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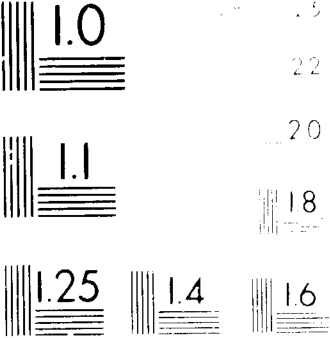
UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org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9 January 1984
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QATAR.

ASSESSMENT AND CONTROL OF INDUSTRIAL POLLUTION

DP QAT/79/001

QATAR

Terminal report*

Prepared for the Government of Qatar
by the United Nations Industrial Development Organization
acting as executing agency for the United Nations Development Programme

Based on the work of S.M. Yunis
pollution control expert

United Nations Industrial Development Organization
Vienna

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Chapter I

Introduction

Objectives and Logic of Project

Qatar's industrial complex at Umm Said 45 km (25miles) south houses the following plants. Fig. 1.

1 Qatar Steel Company (QASCO)
2 Qatar Petrochemicals Company (QAPCO)
3 Flower Mill
4 Qatar Fertilizer Company (QAFCO)
5 Natural Gas Liquids (NGL)
6 National Oil Distribution Co. (NODCO)

The relative locations of the plants within the complex are shown in Fig. 2. The general and long range objectives of the project are as follows:

I.a Examine industrial operations at Umm Said and assess current pollution problems in the complex.

I.b Quantify pollutants discharged to the environment under normal and emergency operations.

I.c Predict the effects of pollutants from all sources on the environment and recommend in-plant remedial and control methods.

I.d Suggest appropriate air, water, noise, and soil standards, threshold limits, and maximum allowable concentrations taking into account the severe climatic conditions in the area.

I.e Suggest pollution monitoring equipment as to types, sizes as well as points of installation for best monitoring emission from all sources.

I.f Train Government personnel in monitoring evaluating pollution control methods and equipment, as well as analyses and evaluation of data.

Upon arrival (July 1980) the expert took several mission to the plants. The major finding was that non of the plants had genuine environmental data. In view of this it was recommended that priority be given to the establishing of an environmental laboratory to generate the necessary data on the nature and extent of pollution. Actually the establishment of a laboratory had been completed by the environmental committee of the Industrial Development Technical Centre (IDTC) before my arrival at Doha. Therefore, the suggestion was immediately adopted and my name was added to the committees membership and we were entrusted with the task of creating a laboratory for monitoring pollution at Umm Said. This became the IMMEDIATE OBJECTIVE of the project, and will be discussed in chapter 4.

In chapter 2 short description of the plants at Umm Said will be given. Chapter 3 will cover potential pollutants and their environmental impacts.

Chapter II

The Industrial Complex

The following is a brief description of the plants covered by the project including capacities, main products and associated facilities such as water and power utilities. Existing and potential pollution problems may sometimes be slightly touched upon here. However detailed information on this subject will appear in chapter 3.

II.1 QASCO. As seen from fig 2, this plant is located at the northeast corner of the complex. It occupies an area of about670,000 m^2. A general layout showing the various components of the plant is given in fig. 3. Manufacturing units feature the material receiving area, direct reduction section, electric arc furnace, and continuous casting shop.

Most raw materials are imported in the form of iron oxide pellets. They are unloaded at the wharf and transported by belt conveyors to the storage area first and then to the direct reduction unit. A small portion of the raw materials comes in the form of iron scrap and is handled by cranes and trucks.

In the direct reduction furnace raw materials are reduced to 'sponge iron' by reducing gas containing hydrogen and carbon monoxide. The sponge iron is then cooled and discharged to the electric arc furnace in which scrap and sponge iron are melted ($t \sim 1680^{\circ}C$). Molten steel is drained into ladles from which it goes to the continuous casting shop where it is moulded into 150mm square billets. Cobalt 60 is used to measure the metal level inside the mould. Production capacity of the shop is 526,800 metric tons per year. The main part of the produced billets sent to the rolling mill section - the final stage in the process. The mill produces 330,000 metric ton/year of 10 to 32 mm steel bars, The product bars are automatically cut into specified lengths which are automatically bundled and shipped to customers.

II.2 QAPCO This plant is located across the road and to the northeast of the flower mill. It occupies an area of about one million square meters. General layout of the plant is shown in Fig. 5. The plant features an ethylene and low density polyethylene (LDPE) units. The feed (600,000 t/year) stock is ethane-rich gas provided by the NGL plant some distance to the south. Ethylene plant has a design capacity of 280,000 tons/year with 99.95% purity, and 5,000 tons/year of technical grade propylene. Ethylene storage can accommodate 30,000m^3 at atmospheric pressure and a temperature of -100°C. Propylene storage has a capacity of 1,000 m^3 at 20 bar gage pressure. LDPE facility is rated for 140,000 tons/year. Accessives for bagging and storage of product are also provided for.

A desulfurization unit utilizing the Claus process is used to remove sulfur from the feed stock gas. H_2S is transfered into solid sulfur and stored in an 8,000 tons warehouse whence it is directed to ships at the wharf. This unit can recovers between 50,000 to 60,000 tons of sulfur per year. The sulfur leaves the unit in a liquid state and is pelletized before storage steam and power generation plant comprises 3 groups of turbo-alternators driven by gas turbines, 2 recuperation boilers, 2 conventional boilers equipped with fuel gas burners on stand-by basis.

Other offsite facilities include a sea water pumping station with four pumps having a capacity of 13,000 m^3 per hour. Usage is limited to 800,000 m^3 on a normal day. Water usage is based on once -through basis with no circulation. Water is returned to the Gulf at a ΔT of about 7°C. They also include a fuel gas compression station, nitrogen production unit, water demineralizing unit and sea water desalination unit.

Accessories at the site include (a) sea water cooling system to cool industrial water, electric furnace, reheating furnace and oil cooler as shown in fig. 4. The total amount is about 24,000 m^3/hr (b) fresh water system. Fresh water is supplied from Ras Abu Fontas distillation Plant to a water closed type basin and then pumped to the plant facilities. Fresh water is reused through a closed loop to minimize water consumption. (c) Oxygen and nitrogen gas are supplied by separating of atmospheric air. The gas first goes through filters to remove particles. Thereafter it is split into two streams: one goes to the steel plant the order to a sulfur removal unit from which it is fed into the direct reduction shop. Composition of the sulfur cake is about 40% sulfur and 45% water. The balance consists of various salts mostly sodium salts. (e) electric power supply. Electricity also comes from Ras Abu Fontas. However, a flicker compensation station was constructed to absorb the filkering of electric power to avoid potential electric troubles.

II.3 Qatar Flour Mill. The plant is located between QAFCO and QAPCO. The first stage of the facility was incorporated in 1969 with a milling capacity of 100 tons per day and a storage capacity of 8,100 tons of wheat. In 1978 storage capacity was increased by 8,700 tons of grain at the cost of 20,000,000 Qatari Riyals.

The entire operation consist of four stages: (1) Unloading of bulk wheat from ships via penumatic conveyors at the rate of 1,000 tons per 24 hours. (2) transport of wheat to silos which is accomplished by three stepped up rubber conveyors (3) storage of wheat, and finally, (4) milling of wheat and the associated operations such as separation of operation, moistering of wheat.

Production of wheat flour and bran in Qatar for the period 1975 - 78 are given below:

	Product (tons)	
	Wheat	Bran
1975	14,379	3,204
1976	15,951	3,764
1977	17,948	4,203
1978	24,892	5,588

The company employs about 100 (hundred) persons, and the only facility within the mill area other than manufacturing is a septic tank which is periodically empties by the Municipality of Umm Said. Other than that, the entire operation is a closed system.

II.4 QAFCO : This plant occupies the major part of the southern corner of the industrial site. A layout showing the various parts of the facility is shown in fig. 6. QAFCO's first nitrogenous fertilizer plants began production late 1973 with a design capacity of 900 tons/day of ammonia and 1000 tons per day of urea. In 1979 additional plants for ammonia and urea were commissioned. The total design capacity now stands at 1800 tons a day of ammonia and 2000 tons per day for urea. Block diagrams of the processes in the plant are depicted in figs. 7,8 and 9. The total cost of the plant is approximately QR. 300,000,000.

Feedstock gas from Dukhan oilfield constitutes the raw material and energy source for the plants. Expansion of the plants has necessitated an increase of gas supply to 100 million cubic feet a day.

Sulfur compounds like hydrogen sulfide are removed before the gas and steam mixture is sent to the reforming section where it is converted to carbon monoxide and hydrogen through a catalytic process. Air is then introduced as a source of nitrogen necessary for bringing about ammonia reaction.

At next stage reformed gas undergoes a different conversion and purification process. Carbon monoxide is converted into carbon dioxide and the carbon dioxide is then separated, forming one of the raw materials for urea.

The gas composed of nitrogen and hydrogen is then compressed and routed to the ammonia synthesis section where it is converted to ammonia at high temperature (800°F/427°C) and a high pressure of 3100 psi. Liquid ammonia is stored in tanks (capacity 47000 tonnes) at low temperature (-34°C). Two thirds of the ammonia produced is used in urea production, the rest is sold. Special ships are used in transporting ammonia at the same low temperature as when it is stored.

For urea production, liquid ammonia and carbon dioxide are introduced in the urea autoclave section at high pressure (3500 psi) to form urea solution.

After crystallizing and centrifuging the urea crystals are ready for melting and prilling. Prilling at the prilling tower completes the process forming a free flowing final product.

In the new urea plant the crystallization step is omitted, the urea being prilled after evaporation of the urea solution.

Prilled urea is finally transported by conveyor to a bulk storage plant, having a capacity 135,000 tonnes, where it is ready for shipping.

Urea is transported to customers either in bulk or bagged form. Special bulk loading equipment is available at the jetty, and four bagging lines feed the bagship loading equipment for showing the bags.on the ship. Urea produced at QAFCO contains 46.3% nitrogen.

QAFCO accessories include: (a) power stations with gas turbine generator sets producing around 30 MW required for the process plants, (b) cooling sea water with a pumping capacity of 231,500 gal/min. Water is not recycled and discharge enters the Gulf at a ΔT of over 10°C. (c) desalination plants (4) with a design capacity of about 1,700,000 gal/day of water, (d) three water storage tanks having a total capacity of 3,000,000 gallons, (e) two nitrogen plants of 1000 m^3 an hour capacity each supplying nitrogen, and (f) three ammonia crackers provide hydrogen for the start of the plant.

II.5 NGL : In March 1971, Qatar started a large project for the processing and export of natural gas liquids (NGL) based on the associated gas produced at the onshore Dukhan Oilfield. This project started production in 1975 and was expanded in 1980. This unit has a daily production capacity of 740 tonnes of propane; 470 tonnes of butane and 310 tonnes of condensate as natural gasoline. In addition, the plant is capable of producing 2.3 million cubic meters per day of ethane-rich gas and 4 million cubic meters of methane-rich gas. The ethane-rich gas is to be utilized in the petrochemical complex, of which details are given later.

In the last months of 1980, Qatar's second NGL plant, based on associated gas recovered in the offshore oilfields and piped to Umm Said on the mainland, was commissioned at Umm Said.

The associated gas recovered at the oil-gas separators at the well head is subjected to preliminary processing (compression, cooling and dehydration) on the production platform. The resultant gas and liquid streams are then transmitted through separate pipelines to the onshore processing plant near Umm Said.

In two-stage process at Umm Said, the methane-rich gas stream is first stripped out of the gas-liquid mixture. The NGL is then further split in a fractionation unit to produce ethane-rich gas, propane, butane and natural gasoline.

Ethane-rich dry gasses are sold to QAPCO as feedstock for the production of ethylene. Propane and butane, which when liquified are referred to as liquified petroleum gas (LPG), are sold largely to export markets.

Natural gasoline will be exported and residual gas will be sold as fuel for other Qatari industries including QASCO.

