## OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

## DISCLAIMER



## FAIR USE POLICY



## CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

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

# Fertilizer production in six selected countries with good natural gas resources

UNITED NATIONS

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
VIENNA

*Report of the meeting of the* Ad Hoc *Expert Group on*

# FERTILIZER PRODUCTION IN SIX SELECTED COUNTRIES WITH GOOD NATURAL GAS RESOURCES

United Nations Headquarters, New York
9—16 December 1966

UNITED NATIONS
New York, 1969

ID/5

UNITED NATIONS PUBLICATION

Sales No.: E. 69. II. B. 5

Price: $US 0.75 (or equivalent in other currencies)

Printed in Austria

CONTENTS

Page



## ANNEXES

## List of tables

References to "tons" indicate short tons and to "dollars" ($), United States dollars, unless otherwise stated. Details and percentages in tables do not necessarily add up to totals because of the use of round figures.

The following abbreviations have been used:

| | | |
|---|---|---|
| ARAMCO | = | Arabian American Oil Company |
| ASTM | = | American Society for Testing Materials |
| atm | = | atmosphere |
| B | = | Venezuelan bolivar |
| b/d | = | barrels per day (1 barrel = 158.8 litres) |
| Btu | = | British thermal unit |
| C or cent | = | $US 0.01 |
| CID | = | Centre for Industrial Development |
| ENI | = | Ente Nazionale di Idrocarburi |
| f.o.b. | = | free on board |
| $ft^2$ | = | square foot |
| $ft^3$ | = | cubic foot |
| gal | = | US gallon = 3.784 litres |
| ha | = | hectare |
| IR | = | Iranian rial |
| IVP | = | Instituto Venezolano de Petroquimica |
| km | = | kilometre |
| kW | = | kilowatt |
| kWh | = | kilowatt hour |
| LNG | = | liquefied natural gas |
| LPG | = | liquefied petroleum gas |
| $m^2$ | = | square metre |
| $m^3$ | = | cubic metre |
| ppm | = | parts per million |
| psi | = | pounds per square inch |
| psig | = | pounds per square inch gauge |
| PVC | = | polyvinyl chloride |
| SAFCO | = | Saudi Arabian Fertilizer Company |
| SIS | = | Special Industrial Services |
| SR | = | Saudi rial |
| t | = | short ton |
| t/d | = | tons per day |
| UNIDO | = | United Nations Industrial Development Organization |
| UNDP | = | United Nations Development Programme |
| °API | = | gravity in degrees as set by the American Petroleum Institute |
| $\Delta T$ | = | difference in temperature |

# Introduction

A MEETING of the *Ad Hoc* Expert Group on Fertilizer Production was organized by the Centre for Industrial Development (CID)[1] of the United Nations to examine the possibilities of large-scale production of fertilizers using natural gas in six selected countries, namely, Iran, Kuwait, Libya, Nigeria, Saudi Arabia and Venezuela. The meeting was held at United Nations Headquarters from 9 to 16 December 1966.

The meeting of the Expert Group was a follow-up of the recommendation made by the Interregional Seminar on Fertilizer Production held in Kiev from 24 August to 11 September 1965. A unanimous resolution of the Kiev seminar had requested the United Nations to organize and conduct studies for the establishment of large fertilizer production projects in areas of the developing countries where abundant natural gas and other raw materials are available. This recommendation was subsequently endorsed by the Committee for Industrial Development in its resolution E/C5/L66 of 5 May 1966 and in resolution 1179/L of 5 August 1966 of the Economic and Social Council.

The purpose of the meeting of the Expert Group was to:

1. Collect and collate the relevant facts relating to the availability of natural gas together with costs, transport possibilities and the like, in connexion with the production of nitrogen fertilizers in Iran, Kuwait, Libya, Nigeria, Saudi Arabia and Venezuela;
2. Analyse and determine the economic and market factors that may be retarding the development of large nitrogen fertilizer projects in these countries;
3. Analyse the technical factors and apply the new technology for the production of ammonia that has been developed during the past five years in industrialized countries;
4. Determine the indigenous consumption of natural gas in the six countries and its transport and export to other developing countries;
5. Examine the possibilities for financing such projects.

Country experts from Libya, Nigeria, Saudi Arabia and Venezuela attended the meeting, but experts from Iran and Kuwait were not able to be present. Five international experts from the United Arab Republic, the United States,

---

[1] Now the United Nations Industrial Development Organization.

Venezuela and the International Bank for Reconstruction and Development (IBRD, the World Bank) participated. Twenty-one international companies sent expert observers to the meeting. The Commissioner, Mr. I. H. Abdel-Rahman; the Director of the Technological Division, Mr. N. K. Grigoriev; the Chief of the Industries Section, Mr. R. C. Desai; and the Interregional Adviser, Mr. M. C. Verghese represented the CID. The meeting of the Expert Group was convened by Mr. Verghese. The list of participants is given in Annex 2.

The inaugural session was opened by Mr. N. K. Grigoriev, who extended a warm welcome to the participants and invited the Commissioner for Industrial Development, Mr. I. H. Abdel-Rahman, to address the meeting. The Commissioner, after giving a general outline of the functions of the new United Nations Industrial Development Organization (UNIDO), established by the General Assembly as an autonomous body within the United Nations to succeed the Centre for Industrial Development (CID), informed the Group of the Special Industrial Services (SIS) Programme that is financed from voluntary contributions and provides assistance, at short notice, to governments in the promotion or implementation of new manufacturing projects. The Commissioner indicated the assistance programmes in the fertilizer field that have been undertaken by the CID in the past and those that will be undertaken by the UNIDO in the future. Although there has been a revolution in fertilizer technology during the last five years in developed countries, it has become increasingly difficult for developing countries to adopt the most significant technological improvements and to build fertilizer projects because of inadequate foreign exchange. He requested the Expert Group to focus attention on the possibility of expanding fertilizer production, not only in the selected six countries, but also in others endowed with such resources as cheap natural gas. The Commissioner's statement is given in Annex 1.

Mr. N. K. Grigoriev then introduced His Excellency Sergei Timofeevich Shevchenko, Permanent Representative of the Ukrainian Soviet Socialist Republic to the United Nations, who addressed the Expert Group on behalf of his Government. He spoke appreciatively of the work of the Centre and stated that the Kiev seminar in which his Government had assisted the United Nations had created world-wide interest in the subject of fertilizer production. The Ambassador subsequently presented a short documentary film on the Kiev seminar to Mr. Abdel-Rahman.

The *Ad Hoc* Expert Group elected Professor Raymond Ewell, Vice-President for Research, University of New York, Buffalo, New York, as Chairman. Mr. Taha Zaky, an international expert from the United Arab Republic, acted as Chairman during the absence of Professor Ewell on 12 December.

The Group adopted the agenda which is given in Annex 3.

At its concluding session, the Group considered the draft outline of the report of the meeting including its conclusions and recommendations. The Chairman thanked the participants for their contributions and the authorities of the United Nations for convening the meeting.

# I. Availability and price of natural gas

THE EXISTENCE OF large natural gas resources in the six countries of Iran, Kuwait, Libya, Nigeria, Saudi Arabia and Venezuela was considered as the basis for the investigation of fertilizer production projects in these countries. Sources of supply include both natural gas fields and fields associated with crude oil production.

### NATURAL GAS FIELDS

Maps showing the locations of natural gas resources in the six countries under discussion are given in Annex 6. Four of the countries have natural gas fields.

Iran has natural gas fields at Sarajeh to the south of Tehran, with an extension of approximately 100 kilometres and at Gorgan, approximately the same distance northeast of the capital.

Libya has eighteen gas fields, mostly in the unexplored eastern part of the country.

Nigeria has twelve important natural gas fields located in various parts of the country, the main one being in the southeast.

Venezuela has four natural gas fields: at Maracaibo and Barinas, situated respectively in the northwest and midwest; at Barcelona and Maturin both in the northeast of the country. Those at Barcelona and Maturin are the two principal fields with a daily production rate of 36 and 2.1 million $m^3$ respectively. The reserves at Barcelona amount to 1.8 million million $m^3$; the gas from these fields is not being utilized.

### FIELDS ASSOCIATED WITH OIL PRODUCTION

The main natural gas resources in the six countries are associated with oil production.

In Iran the quantity of natural gas produced from fields associated with crude oil is approximately seven times as high as that produced from natural gas fields. The present production figure of 42.5 million $m^3$ per day is expected to be doubled by 1975.

The entire natural gas resources in both Kuwait and Saudi Arabia are associated with the production of oil. Present production in Kuwait amounts to 33.5 million $m^3$ per day and is expected to be increased to 51 million $m^3$ per day by 1975. In Saudi Arabia the figures are 28 and 42 million $m^3$ per day respectively (table 1 below).

In Libya 21.6 million $m^3$ per day of natural gas are produced as a by-product from twenty oil fields (March 1965) in the Sirte area. However, the production is flared. The reserves of associated natural gas are estimated at 240,000 million $m^3$.

In Nigeria most of the natural gas resources are associated with oil production. The fields at Afam and Oloibiri, situated east and west of Port Harcourt in Southeastern Nigeria, produce 6.6 million m³ per day. These field are expected to produce 52 million m³ per day in 1975.

In Venezuela 99 per cent of natural gas output is associated with oil production.

### Production, reserves and utilization

Table 1 below shows the natural gas production, reserves and utilization factors in the six countries under review. The utilization factor gives, besides production figures and reserves, a clear view of the availabilty of natural gas for fertilizer projects. Compared with the other countries, it is relatively high in Venezuela and indicates its high industrial development.

About 970 m³ of methane, of which 310 m³ are used as fuel, are necessary for the production of one metric ton of ammonia. Impurities such as $H_2S$ and $CO_2$ have to be eliminated by purification processes.

A large part of the Saudi Arabian natural gas production shown in table 3 below is still flared and only small quantities are collected. Reinjection is being considered for the Abqaiq, Ain Dar and Shedgum gas fields. With the building of pipelines, already planned for the Abqaiq and Shedgum gas fields, the situation with regard to flaring will be improved. At the existing pipeline near Dammam, however, some natural gas is collected.

*Table 1*

NATURAL GAS PRODUCTION, RESERVES AND UTILIZATION

| | *Iran* | *Kuwait* | *Libya* | *Nigeria* | *Saudi Arabia* | *Venezuela* |
|---|---|---|---|---|---|---|
| Daily production (1,000,000 m³) ...... | 42 | 33.5 | 21.6 | 6.6 | 27.7 | 112.6 |
| Yearly production (1,000,000 m³) ...... | 15,330 | 12,227 | 7,800 | 2,376 | 10,710 | 41,084 |
| Daily production, 1975 estimated (1,000,000 m³) ...... | 92 | 51 | 65 | 52 | 42 | 131 |
| Reserves (1,000,000 m³) ...... | 1,840,000[a] | 934,000[a] | 350,000 | 2,500,000 | 123,000 | 2,300,000 |
| Utilization in 1966 (percentages) ....... | 10 | 23 | 0 | 8 | 6.4 | 81 |
| Utilization in 1975 (percentage) ........ | 84 | 100 | 10 | 10 | 10 | 99 |

a At the end of 1961.

*Table 2*

GAS ANALYSIS OF SAUDI ARABIAN FIELDS
*(In volume percentage)*

| | *Abqaiq* | *Ain Dar* | *Shedgum* | *Uthmaniyah* | *Damman* |
|---|---|---|---|---|---|
| $H_2S$ | 2.80 | 1.60 | 1.60 | 1.50 | 1.55 |
| $CO_2$ | 9.20 | 10.13 | 10.13 | 8.88 | 10.75 |
| $C_1$ | 62.24 | 59.29 | 59.29 | 55.55 | 73.02 |
| $C_2$ | 15.07 | 16.99 | 16.99 | 17.95 | 3.87 |
| $C_3$ | 6.64 | 7.85 | 7.85 | 9.76 | 1.08 |
| i-$C_4$ | 0.72 | 0.65 | 0.65 | 0.72 | 0.30 |
| n-$C_4$ | 1.68 | 1.97 | 1.97 | 3.77 | 0.49 |
| i-$C_5$ | 0.53 | 0.36 | 0.36 | 0.48 | 0.15 |
| n-$C_5$ | 0.59 | 0.51 | 0.51 | 0.68 | 0.15 |
| $C_6$ | 0.53 | 0.22 | 0.22 | 0.36 | 0.30 |
| $C_7$ | — | — | — | 0.10 | — |
| $N_2$ | — | 0.43 | 0.43 | 0.25 | 8.34 |
| TOTAL | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |

*Table 3*

PRODUCTION AND CONSUMPTION OF SAUDI ARABIAN FIELDS
*(In million of m³)*

| | *Abqaiq* | *Ain Dar* | *Shedgum* | *Uthmaniyah* | *Damman* |
|---|---|---|---|---|---|
| Daily production . . | 11 | 5.2 | 1.6 | 5.2 | 0.3 |
| 1970 daily production . . . . . . . . | 14 | 5.9 | 4.1 | 6 | 0.3 |
| Present daily consumption . . . . . . . | 1.3 | 0.1 | 0.04 | 0.06 | 0.16 |
| Estimated total production from field . . . . . . . . . . . | 56,583 | 28,547 | 7,307 | 16,624 | 5,636 |

In Libya important associated natural gas fields of which the composition is known are shown in the following table:

*Table 4*

GAS ANALYSIS AND DAILY PRODUCTION OF LIBYAN FIELDS

| | *Amal* | *Dahra* | *Hofra* |
|---|---|---|---|
| *Gas analysis in volume percentage* | | | |
| $H_2S$ | — | 0.05 | 0.37 |
| $CO_2$ | 1.14 | 2.00 | 1.30 |
| $C_1$ | 61.60 | 73.00 | 71.00 |
| $C_2$ | 14.40 | 9.45 | 10.90 |
| $C_3$ | 11.00 | 5.82 | 5.30 |
| i-$C_4$ | 1.83 | 1.03 | 1.60 |
| n-$C_4$ | 3.70 | 2.70 | 2.52 |
| $C_5$ | 2.64 | 3.30 | 4.70 |
| $N_2$ | 3.33 | 1.02 | 1.20 |
| *Daily production in millions of $m^3$* | 1.1 | 6.0 | 4.0 |

The production at present is flared; only at the central field is some natural gas stored. Reinjection is not being considered. It is expected that by 1970 these three fields will be served by natural gas pipelines, two of which are in the planning stage.

Analysis, daily production and consumption of associated natural gas produced in Venezuela are given in table 5 below.

*Table 5*

GAS ANALYSIS, PRODUCTION AND CONSUMPTION OF VENEZUELAN FIELDS

| | *Maracaibo* | *Barcelona* | *Maturin* |
|---|---|---|---|
| *Gas analysis in volume percentage* | | | |
| $H_2S$ | 0.0 | 10 ppm | 0.0 |
| $CO_2$ | 0.2 | 3.80 | 31.5 |
| $C_1$ | 82.0 | 71.0 | 67.3 |
| $C_2$ | 10.0 | 15.39 | 0.5 |
| $C_3$ | 3.7 | 7.49 | 0.3 |
| i-$C_4$ | 0.6 | 0.82 | 0.2 |
| n-$C_4$ | 1.3 | 1.02 | 0.2 |
| $C_5$ | 0.7 | 0.48 | 0.0 |
| $N_2$ | 1.5 | — | 0.0 |
| *Production and consumption in millions of $m^3$* | | | |
| Amount flared (daily) | 34.8 | 6.4 | 3.1 |
| Daily production .... | 44.7 | 12.8 | 3.9 |
| Present daily consumption .... | 9.9 | 6.4 | 0.8 |

The production figures indicate that natural gas is collected; reinjection is under consideration.

### PRICE OF NATURAL GAS

Costs for the exploration and production of natural gas differ according to local conditions and comprise the costs of collection, cleaning, compression and transport. Generally, costs are lower for associated gas.

Processes on which the technical costs are calculated are as follows:

1. Drilling, production, operation;
2. Piping from well head to collection point;
3. Piping from collection point to fertilizer plant;
4. Compression (three stages, from atmospheric or lower pressure if necessary);
5. Removal of $H_2S$ and/or $CO_2$ etc.

Costs of administration and taxes have to be added to the technical costs in several of the countries.

Figures obtained for the six countries from replies to a questionnaire or from other sources of information are shown in table 6 below.

*Table 6*

PRICE OF NATURAL GAS

| | *Cents/1,000 ft³* | *Dollars/1,000 m³* |
|---|---|---|
| Iran | 5 –10 | 1.75–3.73 |
| Kuwait | 5 | 1.75 |
| Libya | 2 | 0.74 |
| Nigeria | 0.4– 0.6 | 0.14–0.20 |
| Saudi Arabia | 5 | 1.75 |
| Venezuela | 8 –10 | 2.96–3.73 |

In Libya, at the time of the investigation, no natural gas was sold. The price of natural gas at the well-head is estimated at 2 cents per 1,000 $ft^3$; by adding the cost of transport and royalties, an end price of 4–5 cents per 1,000 $ft^3$ may be deduced.

For Nigeria, replies to the questionnaire indicated that prices are usually negotiated by prospective users. Price at the well-head is established jointly by the Government and the petroleum enterprises. The indicated price of 14–20 cents per 1,000 $m^3$ might not be realistic taking into consideration the investment necessary. The price of the gas will probably be about 5 cents per 1,000 $ft^3$.

In Saudi Arabia the price of natural gas amounts to 5 cents per 1,000 $ft^3$ Dammam. This figure was determined by the Government in negotiation with Petromin and ARAMCO.

# II. Infrastructure, utilities and labour supply

INFORMATION ON existing infrastructure, utilities and labour supply in the six countries is presented below under the following headings: port facilities, natural gas pipelines, electrical power supply, water and steam supply, gas liquefaction plants, refineries, ammonia and petrochemical plants and labour supply.

### PORT FACILITIES

Taking into consideration the stage of development of the six countries, sufficient port facilities are available for importing the machinery required for the construction of ammonia fertilizer plants and for the export by shipment of their products. Saudi Arabia has only one deep seaport with extensive loading facilities, while Venezuela possesses eight transatlantic ports and eighteen petroleum terminals.

