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KUWAIT.

Technical report:
GLASS FIBRE PRODUCTION

Prepared for the Government of Kuwait by the
United Nations Industrial Development Organization,
executing agency for the
United Nations Development Programme

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INDUSTRIAL DEVELOPMENT AND

CONSULTING BUREAU

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Based on the work of S. M. Cox, glass expert

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Explanatory notes

The monetary unit of the State of Kuwait is the dinar (KD), which is divided into 1000 fils. During the period covered by this report, the value of the Kuwaiti dinar to the United States dollar was KD 1 = $3.30.

A full stop (.) is used to indicate decimals.

A comma (,) is used to distinguish thousands and millions.

References to "tons" are to metric tons.

The following forms have been used in tables:

A dash (-) indicates that the amount is nil or negligible.
A blank indicates that the item is not applicable.

Totals may not add precisely because of rounding.

The following abbreviations are used in this publication:

FRP	fibre reinforced plastics or products
GFRP	Glass fibre reinforced plastics
IBK	Industrial Bank of Kuwait
LPG	liquefied petroleum gas
PVC	polyvinyl chloride
RGF	reinforcing glass fibre

The following technical abbreviations are used in this publication:

c.i.f.	cost, insurance and freight
f.o.b.	free on board
kWh	kilowatt hour
μ (Greek mu)	micron (10^{-3} mm)
rev/min	revolutions per minute
tons/day	tons per day

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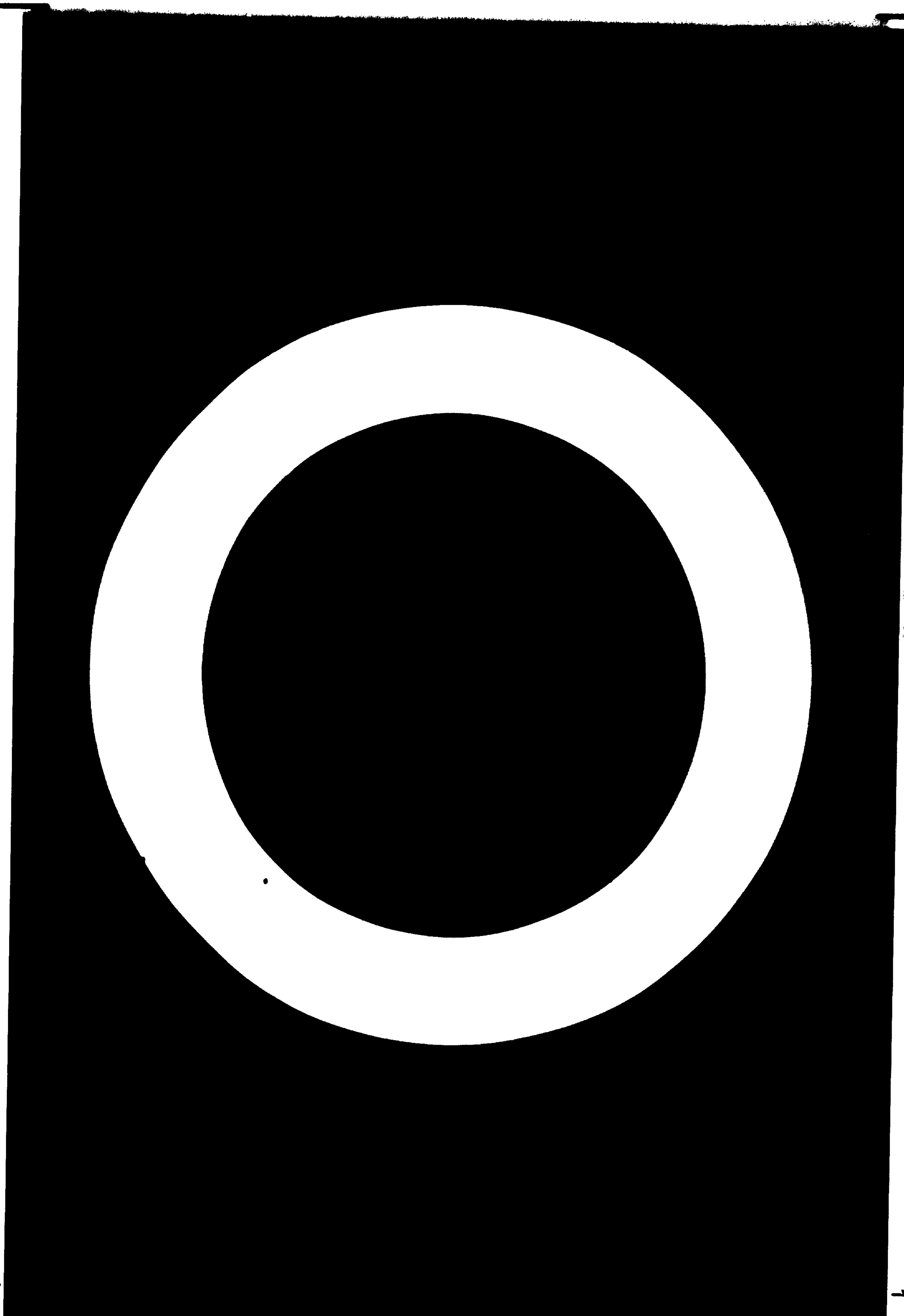
ABSTRACT

This is the report of a mission to Kuwait undertaken as part of the project "Industrial Development and Consulting Bureau" (DP/KUW/71/507) of which the United Nations Industrial Development Organization (UNIDO) is the executing agency. This one-month mission (8 August to 7 September 1976) was undertaken to study the feasibility of making both glass wool for insulating products and continuous glass fibre for reinforcing plastic. It has shown that both should be viable operations in Kuwait provided that investment costs are limited to those actually necessary.

Despite the initial need to import most of the raw materials, manufacturing costs should be comparable to those in Europe; therefore the potential for export is very good. However, the first stage of the project recommended may be limited in output to that which can be absorbed by the domestic market, so that skills and know-how can be established before commitment to greater capital expenditure.

The need to minimize capital investment and its influence on operating cost lead to the recommendation that both manufactures should be operated at a common site with common administration and technical services. It also means, however, that implementation by turn-key contract is unlikely to be feasible, and that it may have to be done by consultants acting as advisers on behalf of the proposed company.

A proposed layout of such a plant is presented and recommendations concerning its financing, staffing and operation are made.



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INTRODUCTION

This is the report of a one-man mission that was sent to Kuwait as part of the United Nations Development Programme (UNDP) project "Industrial Development and Consulting Bureau" (DP/KUW/71/507), of whioh the United Nations Industrial Development Organization (UNIDO) is the exeouting agency. It extended from 8 August to 7 September 1976, and it was undertaken to determine the feasibility of manufacturing, in Kuwait, both glass wool for insulation products and continuous glass fibre for reinforoing plastics. It is shown that both of these operations should be viable provided that investment costs are limited to those actually necessary.

Several small factories exist in Kuwait and the neighbouring countries for the manufacture of such items as water tanks, boats and furniture, utilizing glass fibre reinforced plastics (GFRP). The fibre must now be imported, as are substantial quantities of insulating materials and other products that are either made of glass fibre or might be substituted by it. These industries have high growth rates and, if glass fibre making oould be established as a viable industry in Kuwait, their growth rate would be accelerated, substitution of imports would be achieved and exports to neighbouring oountries oould beoome important faotors.

