CHAPTER 4 PUBLIC UTILITIES

Utilities required for the operation of a refinery include electricity, water and fuel. In the capital area where the refinery being studied is to be located, these three items of utilities are available from the following public supply facilities:

- Electricity: Public power supply system in the capital area under the jurisdiction of the Ministry of Electricity and Water.
- Water: Public water works in the capital area under the jurisdication of the same ministry as above.
- Fuel: Gas pipeline connecting between Yibal natural gas field and the Al Ghubra power generating/seawater desalinating plant.

Each of these public facilities will be discussed below as to the possibilities of utilization.

4.1 PUBLIC ELECTRICITY

All the public power supply activities are put under the direct control of the Ministry of Electricity and Water of Oman. Power is supplied to the capital area from both of Riyam and Al Ghubra power stations owned by the Ministry. Table 4-1 gives the installed capacity and gross production of both plants.

Riyam power plant is equipped with 9 Diesel generators, and is said to have a capacity of 36 MW. After Al Ghubra power station went into normal operation, Riyam has been in charge of emergency use. Since 1977, Al Ghubra power station has been playing a chief role in the supply of public power to the capital area. Its present capacity of 125 MW will be increased to 225 MW by September 1979. A plan is now being examined for further extension to 300 MW, with the target date set for 1985.

When compared with the level of power production contemplated under the extention plans, the power requirement by the refinery now being studied is as small as 3,500 kW. Therefore, there seems to be no problem in the availability of public power, as clearly stated by the Ministry of Electricity and Water.

Table 4-1 Public Electricity in the Capital Area, Installed Capacity and Gross Production

	1970	1971	1972	1973	1974	1975	1976	1977
Installed Capacity (Megawatts)	3.0	3.0	12.2	17.1	37.4	37.4	66.2	116.2
Gross Production (Million KWH)	8.0	12.0	22.2	38.9	72.6	121.9	214.2	329.2

(Source) Statistical Year Book

4.2 INDUSTRIAL WATER

As sources of industrial water for the planned refinery, there can be mentioned ground water and city water from the water works developed in the capital area. Ground water is under the control of the Water Council, and no guarantee was made as to the availability of ground water for use on a long-term basis as industrial water for the refinery. In this section, therefore, study is limited to the water availability from the public water works only.

Within the jurisdiction of the Ministry of Electricity and Water, the water supply from the public water works to the capital area, which stood at 430 million imperial gallons (5,300 tons/day) in 1976, sharply rose to 1,002 million imperial gallons (about 12,000 tons/day) in 1977 and 1,260 million imperial gallons (about 15,700 tons/day) in 1978.

The capital area depends for the water on the Al Ghubra desalinating plant and water wells near Seeb. Recent sharp increase in water supply is mainly owing to the operation of the desalinating plant which completed in 1976. The water producing capacity of the desalinating plant varies to a large extent, depending on the condition of operation temperature. According to the information obtained from an on-the-spot survey, the plant has a daily capacity of about 4.8 million imperial gallons (about 22,000 tons/day) if it is operated at a brine temperature of 90°C or lower. On the other hand, it has a daily capacity of about 7.2 million gallons (about 33,000 tons/day) when operated at a brine temperature above 90°C. Reportedly, the plant was operating as of March 1979, at a capacity of about 18,000 tons/day with a brine temperature of below 90°C. Among the countries in the Peninsular of Arabia, Oman is blessed with much rainfall. The water resources, which can be developed throughout the country in the future, is estimated at about 230 million m^3/yr. ("Water in Oman," March 1977)

However, as long as the capital area is concerned, a highly probable increase in water supply is expected from the extention of the desalinating plant. According to a plan, Al Ghubra desalinating plant would have an increased capacity of producing about 20 million gallons per day (90,000 tons/day) in 1983–84. If this plan becomes a reality, it is considered fully probable for the public water works to meet the industrial water requirement (not more than 2,600 tons/day) of the planned refinery, which is scheduled to start operation during the same period.

4.3 NATURAL GAS

A 20-inch gas pipeline was already laid from Yibal, the major gas field in Oman (with a production capacity of about 140 MMscfd), to Al Ghubra. The gas supply to the power/desalinating plant started in 1978. This pipeline has a design capacity of 140 MMscfd without any compressor. The amount supplied to the Al Ghubra plant is 20 MMscfd, so that there still remains a surplus capacity of gas supply. The power plant may be expanded in the future, and there are plans for gas utilization in, for example, copper smelting and cement production. Even if these increase and additional use of natural gas are taken into account, the refinery's natural gas requirement as a supplementary fuel (not more than 9 MMscfd) would be readily secured.

4.4 COSTS OF UTILITIES

As examined above, it can be estimated that the utilities of electricity, industrial water and natural gas are all available from outside facilities in full amounts. However, before a decision is made on whether utilities should be purchased from outside or not, there must be a comparison of economic efficiency with a case where the utilities are produced within the refinery.

The cost of purchase will be discussed below for each of the utilities, but simple cost calculation is impossible in cases of water and electricity. These items must be judged from a comparison of the entire economic efficiency of the refinery between the case of purchasing from outside and the case of self-sufficiency.

4.4.1 Electricity

The present power rate is set evenly at 20 Baisa/KWH, with no different power rate between the civil and the industrial use. In order to maintain this power rate, the Government is offering a subsidy to make up for the power production cost. A plan is now being discussed within the Government to set a new rate of 56 Baisa/KWH for industrial use, which rate corresponds to the power production cost, although it is not known when this rate actually comes to pass.

If the refinery is to make its own supplies of utilities, naturally it has to be equipped with boilers to produce steam required for the refinery operation, as well as with a small-scale power-generating/desalinating plant to produce a self-sufficient level of industrial water. In that case, cost calculation is far more complicated than a simple comparison of the cost of power generation with the cost of buying outside electricity.

4.4.2 Industrial Water

As described above, a possible case is to buy city water for industrial use. The water price is set at 2 Baisa/imperial gallon in this study, based on the discussion with the Omani Government, water pipeline being laid to the entrance to the refinery site at the expense of the supplier. In the case of self-sufficiency of water, the water production cost cannot be merely compared with the cost of water purchase for the same reason as described in the section of electricity.

4.4.3 Natural Gas

In Oman, the natural gas price is set at a half the crude oil price for the same calorific unit of gas supplied to as far as the entrance to the user's site. Therefore, natural gas can be ranked as a very economic fuel for the refinery, second only to such by-product with no market value as off-gas. Natural gas is thus recommended as a supplementary fuel used to make up for the shortage of off-gas by-product.

CHAPTER 5 REFINERY LOCATION

5.1 THREE CANDIDATE SITES

The Omani Government indicated two candidate sites for the refinery. One is the Mina al Fahal area where P.D.O., Shell and BP have their oil facilities. The other is the Al Ghubra area where the power generating/desalinating plant is located. It was said that "there is no other candidate site." It has been found from an on-the-spot survey that the Mina al Fahal area has two lots of land which look plausible as the refinery site. These two lots are referred to as the proposed sites A and B; and the Al Ghubra site as C.

The Mina al Fahal area and the Al Ghubra area are mapped in Fig. 5-1 which shows the capital area. Fig. 5-2 is another map of the Mina al Fahal area, in which the proposed sites A and B are indicated.

5.2 OUTLINES OF CANDIDATE SITES

5.2.1 Sites A and B (in the Mina al Fahal area)

(1) Terrain

This area is situated west of Muscat, the capital, and about 8 km linearly distant therefrom. To the north, a somewhat inlet-like shore borders on Gulf of Oman. Surrounded by hills on the remaining three sides, the area is rectangular, mostly flat land of 1.5 km from east to west and 1.0 km from south to north. On the east and west sides, hills fall relatively sharply toward the area, whereas on the south side, hills have more gentle slopes. On the whole, the area slopes down slightly from south to north.

Between seashore and 300 to 400 meters inland, there is damp land where salt crystals can be found as in salt fields over various parts of the zone. A map regarded this wet zone as "flooded after rain". It can be supposed that this area had been an inlet until relatively recent years, but that a road constructed along the shore served as a coastal levee, leaving the inside area to reclaimed.

(2) Soil Profile

This area is covered by the surface stratum consisting of sandy silt or sandy clay. This surface stratum has a depth of 3–5 m, under which there are strata of gravelly sand, sandy gravel and sandy silty gravel, these strata appear alternately to form the foundation ground.

This soil profile is a finding obtained from boring data on the spots which are probably near the sea. On the spots far away from sea, the surface stratum is likely to be thinner.

Ground water elevation is shallow, ranging from 1–1.5 m, but is estimated to become somewhat deeper at the hillside.

(3) Ground Subsidence

The gravel stratum at the lower part of ground is not expected to subside to a large extent. However, in cases of the sandy silt and sandy clay layers on the surface, there is a fear of relatively large ground subsidence. This can be estimated from the fact that unlike the past tank designs, BP has adopted a pile-supported system when the company extended its products terminal in this area.

It seems desirable, therefore, to use piling for the foundations of heavy structures, particularly in Site B where the surface stratum is likely to be thick.

(4) Existing Facilities

In this area there exist BP's products terminal on the west and Shell's products terminal on the east end. Between these two bases, various other facilities are arranged, including P.D.O.'s facilities.

There are several buildings in the candidate Site A. This site is also used as a materials stockpiling yard. Some pipes are stockpiled in the open yards of Site B.

With regard to port facilities, this area has a pier for general freights, which is located on a shoreline ranging from the west side of this area to the foot of a hill. There is another temporary jetty at an almost central part of the shoreline in front of the area. At a point 200 to 300 m offshore of this area, Shell and BP respectively have a products S.B.M. Farther offshore in this water, there are 3 other S.B.M.'s for crude oil and marine bunker oil.

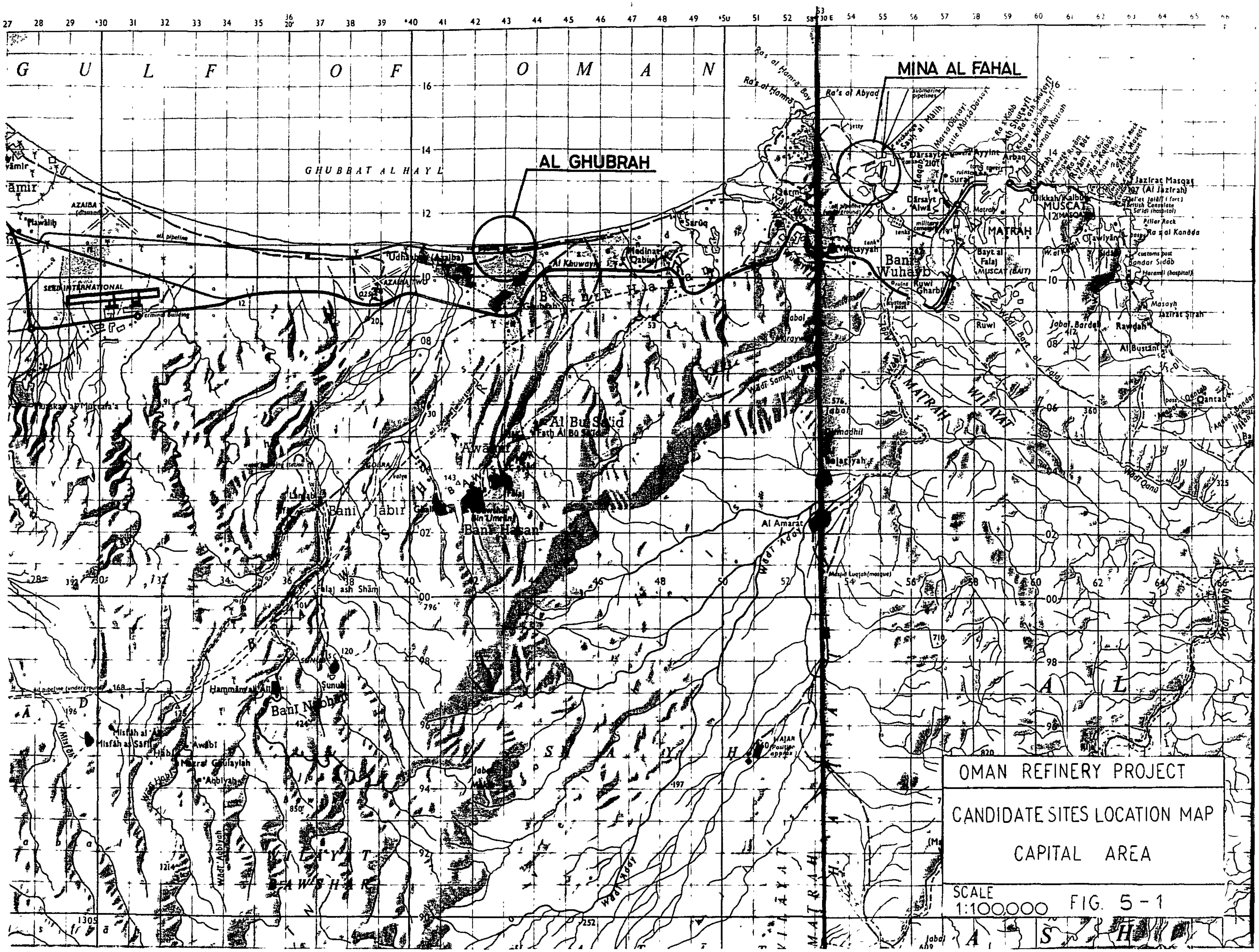
As for roads, a road goes south from the afore-mentioned temporary pier, and across the back hills it is connected to a trunk road. Another road crosses the central part of the area from east to west. Still another road runs along the shoreline and then along the foot of the surrounding hills, going around the area. These roads are one-lane asphalt roads of about 5 m wide.

(5) Conditions of the Road from Mina Quaboos

A road reaches to this area from the commercial port of Mina Quaboos. It is a 2-lane asphalt road of 13 or 14 km long and 7.5 m wide. Along this road there is an overbridge of about 5 m high, a roundabout with a small radius, and a steep slope.

(6) Available Areas

Both sites A and B are sufficient to provide the refinery with a necessary area of 300 m x 400 m wide. It should be noted, however, that Site A has various existing facilities, whereas Site B may include salty damp ground within its site.



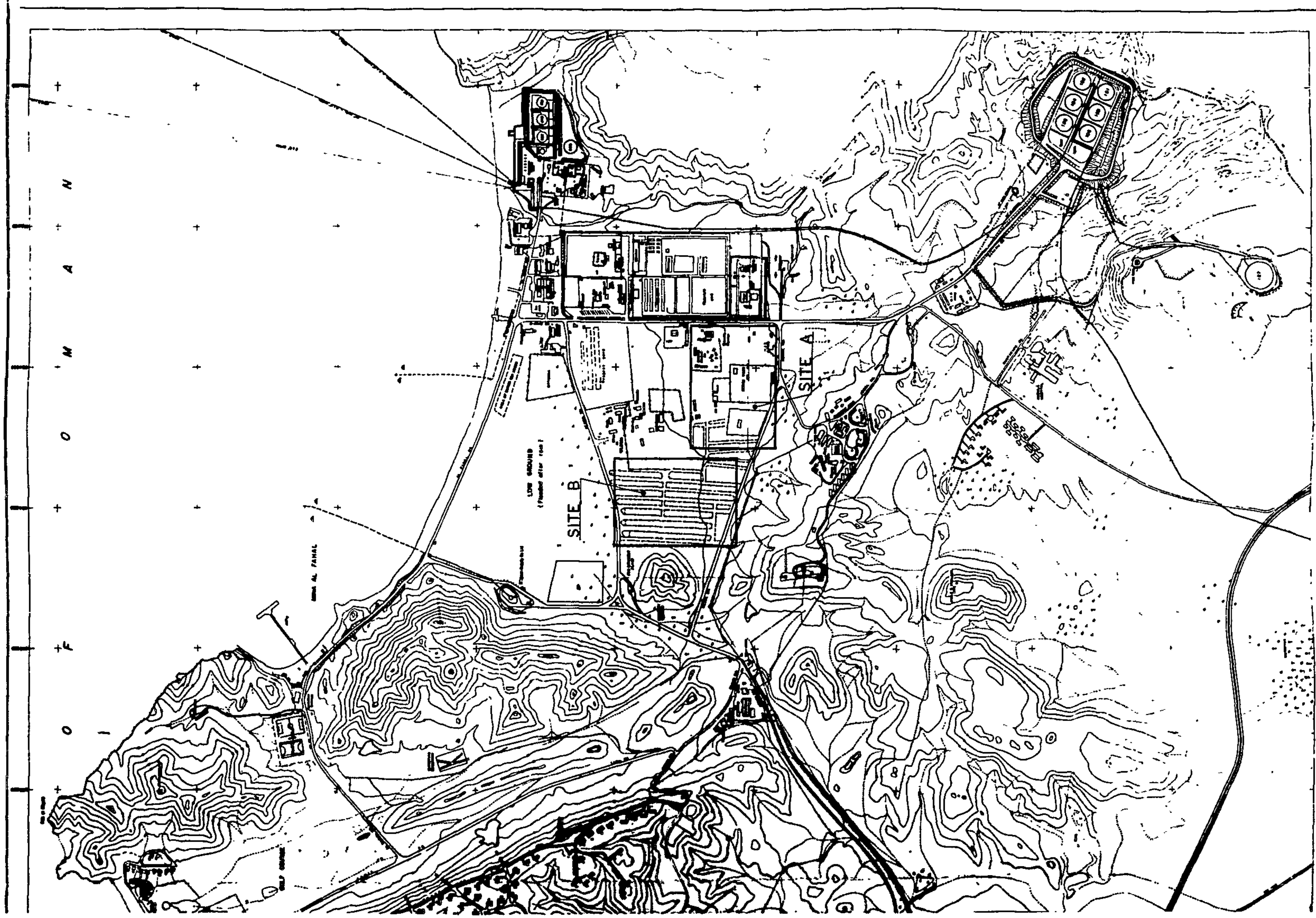
OMAN REFINERY PROJECT

CANDIDATE SITES LOCATION MAP

CAPITAL AREA

SCALE 1:100,000 FIG. 5 - 1

FIG. 5-2 CANDIDATE LOTS LOCATION MAP – MINA AL FAHAL



5.2.2 Site C (in the Al Ghubra area)

(1) Terrain

The Al Ghubra area is situated about 18 km west of Muscat. To the north, a linear shoreline borders on Gulf of Oman. The area is the land of sand dune of about 2 m above sea level. To the east, west and south, the area connects to similar sand dune having relative flatness. In parts of the sand dune, wadis are seen reaching an inland oasis. These wadis, 1–1.5 m lower than the surroundings, consist of slightly damp sand, where shrubs of 1–2 m tall are growing.

(2) Soil Profile

The area is covered by shore sand. Although there is no precise data, the construction work at the time of extention of Al Ghubra power station indicate that the sand layer exists to a considerable depth.

(3) Ground Subsidence

If there is a layer of shore sand to a considerable depth, as mentioned above, the ground is never likely to subside. This can be probably proved by the fact that piling has not been used for the foundations of the expanded facilities at the Al Ghubra power station.

(4) Existing Facilities

On the right eastern side of this site is the Al Ghubra power/desalinating plant, which has a residence for employees on its eastern side. At the midpoint between the proposed site and the plant there remains a part of worker barracks used when the plant was being constructed. Some people still live there. There is a basin for fishing boats at the north shore.

