II. CONSTRUCTION MATERIALS PROJECTS

This Chapter will deal in such construction materials (sans tiles, bricks, glass, pottery and porcelain, which will be treated in Chapter III) as cement and carbonate rock (limestone, marble, dolomite) which are closely related to cement.

1. Construction Activities and Materials Demand and Supply in Oman

1) Building Activities

Since 1970 building works had been active until 1976, when conspicuous number of rental units became unoccupied. The current Five-Year Plan, 1976 - 1985, forecasts decline in civil and architectural construction expenditures after reaching a peak in 1977. As demand and investment will decline, calming down of building activities is in the offing.

Although demand for rental units and other quality housing has topped out, population inflow into cities is still continuing and the shortage of housing for low-income class is being felt. Even if private housing investment declines, it would be difficult for the government to slash its investments in housing. Therefore, it is believed that building investments will gradually level off and start increasing after 1980 as shown by Table II-1, rather than declining after 1978 as predicted by the Five-Year Plan. The building floor area has been estimated on said Table under a simple assumption concerning building cost and includes government and private office buildings. According to the estimate, building activities will amount to (as converted to housing units at 150 square meters per unit): 1,920 units in 1980, 2,060 units in 1985, and 2,670 units in 1990. In other words, investments shown on Table II-1 will result in the construction of about 20,000 housing units during the decade from 1980 to 1990, and the housing situation in Oman will be greatly improved.

Table II-1 Projection of Investment in Building in Oman and Estimated Floor Area Constructed

		1976	1977	1978	1979	1980	1985	1990
Investment	MM R.O.	49	44	44	46	49	54	70
Floor Area	1,000 m^2	277	249	258	271	288	309	400

(Source) JICA MISSION

2) Materials Demand and Supply

Oman depends on imports for the supply of a majority part of construction materials. Construction materials importation data as compiled by the National Statistical Department are shown on Table II-2. Importation of many items has been decreasing due partly to the decline in construction activities in 1976, as indicated before. But, bearing in mind the fact that 1975 saw much importation as an exception, it is believed that importation of timber and wooden products, paints, cement, bricks, tiles, steel structures, and sanitary ware has still been on the increase.

Trend in price of representative construction materials, as prepared by the National Statistical Department, is shown on Table II-3. Price reduction was evident for many of the materials in 1976, indicating that demand slackened in relation to supply.

Assuming the future building trend of Table II-1 demand for necessary concrete blocks, bricks, ceramics, tiles, lightweight concrete panels (ceiling, wall), sheet glass, and so forth has been estimated, using the following as reference:

- o Building Materials Resources Survey, Scott Kilpatrick & Partners Consulting Engineers, 1977
- o Study for a Factory of Autoclaved Calcium Silicate Products, Renardet - I.C.E., 1974.

Table II-2 Value of Recorded Imports of Selected Construction Materials: 1974 - 1978

SITC Group*	Description of Materials	Value (R.O. Thousands) 1974	1975	1978
242	Logs, poles, posts, pilling etc.	236.6	2228.1	1170.8
243	Timber all sorts	2075.6	2810.0	3310.8
273.1	Building and monumental stone	171.8	320.8	341.6
273.2	Gypsum and plasters	1.6	7.5	3.2
273.2(2)	Limestone & other stones for cement manuf.	1.5	23.8	-
273.3	Sand	4.3	6.4	6.6
273.4	Gravel and crushed stone	36.7	21.7	16.7
332.9	Asphalt, bitumen etc.	160.9	1697.0	572.7
533.3	Paints, enamels, lacquers, varnishes etc.	593.8	1293.0	1728.5
631.2	Plywood	860.9	1716.1	2297.2
631.4	Hardboard etc.	349.5	279.9	143.5
632.4	Building materials made of wood	274.1	606.3	2245.2
657.4	Linoleum & other floor coverings	24.7	34.9	10.5
661.1	Lime	301.2	200.0	122.9
661.2	Cement	4305.7	7355.8	6878.8
661.8	Building materials (asbestos)	948.4	689.5	380.5
662.4	Bricks, tiles of ceramic	487.2	1501.7	1165.8
664.6	Wired and sheet glass	31.6	69.8	6.0
664.7	Safety glass	3.3	27.0	-
664.9	Glass n.e.s.	52.9	15.6	4.6
673	Iron and steel bars, rods etc.	2928.5	5103.5	3973.0
674	Iron and steel plates, sheets	489.1	654.0	1615.0
677	Iron and steel wire	64.7	118.9	71.5
678.1	Cast iron pipes, tubes & fittings	369.1	6479.5	1251.2
678.2	Iron and steel pipes, tubes & fittings	1543.9	2243.1	750.8
682.2	Copper bars, rods, sheets, wire etc.	223.4	117.4	175.5
684.2	Aluminium bars, rods, sheets etc.	333.8	148.4	35.8
691.1	Fabricated & finished iron & steel building materials and structures	1010.6	2395.0	1613.3
691.2	Fabricated & finished aluminium building materials and structures	1356.1	1916.7	625.0
693.1	Wire ropes, cables w/o insulation	75.2	173.7	51.4
693.2	All types of fencing wire	367.6	829.3	648.1
694	Miscellaneous builders hardware	1318.6	620.5	547.9
718.4	Construction machinery	8779.2	13637.4	5201.3
723.1	Insulated electric wires & cables	1707.1	3063.1	1996.9
723.2	All electric insulating materials	3217.6	1608.8	1764.4
812.2	Sinks, wash basins etc. (ceramic)	529.4	1137.6	1208.4
812.3	Sinks, wash basins etc. (iron or steel)	157.9	141.8	46.9
812.4	Lighting fixture and fittings	358.9	442.5	104.1
	TOTAL	35777.0	61736.0	42086.4

(Source) National Statistical Department

Table II-3 Average Prices of the Cost of Building Materials to Contractors in Construction Industry : March 1974 = 100

(Unit: R.O.)

Material	Unit	Year	Mar.	June	Sep	Dec.
Ordinary Portland Cement (bagged)	Ton.	1974	31.00	41.54	50.22	37.82
		1975	37.82	39.06	36.27	35.65
		1976	32.86	31.31	39.99	38.12
White Cement	Ton.	1974	59.00	64.31	74.34	80.24
		1975	66.67	68.44	75.52	70.21
		1976	73.75	73.75	74.34	67.85
Mild steel reinforcement	Ton.	1974	178.50	176.22	174.44	167.32
		1975	147.74	140.62	133.50	113.92
		1976	106.80	105.02	105.02	94.34
Timber: hard wood	cu.m.	1974	114.20	120.84	101.46	103.72
		1975	101.46	94.62	92.34	100.32
		1976	92.34	92.94	87.78	83.22
Timber: soft wood	cu.m.	1974	113.40	135.60	119.65	115.26
		1975	122.04	111.87	111.87	105.09
		1976	99.44	101.70	97.18	93.79
Timber: plywood	sq.m.	1974	1.67	1.69	1.67	1.59
		1975	1.34	1.29	1.30	1.25
		1976	1.22	1.32	1.35	1.37
Sand (crusher)	cu.m.	1974	2.15	2.30	2.37	2.37
		1975	2.49	2.62	2.75	2.71
		1976	2.71	2.62	2.71	3.08
Aggregate (crusher)	cu.m.	1974	2.57	2.70	2.67	2.70
		1975	2.72	2.65	2.93	3.26
		1976	3.65	3.65	3.55	4.09
Precast concrete building blocks	1,000	1974	160.00	172.80	201.60	208.00
		1975	206.40	220.80	228.80	227.20
		1976	233.60	240.00	224.00	227.20

Material	Unit	Year	Mar.	June	Sept.	Dec.
Glass	$1m^2$	1974	4.38	5.48	5.65	5.30
		1975	5.56	5.21	5.87	6.40
		1976	5.87	5.13	5.91*	4.69
P.V.C. pipes	1m	1974	1.40	1.40	1.44	1.88
		1975	1.71	1.72	1.69	1.87
		1976	1.58	1.62	1.50*	1.62
Cast iron pipes	1m	1974	1.96	2.25	2.51	2.72
		1975	2.29	2.43	2.35	2.37
		1976	2.23	1.93	+	2.00
Pitch fibre pipes	1m	1974	1.31	1.44	1.74	1.53
		1975	1.64	1.62	1.60	1.70
		1976	1.64	1.64	1.73*	1.61
Emulsion paint	5 Lt.	1974	2.08	2.60	3.12	2.91
		1975	2.58	2.79	2.97	3.10
		1976	3.04	3.04	3.62	2.97
Gloss paint	5 Lt.	1974	2.89	3.41	4.08	3.87
		1975	3.84	3.90	4.16	4.05
		1976	4.10	3.96	5.23	4.45
Cement wash	50 kg.	1974	8.29	8.54	10.28	10.03
		1975	9.62	9.37	9.70	9.62
		1976	9.37	9.37	14.76	12.44
Wage rates	R.O.	1974				
		1975				
		1976				

(Note) * Average prices are based on a small number. + Insufficient data available to complete average prices.

(Source) National Statistical Department

(1) Bulk Building Materials

Because adequate construction data could not be gathered during the recent survey by the JICA Mission, demand for bulk building materials (concrete blocks, bricks, lightweight concrete panels) has been estimated based on the findings of said Renardet report that:

- o The volume of bulk building materials amount to 0.75 times the building floor space.
- o The ratios of necessary bulk building materials to exterior (load bearing) walls, ceilings and floors, interior (partition) walls are 53%, 20% and 27% respectively.

Estimated demand for bulk building materials is shown on Table II-4.

Table II-4 Estimate Demand for Bulk Building Materials

(Unit: 1,000 m^3)

	1978	1979	1980	1985	1990
Demand for Bulk Building Materials	194	203	216	232	300
1. Loadbearing walls	103	108	114	123	159
2. Roofs and floors	39	41	44	46	60
3. Partition walls	52	54	58	63	81

(Source) JICA MISSION

Exterior and interior walls are generally constructed with concrete blocks with reinforced concrete columns. Construction of reinforced concrete slab ceilings and floors have recently increased. Concrete blocks are either made by the contractor or procured from block manufacturers. Ceilings and floors are cast on site, and precast slabs are yet used.

Home made concrete blocks will be replaced by automated machine-made and steam-cured hollow (two or three holes) blocks with a higher strength. Concrete blocks may be substituted for with sand lime bricks or fired clay bricks, and the manufacturing of the former is being started in Oman. These products compete with each other for wall use, but the market is ultimately decided by price and properties. The use of fired clay bricks, which is lightweight, will increase as buildings will go taller in urban areas, as already did in Iran and Saudi Arabia.

Lightweight concrete panels can substitute for on-site cast concrete in parts of ceilings and walls. While the said Renardet report predicted that 80% of ceiling slabs and 15% of interior walls would be replaced with precast lightweight panels, the spread of such panels has been delayed due to the lack of knowledge on the part of building owners and of techniques on the part of contractors (who adhere to the conventional building method) and would remain within 40% of ceiling and 6% of interior walls, unless these panels are adopted for active use in the government low-cost housing construction.

(2) Ceramic Tiles

Demand for ceramic tiles in Oman and other Gulf countries was estimated, as shown on Table II-5, by the 1975 report on ceramic tiles by Harold Whitehead and Partners.

Table II-5 Demand Forecasts for Ceramic Tiles in the Gulk Countries

(Unit: 1,000 m^2)

Countries	1976	1978	1980
Oman	490	590	700
Bahrain, Qatar & UAE	850	930	1,100
Saudi Arabia	2,000	2,400	2,900
Total	3,340	3,920	4,700

(Source) Whitehead

It appears that the Omani demand has been somewhat overstated in comparison with demands of other countries shown. Yet, it has been estimated based on unit import price that about 350,000 square meters of ceramic tiles were imported in 1974, 1,037,000 square meters in 1975, and 780,000 square meters in 1976, and, therefore, said demand estimation might have been realistic after all. In comparison, the demand shown on Table II-6 has been estimated based on building floor area. Again, this estimate appears to be rather high in view of the Omani population and mode of building, and, therefore, if the future production is based on this magnitude of market, a fair portion of the production will have to be exported.

Table II-6 Comparison of Demand Forecasts for Ceramic Tiles in Oman

	1976	1977	1978	1979	1980	1985	1990
Whitehead	490	-	590	-	700	-	-
JICA MISSION	693	623	645	678	720	773	920

(Source) JICA MISSION

(3) Sheet Glass

In addition to those import already incorporated into aluminium window frames, a total of about 11,000 square meters of sheet glass was estimated to have been imported in 1976. In the future the demand will increase in proportion to increase in construction floor area, provided that low-cost housing will not account for a large part of the floor area.

Table II-7 Project Demand for Sheet Glass

(Unit: 1,000 m^2)

	1978	1979	1980	1985	1990
Demand for sheet glass	11.2	11.7	12.5	13.4	16.0

(Source) JICA MISSION

2. Secondary Cement Products

1) Demand for Cement: Current Situation and Source of Supply

From the import quantity presented on Table II-8, it is estimated that the volume of cement consumption in Oman was from 32,000 to 42,000 tons per month or from 450,000 to 500,000 tons per year as of March, 1978. Over the estimated Omani population of 850,000, this comes to an average of 556 kilogrammes per capita, which compares favourably with the 250 kilogrammes of Iran and 750 kilogrammes of Saudi Arabia.

Almost all of cement consumed is used in government projects, whereas private demand for cement is limited. Big government projects have been finished, and it is expected that the demand will diminish in the future.

Table II-8 Estimated Cement Import in Oman

		1974	1975	1976
Value	1,000 R.O.	4,306	7,356	6,879
Quantity	1,000 t	216	472	502

(Source) JICA MISSION

A long-term cement demand forecast which takes into consideration of the structural change in demand has been shown on Table II-9. The completion of the on-going cement project can result in an over-supply of cement in Oman, even after 1990.

Table II-9 Projection of Cement Demand in Oman

(Unit: 1,000t)

	1978	1979	1980	1985	1990
Cement Demand	432	403	331	375	480

(Source) JICA MISSION

Therefore, when cement is to be produced in Oman, it will become necessary that cement-intensive projects such as government housing, irrigation, water supply, and drainage which are comparable in size with the already implemented big projects such as roads, ports and harbours, and airports be newly implemented. Also, it will be necessary to substitute cement for other materials whenever possible in order to support the cement industry.

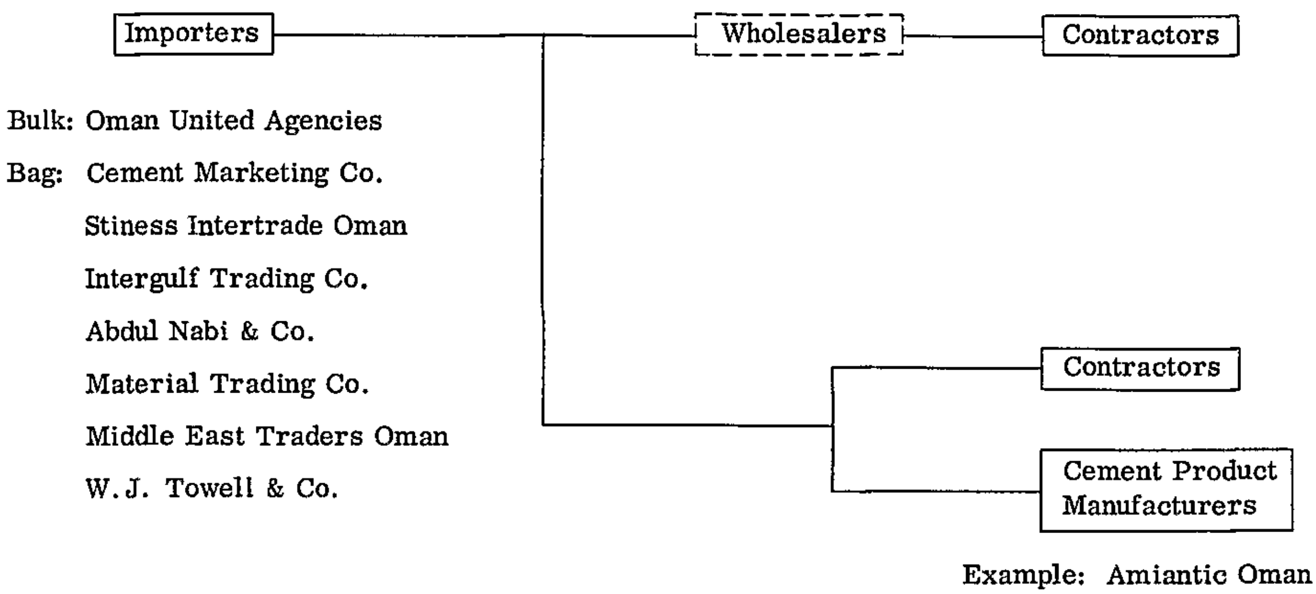


Figure II-1 Cement Distribution Network in Oman

(Source) JICA MISSION

2) Progress and Prospect of Cement Project

In mid 1972 the Government of Oman contracted Cementia Holding A.G. of Switzerland and Associated Portland Cement Manufacturers Limited (APCM) of England to study the feasibility of cement production in Oman. The first phase of the study was directed toward the collection of information on raw material and market, and the findings have been compiled into "A Reconnaissance Survey for Cement Raw Materials", which was submitted in March, 1973.

The report was based on the survey of limestone deposits in Mesozoic, Tertiary, and Recent strata at several locations and the survey of clayey materials (the supplement raw materials) in alluvial sand, phyllites of upper Jurassic period which belongs to Sahtan Group (Wadi Aday), and schists and other rocks (Sayh Hatat Basin) also at several locations. As a result, the area in the east of Wadi Aday at two kilometers south of the northern entrance to the Wadi was selected for limestone quarrying and phyllites in an area on the immediate west of Ruwi downtown were judged most desirable as the source of clayey materials in terms of quarrying ease and quality homogeneity.

However, the production scale of the cement plant has been increased to one million tons per year without any further efforts along said surveys, and a consultant was screened recently for a feasibility study of such a plant, it is reported. It appears that all of these areas covered by said APCM surveys have been abandoned, and an area on the southeast of the Wadi Rusayl Industrial Estate site has been selected for the new feasibility study. This area is about 20 kilometers west of the western edge of the area surveyed by APCM, and it must be assumed that everything is being resurveyed for the cement project, starting from preliminary survey.

It should be assumed that a total of four to five years is necessary from the time preliminary survey is started to the time a million-ton plant is completed, based on the empirical knowledge as follows:

Feasibility study (including materials and plant site investigation)	5 to 8 months
Preparation of tender documents	3 to 4 months
Tenderers' estimate	4 to 5 months
Evaluation of tenders	4 to 5 months
Plant construction	32 to 36 months
Total	48 to 58 months

While time needed by consultants and suppliers, and time needed by client in his decision making have been all included in the above estimation, certain additional time should be allowed in the case of this particular cement project, in which a 40% capital participation is expected from Kuwait, for raising the capital. With additional consideration of possible delay in plant construction in view of the fact that facilities for unloading and transporting of large equipment are not necessarily adequate and that on-site work condition is very unfavourable (particularly due to heat in summer), completion of the cement plant within 1982 would be difficult; it would be more reasonable to assume the completion in the middle or the latter half of 1983.

3) Kinds of Secondary Cement Products and Current Production Situation in Oman

Chief kinds of secondary cement products are listed below:

- o Ready-mixed concrete
- o Concrete products: hollow concrete blocks, concrete poles and piles, panels and slabs, and hume pipes.
- o Autoclaved lightweight concrete (ALC) products
- o Asbestos-cement sheet and pipes
- o Terrazzo (artificial marble) products and artificial stones (cast stones)
- o Cement roof tiles and thick slates
- o Wood-fibre cement panels, wood chip cement panels

Of the above, it appears that production possibility in Oman is limited to hollow blocks, asbestos-cement pipes and terrazzo products.

Hollow concrete blocks are mostly produced in a handicraft scale, and, therefore, analysis of this industry based on data is difficult. As no particular quality standard is apparently being applied to this product, the Mission often observed the display of extremely fragile and poorly appearing blocks on construction sites. It seems, however, that the contractors of big construction works are engaged in somewhat intensified production of blocks to conform with certain quality standard.

On the other hand, the production of asbestos-cement pipes was started by a modern plant of Amiantit (Oman) Ltd. in Rusayl in April, 1977. The plant has a current production capacity of 36,000-ton per year. Amiantit is also engaged in the manufacturing of polyethylene pipes and polyvinyl chloride (PVC) pipes and has the capability of producing glass-fibre reinforced plastic (GRP) pipes, joints, and fittings. Therefore, it is not only capable of supplying all the necessary pipes for water supply systems, sewerage networks, cable-conduits, and irrigation systems in Oman, but also has a surplus capacity with which it is exporting about 80% of the products to U.A.E. and Saudi Arabia. Amiantit is seemingly determined to continue exportation to the Gulf countries until such time the domestic market in Oman will have been fully expanded.

It should be noted here, however, that asbestos, cement, and other raw materials which are used by Amiantit are all imported. This means that, when said plant will start turning out cement, Amiantit will naturally start using the domestic cement. The use of domestic asbestos will also eventually become possible (and Amiantit has received a special licence to explore only asbestos and, through an 18-month intensive research including exploratory drillings, has confirmed the existence of an asbestos deposits worth more detailed investigation). The use of these domestic raw materials will certainly contribute to the minimization of production cost. Thus, it is reasonable to expect that the profitability of Amiantit operation will improve in a long run.

That it is, however, means on the other hand that the market of secondary cement products (particularly concrete pipes, poles, and hume pipes which compete with the products of Amiantit) can become extremely competitive for the other potential newcomers. If, in addition, Amiantit will enter into the production of asbestos-cement sheets with its large production capacity, market will also be dominated by their products. The establishment of a new plant to produce such commodities which will obviously expect to compete from the beginning with asbestos-cement and other product in the inherrently small Omani markets is believed unfavourable. Only, it is likely that ALC panels and blocks, for their insulation and acoustic properties, have a capability of replacing conventional hollow concrete blocks and wall materials in market.

Terrazzo products can be expected as one of promissing industries in Oman in the future. Quarrying of marble to be exported chiefly to U.A.E. for the manufacturing of terrazzo, was engaged in by J & P, Ltd., a Cyprian contractor in the vicinity of U.A.E. border. This has been discontinued due to certain problem pertaining to mining permit. The status of production by a factory in the west of Seeb along the trunk road, owned by Oman Terrazzo Company, a subsidiary of J & P, Ltd., could not be investigated by the Mission. It was said that two other firms are planning on either the quarrying of marbles or the production of terrazzo, but the progress of their plan could not be confirmed. In any event, the Mission could feel strongly favourable for the industrial utilization of marble resources in Oman (as for marble itself, see 3. below in this Chapter). Terrazzo products and cast stones are chiefly used for ornamental purposes. Because they do not directly complete with usual building materials, a stable market can be easily secured for these products.

Terrazzo products and ALC products are the first ones to be named as secondary cement products worth studying for future project purposes. However, because they are rather unique commodities among secondary cement products, they will be treated under 3. below of this Chapter. Of more common secondary cement products, concrete panels and slabs for wall and floor will be reviwed in this Sub-Chapter as they would not much compete with the products of Amiantit. In view of the current tendency in the world of ready-mixed concrete representing an increasingly overwhelming majority of concrete consumption, the establishment of a ready-mixed concrete plant will eventually be considered in Oman sometime in the future. But the materialization of such a plant will have to await for the domestic production of cement itself.