A licence to manufacture glass fibre has already been sought by the Industrial Bank of Kuwait (IBK), which has been aotively investigating the implementation of suoh a project. This bank was therefore oontaoted early in the assignment; it welcomed this parallel work and afforded great assistanoe by disclosing its appraisals.

I. THE NATURE AND USES OF GLASS FIBRE

The nature of glass

At ordinary temperatures glass is an extremely rigid solid and yet completely amorphous, so that in texture, or rather lack of texture, it is more like a liquid and is sometimes spoken of as a supercooled liquid. It is usually transparent, a fact of major importance in many of its uses but of little consequence where, as in the present case, it is attenuated into fibrous form.

An outstanding feature of glass is that it exhibits no sudden melting point but rather changes slowly from a rigid solid to a viscous liquid as the temperature is raised to high values. This characteristic is of great technological importance because it permits the glass to be shaped in a number of different ways, as by blowing, pressing or drawing over a range of temperatures that will be referred to as the working range. There is a limit to the time for which the glass can be held at certain critical temperatures within the working range because of the inherent tendency of glass to "devitrify", that is, for crystalline species of certain components of its composition to settle out, so that the material loses its amorphous nature and its working characteristics causing the articles made from it to be friable and useless.

Common glasses are composed of oxides and, to an overwhelming extent, depend upon the glass-forming properties of silica (silicon dioxide - SiO_2). Not only is silica (quartz) sand one of the most abundant materials, but the properties of pure fused silica are exceptional in that articles made from it are extremely resistant to thermal shock and chemical attack. Unfortunately, pure silica is very difficult to melt in ordinary glass-melting furnaces. Also, to use it to produce articles free from defects, it is necessary to add fluxes, usually sodium oxide (Na_2O) added as soda ash (Na_2CO_3), to make the melt more fluid. Calcium oxide (CaO), as calcium carbonate or limestone, is also added to achieve the best trade-off for obtaining an easily melted glass without too great a loss of the excellent properties of pure fused silica. Thus, most common glasses, such as window glass and bottles, are soda-lime-silicate glasses consisting of about 15% Na_2O, 11% CaO and 70% SiO_2, the remaining 4% being oxides either specifically added to improve physical properties or a consequence of using available raw materials that happen to contain them.

The wide working range of these glasses is such that a rod of them, when heated to soften it, can be drawn out to a thin fibre, the limiting diameter of which is determined by speed of the drawing operation, for the thin fibre soon chills until it is too stiff to elongate further. The technological importance of such fibres depends on the fact that, as long as their surfaces are not damaged, they have a tensile strength about 100 times greater than that usually associated with glass in its massive form. If they are thin, they also are flexible and can be handled on ordinary textile machinery, and indeed can be put to most of the uses of natural textile fibres, but with the added advantages that the substance is an inert inorganic material capable of withstanding high temperatures. The tensile strength of glass fibre yarns is about twice that of cotton yarns and about six times that of wool yarns. Moisture absorption is negligible (0.3% for glass; 7% for cotton; 13% for rayon). Its impervious nature makes it impractical to colour fabrics of glass fibre by dying, which limits its usefulness for ordinary clothing, but woven glass-fibre tapes and cloth are widely used in electrical insulation.

Resistance to chemicals and, particularly, to atmospheric moisture is the consideration that usually receives most attention in the choice of glass composition. In their massive form, all of the glasses shown in table 1 would be rated as having adequate chemical resistance for use as glass containers, for example. However, what is tolerable in massive glass may be unacceptable in fine fibres, where a slight surface crack might cause a serious loss of the diameter of the fine fibre and an even more serious loss of strength. Thus, glasses of the soda-lime types shown in table 1 have compositions similar to that of a glass used for making bottles, and their use can be prescribed only for coarse fibres, as may be seen in table 2, which gives indications for the uses of various types of glass.

Not mentioned in table 2 are some more recent applications that promise to be of great importance. Among these are the use of glass fibre as a substitute for asbestos in asbestos cement and the removal of the risk of asbestos to workers in that industry and the use of glass fibre of special composition for reinforcing concrete.

Other factors that affect the choice of glass composition are ease of melting, ease of working the glass into the desired fibre form and the chemical composition of local raw materials.

Table 1. Chemical composition (per cent) of some glass fibres in common use

Composition (% by weight)	Low-alkali, lime alumina borosilicate	Soda-lime borosilicate	Soda-lime borosilicate	Soda lime	Lime-free soda borosilicate	High-lead silicate
SiO_2	54.5	65.0	59.0	73.4	59.5	34.0
Al_2O_3	14.5	4.0	4.5	2.8	5.0	3.0
CaO	22.0	14.0	16.0	7.8		
MgO		3.0	5.5	2.0		
B_2O_3	8.5	5.5	3.5		7.0	
Na_2O	0.5	8.0	11.0	14.0	14.5	0.5
K_2O		0.5	0.5			3.5
ZrO_2					4.0	
TiO_2					8.0	
PbO						59.0
F_2					2.0	

Table 2. Percentages of oxides yielded by some selected raw materials

Glass type	Fibre use form	Diameter range (mm)	Dominant characteristic	Principal uses
Low-alkali lime, alumino-borosilicate	Textiles and mats	0.0058 - 0.0096	Excellent dielectic and weathering properties	Electric and general textiles, reinforcement for plastic, rubbers gypsum, papers
Soda-lime borosilicate	Mats	0.001 - 0.0015	Acid resistance	Electric battery separators and corrosion-proofing
	Textiles	0.0058 - 0.0096		Acid filter, clothing
Soda-lime borosilicate	Wool[a]	0.010 - 0.018	Good weathering properties	Thermal insulation and caustic production
Soda lime	Filter packs	0.14 - 0.25	Low cost	Coarse fibres only for air and liquid filters
Lime-free soda borosilicate	Wool (fine)	0.00076 - 0.0051	Excellent weathering properties	Light-weight insulation, sound-absorption, cushioning material
	Wool (ultrafine)			All glass filter papers and paper admixtures
High-lead silicate	Textile	0.0058 - 0.0096	X-ray protective capacity	Surgical pac strands X-ray protective aprons

a/ That is, a tangled mass rather than a continuous fibre.

Raw materials and batch composition

The mixture of raw materials that are melted together to form the glass is known as the "batch"; it must be calculated in order to produce the desired glass composition. To do so requires knowledge of the chemical composition of the raw materials, and they must be consistent in composition if the calculation is to remain valid. It will be appreciated that the fibre-making process depends critically on the working properties of the glass, and that the temperatures and pressures must be set accordingly. Any variation in these factors because of variations in composition will invalidate the setting and interfere with smooth production. Local variations of composition may stem from variations in raw materials, improper weighing or mixing, segregation after mixing or improper melting. The physical form of the raw materials is important. The principal component, silica, is slow to melt, and large grains may not be completely melted in the time available in the furnace. On the other hand, if the silica sand is too fine, it becomes dusty when the batch is handled. This is itself objectionable, but in addition the loss of this dust from the weighed batch invalidates the weighing.

Generally, sand grains should be between about 0.05 and 0.5 mm in diameter; grains outside this range should be rejected. To minimize segregation, the other components of the batch should have about the same grain size, although this is less critical.

The geology of Kuwait has not yet been fully explored; so far, no entirely satisfactory glass-making sands have been found. The most promising material is from Umm Negga, a dune sand that could yield a composition of about 95% SiO_2, 1% CaO, 0.2% MgO, 0.6% Al_2O_3, 0.8% K_2O, 0.6% Na_2O and 0.5% Fe_2O_3, provided that it is sieved to retain about 80% grains of a size range between 0.25 and 0.5 mm. The iron content is too high for colourless glass but could be tolerated for glass fibre.

