gross national product is taken into consideration. To obtain the skilled labour required for the petrochemical industry is not expected to be very difficult. A substantial number of workers have acquired experience in the refineries and in the fertilizer and other industries. With proper training, they will constitute an adequate supply of skilled labour.

70. Any inquiries regarding foreign investment should be addressed to the Department of Industry, Djl. Kebon Sirih 36, Djakarta, Indonesia.

Malaysia

71. Industries based on the recovery of sulphur and its use in the manufacture of sulphuric acid, ammonium sulphate fertilizers and synthetic detergents are already in existence. The manufacture of ammonia, nitric acid and nitrogen fertilizers from raw materials derived from petroleum has also been established.

72. The prospects for petrochemical development, such as the manufacture of certain varieties of carbon black, plastics, synthetic adhesives for the country's expanding plywood industry, alkyl and aryl hydrocarbons, acetylene and ethylene cannot yet be forecast accurately. Detailed surveys of the potential growth of the industries that will consume these chemicals are

necessary. A complete feasibility study may have to be undertaken in collaboration with foreign experts before concrete steps can be taken to expand the petrochemical industry.

Pakistan

73. The petrochemical industry is still in its very early stages. Existing capacity is limited to one small PVC plant based on imported calcium carbide, one polyethylene plant based on indigenous molasses and two urea formaldehyde plants based on indigenous urea and imported formaldehyde.

74. West Pakistan has 16 x 10^{12} ft^3 of proven natural gas reserves and East Pakistan 10 x 10^{12} ft^3. Natural gas has so far been used only to make nitrogen fertilizers and as fuel for power generation. In East Pakistan, the Government is considering a scheme costing $200 million for producing annually: PVC, 50,000 tons; acrylonitrile staple, 12,000 tons; acrylonitrile filament, 4,000 tons; polymethyl methylacrylate, 4,000 tons; caustic soda, 42,000 tons; bleaching powder, 1,000 tons; methanol, 37,000 tons; ammonium sulphate, 28,000 tons; urea, 320,000 tons; and surplus acetylene, 3,000 tons. In West Pakistan, where a sizable quantity of naphtha is available from the refineries, a scheme for using naphtha to produce 20,000 tons of ethylene in the first phase is currently under consideration by the Government. The main products envisaged and their annual production are: polyethylene, 10,000 tons; PVC, 15,000 tons; polypropylene, 5,000 tons; caustic soda, 13,000 tons; dodecylbenzene, 5,000 tons; and vinyl chloride monomer, 16,500 tons.

75. The capacities are higher than indigenous demand, and substantial export is envisaged to utilize excess capacity. Although capacities to be built would be ahead of demand in order to reduce production costs, domestic demand is expected to grow rapidly once domestic production is underway. There is a hidden demand for end-use products such as wires and cables, electrical conduits, packing materials, flexible sheets, pipes in roof construction, footwear, coated textiles, synthetic glass and fibres.

76. Despite the availability of cheap raw materials (about 10 cents per 1,000 ft^3 of gas in East Pakistan, for example), limiting factors in the development of the petrochemical industry have been the need for heavy investment and for high capacities and consequent dependence on a highly competitive export market, not to mention the usual bottlenecks such as the lack of trained

manpower. Assistance from UNIDO, particularly in assessing export markets and possibility of long-term contracts to ensure markets would be most welcome.

Philippines

77. The Philippines has advanced rapidly in the manufacture and consumption of finished products based on petrochemical raw materials. It is now investigating the feasibility of setting up a petrochemical complex for the manufacture of basic raw materials centred on a naphtha-cracking plant with a capacity of 100,000 tons/year of ethylene. The Government is participating directly in the development of the industry through the Board of Investments, which in turn has organized a Petrochemical Committee composed of members from the public and the private sectors.

Argentina

78. Since the first United Nations Interregional Petrochemical Symposium, the Argentine petrochemical industry has grown at the remarkable rate of 62 per cent per year, reaching a gross production output of $1[illegible] million in 1968, as compared with $[illegible] million in 1964. However, this output did not reach the level that could have been expected in relation to the increase in the gross national product, largely because much of this growth was attributable to import substitution. The next five years appear more promising in view of a recently issued petrochemical decree (No. 4[illegible]1/69) which, among other things, has established prices for feedstocks to be supplied by the State, at levels equal to those prevailing on the international markets. This should allow local production to compete, by 1975/1976, with imported products bearing duties of only 20 to 40 per cent. By 1973, Argentina expects to be self-sufficient in petroleum and natural gas. The petrochemical industry will thus have a solid base on which to stand. The main impediments to its development are the following: costs due to economies of scale and idle capacity resulting from the relatively small and geographically isolated market; economic and political problems resulting from the substitution of synthetic fibres and plastics for cotton, wool, and leather, all of which are significant natural-resource industries.

Bolivia

79. Bolivia is very close to implementing its first petrochemical projects. Bolivia has a good supply of raw materials important for the petrochemical industry, especially natural gas. For greater efficiency, the Andean countries

(Bolivia, Chile, Colombia and Peru) have agreed to plan the industry on a regional basis. The characteristic problems of the less developed countries and the peculiar transportation problem of Bolivia are the main problems to be solved. An ammonium nitrate fertilizer/explosive project is directed towards the home market, while various alternatives exist for production for the regional market.

Brazil

80. The volume of Brazilian production and consumption, both present and in the near future, of petroleum raw materials and of natural gas, as well as of basic petrochemical products, was described.

81. Since 196[illegible], fiscal and credit incentives have been extended to the chemical industry (including petrochemicals). These have been handled by an agency of the Ministry of Industry and Commerce, the executive group of the chemical industry - GEIQUIM. A list of the petrochemical projects approved by GEIQUIM was presented. Many of these projects are already in operation. The stage of development of others was indicated.

82. In late 1967, the Government decided to create a new company: Petrobrás Química S.A. - Petroquisa, a subsidiary of Petrobrás and wholly controlled by it, with the aim of promoting the petrochemical industry directly or through its association with other Brazilian or foreign private enterprises, even with a minority participation. This was not permitted to Petrobrás itself. As a result of this policy, various projects are now being undertaken as joint ventures between Petroquisa and private investors.

83. The production capacities, the main raw materials required and the basic petrochemical products of existing plants and also of those under construction were listed. These data indicate that Brazil should have a secure supply of basic raw materials for the local petrochemical industry at least until the middle of the next decade.

Chile

84. Current investment in petrochemicals in Chile is about $80 million. It is planned to increase this to $150 million in the period 1970 to 1975. This investment would be provided by the Government (mainly through Petroquímica Chilena S.A.), by private enterprise and by foreign interests. Petroquímica Chilena S.A. was set up in May 1966 and consists of the following divisions: Development, Technical, Commercial, Finance, Administration and Personnel.

In 1968, the Chilean Institute of Plastics was set up largely through the initiative of Petroquímica Chilena S.A. This institute represents the interests of both processing industries and those making the final products.

85. The market for plastics increased five and a half times between 1963 and 1968, and this rate of increase is expected to be maintained up to 1973. This would mean a consumption of plastics by 1973 of 6 to 7 kg per capita.

86. Various organizations have been studying and planning for some time the development of petrochemicals as a whole, and as a result, a complex is now under construction at the San Vicente refinery in the Concepción area. A plant belonging to ENAP (Empresa Nacional del Petróleo) will have an annual capacity of [illegible],000 tons of ethylene, 40,000 to 50,000 tons of propylene and 10,000 tons of butadiene. It is expected to be on stream early in 1970. The ethylene will be used as the chief raw material for the production of vinyl chloride, polyethylene and vinyl acetate. The first two, with capacities of 15,000 and 20,000 tons/year, respectively, will be on stream by mid 1970. To provide the chlorine, a chlorine caustic soda plant is being installed by Petroquímica Chilena S.A. in the same area, to start operating also in 1970. The caustic soda will be used for rayon, cellophane, soap, detergents, textiles and cellulose. The chlorine will have additional uses in cellulose, drinking-water and chlorine derivatives. It is also planned to produce vinyl acetate from ethylene and acetic acid in quantities of 15,000 tons/year, higher alcohols by the oxo process from propylene and synthesis gas (up to 20,000 tons/year of n-butanol and 2-ethyl hexanol).

87. ENAP is also treating natural gas in the Magellan area and producing from it LPG and methane and ethane for other petrochemical uses as ammonia, urea and ethylene dichloride. An aromatics plant is not yet considered justified. Polyester chips will, however, be made from imported dimethyl terephthalate. An alkylate plant for the manufacturing of detergents and possibly a plant for phthalic anhydride will be constructed later.

88. The recruitment of experts and technologists was discussed. Development will depend to a large extent on imported know-how. Raw material can be largely obtained from existing refineries, coupled with planned extensions; the capacities and present output of these refineries were indicated.

Mexico

89. The Mexican petrochemical industry dates from 1958. The industry is regulated by law and is divided into a public and a private sector. Production is widely diversified. Mexican companies, usually with foreign technical assistance, built the installations. The Mexican Petroleum Institute and a private enterprise are developing their own technologies, and success in the near future is confidently expected.

Puerto Rico

90. Puerto Rico has economic problems quite similar to those confronting many developing countries today. Its experience in fostering the development of processing industries and the substantial economic progress it has achieved should offer some guidance for other developing countries.

91. When it began to undertake economic development on a organized basis, Puerto Rico, like many developing countries, had no indigenous mineral resources and was overpopulated. The initial attractions offered to industry were tax exemptions and the availability of low-cost (but unskilled) labour. By encouraging the establishment of petrochemical core industries that could produce low-cost chemical raw materials or intermediates, the Government laid the basis for the subsequent development of various down-stream processing plants. The petrochemical industry in Puerto Rico dates from 1955, when two oil refineries producing conventional fuel products for the local market and for export on a modest scale where installed. At present, major refining and petrochemical complexes have been established around core plants of the Commonwealth Oil, Phillips Petroleum, and Union Carbide companies, and yet another has been started by the Sun Oil Company.

92. The progress to date in Puerto Rico has proved the validity of the concept of developing the petrochemical industry in stages, starting with the basic refining/petrochemical core facilities. Petrochemical raw materials and intermediates are now being exported, but the pattern has already been established for increasing down-stream utilization in Puerto Rico. Developing countries now considering petrochemical installations should review the merits of this approach versus the possibilities of starting initially with an unwieldy and excessively capital-intensive integrated petrochemical complex. Each step could be taken on an economic basis without foreclosing any of the subsequent down-stream processing possibilities, when and if such further installations were economically justifiable.

93. Puerto Rico's good fortune in having a competitively priced source of raw materials within close reach, a strong tariff-free export market on the United States mainland and an established and growing local consumer-goods market is rarely enjoyed by developing countries. It was suggested, however, that the creation of regional markets would in some cases permit the installation of petrochemical facilities of economic size. The advantages to be gained by avoiding duplication or construction of several small units are obvious. Admittedly, the consent of different countries to the pooling of their markets for this purpose would probably have to be contingent on simultaneous pooling of resources and agreements to reduce protective tariffs and customs. Each country providing part of the market for petrochemicals must have incentives for participating in a regional co-operative effort in other ways.

<u>Trinidad and Tobago</u>

94. The economic development of Trinidad and Tobago has been dominated by the growth of the petroleum production and refining sector. Facilities exist for the production of a wide range of petrochemicals, including aromatics, <u>n</u>-paraffins, cyclohexane, and trimer, tetramer and di-isobutylene. Natural gas is utilized for the production of ammonia, urea and ammonium sulphate. Trinidad and Tobago (with a population of one million) lacks an appreciable domestic market, so that the production of petrochemicals is almost exclusively for export. The Government has introduced various institutional measures (including generous tax holidays) to help the industry to expand.

95. Favourable conditions exist for the petrochemical industry, especially as regards the availability of raw materials. The prospects for further development have also been greatly enhanced by recent discoveries of substantial quantities of gas, oil and condensate on Trinidad's south-east coast. Long-term plans for the optimum utilization of these resources are being drawn up.

<u>Uruguay</u>

96. There are no basic or intermediate petrochemical industries in Uruguay. One of the main reasons for this is the limited market. Other reasons include the lack of natural resources, inflation, the lack of a specific policy of promoting the petrochemical industry and difficulties of access to technology. The markets of Brazil, of much of Argentina, and of the Andean region have the disadvantage that long distances must be covered to reach them. If, however,

within the Latin American Free Trade Association (LAFTA), operating mechanisms were created that would allow a balanced and harmonious development of member countries, Uruguay might aspire to undertake petrochemical projects, for it has an adequate infrastructure, a certain degree of industrial development and a qualified labour force.

Venezuela

97. The Morón complex in Carabobo state includes a fertilizer plant with an annual capacity of about [illegible] tons; an industrial explosives plant with an annual capacity of [illegible] tons; and a chlorine-soda plant with an annual capacity of [illegible] tons of chlorine and 11,[illegible] tons of soda. A new fertilizer plant with an annual capacity of [illegible] tons is being set up in this complex. New projects in the El Tablazo complex in Zulia state include a cracker producing annually [illegible] tons of ethylene and [illegible] tons of propylene; and a chlorine-soda plant with an annual capacity of [illegible] tons of chlorine and 40,000 tons of soda.

98. A number of ventures are being carried on jointly with a foreign partner. They include a dodecyl benzene plant with an annual capacity of [illegible] tons and a phthalic anhydride plant with an annual capacity of [illegible] tons. Both plants are in Carabobo state. Projected joint ventures, in Zulia state, include a polyethylene plant with an annual capacity of [illegible] tons; a PVC plant with an annual capacity of [illegible],000 tons and a vinyl chloride monomer (VCM) plant with an annual capacity of [illegible],000 tons; an ammonia and urea unit with an annual capacity of [illegible],000 tons of ammonia and [illegible] tons of urea; and a polyisoprene plant with an annual capacity of [illegible] tons.

99. Venezuelan companies are also participating in joint ventures abroad. Two such enterprises are in Colombia: a caprolactam plant with an annual capacity of 16,500 tons and a fertilizer plant with an annual capacity of 142,000 tons. Another joint venture is in the Dominican Republic: a fertilizer mixing plant with an annual capacity of 90,000 tons.

Iraq

100. While Iraq has no petrochemical industry (a fertilizer plant of [illegible] tons/year capacity is under construction), it is on the threshold of development in this sector. Guidelines for development have been suggested in some reports prepared by consultants during the last few years. These reports, still under study, deal with the possibility of establishing petrochemical

industries such as plastics, fertilizers, synthetic rubber, synthetic detergents and carbon black. The need for building petrochemical industries has become urgent because of the continuously growing demand for petrochemical products and because of the abundance of light distillates, natural gas and refinery gases, which could be utilized by these industries. Plants producing low-density polyethylene and PVC would be the most feasible to build because the demand for these materials is growing at a very rapid rate; it is expected to reach about [illegible] tons/year in [illegible]. The establishment of a co-operative Arab project has been proposed. Such a project should be large enough to be economic and to meet at least the demand of the members of the Arab Common Market that is now under serious consideration. The importance of UNIDO assistance in this respect was emphasized.

Lebanon

101. The petrochemical industry is practically nonexistent in Lebanon and no definite projects are planned for the immediate future. The possibility of establishing the industry was discussed as well as the role that Lebanon could play in the development of an Arab petrochemical industry. Because of the limited home market and the absence of crude oil and natural gas, it was felt that a Lebanese petrochemical industry could not develop outside an Arab development plan. Although Lebanon has scientific and technical staff of high calibre as well as low-cost utilities, there is a shortage of feedstocks in the output of existing refineries and a lack of private and public capital. Furthermore, the oil-producing Arab countries are not expected to invest in Lebanon on any appreciable scale. The main contribution that Lebanon could make to the development of an Arab petrochemical industry is in scientific research, the necessity for which has been emphasized. It was suggested that an Arab centre for petrochemical research be established in Lebanon.

Syria

102. Crude oil is available both from Kirkuk (Iraq) and from local production. The specific gravity of the latter is from [illegible]° to [illegible]4° API, and its sulphur content is high. Associated gas is also available for petrochemical production. The first refinery was established in [illegible]. The capacity has just been increased from 1 to [illegible] million tons/year. Coking is used to increase the yield of middle distillates, with accompanying sulphur production, and further expansion is in view. An ammonium nitrate plant will start production in 1970.

The rapid rate of increase of fertilizer consumption indicates the need for additional nitrogen capacity, probably in urea. The primary emphasis is on increasing fertilizer production and the hydrogenation of the heavy Syrian crude oil. It is envisaged that 40,000 tons/year of ethylene will be produced in the initial stage of a petrochemical complex.

USSR (Azerbaijan Soviet Socialist Republic (AzSSR))

103. The foundation of the petrochemical industry of Azerbaijan was laid in the 1930s. Extensive development of petrochemical science and industry took place in the 1950s and 1960s. During the last two decades, the pyrolysis of oil and casing-head gasolines and middle and heavy petroleum distillates have been extensively investigated, and a new and improved pyrolysis technology, as well as a new integrated scheme for the utilization of all pyrolysis products, has been elaborated. The results of these investigations have found wide commercial application. The technology for the production of high-purity ethylene and propylene has been developed. On the basis of these products, large-scale processes for producing polymers and other valuable petrochemical products have been elaborated, for instance, direct ethylene hydration.

