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ASSISTANCE FOR THE UTILIZATION OF PHOSPHOGYPSUM BY-PRODUCT*,
SI/SYR/78/801,
SYRIAN ARAB REPUBLIC.

Terminal report

Prepared for the Government of the Syrian Arab Republic
by the United Nations Industrial Development Organization,
executing agency for the United Nations Development Programme

Based on the work of Alfred Schmidt, UNIDO expert

United Nations Industrial Development Organization
Vienna

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Explanatory notes

The monetary unit in the Syrian Arab Republic is the pound (LS). During the period coverd by the report, the value of the pound in relation to the United States dollar was $US1=LS 3.90.

References to tons (t) are to metric tons.

ACSAD is the Arab Institute for the Study of Arid Zones and Dry Lands.

Mention of firm and commercial products does not imply the endorsement of the United Nations Industrial Development Organization (UNIDO).

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1. Summary

After start-up of the phosphoric acid plant of the General Fertilisers Company at Homs phospho-gypsum will be produced as a by-product in a quantity of about 900 000 t/a. This material can either be discarded or reprocessed.

For discarding the phospho-gypsum without detrimental effect to the environment it should be transported to the phosphate mines area in the desert and dumped nearby; this will cost about LS 14.- per ton.

In a detailed technical and economic analysis of the problem it is shown that reprocessing the phospho-gypsum can be economically profitable. It is proposed to produce

600 t/d setting retarder and plaster of Paris
400 t/d ammonium sulfate
850/770 t/d sulfuric acid/cement

from it.

The setting retarder production should supply the demand for this material of the cement plants at Homs, Hama, Tartous and Tripoli. The plaster of Paris can be used for the production of plaster or of building blocks by the building materials industry. Ammonium sulfate production will utilise part of the excess ammonia produced at Homs; it is a nitrogen fertiliser specially suitable for irrigated areas. Sulfuric acid and cement are co-produced in one process; the sulfuric acid will be used in the phosphoric acid production; the cement is of standard quality. This process will use about half of the petrocoke produced at the Homs refinery and

so help to solve another environmental problem; it will also save the import of 85 000 t/a of sulfur with a value of more than US$ 6 million annually.

A decision on the sulfuric acid/cement process can only be reached after start-up of the phosphoric acid plant and proving the quality of the phospho-gypsum produced. The other two processes are not so much dependant on the quality of the phospho-gypsum so they can be decided upon immediately.

All products mentioned show good economic profitability at internal rates of return between 13 and 18 %.

It is recommended that detailed feasibility studies should be made for the projects mentioned.

2. Introduction

Within its plans for increasing the food production the Syrian Arab Republic is building a fertiliser production complex at Hom s. There ammonia, urea, phosphoric acid, and triple superphosphate will be manufactured.

After start-up of the phosphoric acid plant a very large quantity of phospho-gypsum will be produced as a by-product. As the proposed dumping of this material in an area nearby might lead to environmental problems, the government of the Syrian Arab Republic asked the United Nations Industrial Development Organisation that an UNIDO expert should

- investigate the possibilities for dumping the phospho-gypsum without detrimental effects to the environment, and
- propose products which could be manufactured by reprocessing the phospho-gypsum.

After selection of the expert the project became operational on 19 May 1979. The expert made a detailed study of the problem in Syria in co-operation with the Ministry of Industry and with General Fertilisers Company at Homs, and after obtaining technical and economic data on a trip to various firms in Austria and the Federal Republic of Germany finalised this technical report in August 1979.

3. Findings

3.1 Phospho-Gypsum - a general review

Phospho-gypsum is a by-product of the manufacture of phosphoric acid by the wet process. Per ton of P_2O_5 in the acid 4.5 to 5.5 tons of phospho-gypsum are obtained, the exact quantity depending on the phosphate rock quality. It is estimated that over 60 million tons of phospho-gypsum are produced annually all over the world.

The phospho-gypsum as it comes from the phosphoric acid plant contains a number of undesirable impurities, such as phosphates, fluorides, silicofluorides, organic matter, as well as 25 to 35 % of moisture. The quantity of impurities in the phospho-gypsum depends on the quality of the phosphate rock, on the phosphoric acid process used, and on the operation of the plant.

Phosphoric acid processes producing the dihydrate directly give a higher level of impurities than dihydrate/hemihydrate, hemihydrate/dihydrate, or hemihydrate processes. Representative compositions of a number of phospho-gypsum samples are shown in annex V. The quality of the phospho-gypsum is very important for all reprocessing processes.

Most of the phospho-gypsum produced in the world is discarded at or near its production site by various methods; but reprocessing is rapidly gaining in interest because of the environmental problems caused by all known dumping practices.

3.1.1 Disposal methods for phospho-gypsum

For discarding the phospho-gypsum one of the following methods can be used:

dumping on land,
dumping into rivers or lakes,
dumping into the sea.

Dumping on land has been widely used where sufficient land is available. For a 100 000 t/a P2O5 phosphoric acid plant an area of about 1.5 km2 is necessary.