There is also a sand pit 5 km southwest of Al-Jahra that is reported to yield sand with 88.1% SiO_2. Since this sand is being processed locally for use as a construction material, it may be possible to extract a part of it that would be more suitable for glass manufacture as regards purity, grain size or both, than the average. These projects should be explored if the project is implemented, but they are too uncertain to rely on; it is felt that the feasibility study should assume that raw materials will generally be imported. A batch calculation must be based on the analysis of the raw materials actually to be used, but for the purposes of estimating costs it may be assumed that these materials correspond to known chemical compounds and that the volatiles such as water and carbon dioxide will be driven off during melting, to leave the non-volatile oxides as components of the final glass composition. In this way one obtains a series of factors for each of the raw materials, of which some examples are shown in table 3.

Table 3. Raw material factors in batch calculation

Raw materials	Assumed chemical formulas	Oxides produced	%
Silica sand	SiO_2	SiO_2	100
Limestone	$CaCO_2$	CaO	56.03
Dolomite	$MgCO_3:CaCO_3$	MgO	21.85
		CaO	30.41
Soda ash	Na_2CO_3	Na_2O	58.48
Feldspar		K_2O	11.15
		NaO	3.24
		Al_2O_3	18.63
		SiO_2	66.23
Borax	$Na_2B_4O_7.10H_20$	B_2O_3	36.51
Boric acid	$B_2O_3.3H_2O$	B_2O_3	56.3

With this information or the true chemical analyses of the raw materials it is possible to formulate a batch mixture that will yield a glass of desired composition, provided there are no losses other than those of the volatiles during melting. In practice, there are such losses that result from the method used for melting. In flame-fired furnaces, the melting glass is exposed to the direct action of the flames over a large area; some of the batch dust may be carried away and deposited in the flues or discharged into the atmosphere, some of the more volatile components such as boron trioxide (B_2O_3) and sodium oxide (Na_2O), both of which are expensive, may be driven off to the extent of 10 to 50% to pollute the atmosphere. In furnaces in which the glass is melted by passing electricity through the melt, these losses are negligible, because the glass is melted beneath a blanket of cold batch, which traps these volatiles.

Where suoh losses occur, they vary from furnace to furnace; allowanoe for them can only be made by trial and error. In oalculating the approximate batoh composition in table 4, such losses have been ignored, so that the formulations are valid only for costing purposes.

Table 4. Approximate batch compositions to produce 100 tons of finished glass (tons)

Raw materials	Low-alkali alumino-borosilicate glass	Soda-lime borosilicate glass	Soda-lime glass
Sand	52.2	56.0	73.4
Soda ash		15.9	23.3
Limestone	39.1	14.9	8.4
Dolomite		25.2	9.3
Alumina	13.8	3.6	2.7
Sodium sulphate			0.8
Feldspar	3.5	4.5	
Borax		9.6	
Borio acid	15.1		
Total batoh weight	123.7	129.7	117.9

In addition to the raw materials whioh form the glass, quantities of lubricants, coupling agents and bonding agents are applied to the fibre as it is formed, depending on the use to which it is to be put. The oost of these sizes may exceed the material cost of the glass itself.

Glass melting

To form a homogeneous glass from the raw materials, they must be heated to a temperature of 1,500°-1,600°C and held there for sufficient time for ohemical reactions to be completed and for gas bubbles to float free. The molten glass is extremely reactive, and the oontaining vessel or tank must resist this activity and the high temperature, so high-grade refraotory materials are used. Even the best of these, used as containing walls 30-cm thiok, have a limited life and must be replaced every three to five years.

In fully industrialised oountries, glass-melting technology has developed based on low-cost fuels and elaborate furnace oonstruotions to attempt to improve the thermal effioienoy, whioh is only 20%-30% even in large furnaces that melt, say, 100 tons/day. By contrast, an electric furnace in which the heat is generated by passing electric current through the melt, which at melting temperatures is sufficiently conductive to act as its own heating element, an efficiency of about 70% is achieved in a much smaller furnace. Of course, in such countries electricity is usually about four to five times more costly than other forms of energy, so that in large melting units its use cannot be justified on the basis of improved efficiency alone. As a rule of thumb, the break-even between, for example, oil-fired and electric furnaces usually occurs at about 15 to 25 tons/day output. However, there are a number of advantages in using electricity that should be reviewed, particularly in developing countries, where the technological environment is normally lower. Some of these are difficult to quantify; for example, the absence of pollutants, silent operation and the fact that the waste heat around the furnace is less than one half that around an oil-fired furnace are all factors that improve working conditions. Also, electrical furnace operation is less dependent on specialized experience, and operators with general electrical knowledge can be instructed.

The quantifiable advantages are best illustrated by example. In developing countries, the fixed costs of a glass factory tend to be disproportionately high, particularly the capital-related costs such as depreciation and interest. The smaller cost of an electrical furnace is therefore important itself, but also because the building to house it is less costly, and a large part of the installation consists of electrical transformers and switch gear, which are usually depreciated over 15 or 20 years instead of 10. Most important is the smaller cost of rebuilding every four years or so, and particularly the much shorter time it takes to get back into production after such rebuilding. The conventional fuel-fired furnace is a complex refractory structure that requires great skill of the masons who build it. In developing countries it is usually necessary to import this skill for the original erection, but the problem remains as to whether local people should be trained to meet such an intermittent need or whether it would be better to rely again on expatriates for re-building. In fully developed countries it takes about six weeks to rebuild; in developing countries it may take three months. During this non-productive time all of the fixed costs continue. In comparison, the electric furnace requires little more than the unskilled placing of preformed blocks and takes only about 14 days.

As an illustration of how these items effect the over-all cost of glass melting, the figures given below were based on offers for furnaces of various types, valid in April 1976, for melting 24 tons/day of a soda-lime glass similar to the type shown in table 1. Six offers for oil-fired furnaces were received, varying from KD 142,000 to KD 384,000.

In reply to a request for bids, six offers for electric furnaces were received. These varied from KD 101,326 to KD 217,635. The best offer for each type is used in table 5 to compare the total costs of melting per year. Furnace rebuildings and maintenance are spaced uniformly over the lives of the furnaces in question. Interest is calculated on an assumed basis of 60% borrowing at 9% interest. The rates for depreciation used are: buildings and civil-engineering works, 5%; electrical equipment, 6.67%; and other equipment, 10%.

Table 5. Comparative costs per year of oil- or gas-fired furnaces and electric furnaces
(Dinars)

Cost elements[a]	Oil- or gas-fired furnaces	Electric furnaces
Additional building, civil engineering work, depreciation and interest	5 200	
Maintenance, spare parts and rebuilding	22 334	11 480
Loss of working days (at 1 000 KD/day)	15 000	4 000
Depreciation and interest on the part not covered by rebuilding:		
Nonelectric	6 749	5 656
Electric	93	1 698
Interest	7 666	6 018
Fuel oil cost (assumed at 8 KD/ton)	15 048	
Electricity cost (2 fil/kWh)	806	15 578
Total cost of melting[b]	72 896	44 430
Melting cost per ton[b]	12.06	7.35

a/ At an average melting rate of 18 tons/day.

b/ Assuming a yield of 92% salable fibre.