*Iran:* The main port is Khurramshahr near Abadan. Other ports on the Persian Gulf are Bandar Shahpur and Bandar Abbas. Port facilities are being improved and expanded under the development plan. Most of the import and export through Khurramshahr are directed to Bandar Shahpur.

*Kuwait:* The major port is Kuwait. A new port is being constructed at Shuaibah, 27 miles south of Kuwait city. The Kuwait oil company maintains a port at Mina Al-Ahmadi for handling bulk petroleum shipments. This is the world's largest crude oil terminal. The other oil loading ports are Mina Abdulla and Mina Saud.

*Nigeria:* Lagos and Port Harcourt handle almost 90 per cent of Nigeria's foreign trade. Other ports include Warri and Burutu (on the Niger delta), and some smaller ports serving a limited hinterland.

### NATURAL GAS PIPELINES

The situation in the six countries differs considerably regarding pipelines. Venezuela has an extensive pipeline system; Iran is constructing a north-south connexion; Saudi Arabia and Nigeria have relatively short lines; in Libya pipelines are still in the planning stage.

### ELECTRICAL POWER SUPPLY

The availability of electrical power is another factor to be considered in evaluating the advisability of building large industrial complexes. Utilization of gas turbines would be a relatively easy method of obtaining the necessary power independently of local and other considerations that might influence the choice of a plant site. A limited quantity of electric power, however, is available in all six countries. Costs vary; for instance, in Saudi Arabia electric power costs from 0.7 to 2.8 cents per kWh according to location.

## Water and steam supply

The required amount of water or steam is available in all six countries. Libya, however, claims to have only a very limited supply. The price varies according to location; for instance, in Venezuela water costs 20 cents per 1,000 gallons and steam $ 1.34 per metric ton. It will be necessary to use air and sea-water cooling extensively for almost all locations.

## Gas liquefaction plants

These plants are used to provide liquid natural gas for transport by ship to overseas customers. However, the provision of such plants and refineries would in many instances be the first step towards building up the industrial potential of a country, and such installations, with their potential of skilled labour and raw material, would attract further industrial projects.

Gas liquefaction plants are planned for Iran, Libya and Nigeria.

## Refineries

Refineries exist in all six countries. Some, however, are only of local importance or small capacity. Large modern refineries equipped with petro-chemical facilities are in operation in Iran, Kuwait, Saudi Arabia and Venezuela.

## Ammonia and petrochemical plants

Ammonia plants exist in Kuwait and Venezuela, and others are planned for Iran, Libya, Saudi Arabia and Venezuela.

Petrochemical plants are planned for Iran [polyvinyl chloride (PVC), polyethylene, detergent feedstocks etc.] and for Kuwait, Saudi Arabia and Venezuela (PVC, polyethylene and the like).

## Labour supply

The labour supply in each of the six countries may prove to be a difficult problem as far as local and specific requirements are concerned. Compared with the four other countries, Iran (200,000 industrial workers) and Venezuela, where numerous types of industrial production are in operation, have good labour resources.

The cost of unskilled labour is relatively low in Saudi Arabia (approximately $ 80 per month), Libya (approximately $ 40 per month), and Nigeria (approximately $ 30 per month). It is higher in the more developed countries, such as Venezuela (approximately $ 160 per month). Skilled labour is cheaper if it is locally recruited. Engineers in Saudi Arabia, for instance, are paid at international rates.

## THE STATE OF UTILITIES AND THE LABOUR FORCE IN THE SIX COUNTRIES

### *Iran*

*Natural gas pipelines:* Two natural gas pipelines are being constructed in Iran. The larger line, with a capacity of 15,000 million m³ per year will run from the coastal fields to central Iran, where it will divide into two branches. One pipeline will serve the Isfahan steel complex, which is in the planning stage, and the other will continue to the Soviet Union where the gas will be sold. The smaller line will supply Tehran with gas from the Sarajeh gas field. The larger line will extend to the Soviet border and will consist of approximately 1,100 miles of 22- and 24-inch pipe. More than half of this line, including seven compression stations, is being constructed by the Soviet Union. The shorter line, approximately 100 miles long, is being built with 20-inch piping.
*Electrical power supply:* The production capacity in 1967 was 23 million kilowatts.
*Refineries:* The refinery at Abadan has a capacity of 430,000 b/d with the following downstream processing facilities:

| | *b/d* |
|---|---|
| Catalytic cracking | 32,000 |
| Catalytic reforming | 19,000 |
| Thermal reforming | 44,000 |
| Hydrogen treating | 19,000 |
| Alkylation | 9,000 |

Besides several small refineries of local importance, a new refinery is planned at Shiraz (70,000 b/d). Near Tehran a new refinery is under construction (85,000 b/d) equipped with a hydro-cracking unit, catalytic reformer and visbreaker.
*Other plants:* A plant to produce sulphur and liquefied petroleum gas (LPG) is planned for Kharg Island. In addition, the Allied Chemical Corporation and an Iranian Government organization, the National Petrochemical Company, are jointly planning to build a chemical complex for the production of ammonia, sulphur, urea and mixed fertilizers. Capital expenditure will be in the 100-million-dollar range. New plants of the Abadan Petrochemical Company are being constructed for the production of PVC, polyethylene and detergent feedstocks.

### *Kuwait*

*Gas liquefaction plants:* Natural gas processing and refinery gas processing are relatively advanced. The LPG project at the Kuwait Oil Company refinery has been expanded to include a plant capable of processing and storing liquid propane at the rate of 6,800 b/d and an equal amount of liquid butane.
*Refineries:* Two oil refineries exist. In the third projected for 1968, with a capacity of 95,000 b/d crude oil, natural gas will be used to provide most of the hydrogen required for all the hydro-treating processes (catalytic reforming, hydro-cracking, and so on). Some consideration has also been given to a Benzene-Toluene-Xylene (BTX) operation by the Kuwait Oil Company which operates a refinery of 250,000 b/d.

*Kuwait Chemical Fertilizer Company:* The Kuwait Government has a 60 per cent share in the plant and Gulf Oil and British Petroleum a 20 per cent share each. The plant has the following capacities:

| | *t/d* |
|---|---|
| Ammonia | 400 |
| Sulphuric acid | 400 |
| Ammonium sulphate | 500 |
| Urea | 500 |

A plant with similar capacities is planned for a joint Kuwait Government and Japanese interest ownership.

## *Libya*

*Port facilities:* The major ports are Tripoli and Benghazi. Oil loading ports are Marsa el Brega, Es Sider, and Ras Lanuf. A further oil loading port, Misrata, will probably be developed in the near future.
*Natural gas pipelines:* The following pipelines are planned: from Zelten to Marsa el Brega and from Dahra to Es Sider.
*Electrical power supply:* A power station owned by the Government.
*Water supply:* Fresh water is in very short supply.
*Gas liquefaction plant:* Esso plans to build a large natural gas liquefaction plant at Marsa el Brega, which should be in operation by late 1968. There are contracts with Ente Nazionale di Idrocarburi (ENI) to supply 235 million $ft^3$ (6.6 million $m^3$) of liquefied natural gas (LNG)/day and 111 million $ft^3$ (3.1 million $m^3$) LNG/day to Spain.
*Refineries:* There are two refineries. Esso Sirte has a 9,000-b/d plant at Marsa el Brega which includes a 2,000-b/d catalytic reformer and a 3,000-b/d hydro-desulphurization unit. Oasis has a small field plant of 2,400 b/d at Dahra. This is intended for coast use at the Waha field.
*Petrochemical plant:* A petrochemical plant is in the planning stage. Continental Oil plans to produce ammonia from natural gas at the Oasis field at Dahra. This ammonia would then be shipped to European markets.
*Labour supply:* Unskilled labour only is available locally, at a rate of $ 1.20 per day. The oil companies, however, have trained personnel.

## *Nigeria*

*Port facilities:* Koko port has deep-sea commercial facilities.
*Natural gas pipelines:* The possibility of a pipeline from the Ughelli field in midwestern Nigeria to Lagos (approximately 260 miles) has been investigated, but is not proposed for construction in the near future owing to large capital requirements and high operating costs. A pipeline is planned from the Afam and Oloibiri fields to nearby industrial plants, and there is a pipeline from Aba to Imo.
*Electrical power supply:* Electricity is available in considerable quantities at prices that vary according to location.

*Gas liquefaction plant:* A gas liquefaction plant is planned. Discussions are under way between the Nigerian Government, the British Gas Council and Conch Methane Service on the possibility of exporting LNG to the United Kingdom.

*Refinery:* A new refinery with a capacity of approximately 40,000 b/d is located at Alesa-Eleme near Port Harcourt.

*Labour supply:* The cost of unskilled labour is $ 360 per year and of skilled labour $ 720 per year. Replies to the questionnaire (24 September 1966) indicated that in the categories of scientist, engineer, accountant and skilled mechanic, labour is readily available.

## *Saudi Arabia*

*Port facilities:* Dammam port consists of three piers and has a total capacity of 300,000 tons per year.

*Electrical power supply:* The Dammam Electric Supply Company operates a 6,000-kW gas turbine; another of the same capacity is being erected. A third turbine unit of 24,000 kW is out to tender. The price of electric power for industrial purposes is 2.8 cents per kWh.

*Water and steam supply:* In Dammam fresh water will be obtained from an underground source at a depth of 300—450 ft. Solid content is 2,000—3,000 ppm; (pH: 7). Steam would be produced by a plant boiler.

*Refineries:* The Arabian American Oil Company (ARAMCO) owns a refinery with 301,000-b/d production at Ras Tanura with facilities for thermal cracking, catalytic reforming, hydrogen treating and alkylation. There are two more refineries in the planning stage at Jidda on the Red Sea (12,000 b/d) and Riyadh (20,000 b/d).

*Petrochemical plants:* The Saudi Arabian Fertilizer Company intends to construct at Dammam a petrochemical plant with the following capacities:

| | *t/d* |
|---|---|
| Ammonia | 600 |
| Sulphur | 35 |
| Urea | 1,025 |

The feed stock will be sour natural gas from the Abqaiq field. Two PVC plants, one with a 60,000-tons-per-year capacity and another with Pakistani interests are planned at Dammam. No LPG or LNG plants are projected for the time being, however.

*Labour costs:* A survey on salaries and wages of various personnel is given in table 7 below. Allowances (holiday, sickness, pension) add a further 22 to 30 per cent to the labour cost.

*Table 7*

LABOUR COSTS IN SAUDI ARABIA

| | *Saudi riyals (SR)[a] per month* |
|---|---|
| Unskilled labour | 300– 360 |
| Semi-skilled labour | 360– 600 |
| Craftsmen | |
| Skilled labourers | 600–1,000 |
| Drivers | 300 |
| Heavy-equipment labourers | 600–1,000 |
| Welders | 500–1,000 |
| ARAMCO steel-pipe welders | 1,944–2,970 |
| Employees | |
| Office staff | 800–1,000 |
| Accountants | 1,000–2,000 |
| Foreign recruitment | |
| Engineers | 2,250 + |
| Technicians | 1,575 + |
| Supervisors | 1,350 + |

[a] $ 1.00 = SR 4.50.

### *Venezuela*

*Port facilities:* Port facilities have a capacity of 4.5 million metric tons per year. There are eight transatlantic ports and eighteen petroleum terminals.

*Natural gas pipelines:* Numerous gas pipelines of a total length of 2,466 kilometres are in existence. Three new lines are planned, as for example, a natural gas pipeline of 28-inch (72-cm) diameter at a pressure of 700 psi (48 atm).

*Electrical power supply:* A power supply of 80,000 kW is reported. As of 1968, hydroelectric power up to 640,000 kW will be available.

The costs per kWh (over 100,000 kWh per month) are:

| | |
|---|---|
| At El Tablazo (Lake Maracaibo) | 0.7 cents |
| At Puerto La Cruz | 0.67 cents |
| In the Middle States | 0.8 cents |

*Water and steam supply:* Fresh water is available at a cost of 20 cents per 1,000 gallons and steam at $ 1.34 per metric ton.

*Petrochemical plants:* Specific plant locations have been established for the Maracaibo area in the west of the country. A complete report regarding the characteristics of this region is available from the Instituto Venezolano de Petroquimica. Table 8 below shows the petrochemical installations and expansion plans which must be examined before considering a new ammonia plant.

*Table 8*

PETROCHEMICAL INSTALLATIONS AND EXPANSION PLANS IN VENEZUELA

| | t/year |
|---|---|
| *Moron* | |
| Present production | |
| Fertilizers | 30,000 |
| Caustic soda (electrolytic) | 11,000 |
| Explosives | 6,000 |
| Expansion plans (estimates) | |
| Fertilizers | 165,000 |
| Explosives (dynamite) | 24,000 |
| Aluminium sulphate and refrigerants | 10,000 |
| Dodecyl benzene | 10,000 |
| *El Tablazo* | |
| Expansion plans (estimates) | |
| Ethylene | 150,000 |
| Propylene | 85,000 |
| Polyethylene | 50,000 |
| PVC | 50,000 |
| Synthetic rubber | 30,000 |
| Ammonia | 300,000 |
| Urea (N) | 500,000 |
| Caustic soda (electrolytic) | 40,000 |
| *Bajo Grande (Maracaibo)* | |
| Expansion plans (estimates) | |
| Ammonia | 540,000 |

*Labour supply:* Labour is available in all categories. Costs for unskilled labour are \$ 4 to \$ 5 per day and those for skilled mechanics \$ 9 to \$ 10 per day. From 20 to 40 per cent supplementary benefits are payable according to area.

# III. Customs duty and taxes

THE SITUATION regarding customs duty and taxes in the six selected countries can generally be regarded as being favourable to industrial investment.

Three situations exist regarding duty payable:

1. Duty-free entry;
2. Duty-free entry under certain conditions; for example, if the goods concerned are not available in the country, importation is specially authorized;
3. Liability to duty of a specific range and limit.

There is no export duty on fertilizers in the fertilizer-producing countries.

Taxes on natural gas are charged according to government regulations, which are based on sale prices, exploitation rights, ground space etc. Company income is taxed at the rate of from 5 to 50 per cent and there are also taxes on profits. Personal income tax varies in the different countries according to whether the person concerned is a resident, a citizen or an alien, or a manual or non-manual worker.

### IRAN

Import duty and commercial profit taxes are imposed on imports. Import duties are lower on machinery and equipment than on consumer goods and lower still on essential products. No import duties or commercial profit taxes are levied on direct imports by the oil consortium companies or by other companies operating in Iran.

Companies are taxed at the rate of from 12 per cent on earnings of Iranian rials (IR)[2] of 100,000 to 34 per cent on earnings of IR 2 million and up to 50 per cent on earnings of over IR 6 million.

### KUWAIT

Four per cent *ad valorem* duty is payable on all imports. Items imported by oil companies for operations are exempt.

Company taxes are assessed on a sliding percentage scale ranging from 5 to 50 per cent, but there is no personal income tax.

### LIBYA

Nearly all imports are subject to customs duty. Duty on essential goods is low. Most imports for the use of petroleum companies and their contractors are exempt from import duty.

---

[2] $ 1.00 = IR 75.75.

There is no federal tax. Taxes are levied separately by the provincial administrations of Tripolitania, Cyrenaica and Fezzan; those on natural gas are being negotiated with the Government. Business profits are subject to a 10 per cent income tax in all three provinces. In Tripolitania a 3 per cent municipal tax is added, plus an additional 4.85 per cent of the total tax due, to cover collection. All personal income is liable to tax, manual workers at the rate of 5 per cent and others at 8 per cent.

### Nigeria

Imports for industry are exempt from duty if the materials are not available locally. At present there is no export duty on finished fertilizers or fertilizer intermediates because there is no production. However, should production be developed, reasonable duties may be imposed. There is no excise tax on natural gas, but a royalty of 10 per cent of the sales price is imposed. There are established scales of income tax for corporations and for citizens and non-citizens, and industrial plants and buildings are liable for tax.

### Saudi Arabia

Imports of plant and raw materials for production are sometimes exempt from customs duty if they are approved by the Ministry of Commerce and Industry, but no export duty is imposed on finished fertilizers or fertilizer intermediates.

No excise tax is payable on natural gas. Company income tax is payable as follows:

20 per cent on profits up to SR 100,000
30 per cent on profits from SR 100,000 to 500,000
35 per cent on profits from SR 500,000 to 1,000,000
40 per cent on profits over SR 1,000,000

Property (industrial or private) is exempt from tax except for Saudi Arabian nationals on whom a 2.5 per cent *zakat* tax (alms tax) is levied. Under certain circumstances arrangements may be made through the Ministry of Commerce and Industry for an income-tax-free period of up to a maximum of five years, depending on the nature of the project. No personal income tax is imposed on citizens. Non-citizens are taxed on personal income at the following rates:

5 per cent on annual income of SR 6,000 to 19,999
10 per cent on annual income of SR 20,000 to 49,999
20 per cent on annual income of SR 50,000 and above

In addition all income is subject to a 2 per cent road tax.

### Venezuela

Neither equipment nor industrial machinery is liable for import duty, and finished fertilizers are also exempt from export duty.

There is an excise tax on natural gas comprising a superficial tax of $ 1 to $ 6 per hectare per year and an exploitation tax of 16 per cent but limited to 2/3 of one per cent net value of the natural gas production. Hydrocarbon products are taxed either according to volume or to heating value. New investors are temporarily exempt from corporate income tax (in most cases for five years), while the complementary progressive tax on industrial income ranges from 5 per cent to a maximum of 45 per cent on an income of over 28 million Bolivars (B).[3] Personal income tax is payable at the same rate by citizens and aliens alike (10 per cent maximum). The basic tax on wages and salaries is 3 per cent for residents and 10 per cent for non-residents. Residents are also subject to a progressive complementary tax ranging from 2 per cent on the first B 8,000 of earned income to 45 per cent on income over B 28 million.

[3] $ 1.00 = B 4.50.

# IV. Investment policies and capital availability

GOVERNMENTS fulfil two principal functions regarding investments in new industries: control and the granting of benefits, privileges and the like. The control function can be carried out regarding authorization for investment, building etc., and capital restrictions and regulations.

### AUTHORIZATION

In Iran authorization for investment in new industries is given by the Government after licences have been obtained from the Ministry of Economy and from the Foreign Investment Control Board.