4) Availability of Raw Materials

(1) Resource Availability

Cement: If everything goes well, domestic production of cement will begin in Oman in the middle or the latter half of 1983. Until then, imports will have to be depended upon for the total supply of cement demand. Cement has been imported from Greece, Cyprus, Pakistan, India and other origins. But, because stable supply system has yet to be developed, cement price fluctuates drastically and it is said that the price sometimes change within a matter of day. Some large contractors enter into a long-term supply contract with the importer, in which case the price is about 1.25 RO per 50-kilogramme bag.

Aggregate: Sand, gravel and crushed stones are used as construction aggregate. For cement aggregate, gravel obtained from sand and gravel plains and Wadi sediments is either screened or crushed, and mixed with cement in all cases at present. Because gravel is ubiquitous in Oman, aggregate of satisfactory quality can be produced for a reasonable price at almost anywhere in the country. Also, limestone, marble, or dolomite could be crushed into high quality aggregate, if the need be.

(2) Market Assessment

Demand for secondary cement products and other bulk building materials in Oman was already discussed in Sub-Chapter 1. above. If, in developing markets for secondary cement products, attention is to be paid to pre-cast concrete panels for use in constructing pre-fabricated dwelling units, it should be taken up as a part of the government's housing project, in view of the mass-productivity of the panels.

If, for instance, low-cost housing project is to build 10% of the estimated total building floor area of 309,000 square metres for 1985, about 600 units would be built each year under the project assuming 50 square metres per unit. This size of market will support the feasibility of prefabrication of low-rise (as opposed to high-rise) and medium tall dwelling units.

In addition, high strength standardised concrete blocks to be mass-produced in factories seem promissing in replacing the existing hand-made blocks in market.

(3) Technology Assessment

While the production of ready-mixed concrete and secondary concrete products which usually does not call for any particularly sophisticated industrial technology, seems more commonly engaged in by small or medium size firms, this is one area wherein production scale is being enlarged and consequently various product patents and know-how are increasing as products are being diversified in developed nations.

Therefore, the establishment of this kind of industry is possible through either of two approaches: (1) to buy a simple small-scale plant and start production relying on ordinary technical services which come with the plant, or (2) to purchase a large-scale newest plant and engage in full-fledged production under a long-term technical guidance arrangement with the payment of patent royalty or know-how fee. The former approach is believed more suitable to secondary concrete products, because their domestic market is small and little can be expected of their exportation. But ready-mixed concrete industry is not without the possibility of taking the latter approach, subject further investigation.

(4) Government Measures

The Omani Government is enthusiastic about the newly started cement plant project, and, along with the progress of this project, a secondary cement products project will eventually become essential, but not in the immediate future.

5) Preliminary Study of Secondary Cement Products Project

While secondary cement products are numerous, manufacturing of concrete panels and slabs, which are not feared to be competed against by the products of Amiantit, will be studied first for the reasons stated in 2.3) above.

Since the construction sector in Oman depends on expatriates for 70 to 80% of labour, prefabricated dwelling units (apartment houses), which can save construction labour and time, would be the one of worthy of detailed investigation projects. This accomplished by the use of precast as the major components of the units.

The following particulars are likely in the case of a project for manufacturing precast panels to supply the construction of from 10 to 20 building of 5-story, 30-unit (six 3-room, about 55-square metre floor size units on each floor) flats per year:

- Total Investment: About 4.5 million US dollars at 10 buildings per year
  About 5.4 million US dollars at 20 buildings per year
  (The above quoted are the values estimated for Saudi Arabia based on the CIF value of plant, plus the costs of foundation works, installation and supervising; it is believed that the values are about right for Oman also.)
- Manufacturing Cost: About 240,000 US dollars (including depreciation and interests expenses) per building at 10 building per year.
  About 200,000 US dollars (including depreciation and interests expenses) per building at 20 buildings per year.

(Depreciation over 10 years, interest at 10% per annum)

- o Manpower Needed: At 10 buildings per year: 9 administrative staff, 45 factory workers, 2 janitors; total 56
  At 20 buildings per year: 12 administrative staff, 75 factory workers, 2 janitors; total 89

- o Construction Cost: About 560,000 US dollars per building at 10 buildings per year
  About 480,000 US dollars per building at 20 buildings per year

  (Construction cost including interior and exterior finish, water proofing, wood working, plumbing, wiring and other necessary costs)

- o Total Building Cost: About 800,000 US dollars per building (about 27,000 US dollars per unit) at 10 buildings per year
  About 680,000 US dollars per building (about 23,000 US dollars per unit) at 20 buildings per year

The above estimated construction cost per unit would be fairly much less than the unit cost of the conventional dwelling units (reinforced concrete or concrete block buildings). With the labour and time saving effects also in mind, this project appears to be worth full attention.

6) Development Impacts

One weakness of the secondary cement products project is that it can be expected to have practically no import-substituting effect in view of the fact that only a small amount of such products are now imported. Also, it will have little impacts on fosteration of related industries. Only certain indirect benefits can be expected from this project, such as the effect of lowering reliance on expatriates by saving on-site construction labour and time.

3. Marble

That which is to be noted as having a high potentiality as the source of marbles in Oman is the geologic unit called "Oman Exotics", which is a lithofacie brought from elsewhere (and, therefore, not in-situ sedimentary) by a large scale tectonic movement, under whose pressure metamorphisation the chiefly limestone consisting unit is expected to have been more or less marblised. Although the industrial utilization of this marble for building stones or as chips for producing terrazzo tiles and blocks has been planned in Oman, no comprehensive and detailed survey of potential resources seems to have been achieved.

Oman Marble Study of 1974 by Frazer Weir Associates, Inc. of the United States is about the only available study, but it remains to be no more than a "very preliminary survey". Although the efforts of the Mission also remained no more than a reconnaissance survey, the result of this survey, together with the findings of said American survey, is very encouraging. While much is to be expected from future investigation, basics of this resource will be discussed in the below.

1) Marble Industry: Current Status and Problems

Although marbles are petrographically limited to limestones and dolomites which have crystallized by metamorphisation, stone cutting industry includes amorphous (non-crystallized) limestones in the category of marble, as long as they have an aesthetic appearance adequate for ornamentel purposes, and also includes serpentines suited for grinding. In a strict sense, only limestones which have granular texture and which polish beautifully are worth the name of marble. Those which show banded or stratified pattern and are somewhat transparent are called onix. In addition, there exist a large variety of so-called marbles bearing name of the place of their origin. In a wide sense of the word, all of these are called marble.

Famous since long ago for marble production and quality is Italy, followed by Portugal, Iran, Greece and Yugoslavia. Taiwan made a big entry into this industry since about 1970, and marble imports from Taiwan rapidly increased in Japan, where the use of marbles has been expanding for general interior decoration purposes, tomb stones, garden ornaments, switchboard, clock frames, and so forth. Importation of marbles and marble products by Japan is shown on Table II-10 and II-11.

Table II-10 Amount of Marble Import to Japan

(Unit: ton)

Calendar year / Country of origin	1955	1960	1965	1970	1975
Italy	325	5,312	5,233	5,898	3,291
Yugoslavia	-	562	1,536	1,034	94
Greece	-	194	1,333	1,317	0
Portugal	-	140	2,844	3,399	1,951
Iran	-	-	-	1,450	430
U.S.S.R.	-	54	-	9	0
Sweden	-	20	-	14	0
France	-	280	-	0	0
China	-	-	435	588	123
Taiwan	-	-	-	2,730	2,297
Others	-	97	2,867	2,365	2,185
Total	325	6,659	14,248	18,804	10,371
Imported Value (Thousand Yen)	5,468	189,865	450,662	627,775	580,010

(Source) Japanese Custom Statistics; Article No. 273 - 120

Table II-11 Amount of Polished Marble Slabs and Products Imported to Japan

(Unit: ton)

Calendar year / Country of origin	1960	1965	1970	1975
China	0	206	495	595
Taiwan	1	6	474	1,857
Korea	0	0	0	160
Italy	41	22	131	804
Rumania	0	0	19	36
Portugal	0	0	60	227
Others	(France) 39	6	82	252
Total	80	240	1,261	3,930

(Source) Japanese Custom Statistics; Article No. 661 - 321 & 661 - 322

Marble production in Taiwan has grown at a breath-taking pace into a foreign exchange earning industry, as shown on Table II-12. This suggests that marble industry can have a potential which should not be ignored for the purpose of Omani industrialization.

Table II-12 Marble Output of Taiwan

Year	Output (ton)
1950	204,023
1955	426,042
1960	729,156
1965	899,480
1970	1,285,653

(Source) Government of Taiwan

Onix, as a special type of marble, is being imported mostly from Iran, Yugoslavia, Turkey, and Brasil for processing into interior wall plates, table tops, and living room furniture. "Art marbles", which have a quality between that of natural marbles and that of terrazzo blocks and, yet, are rich in colour and pattern, are also often used in interior decoration materials and columns.

One thing which the above import statistics testifies is the fact that marbles, which are being imported from remote countries, have a high capability of bearing transportation cost, despite their heavy weight. Marbles of high quality are often imported from elsewhere in the form of crude stone for processing in Italy or sometimes even for using Italian brand for reexport. Then, if Oman will be successful in exploiting a high quality marble resource, marbles can become an important export item of the nation. And, as it will be shown later, Oman is blessed with highly potential marble resources.

2) Sitting Conditions for Marble Industry

(1) Resource Assessment

The first to be eyed as a potential marble resource in Oman is the so-called "Oman Exotics". Another important resource is found in the geological unit called "Oman Melange", an aggregate body of chart, limestone, lava, and serpentine, which has been sheared and re-crystallized by the effect of ordinary pressure metamorphisation and, therefore, it is highly expected that the limestone has been marbleized. In addition, metamorphic sheets consisting of banded amphibolites, marbles, and piemontite quartzites, which are generally smaller in scale than the first two but more highly metamorphosed, are scattered in Oman, and they, too, can be considered potential marble resources of Oman.

The following two locations are covered by the recent preliminary study:

A. "Oman Exotics" about three kilometers southeast of Ghubrah, and

B. Metamorphic sheet about seven kilometers southeast of Bid Bid.

i) Ore Deposit 3 Kilometres Southeast of Ghubrah

This deposit, which was eyed as being the closest exposure of Oman Exotics to Muscat, is a "patch" with a true maximum thickness of about 30 metres which appears as if it was glued onto the mountainside. The deposit has a general strike of N40°N for an extension of about 1.5 kilometres and a dip of 55° NW, which about coincides with the mountainside slope. The thickness which can actually quarried is estimated to be less than 10 metres in average; large minable reserves cannot be expected and the condition of quarrying is disadvantageous.

The ore is light grey or reddish grey in colour, has parts where marbleisation of limestone is incomplete and sedimental layers are still observed, has a large number of round cavities which are believed to have been formed by the discriminative erosion of clayey parts, and is generally heterogenous in quality with fairly developed joints and cracks, as well as parts with attractive appearance. Therefore, this deposit may be exploited for small scale quarrying of marble chips or small stones to be worked into furniture components, but not for the purpose of obtaining large blocks or slabs. The greatest benefit of this deposit, which is close to Muscat and is connected with the trunk road with a 5-kilometre gravel road for easy access, is its closeness to market. While it may be unworthy of a large scale development, it is worth further investigation for exploitation for some minor utilization.

ii) Deposit 7 Kilometres Southeast of Bid Bid

This deposit, consisting of milky white or grey marbleised limestones, is considered a part of a metamorphic sheet. Laminas are observed on weathered surface, which is pealing off into three to five-millimetre flakes in parts. Lower parts are more massive. Parts where laminas are observed show light grey and dark grey stripes, but massive parts are generally milky white, practically non-contaminated, and are fine quality marbles, provided that, even in massive parts, joints and cracks are well developed and, as far as judged from outcrop, mining of large dimension blocks and slabs does not appear to be expectable. But this is because the deposit, which is exposed without surface soil, has been weathered by heat and cold. And it is possible that the number of joints and cracks is less in the deeper part.

The deposit occurs in the shape of two hills on both sides of Wadi, each rising about 40 or 50 metres from the ground. The member of the Mission examined hill on the north, where an oval shape deposit is stretched for about

200 metres in northwest - southeast direction with a maximum width of about 120 metres. Its strike and dip at the peak were measured at N10°N and 15°NE, the strike and dip change gradually to form a gently curving anticlinal or dome structure with the axis in northwest - southeast direction.

So, it was difficult to measure the true thickness, but was estimated to have been at least 20 meters. As the deposit is a hill-shaped one, it is far easier to quarry than the deposit of i) above. But the 6.5-kilometre road between the vicinity of Bid Bid and the deposit is poorly maintained, on which a four-wheel drive vehicle is barely passable; the width of the road must be expanded for an extension of about four kilometres and a new road must be constructed for about 2.5 kilometres.

Frazer Weir Associates, Inc. of the United States, too, made a preliminary survey of this deposit, and, according to Oman Marble Study, one of the four samples taken was graded A (the best grade), two was graded B, and the last one, C. (Grade A marbles, which are the prime grade marbles and used mostly for curving purposes, are no longer available in Italy.) The Report sized up the reserves at about 250,000 tons in total, which appears to have been a rough estimate rather than based on topographic survey. The Mission believes that such an amount can be expected of the north hill alone.

This deposit is only about 80 kilometres from Muscat, is close to the village of Bid Bid so that labourers can be recruited with relative ease, and water is available from near-by Wadi and, therefore, is believed worth undertaking a more detailed investigation.

Seven samples obtained by the Mission during the recent reconnaissance survey have been analysed for CaO, MgO, and Cl contents in order to search for some possibility of using the marbles for purposes other than as stones. Analysis finding was as follows:

Sample No.	M 2-1	M 2-2	M 2-3	M 2-4	M 2-5	M 2-6	M 2-7
CaO (%)	52.8	53.4	53.5	55.3	2.0	53.0	55.2
MaO (%)	0.1	0.0	0.0	0.0	1.0	0.0	0.0
Cl^- (%)	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Note: Sample Number M2-5, a sample of invert stone of hard shale obtained at the lower part of the deposit, has been analysed to offer a comparison.

Judging from the above result, this deposit can also be exploited to offer raw materials to lime industries for the production of not only quick lime and slaked lime, but also, if fine quality raw materials are selectively used, calcium carbonate powder (which will be discussed under Sub-Chapter 4).

iii) Potentialities of Other Deposits

In addition to the deposit in Bid Bid, the following three area have been covered by the preliminary survey of Oman Marble Study:

Nizar - Nizwa Area
Wadi Mabrah Area
Nakhl Area

In Nizar - Nizwa Area, a total of 13 samples were obtained from seven outcrops scattered widely in the south of these two cities. One of them was rated grade A, seven were rated grade B, and five grade C (grades B and C being qualities which may be used as fine or medium class stones).

Such outcrops are reportedly scattered within a radius of at least 30 kilometres for a total reserve of several hundreds of million tons. The report also pointed out the possibility of such marble deposits extending toward east and south. If the report is right, the overall reserve in this area will support the sitting of a largest scale marble industry even by selective mining of only fine quality marbles. This area has a number of advantages for the sitting of a marble industry, such as the availability of a fairly abundant water supply, and is believed worth taking a detailed survey in the future.

In Waki - Mabrah Area, a total of four samples were obtained and all rated as grade B. This area is connected with Muscat by roads for a total extension of about 175 kilometres, 145 kilometres of which is major trunk road connecting Muscat and Sohar but the remining 30 kilometres is poor desert sand track. Water supply is inadequate, distance to the closest well in the village of Mabrah being eight kilometres. This area itself is not believed worth a detailed investigation for its disadvantageous development conditions, but the similar marble deposit the possibility of whose existence in a large scale in the hills from 10 to 20 kilometres northwest of this area suggested by the Report is believed worth inspecting.

Although the American party spent only a short period of time on surveying Nakhl Area in absence of a survey permit, the Report suggests a value of further investigation of this well populated fertile area with abundant water supply. According to the Report, this area is connected with Muscat by an 80-kilometre paved road and a good desert road.

In addition, the Report examined samples obtained fromareas where the party did not conduct any on-site study and reported that some of them had a quality which suggested the value of investigating the areas where the samples came from.

In an overall view of the findings of said American survey, our findings, and potential marble resources suggested by the geology of Oman, the proving of a total reserve of fine quality marbles sufficient to support a marble industry in Oman is highly probable and both extensive and intensive surveys of candidate deposits are believed fully worthwhile.

(2) Market Assessment

Marble producing Gulf countries are Iran, U.A.E., and Ajman. Iran produced 46,000 tons in 1974, 60% of which was exported to Italy. Ajman production is about 25,000 square metres per year, much of which is exported. Marble markets in Gulf area are Kuwait and Saudi Arabia, whose total importation is estimated to be from 15,000 to 20,000 tons per year.

Oman has a small domestic market for marbles and imported estimated 2,000 tons in 1976. Development of marble industry must aim at exportation; if, for instance, the production scale is about 10,000 tons per year, 80% should be exported. Marbles exported from Oman will have to compete with products from not only Iran and Ajman, but also Pakistan and Jordan. Therefore, it will be wise for Oman to mine only high quality marbles in order not to engage in price competition with their products in export markets.

(3) Technology Assessment

The quarrying and processing of marbles involve cutting out and shaping of crude stone, cutting into pieces, griding and polishing. Some of the steps are sometimes skipped or more complicated processes are followed depending on the quality of product. No high technology and large scale equipment are needed for this industry, but high levels of artisan skills are needed for both quarrying and subsequent processing. Quarrier's skill bears heavily on the efficiency of quarrying; it is crucial that the quarrier can discern bedding planes, joints, schistosity, and grains of the rock and decide where to start cutting in order that blocks of possibly maximum dimensions are obtained without introducing cracks. To shape the crude stones efficiently also requires a high degree of skills, and to finish the stone into valuable products requires careful attention and artisan's skills.

Terrazzo manufacturing, on the other hand, requires more facilities and less skills, as the centre of its operation is mechanical processing. In this case, stress is placed more on raw materials quality control and the determination of optimum composition of the admixture rather than on artisan skills.

(4) Assessment of Transportation

Except for ropeway, rail truck, wheel loader and so forth which may be used in the case of a factory located in the vicinity of a quarry, the transportation of both crude stones and products will depend on trucks. In view of the high trucking charge (five to six RO per ton between Muscat and Nizwa and six to seven RO per ton between Muscat and Sohar), it should be more economical to purchase own trucks than to contract a trucking service. In any event, most conveniently located deposits should be selected for exploitation in terms not only of transportation distance, but also of road condition, geographical proximity to the port of shipment, and so forth. In this regard, said Nizar - Nizwa Area is one of highly possible candidates for large scale development (therefore, large scale transportation) in view that, even though the transportation distance to Muscat is rather long at 155 kilometres, the convenience of transportation is unexpectedly high due to its closeness to the Muscat - Fahud trunk road and that the scale of deposit is large.

(5) Government Measures for Marble Industry

No activity has so far been made under the government leadership beyond and above the simple preliminary resource survey, Oman Marble Survey. Development efforts by private investments will be promoted if the government takes leadership in studying economics of the development project together with a comprehensive survey of other economically exploitable mineral resources. Also, because marble deposits occur away from a trunk road, the government will be required to construct access roads leading to deposits to be exploited. Marble industry will most probably become an export industry of Oman as long as fine quality resource is secured, and it is highly desirable that the government will take active measures to assist the development of this industry.

3) Preliminary Study of Marble Industry Project

The feasibility of marble industry (quarrying and processing) is fully governed by the scale and occurrence condition of marble deposit and the quality and physical properties of the stone.

For instance, a small scale deposit of attractive stones will support a family type or handicraft scale industry to manufacture such articles as vases, ashtrays and furniture. On the other hand, a large scale deposit of not so attractive stones with a homogeneous quality will support a large scale quarrying of large stones and a terrazzo manufacturing factory. And the scale of investment will be determined by the scale of operation, but to make even a rough decision is difficult at the present. One thing which can be asserted now is that too large a project would not be wise from the standpoint of market, particularly export market; this industry should probably start in a small or medium scale.

In the case of the deposit in the southeast of Bid Bid, for instance, a small scale operation to produce less than 10,000 tons per year of stones and chips should be considered in view of the minable reserve of a several hundreds of thousand tons. Then, the amount of investment would be one million U.S. dollars at the most and the number of employees, from 30 to 40. The potential reserve in Nizar - Nizwa Area is expected to be several hundreds of million tons, and, if so, it will support large scale quarrying and production only limited by the size of market. The amount of investment needed to establish an industry which will quarry 30,000 tons per year of stones and chips and manufacture terrazzo will be two or three million U.S. dollars, and the number of employees needed will be more than 100. The amount of investment varies substantially depending on development and infrastructural (particularly road construction) costs, and the above are merely rule-of-thumb figures.

4) Development Effects

Marble industry should be deemed as a foreign exchange earner, as in Taiwan, rather than an import-substituting industry. Marble deposits are scattered away from the Metropolitan area, and their exploitation will cause transportation problems. But, if the problems are overcome and exploitable deposits are identified, the development of marble industries will be very desirable as they will grow as local industries and facilitate the fosteration of skilled labour in rural areas. (And the industry need not depend on a single deposit, but can draw upon small scale quarrying of varied qualities of stones from a number of isolated deposits.)

4. Limestone and Dolomite Products

1) Development: Current Status and Problems

Oman is bestowed with fine quality limestones and dolomites, which can be used as raw materials of the following industrial products:

(1) Limestone Products

Limestone has since long ago been used as a construction material and as lime for joint filler. Recent development of cement and steel industries in many countries in the world has resulted in greater consumptions of limestones, while the use of limestones as raw material for sythetic organic materials production has dwindled. In Japan, for instance, about 60% of total limestone consumption is for cement, followed by 20% for iron and steel industry, as Table II-13 shows.

It is common to developed nations that cement represents a major part of limestone consumption, and this is because 1.2 or 1.25 tons of limestone is needed for the production of one ton of cement.

Table II-13 Limestone Output by Uses in Japan

(Unit: ton)

Uses \ Output \ Year	1970		1975	
	Output (ton)	Percentage	Output (ton)	Percentage
Cement manufacturing	70,688,483	59.4	79,593,650	55.3
Iron & steel manufacturing	22,966,804	19.3	27,226,002	18.9
Lime manufacturing	6,705,008	5.6	8,747,339	6.1
Carbide manufacturing	1,741,181	1.5	-	-
Soda & glass manufacturing	1,048,087	0.9	748,201	0.5
Civil construction	11,836,694	9.9	22,520,408	15.7
Calcium carbonate powder	3,014,602	2.5	3,892,259	2.7
Paper & pulp recessing	104,464	0.1		
Sugar refining	147,074	0.1	1,157,080	0.8
Others	808,548	0.7		
Total	119,060,945	100.0	143,884,939	100.0

(Source) Statistics of Ministry of Commerce and Industry of Japan

The role of limestone in iron and steel industry is to lower the melting point of slag and to eliminate such impurities as sulphur and phosphate from pig iron and steel.

After said two major uses, limestone is much used for construction (as crushed stone, aggregate, and for rubble mound), lime (quick lime and slaked lime production), and calcium carbonate powder or stone powder. Limestone used to be consumed in a large volume for the production of calcium carbide, but it has been replaced by petrochemical raw material and is rapidly dwindling (as a worldwide trend); therefore, carbide industry will not be a good purpose for which limestone exploitation is to be planned.

Limestone is used for a wide variety of other purposes such as for soda glass, paper manufacturing, pulp, sugar manufacturing, and so forth, and consumption in such areas has been stable.