NGL 2 has a daily production capacity of 220 tonnes of propane; 730 tonnes of butane; 73 tonnes of condensate; 0.9 million cubic metres of ethane-rich gas and 3 million cubic metres of methane-rich gas.

Both the NGL plants have involved an elaborate network of pipeline facilities, compressors, basic plant and considerable quantities of civil works.

Both units are export-oriented in terms of their principal products - butane, propane and LPG.

Fig. 10 represents a block flow diagram for the plants.

II.6 NODCO The National Oil Distribution Company was established in October 1968 to perform crude oil refining operations and local distribution of oil products in Qatar. The paid up capital of the Company is 40 million Qatar Riyals. NODCO is wholly owned subsidiary of the Qatar General Petroleum Corporation (QGPC). NODCO owns the original Refinery Plant which was established in 1953, with a daily production of 600 barrels of kerosene, petrol and diesel. A contract for the construction at Umm Said of a refinery with a capacity of 6,200 barrels per day was signed in January 1972. It was commissioned in September 1974. Because of the continuous increase in national consumption several modifications were made in the refinery, and the plant was enlarged in 1977 to provide a total throughput capacity of 11,500 barrels per day in 1977. By the end of 1977 NODCO employed 292 persons.

In response to the persistent deficit in national output in relation to national demand, studies were launched during 1974 for a large export-oriented refinery. Eventually a decision was taken to proceed on a more modest basis and a throughout capacity of 50,000 barrels per day was settled upon. IDTC participated in these exercises.

Contracts have now been awarded by QGPC for the construction of this refinery which will be built on a site adjoining the present NODCO refinery at Umm Said. Production is expected to start sometime in 1983, and in the initial years there will be a considerable surplus for export to international markets. The products of the new refinery will include LPG, regular and high octane gasolines, jet fuel, kerosene and gas oil. National distribution to the domestic market will be effected through pipelines from the refinery to new storage facilities to be set up in Doha, the principal market.

Refinery production and local consumption in 1979
(Figures in barrels)

	Production	Consumption
LPG	77,229	98,334
Regular grade petrol	885,231	878,155
High Octane petrol	35,997	362,411
Kerosene	31,798	34,223
Jet fuel	481,226	549,274
Diesel Oil	958,524	1,035,167

Chapter III

Sources of Pollution

A. Air Pollution

III.A.1 QASCO Gaseous emissions are originating from the vent stack and of the midrex iron-making plant, the baghouse on the electric arc dedusting system and the flue gas stack on the rolling mill. Sulfur dioxide resulting from the combustion of natural gas on the reheating furnace is the major source of air pollution at QASCO.

Dust in the form of particulates is emitted the direct reduction and the electric furnace areas, and along the lines of handling the raw materials and the transfer of iron sponge system. However, the plant has a high effiency de-dusting system (bags) almost entirely eliminated any dust from escaping to the atmosphere.

III.A.2 QAPCO Under normal operations the plant will produce gaseaous emissions from cracking furnaces, waste heat boilers, and conventional boilers. These will contain both sulfur and carbon dioxides, hydrocarbons, and nitrogen oxides. Waste gases from the sulfur recovery unit will also emit sulfur dioxide as well as lesser amounts of hydrogen sulfide. In the case of a sudden shutdown of the sulfur recovery unit, excessive amount of sulfur dioxide will be emitted to the atmosphere. On such occasions, the emitted sulfur dioxide will add to the concentrations likely to be present in the atmosphere of QAPCO. Large quantities of ethylene could also be released to the atmosphere particularly from leaking pipes and corroded valves. Under ubnormal operations high concentrations hydrocarbons will be vented to the atmosphere from the processing sections of the plant. Dust from the sulfur storage area could cause sever pollution problems especially at the time of equipment failure

III.A.3 QAFCO

a. Ammonia During normal operating conditions in the plants only minor quantities of ammonia is vented from the plants. Inferts purged from the refridge system in the ammonia loop as well as the refridge system in ammonia storage maker this necessary.

Sulphur dioxide. QAFCO utilize natural gas from different sources in Qatar. This H_2S content will differ from one source to another. Gas for feedstock is treated in desulfurication units and the H_2S is burned to SO_2 in two flores. Firing of reformers, boilers and gas turbines is done with oxygen in excess to H_2S is converted to SO_2.

Fugitive emissions. Small leaks from valve spindles and pump reals in storage area can occur. Necessary purging of pipes will take place from time to time. In the area close to the emission point a smell of ammonia will be present.

Due to the nature of handling flammable gases under pressure and poisenous gases the H_2S and ammonia emergency situations may occur. This means that it is necessary to depressurize and vent plant equipment for natural gas, H_2, CO, CO_2, N_2, Tn, TNH_3. The plants are designed for safe discharge of the vented gases.

b. Urea Plants. There will be continuous emission from the LP absorber, off gas absorber, vent stock and the prill towers. The amount of ammonia and the stack hight will ensure a good dilution of the gas before it reach ground level.

Urea dust discharged from the prill towers can easily be recognized at a long distance from the plants.

III.A.4. NGL This plant is the source of gas for the government grid together with the feed stock to QAPCO.and QAFCO. As in the other plants of the complex, the major atmospheric pollutants from NGL will be sulfur dioxide, hydrogen sulfide, and hydrocarbons.

Under emergency situations huge amounts of hydrocarbons arise from the open pit accompanied with clouds of heavy smoke that reduce visibility around the pit. In emergencies, the NGL plant release large quantities of gas from process unit into the flare stack.

III.A.5. NODCO Crude oil from Dukhan oil field (S =1.14%) is fed into the fractioning tower. Formed gas in each section are drawn to the LPG and fuel gas recovery system. Excess amounts are passed into the flare stack. Bottoms from the tower are also incinerated at the flare stack. Other sources of emission are the naptha cracking, the kerosene treating, the platforming and heating units. Flue gases will in general contain sulfur dioxide, hydrocarbons and nitrogen oxides.

In emergencies all flows are directed to the flare stack.

B. Water

III.B.1 QASCO. There are two pertinent water systems at QASCO. Sea water and industrial(circulated) water systems. sea water is used as a coolant for heat exchangers of industrial water, cooling jackets of furnace walls, oil coolers and others. To guard against the growth of small shells inside the pipe line, sodium hypochlorite solution is added at the water intake. Also as a precaution against contamination will oil due to accidental spills, a pend and an oil fence have been erected at the outlet of the line and before discharging into the Gulf. The main pollution potential emanating from this source is the temperature gradient which varies from 7-10°C. Industrial water system, by contrast, is circulated at the electric furnace, the castingshop and the direct reduction processes. Since this water goes in a closed circuit, pollution problems are not anticipated from this source.

III.B.2 QAPCO. Final effluent at QAPCO composts of cooling water, pH adjusted waters from demineralization unit and boilers boilers blowdown, alkalized column, and purge waters from the quench tower, steam generators, compressor pumps,and plant wash. Alkalized and purge water is collected in a separation basin. Hydrocarbons are skimmed from the surface of the basin are skimmed off and sent to incinerator. Water is then pumped to the main discharge channel. However, the discharge has a characteristically noxious odors which may be due to catalysts escaping from the catalyst room into the main channel. In fact, identifying the odours material and tracing back its source is a priority topic in water pollution at Umm Said.

III.B.3 QAFCO Wastewater from QAFCO is mainly cooling water (50,000 m^3/hr). Minor streams from ion exchange regeneration cycle and boilers blowdown. All leave the plant in one channel at ΔT of about 10^oC to the Gulf. Beside thermal pollution, the effluent contain some corrosion inhibition and scale control chemicals. Their amounts in the waste will be analyzed.

III.B.4 NGL Cooling water from NGL 1&2 combines into one cooling water outfall into the Gulf NGL = 4000 m^3/hr 14 - 16,000 m^3/hr = 18,000 m^3. Most of fresh water from Abu Fontas. Industrial water ~ using desalination ~ 1 ton/hr.

III.B.5 NODCO. Currently all leakes and valves are washed into a separation tank. A steam jet is injected at the surface of the tank to prevent floating oil from vaporizing into the atmosphere. These oils are skimmed and recycled. Water, at the present time, is being pumped into a holding pond out the plant area. However, when the new refinery goes on stream wastewater from the existing and the new plants will be biologically treated using the activated sludge unit.

III.C Characteristics and health effect of major air pollutant are briefly described below:

III.C.1 Particulate Matter

a. Main characteristics: Any solid or liquid particles dispersed in atmosphere, such as dust, pollen, ash, soot, metals, and various chemicals; particles often classified according to size, as settleable particles (larger than 50 microns), aerosols (smaller than 50 microns), and fine particulates (smaller than 3 microns)

b. Principal Health Effects: Directly toxic effects or aggravation of the effects of gaseous pollutants; aggravation of asthma or other respiratory or cardiorespiratory symptoms; increased cough and chest discomfort; increased mortality.

III.C.2 Sulfur Dioxide (SO_2)

a. Main Characteristics: Colorless gas with pugent odor; oxidizes to form sulfur trioxide (SO_3) which forms sulfuric acid with water.

b. Principal Health Effects: Classed as mild respiratory irritant; most SO_2 inhaled is absorbed in upper respiratory tract and never reaches lungs; penetrates when clings to particulate matter; aggravates respiratory diseases including asthma, chronic bronchitis; emphysema; can result in reduced lung function, irritation of eyes, possible increased mortality.

III.C.3 Hydrocarbons (HC)

a. Main Characteristics: Organic compounds in gaseous or particulate form, e.g., methane, ethylene, acetylene; componenet in formation of photochemical smog.

b. Principal Health Effects: Acute exposure causes eye, nose, and thoat irrigation; chronic exposure suspected to causing cancer; some groups of combustion hydrocarbons especially implicated in induction of cancer in laboratory animals.

III.C.4. Nitrogen Oxides (NO_x)

a. Main characteristics : Brownish-red gas with pungent odor.

b. Principal Health Effects: Major role as component in creation of photochemical smog; also has distinct effects apart from those associated with smog; has been shown to be toxic to experimental animals; some studies indicate NO_2 produces disease in animals that have human counterparts (emphysema, other lung disease); in study of school children in high NO_2 area (near TNT plant) found that children contracted significantly more respiratory disease than children in control area; has been shown to aggravate respiratory and cardiovascular illnesses and chronic nephritis.

III.C.5. Carbon Monoxide (CO)

a. Main Characteristics: Colorless, odorless gas with strong affinity for hemoglobin in blood; usually aware of presence of CO only after early poisoning symptoms appear (such as nausea, headache, dizziness, difficulty in breathing).

b. Principal Health Effects: Absorbed by lungs; reduces oxygen-carrying capacity of blood; creates reduced tolerance for exercise, impairment of mental function, affects fetal development, aggravates cardiovascular disease; several studies show at prolonged low-level exposure results in diminution of visual perception, manual dexterity, ability to learn and perform intellectual tasks; other studies have produced no such adverse effects at low levels of exposure.

III.C.6. Photochemical Oxidants (Smog)

a. Main Characteristics: Oxidizing type of pollutant found in many urban areas; results from chemical combination of reactive hydrocarbons vapors with nitrogen oxides in presence of sunlight; the resulting production of photochemical oxidants consists of a number of toxic compounds: Ozone, peroxyacetyl nitrates (PAN), aldehydes, other chemical compounds.

b. Principal Health Effects: Aggravation of respiratory and cardiovascular diseases, irritation to eyes, respiratory tract, impaurment of cardiopulmonary function; some concern about possible mutagenic effects of ozone; in Los Angeles one study showed no association between "alert days" when oxidant levels were high and mortality increase; poorer athletic performance has been related to high oxidant levels; possibility of developing tolerance to oxidant pollution such as has been shown for experimental animals may account for the relatively few changes associated with chronic exposure.

Source : Baumol W.J., Oates W.E.,
"Economics, Environmental Policy and the
Quality of Life" Princeton Hall 1979.