104. Important studies have been undertaken with a view to further developing the synthetic rubber industry. These include studies on the production of butadiene and isoprene by catalytic dehydrogenation of oil processing gases, the development of the technology for ethylene-propylene rubber production and the elaboration of oxidative dehydrogenation processes. Azerbaijan's scientists have carried out investigations on hydrocarbon oxidation and oxidative ammonolysis (production of acrolein, maleic and phthalic anhydrides, ethylene and propylene oxides, acrylonitriles). The production of chloro-organic compounds has assumed great importance in Azerbaijan's petrochemical industry. One of the new trends is towards the production of polymeric materials. This involves the elaboration of a new and original technology for polyethylene production, using oxidation catalysts.

Czechoslovakia

105. Petrochemical production started in 1961, when the large-scale import of crude oil from the USSR began. Crude oil and natural gas coming by pipeline now provide the raw material basis for the petrochemical industry. The production of petrochemicals in recent years has been divided into three basic groups: (a) production of olefins in two separate small-capacity units with down-stream

petrochemical processes producing synthetic ethanol; (b) ethylbenzene and styrene, ethylene oxide and glycols based on ethylene and oxo-alcohols; and (c) cumene-phenol and polypropylene based on propylene. Butadiene is extracted from the C_4-fraction and is used for synthetic rubber production. The production of aromatics from petroleum uses diethylene glycol extraction. Benzene is used for ethylbenzene and cumene production. Para-xylene and ethylbenzene are prepared from mixed xylenes. Natural gas is used as a feedstock to produce synthesis gas for ammonia and methanol production, with eventual co-production of acetylene.

106. To ensure a supply of raw materials for the production of plastics and other chemicals for the period up to 1980, it will be necessary to erect, in co-operation with neighbouring countries, two large ethylene units with a total capacity of 200,000 to 300,000 tons/year of ethylene, and to increase the production of existing units. New plants will be erected, such as high-density polyethylene, vinyl chloride, vinyl acetate, acetaldehyde, polypropylene and acrylonitrile, based on ethylene and propylene. A new aromatics-recovery plant has been erected, including dealkylation of toluene. Benzene will be used for the production of caprolactam. The production of ammonia is to be tripled in the same period, using steam reforming of natural gas or partial oxidation of fuel oil.

107. An important part of the petrochemical units already installed in Czechoslovakia was developed, engineered and executed by Czechoslovak institutes and companies. The machine industry delivered equipment for their own and foreign-licensed petrochemical processes such as olefin production, ammonia, synthetic ethanol and PVC production and styrene and polystyrene foam production. Processing development has been achieved for modified types of butadiene-styrene rubbers and for polystyrene.

Poland

108. The use of petrochemical raw material in Poland began in 1964. Several plants for the production of ammonia, methanol and acetylene from natural gas have been built. Existing capacity and installations coming on stream will attain a production of 7,000 tons/day in 1973. Refining and petrochemical processes based on crude oil have been developed. Petroleum refinery capacity rose to [illegible] million tons/year in 1969 and is expected to attain a level of 13.5 million tons/year before 1975.

109. The first small plant for steam cracking naphtha went into operation in 1967, and the production of polyethylene, ethylbenzene, cumene phenol and acetone was begun. The xylenes from the platformer were utilized for the manufacture of DMT for production of polyester fibres.

110. In 1970/1971, the production of basic olefins will reach only 100,000 tons/year of ethylene and 50,000 to 60,000 tons/year of propylene. The production of butadiene will range from [illegible] to [illegible] tons/year (mainly from Houdry's process). In the five-year plan 1971-1975, a new steam-cracking plant with a capacity of [illegible]00,000 to 400,000 tons/year of ethylene is to be erected. After 1975, a second cracking plant with the same capacity will be needed. In the planned development of petrochemical products, priority will be given to polyolefin plastics, synthetic fibres, various resins and new kinds of synthetic rubber.

<u>Romania</u>

111. Two main lines of development, based on two raw material sources, methane and petroleum refinery products, can be distinguished in Romania's petrochemical industry. The production of ammonia, vinyl chloride, trichloroethylene, acetic acid, vinyl acetate and its polymers are based on methane. Petroleum refinery gas is used to produce isopropyl benzene, which is an intermediate for the production of phenol-acetone and of synthetic rubber, and for pyrolysis for the production of high-purity ethylene and propylene, which is then transformed into polyethylene, ethylene oxide, glycols and phenol. Liquid petroleum products are now used as raw materials for the production of ethylene. In a relatively short time the petrochemical industry of Romania has stimulated industrial production in general and technical achievements in all areas of the national economy.

<u>Yugoslavia</u>

112. The problems of the basic organic chemical industry in Yugoslavia, which is represented by plastics, synthetic fibres and organic chemicals, and which was developed according to forward and backward integration models, was described. Gross production of the basic organic chemicals in Yugoslavia, together with production of the final products and intermediates, increased in 1963 from 73,996 tons to 224,340 tons in 1968. The major part of this output took place in the plastics field, together with the plasticizers needed in compounding plastics. In 1968, about 88.3 per cent of the total basic organic

chemical production consisted of plastics and intermediates of the first and second generation. These intermediates are mainly used for the synthesis of plastics and plasticizers. According to carbon content, Yugoslav production of first-generation intermediates is based 55 per cent on hydrocarbons from petroleum and 45 per cent from coal. By 1971, after completion of the aromatics plant now under construction, the hydrocarbons from petroleum will amount to 89 per cent of the total carbon content.

113. All the problems encountered in the early stage of development of the basic organic chemical industry in Yugoslavia arose because the prices of organic chemicals were considerably higher than those produced by the developed countries. Owing to import liberalization after the economic reforms, the non-competitiveness of indigenous production was not only reflected in the world market but also in the domestic market. The non-competitiveness of indigenous production was due to internal conditions in Yugoslavia, which are different from those in the countries that control the world prices for chemicals. A limited domestic market does not justify large-capacity installations or major concentration of production in complexes. Yugoslav enterprises thus found themselves unable to compete with the major world companies.

114. More critical than the cost of basic production was the shortage of capital; plants erected had to be financed by domestic and foreign loans. The terms of these loans were often very rigid and made it impossible to pursue a flexible price policy. Further purchases of licences and know-how not only absorbed considerable amounts of foreign currency but also increased the final price of the product. Quite apart from this, there was neither a consistent development programme nor an adequate economic policy to integrate petrochemical technology into the Yugoslav economic structure. One great disadvantage for a developing country is that it is not possible to predict the results of further development in industrialized countries. Thus, when it was decided in 1960 to erect the OKI and OHIS plants, it was calculated that, by choosing the technology carefully and by producing at a reasonable capacity, Yugoslavia would be able to meet the prices then prevailing in most European countries. However, before these complexes were completed, the world prices of their products began to decrease significantly. It is now too late to make alterations and thus to adapt the plants to these new conditions. Hence indigenous production has been put on the domestic market at prices considerably above those of the imported products that had previously supplied the needs of the processing industry.

115. Yugoslav experience has shown that, under the conditions of a free market and of decentralized investment decisions, the growth of a domestic basic organic chemical industry in a developing country can only be achieved by using economic policy as an instrument to maintain a certain price level for organic chemical products. This price level must be adjusted to harmonize with the current rate of exchange, with tariffs and with the prevailing foreign trade position. This would provide a certain degree of stability and enable the optimum capacity to meet the fixed price to be established and thus reduce the commercial risks to normal limits.

116. By 1985, Yugoslavia is expected to achieve the status of an industrially developed country, with a national income nearing $[illegible],000 per capita. During the period up to 1985, all fields of industry that use products of the chemical industry as their raw material will be developed. This emphasizes the necessity for further development of basic organic chemicals and, in particular, the manufacture of plastics, synthetic fibres, synthetic rubbers and a series of organic intermediates. It is expected, however, that the future economic policy of Yugoslavia will be such that it can play a really creative role in the dynamic development of the world petrochemical industry. One of the factors that must be emphasized is the importance of joint ventures in the development of the petrochemical industry in Yugoslavia - an opportunity exists for foreign and Yugoslav enterprises to work together to build up the Yugoslav industry.

Spain

117. The presentation on the development of the petrochemical industry in Spain included the following points: present situation of the industry, with a tabulation of installed capacities for all petrochemical products; future prospects, with a tabulation of plants under construction and short-range projects; major problems; and the need for technical and financial assistance.

Turkey

118. The first petrochemical complex in Turkey began operating in October 1969. It is located in Yarimca, about 35 kilometres from Istanbul, and belongs to Petkim Petrokimya A.S., a Turkish state company that has been entrusted with the task of establishing and operating the petrochemical industry in Turkey. The Yarimca complex comprises fourteen units, which are to be realized in three phases. The first-phase units will go into operation one by one, as completed, as follows: a naphtha steam cracker producing 1[illegible],000 tons/year

of naphtha; a polyethylene unit producing 12,000 tons/year; a vinyl chloride monomer unit producing 27,000 tons/year; a polyvinyl chloride unit producing 26,000 tons/year; a chlorine-alkali unit producing 18,500 tons/year of chlorine and 20,300 tons/year of caustic soda; and a dodecyl benzene unit producing 10,000 tons/year.

119. The rapid development of the market has necessitated the expansion of all the first-phase units except the dodecyl benzene unit. The expanded capacities of these units will be as follows: naphtha steam cracker, 250,000 tons/year of naphtha; polyethylene unit, 27,000 tons/year; vinyl chloride monomer unit, 54,600 tons/year; PVC unit, [illegible] tons/year; chlorine-alkali unit, [illegible] tons/year of chlorine and [illegible] tons/year of caustic soda. The units that are to be incorporated into the Yarimca complex in the second phase are as follows: carbon black unit, 30,000 tons/year; styrene unit, 25,000 tons/year; polystyrene unit, [illegible] tons/year; butadiene extraction unit, 33,500 tons/year; SBR unit, [illegible] tons/year; BR unit, 13,500 tons/year; acrylonitrile unit, 10,000 or 20,000 tons/year; caprolactam unit, 15,000 tons/year; polypropylene unit, 12,000 tons/year; and ABS unit, 10,000 tons/year.

120. To meet the increasing demand of the Turkish market, a second complex, parallel with the Yarimca complex, is planned. This second complex is to be in Izmir and is to be completed by the end of 1975. The units of the Izmir complex are to be the following final-product units: low-density polyethylene unit, 45,000 tons/year; high-density polyethylene unit, 30,000 tons/year; polypropylene unit, 35,000 tons/year; PVC unit, 65,000 tons/year; ethylene oxide unit, 46,000 tons/year; ethylene glycol unit, 30,000 tons/year; triethanolamine unit, [illegible] tons/year; DMT unit, 40,000 tons/year; and phthalic anhydride unit, 20,000 tons/year. There will also be the following intermediate units: naphtha steam cracker, 650,000 tons/year of naphtha and 62,600 tons/year of chlorine; vinyl chloride monomer, 94,500 tons/year; and styrene 46,500 tons/year. The aromatic separation facilities will yield para-xylene, 27,000 tons/year; ortho-xylene, 27,700 tons/year; and benzene, 82,800 tons/year.

Discussion

121. Developing countries fall into three broad categories. The first category consists of countries with large petroleum resources, limited domestic markets and a generally favourable balance-of-payments position, which enables

them to invest in capital-intensive petrochemical plants, the products of which must be exported. The problem for these countries is to identify the petrochemicals for which export markets can be found and to develop a strategy to gain a secure position in these markets so that viable petrochemical plants may be built. The second category consists of countries with potentially large domestic markets and a reasonably good supply of raw materials. Their problem is how to realize the potential market at an early date so that production plans for petrochemicals can be accelerated and viable plants erected. Countries lacking both a large potential domestic market and suitable raw materials fall into the third category. It may still be possible for some of these countries to manufacture selected petrochemical products, but these products may have to be of high value, and the country should be in a favourable position to produce them.

122. During the last five years, developing countries have progressed rapidly in knowledge and understanding of the problems of promoting petrochemical manufacture. The quality of market studies undertaken by developing countries has improved vastly. However, assistance in studying export markets for petrochemical products is often required. This is especially true for fabricated articles, for which export markets may be more promising and substantially more remunerative. It is necessary to identify just what can be sold and where and to learn how to develop a sound market strategy to penetrate and hold export markets.

123. Developing countries have begun to prepare sound feasibility reports, using modern techniques of economic and financial analysis. Since more is now known about petrochemical processes and their relative economic merits, several developing countries are in a better position than ever to select products and processes. However, a real need is felt for the regular publication of detailed information on processes available in other countries, the names of process licensers, and plants built elsewhere in the world using these processes. This would greatly assist developing countries to take advantage of the competitive situation in developed countries with respect to the purchase of technology, and thus enable them to negotiate the purchase of technology on reasonable terms.

124. A number of process licensers from developed countries continue to impose conditions that restrict the freedom of the licensee to export products manufactured on the basis of their processes. This policy acts as a particularly

severe constraint on the rapid development of petrochemical manufacture in developing countries, and United Nations organizations could render valuable assistance to developing countries by studying how process licensers might be persuaded to eliminate these restrictions.

125. Several developing countries have purchased plants that cannot operate at their designed capacity, since the basic design is often faulty and, more often, badly adapted to local raw materials, operating skills and other relevant local conditions. The importance of proper preparation of bid documents that take into account important local conditions was emphasized. Some developing countries have reached the stage of preparing bid documents themselves, and they, as well as United Nations organizations, could help other developing countries to reach this stage quickly.

126. Many developing countries face an acute shortage of foreign currency, and this severely inhibits the rapid development of the petrochemical industry even though other conditions are favourable. An analysis of the foreign currency cost of petrochemical plants erected in the last five years in certain developing countries shows that as much as 15 to 20 per cent of the total cost of such projects is for overseas engineering design and construction services payable in foreign currency. Many developing countries now have a sufficient number of highly trained technologists and engineers to establish engineering design organizations that should increasingly be able to provide engineering design and construction services in the country. This would save substantial amounts of foreign currency. With the much lower level of salaries and wages in developing countries, it would also make possible substantial economies in the total cost of a project, thereby improving its competitive position.

127. The establishment of domestic engineering design and construction firms leads to a significant increase in domestic procurement of equipment. These firms provide challenging and therefore satisfying employment opportunities for the highly educated and trained local scientists and engineers and are vital to the development of domestic technology. Developing countries should study this important area. Assistance in such ventures should be available from other developing countries who have established such firms and from United Nations organizations.

128. Most developing countries now entering the field of petrochemical manufacture face a shortage of skilled manpower. It is expensive to obtain

such manpower from developed countries, and process licensers seldom make it possible for training to take place in overseas plants. Thus a well-organized training programme, established well in advance of production, is a necessity. Such assistance in this area can be obtained from United Nations organisations as well as from other developing countries that have already erected petrochemical plants and established training programmes.

129. Experience in certain developing countries appears to indicate that technology for some petrochemical processes, many of which are of immediate interest to developing countries, can be developed relatively inexpensively. It has also been found that mere purchase of overseas technology is not enough. Knowledge and basic scientific understanding of the technology are required to adapt what is purchased to local conditions arising from such matters as operation and maintenance methods, specifications of local raw material and equipment and utilization of by-products. Continuing technological development is required to obviate obsolescence and the purchase of overseas assistance at high cost. This adaptation and technological development necessitates the establishment of domestic research and development facilities at an early stage of petrochemical manufacture, and United Nations organizations should consider how they might be able to assist developing countries in such efforts.

130. Substantial reductions in cost can be achieved in developing countries if the gestation period of petrochemical projects, which is still much longer than in developed countries, can be cut down. There are several well-developed techniques that can help in this respect, and experts in this area could be made available by United Nations organizations.

131. Studies carried out recently by the United Nations economic commissions indicate that regional co-operation in joint ventures by member countries can bring tangible advantages. Much detailed work is still required in preparing detailed project reports and finding acceptable solutions to a number of complicated problems, such as patterns of ownership and management, offtake agreements, tariffs and, possibly, trade balances. Attention was drawn to past resolutions of United Nations meetings calling on developed countries to lower tariffs to encourage imports from developing countries. Lower tariffs on their exports would certainly assist developing countries to achieve viable production plants by increasing unit sizes. Developing countries are concerned that constraints in economic development may inhibit the erection of viable units at an early date and that the gap between the developed and the developing countries appears to be increasing.

CHAPTER 2

BASIC PETROCHEMICAL PRODUCTS AND RAW MATERIALS

Production of olefins - main developments since 1964

132. The rapidly expanding demand for plastics, fibres and detergents is leading to the planning and erection of extremely high-capacity olefin plants. In the industrialized countries, such plants reach outputs of 300,000 to 350,000 tons year. Relations between producers and consumers of the basic petrochemical raw materials as well as some of the intermediates have been planned so that it is possible to use these high-capacity units in such a way that all of their products can be fully used with the maximum of economy.

133. Long-distance transport of ethylene, propylene and C_4 fractions, either by pipeline or by ship, is becoming usual in many developed countries, and developing countries should take full advantage of the techniques available. The demand for both ethylene and propylene is increasing rapidly, but it appears likely that long-term demand for these products will settle down at a ratio of approximately 2:1. This ratio can be readily obtained by fairly severe conditions of pyrolysis. Ethylene is now being used for vinyl chloride, acetaldehyde and vinyl acetate, all of which were previously made from acetylene. Propylene is being used increasingly for polypropylene and, in addition, acrylonitrile, which was previously made from acetylene, but which is now being made almost entirely from propylene.