Oman has rich limestone resources. Yet, they are not being effectively exploited except that limestone is being used chiefly for construction purposes (crushed stone, aggregate and for rubble mound). While the consumption of limestone will be increased by a big stride when the cement plant will start its operation, it is considered important to the industrial development strategy of Oman to promote other limestone-based industries. In view, however, that, of the above listed uses, iron and steel making, carbide, paper manufacturing, pulp and sugar manufacturing are not likely in Oman and other Gulf countries for some length of future time, possibility is limited to lime (quick lime, slaked lime) and calcium carbonate powder industries.

Lime industry is a very simple operation of calcining lime into quick lime and slaking quick lime into slaked lime. But the recent rapid development of chemical industries has resulted in a high demand for lime and the advancement of their technology has resulted in more severe requirements on the quality of lime. Phosphate, sulphur, chlorine, vanadium, manganese, chromium, alkaline, and other impurities previously constituted no problems; now, even the trace of them is subject to complain. Because these trace elements in lime are governed by their original contents in limestone, it is a vital condition to the success of this industry that only fine quality limestones are used. Such a fine quality limestone resource has been reported in Oman and the manufacturing of industrial lime presents an encouraging prospect.

Calcium carbonate industry produces mechanically ground high-gravity calcium carbonate powder and chemical processed low-gravity (sedimental) powder. The latter is a fine grained powder obtained by slaking quick lime into milk of lime, which is exposed to carbon dioxide gas. It is exclusively used for coating paper because of its high reflectivity. The high-gravity powder was produced first and was much used initially as agricultural fertilizer. Recently, industrial demand for this powder has increased, such as for filling material in asphalt paving, rubber filling material, paint, paper manufacturing, vinyl tile filler, and so forth. Because high purity and whiteness are generally required for calcium carbonate powder for industrial use, it is necessary that such powder is made from limestones of a fine quality. Usually, white crystal limestone (marble) is used for this purpose, but such is becoming harder to procure.

Although limestones of such a fine quality are not necessarily found widely in Oman, the nearly pure white marble found in the deposit about seven kilometres southeast of Bid Bid (see Sub-Chapter 3) (1) above) suggests a high possibility of the occurrence of similar marble in elsewhere. While some high quality low-gravity calcium carbonate powder commands the price of 100 to 120 RO per ton, it is questionable if markets for such product can be developed in Oman and other Gulf countries. Therefore, production of only high-gravity powder should be considered for immediate future. Presently, there is no factory dedicated for the production of calcium carbonate powder in Oman, and low grade stone powder obtained as a by-product of limestone crushing is spontaneously used in asphalt pavement and walls.

(2) Dolomite Products

Chemically, dolomite is a complex salt composed of calcium carbonate and magnesium carbonate and has a theoretical composition of 45.75% $MgCo_3$ and 54.25% $CaCO_3$. Dolomite can be positioned between calcite and magnesite based on its chemical constituency and physical properties as compared on Table II-14.

Table II-14 Comparison of Calcite, Dolomite & Magnesite

Name of minerals		Calcite	Dolomite	Magnesite
Chemical formula		$CaCO_3$	$CaCO_3 \cdot MgCO_3$	$MgCO_3$
	CaO (%)	56	30.4	-
Theoretical value	MgO (%)	-	21.9	47.6
	CO_2 (%)	44	47.7	52.4
Specific gravity hardness		2.3	2.8 - 2.9	2.9 - 3.1
		3.0	3.5 - 4.0	3.5 - 4.5

(Source) JICA Mission

Few commercially available dolomites conform with the above theoretical values. Those sold in Japan, for instance, usually have somewhat higher lime (CaO) and contain some volume of silica (SiO_2). The quality of dolomite is expressed in terms of magnesia content (MgO%), and those usually used for industrial purpose have 18% or higher magnesia. Analysis of two samples of Omani dolomite obtained during the recent survey resulted in 20% or higher magnesia reading, which guarantees their commercial value.

Together with magnesite, dolomite has a high demand for use as refractories for steel making, which represents 35% of total dolomite demand in Japan. Also, dolomite is calcined at 1,500 to 1,650°C and made into dolomite clinker, which is used as raw material for making stamping materials and dolomite refractory bricks.

Aside from these, dolomite is also used in plaster, fertilizer, and glassware, in making dolomite earthenware, mixed into asphalt for road pavement, and as a general use construction aggregate. Table II-15 presents dolomite shipment volume in Japan by use.

Table II-15 Dolomite Output by Uses in Japan

(Unit: Thousand tons)

Uses	1960	1965	1970	1975
Iron & steel manufacture	236	219	393	1,683
Dolomite clinker manufacture	779	580	642	
Glass manufacture	90	131	315	248
Magnesian calcium carbonate	118	306	582	544
Others	529	367	220	952
Civil construction	-	-	423	1,164
Total	1,752	1,603	2,574	4,591

(Source) Compiled from Statistics of Ministry of Commerce and Industry of Japan and those of Institute of Limestone Quarrying of Japan.

Dolomite plaster is manufactured by calcining dolomite stones at the temperature of 900 to 1,100°C, adding water to it for slaking, maturing, and, then, finish grinding by a ball mill into very fine grain powder by controlling particle size (1% minus 590 microns and 85% plus 88 microns). Dolomite plaster thus obtained not only has a high fire resistance, low moisture permeability and a low heat conductivity, but also has excellent viscosity and adhesion properties for a workability suited to be used as both interior and exterior wall material. In Oman, well developed dolomite deposits are found in Sayh Hatat Basin, south of Muscat, and so forth. Dolomite plaster manufacturing is one of industries which should be eyed for the purpose of industrialization in Oman.

On the other hand, dolomite fertilizer (commercially called "magnesium carbonate fertilizer") has recently come to represent a high demand for dolomite (about 30%), following refractory uses, in Japan. This is because magnesia (MgO) content of dolomite facilitates the formation of chlorophil in plant, plant' absorption of phosphate, and the improvement of soil. Both "magnesian calcium carbonate fertilizer", which is made by grinding dolomite stones into powder, and "magnesian lime fertilizer", which is made by calcining the stones at 900 to 1,000°C, are available. But markets for this commodity in Oman and other Gulf countries are feared to be too small at the present for immediate starting of this industry, although the use of dolomite fertilizer should be encouraged. Depending on the soil, farmers should be educated on the use of lime or magnesia fertilizer as appropriate, in the future.

Of the above discussed uses of dolomite, manufacturing of dolomite plaster should be considered as being most promising in the immediate future, because the use as refractories in steel making is accompanied by market and technology problems in view of the current situation in Oman and other Gulf countries and use for fertilizer, too, seems to have limits.

2) Siting of Lime/Dolomite-Based Industries

Here, siting conditions will be reviewed for i) lime industry (manufacturing of quick lime and slaked lime), ii) calcium carbonate powder industry, and iii) dolomite plaster industry.

(1) Resource (Availability) Assessment

While Oman is considered to have rich limestone and dolomite resources, the above referred APCM survey on cement raw materials (see Chapter II, 2. 2)) appears to be the only industrial exploitation-oriented survey of deposits. Because lime industry and calcium carbonate powder industry require certain quality standards for their raw materials, assessment of resources as their raw materials must await detailed investigation to be conduced in the future.

Here, only quality of limestone and dolomite required for industrial uses and their availability will be reviewed.

i) Lime Industry

Raw material limestone should be micro-crystalline stones of a high purity. Stones of a developed large crystalline structure are said to easily break during calcining process and tend to hinder ventilation in shaft kiln and to make their decomposition rate low. Even with a micro-crystalline stucture, those stones which are porous as chalk have a low heat conductivity and a low decomposition rate. Also, in lime industry limestones are first crushed into a manageable sizes, and stones which produce least dust upon crusing are desirable.

Limestone samples obtained near the proposed Rusayl Industrial Estate site during the recent survey, have been analysed, as shown on Table II-16; they have been generally found to contain little impurities and, particularly, four samples, L-1 to L-4 can be said of a fine quality.

Table II-16 Analysis of Limestone from Rusayl Area

Sample No. / Element	L-1	L-2	L-3	L-4	L-5	L-6	L-7	L-8
CaO (%)	54.3	55.2	54.4	54.6	52.2	53.5	54.4	53.2
MgO (%)	0.2	0.0	0.1	0.2	0.3	0.3	0.2	0.2
Cl^- (%)	0.000	0.000	0.000	0.013	0.035	0.000	0.000	0.026

(Source) Analysis by Onoda Cement Analysis Center

Of the above samples, L-1 through L-4 are Mesozoic limestone, and L-5 through L-8 are Tertiary limestone. The analysis was done in order to compare the qualities of the two kinds, and the finding was that the Mesozoic stones had a better quality than the other. The former was observed to have a micro-crystalline structure-- a desirable feature for calcining into quick lime, whereas the latter (Tertiary) was somewhat porous and suspected to produce greater volume of dust upon crushing.

The Mesozoic samples were obtained from a hill facing the proposed industrial estate site (on the immediate south of the Amiantit plant), which is suitable for plant location. Therefore, this is a strong candidate for detailed investigation. The limestone deposits at five locations which were surveyed for the purpose of obtaining raw material for cement by APCM have been abandoned, but they might be worth reconsideration for lime industry purposes.

ii) Calcium Carbonate Powder Industry

Whitish and crystalline limestones are preferred for production of calcium carbonate powder. In this case, large crystalline structure poses no problem, but the industry requires stones with a high degree of whiteness and low impurities. Those with a high iron content, which is the greatest cause for colouring, are particularly rejected. So, quality requirement is more severe by this industry and the availability of acceptable limestones is more limited for this industry.

Even the Mesozoic limestone referred to in the above appears to contain some volume of iron and it is highly possible that limestones are unacceptable as the raw material of calcium carbonate powder. (They are believed acceptable for asphalt pavement and fertilizer purposes wherein whiteness of the stone is not a strong requirement.) Therefore, the white parts of marble deposits discussed in Sub-Chapter 3. 2) (1) above should be considered for the purpose of this industry.

iii) Dolomite Plaster Manufacturing

Japanese Industrial Standard (JIS) A6903 defines the chemical composition of dolomite plaster as presented on Table II-17. Calcined dolomite is classified into that for top coating and that for under coating depending on the colour upon discharge from the kiln (white part is used for top coating).

Table II-17 Chemical Composition of Dolomite Plaster

Classification	CaO (%)	MgO (%)	CO_2 (%) Inside the plant	CO_2 (%) Outside the plant
for finish coating	more than 42	more than 20	less than 10	less than 15
for first coating	more than 37	more than 15	less than 15	less than 20

(Source) Specification by JIS-A6903

The findings of preliminary analysis of two most representatives of samples obtained from Sayh Hatat Basin (south of Muscat) during the recent survey are presented on Table II-18, together with calculated chemical composition values for plaster, should it be obtained through calcining and slaking these samples.

Table II-18 Chemical Composition of Dolomites from Sahy Hatat

Remark / Element / Sample No.	Raw dolomite sample		After calcination slaking	
	CaO	MgO	CaO	MgO
D2-1	30.1	20.7	41.4	28.4
D2-2	29.4	20.1	39.8	27.1

(Source) Analysis by Onoda Cement Analysis Center

A comparison of the above two Tables shows that the plaster processed from these dolomite stones would have excessive MgO and be somewhat short of CaO according to the JIS standard for top coating. This means that the dolomites are too pure (MgO content is too high) and will require co-mixing with some impure stones (having a higher CaO content) for the purpose. But in real life it is inevitable that pure and impure stones are co-mixed in the process of quarrying, and, therefore, the "optimum purity" is obtainable without effort. But because stones with a high degree of whiteness are desired for plaster industry, too, deposits of stones with a low iron content and homogeneous quality should be identified through exploration.

(2) Market Assessment

The use of lime, calcium carbonate powder, and plaster is almost non-established in Oman. Trade statistics shows the importation from India of a total worth of 3,152 RO in 1976 under the item of "gypsum and plaster". In Kuwait, however, about 15,000 tons are imported yearly, and a fair amount is believed to be used for building.

The difference comes from the different building methods used in the two countries, it is believed, and cement importers see a potential market for these products in Oman. Paints and colour cement, which are now used for coating interior and exterior walls, can be replaced with plasters, and an annual demand of more than 5,000 tons can be expected. In addition, fertilizer demand can be developed in the future.

If calcium carbonate powder can be manufactured with a high degree of purity (that is, whiteness), the powder can be exported as an industrial chemical (little can be expected of domestic Omani market).

(3) Technology Assessment

i) Lime Industry

The process of Lime industry consists of quarrying, crushing, lime calcination, slaking, maturing and finish grinding, the most important step of all being calcination. Calcination is generally accomplished with the use of either a shaft kiln or a rotary kiln (the former represents the majority of cases in Japan). The shaft kiln is used for either mixing-calcination (wherein lime and cokes or anthracite are alternately charged into the kiln) or calcination by burning residual oil or gas. While the former method used to represent a majority of cases previously, modern large plants of the recent often use the latter method. Residual oil or natural gas should be used for this purpose in Oman.

In any event, the grain size of limestone, calcining temperature, and the location and shape of calcining zone in kiln must be controlled in order that ideal calcination is obtained. This requires a fairly high degree of skill.

ii) Calcium Carbonate Powder Industry

Of calcium carbonate powder, high-gravity powder is obtained simply by mechanical crushing of limestone and the product quality is governed by the quality of raw material stones used. Therefore, it is of a primary requirement that deposits of fine quality limestones be exploited and effective quality control exercised. On the other hand, low-gravity (sedimentary) powder, which is chemically produced, involves more complex process and requires a high degree of whiteness for the product. In this case, much know-how about the manufacturing process is called for in addition to the use of raw materials of an acceptable quality.

In view of the difficulty involved in the manufacturing of low-gravity calcium carbonate powder, Omani attempt in this area should be directed to the manufacturing of only high-gravity powder at least in the initial stage. In case a deposit of extremely high quality limestone (marble) is discovered, however, manufacturing of low-gravity powder might be enterprised jointly with foreign investment and technology.

iii) Dolomite Plaster Industry

The process of dolomite plaster industry consists of quarrying, crushing, calcination, slaking, maturing and finish grinding, which is essentially the same as that of lime industry. Therefore, the technology assessment findings for lime industry are also applicable to this industry.

(4) Assessment of Means of Transportation

i) Lime Industry

The areas in the vicinity of the proposed Rusayl Industrial Estate and the five areas surveyed by APCM are all close to a truck road and to the Metropolitan area and, therefore, invariably offer convenience of transportation for the siting lime industry. Raw material limestones will be transported by dump trucks, and the products will be transportation in paper bags by trucks.

ii) Calcium Carbonate Powder Industry

As there is no way of assuming the location of fine quality limestone (marble) deposit for this industry at the present, the necessary means of transportation may neither be assessed. It is quite likely that the source of raw materials for this industry is located in a greater distance than for lime industry. This industry will use the same means of transportation as will lime industry.

iii) Dolomite Plaster Industry

Dolomite stones will be obtained mostly likely from Sayh Hatat Basin. The dolomite outcrop closest to Muscat is about 38 kilometres from the capital, and larger dolomite deposits are scattered in about 50 to 55 kilometres from the capital. These deposits are close to the road, which connects Muscat and Qurayat. For about 25 kilometres from Muscat is a paved road, after which is a dirt road which runs along Wadi Manzariah. Pavement works are currently being undertaken on the dirt road; therefore, these deposits should be said to have a rather good access in terms of transportation.

Dolomite stones will be carried in by dump trucks, and the products will be shipped out in paper bags by motor trucks.

(5) Government Measures

It appears that no attention is being paid to dolomite resources in Oman, and the Mission heard about no plans for mineral resource survey or industrial exploitation of the resource. The Omani Government itself has not yet considered any dolomite-based industry, and appears to have no particular measures for such an industry.

3) Preliminary Study of Limestone/Dolomite Exploitation Project

(1) Lime Industry

The minimum feasible scale of lime production is believed to be 60 tons per day (18,000 tons per year, assuming 300 operation days per year) in terms of product lime. Capital funds necessary for such a plant is estimated based on F.O.B. (Japan) price as follows (assuming that all volume of quick lime is turned into slaked lime):

Quarrying and Transportation Facilities:	US$ 0.25 million
Crushing Facility:	0.40
Calcination Facility (Rotary Kiln Plant):	1.65
Slaking and Grinding Plant:	0.52
Packing Plant:	0.18
Total:	US$ 3.00 million

After the addition to the above of freight charge, customs duties, civil and construction works, and other installation cost, the total capital outlay is usually estimated at about double the F.O.B. price, and, in this case, an estimation of six million US dollars would be reasonable.

For the operation of a lime industry in said scale will require the following manpower in rough estimation:

Administration	5 x 1 shift = 5
Quarrying and Transportation (Shipping)	12 x 1 shift = 12
Crushing	4 x 1 shift = 4
Calcination	5 x 3 shifts = 15

Slaking and Grinding	4 x 3 shifts = 12
Packing	7 x 1 shift = 7
Total:	55 man

(2) Calcium Carbonate Powder Industry

Assuming the manufacturing of only high-gravity calcium carbonate powder for coating purpose, minimum feasible scale of production is considered to be about 3,000 tons per year. For such a plant, a total capital outlay of from one to 1.2 million dollars and a total manpower of from 15 to 20 are estimated.

(3) Dolomite Plaster Industry

Because the manufacturing of dolomite plaster is essentially the same operation as the manufacturing of lime, the total capital outlay and the total manpower estimated for lime industry are believed also applicable to this industry. The production scale can be small if only the plaster is to be manufactured, but it is common practice that production scale expansion is attempted by producing partly for fertilizer purpose also so that unit production cost can be reduced.

4) Development Impacts

All of the three products which have been taken up in this Sub-Chapter are important from the standpoint of efficient utilization of domestic resources. But, because these products are not currently being consumed in Oman, domestic manufacturing of these products will have little import-substituting effect (except for some colour cement imports). Rather, these projects can be conceived of as export-oriented industries. Products may be exported to Kuwait and Saudi Arabia if the quality is appropriate.

Facilities investments required for these industries will be relatively small and the required technology will be generally unsophisticated (with some exception). Therefore, as long as adequate markets can be developed for them, these industries are among those which can be started relatively easily in Oman.

5. Autoclaved Lightweight Concrete Products

Autoclaved (aerated) lightweight concrete (ALC) evolved from cellumar (or aerated) concrete which was invented in Sweden in 1923 and the curing of the cellular concrete by the means of autoclave was started by a firm in 1932. But it was after the World War II that the full fledged manufacturing of ALC started as an industry in various countries. Recently, ALC has found rapidly expanding uses in building in advanced nations not only for its lightweight but also for its excellent thermal insulation and acoustic properties.

In Oman, Study for a Factory of Autoclaved Calcium Silicate Products was done by Renardet I. C. E. of France. This Study reviewed the feasibility of ALC manufacturing in Oman in a fair detail. So, the findings of this Study will be referred to and commented here for the purpose of this report.

1) Development: Current Status and Problems

Said Study concluded that ALC manufacturing was a promising industry and recommended that a second phase study (preliminary design, technical and economic production studies) be undertaken. It is suspected that the reason for this lack of progress in this project was that such studies could wait for the start of cement production in Oman, which has since been delayed substantially from the initially scheduled mid 1977.

2) Siting Conditions for ALC Industry

(1) Availability of Raw Materials

Raw materials of ALC is silica sand (or powdered quartzite) for about 60% and cement and/or quick lime for about 40%. Water corresponding to 30% of the total volume of these raw materials is added together with aluminium powder as expansive reagent corresponding to 0.1 or 0.2% of the weight of the raw materials.

Silica sand can be obtained by crushing quartzite found in Sayh Hatat Basin. Renardet tested ALC pieces made with this silica sand and found them to be of a good quality, judged that the silica sand was comparable in quality to Fountainebleau sand, which was noted for its fine quality for ALC manufacturing in France, and, because the quartzite was abundantly available, concluded that ALC industry was possible in Oman.

Imported cement will have to be used for this purpose until the domestic production of cement will begin. Aluminium powder needs to be procured from a specific dealer in overseas. Also, small amounts of soda and chlorides are added as catalyzers, and for the production of coloured products, metallic coloured oxides, stabilizers, and wetting agents are also added; these will also have to be imported.

It should be pointed out that water added to ingredients for the manufacturing of ALC must be potable and must not change the setting time of the binder-cement or lime. Renardet remained silent on the availability of such water, but, in view that this industry will require not only such water but also processing water (cooling, washing), water should constitute an important element of siting this industry in Oman and should be fully investigated.

(2) Market Assessment

Table II-4 is again referred to for forecast demand for bulk building materials in Oman. Renardet estimated on similar forecast that in the 1980's ALC products would replace bulk materials for 10% of exterior walls, 80% of ceilings, and 15% of interior walls. But, in view of the conventional building method now employed in Oman, this estimate appears to have been too optimistic, and to launch on the production of 50,000 square metres of ALC per year, as recommended by Renardet, would be much risky. This scale of production will be possible only when ALC has been fully incorporated into the Government's low-cost housing project. Another factor for the spread of ALC is rise in construction labour cost, which will accelerate the prefabrication of buildings for an increased use of ALC products.

(3) Technology Assessment

Although the process of ALC manufacturing is not so complicated, the production method and facilities are patented. It is expected that if this industry is to be established in Oman, it should pay patent royalty and know-how fee.
A foreign partner would be helpful in establishing and carrying out necessary

advertisement and marketing systems in order to promote the use of new product such as ALC.

At any rate, ALC industry will need all-out cooperation on the part of the user, particularly the Government, for accomplishment of its development.

III. CEMENT, GLASS, CERAMICS AND REFRACTORY PROJECTS

1. Products and Current Status

1) Characteristics of the Industries

This Chapter deals with industries in which various minerals and metals are processed at a high temperature in a kiln to produce cement, glass, ceramics, bricks, and refractories. Varieties of these products and their raw materials include:

Cement: Various types of Portland cement (ordinary, early strength, moderate heat and white), slag cement, silica cement, flying ash cement, and special cements; made from limestone, clayey materials, (siliceous materials, ferruginous materials as needed), and gypsum.

Glass: Sheet glass, glass containers, blown glass, glass tubes, glass fibre, optical glass, and special glasses; made from siliceous materials (silica sand, quartzite), boric materials (boric acid, borax), alumina materials (feldspar, aluminium hydroxide), alkaline materials (sodium sulfate, soda ash, borax, sodium nitrate) and lime materials (limestone or quick lime).

Ceramics: Hard and soft ceramics, industrial ceramics, electric insulators, chinaware, art pottery, building porcelain, stoneware and terracotta; made from plasticizing materials (kaolin, mica, porcelain stone, pyrophylolite) and non-plasticizing materials (feldspar, silica stone or silica sand, calcium carbonate, and, as needed, magnesite, dolomite, wollostonite, talc, and bone ash).

Bricks and Refractories: Clay (red) bricks, refractory bricks, tiles, mortar, and stamping materials; made from different raw materials depending on the product, as shown by Table III-1.

