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INDUSTRIAL DEVELOPMENT AND
CONSULTING BUREAU

DP/KUW/71/507.

KUWAIT

Technical report: Feasibility of establishing a plant for manufacturing synthetic adhesives.

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

Based on the work of Ole Grønvold, expert on synthetic adhesives

United Nations Industrial Development Organization
Vienna

id.77-3985

Explanatory notes

References to dollars ($) are to United States dollars.

The monetary unit in Kuwait is the dinar (KD) = 1,000 fil. The relation used in this report to convert dinars to dollars was KD 1 = $3,41.

References to tons (t) are to metric tons.

The following notes apply to tables:

Three dots (...) indicate that data are not available or are not separately reported

A dash (-) indicates that the amount is nil or negligible

A blank indicates that the item is not applicable

When numbers rounded to different extents are combined, the resultant number is rounded to the same extent as the number that has been rounded the most

Besides the common abbreviations, symbols and terms, the following have been used in this report:

Technical abbreviations

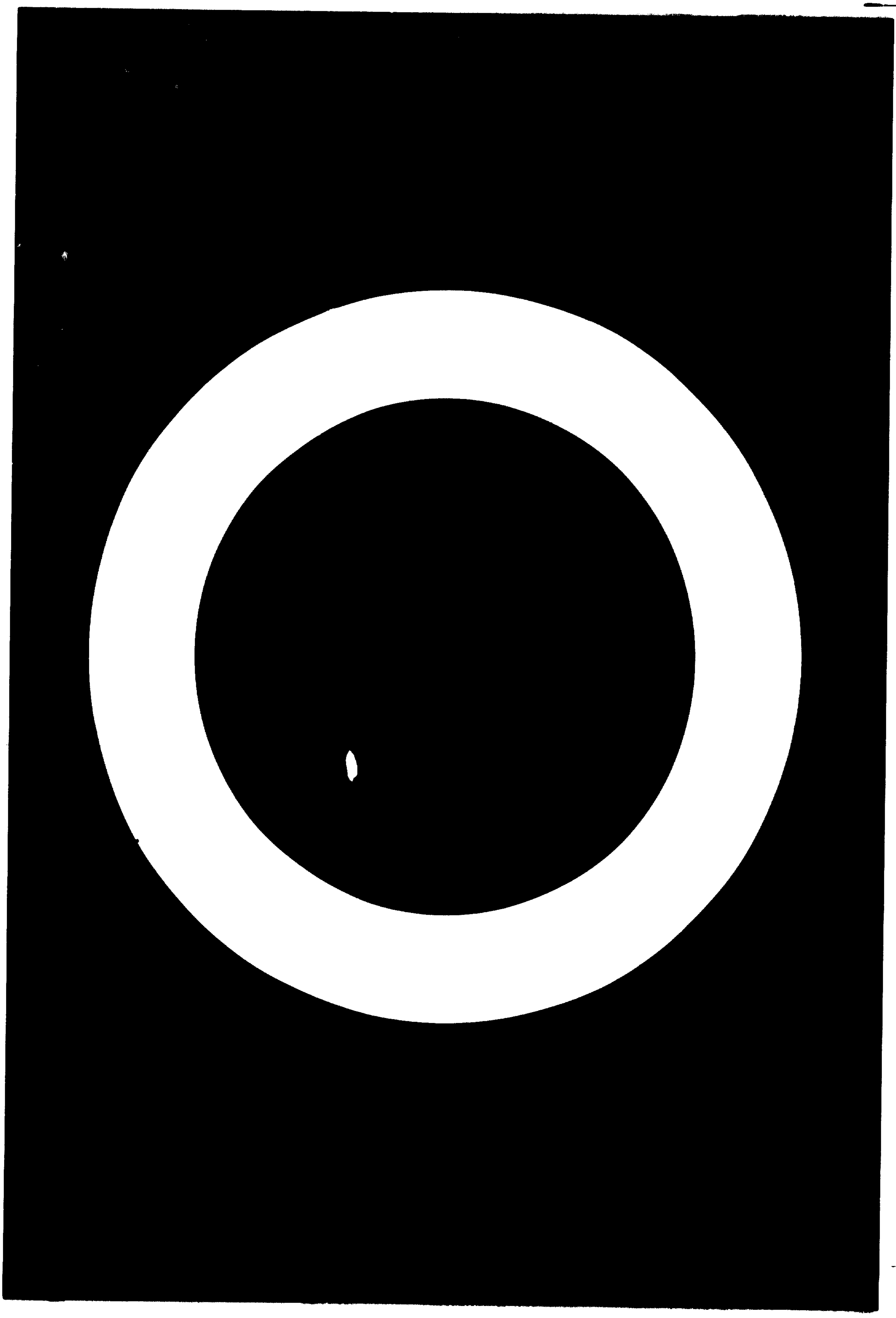
t/a	ton per year	BS	British Standard
kt/a	kiloton per year	DIN	Deutsche Industrie-Norm
Nm^3/h	normal cubic metre per hour	PVA	polyvinyl acetate

Organizations

FAO	Food and Agriculture Organization of the United Nations
ASTM	American Society for Testing and Materials
PIC	Petrochemical Industries Company

ABSTRACT

In conjunction with the United Nations Development Programme (UNDP) project DP/KUW/71/507, "Industrial Development and Consulting Bureau", the United Nations Industrial Development Organization (UNIDO), executing agency for the project, sent an expert to Kuwait for two months, October-November 1976, to investigate the possibilities for the manufacture and sale of urea- and melamine-formaldehyde adhesives. It was found that if a formaldehyde plant and a resin plant were built on the same site at the Shuaiba Industrial Area, where two of the raw materials are made and a third readily imported and stored, their output (10,000 t of resin per year) could be sold in Kuwait and other countries of the Gulf area with a satisfactory return (40%) on the original investment ($3 million).



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INTRODUCTION

As part of United Nations Development Programme (UNDP) project DP/KUW/71/507, "Industrial Development and Consulting Bureau", an expert was sent by the United Nations Industrial Development Organization (UNIDO), the executing agency for the project, to Kuwait for two months, October-November 1976, to determine the feasibility of establishing a plant for manufacturing synthetic adhesives in Kuwait. (See the job description, annex I.)

In this report, the expert first analyses the market for synthetic adhesives in Kuwait and the Gulf area to determine what size plant is required, and then describes the technology of producing urea- and melamine-formaldehyde resins, the bases of the synthetic adhesives that the expert believes can be marketed successfully in the area. A rather detailed description of the plant, its equipment and the recommended site is given. Finally, the profitability of the various options (choice of raw material, location of plant, export possibilities) is studied. The plant is indeed feasible, although the profitability depends markedly on the options, and its building can be recommended (see "Conclusions and recommendations").

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

1. A complete synthetic-adhesive production facility requires two plants, a plant to make formaldehyde from methanol and one to combine the formaldehyde with urea or melamine to make the resin. The latter plant can be built alone and the formaldehyde imported.

2. The fact that two of the principal raw materials, urea and melamine, are produced in Kuwait by the Petrochemical Industries Company and the Kuwait Industrial Melamine Company at the Shuaiba Industrial Area, gives the project a great economic advantage, which would be optimized by erecting the resin plant close to the urea and melamine production units. A further advantage is realized if the formaldehyde plant is close to dock facilities to save on the cost of handling the one raw material that must be imported, methanol.

3. Even with all such economic advantages exploited, a far larger turnover than is possible on the local market is necessary to make the project feasible.

4. Local and near-by export markets are large enough to support a production rate in excess of 5,000 t/a. A rate of 10,000 t/a is feasible in the Shuaiba Industrial Area, the authorities of which consider the project to have a high priority.

5. The return on total investment for an annual turnover of 10,000 t/a of resin per year would be 37% for the resin plant alone and 40% for the two plants operating together.

6. An investment of about $3 million is required to build both plants.

Recommendations

1. Of the two possible methods described for making formaldehyde, the oxide-catalyst method should be chosen.

2. The facility should be build at Shuaiba.

3. The resin plant should not be build unless the formaldehyde plant is erected at the same site.

4. The financing recommended is to obtain a share-holding capital of $1.25 million and to borrow $1.8 million from the Industrial Bank of Kuwait; the return on the share-holding capital should then be extremely high.

I. MARKET SURVEY

Statistios for Kuwait

Some statistical information on imports and exports of synthetic resins and "prepared glues" was obtained from the Ministry of Commerce and Industry. In 1974, imports were 1,442 t and exports about 38 t. In 1975, imports were 1,261 t, a 13% decrease. That did not neoessarily mean a reduction in the production of furniture. It may also have been caused by alterations in manufacturing techniques. The exports in 1975 increased by 17 t, or almost 45%. This may have been caused by direct transit of goods and not export of resins produced in Kuwait. It is, however, possible that some modified PVA-emulsion-adhesives were exported, as some semi-teohnical chemical factories in Kuwait add fillers, thiokeners etc. to imported polymers and resell the product as a new adhesive. The amount rate of consumption of synthetic adhesives in Kuwait is approximately 1,500 t/a.

The statistics mentioned above did not distinguish the imported adhesives by type. Information on type breakdown could be found through visits to the importers and consumers of the adhesives, however.

Summary of visits to adhesive oonsumers

The main consumers of urea-formaldehyde resins in Kuwait are carpenter shops. They number about fifty and are all located in or around Kuwait City. Only five of them are of such a size that any amount of veneering with urea-formaldehyde resin is done. (Urea-formaldehyde adhesives are not suitable for jointing and other general carpentry work. On these jobs different types of PVA glues are usually used.) These five shops consume about 220 t of the 270 t of urea-formaldehyde adhesives imported into Kuwait each year, with the largest importer, the Shuwaikh Carpentry Workshop WLL, consuming about 180 t. Most of the adhesive consumed by Shuwaikh is used in a small chipboard production line set up to utilize all the waste wood from the different carpenter lines in the shop. The chipboard production capacity is about 1,000 t/a. The need for chipboard in future production, however, will be higher, and it would also be desirable to use more of the waste, such as that from sawing and sanding operations. The company therefore wants to rebuild the chipboard line and increase the capacity to about 3,000 t/a. The rate of consumption of urea-formaldehyde powder adhesive will then increase to about 400 t/a.

In the next five years, the rate of consumption of urea-formaldehyde adhesives in Kuwait will most likely not be higher than about 1,000 t of 65% adhesive per year.

The five shops mentioned above also import some 170 t of other adhesives at prices ranging from $900 to $1,350 per ton. The prices paid for urea-formaldehyde adhesives range from $570 to $780 per ton depending on the quantity bought.

The main importers of PVA adhesives import some 650 t per year at prices ranging from $280 to $400 per ton.

The moulding resins are also of interest. In Kuwait the consumption rate of moulding urea resin is about 30 t/a, of the melamine type, about 90 t/a. The market for moulding resins must, however, be studied in connection with the consumption of these types of resin in the whole Gulf area.

The oonsumption of urea-formaldehyde adhesives in the Gulf area

It was rather difficult to determine the consumption of urea-formaldehyde adhesives in the Gulf area as a whole; the consumers have relatively small production units. A closer estimation of this market should be made by visits not only to different countries, but also to the different local markets.

Table 1 shows the resin needs of plywood and ohipboard plants in six other oountries in western Asia, based on information from UNIDO and FAO. (The oonsumption of urea-formaldehyde in the carpentry industry is not taken into consideration here.)