134. With the increase in the capacities of ethylene and propylene production, it appears that all requirements for butadiene will be served by extraction from the C_4 fraction mixture. Considerable attention is therefore being paid to the most economic methods of separating the C_4 fractions, such as advances in butadiene extraction by different solvents, particularly N-methyl pyrrolidone, and the extraction of isobutylene by sulphuric acid. New methods are being worked out for the direct polymerization of the olefinic and diolefinic

compounds in the C_4 fraction, which may prove particularly suitable for developing countries. An economic use of the C_4 fraction after removal of the butadiene is particularly important so that all the by-products can be utilized. The time may come when selective polymerization of olefins from a mixed gas stream will be possible by the use of different catalysts in series.

Production of acetylene and acetylene-ethylene mixtures

135. Development in the field of autothermic oxidation has been concentrated on the possibility of using crude oil directly as the raw material. This has resulted in mixed acetylene and ethylene production as basic intermediates for down-stream processes. It makes possible the direct use of crude oil as a raw material. It opens the way to the relatively cheap production of acetylene as a raw material for plants when the use of ethylene is not practicable. The most important processes are the HTP process developed by Farbwerke Hoechst and the processes developed by Badische Anilin und Soda Fabriken (BASF). It is possible by these methods to obtain 40 per cent of the C_2 fraction from the primary crude. Some details of the processes and, in particular, advances made in recent years are given below.

136. Production of ethylene from crude oil using a fluidized-bed process involves preheating crude oil and injecting it into a fluidized bed of petroleum coke; its efficiency in comparison with the older processes is appreciable. With this new method, 3.6 tons of crude oil are required for the production of 1 ton of ethylene, while as co-products 0.5 tons of propylene and 0.45 tons of the C_4 fraction containing 35 per cent by weight of butadiene are obtained. The production of acetylene and ethylene using the submerged-flame process involves burning oxygen underneath the surface of the oil, as a result of which cracking of the oil at a very high temperature (close to the flame temperature) takes place. The large volume of oil present brings about rapid quenching of the products of cracking, and hence much of the acetylene produced at a very high temperature is conserved. For the production of 1 ton of acetylene and 1.18 tons of ethylene, 8.27 tons of crude oil and 5.1 thousand m^3 of oxygen are required.

137. The cracking of crude oil by the HTP process is still in the development stage. The principle lies in the combustion of the tail gas from the cracking operation with oxygen followed by the injection of a secondary stream of the hydrocarbon fraction to be cracked. The temperature is controlled by the quantity of hydrocarbon injected, which itself determines the acetylene-ethylene

ratio. Older processes for the manufacture of acetylene include those in which natural gas or straight-run naphtha is cracked by the heat developed from the incomplete combustion of the raw material with oxygen. A much higher yield of acetylene from hydrocarbon raw materials can be obtained by the hydrogen-electric arc process; hydrogen is used as a carrier gas, and techniques are available for avoiding soot and burning of the electrode.

Advances in down-stream processes

138. Acetaldehyde is one of the more important chemicals now made from ethylene rather than acetylene. New processes are available for producing acetaldehyde from ethylene by one- or two-stage processes, using oxygen or air, respectively. The ethylene is oxidized by palladium salts (palladium chloride) in aqueous solution, the palladium chloride being reduced to a metal. The metal is then re-converted to palladium chloride by cupric chloride, which is reduced to cuprous chloride. The cuprous chloride is then re-oxidized by oxygen to cupric chloride. In the single-stage process, ethylene and oxygen are passed into a vertical reactor containing a catalyst solution, regeneration of the catalysts taking place continously. In the two-stage process, air is used to regenerate the catalyst in a separate reactor, and the oxidation of ethylene is carried out with air. Plants for the production of acetaldehyde from ethylene have already reached a combined capacity of 1.2 million tons/year.

139. Vinyl acetate has for many years been made from acetylene and acetic acid, but processes for its production from ethylene, acetic acid and oxygen are now available. In the Hoechst method, the palladium salt catalytic route is used by which acetaldehyde is obtained as a co-product. Ethylene and oxygen are reacted at 120^{o} to $130^{o}C$ at a pressure of 30 to 40 atm in the presence of the catalyst dissolved in aqueous acetic acid. In the Bayer method, ethylene and oxygen are recycled through a vaporizer in which they pick up acetic acid vapour. Fresh oxygen is added, and the gaseous mixture is passed at 140^{o} to $250^{o}C$ and 5 to 10 atm over a noble metal catalyst. The total capacities of operating units or those under construction are already 250,000 tons/year.

140. In the past five years, the Hüls process for the manufacture of ethylene oxide has been improved, giving better yields, a longer life of the catalysts, and some other advantages. The ethylene is oxidized with air in the gas phase

on a stationary silver catalyst at 250° to 350°C at an elevated pressure in two stages. The heat of reaction is dissipated by the evaporation of water contained in the jacket space of the catalyst reactor.

141. Just as ethylene is oxidized to acetaldehyde, propylene is oxidized to acetone. Propylene and a catalyst solution are fed into a continous reactor system in which virtually all of the propylene is converted to acetone in a single stage. The reaction takes place at a low pressure at about 100°C. Air is used as the oxidizing agent, and the reaction is so efficient that the air leaving the reactor is almost completely oxygen-free.

142. A new process is available for the manufacture of acetic acid by the oxidation of normal butene. Direct oxidation tends to produce undesirable by-products, but this tendency has been overcome by the preliminary formation of butyl acetate. Normal butene is treated with excess acetic acid in the liquid phase at high temperature and pressures in the presence of a finely divided catalyst suspended in the reaction mixture and recycled. The butyl acetate in acetic acid solution thus formed is oxidized with air at elevated temperatures and pressures during the liquid phase, with a high recycle, to yield acetic acid.

Advances in aromatic production

143. The increase in the proportion of aromatics made from oil as compared with aromatics made from coal has continued to increase. Thus, between 1958 and 1960, the proportion of benzene made from oil increased from 50 per cent to 85 per cent; in France, from virtually nil to 61 per cent. The over-all demand for aromatics has also increased. Consumption of benzene for 1960, 1965 and the estimate for 1970 in the United States, the European Economic Community (EEC) and Japan are shown in the following table:

	1960	1965	1970
	thousand tons		
USA	1,562	2,650	3,600
EEC	608	1,158	1,910
Japan	387	850	...

The major products made from benzene are styrene, phenol and cyclohexane.

144. Consumption figures for ortho- and para-xylenes are given below.

	Ortho-xylenes		Para-xylenes	
	1965	1970	1965	1970
	thousand tons			
USA	50	200	150	500
EEC	140	350	130	400

Ortho-xylene is mainly used for the production of phthalic anhydride, and para-xylene for polyester fibres.

145. Aromatics from petroleum are produced by two main routes. The first is by catalytic reforming of suitable naphtha. This process is also used to produce high-octane gasoline. The second is obtained in the steam cracking of naphtha to produce pyrolysis gasoline with aromatics as a by-product.

146. Catalytic reforming produces a higher proportion of xylenes, while pyrolysis gasoline contains more benzene. The latter also contains olefins and diolefins that must be catalytically hydrogenated before removal of the paraffins. Fractionation is not a satisfactory method of separation, owing to the formation of azeotropic mixtures. Solvent extraction is, however, widely practised. The principal solvents used are ethylene glycol, sulpholane and N-methyl pyrrolidone and, to a lesser extent, dimethyl sulphoxide and formyl morpholine. All of these preferentially dissolve the aromatics.

147. Assuming a 50 per cent aromatic content in the input, sulpholane can extract 99 per cent of the benzene, 98 per cent of the toluene and 96 per cent of the xylene. Benzene, toluene and the three xylenes together can be readily separated by fractionation, and ethylbenzene can be separated from the xylenes by superfractionation. Of the three xylenes, the ortho can be separated by fractional distillation from the other two, but the boiling points of the meta and the para lie too close together to be separated in this way.

148. Para-xylene can be separated by freezing out, but only about half of this compound can be separated in a single pass. The residue is therefore isomerized by a catalytic process using, for example, noble metals or a silica-alumina catalyst. Hydrogen is needed with the first catalyst to prevent deposition of carbon, but it has the advantage of also isomerizing ethylbenzene. Recently a new process has appeared, called Essoforming, which uses a cheaper catalyst with long life. It needs hydrogen, but it does not isomerize ethylbenzene, which must be removed by superfractionation to prevent accumulation. The isomerization roughly restores the value of the isomers to their original values, and the whole process can be repeated.

149. Two entirely new processes for the separation of xylenes have been announced. In the Japan Gas Chemical Company process, a complex is formed between meta-xylene and boron trifluoride, and the other isomers can be separated by fractionation. The Parex process (Universal Oil Products) uses a solid absorbent to extract para-xylene instead of freezing it out. It takes out all the para-xylene present, but isomerization is still needed to make use of the meta-xylene. This process may prove to be cheaper than the conventional crystallization process.

150. Unfortunately, the production of benzene, toluene and xylene, particularly on the basis of the reforming process, by which the greater amount of aromatics is produced, does not correspond to market demand. Too little benzene is formed, and a large part of the toluene, the demand for which as a solvent or chemical raw material is relatively small, is dealkylated to benzene. This is carried out by submitting the toluene fraction, mixed with hydrogen, to a temperature of 650° to $750^{\circ}C$ at a pressure of 200 to 1,000 lb/in^2. Methane is the principal by-product.

151. Two new processes for dealing with the toluene are disproportionation and transalkylation. Disproportionation (Sinclair Research Inc. and Toyo Rayon) converts the toluene to benzene and mixed xylenes. Transalkylation converts toluene and a trimethyl benzene to mixed xylenes.

152. New units for the production of aromatics are being brought on stream at frequent intervals in the developed countries. It is believed that production units are operating at about 90 per cent capacity in the United States, and from time to time the possibility of scarcity has caused concern in many countries. It is expected that the United States (including Puerto Rico) will increase its capacity by 50 per cent between 1965 and 1970, that is, to 1.5 million tons. In Western Europe, production capacity for aromatics might be estimated at 1.9 million tons in 1965 and should exceed 3 million tons by 1970. Coal carbonization is still a major method of producing benzene in the Federal Republic of Germany and in the CMEA countries. Work is in progress in the United States to develop a viable process for the hydrogenation of coal, and preliminary results show a 60 per cent yield of an oil that can then be treated by conventional oil processes. This process, which has been developed by Hydrocarbons Research Inc., carries out the hydrogenation of a pulverized coal and oil slurry in a bubbling catalyst bed (similar to a fluid-bed operation).

Some advances in down-stream aromatic processes

153. Some development work has been going on in the production of chemical intermediates. A new process for the production of diphenylol propane has been described in which phenol and acetone are condensed in the presence of ion-exchange resins with certain additives. High-quality diphenylol propane is produced with little by-product formation; the reaction mixture is non-corrosive; the process is continuous; and, owing to better conversion of phenol, there is less need for recycling. Diphenylol propane is used for the production of epoxy resins and polycarbonates.

154. Divinylbenzene is mainly used in the production of ion-exchange resins, but it can also be used to cross-link with other monomers. This compound is normally produced by the catalytic dehydrogenation of diethyl benzene, but co-products are formed that are separable only with difficulty. An improved process has been developed that involves the following steps: (a) oxidation of diethyl benzene to diacetyl benzene in the liquid phase, using cobalt stearate as a catalyst at 110° to 130°C; (b) reduction of diacetyl benzene to the corresponding di-hydroxyethyl benzene by hydrogenation in presence of a suspended-bed nickel catalyst; (c) dehydration of the di-hydroxyethyl benzene to divinylbenzene over magnesium sulphate.

155. The production of synthetic glycerine by the hot chlorination of propylene or from the same starting material via acrolein is well known. A method starting from propylene oxide has been developed in which the starting material is isomerized to allyl alcohol over lithium phosphate and other components. The allyl alcohol, itself a useful intermediate, is then oxidized directly to glycerol by hydrogen peroxide in presence of a tungstic acid catalyst.

Surface-active agents

156. Many surface-active agents are based on synthetic alcohols. Three different processes are under development for the production of fatty alcohols from paraffin by oxidation:

(a) Paraffins are oxidized to fatty acids in the presence of manganese catalysts. These fatty acids are reduced to alcohol by hydrogen under pressure.

(b) Some higher fatty alcohols are produced as by-products in the production of fatty acids by the oxidation of paraffins: these alcohols are concentrated in the unsaponifiable fraction, which is separated from the acid by crystallization. These alcohols are about 80 per cent primary and 20 per cent secondary, and are isolated through their boric acid esters.

(c) Secondary alcohols can be produced by the direct oxidation of normal paraffins in the presence of boric acid.

157. Primary alcohols are processed to alkyl sulphates: sulphonic acids, oleum, chlorosulphonic acid, gaseous sulphur trioxide and others are used as sulphonating agents. From 80 to 96 per cent of the alcohols is converted, depending upon the sulphonating agent used. Secondary alcohols and all alcohols from other saponifiables are most readily converted into surface-active agents by treatment with maleic anhydride to form the monoester, and the monoesters are then treated with salts of sulphuric acid. This gives alkyl sulphosuccinates, the degree of conversion being 90 to 94 per cent. On the basis of the above-mentioned surface-active agents, formulations have been worked out for the manufacture of liquid, paste and powder synthetic detergents for domestic and industrial use.

Factors affecting the production of basic petrochemicals and intermediates in developing countries

158. Factors affecting the production of basic petrochemicals and intermediates in developing countries include:

(a) The availability of raw materials, such as naphtha from a refinery or natural gas.

(b) The market and price for the range of petrochemicals it is proposed to make. It is of little use to put up a steam cracker based on naphtha if there is a good market for ethylene but not for propylene. On the other hand, if ample supplies of ethane and propane are available, such as from natural gas or even from the distillation of crude petroleum, cracking under these market conditions may be worth considering, owing to the much higher proportion of ethylene produced.

(c) The possibility of export at remunerative prices, if the home demand is insufficient.

(d) The willingness of the Government to give protection through tariffs or restrictions on imports in suitable cases.

(e) The availability of a suitable site, for example, one near a refinery or with harbour facilities and with adequate process water, power supplies and means of disposing of effluents cheaply.

(f) The availability of either skilled labour or labour capable of being trained easily.

(g) The possibility of obtaining the necessary capital, including foreign exchange, either through local participation, with or without government support, or through foreign participation, e.g. in a joint venture. In the latter case, the foreign participant may assist in (b), (c) and (e).

(h) The availability of a technical process and know-how in the desired field at a reasonable charge.

(i) The possibility of making an intermediate product from imported raw material, for example, diphenylolpropane from phenol and acetone. Considerable savings in foreign exchange will result if the intermediate product is produced locally rather than imported.

Assessing petrochemical processes

159. Work has been actively progressing on better methods of evaluating petrochemical processes. Conventional evaluation standards such as payout time do not take into account the full life of the project. Better results are obtained by a method that sets out the capital used against the net income anticipated over the life of the project. Neither of these methods, however, takes into account the time value of money. Money due to be paid or received in ten years time is worth less now, owing to the interest that could be earned over the intervening period. This is taken into account by the discounted cash flow method in which the value of receipts and payout over the lifetime of a project are discounted back to zero year. By trial and error, the discounted rate is found that enables receipts and payouts just to balance over the extended life of the project. The higher the discounted rate or earning power of the process, the more advantageous it will be. The idea can be readily understood if it is realized that money received in the first five years of a ten-year project is worth more than the same money received during the last five years.

160. When co-operation among several plants in the same or different countries is being considered, it is useful to have a tool by which the most economical way of transferring raw materials, intermediates etc. from one plant to another, taking into account such factors as excess production, the means of transport available and the market in various areas, can be assessed. A mathematical model has been demonstrated that enables problems of this type to be solved.

Discussion

161. The advisability of acetylene production was discussed, and it was suggested that the submerged-flame process might be used for making both

ethylene and acetylene as a base raw material for companies with access to crude oil but little or no refinery capacity. The sulphur content might prove to be a problem as the limit on the crude is 0.4 per cent. The plasma process for producing acetylene was considered, but it was pointed out that this process is only at the pilot-plant stage. The HTP process, when operated to give maximum C_2 output, gives a ratio of acetylene to ethylene of 40:60. These high-temperature processes are not greatly affected by the exact specification of the crude oil. The use of tubular furnaces for ethylene crackers was discussed, and it was explained that raw materials in the range of ethane to gas oil can be used.

162. With respect to the production of aromatics, it was explained that the disproportionation of toluene is normally carried out in the vapour phase over a fluid-bed catalyst. On the subject of fatty acid production, it was explained that fatty acids are produced from either hard paraffins with a melting point above 50°C or soft paraffins separated by the urea process from a gas oil fraction. Development is in hand for the production of higher alcohols.

CHAPTER 3

PLASTICS

163. The rapid growth of the plastics industries during recent years has had a tremendous impact on the industrialization of many developing countries. Indeed, the horizon for growth is unlimited for both industrialized and developing countries, and there is great scope for the production of plastics raw materials. At present, the average annual consumption of these materials in developing countries is only from 0.2 to 1 kg per capita, since most of the plastics products consumed are imported in semi-finished or finished form. This means that the development of some of the major plastics such as polyethylene, polyvinyl chloride and polystyrene in developing countries must be considered very seriously. Current developments in technology, the areas of constraint and the trend of product application must therefore be studied carefully. On the other hand, the production of monomers is a field that developing countries should approach with some caution.