(5) Conditions of the Road from Mina Quaboos

The road from Mina Quaboos to as far as Mina al Fahal has been described in (5) of Section 5.2.1, above. This road farther extends to reach the Al Ghubra area. From Mina al Fahal to Al Ghubra, the road is 12 or 13 km. On Way to the site, this trunk road is overbridged by another road at a point southeast of Intercontinental Hotel, and a concrete bridge of about 6 m high passes across the trunk road.

(6) Available Area

The place, being vast sand dune, has no obstruction to lay out a necessary site area.

5.3 COMPARISON OF PROPOSED SITES

5.3.1 Site Preparation

Sites A and B slopes down to the sea, although gently. Therefore, cut-and-fill work amounting to about 72,000 cubic meters would be required.

On the other hand, Site C is relatively flat. Only the levelling of ground is considered enough for this site.

5.3.2 Piling

Surrounding situations and the results of the foundation work for independent power plant at the adjacent P.D.O. base indicate that Site A would not require piling work for the foundation work.

In the case of Site B, piling would be required for the foundations of heavy equipment to be arranged on the sea side, because the seaside parts has thicker silt and clay strata.

In the case of Site C, piling would not probably be required, seeing that piling has not been used for the extension work at the adjacent power station. Nothing can be said definitely, of course, until data on the construction of this plant are available.

5.3.3 Acceptance of Utilities

(1) Electric Power

If the refinery purchases the required power from the public power system, either proposed site will connect service wire to Al Ghubra power plant. Among the sites, Site C would call for only a short service line to accept power from the adjacent power station.
Attention should also be paid to the supply of about 500 kw necessary during the construction period.

(2) Water Supply

Water is either supplied from the public water works, or the refinery would have a seawater desalinating plant combined with independent power generation within the refinery site. If water is supplied by the public water works, the service line branching from the mains would be shorter for Site C than for Sites A and B.
Construction of a temporary water service line will have to be considered to meet water demand in the range of 200–300 m^3/day during construction period.

(3) Seawater

In cases of Sites A and B, the seawater intake line must not interfere with existing S.B.M's nor obstruct the navigation of those ships which utilize the jetty. In order to avoid these situations, it will be necessary for the intake line to be extended to a point where there is no interference with existing facilities. This involves laying

2 km of pipeline onshore.

Site C with no existing facilities hardly requires an onshore intake line.

5.3.4 Transportation

(1) Port Facilities

Mina Quaboos port is a commercial port with a long history. As a result of re-modelling and development in recent years, it can now accommodate 24,000-DWT vessels. The port has 13 berths, with the largest berth being as wide as 228 m x 9.8 m.

The port is equipped with a movable crane which can lift a maximum of 150 tons, and 10 other cranes of smaller sizes. The Port Authority officials believe that the unloading facilities will have no problem in unloading towers of 4 m in diameter and 35 m tall, weighing 60 tons, which are considered the largest equipment of the refinery.

(2) Unloading Facilities near the Proposed Sites

On the shoreline in front of Sites A and B, there is a temporary jetty which was used in the past. The pier is 15 m x 10 m and 3 m high from the sea level. It is directly connected to a main road in the area. The pier is of a construction that concrete slabs are mounted on steel piles which are driven into the sea bed and reinforced by concrete-filled drums and pieces of rubble. The steel part has been corroded moderately, but with appropriate repairs, it seems still usable.

There is another pier for general freights, located on the western shoreline at the foot of a hill about 1.5 km west of the sites. This pier is of a construction that precast concrete slabs are mounted on a structure of steel pipe columns and steel beams. Although its unloading capacity is unknown, a considerable quantity of equipment and construction materials will possibly be unloaded here by way of barge transport.

On the other hand, Site C has no existing unloading facility. Therefore, materials will have to be unloaded at Mina Quaboos or Mina al Fahal, or otherwise it will be necessary to prepare a temporary jetty near the site.

(3) Land Transportation from Mina Quaboos Port to Each Site

The trunk road coming from Mina Quaboos to as far as the inlet to the Mina al Fahal area is common to all proposed sites. As already described, there exist some obstructions including an overbridge and a roundabout with a small radius. The overbridge, made of prefabricated concrete, can be temporarily removed. As for the roundabout, there is a fear that a vehicle carrying a long object of 35 m may not be able to turn the curve. In this respect, a more exact survey will be required. At any rate, this can be overcome by destructing it on condition that it is recovered at a later time.

Farther from the trunk road to the Mina al Fahal area, the road to Sites A and B has a steep slope, and the road to Site C is overbridged by another road in the vicinity of Intercontinental Hotel. In addition to the problem of the permanent concrete bridge of about 6 m high, another problem is the lack of any road connection from the vicinity of Al Ghubra power plant to the proposed Site C. A skillful driver can get over the steep road slope, but he has to bypass the viaduct. Coming from Mina Quaboos, the trucks thus turn south on this side of the viaduct, and go along a 5 m wide asphalt road running parallel to the trunk road.

A road branches from the trunk road at Al Ghubra, and runs perpendicular to the shoreline until it arrives at the power station. Farther ahead of the power station, there is no road to Site C, and a new road will have to be constructed.

5.3.5 Pipelines of Crude Oil and Products

(1) Crude Oil

P.D.O. has its crude oil tanks near Sites A and B. A pipeline connects these tanks with Al Ghubra power station. This line was used when the power plant depended on crude oil for its fuel. Therefore, as far as crude oil supply is concerned, it will be sufficient for either site to lay only a short pipeline additionally.

(2) Products

The new refinery is going to use, as the products storage tanks, a part of the tanks existing in the Shell and BP products bases in the Mina al Fahal area. In order to transport products from the refinery to existing tanks, it will be sufficient to lay additionally a short pipeline in cases of Sites A and B. On the other hand, Site C has to lay a 10-km pipeline.

5.3.6 Wastewater Disposal

In either site, the wastewater from the refinery is treated at disposal facility before it is discharged to sea.

In cases of Sites A and B, it will be necessary to devise some measures so that no impact will be given to existing facilities or the seawater intake line. The same applies to Site C. Special attention should be paid so as not to give any impact on the seawater intake of the Al Ghubra desalinating plant.

5.3.7 Economic Comparison

Among the afore-mentioned items of comparison, those items, which can be compared in terms of costs, include such civil work as site preparation and piling, and construction of seawater intake pipeline and products pipelines. The comparison between the Mina al Fahal area and the Al Ghubra area was attempted by calculating the costs of such civil work and pipeline construction.

The civil work cost required is less for Al Ghubra, where there is requirement for neither cut-and-fill nor piling because of flat sandy ground, than for Mina al Fahal, although the difference is quite small.

As regards seawater intake pipeline, the Mina al Fahal area requires much higher cost than the Al Ghubra area, due to the necessity of avoiding possible interferance with existing facilities.

As regards products pipelines, the Mina al Fahal area naturally requires a less construction cost, because this area is close to existing products terminals. The difference in products pipeline costs is larger than the difference in the seawater intake line costs.

On the whole, it is concluded from this comparison that Mina al Fahal is slightly more advantageous than Al Ghubra. It should be noted, however, that the costs for the types of work that have been picked up here would account for only a few percent of the total refinery construction cost. And the cost difference between both areas falls within 1 percent of the total construction cost. Therefore, this economic comparison is not considered as a decisive factor in evaluating the site areas.

5.4 OVERALL EVALUATION

When all the location factors described in the previous section 5.3 are taken into consideration, the following conclusion may be given.

The Mina al Fahal area is advantageous in the following point: (1) The area is situated near existing facilities owned by P.D.O., Shell and BP, and a part of facilities can be used for the construction and operation of the refinery. (2) If refinery equipment and construction materials are to be unloaded at Mina Quaboos port, the area is encountered with less troubles in land transportation.

On the other hand, the Al Ghubra area is advantageous for its wide and flat land, good ground conditions, a short distance to Al Ghubra power generation/desalinating plant, and little existence of nearby facilities that may cause troubles. In spite of these advantages, this area has remarkable disadvantages in the following points; (1) The area is more than 10 km distant from the Mina al Fahal area in which the crude oil and products terminals are located. (2) As found from the above economic comparison, a high cost is required to construct products pipelines. (3) Difficulties in operation can be expected, such as long-distance go-and-return transport of raw material and products, and location of products tanks in two separate places.

When these merits and demerits are weighted, it is concluded that the Mina al Fahal area is more suitable as a refinery site than the Al Ghubra area. Between the two sites in Mina al Fahal, Site A with its better ground conditions is considered superior to Site B. Thus, Site A is recommended here as the refinery site.

This does not certainly mean that Site B in Mina al Fahal or Site C in Al Ghubra is totally unsuitable as a refinery site, or that these two sites are decisively inferior to Site A.

CHAPTER 6 OUTLINE OF A REFINERY TO BE CONSTRUCTED IN OMAN

6.1 PRODUCTS

This planned refinery is to manufacture seven kinds of products for which future demand is expected in Oman, that is: LPG, premium and regular motor gasolines, jet A-1, domestic kerosene, gas oil and marine bunker oil.

As already described, demands were forecasted for products other than the above-mentioned, namely, aviation gasoline, heavy fuel oil, bitumen, and lubricating oil. However, they are not included in the products of the planned refinery. The reasons are as follows:

Aviation gasoline is expected to have a future demand of as little as 5,000 bbl per year (15 bbl/day) and manufacture of aviation gasoline in this small quantity is determined to be uneconomical.

Heavy fuel oil will also have so little demand that it could be easily absorbed by fluctuations in demand-supply of marine bunker oil. In other words, future demand for heavy fuel oil, if any, will be met by a small portion of marine bunker oil to be produced.

Bitumen, for which present demand is not very large, will in future even suffer a decrease in demand, since the road construction in Oman is meaning a state of saturation.

Lubricating oil is difficult to produce economically by a refinery of the scale considered here. Also its demand is too little to justify commercial production.

The specification of the product to be produced by this planned refinery are shown in Table 6-1. These specifications are those applied internationally.

Table 6-1 Specification of Petroleum Products

Products	Properties	Specification
Premium Gasoline	Research Octane No.	Min. 97
	Lead Content, GPb/ℓ	0.05 – 0.62
	End Point, °C (ASTM D-86)	Max. 205
	Density @ 15°C, kg/ℓ	Min. 0.7
Regular Gasoline	Research Octane No.	Min. 90
	Lead Content, GPb/ℓ	0.05 – 0.62
	End Point, °C (ASTM D-86)	Max. 205
	Density @ 15°C, kg/ℓ	Min. 0.7
Kerosene	Flash Point, °C	Min. 38
	Smoke Point, mm	Min. 23
	Sulfur Content, wt %	Max. 0.03
	ASTM Distillation 95%, °C (D-86)	Max. 280
Jet A-1	Specific Gravity	0.7753 – 0.8299
	Flash Point, °C	43.3 – 65.6
	Freezing Point, °C	Max. –48
	Sulfur, wt %	Max. 0.3
	Aromatic Content, vol %	Max. 20
Gas Oil	Specific Gravity	Min. 0.83
	Flash Point, °C	Min. 73.9
	Sulfur Content, wt %	Max. 1.0
	Cetane Number	Min. 50
	Viscosity @ 38°C, cst	3.5 – 4.5
Marine Fuel Oil	Flash Point, °C	Min. 73.3
	Sulfur Content, wt %	Max. 3.0
	Viscosity @ 50°C, cst	Max. 176
	Pour Point, °C	Max. 15.5

(Source) Ministry of Commerce & Industry

6.2 CRUDE TO BE PROCESSED AND CRUDE THROUGHPUT CAPACITY

6.2.1 Crude

This planned refinery is to process Oman Crude.

6.2.2 Crude Throughput Capacity

Crude throughput capacity of this refinery is to be determined with a view to fulfilling Omani domestic demands for the selected petroleum products in 1985 as far as possible, and also to keeping away from producing any surplus products, if possible.

6.3 REFINERY CONFIGURATION

6.3.1 Processing Units

Characteristics of Oman Crude (Table 3-2) and estimated 1985 demands for the seven products selected in Table 2-2 as well as the specifications of the products (Table 6-1) are closely compared to each other and examined to reach a conclusion that the aims of the refinery stated in the preceding paragraph 6.2.2 are to be achieved by a relatively simple processing scheme, that is:

The crude oil is firstly fractionated by an atmospheric distillation unit into the four main fractions below:

- naphtha (cut point: below 177°C)
- kerosene (177 – 232°C)
- gas oil (232 – 350°C)
- residue (over 350°C)

And then some of the fractions are processed by one or two secondary processing units as follows to yield products as specified:

Naphtha fraction in which LPG components are contained will in the first place be processed by a hydrodesulfurization unit, and then separated into LPG, light naphtha, and heavy naphtha.

A portion of heavy naphtha is to be processed by a naphtha catalytic reforming unit with the purpose of improving its octane number. Reformate with an octane number (RON) of 100 is to be produced.

LPG coproduced by the reforming unit is to be combined with that come from hydrodesulfurization unit, and then treated by gas recovery unit, where it is separated into propane and butanes and the both are liquefied.

Premium and regular gasolines as specified are to be manufactured by blending light and heavy naphthas, as well as reformate in pre-determined ratios, and then by adding small quantities of tetraalkyl lead liquor. Also added is a such quantity of butane that the specified vapor pressure of gasoline is fulfilled.

Kerosene fraction is to be processed into Jet A-1 and domestic kerosene of specified qualities only by treating in a kerosene sweetener.

Gas oil fraction is fit to the specification without any secondary processing, a portion of the gas oil is also used to reduce the viscosity of the residue to yield marine bunker oil of specified quality.

6.3.2 Processing Capacity of Each Processing Unit

(1) Export Dependent Type

The aim of fulfilling 1985 demands in Oman for the selected petroleum products as far as possible is to be realized by setting up an atmospheric distillation unit with a crude throughput capacity of 40,000 BPSD as shown in Fig. 6-1-(A). The processing capacity of each of the processing units is as shown blow:

- Crude atmospheric distillation unit 40,000 BPSD
- LPG and naphtha hydrodesulfurization unit: 8,910 BPSD
- Gas recovery unit: 1,030 BPSD
- Naphtha catalytic reforming unit: 6,000 BPSD
- Kerosene sweetening unit: 4,680 BPSD

The amounts of products to be produced from this type of refinery are as shown in Table 6-2 below.

Production of LPG is limited to 230 BPSD against the forecasted demand of 380 BPSD. The rationale is, as already discussed in the Chapter of Market Study, that an LPG bottling plant at Rusayl in the outskirt of Muscut is expected to start production of 150 BPSD of LPG, and domestic demand for LPG is to be met by the production of both the bottling plant and this planned refinery. In this refinery, LPG component gas produced in surplus is to be used as refinery fuel.

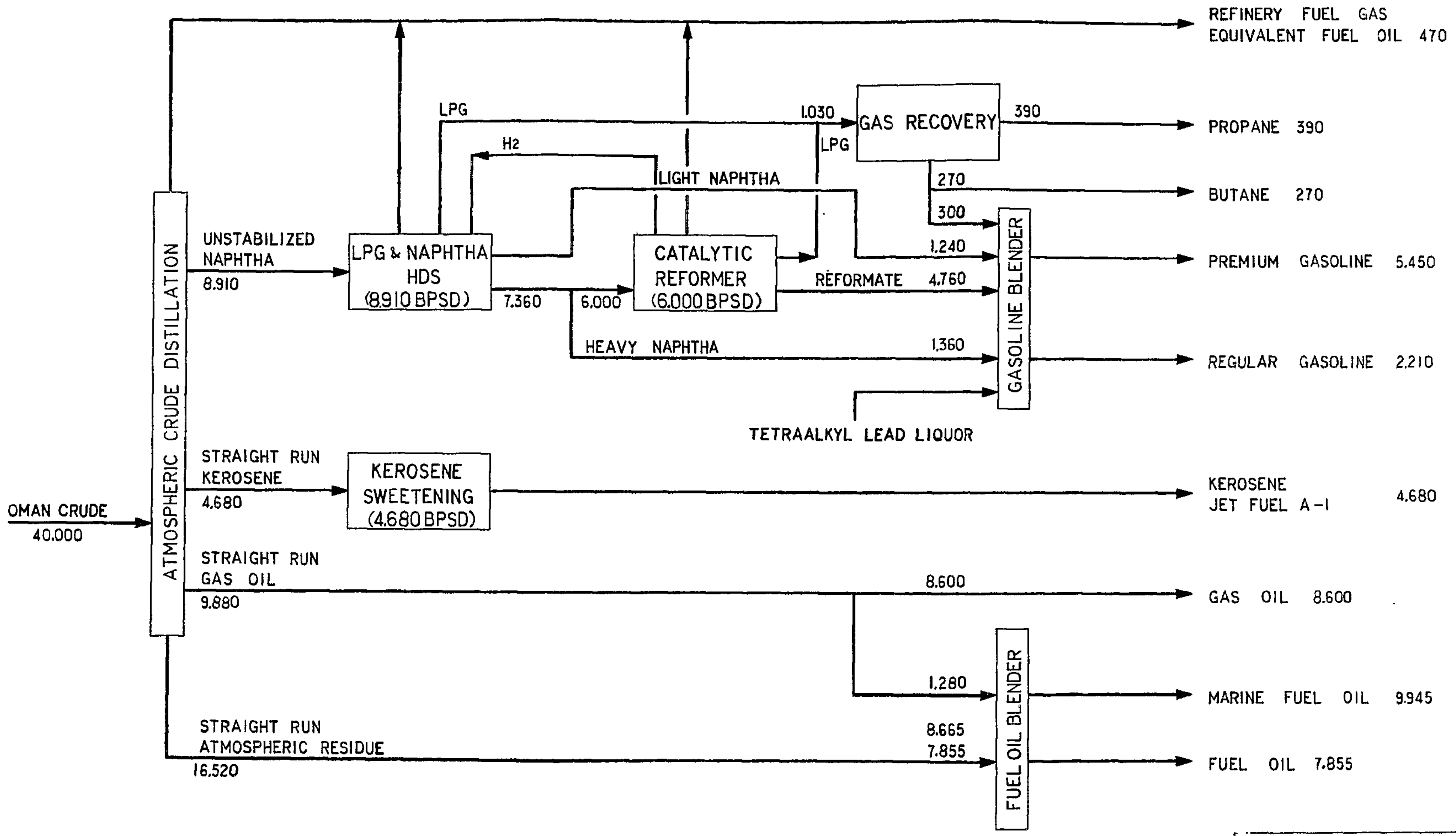
Table 6-2 Product Mix of Export Dependent Type Refinery

(Unit: BPSD)

	LPG	Premium Gasoline	Regular Gasoline	Kerosene/ Jet A-1	Gas Oil	Marine Bunker Fuel	Heavy Fuel Oil
Production	230 (+150)*	5,450	2,210	4,680	8,600	9,945	7,855
Demand in 1985	380	5,510	2,160	4,060	8,730	9,945	–
Rate of Self-sufficiency (%)	100	98.9	102.3	115.3	98.5	100.0	–

(Source) JICA Mission

* Production from Rusayl LPG Plant



UNIT: BPSD

OMAN REFINERY PROJECT

BLOCK FLOW DIAGRAM

FIG. 6-1-A

As seen from the table, self-sufficiency for all of the products will be achieved wifh-in a range of errors in estimation. There is one problem. Heavy fuel oil is produced in surplus to amount to 7,855 BPSD, that is, 400,000 tons annually.