Unfortunately, although Lebanon and Turkey together account for over half the resin required by the six countries, they are the least likely candidates for an export market. The plants in Iran are seen to be relatively small; there may be one large plant and a number of smaller units, together with carpentry shops, located around the larger cities.

A very rough conclusion is as follows: to supply fully the market for urea-formaldehyde adhesives in Iraq and Kuwait and 20% of that in Iran, a production rate of more than 5,000 t/a is required. A rate of 10,000 t/a of liquid resin would be possible at a plant situated as recommended below.

Table 1. Resin needs of plywood and chipboard plants in western Asia

Country	Plywood plants		Chipboard plants		Total resin need (kt/a)
	Number	Resin need (kt/a)	Number	Resin need (kt/a)	
Iran	7	2.4	6	6.0	8.4
Iraq	-	-	2	2.5	2.5
Lebanon	4	4.5	2	2.0	6.5
Pakistan	15	2.4	5	2.0	4.4
Syrian Arab Republic	2	6.5	1	1.2	7.7
Turkey	13	7.9	8	22.7	30.6
Total	41	23.7	24	36.4	60.1

Note: The resin need in kilotons per annum is taken to be exactly one tenth of the plant capacity in thousand cubic metres per annum.

II. PRODUCTION OF UREA- AND MELAMINE-FORMALDEHYDE ADHESIVES

In a 1:2 molecular proportion, urea and formaldehyde, under neutral or slightly alkaline conditions, form dimethylol urea in accordance with following equation:

$$NH_2CONH_2 + 2HCHO \longrightarrow CO(NHCH_2OH)_2$$

This chemical reaction is fundamental for all urea-formaldehyde condensation products and must be closely controlled during the production period.

If the condensation of the dimethylol urea is allowed to proceed under reflux at elevated temperatures and with acidic catalysts in an aqueous solution, an amorphous colourless compound is formed, dissolved in a colloidal solution. The solution increases in viscosity as the condensation progresses and finally gels. Further heating results in the formation of a colourless, infusible, transparent solid. During this period formaldehyde and water are liberated.

When producing synthetic resins, the condensation is controlled and is stopped when the desired amount of polymerization is obtained, by increasing the pH of the aqueous solution to about 8. Then the molecular ratio between urea and formaldehyde is adjusted with urea and the water distilled off until the desired dry-solid content is reached.

The principles given above are the main ones involved in the production of both urea- and melamine-formaldehyde adhesives. (Although for the latter the molecular ratios differ from those used when the urea-formaldehyde adhesives are formed, owing to differences in reaction positions in the urea and the melamine structures, the general procedure is the same.) Many complicated chemical side-reactions occur during the time of condensation and a great number of different methods and techniques have been tried and patented in order to be able to control and regulate the condensation of urea- and melamine-formaldehyde resins. These ideas are, however, far beyond the scope of this presentation and will therefore not be discussed here.

Urea-formaldehyde adhesives have many advantageous properties. First of all, it is low-priced but performs well when used properly and in the right combinations. It is thermosetting and is not be affected by temperature variations under otherwise normal conditions. High temperatures together with moisture will, however, have a hydrolyzing effect on the internal bonds of the adhesive and will decrease its strong adhesive bonds. Urea-formaldehyde adhesives should therefore not be used under such conditions. The urea adhesives are thus classified as "water-resistant" but not as "waterproof".

Melamine-formaldehyde adhesives are more costly to produce but have a higher resistance to hydrolysis and are for this reason rated higher in durability in the various national and international standards systems (ASTM, DIN, BS).

Both the adhesives have the advantage of being colourless. Also, they are cured by the same hardeners during the later stages of processes such as veneering and board production, and in many instances the water resistance and other properties of the urea adhesives may be improved by adding 10%-30% of melamine. The melamine adhesives require, however, under otherwise unchanged conditions, a higher curing temperature than the urea adhesives.

The plain urea resin, and to a certain degree also the melamine types, will be subjected to internal stresses during curing, first of all due to the splitting off of water, followed by a natural decrease of the actual volume. This is normally no problem in the very thin glue lines formed during veneering or pressing of chipboards. Moulded units, however, must be produced using modified resins, possibly with fillers. These processes and products will not to be discussed here.

Melamine-impregnated papers represent, on the other hand, a type of product that must be of interest in Kuwait.

Both urea- and melamine-formaldehyde resins may be considered to be non-corrosive and may be stored and transported in equipment made out of such materials as mild steel. They are not classified as toxic, either, even though they contain formaldehyde. Some people are allergic to formaldehyde and may develop eczema when handling the resins, either by direct contact or via the formaldehyde fumes escaping from the resin, particularly during the curing operation. However, the problem is so unusual as to be of little practical importance.

Both resins are non-flammable and no special precautions need be taken to protect against fire.

The condensation reaction is accelerated by higher temperatures. Hence storage temperatures should be kept as low as possible. Under normal conditions, i.e. up to about 20°C, the storage time may be 2-3 months. At higher temperatures, the time will decrease considerably, and in the area of the Gulf, cooling or isolation of the storage tanks will be necessary.

On the other hand, high, controllable reactivity of the resin is desirable. In other words, the resin should react quickly on contact with the hardener, but usually only when the temperature of the mixture is elevated somewhat. It is a practical problem for the producer of the adhesive to find a resin-hardener mixture that will have good stability at room temperatures (long pot-life) but high reactivity during a pressing operation done at relatively low temperature.

Some problems may also occur in cleaning operations. As already mentioned, the resins form colloidal systems, not true solutions. A colloidal system is distinguished from a true solution primarily by the particle size of the interspersed phase; the resin particles are larger than 0.5 µm and are held in suspension by Brownian motion. By diluting the system, the Brownian is reduced, and the particles tend to combine and fall out of the system. When cleaning kettles, tanks, pumps etc. after they have been used for urea or melamine resins, the system is diluted considerably and the resin particles often fall out as a viscous, sticky mud. This is particularly the case when cleaning with cold water. A good resin should have what is called "good water tolerance": it should have little tendency to form this sticky precipitate when cleaned with cold water.

As one will understand, many considerations should be taken into account when a certain urea- or melamine-formaldehyde resin is to be produced. The producer must have the most thorough knowledge of the mechanism behind the condensation reaction and a clear picture of the physical and chemical requirements of the final product. A practical knowledge of his own, as well as the consumer's, production line is absolutely necessary.

III. RAW MATERIALS

Formaldehyde (formalin)

Formaldehyde is one of the most important chemicals in the production of synthetic adhesives; it is one of the two dominating chemicals in the production of urea-, melamine-, phenol- and resorcinol-formaldehyde adhesives, to mention some of the most important ones on the market today.

Formaldehyde is a gas in normal conditions; its boiling-point is -21°C. The only practical way to store and transport this gas is dissolved in water. The 36.8% (by weight) solution is called formalin. Formaldehyde has a tendency to polymerize to paraformaldehyde in this solution. This is to a great extent prevented by adding methanol to a concentration of 3%-5%. Formalin is usually sold on the international market with the following specifications on impurity content (%):

Formic acid	Max. 0.02
Residue after distillation	Max. 1.5
Iron content	Max. 0.01
Methanol	3-5

Thus, about 60% of the formalin is water, a great drawback, not only during transportation, but also under storage. Moreover, the solution is sensitive to low temperatures. Finally, formalin has a low pH (less than 3) because of the presence of formic acid, further complicating transportation and storage.

It is therefore obvious that economically it is impossible to base the production of any adhesive connected with formaldehyde on importation of this raw material. Formaldehyde is not being produced in any of the countries around the Gulf, and if one or more of the above-mentioned adhesives is going to be produced, it is also necessary to produce formaldehyde.

All formaldehyde sold in large quantity is produced by the oxidation of methanol.

Paraformaldehyde

If formaldehyde is not to be produced, the earlier mentioned paraformaldehyde may be a temporary solution. It is a powder with 86%-92% dry-solid content and is, for this reason, not so sensitive to transportation.

The amount of 37% formalin needed per ton of resin is 910 kg; a production rate of 5,000 t/a resin requires 4,550 t/a of formalin.

Commercial paraformaldehyde is sold in various grades from coarse granules to fine powder. This powder dissolves slowly in cold water, more rapidly in warm. During this process, it depolymerizes; the result is a formaldehyde solution.

Paraformaldehyde liberates fumes of formaldehyde and is just as unpleasant to handle as formalin. Paraformaldehyde is also very hygroscopic and will, when exposed to normal atmospheric oonditions, become hard. When more water is absorbed, the material is completely wet.

Paraformaldehyde is poisonous and must be handled with great care.

Methanol

Methanol, or methyl alcohol, the simplest aliphatic alcohol, has a boiling point of 64.5°C and is soluble in water in all proportions. It has a pH close to 7 and has no corrosive effect on steel or other material that may be used for containers, for tubes or in pumps. This alcohol is, however, poisonous and may cause blindness if drunk. Its viscosity is about the same as that of water. Methanol is, unfortunately, flammable, and precautions should be taken during transportation and storage.

Methanol is usually transported in bulk and small tankers of 500-1,000 t. When they carry methanol, they carry nothing else. That means that of all the raw materials for adhesive manufacture, methanol is the one best suited for transportation. The holds of the vessels are mostly of mild-steel plates without any protective coating. This is usually sufficient even though the international standards for methanol do not tolerate iron. Many methanol users prefer, however, to have coated tanks because both the usual methods for producing formalin are highly sensitive to iron ions. When buying methanol in bulk the international rules for such shipments should be observed. Test samples must, be taken when pumping from ship starts, in the middle of the pumping period and at the end. If the buyer does not accept the cargo, the vessel carrying the methanol has no obligation to take the cargo back. That is a problem strictly between the seller and the buyer. Anyone receiving methanol must, therefore, always have an empty, clean tank big enough to hold all the cargo. That means that the buyer must have at leat two tanks for methanol storage.

On the average, a well trimmed formaldehyde plant will produced about 2.2 t of formalin per ton of methanol. If 5,000 t is to be produced per year, about 2,300 t of methanol must be delivered to the formaldehyde plant in the same period.

Urea

Large amounts of high-grade urea are produced in Kuwait. Indeed, that is one of the reasons for thinking of adhesive production in this area in the first place.

Urea is a white crystalline solid melting at 132.6°C and readily soluble in water. Unfortunately, it is very hygroscopic; it picks up water fast and in huge amounts when it is merely left out in the open air. In the process, solid lumps or even blocks that complicate storage and transportation are formed. Urea is therefore often transported in strong paper sacks with a polyethylene lining. The sacks are costly and it is of great advantage to be able to erect a resin factory so close to the production area of urea that the problems here described are reduced to a minimum.

The amount of urea needed is about 420 kg per ton of resin produced. A production rate of 5,000 t/a of urea-formaldehyde resin therefore requires a rate of supply of urea of about 2,100 t/a.

The urea should have the following specifications:

Nitrogen	46.3%
Water	Max. 0.3%
pH of 20% aqueous solution	8-9.5

Melamine

As urea is already being produced in Kuwait, it is assumed that a method of direct conversion of urea to melamine will be selected. Carbon dioxide and ammonia will be by-products.

As normally obtained, melamine is a white crystalline powder. When pure it melts at 354°C. The solubility of melamine in water under normal conditions is low.

What was said about urea with regard to hygroscopicity is also true for melamine, but to a somewhat smaller extent. Therefore the same problems with transportation and storage exist. It is vitally important to erect the factory close to where the urea and melamine are being produced.