However, since sulfur and its compounds constitute the major part of air pollution at Umm Said, further information on presence of sulfur in the environment may be found in annex 1.

Chapter IV

The Immediate Objective

As already indicated in chapter one, the immediate objective of the project has been the establishment of an environmental laboratory at Umm Said. For all practical purposes, this objective has been achieved. Actually there are two laboratories: (a) mobile, and (b) conventional pollution monitoring and analysis facilities.

IV.a. The mobile unit, supplied by Environmental Science and Engineering (ESE), Gainseville Florida, USA, consist of a truck mounted cubicle measuring (meters) 4L x 2W x 2H, with fully insulated interior fitted with cold storage area, working space and storage cabinets.

Basic equipment in the unit consist of water and liquid effluents as well as air sampling and analysis. As part of the purchase agreement ESE was to provide on site training to IDTC laboratory personnel in the operation and maintenance of the unit and its instrumentations.

Details on this mobile laboratory and the service agreement between ESE and IDTC can be found in annex 2. The training programme was initiated on Feb. 1983. So far two ESE experts have been to Doha. Their accomplishment are reported in annexes 3 and 4.

IV.b. An old building at Umm Said houses the conventional laboratory The building is being repaired and renovated now. Furniture has been already installed. Equipment is in storage and will be in place as soon repair work is complete - before the end of October. Details on furnishings and equipment are listed in annex 5, 6 and 7.

IV.c. Conclusions.

IV.c.1 A two-part environmental laboratory at Umm Said has been in the planning for the past three years. The mobile unit has been delivered and is partly in operation.

IV.c.2 Furniture and equipment for the conventional unit are already on site and the building in being renovated. It is expect that this laboratory will be in operation within the next two months.

IV.c.3 A major difficulty has been the recruitment of adequate and qualified manpower to run the laboratories. IDTC management is trying to fill this gap.

IV.d. Recommendations

IV.d.1 Appropriate platforms and ladders around selected stacks (Table 1), should be erected as soon as possible. Source emissions constitute themost serious cause of atmospheric pollution at Umm Said and vicinity. Therefore no work can be complete without testing stacks flue gases.

IV.d.2 At least two more laboratory analysts should be added to the existing two as soon as possible - preferably a biochemist and an instrumentation expert.

IV.d.3 A project document for the second phase should be prepared outlining the pollution control program and discussed with the Government.

IV.d.4 If left alone, some of the pollution problems at Umm Said may cause irrevirsable environmental effect. Therefore, the second phase should be implemented as soon as possible.

ANNEX - 1

SULFUR IN THE ENVIRONMENT
THE STATE OF THE ART

Introduction

Sulfur is a non-metalic element occuring naturally in yellow orthohombic crystals, in masses, crusts or powder. Symbol S, atomic No. 16, atomic weight 32. It burns in air with a blue flame and suffocating odor. It is used in gunpowder, medicine, and rubber vulcanizing.

Because sulfur can have oxidation numbers ranging from +7 as in persulfate (S_2O_8) to -2 as in sulfide (H_2S), it can from a large number of organic and nonorganic compounds. From environmental view point, however, only three species (the sulfates, oxides, and sulfides) are of interest to us. However, a knowledge of the sulfur cycle in nature as represented in fig. 13 is essential in understanding the transformations that occur.

Sulfates (SO_4)

Sulfate ion is one of the major anions occuring in natural waters. It is of importance in public water supplies because of its cleansing effects upon humans when it is present in excessive amounts. Also waters containing large amounts of sulfates tend to form hard scales in boilers and heat exchangers.

Sulfates are of considerable concern in sewage and industrial wastes because they are indirectly responsible for two serious problems when handling or treating sewage, namely odor and sewer-corrosion due to the reduction of sulfates to hydrogen sulfides in the absence of oxygen in accordance with the following equation:

$$SO_4 + \text{anaerobic bacteria} + H_2O \longrightarrow H_2S + CO_2$$

Sulfate ions can be precipitated from solution by the addition of barium. The reaction that takes place is as follows:

$$SO_4 + Ba \longrightarrow BaSO_4$$

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Determination of sulfates could be achieved by gravimetric, or colorimetric methods.

Hydrogen Sulfide (H_2S)

Hydrogen sulfide is an obnoxious gas having an odor threshold of 0.10 ppm. Lower concentrations may not be detected as an odor. The odor is similar to that of rotten eggs. In liquids such as sewage, the formation of H_2S, and hence, intensity of odor is pH dependent with maximum values at pH of 7 - 8.

Sewers, especially gravity type, provide an ideal environment for chemical changes of sulfur compounds present in sewers. One such change is brought about by bacterial action as stated above resulting in the transformation of sulfur in to hydrogen sulfide. Because of the serobic conditions normally prevailing in sewers above the sewage, these bacteria oxidize the sulfide into sulfuric acid as follows:

$$H_2S + 2O_2 + \text{bact} \longrightarrow H_2SO_4$$

H_2SO_4, being a strong acid, attacks sewer lines especially at points where drainage is minimum.

Fig. 14 summarises the main aspects of odor and corrosion problems in sewers.

Hydrogen sulfide may be determined by wet chemical techniques. It can be scrubbed from sample and determined titrimetrically. However, more sophisticated methods namely colorimetric are now used.

Toxicity

Hydrogen sulfide is not known to produce chronic diseases in humans but may interfere with apetite at 5 ppm. Respiratory tract irritation were reported at 50 - 100 ppm for one hour. Acute sickness and death may occur at a concentration of several hundred ppm. (Source : Dept. of Public Health, Calif. U.S.A.)

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Sulfur Dioxide (SO_2)

Sulfur dioxide is produced by the combustion of sulfur compounds present as impurities in many coals.

Its main characteristics is that it is a colorless gas with pungent odor, oxidizes to form sulfur trioxide (SO_3) which forms sulfuric acid in water.

Toxicity

Its effects on humans have been already summerised in upper respiratory tract and never reaches lungs; penetrates when clings to particulate matter; aggrevates respiratory diseases, can result in reduced lung function, irritation to eyes, and possible increase mortality. (Source : Baumol J.W. "Economics, Environmental Policy and the Quality of Life, Princeton Hall 1979). Most serious, are the catastrophic effects on people's health during unfavourable meteorological conditions such as rain or snow where the emitted SO_2 is returned to the surface of the earth as 'acid rain'. Such calamities took place in the mill town of Dorona, near Pittsburgh PA, U.S.A., in 1948 and in London 1952 where some lost their lives, while many more were hospitalized.

Standards.

Unfortunately there is not one fixed international standard for SO_2. Rather standards vary from country to another and sometimes from one place to another and from time to another within the same country. The following quoted values will illustrate this point.

Country	Standard		
U.S.A. 1971	80 g/m^3	(.03ppm)	Yearly mean
	365 g/m^3	(14ppm)	Maximum
U.S.S.R., 1969	50 g/m^3		24 hour avg.
	500 g/m^3		30 min. avg.
Sweden 1970	150 g/m^3	(0.05ppm)	monthly mean
	300 g/m^3	(0.10ppm)	24 hr. avg.
	750 g/m^3	(0.25ppm)	30 min. avg.
Czechoslovakia, 1972	500 g/m^3	(0.05ppm)	24 hr. avg.
Canada, 1973	30 g/m^3	(0.01ppm)	yearly mean
	510 g/m^3	(0.04ppm)	Daily avg.
	300 g/m^3	(0.10ppm)	hourly avg.

Source : JAPCA, Vol. 23, No. 11, Nov. 1973

REMOVAL TECHNOLOGY

A. Hydrogen Sulfide.

The widely used Claus Process can only achieve about 92% conversion to sulfur. A new set of add-on processes that can remove the last traces of hydrogen sulfides from gas streams have been recently developed. Most of these processes will yield elemental sulfur, so there are no secondary pollution problems. A list of these processes together with brief descriptions are presented below.

Table 2. Add-on Processes for H_2S Removal

Process & Developer	Description
Stretford/Takahax U.K. North Western Gas Board.	H_2S, absorbed as bisulfide, is oxidized in solution by a two-stage oxidation-reduction couple involving vanadate and anthraquinone desulfonic acid (AQDSA) as oxygen carriers. Takahax uses napthoquinone and avoids vanadate.
Beavon, Ralph M. Parsons Co.	Preliminary gas-phase hydrogenation of all sulfur compounds to H_2S, followed by Stretford processing. COS and CS_2 are reduced.
Cleanair, J.F. Pritchard Co.	H_2S rich tailgas is water cooled to continue the claus reaction and to hydrolyze COS and CS_2; sulfurous stream is then fed to Stretford unit.
Solution Claus, Institut Francais du Petrole	Essentially a Claus redox reaction with or without added catalyst. High boiling solvent preferred to acept hot gasses without extensive cooling.

Cataban, Rhodia, Inc.	Ferric ion, kept in solution by organic chelating agent, oxidizes H_2S to S. Resulting ferrous ion is immediately oxidized back to ferric state by air in a quantity at least 4 times stoichiometric.
Sulfreen, S.N.P.A.	Catalytic use of active carbon for high efficiency Claus redox reaction to yield sulfur rather than oxidize SO_2 to SO_4 requires both H_2S and SO_2 in feedstream. Westvaco has similar process.

Source : May 15, 1972/Chemical Engineering.

In addition to the above there are several processes used to remove H_2S from hydrocarbons, typically refinery fuel-gas send it on to a recovery unit for final deposition. These include the Girbotol, Koppers carbonates, Shell phosphate routes, and molecular-sieve absorption processes. Fig. 15 is a typical removal flow sheet.

B. Sulfur Dioxide.

SO_2 removal processes are usually classified either as throwaway processes or regenerative processes. There are wet and dry throwaways and regeneratives. However, for the ease of description, processes are often grouped by general categories including dry injection, dry absorption, wet absorption, adsorption, and catalytic oxidation.

Table 3 lists the categories of SO_2 removal processes whereas table 4 list their comparative costs.

Table 3

SO_2 Removal Processes - Six Categories

For purposes of organization and clarity, SO_2 removal processes mentioned in this article have been broken down into six categories:

Regenerative alkaline: An alkaline agent strips SO_2 from the flue-gas stream, combining chemically with SO_2. In a separate regeneration step, the agent is re-constituted and sulfur is recovered usually as liquid SO_2 or sulfuric acid. Some of the agents used include magnesium oxide, sodium sulfite, metal carbonates, and manganese dioxide.

Nonregenerative alkaline: This category is made up of so-called throwaway processes. As in the regenerative routes an agent combines chemically with SO_2 in the flue-gas stream, but in this case it is cheap enough to throw away the product on a once-through basis. Commonly used agents are limestone, lime, dolomite, and solid carbide wastes from acetylene manufacturing.

Furnace Injection : This method, also a throwaway process, differs from the last in that the agent is injected directly into the furnace, and the sulfated product is subsequently scrubbed out of the flue gas with water. Part of the SO_2 is captured chemically within the furnace, the rest in the scrubbing step.

Catalysis : Using a catalyst to promote oxidation of SO_2 to SO_3 this method recovers sulfuric acid. High inlet-gas temperatures are required.

Regenerative Solid absorption : This category comprises several activated-char processes, in which SO_2 is adsorbed on char. In most routes, subsequent desorption leads to the production of sulfuric acid. None of these processes has reached true commercial scale.

Regenerative organic absorption : This differs from alkaline absorption in that an organic absorbing medium is used. A few processes are under investigation, but none is tryly commercial.

Source : June 12, 1972/Chemical Engineering.