(2) Import Dependent Type

This surplus of heavy fuel oil could be eliminated by scaling-down the whole refinery to set up an atmospheric distillation unit with a crude throughput capacity of 20,000 BPSD. The processing capacities of other secondary units will have to be reduced accordingly, as shown below. However, refining scheme itself is idential with the former type of the refinery, as shown in Fig. 6-1-(B).

- Crude atmospheric distillation unit: 20,000 BPSD
- LPG and naphtha hydrodesulfurization unit: 4,460 BPSD
- Gas recovery unit: 520 BPSD
- Naphtha catalytic reforming unit: 3,000 BPSD
- Kerosene sweetening unit: 2,340 BPSD

Product mix of this type of refinery is as shown in Table 6-3 below. As easily seen from the Table, self-sufficiency is achieved only for LPG and marine bunker fuel and other products will have to be imported as before. A matter of importance may be that the demands for motor gasolines and gas oil, both of which are expected to amount to substancial levels in Oman, are to be fulfilled only to less than half.

In Table 6-4, configurations of process units and product mixes of the two types of the refinery are summarized.

Table 6-3 Product Mix of Import Dependent Type Refinery

(Unit: BPSD)

	LPG	Premium Gasoline	Regular Gasoline	Kerosene/ Jet A-1	Gas Oil	Marine Bunker Fuel	Heavy Fuel Oil
Production	230 (+150)*	2,730	1,100	2,340	3,720	9,480	–
Demand in 1985	380	5,510	2,160	4,060	8,730	9,945	–
Rate of Self-sufficiency (%)	100	49.5	50.9	57.6	42.6	95.3	–

* Production from Rusayl LPG Plant
(Source) JICA Mission

Table 6-4 Refinery Configuration and Product Mix

Configuration of Process Units

(Unit: BPSD)

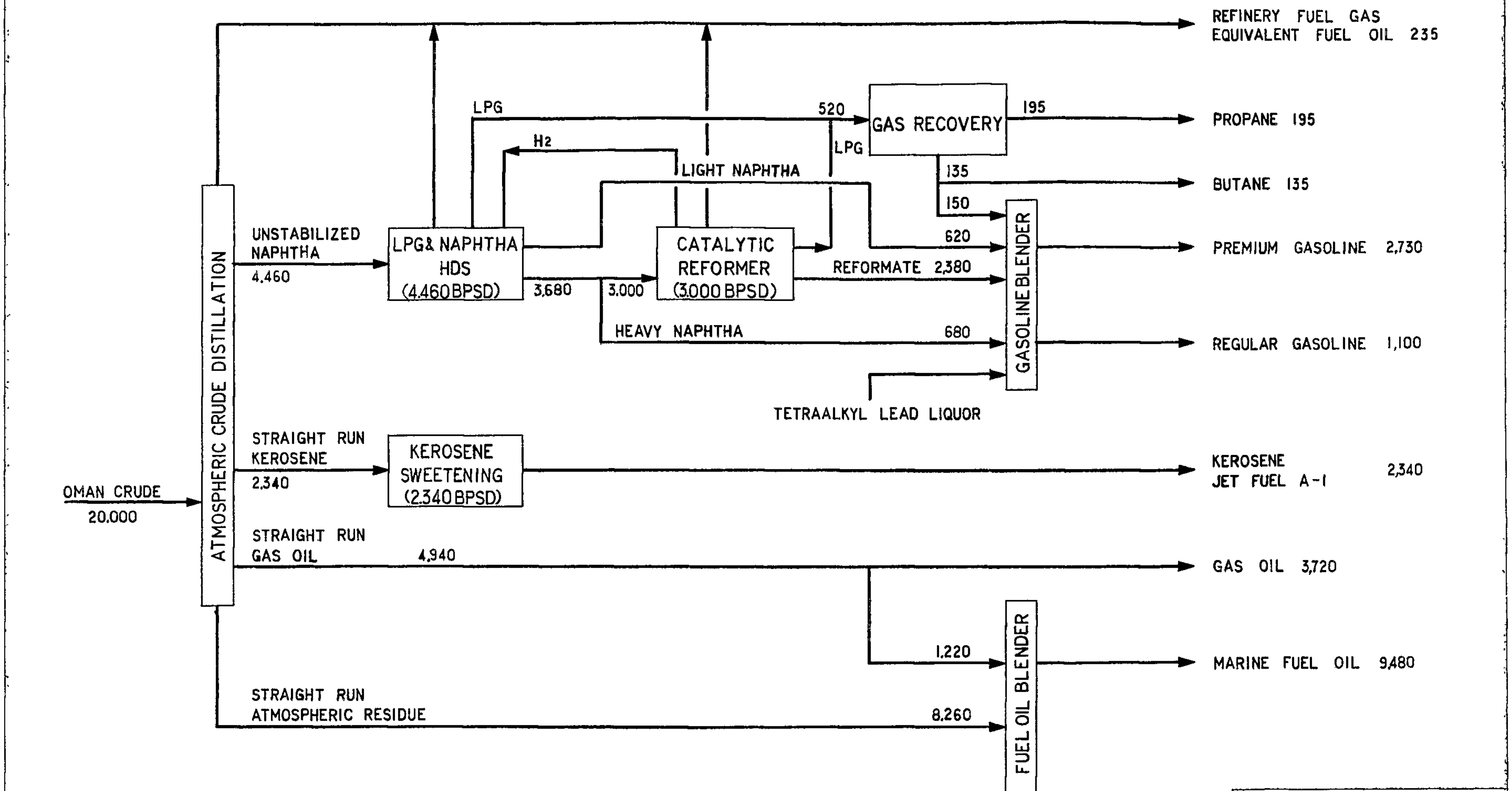
Process Unit	40,000 BPSD	20,000 BPSD
Crude Atmospheric Distillation Unit	40,000	20,000
LPG/Naphtha Hydrodesulfurization Unit	8,910	4,460
Naphtha Catalytic Reforming Unit	6,000	3,000
Kerosene Sweetening Unit	4,680	2,340
LPG Recovery Unit	1,030	520

Demand and Product Mix

(Unit: BPSD)

	Demand in 1985	40,000 BPSD	20,000 BPSD
LPG	380	230*	230*
Premium Gasoline	5,510	5,450	2,730
Regular Gasoline	2,160	2,210	1,100
Kerosene/Jet A-1	4,060	4,680	2,340
Gas Oil	8,730	8,600	3,720
Marine Bunker Fuel	9,945	9,945	9,480
Heavy Fuel Oil	–	7,855	–

* Another 150 BPSD of LPG will be supplied from Rusayl LPG Plant.
(Source) JICA Mission



OMAN REFINERY PROJECT
BLOCK FLOW DIAGRAM
FIG. 6-1-B

6.3.3 Alternatives of the Refining Scheme

(1) In order to save initial investments, a refinery scheme was worked out in which middle distillates (kerosene and gas oil) are produced but no gasolines (that is, so-called "topping plant").
In this scheme, LPG and naphtha hydrodesulfurization unit and naphtha reforming units are omitted from the previous scheme illustrated in Fig. 6-1. Also omitted or the capacity reduced is the gas recovery unit.
This type of refinery will, however, produce no motor gasolines for which a substantial demand is expected in Oman, and instead, 8,600 BPSD (in 40,000 BPSD crude throughput case, 4,300 BPSD in 20,000 crude case) of naphtha is produced. As to naphtha there will be no market in Oman at least for the foreseeable future.

(2) To deal with the surplus heavy fuel oil in the "Export dependent type" of refinery, it could be conceivable to crack the heavy fraction and convert it to gasoline and other light products. One of this type of refining scheme is to process the atmospheric residue by a vacuum flushing unit to separate it into vacuum gas oil and vacuum residue, and then the vacuum gas oil is converted by a catalytic cracking unit into lighter oil fractions such as a high octane gasoline blend stock, among others. A refinery configuration was worked out with a view to avoiding surplus products over estimated 1985 demand, as shown below:

– Crude atmospheric distillation unit:	30,000 BPSD
– Vacuum flushing unit:	5,630 BPSD
– LPG and naphtha hydrodesulfurization unit:	6,680 BPSD
– Fluid catalytic cracking unit:	4,500 BPSD
– Naphtha catalytic reforming unit:	3,500 BPSD
– Gas recovery unit:	770 BPSD
– Kerosene sweetening unit:	3,510 BPSD

This type of refinery includes additional processing units with relatively small scale, so that the construction cost is to be unproportionally high, whereas the productions of jet A-1/kerosene and gas oil are only 3,510 BPSD and 6,590 BPSD, respectively, both in short of the estimated 1985 domestic demand in Oman.

In conclusion, the above two alternatives are both unsuitable to the aim of self-sufficiency in petroleum products in Oman. Besides, the economies of these alternative schemes are apparently difficult to be superior to the one as illustrated in paragraph 6.3.1.
Therefore, it was decided that these alternatives be excluded from the consideration in this study report.

6.3.4 Utility Facilities

(1) Purchase or Self-Supply of Utilities

As already discussed in Chapter 4 "Public Utilities", supply of industrial water and electric power, which the planned refinery requires from the public supply system could be safely expected.

On the other hand it is suggested by the Omani Government that the planned refinery be equipped with its own power-generation and sea water desalination plants to attain self-supply in these utilities.

As discussed earlier, steam generation, power generation and desalination plants are likely to be constructed as one combined unit, so that it is not easy to calculate the costs of power and water separately and to compare them with their prices from the public supply systems.

Accordingly, the judgement on the installation of a power generation/desalination unit in the planned refinery must be depend, ultimately, on the total economy of the whole refinery.

Then, for each of the two types of the reinfery presented previously, that is 40,000 BPSD and 20,000 BPSD in crude throughput capacity, two cases could be consiered: One is equipped with its own power generation/desalination unit and is self-sufficient in these utilities, the other has no such unit and depends its supply of the utilities on purchase from outside.

Consequently, there are four cases of the planned refinery to undergo economic examination hereafter in this study, namely:

I.	40,000 BPSD/Utility outside purchase	(40/P)
II.	40,000 BPSD/Utility self-supply	(40/S)
III.	20,000 BPSD/Utility outside purchase	(20/P)
IV.	20,000 BPSD/Utility self-supply	(20/S)

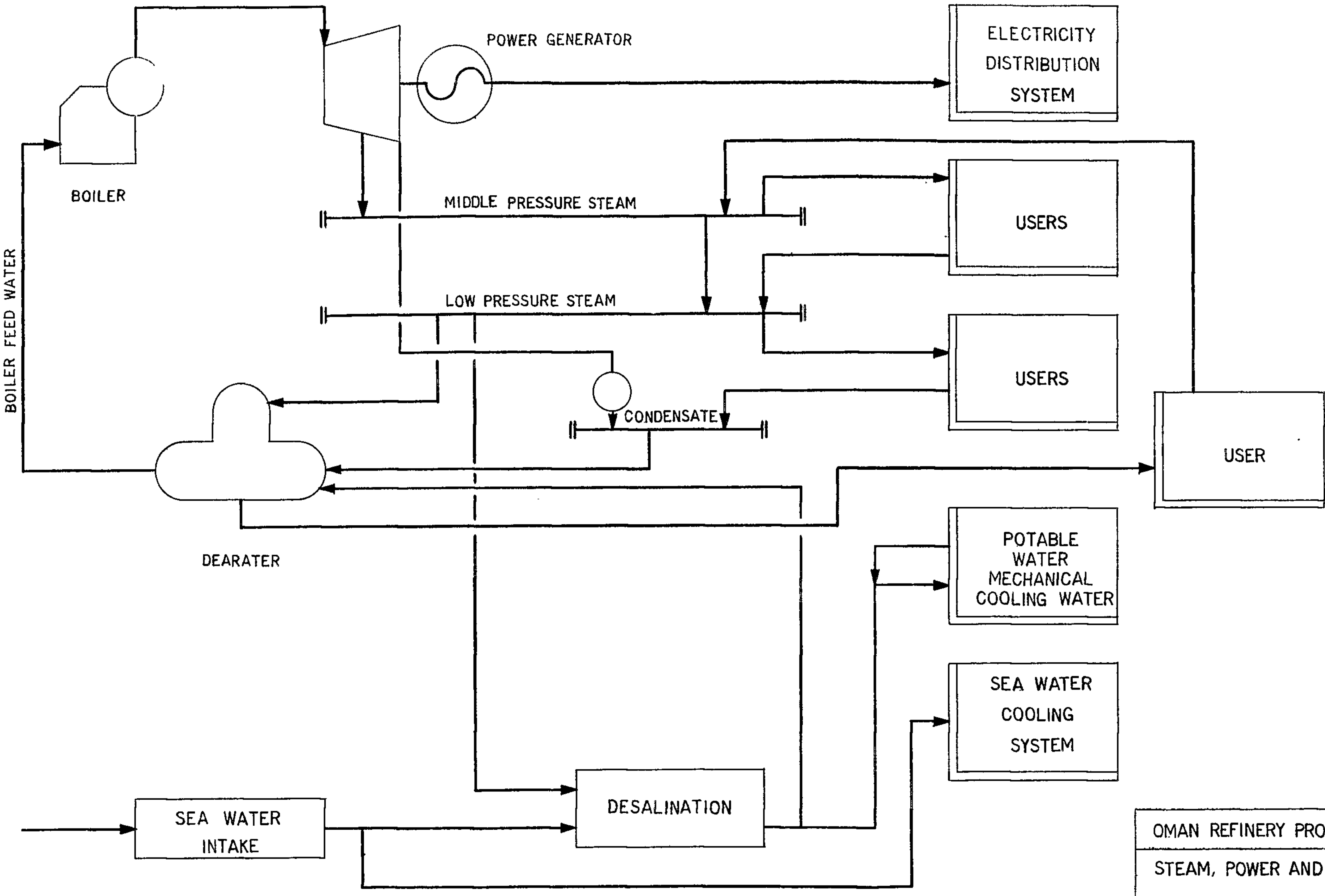
An outline of the utilities supply system of the refinery is described below.

(2) *Utilities Supply System*

The main system for utility supply in case of self-supply in power and water is as illustrated in Fig. 6-2.

In this refinery, steam is utilized at the three pressure levels below.

– High Pressure Steam	45 kg/cm^2G, 360°C
– Medium Pressure Steam	15 kg/cm^2G, 260°C
– Low Pressure Steam	3.5 kg/cm^2G, 150°C



OMAN REFINERY PROJECT

STEAM, POWER AND WATER SYSTEM DIAGRAM

FIG. 6-2

The high pressure steam is to be produced by a steam generator (boiler) and used to drive a turbine electricity generator. This turbine is of the steam extraction – condensation type.

The steam extracted from this turbine and that generated by the economizer in the feed oil heater of the catalytic reforming unit can be used as medium pressure steam to drive pumps attached to the crude atmospheric distillation unit, blowers for the steam generator, and water supply pumps.

The low-pressure steam becomes available as exhaust steams from the above-mentioned drivers and by reducing the pressure of the medium pressure steam. The services of the low pressure steam are desalination of sea water and heating of tanks, among others.

Condensate water of the steam is to be recovered as far as possible and is to be re-used for steam generation.

Cooling of the processing units is to be done by one-pass use of sea water where possible.

On the other hand, in the case of utilities purchase from outside, the turbine-driven power generator and the sea water desalinating unit are to be eliminated from the system illustrated in Fig. 6-2. The capacity of the steam generator is to be reduced accordingly. Instead, receiving facilities for power and water become necessary.

Three kinds of fuel are to be used in the planned refinery, that is.

- Off-gas (mainly C_1 and C_2 hydrocarbons) from the refining operation
- Surplus LPG
- Natural gas to be purchased from outside

The natural gas is to be purchased to such an extent that the off-gas and the LPG can not fulfill the requirements of the refinery.

In addition, facilities for generating air and inert gas required for the operation of the refinery as well as those for distribution of all the utilities have to be installed regardless of the self-sufficiency nor purchasing in power and water.

(3) Utility Balance and Capacities of Utility Facilities

Utility balance in 40,000 BPSD case of the planned refinery is as shown in Table 6-5. Utilities consumption and capacities of utility facilities for each of four refinery cases are summerized in Table 6-6 and Table 6-7, respectively.

Table 6-5 Utility Balance (40,000 BPSD)

	Electricity (KW)	Fuel (10^6 Kcal/Hr.)	Steam (Ton/Hr.)					Industrial Water (Ton/Hr.)	Sea Water (Ton/Hr.)
			HP	MP	LP	Con-densate	BFW		
On-Site Total	2,414	56.8	–	7.5	(–) 6.6	(–) 5.2	7.5	14.9	1,140
Off-Site Total	700	–	–	–	10	(–) 8.0	–	2.0	–
Utility Facilities									
Steam Generation System	7	27.5	(–) 36	11.7	(–) 11.3	–	37.2	–	–
Power Generation System	(–)3,590	–	36	(–) 20	–	(–) 16.0	–	–	690
Desalinator	27	–	–	0.2	4.8	–	–	(–) 34.0	330
Sea Water Intake	341	–	–	–	–	–	–	–	–
Others	99	–	–	0.6	(–) 1.1	29.2	(–) 44.7	17.1	110
Utility Facilities Total	3,116	27.5	0	(–) 7.5	(–) 3.4	13.2	(–) 7.5	(–) 16.9	1,130
Refinery Total	±0	84.3	±0	±0	±0	±0	±0	±0	2,270

(Source) JICA Mission

Table 6-6 *Utility Requirements Summary*

Case		40,000 BPSD		20,000 BPSD	
		Purchase	Self-Supply	Purchase	Self-Supply
Electricity	KW	3,410	3,590	1,950	2,060
Fuel	10^6 Kcal/D	1,590	2,030	790	1,060
Steam	Ton/D	310	864	151	494
Cooling Water (Fresh Water)	Ton/D	2,640	2,640	1,730	1,730
Cooling Water (Sea Water)	Ton/D	30,100	46,600	15,600	25,700
Net Sea Water Intake	Ton/D	30,100	54,500	15,600	30,600
Net Fresh Water Intake	Ton/D	670	–	410	–

(Source) JICA Mission

Table 6-7 Utility Facilities Summary

Case	40,000 BPSD		20,000 BPSD	
	Purchase	Self-Supply	Purchase	Self-Supply
1. Steam System				
Steam Generator	14 Ton/Hr.	40 Ton/Hr.	7 Ton/Hr.	23 Ton/Hr.
Deaerator	"	"	"	"
2. Electric Power System				
Turbine Generator	–	3,600 KW	–	2,100 KW
Diesel Engine Generator*	400 KW	400 KW	300 KW	300 KW
Power Engine Generator	3,410 KW	–	1,950 KW	–
Distribution Facility	3,810 KW	4,000 KW	2,250 KW	2,400 KW
3. Water System				
Sea Water Intake	1,250 Ton/Hr.	2,270 Ton/Hr.	650 Ton/Hr.	1,280 Ton/Hr.
Desalinator	–	22 Ton/Hrx2	–	14 Ton/Hrx2
Cooling Water Distribution	1,250 Ton/Hr.	2,000 Ton/Hr.	650 Ton/Hr.	1,070 Ton/Hr.
Mech. C.W. (Fresh Water) System	110 Ton/Hr.	110 Ton/Hr.	70 Ton/Hr.	70 Ton/Hr.
Fresh Water Receiving Facility	31 Ton/Hr.	–	17 Ton/Hr.	–
Demineralizer	7 Ton/Hr.	–	3 Ton/Hr.	–
4. Others				
Air System	800 Nm^3/Hr.	800 Nm^3/Hr.	800 Nm^3/Hr.	800 Nm^3/Hr.
Fuel Gas System				
Inert Gas System	300 Nm^3/Hr.	300 Nm^3/Hr.	250 Nm^3/Hr.	250 Nm^3/Hr.