Less melamine is used in producing 1 t of melamine-formaldehyde resin than urea in producing 1 t of urea-formaldehyde resin, but the amount varies considerably depending on the type of resin to be produced. As an average, about 300 kg of melamine will be used to produce 1 t of resin. Usually, less melamine-formaldehyde resin is produced than urea-formaldehyde. In the case of adhesive production, most of the melamine will probably be used for combined urea-formaldehyde and melamine-formaldehyde adhesives.

IV. PLANT DESCRIPTION

Location of the plant

The plant should, if possible, be located in the Shuaiba Industrial Area, at or close to the waterfront. These important savings would result:

(a) As can be seen from the cost data in annex II, location of the plant at Shuaiba rather than Shuaikh would save $82,400 a year on the cost of cooling water for a capacity of 5,000 t of 37% formalin a year. A further saving of $36,200 would be realized if the plant at Shuaiba were located on the waterfront so that sea water could be used for cooling. The savings are great and could justify an investment of more than $1 million. The fact that the cooling would be carried out with sea water of relatively high temperature has been taken into consideration in the construction of the cooling system of the plant. At the first capacity level about 40 t of water is needed per hour. The cooling water capacity should, however, be based on a yearly production of 10,000 t of resin, which requires 80 m^3 of water per hour;

(b) If the plant is built at Shuaikh, the methanol must be transported by tankers to the formaldehyde factory and a new methanol tank must be built. The tank, with all equipment, would cost about $20,000. Assuming 10% interest and 10 years for full depreciation, the yearly cost would be $4,000. The yearly cost of transportation of the methanol and urea from the Shuaiba area to Shuaikh would be about $30,000 (KD 20 for 12.5 t). The extra cost if sacked urea were used would be unreasonably high.

The total of the direct savings explained above is over $150,000, or 10% of the cost of producing urea-formaldehyde resin in the Shuaiba area.

The authorities in the Shuaiba Industrial Area consider the resin plant as a project with priority. It therefore seems possible to get a site with an area of 10,000 m^2 close to the urea factory. The main problem would be to discharge the small tankers, each transporting up to 1,000 t of flammable methanol. The port constructed for tankers does not take small vessels. A container port has been built for small vessels (max. 1,500 t), and some type of container transport of methanol will be considered by the authorities. A possible solution being considered is to construct a light, floating quay at or near the site for the plant, equipped with a 4-in. (10-cm) plastic pipeline and pumping facilities. The small tankers have shallow drafts and the length of the quay does not need to be long. Two buoys and a flexible connection from the pumping equipment to the tankers would be needed.

A map of the Shuaiba area, with the recommended plant site indicated, is in figure I. Figure II shows the arrangement of the different units of the plant, and figure III shows the plant in perspective.

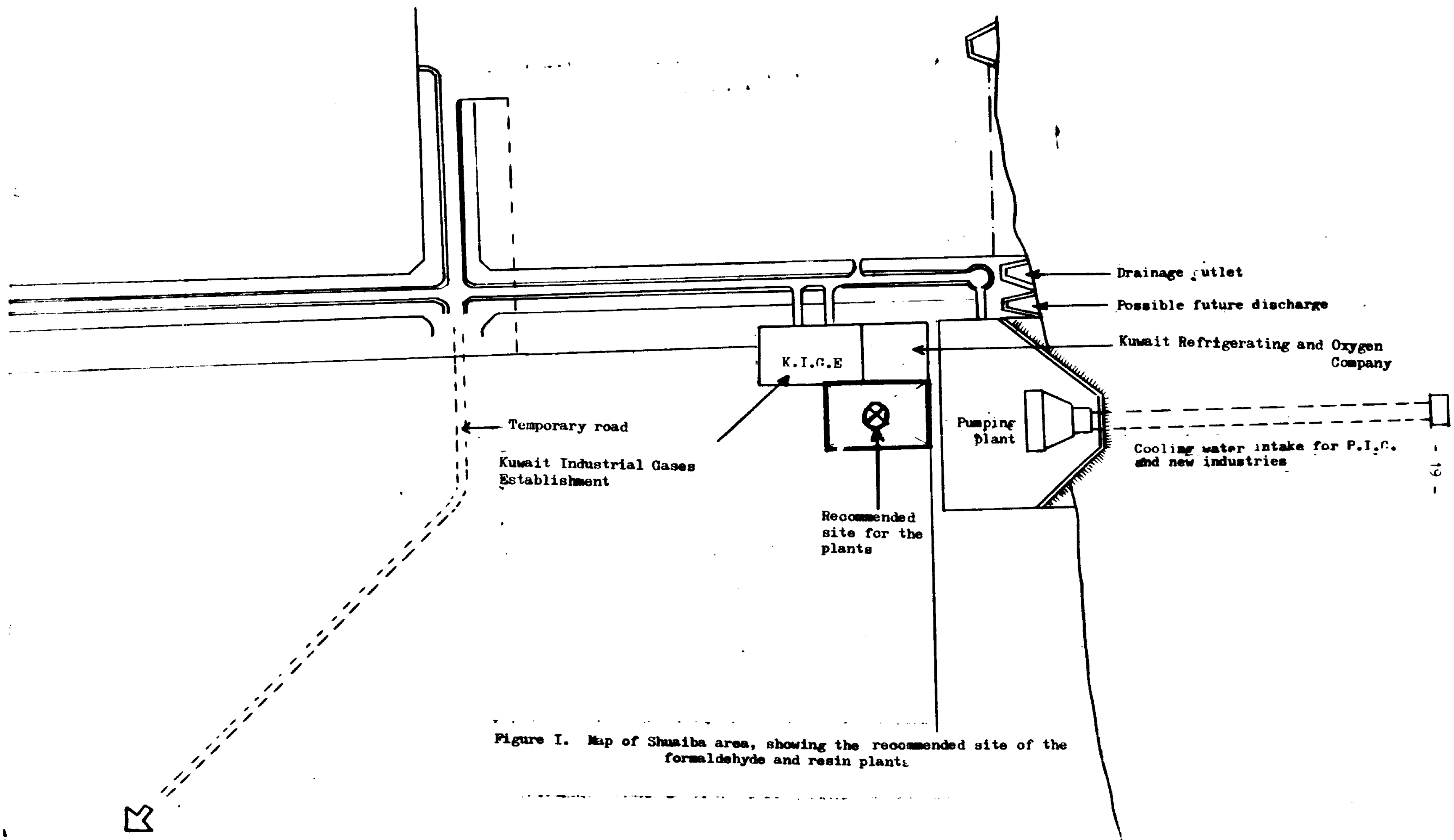


Figure I. Map of Shuaiba area, showing the recommended site of the formaldehyde and resin plants