It will be seen that, at Kuwaiti energy prices, electric melting is cheaper than oil melting on the basis of energy alone. This situation is unusual and presumably reflects a subsidy policy. In fact, electricity is available at 1 fil/kWh in certain districts of Kuwait, so that electric melting there would be even more advantageous. Although natural gas is also very low in price, it should be noted that, even if fuel cost nothing, electricity at 2 fil/kWh would prove more economic when the total melting costs are compared.

Fibre forming

If molten glass is allowed to flow through a small orifice it tends to gather into a bead owing to surface tension forces until the weight of the suspended bead becomes too great. Then, as the bead falls, the glass between the bead and the orifice is drawn out into a fibre, which ever becomes thinner until it chills into rigidity. The art of efficient fibre-making depends on the ability to produce much fibre and few and small beads (called "shot") and to do so at a rate that will be economically viable. The mass $\underline{m}$ of the bead which starts to drop is given approximately by

$$\underline{m} = 2\pi\underline{a}\gamma/\underline{g}$$

where $\underline{a}$ is the radius of the orifice, γ is the surface tension per unit length and $\underline{g}$ is the gravitational acceleration. If $\underline{g}$ could be replaced by an acceleration greater than gravity, the bead mass would be reduced. There are three general methods of doing this:

> The falling bead is accelerated downwards by a blast of air or steam.
>
> Gravitational acceleration can be replaced by centrifugal force; the fibres are thrown off the rim of a high-speed rotating disk fed with molten glass at its centre.
>
> The fibres can be drawn as continuous filaments if they are caught and pulled mechanically at a rate equal to that at which the glass flows through the orifice.

The first two processes (which are combined in the TEL process described below) yield relatively short, thin fibres which, if they are less than about 12 microns (μ) diameter and long enough, can be twisted into yarn and, with suitable sizing, several of them can be twisted into a textile yarn. More generally, however, processes are used to make "wools" (tangled masses, as distinguished from continuous filaments) and bonded mats or felts by collecting the fibres at random. The last process, which involves a positive connexion between the winding spool and the orifice, calls for much closer control, but the product, being a continuous filament, can be used for textiles without twisting, or the fibres may be chopped subsequentlv to form random mats and fibres suitable for plastic reinforcement.

The TEL process is a combination of the first two methods. The molten glass is poured through the hollow shaft of an eleotric motor, spinning at about 3,000 rev/min, into a disc that distributes it and throws it against another rotating perforated disc, which foroes it to be sprayed out as relatively fine fibres. An annular burner surrounding the spinner projects a blast of hot gas downwards, forcing the horizontal fibres to change to the vertical and attenuating them to long fibres of about 6μ diameter.

The fibres fall into a conveyer, being sprayed with a suitable binder as they fall. The speed of the conveyer is adjusted so that the requisite thickness builds up. The conveyor carries the fibre through a drying or baking tunnel where it is compressed to the final thickness. Thereafter, the mat may be faced with kraft paper, aluminium foil or the like or be cut to required size.

Viability criteria, markets and selling prices

The final products for which the production of glass fibre is to serve may be classified according to whether the purpose of the fibre is to strengthen the product as reinforcement or to provide thermal or sound insulation by trapping air. The materials for these two classes of produots are made in different ways: the fibre for reinforoement is generally made as a continuous filament, whereas the insulating fibre is made as a wool. One can thus speak of fibre reinforoed plastics or produots (FRP) and of glass wool products.

In both oases there are two prinoipal stages of manufaoture: the first is the production of the wool or fibre, the second is their use in many different ways to make the final produots. The primary stage involves a continuous 24-hour process requiring large oapital investment; the secondary process need not involve oontinuous working, although there may be an economic advantage in running it in line with the primary produotion. In the oase of FRP products, for example, secondary produotion of items suoh as tanks and boats is done in different faotories that work single or double shifts only.

From the aspect of profitability, all that matters is that the over-all profit of the factory, including such secondary processes as may be employed in it, should be satisfactory. However, this is not a good basis for judging viability, because the value added by the secondary processes may cover an uneconomic primary process, in which case a more profitable operation would be to import the primary product as a raw material and acquire equipment at low investment cost, for secondary production only.

In a developing country, it is usual that a large variety of articles is imported which have the same function, because there is the whole world to choose from. When domestic production starts, it would be a grave mistake to attempt to reproduce this multiplicity. Every effort should be taken to standardize items and thus reduce costs through long production runs and low inventories. If the primary production of glass fibre or wool is itself profitable, there is freedom of choice in the types of end-products that can be made, standardization can be maximized and the viability of the operation as a whole can be assured.

For these reasons, viability should be judged on the basis of the primary processes of producing glass wool and/or continuous glass fibre. In assessing the market, the glass content of the final products is of key interest; the value added by secondary processes is of less consequence.

II. THE MARKET FOR GLASS FIBRE

Reinforcing glass fibre (RGF)

The manufacture of water tanks, boats and the like in Kuwait was started by United Group Co. in 1969, but the industry has expanded rapidly and at this writing (1976) six major factories each use about 150 tons of chopped strand or rovings, and all have expansion plans either for their present products or for new ones. Their over-all requirements for glass fibre are expected to double by 1978. It appears that about 20% of these products are exported.

While the import/export statistics do not record imports of this type of fibre separately, they do record the export of fibre glass tanks (which are about 45% glass fibre), as shown in table 6.

Table 6. Exports of glass fibre tanks

1973		1974		1975 a/	
Value (KD)	Weight (tons)	Value (KD)	Weight (tons)	Value (KD)	Weight (tons)
5,226	8.295	5,915	11.170 b/	4,814	11.300

a/ Projected from first 9 months.

b/ Bahrain, 1.0; Iraq, 0.6; Saudi Arabia, 9.3; United Arab Emirates, 0.3.

The imports are funnelled through a relatively few fabricators and it was possible to visit all of them. The information gained during these visits is presented in table 7. This information is believed to cover 90% of the domestic market.

The very high growth rates anticipated by the users of RGF reflect their intentions to enter new markets rather than any growth of existing outlets, so that, sooner or later, this growth would be expected to slow to a much lower rate. At present, most of the consumption of glass fibre is for the manufacture of tanks for various purposes, and the basic growth rate of this business would be expected to follow the same trend as that of new buildings. According to IBK, this is expected to be about 6% per annum, as discussed in the next section.

Table 7. Demand for reinforcing glass fibre
(Tons)

User	Chopped strand	Rovings	Woven rovings	1976 total	Expansion plans	1978 estimated total	Exports
Al-Rodhan	140	-	-	140	60-70% per annum	300	50%
Poly Glass	150	30	20	200	25% per annum	300	15%
United Trading	130	-	-	130	a/	760	130 tons for factories abroad
Al-Buraq	70	10	10	90	b/	300	...
El-Yousifi	120	-	20	140	50% per annum	280	0
Kuwait Fibre Glass	150	-	-	150	c/	300	About 10 tons re-exported
Decora	2	-		2			
Roofing Specialists	-	-	360	360	d/	470	
Total	762	40	410	1 212		2 710	

Notes: a/ Plans to make glass fibre pipes.

b/ Plans to expand work-force to 150 or 200 and make caravans.

c/ Expects to make furniture and double production by 1978.

d/ This is woven mesh for bitumen reinforcement. A growth rate of 15 per cent is estimated by the Industrial Bank of Kuwait.