* for emergency

(Source) JICA Mission

6.3.5 Oil Storage and Oil Handling Facilities

(1) Crude Oil Tank

This planned refinery is to be supplied with crude oil from the existing crude tankage owned by P.D.O. in the Mina al Fahal area, which is composed of six 51,000 KL tanks and one 143,000 KL tank, totalling 449,000 KL of storage capacity.

The above storage capacity is more than enough for the planned refinery, so that only service tanks are to be installed to store crude oil which correspond to the crude troughput for three days, namely;

- in cases 40/P and 40/S, two 10,000 KL floating roof type tanks
- in cases 20/P and 20/S, two 5,000 KL floating roof tanks

(2) Tanks for Final and Intermediate Products

i) Premises for planning of the products tankage

The products tankage of this planned refinery will have to serve as the final and intermediate products storage required for the smooth operation of the refinery.

In addition, the products tankage is to function as the distribution terminal for the market in the northern part of the country, and also as the shipping terminal to the oil products depot at Salalah in the southern part of the country.

In consideration of the above, this planned refinery is to be equipped with product storage capacity which corresponds to the amount of final product produced during 30 days' operation. 30 days is a period required for a shut-down maintenance of the refinery.

Among the above-mentioned storage capacity of 30 days' production, tanks for blend stocks of gasoline are to have capacity which corresponds to 7 days' production, and for atmospheric residue, a blend stock of marine bunker oil, 4 days' production.

Meanwhile, Shell and BP own their oil product terminals for import and distribution purposes at Mina al Fahal in the capital area. When the planned refinery is completed and self-sufficiency of Oman in petroleum products is achieved, the function of the above products terminals is supposed to be changed and the facilities could be used, at least partially, as the products storage of the refinery.

Accordingly, before determining the capacities of products storage to be installed to the planned refinery, it is necessary to have an understanding of these existing products terminals.

In Table 6-8, storage capacities of terminals at Mina al Fahal and Salalah are summerized in comparison with 1978 demands for oil products in northern and southern parts of the country.

Table 6-8 Existing Product Terminals, Storage Capacities

	Demand in 1978		Storage Capacity and Storage Periods	
	Norhtern Market bbl (%)	Southern Market bbl (%)	Mina Al Fahal KL (days)	Salalah KL (days)
Premium Gasoline	651,000 (80)	161,500 (20)	10,310 (19)	5,700 (71)
Regular Gasoline	606,200 (96)	23,800 (4)		
Jet A-1	630,900 (85)	111,100 (15)	9,100 (29)	5,000 (92)
Kerosene	87,600 (87)	13,400 (13)		
Gas Oil	1,170,300 (75)	386,700 (25)	20,800 (41)	9,600 (57)
Marine Bunker Fuel	4,242,000 (100)	–	80,000 (43)	–

(Source) Ministry of Commerce & Industry
JICA Mission

And then a supposition is made that the ratio of demand shared by the two parts of the country would remain unchanged in 1985 as it was in 1978, namely:

	Northern Market	Southern Market
Premium Gasoline	80 %	20 %
Regular Gasoline	95	5
Jet A-1/Domestic Kerosene	85	15
Gas Oil	75	25
Marine Bunker Fuel	100	–

In cases where the crude throughput capacity of the refinery is 20,000 BPSD, a part of the demands for distillate products is still to be met by import. In such cases, it is presupposed that the imported products are in the first place to be bound to Salalah, and that import to the Mina al Fahal is limited only to such an amount that production from the refinery can not fulfill the demands in the northern market.
For the products to be imported to Mina al Fahal, it is presupposed that storage

capacities corresponding to the present storage periods indicated in Table 6-8, that is, import amount for 19 days for gasolines, 29 days for jet A-1/kerosene, 41 days for gas oil, are still required within the existing terminals. The rest of the tanks in the existing terminals could be used by the planned refinery.

Therefore, products storage capacity to be newly installed in the planned refinery is to be calculated by an equation:

(Capacity to be newly installed) = (Capacity to be owned) – (Usable capacity in the Mina al Fahal terminal)

Shipping to the Salalah terminal from the planned refinery is supposed to be made four times per month by mixed cargo on a 2,800 DWT tanker.

In cases where heavy fuel oil is produced in surplus this surplus fuel oil will have to be exported. A lot of export is supposed to be 30,000 KL per trip.

ii) Procedure of planning products tanks

On the basis of the presuppositions described in the preceding paragraph, a plan is worked out for the products tanks of a 20,000 BPSD refinery. The procedure is summarized in Table 6-9.

In the table, 4,200 KL of existing storage capacity for gas oil is usable by the refinery in calculation. Actually, however, there exist only one 20,000 KL tank and one 800 KL tank in the Mina al Fahal terminal. These two tanks are not convertible to the use of the planned refinery by reason of tank operation, so that all gas oil storage required has to be newly installed in the refinery. This is not the case for other kinds of the products and all storages as calculated are to be converted to the use of the refinery.

In case of a 40,000 BPSD refinery there is no need of considering the storage capacity for imported products and all the existing tanks in the Mina al Fahal terminal may be used by the planned refinery. Consequently, the planning procedure is much simpler, as summarized in Table 6-10.

For the final and intermediate products that are not indicated in Table 6-9 and 6-10, there are no existing tanks, so that the tank capacities calculated from the presupposed storage periods are to be newly installed in the planned refinery.

In this way, storage capacities required for final and intermediate products were calculated. Supposing that storage is 85 percent full on average, and also considering the convenience in oil handling, sizes and numbers of tanks to be installed were determined.

Table 6-9 Planning Procedures for Product Tanks of a 20,000 BPSD Refinery

	1985 Demand			Production	Import to Capital Area	Storage Period for Imported Products	Tank Capacities				Storage Period	Tank Capacity Required	Tank Capacity to be Installed
	Whole Oman	Share of Capital Area(%)	Capital Area				for Imported Products	Existing	Utilizable in Calculation	Utilizable Actually			
	1	2	1 X 2 = 3	4	3 – 4 = 5	6	5 X 6 = 7	8	8 – 7 = 9	10	11	4 X 11 = 12	12 – 10
	BPSD	%	BPSD	BPSD	BPSD (BPCD)	DAYS	KL	KL	KL	KL	DAYS	KL	KL
Premium Gasoline	5,510	80	4,410	2,730	1,680 (1,510)	19	7,500	10,300	2,800	2,800	23	10,000	(8,000) 11,200
Regular Gasoline	2,160	95	2,050	1,100	950 (855)						23	4,000	(3,200)
Jet/Kerosene	4,060	85	3,450	2,340	1,100 (1,000)	29	4,800	9,100	4,300	4,300	30	11,200	6,900
Gas Oil	8,730	75	6,550	3,720	2,830 (2,550)	41	16,600	20,800	4,200	0	30	17,700	17,700
Marine Bunker Fuel	9,945	100	9,945	9,480	465 (420)	43	2,870	80,000	77,130	77,130	30	45,200	–

(Source) JICA Mission

Table 6-10 **Planning Procedures for Product Tanks of a 40,000 BPSD Refinery**

	Production	Storage Period	Storage Capacity	Tank Capacity Existing	Tank Capacity to be Installed
	1	2	1 X 2 = 3	4	3 – 4
	BPSD	DAYS	KL	KL	KL
Premium Gasoline	5,450	23	19,930	10,300	(12,600) 17,710
Regular Gasoline	2,210	23	8,080		(5,110)
Jet/Kerosene	4,680	30	22,320	9,100	13,220
Gas Oil	8,600	30	41,020	20,800	20,220
Marine Bunker Fuel	9,945	30	47,440	80,000	–

(Source) JICA Mission

iii) Considerations on oil shipping and handling

In a 40,000 BPSD refinery, heavy fuel oil in surplus will have to be exported. By the supposition that the lot of export is 30,000 KL per trip, a tank capacity which corresponds to this cargo lot becomes necessary. At persent there exist one 40,000 KL tank and two 20,000 Kl tanks, for 80,000 KL of marine bunker oil in total at the Mina al Fahal terminal and they are connected to offshore loading-unloading facilities. Among these tanks, two 20,000 KL tanks are to be converted for heavy fuel oil export. And as their substitutes, two new 20,000 KL marine bunker oil tanks are to be installed in the refinery.

Also in a 40,000 BPSD refinery a part of its products is to be shipped to the Salalah terminal. It is presupposed that the shipment will be done four times a month (every eight days), so that one tank for each type of products with a capacity corresponding to the cargo lot. Taking convenience in oil handling into consideration, the necessary sizes and number of tanks are determined as shown in Table 6-11.

Table 6-11 **Products Tanks for Shipping to Salalah Terminal**

	Demand in Southern Region	Cargo Lot per Trip	Tank Required Size x Number	New Installation Required
	(BPSD)	(KL)	(KL)	
Premium Gasoline	1,100	1,400	2,000 x 1	no
Regular Gasoline	110	140	200 x 1	no
Jet/Kerosene	610	780	1,200 x 1	no
Gas Oil	2,180	2,610	4,000 x 1	yes

(Source) JICA Mission

For premium and regular gasolines as well as for jet A-1 and koresene, there already exist suitable tanks at the Mina al Fahal terminal so that no new installation is needed. However, for gas oil there is no suitable tank among existing ones and therefore installation of one 4,000 KL tank becomes necessary.

(3) Result of Tankage Planning

As the result of considerations described in forgoing paragraphs (1) and (2), all tanks to be installed in the planned refinery are determined as summarized in Table 6-12, in which also summarized are existing tanks in the Mina al Fahal terminal.
Fig. 6-3 shows the system relationships of the tanks.

(4) Product Transfer to Mina al Fahal Terminal

As described above, existing product tanks in the Mina al Fahal terminal are to be operated at least partially as a part of product storage of the new refinery. However, at the same time, another function of the terminal, that is, a distribution base of the petroleum products to the domestic market, should be maintained and it is expected that the necessary expansion and improvement be made on the shipping facility of the terminal in accordance with the expected increase of the domestic demands.
Consequently, the shipment of the products from the planned new refinery is to transfer them to existing terminal in Mina al Fahal. This will be carried out by the following products pipelines.

- To Shell terminal: One pipeline to transfer marine bunker oil and heavy fuel oil for export (in 40,000 BPSD case only), operated 24 hours a day; and one pipeline to transfer gasolines, kersosene/jet A-1, and gas oil alternately, operated during daytime only.
- To BP terminal: One pipeline to transfer gasoline, jet A-1/kerosene and gas oil alternately, operated during daytime only.

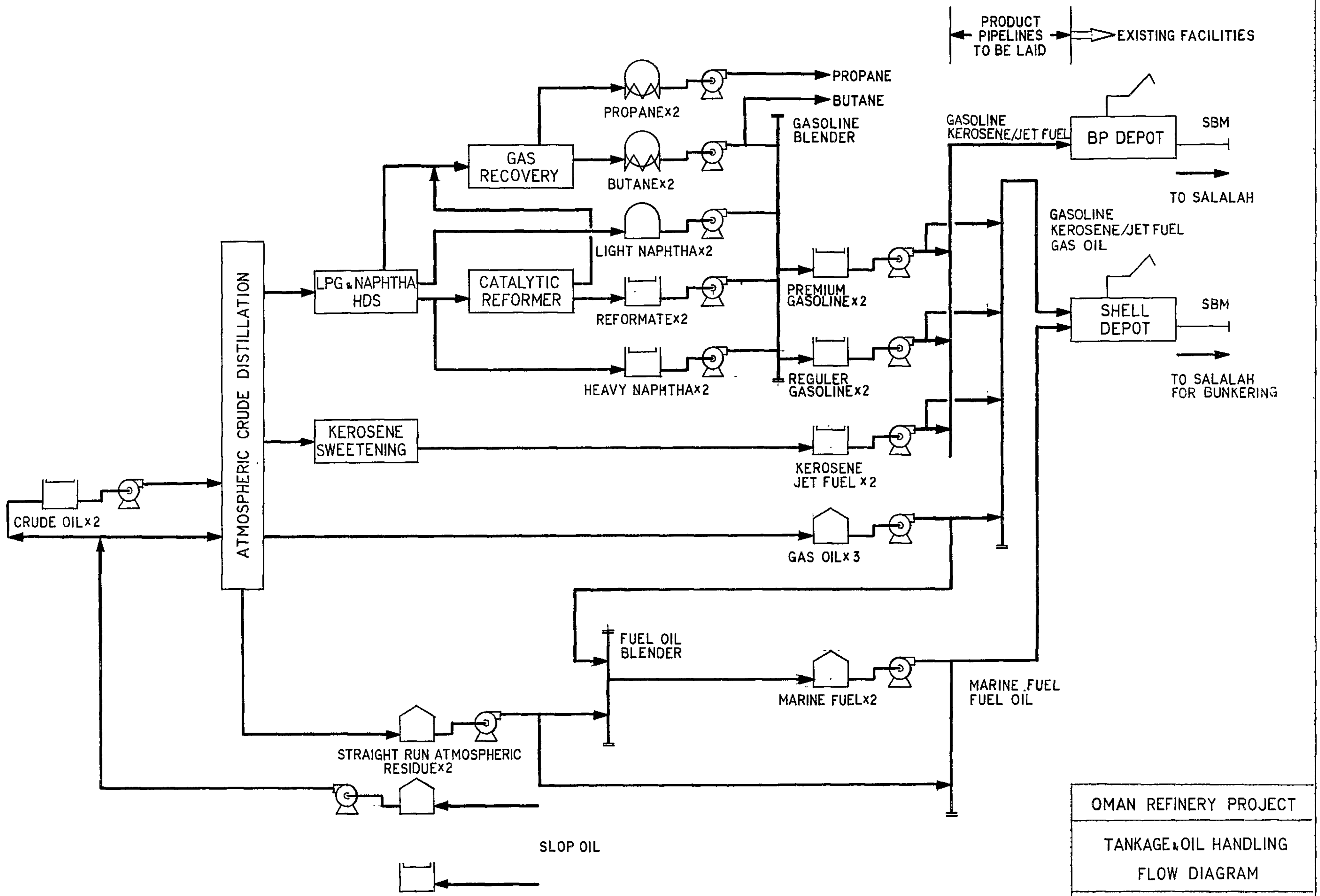
These pipelines are indicated on the tank system diagram, Fig 6-3.

Table 6-12 Tankage List

		Existing Tankage (Mina Al Fahal Area)						Tankage to be installed					
		PDO		SHELL		BP		20,000 BPSD			40,000 BPSD		
		KL	NO.	KL	NO.	KL	NO.	KL	NO.	TYPE	KL	NO.	TYPE
Crude		51,500 143,000	6 1					5,000	2	FR M	10,000	2	FR M
Final Products	Gasoline			3,000 1,750 500 260	1 1 1 1	2,100 1,000 500 400 75	1 1 1 1 4	5,000 2,000	2 2	FR FR	7,500 3,000	2 2	FR FR
	Kerosene/Jet A-1			750 500 250	1 1 1	3,800 1,900 900	1 1 2	4,000	2	FR	8,000	2	FR
	Gas Oil	20,000	1	800	1			10,000	2	CR	10,000 4,000	2 1	CR CR
	Marine Bunker Fuel & Heavy Oil	20,000 40,000	2 1					5,000	2	CR	20,000	2	CR
	Propane	–		–		–		500	2	SP	500	2	SP
	Butane	–		–		–		500	2	SP	600	2	SP
Intermediate	Lt. Naphtha	–		–		–		400	2	DOME	700	2	DOME
	Reformate	–		–		–		1,500	2	FR	3,000	2	FR
	Hy. Naphtha	–		–		–		400	2	FR	800	2	FR
	Reduced Crude	–		–		–		5,000	2	CR	5,000	2	CR
Slop	Lt. Slop							1,300	1	FR	3,000	1	FR
	Hy. Slop							1,300	1	CR	3,000	1	CR

Notes: FR ; FLOATING ROOF TANK DOME ; DOME ROOF TANK M ; TANK MIXER
CR ; CONE ROOF TANK SP ; SPHERICAL TANK

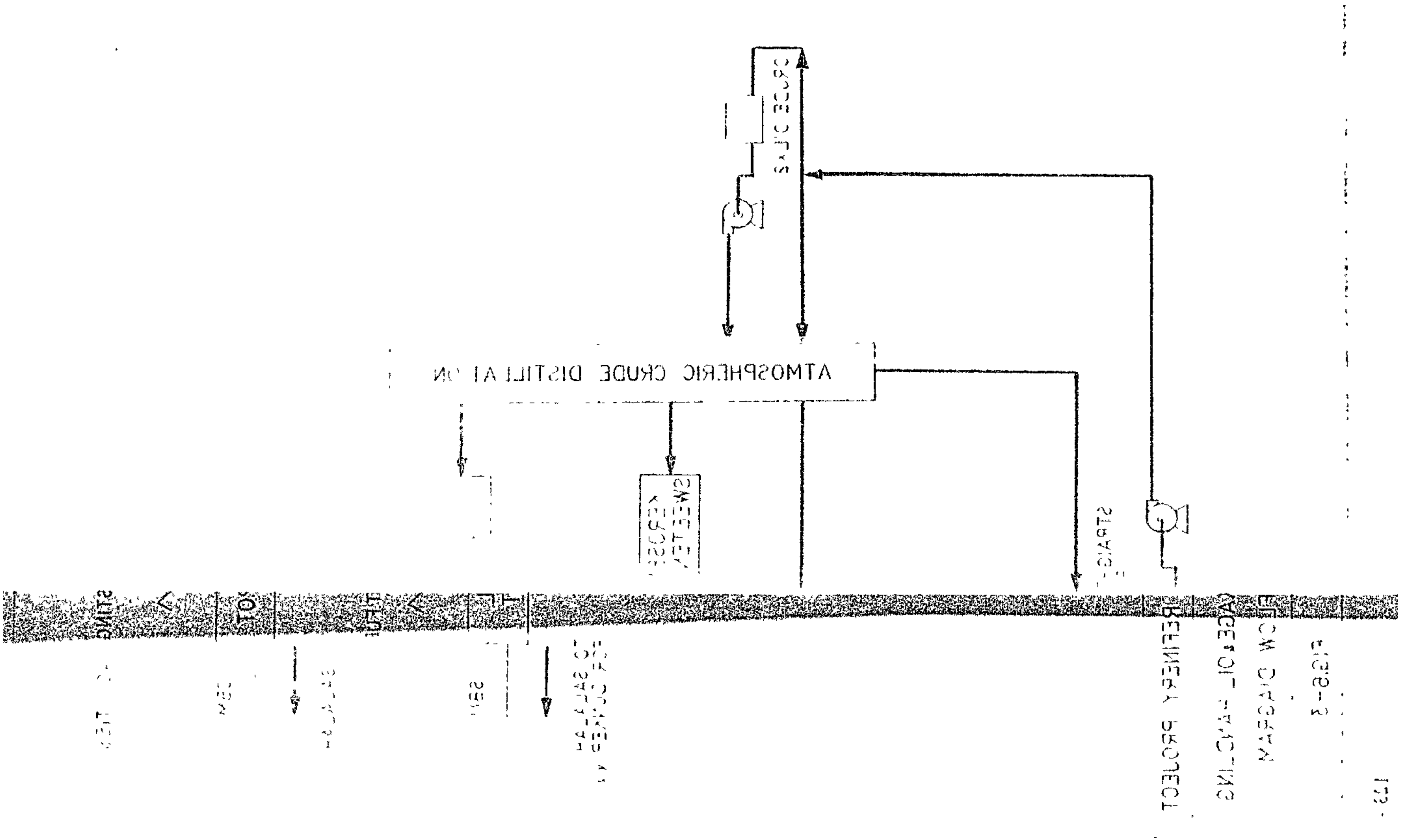
(Source) Ministry of Commerce & Industry
JICA Mission



OMAN REFINERY PROJECT

TANKAGE & OIL HANDLING FLOW DIAGRAM

FIG.6-3


ATMOSPHERIC CRUDE DISTILLATION
CRUDE OILS
KEROSENE SWEETENING
REFINERY PROJECT
STORAGE & OIL HANDLING
FLOW DIAGRAM
FIG.6-3

6.3.6 Other Auxiliary Facilities

(1) Fire Fighting Facilities

To cope with possible fire accident in the refinery, fire alarms and fire fighting water nozzles (fire hydrants) are to be distributed all over the refinery. Sea water is to be used for fire fighting purposes and taken from an intake basin to a hydrant header at a raised pressure via pump. Foam distinguish systems and one chemical fire engine also to be held by the refinery.