In Libya and Nigeria government permission is necessary before an investment can be made.

In Saudi Arabia investment in economic development projects has to be approved by the Ministry of Commerce and Industry; further licences required are given by Petromin, a government organization responsible for the establishment of new industries.

In Venezuela a permit for investment in a fertilizer plant is given by the Instituto Venezolano de Petroquimica. For the construction of a plant it is necessary to obtain a permit from the Ministry of Sanitation and Public Works.

### CAPITAL REGULATIONS

As far as capital regulations are concerned, Kuwait requires a foreign investor to have a Kuwaiti partner or a Kuwaiti acting agent as a representative.

In Libya foreign ownership of an undertaking is limited to a maximum of 49 per cent, as 51 per cent must by Libyan-owned. However, for the conversion of dividends or profits into other currencies, negotiation with the Government or special permission is necessary.

In Nigeria there are no restrictions on foreign ownership of industrial enterprises. For the conversion of dividends, the approval of the Exchange Control Office must be obtained.

Saudi Arabia allows a 75 per cent foreign capital control of investments and imposes no further restrictions on foreign ownership of industrial enterprises, not even on the conversion of dividends or profits into other currencies.

In Venezuela there are no restrictions on the ownership of industrial enterprises. As profits can be repatriated without restriction, foreign capital is fully guaranteed.

### Benefits

Government aid in attracting foreign investment for development projects may take the form of import authorizations (Iran under its third plan).

Libya gives privileges and guarantees to the foreign investor, such as exemption from duties and taxes for specific periods.

Saudi Arabia allows unrestricted payment of interest on foreign capital. However, service fees of from 5 to 7 per cent are charged.

Venezuela exempts investors from income tax and customs duty, gives equity in respect of interest rates with domestic capital and encourages the formation of joint capital ventures with state agencies.

### Capital availability

Libya claims that there is private and government capital readily available for building plants.

Nigeria has government capital amounting to approximately £1 million available for a fertilizer project.

In Saudi Arabia, Petromin, a government organization, provides capital for investment. It also participates in joint ventures with foreign investors.

In Venezuela capital is available through government agencies on a shared basis. The interest rates range from 6 to 10 per cent.

# V. The fertilizer industry in the six selected countries: at present, planned and potential

THE SIX SELECTED countries under review can be broadly divided into two groups. The first consists of those countries where no nitrogen fertilizer industry has so far been installed—Libya and Nigeria. The second group includes the countries in which the nitrogen industry has already been established, although some have only installed small plants. This group includes Iran, Kuwait, Saudi Arabia and Venezuela.

All the six countries offer excellent locations and cheap natural gas for nitrogen fertilizer development.

## COUNTRIES WITH NO NITROGEN FERTILIZER INDUSTRY (LIBYA AND NIGERIA)

Recently, there has been a great deal of interest shown by international companies in the erection of large ammonia plants in Libya, where conditions are expected to be conducive to such projects. Although Nigeria, in view of its vast oil and natural gas resources, was considered by several international firms as suitable for the building of an ammonia plant, interest seems to have lagged.

## COUNTRIES WITH EXISTING NITROGEN FERTILIZER PLANTS (IRAN, KUWAIT, SAUDI ARABIA, VENEZUELA)

### *Iran*

Iran has two fertilizer plants. A small unit at Shiraz with an annual capacity of 27,200 tons of nitrogen has been in existence for several years. The National Iranian Petrochemical Company, in partnership with Allied Chemical of the United States, is at present completing the construction of a project at Bandar Shahpur. The present ammonia capacity is 1,000 metric tons per day, and there is the possibility of installing another two streams, each of 1,000 tons capacity per day.

### *Kuwait*

The Kuwait Chemical Fertilizer Company was inaugurated on 19 February 1967. The annual capacity of the plant is 105,000 metric tons of nitrogen that is converted to ammonium sulphate and urea. The plant has already gone into production and there have been exports to nearby countries. Kuwait is considering the installation of a plant of a capacity of 1,000 metric tons per day of ammonia. This plant would be adjacent to the present complex so that the existing gas line could be used for bringing in additional raw material.

*Saudi Arabia*

The Saudi Arabian Fertilizer Company (SAFCO) is a joint stock company in which 51 per cent is owned by Petromin (Petroleum Ministry) and 49 per cent by share subscription. The capacity of the plant is 600 metric tons per day of ammonia that is converted to 1,025 metric tons per day of urea. The process requires 30 million $ft^3$ of natural gas per day. The total capital of the company is 100 million Saudi rials. It has been reported that the project began production in 1968.

In this project, Petromin has secured the co-operation of two United States companies for a period of twenty years. The Occidental Petroleum Corporation is undertaking the operation of the plant and the products will be sold through the International Ore and Fertilizer Corporation. Occidental will be in charge of training SAFCO's personnel.

A proposal to put up another project of a capacity of 1,000 metric tons per day of ammonia is said to be under consideration.

*Venezuela*

Venezuela has now in production a nitrogen fertilizer plant at Moron with a capacity of 27,000 tons of nitrogen per year. This project is owned by the Instituto Venezolano de Petroquimica (IVP). An expansion of this plant has been under review for some time.

IVP has made feasibility studies for a 1,000-metric-tons-per-day plant in the Maracaibo region. Various international companies have also been interested in setting up large ammonia projects in this region.

# VI. Production costs of ammonia and solid nitrogen fertilizers

THIS CHAPTER presents some typical costs and production costs for ammonia and solid nitrogen fertilizers in countries rich in natural gas (tables 9 to 12 below). A single-stream unit for 1,000 metric tons per day is chosen to illustrate the most economic production of ammonia. Urea is selected as the solid nitrogen fertilizer and the costs for a single-stream unit for 1,000 metric tons per day are shown. Capital cost and costs of production are also given for a combined 1,000-metric-tons-per-day ammonia unit and two urea units of 900-metric-tons capacity each. This is to convert all the ammonia to urea and to demonstrate the advantages of an integrated unit. Two urea units are also chosen, because a single-stream urea plant of more than 1,500 metric tons per day has not been reported, and, since 1,800 metric tons of urea have to be produced, this has been split into two units. Data on capital investment and requirements, as well as operating costs, are given in table 9 below.

*Table 9*

PRODUCTION COSTS FOR A GRASS ROOTS AMMONIA PLANT[a]

| | Millions of $ |
|---|---|
| *Capital investment*[b] | |
| Battery limits—Gulf USA basis including royalties and catalyst charge | 14 |
| Allowance for ex-US location and erection including freight but no customs duty[c] | 6 |
| Off-site and site preparation costs[d] | 6 |
| Spare parts, maintenance tools, warehouse and operating materials | 1 |
| Spare catalyst and centrifugal compressor spare parts | 1 |
| Total fixed capital | 28 |
| *Other capital requirements* | |
| Operating capital (based on 90 day accounts receivable, bank financed) | (3) |
| Cost of capital during construction period and allowance for training and start-up costs[e] | 2 |
| Total invested capital | 30 |

*Table 9 (continued)*

| *Operating costs* | *$/metric ton* |
|---|---|
| **A.** *Raw materials and utilities* | |
| Natural gas (40,000 ft³ at 10 cents/1,000 ft³) .......... | 4.00 |
| Power (50 kWh/t at 0.8 cents/kWh) ................ | 0.40 |
| Water: boiler feed (500 gal/t at 40 cents/1,000 gal) .... | 0.20 |
| cooling water circulation (60,000 gal/t at 2 cents/1,000 gal) .............................. | 1.20 |
| Credit for carbon dioxide to 330,000 metric tons/year urea plant at $ 1/t $CO_2$ utilized .................. | (0.70) |
| **B.** *Operations* | |
| Operating labour 6 men/shift at $2/hour (Foreign operation) .................................. | 0.30 |
| Maintenance labour (1½ per cent battery limits + ½ per cent miscellaneous off sites/year) ........... | 1.00 |
| Maintenance materials .......................... | 1.00 |
| Catalyst and operating materials .................... | 0.60 |
| Supervision, general plant overheads, labour benefits... | 1.30 |
| **C.** *Capital charges* (excluding interest on capital) | |
| Depreciation at 10 per cent/year on $28 million.... | 8.00[f] |
| Taxes, insurance, miscellaneous 2 per cent/year on $28 million .................................. | 1.60 |
| Plant production cost per metric ton ............ | $ 18.90 |
| Plant production cost per short ton ............. | $ 17.10 |

a Natural gas at 600 psig, centrifugal compressors, single stream, 1,000 metric tons/stream day, 350,000 metric tons/year. This is a mature plant rate. It should be possible to reach this rate during the second ,ear of operations.

b Seacoast plant site location. No capital investment shown for land purchase, extraordinary plant site development cost or road or port development, colony housing, off-site power generation, or raw water development.

c The allowance for extra capital requirements will vary widely. It is less than 10 per cent above US battery limits cost for Venezuela, and could be as much as 50 per cent higher in more remote developing areas of the world.

d Off-site costs include buildings, warehouses and shops, cooling water, utilities and distribution, fencing. site-drainage and normal effluent disposal, and on-site roads and railways etc. They also include $ 1.5 million for 30,000 metric tons atmospheric, anhydrous ammonia storage single wall, insulated tank on piling, with associated equipment such as heat loss (holding) compressors, high-capacity loading pumps, high-head pumps, vaporizer and piping. No marine terminal is included since this is assumed to be part of the urea plant installation.

e These capital requirements may be capitalized and depreciated, or charged directly as operating expenses, depending on the accounting policy of the individual company.

f Would be $ 5.30/metric ton at 15-year depreciation period against $ 8.00 for 10-year period.

*Table 10*

PRODUCTION COSTS FOR UREA PLANT[a]

| | Millions of $ |
|---|---|
| *Capital investment* (as part of, and incremental to, the ammonia plant complex referred to in table 9) | |
| Battery limits (including royalty and one large prilling tower: Gulf USA) | 8 |
| Allowance for ex-US location and erection, including freight but no customs duty[b] | 4 |
| Bulk storage (80,000 metric tons, dehumidified); high rate bulk loading, handling and conveying; marine dock | 4 |
| Other off-site facilities (integrated with ammonia plant), spare parts, warehousing materials, operating materials inventory | 2 |
| Total fixed capital | 18 |
| *Other capital requirements* | |
| Additional operating capital to that shown in table 9 (based on 90 day accounts receivable, bank financed) | (2) |
| Cost of capital during construction period and allowance for training and start-up expenses[c] | 1 |
| Total invested capital | 19 |

| *Operating costs* | $/metric ton |
|---|---|
| A. *Raw materials* | |
| Ammonia 0.58 t/t at $ 18.90/t (production cost) | 11.00 |
| Carbon dioxide 0.75 t/t at $ 1.00/t (credit ammonia cost) | 0.80 |
| B. *Utilities* | |
| Steam (low pressure) 3,000 lb./t at 40 cents/1,000 lb. | 1.20 |
| Power 180 kWh/t at 0.8 cent/kWh | 1.40 |
| Cooling water circulation 20° Δ T. 20,000 gal/t at 2 cents/1,000 gal | 0.40 |
| C. *Operations* | |
| Operating labour 6 men/shift at $ 2/hour (foreign operation) | 0.30 |
| Maintenance labour (2 per cent battery limits + 1 per cent miscellaneous off sites/year) | 1.00 |
| Operating materials and maintenance materials | 1.00 |
| Supervision, general plant overheads, labour benefits | 1.30 |

*Table 10 (continued)*

| | $/metric ton |
|---|---|
| D. *Capital charges* (excluding interest on capital) | |
| Depreciation at 10 per cent/year on $ 18 million ...... | 5.40[d] |
| Taxes, insurance, miscellaneous 2 per cent/year on $ 18 million ...... | 1.10 |
| Total production cost (bulk) per metric ton ...... | $ 24.90 |
| Total production cost (bulk) per short ton ........ | $ 22.50 |

a Total re-cycle, single stream, maximum 0.3 per cent biuret, prilled, 1,000 metric tons/stream day 330,000 metric tons/year. This is a mature plant rate and should be reached during the second year of operation

b The allowance for extra capital requirement for building plants outside the United States will vary considerably. It is less than 10 per cent of the US battery limits cost in Venezuela, but could be as much as 50 per cent higher in the more remote developing areas of the world.

c These capital requirements may be capitalized and depreciated or charged directly as operating expenses, depending on the accounting policy of the individual company.

d Would be $ 3.60/metric ton for urea plant if 15-year depreciation period used, vs. $ 5.40 for 10 years

*Note:* If bagged urea is required, add $ 1 million to capital investment for coating and bagging facilities that would include all auxiliary and automatic equipment. This would add about $ 5.00/metric ton for the product in bags and would include labour, depreciation, bags, and the like.

*Table 11*

RETURN ON INVESTED CAPITAL AND ESTIMATED PLANT PRICE

| | |
|---|---|
| A. *Return on invested capital*[a] | *Millions of $* |
| *Total invested capital* (including working capital) | |
| Ammonia plant ........ | 30 |
| Urea plant ........ | 19 |
| *Product sales at full capacity rate* | *Metric tons/year* |
| Ammonia ........ | 160,000 |
| Urea ........ | 330,000 |
| B. *Estimated f.o.b. plant price*[b] | *$/metric ton* |
| *Ammonia* | |
| Cost of production ........ | 18.90 |
| General administration and sales allowance ........ | 3.00 |
| 20 per cent pre-tax profit ammonia sales ........ | 17.10 |
| Total f.o.b. price per metric ton ........ | 39.00 |
| Total f.o.b. price per short ton ........ | 35.40 |
| *Urea* | |
| Cost of production ........ | 24.90 |
| General administration and sales allowance ........ | 4.00 |
| For 20 per cent ammonia plant return ........ | 9.90 |
| 20 per cent pre-tax profit urea sales ........ | 11.50 |
| Total f.o.b. price in bulk per metric ton ........ | 50.30 |
| Total f.o.b. price in bulk per short ton ........ | 45.50 |

a Excluding borrowed capital; transport and distribution capital investment and their costs.

b Allow $ 3/metric ton for ammonia and $ 4/metric ton for urea for general administration, sales and corporate overhead expenses on a wholesale basis. At 20 per cent pre-tax return on above investment.

*Table 12*

PRODUCTION COST FOR AN AMMONIA-UREA SINGLE PRODUCT PLANT[a] AND ESTIMATED SELLING PRICE OF BULK UREA

| | Millions of $ |
|---|---|
| **A.** *Production cost* | |
| *Capital investment*[b] | |
| Battery limits—Gulf USA basis, including royalties and initial catalyst charge ... | 28 |
| Allowance for erection ex-US location, including freight, but excluding duties; sea coast plant site; level, 50 acres, assumed but not included in capital ... | 12 |
| Bulk and bag urea storage (150,000 metric tons); dehumidified, high capacity handling, conveying and loading; marine dock and wharf facilities ... | 7 |
| Plant site preparation; off-site facilities including 30,000 t ammonia storage and integrated urea off-site facilities ... | 8 |
| Spare parts (with extensive centrifugal compressor spares), warehousing materials, operating materials and catalyst inventory, maintenance tools and minimum mobile equipment ... | 5 |
| Total fixed capital ... | 60 |
| *Other capital requirements* | |
| Operating capital (based on 90-day accounts receivable, bank financed) ... | (5) |
| Cost of capital during construction period of two years[c] ... | 2 |
| Allowance for training, pre-operating, and start-up expenses[c] ... | 2 |
| Total capital invested ... | 64 |
| *If required* | |
| Capital investment for coating and bagging with all auxiliary equipment ... | 2 |

| *Over-all ammonia—urea plant operating costs* | *Millions of $/year* | *$/metric ton urea* |
|---|---|---|
| Raw materials and utilities (no cost allowance for small $CO_2$ deficit) ... | 3.8 | 6.30 |
| Operating labour (developing country, 18 men/shift excluding bagging) ... | 0.3 | 0.50 |

*Table 12 (continued)*

| | *Millions of $/year* | *$/metric ton urea* |
|---|---|---|
| Labour for maintenance | 0.8 | 1.30 |
| Catalyst, operating and maintenance materials | 1.1 | 1.80 |
| Supervision, general plant overheads, labour benefits and overtime | 1.0 | 1.70 |
| Depreciation at 10 per cent/year on $ 60 million depreciable investment (would be $ 6.70/metric ton urea if 15 year depreciation period used vs. 10 years) | 6.0 | 10.00 |
| Taxes, insurance, miscellaneous at 2 per cent/year on $ 60 million investment | 1.2 | 2.00 |
| **Bulk urea—Total plant production cost** | **14.2** | **23.60** |

**B.** ***Estimated f.o.b. selling price of bulk urea***

| | | |
|---|---|---|
| 1. ***Plant production at 100 per cent capacity—600,000 tons/year*** | | |
| Plant production cost | 14.2 | 23.60 |
| General administration, corporate overheads, and sales cost allowance | 2.4 | 4.00 |
| 20 per cent pre-tax return on $ 64 million | 12.8 | 21.40 |
| Total (1) | 29.4 | 49.00 |
| 2. ***Plant production at 75 per cent capacity—450,000 metric tons/year*** | | |
| Plant production cost (assume same staff as for 100 per cent case) | 13.3 | 29.50 |
| General administration, corporate overheads, and sales cost allowance | 2.4 | 5.30 |
| 20 per cent pre-tax return on $ 64 million | 12.8 | 28.40 |
| Total (2) | 28.5 | 63.20 |

a Assume basic conditions of tables 9 and 10. Total product 600,000 metric tons/year prilled urea with 0.3 per cent maximum biuret content. Ammonia plant capacity—1000 tons/stream day, single stream. Two urea plants at 900 tons/stream day capacity each. One large prilling tower serving both units.

b No capital investment included for public utilities, public housing, public works, extensive transport or a distribution system. No estimate was made on plant required to supply small $CO_2$ deficit.

c These may be capitalized and depreciated or charged directly as operating expenses, depending on the accounting policy of the individual company.

*Note:* If bagged urea is required, $ 2 million to capital investment must be allowed for coating and bagging equipment, labour, depreciation, bags and the like. This would add about $ 5.00/t for urea in bags.