Advances in the technology of the production of monomers and polymers

164. The manufacture of monomers requires modern sophisticated technology. Production units must normally be large in order to be economic; only rarely can a small plant justify itself. Difficulties occur if an expensive raw material is used, as the production of vinyl chloride has well demonstrated. The use of calcium carbide as a raw material - the preferred method until a decade or so ago - has proved to be much too expensive. Raw materials derived from petrochemicals such as methane, ethylene or acetylene have become gradually less expensive, and vinyl chloride is now normally made either from acetylene or ethylene of petrochemical origin. The production of vinyl chloride by the ethylene route in particular is now predominant, and, with the development of the oxychlorination process, utilization of by-product hydrogen chloride can be fully realized. There are, however, alternative methods of using ethylene.

It can be chlorinated by replacement, producing vinyl chloride without a cracking stage, while the hydrogen chloride produced by this or other processes can be oxidized separately by a modern version of Deacon's process.

165. Many factors, less often discussed, such as licences and technical know-how, can increase costs. Developing countries have found that engineering design and maintenance can be very expensive. Some countries are trying to establish their own engineering groups.

166. Technology in the polymer field is changing rapidly. High-density polyethylene has gone through several stages: solution polymerization, solution/suspension mixtures, and suspension systems only (for blow moulding and, recently, blow-injection moulding). Gas-phase polymerization appears to be cheaper and has already been commercialized for producing polypropylene. In the manufacture of low-density polyethylene, the advantages of tube reactors over autoclaves are still being debated. Although autoclaves have a higher conversion factor, tube reactors give better heat-transfer efficiency, permit higher pressures to be used and, owing to the absence of moving parts, simplify maintenance. Radiation techniques can be used to cross-link polyethylene articles normally after extrusion, thus preventing stress cracking. Developments are in progress that may eventually lead to the polymerization of ethylene by radiation techniques. This should substantially reduce the capital costs of plants.

167. A novel technique is being developed for the bulk polymerization of vinyl chloride. Polymerization is generally carried out at 40° to $70^{\circ}C$, starting at 5 to 12 kg/cm^2. Powerful agitation is needed, and plant construction is rather critical. In comparison with polymers made by the conventional methods, bulk PVC possesses a higher viscosity and its absorption rate for plasticizers is thus greater. It also requires a shorter period of gelation during processing. It is more transparent, the "fish-eye" problem having been solved. Research is continually in process to make PVC more competitive.

168. Although polystyrene is well established in many developing countries, in many cases this polymer must be produced from imported monomer. Before a new project is undertaken, the delivered cost of monomer and the possibility of correlating production of polystyrene with the production of styrene butadiene synthetic rubber must be very carefully ascertained. The necessary technology and know-how for the production of general-purpose grades has very often been self-developed. Production of more specialized impact and

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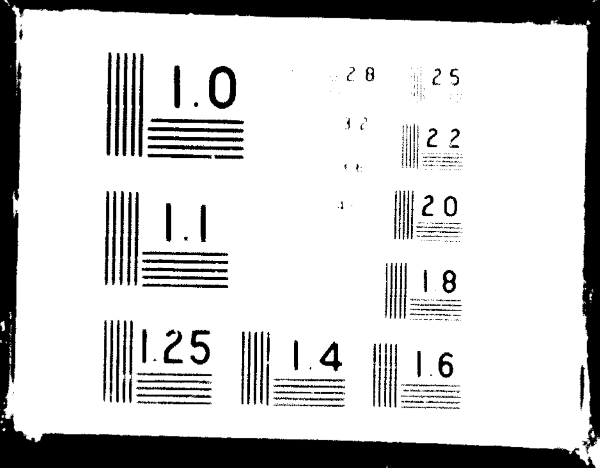

high-heat-resistant types is more difficult. Thus, one of the problems for the developing country is to decide the number of grades required to cover the market. Flexible multipurpose equipment has been designed that permits the range of grades to be obtained.

169. New polymers are constantly being developed, and a wide range of ion-exchange resins is now available. These resins can be used for desalinating water, but they also have newer applications, such as the desilication of water that has already been de-ionized, amine exchange and extraction of uranium from solutions after leaching out the poorer ores. Many of the earlier types were based on sulphonic acids of polystyrene containing divinylbenzene as a cross-linking agent, but in more recent years many new types have been developed based on methylacrylic acid, melamine formaldehyde, polyethylene-polyamine, and even special phenol formaldehyde resins.

170. New polyolefins are being developed. Polymethyl pentene-1 is already made on a commercial scale. It has a very low density and good transparency, heat-resistance and electrical properties. Polybutene-1 also shows great promise but is still under development.

171. Polymers with a high heat resistance are being developed, but these usually need specialized processing equipment. Polyimide made from pyromellitic dianhydride and an aromatic diamine is a typical example. Polyphenylene oxide has good heat resistance and electrical properties and, combined with polystyrene, is becoming a commercial plastic material. Most of these incorporate techniques too sophisticated to be of immediate interest to developing countries, but it is important that progress in this field be noted.

172. Water-soluble polymers such as polyacrylamides, polyethyleneimine and polyethylene oxide are another recent commercial development. They are used in water treatment, in mining and in petroleum recovery. Injection-mouldable saturated polyesters (glass-filled) exhibit excellent properties as engineering plastics and should be of interest to developing countries that have the appropriate raw materials.

173. The plastics-processing industries have also undergone revolutionary changes. The trend is towards automation in machine operations in order to increase production speed, to maintain product uniformity and to reduce rejects. Parallel with this progress, the use of control or sensing devices for monitoring the quality of products is also gaining popularity. In one instance, installation of thickness gauges in calenders has saved millions of

dollars annually because of the improvement in efficiency and reduction of off-quality products. The designs of injection-moulding machines, blow-moulding machinery or vacuum-forming equipment and the like have been tailored to the physical properties of the polymer to be processed. This development has added to the difficulty in selecting the right equipment for production, but as long as the quality of finished products is decisive in market competition, the correct selection will be critical.

Typical applications of plastics products of special interest to developing countries

174. Application of plastics in agriculture is certainly of interest to developing countries whose economies are based on agriculture. Such application will increase agricultural production and will also provide a ready market for plastics. Thus, the efficiency of irrigation can be improved or the nature of soils modified. For instance, the ploughing of closed-cell polystyrene foam into the soil makes it more permeable to water. Plastic sheets are used in a variety of ways to protect the growth of crops. Difficulties in irrigating sandy soils have been overcome by placing plastic materials underneath the top soil.

175. The ever-increasing use of polyethylene or PVC sheets in the packaging of agricultural products and fertilizers has changed the picture of hard-fibre consumption. Plastic containers give better performance during storage. Sacks for fertilizers to be used in humid climates are probably best made of PVC, but polyethylene linings containing carbon black are also effective. Cross-linked polyethylene films are used for wrapping. Silos for grain storage can be constructed from reinforced polyester resins.

176. Plastics have made important contributions in the field of construction materials. Urea-formaldehyde resins and, to a lesser extent, phenol formaldehyde resins are indispensable to the plywood and chipboard industries. PVC and fibre-reinforced unsaturated polyesters (FRP) are the common plastics used for corrugated sheets and panel products. Wood-plastic composites have been gaining in the market for parquet flooring. Polyethylene, PVC and FRP are economic materials for tubes and piping, and many different plastics are used extensively as electrical insulating materials.

177. Furniture made from injection-moulded polystyrene, cast polyurethane or FRP laminates will play an important role in the future. Polyethylene foams have just begun to gain ground in the manufacture of toys and household

appliances and will compete with polystyrene foams as insulating material in refrigeration. Paints and surface coatings based on alkyds, acrylics, unsaturated polyesters and epoxies are durable and weather-resistant. Special formulations can meet the demand for service under severely corrosive or high-temperature conditions. Coated polystyrene film has been developed for printing purposes.

178. Because of their strength, durability and light weight, plastics have many uses in the transport sector. FRP is being used in the construction of vehicles for road, rail, sea and air transport. The building of small boats is a major application in this field. Many polymers have been used in molten form to produce fibres and webs, following the spun-bonding process. Such webs have found application as wallpaper or as disposable linen for hospitals.

Factors affecting the development of the plastics industry

179. In planning for their plastics industries, developing countries should consider carefully the size and nature of local and export demand, availability of raw materials and comparative conversion processes. Efforts should also be made to produce finished products at a premium price to replace imported consumer goods. The establishment of plastics industries can be linked with the improvement of living standards; the production of plastics for household appliances, food packaging, construction materials and use in agriculture can be vitally important for both the national economy and export promotion. It is necessary to emphasize that only balanced production and market planning will justify the huge investment required for establishing the petrochemical and polymer industries.

180. Extrusion moulding, injection moulding and blow moulding are the predominant processing techniques for making finished articles. Many developing countries have successfully designed their own equipment in order to save foreign exchange and capital investment; but, owing to the lack of precision or experience in mould-making industries, as well as to inadequate quality control, the finished products have been unable to compete on the international market, and high rates of rejection and waste have resulted in non-economic operation. It is thus important to improve mould-making practice and to increase the flexibility of processing facilities in developing countries.

181. Many problems that could impede the growth of plastics industries in developing countries arise from social and economic conditions in these countries. Although it is impossible to suggest a generally acceptable solution for all cases, the pooling of limited manpower and material resources within a given country or region may be one way of solving a number of problems. A useful proposal is to start with plastics that can be processed by simple and easily adaptable techniques in a country or region where market and technical facilities are favourable. Gradual build-up by backward integration, that is, from polymer processing to polymer and monomer manufacturing, can be considered as the local plastics industry grows.

Suggestions for future development

182. The following suggestions for future development have been made:

(a) The establishment of polymerization control techniques to be used in developing countries;

(b) Programmes for economic batch cycling for efficient utilization of polymerization equipment;

(c) Dissemination of information on handling and transport of monomers in bulk or in tankers;

(d) Systematic studies of formulation problems in developing countries;

(e) Promotion of high-strength plastic films for use in food packaging and agriculture;

(f) Modification of polymers by grafting and cross-linking;

(g) Research in the use of plastics and composite materials for prefabricated housing and furniture;

(h) Cost reduction in the production of plastic foams;

(i) Studies of polymer flow characteristics during the moulding process and evaluation of stresses in finished articles.

Discussion

183. The subject of the economic plant size was of considerable interest to most participants in the Symposium. While it is well known that the capital costs and production costs per unit of product decrease as production volume increases, simple comparisons can be very misleading. If the time factor is fully taken into account, including not only the time required for construction but also the time needed to get the plant into operation approaching full capacity, the real advantage of very large plants is not so great as might appear from the first, simple calculation. It therefore appears that there

is a case for re-examining the economics of small and medium-sized plastics plants. Many participants raised the question of export as a means of disposing of surplus production. It is obvious that not every country can export its surplus production; there must be markets in a substantial number of non-producing countries, and very careful investigation is necessary before any plant is erected that would require a significant amount of its production to be exported. In any case it is necessary to take into account world prices for the product. A joint venture with a manufacturer in a developed country may be worth while, particularly if the manufacturer already has access to markets in a number of countries. The possibility of developing a plastics industry sheltered by a high tariff wall was considered. It was realized that such a policy would lead to high prices on the domestic market and very few opportunities for export.

184. As has been noted elsewhere in this report, the plastics industry lends itself to regional arrangements among neighbouring developing countries, with one plant serving the domestic needs of three or four countries. There is also a strong desire to acquire know-how in engineering design and equipment fabrication from industrialized countries. Since many participants expressed a wish for training for operatives, it was suggested that UNIDO could be of assistance in this area.

CHAPTER 4

SYNTHETIC FIBRES

Recent developments

185. World production of synthetic fibres has increased sharply since 1964. At that time, the share of true synthetics was 9.5 per cent by weight of the total fibre market, but by 1967 it had risen to 16 per cent and at present it is closer to 20 per cent. In actual covering power, the usefulness of synthetics is even higher because of their lighter weight. Between 1964 and 1967, the growth rate was about 20 per cent per year, similar to previous growth rates; actual production was 2.96 million tons in 1967. Since then, the growth rate has been over 30 per cent. However, 80 per cent of the total world production in 1967 was in Western Europe, the United States and Japan.

186. In developing countries, the growth rate of demand in fourteen countries for which data are available for 1963 and 1967 shows wide variations, from as little as 2.2 per cent to as high as 65 per cent per year. In many cases, however, the lower rate has been attributed to ambiguity in definition of synthetic fibre consumption, but actual demand growth in developing countries has been high. In some developing countries, the demand has reached levels of 3 kg per capita, which corresponds to European consumption, although, in general, consumption in developing countries is substantially lower.

187. While a number of developing countries now produce synthetic fibres, imports still account for 60 per cent of consumption in these countries. Although polyamides still occupy first place in world production of synthetic fibres and their production has grown in absolute terms, their share dropped from 53 per cent in 1964 to 43 per cent in 1968. The share of polyester fibres in world production, on the other hand, has grown from 20 per cent to 29 per cent, while that of acrylics and other synthetic fibres has remained stationary at 18 to 19 per cent and 9 per cent, respectively. It is probable that the share of the polyesters will rise still further in future. The

structure of fibre use in developing countries is, however, difficult to estimate and is often based upon local factors, such as the historical development of the market and import restrictions.

188. The size of synthetic fibre plants, as differentiated from monomer plants, is not great when compared with other branches of the petrochemical industry. Thus in 1968, the average size in the United States was 1[illegible],500 tons/year; in Japan, 8,[illegible] tons/year; in Western Europe, 7,[illegible]00 tons/year; and in Eastern Europe, 4,000 tons/year. In developing countries, plants are smaller, averaging about 1,000 tons/year. The increase in size of the average plant has been only about 20 per cent since 1965 even in developed countries. Monomer plants, on the other hand, have grown substantially larger, with the result that only a few developing countries, e.g. Colombia, India and Mexico, have plants under construction, although projects are being planned in other developing countries.

<u>Production of monomers of special interest to developing countries</u>

189. The main monomers of interest to developing countries are caprolactam (for nylon-6), acrylonitrile (for acrylic fibres) and dimethyl terephthalate/terephthalic acid (DMT/TPA) and ethylene glycol (for polyester fibres). World production of caprolactam, acrylonitrile and DMT is all concentrated in the developed countries, with the exception of 17,000 tons/year of caprolactam. In the production of caprolactam, the main raw materials continue to be cyclohexane and phenol, although a process has been developed in Italy that uses toluene. Although cyclohexane is now replacing phenol, with the changing position of the availability of hydrogen in refineries, phenol may regain its position.

190. The processes used in 1964, with a few exceptions, produced as a by-product 4 to 5 tons of ammonium sulphate per ton of caprolactam. With increasing difficulties in selling ammonium sulphate, several processes have been developed that sharply reduce ammonium sulphate production (to around 2 tons per ton of caprolactam) or replace it with nitrophosphates and, in some cases, eliminate the production of by-product fertilizers altogether. One of the processes that has been developed substantially since 1964 is the photonitrosation of cyclohexane (PNC process) developed in Japan, the details of which were given to the Symposium. The advantage of the process is that it produces cyclohexanone oxime from cyclohexane in a single step. It produces only half as much ammonium sulphate as conventional processes.

191. In the production of acrylonitrile, propylene has almost totally replaced acetylene. Since 1964, a process using acetaldehyde has been developed in the Federal Republic of Germany, but it has not been used widely at present, and propylene is likely to be the preferred raw material for many years. The use of the propylene route involves the production of acetonitrile and hydrocyanic acid as by-products, but substantial efforts are being made to minimize the production of these by-products.

192. In the production of monomers for polyesters (such as DMT and TPA), three main processes, the Witten, Mid-Century and Henkel processes, can be used, but the preferred process is the Witten process. The development of high-purity terephthalic acid has resulted in the introduction of newer processes based upon this material.

193. Among monomers for other fibres may be mentioned the raw materials for vinylon fibres, which are obtained from vinyl acetate and methanol. The former is still produced substantially from acetylene, although ethylene is now being widely and increasingly used. Among other monomers are propylene and vinyl chloride; these are produced in the same manner as for plastics, except for more rigid specifications.

Production of fibres of special interest to developing countries

194. Developing countries continue to be interested mainly in nylon, polyester and acrylic fibres, although there has been some increase in the production of PVC, polypropylene and vinylon fibres. There is also a growing interest in more specialised fibres such as fibres that more closely resemble silk. The production of nylon-6 and nylon-66 is based on well-established techniques. While other nylons are being produced in the developed countries, these are not currently of interest to developing countries. The development in the USSR of a continuous process for the direct spinning of nylon-6 was reported to the Symposium. This process, which applies vacuum demonomerization to bypass more complicated steps, produces high-quality industrial yarns. A plant with a capacity of 4.5 tons/day is in operation in the USSR, and it was claimed that investment costs for producing the polymer are about 50 per cent below those of conventional processes.

195. No special developments were reported in the techniques for producing polyester fibres, but the production of these fibres is rising sharply. Polyester staple is increasingly being blended with natural fibres, and greater

use is being made of polyester filament in industry (e.g. for tire cord). Polyester fibres continue to be manufactured by the ester interchange methods or by the direct esterification method, depending on whether DMT or TPA is used. In earlier processes, the production of polyester chips before spinning was usual, but new technical methods have been developed for the melt-spinning of the polymer without chips and this can be combined with continuous polymerization methods.

196. In the production of acrylic fibres, new solvents are being used. Among solvents in use are DMF, DMAA, DMSO, ethylene carbonate, inorganic salt solutions, such as zinc chloride. DMF and DMAA continue to be widely used, but the newer solvents are of importance.