(2) Waste Water Disposal System

Drainage from a refinery is classified into three categrories according to the characteristics of waste waters, that is, process waste water, oily waste water, and clean waste water. They are separately collected and gathered to respective water disposal plants.

Process waste water is treated by a foul water stripper, oily waste water by a CPI oil separator, and then exhausted to the sea via guard basin.

(3) Buildings

Buildings to be built in the refinery are shown in Table 6-13.

(4) Flare Stack

To collect and incinerate waste gases exhausted from refinery facilities, one flare stack is to be installed.

(5) Civil Works

The candidate site at Mina al Fahal leans to the seaside with a gradient of about one to fifty.

Therefore, for site preparation work, around 72,000 cubic meters of soil will have to be cut and filled.

Earth surfaces around equipment in process and utility area are to be paved with concrete, and the roads are paved with asphalt-concrete. Wire fence is to be installed surrounding the refinery site.

Table 6-13 Building Summary (40,000 BPSD)

Buildings	No.	Total Floor Area	
Administration Building	1	2 stories	1,000 m^2 *
Mainbenance, Shop, Machine House & Ware House	1	1 story	800 m^2
Change House	1	1 "	100 m^2
Rest House	1	1 "	50 m^2
Control House	1	1 "	600 m^2
Power House	1	1 "	150 m^2
Sub Station	1	1 "	150 m^2
Fire House	1	1 "	100 m^2
Gate House	2	1 "	40 m^2 x 2

*includes canteen, first aid and laboratory
(Source) JICA Mission

6.3.7 Plot Plan of the Refinery

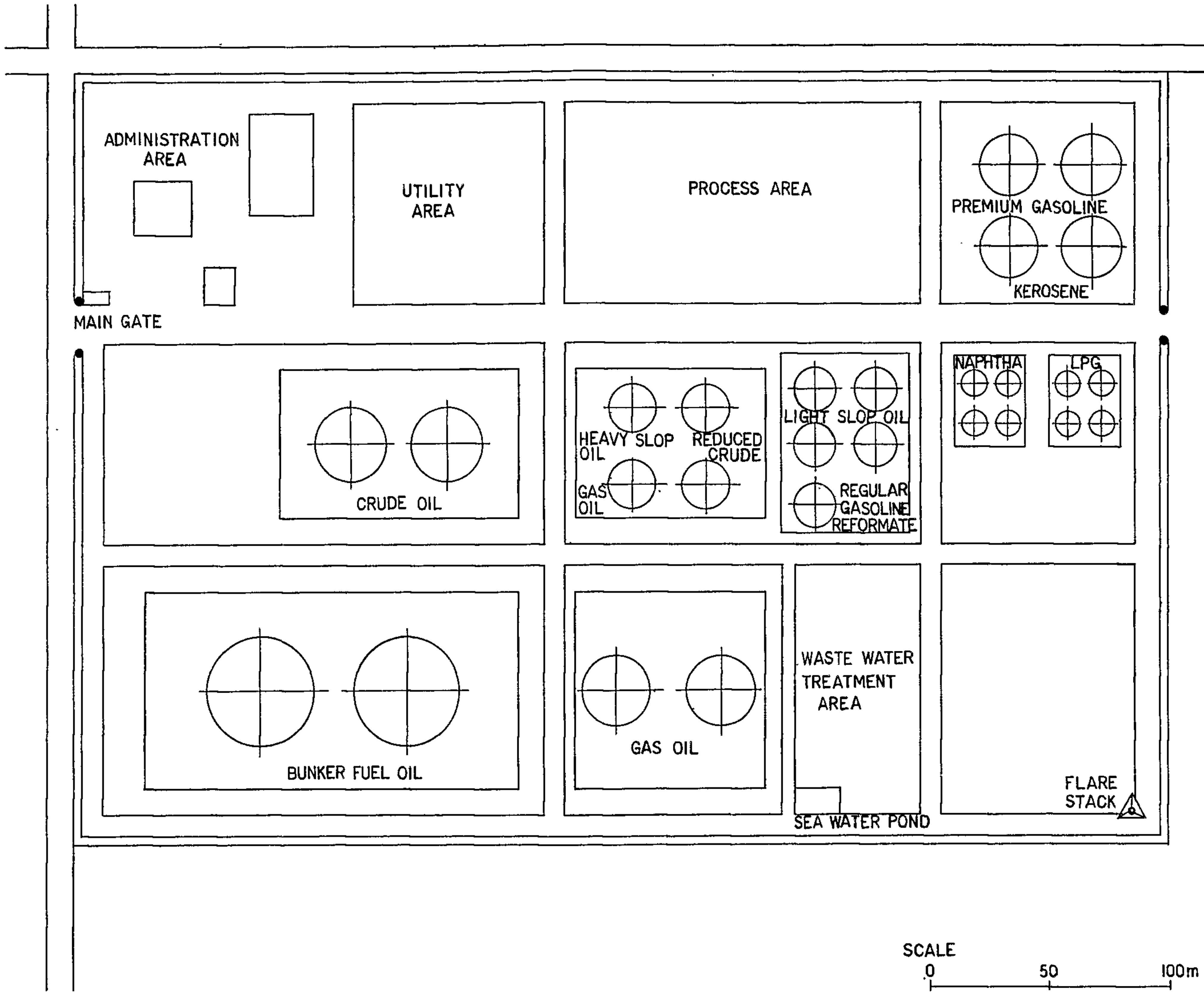
Fig. 6-4 is a preliminary plot plan of a 40,000 BPSD refinery. The refinery site is divided into administration area, processing area, utilities area, tankage area and waste disposal area.

The arrangement of each of the above areas is determined taking the following factors into consideration.

- Connection of main roads in the refinery to the existing roads.
- Efficiency in material handling.
- Safety and Hazard Prevention.

Required land area is estimated for each of the refinery cases as follows.

40/P	130,000 m^2
40/S	135,000 m^2
20/P	92,000 m^2
20/S	94,000 m^2



OMAN REFINERY PROJECT

GENERAL PLOT PLAN

FIG. 6-4

6.4 REFINERY ORGANIZATION AND MANNING PLANS

This section deals with the refinery organization and manning plans. The personnel requirements by type of jobs estimated herein are used as a basis for 7.1 "Cost Estimation".

6.4.1 Refinery Organization

The refinery will be composed of 4 departments – production, technical services, maintenance, and general affairs – headed by a refinery manager and an assistant manager who assume all the responsibilities for refinery operation.

Fig. 6-5 illustrates an organization for the refinery. It shows the four departments and the divisions in each department. This organizational structure is common to all the refinery cases now being studied.

6.4.2 Departmental Tasks and Manning Plans

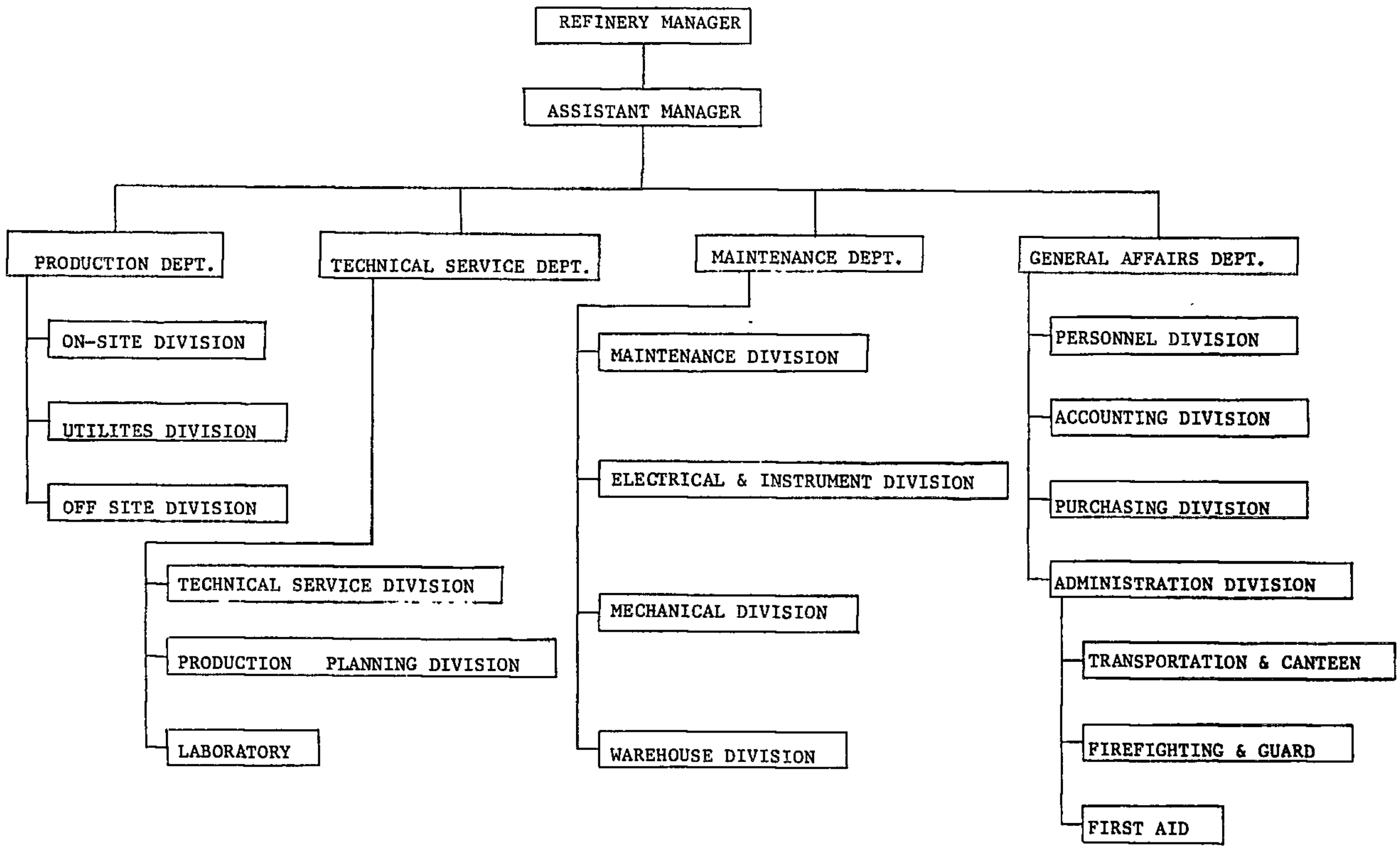
The manning plans described below have been worked out on the basis of this organizational structure. In calculating the personnel requirements of those departments working in shifts, it has been assumed that 4 teams of workers work in 3 shifts, with each shift team having an additional worker who stands by to replace someone who is absent. Table 6-14 summarizes the total personnel requirements in all the refinery cases.

Table 6-14 Required Refinery Personnel

Position \ Case	40,000 & 20,000 BPSD	
	Self-Supply	Purchase
Refinery Manager	1	1
Assistant Refinery Manager	1	1
Secretary	2	2
Production Dept.	92	80
Technical Service Dept.	23	23
Maintenance Dept.	39	38
General Affairs Dept.	55	55
Total	213	200

(Source) JICA Mission

FIG. 6-5 ORGANIZATION CHART



(1) Refinery Manager and Assistant Manager

These two men are the top management of the refinery who supervise all the tasks of the above four department. They are also responsible for making decision on the refinery organization and personnel. Each of them has a secretary.

(2) Production Department

The management group of this department consits of the manager, an assistant manager, and three supervisors, a head for each of On-site, Off-site, and Utilities Divisions. They are in charge of major tasks of controlling refinery operation in accordance with a production plan, and taking corrective measures when operation is in abnormal conditions. Engaged in actual operation are the shift teams set up in each division. A shift team consists of a foreman and several operators. The personnel requirements were calculated on the basis of the features of facilities to be operated and the aforementioned shifiting schedule. Table 6-15 gives a manning plan for the Production Department classified by divisions and by type of jobs.

(3) Technical Service Department

This department consists of three divisions – Technical Service Division, Production Planning Division, and Laboratory – directed by the department manager and an assistant manager. Each division is under control of a chief engineer. These five personnel compose the management group of this department.

The main task of Laboratory is the quality control of products through daily inspections of products and intermediates. The Laboratory will be also responsible for inspecting refinery wastewater, for the purpose of preventing water pollution.

Technical Service Division is in charge of solving technical problems encountered in refinery operation, and gives instructions as to remedial measures. When large-scale construction work, such as re-modelling and expansion of the refinery, is conducted, this division shall play a central role in working out a construction plan.

Production Planning Division is in charge of preparing yearly and monthly production plans and keeping always informed of the real operating situations. Table 6-16 gives a manning plan for the Technical Service Department. As shown in this table, the department does not work in shifts, and there is no difference in the number of personnel among refinery cases.

(4) Maintenance Department

This department headed by department manager has four divisions – Maintenance, Electrical & Instruments, Mechanical, and Warehouse – directed by the corresponding division chiefs.

The three divisions of Maintenance, Electrical & Instruments, and Mechanical work in shifts, and are responsible for daily inspections of equipment, repairs, planning on periodical repair work, and accomplishment and control of actual work, in their respective fields, as folows:

Maintenace Division:	General maintenance work in the refinery, including welding and painting; maintenance of pipes, heat exchangers, etc.
Mechanical Division:	Maintenance and inspections of mainly rotary machinery such as pumps, compressors, etc.
Electrical & Instruments Division:	Maintenance and inspections of control instruments and electric systems.

Warehouse Division is generally in charge of inventory control for the parts required for refinery operation and repairs.

Table 6-17 gives a manning plan for the Maintenance Department classified by divisions and by type of jobs. The difference in personnel requirement between the utilities self-sufficiency case and the corresponding purchase case is found in the Maintenance Division where one more worker is required in the self-sufficiency case.

(5) General Affairs Department

This department headed by department manager and an assistant manager has four divisions – Personnel, Accounting, Purchasing and Administrations. Each division has both a chief and an assistant chief with exception of the Administration Division. Administration Division is in charge of transportation, fire-fighting, mess-hall operation and first aids. The tasks of all divisions in this department are similar to those for ordinary factories. These tasks will not have to be described in detail. Table 6-18 gives a manning plan for this department classified by divisions and by type of jobs.

Table 6-15 Manning Plan for Production Department

Position \ Case	40,000 & 20,000 BPS'D			
	Self-Supply		Purchase	
	Day	Shift	Day	Shift
Manager and Assistant	2		2	
Clerk	3		3	
On-Site Division				
Supervisor	1		1	
Foreman		1		1
Operator		9		9
Utilities Division				
Supervisor	1		1	
Foreman		1		1
Operator		5		2
Off-Site Division				
Supervisor	1		1	
Foreman		1		1
Operator	4	3	4	3
Sub Total	12	20	12	17
Total	92 (20x4+12)		80 (17x4+12)	

(Source) JICA Mission

Table 6-16 Manning Plan for Technical Service Department

Position \ Case	40,000 & 20,000 BPSD	
	Self-Supply	Purchase
Manager and Assistant	2	2
Clerk	1	1
Laboratory		
Chief	1	1
Tester	10	10
Clerk	2	2
Technical Service Division		
Chief	1	1
Engineer	1	1
Draftman & Technician	2	2
Clerk	1	1
Production Planning Division		
Chief	1	1
Engineer	1	1
Total	23	23

(Source) JICA Mission

Table 6-17 Manning Plan for Maintenance Department

Position \ Case	40,000 & 20,000 BPSD			
	Self-Supply		Purchase	
	Day	Shift	Day	Shift
Manager	1		1	
Clerk	1		1	
Maintenance Division				
Chief	1		1	
Foreman		1		1
Technician	2	1	1	1
Clerk	1		1	
Electrical & Instrument Division				
Chief	1		1	
Foreman		1		1
Technician	2	1	1	1
Clerk	1		1	
Mechanical Division				
Chief	1		1	
Foreman		1		1
Technician	1	1	1	1
Clerk	1		1	
Warehouse Division				
Chief	1		1	
Staff	2		2	
Clerk	1		1	
Sub Total	15	6	14	6
Total	39		38	

(Source) JICA Mission

Table 6-18 Manning Plan for General Affairs Department

Case / Position	40,000 & 20,000 BPSD			
	Self-Supply		Purchase	
	Day	Shift	Day	Shift
Manager	1		1	
Assistant	1		1	
Clerk	2		2	
Personnel Division				
Chief	1		1	
Staff	3		3	
Clerk	1		1	
Purchasing Division				
Chief & Assistant	2		2	
Staff	2		2	
Clerk	1		1	
Accounting Division				
Chief & Assistant	2		2	
Accountant	2		2	
Cashier	2		2	
Clerk	1		1	
Addministration Division				
Chief	1		1	
– First Aid				
Nurse	1		1	
Clerk	1		1	
– Fire-Fighting & Guard				
Chief	1		1	
Firmen		1		1
Guard	2	2	2	2
– Transportation & Canteen				
Chief	1		1	
Tel. Operation	2		2	
Driver	4		4	
Canteen	4		4	
Clerk	2		2	
Sweeper	3		3	
Sub Total	43	3	43	3
Total	55		55	

(Source) JICA Mission

CHAPTER 7. ECONOMIC EVALUATION

7.1 COST ESTIMATION

This Section deals with all the items included in the total capital requirement (total investment cost) and production cost. These constitute the basis for financial analysis which will be described in the next section.

7.1.1 Total Capital Requirement

The total capital requirements refers to the total capital cost invested by the time when the refinery starts commercial operation. Due to the different nature of the targets, it is divided into fixed capital and working capital.