With regard to exports, table 6 shows the pattern in recent years. Whereas it refers only to glass fibre tanks, one would expect other FRP to follow a similar pattern and thus find exports increasing as the domestic market becomes satisfied.

Glass wool

The importance of thermal insulation of buildings in Kuwait is great because of the very high summer temperatures and the need to improve personal comfort and reduce the air-conditioning load and the capital cost of air conditioning. In Kuwait, roof insulation, where practised, is usually done with foam concrete, which requires weatherproofing, usually with bitumen. To prevent the bitumen from tearing, it is best reinforced by glass fibre; the last item of table 7 is woven rovings used for this purpose. In industrial buildings clad with corrugated iron or asbestos, insulation may be provided by, let us say, 5 cm of glass wool. The blanket of glass wool is usually faced with kraft paper, polyvinyl chloride (PVC) or aluminium foil which will, for example, seal it and enclose the purlins that support it against the cladding.

These insulating blankets usually have a density of 12 kg/m^3. By increasing the density by compression with additional binding resin, the glass wool can be supplied in the form of a semi-rigid or rigid board, which is self supporting. Since the insulating properties result from their trapped air, the insulation value of these boards is no higher, per unit of thickness, than for the blanket, although it contains more glass wool in proportion to its density per unit area. Insulation board is very suitable for making air conditioning ducting but, because of its high price, is seldom used in Kuwait. Ducts of other materials are more usual and are insulated by 2.5–6.0 cm of glass fibre blanket faced with aluminium.

There are three principal agents for these products: Specialities, Al-Hamra and Behbehani. Each of these have been visited; table 8 summarises the information obtained from them. Because of direct buying by users, it is thought that these figures represent only part of the present market. Furthermore, the figures given are less accurate than could be wished because agents tend to think in terms of enquiries or orders on hand; converting these impressions into annual requirements is uncertain. Estimates of requirements by York Corporation, an air conditioning contracting firm, and by Kirby, a prefabricated industrial buildings manufacturer, are also included in table 8.

Import/export statistics record "glass wool", which may include chopped strand mat. Table 9 is derived from these figures.

The contribution of construction to the gross domestic product (GDP), in Kuwait increased by 17.7% from 1971 to 1972 and by 7.5% from 1972 to 1973. The IBK's projection of the superficial area of new buildings is more conservative (about 6%). IBK applied factors to these projections to allow for the

Table 8. Agents' estimates of imports of glass-fibre insulation products

Agent	Comments		Estimated glass wool imports (tons)
Specialities	Unfaced blanket	20 000 m^2	
	Kraft-faced	55 000	
	PVC-faced	60 000	
	Aluminium foil-faced	10 000	97
Al-Hamra	Total bill for insulation in 1975: KD 12 000		30
Behbehani	Glass wool blanket insulation ceiling tiles 5/8 in. (about 1.6 cm) thick retails at 300 to 950 fils/ft^2 (0.093 m^2) Estimate of the total Kuwaiti market in 1976		200 400 tons

Table 9. Import/export statistics: 664.901 a/ glass wool

	1973	1974	1975 b/
Imports	514 tons	781 tons	580 tons
c.i.f. price	KD 482/ton	KD 549/ton	KD 800/ton
Re-exports	9.2 tons	72.4 tons c/	90.2 tons
f.o.b. price exports	KD 703/ton	KD 874/ton	KD 619/ton
Net imports	505 tons	708 tons	490 tons
c.i.f. price (KD/ton):			
ex Turkey	378	453	563 (in Sept. 1975)
ex United Kingdom	397	413	566 (in Sept. 1975)
ex United States	543	790	800 (in Oct. 1975)

a/ Brussels nomenclature.

b/ Projected from first 10 months.

c/ Bahrain 4.0: Irag 0.3: Jordan 4.3: Qatar 8.1: Saudi Arabia 44.1: United Arab Emirates 10.0.

probable extent of insulation and the expected share in terms of glass-wool insulation, to arrive at estimates of the requirements for glass wool in various forms. These estimates, again, seem conservative. However, adopting their figures, but considering only the glass fibre content of these requirements (the IBK weight estimates include facing material etc.) the projections given in table 10 have been arrived at.

Table 10. Projected demand for glass wool heat-insulating materials

Use	Density (kg/m2)	Tons of glass wool		
		1978	1982	1985
Roof Insulation	0.6	41.7	116.5	202.7
Air conditioning:				
Insulation rolls	0.6	451.8	701.0	1 109.2
Rigid ducting	2.5	-	386.3	900.0
False ceilings	0.3	1.2	2.7	3.8
Side-wall insulation	0.6	43.1	116.4	168.9
Cladding	0.6	5.9	17.3	25.0
Cold storage	5.0	20.0	29.3	39.0
Total		563.7	1 369.5	2 448.6

By 1974 there was already a 10% re-export of glass wool from Kuwait to neighbouring countries. If there were a manufacturing centre in Kuwait, it seems certain that this proportion would be much higher. The assessment made by IBK assumes 50% exports, and on this basis the demand is projected as 1,446 tons in 1978, 2,054 tons in 1982 and 3,673 tons in 1985.

Prices

The c.i.f. prices of glass fibre and glass wool in Kuwait show considerable variation, owing, in part, to differences in transport costs. Fibre for reinforcing, for example, is often ordered at the same time as the resins and, although the glass has an indefinite shelf life, the resins have a shelf life of only about six months in the hot climate of Kuwait. Delivered as deck cargo, they may have already gelled on arrival. Therefore, the resins are usually delivered by truck, and often the fibre as well. This may add about 200 fils/ton to the cost. The general level of prices may be obtained from the import-export statistics given in table 9, but the United States component is best excluded because it is believed to consist of relatively high-priced proprietary articles. Glass wool from Iran is low in price, but it is considered to be of poor quality. The most usual price for chopped strand reinforcement material was KD 404/ton, but figures as low as KD 257/ton (from Turkey) and as high as KD 896/ton were mentioned. For woven rovings, a price of KD 1,830/ton was mentioned. For glass wool blanket material, the cost of the unfaced product was KD 612/ton, with additional costs for facing it with kraft paper, PVC or aluminium foil (40, 174 and 206 fils/m^2, respectively). The density of the material was 12 kg/m^3.

In the United Kingdom, in 1975, the cost of production of reinforcing glass fibre was about KD 263/ton, while the selling price was KD 368/ton. It would thus appear that the price of KD 257 from Turkey quoted above is artificially low. In France, the job price for glass wool is quoted at KD 440/ton.

Price estimates based on import-export statistics are unreliable because the nature of the items included is unknown. In table 9, for example, it will be noticed that the f.o.b. export price, which might be said to represent retail prices, in 1975, was much lower (KD 619/ton) than the c.i.f. import price (KD 800/ton). The latter figure must therefore relate, to a great extent, to, let us say, aluminium-faced material.

The best estimates (KD/ton) of the current prices for the basic materials seem to be:

Rovings and chopped-strand mat	404
Woven rovings (depending on the weave) up to	1 800
Unfaced glass wool	612

For a range of production with various facing materials in the proportions used by the firm Specialties in table 8, the total selling value, inclusive of the facing material, would amount to KD 864/ton.