Table 1

Stacks to be Scaffolded/Tapped

NGL		
	2	Gas Turbines
	2	Hot Oil Heaters
	2	Regn. Gas Heaters
	2	Glycol Reboilers
	8	
QAFCO		
	1	Gas Generator Stack
	1	Sour Gas Flare
	1	Reformer
	1	Aux. Boiler
	1	H.P. Fired Boiler
	1	Prill Tower
	6	
QAPCO		
	1	Furnace
	1	Sulfur Unit
	1	Incinerator
	1	Gas Turbine
	1	Boiler
	5	
QASCO		
	1	Rolling Mill
	1	Direct Reduction
	2	
REFINERY		
	1	Crude unit
	1	Naphtha Treating
	1	Kerosene Treating
	1	Platforming
	1	Gas Oil Treating
	5	
Grand Total		26 Stacks.

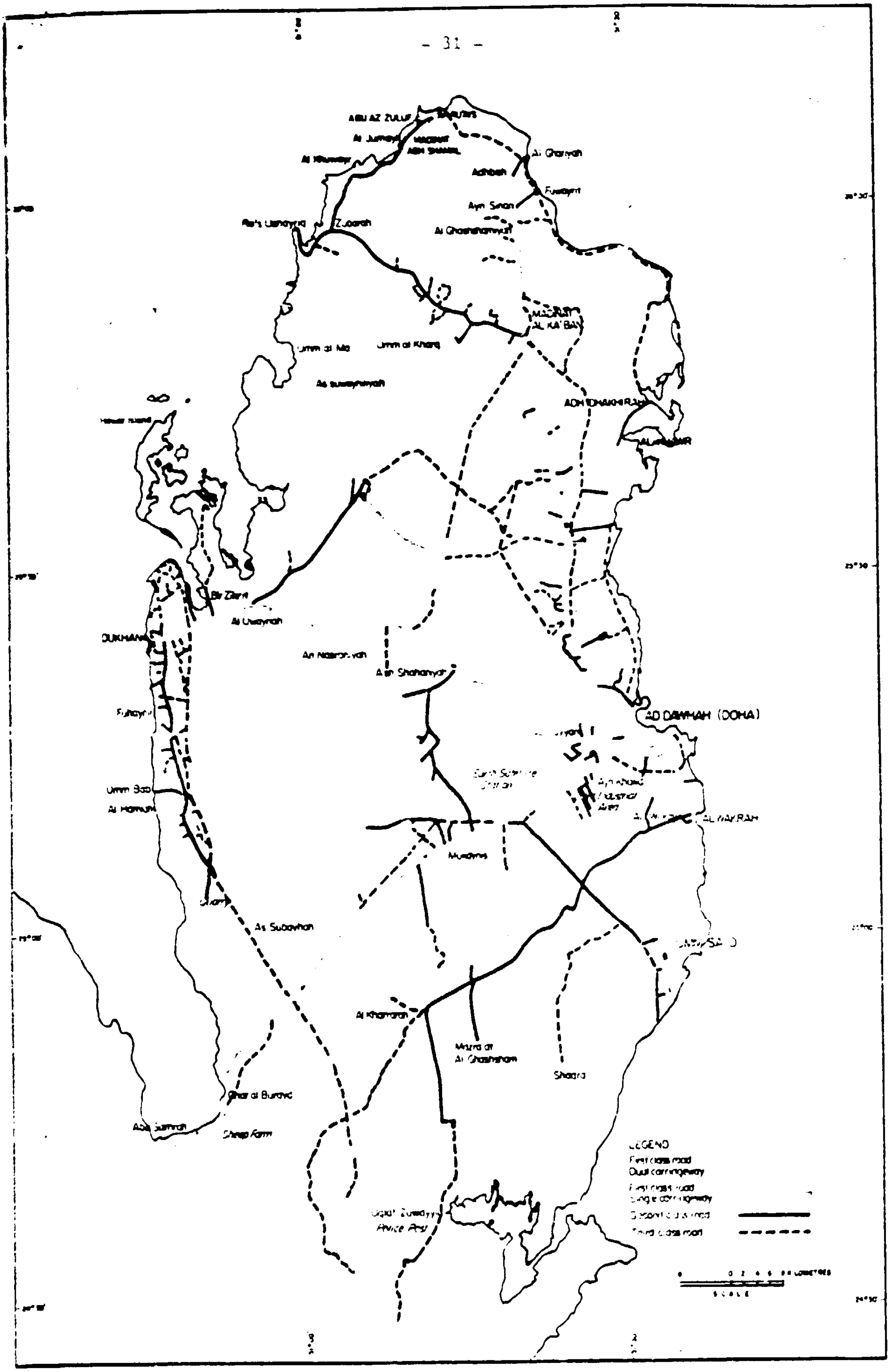
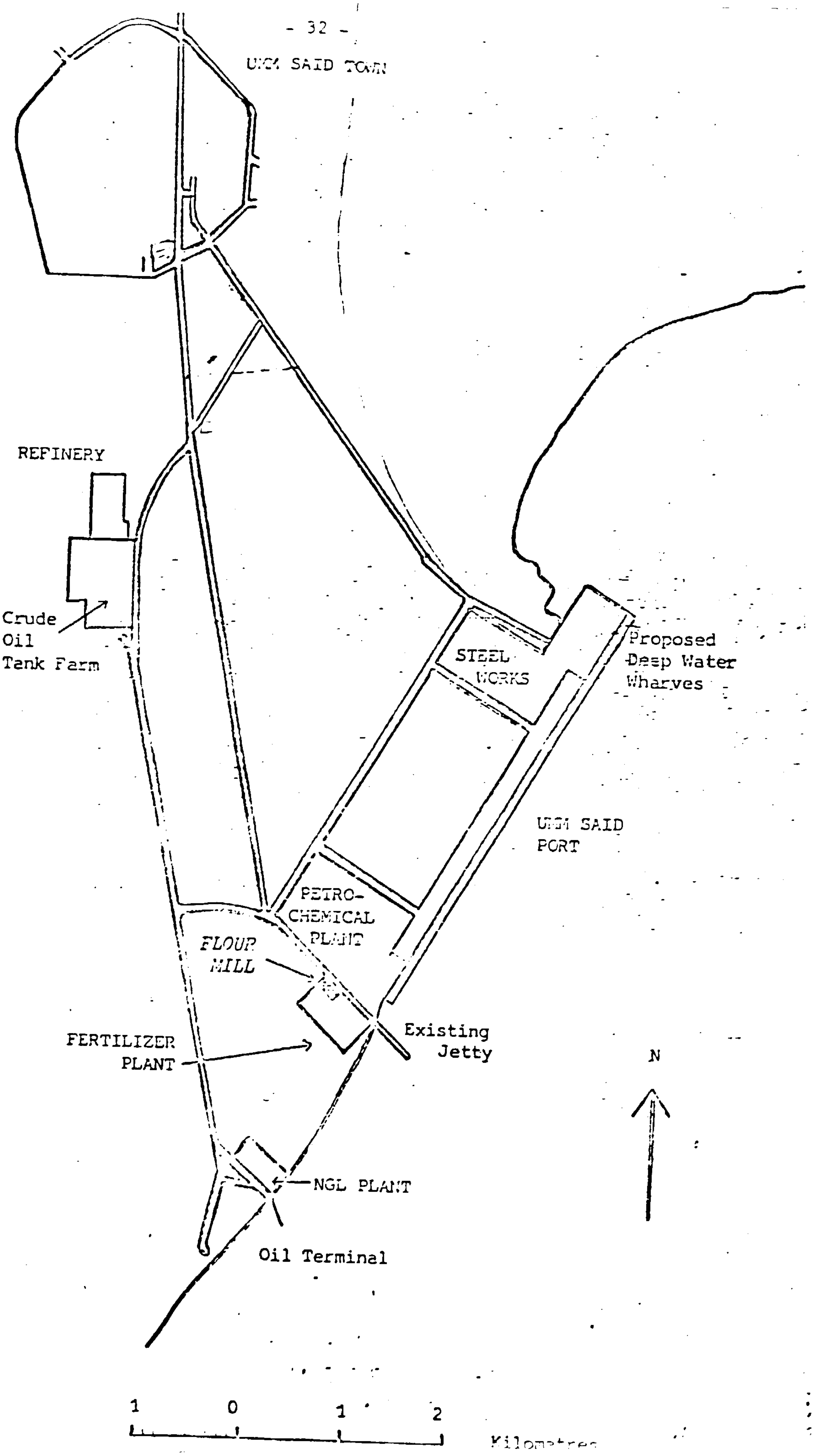


FIG. 1 Map of Qatar


UMM SAID TOWN
REFINERY
Crude Oil Tank Farm
STEEL WORKS
Proposed Deep Water Wharves
UMM SAID PORT
PETRO-CHEMICAL PLANT
FLOUR MILL
FERTILIZER PLANT
Existing Jetty
N
NGL PLANT
Oil Terminal
1 0 1 2
Kilometres