# VII. Marine transport of liquid anhydrous ammonia

THE EVER-INCREASING world requirements for nitrogen, a primary element in world food production. have brought about new and improved methods of making this important material available in the areas in need of it. The world shortage of this basic protein building block has long been recognized. It was not until early in 1964, however, as the result of a concept of W. R. Grace & Co., that the first ocean-going tanker specifically designed to transport ammonia was put into service, thus enabling this highly efficient form of nitrogen to be sent all over the world. It is interesting to note that although an ammonia tanker has basically the same design as a liquefied petroleum gas (LPG) carrier, the world's total LPG fleet in 1964 comprised only five fully refrigerated vessels that were of significant tonnage and were technically suited to carry ammonia.

With the successful application of the new concept, a very real effort has been made to provide economic sea routes as a measure of satisfying world nitrogen requirements, particularly those of the developing countries.

In any consideration of aspects of the ocean transport of ammonia, it is important to direct attention to the economic and time-saving benefits that can be obtained in those areas at present being investigated for the local production of fertilizer materials. It is now evident, through the stimulation and support of the United Nations agencies and, to a certain degree, through the interest of private undertakings also, that many of the developing nations have been, or are in the process of, planning for their fertilizer needs. They are, however, in need of guidance if the target of increased food production is to be achieved.

The pace of technical progress in the field of agricultural chemical manufacture is rapid and demanding, particularly that of ammonia production. But in spite of the wide publicity directed to these technological advances that have resulted in more economic methods of distribution, the question of the limited capital available to a developing country could be unduly stressed. To illustrate this point let us consider an ammonia plant designed to produce a quantity of ammonia sufficient to satisfy the immediate and short-term needs of a given country or area at a low annual volume, but which may develop excessively high costs of production when compared with the acknowledged low production costs involved in operating the new type of ammonia plants of the 1,000 to 1,500 t/day type. An equally negative effect occurs when a high-capacity plant is installed, but because of lack of markets, cannot work to capacity except over a long period. In the first of these undesirable situations, the high cost of the basic fertilizer ingredient produced in a plant of inferior economic level will have a negative effect on the entire fertilizer system of the area. In the second case, a high-capacity plant that is not utilized to its optimum will leave useful capital tied up in unproductive hardware.

After consideration of these aspects of the question, the next step is to examine the possibility of making this basic material, ammonia, available for local fertilizer manufacture in required quantities at a reasonable cost, by means of modern marine transport.

### Characteristics of marine ammonia carriers

The two primary elements in a system for the ocean transport of ammonia are the ocean tankers themselves and the on-shore receiving terminals. Both must be designed to meet the logistic demands made upon them, taking into consideration the geographical distances separating the source of supply from the point of consumption.

The vessels used in the existing service are basically of the LPG type, designed to carry refrigerated or semi-refrigerated cargoes. Their size, in terms of ammonia tonnage, currently ranges from 2,400 to 14,000 metric tons, and their speed from 10 to 16 knots. There is considerable difficulty and speculation with respect to the determination of the capacity-speed design factor for vessels of this type, because of the comparatively short period that this type of vessel has been in use, compared with oil tankers and dry cargo vessels, where statistics are readily available.

Some idea can be had of the characteristics of an ammonia tanker fleet and its utilization by an examination of the fleet of W. R. Grace & Co. of the United States. This company has a captive fleet with a capacity of carrying 32,000 tons of ammonia and can transport an additional 32,000 to 40,000 tons on a first option basis.

The basic characteristics of the vessels are indicated in table 13 below.

*Table 13*

Basic characteristics of selected ammonia tankers

| *Design* | *M. P. Grace* | *W. R. Grace* | *J. P. Grace* |
|---|---|---|---|
| Over-all length | 532 ft | 513 ft | 513 ft |
| Moulded beam | 76 ft 1 in | 69 ft 6 in | 69 ft 6 in |
| Moulded depth | 47 ft 1 in | 41 ft | 41 ft |
| Draft in sea-water | 26 ft | 24 ft 8 in | 24 ft 8 in |
| Speed | 16 knots | 16 knots | 16 knots |
| Deadweight tonnage (long tons) | 14,600 | 9,850 | 9,850 |
| International gross registered tonnage | 14,900 (estimated) | 10,001 | 10,001 |
| International net registered tonnage | 8,900 (estimated) | 6,061 | 6,061 |

In order to secure the maximum efficiency required in the carriage of ammonia cargoes, the tankers were designed to meet specific requirements. They were designed to carry either a complete cargo of anhydrous ammonia at a temperature of −28° F, or a complete cargo of propane at a temperature of −44° F, both cargoes being transported at an atmospheric pressure of essentially 0.5 to 2.5 pounds per square inch gauge (psig).

These tankers were built to the specifications of the American Bureau of Shipping at their highest class, + A 1 (E), with a special provision that the cargo holds are suitable for carrying LPG cargoes at atmospheric pressure and at temperatures as low as −50° F. They also meet the full requirements of the United States Coast Guard for the transport of cargoes of anhydrous ammonia and the LPGs—propane, butane and butadiene.

For specific details the M.V. *J. P. Grace* may be taken as an example. The hull is of welded standard ship's steel. The ammonia cargo is carried in four insulated individual cargo holds built of normalized carbon steel that has been specially heat-treated to improve its notch-toughness, that is, its ability to resist brittle fracture at temperatures between −20 and −50° F. Each hold is surrounded by a secondary barrier capable of containing the chilled cargo should a leak occur in one of the primary containers. A dry inert gas is circulated through the void that exists between the primary container and the secondary barrier. The empty space is maintained at approximately 0.5 psig with inert gas to prevent the infiltration of moist sea air into the environment surrounding the chilled cargo tanks.

The four holds have a combined capacity of 9,300 tons of anhydrous ammonia, that has a specific gravity of 0.68 at an operating temperature of −28° F.

The cargo is loaded onto the tanker from shore storage tanks at a temperature of −27 to −28° F. A heat gain in the cargo holds and in the loading lines is removed by a process known as auto-refrigeration of the cargo. By this method, the cargo vapours that are released from the free liquid surface are withdrawn into the first stage of a two-stage compressor and condensed at approximately 200 psi pressure against a sea-water coolant. The condensed liquid ammonia is flashed back to atmospheric pressure into the cargo tanks to maintain the holds at a steady state temperature of −27° F to −28° F. Two identical refrigeration units are installed in the midship deckhouse. Both units are operated during loading operations; however, only one unit is used on an intermittent basis when the vessel is in the sea-way in either the fully loaded or ballast condition, in order to maintain the low level of temperature required.

Cargo is discharged by four deep-well pumps of sufficient capacity to empty the tanker in 12 hours. These four pumps can deliver up to 5,600 gallons per minute of ammonia at a pressure of 100 psig into the receiving terminal's unloading line.

The cargo tanks are equipped with liquid level indicators, temperature probes and pressure gauge equipment. Pressure and vacuum relief valves are installed as standard equipment. Should a fracture occur in the cargo container, the presence of a leak into the inert gas stream would be immediately detected by a continuous sampling analyser that would sound an alarm. Any abnormal increase or decrease in the temperature of the empty space is sensed by temperature probes equipped with alarm overrides. All instruments for the control of the cargo pumps and for the supervision of the cargo system are located in a special control room adjacent to the aft deckhouse. Finally, accommodation is provided in air-conditioned quarters for a crew of 38.

The vessel is propelled by a MAN-type K8Z70/120D diesel engine that develops 9,600 metric brake horsepower at 135 rev/min. This equipment can propel the vessel at a speed of 17 knots.

The economic aspects of the carriage of ammonia by ocean tanker are best examined by using a well-known transport index: the cost per ton per mile. Table 14 below gives costs for LPG/ammonia tankers of various sizes now in use.

*Table 14*

COSTS FOR LPG/AMMONIA TANKERS OF VARIOUS SIZES

| *Vessel capacity (deadweight tonnage)* | *$/t/sea mile* |
|---|---|
| 1,000 | 0.1511 |
| 3,000 | 0.1302 |
| 9,500 | 0.1180 |
| 10,500 | 0.1154 |
| 11,000 | 0.1280 |
| 16,000 | 0.08–0.104 |

The data given above clearly demonstrate that costs bear no direct relation to the size of the tanker. Variables such as the speed and the type of vessel (fully refrigerated or semi-refrigerated) make a considerable difference in operating costs. What is established, however, is the economic advantage of employing large, fully refrigerated vessels.

Earlier in the report it was stated that ammonia carriers are essentially LPG-type vessels. For the most part, this is so. However, one very important difference in design is that tankers intended to transport ammonia must have all copper, brass and other copper alloys eliminated from the cargo-holding system. A list of LPG tankers that meet this requirement is given in Annex 7.

## RECEIVING TERMINALS

Marine transport of anhydrous ammonia, although relatively new and unique, is in itself only one key element in the global distribution system. In planning an ocean transport system it is also essential to draw up a practical and economic plan for the reception and storage of the ammonia, bearing in mind that anhydrous ammonia is best handled in its liquid form, according to the principle generally accepted in the chemical industry that liquid cargoes are more economical to handle than solids or gases.

Over the past eleven years, W. R. Grace & Co. has had experience in storing anhydrous ammonia under pressure as a liquid, in standard spheres or hortonspheres and in the form of aqua ammonia, in large carbon steel tanks of the oil storage type. These units have certain limitations, however, particularly if the quantities to be stored are over 6,000 tons. Hortonspheres have a size limitation and, at present, about 3,000 tons is the maximum that can be stored in a single unit because of excessive physical size and the resultant cost. It is obvious that an exceedingly large number of storage tanks would be required to contain aqua ammonia of 28 per cent ammonia content equivalent to 6,000 tons of anhydrous ammonia. In addition, aqua ammonia has the disadvantage that it requires suitable facilities for the recovery of the anhydrous ammonia for use in other processes or applications. Another drawback is that aqua ammonia is a dilute solution and, consequently, its shipment incurs a high cost penalty owing to the large amount of water being transported.

Incidentally, considerable experience has been acquired in the shipment by rail of anhydrous ammonia in single-unit pressure tank cars with a carrying capacity of 72 tons. Also, trucks with a carrying capacity of between 12 and 20 tons of anhydrous ammonia for local deployment are now in service.

Some five years ago a technological and economic study was made that compared the storage of ammonia in large tanks in the form of aqua ammonia, in pressure spheres and in refrigerated tanks. The study defined conclusively the point at which pressure storage spheres become uneconomic because of their limited size and the consequent large number of units required to store, say, 20,000 tons of anhydrous ammonia. This amount of storage can be accomplished in a single refrigerated storage tank at a considerably lower capital investment.

During the last six years, Grace operations have already built, or are now building, five 20,000-metric-ton refrigerated terminals, three 16,000-metric-ton units, three 15,000-metric-ton units and one 12,000-metric-ton tank. Operational experience with these units has been very good and has confirmed the original conclusions that, for large tonnage storage, refrigeration is the most economical technique. Therefore, a developing country that wishes to take advantage of this method of storage because of its small annual output (12,500 to 30,000 tons per year) might well consider the construction of a refrigerated terminal with a capacity of 10,000 or 14,000 tons.

According to the latest quotations, a 14,000-ton terminal would require a capital investment of approximately $ 1,200,000 and a 10,000-ton terminal an investment of $ 950,000. A detailed breakdown of these figures is shown in table 15 below.

*Table 15*

CAPITAL COST FOR A 14,000-TON AMMONIA TERMINAL

| | $ | *Percentage of cost* |
|---|---|---|
| Storage tank | 412,000 | 34.5 |
| Insulation | 196,000 | 16.4 |
| Compressors | 157,000 | 13.0 |
| Electrical | 75,000 | 6.1 |
| Foundations, buildings etc. | 360,000 | 30.0 |
| TOTAL | 1,200,000 | 100.0 |

In order to receive anhydrous ammonia by ship it is, of course, essential that the terminal site be adjacent to suitable deep-water harbour facilities. This is necessary, not only to ensure access from the ship to the terminal, but also to keep the ship unloading line to a minimum length, in order to minimize its cost and to reduce line friction and mechanical work on the anhydrous ammonia while pumping it. These effects result in a rise in temperature and flashing of the ammonia as it discharges into the terminal tank. These flashed vapours must be recompressed and returned to the storage tank as a liquid, an operation that increases the operating costs of the terminal refrigeration system.

The total land area required for a 14,000- to 16,000-ton terminal is approximately one acre. A typical example is the Grace terminal in Tampa, Florida, which occupies an acre and a half. It consists of a 16,000-ton storage tank, refrigeration machinery, tank truck and rail tank car loading and weighing facilities and a small office.

There are special requirements for foundations to support the storage tank and compressors according to the particular soil conditions. In the case of the Tampa terminal, the site was filled in the course of dredging for the adjacent waterway. It was necessary to drive in piles to support the intended load, the length of piles being determined by soil-boring tests. Some 400 piles support the main storage structure, rising approximately 20 inches above ground level. The piles were trimmed off and overlaid with a 36-inch reinforced-concrete slab that resulted in a pedestal effect with a free air space of 20 inches between the bottom of the slab and the ground. This free air space is necessary in order to prevent the freezing of moisture in the soil which might cause heaving and make the tank foundations give way.

In some locations, the bearing conditions of the soil were found sufficiently high to make it possible to pour the 36-inch concrete slab directly on the ground. In such cases a suitable electric heating grid was installed in the concrete foundation slab to prevent ground freezing.

The tank is constructed of normalized carbon steel and is guaranteed to be Charpy-tested at 15 ft-lb at −50° F with an allowable stress of 21,000 psi. The top and bottom of the tank are constructed of carbon steel of the American

Society for Testing Materials (ASTM) A-201 B type, with an allowable stress of 18,000 lb/in$^2$. The above stress values are based on 0.3 of ultimate strength or 0.6 of yield strength according to American standards. This system is believed to have adequate safeguards since no difficulties have been experienced in the many installations now in operation.

All horizontal welds were made with automatic welding machines. All vertical shell welds were fully X-rayed, except near the top, where minimum plate thickness was used, and spot X-raying employed. There are no established code specifications for this type of tank. However, the code procedure was followed as detailed under American Petroleum Institute (API)-620 where applicable. All nozzle connexions are made from ASTM A-333-type carbon steel.

Insulation of the tank is by a 5-inch thickness of Pittsburgh-Corning Foamglas. The first layer of insulation ($2^1/_2$ inches thick) was set up in hot asphalt, with the edges dipped and set in place with the dry side next to the tank and the tank wall free from moisture. A half-inch air gap was allowed between the first and second $2^1/_2$-inch layer of Foamglas insulation which, again, was dipped in hot asphalt and set in place. This second layer of insulation was held in place by stainless steel bands placed on 2-foot centres and machine stretched. The necessary expansion joints were allowed for in each layer of insulation and sealed with a vapour barrier.

After banding, the surface of the second layer was given a spray coat of an asphaltic mastic. When the mastic had dried, the entire surface was covered with 0.020-inch corrugated aluminium sheeting held in place with pop rivets and suitable banding for additional protection of the insulation against the weather. The tank roof was insulated in the same way. Instead of corrugated aluminium, however, the roof surface was covered with glass cloth and finished with a mastic coating.

The Pittsburgh-Corning Foamglas used has a thermal conductivity (K) factor of 0.37 Btu/hr/ft$^2$ °F/in and, using a heat leak factor for this type of insulation, was applied as previously described in the case of 10.2 Btu/hr/ft$^2$.

The holding and filling compressors are adjacent to the tank, and the entire system is graphically panelled with controls and instruments so that one man can easily operate the unit; the Tampa, Florida, operation is, in fact, completely automatic and can be made to operate unattended. The operator is needed primarily to load tank trucks and rail tank cars for inland distribution.

## SUMMARY

In conclusion, the system of large, refrigerated ammonia tankers (see list in Annex 7) allied to on-shore terminal facilities is now an approved method for the global distribution of ammonia. Through the use of this system, areas of the world lacking in nitrogen can in future be served rapidly and economically. Finally, this system has the added advantage for developing countries requiring increased food production, of a reduced capital commitment.

# VIII. Markets

THE EARLIER chapters of the present report have indicated clearly that large quantities of low-cost nitrogen fertilizer could be made in the six selected countries. In fact, it is probable that these countries could produce nitrogen fertilizer at a cost which would be lower than any in the world. Similar situations exist in some other countries with good natural gas resources such as Algeria, Argentina, Brunei, Burma, Colombia, Indonesia, Iraq and Mexico.

The most important problem concerning the development of the nitrogen fertilizer industry on a large scale in these countries is where to market the fertilizer produced.