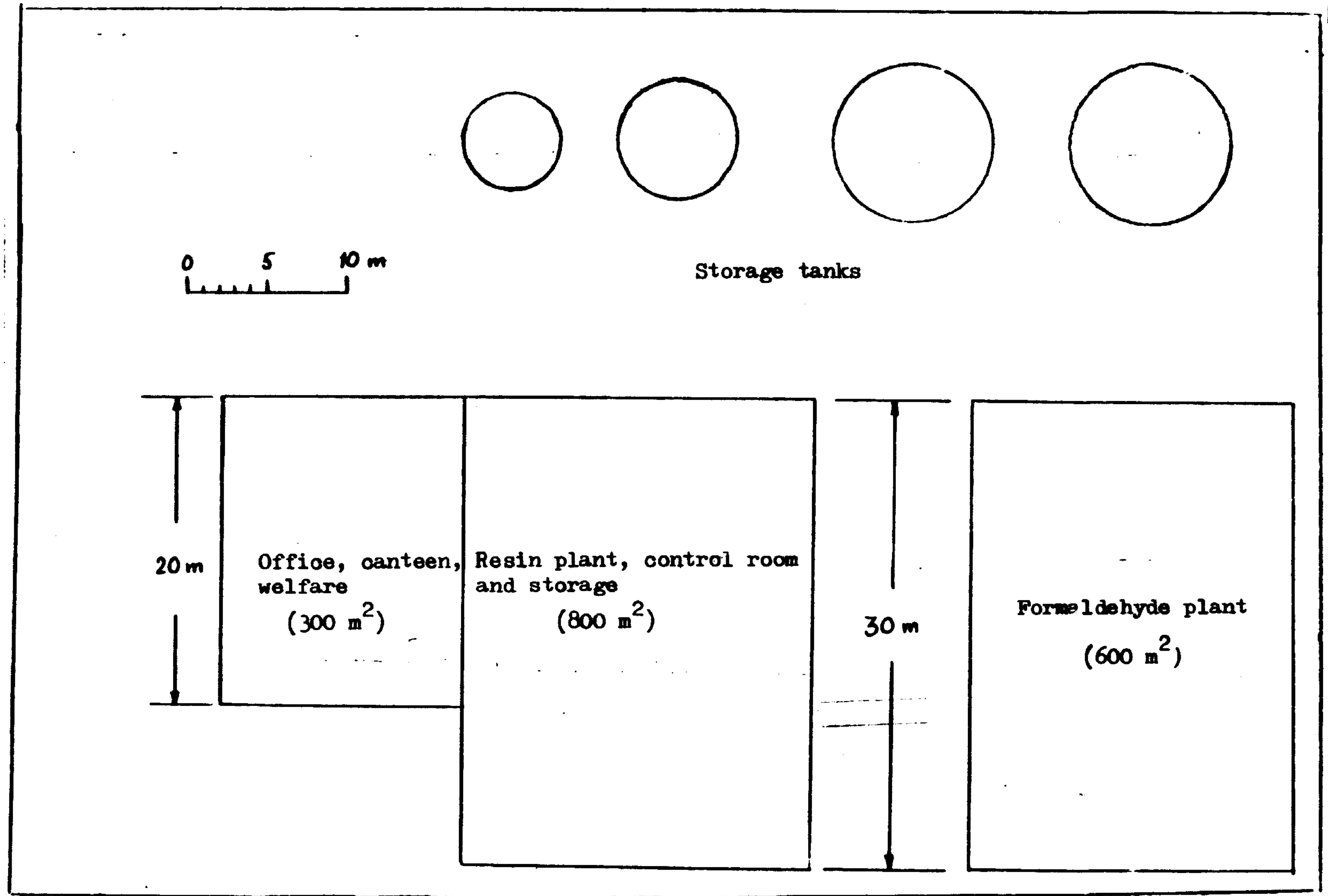


Figure II. Layout of plant site

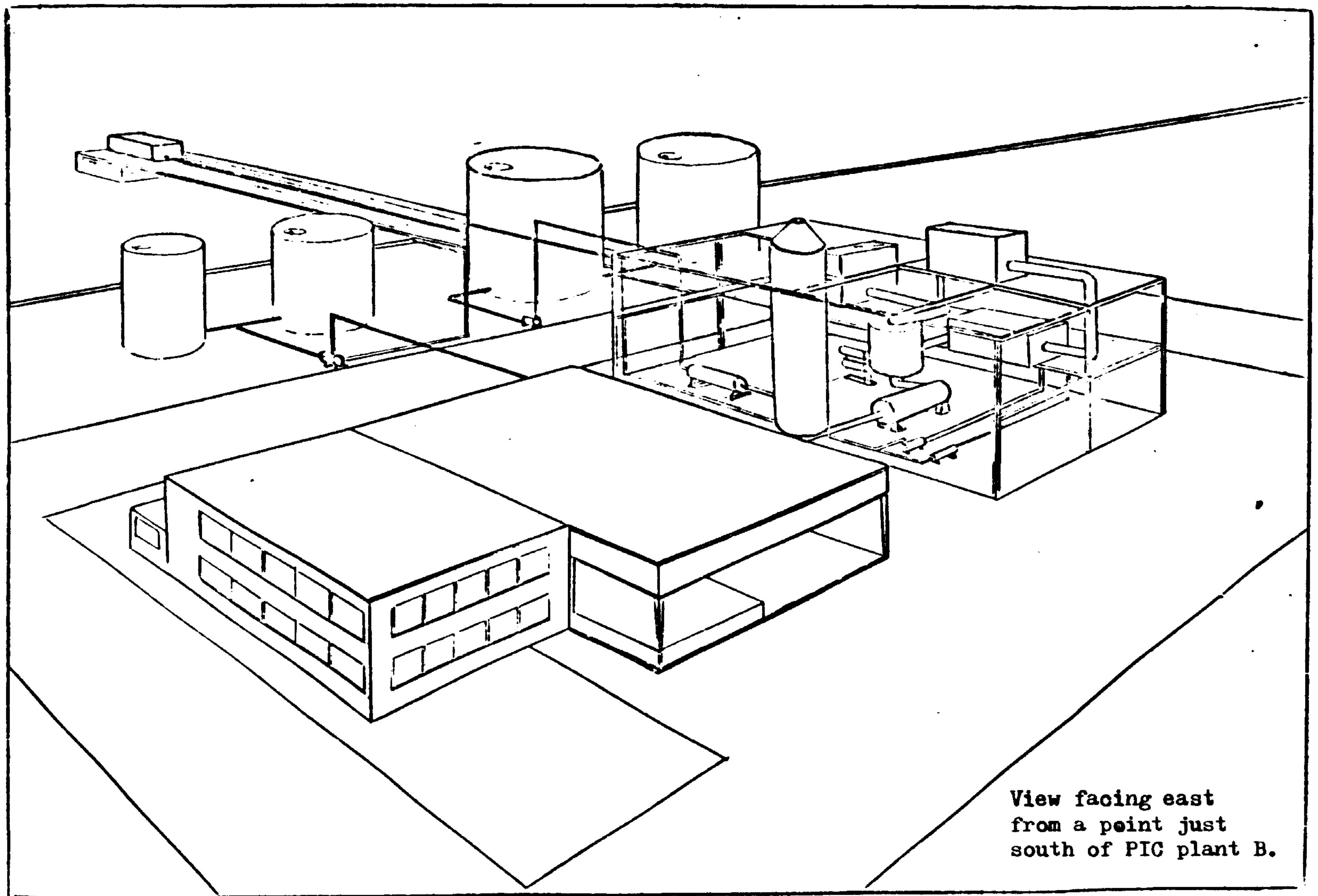


Figure III. Perspective view of plant site

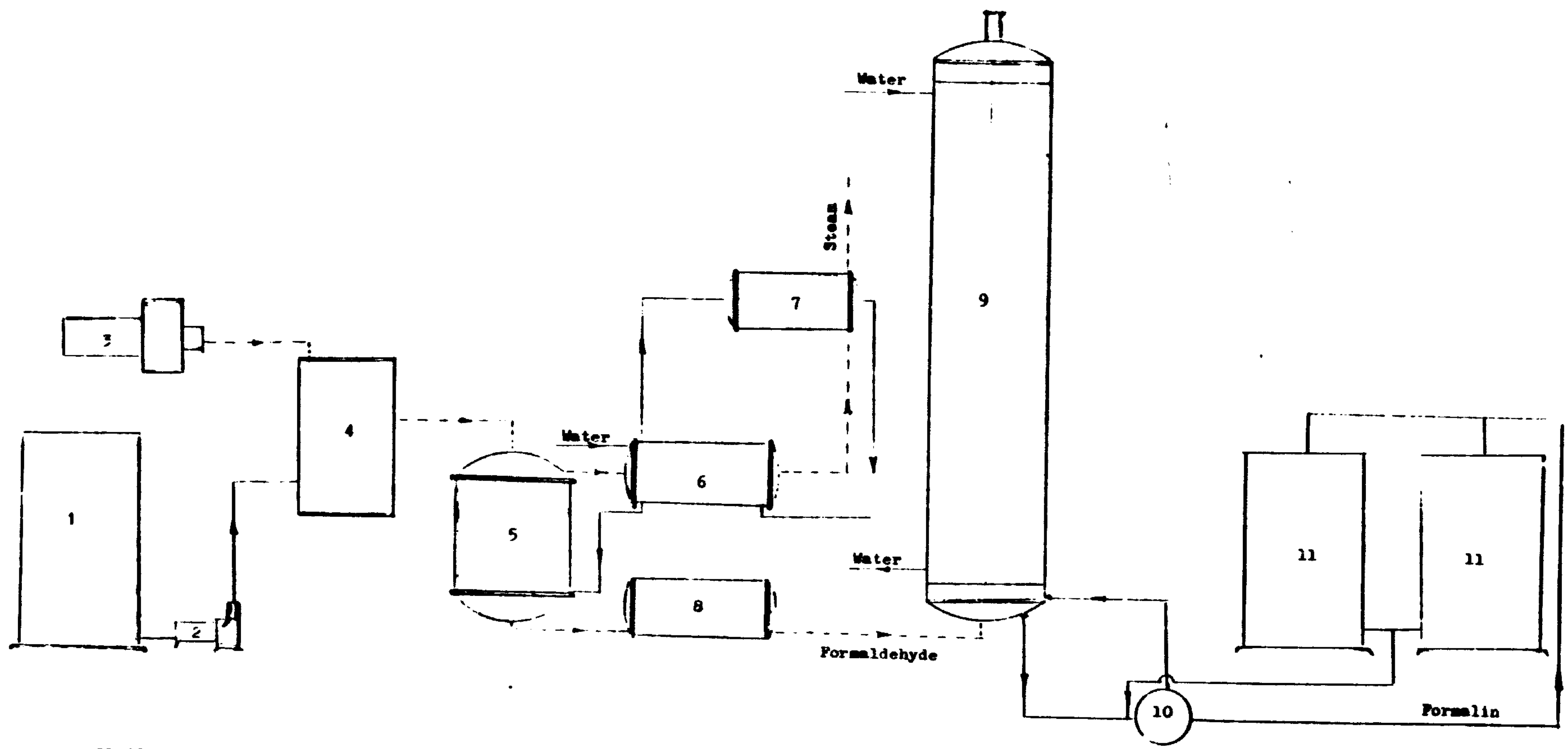
The soil in the area has more than enough compressive strength to support the plant structures. Waste-water discharge is no problem at this location, nor are there any problems in connection with roads, treated water, telephone, telex or electricity.

Formaldehyde plant

The break-even point of a resin/formaldehyde production line is often at sales of 4,000-4,500 t of resin per year. In Kuwait it is possible that this point will be somewhat lower owing to a favourable raw-material and market-price situation. However, few, if any, formaldehyde plants with a capacity of less than 10,000 t/a are ever erected. A 10,000-t/a plant costs only 15%-20% higher, on a turnkey basis than a 5,000-t/a unit. Furthermore, it is clearly bad policy to erect a factory with a capacity close to a likely break-even point. For the same reasons, it is also somewhat awkward to ask for a 5,000-t/a unit where all calculations, drawings and dates, from many years of experience, are based on a capacity of 10,000 t/a. The estimates here will therefore be based on a maximum capacity of 10,000 t/a with 50% utilization.

The principal method of manufacturing formaldehyde is the catalytic oxidation of methanol vapour. Formerly, the most accepted method was to let a mixture of methanol vapour and air pass over a heated bed of silver (the silver method). During the last 20 years, new oxidation processes have been developed. The converter unit consists of a bed loaded with a catalyst composed of a mixture of easily reducible inorganic salts. The oxidation reaction is highly exothermic, and the liberated energy must be removed from the bed by means of circulating high-temperature cooling oils. The two methods have been thoroughly investigated by many experts in the field, but it is hard to say that one method is better than the other. The following explanation is based on the latest method using a salt-catalyst bed.

It is now of interest to describe briefly the methanol formaldehyde process. The flow diagram (figure IV) roughly indicates the production system. The methanol is fed into the system at a closely controlled rate: the signals from flow meters are fed back into the main control unit for the plant to provide immediate automatic correction of the speed of the pump. The methanol is fed into the vaporizer where, in the vapour phase, it meets the air from the blower.



1. Methanol tank
2. Methanol feed pump
3. Air blower
4. Methanol vaporizer
5. Formaldehyde converter
6. Cooling-oil vapour separator
7. Cooling-oil condenser
8. After-cooler
9. Absorption tower
10. Formalin pump
11. Formalin-storage tanks

Figure IV. Formaldehyde plant: flow diagram

The blower must be of a low-pressure, high-volume type (6–7) x 10^3 Nm^3/h. The amount of air needed is often regulated by bleed-off valves. In order to get the right amount of air into the system, the air temperature and volume must both be measured. It is important to have an exact ratio between methanol and air, as this highly affects the physical and economic efficiency of the plant. The practical maximum-efficiency ratio is also very close to the explosion ratio between air and methanol, another good reason to keep the operation under control.

The air-methanol mixture next enters the formaldehyde converter, which contains many fine tubes loaded with the catalyst. The tubes are immersed in a high-temperature cooling oil. To start the reaction, the oil is heated in pre-heaters. After the exothermic reaction has started, the oil carries the liberated energy to the vapour separator, which acts as a heat exchanger, producing steam on the water side of the system. Further heat exchange takes place in the condenser before the oil returns to the separator and finally again to the converter. The working temperature in the bed is 230°-$250^{\circ}C$.

After the oxidation has taken place, the formaldehyde gas (converted methanol) is forced through the after-cooler before entering the absorption tower, where it passes through a row of absorption trays equipped with "bubble cops" and containing water. Here, formalin is formed as the formaldehyde gas is absorbed by the water on the trays. The formalin drains out of the bottom of the tower. The strength of the formalin, that is, how much formaldehyde is absorbed in the water on the trays around the bubble cops, is regulated by the input of methanol and the amount of water fed into the tray sections. The formalin is transported by a pump to the storage tanks.

The formaldehyde plant is erected in the open with almost all parts insulated and covered with aluminium sheets. It covers an area of about 600 m^2 and its highest point is about 14 m. The methanol tanks, including all protective devices, pumps, tubes etc., need an area of another 600-700 m^2. The formalin tanks, pumps, tubes and other equipment cover about 300 m^2. The net area needed for the formaldehyde production is therefore about 2,000 m^2.

In annex II some important data about the economics of formaldehyde production are given.

The resin plant

The basic cost data for the resin plant are given in annex II, and the production process was described above. The discussion will therefore concentrate on how the plant is built. The production unit to be described is suitable for the production of urea-, melamine-, phenol-, and resorcinol-formaldehyde resins since the production form of these types of adhesive utilizes typical batch-type reactions. The general layout of the plant is shown in figures V,VI and VII.

The resin factory building is usually best built as a lofty, one-storey steel-framed building with walls of concrete block and partly of corrugated asbestos sheet, aluminium-sheet roofing on steel frames, a concrete floor, adjustable lounge windows and steel sliding doors. This construction may of course be altered to fit local construction practice. The mezzanine floor of the building should be partly steel-framed concrete and partly chequer plate. On this floor is an office, a toilet, a shower, a locker room, a laboratory and finally the main production area with the reactors. This mezzanine floor should have an area of approximately 200 m^2 of which about 150 m^2 is given over to production.