4. Sea water cooling system

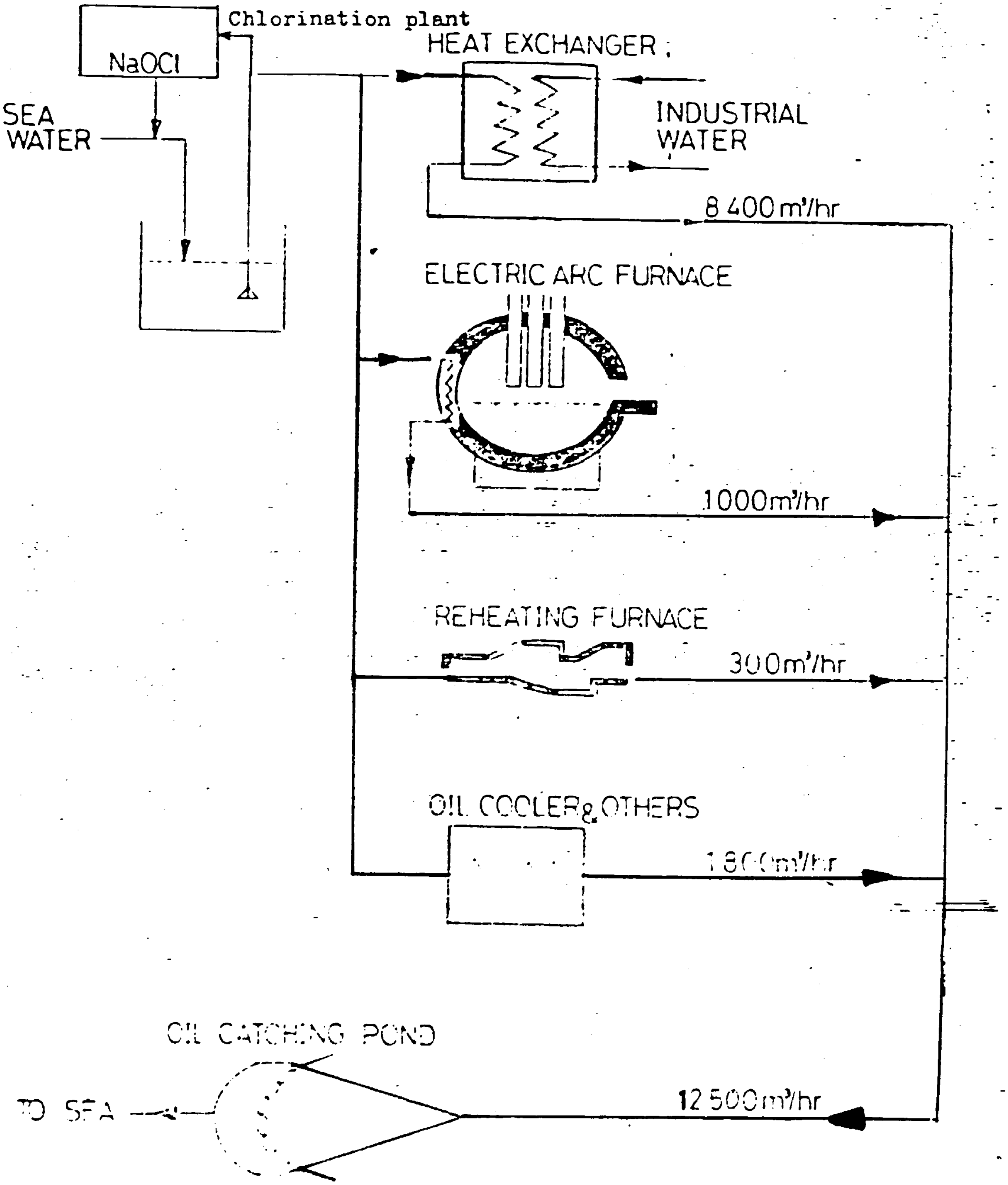
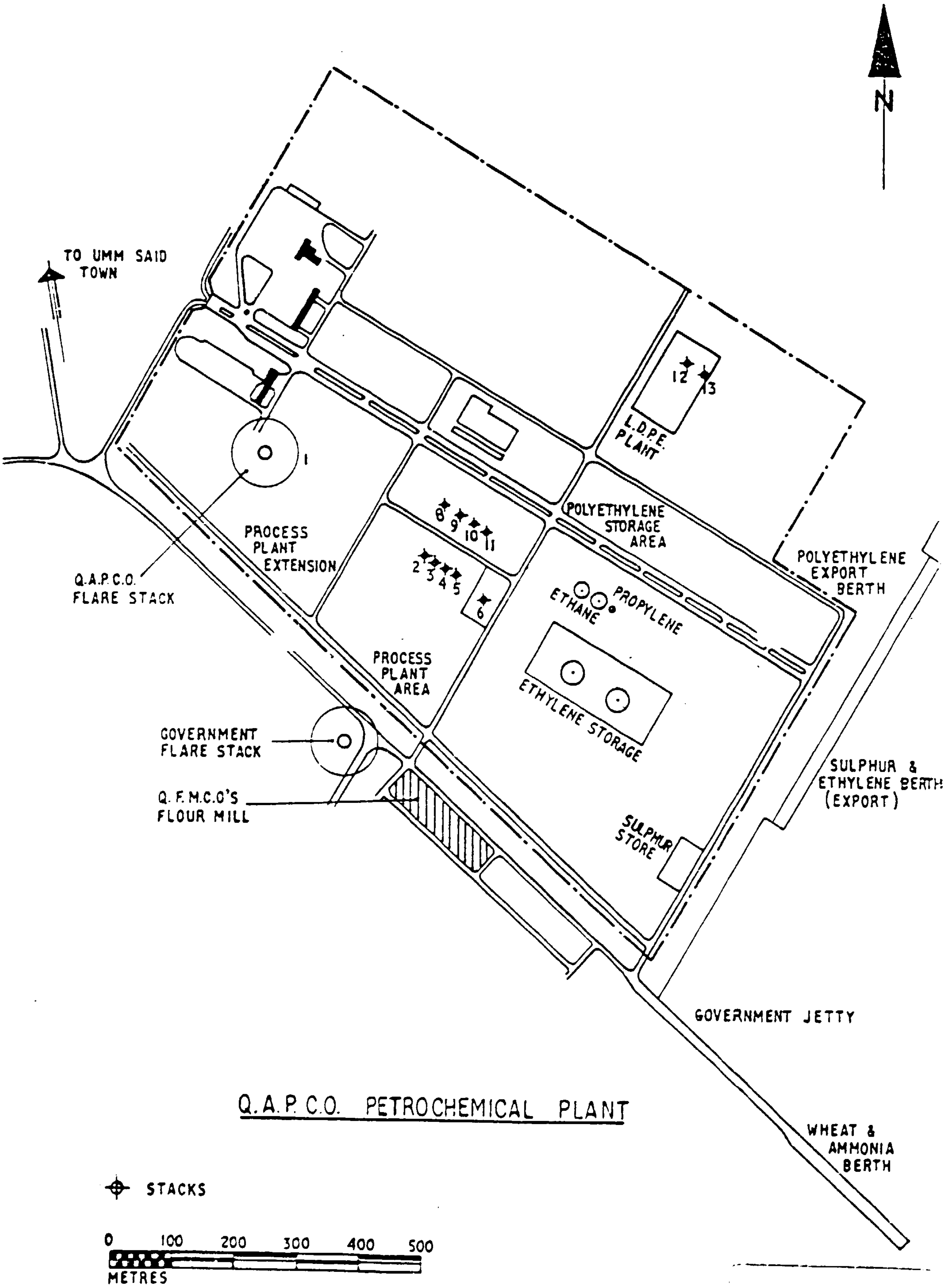
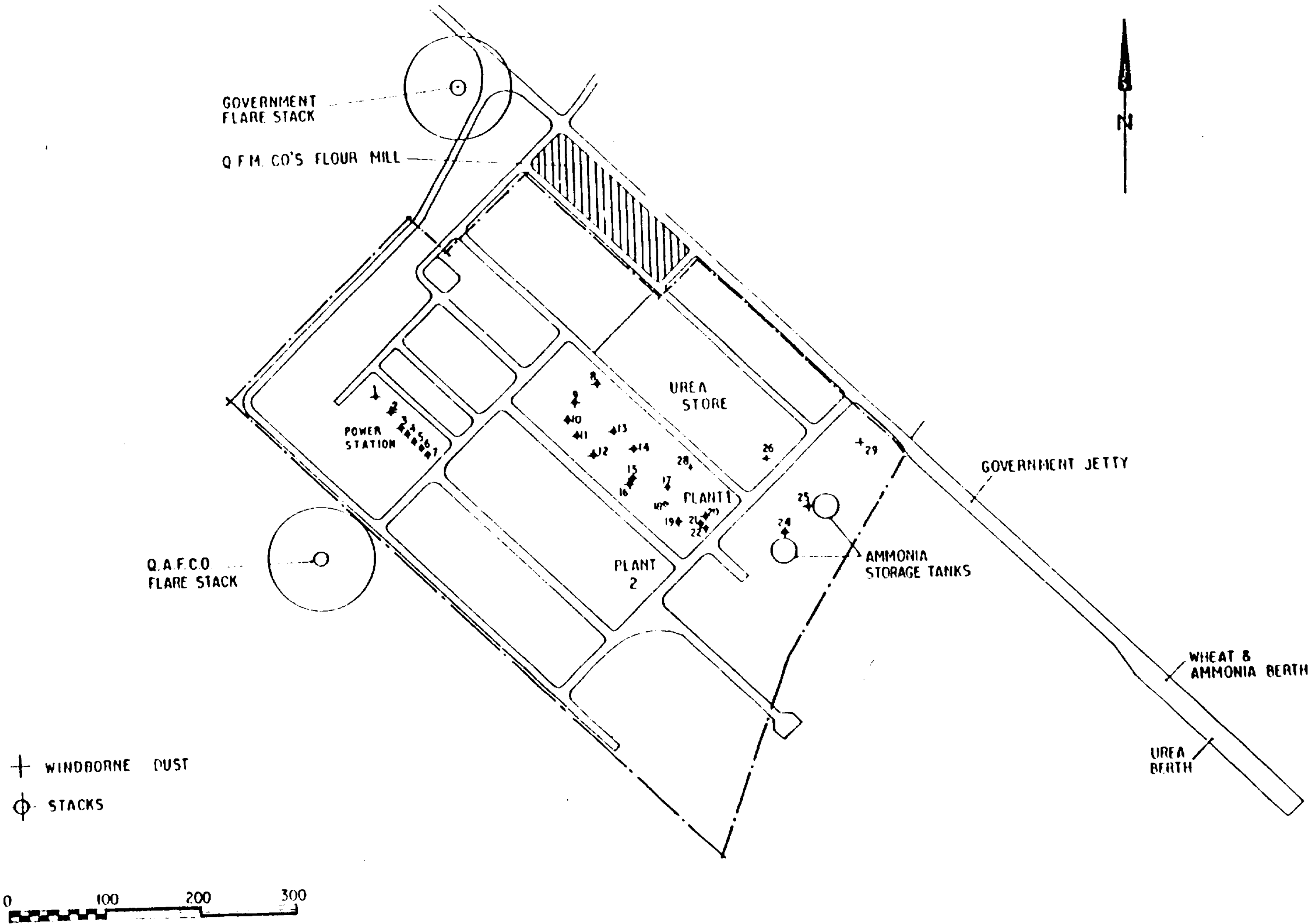