Potential marketing areas may be summarized as follows:

| *Production* | *Potential markets* |
|---|---|
| Middle Eastern countries (Iran, Kuwait, Saudi Arabia and others) | Asia, including West Asia, South Asia and East Asia<br>Africa, particularly East Africa<br>Oceania |
| North African countries (Libya and others) | Africa, particularly North Africa<br>Europe<br>Latin America |
| West African countries (Nigeria only) | Africa, particularly West Africa<br>Europe<br>Latin America |
| Latin American countries (Venezuela and others) | Latin America |

Table 16 shows the production/consumption situation in Asia, Africa and Latin America in 1965/1966 with estimates for 1975/1976. The nitrogen deficits in the areas shown in the table may be summarized as follows (in metric tons of nitrogen):

*Table 16*

**Areas of nitrogen deficiency: 1965/1966 and 1975/1976**

*(In 1,000 metric tons of nitrogen)*

| | 1965/1966 Consumption | 1965/1966 Production | 1965/1966 Deficit or surplus[a] | 1975/1976 Estimated consumption | 1975/1976 Estimated production | 1975/1976 Deficit |
|---|---|---|---|---|---|---|
| *Asia (except Japan)* | | | | | | |
| China (mainland) | 1,050.0 | 500.0 | 550.0 | 3,000 | 2,000 | 1,000 |
| India | 582.6 | 233.4 | 349.2 | 3,000 | 2,000 | 1,000 |
| Ceylon | 42.5 | — | 42.5 | | | |
| China (Taiwan) | 145.0 | 158.6 | (13.6) | | | |
| Indonesia | 60.0 | 25.0 | 35.0 | | | |
| Korea, Rep. of | 201.2 | 65.0 | 136.2 | | | |
| Malaysia | 40.5 | — | 40.5 | | | |
| Pakistan | 132.7 | 93.4 | 39.3 | 2,500 | 2,000 | 500 |
| Philippines | 58.0 | 16.0 | 42.0 | | | |
| Turkey | 72.3 | 32.0 | 40.3 | | | |
| Viet-Nam, Rep. of | 35.0 | 0.7 | 34.3 | | | |
| Other deficit countries | 235.0 | 151.0 | 84.0 | | | |
| TOTAL | 2,655 | 1,275 | 1,380 | 8,500 | 6,000 | 2,500 |
| *Africa* | | | | | | |
| Algeria | 17.0 | — | 17.0 | | | |
| Kenya | 12.0 | — | 12.0 | | | |
| Mauritius | 10.0 | — | 10.0 | | | |
| Morocco | 12.2 | — | 12.2 | | | |
| South Africa | 100.0 | 75.0 | 25.0 | 2,000 | 1,600 | 400 |
| Sudan | 31.0 | — | 31.0 | | | |
| United Arab Republic | 300.0 | 160.0 | 140.0 | | | |
| Zambia/Rhodesia | 40.0 | — | 40.0 | | | |
| All other countries | 18.0 | 5.0 | 13.0 | | | |
| TOTAL | 540 | 240 | 300 | 2,000 | 1,600 | 400 |

| | | | | | | |
|---|---|---|---|---|---|---|
| *Latin America* | | | | | | |
| Argentina | 25.0 | 4.0 | 21.0 | | | |
| Barbados | 2.9 | — | 2.9 | | | |
| Brazil | 60.0 | 10.0 | 50.0 | | | |
| Chile | 40.0 | 178.0 | (138.0) | | | |
| Colombia | 60.0 | 55.0 | 5.0 | | | |
| Cuba | 100.0 | 10.0 | 90.0 | | | |
| Dominican Republic | 10.0 | — | 10.0 | | | |
| Ecuador | 4.9 | — | 4.9 | | | |
| El Salvador | 33.0 | 12.0 | 21.0 | | | |
| Guadeloupe/Martinique | 8.0 | — | 8.0 | | | |
| Guatemala | 7.3 | — | 7.3 | | | |
| Guyana | 6.2 | — | 6.2 | 1,500 | 1,000 | 500 |
| Honduras | 9.0 | — | 9.0 | | | |
| Jamaica | 15.0 | — | 15.0 | | | |
| Mexico | 118.2 | 88.6 | 29.6 | | | |
| Netherlands Antilles | 5.0 | 20.0 | (15.0) | | | |
| Nicaragua | 15.0 | — | 15.0 | | | |
| Panama | 8.0 | — | 8.0 | | | |
| Peru | 64.2 | 43.4 | 20.8 | | | |
| Trinidad and Tobago | 16.0 | 30.0 | (14.0) | | | |
| Uruguay | 8.3 | — | 8.3 | | | |
| Venezuela | 30.0 | 28.0 | 2.0 | | | |
| Other deficit countries | 34.0 | 31.0 | 3.0 | | | |
| TOTAL | 680 | 510 | 170 | 1,500 | 1,000 | 500 |

a Brackets () denote surplus.

| | *1965/1966* | *1975/1976* |
|---|---|---|
| Asia (except Japan) | 1,380,000 | 2,500,000 |
| Africa | 300,000 | 400,000 |
| Latin America | 170,000 | 500,000 |
| TOTAL | 1,850,000 | 3,400,000 |

These figures indicate large potential markets in 1975/1976. It may be noted in table 16 that China (mainland) and India are likely to be by far the largest markets in 1975/1976, as they account for over half of the total world deficit in nitrogen. Other substantial markets in this period will probably be Cuba, Indonesia, Kenya, Rhodesia, the United Arab Republic and Zambia. The demand of all other countries deficient in nitrogen fertilizer is likely to be small, but in the aggregate it could be substantial.

The deficiencies in these areas, however, are now being met by surplus production in Western Europe, North America and Japan (the Union of Soviet Socialist Republics is also a surplus producer, but its surplus goes mainly to Eastern Europe at present). The three big areas in which there is a surplus of nitrogen, Western Europe, North America and Japan, will probably continue to be surplus producers and, in fact, will probably have even bigger surpluses in 1975/1976 than they had in 1965/1966. In addition, the Soviet Union will probably be a large surplus producer by 1975/1976 as will Eastern Europe, which is now a deficiency area.

All these surplus areas will, therefore, be competing for the markets in the deficiency areas of Asia, Africa and Latin America at least as strongly in 1975/1976 as in 1965/1966 and probably even more strongly than at present.

This poses a problem for the countries with good natural gas resources that are not currently producing nitrogen fertilizers, or are just beginning to produce them. The potential of the newly developing natural gas countries to capture some of the markets in Asia, Africa and Latin America will be tested by the new nitrogen plants now operating, or under construction, in Iran, Kuwait and Saudi Arabia.

The above conclusions are based, of course, on a continuation of the growth of the nitrogen fertilizer industry in Western Europe, Eastern Europe, the Soviet Union, North America and Japan. The nitrogen fertilizer industry has been growing steadily in all these areas since 1945, and in fact, its rate of growth has accelerated since 1960, particularly in the Soviet Union and Eastern Europe.

Table 16 summarizes the world production and consumption of nitrogen fertilizer in 1965/1966 and 1975/1976. The figures for 1975/1976 were derived from estimates for each region based on data from 1955/1956 to 1965/1966. These estimates are subject to all the shortcomings that projections suffer from, but they are believed to be as realistic as it is possible to make them. The consumption figures are intended to relate to probable consumptions and are not intended to be estimates of need. The need for fertilizer in Asia, Africa and Latin America, in order to eliminate food deficits in these areas, is, of course, much greater than the probable consumption, at least in most of the countries, as for example, India and China (mainland).

At the present time there are very few countries possessing a nitrogen surplus in Asia, Africa and Latin America. Apart from Japan, surpluses of nitrogen were produced in 1965/1966 by Chile, China (Taiwan), the Netherlands Antilles (Aruba and Curaçao) and Trinidad and Tobago. Chile's production is, of course, all in the form of natural sodium nitrate. In addition, several countries were self-sufficient in nitrogen, or nearly so, in 1965/1966, including Colombia, Costa Rica, Iran, Israel, North Korea and Venezuela. All other countries in Asia, Africa and Latin America had nitrogen deficits in 1965/1966.

The situation with regard to potential markets in Asia, Africa and Latin America is shown in table 17 below.

*Table 17*

ESTIMATED STATUS OF NITROGEN MARKET IN 1975/1976

| *Probable surplus producers* | *Probably self-sufficient* | *Probable deficits* |
|---|---|---|
| | *Africa* | |
| Algeria | Sudan | Kenya |
| Libya | | Malawi |
| Nigeria | | Morocco |
| South Africa | | Rhodesia |
| | | Tanzania |
| | | Tunisia |
| | | Uganda |
| | | United Arab Republic |
| | | Zambia |
| | | All other Central African countries |
| | *Asia* | |
| Brunei | Ceylon | Afghanistan |
| Iran | China (Taiwan) | Burma |
| Iraq | Israel | Cambodia |
| Japan | Malaysia | China (mainland) |
| Kuwait | North Korea | Cyprus |
| Saudi Arabia | Pakistan | India |
| | Philippines | Indonesia |
| | Republic of Korea | Jordan |
| | Syria | Laos |
| | Turkey | Lebanon |
| | | Nepal |
| | | North Viet-Nam |
| | | Republic of Viet-Nam |
| | | Thailand |

*Table 17*

ESTIMATED STATUS OF NITROGEN MARKET IN 1975/1976 *(continued)*

| *Probable surplus producers* | *Probably self-sufficient* | *Probable deficits* |
|---|---|---|
| | *Latin America* | |
| Chile | Argentina | Bolivia |
| Colombia | Brazil | Ecuador |
| Mexico | Peru | Guyana |
| Netherlands Antilles | | Paraguay |
| Trinidad and Tobago | | Uruguay |
| Venezuela | | All Caribbean countries except Netherlands Antilles and Trinidad and Tobago |
| | | All Central American countries |

# IX. Regional co-operation in production and marketing

ONE OF THE handicaps facing large-scale fertilizer production in the six countries, namely, Iran, Kuwait, Libya, Nigeria, Saudi Arabia and Venezuela is that in marketing the products they will have to compete with well-established international companies. Some of the projects, especially those in Iran and Saudi Arabia have partnerships with foreign companies which have considerable experience in world marketing. Kuwait has sold fertilizers in the Red Sea area, East Africa and Asia. Estimated sales targets in the Middle East amount to some 20,000 tons of nitrogen, and the same quantity in the Red Sea market. They are expecting 12,000 tons of nitrogen to be sold in the East African market and 15,000 tons of nitrogen in the Asian market.

Another problem to be solved by the six countries in exporting fertilizers is that of credit facilities. Since their own internal consumption is small, from 60 to 70 per cent of their production has to be exported. Unfortunately, the large potential importers of fertilizers like China (mainland) and India have the majority of their imports tied to credit from the United States, Europe or Japan. It has been felt, especially by Kuwait, that if large quantities of fertilizer are to be sold from regions rich in gas to large consuming countries, then some form of credit facilities will have to be extended.

In an analysis of the over-all picture of plant production and future markets of Iraq, Jordan, Kuwait, Libya, Morocco, Saudi Arabia, the Sudan, Syria and the United Arab Republic, the current nitrogen production capacity is estimated to be 283,000 metric tons per year. There is a capacity of 353,000 metric tons per year under construction. This makes a total of 636,000 metric tons per year. If we take into account the 1,000-metric-tons-per-day ammonia plants under construction in Algeria and in Iran, they will add another 500,000 metric tons of nitrogen per year. The total capacity in the next two to three years will, therefore, be 1,136 million metric tons per year.

According to a market study made by the Kuwait Chemical and Fertilizer Company, the present imports into the natural marketing areas of these countries is about 2 million metric tons of nitrogen per year. As can be seen in table 18 below, these countries are planning an additional 690,000 metric tons per year. Thus, there will be a shortage of 200,000 metric tons of nitrogen to meet the present demand.

*Table 18*

PRODUCTION OF NITROGEN

| | Metric tons of nitrogen per year | | |
|---|---|---|---|
| | *In production* | *Under construction* | *Planned* |
| Iran | – | – | 60,000 |
| Jordan | – | – | 28,000 |
| Kuwait | 105,000 | – | 370,000 |
| Libya | – | – | not available |
| Morocco | 24,000 | – | – |
| Saudi Arabia | – | 200,000 | not available |
| Sudan | – | – | 50,000 |
| Syria | – | 38,000 | – |
| United Arab Republic | 154,000 | 115,000 | 182,000 |
| TOTAL | 283,000 | 353,000 | 690,000 |

These figures do not take into account the indigenous consumption of nitrogen in these countries. If the demand grows at the rate of 15 per cent per year, the future demand will be as follows:

| | | |
|---|---|---|
| 1967 | 2 | million metric tons |
| 1968 | 2.3 | million metric tons |
| 1969 | 2.65 | million metric tons |
| 1970 | 3.05 | million metric tons |

Thus it can be seen that even by 1968 there is scope for 500,000 metric tons of extra capacity to meet the demand.

There has been some success in regional co-operation in marketing fertilizers. As an example, it is reported that Kuwait will build an end-products plant in Turkey on a long-term credit basis, and will export ammonia to be used in this plant. It has also been reported that the National Iranian Petrochemical Company and Allied Chemical are negotiating in India with a large private company to install end-products production facilities and to sell ammonia in ocean-going tankers.

# Conclusions

A LARGE POTENTIAL exists for the production of nitrogen fertilizer in Iran, Kuwait, Libya, Nigeria, Saudi Arabia and Venezuela at costs substantially below production costs in the principal fertilizer-producing countries at the present time.

This potential is based on the availability of large quantities of natural gas at prices ranging from $ 1.75 to $ 2.80 per 1,000 $m^3$ (5 to 8 cents per 1,000 $ft^3$) delivered to the fertilizer plant.

Approximately 45,000 million $m^3$ (1.6 million million $ft^3$) of natural gas per year is now being flared in the six countries concerned. This is equivalent to approximately 40 million tons of fixed nitrogen per year, compared with the present world production of about 24 million tons of nitrogen (1965/1966).

Similar potentials exist in other countries with good natural gas resources, such as Algeria, Argentina, Bolivia, Brunei, Burma, Indonesia, Iraq, Mexico, Pakistan and Peru.

The potentials in the six countries with potential for the production of nitrogen fertilizer are not being utilized at present, except on a small scale in Kuwait (100,000 tons of N per year) and in Venezuela (30,000 tons of N per year). Much larger plants are under construction in Iran (300,000 tons of N per year) and in Saudi Arabia (200,000 tons of N per year). A major expansion is being planned in Venezuela (165,000 tons of N per year).

Capital requirements for developing this production potential would be approximately $ 200 to 300 million per million tons of annual nitrogen capacity, with urea as the end product.

A larger fraction of the potential in these countries is not at present being utilized because of the difficulties of finance and marketing, of which the marketing of the products is the more basic problem.

Despite the potentially low cost of production in the six countries, they will still have to compete for markets with the established nitrogen-exporting countries, including Western Europe, the United States, Canada and Japan. The Soviet Union and Eastern Europe may also become large exporters of nitrogen.

Markets for the new nitrogen plants in the six countries concerned in this report will probably fall into the following pattern:

| | |
|---|---|
| *Iran, Kuwait, Saudi Arabia...* | Middle East<br>Asia<br>East Africa |
| *Libya* .................. | North Africa<br>Central Africa<br>Middle East<br>Europe<br>Latin America |

| | |
|---|---|
| *Nigeria* .................. | West Africa<br>Central Africa<br>Latin America |
| *Venezuela* ............... | South America<br>Central America<br>West Indies |

The largest potential markets for nitrogen fertilizer during the next decade appear to be China (mainland), Cuba, India, Indonesia and the United Arab Republic, although many other countries will provide smaller potential markets. Most of these countries have limited foreign exchange resources and, therefore, credit for the sale of fertilizers will be a serious problem.

Nitrogen requirements of the developing countries, sufficient to keep pace with the expected population increase and to maintain present nutritional levels, are estimated at 8 million metric tons of nitrogen in 1970 and 23 million metric tons in 1980. These estimates compare with nitrogen fertilizer consumption by the developing countries of 4 million tons in 1965/1966 and 19 million tons global consumption. The above estimates of future needs are based on the assumption that 67 per cent of nitrogen will be used on food crops, and 33 per cent on non-food crops. Developing countries in this context include all countries of Africa, Asia and Latin America, except China (mainland), Japan, North Korea and North Viet-Nam.

There are possibilities for regional co-operation in the production and marketing of fertilizers, such as in West Africa, with Nigeria as the principal producing centre, and in South America, with Venezuela as the principal producing centre.

There is merit in the concept that the fertilizer-deficit countries should import liquid ammonia for conversion into solid fertilizer, or for direct application. The water transport of liquid ammonia at low rates is now becoming common.

# Recommendations

The Expert Group recommends that the Governments of countries with natural gas resources give exceptionally high priority to the greater utilization of such resources for the manufacture of nitrogen fertilizers. The Group further recommends that these countries seek the necessary capital for such development through all possible channels.

In view of the basic importance of fertilizers in agricultural production and to economic development generally, the Group recommends that the United Nations and affiliated organizations, including the United Nations Industrial Development Organization, the World Bank and other international and financial institutions develop some new machinery for the channelling of more capital into the development of natural gas resources for fertilizer production.

Specifically, the Group suggests that the United Nations and other international organizations consider a new concept for treating the fertilizer industry as a part of infrastructure, similar to irrigation, transport, communication and education, and make capital available to fertilizer projects on the same terms now being extended to other infrastructure projects.

The Group recommends that oil-producing countries should negotiate with the petroleum companies operating in their countries to channel part of the capital generated by these companies in the oil-producing countries into the development of new fertilizer industries.

The Group recommends that UNIDO undertake further studies on the potentialities for the production of fertilizers in other countries with natural gas resources, in addition to the six countries considered in the present report.

The Group recommends that UNIDO develop a World Fertilizer Production Programme based on the latest information on world needs for agricultural products.

The Group recommends that UNIDO make a study of the causes of the substantial difference between the capital cost of fertilizer plants built in the developing countries and that of plants constructed in the industrialized countries.

The Group recommends that UNIDO make a study of the start-up and operational experiences of new large-scale fertilizer plants based on the new technology, with a view to assisting developing countries that are building fertilizer plants of this type.

The Group recommends that fertilizer-deficit countries give serious consideration to the importation of liquid ammonia for conversion into solid fertilizer as an alternative to producing ammonia domestically, or as an alternative to importing solid fertilizers.

The Group recommends that fertilizer-deficit countries explore the possibility of investing in fertilizer production facilities in countries with good natural gas resources as an alternative to building domestic facilities.

The Group recommends that countries interested in developing their fertilizer industries review their present policies and regulations affecting capital investment and try to simplify, and, if possible, eliminate regulations and restrictions that now obstruct the development of the fertilizer industry.

The Group recommends that countries interested in developing their fertilizer industries review their present taxes and customs duty with a view to modifying them in a way that would stimulate development of the fertilizer industry. Specifically, the Group suggests the elimination of all import duty on fertilizer plant equipment, spare parts, chemicals, catalysts, raw materials and other products needed for fertilizer production.

## *ANNEX 1*

### STATEMENT BY MR I. H. ABDEL-RAHMAN, COMMISSIONER, CENTRE FOR INDUSTRIAL DEVELOPMENT[1]

I HAVE GREAT PLEASURE in welcoming you to this meeting of the *Ad Hoc* Expert Group on Fertilizer Production. We are extremely grateful to the experts from developing countries, the international experts and the high officials of international companies for arranging to be present today.

Some of you are aware that the Centre for Industrial Development conducted a most useful and successful Interregional Seminar on Fertilizer Production in Kiev from 24 August to 11 September, 1965. The seminar passed a unanimous resolution requesting the United Nations to organize and conduct studies for the establishment of large fertilizer production projects in areas of the developing countries where abundant natural gas and other raw materials are available. This meeting of the Expert Group is a follow-up of the recommendation of the Kiev seminar. Other recommendations of the seminar are being put into effect according to the directions contained in the resolution (E/C.5/L.56) dated 5 May, 1966 of the Committee for Industrial Development and resolution 1179 (XLI) of 5 August, 1966 of the Economic and Social Council.