Normal practice is to slurry the gypsum cake from the gypsum filter with water to obtain a suspension with 10 to 15 % solids contents. This slurry is pumped to the disposal area, which has to be surrounded with dikes.

The water requirement for slurrying the gypsum is high, approx. 500 m3/h for a 100 000 t/d P2O5 plant. Part of this water can be recovered from the disposal area after the gypsum has settled. But this recycled water contains phosphoric acid and fluorides, which lead to corrosion problems in the slurry system.

Alternatively it is possible to dump the phospho-gypsum as it comes from the filter, i.e. in a relatively dry state (25 to 35 % moisture).

Difficulties from phospho-gypsum deposits come mainly from ecological considerations. Leach liquids from the deposits will find their way into the ground water; these liquids are highly acidic and contain fluorides and calcium sulfate. These impurities will render the ground water insuitable for agricultural use, as well as for animal and human consumption. Contaminated ground water will also attack concrete foundations and steel reinforcements in the concrete. Furthermore during the hot and dry summer season fluorine vapors will be evolved from the deposits, and winds will carry away dust and so create another nuisance.

Because of these difficulties phospho-gypsum disposal on land is no longer allowed in most European countries.

Dumping of phospho-gypsum into rivers and lakes has been practised with small quantities in Europe. The solubility of gypsum in water is 2.5 kg/m3 water; so for one ton of gypsum 40 m3 of water are required. This practice has been prohibited by goverment regulations for the conservation of clean water in most countries.

Dumping the phospho-gypsum into the sea is the most widely practised method for disposal at present. It is used in western Europe, the USA, North Africa and Australia. The phospho-gypsum is usually slurried with sea water (5 % solids concentration) and pumped a few hundreds of meters out into the sea. The solubility of gypsum in sea water is somewhat higher than in fresh water (3.5 kg/m3), so it dissolves fairly quickly around the point of discharge.

Experience in Tunesia has shown that this method is not suitable everywhere. The Gulf of Gabès has an area of 3000 km2, but a maximum depth of 50 m only. Since the start-up of the phosphoric acid plants at Gabès in 1971 all fish and lobster have vanished from the whole gulf.

It appears that up to now no really safe disposal method has been found for the phospho-gypsum.

3.1.2 Reprocessing of the phospho-gypsum

As natural gypsum is used in industry for the production of a number of products, it has been attempted to substitute phospho-gypsum for it. Difficulties in this respect have been encountered because of the impurities and the high moisture content of the phospho-gypsum. In most countries natural gypsum is cheaper, and phospho-gypsum was reprocessed in countries only which have no adequate supplies of natural gypsum. But as government regulations increase the cost of phospho-gypsum disposal, reprocessing gets more interest.

The quantity of natural gypsum mined all over the world is about 70 million tons annually, so all of the phospho-gypsum could be utilised to substitute it. Japan, for instance, which has no natural gypsum deposits, uses more than 5 million tons of phospho-gypsum annually at present. Other countries include Austria, Belgium. Finland, France, Federal Republic of Germany, Ireland and Senegal.

Principal uses of natural gypsum in industry are:

- setting retarder for portland cement
- plaster
- plaster board
- building blocks.

All these uses are connected with the building materials industry.

In times of sulfur shortage during World War I two processes were developed in Germany, which are also based on gypsum

- ammonium sulfate
- sulfuric acid and cement.

Ammonium sulfate is a nitrogen fertiliser used especially on alkaline soils, and with special crops, such as rice. But the sulfuric acid/cement process (both products are produced simultaneously) is also interesting, as it produces the sulfuric acid needed for the production and thus recycles the sulfur.

For all the processes mentioned licenses, know-how, and production experience from plants operating on phospho-gypsum are available. The selection of the most suitable process depends on local conditions of supply and demand of the various products, i.e. on economic considerations.

Besides the processes mentioned phospho-gypsum itself can be used as such as a soil conditioner for soils of high sodium contents. A number of further uses of phospho-gypsum are conceivable - such as the production of sodium sulfate -, but would be of local interest only.

3.1.2.1 Setting retarder for cement

Gypsum is added to portland cement in a quantity of about 5 % to retard the beginning of the setting of the concrete. Usually crushed gypsum is co-ground with the burnt clinker.

Phospho-gypsum can be used to substitute the natural gypsum, but it has to be purified, dried, and granulated. The granulation is necessary as the existing feeders for the gypsum in the cement plants cannot operate with fine grained material, and thus new feeders would have to be installed. It is, therefore, preferable to granulate the purified phospho-gypsum to avoid this additional investment.

Various impurities of the phospho-gypsum, especially the phosphate, tend to reduce the initial strength of the concrete without changing the final strength. In some countries, e.g. in Yugoslavia, this is tolerated, so a very simple purification system for the phospho-gypsum is sufficient to render it suitable as a setting retarder. In most other countries this is not the case and at least part of the phosphate has to be removed or rendered harmless by neutralisation. To achieve this the phospho-gypsum will have to be recrystallised or dehydrated and neutralised.