197. The production of polyvinyl alcohol (vinylon) fibre, currently largely confined to Japan, is of some interest to other countries. Although it has many advantages, such as better moisture absorbency and excellent durability, it has some disadvantages, such as lower softening point under wet heat and rather poor elasticity. In Japan, vinylon is mainly used for industrial purposes (about [illegible] per cent). It is also widely used for utility clothing. A part of the market for vinylon has been replaced by other synthetic fibres, but vinylon is still making inroads into new areas such as paper-making, soluble fibres, and silklike fibres.

198. With the growth of the PVC plastics industry in developing countries, the production of PVC fibre, a low-cost fibre, is of interest. However, conventional PVC fibres have drawbacks that have restricted their field of application. Among these drawbacks are poor shrinkage and heat-resistance. A new development in Italy, details of which were given to the Symposium, is the manufacture of a new PVC fibre with substantially improved dimensional stability under heat, achieved by the introduction of a low-temperature polymerization technique, utilizing catalysts such as organic hydroperoxides, sulphurous anhydride and an alkali or alkaline earth alcoholate.

199. Since 1964, there has been a substantial development in the production of polypropylene fibres, although not so much as was at one time predicted. The most important use of these fibres is for floor coverings. Combining the factors of the wide availability of polypropylene resin, the simple conversion process from resin to fibre and low-cost pigment dyeing with the technical and economical aspects of the needle-punch process, the polypropylene needle-punch carpet now meets the requirements for low-cost floor coverings. In 1967,

about 70 million m^3 of floor coverings were made of polypropylene, corresponding to more than 13 per cent of the total carpet production in the United States and Europe. These figures suggest that there are good possibilities for future application in the developing countries.

200. In recent years, there has been substantial interest in the development of silklike fibres. These fibres have been developed mainly in the United States and in Japan. Recently, the relationships between the structure and the texture of silk fibres have been clarified. This knowledge, together with recent advances in fibre production and processing techniques, has allowed the production of more silklike fibres by physical and chemical modification of fibres already in use and by new polymers. Silklike nylon and polyester fibres are obtained by the modification of the cross-section into triangular or hexagonal shapes. Vinylon filament produced by a dry spinning process is silklike, and acrylic filament is also produced as a silklike fibre. Benzoate fibre, which is made from polyethylene oxybenzoate, is a new silklike fibre. Acrylonitrile-protein copolymer fibre is made by chemically bonding natural protein and acrylonitrile. The presence of natural protein makes it significantly different from other silklike fibres.

201. Nylon and polyester are the most popular of all synthetic fibres. Nylon, owing to its soft texture, is suitable for knitting, and polyester, because of its excellent blending properties, is replacing natural fibres. Recently, the use of fabrics made from textured polyester yarn has been increasing rapidly. Nylon has many industrial uses, but polyester has come to be preferred in spite of its higher price.

202. Although the production of textiles or other materials from synthetic fibres cannot strictly be considered a part of the petrochemical industry, the use of radically new techniques, such as web formation, is of interest to the industry. With the appearance of the new synthetic high polymers and fusible polymers, e.g. polyolefins, polyesters, and polyamides, modern processes of web formation have been invented. The possible application in developing countries of one of these, the spun-bonding process, was discussed. The direct web-spinning process has a promising future in view of its economic advantages.

Suggestions for the establishment of a synthetic fibre industry

203. The establishment of a synthetic fibre industry in a developing country presents certain basic problems that are somewhat different from those presented by other petrochemical industries. A synthetic fibre industry is often dependent upon the growth of the textile industry and its ability to absorb new fibres requiring new operations. The first essential step, therefore, is not only to survey existing textile-processing plants, but also to provide the investment required for modifying them. Often the investment does not have to be large; for instance, the conversion of a 5,000-spindle cotton-spinning unit to the use of polyester-cotton blends requires less than $100,000, but the necessary foreign exchange and other facilities must be provided. Blends of natural and synthetic fibres are of special interest to developing countries.

204. The next step is the manufacture of the fibres themselves. Developing countries should concentrate first on the conventional synthetic fibres (nylon and polyester) and, in colder climates, acrylics. The development of more exotic fibres must wait until a market for these fibres exists. Synthetic fibre plants can be established that use imported chips or, where foreign exchange problems exist, imported monomers, and can be of relatively small size. However, the production of a good grade of fibre based on the use of established processes is important. The textile industry judges fibres by their quality, and the production of poor-quality synthetics would retard the growth of the industry.

205. In integrating the fibre industry back to petrochemicals, the final step is the production of monomers. Monomer plants are rather large, and the production of monomers is possible only where a substantial growth of the industry has taken place. Thus DMT plants with a capacity of less than 25,000 tons/year and usually not less than 50,000 tons/year are seldom economic. One method of overcoming this difficulty is to set up monomer facilities serving more than one country, such as those being planned between Iran and Pakistan and between other countries of the ECAFE region.

Discussion

206. The Symposium discussed whether developing countries should commence fibre production based upon imported monomers or produce both the monomer and the fibre. Based on the experience of some developing countries, such

as India, it was felt that the import of monomers in the first instance would be advantageous, since this would permit substantial savings in foreign exchange to be made and markets need to be created.

207. The size of polymer plants was discussed. It was pointed out that the cost of producing nylon, for instance, is about [illegible] to [illegible] per cent higher in a unit with a capacity of 1,000 tons/year than in a unit three times as large. Since synthetic fibres can be sold at premium prices in most developing countries, it was felt that a beginning could be made even with plants of small capacities, such as 1,000 tons/year for nylon and [illegible],000 tons/year for polyester. Interest was shown in the possible integration of facilities for producing silklike fabrics at relatively low capacities with existing small polyester and nylon plants. It was noted that this is feasible with a relatively low capital investment.

208. Competition between fibres was discussed, and it was felt that, while nylon will continue to be important in the filament field, polyester will be increasingly important in the field of blends with natural fibres and will win a greater share of the market. With regard to tire cord, where polyester is now making some inroads, it was felt that, in general, nylon will continue to be preferred for heavy-duty tires.

209. There was much discussion of the production of polyvinyl alcohol (vinylon) fibre. The suitability of vinylon as a substitute for long-staple cotton was discussed. However, vinylon is not spun commercially beyond 60 counts, and experiments in India showed that, when mixed with medium-staple cottons, it is not spinnable beyond 50 counts. Consequently, only industry will continue to use it as a substitute for cotton, although competition from nylon and polyester will limit its use in certain fields, such as production of tire cords.

210. The likelihood that new fibres will be introduced that might compete with the principal existing synthetic fibres was discussed. It was felt that current fibres meet most of the demand, and their prices are falling; thus new fibres would have difficulties in breaking into the field. However, there is a market for silklike fibres, and their production will grow. While the prices of some of these, such as benzoate fibres, are high at present, costs are likely to come down as production increases. With regard to the competition of synthetic fibres with rayon, it was felt that nylon and

polyester are making substantial inroads upon rayon filament, particularly in the industrial field. However, polynosic rayon staple is holding its own in the cotton blend market.

211. Keen discussion took place on other papers presented to the Symposium, in particular the paper on the [illegible] process for caprolactam because the details of this process were revealed for the first time in public at the Symposium.

CHAPTER 5

SYNTHETIC RUBBERS

Recent developments

212. Major developments have occurred in all aspects of the rubber industry, that is, in the production, processing and use of both natural and synthetic rubbers. The ratio of synthetic to natural rubber has continued to increase, and in both the United States and the USSR approximately 80 per cent of all rubber used is synthetic. The growth rate for total world rubber consumption is approximately 4.6 per cent per year, with synthetic rubber growing at 5.7 per cent and natural rubber at 2.4 per cent. In developing countries the growth of rubber consumption is considerably greater: in India, for example, the growth rate is between two and three times the world average. In many developing countries the markets are largely unsaturated, and growth is determined by availability of raw materials, processing equipment and management and operating staff.

213. In recent years many changes in technology have resulted from the need to improve efficiency and reduce costs in both production and fabrication of rubbers, and automation has frequently led to increased productivity. This has created a need for high-quality raw materials with a high level of consistency, as demonstrated by the quality (in consistency and processability) of modern styrene-butadiene rubbers (SBR) and also by the steps taken by the natural rubber producers to improve quality. Continuous mixing has been introduced by one company, and tire companies have reached a high degree of automation in tire building. In the production of mechanical goods, injection moulding and continuous vulcanization are being widely adopted.

214. In tire manufacture, the level of rubber in a passenger tire has decreased through the increased use of both oil-extended SBR and <u>cis</u>-polybutadiene. This combination of rubbers permits higher loadings of carbon black and oil in tread compounds, particularly with the intermediate structure furnace blacks. In truck tires, the most significant development is the use

of the dual tread. The portion of the tread in contact with the road is formulated to be resistant to abrasion and chunking, with the under tread being highly resilient in order to minimize heat build-up. This development, which replaces a single tread of highly resilient rubbers, permits the use of a substantially higher level of synthetic rubber, including SBR, in truck-tire treads. (The average composition of the total tread using the dual tread is natural rubber (70 per cent), cis-polybutadiene (15 per cent) and SBR (15 per cent), compared with natural rubber (75 per cent), cis-polybutadiene (25 per cent) for single-tread construction).

215. Specialized new polymers have been developed, including rubbers with greater resistance to extreme conditions such as high temperatures, exposure to special lubricants. These include polyacrylates, silicone and fluorinated polymers. A new family of rubbery polymers, called thermoplastic rubbers, has been introduced. These products can be processed like thermoplastics and yet behave like rubber on cooling. Thus far their use has been limited to applications where temperatures do not rise above 60° to 65°C, but further improvements are possible.

216. Another major trend during recent years has been the blending of rubbers and plastics to achieve special properties. Some examples are the use of cis-polybutadiene with styrene to give high-impact polystyrene and the blending of nitrile rubbers with PVC to achieve impact resistance; the nitrile rubbers act as a non-migratory plasticizer in the PVC. There have been many developments in the field of synthetic latices, and many new types and applications have arisen. This stems from the fact that the application of latices involves liquid handling equipment instead of the heavy high-shear equipment used in rubber and plastics processing. Latex technology is therefore one of the major ways in which the rubber industry is simplifying its operations. New latices, particularly carboxylated types of SBR and nitrile rubber, and new methods (pressure agglomeration) for the manufacture of high-solids latices have been introduced in recent years.

Selected technologies (polymer production) of special interest to developing countries

217. Many factors are important in the selection of technologies for the production of synthetic rubber in developing countries. These factors include the ability of the process to produce a range of rubbers that will permit a reduction in imports of specialty rubbers; the availability of

local raw materials, including catalysts and other chemicals; the ability of the process to use locally manufactured components and spare parts; the reliability of the process; the vulnerability of the process to variations in monomer purity; and the specific nature and size of the market to be served. The technologies that require consideration for basic plants are those for the production of: *cis*-polyisoprene; *cis*-polybutadiene; olefin polymer; solution SBR/low *cis*-polybutadiene; emulsion SBR/butadiene rubber (BR) latex and nitrile. Other technologies, to produce ethylene propylene *ter*-polymers, butyl rubber and polychloroprene, which has specialized uses, should be considered only as the industry develops.

218. *Cis*-polyisoprene has been widely considered as a means of providing highly resilient rubber for large tires, particularly in areas where there is a desire to become independent of natural rubber. *Cis*-polyisoprene also offers a technical advantage to the user, in that its viscosity has, up to now, been more tightly controlled than the natural product and has minimized the premastication time required in processing natural rubber. However, *cis*-polyisoprene is not without its disadvantages. For example, its green strength and tack are low, which makes the fabrication of tires more difficult.

219. The most important aspect of *cis*-polyisoprene production in most areas of the world is monomer cost and availability. All currently known processes result in an isoprene monomer that is considerably more expensive than butadiene. Further developments must be expected, but it seems likely that until new processes are developed and applied on a very large scale, isoprene will be an expensive monomer, and polyisoprene an expensive polymer relative to SBR and polybutadiene. Owing to new techniques for producing natural rubber that have lowered production costs and are suitable for use in Malaysia, Indonesia, India, West Africa and other developing areas, the desirability of using technological resources to replace a product that can be produced from natural resources must be questioned.

220. The position of *cis*-polybutadiene differs from that of polyisoprene in that the monomer will be available from steam crackers. *Cis*-polybutadiene consumption has grown very rapidly during the last five years because polybutadiene improves the abrasion resistance of passenger, truck and bus tires in blends with SBR and natural rubber. It has also virtually eliminated the groove-cracking problem that was encountered in North American passenger tires.

221. A major problem with polybutadiene continues to be the tendency of tires, especially large ones for buses, trucks etc., to chip and chunk. This tendency has resulted in very low use of polybutadiene in service requiring a proportion of "off-the-road" driving or of driving on poor roads. Cis-polybutadiene can be used to best advantage for tires for trucks and buses employed continuously in highway driving and for North American passenger car tires. Because the wet traction (skid resistance) of tires decreases with increasing cis-polybutadiene content, it is unlikely that use of cis-polybutadiene will increase beyond the level in North America. In Europe, where roads are frequently wet and traffic density is high, polybutadiene is used even less than in North America, owing to the emphasis on road safety.

222. Cis-polybutadiene and other polybutadienes are being used in increasing amounts as components of carcass compounds in both truck and bus tires. They have better dynamic properties and aging characteristics than natural rubber compounds. BR is also frequently used in carcass compounds to reduce the tendency of natural rubber compounds to soften with extended use at high temperatures. Until the present, very little polybutadiene has been used outside the tire segment of the rubber industry. Its only other major use is as an impact modifier for certain grades of high-impact polystyrene.

223. Several processes are available for the manufacture of cis-polybutadiene, covering a range of cis-content and with some differences in properties. High cis-polybutadiene based on the cobalt process has been found to provide the best processing properties and, in particular, to give least "bagging" when its compounds are milled. This consideration is particularly important in areas where the installed equipment was designed around natural rubber, i.e. with high friction ratio mills. The titanium-catalyzed polybutadiene is superior to the lithium-catalyzed polymer, but is inferior to cobalt-catalyzed in processing behaviour.

224. Recently, a strong trend to the use of oil-extended polybutadiene has taken place, as through this route maximum advantage can be taken of high levels of oil and black to reduce compound costs without sacrifice of properties. Owing to the relationship between solution viscosity and molecular weight found with the cobalt system, it is found more economical to produce oil-extended BR in the cobalt system than in the titanium system. It is also possible to vary properties of polybutadiene in the cobalt system through changes in reaction conditions and thereby produce polymers that act like

titanium polymers where this is required. In this way, the cobalt system becomes extremely useful in producing polybutadiene for a range of end uses.

225. To determine the desirability of building a polybutadiene plant, it is necessary to assess road conditions and the nature of road transportation systems in a developing country. As a region develops, a _cis_-polybutadiene plant will be required, but a more versatile plant is usually required at first.

226. Although the Alfin process might be considered as a potential route to additional rubber for developing countries, it must be recognized that it has yet to prove itself on a commercial scale, and the rubbers available from this process have not been adopted and used by any of the major rubber companies. In time, however, this process may become important.

227. Since the growth of a developing country's rubber consumption depends on all segments of industry - rubber is needed for bicycle components, footwear, belting, hose and automotive products etc. - a combination process of the solution or emulsion SBR/BR type must also be given serious consideration. The solution type of SBR/BR plant is versatile in that it is able to produce random-type SBR for the tire industry, block-type SBR for footwear and polybutadiene for tires. Experience with these random SBRs shows that they have good dynamic properties and that their abrasion resistance is equal to that of conventional SBR. Difficulty in processing has been a serious disadvantage to date; although the process can be modified to make easier-mixing polymers, these modified products show low green strength and building tack, which makes the building of tires more difficult, particularly when high standards of quality and uniformity are required. The block-type SBRs produced for application in moulded products such as footwear show good moulding behaviour, but, because they have low green strength, considerable difficulties are encountered in mill mixing, and production rates are adversely affected. Thus, the solution SBRs have interesting and useful properties, but they are not interchangeable with conventional SBR without the use of special compounding and processing technology.

228. Polybutadiene produced in this combined solution SBR/BR system is similar to the lithium type of polybutadiene and has relatively low _cis_ content. North American experience with this type of product shows that it can be widely used wherever the high _cis_ types are used; but because of the lower _cis_ content, its dynamic properties are slightly poorer, and its mixing

and extrusion in blends with both natural rubber or with SBR are also slightly reduced and result in slower throughput because of slower mixing and because tread extrusions run hot, occasionally causing scorching.

29. From the standpoint of the manufacturing process, the combined solution SBR/BR process permits considerable flexibility. However, the changes from polybutadiene to SBR require a short period of shutdown (up to a few days, depending on the equipment installed) between types. The process is also capable of using dilute streams of butadiene, provided appropriate recycle facilities do not result in concentration of impurities in the diluents. It is also important to recognize that this process uses organometallic catalysts. Consequently, although dilute butadiene has been used, the butadiene must be free from polar impurities, including moisture. Ideally, as with all the organometallic systems, including the Ziegler-Natta catalysts used to produce the high cis-polybutadienes, the best control of the process is achieved with raw materials of high and consistent purity. The process is therefore sensitive to upsets, for example, in the cracking operations providing the monomers.