Table III-1 Kinds of Refractories and Their Raw Materials

Kinds of Refractories		Principal Raw Material	Secondary Raw Material	
Silica	Brick Mortar Stamping material	Silica-stone Fragments of silica brick (silica sand)	Lime Clay, Bentonite Fire clay	As for the mineralizer, open hearth furnace slag, as for the binder, treacle, pulp waste fluid liquid glass are used.
Semi-silica	Brick	Silica-stone Fragments of silica brick Siliceous clay Fire clay	Chamotte (Grog)	
Roseki (Pyrophyllite)	Brick Mortar Stamping material	Roseki (Pyrophyllite) Fragments of Roseki brick	Roseki (Phyrophyllitic) Clay, Fire clay	
Fire clay	Brick Mortar Stamping material	Fragments of brick Chamotte (Grog) Hard clay	Fire clay	As for chamotte, fired fire clay, fired coal shale or fragments of Roseki brick etc. are used.
High-alumina	Brick Mortar Stamping material Electrotype product	High-alumina chamotte High-alumina material High-alumina shale bauxite	Fire clay	As for high-alumina material, diaspore, aluminous shale, sillimanite, bauxite, alumina etc. are used.
Carbon	Brick Mortar Stamping material	Graphite Anthrocite Pitch coke	Tar, Pitch Fire clay	
Silicon carbide	Brick Mortar	Silicon carbide	Fire clay Liquid glass etc.	
Chrome	Bric Mortar Stamping material	Chromite	Magnesia clinker Lime Fire clay	As for the binder, bittern, pulp waste fluid, liquid glass are used, and for the castable, alumina cement is used.
Chrome-magnesia Magnesia-chrome	Brick Mortar	Chromite Magnesia clinker		As for the binder, bittern, magnesium sulphate, liquid glass etc. are used.
Magnesia	Brick Mortar Stamping material	Magnesia clinker	Pyrite sinter, Scale (iron oxides), Iron ore, Open hearth furnace slag	As for the binder, bittern, magnesium sulphate, liquid glass, tar etc. are used.
Forsterite	Brick Mortar	Dunite Fired serpentinite	Magnesia clinker	As for the binder, bittern is used.
Dolomite	Brick Stamping material	Dolomite clinker	Magnesia clinker chromite	As for the binder, tar is used.

(Source) Modified and translated from "Ceramic Technology Handbook" (Japanese version)

2) Ceramic Industry in Oman: History and Current Status

No written history of ceramic industry is found in Oman, but many fragments of pottery have been discovered from remain elsewhere in Oman to suggest that (if the pottery was not imported) the history goes back to one or two centuries before Christ.

In view of the fact that activities at ancient copper mines included even the smelting of ores, it is quite likely that technical level of Omanis was high enough for the on-site production of pottery needed for the mine only if acceptable clay was available.

But, in fact, due mostly to the very limited occurrence of ceramic materials, particularly the raw materials of pottery and porcelain, ceramic history of Oman has remained quite dormant and the current activities are almost limited to the firing of earthenware at a low temperature in family potteries, none of them in an industrial scale.

Now that in the world, cement, glass, ceramics and refractory industries have been much developed and diversified, some of them are suited to the natural resources available in Oman. Particularly, cement is the most promising project from the standpoint of raw materials availability in the nation, and the production of cement is to be started in the future. Whitehead, a British consulting firm, has reported that raw materials support the possibility of lime manufacturing in Oman. On the other hand, GETCO, a private company in Oman, is reportedly engaged in a glass container manufacturing project and has confirmed the presence of a promising quartzite deposit.

3) Development Possibilities in Oman

(1) Cement Industry

Cement industry depends on limestone for approximately 80% of its raw materials, and limestone is one of the most abundant natural resources of Oman. APCM has reported that their reconnaissance survey revealed the availability of acceptable clay materials (phyllites, schists) also. Even though this finding may not be directly applicable because the current cement project will be based on the survey of areas other than that which was surveyed by APCM, this project should be judged feasible at least from the raw materials point of view because the same or similar strata have been found to have extended into areas other than that surveyed.

The current total reliance on imported cement is undesirable for Oman, and the expeditious implementation of this project is strongly desired. But, because a consultant has been selected for the necessary studies toward the realization of this plant, this project will not be discussed in this report any further, although it will be beneficial for the Government of Oman to have the Mission review the findings and recommendations of the consultant, as appropriate.

(2) Glass Industry

Glass industry, which depends on silica sand as the source of silica (S_iO2) which is the main constituency of glass (for 50-70% content depending on the variety of glass), is in disadvantageous position in Oman, where silica sand deposit has not been discovered and the possibility of its discovery is considered very small. Wahiba sands show the following average particle size distribution according to the analysis by Renardet ICE and, therefore, little use of the sands as a source of silica sand can be expected:

62% quartz and chert
31% calcium carbonate
7% igneous rock

The possibility of a silica sand deposit is generally very low in areas dominated by igneous rocks and carbonate rocks (limestone, dolomite) such as Oman. Any possibility in Oman would be limited to areas where quartzites, sandstones, schists and other siliceous rocks are widely developed as in Sayh Hatat Basin (more on this later) and the peripheral areas. But the recent preliminary survey resulted in the discovery of no industrially exploitable silica sand deposit in said Basin, either.

Possible sources of silica are quartzite, quartz, and sandstone in Sayh Hatat Basin and quartz dikes are developed in the area from Wadi Adi through the northern part of the Basin. The former are widely spread, and Renardet estimated the ore reserves of only three outcrops to have been 12.8 million tons in total. Their average mineral composition is as follows:

98% quarts

2% hydrated muscovite, briotite, sphene, and iron oxides

Samples obtained during the recent preliminary survey have been chemically analysed, and the findings are presented on Table III-2. Problematic ingredient of silica for glass manufacturing is Fe_2O_3, which colours glass blue-green. Tolerable maximum iron oxide contents for various products are given by Table III-3 against which the iron oxide contents of the samples can be checked.

Table III-2 Analysis of Quartzites from Sayh Hatat Basin

Sample No.	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	Total
Q2 - 1	97.0	0.7	0.2	0.7	0.0	0.04	0.20	98.84
Q2 - 2	97.2	1.0	0.1	0.4	0.0	0.00	0.20	98.90
Q3 - 1	87.8	7.8	0.5	0.6	0.0	0.00	1.92	98.62
Q3 - 2	85.4	9.6	0.3	0.5	0.0	0.02	2.44	98.26
Q3 - 3	95.8	0.2	0.1	0.5	0.0	0.00	0.14	96.74

(Source) Analysis by Onoda Cement Analysis Center

Table III-3 Allowable Limit of Fe_2O_3 Content in Silica Material for Glass

Kinds of Glass	Allowable limit of Fe_2O_3 (%)
Utla-violet ray transmissive glass	0.0001
Optical glass, crystal glass	0.02
Tableware glass	0.04
Mirror panel glass, thick polished panel glass	0.06
Window glass, general glassware, glass for physico-chemical uses	0.1
Bluish green coloured glass bottles	0.3
Green-colored or ambre-coloured glass bottles	1.0
When decolorizer is to be used to produce colourless glass	0.05

(Source) Quoted and translated from a Japanese book "Ceramic Technology Handbook"

Thus, quartzites from Sayh Hatat can be judged generally acceptable for the manufacturing of glass containers and, if high quality parts are selectively mined, for window panes (sheet glass) and ordinary glass equipment. Quartz dikes at Wadi Adi will have to be depended on for the manufacturing of table glassware and so forth which require high quality raw materials with low iron content. Exploitable dikes are scattered for about 12 kilometres along the Wadi Adi (20 to 32 kilometres from Muscat), and the total ore reserves of ten outcrops have been estimated by Renardet at 34,400 tons. At these outcrops, quartz appears milky in colour, sometimes contains iron oxide (Fe_2O_3) nodules, and occasionally contains drunes having calcite in them, but these impurities do not exceed 0.5% of the total mass, it is reported.

There are other outcrops worth exploring and possibility still remains of discovering deposit(s) of higher grade raw materials. But the selection of these raw materials and the elimination of impurities therefrom involve a high technology and know-how, and the project formulation in this area should be based on the realistic current situation of Oman.

(3) Ceramic Industry

Ceramic industry deals in a wide variety of products with varied assortments and compositions of diverse raw materials. According to the representative classification method adopted by Japan and France, ceramics are classified into porcelain, earthenware, stoneware, and clayware, as well as special ceramics with some special compositions and properties. See Table III-4 for this classification.

According to the Outline Feasibility Study; Ceramic Products Manufacture (May 1975) by Whitehead, the only promising ceramic industry in Oman is the manufacturing of ceramic tiles. But it believed that other possibilities should not be denied too hastly in view that, for instance, rough earthenware (coarse pottery) and clayware (red bricks, for example) can be manufactured from low grade coloured clay without any high technology and with an acceptable level of economy even in a small scale operation.

In the overall view of the foregoing discussions, the following four industries will be further examined in rest of this Chapter:

Ceramic Tiles Manufacturing

Brick Making (Refractory Bricks and Red Bricks)

Glass Manufacturing (Particularly Sheet Glass and Glass Containers)

Pottery

Table III-4 Classifications and Uses of Ceramic Ware

Classification	Kinds	Manufacturing conditions: Body	Manufacturing conditions: Glaze	Manufacturing conditions: Firing temp.	How to distinguish: Colour (Body)	How to distinguish: Sound when hammered	Products
Clayware		Coloured clay	Usually unglazed	Around 800°C	Mostly coloured	Dull sound body, porous & water permeable	Water jars (jugs), flower-pots, red bricks, clay dolls, biscuits for batteries
Earthenware	Coarse Earthenware	Coloured clay	Lead glaze Fritted glaze Ash glaze	1,000°C - 1,200°C	Coloured	Thick sound body: large water absorption	Hand-moulded earthenware, earthen pots, casseroles, roof tiles tableware, flower bases & bowls etc.
	Fine earthenware Semi porcelain, Hard china, Dolomite earthenware	White clay feldspar, silicastone, pottery stone limestone, dolomite	Mostly fritted glaze. Body firing: around 1,200°C Glaze firing: 1,050 - 1,100°C		Usually white (no translucency)	Thick sound body: water absorption - less than 10%	Sanitary earthenware, dinnerware, wall tiles, earthen toys and ornaments
Stoneware		Coloured clay	Mostly unglazed (Salt glaze, manganese glaze)	1,200°C - 1,300°C	Coloured (almost no translucency)	Hard sound body water absorption 0 - 3%	Stoneware pipes, outdoor wall tiles, floor tiles, teathing, high-grade bowls & pots, acid resisting bottles
Porcelain	Soft porcelain	white clay feldspar	Lime glaze Talc glaze (Transparent glaze)	Around 1,250°C	White (Translucent)	Metallic sound body: no water absorption, conchoidal fracture	Tableware, artistic handicrafts, dental porcelains, bone chinas
	Hard porcelain	silicastone + potterystone		1,300°C - 1,400°C			Tableware, electrical porcelain, outdoor wall times mosaic tiles, physical & chemical porcelains,
		Alumina porcelain, Steatite porcelain, Mullite porcelain, Magnesia porcelain, Forsterite porcelain, Titania porcelain, Zircon porcelain, Dielectric material, High-frequency insulators, Heat-resisting wares					

(Source) Modified and translated from a Japanese book "Knowledge and Dealing of Mineral Products".

2. Ceramic Tile Manufacturing

1) Current Status and Problems

Despite the above mentioned report of Whitehead that the manufacturing of ceramic tiles was promising, there appears to have been no progress in this area and Oman still depends on imports mainly from West Germany and the United Kingdom for all the tiles which it uses.

2) Feasibility

No detailed investigation about tile manufacturing was conducted during the recent preliminary survey, and, therefore, The Whitehead Report will be commented on in the following.

(1) Raw Materials Availability

Clay deposits in Bahla and Nakhal appear to have been exploited to support small scale local activities in clayware, but Whitehead have found, through their analysis and test of three kilogrammes of raw clay sample which they obtained from the Nakhal deposit, that the clay contained 7% MgO and 5% CaO and that, therefore, could be used for tile manufacturing without any additives. Whitehead added that the clay is suitable only for ceramic tile production. It cannot be used, for instance, in the manufacture of sanitary ware or of mass produced pottery of the type imported into Oman according to Whitehead's finding.

Although the sample was found suitable for the purpose as a result of laboratory analyses and tests, it should be noted here that neither the existence of similar grade clays with a material homogeneity nor the quantity of clay reserves has been clearly confirmed, as pointed out by Whitehead.

With regard to the clays from Bahla, on the other hand, Whitehead claimed that "it is entirely possible that those clays would yield a body suited to the manufacture of wall tiles, even though the clays have not yet been tested." The report remained silent on the base of this claim, and said nothing about the quantity of the reserve. Therefore, detailed mineral surveys of these deposits are necessary in order to determine the exploitable volume of the resource and to assess the feasibility of this industry from the viewpoint of raw materials.

Also, Whitehead said that "conversation with potters at Nakhal suggest... that the deposit covers at least one square kilometre, in a seam three metres deep, five metres below the ground surface." One cannot believe this immediately, because the description, if true, means that the reserve would amount to at least a huge 300 million cubic metres (six or seven million tons). Nevertheless, a more detailed survey can be justified by this Report.

(2) Market Assessment

Chapter II, Sub-Chapter 1 "Building Materials: Trend and Demand" is referred to for the assessment of ceramic tile market.

(3) Technological Assessment

As opposed to the manufacturing of ceramics for electrical insulators, laboratory ware, and sanitary ware, which involves a high industrial technology and requires a very large scale of operation to achieve especially economic feasibility, the manufacturing of tiles (especially of monocolour floor tiles) does not require any particularly high technology. In view, however, that clays from Nakhal have a low melting point and requirement that firing temperature be closely controlled, are very dry and difficult to saturate with moisture, and are quite difficult to blunge, special know-how will be required if these clays are to be used as the raw material.

Because the production of tiles will have to be started at a minimum output level which economy will allow for the reasons to be discussed later, the industry will have a low profitability, if any. Such an industry would have difficulty in attracting any foreign investment, and, therefore, the introduction of know-how and technical cooperation needed for this industry is feared to be difficult. And the capability of any private enterprise or enterprises in Oman alone cannot be seemed adequate for the development of this industry, and active involvement by the Government is required in this project.

(4) Assessment of Means of Transportation

Regardless of which clay deposit (Nakhal or Bahla) will be used, clay will have to be brought-in by dump trucks, and the products will have to be packed in, for instance, jute bags which will protect the product or, in the case of small mosaic tiles, for instance, stuck on a paper board and shipped out by trucks.

Transportation distance to Muscat is shorter from Nakhal and is about 110 kilometres, about 40 kilometres of which between Nakhal and the truck road which connects Muscat and Sohar is a passable but rather difficult unpaved dirt road.

(5) Government Measures

In view that nothing has been done after the Whitehead Report, which was made under the request of the Ministry of Commerce and Industry, it is assumed that the consideration of specific government measures for ceramic tile industry is still premature and should be preceded by a detailed clay deposit survey which should be done by the Ministry under the cooperation of the Ministry of Agriculture, Fishery Petroleum and Minerals.

3) Preliminary Study

The minimum output level required to justify investment was estimated at about 800,000 square metres per year by Whitehead, which appears to be rather high. In Japan, tile manufacturing activities are carried out in three general classes: (1) manufacturing of interior wall tiles is engaged in by large companies with about 300 employees, (2) interior and floor tiles by medium or small enterprises with from 50 to 100 employees, and (3) mosaic tiles (those 50 square centimetres or smaller per piece) by small enterprises with 50 or less workers. The scale of production varies by the class but the average per enterprise is only about 3,000 tons (roughly 100,000 square metres). The above 800,000 square metres is believed applicable only to large enterprises.

Tiles made by firing clays from Nakhal,on the other hand, bear pinkish grey colour, which is generally considered unwelcome by the consumer and to make the tiles little competitive with the imports. But Whitehead judged that such tiles could be a good merchandise because they were fully acceptable for floor uses, even with such colour, due to their high strength and durability. This judgement is right. Nakhal clays can be used for the production of chiefly floor tiles commonly engaged in by a small or medium size enterprise with 60 or 80 workers. While this enterprise can be possible from the scale of 200,000 or 300,000 square metres per year, production of about 500,000 square metres per year will make the tiles fully competitive with the imports. The scale of investment may not be estimated in absence of information pertaining to the clay deposit exploitation conditions, infrastructure, and production process, but three or four million U.S. dollars may be a good approximately estimate.

4) Development Impacts

As Oman now depends on imports for the entire volume of tiles it consumes, the development of this industry can be fully expected to result in import-substitution. Beside, precedents in the world show that this industry has developed as a local industry depending on local availability of clay (about 45% of total volume of tiles made in Japan is manufactured in Gifu Prefecture and about 30% in Aichi Prefecture), and the promotion of this industry will much facilitate rural development in Oman. And, even if the manufacturing of only floor tiles is to be promoted in the beginning, the industry will stimulate the existing cottage potters who are engaged in the production of clayware and bricks in the vicinity of Nakhal and Bahla, thereby having an indirect effect of promoting general ceramic industries in connection therewith.

3. Brick Making

Manufacturing of refractories and the production of red bricks involve distinctly sizes of business operation. So, the two will be contrasted in the discussions to follow.

1) Current Status and Problems

There is no refractories manufacturing project in Oman. But the completion of the cement plant will result in the creation of a fair size of demand for refractories. In view of the fact that cement plants are being constructed one after another in the Gulf countries, it is very likely that this project will eventually come up.

Small scale brick making activities engaged in by the inhabitants of Nakhal, Bahla, and Nizwa could not be surveyed by the Mission, and it is unknown whether they fire the bricks even at a low temperature or sun-dry the bricks. (Most likely the both are being done.) There seemed to be no project for the industrial production of building bricks, and one contractor enthused that "if suitable clay could be found, I want to get into that business myself."

2) Prefeasibility

(1) Raw Materials Availability

Domestic raw materials are available for such refractories as silicate bricks, chrome bricks, chrome-magnesium or magnesium-chrome bricks, and dolomite bricks (see Table III-1). Quartz and dolomite can possibly be obtained from the well developed quartzites and dolomite beds in Sayh Hatat Basin, respectively. Chromium can possibly be obtained from chromite deposits found in various locations in the nation. These prospective sources should be fully checked out to see if they will actually support the industry in terms of quality and volume.

No specific survey has been taken on clays, per se, and therefore, no suitable clay deposit has been reported for red brick production. But, in view that quality requirement is lower for bricks than for tiles, it is highly possible that suitable source of clay will be found for this industry. Nakhal clays, for instance, "have reasonable plasticity and excellent dry strength, display very little size variation over a considerable range of firing temperature, and fire to porous, terracotta-coloured biscuit" (according to Whitehead analysis) and, therefore, are suited for brick making, too, with the admixture of sand and soil as appropriate.

But to use clays good enough for tiles for brick making is ordinarily considered a waste of resource, and clays for brick purposes should be widely explored for. Discovery possibility should be high in Wadi sediments, clay beds in alluvial plains, and such weathered products of clayey rocks as terra rossa (residual soil from weathered quartzite) and shale.

(2) Market Assessment

It is believed that refractories market is non-existence in Oman, where there is no iron and steel industry and where ceramic and metal smelting industries have not yet started. Excepting some plants in Iran, Qatar, and Bahrain, steel mills and metal smelting plants are not found in other Gulf countries, either. However, as a number of cement plants are being constructed, refractories market is being expanded. Yet, in view of the fact that a majority (12 - 75% in Japan) of refractories demand in advanced nations comes from their iron and steel industry, it is believed that sufficient demand for refractories to suppot the industry will never develop before an iron and steel industry has been established. Therefore, this project should be set aside for future consideration.

Ordinary bricks market may not be accurately sized up, but the Statistical Year Book of Oman records the total importation of bricks and tiles at 487,200 RO in 1974, 1,501,700 RO in 1975, and 1,165,800 RO in 1976, suggesting the existence of a fair size market. As it was discussed in Chapter II. 1., it might be reasonable to estimate future demand for bricks at not more than 50,000 cubic metres per year assuming that bricks will replace concrete blocks for interior walls.

(3) Technological Assessment

The only important difference between ordinary bricks and refractory processing lies in firing process. The need of firing refractories at a temperature higher (1,450 - 1,900°C) than the temperature at which the products will be used requires the use of a modern tunnel or round kiln, which makes the plant complicated and bulky. In view of a high accumulation of know-how with regard to raw materials proportioning and firing process, manufacturing of refractories can be called a technology-intensive industry.

Production of ordinary bricks, which involves a firing temperature less than 1,000°C, requires relatively simple facilities and technology, and can be operated in a small scale.

The foregoing observations can be summarized as follows. Manufacturing of refractories will not be feasible within the near future in view of market and technology, despite the probability of raw materials availability. On the other hand, ordinary brick making seems feasible from market and technology points of view but the quality and quantity of reserve of clay, the major raw material, should be ascertained first.

4. Glass Manufacturing

1) Current Status and Problems

For the purpose of this Sub-Chapter, manufacturing of sheet glass and glass containers will be considered.

The feasibility of a glass container production project of GETCO has been conducted by Indian Head of the United States. While the details of this project are unknown, it aims at the production of 10,000 tons of soft drink bottles for markets not only in Oman but also in other Gulf countries. There is no sheet glass or other glass project in Oman at the present. Demand for sheet glass is currently 100% supplied with imports from India, Japan, and England.

2) Prefeasibility

The main raw materials for the production of glass are quartz sand and soda ash. Natural quartz sand is not found in Oman, but quartz dike in the vicinity of Sayh Hatat can be utilized as raw material of quartz sand, by crushing and grinding under particle size control. Sub-Chapter 1. 3) (2) above is referred to for the condition of occurrence of glass raw materials and the possibility of establishing a glass industry in Oman. The kinds of raw materials, their required quality, their availability, and price are summarized on Table III-5.

Table III-5 Possible Glass Manufacture in Oman

Type / Material			Quality Requirements: For Sheet Glass	Quality Requirements: For Glass Products	Availability of Raw Materials	Price (R O /ton)
Quartz sand	Chemical Components	SiO_2	More than 97%	Tableware; less than 0 04%	Raw Materials for both sheet glass and glass products are available within the country	
		Fe_2O_3	Less than 0 08%	Blue or brown glass bottle:		
		Al_2O_3	1 3 - 2 3%	Less than 2 5%		
		CaO·MgO	Less than 0 5%	Less than 3%		
	Moisture content size		Less than 6% 0 1 - 0 5 mm (granules under 115 must not exceed 15% of the total volume)			4 2 R.O /t
Soda ash	Na_2CO_3	99%			not available	Import 70.0 O.R. /t
Limestone	$CaCO_3$	97%, P_2O_5 1%, Fe_2O_3 0.1%, size 40 - 70 mm			available	1.4 R.O /t
Feldspar	Al_2O_3	18%, Fe_2O_3 0.6%, K_2 - Na_2O 1%			not available	Import 7 0 - 11 0 R O./t
Dolomite	MgO	18%, Fe_2O_3 1%			available	4 9 R O /t
Thenardite	Na_2SO_4				not available	Import 56.0 R O /t
Cullet					available	14 0-18 0 R.O /t

(Source) JICA MISSION

3) Market Assessment

(1) Domestic Market

Recent glass importation statistics of Oman is presented on Table III-6. Reflecting demand fluctuation due to the rise and fall of building boom of 1970 on, the imports have declined in 1976 after reaching a peak in 1975.

Table III-6 Imports of Glass Products in Oman

(R.O. thousands)

Kinds	1974	1975	1976
Wire and sheet glasses	31.6	69.8	6.0
Safety glass	3.3	27 0	48.7
Glass n.e.s.	52.9	15.6	4.6
Glass bottles	N.A.	N.A.	522.6
Glass products n.e.s.	N.A.	N.A.	690.9

(Source) Statistical Yearbook,
Oman Trade Statistics

The glass industry meets demand for a wide variety of products for varieties of uses, but the products can be generally grouped into three: sheet glass, glassware (containers, moldings), and glass fibre products. A review of the composition of intermediate demands for glass products in Japan, presented on Table III-7, indicates that the industry heavily depends on demands in the areas of (a) food and beverages, (b) housing and construction, (c) electric equipment, and (d) automobiles.

The table also reveals that the total demand for glass products is not so large in terms of value but that the industry is deeply related to all aspects of the daily life. This means that, as the standard living will improve in Oman, glass products will be called upon to satisfy the people's new needs in various aspects of life and the total demand can be expected to grow substantially.