Fig. 4 SEA WATER COOLING SYSTEM



Q.A.P.C.O. PETROCHEMICAL PLANT



Q.A.F.C.O FERTILISER PLANT

Fig.7 BLOCK DIAGRAM OF AMMONIA PROCESS PLANTS

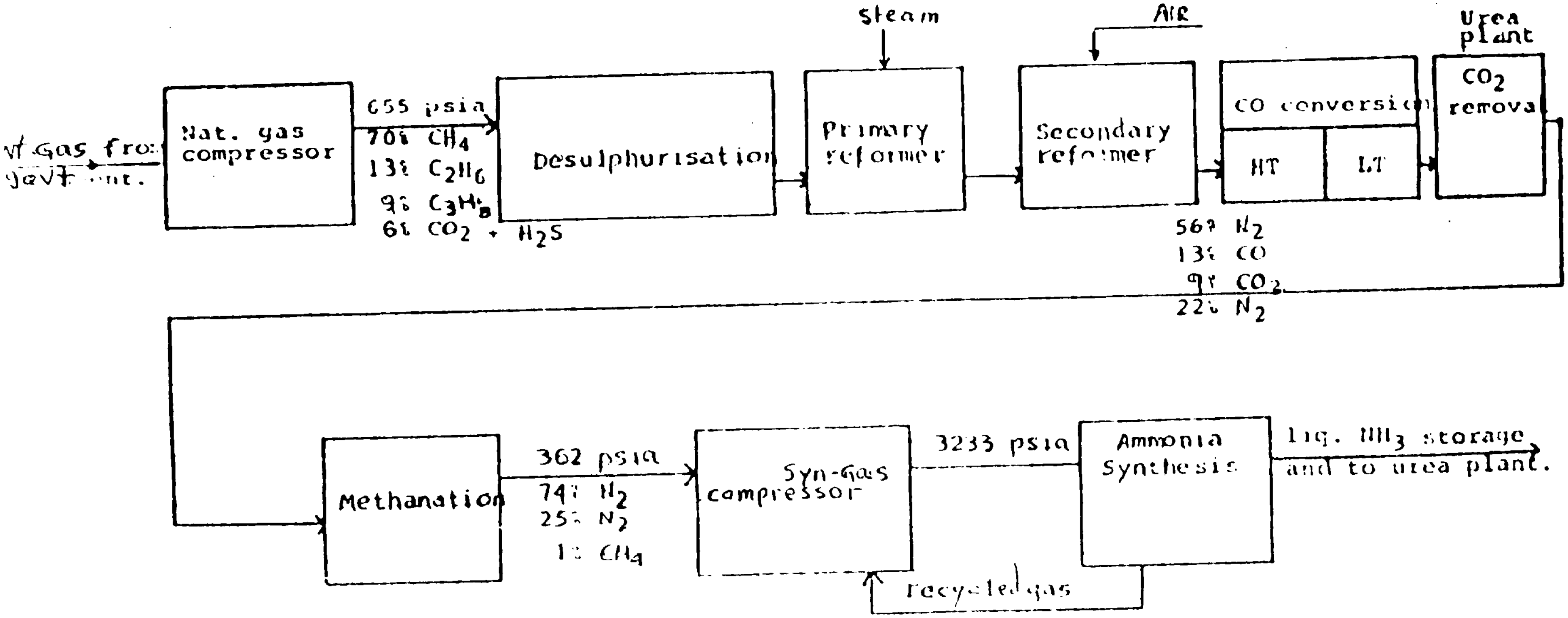


Fig 8 BLOCK DIAGRAM OF UREA PROCESS PLANT NO 1

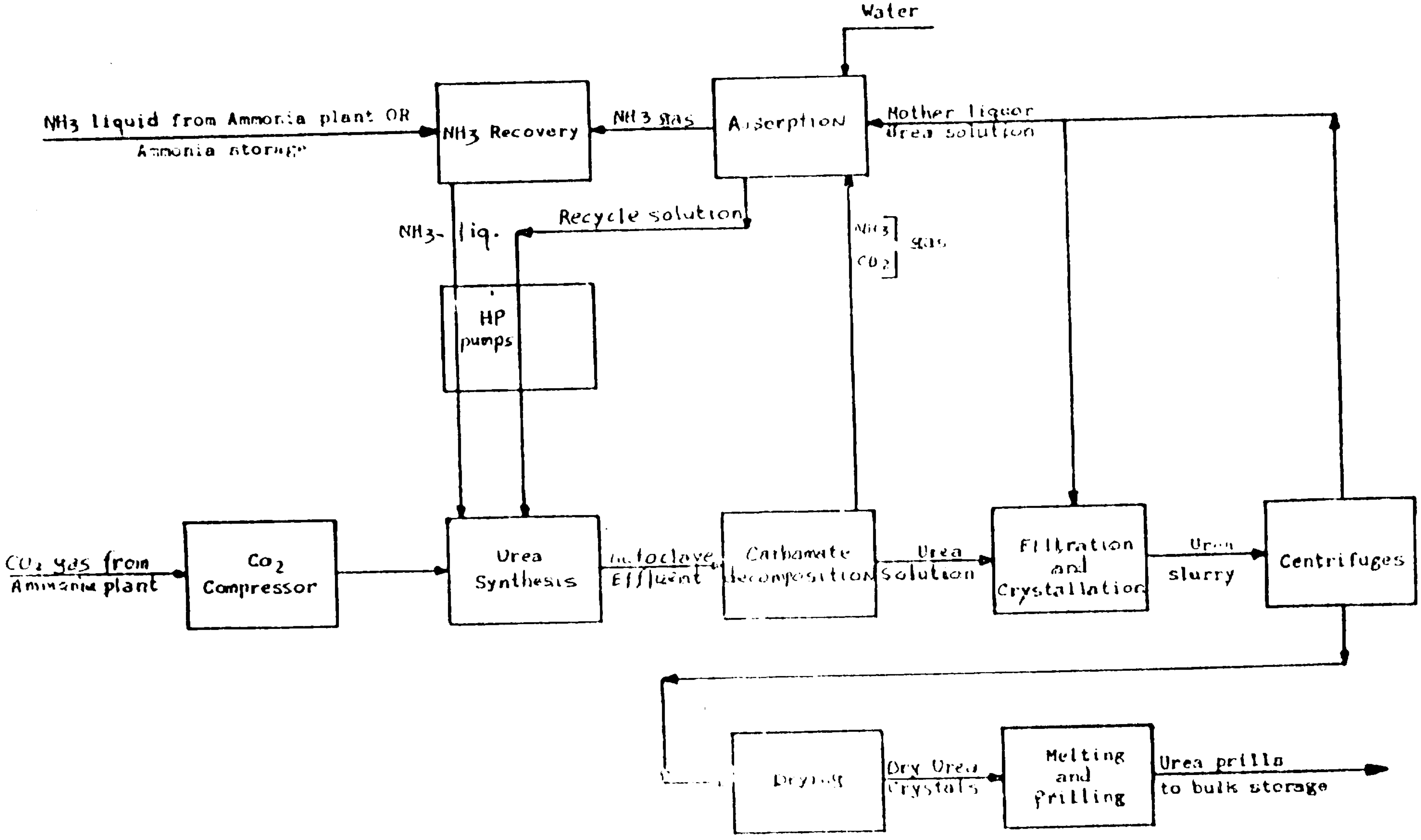


FIG. 9

BLOCK DIAGRAM OF UREA PROCESS PLANT NO 2

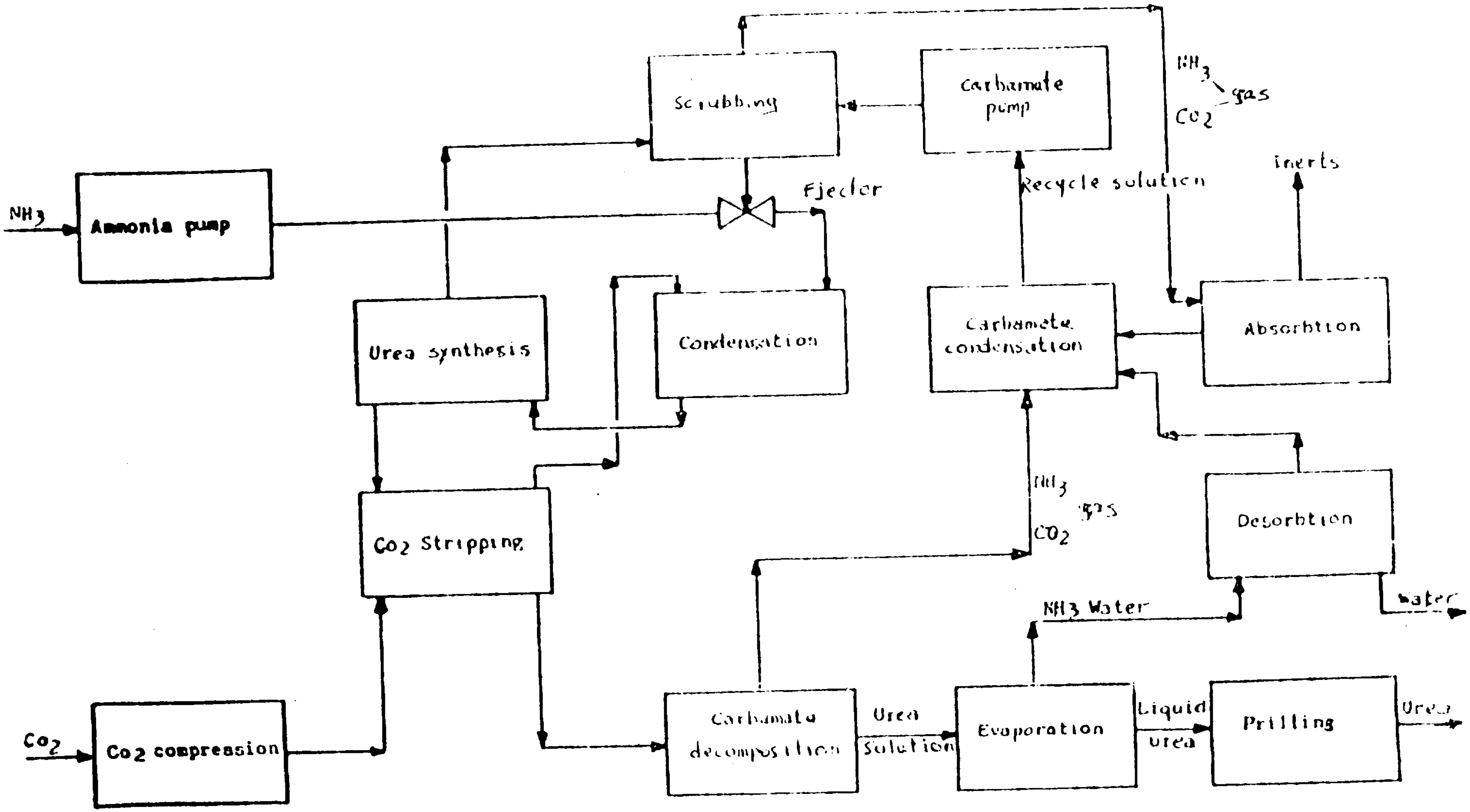
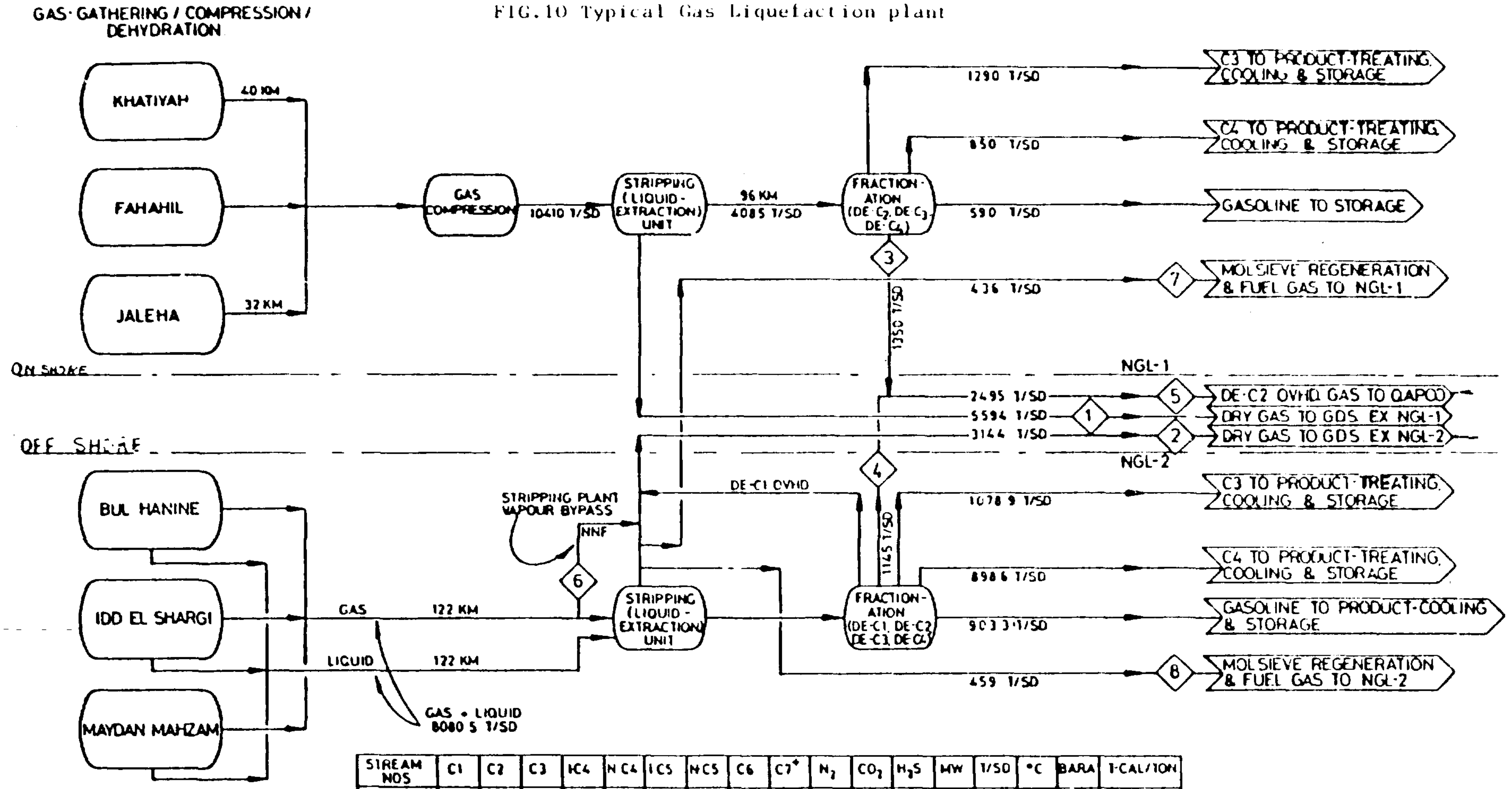