30. The alternative combination process, which is the conventional emulsion process for producing SBR, as well as emulsion polybutadiene, is also extremely versatile. The system is capable of producing a wide range of unextended and oil-extended polymers that are well known in industry and for which the process and application technologies are well defined. More recently, further research has yielded SBR with a superior combination of processing dynamic and conventional physical properties, coupled with an unusually high degree of product uniformity. These improvements have resulted in reduced mixing cycles and improved extrusion rates, which have permitted an increase in the effective capacity of tire factories without additional equipment. The greater uniformity of raw material has also contributed to increasing productivity in tire building through the reduction of reject rates. Because of these changes in SBR product quality and the recent changes in the design of truck tires (where a combination tread is used, for example, an abrasion-resistant wearing surface based on SBR/neoprene rubber (NR) or SBR/BR/NR over a highly resilient under tread based on NR or BR/NR) the use of SBR is increasing substantially in North America. These factors will also be relevant in developing countries, provided that the equipment for producing the dual tread is installed.

231. The emulsion system also permits the production of polybutadiene. This polymer has an even lower *cis* content than the lithium-catalyzed product produced along with solution SBR. It can be processed easily and contributes some improvement in the abrasion resistance of blends with both natural rubber and SBR. This improvement in abrasion resistance, however, is not so great as with the high *cis*-polybutadiene or polybutadiene of the lithium type.

232. The emulsion system is the simplest of all synthetic rubber processes to operate and control efficiently, and it also permits the greatest variation in monomer purity. Because the polymerization medium is an aqueous emulsion, solvent recovery is eliminated (together with solvent losses), and continuous grade changes are in widespread use, thus ensuring minimum upsets to polymerization chain conditions. (In many plants, the continuous grade change is also very attractive from the economic viewpoint, as the non-standard material produced during a grade change can be segregated but still used as "off-specification" rubber for less critical applications.) An emulsion polybutadiene process becomes very attractive in combination with SBR because, during its manufacture, the "stripping" column, used for separating unreacted styrene, is not required. Since the column must be cleaned periodically, polybutadiene can be produced during these periods without curtailing the polymerization reactors and finishing systems. The capacity of the plant is thereby increased. A further advantage of this process is that, as the need arises for specialty products such as nitrile rubbers for oil-resistant applications or latices for tire cord and textile and paper coatings, the technology to produce such polymers can be acquired and used with minimum additional investment.

233. The potential to produce latices, which is provided by the emulsion system, also permits advantage to be taken of the recently developed technology for producing high-solids latex by pressure agglomeration. This technology permits entry into applications in moulded and spread foam in addition to the use of conventional latices in carpet and fabric backings, adhesives, tire cord dips etc.

234. It is obvious that no single rubber can be specified as the most suitable for production in a given country. The choice of rubber must be based on the local requirements of the market, with the country's plans for over-all economic development taken into consideration.

Selected techniques of special interest to developing countries for processing and fabricating synthetic rubbers

235. Developments in the processing and fabrication of rubber continue to provide increased operating efficiency through the introduction of new methods and the optimization of the older ones. The advantage of latex technology in making it possible to use simple equipment for fabricating rubber has already been noted; this trend is continuing.

236. In rubber mixing, high-speed/high-pressure Banbury mixers permit substantial reduction in mixing cycles, together with improvements in dispersion. This provides rubber vulcanizates of higher quality. A process based on the Banbury mixer is by its nature a batch process, but a very high degree of automation is now used in modern mixing rooms, with automatic weighing and filling equipment and automatic take-off facilities. One North American company has introduced continuous mixing (Intermix) in its latest tire plants and claims reduced capital and operating costs for this new process, which can be adapted to a range of mixing capacities.

237. Extruders have been developed further, and cold-feed extruders are now widely used. The dual tread for truck tires is a further example of extruder developments.

238. The use of injection moulding of rubber, although extensive, is in general confined to products that permit long production runs. In certain applications it offers benefits by reducing the costs for moulds, as fewer of them are required. Many different injection-moulding presses are now available commercially.

239. Continuous vulcanization of extruded sections is also being more widely used. The technology was developed by the Rubber and Plastics Research Association at Shawbury, United Kingdom, a research institute partly financed by industry.

240. A number of improvements have been made in tire retreading (e.g. the Orbitread process). Tire retreading is particularly important, as the most complex part of a tire is the carcass, and its reuse, through retreading, can be a highly economic means of increasing the effective production capacity of a developing country's tire industry.

Possible areas of application of synthetic rubbers of special interest to developing countries

241. The main areas of application for synthetic rubbers are well known; some examples are tires, conveyor and transmission belting, hose, rollers, including printing rollers, footwear, and chemical-plant linings. However, several new applications have been developed, and some of these are extremely important for countries wishing to acquire the latest technology as quickly as possible. Carpet manufacture provides an excellent example of a new application. Using carboxylated SBR latex to lock the tufts, a manufacturer can begin to produce tufted carpets without having to progress through woven-carpet technology.

242. The most interesting major areas of application are:

(a) Construction - rubber window seals, flashings, waterproofing membranes for foundations and roofing and adhesives. All of these applications are important for improving the efficiency of construction and for minimising building maintenance.

(b) Furnishings - upholstery (cushioning, curled hair or foam), mattresses, car seats, carpet backing (tufted carpets), carpet underlays (foam), furniture (high-impact polystyrene as a substitute for wood). The attractiveness of these applications depends on local conditions; for example, a country without timber may find high-impact polystyrene, which uses rubber to gain impact strength, very important. Countries with indigenous coarse fibres (coconut, animal hair) will probably prefer to use latex-impregnated curled hair for cushioning, whereas those without these fibres may prefer to use latex foam for this purpose.

(c) Agriculture - rubber membranes for grain silos, for irrigation ponds, ditches and dams; latex for soil stabilization (wind erosion).

(d) Plastics modification - polystyrene (regular and high impact) for furniture, packaging, PVC modification with nitrile rubbers, ABS manufacture and modification (nitrile rubbers).

Factors affecting the synthetic rubber industry in developing countries

243. The establishment of a synthetic rubber industry in developing countries is an extremely complex undertaking, and many factors must be considered. Since the synthetic rubber producers in the developed countries operate on a large scale and the markets in developing countries are small, no developing country can establish a synthetic rubber industry and operate it profitably without taking measures to protect it from competition. Such measures may be

justified if the establishment of the industry makes the best use of available resources from the standpoint of the over-all economic development of the country.

244. Since producers in developing countries lack the experience in meeting quality standards and in marketing for export that producers in developed countries have acquired, it is unlikely that a plant in a developing country will be able to export its products profitably. It must therefore depend on its domestic market. The size and rate of growth of this market is very closely linked to the over-all economic development of the country, as reflected in improved distribution of agricultural and mining products, the use of road-truck transport in addition to rail transport and the establishment of an automotive industry. Since the construction of as large a plant as possible is required, it is necessary to forecast the implications of economic development on the demand for rubber. It is not sufficient to extrapolate current growth rates of rubber consumption, since restriction of rubber imports may have been the factor determining the growth of industries consuming rubber. In many cases growth rates have been rapid as soon as products have become freely available from a domestic producer. In a similar way, the establishment of a domestic automobile producer or assembler creates opportunities for the domestic production of components and spare parts. This can provide an unforeseen increase in consumption.

245. In addition to the market, it is also necessary to consider the resources for successful promotion. These include the availability of:

(a) Modern technology to minimise delays in construction, start-up and market acceptance (and future improved technology);

(b) A strong equipment-producing industry coupled with local engineering staff to minimise foreign currency expenditures;

(c) Raw materials;

(d) Experienced or readily trainable manpower for management, supervision, operation and maintenance of the industry;

(e) Resources for training staff.

As assistance is likely to be required in ensuring the availability of some or all of the above resources, it is also important to consider factors affecting the licensing of technology and patents, government policies regarding joint ventures, local participation, repatriation of profits, protection of foreign investors in the event of nationalization, and the nature of protection to be provided to the industry.

Discussion

246. There was considerable discussion on isoprene monomer and _cis_-polyisoprene manufacture in the USSR. Isoprene monomer is produced in the USSR both by dehydrogenation of amylenes and from isobutylene and formaldehyde. The economic size of a plant based on isobutylene was given as 80,000 to 100,000 tons/year. The USSR has developed a technology for producing truck tires made entirely of synthetic rubber; the proportion of synthetic rubber used in all tires increased to 72.5 per cent by 1968. As an alternative to producing synthetic _cis_-polyisoprene, it was suggested that advanced techniques may make it possible to produce natural rubber more cheaply than synthetic rubber for many years.

247. With respect to specialty rubber production, it was stated that, since the volume of consumption is so small, it is not practical to produce highly specialized rubbers, such as the fluorinated rubbers, in developing countries. It might be desirable, however, to produce latices in order to save on the relatively high transport costs of these forms of rubber.

248. The importance to a developing country of obtaining technology and not just rights to use a patent was emphasized. It was also stressed that even when a basic patent expires, improvement patents are often still valid. Consequently, efforts must be made to obtain the latest technology (and patents) available; otherwise the producer in a developing country will find himself at a further disadvantage with respect to cost and quality.

249. The need to base synthetic rubber industries on versatile plants was emphasized.

250. It was suggested that, since the value of petrochemicals in a finished rubber product is low, it may be more advantageous for a developing country to devote its resources initially to building up a rubber-fabricating industry rather than a petrochemical industry. However, certain countries have import restrictions that make it extremely difficult to build up a manufacturing industry based on imported raw materials. It is therefore still desirable, in some areas, to build plants that may not be competitive in production costs relative to existing plants of large producers.

CHAPTER 6

GROWTH OF THE PETROCHEMICAL INDUSTRY DURING THE SECOND DEVELOPMENT DECADE

251. Attempts at projecting world demand for petrochemicals have been made by the United Nations regional economic commissions and by Karl H. Rönitz of Farbwerke Hoechst AG (for UNIDO). The results of these projections are presented in the following tables. The tables include estimates of projected consumption of petrochemicals for 1975 and 1980, divided into regions and into different groups of petrochemicals. More specifically, the Rönitz report (tables 1 and) deals with the developing countries of the world, divided into the developing countries of Africa, the Americas and Asia.

252. Data derived from the Rönitz report for the different regions of the world could be used as a basis for giving a rough estimate of world demand for petrochemicals in 1975 and 1980. However, the two sets of data given by Rönitz and by the regional economic commissions are, in most cases, neither comparable nor uniformly classified. For this reason UNIDO should evaluate in depth the consistency and comparability of the data given in the two sources.

253. According to the Rönitz study, total world consumption of major thermoplastics will amount to 35 million tons in 1975 and to 60 million tons in 1980 (see table 1). Of this total, the consumption of major thermoplastics by the developing countries will amount to 2.87 million tons in 1975 and to 5.91 million tons in 1980. No data for the total world consumption estimates of synthetic rubber have been prepared by Rönitz. However, estimates of consumption of synthetic rubber by the developing countries are available. These amount to 430,000 tons in 1975 and 672,000 tons in 1980. The estimated consumption of synthetic fibres by all the developing countries will amount to 996,000 tons in 1975 and to 1.53 million tons in 1980. Total world consumption of synthetic fibres is not given.

Table 1

Expected consumption of some petrochemical end products in the developing countries in 1975 and 1980

Developing countries in	Major thermoplastics 1975	Major thermoplastics 1980	Synthetic rubber 1975	Synthetic rubber 1980	Synthetic fibres 1975	Synthetic fibres 1980
Africa	223.5	488.3	...	...	65.0	120.0
The Americas	1,172.3	2,400.9	336.0	528.0	290.0	440.0
Asia	1,246.3	2,571.5	48.0	72.0	560.0	750.0
Europe	223.5	454.0	48.0	72.0	81.0	121.0
Total developing countries	2,866.0	5,914.0			996.0	1,431.0
Rest of the world	32,134.0	54,086.0	...	...	...	...
Total world	35,000.0	60,000.0	...	...	...	...

Source: Karl H. Rönitz, "Perspectives for the Petrochemical Industry in the Developing Countries up to 1980", 30 September 1969 (unpublished study commissioned by UNIDO).

Note: The above figures exclude figures from CMEA countries and China (mainland).

	[illegible]		[illegible]		[illegible]		[illegible]		Total developing countries	
	1970-[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]-1980
Major thermoplastics										
Low-density polyethylene	-	-	[illegible]	[illegible]	[illegible]	[illegible]	.	.	.	[illegible]
High-density polyethylene	-	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.	.	[illegible]
PVC	[illegible]	44.5	49.5	[illegible]	63.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Polystyrene	-	12.0	22.5	24.5	29.0	45.5	4.0	17.0	[illegible]	44.0
Polypropylene	-	-	50.0	100.0	30.0	130.0	-	30.0	[illegible]	260.0
	9.0	56.5	246.0	455.5	252.5	649.5	68.0	94.5	575.5	1,256.0
Synthetic rubber										
Polybutadiene and styrene-butadiene	-	-	32.0	64.0	-	8.0	16.0	8.0	48.0	80.0
Synthetic fibres										
Acrylic	18.0	18.0	12.0	18.0	42.0	42.0	-	12.0	72.0	90.0
Polyamide	39.2	52.5	154.0	52.5	491.7	376.0	28.0	21.0	712.9	502.3
Polyester	32.0	72.0	36.8	107.4	294.5	391.8	48.5	40.0	411.8	611.2
	89.2	142.5	202.8	177.9	828.2	809.6	76.5	73.0	1,196.7	1,203.5

Source: Karl H. Rönitz, "Perspectives for the Petrochemical Industry in the Developing Countries up to 1980" 30 September 1969 (unpublished study commissioned by UNIDO).

Table 3

Expected consumption of some petrochemical end products in the developing countries in 1975 and 1980
(thousand tons)

	ECAFE region		UNESOB region a/		Africa		Total	
	1975	1980	1975	1980	1975	1980	1975	1980
Major thermoplastics	...	2,110.1	105.0	[illegible]			...	2,673.0
Synthetic fibres	...	656.1	20.0	50.0	58.3	103.0	...	809.1
Synthetic rubber	...	335.2	30.0	40.0	87.4	140.7	...	515.9

Sources: Unpublished studies prepared for UNIDO (Baku Symposium) by ECAFE, ECA and UNESOB.

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a/ Iraq, Jordan, Kuwait, Lebanon, Saudi Arabia and Syria.

Table 4

Growth of installed capacity of basic petrochemicals in Latin America
(thousand tons)

	Installed capacity 1967/1968	Growth of installed capacity, 1972-1975
Ammonia	489.5	2,241.2
Butadiene	80.0	64.0
Benzene	229.0	346.0
Ethylene	134.3	1,219.2
Methanol	55.5	54.6
Naphthalene	10.8	7.2
Carbon black	117.1	11.2
Propylene	236.0	289.8
Carbon sulphide	19.5	-
Toluene	100.0 a/	111.0 b/
Xylenes	59.0 a/	80.2 b/
Total	1,530.7	4,424.4

Source: Unpublished studies prepared for UNIDO (Baku Symposium) by ECLA.

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a/ Figures for Mexico only; for all other countries included as benzene-toluene-xylenes (BTX) under benzene.

b/ Figures for Brazil, Colombia and Mexico only; for all other countries included as BTX under benzene.

254. The estimated investment requirements of the developing countries are given in table 2. According to these figures, the total capital required by the developing countries in the two periods, 1970-1975 and 1975-1980, is as follows:

	1970-1975	1975-1980
	million dollars	
Major thermoplastics	575.0	1,256.0
Synthetic rubber	48.0	80.0
Synthetic fibres	1,196.7	1,203.5

While the figures in table 2 give orders of magnitude of the investments required during the development decade, they should be further scrutinized and correlated by UNIDO. Tables 3 to 7 give projections prepared by the regional economic commissions and the United Nations Economic and Social Office in Beirut (UNESOB).

255. Using both sources, it appears that only figures for Africa are comparable. The figures for 1975 and 1980 as given by the Economic Commission for Africa (ECA) and by Rönitz are summarized below:

	ECA		Rönitz	
	thousand tons			
	1975	1980	1975	1980
Major thermoplastics	233.7	437.9	[illegible]	488.3
Synthetic rubber	58.3	103.0	...	...
Synthetic fibres	87.4	140.7	65.0	120.0

256. It must be borne in mind that figures for consumption of plastics, synthetic rubber and synthetic fibres are subject to serious misinterpretation unless it is made quite clear whether consumption refers to raw materials only or includes products made from the raw materials or, for example, the plastics contained in such imported goods as motor cars and engineering equipment.

Table 5

Consumption of petrochemicals in Western Europe in 1970 and 1975 a/ (thousand tons)

Ethylene derivatives	1970	1975
Polyethylene	3,175	6,500
Ethylene oxide	975	1,790
Ethylbenzene	507	900
Vinyl chloride	735	1,570
Synthetic ethanol	250	350
Acetaldehyde	263	450
Others b/	210	430
	6,115	12,000
Propylene derivatives		
Acrylonitrile	750	1,730
Polypropylene	350	970
Cumene	360	500
Propylene oxide	275	415
Oxo alcohols	650	1,115
Isopropyl alcohol	485	600
Others b/	365	420
	3,235	5,750
Butadiene derivatives		
SBR	420	650
Polybutadiene	210	320
Nitrile rubber	38	60
ABS resins	32	70
Others c/	45	60
	745	1,160

Source: Unpublished studies prepared for UNIDO (Baku Symposium) by ECE.

a/ EEC, EFTA and other countries in Western Europe.

b/ Mainly tetramer, trimer and synthetic glycerine.

c/ Chloropene, adiponitrile, trimer etc.