To produce at the rate of 5,000 t/a only one reactor with a capacity of about 10 t is needed. We have included in the plan an extra, smaller (5-t) reactor that may be used for melamine- or phenol-formaldehyde production if needed. It is also a good insurance to have two reactors in case one should break down.

The production unit located on the mezzanine floor consists of a reactor (1 in Figure V), usually all stainless steel, steam-heated, water-cooled, insulated and with aluminium covering, equipped with an agitator (2) with a speed reducer, various valves and instruments, and finally a condenser (3), with the necessary fittings. Under the floor is the adjustment tank (4), with a capacity of approximately 25 t, equipped with an agitator (5), a transfer pump (6), and associated fittings. It is also convenient to install an overflow tank (7) of slender construction; this enables measurement of the amount of water distilled off during the vacuum period. The two vacuum pumps, which operate in parallel, should be situated in a separate room to reduce noise. A formalin and an NaOH day-tank, complete with pumps and piping, should also be installed. The glue-storage tanks are located outdoors.

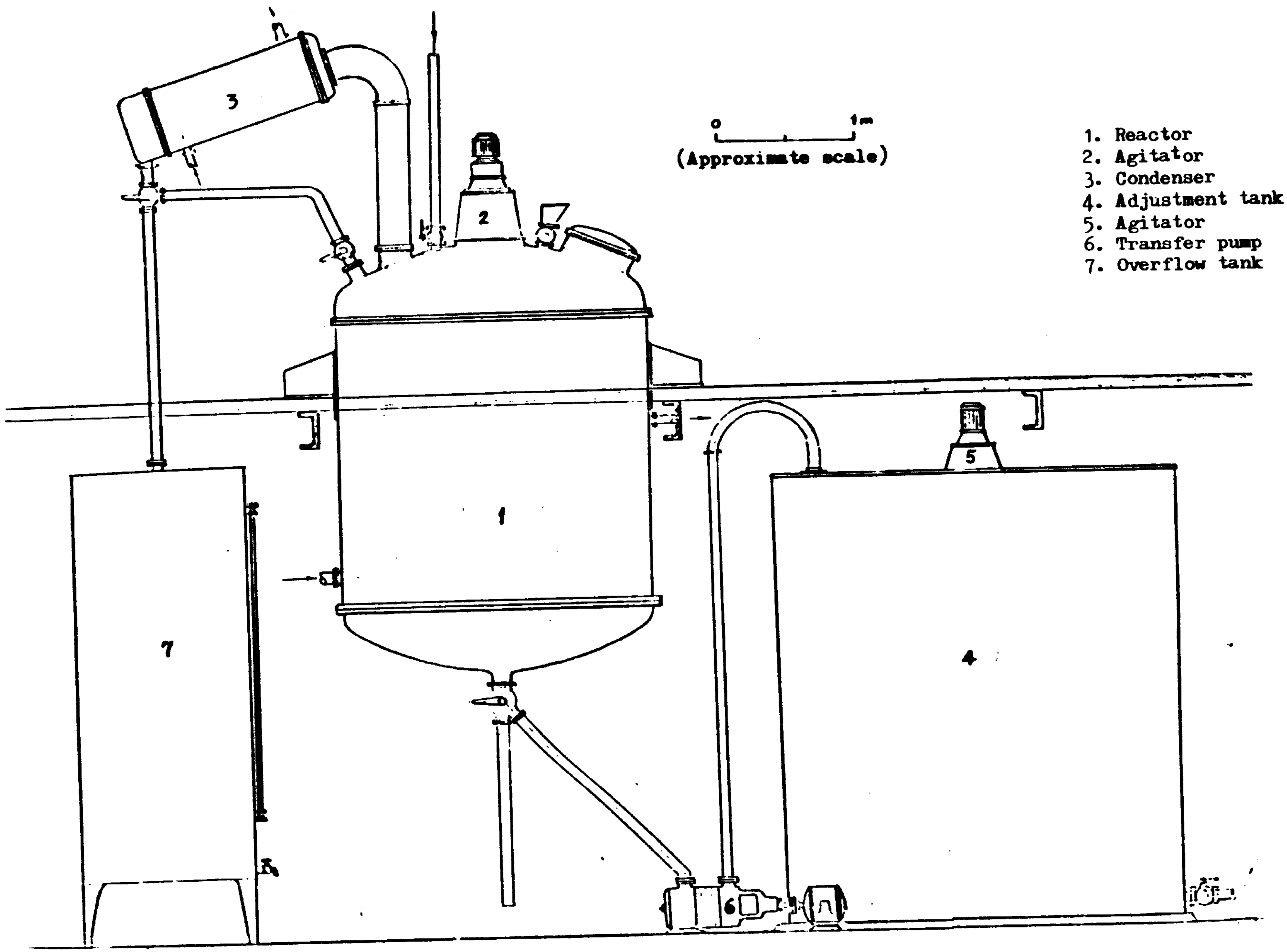


Figure V. Resin plant: flow diagram

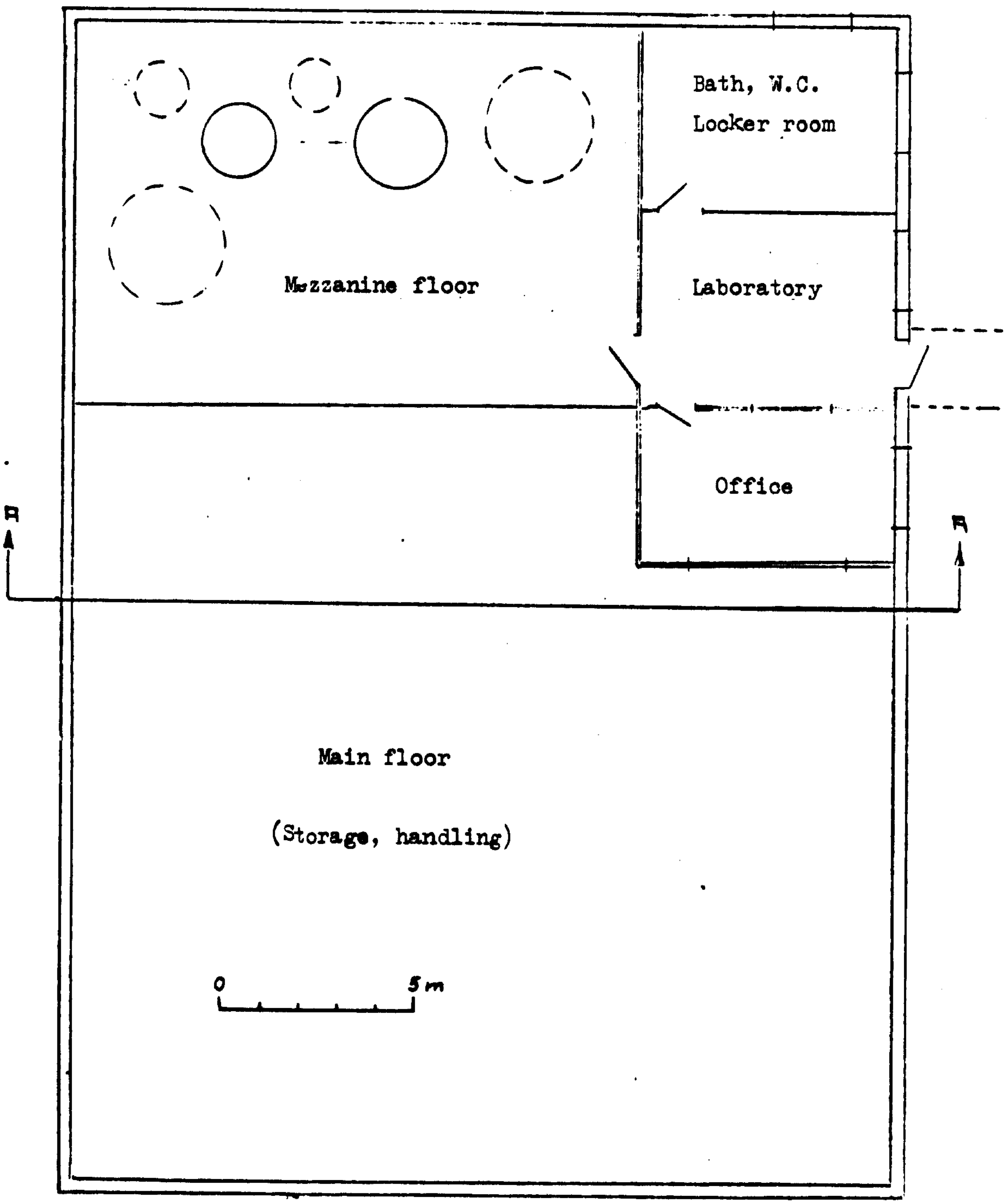
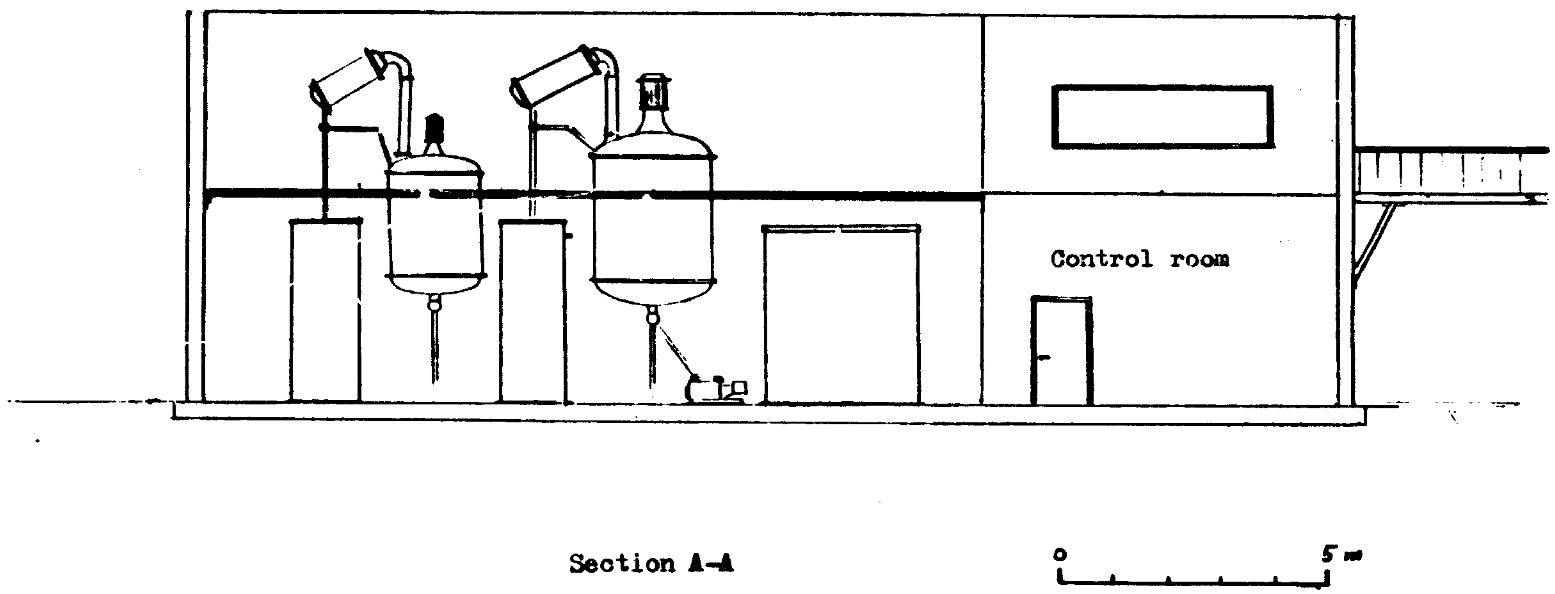


Figure VI. Resin plant: plan and equipment layout



Section A-A

Figure VII. Resin plant: vertical elevation (cross-section of figure VI)

A platform scale with capacity of about 350 kg and an electric hoist should also be on the production platform.