Table III-7 Demand Shares of Glass and Glass Products in Japan

(1970)

Demand Sector	Share (%)	
Food	6.5%	
Liquor	12.7%	20.0%
Soft Drink	0.8%	
Medicine and others	4.3%	
Glass Products	5.7%	
Electric Machinery	11.8%	
Automobile	6.4%	6.8%
Automobile Repair	0.4%	
New Residential Building	8.2%	
New Non-Residential Building	9.0%	24.6%
Construction and Repair	7.4%	
Optical Instrument	1.9%	
Furniture and Metallic Furnishings	1.6%	
Fabric and Garments	-	
Medical Care	2.2%	
Others	21.1%	

(Source) JICA MISSION

(2) Possibility of Export

Importation of glass products by Gulf countries are recorded by the Trade Statistical Yearbook of 1975, as presented on Table III-8. While the difinition of "glass" and "glass products" by the classification of this yearbook is unknown, both of them have shown yearly increases. There is no glass industry in any of these countries at present, and the products of Omani glass industry, when established, will possibly be exported to the Gulf countries. Detailed market surveys should be taken of these countries, and every conceivable measures be taken to strengthen competitiveness of the products against those imports from England, Japan, Belgium, India, Singapore, and Taiwan in these markets.

Table III-8 Imports of Glass Products in the Gulf States

(1,000 U.S.$)

Countries		1971		1972		1973		1974	
Iraq	glass products	4,261	32%	3,545	25%	3,222	16%	8,553	28%
Kuwait	ditto	1,898	15%	1,578	11%	3,586	18%	7,140	24%
Saudi Arabia	ditto	2,388	18%	2,040	15%	2,587	13%	3,958	13%
Qatar	Glass	277	2%	494	4%	629	3%	1,270	4%
Iran	ditto	4,319	33%	6,317	45%	9,919	50%	9,193	3%
Total		13,143	100%	14,041	100%	19,943	100%	30,114	100%
World's Total Import		775,778		954,410		1,237,835		1,389,218	
World's Total Export		871,194		1,088,638		1,436,107		1,540,504	

(Source) Trade Statistical Yearbook, 1975

4) Technological Assessment

The industrial characteristics of glass manufacturing are as follows. The production process follows the steps of melting, molding, and fabrication, and it is common that a high temperature melting furnace (crucible or tank furnace) is used. Because melting process is done at a temperature of 1,300°C or higher, this industry requires fine refractories and excellent technology for saving energy. Also, because glass manufacturing is a continuous operation from the raw materials to the finished product (as opposed to metal industry, which involves separate steps of process), value added is high in glass industry. Many glass factories use heavy oil for fuel, and the control of air pollution by the factory emission is an important problem to this industry. For small tank furnace operation, electro-melting has rapidly developed as a pollution-free technology.

Glass products are often incorporated into automobiles and television sets and exported. Glass products, per se, have little export competitiveness due to their fragility, which requires costly packing, and to their high volume-to-weight ratio.

Sheet glass production, glassware production, and glass fibre production have different industrial characteristics.

Sheet glass manufacturing is a typical process industry engaged in continuous production by large-scale melting furnace and requires substantial capital outlay.

Glassware manufacturing is either mass-production industry using a medium-scale tank furnace and an automated molding machine or novelty industry engaged in the small production of a varied types of products by a small-scale tank or crusible furnace and semi-automatic molding machine or hand blowing.

Glass fibre manufacturing is, so to speak, a hybrid of textile industry and glassware industry. Long fibre industry is divided between fibre making companies and weaving processing companies. Fibre production is usually carried out in a continuous operation. Staple (short fibre) industry products heat-insulating mats for buildings, whose transportation cost is high in relation to the product price.

Of the above three, sheet glass manufacturing involves the highest level of technology.

5) Assessment of Means of Transportation

Primary glass products are fragile, and care must be used in transporting them. For packing of glass products, timber and wooden frames are used generally. No substitute for timber as packing material of glass products, particularly of sheet glass, has been found, and, therefore, when a glass industry has been established in Oman, where timber resource is rather scarce, efforts will have to be made to secure the supply of timber, whose shortage can hinder the shipment of the products.

6) Preliminary Study of Glass Industry Project

Sheet glass (plate) is commonly classified by the method of production and by the type of product into ordinary sheet glass, rolled glass, and polished (float) plate glass. Ordinary sheet glass is made by the vertical drawing of melted glass into sheets of glass ordinarily used as window panes and show cases parts. Rolled glass includes roll-embossed semi-transparent sheets and plates and wired glass for window and furniture. Polished sheet glass is made by polishing ordinary sheet (plate) glass into distortion-free surface(s) and is used for mirrors and luxurious windows or processed into automobile windshield glass.

Table III-9 Shipments of Glass Products in Japan

(1976)

Classification	Shipments (ton)	%	Value (dollar million)	%	@ dollar/t
Industrial Use					
Glass tube for ampules	11,587	0.5	8,910	0.8	769
Electric glass bulb	67,025	2.7	53,232	4.6	794
Electronic tube glass	160,562	6.4	270,732	23.4	1,686
Optical glass gob	3,189	0.1	20,120	1.7	6,309
Lighting signal glass	9,630	0.4	15,540	1.3	1,614
Physical, chemistry and medical glassware	12,490	0.5	18,706	1.6	1,498
Container (bottle)	1,931,784	77.1	492,737	42.6	255
Household Use					
Kitchenware, tableware	166,882	6.7	158,423	13.7	949
Vase, Ashtray	31,784	1.3	31,173	2.7	981
Others	110,385	4.4	86,276	7.5	782
Total	2,505,318	100.0	1,155,849		

(Source) JICA MISSION

Glassware includes everything except sheet glass, glass fibre, and optical glass. A review of shipment composition in Japan on Table III-9 reveals that about 80% of glassware is containers (bottles). Glass bottles are widely used to contain beverages, food, cosmetics, chemicals, and many others, and they represent the greatest volume of production among glassware. In terms of value, bottles, which are mass-produced low cost products, represent about 42% of the total value of glassware produced. But bottles with a high value added are also produced by the use of glass of a special constituency, by precision molding, and artistic processing. Representative method of molding (and products) are blow-mold (bottles, electric bulbes, laboratory ware, art glass), press mold (dishes, bowles, sheet beams), and tube drawing method (fluorescent light tubes, ampoules, thermometres). Each of these methods is accomplished either manually or mechanically. Expensive plates and bowls, flower vases, ashtrays, and other art glass products which hand-making process still constitutes major manufacturing method also form important market segment.

Based on the above observations, it is believed that any possibility of glass industry in Oman is to be looked for in the areas of sheet glass, glass containers, kitchenware, tableware, flower vases, ashtrays, and so forth. Particulars of these activities are summarized on Table III-10.

Table III-10 Summary of Glass Manufacturing Project

	Sheet Glass	Glass Products	
Products	Sheet Glass	Container (Bottle)	Kitchenware, Tableware, Vase, Ashtray
Technology	x high	low	relatively low
Investment	x large 10 Mil. R.O.	medium 5 Mil. R.O.	o small 0.1 - 1 Mil. R.O.
Scale of Production	x Profitable Scale = 10,000t/Yr	1,000 - 10,000t/Yr (large to medium scale)	o 1 - 500t (small scale)
Site	x large	medium	o small
Market	x Most of products will be exported to Gulf Countries.	x ditto	o daily use, craftwork (partly exported)
Price	14.0 R.O./t	x 8.0 R.O./t high	o 28.0 R.O./t
Labourer	x 100 - 1,000	about 100	o -50
Cost -material energy	50%	45%	50%
-depreciation management	25%	25%	15%
-labour	25%	30%	35%
Raw material	x Mainly Imported	Half of main materials may be imported.	o Domestically supplied.
Summary	x Difficult	Possible when market is identified.	o Product must be identified.
Remarks	Markets in Gulf Countries must be included.	Manufacturer of glass bottles is under construction.	Market survey must be made.

(Note) o: Suitable x: Unsuitable

Small scale sheet glass production is not believed to have a possibility from the standpoint of international competitiveness. Also, small scale production of containers is not considered possible, except for certain novelty items. Then, what determines the possibility of sheet glass making is market--particularly markets in the Gulf countries. A joint-development (capital investment, product marketing, etc.) with a Gulf country or countries should be included in project possibility considerations.

In contrast to sheet glass, glass container production appears to be suitable to medium size operation for many reasons. Gulf countries are believed to have a total demand of several thousand tons of soft drink bottles and food containers.

On the other hand, an overall judgement based on technology, capital outlay, raw materials, and labour indicates that the glass project which can be started with the greatest ease is the manufacturing of kitchenware, tableware, flower vases, and ashtrays. It is hoped that multi-faceted survey be conducted with regard to the product variety, specification, volume of production, and so forth. Manufacturing of glass, which is to be based on domestic resources, can become an important core for the fosteration and development of local industries in rural areas.

5. Pottery

This Sub-Chapter will treat the manufacturing of ceramics in the narrow sense of the word, excluding tiles and bricks.

1) Current Status and Problems

It appears that local inhabitants are engaged in the cottage pottery in areas where clay deposits are found, such as in Nakhal, Bahla, and Nizwa. While the detail of such activities could not be surveyed, it is judged from Oman Guidebook and other literature that they are engaged only in ceramics which are classified as clayware (unglazed earthenware obtained by firing shaped clayey material at a low 700 - 800°C temperature). The immediate future task to be performed is to extend this operation to the manufacturing of stoneware and earthenware (see Table III-4) which are glazed and fired at a higher temperature and to develop markets for such products.

2) Market Assessment

Under the limited activities as discussed in the above, market is also limited. But when the activities have been expanded to include stoneware and earthenware, the products will cover tableware, pots, dolls, and other ornamental articles, and the type of market will drastically change. Such new products can be expected to replace not only the kind of ceramics now imported but also some of other products (metal, glass, plastic, and so forth). But the rate of substitution will be fully governed by the product quality in the case of these products which sell on the strength of aesthetic appeal, and quantitative definition is very difficult. This type of industry will accomplish rapid development only when an influential manufacturer or dealer in a developed nation has eyed the raw materials and market in Oman and has made a substantial investment in the industry. Otherwise, the regular process would be that each individual small scale potter makes efforts for increased sales and gradual expansion of production scale. Therefore, efforts should be made to meet practical daily use demand.

3) Technological Assessment

Technical base must be said to exist in Oman in view of the fact that ceramic production is being currently engaged in, even though in a very small scale. But much is to be learned of modern ceramics technology, in view that present activities involve only low firing temperature and no glaze. At any rate, ceramics manufacturing requires artisan skills and experience, and certain degree of trial and error would be inevitable. For this very reason, promotional measures of the government (for instance, a ceramics laboratory, potters training centres, protection of domestic ceramic products, etc.) will have important efforts on the fosteration of this industry.

IV. METAL AND PLASTIC FABRICATION

1. Copper Refining and Fabrication

The condition of copper resource occurrence in the nation and status of its exploitation are as discussed in PART ONE, Chapter 2. Copper refining and fabrication will be discussed here, mainly based on the currently progressing copper development project.

Mining is one of the important industries of Oman. Particularly, copper resource is most promising, and it is expected that copper-related industries will grow to contribute much to economic development in the near future. Such industries consume much energy, and the fortunate existence of unexploited natural gas resource of Oman will furnish low cost energy to those industries so that their products are hoped to have ample international competitiveness. Market assessment reveals that insulated electric wires represent a majority of copper demand, and, therefore, electric wires and cables industry should be emphasized upon for the future project.

1) Summary of Copper Project

The currently progressing operation plan of the Oman Mining Company to be established at about 30 kilometres into the interior from Sohar (see Figure IV-1) is as follows:

(1) Operation Plan

i) Mining: Production 3,500 tons per year at two 8-hour shifts per day, 300 operation days per year.

ii) Ore Dressing: Dressing 3,000 tons/day, 7 days/week, 350 operation days per year. Dressing recovery, 92%; copper content 26%, concentrate production, 78,000 tons per year.

iii) Smelting: By Autokumpu flash smelter, production of Cu 99.5% fire refined copper, 20,000 tons per year. Operation 24-hour/day, 7-day/week.

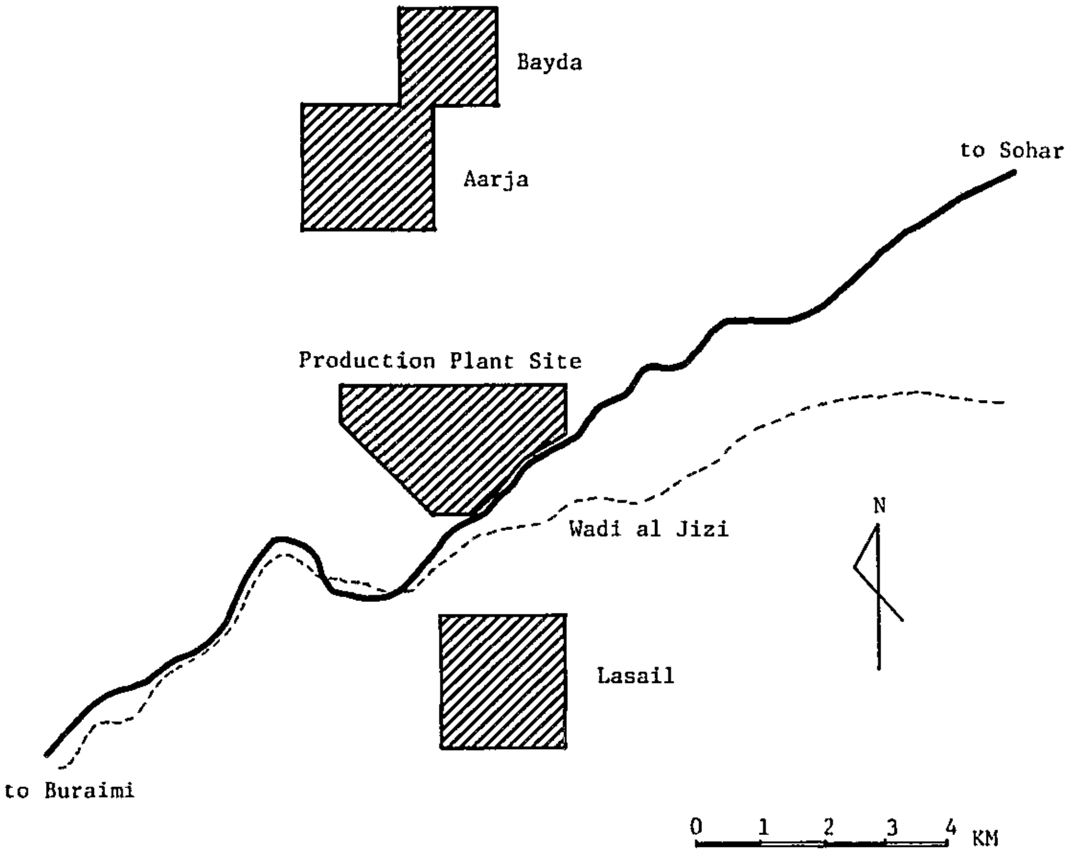


Figure IV-1 Location of the Oman Mining and Company

Smelting recovery rate of 97.5% estimated. Plan is to export the product from a new port (location yet to be decided at about 20 kilometres north of Sohar) to Japan and/or E.C. countries (no export market confirmed).

iv) Service Facilities: Power station, repair shops, desalination plant, port facility, townsite, and so forth.

(2) Development Plan

Mine development is to be accomplished within a construction period of 36 months after financial agreement is signed. Development facilities in each section include the following:

i) Mining Section: Heavy equipment, mine office outfit room, compressor plant, explosives storage, mine ventilation facility, water supply system, sewage facility, fuel storage.

ii) Ore Dressing Section: Crushing, grinding plant, ore storage, flotation plant, tailing disposal.

iii) Supporting Section: Water supply system, power station, power distribution network, fuel storage, office, testing laboratory, workshops, port, stock yard, pumping station.

iv) Smelting Section: Combination of a relatively small electric smelted and a flash smelter.

For the above plant, a start-up cost (investment) of 120 million dollars is estimated.

Dressing and smelting will be started at the same time, and roughly 200 workers are expectedly needed. Recruitment of workers not only from domestic sources, but also from Pakistan, India, Indonesia, and so forth is being conceived of.

If Japan should import the concentrate of this mine, the price would be estimated by Discounted Cash Flow (Rate of Return) Method as follows (assuming 8% per annum interest on fund loan):

Start-up Cost (8% over 11 years)	29.2 cent
Operation Cost	28.2 cent
Transportation Cost	6.7 cent
Total:	64.1 cent

Then, this mining development will be feasible if the market price of copper is at least:

64.1 ¢/Lb + T/C + R/C

Wherein: ¢/Lb = Cent/pound

T/C = Smelting Cost

R/C = Refining Cost

The current stagnation of copper price casts shadow over the new copper development plans, but this project will become feasible when the price exceeds the level of 85 ¢/Lb. Future copper price prospect, interest, and government supporting measures should be also studied.

(3) Problems

The development plan is assessed as follows:

i) Based on the ore reserve and proposed mining rate, the mine life comes to a short 11 years. It will be desirable from the standpoint of loan repayment and interest payment that mining life was longer. Exploratory efforts should be made to discover additional deposits of high grade ore in order that the total reserve will become greater.

ii) While the use of seawater flotation may be inevitable in view of the locational condition of the mine, local water resource should be secured for industrial and cooling water. Care should be used in tailing operation so as not to cause any subterranean water pollution. Thus, local water system should be surveyed from the view of both finding a source of water and effective control of waste water.

iii) While the ore dressing plan is not to deal with recovery of pyrite, care should be given to this on a long term basis because pyrite is a source of sulfuric acid--a major raw material of future chemical plants-- and sulfur dioxide is a source of environmental pollution.

iv) The final product of this mine is fire refined copper, according to the plan. In view that world's demand for this product is believed to be limited, thoughts should be given to the further process (by electrolysis) of the product into electrolytic copper for which demand is much higher.

2) Market Assessment

(1) Copper Demand

A review of copper productions by major producing countries of the world on Table IV-1 reveals that ore reserves are concentrated in specific areas and 67% of the world's total is found in only five countries, namely the United States, Chile, Canada, Zambia, and Peru, which also represent 63% of the world's total ore production. On the other hand, major cathode copper producers in the world are the United States, USSR, and Japan. Now, developed and developing nations produce respectively 60% and 18% of the world's total cathode copper production, but their copper consumptions compare at 74% against 5%, indicating an overwhelming predominance of developed nations in copper consumption. Japan is a big cathode copper consumer next to the United States, the two nations representing about 40% of the world total consumption.

Table IV-1 World Copper Production

(1) Production by Major Producing Countries (1972)

	1	2	3	4	5	World Total
Ore Reserve (in Million Ton of Copper Contained)	U. S. A. 73.5 (23.8%)	CHILE 50.8 (16.5%)	CANADA 27.2 ((8.8%)	ZAMBIA 24.5 (7.9%)	PERU 20.2 (6.5%)	308.4
Ore Production (in Thousand Ton of Copper Contained)	U. S. A. 1,490 (21.2%)	U.S.S.R. 1.050 (14.9%)	ZAMBIA 717 (10.2%)	CHILE 717 (10.2%)	CANADA 709 (10.1%)	7,034
Copper Production (in Thousand Ton)	U.S.A. 1,989 (24.9%)	U.S.S.R. 1,080 (13.5%)	JAPAN 810 (10.1%)	ZAMBIA 615 (7.7%)	CANADA 496 (6.2%)	7,997
Copper Consumption (in Thousand Ton)	U. S. A. 2,023 (25.3%)	JAPAN 954 (12.1%)	U.S.S.R. 910 (11.5%)	GERMANY 672 (8.5%)	ENGLAND 525 (6.6%)	7,883

(2) Production by Groups (1972)

	JAPAN	CIPEC	NON-COMMUNIST		Communist	World Total
			Developed	Developing		
Ore Reserve (in Million Ton)	1.5 (0.5%)	111.3 (36.8%)	272.1 (85.2%)		36.3 (11.8%)	308.4
Ore Production (in Thousand Ton)	112 (1.6%)	2,116 (30.1%)	2,926 (41.6%)	2,692 (38.3%)	1,416 (20.1%)	7,034
Copper Production (in Thousand Ton)	810 (10.1%)	1,232 (16.7%)	4,841 (60.5%)	1,440 (18.4%)	1,686 (21.1%)	7,997
Copper Consumption (in Thousand Ton)	954 (12.1%)	50 (0.6%)	5,883 (74.0%)	360 (4.6%)	1,690 (21.4%)	7,883

(3) Trade by Major Countries (1973)

	1	2	3	4	5	World Total	CIPEC
Export (in Thousand Ton of Copper)	ZAMBIA 760 (14.3%	CHILE 657 (14.1%)	CANADA 633 (13.6%)	ZAIRE 488 (10.5%)	BELGIUM 322 (6.9%)	4,669	2,021
Import (in Thousand Ton of Copper)	JAPAN 1,223 (25.7%)	GERMANY 774 (16.3%)	U. S. A. 540 (11.3%)	ENGLAND 466 (9.8%)	BELGIUM 446 (9.4%)	4,760	

(Source) Ore Reserve Commodity Data Summaries Others Metalgesellshaft

The biggest demand for copper is electric wire. According to copper demand composition in Japan presented on Table IV-2, nearly 70% of copper went into electric wires. The time series data covering the period of 1973 to 1976 reveal the demand composition remained stable in Japan.

Table IV-2 Refined Copper Demand in Japan (1973 - 1976)

(Unit: thousand ton)

	Electric wire	Mill product	Alloys casting etc.	Total
1973	849 (71%)	307 (26%)	38 (3%)	1,194 (100%)
1974	502 (69%)	204 (28%)	34 (3%)	740 (100%)
1975	577 (67%)	254 (29%)	31 (4%)	862 (100%)
1976	761 (69%)	315 (28%)	29 (3%)	1,105 (100%)

(Source) Journal of the Electric Wire of Japan (1978)

Further examination of copper demand using the example of Japan indicates that, of electric wires, covered wires accounted for the greatest 40% of the total demand, followed by communication cables, wires for winding, uninsulated (copper) wire, and power cables. (See Table IV-3).

Table IV-3 Electric Wire Demand in Japan (1973 - 1976)

(Unit: thousand ton)

	Uninsulated wire	Wire for winding	Power cable	Communication cable	Covered wire	Total
1973	93 (10)	194 (21)	109 (11)	168 (18)	372 (40)	936 (100%)
1974	76 (12)	123 (20)	66 (10)	120 (19)	241 (39)	626 (100%)
1975	110 (17)	110 (17)	69 (11)	134 (22)	207 (33)	630 (100%)
1976	126 (17)	155 (20)	92 (12)	106 (14)	277 (37)	756 (100%)

(Source) Journal of the Electric Wire of Japan (1978)

Among these wires, communication cables, covered wires, and power cables command higher prices in Japan, as shown by Table IV-4, because production of these involves higher degree of technology. Average process value (with that of electrolytic copper at 100) is 127 in the case of uninsulated wires, whereas it is 268 in the case of communication cables.

Table IV-4 Order Price of Electric Wire in Japan

(Unit: dolls/ton)

	Uninsulated wire	Wire for winding	Power cable	Communication cable	Covered wire	Average	Price cathode copper
1973	2,132	2,647	3,860	4,191	3,852	3,529	1,871
1974	2,320	3,170	4,088	4,094	4,094	4,023	2,081
1975	2,270	2,300	3,170	4,330	3,570	3,100	1,300
1976	1,780	2,470	3,370	4,480	3,800	2,330	1,470
relative	127	158	228	268	242	197	100

(Source) Journal of the Electric Wire of Japan (1978)

(2) Dolomite Market

Domestic demand for copper in Oman is as presented on Table IV-5.