(1) Fixed Capital

In this study, the fixed capital was estimated for each of items of which the total fixed capital is composed. Table 7-1 gives these capital requirements and the sums thereof. Such items include:

- Plant construction cost.
- Pre-operating expenses.
- Paid-up royalties.
- Initial costs of catalysts and chemicals.
- Interest paid during the construction period.

These items will be dealt with below in this order.

Plant Construction Cost

Table 7-2 gives a summary of refinery construction cost estimated for all the 4 cases which have been presented in Chapter 6. "Cost Estimation" is based on the following premises:

Table 7-1 Summary of Fixed Capital Requirements

(Unit: MM R.O.)

Item \ Case	40,000 BPSD		20,000 BPSD	
	Self-Supply	Purchase	Self-Supply	Purchase
1. Plant Construction Cost	24.36	22.33	16.07	14.65
2. Pre-Operating Expenses	1.20	1.19	1.20	1.19
3. Paid-up Royalty	0.27	0.27	0.13	0.13
4. Initial Cat. & Chemicals	0.26	0.26	0.13	0.13
5. Interest paid during Construction Period	1.00	0.93	0.67	0.61
Total Fixed Capital	27.09	24.98	18.20	16.71

(Source) JICA Mission

1) The refinery construction cost was estimated on the current cost basis, in which equipment and materials costs as well as labor cost were used as of April 1979.
2) The refinery construction project is dealt with as a Governmental project, and as such, the major equipment and construction materials to be procured from overseas shall be imported with exemption of customs duties.
3) The refinery shall be erected at the proposed site A in the Mina al Fahal area.
4) Concerning the supplies of crude oil, natural gas, electric power and industrial water, the necessary facilities to supply them as far as the refinery fence shall be laid at the expenses of respective suppliers.

Pre-operating Expenses

The pre-operating expenses include the items described below. The cost estimation is given in Table 7-3.

Table 7-2 Summary of Plant Construction Cost

	Refinery Capacity	40,000 BPSD				20,000 BPSD			
	Utility	Purchase		Self-Supply		Purchase		Self-Supply	
	Capacity Unit	Capacity	Cost (MMR.O.)	Capacity	Cost (MMR.O.)	Capacity	Cost (MMR.O.)	Capacity	Cost (MMR.O.)
1. Process Units									
Crude Atmospheric Distillation	BPSD	40,000	4.74	40,000	4.74	20,000	3.14	20,000	3.14
LPG & Naphtha Hydrodesulfurizer	BPSD	8,910	1.65	8,910	1.65	4,460	1.09	4,460	1.09
Catalytic Reformer	BPSD	6,000	2.87	6,000	2.87	3,000	1.83	3,000	1.83
Kerosene Sweetning	BPSD	4,680	0.40	4,680	0.40	2,340	0.26	2,340	0.26
Gas Recovery	BPSD	1,030	0.38	1,030	0.38	520	0.25	520	0.25
Sub Total:			10.04		10.04		6.57		6.57
2. Utility Facilities									
Steam System	Ton/Hour	14	0.36	40	0.86	7.0	0.26	23	0.61
Electric Power System	KW	Deisel 400	0.64	3,600	1.29	Diesel 300	0.39	2,100	0.86
Water System	Ton/Hour	1,250	0.60	2,270	1.39*	650	0.43	1,280	0.97*
Air, Refinery Fuel, Inert Gas System	Air NM^3/Hour	800		800		800		800	
	Fuel MMKCal/Hour	66	0.22	84	0.21	33	0.20	44	0.20
	Inert Gas NM^3/Hour	300		300		250		250	
Sub Total:			1.82		3.75		1.28		2.64
3. Offsite and Auxilialies									
Tankage & Oil Handling	Number of Tanks	27		27		25		25	
	KL	148,200	7.25	148,200	7.25	76,200	4.46	76,200	4.46
Waste Water Treatment & Sewer			0.65		0.67		0.44		0.45
Others			2.32		2.40		1.72		1.77
Sub Total:			10.22		10.32		6.62		6.68
4. Site Preparation	Cutting Volume (M^3)	50,000		50,000		30,000		30,000	
	Filling Volume (M^3)	12,000	0.17	12,000	0.17	7,000	0.10	7,000	0.10
5. Product Pipeline	8Bφx1 Km	1.4		1.4		1.4		1.4	
	6Bφx1 Km	1.4	0.08	1.4	0.08	1.4	0.08	1.4	0.08
	4Bφx1 Km	1.8		1.8		1.8		1.8	
Total			22.33		24.36		14.65		16.07

* includes construction cost of desalinator

(Source) JICA Mission

Table 7-3 Summary of Pre-operating Expenses

(Unit: 1,000 R.O.)

Item \ Case	40,000 BPSD		20,000 BPSD	
	Self-Supply	Purchase	Self-Supply	Purchase
Training Fee	547	528	547	528
Administration Cost	346	346	346	346
Start-up Expense	309	311	309	311
Total	1,202	1,185	1,202	1,185

(Source) JICA Mission

a) Training Fee

The personnel training cost consists of:

- Salaries to be paid to trainees during the training period.
- Direct expenses required for training (the cost for trainers, and expenses of overseas stay and travel cost to be paid to trainees during an overseas training period).

Cost calculation is based on a training plan described in Section 8.3 "Personnel Training Plan".

b) Administration Costs

On an assumption that the administration staff listed below would be employed 1 year prior to the start-up of commercial operation, the salaries to be paid them in a year and the accompanying indirect cost were summed up and contained in the pre-operating cost.

The administration staff include:

- Refinery manager and an assistant refinery manager, with 2 secretaries.
- Department managers.
- Staff of General Affairs Department (such as division cheifs and members of Personnel Div., Accounting Div. and Purchase Div., and drivers)
- Clerks of each department.

c) Start-up Expense

This item includes the cost for test run instructor sent by process licensors and the contractor, the cost of chemicals used in test runs, and the cost of utilities during the test-run period.

Royalties and Initial Costs of Catalysts/Chemicals

Royalties are essentially determined between a licensor and a licensee in individual cases. For convenience of this study, those values of royalties given in Table 7-4 were assumed as standard figures for the 4 cases, and were included in the fixed capital requirement. The table also gives the costs of catalysts and chemicals to be charged at the time of refinery start-up.

Table 7-4 Summary of Paid-up Royalty and Initial Cost for Catalysts and Chemicals

(Unit: 1,000 R.O.)

Item \ Case	40,000 BPSD		20,000 BPSD	
	Self-Supply	Purchase	Self-Supply	Purchase
Paid-up Royalty	267	267	133	133
Initial Cat. & Chemicals	258	258	130	130
Total	525	525	263	263

(Source) JICA Mission

Interest paid during Construction Period

The afore-mentioned fixed capital requirements shall be paid during the construction period on the following terms:

- Refinery construction cost: A standard sigmoid payment curve was assumed for the construction period of 30 months. Yearly payments of construction cost were then calculated over the period starting with the engineering start (April 1980) and ending with complete construction work (September 1982).
- Pre-operating expenses: Paid totally in 1982.
- Royalties and costs of catalysts/chemicals: These are earmarked for 1983, the year of commercial operation start.

If the above yearly capital expenditures cannot be met by owned capital (paid-up capital), it has been assumed that the deficit would be covered by long-term loans. The interest payments during construction period were calculated and added in the fixed capital.

Table 7-1 gives a sum of interest payments calculated for the construction period. The borrowing conditions on the long-term loans will be described later in details in Paragaph (5) "Fund Arrangement Plan" of Section 7.2.1. It will be sufficient to mention here that an annual interest rate of 7.5 percent was set.

(2) Working Capital

The working capital refers to a fund required by a firm to continue its daily production activities smoothly.

It is defined in this study as a balance as a result of deducting accounts payable from a sum of the later-described operating cash, inventories of crude oil and products, and accounts receivable.

Operating Cash

It has been assumed that the 2-month expenditures for direct production cost items except crude oil payments, e.g., labor and utilities costs, would always be held in cash.

Raw Material Inventory

An average volume of crude oil in stock was calculated on an assumption that crude oil would be in stock at an average rate of 60 percent of the total tank storage capacity. An inventory for the crude oil stock was then calculated by multiplying the stock volume by a unit cost of crude oil.

Products Inventory

An average stock of products was calculated using an average stock rate of 50 percent. A value for the products stock was then calculated by multiplying the stock volume by the unit direct production cost of the product.

Accounts Receivable

A credit terms of 1 month has been set for sales, and total sales in a month was summed up as the accounts receivable.

Accounts Payable

A credit terms of 1 month has been set for the payment of production cost, in which cost of crude oil occupies a major part, and the accounts payable in a month were calculated.

As obvious from the foregoing definitions of working capital items, the working capital requirement varies with the changes in production level. This trend of working capital requirement can be seen in the attached "Fund Outlook." It will be sufficient here to give the initial working capital required for the year of operation start in Table 7-5.

Table 7-5 Summary of Initial Working Capital

(Unit: MM R.O.)

Item \ Case	40,000 BPSD		20,000 BPSD	
	Self-Supply	Purchase	Self-Supply	Purchase
1. Operating Cash	0.44	0.48	0.32	0.35
2. Inventories				
Crude Oil	0.29	0.29	0.15	0.15
Product	2.43	2.43	1.24	1.24
3. Account Receivables	5.17	5.17	2.59	2.59
4. Sub Total	8.33	8.37	4.30	4.33
5. Account Payables	4.86	4.87	2.49	2.49
6. Initial Working Capital	3.47	3.50	1.81	1.84

(Source) JICA Mission

7.1.2 Production Cost

This section deals with the basis for production cost items. These basic items are described here in the same order as in the "Income Statements" attached to this report. The estimated production cost for respective case will be discussed in the next section.

(1) Direct Production Cost

Raw Material Cost

For the analysis on a "current price" basis, the raw material cost was calculated by multiplying an annual throughput by a crude oil cost of 5.186 R.O. (U.S.$ 15.0) per bbl. However, when the raw material cost was analyzed on an "1978 price" basis, as requested by the Omani Government, another crude oil cost of 4.494 R.O. (U.S.$ 13.0) per bbl was used.

Operating Labor Cost

The total labor cost was calculated annually from the labor requirements of the refinery, as set in 6.5, and the payroll system given in Table 7-6. The results are given in Table 7-7.

Table 7-6 Job Classification and Annual Payrolls

Class	Job Classification	Annual Payrolls	
		10^3 R.O.	10^3 US$
A	Refinery Manager/Assistant Refinery Manager	17.3	50.0
B	Department Manager/Assistant Dept. Manager	12.1	35.0
C	Division Manager/Supervisor/Chief/ Engineer	8.6	25.0
D	Foreman/Secretary/Accountant/Nurse	5.2	15.0
E	Operator/Draftman/Tester/Fireman/ Tel. Operator/Driver/Guard	3.5	10.0
F	Clerk	2.4	7.0
G	Sweeper	1.0	3.0

(Source) JICA Mission

Table 7-7 Required Personnel and Total Annual Payrolls

Case / Class	40,000 BPSD		20,000 BPSD	
	Self-Supply	Purchase	Self-Supply	Purchase
A	2	2	2	2
B	7	7	7	7
C	20	20	20	20
D	29	29	29	29
E	122	109	122	109
F	30	30	30	30
G	3	3	3	3
Total	213	200	213	200
Total Annual Payroll (10^3 R.O.)	940	895	940	895

(Source) JICA Mission

Utilities Cost

The utilities cost contained in the production cost includes the costs of electricity, industrial water and natural gas purchased from outside. The utilities cost goes up or down with the changes in the operating rate. Table 7-8 gives the utilities requirements and the costs of purchase for 1985, the first year in which the refinery is in full-scale operation. As described in 6.3.4, it has been assumed in this study that surplus LPG (in excess of the domestic demand) would be consumed as a fuel for the refinery. Therefore, the purchase of natural gas can be saved for a while until the day will come when the domestic LPG demand outruns the production.

Table 7-8 Utilities Purchase, Requirements and Costs

Utility \ Case	40,000 BPSD		20,000 BPSD		Unit Cost
	Self-Supply	Purchase	Self-Supply	Purchase	
Electricity (MM KW H)	0	27.0	0	15.4	0.02 R.O./KWH
Industrial Water (10^3 ton)	0	118.0	0	58.6	0.44 R.O./ton
Natural Gas (10^9 BTU)	1,260	670	830	480	0.484 R.O./MMBTU
Annual Purchasing Cost (1,000 R.O.)	610	917	402	566	

(Source) JICA Mission

Table 7-9 Annual Expense for Catalyst & Chemicals

(Unit: 1,000 R.O.)

Annual Expense \ Case	40,000 BPSD		20,000 BPSD	
	Self-Supply	Purchase	Self-Supply	Purchase
for Cat. & Chemicals	159	159	80	80

(Source) JICA Mission

Other Direct Production Cost Items

These other items include:

- Maintenance cost: This was set annually at 4 percent of the refinery construction cost.
- Operating supplies cost: This is the cost of expendable supplies, e.g., office supplies, vehicles gasoline, etc., which is not included in either the raw material cost or the maintenance cost. This cost was set in this study at 0.2 percent of the refinery construction cost annually.
- Cost of catalysts & chemicals: The refinery operation calls for the use of these materials. The cost for procurement of these materials was estimated as given in Table 7-9 on an annual basis, and summed up into the direct production costs.

(2) Depreciation Cost

The cost of depreciation was calculated by applying the following depreciation method to the fixed capital requirement described in Section 7.1.1 (1) "Fixed capital".

- Depreciation method: Straight-line method.
- Depreciation period: 10 years (Starting from the year of operation start)
- Salvage value rate: 10%

(3) General Expenses

The general expenses herein include all the cost items corresponding to the indirect cost. The annual general expenses were calculated as 50 percent of a sum of the labor and maintenance costs, plus 0.1 percent of annual sales. The following cost items fall under this category:

- Plant overhead cost.
- Administration cost.
- Distribution and marketing costs.

(4) Interest Payments

As mentioned in Section7.1.1 (1) "Fixed capital", long-term loans are borrowed to meet the financial demand for fixed-capital investment. The interest from these loans to be paid during the construction period is incorporated into the fixed capital.

Therefore, the interest payments to be summed up as annual production cost item is a sum of the following two types of interest.

- Annual payment of interest from long-term loans to be paid after the refinery is put into commercial operation (from 1983 onward).
- Annual payment of interest from short-term loans, which would be borrowed to make up for the deficit of funds required after the start of operation.

Conditions of borrowing these long- and short-term loans will be described in the next section 7.2.1(5), "Funds Arrangement Plan".

(5) Income Tax

It is assumed that no income tax is imposed on this refinery project based on the discussion with the Omani Government.

(6) Dividend

No dividend is taken into account in this financial evaluation.

7.2 FINANCIAL ANALYSIS

Financial analysis was carried out by preparing financial statements, using the results of estimations of all items in this refinery study. These financial statements include:

- Income Statement.
- Funds Outlock.
- Cash Flow Analysis Table.
- Balance Sheet.

The premises used in the analysis are described first. Results of analysis are then presented.

7.2.1 Premises for Analysis

(1) Project Period after Operation Commencement

It has been assumed from the results of discussion in 8.1 that the refinery was scheduled to start commercial operation in January 1983. Fifteen years thereafter, that is, the period from January 1983 to December 1997, was taken as the project period for the analysis.

(2) Operating Rates

The operating rates for the first year of commercial operation (1983) and the second year (1984) were set at 85 and 95 percent, respectively, of the design capacity, with an assumption that the refinery would go on with full-scale (100%) operation from 1985 onward.

(3) Total Capital Requirement (Fixed Capital plus Working Capital)

Results of the study in Section 7.1.1 "Total Capital Requirement" were used without taking future price change into consideration.

(4) Production Cost

Like the total capital requirements, above, figures set in Section 7.1.2 "Production Cost" were used without taking future price change into consideration.

(5) Funds Arrangement Plan

a) Capital Funds

In all the cases, 40 percent of the refinery construction cost shall be covered by the paid-up capital which corresponds to the owned capital.

b) Borrowing Conditions for Long-Term Loans

As mentioned 7.1.1, if fixed-capital expenditures cannot be covered by the owned capital, the deficit shall be covered by long-term loans. The interest rate and the repayment of the principal are on the following conditions:

Interest rate: 7.5% annually.

Repayment of principal: Reapyment starts from the second year (1984) of operation start under the conditions of evenly divided annual amounts over a repayment period of 8 years.

c) Short-Term Loans

If cash requirement cannot be met after the refinery goes into operation, the deficit shall be covered by short-term loans to be borrowed on the following conditions:

- Interest rate: 11.0% annually (LIBOR + about 1%)
- Repayment of the principal: When fund becomes surplus in later time, the surplus is earmarked to repay the short-term loans within a limit of outstanding loan accounts.

The trends of fund raising from the above sources and repayment thereto are given in Table A-1 to A-4, Fund Outlook for each refinery case.

(6) Sales Revenue

It has been assumed that petroleum products would be first marketed to meet domestic demand, and exported only when there are surpluses of products. In accordance with the review in 2.5 "Products Prices", the domestic market prices shall be equal to the CIF prices of imported products, and the export prices shall be equal to the FOB prices at Bandar Mah Shah, Iran. Table 7-10 (A) gives the domestic and export prices (as of February 1979) of products. These prices were used in the analysis based on "current prices", which constitute fundamental premises in financial analysis.

Table 7-10(B) gives corresponding prices used in the financial analysis based on the "1978 prices". This analysis was conducted as a reference, on request from the Omani Government.

Table 7-10 Domestic and Export Prices of Products (A) (as of Feb., 1979)

(Unit: R.O./BBL)

Destination / Product	Product Price	
	For Domestic	For Export
LPG	3.549*1	–
Premium Motor Gasoline	8.357	7.741
Regular Motor Gasoline	7.611	6.891
Kerosene & Jet A-1	7.655	7.005
Gas Oil	6.908	6.426
Marine Bunker Fuel	–	4.213
Heavy Fuel Oil	–	3.856

Table 7-10 Domestic and Export Prices of Products (B) (as of 1978)

(Unit: R.O./BBL)

Destination / Product	Product Price	
	For Domestic	For Export
LPG	3.540*1	–
Premium Motor Gasoline	7.334	6.845
Regular Motor Gasoline	6.665	6.099
Kerosene & Jet A-1	6.752	6.245
Gas Oil	6.100	5.652
Marine Bunker Fuel	–	4.054
Heavy Fuel Oil	–	3.868

*1: LPG Price of FOB Bandar Mah Shar for bulk users is applied due to the reason that the CIF price in table 2-21 is for cylindered LPG.

(Source) JICA Mission, Ministry of Commerce & Industry

7.2.2 Results of Financial Analysis

Results of financial analysis are presented here for each of the following 4 cases set in Chapter 6.

Case Code	Refinery Scale	Utilities
Case 40/S	40,000 BPSD	Self-sufficient
Case 40/P	40,000 BPSD	Purchase
Case 20/S	20,000 BPSD	Self-sufficient
Case 20/P	20,000 BPSD	Purchase

Methods and sequences of evaluation are as follows:

– Comparison of the above 4 Cases

The four cases are compared on a "current price" basis mainly from a profitability point of view. Due to the nature of the 4 cases, emphasis of evaluation is put on the following two points:

i) Does the refinery scale affect profitability and financial state, and how?

ii) Which of self-sufficient or purchased utilities is better from a profitability point of view?