The rest of the main floor, an area of about 600 m^2, is used for hardener production and storage, storage of smaller containers, tapping equipment, and loading and unloading facilities for raw materials and finished products. A 2-t fork-lift is essential.

Training

About 12 months after the formaldehyde resin plant is ordered the first part of the machinery will be delivered on site. As all key personnel should take part in the erection of the factory, thus getting a fundamental understanding of the production units, the first step in the training must have been ended. This first training period should consist of a visit of 3-4 months to a formaldehyde resin factory where the visiting personnel should take part in the operating procedures besides learning the theory behind them. Not less than four operators must take part in this very important training period.

The cost of this education is usually borne by the buyer. It consists of the wages, travelling expenses and room and board for the operators during training. Some variations will occur depending on where the training will take place. The total costs, including and allowance for unforeseen expenses, are estimated at $50,000. Of this total, $30,000 is charged to the formaldehyde, and $20,000 to the resin plant.

The cost of the rest of the training of personnel is usually taken care of in the regular fees, including the stay of a person for one year in Kuwait to help and give instruction in running the plant and introducing the new products on the market.

Choice of method

The direct oxidation of propane and butane to formaldehyde is possible. However, the process is quite complicated and expensive and is carried out under relatively high pressure and temperature. Furthermore, formation of many by-products, such as acetaldehyde, acetone, various alcohols and organic acids, must be expected. The subsequent refining procedures are rather complicated and costly, and since no exact reactor design has been disclosed, the process can hardly be recommended.

The production of formaldehyde by oxidation of methanol is by far the most popular method in use. The oldest of the two processes based on it is the so-called "silver-bed method". A rich mixture of methanol and air is fed into a converter unit equipped with the silver catalyst bed; burners keep the reaction temperature at 600°C. The converted vapours are cooled and dissolved by water in scrubbers. The conversion factor's far from 100%, however, and relatively large amounts of methanol will be found in the solution. The excess of methanol must be removed by fractionation.

The other process, the oxide-catalyst process, was described earlier. A higher yield is supposed to be obtained than in the silver-bed process; a higher conversion factor makes a later removal of methanol unnecessary. The yield is of special importance since the cost of methanol accounts for more than 50% of the cost of manufacturing formaldehyde.

The oxide-catalyst method is especially attractive when formalin with low methanol content is required, as it is in this case. Since the erection costs of the two types of plant do not differ greatly and the operation of the oxide-catalyst type is relatively easily understood, it is believed that this is the type that should be chosen.

Information about the oxide-catalyst type plant may be obtained from the following firms, which will also be able to furnish information, know-how and training for the production of the formaldehyde-type resins, such as urea- and melamine-formaldehyde.

Ciba-Geigy (UK) Ltd
Plastics Division
Duxford, Cambridge CB2 4QA
United Kingdom of Great Britain
and Northern Ireland

A/S Jotun Gruppen
Sandefjord
Norway

Montecatini Edison F.T.A.
Divisione petrochimica e resine
Foro Bonaparte 31
I-20121 Milano
Italy

Reichholds Inc.
White Plains, New York
United States of America

V. PROFITABILITY OF THE PLANT

The basic cost data for the study of profitability of the formaldehyde and resin plants are in annex II.

Investment

Table 2 gives the capital investments required for the two plants. Land is not included, since it will be rented by the Government; the rental cost is a fixed production cost item (see below). The main transformer is also not included, since it will be installed by the electric company. The size required is calculated in annex III.

Table 2. Investments for the formaldehyde and resin plants
(Thousands of dollars)

Item	Formaldehyde	Resin	Total
Fixed capital			
Buildings		205	205
Equipment	1 265	235	1 500
Water system (for cooling etc.)	40	10	50
Office and laboratory equipment	25	25	50
Spare parts and catalyst	13	10	23
Methanol tanks	140		140
Civil works	40	10	50
Boiler		30	30
Pilot plant		50	50
Internal transport		30	30
Training	30	20	50
Fees	135	175	310
Miscellaneous	50	-	50
Total fixed capital	1 738	800	2 538
Working capital		500	500
Total	1 738	1 300	3 038

The assumed working capital is approximately 30% of the probable annual turnover of final product. The amount, $500,000, is assigned to the resin plant, since if the formaldehyde plant is not built a considerable stock of paraformaldehyde must be carried.

Production cost

Table 3 gives the fixed production costs for the two plants and table 4, the variable costs. In computing the latter, the following data were used.

Formaldehyde plant

A production rate of 5,000 t/a of 37% formalin in the Shuaiba area was assumed.

The cost of raw material methanol was taken as $170 per ton and the licence fee as $1.20 per ton of product.

Resin plant

A production rate of 5,000 t/a of 65% urea-formaldehyde resin in the Shuaiba area was assumed. The raw material formaldehyde was assumed to be supplied by the formaldehyde plant as 37% formalin and was charged at the price of $160 per ton. At this price, the formaldehyde plant breaks even, if the interest on the investment is not included in the total fixed cost of production. (See analysis below.) The cost that would be charged for this raw material if the interest is not deducted is shown in parentheses in table 4.

The price of raw material urea was taken as $120 per ton. The licence fee was taken as 3% of the turnover at full capacity at the price of $367.50 per ton of product (see analysis below).

Total production cost

The sum of the fixed and variable costs in each case are as follows (thousands of dollars):

	Formaldehyde		Resin	
	With interest	Without interest	With interest	Without interest
Fixed costs	494	355	301	197
Variable costs	415	415	1 308	1 127
Total	909	770	1 609	1 324

Table 3. Fixed production costs of the formaldehyde and resin plants
(Thousands of dollars)

Item	Rate (%)	Formaldehyde		Resin		Total	
Interest	8[a]		139.0		104.0		243.0
Insurance	0.5[b]		8.69		4.00		12.69
Upkeep	1.5[a]		26.07		19.50		45.57
Land rental			1.28		1.28		2.56
Depreciation:			182		88		270
Buildings	5			10.2		10.2	
Equipment	10	130.5		23.5		154.0	
Office and lab. equipment	10	2.5		2.5		5.0	
Methanol tanks	10	14				14	
Civil works	5	2		0.5		2.5	
Boiler	10			3		3	
Pilot plant	10			5		5	
Internal installations	20			4		4	
Training	20	6		4		10	
Fees	20	27		35		62	
Labour			137		83.9		221
Total			494		301		795
Total, less interest			355		197		552

a/ Of total investment.

b/ Of fixed capital.

Table 4. Variable production costs of the formaldehyde and resin plants
(Thousands of dollars)

Item	Formaldehyde	Resin
Water, cooling	1.4	0.26
Water, other	0.6	[a]
Electricity	2.0	0.34
Catalyst	6	
Spare parts etc.	13	10
Repair and maintenance		2.5
Raw material:		
Methanol	386	
Formaldehyde		728 (909)[b]
Urea		252
Other chemicals		4
Drums		75
Licence fee	6.0	55.1
Total	415	1 127 (1 308)[b]

[a] Included in cooling water cost.

[b] The figure in parentheses is the cost including interest on the formaldehyde plant investment, the other figure, excluding interest.

Profitability analysis

Formaldehyde plant

The only possible way to produce urea or melamine-formaldehyde resins without also producing formaldehyde is to import paraformaldehyde.

Paraformaldehyde must be imported in sacks. At the time of this mission the price was 500 $/t c.i.f. Kuwait. There is 7% charge in the harbour. The delivered price would therefore be 535 $/t. Breakage and handling problems would increase that by more than 10%. The price, as 37% formalin, would therefore be 242 $/t. The total annual turnover then is 5,000 t x 242 $/t = $1,210,000.

The figures above are plotted in the graph of figure VIII. It is seen that the break-even point comes at a production rate of about 3,100 t/a. At a production of 5,000 t/a, the surplus after ordinary depreciation will give a profit on invested capital of 25%. At 10,000 t/a the profit will be about 71%.

Resin plant

The market price for urea-formaldehyde resin in powder form was studied very closely. The lowest price found was 1,472 DM/t c.i.f. Kuwait. Total charges in the harbour increase this by 7%. The price of resin delivered in the harbour would therefore be 1,575 DM/t. Assuming that DM 1 = KD 0.120, the lowest price found for a urea-formaldehyde resin in Kuwait would be KD 189 or about $645 per ton.

The powder resin does not have a 100% dry resin content. Additives are always used to keep the powder workable, some water is present and over-cured insoluble particles will be found. The effective dry resin content will never exceed 95%. Converted into 65% dry resin content, which is normal for liquid resins, the price is 441 $/t.

If the selling price is fixed at a level that leaves room to increase the price by 20% and still not exceed the current market price, it will be 367.50 $/t.

Since the formaldehyde plant was evaluated separately, the fixed costs in the resin plant project are relatively low ($301,000). The variable costs are, however, very high, mainly because of the high formaldehyde price, which, in turn, is high because of the high methanol price.