Table 6

Production of petrochemicals in the CMEA countries and Yugoslavia
(thousand tons)

	1970	1975	1980
Plastics and synthetic resins	1,673.0	...	...
PVC	636.0	...	...
Polyethylene	494.0	...	...
Polystyrene	148.5	318.0	...
Propylene	395.0	819.0	1,551.0
Ethylene	1,000.0	...	...

Amino plastics (1966) = 320.1

Acetylene (1966) = 975.0

<u>Source</u>: J. Müller, "Development of plastics from the petrochemical industry in the COMECON countries and Yugoslavia" ID/WG.34/6.

Table 7

Investment requirements for the development of petrochemicals in 1975 and 1980
(million dollars)

	Africa		ECAFE region		UNESOB region a/	
	1975	1980	1975	1980	1975	1980
Petrochemicals	435.0	876.0	-	-	-	300.0
Plastics	-	-	-	470.0	-	-
Synthetic fibres	-	-	-	919.0	-	-
Synthetic rubber	-	-	-	116.5	-	-

<u>Source</u>: Unpublished studies prepared for UNIDO (Baku Symposium) by ECA and ECAFE.

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a/ Iraq, Jordan, Kuwait, Lebanon, Saudi Arabia and Syria.

CHAPTER 7

WAYS IN WHICH UNIDO COULD ASSIST THE PETROCHEMICAL INDUSTRY

257. During the Symposium, discussions were held with the participants from developing countries concerning possible UNIDO assistance to the petrochemical industry in their countries. A document[6/] distributed during the Symposium outlined the main topics for these discussions under the following three headings: (a) planning and implementation of petrochemical facilities; (b) assistance in solving problems connected with the operation of petrochemical plants; and (c) assistance towards the installation of small petrochemical plants for which UNIDO/UNDP could provide the foreign-currency component. In the course of these discussions, the problems confronting a petrochemical industry in the country represented by each participant from a developing country were reviewed one by one, and ways in which UNIDO could assist in solving these problems were considered and recommendations drawn up.

258. The discussions were carried out with the understanding that, on their return to their home countries, the participants would be instrumental in trying to generate official requests for UNIDO assistance from their Governments, to be channelled through the UNDP resident representatives. It was understood that such requests would not be binding on UNIDO; one of the purposes of the discussions was to assist UNIDO to obtain information on the needs of the developing countries and to determine priorities for technical assistance to member countries.

259. The main sectors of the petrochemical industry in which UNIDO can assist the developing countries are indicated below, together with the number of requests and the source of financing of the assistance. The abbreviations used are for United Nations Development Programme/Special Fund projects (UNDP/SF), for Special Industrial Services (SIS) and for assistance under the regular programme (TA).

6/ ID/WG.34/78. See annex 2.

It should be noted here that, for the sake of easier classification, the training component is understood as included in the group headings.

<u>Group 1</u>: Covering the sector from preliminary feasibility studies to bankable projects, backed by market research and economic studies. UNDP/SF, 4; SIS, 11.

<u>Group 2</u>: Market research, marketing, technical service to sales promotion and marketing. UNDP/SF, 2; SIS, 6.

<u>Group 3</u>: Process and product selection. SIS, 3.

<u>Group 4</u>: Preparation of tender specifications and evaluation of tenders. SIS, 2.

<u>Group 5</u>: Small petrochemical plants for which UNIDO/UNDP could provide the foreign-currency component. UNDP/SF, 7.

<u>Group 6</u>: Materials inspection for petrochemical plants under construction. SIS, 1.

<u>Group 7</u>: Increasing operating efficiency of petrochemical facilities. SIS, 1; TA, 2.

<u>Group 8</u>: Effluent-disposal problems for operating petrochemical plants. SIS, 1.

<u>Group 9</u>: Promotion of financing, identification of partners for joint ventures. SIS, 2.

<u>Group 10</u>: Legal aspects of establishing joint ventures and of investment promotion. SIS, 1.

<u>Group 11</u>: Process engineering design in the petrochemical industry. TA, 1.

260. In conclusion, the discussions held with the participants of 25 developing countries led to the identification of 13 UNDP/SF projects, 28 SIS projects and 3 TA projects under the regular programme, for a total of 44 projects.

CHAPTER 8

CONCLUSIONS AND RECOMMENDATIONS

Development of the petrochemical industry in developing countries

261. The Symposium recommended that in establishing a petrochemical industry, developing countries should undertake detailed market studies for end products, including the impact of the production of such end products on more conventional materials. When the necessary services are not available within a country, the services should be obtained from other developing countries that have already progressed in the establishment of their petrochemical industries and have faced similar problems.

262. The Symposium suggested that developing countries wishing to establish a petrochemical industry could greatly benefit from the experience in this field that other developing countries have gained and from information on available processes. The Symposium therefore, suggested that:

(a) Country papers at future conferences should place more emphasis on discussing problems faced in the establishment of petrochemical industries and the measures undertaken to solve them; UNIDO or regional commissions such as ECAFE and ECLA should prepare reports on experience in establishing petrochemical industries in selected developing countries rather than only statistical data.

(b) The United Nations Conference on Trade and Development (UNCTAD) and UNIDO should collect data on the imports and exports of petrochemicals in developing countries.

(c) A mechanism should be worked out for collecting a catalogue of processes and for publishing, on a regular basis, detailed information on processes available for licensing.

263. The Symposium recommended that developing countries offer facilities for undertaking pre-investment studies, feasibility and detailed project reports, engineering design and construction, plant commissioning and operation, and research and development to other developing countries.

264. The Symposium emphasized the importance of adequate training in all branches of the petrochemical industry. It recommended that developing

countries that have established petrochemical plants should provide facilities for training personnel from other developing countries. The use of facilities at specialized institutions in developed countries, such as the specialized rubber institutes in the United Kingdom, France and the Soviet Union is also of importance.

265. Discussions during the Symposium clearly indicated that developing countries planning large investments in the petrochemical industry should develop their own design, fabrication and construction engineering facilities step by step. To build up the technical know-how and to reduce over-all costs of projects, countries embarking on petrochemical projects should build up a nucleus of design engineering facilities.

266. The Symposium emphasized the importance of adequate repairs and maintenance in the petrochemical industry and endorsed the efforts of UNIDO in the field of repairs and maintenance in developing countries. It recommended that UNIDO take up in depth the problem of repair and maintenance of petrochemical plants and assist developing countries by training maintenance and instrument engineers abroad and possibly by sending a mobile team of maintenance experts to developing countries to advise project managers.

267. To be economic, plants of the main petrochemical industries - basic petrochemicals, plastics, synthetic fibres and synthetic rubber - must be large. The demand in many of the developing countries is not great enough to justify large-scale production, and the Symposium recommended that regional development of the industries be considered. In this connexion, the Symposium suggested that UNIDO undertake a study of the problems and cost of transport of petrochemicals.

268. To meet the criterion of "economic size", many countries are considering developing industries mainly based upon exports. Several participants at the Symposium suggested that exports of petrochemicals at marginal costs will be possible only if a substantial home market exists that can meet the base production costs. Only in exceptional cases, as in oil-producing countries with their specialised raw materials, can large-scale plants intended exclusively for export be considered.

269. In view of the resolutions of the United Nations General Assembly to the effect that computer technology should be introduced into developing countries where appropriate, a position supported by the Advisory Committee on Science and Technology, and on the basis of the discussions of the Symposium, it is recommended that developing countries encourage the use of computer technology

in research and in design of petrochemical plants, using assistance from UNIDO if necessary.

Basic petrochemicals

270. Several developing countries possess considerable reserves of natural and associated gas containing substantial fractions of ethane, propane and higher hydrocarbons. The Symposium recommended that, as these fractions are of special economic advantage in the production of ethylene, permitting entry into the field of petrochemicals without investment in a number of down-stream processes, countries with such resources should pay special attention to their utilization.

271. The Symposium noted the development of processes for the production of olefins from relatively inexpensive and readily available raw materials such as crude oil and fuel oil, and recommended an examination of such processes by countries where conventional raw materials are not easily available and especially where manufacture of products such as PVC is desired.

272. The Symposium suggested that, in view of delays in bringing large olefin plants up to capacity, the economics of smaller ethylene plants in relation to larger plants should be re-examined, especially in the context of optimum integration of such plants with refineries and with down-stream processing units.

Intermediates for the plastics industry

273. The Symposium noted that present trends are for the use of ethylene in the manufacture of vinyl chloride, rather than acetylene, except under exceptional circumstances, and integration of facilities with ammonia and methanol production. The Symposium also noted the satisfactory commercialization of a number of oxychlorination processes using ethylene, which eliminate the problem of disposal of hydrochloric acid.

274. The Symposium noted the satisfactory commercialization of processes for the manufacture of vinyl acetate from ethylene that should be of special interest to developing countries in view of the wide range of application for this product.

Plastics industry

275. The Symposium noted with interest the results achieved in research on the production of polyethylene based on radiation techniques.

276. The Symposium noted that the relatively newer plastics have so far succeeded in capturing only specialized markets of relatively low volume. Polyethylene, PVC, styrene plastics and polypropylene continue to dominate the thermoplastics market, with rates of growth in developing countries often exceeding those of developed countries. The Symposium suggested that developing countries concentrate, in the first instance, on the manufacture of these thermoplastics.

277. The Symposium noted that substantial improvements in the properties of plastics have been achieved at relatively low cost by the use of reinforcement materials and blends. This means that developing countries can limit production to a relatively small number of basic plastics and yet diversify the range of use of such plastics.

278. The Symposium recommended that developing countries: (a) establish facilities for research on polymerization technology, formulation of plastics and compounding and for quality control of finished products; and (b) pay special attention to setting up adequate facilities for the plastics-processing industry such as product design and shops for the manufacture of moulds and dies and for their maintenance.

279. The Symposium recommended that, in planning the establishment of the plastics industry, developing countries pay special attention to the use of plastics as substitutes for scarce traditional materials and also take into account particular consumption patterns of such traditional materials in their own country, which are often different from materials in other countries. This replacement has a special role to play in the substitution of imports, not only of plastics but also of such products as steel and non-ferrous metals and could lead to substantial savings in foreign exchange.

Synthetic fibres

280. The Symposium recommended that, before embarking on large-scale synthetic fibre production, developing countries should carefully survey existing textile-production facilities from the standpoint of their ability to absorb synthetic fibres. Investment required for modifying such plants or for building new facilities should be made available to the textile industry.

281. The Symposium suggested that developing countries entering the synthetic fibre field could start by establishing relatively small synthetic fibre plants based on imported monomers. They should however, concentrate at first on the manufacture of the high-volume fibres such as nylon, polyester and, in colder climates, acrylic fibres.

Synthetic rubber

282. Several developing countries are located in regions where natural rubber is produced but where demand for synthetic rubber is increasing. The Symposium recommended that UNIDO undertake a study projecting, country by country, the economic advantages of natural rubber relative to synthetic rubber.

283. Current technologies in the synthetic rubber field are designed for relatively large plants. The Symposium felt that it is technologically possible to set up economic small plants and suggested that specialized companies and institutes be approached to do this, in association, when possible, with developing countries.

284. The Symposium emphasized that the stimulation of rubber demand in a developing country is possible only through co-operation between the rubber companies and the rubber producers and recommended that institutional facilities be provided in developing countries for this purpose.

285. The Symposium felt that an exchange of information between countries such as Argentina, Brazil, India and Mexico with other developing countries would be of help in planning synthetic rubber industries in the latter countries. It recommended that UNIDO call an expert group meeting to consider possibilities in this connexion.

United Nations Second Development Decade

286. The Symposium noted with interest the work being undertaken by the United Nations in establishing data for the projections of production, consumption and investment in petrochemicals. It recommended that UNIDO convene a meeting of experts to correlate available data from this Symposium and other sources.

UNIDO technical assistance

287. The Symposium noted the interest shown by developing countries in technical assistance projects and welcomed action by UNIDO to initiate such

projects. It recommended that member countries and UNIDO expedite completion of formalities and the implementation of the projects identified during the Symposium without undue delay.

288. The Symposium discussed the possibilities of obtaining UNIDO assistance and help in a number of fields. Among the more important recommended for consideration by UNIDO were:

(a) Preparation of market studies in close co-operation with local organizations, application of end products and pre-investment studies for specific projects and recommendations on availability of consulting services;

(b) Guidance in the selection of processes, process licensers, engineering design and location of plants;

(c) Guidance in formulating plans for building up the petrochemical industry step by step in countries where capital investment and financial factors necessitate this approach;

(d) Examination by UNIDO of guidelines for the establishment of plants of the minimum capacity that is economic under the specific conditions of various countries;

(e) Assistance by UNIDO after start-up, such as continuing technology for process, marketing and product application;

(f) Assistance in setting up abroad exhibitions of finished products from developing countries;

(g) Help in establishing and maintaining quality controls in products such as synthetic fibres and finished plastic products and in establishing standards for these products;

(h) Advising countries on the establishment of research and development centres for various branches of the petrochemical industry;

(i) Studying the problems of plants in developing countries that are in difficulties because of obsolescence or other problems;

(j) Help in the solving of problems of disposal or further processing of by-products and surplus intermediates;

(k) Advising on the problems of the handling of petrochemicals, safety regulations and waste disposal;

(l) The establishment of training programmes in petrochemical technology in developing countries that have already progressed in the petrochemical industry in order to obtain information on the experience of those countries.

289. The Symposium recommended that financing institutions such as the International Finance Corporation (IFC) or the Asian Development Bank be approached for assistance in financing petrochemical projects in developing countries.

Co-operation with the International Atomic Energy Agency (IAEA)

290. The Symposium suggested that UNIDO convene a meeting on the Plastics Processing Industry at an early date.

291. The Symposium noted with interest the development of radiation techniques for various petrochemical processes. The Symposium recommended continuing co-operation with IAEA in developing such processes, which are of special interest to developing countries.

Research and development

292. The Symposium recommended that continued attention be paid to research and development in the field of petrochemicals, including work in the developing countries, and suggested that exchange of information and data in this connexion would be of great advantage, particularly among developing countries.

293. The Symposium recommended that UNIDO make suggestions to the appropriate United Nations agencies, so that a techno-economic evaluation of the petrochemical industry could be carried out by regional centres.

Future meetings and other activities

294. The Symposium welcomed the fact that UNIDO holds conferences and symposiums on the petrochemical industry at regular intervals and recommended that a future conference be held within three to four years. Suggested locations for the conference were Mexico, Algeria, Iraq and India.

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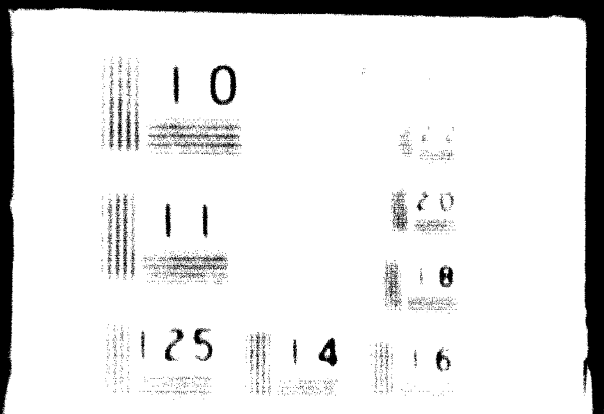

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[illegible]	[illegible]
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[illegible], Salem Ahmed	Centre for [illegible] Development for [illegible] Cairo United Arab Republic
[illegible], Mohamed	Engineer Institut algérien du pétrole Alger Dar-El-Beida Algeria
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TRIVEDI, Druman M.	Project Manager Synthetics and Chemicals Ltd. Bombay India
TSUNEO, Betsuno	Japan Chemical Fibre Association Okada City Osaka Japan
VASETTI, Fernando	Sales Management Assistant SNAM Progetti SpA Milan Italy
WUNDER, Dietrich	Verband der chemischen Industrie Frankfurt am Main Federal Republic of Germany

ANNEX [illegible]

STATEMENTS TO THE SYMPOSIUM

Statement of Mr. I. H. Abdel-Rahman, Executive Director of UNIDO

Opening statement of Mr. [illegible] I. Sorokin, Deputy Minister, Ministry for the Oil-Processing and Petrochemical Industries of the USSR, Chairman of the Organizing Committee for the Symposium

Statements by UNIDO on technical assistance to developing countries and on the United Nations Second Development Decade

Closing statement of Mr. F. A. [illegible], Deputy Chairman of the Council of Ministers of the AzSSR

Closing statement of Mr. A. I. Litvinenko, Assistant Head of Division, Ministry for the Oil-Processing and Petrochemical Industries of the USSR, Director of the Symposium

Closing statement of Mr. R. I. Ismailov, President, Academy of Sciences of the AzSSR, Chairman of the Symposium

Closing statement of Mr. M. [illegible] Verghese, Chief of Fertilizers, Pesticides and Petrochemicals Industries, UNIDO, Director of the Symposium

Statement [illegible] [illegible]el-Rahman

First of all, I [illegible] [illegible]s of the [illegible] Socialist Republics and [illegible] [illegible] Socialist Repu[illegible] all the necessary arra[illegible] [illegible] Symposium. [illegible] ful to the USSR State [illegible] [illegible] Relations, [illegible] Committee of [illegible] [illegible] for the Oil-[illegible] Petrochemicals Industries [illegible] [illegible] Azerbaijan SSR.