– Sensitivity Analysis

Among the basis for financial analysis discussed in the former half of this chapter, the 4 items listed below were selected and analyzed for the extent in which their changes might affect the profitability.

- Refinery construction cost.
- Simultaneous changes in crude oil prices and products prices.
- Production cost.
- The operating rate in the first year of commercial operation (1983).

– Calculation on the 1978 Basis

Profitability was calculated on the basis of the 1978 prices of crude oil and products.

On this basis, a crude oil price of 4.494 R.O. ($13.0/bbl) was set. This setting caused the natural gas purchasing cost to change, as it is set at 1/2 of the crude oil price on a calorific basis. This change was taken into account in the calculation.

(1) Comparison of 4 Cases (on the current price basis)

Financial statements were prepared for each case. Table 7-11 summarizes the results. Financial statements for all the cases are given at the end of this report in respective table numbers.

Table No.	Case Title	Case Code
Table A-1	40MBPSD/Reformer/P	Case 40/P
Table A-2	40MBPSD/Reformer/S	Case 40/S
Table A-3	20MBPSD/Reformer/P	Case 20/P
Table A-4	20MBPSD/Reformer/S	Case 20/S

a) Comparison in Terms of Refinery Scale

As shown in internal rates of return (IRR) given in Table 7-11, the profitability of the 40,000-BPSD case is far higher than that of the 20,000-BPSD case. As obvious from the comparison of cost items in the table, this is because all cost items (except the cost of crude oil) in the 20,000-BPSD case have to bear higher proportions of costs in the sales revenue than the counterparts in the 40,000-BPSD case. In other words, the former case suffers from the disadvantages caused by small-scale production. As a result, yearly fund raising has to depend on continued borrowing of short-term loans, and subsequent interest payments result in higher production cost. Caught in such a vicious cycle, the 20,000-BPSD case shows a very unhealthy trend of financial state.

b) Comparison in Terms of Utilities Supply Methods

Comparison of economic efficiency between the self-sufficient utilities case and the power/industrial water purchasing case can be summarised in Table 7-12 in case of the 40,000-BPSD refinery. The table indicates that the utilities purchase case has better economic efficiency for two reasons of saving in initial investment and somewhat higher profitability, as far as the electricity purchasing cost is kept at 20 Baisa/KWH, as indicated by the Omani Government. However, the difference in profitability is slight, and if the utilities purchasing cost goes up, their relative positions are easily reversed. If a new power rate of 56 Baisa/KWH is applied, as pointed out on this possibility in a section of "Public Utilities" in Chapter 4, Table 7-12 shows that the self-sufficient case becomes superior in terms of profitability.

Table 7-11 Summany of Financial Evaluation

(Unit: MM R.O.)

	40,000 BPSD						20,000 BPSD					
	Self-Supply			Purchase			Self-Supply			Purchase		
	1985	1995	1983 ~1997	1985	1995	1983 ~1997	1985	1995	1983 ~1997	1985	1995	1983 ~1997
I) Cost & Income												
Sales Revenue	76.0	76.2	1,127.2	76.0	76.2	1,127.2	38.1	38.2	565.6	38.1	38.2	565.6
Direct Production Cost												
Raw Material Cost	68.5	68.5	1,013.2	68.5	68.5	1,013.2	34.2	34.2	506.6	34.2	34.2	506.6
Labour Cost	0.9	0.9	14.1	0.9	0.9	13.4	0.9	0.9	14.1	0.9	0.9	13.4
Utility Cost	0.6	0.7	9.8	0.9	1.0	14.4	0.4	0.4	6.5	0.6	0.6	8.9
Others	1.2	1.2	17.7	1.1	1.1	16.4	0.8	0.8	11.3	0.7	0.7	10.4
(Sub Total)	(71.2)	(71.3)	(1,054.8)	(71.4)	(71.4)	(1,057.4)	(36.3)	(36.4)	(538.4)	(36.4)	(36.4)	(539.3)
Depreciation	2.4	–	24.4	2.2	–	22.5	1.6	–	16.4	1.5	–	15.0
General Expense	1.0	1.0	15.5	1.0	1.0	14.5	0.8	0.8	12.4	0.8	0.8	11.7
Financing Cost	1.4	–	8.2	1.3	–	7.6	1.2	2.3	26.3	1.2	2.1	23.9
Total Production Cost	76.1	72.3	1,102.9	75.9	72.4	1,101.9	40.0	39.5	593.5	39.8	39.3	589.9
Net Income	-0.1	3.9	24.4	0.1	3.8	25.3	-1.9	-1.3	-27.9	-1.7	-1.0	-24.3
II) Cash From Operation	2.3	3.9	48.7	2.3	3.8	47.7	-0.3	-1.3	-11.5	-0.2	-1.0	-9.2
III) Cash Flow	3.7	3.9	26.4	3.6	3.8	26.9	1.0	1.0	-5.3	1.0	1.0	-3.9
IV) Cumulative Short Term Loan	2.5	0		2.3	0		6.0	22.4		5.6	19.9	
V) Pay Out Time (year)	9.56			9.05			not recoverable			not recoverable		
VI) Internal Rate of Return on Total Capital (%)	7.89%			8.52%			-3.23%			-2.52%		

(Source) JICA Mission

Table 7-12 Economic Comparison, Self-Supply vs. Purchase of Utilities

(Unit: MM R.O.)

Items \ Case	40,000 BPSD		
	Self-Supply	Purchase*1	Purchase*2
I) Investment Cost			
1) Fixed Capital	27.1	25.0	25.0
2) Initial Working Capital	3.5	3.5	3.5
3) Total Capital Requirements	30.6	28.5	28.5
II) Production Cost (during Operating Periods)			
1) Total Production Cost	1,102.9	1,101.9	1,123.1
2) Utility Cost	9.8	14.4	28.8
III) Internal Rate of Return (%)	7.89%	8.52%	4.31%

*1 Electric Power Rate = 0.02 R.O./KWH
*2 Electric Power Rate = 0.056 R.O./KWH
(Source) JICA Mission

It should be noted that even in the self-sufficient utilities cases, the trend of natural gas price serves as a key factor governing the cost of utilities. In making decision on the method of utilities supply, it will be necessary to study the cases in more details.

(2) Sensitivity Analysis

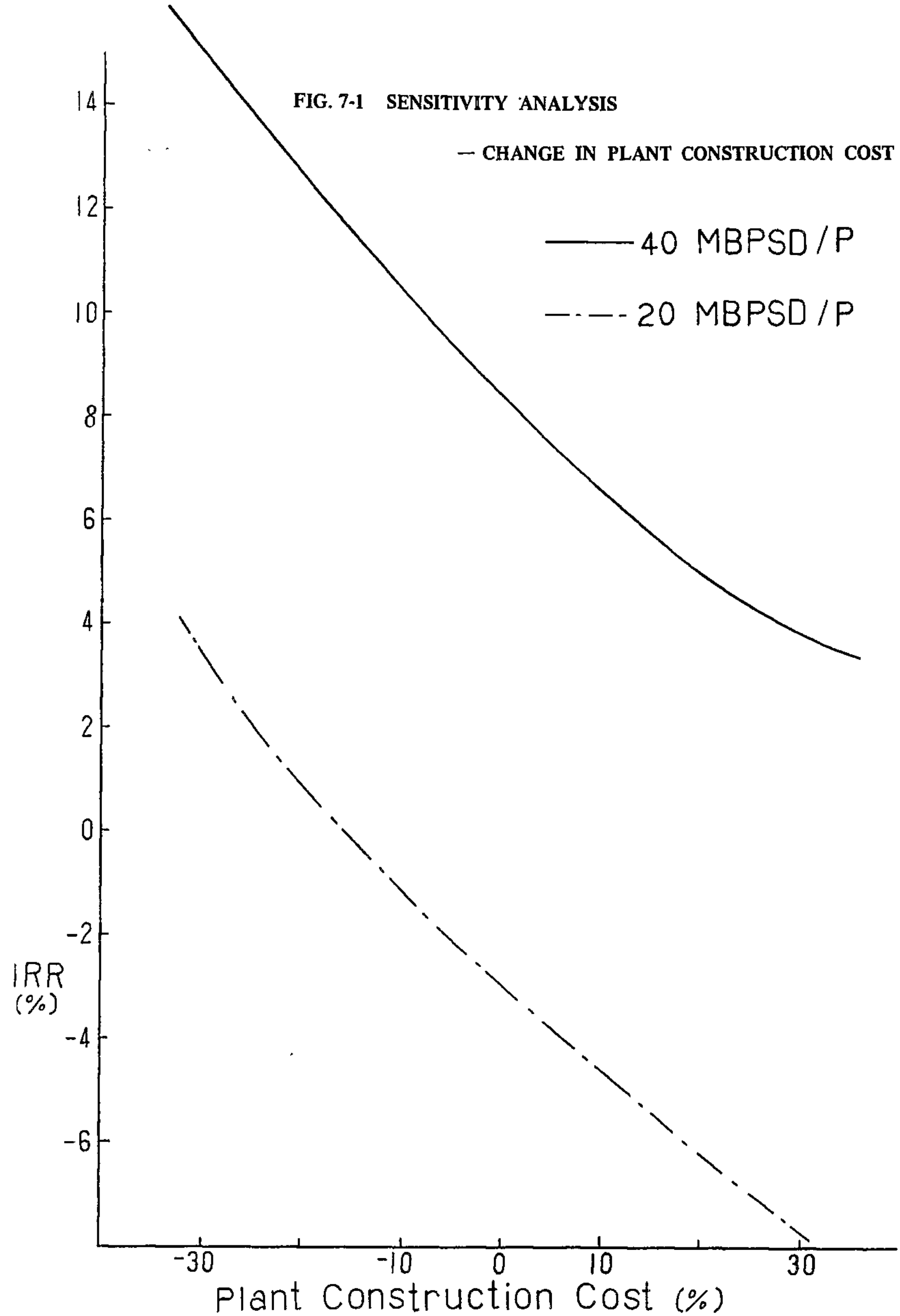
a) Changes in Refinery Construction Cost

The changes in refinery construction cost have impacts on not only on the total capital requirement, but also on the production cost through the changes in depreciation and maintenance costs.

These impacts on profitability was calculated within a range of ±30 percent change in construction cost for the two cases of 40/P and 20/P, using internal rates of return as the indicator. Results are given in Fig.7-1.

FIG. 7-1 SENSITIVITY ANALYSIS

— CHANGE IN PLANT CONSTRUCTION COST



In both cases, the profitability is not so sensitive to the refinery construction cost. A change in investment by 10 percent resulted in a change in internal rate of return by about 2 percent. As also shown in Table 7-11, this is because cost of crude oil occupies a very large part in the cost of refined products. As a result, the depreciation cost and other refinery construction cost related items, which comprise a part of added value, relatively reduce their shares, causing profitability to get less sensitive to the changes in refinery construction cost.

b) Changes in Crude Cost and Product Prices

An economic equilibrium is likely to exist between the crude oil cost and product prices as of February 1979, which is used in (1) "Comparison of 4 cases on a current price basis" of this paragrph. That is, it seems to be hardly possible for the crude cost and product prices to shift to opposite directions to each other.

Actually, however, a recent pattern of oil price formation tends to be such that crude price is raised in the first place, and rise in product prices lags behind. This pattern seems to be maintained for the future.

In this study, therefore, changes in IRR are calculated in cases where crude and products prices rise. In some of the cases rates of price increase is the same for both crude and products, in others crude price increase at a higher rate than products prices. The results are summarized in Table 7-13.

c) Changes in Production Cost

A possibility still remains that cost may change in those items other than the raw material cost and the depreciation cost. Thus the sensitivity was analyzed here using internal rates of return as a measure on an assumption that the annual production cost in those items would have changed in a certain amount. Results of calculation are given in Table 7-14.

Take the 40,000-BPSD, utilities purchase case, for example. A change of annually 500,000 R.O. in the production cost accounts for about 10 percent change of the total production cost excluding the costs of raw material and depreciation, but it accounts for only 0.7 percent of the raw material cost. Table 7-14 indicates that this case is resistant in the aspect of profitability even when the production cost rises by 500,000 R.O. in a year. At the same time, the table also suggests that the profitability of project would be greately affected if the cost of raw material rises by several percent without any change in products prices.

Table 7-13 Sensitivity Analysis – Change in Crude Oil and Products Prices

Change in Price		40,000 BPSD
Products	Crude Oil	Purchase
(%)	(%)	IRR (%)
± 0	± 0	8.52
+ 5	+ 5	9.91
+ 5	+ 7	4.24
+ 5	+ 9	-3.50
+ 5	+10	-9.49
+10	+12	5.88
+10	+14	-1.08
+10	+15	-5.87
+15	+15	12.48
+15	+17	7.41
+15	+20	-3.05
+20	+25	-0.68
+25	+30	1.38
+30	+35	3.23

(Source) JICA Mission

Table 7-14 Sensitivity Analysis – Change in Production Cost

Change in Production Cost	40,000 BPSD Purchase
(MM R.O./Yr.)	IRR (%)
± 0	8.52%
+ 0.5	6.42%
+ 1.0	4.15%
+ 1.5	1.62%
-0.5	10.47%

(Source) JICA Mission

d) Changes in the Operating Rate in the First Year of Commercial Operation

Any delay in the project schedule will lead to a reduction in the operating rate for 1983, the first year of commercial operation.

As shown in Table 7-15, the 40,000-BPSD, utilities purchase case was taken up to calculate the changes in internal rate of return caused when the operating rate for the first year is set at 70%, 50% and 35%. The results indicate that a reduction in the operating rate in the first year hardly causes a reduction in profitability. The largest reason for this would probably be that the variable cost, especially the cost of raw material, go down concurrent with decreased operating rate, thus giving little effect on the profitability for the first year.

Table 7-15 Sensitivity Analysis – Change in Operating Rate in 1983

Operating Rates in 1983 (%)	40,000 BPSD Purchase IRR (%)
85	8.52
70	8.37
50	8.16
30	7.93

(Source) JICA Mission

(3) The 1978 Price Basis

Upon request from the Omani Government, a financial analysis was attemped for the 40,000-BPSD, self-sufficient utilities case on the 1978 price basis. The differences in the premises and calculation results between the 1978 basis and the current price basis can be summarized as follows:

	Current Price Basis	1978 Price Basis
Product Price	Table 7-10 (a)	Table 7-10 (b)
Crude Oil Price	5.186 R.O./BBL	4.494 R.O./BBL
Natural Gas Cost	0.484 R.O./MMBTU	0.419 R.O./MMBTU
Internal Rate of Return	7.89%	16.24%

Internal rate of return on the 1979 basis was far lower than that on the 1978 basis. As shown in Table 7-16, this is because the products prices, particularly the export fuel oil price, increased at lower rates than the crude oil price since 1978. Both the products prices and crude oil prices have already downward rigidity. Now there is few possibility of going down of these two prices so that the results of calculation on the 1978 price basis will serve only as a reference.

Table 7-16 Price Increase, Products and Crude Oil (1978 vs. Feb., 1979)

Porduct \ Price	1979 Price (1978 price = 1.0)	
	For Domestic	For Export
LPG	1.003	–
Premium Mogas	1.139	1.131
Regular Mogas	1.150	1.147
Kerosene & Jet A-1	1.134	1.122
Gas Oil	1.132	1.137
Marine Bunker Fuel	–	1.039
Heavy Fuel Oil	–	0.997
Crude Oil	1.154	

(Source) JICA Mission

7.3 NATIONAL ECONOMIC EVALUATION

7.3.1 Bases of National Economic Evaluation and Analysis

As the benefits of setting-up a refinery in Oman, following are conceivable:

1) Increases in the value added to crude oil.
2) Improved trade balance.
3) Improved self-sufficiency in petroleum products.
4) Larger opportunity of employment and transfer of technology.
5) Propagative effects on other industries.

As the demerits, there may be mentioned:

1) Environmental pollution.
2) Unbalanced distribution of resources.

As for those benefits which can be evaluated quantitatively, such factors as economic internal rate of return (EIRR), national economic profitability, and foreign exchange effect are estimated. Qualitative evaluation of the benefits is limited to brief consideration.

7.3.2 Economic Internal Rate of Return (EIRR)

The premises for EIRR calculation are the same as those used in the financial analysis. These include:

1) The price of raw material (crude oil) is an international price, i.e., an export FOB price.
2) Ex-refinery prices of products are the import CIF prices to Oman.
3) None of import duties are imposed on the imported equipment, materials and chemicals.

Therefore, there is no need of a shadow exchange rate. Other cost components, e.g., wages and utilities, account for only 2-3 percent of the total operating cost. Shadow prices were not set for these negligible items.

In order to calculate the cost and benefit of the project, the effects of the setting-up of a refinery ("with" column) were compared with the case where the refinery is not constructed ("without" column of Table 7-17).

Table 7-17 "With" and "Without" Refinery

	With	Without
Investment	Refinery Facilities	Petroleum Products Storage Tanks
Crude Oil	Decrease of Crude Oil Export	
Petroleum Products	Petroleum Products Self-sufficiency and Export	Petroleum Products Import

With these effects kept in mind, the cost and the benefit were defind as follows:

1) The cost is set as the value obtained by subtracting the incidentally required investment on product storage tanks from a sum of the total capital investment and the total production cost of a refinery.
2) The benefit is set as a sum of the domestic sales and exports of petroleum products, namely the sales revenue.

With regard to the cost definition 1) above, the reason why the cost of product storage tanks is to be subtracted from the total investment cost is that, theoretically, there is no requirement for storage, as long as the refinery is in operation to keep continuous supply of petroleum products. If a refinery is not constructed, the investment on the storage of products becomes necessary from a national security point of view. Therefore, such a cost can be excluded from the present capital investment on the refinery construction, for the reason that it can be considered as a minimum security cost of a sort. Two types of investment on the storage tanks are given in Table 7-18.

Table 7-18 Cost of Product Storage Tanks

Case	Petroleum Products Storage Tank Capacity (Kl, Unit)		Investment Cost (MM R.O.)
40,000 BPSD	61,000	9	2.6
20,000 BPSD	42,000	8	2.0

(Source) JICA Mission

When the refinery starts operation export of crude oil will partly decrease, because a part of crude oil is used as the raw material. It is considered,however, that this decrease has nothing to do with the benefit because the refinery would buy the crude oil at an international price.

EIRR was calculated for the following 4 cases.

	40,000 BPSD	20,000 BPSD
Utility Purchase	X	X
Utility Self-Supply	X	X

Table 7-19 gives a comparison of cost vs. benefit of 40,000 BPSD/P case. In the table, the security costs are given as negative values because they are subtracted from the total investment. The cost/benefit ratios in these 4 cases are given in Table A-5 to A-8 annexed to this report.

Table 7-20 summarizes the results of EIRR calculation.

Table 7-19 Cost and Benefit Stream (40,000 BPSD/P* Case)

(Unit: MM R.O.)