I am now able to refer briefly to the new organization into which the Centre for Industrial Development is being transformed. The General Assembly of the United Nations has just approved the creation of the United Nations Industrial Development Organization (UNIDO) by resolution 2152 (XXI). It is being established as an organ of the General Assembly and will function as an autonomous organization within the United Nations. The purpose of the organization is to promote industrial development in accordance with the Charter of the United Nations and, by encouraging the mobilization of national and international resources, to assist in, promote and accelerate the industrialization of the developing countries with particular emphasis on the manufacturing sector.

In the fulfilment of its purpose, the organization will undertake in particular the following operational activities: make recommendations for national, regional and international action to achieve the more rapid industrialization of developing countries, contribute to programming and planning; the building and strengthening of industrial institutions; dissemination of technological information; the formulation of industrial development policies; preparation of specific industrial projects; the organization of feasibility studies; the co-operation with regional economic commissions; adoption and co-ordination of measures for industrialization; the offering of advice and guidance on the exploitation and use of natural resources; the training of technical personnel; improvement of the international system

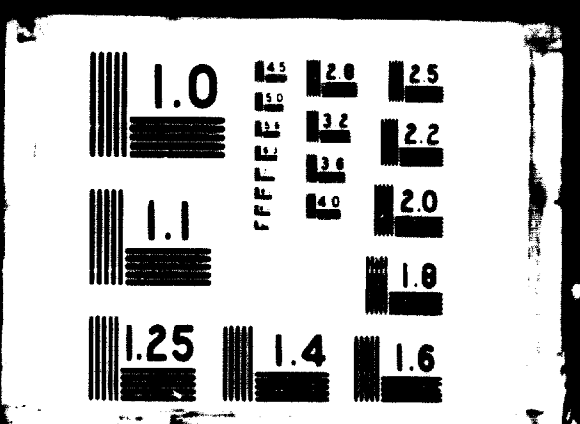
[1] The Centre for Industrial Development (CID) became, on 1 January 1967, the United Nations Industrial Development Organization (UNIDO).

# 4.9.74

# 2 OF 2

# D O

# 1462



of protecting industrial property and the rendering of assistance at the request of developing countries in obtaining external finance. Studies and research projects for action programmes will be carried out that are designed specifically to facilitate the activities mentioned above.

There is an area in industry which calls for more flexible means of assistance, in addition to the relatively long-term projects financed at the present time under the Special Fund (UNDP) type of operation and the medium-term activities programmed on a biennial basis under the technical assistance component of UNDP. This area includes services required for the implementation of certain projects in the manufacturing field after the initial feasibility study has been completed and before the financing of the capital investment is assured, as well as assistance to existing industries running into difficulties, in order to improve their performance. This is why the United Nations has recently established a new programme of aid for industry, namely, the Special Industrial Services (SIS) programme.

The following list gives illustrations of the nature of assistance under this scheme:

*(a)* *Ad hoc* assignment of high level experts at short notice to advise countries about specific questions relating to the preparation and implementation of industrial projects;

*(b)* Assistance at different stages of a project before the necessary finance is assured;

*(c)* Availability of expert services on an intermittent basis during the development of a project;

*(d)* Group services of experts in projects involving complex manufacturing techniques;

*(e)* Bringing a team of experts from developing countries to work at the source of specialized knowledge in industrialized countries;

*(f)* Confidental consultations at a high policy level;

*(g)* Assistance of experts of a trouble-shooting nature.

Thus, UNIDO is moving forward, not only continuing to undertake the activities of the CID, but also by formulating and executing dynamic programmes for accelerated industrial development in developing countries. In this programme, UNIDO desires to establish contact and continue discussions with industry in both the developed and the developing countries. Operational activities under the regular programme of technical assistance and the United Nations Development Programme, including the Special Fund and the expanded programme of technical assistance have been and will be a continuing activity of UNIDO. For example, the CID has carried out operational activities in Iran through its industrial survey mission of 1964, by its existing Special Fund projects in Algeria on industrial and marketing studies on petroleum derivatives and natural gas, and in Pakistan on studies for the promotion of fertilizer and petrochemical industries. Assistance has been made available to the fertilizer industry by the provision of experts and the dispatch of missions of staff members to Jordan, Peru, Trinidad, Tunisia, the United Arab Republic and Venezuela. In the near future assistance in the fertilizer field will be extended to several developing countries, such as Cyprus, India, the Sudan, Turkey and the United Arab Republic.

Further assistance in tackling specific technical problems is contemplated for 1967 in more than twelve countries. Detailed information on this project will be made available to you.

As you are aware, this meeting has been convened to discuss the techno-economic problems connected with establishment of fertilizer production facilities, particularly synthetic ammonia, in areas of the world that are rich in natural gas. We have selected six countries, namely, Iran, Kuwait, Libya, Nigeria, Saudi Arabia and Venezuela for a detailed study. You will be discussing the availability and price of natural gas in these areas, the location and capacities of future projects, capital costs and the means of finance. The local consumption of fertilizers in regions of the world endowed with natural gas is low and there is scope for increasing consumption. But the most important aspect of the problem is that, although it is possible to produce cheap nitrogen in such areas, unless there is regional and interregional co-operation, the marketing and selling of fertilizers to neighbouring areas where consumption is high becomes difficult. I feel sure you will give particular attention to this problem during your deliberations.

The second question of importance which should be given consideration is that of the financing of fertilizer projects. Although there has been a revolution in fertilizer technology during the last five years in developed countries, it has become increasingly difficult for developing countries to adopt the more significant changes in technology and build fertilizer projects as a result of the difficulty of finding foreign exchange, either from their own resources or through bilateral or multilateral aid. Countries that have a high rate of consumption and need fertilizers to increase food production sufficient only to meet the requirements of an increase in population find it difficult to obtain foreign exchange for the importation of the fertilizers necessary and much more difficult to find their own resources, or the external aid with which to build their own projects.

Your group will be studying the laws and regulations existing in the six countries which, in some cases, may attract and, in other cases, may inhibit the flow of domestic and external capital required for the building of projects using natural gas, now mostly being flared. The infrastructure existing in these countries, as well as the availability of skilled personnel, will also be examined.

It is hoped that during your discussions, in addition to your task as indicated by the agenda, you will have an opportunity of becoming more familiar with the working of the Centre for Industrial Development and the future organization, the United Nations Industrial Development Organization. I trust that this meeting, as well as your interest in our work, will lead to a fruitful co-operation in the future.

The *Ad Hoc* Expert Group will have achieved its main purpose if, after your deliberations, a report is made focusing attention on the possibilities of expanding fertilizer production in the six countries and others endowed with such resources as cheap natural gas.

I wish your deliberations all success.

## *ANNEX 2*

### LIST OF PARTICIPANTS (INCLUDING OBSERVERS)

| | *Name* | *Company and Address* | ***Position*** |
|---|---|---|---|
| 1. | **Allen ABRAHAMS** | Interamer Research Corporation<br>535 Fifth Avenue<br>New York, New York | **Consultant** |
| 2. | **T. W. ALLEN** | Allied Chemical Corporation<br>40 Rector Street<br>New York, New York | **International Marketing Development** |
| 3. | **L. C. AXELROD** | The M. W. Kellogg Company<br>711 Third Avenue<br>New York, New York | **Chief Engineer** |
| 4. | **Bharat B. BHALLA** | Allied Chemical Corporation<br>40 Rector Street<br>New York, New York | **Market Research and Planning** |
| 5. | **R. V. BOTSFORD** | American International Oil Co.<br>555 Fifth Avenue<br>New York, New York | **Commercial Development** |
| 6. | **A. J. BRUNO, Jr.** | W. R. Grace & Company<br>3 Hanover Square<br>New York, New York | **Director of Technical Planning, Agricultural Chemical Group** |
| 7. | **Atilio CASTILLO** | Instituto Venezolano de Petroquímica<br>Caracas, Venezuela | **Plant Manager (Country Expert)** |
| 8. | **J. CHANMUGAM** | International Finance Corporation (World Bank Group)<br>1818 "H" Street, N. W.<br>Washington, D. C. | **Senior Engineer (International Expert)** |
| 9. | **Allan M. CHYTROWSKI** | Chemical Construction Corporation<br>320 Park Avenue<br>New York, New York | **Marketing Research Manager** |
| 10. | **W. T. CORL** | Texaco, Inc.<br>135 East 42 Street<br>New York, New York | **Manager** |
| 11. | **R. M. DORMAN** | Bechtel Corporation<br>San Francisco, California | **Vice-President** |

| | Name | Company and Address | Position |
|---|---|---|---|
| 12. | C. L. EISENHART | American Cyanamid<br>Wayne, New Jersey | International Marketing |
| 13. | Raymond EWELL | State University of New York at Buffalo<br>Buffalo, New York | Vice-President for Research (International Expert) |
| 14. | Gerard H. FAIRTLOUGH | Asiatic Petroleum Corporation<br>One Rockefeller Plaza<br>New York, New York | Chemical Manager |
| 15. | Lionel S. GALSTAUN | Bechtel Associates<br>485 Lexington Avenue<br>New York, New York | Manager, Process Engineering |
| 16. | M. GARFINKEL | Chemical Projects Associates, Inc.<br>30 Rockefeller Plaza<br>New York, New York | Consultant |
| 17. | T. Edward GAVIN | American Cyanamid<br>Wayne, New Jersey | Commercial Development |
| 18. | Charles A. HERSTER | Mobil Chemical Company<br>150 East 42 Street<br>New York, New York | Project Manager, International Chemical Development |
| 19. | A. S. HESTER | American Cyanamid Company<br>Wayne, New Jersey | Market Research |
| 20. | Everett W. HOWARD | Universal Oil Products Company<br>1270 Ave. of the Americas<br>New York, New York | Marketing Department |
| 21. | Brian L. HUSON | The Lummus Company<br>385 Madison Avenue<br>New York, New York | Commercial Development |
| 22. | J. J. JOHNS | Interamer Research Corporation<br>535 Fifth Avenue<br>New York, New York | Consultant |
| 23. | H. Turner LOEHR, Jr. | International Minerals and Chemicals Corporation<br>Skokie, Illinois | Director, Latin American Development |
| 24. | L. L. LORTSCHER | U.S.S. Chemicals Division of U.S. Steel Corporation<br>71 Broadway<br>New York, New York | Marketing Representative |
| 25. | Edmund S. MALLOCH | American International Oil Co.<br>555 Fifth Avenue<br>New York, New York | Negotations Representative |
| 26. | B. F. MCAVOY | Gulf Oil Corporation<br>Gulf Building<br>Pittsburgh, Pennsylvania | Technical Adviser US Chemicals Co-ordinator |

| | *Name* | *Company and Address* | *Position* |
|---|---|---|---|
| 27. | Calvin C. McKEE | Gulf Oil Corporation<br>Gulf Building<br>Pittsburgh, Pennsylvania | Co-ordination Director, Gas and Gas Liquids |
| 28. | W. T. McLAUGHLIN | W. R. Grace & Company<br>3 Hanover Square<br>New York, New York | Transport Specialist |
| 29. | Arthur P. NARINS | Occidental Agricultural Chemicals Corporation<br>1301 Ave. of the Americas<br>New York, New York | Executive Director, Technical and Engineering Division |
| 30. | Herman K. NIEUWENHUIS | Chemical Projects Associates, Inc.<br>30 Rockefeller Plaza<br>New York, New York | President |
| 31. | A. L. NORMAN, Jr. | Gulf Oil Corporation<br>Gulf Building<br>Pittsburgh, Pennsylvania | Foreign Project Coordinator, Chemicals Department |
| 32. | R. H. OLIVER | Esso Chemical Company, Inc.<br>60 West 49th Street<br>New York, New York | Project Development Manager, Agricultural Chemicals |
| 33. | Christopher J. PRATT | Mobil Chemical Company<br>150 East 42 Street<br>New York, New York | Manager, Agricultural Chemical Development |
| 34. | Robert S. RAY | 710 Rodeo Road<br>Fullerton, California | Consultant (International Expert) |
| 35. | Soleman Saleh ROBAISHY | General Petroleum & Mineral Organization (Petromin)<br>Riyadh, Saudi Arabia | Technical Adviser (Country Expert) |
| 36. | Miguel SALAS | Instituto Venezolano de Petroquimica<br>Caracas, Venezuela | Chief of Division (Country Expert) |
| 37. | Tewfik SAGHIZLY | Ministry of Industry<br>Tripoli, Libya | Technical Adviser (Country Expert) |
| 38. | Gerald E. SPECK | Tennessee Corporation<br>61 Broadway<br>New York, New York | Project Appraisal Specialist |
| 39. | J. H. SPRAGUE, Jr. | Esso Chemical Company, Inc.<br>60 West 49th Street<br>New York, New York | Marketing Research Adviser |
| 40. | Robert S. STEINBOCK | American International Oil Co.<br>555 Fifth Avenue<br>New York, New York | Fertilizer Development Manager |
| 41. | Samuel STRELZOFF | Chemical Construction Corp.<br>320 Park Avenue<br>New York, New York | Vice-President, Consulting Division |

| | *Name* | *Company and Address* | *Position* |
|---|---|---|---|
| 42. | M. C. VERGHESE | Centre for Industrial Development<br>United Nations Headquarters | Interregional Adviser |
| 43. | Taha ZAKY | Egyptian Chemical Industries KIMA<br>Cairo, United Arab Republic | President of Board and Managing Director (International Expert) |
| 44. | C. A. TUGBOBO | c/o J. Joladipupo<br>Permanent Mission of Nigeria to the United Nations<br>757 Third Avenue, 20th Floor<br>New York, New York | Country Expert |
| 45. | Robert E. NOLLE | American International Oil Company<br>555 Fifth Avenue<br>New York, New York | Fertilizer Manager |

## *ANNEX 3*

### AGENDA

| | |
|---|---|
| 9 Dec.<br>Friday | Opening of meeting by the Commissioner for Industrial Development, Mr. I. H. Abdel-Rahman<br>Statements by experts from Iran, Kuwait and Libya |
| 10 Dec.<br>Saturday | Statements by experts from Nigeria, Saudi Arabia and Venezuela<br>Discussion on the availability, analysis, transport and cost of natural gas for fertilizer production in the six countries |
| 12 Dec.<br>Monday | Discussion on locations, capacities and product mix, economies of scale, costs of production<br>Capital costs and financing of fertilizer projects. Availability of local capital. Rules and regulations concerning the repatriation of dividends and the capital of foreign investors. Port facilities, electric power, water and other infrastructure. Wages and availability of skilled personnel |
| 13 Dec.<br>Tuesday | Indigenous consumption and export markets. Import and export duties, taxes, legal and other aspects of foreign capital collaboration<br>Transport of solid and liquid fertilizers |
| 14 Dec.<br>Wednesday | Drafting the outline of the report and the conclusions and recommendations |
| 15 Dec.<br>Thursday | *Idem* |
| 16 Dec.<br>Friday | Consideration of the draft outline of the report and the conclusions and recommendations<br>Concluding meeting |

## *ANNEX 4*

### QUESTIONNAIRE

***Factors relating to fertilizer production based on the conversion of natural gas to ammonia***

| | Fields | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | *A* | *B* | *C* | *D* | *E* | *F* | *G* | . . . |
| **1. *Natural Gas Fields*** | | | | | | | | |
| *(a)* Name of field | | | | | | | | |
| *(b)* Location | | | | | | | | |
| *(c)* The relation of the Location to the nearest city | | | | | | | | |
| The relation of the Location to the nearest deep-sea commercial port | | | | | | | | |
| *(d)* Ownership of gas | | | | | | | | |
| *(e)* Does field produce condensate? | | | | | | | | |
| *(f)* If so, how much per million $m^3$? | | | | | | | | |
| *(g)* Gravity in °API of condensate | | | | | | | | |
| *(h)* Can condensate be transported? | | | | | | | | |
| *(i)* Is recycling considered? | | | | | | | | |
| *(j)* Analysis of dry gas by volume per cent: | | | | | | | | |
| Hydrogen sulphide | | | | | | | | |
| Carbon dioxide | | | | | | | | |
| Nitrogen | | | | | | | | |
| Methane | | | | | | | | |
| Ethane | | | | | | | | |
| Propane | | | | | | | | |
| Isobutane | | | | | | | | |
| Normal butane | | | | | | | | |
| Heavier | | | | | | | | |
| *(k)* Is field on a natural gas pipeline? | | | | | | | | |
| *(l)* If not, is one planned? | | | | | | | | |
| *(m)* Capacity of line initially from this field | | | | | | | | |
| *(n)* Ultimate capacity of line from this field | | | | | | | | |
| *(o)* Pipeline pressure | | | | | | | | |

| | *Fields* | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | *A* | *B* | *C* | *D* | *E* | *F* | *G* | ... |
| *(p)* Destination of line | | | | | | | | |
| *(q)* Daily availability in million m³ | | | | | | | | |
| *(r)* Present daily consumption in million m³ | | | | | | | | |
| *(s)* Present use | | | | | | | | |
| *(t)* Reserves in million million m³ | | | | | | | | |
| *(u)* If not proven, estimated reserves | | | | | | | | |

2. *Gas associated with oil production*

*(a)* Name of field
*(b)* Location of field
*(c)* Ownership of field
*(d)* Analysis of typical gas by volume per cent
  Hydrogen sulphide
  Carbon dioxide
  Nitrogen
  Methane
  Ethane
  Propane
  Isobutane
  Normal butane
  Heavier
*(e)* Is gas being flared?
*(f)* Is associated gas being collected?
*(g)* Is reinjection being considered?
*(h)* Is field near natural gas pipeline?
*(i)* If not, is one planned?
*(j)* Daily production rate of associated gas in million m³
*(k)* Estimated daily production rate in 1975
*(l)* Present consumption
*(m)* For how many years?
*(n)* Estimated total production from field

3. *Price of natural gas*
   *$/1,000 $m^3$*

| Present price | Possible price (if none at present) |
| --- | --- |
| at well head | |
| at major consuming points. | |
| A. | |
| B. | |
| C. | |
| D. | |
| . | |
| . | |
| . | |

4. *Explain how the price of natural gas is determined*
   By private owners? If so, by whom?
   By the Government? Through what mechanism?
5. *Availability, location and price of other fertilizer raw materials*
   Phosphate rock (quantity? where? price?)
   Sulphur (quantity? where? price?)
   Potash (quantity? where? price?)
6. *Indicate availability of electric power, steam and fresh water and costs per kWh, per thousand $m^3$, and per 1,000 US gal for use in large industries*
7. *What is the supply of labour in the five categories?*
   Engineers
   Scientists
   Accountants
   Skilled mechanics
   Unskilled labour
8. *What is the general level of wages for the two categories?*
   Skilled mechanics
   Unskilled labour
9. *What is the present status of port facilities at natural gas location?*
10. *Is there an excise tax on natural gas?*
    If not, what is the probability that an excise tax might be imposed?
    How is natural gas evaluated for tax purposes?