III. RAW MATERIALS AND OTHER INPUTS

Raw materials

By weight, the principal material for glassmaking is silica sand. Although Kuwaiti sand contains much silica and some limestone, which is another necessary material, the uniformity of the mix is far too irregular for batch calculations to be based upon it. The best sand is believed to be from Umm Negga, but at best it contains no more than 90% silica, and it has a content of iron that would disqualify it for making colourless glass. For fibre-making, however, colour is not important, although too high an iron content can impair the platinum of the furnace, and it can also make the fibres brittle. It therefore appears that a domestic source of silica should be developed. In the meanwhile, for the small amounts (5,000 to 10,000 tons/year), it is probable that the costs of beneficiation would be as high as that of importing good-quality sand. It is therefore recommended that the required silica sand be imported initially and that a separate study be made at a later date to test the practicability of substituting domestic sand for the imported material.

Soda ash contributes most to the cost of the batch for the glass considered here. It should be noted that about 2,000 tons of broken glass are exported from Kuwait at a price of about KD 7/ton. This glass contains about 15% sodium monoxide. Instead of being exported, this broken glass could be used (up to 30%) as a low-cost source of all of the components of glass wool batch.

While there are sources of limestone in Kuwait which, to judge from their quoted analyses, could be used in the production of glass wool, their use for reinforcing fibre is more doubtful because of their magnesia content.

When studying feasibility, it is safest to assume that all raw materials will be imported initially. The costs itemized in table 11 are calculated accordingly.

Table 11. Batch costs

Material	Assumed price (KD/ton)	Batch costs (KD/ton of melted glass) Glass wool	Reinforcing fibre
Sand	2.8	2.05	1.46
Soda ash	45.0	10.50	-
Limestone	2.0	0.17	0.78
Dolomite	2.0	0.19	-
Alumina	70.0	1.89	9.66
Feldspar	15.0		0.53
Boric acid	104.0	-	15.60
	Total	14.80	28.03

Other consumable materials

In addition to the glassmaking materials, binding resins are required for the wool and binders, lubricating materials and coupling agents for the continuous fibre. The binding resins and solvents, at a cost of KD 77/ton, are added to the extent of about 18% by weight and thereby increase the apparent yield of wool. Lubricants, binders and coupling agents are applied to the reinforcing fibre according to its end-use. For rovings that are to be woven into fabrics, the lubricants required may be excessive for FRP and may have to be removed, but for chopper strand mat and rovings, which are by far the largest requirement in Kuwait, the minimum amount of size is used, and an allowance of KD 5/ton is made to cover its cost.

A glass-melting furnace has a limited life (three to five years) before it must be rebuilt and much of the refractory material replaced. This refractory material is considered consumable; only the remainder is depreciated (at 10% yearly).

For storage and delivery in Kuwait, simple packing in polyethylene bags should serve; any more elaborate packing for export is assumed to be recovered in the price. An estimate of KD 2/ton of product is assumed.

Power, fuel and water

Electricity	2 fil/kWh (1 fil/kWh in certain industrial areas)
Liquefied petroleum gas (LPG)[1/]	40 KD/ton
Potable water	KD 0.176/m^3 in Shuaikh industrial area KD 0.055/m^3 in Shuaiba industrial area
Seawater	KD 0.006/m^3 in Shuaiba industrial area

Manpower

The following rates of pay are assumed, to which 10% should be added for social charges.

Job title	KD/month
General Manager	700-800
Manager	500-600
Engineer	300-500
Foreman	150-250
Secretary	125-150
Typist	100-120
Skilled labour	120-150
Semi-skilled labour	90-100
Unskilled labour	70-80
Driver	100-120
Storekeeper	100-150
Accountant	120-150
Porter	60-70
Office boy	60-70

1/ Natural gas will not be available for new projects.

IV. PROPOSALS FOR GLASS FIBRE PRODUCTION IN KUWAIT

The concept of setting up facilities for the manufacture of glass fibre in Kuwait appears to be well founded. It is a product that would exploit Kuwait's low-cost fuel situation; the reinforcing fibre product helps to promote the workshop activities of FRP manufacture with their low investment and suitability to Kuwaiti entrepreneurship. The insulating products should help to promote higher standards of low-cost housing.

The State's incentives of a ten-year tax moratorium and duty-free raw materials and equipment are factors of considerable importance in setting up a viable operation, but from the technical point of view, if an industry is to be well founded, it must be designed to make the most of the natural advantages, in this case low fuel and power costs.

The glass industry has generally developed through its ability to make high-quality bottles, window glass and the like from low-cost local raw materials. The technology has been directed at reducing fuel costs by using large and sophisticated melting furnaces capable of burning low-cost fuels and by mechanizing the forming process.

The economy of Kuwait has quite a different background. Since it is a country of low fuel cost and high capital costs, a modern plant designed for operation in one of the developed western countries would therefore not necessarily be the best solution for Kuwait. This presents a problem in implementation, because plants installed as "turn-key" operations are likely to be excessively high in capital cost, and therefore also in production cost through depreciation and interest, if they are based on conventional practice.

In the estimates that follow, the policy has been followed of attempting to minimize capital cost and in the case of both glass wool and continuous filament production, electric melting is advocated. The advantages of electric melting have been referred to in the section on glass melting (page 13).

Generally speaking, it is preferable to avoid operating different technologies on the same factory site so as to avoid confusing responsibilities, budgetary control and so on. In this case, however, where both wool-making and continuous-filament production are minimal, this would mean duplicating much of the capital provision, which would affect the viability of both manufactures.

The proposal in this oase is illustrated in figures I and II and tables 12, 13 and 14, from which it will be seen that the two production departments are to be kept separate, whereas the staff funotions will be common for the most part. In the event of proceeding with one produot only, the whole of the cost of the common functions would have to be carried by it.

Capital oosts

The cost estimates for the glass fibre plant desoribed in figure I and figure II are presented in table 12. It should be noted that these estimates are based, as far as possible, on the best offers reoeived after a request for oompetive quotations (April 1976). Turn-key offers are likely to be higher. The figures given are c.i.f., including design and supervision of erection. Inoluded are inland freight, port clearance, local building labour and the living and travel costs of the expatriate supervisors.