Table IV-5 Value of Recorded Import of Copper Products (1974 - 1976)

Value (R.O. thousands)

Description of Materials	1974	1975	1976
Copper bars, rods, sheet wire etc.	223.4	117.4	175.5
Insulated electric wire & cables	1,707.1	3,063.1	1,996.9
Total	1,930.5	3,170.5	2,171.4

(Source) Statistical Yearbook 1976

Rough estimates of demand volumes based on estimated prices in 1976 are about 200 tons of rods and sheets, and about 2,000 tons of wires and cables--not a big demand. While basic trunk facilities have seemingly been completed for power supply and communications networks in Oman, electrification is believed to advance rapidly in order to improve the standard of living and the communications network will be much expanded in the future. Therefore, it is expected that demand for electric wires and cables and copper products will start growing again.

(3) Markets in Gulf Countries

Iran's Sar Cheshmeh appears to be about the only copper mine which is now in operation in Gulf countries, which, therefore, depend on imports for their electric wires and other copper products. Their copper products importation from Japan in 1977 exceeded their imports from all sources in 1973, as shown on Table IV-6, indicating sudden increases in their importation of these products. Import values of covered wires and cables were nearly three time the values of rods and sheets. Of these countries, Iran has seven electric wire factories, Iraq has two, U.A.E. has started the construction of one, and Bahrain has an aluminium wire factory. Most of these factories produce from 200 to 400 tons per month. Thus, it can be concluded that Gulf nations have a large demand for copper; they are not only product markets but also they can be expected to become markets for electrolytic copper.

Table IV-6 Total Imports of Copper in Gulf States (1973) [1] & Imports from Japan (1977) [2]

Country	Insulated Electric Wire & Cables	Rod, Sheets Wire etc.	Total (1,000$)	Import from Japan (1977)	
				Amount (metric ton)	Value (1,000$)
Iran	41,520	21,486	63,006	14,499	31,950
Saudi Arabia	17,560	N.A.	17,560	8,472	35,836
Kuwait	16,002	N.A.	16,002	3,021	15,972
Iraq	7,821	2,375	10,196	4,934	11,345
Lebanon	N.A.	6,178	6,178	2	5
Bahrain	N.A.	N.A.	N.A.	134	613
Qatar	N.A.	N.A.	N.A.	999	5,418
U.A.E.	N.A.	N.A.	N.A.	9,090	40,570
Oman	N.A.	N.A.	N.A.	253	700
Total	82,903	30,039	112,942	41,403	141,509
World	1,163,720	751,445	1,915,165		

(Source) 1) Yearbook of International Trade Statistics (1975)
2) Journal of the Electric Wire of Japan (May 1978)

3) Processing Project

The currently progressing project contemplates on the production of refined copper, which is feared to have little advantage in view that fire refining is suited to ores of simple composition with limited impurities and that it represents only about 10% of copper smelting facilities in the world. Concentrate grade and predicted analysis values of fire refined copper are compared on Table IV-7.

Table IV-7 Analyses of Oman Mining & Co.

	Concentrate	Predicated analysis of Fire refined copper
Cu	25.7%	99.8%
Fe	30.7%	0.01%
Zn	2.84%	nil
S	37.8%	0.01
Mg	3.5 ppm	nil
SiO_2	0.96%	
As	0.014	0.004
Sb	0.015	0.005
Au	49.03 g/T	
Ag	0.79 g/T	200 g/T
Pb	0.012	0.003
Se	0.0067	0.005
Te	0.008	0.004
Bi	0.014	0.0005
Ni	0.005	0.005
Co	0.017	trace
O_2	-	0.05

(Source) Prospection Ltd.

Copper is a versatile metal with high malleability, ductility, and electrical conductivity and is much used in electric wires and cables. The effects of impurity elements on the electric conductivity of oxygen-free copper are shown by Figure IV-2. The presence of only 0.005% of arsenic in electrolytic copper (with oxygen content of 0.03%) reduces the copper's electric conductivity by 2%, thus, a minute amount of arsenic, antimony, nickel, and other impurities can deteriorate copper's conductivity substantially. It follows that to use fire refined copper for electric wires under the current project can have an undesirable consequence when these impurities have not been successfully removed. In view that not only electric

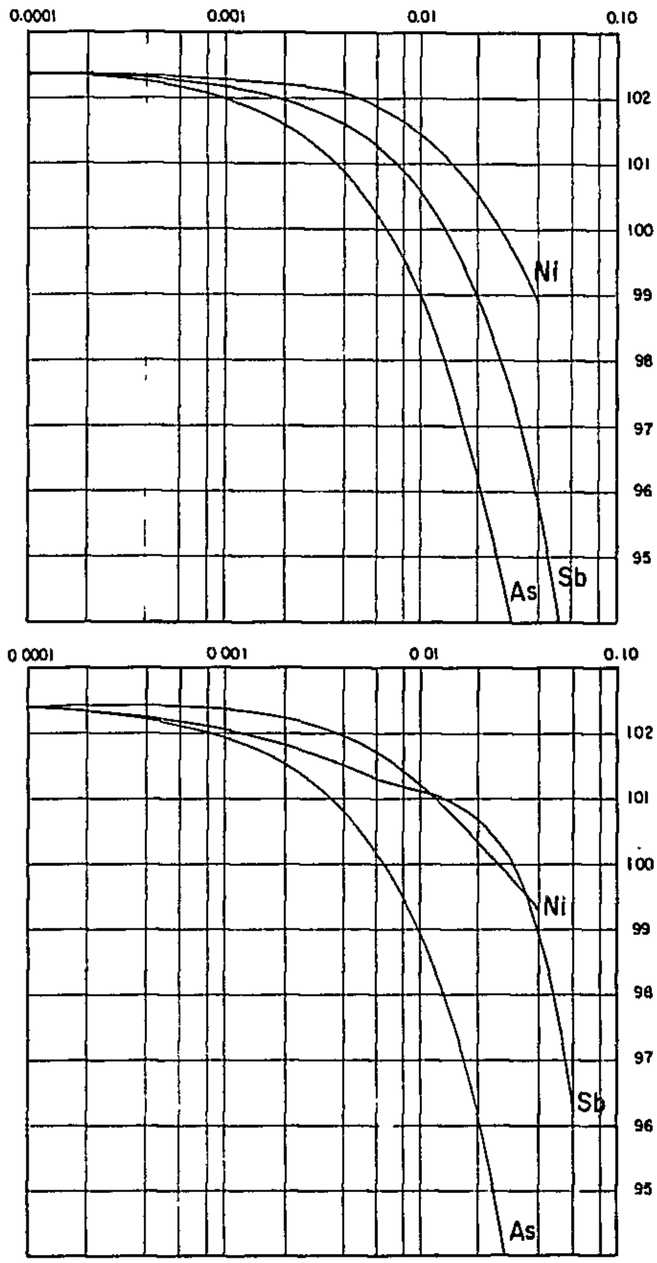


Figure IV-2 Effects of Impurity Elements on the Electric Conductivity

wires but also other copper-related industries are feasible in Oman, it is believed that to modify this project into the production of 99.9% grade electrolytic copper would be more advantageous from the standpoint of securing a greater market.

The project to be reviewed for feasibility in this report provides for the consecutive flow of process starting with the production of anode copper for further processing into cathode (refined copper) to be drawn into wire rod either for exportation or for later production of insulated wires and cables for domestic markets. This process is illustrated by Figure IV-3.

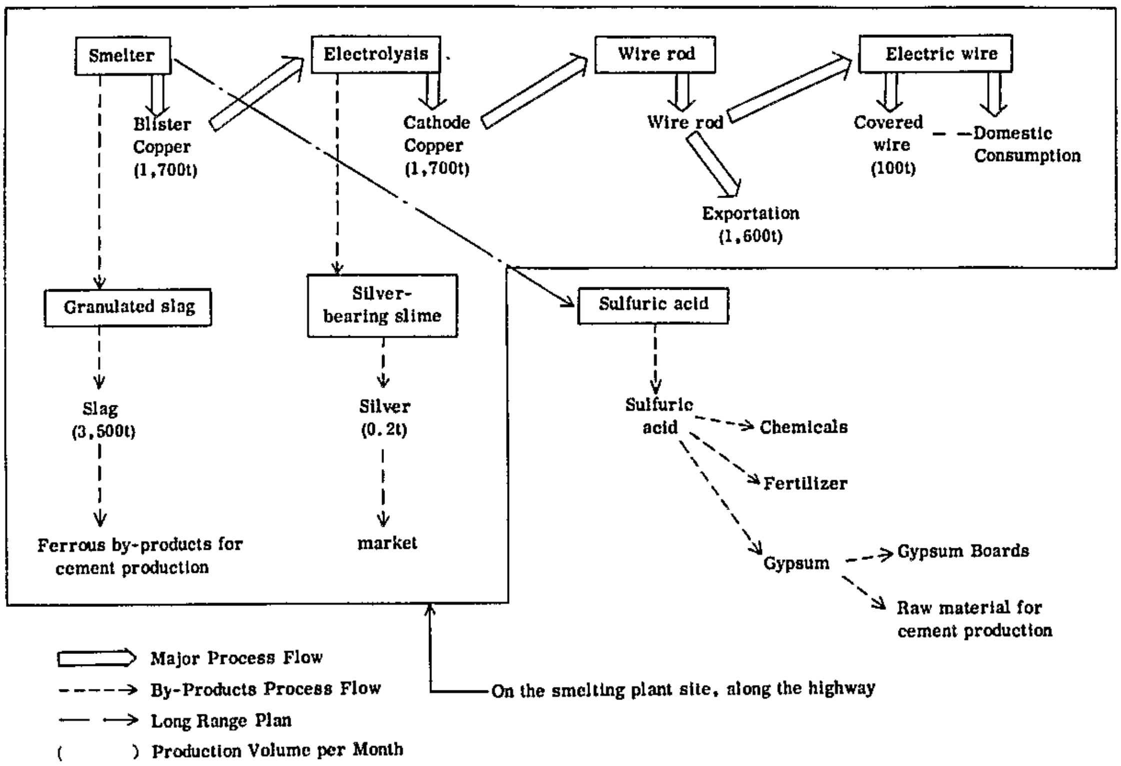


Figure IV-3 Copper Fabrication Process

(1) Smelting

Copper smelting process is summarized by the diagram of Figure IV-4.

In the reverberatory furnace, metal sulfide is separated from gangue by melting ore or concentrate. In other words, when copper concentrate is melted, matte (a molten mixture of copper sulfide and iron sulfide) and slag (a molten oxide of surplus iron, silica-flux, and lime-flux) separate from each other by

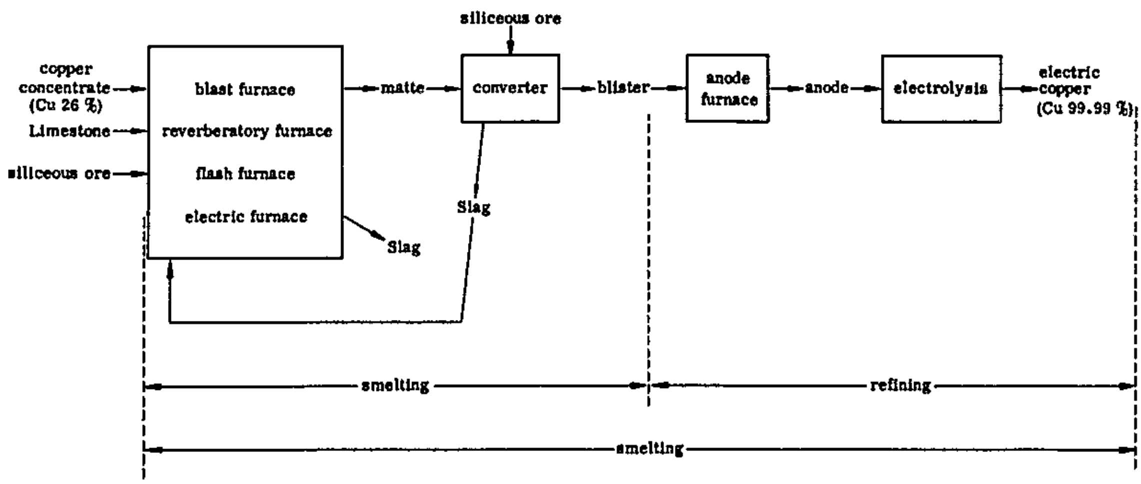
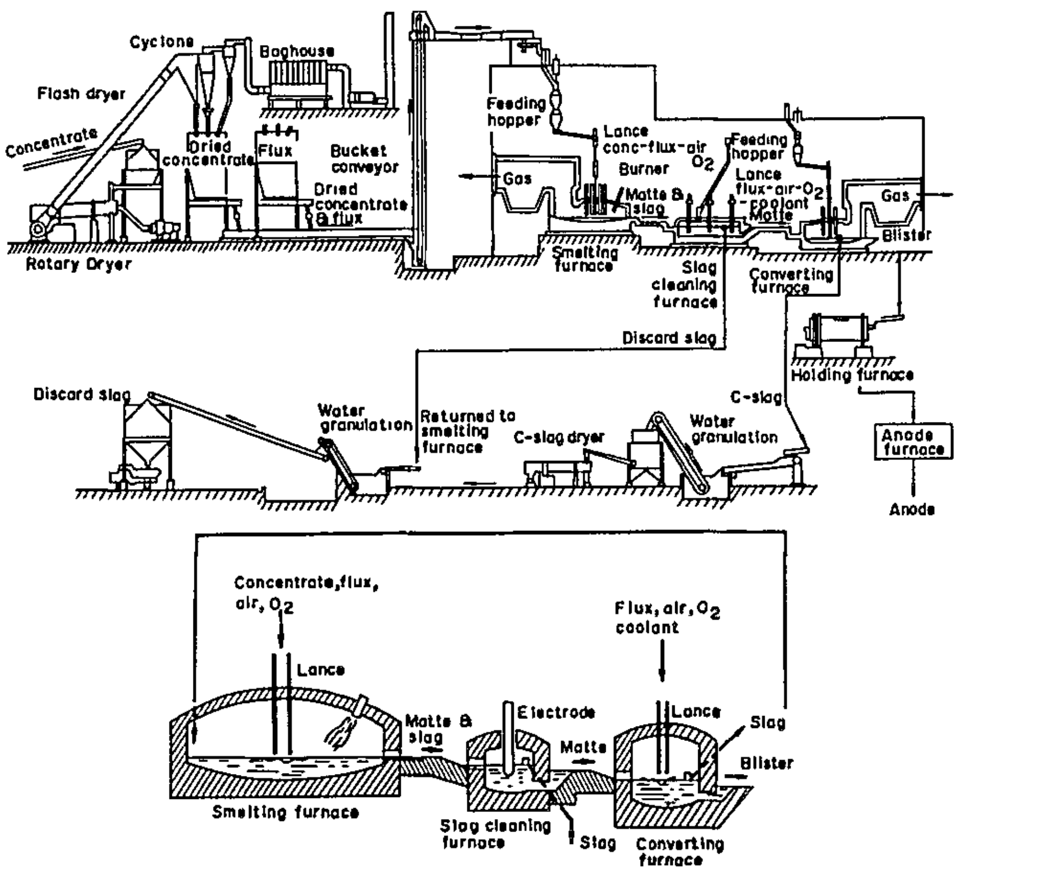


Figure IV-4 Copper Smelting Process

difference in their specific gravity. In converter, air is blown into matte in molten state in order to oxydize iron and sulfur, and remove them from the melt as slag and sulfur dioxide. What is left is blister, whose purity is not so high yet. The minute amounts of iron, sulfure, and oxygen contained in blister are removed by blowing reducing gas into the blister in anode furnace, and then anode copper is obtained. Gold, silver, antimony, and other trace elements, as well as oxygen, are removed by electrolysis to obtain pure cathode copper.

Thus, conventional copper smelting has been done by batch operation whereby copper ore is melted in a reverberatory furnace or a flash furnace and the melt is transferred to converter by ladle. But because such batch operation accompanies a number of bottlenecks, continuous smelting methods have been developed in countries of the world, one of which is Japan's MI Process, which was demonstrated by a 4,000-ton/month scale commercial unit as shown by Figure IV-5 and 6, after long period tests of a 1,500-ton/months semi-commercial plant since 1968. The MI Process is noted for the smallness of capital outlay it



Flowsheet of MI Furnaces (Source) JICA Mission

Figure IV-5 Schematic Flowsheet of MI Smelter

Figure IV-6 Comparison of Construction Costs, Production Costs, Energy Consumption

	Construction Costs				Production Costs					Energy Consumption			
	smelting	pollution control	other	total	direct	indirect	repayment	interest	total	smelting	sulfuric acid	other	total
Reverberatory	60	46	25	131	59	12	34	24	129	85	57	13	155
Flash	61	42	25	128	54	11	33	23	121	76	33	13	122
MI	54	25	21	100	47	9	26	18	100	74	24	2	100

(Source) Journal of the Mining and Metallurgy of Japan (1977)

requires and excellent energy-saving, and pollution-free merits which it accomplishes. Therefore, selection of such a continuous smelting system would be worth consideration for Oman.

(2) Electrolysis

In this step, fire refined copper (anode) is electrolysed to obtain cathode copper. The electrolysis is done by having anode copper an anode and mother blank as cathode, using copper sulfate solution as electrolyte. Anode copper dissolves into the solution, carried by electric current, and precipitates onto the cathode mother blank to form a cathode copper (99.99% copper). During the process of electrolysis, gold, silver, and selenium settle down into anode slime. Silver is the highest of all in content, and the production of 200-kilogramme/month is expected. Because this volume is too small for further processing, silver is to be sold as is. Also, copper sulfate and nickel sulfate are extracted from spent electrolyte. Particulars of production are:

i) Production Volume: 1,700 tons per month
ii) Start-up Cost: About 2,780,000 RO.
iii) Building: 30 metres x 100 metres
iv) Personnel: Two engineers, 30 workers
v) Operation: Three 8-hours shifts/day, 7-day/week
vi) Water Consumption: 30-kilogramme/ton (total 25-mg/1 or less)
vii) Steam Consumption: 500-kilogramme/ton
viii) Power Consumption: 370-KWH/ton
ix) Sulfuric Acid Consumption: 3-kilogramme/ton

(3) Wire Rod Production

Wire rod may be produced either by the traditional method which has been used for over 100 years (hot rolling of wire bar) or SCR method* or CONTIROD method which have been developed recently.

SCR method, whose particulars are presented below, would be recommendable to this project for the smallness of facilities it requires and the benefit that acid-pickling can be performed within the system:

i)	Production Volume	:	1,700-ton/month
ii)	Size	:	8-millimetre
iii)	Investment	:	About 3,470,000 RO.
iv)	Site Area	:	100 metres x 200 metres
v)	Building	:	22 metres x 65 metres
vi)	Construction period	:	24 months
vii)	Operation	:	8-hours/day, 7-day/week
viii)	Operation Personnel	:	Two engineers, 15 workers
ix)	Power Consumption	:	236 MWH/month
x)	LPG Consumption	:	88-ton/month

(4) Copper Cable Production

Markets in Oman and other Gulf countries should be fully surveyed for the right selection of wires and cables to be produced. But, for the purpose of analysis here, initial production of 100-ton/month of ordinary indoor wiring wires for the domestic market will be considered, with the hope of expanding the scale and scope of production in response to demand expansion in the future.

i)	Production Capacity	:	100-ton/month PVC insulated wires
ii)	Operation	:	One 7-hour shift

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* SCR Method: Southwire Continuous Rod Method

Material	Melting Furnace	Casting Machine	Rolling Mill
Cathode Copper	Shaft Furnace	Southwire	Morgan

iii)	Product Composition	:	15 tons of solid wires (1.2, 1.6, 2.0 mm)	
			20 tons of stranded wires (0.9 - 8 mm)	
			65 tons of stranded wires (14 - 38 mm)	
iv)	Facilities	:	3 drawing machines	: 237,000 RO
			3 stranding machines	: 144,000 RO
			2 extruder machine	: 164,000 RO
			1 annealing machine	: 54,000 RO
			1 spooler machine	: 38,000 RO
			Power plant (1,500-KWH)	: 45,000 RO
			Inspection facility	: 18,000 RO
			Miscellaneous works	: 90,000 RO
			Building (25 x 150 m)	: 340,000 RO
			Total	: 1,130,000 RO
v)	Personnel	:	20	
vi)	Profitability	:	Varies by copper price and interest rate. Estimated for current condition (copper price 500 RO/ton, interest, 8%):	
			Sales	: 97,000 RO
			Raw Material Cost	: 54,000 RO
			Personnel Expenses	: 18,000 RO
			Administration Expenses	: 10,000 RO
			Profit (Profit Rate, 16%)	: 15,000 RO

(5) Conclusion

Mining industry, which encompasses from the mining of ore to the smelting of copper, and the downstream fabrication industry are compared for the start-up investment, personnel, and sales (see Table IV-8). The advantages of copper fabrication industry over copper mining industry is clearly illustrated by the lower investment (20% of mining) and fewer personnel (25% of mining) required for fabrication, by greater (1.3 times the mining) amount of sales per employee, and by the comparison of ratio of investment to sales of fabrication's 0.4 against mining's 0.64.

Although the world's copper market currently appears depressed and does not offer reasons to be optimistic about the future of copper fabrication industry, the feasibility of this industry should be studied in order to establish the policy for the fosteration and development of this industry, now that the copper mining industry is starting up on its way in Oman.

4) Government Measures for Promotion

The government must make aggressive efforts toward the importation of necessary plant facilities in order to assist and promote development in this area. Also, in view that world market price of copper fluctuates substantially due not only to the gap of demand and supply in international market but also to speculations upon changes in world political situations. The Government should offer guarantee for loan, should the industry need to finance its operation expenses. Stable mining operation cannot be guaranteed unless appropriate measures are taken by the Government against copper price fluctuations, and "copper price fluctuation reserve" system should be introduced into the Corporate Income Tax Law.

Table IV-8 Summary of Copper Project

	Products	Consumption period	Investment cost (R.O. thousands)	Labour (person)	Work shift/day	Annual sales copper price 830 R.O /ton
Mining	300T/D	1 / 2 / 3 year	41,520	200	1st shift	
Smelting	1,700M/T	F/S		100	dressing	
Total			41,520	300		16,700 R O. thousands
Electrolysis	1,700T/M	F/S	2,870	32		
Wire rod	1,700T/M		3,470	18		
Electric wire	100T/M		1,130	20		
Total			7,380	70		4,700 R.O thousands
Grand Total			48,900	370		21,400 R O thousands

2. Plastic Product Manufacturing

Thermosetting resin (phenol, urea) and thermoplastic resin (polyvinyl chloride, polyethylene) are generally referred to as plastics. Demand growth has recently been faster for thermoplastic resin.

In Japan, plastics are used to make a wide variety of goods from containers, electric parts, machine parts, and transportation equipment parts to various construction (chiefly interior furnishing) materials in addition to sundry of consumer goods. (See Table IV-9) Plastics and other intermediate products (aluminium, steel, timber) are considerably substitutional to each other in many uses in every industrial sector.