FIG.10 Typical Gas Liquefaction plant



STREAM NOS	C1	C2	C3	IC4	N C4	I C5	N C5	C6	C7$^+$	N_2	CO_2	H_2S	MW	T/SD	°C	BARA	T-CAL/TON
1.	78.23	12.01	2.74	0.15	0.26	0.02	0.02				5.81	0.76	20.5	5594	32	32.1	10180
2.	76.81	9.26	1.46	0.08	0.14	0.01	0.01			2.51	8.07	1.65	20.7	3144	28	23.0	9996
3.	22.20	59.55	1.06								12.44	4.75	29.0	1350	32	23.5	8853
4.	25.14	52.62	0.93							0.09	10.78	10.94	28.5	1145	30	22.8	8624
5	23.56	56.35	1.00							0.04	11.44	7.61	28.8	2495	31	22.8	8748
6 SUMMER	66.16	11.69	6.35	0.83	1.83	0.37	0.40	0.18	0.06	2.36	7.36	2.41	24.0	4769	23	23.0	9422
6 WINTER	69.66	10.32	5.11	0.63	1.39	0.27	0.30	0.13	0.04	2.70	7.32	2.13	23.0	3787	12	23.0	9384
7	78.34	8.20	1.70	0.10	0.16	0.07	0.01			2.80	7.17	1.50	20.4	436	30	25.5	10324
8	78.34	8.20	1.70	0.10	0.16	0.07	0.01			2.80	7.17	1.50	20.4	459	30	25.5	10324

STREAM COMPOSITION AS MOL%.
REF DRWG T-1318088-0

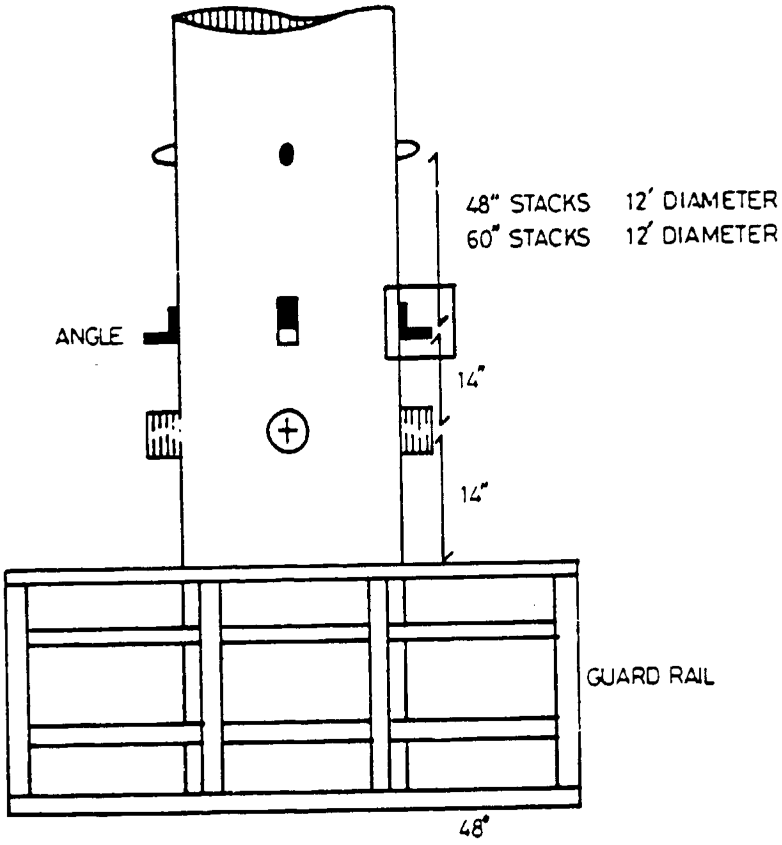
DRAWN	BAM	DATE	2/81
CHECKED	SH	APPROVED	KAM
SCALE	NONE		

GAS INTEGRATION BLOCK FLOW DIAGRAM
FOR NGL-1 & NGL-2.

LOCATION	QATAR	PLANT	NGL QGPC
REV. NO.	0	DRG. NO.	NG-122

2 of 2

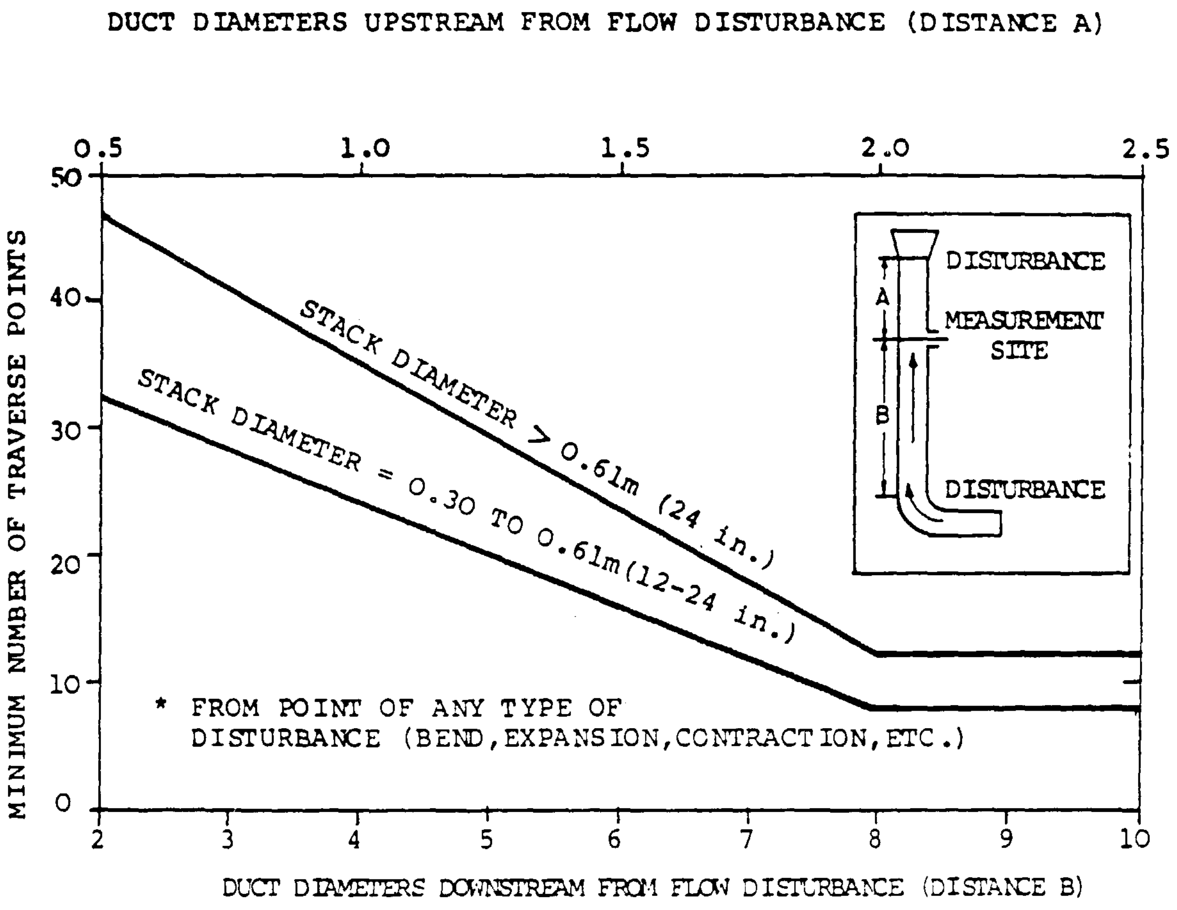
FIG.11



IF EYEBOLT IS MORE THAN 120 INCHES ABOVE THE PLATFORM A PIECE OF CHAIN SHOULD BE ATTACHED TO IT TO BRING THE POINT OF ATTACHMENT WITHIN SAFE REACH. THE EYEBOLT SHOULD BE CAPABLE OF SUPPORTING A 500 POUND WORKING LOAD.

FIG. 12

MINIMUM NUMBER OF TRAVERSE POINTS FOR PARTICULATE TRAVERSES



1. Determine number of duct diameters upstream and downstream from measurement site to disturbances.
2. On top line (Distance A) locate the point that equals the number of duct diameters upstream. Draw a vertical line down to the line that represent duct diameter. From this point draw a horizontal line to the left and record the value.
3. On the bottom line (Distance B) locate the point that equals the number of duct diameters downstream. Draw a vertical line that represents duct diameter. From this point draw a horizontal line to the left and record the value.
4. Select the larger value obtained in steps 2 and 3 that is divisible by 4. (If the number is not divisible by four, increase the number until it is.) This is the minimum number of traverse points for a circular stack.
5. If the stack is rectangular, take the larger value recorded in steps 2 and 3 and go to Table 1-1. If this value is not listed in the left column of Table 1-1, increase the value to the next highest number in the table. This value is the minimum number of traverse points for a rectangular duct.

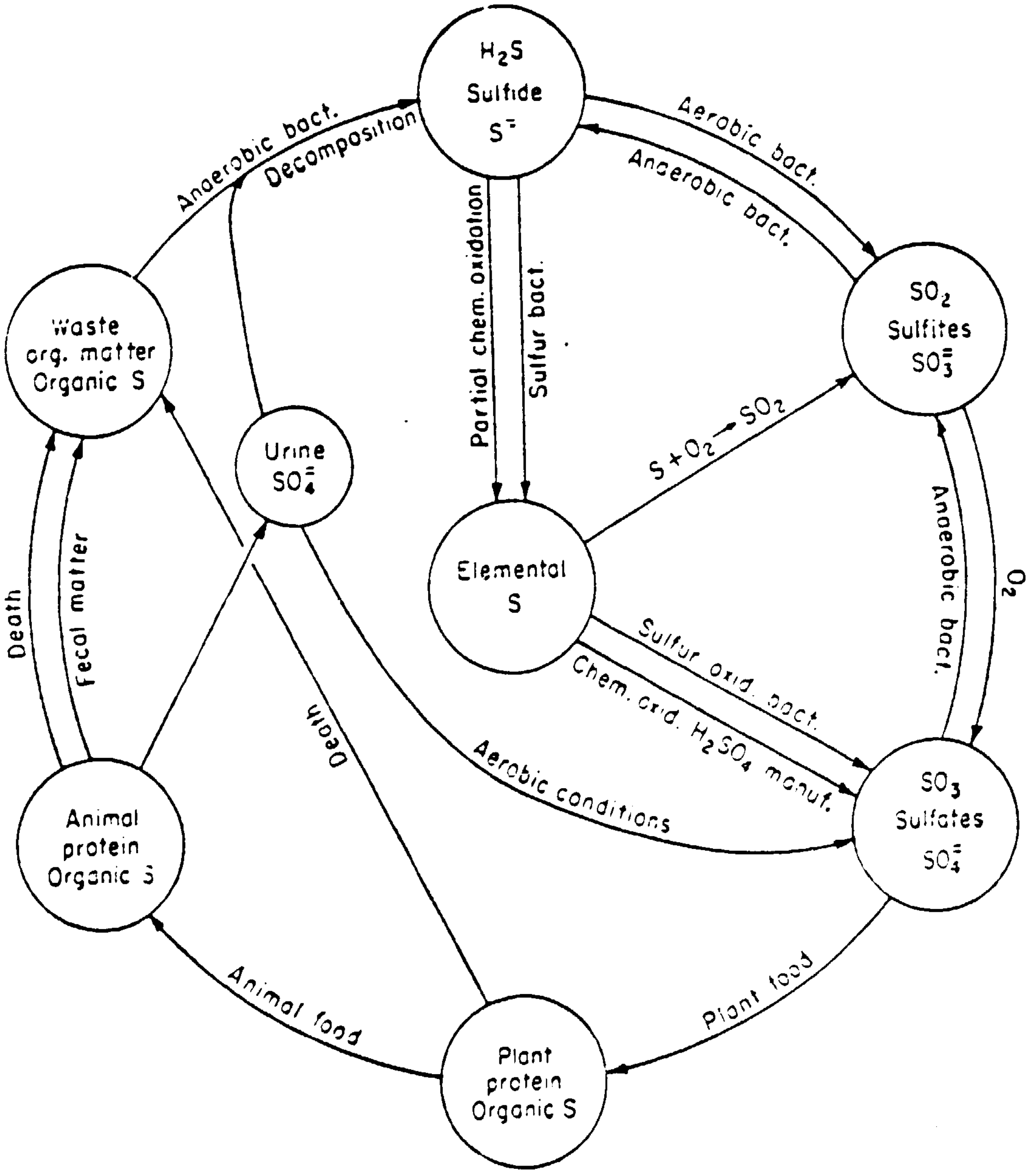


FIG. 13. The sulfur cycle.