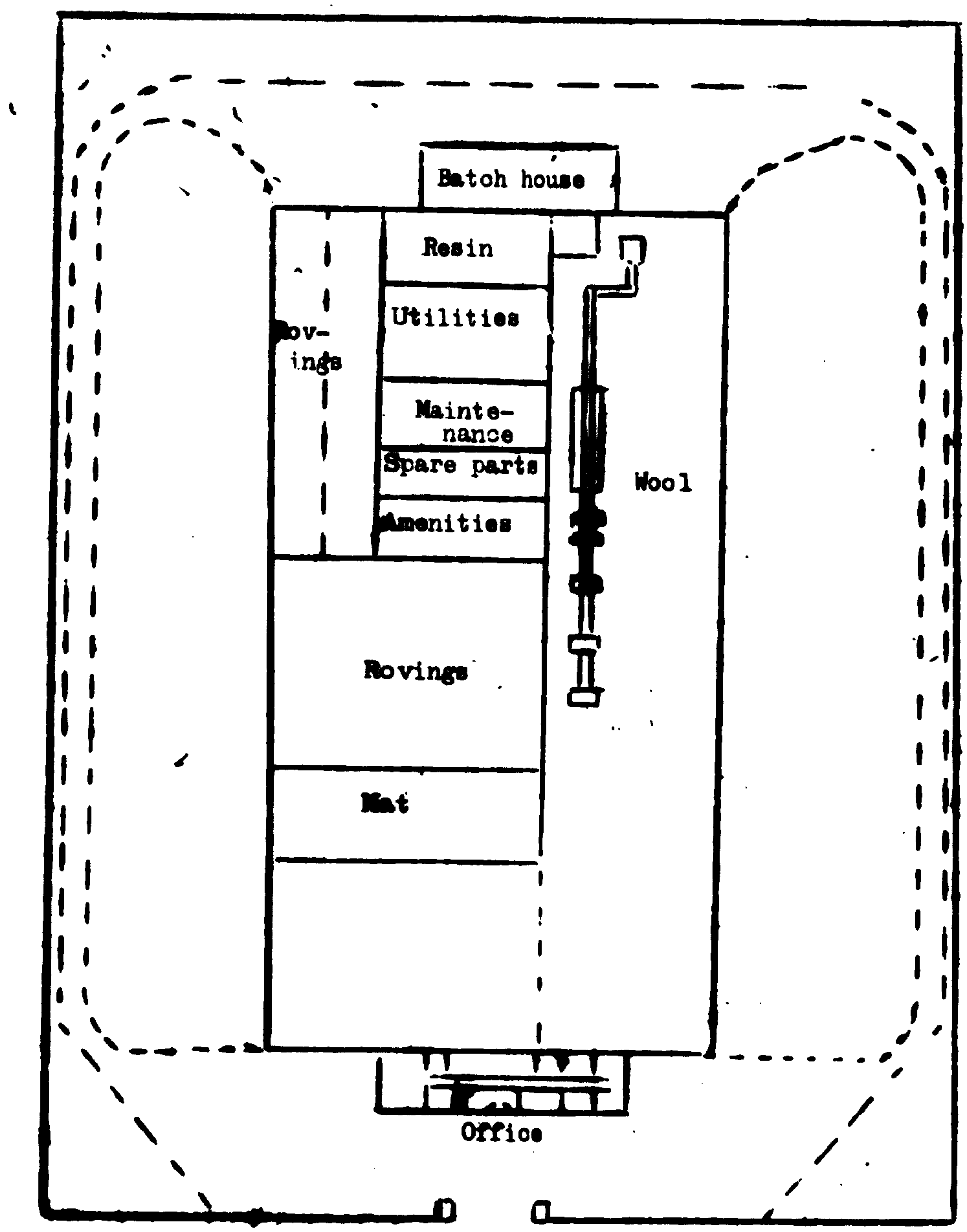
Viability caloulations

Scale of operation

The manufacturing capacity of a minimum facility for making glass wool is about 2,000 tons/year. The corresponding figure for reinforcing fibre is about 1,500 tons/year. From the market surveys, it seems oertain that the demand for each of these materials already exceeds 1,000 tons, and the projections made suggest that the demand in each case will soon exoeed these minimal capaoities. Therefore, the proposals made here are designed, in the first phase, to meet the 2,000 and 1,500 tons/year limits only on the grounds that, if such a scale proves viable, it is certain that a doubling of output would be even more profitable. The additional capital expenditure necessary to meet suoh inoreases are minimized by providing buildings and space to allow a doubling of capacity with additional equipment only, and a redoubling by extending the buildings.

This approaoh has much to oommend it: it minimises the risk; one tends to operate in a seller's market; and, particularly important, it allows the requisite skills to be developed naturally. Only if this initial volume is insuffioient to make the projeot viable would one be justified in taking both steps at onoe.

Figure I. Proposed layout of the glass fibre plant



Key	Size (m^2)	Unit cost (KD/m^2)	Total cost (KD)
Site area	23 000		
Paved areas	5 030	10	50 030
Perimeter fence	305	10	3 050
Batch house	300	40	12 000
Rovings factory	3 550	40	142 000
Wool factory	3 000	40	120 000
Common buildings	1 250	40	50 000
Office	240	60	14 400
			391 480

Figure II. Proposed organisation of the glass fibre plant

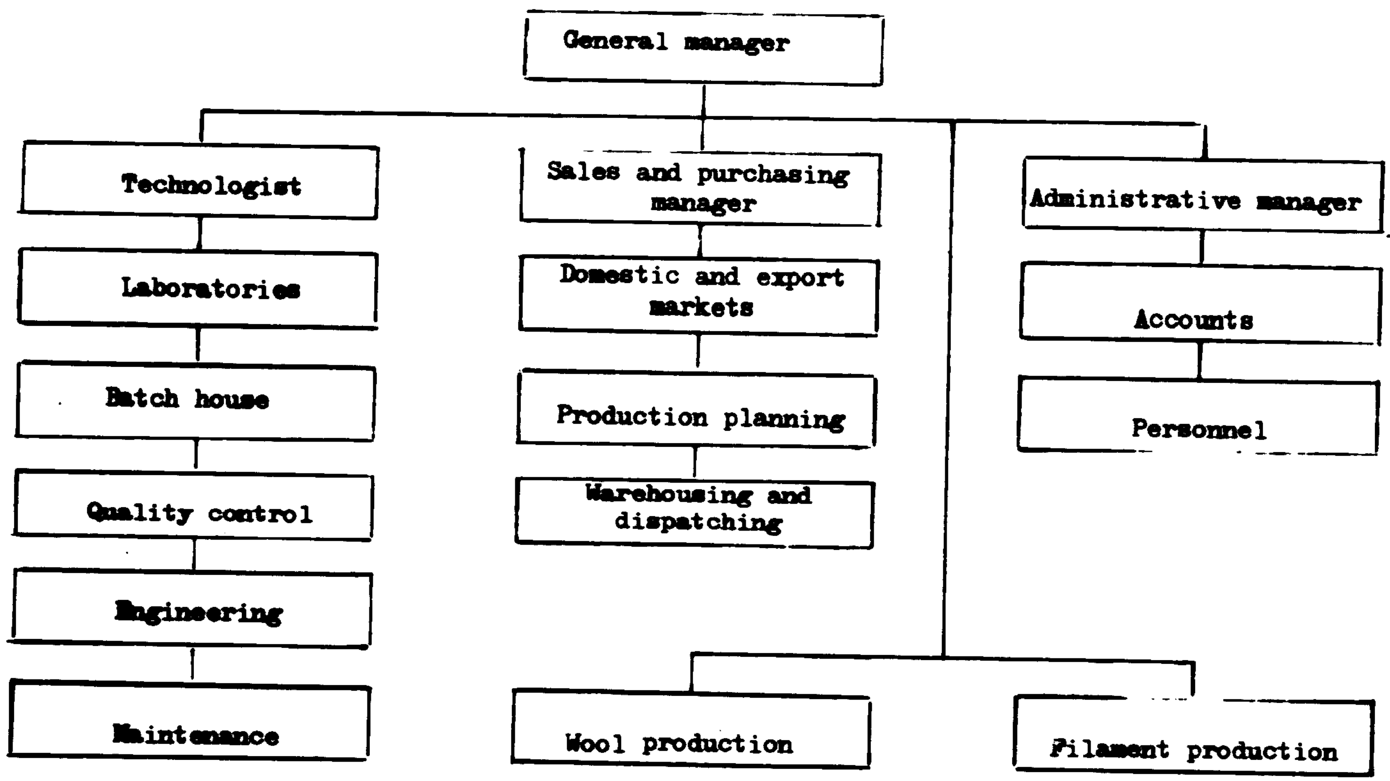


Table 12. Estimated capital costs of the projected glass fibre plant

Item	Depreciation rate (per cent)	Common (both plants) (KD)	Wool plant (KD)	Filament plant (KD)
Design	20	9 000		
Roads and fences	5	53 080		
Batch house	5	12 000		
Offices	5	14 400		
Factory	5		120 000	142 000
Furnace (electrical)	6.7		25 800	27 000
Non-consumable	10		185 000	100 000
(a) Consumable	-		(a) 41 700	20 000
(b) Channel	10		(b) 12 000	12 000
(c) Platinum	2.5		(c) 15 000	80 000
(d) Fiberizer	10		(d) 15 000	30 000
(e) Line equipment	10		(e) 404 500	200 000
(f) Resin equipment	10	(f) 50 000		
(g) Batch plant	10	(g) 60 000		
(h) Laboratory equipment	33.3	(h) 13 000		
(i) Workshop	10	(i) 15 000		
(j) Substation	6.7	(j) 30 000		
(k) Vehicles and miscellaneous	33.3	(k) 20 000		
Furniture	20	10 000		
	Total	286 480	819 000	611 000
	Distributed totals		962 240	754 240
	Two years spare parts cost[a]		65 550	55 750
	Depreciations		86 389	61 745

a/ The spare parts cost breakdown is as follows:

Common (both plants) (KD)		Wool plant (KD)		Filament plant (KD)	
(f)	1 000	(a)	3 000	(a)	1 000
(g)	500	(b)	2 300	(b)	2 000
(h)	1 000	(c)	7 500	(c)	36 000
(i)	1 000	(d)	9 000	(d)	3 000
(j)	2 000	(e)	40 000	(e)	10 000
(k)	2 000		61 800		52 000
	7 500				

Table 13. Estimated operating costs of the projected glass fibre plant[a]

	Wool[b]		Filament[c]	
	Fixed costs (KD)	Variable costs (KD/ton)	Fixed costs (KD)	Variable costs (KD/ton)
Raw materials		14.8		28.03
Other consumable goods	7 457		3 000	
Refractories		3.2		1.5
Resins		13.9		5.0
Packing materials		2.0		2.0
Wages and salaries	138 996		141 372	
Energy				
Melting	7 000	1.0	3 180	1.0
Power	5 000		3 000	
Water	500		1 300	
LPG	5 500		5 000	
Maintenance	29 025		9 875	
Platinum reworking	500		5 000	
Rents, consultants' fees, royalty	575	12.5	575	12.5
Subtotal	194 553	47.4	172 302	50.03
Working capital, 4 months at maximum output	93 923[d]		75 848[d]	
Interest at 5 per cent on 50 per cent of capital employed	26 404		20 752	
Depreciation	86 389		61 745	
Amortization and preliminary expenses, including training	10 000		10 000	
Selling expenses		10.0		5.0
Total operating cost	317 346	57.4	264 799	55.0

a/ An equity of 50% is assumed.

b/ Maximum tons, 2,000; salable tons, 1,840.

c/ Maximum tons, 1,500; salable tons, 1,380.

d/ Not included in totals.

Table 14. Estimated staffing costs of the projected glass fibre plant[a]

Job titles	Monthly cost (KD) (wool)	Personnel[b]			Monthly costs (KD) (Filament)
		Common	Wool	Filament	
General manager	350	1	-	-	350
Managers	800	3	-	-	800
Shift supervisor	1 000	-	4	4	1 000
Maintenance engineer	200	1	-	-	200
Physicist/chemist	200	1	-	-	200
Assistants and secretaries	500	8	-	-	500
Quality inspectors	560	-	4	4	560
Batch foreman	100	1	-	-	100
Helpers	150	2	-	-	150
Furnace man	600	-	4	4	600
Fiberizing	600	-	4	12	1 800
Workers	2 000	-	20	15	1 500
Maintenance (10 to 12)	1 600	22	-	-	1 200
Warehouse	600	2	4	4	600
Drivers	720	3	4	4	600
Guards and miscellaneous	550	10	4	4	550
Totals	10 530	54	48	51	10 710
Total yearly costs for wages and salaries, including 10% social costs	138 996				141 372

a/ See the pay rates tabulated in the section on manpower (page 26).

b/ Assuming three-shift operation of the wool and filament plants.

Operating costs

Operating costs can be assembled from the information given elsewhere in this report and are shown in table 13 according to whether they are fixed or variable. It should be noted that the cost of facing materials for the wool are not included. They can, however, provide a secondary source of profit and improve the break-even situation as given here, which refers to the basic production of glass wool.

Table 15. Break-even and profitability data for the projected glass fibre plant

	Wool	Filament
Selling price (KD/ton)	612	404
Break-even tonnage	572	738
Fixed assets (KD)	962 240	754 240
Capital employed (KD)	1 056 163	830 088
Equity assumed (per cent)	50	50

Wool				Filament			
Product (tons)	Sales value ((KD)	Profit (% of sales)	Profit (% of equity)	Product (tons)	Sales value	Profit (% of sales)	Profit (% of equity)
750	459 000	21.5	18.7	750	303 000	12.6	9.2
1 000	612 000	48.1	55.8	1 000	404 000	34.5	33.5
1 250	765 000	58.5	84.8	1 250	505 000	47.6	57.9
1 500	918 000	65.4	113.7	1 380	557 520	52.5	70.5
1 840	1 126 08[illegible]	71.8	153.1	-	-	-	-

It will be seen that the break-even point in both cases corresponds to a sales volume lower than that of the present (1976) market, and that if the anticipated growth rate is only half realized, the venture becomes so highly profitable that satisfactory dividends could be paid and still leave ample room to generate funds for further expansion. Because the selling price used is internationally competitive, there is excellent scope for exports. There seems little doubt that such expansion would soon become desirable.

Factory location

There are no special features of the proposal that might dictate the site of the factory. Electricity and water must be available, and the industrial electric power rate of 1 fil/kWh in certain areas is an attraction, but not a vital one.

In general the products are of low density, so the cost of transport favours a location near the customer. On the other hand, for exports of manufactured goods and import of raw materials, the transport cost is likely to be least for a location near a port.

V. RECOMMENDATIONS

The favourable situation shown in table 15 has been reached as a consequence of restricting capital expenditure; the wages bill is now the largest single cost item. The successful implementation of the project requires proper attention to both of these items and forms the basis of the main recommendations. In developing countries it is common to find that both the capital equipment employed and the labour are excessive. The first situation arises either because it seemed wise to grant a turn-key contract or, in any case, because there has not been an independent adviser knowledgeable enough to withstand the pressure of the suppliers' salesmen. The second usually arises because of inexperienced management and ill-conceived training of personnel.

Implementation

The promoter should engage the services of an independent adviser, an international expert or consulting firm and appoint a local project team as recipients of the advice and who would acquire training thereby. The project team should be of executive calibre and should expect to be first in line for permanent positions in the factories. The higher the quality of this team, the more can competitive offers of different suppliers be dovetailed, with resulting cost economy.

Management

The same team and advisers should study the staffing requirements and skills to be developed by training. The organization should be planned for economy of labour and with a view to proper budgetary control, with suitable separation with respect to the two factories so that control will be effective.

Weaving

The demand for woven rovings is not great and was not adequately studied in the time available. It is suggested, however, that such material might be produced by hand, using Kuwaiti skills, or by recruitment from nearby countries. This possibility should be investigated.

Local sand

Although it is of little economic significance for this projeot, the possibility of using local sand should be explored. This would, it is suggested, make a good research project for a student at one of the training institutes. Uniformity of composition rather than purity should be emphasised. It may be possible to aohieve this by mixing on a scale sufficiently large that chemical analysis of a small sample would be representative of the supply.

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