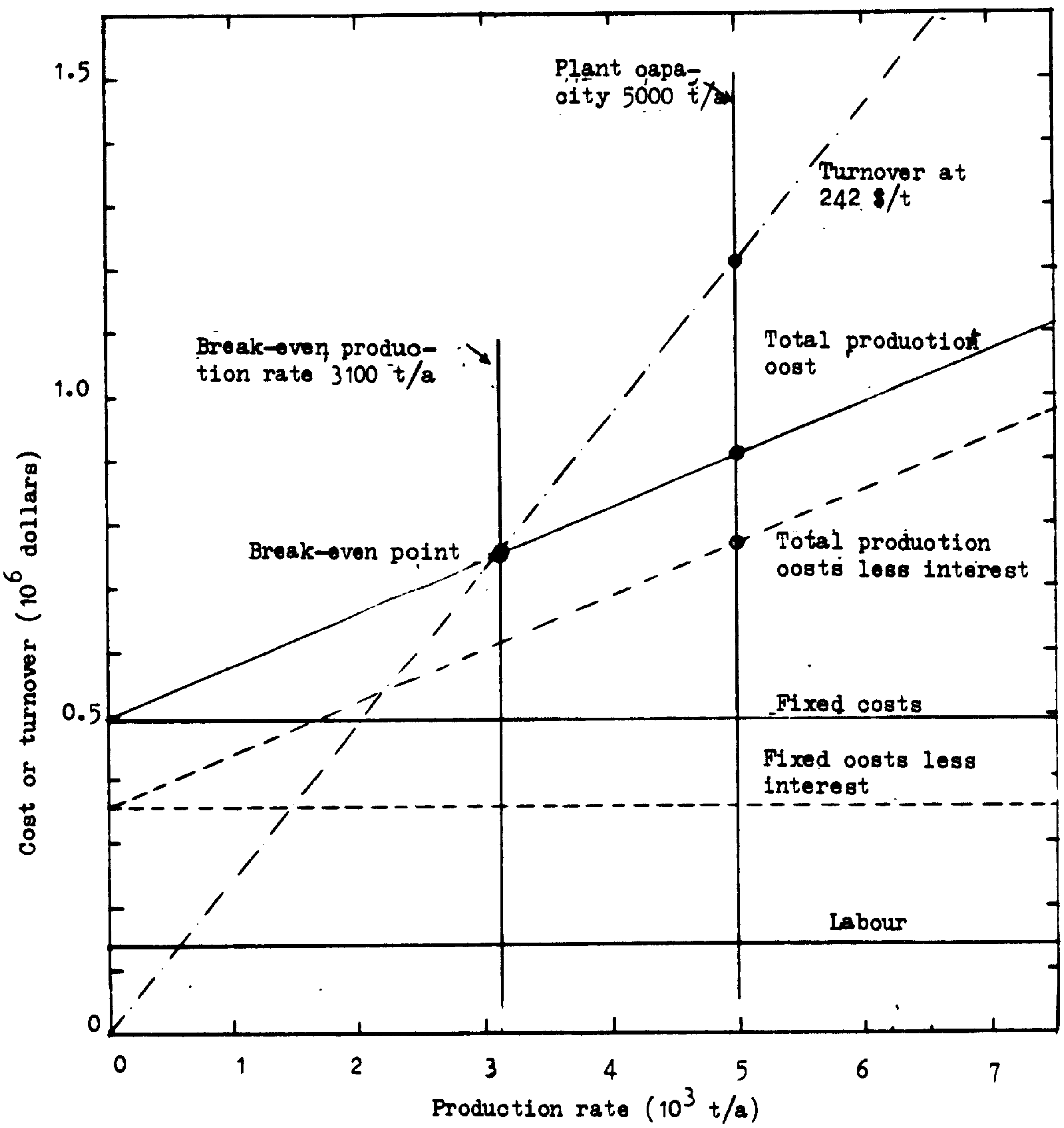


Figure VIII. Cost and turnover curves for the formaldehyde plant

At a production rate of 5,000 t/a, the resin plant, considered by itself and buying formalin at the market price, would have a surplus after ordinary depreciation that would give a return on invested capital of about 11%. If the production is increased to 10,000 t/a, the profit rises to 37%.

With the estimated selling price, the break-even point for the resin plant using formalin from the formaldehyde plant will be at a production rate of about 2,800 t of 65% urea-formaldehyde resin per year (see figure IX).

If the break-even price of the product of the formaldehyde plant (5,000 t produced at a cost of $909,000 means a break-even price of $182 per ton) is used to calculate the cost of raw material for the resin plant, the profits of the resin plant give a return of only 8% on the combined investment in the two plants. A more correct economic picture would probably be given by using a price that is somewhat higher than the break-even price based on costs that do not include the interest on the invested capital in the formaldehyde plant. This price is taken as $160 per ton (5,000 t produced at a cost of $770,000 means a break-even price of $154 per ton). and only the actual amount of formalin used in resin production (4,550 t) is charged for.

If the total annual production of 5,000 t/a is sold, the total turnover will be $1,837,500. The profit, after subtracting the production cost without interest (see above), is $514,000, representing a 17% return on the capital invested in both plants.

If the annual production is increased to 10,000 t and it is all sold, the total production expenses excluding interest on capital will be about $2,451,000 and the total turnover will increase to $3,675,000. The return on total invested capital will then be 40%.

Summary

In order to find the feasibility of the formaldehyde plant as a production unit, a separate study was carried out. The return on investment is good at a production level of 5,000 t/a and extremely high at 10,000 t/a. The production cost is, however, relatively high, mainly because of the high price of the imported methanol (170 $/t). This price, on the other hand, fluctuates up and down on the world market and all buyers have the same opportunity to obtain the best price on the market at any given time.

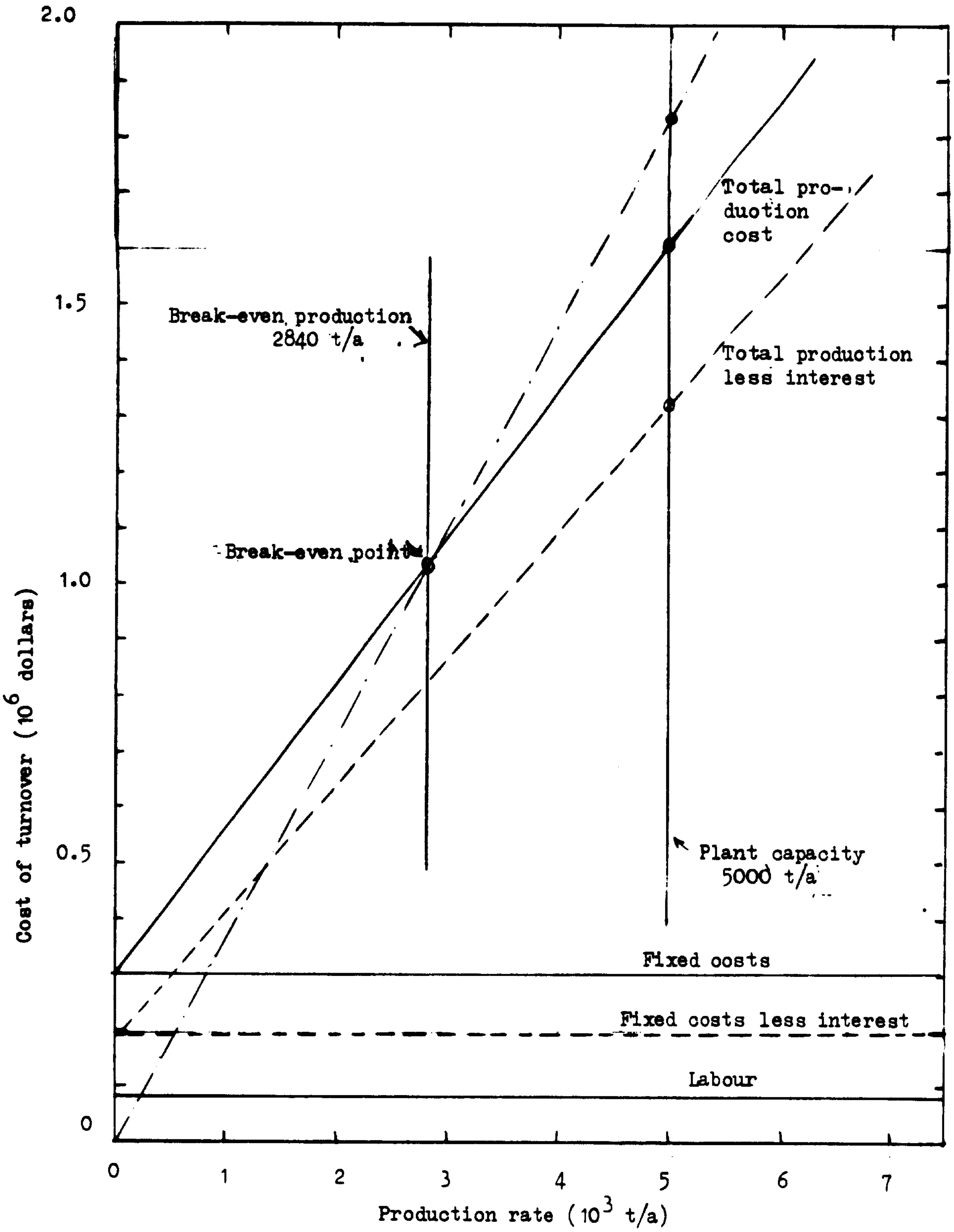


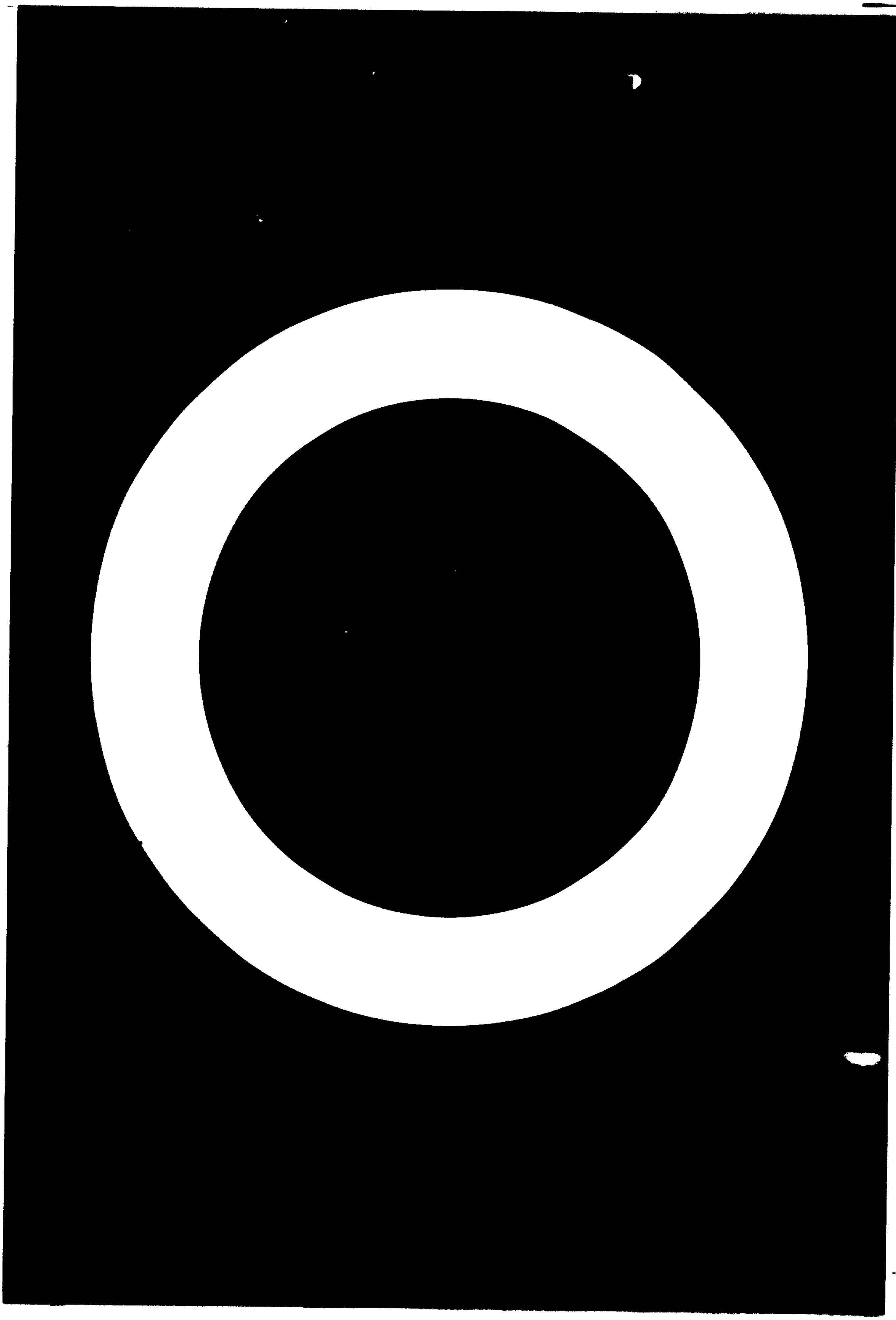
Figure IX. Cost and turnover curves for the resin plant

With a turnover of 5,000 t or more per year, the erection of a formaldehyde plant seems to be sound.