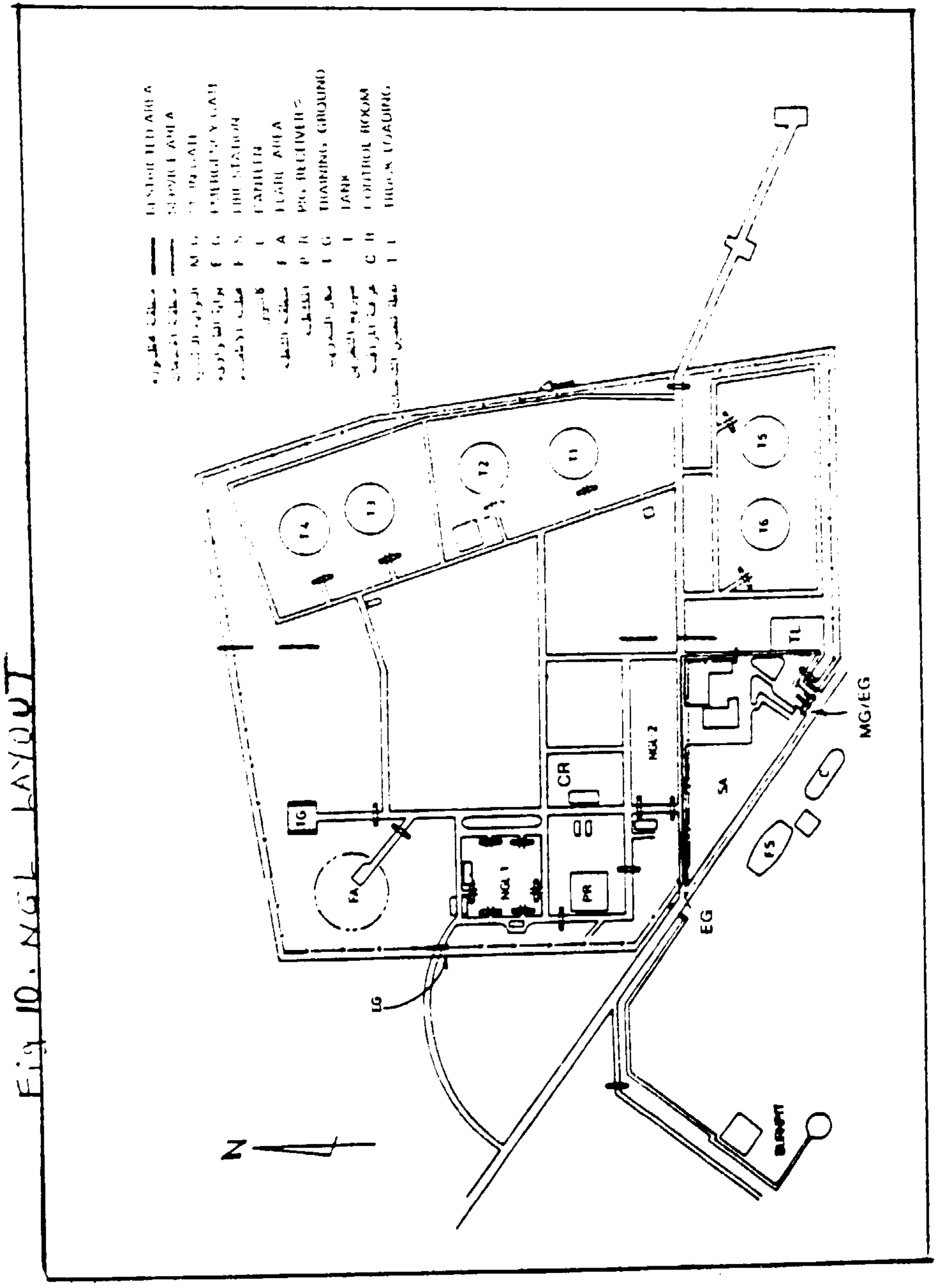


Fig 10. NGL LAYOUT

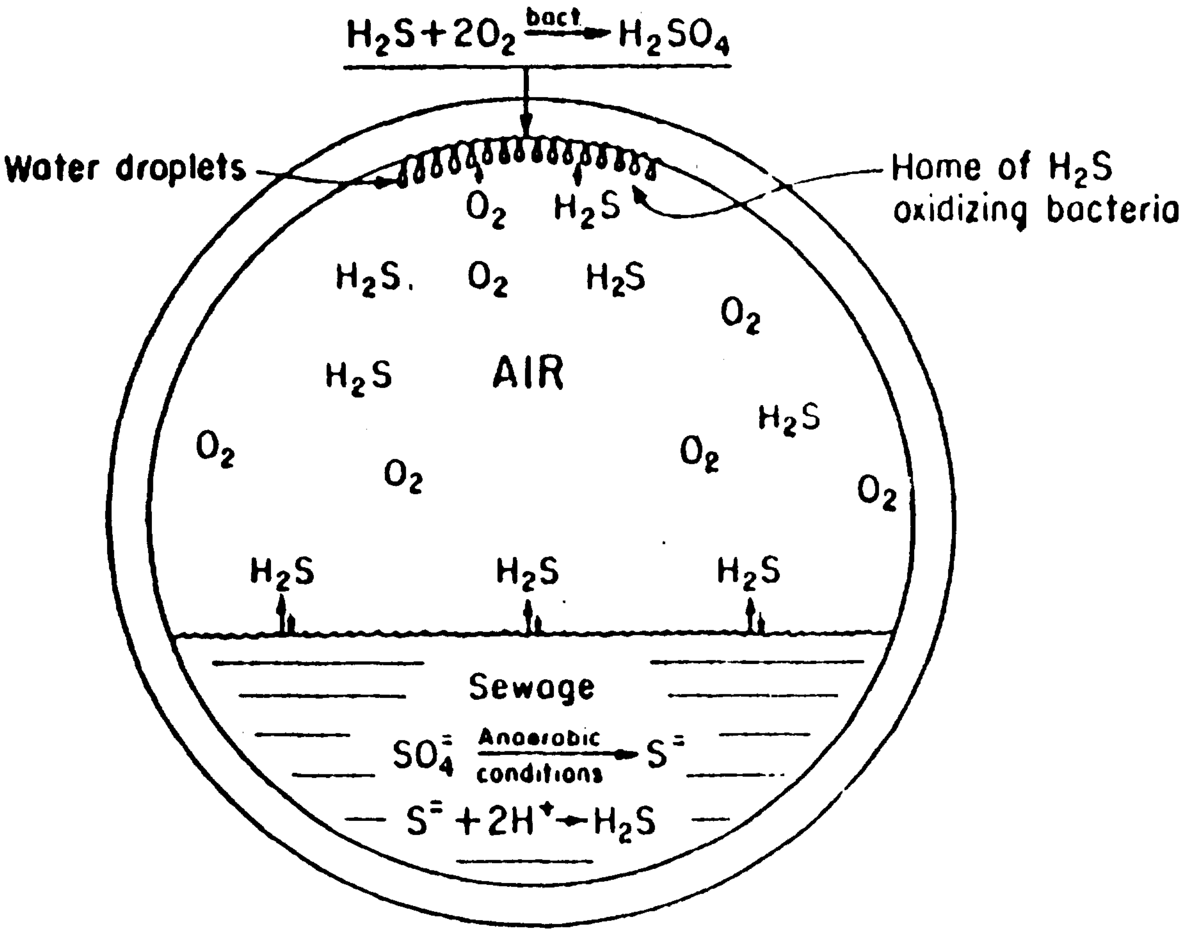


FIG. 14. Formation of hydrogen sulfide in sewers and "crown" corrosion resulting from oxidation of hydrogen sulfide to sulfuric acid.

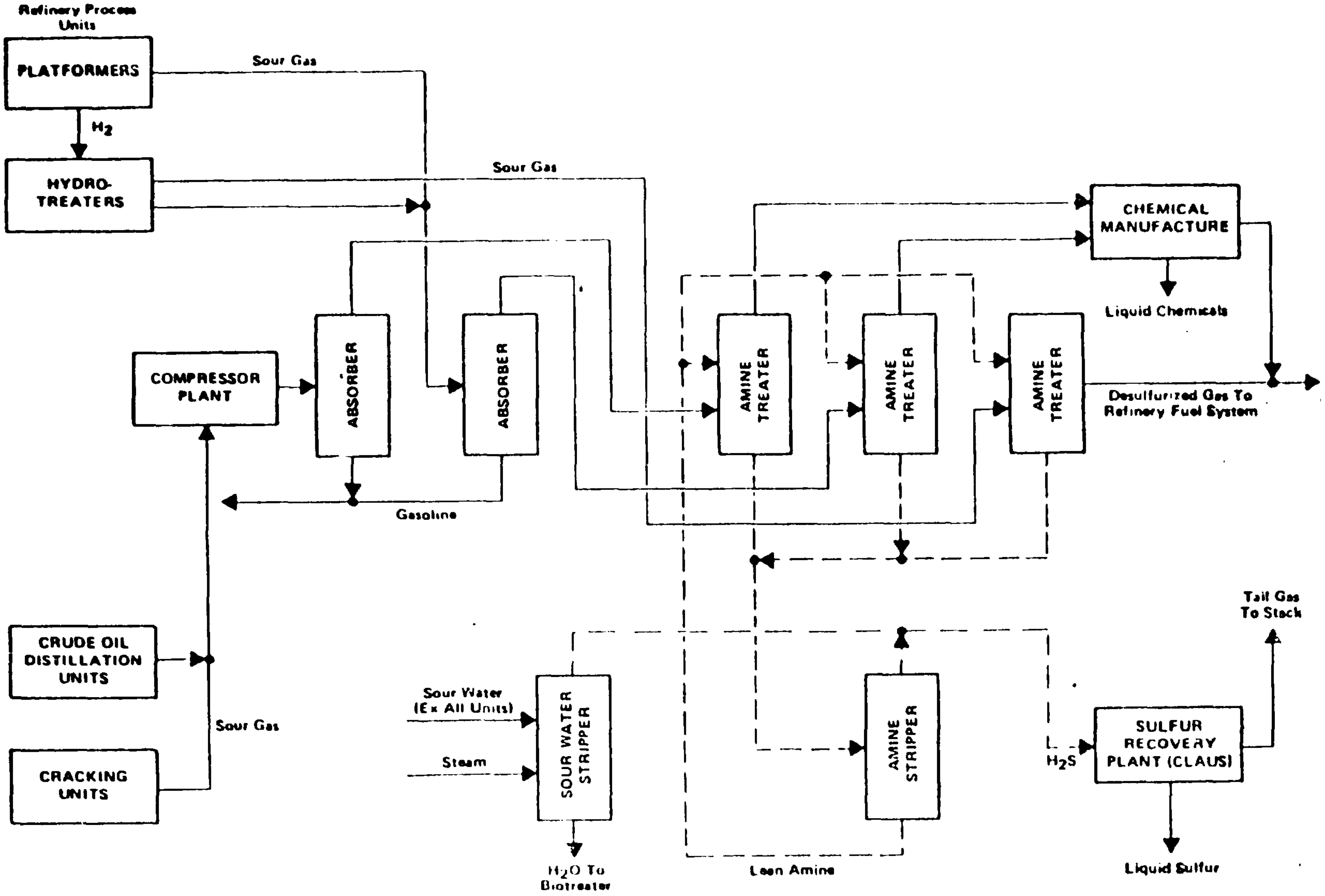


Figure 15 Simplified Flow Diagram of Sour Gas and Sulfur Recovery System.