Year	Cost				Benefit
	Investment	Operation	Security	Total	Revenue
1980	3.3	0.0	0.0	3.3	0.0
1981	14.1	0.0	−1.6	12.5	0.0
1982	7.0	0.0	−1.0	6.0	0.0
1983	4.0	61.9	0.0	65.9	64.6
1984	0.0	68.9	0.0	68.9	72.1
1985	0.0	72.4	0.0	72.4	76.0
1986	0.0	72.4	0.0	72.4	76.0
1987	0.0	72.4	0.0	72.4	76.1
1988	0.0	72.4	0.0	72.4	76.2
1989	0.0	72.4	0.0	72.4	76.2
1990	0.0	72.4	0.0	72.4	76.2
1991	0.0	72.4	0.0	72.4	76.2
1992	0.0	72.4	0.0	72.4	76.2
1993	0.0	72.4	0.0	72.4	76.2
1994	0.0	72.4	0.0	72.4	76.2
1995	0.0	72.4	0.0	72.4	76.2
1996	0.0	72.4	0.0	72.4	76.2
1997	0.0	72.4	0.0	72.4	76.2

*Utility purchase

Internal Rate of Return = 9.9%

(Source) JICA Mission

Table 7-20 Economic Internal Rate of Return

(Unit: %)

Case	EIRR
1. 40,000 BPSD/Utility Purchase	9.9
2. 40,000 BPSD/Utility Self-Supply	9.0
3. 20,000 BPSD/Utility Purchase	minus
4. 20,000 BPSD/Utility Self-Supply	minus

(Source) JICA Mission

7.3.3 Sensitivity Analysis

Among the factors affecting EIRR, the following factors have been selected:

1) Primary influencing factors: The prices of crude oil and products simultaneously changes in the range of -5%, +5%, +10%, and +15%.
2) Secondary influencing factors: Investment cost changes among -10%, +10%, and +20%; operating cost changes +10%; and capacity utilization changes -10%.

Sensitivity was analysed for the two cases of: (1) Crude throughout capacity of 40,000 BPSD, with utilities purchased from outside; (2) Crude throughout capacity of 20,000 BPSD, with utilities purchased from outside. Table 7-21 gives results of the sensitivity analysis.

Following findings can be given from these results:

1) As described for the base case (Table 7-20), a 20,000-BPSD refinery cannot be justified from the viewpoint of national economy unless the prices of products, as inter-related with the crude oil price, rise by 10-15 percent.
2) An increase of investment cost by 10 percent would not give a damage to the economic efficiency of the refinery, but the rise of operating cost by 10 percent is hardly desirable, because it would aggravate the economic efficiency in all cases.
3) A decrease in the rate of operation by as small as 10 percent (=33 days) would not seriously affect the economic efficiency of the refinery.
4) As long as the crude oil price is inter-related with the prices of oil products, with both prices changing simultaneously at a certain rate, any price rise results in improved economic efficiency. In general, however, the prices of products would give smaller rising rates than that of crude oil, so that the real economic efficiency is even smaller.

Table 7-21 . Result of Sensitivity Analysis – Economic Internal Rate of Return

(Unit: %)

Case		Crude Oil and Petroleum Products Prices				
		–5%	0%	+5%	+10%	+15%
1. 40,000 BPSD/P*						
Base Case		8.3	9.9	11.5	12.9	14.3
Investment Costs						
Up	10%	6.8	8.4	9.8	11.2	12.6
Up	20%	5.6	7.0	8.4	9.8	11.1
Down	10%	10.0	11.7	13.4	14.9	16.4
Operating Costs						
Up	10%	minus	minus	minus	minus	minus
Capacity Utilization						
Down	10%	6.8	8.4	9.8	11.2	12.6
2. 20,000 BPSD/P*						
Base Case		minus	minus	minus	2.4	4.1
Investment Costs						
Up	10%	minus	minus	minus	1.1	2.8
Up	20%	minus	minus	minus	minus	1.6
Down	10%	minus	minus	1.9	3.8	5.6
Operating Costs						
Up	10%	minus	minus	minus	minus	minus
Capacity Utilization						
Down	10%	minus	minus	minus	1.1	2.8

* Utility Purchase

(Source) JICA Mission

7.3.4 National Economic Profitability

The return on investment such as evaluated in private sectors is also applicable to the public investment on industrial sectors. The national economic profitability is calculated from the following equation:

$$\text{National Economic Profitability (NEP)} = \frac{\text{Average Annual Benefit} - \text{Average Annual Operating Cost}}{\text{Total Investment Cost}}$$

As in the EIRR calculation, the average annual benefit is defined as a sum of the sales of refined petroleum products (that is, the domestic sales calculated by means of import CIF prices), and the sales of marine bunker oil and other surplus products in export markets. This benefit, therefore, is a sum of the savings in foreign exchange payments as a result of substitution for imports and the foreign exchange eranings from exports. As in the EIRR calculation, a minimum security cost, assumed to be required when there is no refinery, is subtracted from the total investment cost.

NEP's were calculated for the same 4 base cases as in Table 7-20, and are given in Table 7-22.

Table 7-22 National Economic Profitability

Case	Avg. Annual Benefits (MM R.O.)	Avg. Annual Operating Costs (MM R.O.)	Total Investment Costs (MM R.O.)	NEP (%)
1. 40,000 BPSD/P*	75.1	72.0	25.9	12.0
2. 40,000 BPSD/S**	75.1	71.9	28.0	11.4
4. 20,000 BPSD/P*	37.7	38.4	16.5	–4.2
5. 20,000 BPSD/S**	37.7	38.5	18.0	–4.4

* Utility Purchase
** Utility Self-Supply
(Source) JICA Mission

The 20,000-BPSD refinery cases showed a negative NEP values, just as they gave negative EIRR values.

7.3.5 Foreign Exchange Effect

Factors affecting the foreign trade balance include:

1) Foreign exchange outflow, such as import of plants, payments for imported chemicals and catalysts, wages paid to expatriate workers, and interests on long-term loans.

2) Foreign exchange balance of crude oil/petroleum products, such as derived as a result of decreased crude oil export and products import.

Estimated total foreign exchange balances attained by the refining project is summarized in Table 7-23.

The accumulated surplus throughout the proejct life (1980-1997) is estimated at approximately 70 to 73 MM R.O. for the case of 40,000 BPSD refinery and at approximately 27 to 29 MM R.O. for the case of 20,000 BPSD refinery.

There is no doubt about the contribution of this refinery project to a considerable increase in trade surplus.

Table 7-23 Accumulated Foreign Exchange Balance of the Project

(Unit: MM R.O. in 1979 Prices)

Case	Outflow 1)	Export/Import Balance 2)	Foreign Exchange Surplus
1. 40,000 BPSD/P	– 40.0	113.1	73.1
2. 40,000 BPSD/S	– 42.6	113.1	70.5
4. 20,000 BPSD/P	– 29.6	58.9	29.3
5. 20,000 BPSD/S	– 32.2	58.9	26.7

1) Total of capital investment, operating costs and financing costs for the project life.

2) Total balance of petroleum products sales revenue minus crude oil cost for the project life.

(Source) JICA Mission

7.3.6 Evaluation of Other Benefits

Employment opportunities in all the alternative cases of this project are given in Table 7-24. As far as the number of employees is concerned, the project fails to give large opportunities of employment. Most of the employees would be skilled plant operators. Except those who have been trained outside the country of Oman, a few number of engineers and skilled workers suitable for the refinery operation are found only at PDO plants or Al Ghubra desalination/power plant. In starting operation, the refinery will have to depend for its operation on many expatriate engineers and workers. In that case, the refinery can go on with its Omanization through OJT (On-the-job training) of Omani employees, while keeping a normal operating rate. It will take several years for this type of Omanization.

Table 7-24 Employment at the Refinery

Case	Number
1. 40,000 BPSD	213
2. 20,000 BPSD	200

(Source) JICA Mission

Construction and operation of the refinery calls for the help from related industries or supporting industries. Types of these supporting industries are given in Table 7-25. Among them, various types of contractors are either already in existence in Oman, or some may be introduced from the overseas. Piping and electrical wiring, for example, will need the help of a foreign contractor. Among operation-related industries, there exist automobile repair garages, iron works and structure-fabricating works, although the latter two are of small scales.

Table 7-25 Supporting Industries for a Refinery

Stage	Type of Supporting Industries
1. Construction	* Building Materials Supply * Steel Works and Metal Fabrication * Transportation of Goods * Contractor – Site Preparation, Foundation, Erection, Electrical Wiring, Piping etc.
2. Operation	* Automobile Garage (Repairing) * Repair Workshops – Valve Repairing, Electrical Machinery Repairing, Heavy Machinery Repairing * Reconditioning of Meters and Gauges * Steel Works and Metal Fabricators * Foundry and Forging Works * Electroplating and Galvanizing Works * Machining Shops

(Source) JICA Mission

Various types of repair shops are indispensable for plant operation, and they need be located near the refinery. It is not necessary for the time being for Oman to manufacture high-quality parts and simple machines by introducing such industries as casting, forging, machining and electroplating. Employment in the peripheral industries to be created when the refinery is in operation is estimated at 100 workers.

The impact of the project on regional development may differ, depending on site to be selected. Table 7-26 gives a comparison of the planned two sites. The Al Ghubra area is reported to have been designated as "Reserved for future development" under the Capital Area Strategic Plan of the Ministry of Land Affairs and Municipalities. If the refinery is to be located here, coordination will be required within the Government. Although primary infrastructures are already in existence in both areas, a future need is houses for employees. Construction of a refinery within the PDO site requires less additional investment in community development, and thus has less impact on regional development.

Table 7-26 Economic Impact on Regional Development

	PDO Compound	Al Ghubra[1]
1. Land Classification	* Open – Land use is under the control of PDO	* Reserved by the Ministry of Land Affairs and Municipalities for future development
2. Infrastructure	* Existing but minor modification necessary	* Water and power available but social infrastructure such as housing to be developed
3. Access Road	* Existing	* A feeder road to be constructed
4. Environmental Consideration	* Possible halt of exhaust and waste gas within the compound due to topography * Ease of effluent discharge with possible adverse effects on fisheries and tourism	* Easy diffusion of exhaust and waste gas * Ease of effluent discharge with possible adverse effects on fisheries and tourism

1) Next to the power station

(Source) JICA Mission

With respect to environmental conservation, the PDO site may pose a problem of air pollution to some extent. Three sides of the site are surrounded by hills, and there is a fear that a northerly breeze may cause waste gas to stay above the site. On the other hand, as the Al Ghubra area is flat, waste gas will easily diffuse. Wastewater seems to cause less problems if it is fully treated before discharged to sea, although it may have some impacts on coastal fishing.

The largest effect which the project has on Oman is the enhanced national security; that is, the country can get out of her dependence on imports of petroleum products – a discrepancy of a petroleum producing country. At present, petroleum products are imported by Shell and BP from refineries located in the Gulf area. There are possibilities that the imports may be partially cut off or utterly discontinued in the following cases:

1) A supplying refinery or refineries are closed due to technical accidents or for other reasons, as found in Iran in early 1979.
2) The supplying petroleum products depot is closed due to accident or other causes.
3) Tankers cannot pass through the Hormuz Strait due to accidents, blockade or for other reasons.

These uncertain factors can be eliminated by constructing a refinery within the country. In the event the refinery is not constructed, the above uncertain factors have to be overcome by constructing a petroleum products storage base, in addition to the existing ones. Investment on such construction is not required if a refinery is constructed. This cost of storage tanks was subtracted from the refinery construction cost in the EIRR calculation, assuming that such a cost is contained in the national economic expenditures as a security cost of a kind.

There is another national economic advantage of holding a refinery within the country. Under the circumstances in which the prices of petroleum products are rising inter-relatedly with the rise of international crude oil prices, the petroleum producing country having its own refinery can offer the nation with petroleum products at stable prices through the control of the crude oil price. In other words, the Government of such a country can work out a policy, so as not to introduce direct impacts of rising international crude oil prices on national economy, as encountered by many oil-importing countries.

7.4 ALL-OVER EVALUATION

Four cases of refinery are presented in Chapter 6, that are to undergo economic evaluation. They are:

- 40,000 BPSD/utility self-supply (40/S)
- 40,000 BPSD/utility purchase (40/P)
- 20,000 BPSD/utility self-supply (20/S)
- 20,000 BPSD/utility purchase (20/P)

The 40,000 BPSD cases are expected to meet the estimated 1985 demand for petroleum products in Oman almost completely, but they are destined to produce surplus heavy fuel oil (7,855 BPSD) for which no domestic demand is expected and, therefore, which will have to be exported. Contrary, in the 20,000 BPSD cases, no surplus heavy fuel oil is to be produced, while domestic demand for petroleum products will be satisfied only partially, so that the shortage will have to be filled by import.

In the preceding paragraphs 7.1 to 7.3 these four cases are analyzed and examined from both viewpoints of commercial profitability and of national economic benefits.

7.4.1 Comparison of the Refinery Cases

The results of the foregoing analyses and examination could be summarized as follows:

In the refinery cases with a crude throughput capacity of 40,000 BPSD (40/P and 40/S), IRR values of 8 to 8.5 percent without tax are to be achieved. While this level of IRR value seems to be rather low for a commercial project that should seek profit, it could be fully acceptable in such kind of governmental project as this refinery which has as its aim economic security and other national economic benefits. The same is also to be said from the results of other analyses such as EIRR and NEP.

In the 40,000 BPSD cases, the IRR value holds positive even with an overrun by as much as 30 percent in the construction cost, which is the biggest component of the production cost except the cost of crude oil. Also, it could be safely said that this type of projects seems to be relatively stable in its profitability, judging from the results of sensitivity analyses as regards other cost factors. In contrast with these, IRR, EIRR, and NEP have all negative values in the cases where the crude throughput capacity is 20,000 BPSD (20/P and 20/S). This indicates that a refinery of this size is not economical with regard to commercial profitability as well as national economic benefits. From the financial aspects, the costs and expenses of this refinery are to overrun its products sales revenue throughout the whole project life, and the debt will be accumulated, accordingly.

7.4.2 Result of Comparison

Consequently, it could be said as a conclusion that the 40,000 BPSD cases are superior to the 20,000 BPSD cases as far as the economy is concerned. However, this conclusion has an important premise that the heavy fuel oil (7,855 BPSD) that is produced by the 40,000 BPSD refinery and for which no Oman domestic demand is to be expected is wholly sold to the export market.

As was already examined in Section 2.4, there is a possibility of an enormous surplus of petroleum products in around 1985 in the Arabian Gulf area, which may be regarded as an unfavorable circumstance for the export of heavy fuel oil from the Oman refinery. Should the export revenue of the heavy fuel oil be reduced by 25 percent due to reduction in the export price and/or the export volume, the economy of the 40,000 BPSD refinery would certainly be inferior. to that of the 20,000 BPSD refinery which produces no surplus product. However, it should be noted that the inherent noneconomy of the 20,000 BPSD refinery as aforementioned is never to be changed.

Construction of a 20,000 BPSD refinery will only be justified by such reasons that are beyond ordinary economic considerations, for example, that there is an absolute necessity to save the investment cost of the refinery construction, or, that the risk of unexportable surplus product should be avoided by all means.

Then, among the 40,000 BPSD cases, comparison is made on self-supply (40/S) vs. purchase (40/P) of utilities. The 40/P case is judged to be more advantageous since the construction cost is cheaper by the amount of additional utility facilities and it enjoys a higher IRR value compared with the 40/S case.

As a conclusion of the above considerations, a refinery with a crude throughput capacity of 40,000 BPSD and that purchases required utilities from outside is judged to be recommendable to be newly set up in Oman.

7.4.3 Premises and Conditions

However, there are a number of premises for the above conclusion in addition to the one as already mentioned, that is, surplus heavy fuel oil will have to be exported.

Firstly, prices of products should be raised keeping their pace with the possible future increase of crude oil prices. Otherwise, as indicated by the result of a sensitivity analysis (Table 7-13), the profitability of the refinery would be badly damaged. The comparison between the results of the 1978 price-based profitability analysis and of the 1979 price-based analysis, where the crude price increased from the preceding year but the products prices still failed to follow, is the evident testimony to the above effect.

Accordingly, if the Omani government with its own refinery intends to hold the low-price policy for the petroleum products, some subsidizing measures will have to be introduced; for example, to supply crude oil to the refinery for lower price than export price.

In relation to the above, it deserves a brief mention that the result of a sensitivity analysis of EIRR of the 20/P case indicates that a negative value under the present crude oil/product price relationship will shift to positive if the prices of both crude oil and products rise by 10 percent or more. However, this improvement in the EIRR value is easily cancelled by an increase by the same percentage in the construction cost of the refinery.

Secondly, the 40/P case is superior to the 40/S one only under the present price system of utilities. The difference between the IRRs of these two cases is only a minor one, and therefore can easily be reversed if, for example, the electric power rate for industrial use is raised as is said to be discussed among government authorities. If such is the case the 40/S may be more preferable despite its additional construction cost for utility facilities.

7.4.4 Benefits of the Refinery

Now, what kind of benefits will be expected from the realization of a refinery of the 40/P type recommended here?

The most important thing will certainly be that the refinery will form a basis for stable self-supply in petroleum products for Oman by eliminating the nation's past and present dependence on imports for the products. This will undoubtedly be an enormous contribution to the security of the Omani national economy. In addition, such unproductive investments as the once-planned storage terminal for imported petroleum products are to be saved.

Secondly, self-sufficiency in petroleum products will surely contribute to improving the foreign exchange balance of Oman. Oman has spent a considerable portion of its foreign exchange earned by exporting its crude oil for the import of petroleum products with higher added values. With a refinery, Oman will be able to save the outflow of foreign exchange by taking the value added on the refined products into its own domestic economy. This saving of foreign exchange is undoubtedly more than enough to compensate the possible decrease in the nation's foreign exchange earnings caused by sharing a portion of crude oil for export to feed the refinery.

Meanwhile, not so much is expected as to the employment effects by the refinery. The employment effects should be divided into two, namely, those during the construction phase and those after the start-up of the refinery.

During the construction phase, as will be discussed later, more than eight hundred workers will have to be mobilized at the construction site in the peak period. However, in the light of the past examples of construction work in the country, most of the work force will be composed of foreign workers. This employment during the construction phase is by no means a permanent one, and is surely to fluctuate to a considerable extent during the course of 30 months of the refinery construction period. Therefore, employment of foreign workers may be regarded as a wise selection with a view to preventing probable disturbance in the labor market in Oman that is still in the early stage of its development.

Employment by the refinery for its operation is, as already examined in Section 6.4, only about two hundred, and most of them will be, at least in the beginning, filled by foreign engineers, technicians, and workers. For the expected Omanization of these refinery staff, a long-term effort to achieve effective transfer of technology will be needed.

Also, not much is expected as to the inducing effect on the development of refinery-related or -supporting industries. Most of the kinds of supporting industries for the refinery are either those already established in Oman, or those which are not easily developed in Oman due to their sophisticated requirements for techniques and skills. Accordingly, the chances seem to be slight, if any, to establish and develop new industries in Oman in line with the establishment of the refinery.

The recommended location for the refinery is the Mina al Fahal area, as already discussed in Chapter 5. The area has better suitable features as the site for the refinery, of the two candidate locations indicated by the Government. One thing calls for a cautious consideration: On the rear slopes of the hills that surround the area are dotted with housing and other facilities for the employees of the existing oil related industries so that sufficient measures should be taken to prevent the probable air pollution by the flue gas from the refinery.