I should parti[illegible] [illegible] the Council of [illegible] the Azerbaijan SSR, Mr. [illegible] [illegible]irman, Mr. [illegible], Chairman of the Bak[illegible] [illegible], Mr. Abdullaev. [illegible] all the preparati[illegible] [illegible] the organizing [illegible] the Deputy Minister [illegible] [illegible]-Processing and [illegible] Industries of the [illegible], [illegible] [illegible]rman. The eff[illegible] organizing committee [illegible] [illegible]ank its members.

Next, I should like [illegible] [illegible]ticipants from the devel[illegible] developed countries [illegible] [illegible] able they have [illegible] to this Symposium. [illegible] [illegible] owing to other comm[illegible], cannot be prese[illegible] wi[illegible] [illegible]tend to all of you my [illegible] greetings and hope [illegible] [illegible] most fruitful and th[illegible] have an enjoyable [illegible] [illegible] Caspian Sea.

When many of [illegible] [illegible] the First United [illegible] Interregional Conf[illegible] [illegible] of Petrochemical Industries [illegible] Developing Countr[illegible], [illegible] the gathering was [illegible] its predecessor, [illegible] [illegible]r Industrial Develop[illegible], co-operation with [illegible] Assistance Operations [illegible] Nations Department [illegible] [illegible]fairs and the various [illegible] commissions. [illegible] [illegible] said that one of the [illegible] problems was [illegible] [illegible] the developing [illegible] fruits of scient[illegible] [illegible] basic tool in [illegible] for developme[illegible]. [illegible] [illegible] through the form[illegible] and today [illegible] [illegible] the new organi[illegible]

In fulfil[illegible] [illegible]ndustrial development and assist in accelerating the [illegible] the developing countries, [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

Some of the obstacles in the way of intensification of assistance programmes are the following:

(a) Delays in recruiting and providing experts;

(b) Difficulties in finding suitable experts;

(c) Delays in getting nomination of experts accepted by requesting Governments;

(d) Difficulties in finding suitable materials for training;

(e) Lack of appreciation of, or unwillingness to accept, certain projects not originated by the country concerned.

On the last item of this list I would like to quote certain examples. The General Assembly had passed a resolution requesting UN agencies to introduce computer techniques in developing countries, where appropriate. To one developing country [illegible] at present has one million tons of nitrogen capacity and many petrochemical units and which is designing and constructing further nitrogen and petrochemical plants, a suggestion was made for the use of computers for design purposes. Computer and expert services, as well as training of nationals, could have been provided from UNDP funds, but this suggestion did not receive support. Similarly, schemes to put up demonstration [illegible] for direct application of liquid fertilizers, ammoniation and granulation of superphosphates, and a survey of reasons for underutilization of existing [illegible] have been made, but requests for assistance in these field have not been received.

It [illegible] there that the participants from developing countries [illegible] influence their Governments to use the assistance which can be extended from UNIDO. If you originate requests of the above nature or others of immediate interest and see that they are submitted [illegible] through Government channels, I am sure that fuller utilization of the funds available under the various categories of UNIDO assistance [illegible]. Evaluations of training in various branches of petrochemicals [illegible] attention.

The United Nations Second Development Decade

In December 1967, The General Assembly of the United Nations voted unanimously to start preparations for a Second Development Decade, commencing in 1971. Subsequent resolutions of the General Assembly have spelled out the procedures to be followed in preparing a strategy for this decade, which will help to ensure that during these ten years major and permanent progress will be registered by the two thirds of the world's population who live in developing countries. The 54-nation preparatory committee established by the General Assembly has completed its first round of substantive discussions.

As the organization primarily responsible for the industrialization of the developing countries, UNIDO will participate in the collective effort of the United Nations family. However, it should be noted that UNIDO has not had time during its three years of existence to accumulate information and studies of a basic nature on the general problems related to the industrialization of developing countries.

However, UNIDO is adopting a sectoral approach to design the perspectives of development for some of the main branches of industry. These "prospects" will be prepared, using projective methods as well as direct information on the existing plants and future projects. During this Symposium, papers have been presented by the economic commissions and countries of the various regions giving figures for the present production and future projections for 1975 and 1980. In addition, UNIDO commissioned a study by Mr. K.H. Rönitz of Farbwerke Hoechst AG to determine how independent estimates and projections will compare with regional and country estimates. In chapter 6 of the Symposium report we have endeavoured to summarize the regional projections and the Rönitz projections. These different projections must be reconciled, and this work will be done by UNIDO. Estimates of capital requirements have also been made and will be presented by Mr. Jowhari of UNESOB. UNIDO will undertake similar studies in the fertilizer field and will project capital requirements up to 1975 and 1980.

In addition to these projections and capital requirements estimates, UNIDO also proposes to prepare the following studies:

(a) Review of the past trends and problems;

(b) Perspectives of development as they appear from the experience of existing projects, already under way or planned;

(c) Developments in technology, transport, economies of scale and input structure affecting future trends in location, product mix, raw materials etc.;

(d) Policy recommendations to be carried out at the country level and at the international level.

The United Nations Industrial Development Board, during its third session in Vienna, adopted a resolution deciding that the work of UNIDO in accelerating industrial development in developing countries for the Second Development Decade should receive high priority, particularly in the less developed of the developing countries. UNIDO is carrying out this resolution, and part of our work in this Symposium has been in this direction.

Closing statement of Mr. K. A. Guseynov

The Interregional Petrochemical Symposium on the Development of the Petrochemical Industries in Developing Countries organized by UNIDO will end today. The work of our Symposium has been fruitful. Problems directly related to the development of the economy and improvement of the standard of living in developing countries have been considered and discussed, and important recommendations have been made.

One of the remarkable features of the Symposium was that it was a wide international forum, with many people from many different countries taking part. It was a pleasure for us that Azerbaijan was selected as the meeting place for this Symposium, and we have tried to do our best to make the work of the Symposium really effective.

The programme of the Symposium in Baku permitted our scientists to participate in its work and to acquaint our guests with the work that has been carried out by our scientists in developing the petrochemical industry in Azerbaijan. We consider such creative co-operation of people from many different countries to be of real value, and we are ready to contribute our efforts for its continuation.

May I express the wish to all participants of the Symposium that the recommendations adopted will be realized and that their valuable work will have successful results.

Closing statement of Mr. A. G. Litvinenko

Today we are considering the results of the Interregional Petrochemical Symposium on the Development of the Petrochemical Industry in Developing Countries. We are sure that the Symposium will play a significant part in the development of the world petrochemical industry.

I should like to emphasize that it would have been impossible to organize the Symposium at such a high level without the help of all participants, consultants, observers and administrative staff of the Symposium and without the hospitality of the people of Baku and of the petrochemical enterprises of the Azerbaijan SSR. We shall long remember the meetings that have taken place here in the course of the Symposium.

All participants in the Symposium have done their best either in organizing the Symposium or in creating the kind of good atmosphere in which the work of UNIDO can be carried on. I thank you all very much.

On behalf of the Organizing Committee I wish all participants a safe journey home and success in the development of petrochemical industries in their respective countries.

Closing statement of Mr. R. G. Ismailov

First of all, I wish to thank the representatives of UNIDO for making all the necessary arrangements for the successful functioning of the Symposium. I should like to thank all participants of this Symposium who have given time and effort to its organization and operation. I hope that the results obtained and the relations among all participants were fruitful and they will help all participants in their work aimed at the development of petrochemical industries in their respective countries.

The very fact that [illegible] papers were contributed by participants from 36 countries gives an idea of the scope of the Symposium. Each of these papers is certain to evoke considerable interest among scientists and specialists. The present situation and prospects of petrochemical industries have been discussed. The participants of the Symposium have had an opportunity to visit some petrochemical enterprises of Azerbaijan and scientific research institutes working in this field.

I hope the new personal contacts made will prove of real value.

In conclusion, I wish to thank once more all participants and organizing staff and declare the Symposium closed.

Closing statement of Mr. M. C. Verghese

At this concluding session of the Symposium it is my duty, privilege and pleasure to say a few words.

First of all, I wish to thank the Organizing Committee of the USSR and the Azerbaijan SSR for their kind co-operation and hard work to bring this Symposium to a successful conclusion. As all of you know, Minister Sorokin has been with us till the last day and has helped us in many difficult situations. Minister Guseynov, Deputy Minister Babayev and Deputy Minister Mamedov have been of great assistance during the Symposium. To Mr. Litvinenko, who was the key man in the Organizing Committee, and his co-workers I extend our congratulations and appreciation. Our special thanks are due to Mr. Ahmedov, Chief of the Board of Foreign Tourism under the Council of Ministers of Azerbaijan, who took particular care of those of us who became ill or who needed assistance with their travel plans.

In spite of some difficulties and personal inconveniences, the participants from developing countries and the participants and observers from developed countries have co-operated and have contributed greatly to the success of the Symposium. I would like to apologize to them for any personal inconveniences or difficulties experienced during the Symposium.

As you know, this Symposium has been financed by the contributions of the member countries to the United Nations and the voluntary contribution of the USSR to UNIDO. The time, effort and money spent can only be justified by the results of the Symposium. There is a growing feeling that the cost-benefit ratio of such large symposia should be advantageous for sponsoring any future meetings. I hope that the participants from developing countries have been able to benefit from the papers presented, the discussions that followed and the contacts they have made during the Symposium. Some suggestions have been made for possible technical assistance in the petrochemical field by UNIDO. We shall certainly follow up these suggestions from the UNIDO side, but shall look forward to your co-operation in developing these ideas after your return to your respective countries. We shall also look forward and expect all of you to maintain contacts with UNIDO and help us as the contact points in your respective countries. Many of the participants from the developed countries have contributed their valuable time and experience to this Symposium. I wish to thank them and request them to continue their co-operation with UNIDO.

We are especially grateful to the distinguished participants from the USSR, the academicians, scientists, engineers and chemists who contributed to the substance of the Symposium. To the President of the Academy of Sciences of Azerbaijan and Chairman of the Symposium, Mr. Ismailov, we are extremely grateful for receiving permission to hold the Symposium in the hall of the Academy of Sciences.

Next, I should like to thank all our consultants, sectional chairmen, sectional co-chairmen, rapporteurs and the technical co-director for the able way in which they carried out their functions. But for their hard work and co-operation we could not have carried out the programme in time and prepared the draft report.

To my colleagues from UNIDO and from the USSR side, I wish to say that their co-operation and assistance have helped in completing our work in time satisfactorily. During the last two days they had to work hard and long hours to compile and reproduce the draft report. I express my gratitude and thankfulness to them.

The interpreters and the supporting staff from the USSR and the Azerbaijan SSR have done a wonderful job in their extremely difficult tasks, and I wish to thank them and record our appreciation of their co-operation.

I also wish to thank the authorities of the Baku refinery, the authorities of the off-shore drilling facilities in the Caspian Sea, the olefins and petrochemical research institutes and the authorities of the Sumgait refinery and petrochemical plants for arranging visits and for their hsopitality.

To the honourable mayors of Baku and Sumgait I convey the appreciation of all participants of the Symposium for their hospitality.

To all participants of the Symposium I extend my warmest greetings and hope you will have a pleasant trip home.

ANNEX 3*

LIST OF WORKING PAPERS

* This documentation is not available for general distribution, but a representative selection will be published as Proceedings of the Symposium.

		AUTHOR
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SYMBOL	TITLE	AUTHOR
ID W[illegible] and SUMMARY	Factors [illegible] amount [illegible] developing country [illegible] industry	[illegible]
ID W[illegible]	[illegible] region	V. [illegible]
ID W[illegible] and SUMMARY	[illegible] the development of high-pressure polyethylene [illegible]	[illegible]
ID W[illegible] SUMMARY [illegible]	Recent [illegible] of polyolefins	[illegible] and A. [illegible]
ID W[illegible] and SUMMARY	The polymerization, structure and properties of [illegible] PVC in comparison with [illegible] PVC	[illegible]
ID W[illegible] and SUMMARY	Development [illegible] and their application [illegible] for [illegible]	W. [illegible] and D. W[illegible]
ID W[illegible] and SUMMARY	Polyvinyl alcohol fibres (Vinylon)	[illegible]
ID W[illegible] and SUMMARY	Petrochemistry and technology of [illegible]	[illegible]
ID W[illegible] and SUMMARY	[illegible]	[illegible]

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SYMBOL	TITLE	AUTHOR
ID/WG.34/61 and SUMMARY	Latest achievements in the synthesis of polymeric reagents and their application	A. P. Pashkov USSR
ID/WG.34/62 and SUMMARY	Continuous process of producing synthetic fibres from ε-caprolactam	V. M. Kharitonov USSR
ID/WG.34/63 and SUMMARY	Production of isoprene and isoprene rubbers	O. E. Batalin, S. K. Ogorodnikov and O. B. Estrin USSR
ID/WG.34/64 and SUMMARY	Technical and economic background for the organization of synthetic rubber production in developing countries	A. P. Troitsky and A. P. Nikandrov USSR
ID/WG.34/65 and SUMMARY	Technical and economic results and perspectives of the application of synthetic [illegible]	F. I. Yushunskaya and E. A. Karunovskaya USSR
ID/WG.34/66 and SUMMARY	[illegible]	R. Jean-Pierre France
ID/WG.34/67 and SUMMARY	[illegible]	[illegible] Lederer, [illegible] France
[illegible]	[illegible]	
[illegible] and SUMMARY	[illegible]	[illegible] United States
[illegible]	[illegible]	[illegible]

SYMBOL	TITLE	AUTHOR
ID/WG.34/71 and SUMMARY	Petroleum and petrochemical industry in the Caribbean region (a techno-economic study)	H. D. Huggins and G. M. Richards Trinidad and Tobago
ID/WG.34/72	Development of the petro-chemical industry in Ecuador	R. Bucaram Ecuador
ID/WG.34/73	Development of the petro-chemical industry in Brazil	O. V. Perroni Brazil
ID/WG.34/74 SUMMARY only	Development of the petro-chemical industry in Lebanon	E. Samaha Lebanon
ID/WG.34/75 SUMMARY only	Development of the petro-chemical industry in Chile	E. [illegible] Simian Chile
ID/WG.34/76	Development of the petro-chemical industry in Indonesia	N. Kansil Indonesia
ID/WG.34/77	Presentation of the Symposium staff	UNIDO
ID/WG.34/78	Note to participants on technical assistance concerning possible requests for UNIDO assistance on technical and economic problems in petrochemical development	UNIDO
ID/WG.34/79	Note for the participants from developing countries on background information concerning existing and planned petro-chemical industries in their countries	UNIDO
[illegible]	[illegible]	
[illegible]	[illegible]	
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SYMBOL	TITLE	AUTHOR
ID/WG.34/83	Closing statement of A. G. Litvinenko	
ID/WG.34/84	Closing statement of R. G. Ismailov	
ID/WG.34/85	Closing statement of M. C. Verghese	
ID/WG.34/86	Introductory note on United Nations Second Development Decade	UNIDO
ID/WG.34/87	Note on technical assistance to developing countries from UNIDO	UNIDO
ID/WG.34/88	Development of the petrochemical industry in Nigeria	S. A. Kufeji Nigeria
ID/WG.34/89	Development of the petrochemical industry in Czechoslovakia	V. Miller Czechoslovakia
ID/WG.34/90	Development of the petrochemical industry in Bolivia	V. F. Antezana Bolivia
ID/WG.34/91	Development of the petrochemical industry in India	S. P. Bhattacharya India
ID/WG.34/92	Development of the petrochemical industry in Spain	J. L. Ortiz de la Torre Spain
ID/WG.34/93	Development of the petrochemical industry in Romania	L. Badea Romania
ID/WG.34/94	Development of the petrochemical industry in Poland	W. Werbachowski Poland
ID/WG.34/95	Development of the petrochemical industry in Ceylon	M. S. Sulaiman Ceylon

SYMBOL	TITLE	AUTHOR
ID/WG.34/96	Development of the petrochemical industry in Iraq	Z. Al-Haidary Iraq
ID/WG.34/97	Development of the petrochemical industry in Algeria	M. Haichour Algeria
ID/WG.34/98	Development of the petrochemical industry in the Syrian Arab Republic	M. Z. Sawaf Syria
ID/WG.34/99	Development of the petrochemical industry in Venezuela	E. A. Acosta-Hermosa Venezuela
ID/WG.34/101	Development of the petrochemical industry in Pakistan	M. Hossain Pakistan
ID/WG.34/102	Development of the petrochemical industry in Uruguay	M. E. Villemur Uruguay
ID/WG.34/103	Development of the petrochemical industry in Burma	Tin Maun Aye Burma
ID/WG.34/104	Development of the petrochemical industry in Turkey	M. Solim Turkey
ID/WG.34/105	Development of the petrochemical industry in Malaysia	Surinder Singh Malaysia
ID/WG.34/106	Development of the petrochemical industry in Iran	S. Sharifi Iran
ID/WG.34/107	Development of the petrochemical industry in Morocco	M. Hajjaji Morocco
ID/WG.34/108	Development of the petrochemical industry in the Philippines	E. Tordesillas Philippines
ID/WG.34/109	Research and training of personnel for petrochemical industries in India	K. K. Bhattacharya India

SYMBOL	TITLE	AUTHOR
ID/WG.34/110	The process for the production of maleic anhydride through direct oxidation of n-butylenes	T. N. Shahtakhtinsky USSR
ID/WG.34/111	Investigations into the synthesis and production technology of chlorinated alkenes and chlorinated carbon compounds	R. G. Ismailov and M. M. Guseynov USSR

19.6.74