11. *Other taxes*
    Personal income tax:
        On citizens
        On non-citizens
    Corporate income tax
    Property tax on industrial property
12. *Are there any import duties relating to the fertilizer industry?*
    On machinery
    On spare parts
    On fertilizer raw materials
13. *Are there any export duties on finished fertilizers or fertilizer intermediates (such as ammonia) and at what value are such duties imposed?*
14. *What permits or other government sanctions are necessary to begin construction of a fertilizer plant?*
15. *What are the restrictions, if any, on the foreign ownership of industrial enterprises?*
16. *What local capital is available for participation in a fertilizer project?*
    Private capital
    Government capital
    Rates of interest
17. *What are the conditions for the conversion of dividends or profits into other currencies?*
    What are the conditions for the repatriation of foreign capital?
18. *Are there any treaties or regulations regarding guarantees on foreign capital?*
19. *Are there any industrial uses for such typical fertilizer products or by-products as carbon dioxide, ammonia, urea, nitric acid, ammonium nitrate (for explosives) or industrial phosphates?*
    Are there any projects for the manufacture of fertilizer using natural gas?
20. *Are there any industrial uses for typical petrochemicals such as methanol, or any planned, or existing projects, for the manufacture of petrochemicals?*

## *ANNEX 5*

### LIST OF WORKING PAPERS

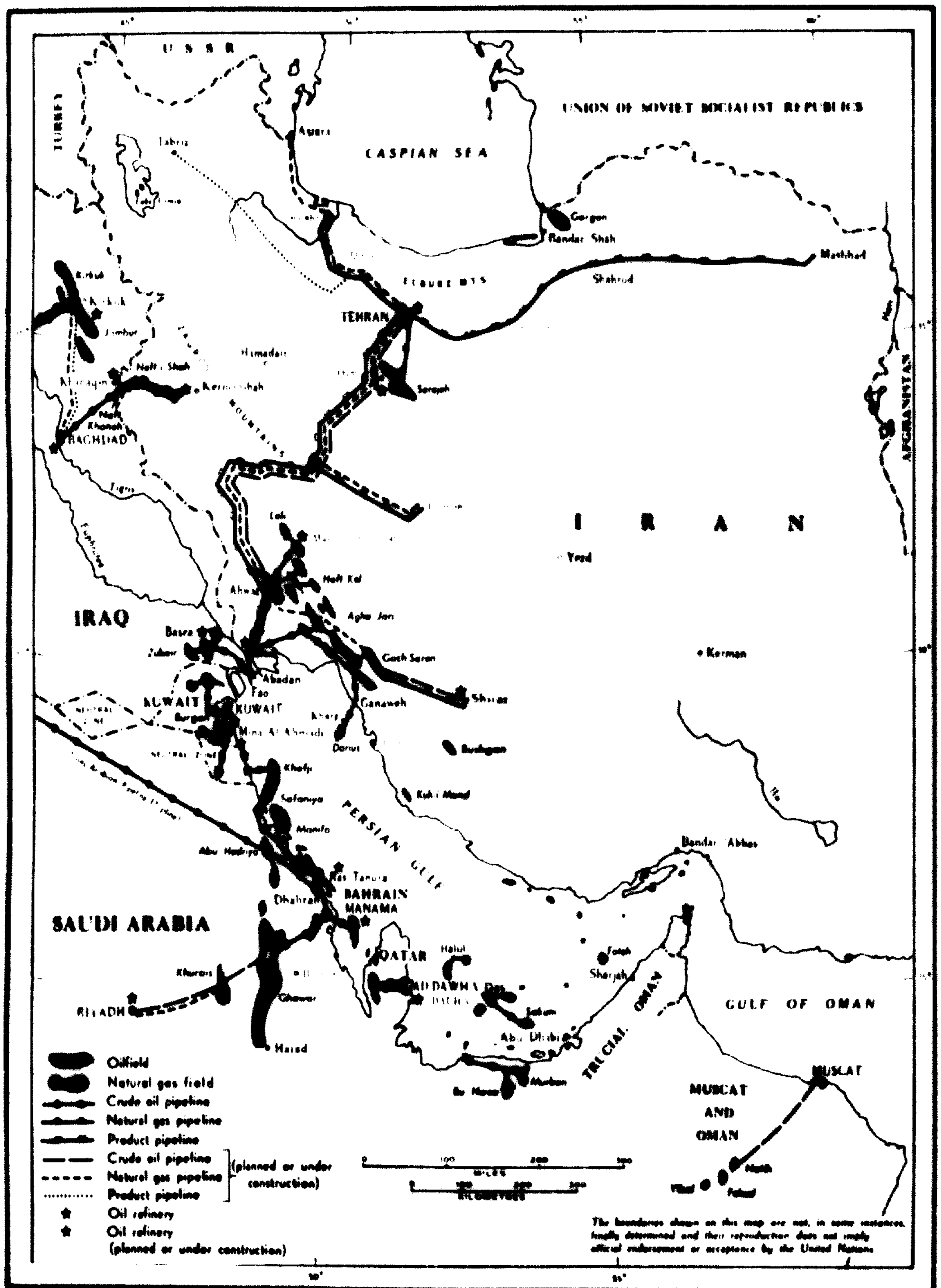
| | |
|---|---|
| *FERT*/Ad Hoc *Group/1* | Estimates of Natural Gas Reserves and Actual Production in Iran, Kuwait, Libya, Nigeria, Saudi Arabia and Venezuela<br>Source: *World Oil*—International Outlook, 1966 |
| *FERT*/Ad Hoc *Group/2* | World Production and Consumption of Fertilizers, 1964–1965<br>Source: *Fertilizers*—An annual review of world production, consumption and trade, FAO, 1965 |
| *FERT*/Ad Hoc *Group/3* | Actual Consumption and Estimated Requirements of Fertilizers N, $P_2O_5$ and $K_2O$ in Latin America<br>Source: Oferta de Fertilizantes en America Latina 3 November 1966 (E/CN. 12/761) |
| *FERT*/Ad Hoc *Group/4* | Prospects for Regional Co-operation in the Field of Fertilizers in the ECAFE region<br>Asian Industrial Development Council, First Session Economic Commission for Asia and Far East 8 August 1966 (I & NR/AIDC. 1/12) |
| *FERT*/Ad Hoc *Group/5* | Fertilizer Production and Consumption in Africa<br>Paper presented at the United Nations Interregional Seminar on the Production of Fertilizers, Kiev 24 August to 13 September 1965<br>Economic Commission for Africa (FERT/CONF. 1/39) |
| *FERT*/Ad Hoc *Group/6* | Developing the Petrochemical Potentials of North Africa and the Persian Gulf<br>by Herman K. Nieuwenhuis<br>Paper presented at the UN Interregional Conference on the Development of Petrochemical Industries in Developing Countries<br>Tehran, October 1964 (PET/CHEM/CONF. 64) |
| *FERT*/Ad Hoc *Group/7* | The Economics of International Distribution of Anhydrous Ammonia<br>by William J. Haude<br>Paper presented at UN Interregional Conference on the Development of Petrochemical Industries in Developing Countries<br>Tehran, October 1964 (PET/CHEM/CONF. 67) |
| *FERT*/Ad Hoc *Group/8* | United Kingdom chemical industry bids for North Sea gas, price issue flares for North Sea gas<br>Source: *European Chemical News*, 25 November, 1966 |

| | |
|---|---|
| | (Compromise plan on fertilizers is under study) Source: «*The Times of India*» News Service 19 November, 1966 |
| | International Finance Corporation invests $ 10,658,000 in Brazilian Fertilizer Company. Office of Public Information, United Nations |
| *FERT*/Ad Hoc *Group/9* | Replies to questionnaire on natural gas from Saudi Arabia |
| *FERT*/Ad Hoc *Group/10* | Replies to questionnaire on natural gas from Venezuela |
| *FERT*/Ad Hoc *Group/11* | Statement on availability of gas for industrial use in Saudi Arabia |
| *FERT*/Ad Hoc *Group/12* | Replies to questionnaire on natural gas from Libya |
| *FERT*/Ad Hoc *Group/13* | Information Summary: Iran, Kuwait, Libya, Nigeria, Saudi Arabia, Venezuela |