In the feasibility study of the resin plant, use was made of the economic advantage of own formaldehyde production, as this raw material was "sold" to the resin plant at the break-even price. If the formaldehyde and resin plants are considered as one unit when calculating the return on invested capital, it is found that the unit is as feasible as the formaldehyde unit alone. Even at a total annual turnover of only 4,000 t the profitability is 12%. That turnover would already be reached if the market were only Iraq and Kuwait.

If a company is formed to carry out the erection of the production unit and produce and sell resins, a share-holding capital of about $1,250,000 is recommended. The rest of the capital, about $1,800,000, may be borrowed on the local market. In all calculations an interest of 8% on invested (or borrowed) capital was assumed, even though it should be possible to borrow money from the Industrial Bank for Loans in Kuwait at an interest rate of 5%. In these conditions, the profit on the share-holding capital will be extremely high.

The conclusion is that it is quite feasible to establish a synthetic adhesives manufacturing plant in Kuwait.



Annex I

JOB DESCRIPTION

DP/KUW/71/507/11-10/05

Post title: Short-Term Consultant in the Field of Synthetic Adhesives

Duration: Two months

Duty Station: Kuwait

Purpose of project: To provide sufficient information and guide-lines to enable investors to take a decision in regard to establishing a synthetic adhesives manufacturing plant

Duties: The consultant will be attached to the Industrial Development and Consulting Bureau and, as a member of a team of international experts under the leadership of the Project Manager, will be expected to:

(a) Visit local importers of different synthetic adhesives;

(b) Assess the present requirements for domestic and export markets as well as future potentials;

(c) Prepare a feasibility study for setting up a factory for the production of synthetic adhesives. The feasibility study should include:

(i) Marketing of the adhesives produced for local consumption and export

(ii) Advice on techno-economic problems of establishing the plant including location, appropriate capacity, engineering, raw materials, utilities, manpower and organization

(iii) Descriptions of manufacturing processes

(iv) Descriptions of machinery and equipment

(v) Tabulation of estimated project costs, estimation of working capital and suggested capital structure

(vi) Estimation of unit cost of production and profitability statements for local and export markets

(vii) Recommendations of sources for more information

Qualifications: University degree in chemical engineering with extensive experience in the synthetic adhesives industry and in the preparation of pre-feasibility studies

Language: English

Background information:

Kuwait is one of the major oil-producing countries, and revenues from oil constitute the majority of the total revenues of the country. Among the objectives of the country's development policies, diversification of the economy is an important objective. The substitution of nationally manufactured goods for imported products and the establishment of viable industries are recommended.

There are several factories for wood furniture as well as one for chipboard. A large wood-processing complex is also under consideration. Two projects for PVC and asbestos vinyl tiles have been licensed. All these industries are consumers of synthetic adhesives.

The Industrial Development and Consulting Bureau is primarily concerned with promoting investment opportunities in industry by identifying viable projects through carrying out pre-feasibility studies and evaluating those submitted by local entrepreneurs, as well as by assisting the Ministry of Commerce and Trade in other industrial development objectives.

Annex II

BASIC COST DATA

Rates

Utilities

Water

Shuaikh Industrial Area

An area for light industry, located inland.

Water costs 800 fils per 1,000 Imperial gallons
= 176 fil/t = 0.60 \$/t

It may be possible to drill for water.

Shuaiba Industrial Area

Located on the Gulf, meaning that sea water can be used for cooling, at a cost of 1.99 fil/m^3

= 2 fil/t = 0.007 \$/t

Treated water here costs 250 fils per 1,000 Imperial gallons
= 55 fil/t = 0.188 \$/t

Electricity

Shuaikh Industrial Area

2 fil/kWh = 0.007 \$/kWh

Shuaiba Industrial Area

1 fil/kWh = 0.003 \$/kWh

Labour

	Salary (KD/month)
Unskilled labour	100
Skilled labour	250
Engineer	500

Buildings

Building costs are 35-60 KD/m^2, depending on type of construction.

Land

Annual rentals (per 1,000 m^2):

At Shuaikh KD 7 ($24)

At Shuaiba KD 75 ($256)

Fees

The fees for the plants are apportioned as follows (thousands of dollars):

Type of fee	Total	Formaldehyde	Resin
Consulting	50	25	25
Turn-key	200	50	150
Engineering	60	60	-
Total	310	135	175

Costs of the formaldehyde plant

(Production rate 5,000 t/a)

Utilities

Water for cooling

Requirement per unit of product: 40 t/t

Annual requirement: 200,000 t

Annual cost ($):

	Total	Per ton HCHO
Shuaikh	120,000	24
Shuaiba	37,600	7.5 (treated water)
	1,400	0.3 (sea water)

Water for other purposes

Treated water must be used.

Requirement per unit of product: 0.6 t/t

Annual requirement: 3,000 t

Annual cost:

	Total	Per ton HCHO
Shuaikh	1,800	0.36
Shuaiba	1,960	0.39

Electricity

Annual requirement: 560,000 kWh

Annual cost ($):

	Total	Per ton HCHO
Shuaikh	3,920	0.78
Shuaiba	1,960	0.39

Steam

Steam is not a requirement; it is actually produced in the process of making formaldehyde, in this case at the rate of 1,500 t/a. Most of this steam will be used, if needed, to evaporate water from the resin reactor after condensation (see below).

Labour

Labour requirements for continuous operation

Job	Number	Salary (KD/month)	Annual cost (1,000 KD)
Manager[a], engineer, office, laboratory	1 each		15.0
Electrician	2	250	6.0
Mechanic	1	250	3.0
Skilled operator	5[b]	250	15.0
Unskilled	1	100	1.2
Total			40.2 ($137,000)

[a] Also manages the resin plant.

[b] Two on day shift, one on each of the other shifts, one extra.

Annual cost per ton HCHO: $27.

Buildings and equipment

The cost of the buildings is charged to the resin plant (see below).

The cost of the equipment is $1,265,000 for the formaldehyde plant and $40,000 for the sea-water cooling system.

Land

The oost of land rental is divided equally between the formaldehyde and resin plants. For the 10,000 m^2 needed, the formaldehyde half is ($/a):

	Total	Per ton HCHO
Shuaikh	102	0.02
Shuaiba	1,280	0.26

Office and laboratory equipment

The total cost, $50,000 ($30,000 for the offioes and $20,000 for the laboratory), is divided equally between the formaldehyde and resin plants. The formaldehyde half, when depreciated at the rate of 10% per annum, represents an annual cost per ton of HCHO of $0.50.

Spare parts and catalyst

The smaller and oheaper spare parts should be kept on hand, relying on the manufaoturer to supply the larger parts when neoessary. One extra oharge of oatalyst should be kept on hand in case the working catalyst is aooidentally lost.

Total estimated oost: $13,000

Per ton of HCHO: $2.60

Methanol storage tanks

Requirement: 3,000 t/a or 1,000 t every four months. Tank oapaoity should be 1,000 m^3, but two are needed (see text).

Total cost for two tanks, 10 m diameter, 13 m high, inoluding installation: $140,000. At 10% depreoiation annually, annual oost per ton HCHO is $2.80.

Civil works

Estimated: $40,000

Depreciation: 5% per annum

Annual oost per ton HCHO: $0.40

Fees

The total consulting, turn-key and engineering fee oharged to the formaldehyde plant is $135,000 (see section headed "Fees" above in this annex), which when depreciated at the rate of 20% per annum amounts to an annual oost per ton of product of $5.40.

Costs of the resin plant

(Production rate 5,000 t/a)

Utilities

Water for cooling

Requirement: 36 t of 15°C water twice a day to cool reactor.

For purposes of estimate, rate of use is assumed to be 100 t/d, or 36,500 t/a.

Annual cost ($):

	Total	Per ton resin	
Shuaikh	21,900	4.38	
Shuaiba	6,862	1.37	(treated water)
	256	0.05	(sea water)

Water for other purposes

Requirement: Small; included above by overestimating amount needed for cooling.

Electricity

Annual requirement: 100,000 kWh

Annual cost ($):

	Total	Per ton resin
Shuaikh	700	0.14
Shuaiba	340	0.07

Steam

Steam is mainly used to evaporate water from the condensed resin. Most of the water comes from the formalin, which in its commercial form is 58-60% water. It is not practicable to ship more strongly concentrated formalin. If it is made locally, however, it may have a higher concentration, say 42.4% formaldehyde rather than the commercial 36.8%. With that concentration, condensation time is shorter, and if the resin is marketed at a dry content of about 61%, it is not necessary to evaporate water after condensation. That will save time, energy, methanol and labour.

In the feasibility estimates, a product with a dry resin content of 65% is assumed. In this case, about 200 kg of steam at 4 bar is needed per ton of resin produced. With an energy-buffer in the boiler, the heat produced during the exothermic reaction in the formaldehyde plant should be sufficient for the evaporation (see above). However, a separate boiler should be installed, as it may be necessary to produce resin when the formaldehyde plant is not in operation.

After considering four possible ways of obtaining the requisite amount of heat flow (2.5×10^9 J/h), namely, low-pressure steam, high-pressure steam, hot water and steam-oil heat exchanger, the expert recommends the installation of high-pressure boiler with a maximum working pressure of 8 bar (slightly higher than the working pressure in the formaldehyde plant) and a heating capacity of 6.3×10^9 J/h to cover possible future expansion.

Cost: about $30,000

Labour

Labour for two-shift operation

Job	Number	Salary (KD/month)	Annual cost (1,000 KD)
Engineer	1	500	6.0
Skilled operator	5[a]		15.0
Laboratory help	1	150	1.8
Storekeeper	1	150	1.8
Total			24.6 ($83,900)

[a] Two per shift, one extra.

Annual cost per ton resin: $16.80.

Building and equipment

Building	Area (m^2)	Cost per unit area (KD/m^2)	Annual cost (1,000 KD)
Resin factory	300	40	12
Office and welfare	300	60	18
Control room	100	60	6
Compressor	50	60	3
Storage	600	35	21
Total			60 ($205,000)

Depreciation rate: 5% per annum

Annual cost per ton resin: $2

The cost of equipment is $235,000.

Land

See above under the corresponding entry for the formaldehyde plant.

Office and laboratory equipment

See above under the corresponding entry for the formaldehyde plant.

Spare parts

Estimated requirement: $10,000

Per ton of resin: $2

Civil works

Estimated: $10,000

Depreciation: 5% per annum

Annual cost per ton resin: $0.10

Fees

The total consulting, turn-key and engineering fee charged to the resin plant is $175,000 (see section headed "Fees" above in this annex), which when depreciated at the rate of 20% per annum amounts to an annual cost per ton of resin of $7.00.

Annex III

MAIN TRANSFORMER REQUIREMENT

In order to estimate the capacity of the main transformer, it is necessary to add up the power requirements of the installed equipment, as follows (kW):

Formaldehyde plant

Air blower

Two blowers should be installed for safety. The blower is the heart of the formaldehyde plant. Only one will be in operation at a time, so only the rating of one is included 200

Pump

Centrifugal pump	3
Centrifugal pumps, 2 x 7.5 kW	15
Vacuum pump	3
Transfer pumps, 2 x 1.5 kW	3
Transfer pumps, 2 x 5.5 kW	11
Total	235

Resin plant

Transfer pump	1
Motors on two mixing tanks	6
Motors on two mixing tumblers	2
Motor on 10-t reactor	5
Motor on 5-t reactor	5
Adjustment tank	10
Rotary pump	5
Adjustment tank	4
Rotary pump	5
Vacuum pump	11
Rotary pump	3
Water pumps	3
Total	60
Total both plants:	295

Recommended:

At least one 500-kW transformer.

C-700

78.12.12