Table IV-9 Plastic Products in Japan (1976)

	Production (1,000 tons)	Share (%)
Film	785	25.5
Sheet	178	5.8
Plate	112	3.6
Synthetic leather	130	4.2
Pipe	380	12.3
Jount	38	1.2
Machine tools parts	354	11.5
Daily commodities etc.	233	7.6
Container	148	4.8
Construction material	207	6.7
Foamed product	152	5.0
Rainforced products	80	2.6
Others	283	9.2
Total	3,080	100.0

(Source) Journal of Statistics
Ministry of Trade & Industry of Japan

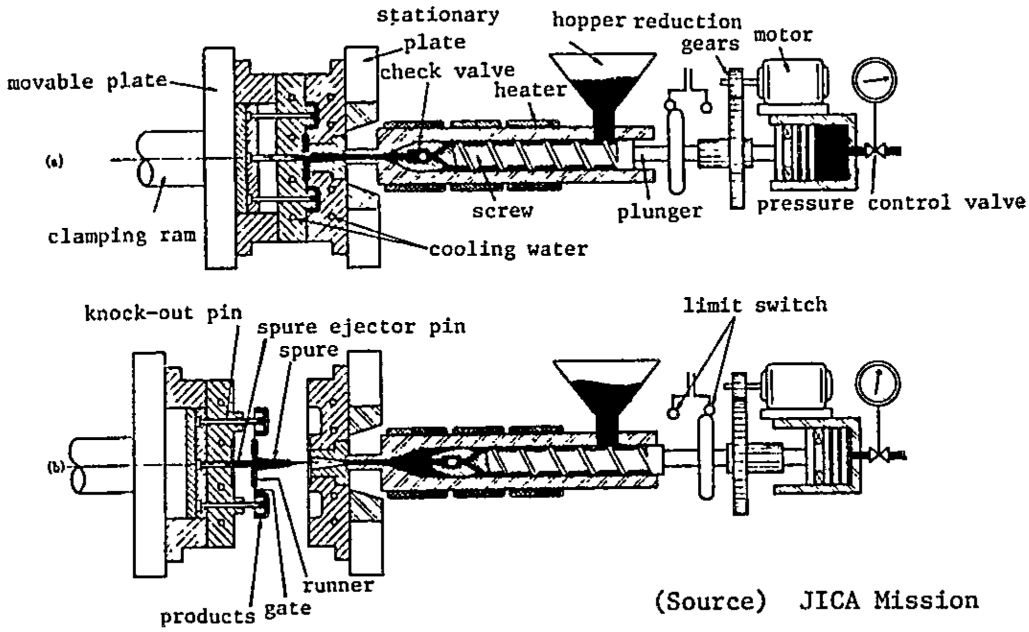
The plastics industry in Japan accomplished a complete cycle of process from importation, domestic market development, domestic production, and exportation within a time frame of 10 years. In view of this and the wide application of plastics, the potential of the plastic industry in Oman must not be assessed too low.

1) Development Prospect and Guideline

Oman imported plastic products for a total value of 656,000 RO in 1976. Breakdown of the products is unknown but it is believed that a wide variety is covered by the imports. A survey to clarify types of plastic products in demand and market size for each type of the products, in order to select right products for new industrialization projects, will be worth consideration. Industrialization efforts should probably start with plastic containers and sundry use goods in view of market size and the technology involved.

Plastic molding industries are classified as follows by the method of molding:

(1) Injection molding: Contàiners, industrial parts (electronic parts, automobile parts, batteries), medical apparatus (injection syringes), daily use home goods (toys, kitchen utensils)...see Figure IV-7.



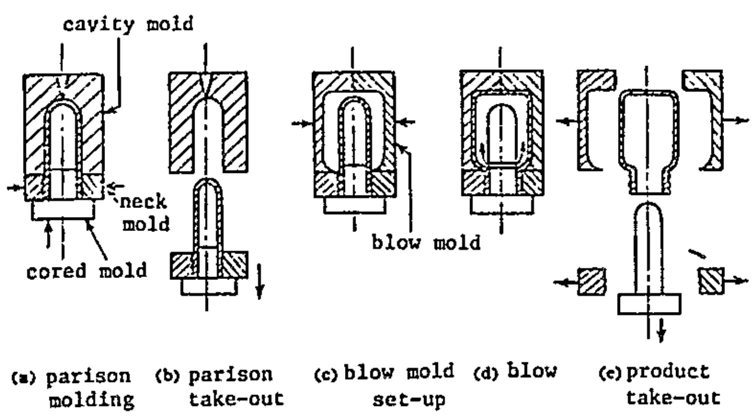
(Source) JICA Mission

Figure IV-7 Injection Molding Machine (Inline Screw Style)

(2) Film extrusion: Packaging film

(3) Extrusion: Pipes (conduits, water and irrigation pipes)

(4) Blowing: Bags (for cement, fertilizer), containers, fishing nets, ropes... See Figure IV-8.



(Source) JICA Mission

Figure IV-8 Principle of Blow Molding

In order to develop import-substituting plastic molding industries, an adequate market survey should be taken in order to identify and assign priority order to products for domestic production. In absence of such information at present, attention should be paid to the following products: Kitchen utensils, packaging materials, water pipes, bags (for cement industry), containers (for transportation of kerosene, petrol, water, and so forth, outdoor water container), and so forth. Another element which should be taken into consideration is that the injection molding usually requires a substantial initial investment, but blow molding can be started in a small scale with a small investment.

2) Summary of Development Project

(1) Plastic Containers Molding

Securing of agricultural and home use water is a crucial problem outside certain urban areas in Oman. Except for areas where a water supply system with pumps and pipings has been developed, water must be hauled in from elsewhere in a container and stored in a container.

Containers play vital roles in the people's living not only for the transportation and storage of water, but also other necessities of life. Plastic containers have advantages over porcelain and metal containers of air-and liquid-tightness, anti-corosion property, sanitation, appearance, lightness, and general ease of handling. Mass-production and supply of such containers for a reasonable price will immensely contribute to the improvement of quality of life in Oman. So, plastic containers molding industry will be discussed here.

The blow molding, which is used for molding plastic containers, is advantageous compared with extrusion molding, because it requires investment of a small scale and involves simple techniques. The size of container is governed by the use. Here, 20-litre containers for the storage of water and other liquid at homes and 2-cubic metre containers, which can be used for storing industrial chemicals, for effluent treatment, for agricultural water storage, and so forth will be considered.

i) 20-Litre Polyethylene Containers

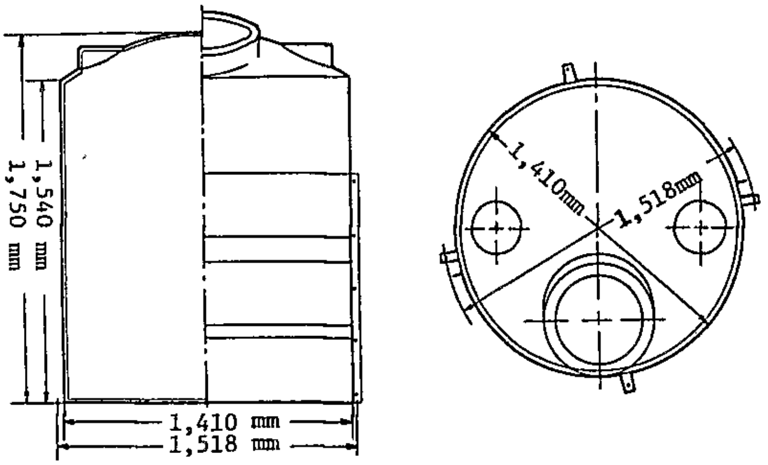
Production of 3,000 pieces of 20-litre containers per month by blowing is considered. Molding of the containers and forming of lids will require separate machines. Factory building will be 7 metres x 12 metres for a floor space of 84 square metres on which the two machines will be installed and some product containers will be stored. Of the initial investment, 50,000 RO will be needed for machines (to be depreciated over five years). Building will cost about 9,000 RO (and depreciated over 10 years). Assuming the product price of 2 RO per container, monthly profit and loss statements are as shown on Table IV-10. This industry will be required to have an in-house workshop to maintain and repair molds and machines.

Table IV-10 Profit and Cost of Manufacture of 20-Litre Plastic Container

Total Sales		6,000 (R.O.)
Total Cost		4,880
Raw Material polyethylene import pirce 0.3 R.O./kg	1,000	
Manufacturing Cost	2,780	
Equipment (including 150 of cooling water)	200	
Labour (4)	1,400	
Electricity (1,500 KW)	30	
Repair	250	
Depreciation	900	
Management Cost (Interest, Administrative Cost)	1,100	
Gains (19%)		1,120

The price of a plastic container 2 RO is not unreasonably high in view of the functionality and durability of other competing products. If the entire area of Oman is to be supplied by this one factory, transportation cost will push up the price for end users to 2.5 or 3 RO a piece.

The site of this plant should be determined on the balance of purchasing power concentrated in the Metropolitan area, demand for containers in rural areas, and cost of transportation needed between the point of production and market. A site in Nizwa or other Interior location might be as reasonable as a site within the Metropolitan area.



capacity ℓ	thickness mm	weight kg	supporting frame	frame weight
2,000	7	75	attached	(72)

(Source) JICA Mission

Figure IV-9 Dimension of 2,000ℓ Tank

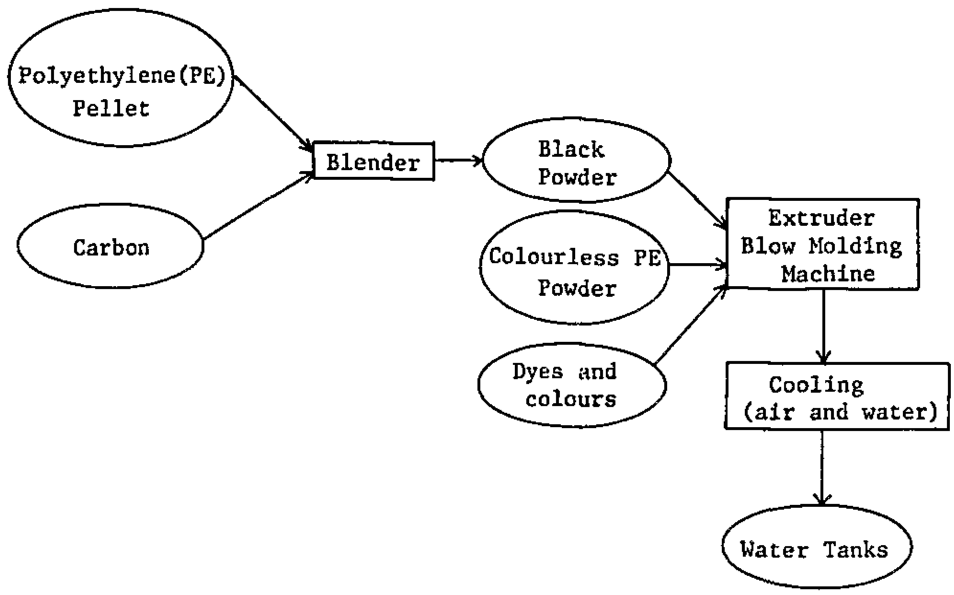


Figure IV-10 Manufacturing Process of Plastic Water Tanks (Large Containers)

ii) Water Tank (2 cubic metres)

Production of 250 polyethylene water tanks per month is considered. The geometry of the 2-cubic metre tank is given by Figure IV-10. This factory will be larger than the 20-litre container plant and a building with a floor area of about 2,000 square metres will be needed. Such a building will cost about

256,000 RO (with useful life of 20 years for depreciation). Total cost of machines (depreciated over 10 years) will be about 100,000 RO. Product price is set at 140 RO, which is 17% higher than in Japan. Monthly profit and loss statements of this factory are shown on Table IV-11.

Table IV-11 Profit and Cost of Manufacture of $2m^3$ Water Tank

Total Sales		35,000 (R.O.)
Total Cost		30,250
Raw Material (Polyethylene) Cost	9,700	
Manufacturing Cost	13,550	
Equipment	1,650	
Labour (25)	8,750	
Utilities	500	
Repair	750	
Depreciation	1,900	
Management Cost (Interest, Administrative Cost)	7,000	
Gains (14%)		4,750

V. PETROLEUM AND RELATED INDUSTRIES

1. Petroleum Utilising Industries: Current Status and Potentials

Petroleum is the mainstay of the Omani economy, earning more than 80 percent of its foreign exchange receipts. Yet, Oman has no industry which uses this resource aside from electric power generation which partly uses crude oil as fuel. Crude oil will be replaced by natural gas upon the comissioning of the gas pipeline.

All petroleum products needed in Oman--regular and premium grade petrols (gasoline), aviation gasoline and JET-A-1 (civil aviation jet fuel) kerosene, light oil (diese fuel), heavy oil, lubricants, asphalt, and liquefied petroleum gas (LPG)--are imported and sold by Shell Markets (Middle East), Ltd. or BP Arabian Agencies Ltd. A certain portion of imported jet fuel and almost entire imported heavy oil are re-exported.

1) Demand and Marketing of Petroleum Products

Table V-1 presents petroleum products consumption statistics covering 1972 through 1977.

Table V-1 Consumption of Petroleum Products

	1972	1973	1974	1975	1976	1977
Premium motor gasoline	0.1	0.1	0.3	0.5	1.0	1.8
Regular motor gasoline	0.6	0.7	1.1	1.3	1.5	1.6
Light oil (Diesel Fuel)	0.9	0.9	1.4	2.6	4.6	4.0
JET-A-1 and kerosene	0.2	0.3	0.7	1.3	1.6	2.0
Total of distillate fuels	1.8	2.1	3.5	5.9	8.8	9.4
Heavy fuel oil	26.2	22.4	18.6	14.6	15.2	16.0
Total	28.0	24.5	22.1	20.5	24.0	25.4

(Notes) (1) Unit: 1,000 barrels/day 365 days/year

(2) Octane number of premium motor gasoline is 97.

(3) Octane number of regular motor gasoline is 90.

(4) The numbers are rounded at one decimal.

(Source) Statistical Yearbook and Ministry of Commerce and Industry

In view of the fact that heavy oil is a bunker fuel supplied to ocean going ships, the domestic demand of Oman for petroleum products has barely reached ten thousand barrels per day. The Omani Government forecasts increases in petroleum products demand as shown by Table V-2.

Table V-2 Estimated Demand for Petroleum Products

	1978	1979	1980	1981	1982	1983	1984	1985
Premium motor gasoline	2.5	3.2	3.8	4.3	4.8	5.2	5.7	6.0
Regular motor gasoline	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5
Light oil (Diesel Fuel)	4.8	5.5	6.2	6.8	7.5	7.8	8.2	8.7
JET-A-1 and kerosene	2.4	2.8	3.1	3.4	3.6	3.7	3.9	4.1
Total of distillate fuels	11.5	13.4	15.1	16.6	18.1	19.0	20.2	21.3
Heavy fuel oil	15.0	14.0	13.0	12.0	10.0	10.0	10.0	10.0
Total	26.5	27.4	28.1	28.6	28.1	29.0	30.2	31.3

(Notes) (1) Unit: 1,000 barrels/day 365 days/year

(2) Octane number of premium motor gasoline is 97.

(3) Octane number of regular motor gasoline is 90.

(4) The numbers are rounded at one decimal.

(Source) Ministry of Commerce and Industry

The shown forecast has been translated into annual growth rate over each previous year on Table V-3.

Table V-3 Rate of Increase in Demand for Petroleum Products

	1978/79	79/80	80/81	81/82	82/83	83/84	84/85
Premium motor gasoline	28	19	13	12	8	10	5
Regular motor gasoline	6	5	5	5	5	4	4
Light oil	15	13	10	10	4	5	6
JET-A-1 and kerosene	17	11	10	6	3	5	5
Total of distillate fuels	17	13	10	9	5	6	5
Heavy fuel oil	-9	-9	-9	-8	0	0	0

(Unit) Percent of increase compared to the previous year

(Source) JICA MISSION

It is predicted that the demands for distillate fuels -- motor petrols, kerosene, JET-A-1, and light oil -- will increase in volume but decrease in rate of growth. Of the distillate fuels, the forecast growth of the demand for premium grade petrol is conspicuous. After 1981 premium grade petrol will be consumed in more than twice the volume of regular petrol. Both grades of petrol are leaded. Light oil is used for many purposes, particularly for large motor vehicles, construction equipment, power generation. Growth in the demand for light oil will drop when natural gas comes to be used for power generation and industrial purposes in the Metropolitan area. Consumption of JET-A-1 will depend on the growth of civil aviation. Heavy oil is almost non-consumed within Oman but is supplied to ships as bunker fuel at Mina Al Fahal, Mina Qaboos, and Mina Raysut. The reason to the predicted decline in heavy oil may be supplied at other Gulf ports.

From 60 to 70 percent of distillate fuels other than JET-A-1 is sold by Shell Markets (Middle East) and the rest almost entirely by BP Arabian Agencies. Shell Markets covers the entire area of Oman and brings petroleum products except light oil from the Shell Depot in Dubai to Mina Al Fahal, Masirah Island, and Mina Raysut via coastal tankers of from 1,000 to 3,000 tons. Light oil is imported directly from refineries on the Gulf coast and in Iran. Arabian Agencies also brings their products directly from refineries in Iran.

2) Petroleum Products Prices

Petroleum products prices upon arrival to Oman are estimated as shown by Table V-4.

Table V-4 Import Prices of Petroleum Products

	Baiza/litre	US$/ton
Premium motor gasoline	46	-
Regular motor gasoline	42	-
Light oil	39	-
JET-A-1 and kerosene	42	-
Heavy fuel oil	-	70

(Note) 1,000 baiza = 1 Oman Rial = US$3.0

(Source) JICA MISSION

The above estimated import prices are considered right when compared with the retail prices of the products at service stations in the vicinity of Muscat which are presented on Table V-5.

Table V-5 Retail Prices of Petroleum Products

	Baiza/litre
Premium motor gasoline	60
Regular motor gasoline	56
Light oil	50
JET-A-1 and kerosene	50

(Source) JICA MISSION

3) A refinery Project and its Pre-feasibility Study

Oman currently depends on imports for the supply of all petroleum products which it consumes, as pointed out earlier. In view of the current level of demand of 10,000 barrels per day, a refinery projects is not considered feasible if based solely on the domestic markets. The forecast 1985 demand of 21,300 barrels per day of distillate fuels and 31,300 barrels per day of all petroleum oils may, however, be regarded as large enough to warrant investigation into the feasibility of a refinery of an economic scale.

There appears neigher a definite plan nor has a feasibility study been conducted for construction of a refinery by the Government or private firms though proposals for feasibility study have been submitted to the Government by several companies including PDO. Nevertheless, construction of a refinery is one of the most talked-about projects in Oman.

Two types of refinery can be conceived of for Oman: One is what is generally called refinery with a complete line of facilities for the production of all products covering premium and regular grades of petrol, light oil, JET-A-1, kerosene, and heavy oil, and the other is what might be called a topping plant to be equipped with a crude distillation unit and minimum facilities for the production of only light oil, JET-A-1, kerosene and heavy oil but not petrol.

The Japanese Government Mission mentioned in the Interim Report which the mission submitted on the last day of the stay in Oman that the mission would conduct a preliminary evaluation of a refinery as presented on the subsequent several pages.

It should be noted here that the purpose of the preliminary evaluation is not to establish feasibility of the refinery project but to survey some of the important factors that may affect the feasibility of the project and thereby to measure the degree of the possibility of the project becoming feasible and also to indicate what are the most crucial problems that must be solved by the feasibility study. Therefore, as will be seen in the following discussions, this preliminary evaluation will not definitely show whether the project is feasible or not but will point out the central problems that will need more investigation if the refinery project is to be further studied.

(1) Factors affecting the Feasibility of Refinery

The following factors will affect the economic and technical feasibility of a refinery and will be evaluated by this preliminary evaluation: (a) The availability and quality of feed stock, (b) the size of domestic demand for petroleum products (feasibility of a refinery for export purposes is not considered), (c) the availability of a suitable site for the refinery and quality and of the natural and social environment of the site, (d) the quality and capacity of infrastructure (including utilities) available at the site, (e) the availability of manpower and technology, (f) the technical reliability of the processes to be used, (g) the price and quality competitiveness of the products, and (h) the returns of investment.
These items will be discussed below.

i) Feed Stock

The Oman crude oil produced by PDO in the northern region is satisfactory as feed stock both in terms of quality and, for the time being, quantity. While additional investigation will be necessary in order to determine whether the Omani demand for petroleum products will be better met by processing only Omani crude oil or by processing a blend of Omani crude and crude oils from other neighbouring source(s), this preliminary evaluation assumes the refining of only Omani crude oil. Raw materials other than crude oil can almost be ignored for the purpose of evaluation. It may be concluded that this item--the availability and quality of feed stock--is satisfied.

ii) Domestic Demand

A government demand forecast on which we base this preliminary evaluation puts the 1985 demand at 21,300 barrels per day for distillate fuels and 31,300 barrels per day for all petroleum oils. Considering all preparatory works that will be required before the refinery is placed onstream, the 1985 demands may be considered right as basis for the determination of the capacity of the refinery. As will be shown later, the 1985 demands would justify a refinery of an economic size; and therefore, this item is considered fulfilled.

iii) Site

A site which will support a refinery with a capacity of about 50,000 barrels per day is available in Mina Al Fahal, which is now being used as a port for the shipment of crude oil and for the importation and domestic distribution of petroleum products. Mina Al Fahal now has such facilities as single buoy moorings for crude and heavy oil tankers, the jetties for the importation and distribution of petroleum products, six 300,000-barrel crude oil tanks, one 900,000-barrel crude oil tank, several petroleum products tanks, buildings, and material storage facilities. Most of these facilities may be used for the same purposes after the construction of a refinery, although some of them will have to be relocated within Mina Al Fahal and a few of them may have to be moved to outside Mina Al Fahal. The relocations of the facilities can be limited to a minimum and would not constitute a major constraint.

As long as only Omani crude oil is to be refined, no crude oil receiving facilities will be necessary except for an additional crude service tank with a capacity of about 150,000 barrels. Products of the refinery can be handled and shipped using the existing tanks and the jetties though slight modification or expansion of the facilities may be required.

While the soil and marine conditions and other natural conditions of Mina Al Fahal will have to be investigated in detail as a part of a feasibility study if the refinery project is to be further promoted, it may be safely assumed at this preliminary stage that these natural conditions would not present serious constraints.

iv) Infrastructure

Mina Al Fahal may be easily approached by sea and by road. Mina Al Fahal is connected with the Muscat-Seeb Airport Trunk Road via a feeder road of sufficient width which will facilitate transportation to and from Mina Al Fahal of the materials and manpower needed for the construction and operation of the refinery and shipment of the products. Another advantage associated with locating the refinery at Mina Al Fahal is availability of such urban functions in and around Muscat, Mutrah and Ruwi as hospitals, schools, supermarkets, shops of various commodities, banks, insurance companies, telephone and telegraph services, international and domestic airlines, hotels and so forth. Availability of these conveniences would constitute a significant advantage compared to locating a refinery in a place where no such facility exists.

If expansion of the existing jetties is needed, there is adequate room in Mina Al Fahal. Electric power, steam, water and other utilities essential to refinery operation can be supplied by the addition to the refinery of power generators, boilers, sea water desalination units and cooling towers of adequate capacities. As for fuel, refinery off gas and heavy oil produced by the refinery itself are usually used. If natural gas is preferred for economic consideration, natural gas may be obtained by laying a pipeline from Al Ghubra. Currently, utilities do not exist in adequate quantity for refinery operation in this area. However, this is not considered to constitute a major constraint because utilities may be easily made available once a refinery is constructed.

v) Manpower and Technology

In absence of petroleum refining industry and other similar process industries in Oman, it is believed that this nation does not possess a sufficient number of experienced engineers capable of refinery basic planning, technical evaluation, process selection, designs, equipment and materials procurement, construction, operation, and so forth.