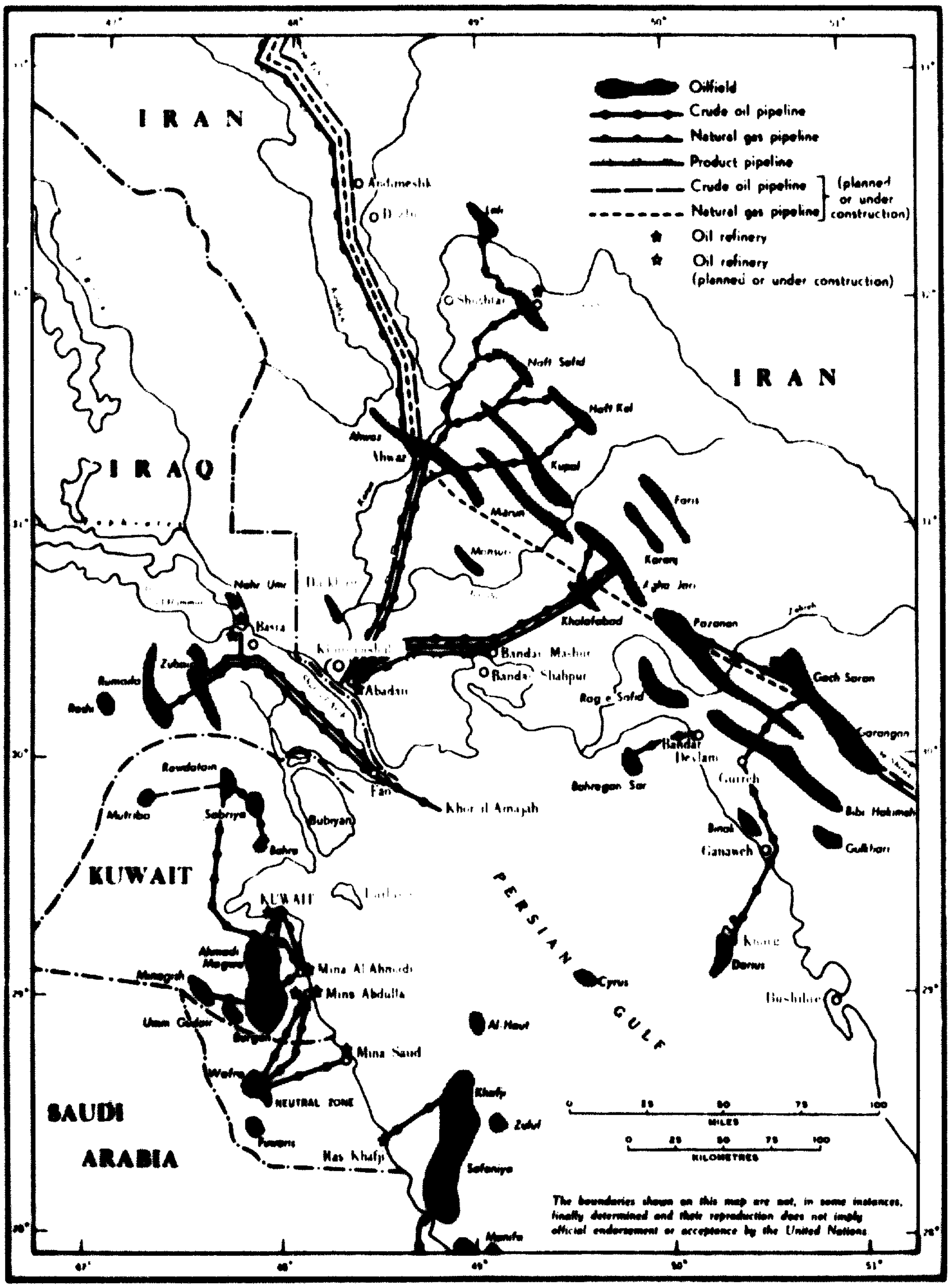
## ANNEX 6

**Maps of the six selected countries: Iran, Kuwait, Libya, Nigeria, Saudi Arabia, Venezuela**

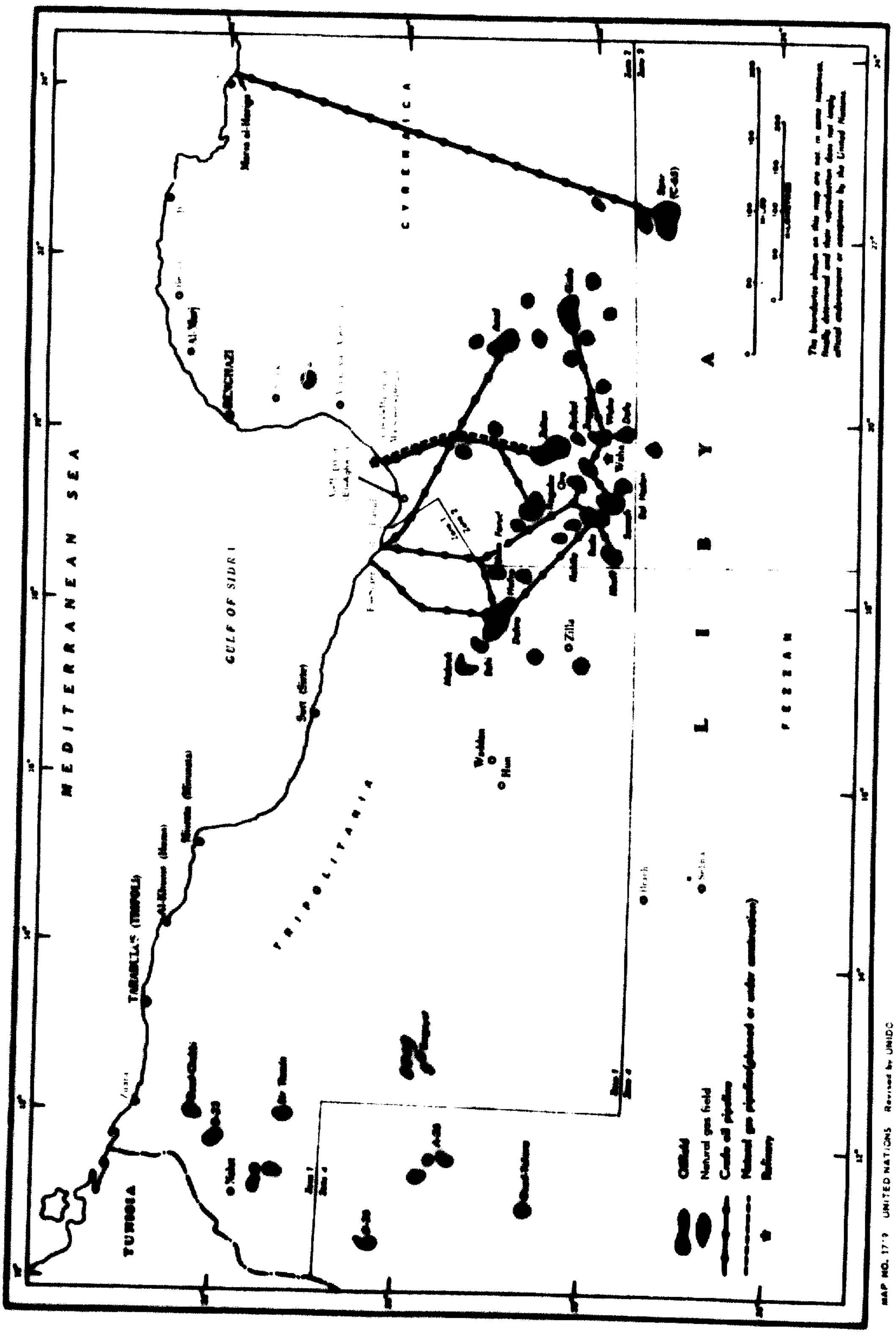
*(Overleaf)*

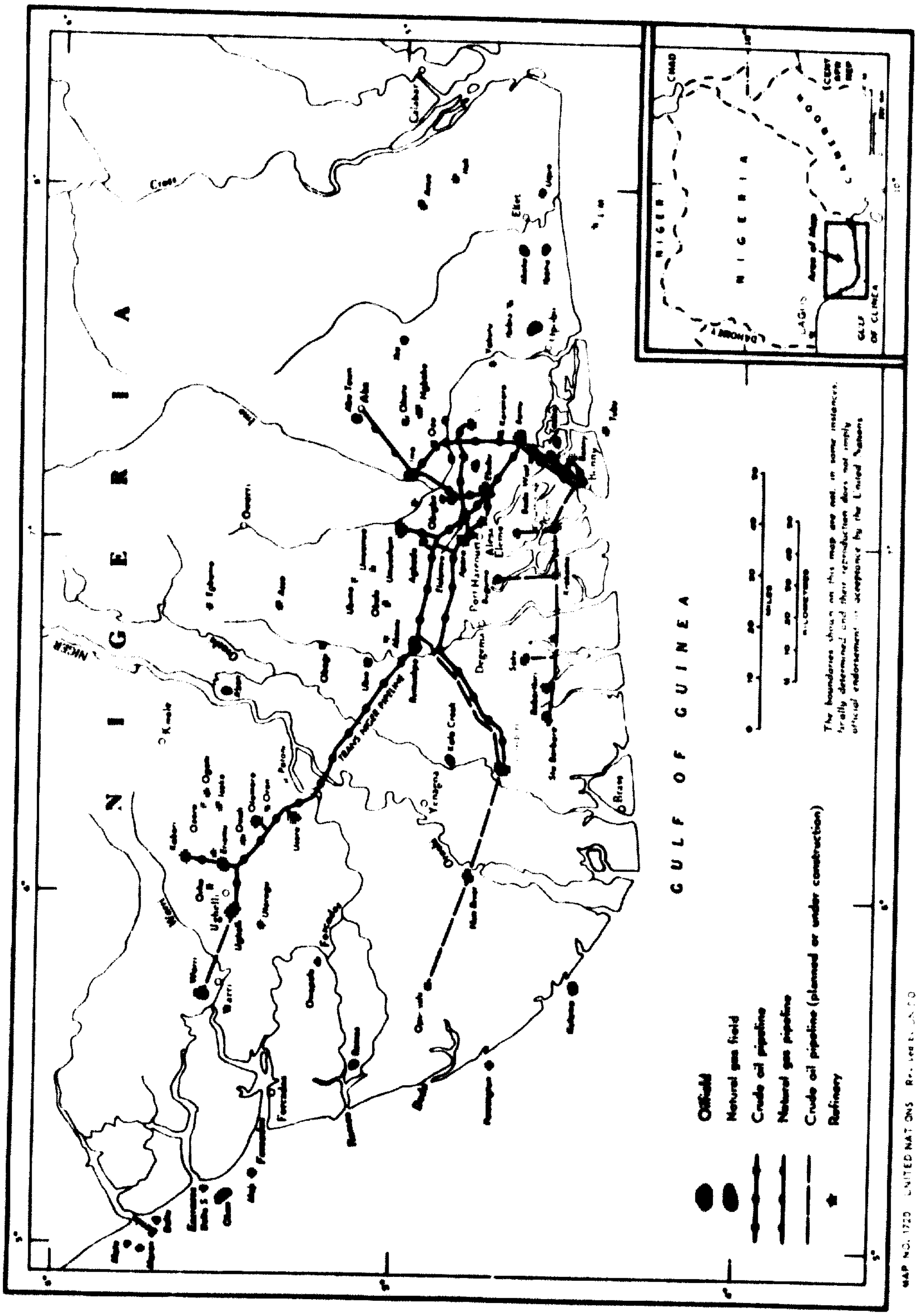


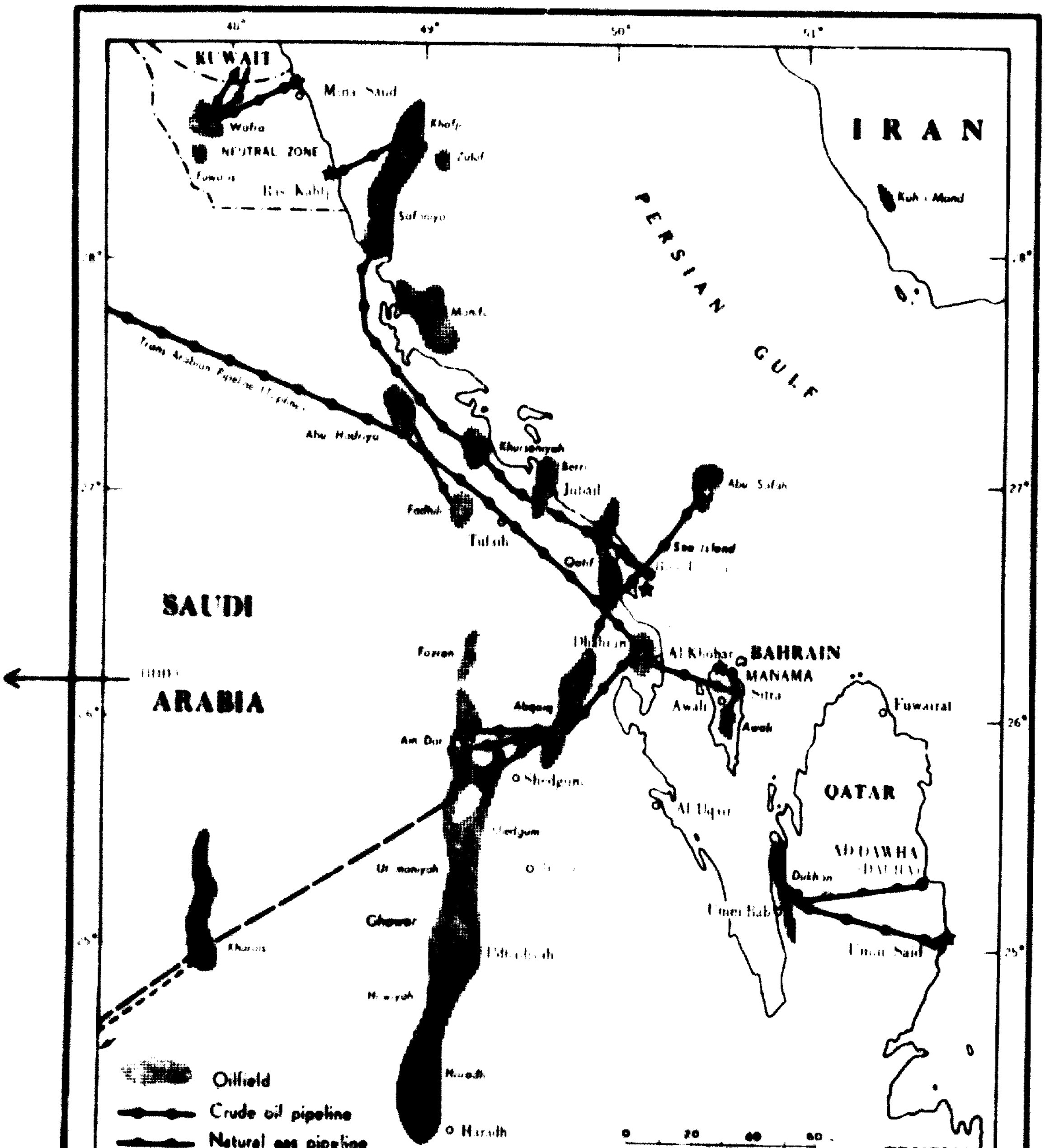

MAP NO. 1716 UNITED NATIONS Revised by UNIDO
JUNE 1967

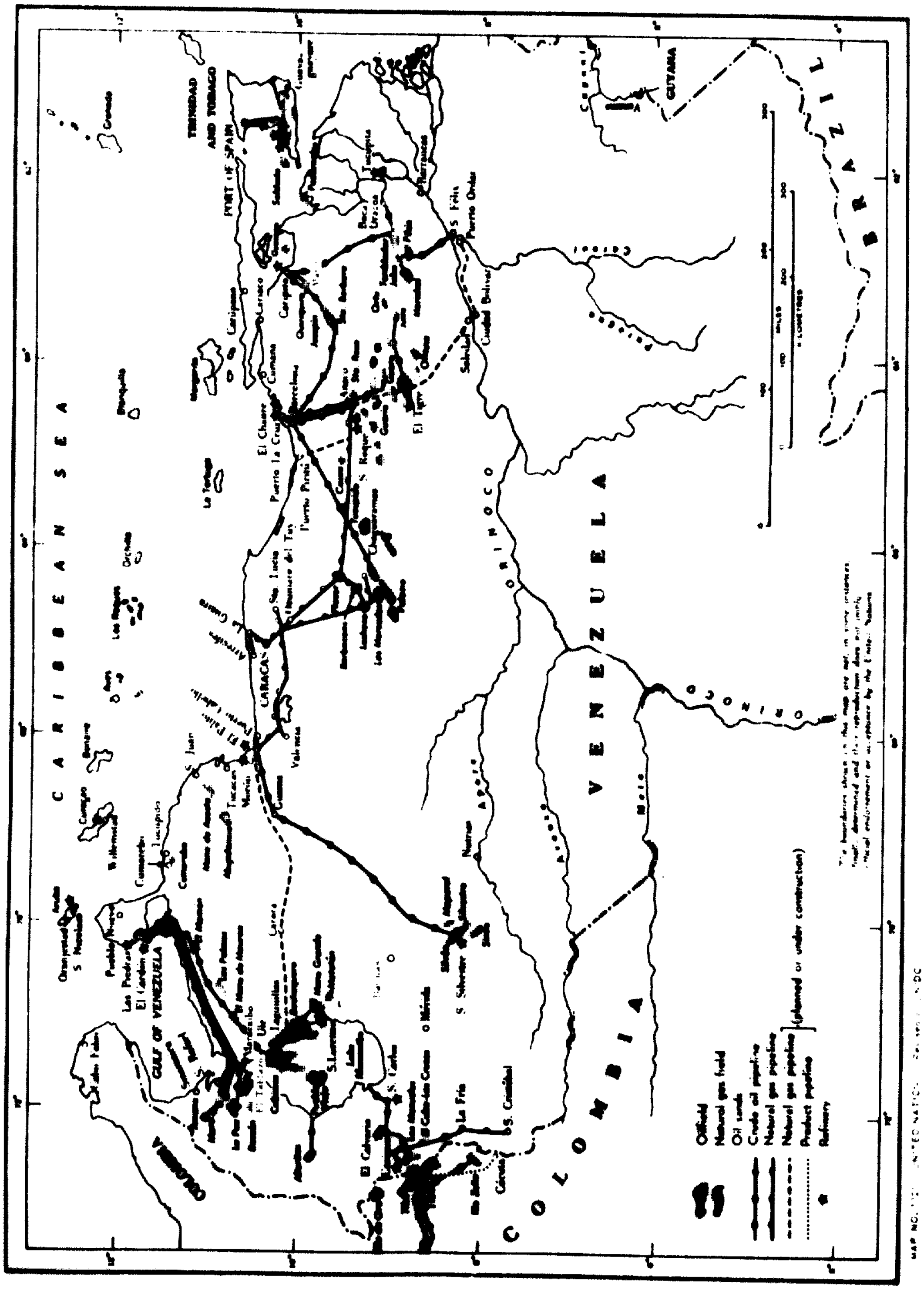



MAP NO. 1718 UNITED NATIONS Revised by UNIDO
JUNE 1967


MEDITERRANEAN SEA
GULF OF SIDRA
TUNISIA
TRIPOLITANIA
CYRENAICA
LIBYA
FEZZAN
BENGHAZI
Sirt (Sirte)
Oilfield
Natural gas field
Crude oil pipeline
Natural gas pipeline (planned or under construction)
Refinery
MAP NO. 1779 UNITED NATIONS Revised by UNIDO
JUNE 1967


N I G E R I A
GULF OF GUINEA
TRANS NIGER PIPELINE
Oilfield
Natural gas field
Crude oil pipeline
Natural gas pipeline
Crude oil pipeline (planned or under construction)
Refinery
Port Harcourt
Warri
Forcados
Brass
Bonny
Calabar
Degema
Yenagoa
Owerri
Ughelli
Okan
Afam
NIGERIA
Area of Map
LAGOS
GULF OF GUINEA
DAHOMEY
NIGER
CHAD
CAMEROON
The boundaries shown on this map are not, in some instances, finally determined and their reproduction does not imply official endorsement or acceptance by the United Nations


49°
50°
KUWAIT
Mina Saud
Wafra
NEUTRAL ZONE
Khafji
Safaniya
IRAN
Kuh-i-Mund
PERSIAN GULF
Abu Hadriya
Khursaniyah
Berri
Jubail
Abu Safah
Fadhili
Qatif
Sea Island
SAUDI
ARABIA
Dhahran
Al Khobar
BAHRAIN
MANAMA
Sitra
Awali
Fazran
Abqaiq
Ain Dar
Shedgum
Ghawar
Haradh
QATAR
Fuwairat
Dukhan
Umm Bab
Umm Said
TRUCIAL
OMAN
26°
25°
24°
27°
48°
49°
50°
51°
Oilfield
Crude oil pipeline
Natural gas pipeline
Crude oil pipeline
Natural gas pipeline
(planned or under construction)
Refinery
MILES
KILOMETRES
The boundaries shown on this map are not, in some instances, finally determined and their reproduction does not imply official endorsement or acceptance by the United Nations.


CARIBBEAN SEA
VENEZUELA
COLOMBIA
BRAZIL
GUYANA
TRINIDAD AND TOBAGO
PORT OF SPAIN
GULF OF VENEZUELA
CARACAS
ORINOCO
Oilfield
Natural gas field
Oil sands
Crude oil pipeline
Natural gas pipeline
Natural gas pipeline (planned or under construction)
Product pipeline
Refinery

## ANNEX 7

**LIST OF REFRIGERATED VESSELS SUITABLE FOR CARRYING ANHYDROUS AMMONIA**

M. T. *Esso Centro America* (Panama)
5,748 $m^3$ cargo capacity, 3,100 metric tons
M. T. *Havgas* (Norway)
11,200 $m^3$ cargo capacity 6,250 metric tons propane or 7,350 t for ammonia on 27 ft 4 in
M. T. *Havfrost* (Norway)
11,400 $m^3$ cargo capacity, 6,250 metric tons propane or 7,350 t for ammonia on 27 ft 3 in
M. T. *Clerk Maxwell* (United Kingdom)
11,753 $m^3$ cargo capacity, 6,500 metric tons on 25 ft 2¼ in for propane
M. T. *Alexander Hamilton* (Panama)
10,800 $m^3$ cargo capacity, 6,500 metric tons
Newbuilding *No. 763*, Hawthorn Leslie Shipyard (Mexico)
11,760 $m^3$ cargo capacity, 7,600 metric tons, delivery 1968
Newbuilding *No. 711*, Scotts (Norway)
11,760 $m^3$ cargo capacity, 7,600 metric tons, will carry and load/discharge simultaneously 2 grades of liquid gas, 1968
Newbuilding *No. 163*, A/S Moss (Norway)
12,000 $m^3$ cargo capacity, about 8,760 metric tons, delivery 1969
M. T. *Joseph P. Grace* (Liberia)
12,975 $m^3$ cargo capacity, 8,844 metric tons
M. T. *William R. Grace* (Liberia)
12,975 $m^3$ cargo capacity, 8,844 metric tons
M. T. *Butanueve* (Spain)
13,800 $m^3$ cargo capacity, 8,500 metric tons, delivery 1968
M. T. *Arquimedes* (Panama)
14,000 $m^3$ cargo capacity, 9,360 metric tons
M. T. *Capella* (Sweden)
14,000 $m^3$ cargo capacity, 8,200 metric tons
Newbuilding *No. 1,374*, Aeolos I (Liberia) 14,800 $m^3$ cargo capacity, 8700 metric tons, delivery 1967
Newbuilding *No. 1,375*, Aeolos II (Liberia)
14,800 $m^3$ cargo capacity, 8,700 metric tons, delivery 1967
Newbuilding *No. 766*, Hawthorn Leslie (United Kingdom)
15,470 $m^3$ cargo capacity, 10,000 metric tons, delivery 1968
Newbuilding *No. 1,191*, Howaldtswerke (Sweden)
18,220 $m^3$ cargo capacity, 10,400 metric tons propane or 12,200 t ammonia on 29 ft 6 in, delivery 1968

M. T. *Isfonn* (Norway)
18,790 m³ cargo capacity, 10,800 metric tons
Newbuilding *No. 160*, A/S Moss Vaerft (Norway)
19,000 m³ cargo capacity, 11,170 metric tons, delivery 1968, also Newbuilding 155
M. T. M. P. *Grace* (Liberia)
19,440 m³ cargo capacity, 13,250 metric tons
M. T. *Kristian Birkeland* (Norway)
22,000 m³ cargo capacity, 12,500 metric tons propane, delivery 1968
Newbuilding *No. 255*, La Ciotat (Norway)
22,000 m³ cargo capacity, about metric 16,060 tons, delivery 1969
M. T. *Paul Endacott* (Sweden)
25,102 m³ cargo capacity, 13,700 metric tons propane
Newbuilding *No. 1366*, Weser (Netherlands)
29,200 m³ cargo capacity, about 21,316 metric tons, delivery 1968
Newbuilding *No. 1376*, CNIM (France)
29,948 m³ cargo capacity, 22,313 metric tons, delivery 1968
Newbuilding *No. 113*, Española (Spain)
4,500 m³ cargo capacity, about 3,285 metric tons, delivery 1967

## List of semi-refrigerated vessels suitable for carrying anhydrous ammonia

M. T. *Cape Corso* (United Kingdom)
3,500 m³ cargo capacity, 2,195 metric tons, can load propane, −42° C.
Newbuilding *No. 158*, A/S Moss Vaerft (Norway)
3,700 m³ cargo capacity, 2,175 metric tons, delivery 1968
Newbuilding *No. 162*, A/S Moss Vaerft (Norway)
3,700 m³ cargo capacity, 2,175 metric tons, delivery 1968
M. T. *Rita* (Norway)
3,700 m³ cargo capacity, 2,175 metric tons, delivery 1968
M. T. *Uranus* (France)
3,800 m³ cargo capacity, 2,150 metric tons
M. T. *Nordfonn* (Norway)
4,050 m³ cargo capacity, 2,320 metric tons
M. T. *Frostfonn* (Norway)
4,100 m³ cargo capacity, 2,215 metric tons
M. T. *Sydfonn* (Norway)
4,100 m³ cargo capacity, 2,320 metric tons
M. T. *Lavoisier* (France)
5,230 m³ cargo capacity, 2,900 metric tons LPG/solvents
M. T. *Mundogas Bermuda* (Norway)
6,000 m³ cargo capacity, 3,500 metric tons
M. T. *Pascal* (France)
6,250 m³ cargo capacity, 3,600 metric tons
M. T. *Humbolt* (Chile)
6,250 m³ cargo capacity, 3,600 metric tons, delivery 1968

M. T. *Mundogas Brasilia* (Norway)
7,739 m³ cargo capacity, 4,060 metric tons LPG/oil
Newbuilding *No. 164*, A/S Moss Vaerft (Norway)
8,500 m³ cargo capacity, 6,105 metric tons, delivery 1969
M. T. *Cap D'Antibes* (France)
9,000 m³ cargo capacity, 6,775 metric tons, delivery 1968
M. T. *Cap Martin* (France)
13,196 m³ cargo capacity, 7,650 metric tons

4.9.74