As for storage, transportation and marketing of petroleum products, a number of Omanis in Shell Markets and BP Arabian Agencies have presumably had enough experience. It is questionable however whether the new refinery and associated marketing operation can secure sufficient experienced manpower. Therefore, establishment of an oil refinery in Oman will depend appreciably on experienced expatriates. These people are not difficult to obtain but costly.

vi) Refining Process

The necessary refining facilities will include a crude oil distillation unit, light straight-run sweetening plant, heavy straight-run pretreater and reforming unit. JET-A-1 and kerosene sweetening plant, and LPG recovering unit; neither light and heavy oil desulphurisation unit nor hydrogen plant is needed. The necessary utilities will require power generation, boiler, desalination, and cooling tower facilities. The off-site facilities will be a service tank for crude oil and products tanks, as well as shipping, fire fighting, and waste water treating facilities. The construction of all of these facilities will not involve technical difficulties.

Only those processes and facilities whose technical reliability has been proven can be selected for this refinery project. Problems may be in securing enough well experienced and capable manpower and also in the maintenance of communications and coordination among people of different nationalities, cultural backgrounds, and languages.

vii) Competitiveness

As far as the qualities of the products are concerned, the facilities mentioned under vi) above, if combined with satisfactory management and operation of the refinery, will produce products of acceptable quality.

A question which must be seriously examined is the price competitiveness of the products from the planned refinery with imported products. The forecast demands for petroleum products in Oman of 30,000 barrels per day will constitute a very small portion of the entire refining capacity in the Arabian Gulf and Iran; and consequently, the Omani demand may easily be supplied from these neighbouring countries without causing any strain in the supply of petroleum products in this area. Supply capabilities in Arabian Gulf countries and Iran are shown on Table V-6.

The predicted surplus in supply capacity will become even greater if the following refineries for export purposes actually start operation by 1985. (See Table V-7).

Table V-6 Capacities of Refineries and Demand for Petroleum Products in the Gulf Countries

Countries	Capacity of Refinery (1,000 barrels/day)			Estimated Demand for Petroleum Products in 1985 (1,000 barrels/day)
	Present capacity	Planned capacity under construction	Total	
Bahrain	781	449	1,230	850
Iraq	169		169	200
Kuwait	685		685	150
Qatar	9		9	
Saudi Arabia	603	214	817	600
United Arab Emirates	15	120	135	50
Oman	0	0	0	30
Total	2,262	783	3,045	1,880

(Source) International Petroleum Encyclopedia 1977

Table V-7 Construction Projects of Oil Refineries for Export in the Gulf

Countries	Site	Capacity (1,000 barrels/day)
Iraq	Basra	300
Saudi Arabia	Al Jubayl	250
	Yanbu	500
Kuwait	Shaiba	250
Iran	-	500

(Source) JICA MISSION

In view of the above, the price competitiveness of the petroleum products from the Omani refinery vis-a-vis the products of these large scale refineries in the neighbouring Gulf nations should be fully investigated as a part of the feasibility study.

viii) Profit

While there is a wide range of production capacity that may be considered for the refinery, 50,000 barrels per day capacity has been selected for the purpose of this preliminary evaluation. The economy of investment will be evaluated in terms of internal rate of return (IRR). At this capacity the nation will still have to import quite a volume of petroleum products while on the other hand surplus products to be exported are even more. This is attributable to the disproportionately large demands for distillate fuels.

If the capacity is increased to 60,000 barrel per day to meet more of the domestic demand, as much as 47 percent of the products will have to be exported based on the forecast 1985 demands. If the capacity is decreased, say to 30,000 barrels per day, there will be a larger economic penalty. Besides, more of such essentially important products as petrol and light oil must be imported. This is the reason why 50,000 barrels per day capacity has been selected, even though the selection of this capacity will result in the production of 37 percent of surplus products that will have to be exported.

On Table V-8 are shown surplus and deficits of the products in the cases of 29, 50 and 60 thousand barrels per day capacities.

Table V-8 Products Surplus and Deficit at Various Refinery Capacities

	Demand is 1985	Yield/Omani Crude Oil		Maximum Refinery Capacity (BPCD)			Minimum Refinery Capacity (BPSD)			50,000 BPSD Refinery		
	(BPCD)	wt %	vol.%	Production	Surplus	Deficit	Production	Surplus	Deficit	Production	Surplus	Deficit
Gas		0.35										
LPG		1 53	2 40	1,440	1,440	0	703	703	0	1,084	1,084	0
Motor gasoline	8,500		14.3	8,500	80	0	4,188	0	4,312	6,464	0	2,036
Jet-A-1 and Kerosene	4,100		14.0	8,400	4,300	0	4,100	0	0	6,329	2,229	0
Light oil	8,700		14.5	8,700	0	0	4,246	0	4,454	6,555	0	2,145
Heavy oil	10,000		52.5	31,500	21,500	0	15,375	5,375		23,733	13,733	
Total	31,300			58,620	27,320	0	28,612	6,078	8,766	44,165	17,046	4,181
Omani crude oil				60,000			29,286			45,205		

(Source) JICA MISSION

Table V-9 presents net profit/loss computation for a 50,000-barrel/day refinery at current crude oil and products prices, together with a sensitivity analysis for a 5% downward fluctuation of the prices of all products conducted to show the economic impacts, should predicted surplus supply capacities in the Gulf nations result in a decline of such prices.

Table V-9 Net Profit/Loss of 50,000-Barrel/Day Refinery

	Based on Current Price					Sensitivity Analysis		
	A Production (barrel/day)	B Production (1,000bls/year)	C Price (US$/barrel)	D Sales (Million US$)	E Profit (US$/BBL)	C' Price (USR/barrel)	D' Sales (Million US$)	E' Profit (USR/BBL)
LPG	1,084	396	11.2	4.44		10.6	4.22	
Premium motor gasorine	4,563	1,665	21.9	34.46		20.8	34.64	
Regular motor gasorine	1,901	694	20.0	13.58		19.0	13.19	
JET-A-1 Kerosene	6,329	2,310	20.0	46.20		19.0	43.88	
Light oil	6,555	2,393	18.6	44.51		17.7	42.28	
Heavy oil	23,733	8,663	11.3	97.89		10.7	93.00	
Total	44,165	16,121	Av=15.10	243.38		14.3	231.21	
	Consumption (barrel/day)	Consumption (1,000bls/year)	Price (US$/barrel)	Material Cost (Million US$)			Material Cost (Million US$)	
Crude oil	45,205	16,500	13.0	214 50				
Fuel gas	1,130	413	6.5	2.68				
(converted to oil volume)				217.18			217 18	
Sales (gross)				26.20	1.58		14.03	0.85
Operation cost				6.90			6.90	
Net profit				19.30	1.16		7.13	0.43

(Source) JICA MISSION

Nets, internal rates of return have been computed for the following six cases as shown on Table V-10:

Case I: Investment, 50 million dollars; products prices, as currently preveiling; project life, 10 years.

Case II: Investment, 50 million dollars; products prices, 95% the currently preveiling prices; project life, 10 years.

Case III: Investment, 40 million dollars; products prices, as currently preveiling; project life, 10 years.

Case IV: Investment, 40 million dollars; products prices, 95% the currently preveiling prices; project life, 10 years.

Case V: Investment, 60 million dollars; products prices, as currently preveiling; project life, 10 years.

Case VI: Investment, 60 million dollars; products prices, 95% the prices currently preveiling; project life, 10 years.

Table V-10-1 Internal Rate of Return (Case 1, Case 2)

Year	Case 1 Investment MM US$	Case 1 Revenue MM US$	Case 1 Rate of Return DCF 28%	Case 1 Rate of Return DCF 29%	Case 2 Investment MM US$	Case 2 Revenue MM US$	Case 2 Rate of Return DCF 5%	Case 2 Rate of Return DCF 6%
0	(10)		1.0000	1.0000	(10)		1.0000	1.000
1	(20)		0.7813	0.7752	(20)		0.9524	0.9434
2	(20)		0.6104	0.6009	(20)		0.9070	0.8900
3		19.30				7.13		
4		"				"		
5		"				"		
6		"	1.9952	1.9098		"	7.0038	6.5505
7		"				"		
8		"				"		
9		"				"		
10		"				"		
11		"				"		
12		"				"		
Present value (MMUS$)			0.6734	-0 6629			2.7491	0.0371

(Source) JICA MISSION

Table V-10-2 Internal Rate of Return (Case 3, Case 4)

Year	Case 3 Investment MM US$	Case 3 Revenue MM US$	Case 3 Rate of Return DCF 35%	Case 3 Rate of Return DCF 34%	Case 4 Investment MM US$	Case 4 Revenue MMUS$	Case 4 Rate of Return DCF 10%	Case 4 Rate of Return DCF 11%
0	(8)		1.0000	1.0000	(8)		1.0000	1.0000
1	(16)		0.7407	0.7463	(16)		0.9091	0.9009
2	(16)		0.5487	0.5569	(16)		0.8264	0.8116
3		19.30				7.13		
4		"				"		
5		"				"		
6		"	1.4897	1.5502		"	5.0782	4.7798
7		"				"		
8		"				"		
9		"				"		
10		"				"		
11		"				"		
12		"				"		
Present value (MMUS$)			0.1208	1.0677			0.4396	-1.3200

(Source) JICA MISSION

Table V-10-3 Internal Rate of Return (Case 5, Case 6)

Year	Case 5 Investment MM US$	Case 5 Revenue MM US$	Case 5 Rate of Return DCF 23%	Case 5 Rate of Return DCF 34%	Case 6 Investment MM US$	Case 6 Revenue MM US$	Case 6 Rate of Return DCF 2%	Case 6 Rate of Return DCF 3%
0	(12)		1.0000	1.0000	(12)		1.0000	1.0000
1	(24)		0.8130	0.8065	(24)		0.9804	0.9709
2	(24)		0.6610	0.6504	(24)		0.9612	0.9426
3		19.30						
4		"						
5		"						
6		"						
7		"	2.5112	2.3945		"	8.6338	8.0405
8		"				"		
9		"				"		
10		"				"		
11		"				"		
12		"				"		
Present value (MMUS$)			1.0902	-0.7518			2.9606	-0.5952

(Source) JICA MISSION

The internal rates of return on various investments studied in Case I through VI are summarized on Table V-11.

Table V-11 Internal Rate of Return of Each Case

Investment	Based on present prices of products	Based on 95% of present prices of products
50 M. US$	28.5% (Case 1)	6.0% (Case 2)
40 M. US$	35.1% (Case 3)	10.2% (Case 4)
60 M. US$	23.6% (Case 5)	2.9% (Case 6)

(Source) JICA MISSION

Note that the product prices and crude oil cost employed in the evaluation are 1978 current prices and cost. In order to be consistent, the refinery construction cost is estimated on 1978 onstream base. It is extremely difficult to foresee prices and costs of the future and this is where subjective judgements by individuals often affect the conclusions. To prevent such subjective judgement from affecting the evaluation, use of projected prices or costs in 1985 or onwards is avoided.

The results of the above case study may be taken to indicate, though very preliminary at this stage and subject to modification when more definite estimates are made, that if the total investment is held below 60 million dollars on the present cost base, there is possibility of the refinery project becoming economically feasible. This does not necessarily indicate that the refinery project become economically feasible at future prices and costs. All that may be derived from the above result is that the possibility of the refinery project becoming economically feasible does exist and therefore worth further investigation by a feasibility study if the refinery project is to be taken up.

Also, it should be noted that fluctuations in the amount of investment and in products prices will substantially affect the internal rate of return. Particularly with regard to products prices. Developments in the large refinery projects in Gulf nations and Iran will have a great influence and therefore should be carefully watched.

(2) Summary of Refinery Project

The factors affecting the feasibility of the refinery project in Oman that were discussed above can be summarized as follows:

Feed Stock: Crude oil supply of an acceptable quality can be secured from the domestic sources in an adequate quantity;
Domestic Demand: A demand which will support a refinery will develop in Oman by 1985;
Site: A site of acceptable natural environment is available in Mina Al Fahal;
Infrastructure: The existing facilities of Mina Al Fahal must be expanded as needed, and the electric power, water, and other utilities;
Manpowre and Technology: The refinery must depend on expatriates for management and know-how;
Refining Process: Technically proven processes may be employed;
Competitiveness: Products will be competitive in quality. Competitiveness of the products in price with imported products must be further examined, particularly in regard to the forecast surplus of the products in the Gulf area;
Profit: Unless said supply surplus will result in the decline of products prices

there is good chance of the refinery project found economically feasible by a feasibility study.

The results of the tests by the above items are generally favourable. But the feasibility of such a refinery should be fully investigated based on carefully estimated future prices in a complete feasibility study. Overall net national benefit to be expected of the construction of a 50,000-barrel/day refinery should be weighed against the continued importation of products from large refineries in neighbouring Gulf nations.

2. Gas-Utlising Industries: Current Status and Potentials

Natural gas occurs in Oman in the form of both associated gas and gas field gas. The major gas field is located in the vicinity of Yibal, the size of which is estimated to be able to support the production of 140 MMSCFD of natural gas for a period of 80 years (MMSCFD stands for one million cubic feet per day at 15°C under one atomospheric pressure). A 2-inch pipeline has been installed between Yibal and Al Ghubra. The capacity of the pipeline is 140 MMSCFD without the use of a compressor and 320 MMSCFD with the use of compressors. The installation work was in the final stage when the Mission conducted the survey in March. Together with the installation of the pipeline, facilities were constructed in Yibal for recovery of liquefied petroleum gas (LPG) and natural gasoline (NGL) from natural gas.

The completion of the above gas pipeline has made a cheap industrial energy available in the Metropolitan area, which may be counted as additional advantage to industrialization of Oman. The power plant (78-MW) in Al Ghubra will start using about 20 MMSCFD of natural gas in 1978, which will be only about 15 percent of the supply capacity of 140 MMSCFD.

Some of the more important industries which have been considered for establishment in Oman based on the natural gas resource are production of ammonia and urea, production of cement, smelting of copper and production of reduction iron. If a refinery is constructed it can burn natural gas instead of fuel oil. The approximate volumes of gas these industries would consume are estimated as shown on Table V-12.

Table V-12 Estimated Amount of Consumption of Natural Gas

Industry	Production capacity	Demand for Natural Gas (MMSCFD)
Refinery	50,000 BPSD	10
Ammonia	1,000 T/D	40
(Urea)	(1,700 T/D)	
Power station	200 MIV	50
Cement	1,000,000 T/Y	15
Reduced iron	400,000 T/Y	20
Copper refinery	20,000 T/Y	5
Total		140

(Source) JICA MISSION

The pipeline, with the maximum capacity of 320 MMSCFD, is fully adequate to support the above industries and a number of other small scale gas-using industries.

1) Gas-Using Petrochemical Industries

A preliminary evaluation has been conducted as described below of the feasibility of petrochemical industries to produce ethylene and their derivatives by cracking of ethane that may be obtainable by extraction from the natural gas stream.

(1) Feeder Stock Supply

The first thing that must be done is to determine whether the natural gas stream contains enough ethane and heavier hydrocarbons to support an ethylene plant of a commercial size. Table V-13 below (or the next page) gives an assumed composition in mole percentage and the amount of each component contained in 100 MMSCFD gas in terms of thousand ton per year.

It is now generally accepted, though there are many exceptions, that an ethylene plant should be sized at 300 to 500 thousand product tons per year in order to be economically viable. If Oman is to build a 150 thousand ton plant at some economic penalty, the plant would need about 200 thousand tons of ethane as feed. In order to provide a natural gas stream large enough to permit extraction of 200 thousand tons per year of ethane, as may be noted from Table V-13,

Table V-13 Elements of Natural Gas

Element	Molecular formula	Mole %	1,000 ton/year*
Methane	CH_4	80.9	512
Ethane	C_2H_6	8.0	95
Propane	C_3H_8	4.5	79
Iso butane	C_4H_{10}	0.57	14
Normal butane	C_4H_{10}	0.68	15
Iso pentane	C_5H_{12}	0.07	2
Normal pentane	C_5H_{12}	0.05	1
Hexane	C_6H_{14}	0.01	-
Nitrogen	N_2	4.5	5
Carbon dioxide	CO_2	0.7	12
Total			735

* Operated for 330 days a year

(Source) JICA MISSION

there must exist an industrial gas demand as large as 200 MMSCFD, which is not very likely to develop in the near terms. To sum up, extraction of ethane from the natural gas stream would not provide enough ethane needed for cracking. Technically speaking, it is possible to add propane, isobutane, n-butane and NGL to the cracker feed; however, it would be more lucrative to sell these hydrocarbons as LPG and NGL.

The above discussion has been based on an assumption of 8.0 mole percent content of ethane in natural gas. Any lower content of ethane, which will be very likely the case, will lower the supply of ethane or require a larger industrial gas demand.

(2) Saudi Arabian Petrochemical Plan

Saudi Arabia has projects for three large scale petrochemical complexes as shown in Table V-14 all scheduled to start around 1982/83. The capacities of these complexes are all very large with an aggregate ethylene production capacity

Table V-14 Petrochemical Industrial Projects in Saudi Arabia

Promoter	Site	Production of Ethylene (ton/year)	Production of Derivatives (ton/year)	
SABIC*/Shell	Al Jubayl	656,000	Low-density polyethylene	240,000
			Styrene	295,000
			Ethylene dichloride	454,000
SABIC/Mobil	Yanbu	450,000	Low-density polyethylene	200,000
			Ethylene glycol	200,000
			Styrene	320,000
SABIC/DOW	Al Jubayl	400,000	Low-density polyethylene	200,000
			Ethylene glycol	300,000

* SAUDI ARABIAN BASIC INDUSTRIES CORP.

(Source) OIL & GAS JOURNAL, March 6, 1978

of about one and half million tons a year. These petrochemical plants will feed plentifully available ethane extracted from associated gas which would otherwise have to be disposed of as low-priced industrial fuel. The Sabic/Shell plant is scheduled to start in 1982. Shell will market the products mainly in the United States and Europe. The Sabic/Mobil and Sabic/Dow plants will start in 1982.

Under such circumstances where there will be a large supply capacity in Saudi Arabia while the demands for petrochemical products are forecast to be low as are at present, an attempt to establish a similar but smaller petrochemical complex in Oman would not make economic sense.

(3) Summary of Conclusion

The discussion so far presented may be summarized as follows:

a) The supply of ethane as raw material may not be sufficiently available from the natural gas stream. Use of propane, butane or NGL as feed is technically possible but not economically desirable.

b) The large scale petrochemical complexes scheduled to start around 1982/83 in Saudi Arabia would make the smaller Omani project less competitive.

c) There is virtually no industry in Oman which depends on ethylene or its derivatives. When the demands for finished products like polyvinyl chloride or polyethylene pipes and other plastics products have grown large enough, small or medium scale industries which process imported polymers may be established. If these processing industries should become large enough, upstream industries may become worthy of consideration.

There are many other problems which must be given serious consideration in association with establishment of petrochemical industries. These include huge capital outlays, difficulties associated with operation of the facilities and marketing of the products, inflexibility of operation, etc. No doubt petrochemical complex would create a large employment opportunity. Whether this is a possible contribution to Oman is questionable when Oman is dependent on many expatriates. Conversely, petrochemical industry would freeze many capable Omanis in the management of the complex who ought to have many other roles to play to promote the developments of other sectors.

2) Liquefied Natural Gas Industry

The United States, Europe and Japan are great importers of liquefied natural gas (LNG). Today, commercial LNG projects are sized more than two and half million tons per year which require about 500 MMSCFD of natural gas stream. As was stated before the natural gas resource of Oman is capable of supplying 140 MMSCFD over a period of 80 years. For the sake of simplicity, let a very simple and rough assumption be made that four times as much gas as 140 MMSCFD would be produced but production would last for a quarter period: that is to say, 500 MMSCFD gas is produced for about twenty years.

This would indicate the possibility of two and a half million ton per year of LNG project for twenty years. This would also mean that at the end of twenty years the natural gas reserve will have been depleted. It would not be, in the opinion of the Mission, in the best interest of Oman to execute one large project and exhaust all the resource on it. The natural gas resource of Oman should be utilized in such a manner as to make a best conceivable contribution to the industrialization of the nation. The natural gas should be supplied to various industries, including small and medium sized industries, at a price low enough to provide sufficient incentive to the establishment and development of many industries.

3) Manufacturing of Ammonia and Urea

A feasibility study was made in 1974 of a project consisting in the production of 2,000 tons of ammonia and covering about half of the produced ammonia into 1,500 tons per day of urea. There has been keen interest in this project although the project has been shelved since then. About 40 MMSCFD of natural gas is required for the production of 1,000 tons per day of ammonia, which in turn will produce about 1,700 tons per day of urea. At the present level of technology, both 1,000 tons per day of ammonia and 1,700 tons per day of urea per single train are considered economic. If Oman installs one or two 1,700 tons per day trains, Oman will produce as much as 560 or 1,100 thousand tons per year urea.

Let us now turn to the question of manufacturing ammonia and urea in Oman. Technology has been established for the production of both ammonia and urea. There will be a stable and dependable supply of raw material which is the natural gas stream. There is, however, virtually no domestic demands for the products; and therefore, almost entire products will have to be exported. The crucial point is, consequently, whether the manufactured products will be exported at prices and in quantities sufficient to support the economics of the project.

Our forecast indicates that the worldwide supply and demand of nitrogenous fertilizers will be balanced in 1985. However, we foresee a considerable supply surplus in the areas that would be tributary to the Oman ammonia/urea project as shown on Table V-15; these areas include South Asia -- Afghanistan, Bangla Desh, Pakistan, Sri Lanka, India, etc. --, West Asia -- Iran, Iraq, Kuwait, Qatar, Saudi Arabia, Turkey, Israel, Syria, etc. -- and entire Africa.

Table V-15 Demand and Supply of Nitrogen for Fertilizer in the World

	Supply	Demand	Balance
World	26.2	26.2	0
South Asia	5.9	6.1	-0.2
West Asia	3.1	1.8	1.3
Africa	0.8	1.0	-0.2
Total of above 3 areas	9.8	8.9	0.9

(Unit) Million nitrogen ton

(Source) JICA MISSION

The predicted 900,000-ton surplus in South and West Asia and Africa corresponds to 3,300-ton/day in terms of ammonia plant capacity. Under these circumstances it is of vital importance to secure a sure market before the project is committed in order to successfully implement the project. There will be immeasurably great risks in attempting to sell the products in the competitive international market.

3. Summary

As a summary of this chapter the results of the preliminary evaluations of oil refinery, petrochemical complex to manufacture ethylene and its derivatives, natural gas liquefaction, and ammonia/urea production will be briefly presented below.

1) Oil Refinery

The preliminary evaluation of a 50,000 barrels per day refinery starting in 1985 indicates that the greatest problem that would conceivably be encountered is the forecast surplus of petroleum products in the Gulf area. Therefore, a feasibility study should include a study on the effect of the competition with imported products from other refineries in the Gulf nations on the economics of the project.

2) Petrochemical Industry

Cracking of ethane extracted from natural gas to produce ethylene and its derivatives is not recommendable, because: (1) ethane contained in the natural gas stream will probably be insufficient to support a commercial scale cracking plant, (2) the planned Saudi Arabian projects with a total capacity of 1.5 million tons of ethylene per year would make the Oman project comparatively less competitive, and (3) the employment opportunity to be created would not make a positive contribution to the nation when the nation is heavily dependent on imported labours.

3) Natural Gas Liquefaction

The implementation of a commercial LNG would result in the exhaustion of practically all natural gas resource in Oman leaving very little for Omani industrialization. Therefore, the project is not recommended.

4) Ammonia/Urea Manufacturing

This project should not be implemented unless secure markets have been obtained under long-term arrangements at product prices good enough to make the project viable.