For recrystallisation the Giulini process is suitable, fig. 1. In this process the phospho-gypsum is purified in hydrocyclones or by flotation and afterwards recrystallised from water under pressure to remove the co-crystallised phosphate. In this way calcium sulfate hemihydrate is obtained, which can be granulated with water to a very pure gypsum.

As it is not necessary to remove the co-crystallised phosphate from the phospho-gypsum, but is sufficient to render it harmless by transforming it into tricalcium phosphate by neutralisation, another process can also be used for the production of the setting retarder, fig. 2. Here the phospho-gypsum is also purified by hydrocyclones or by flotation, but after this it is dried and dehydrated to the hemihydrate. During this calcination process the co-crystallised phosphate is set free. The calcinated product is then neutralised with milk of lime and granulated at the same time.

Phospho-gypsum is used in large quantities by cement manufacturers in Brazil, Federal Republic of Germany, Japan, Yugoslavia and in other countries. The only problem is the competition of natural gypsum which is sometimes hard to meet.

Technology for the production of setting retarder from phospho-gypsum is available from:

FIG. 1 GIULINI PROCESS FOR SETTING RETARDER AND HEMIHYDRATE

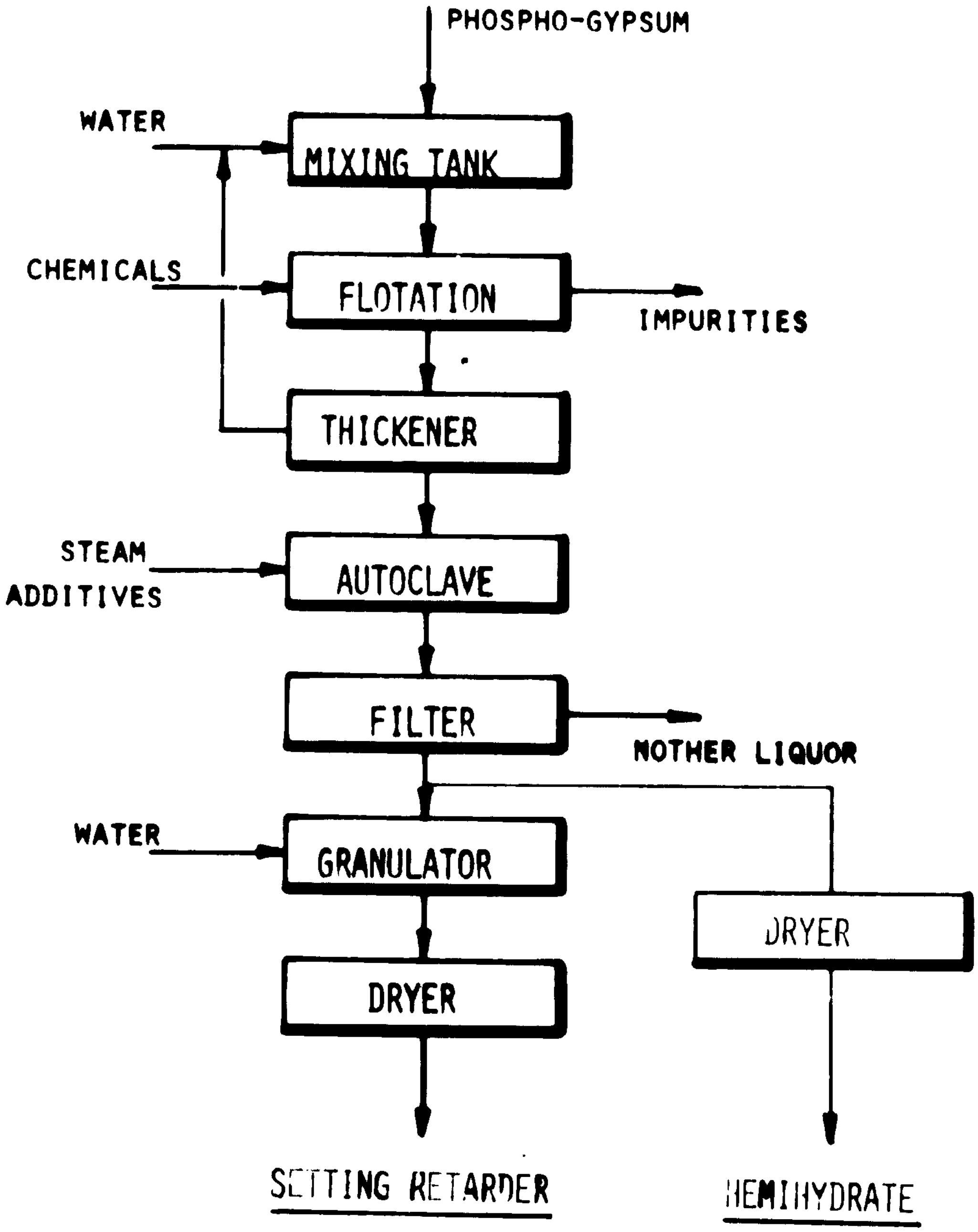
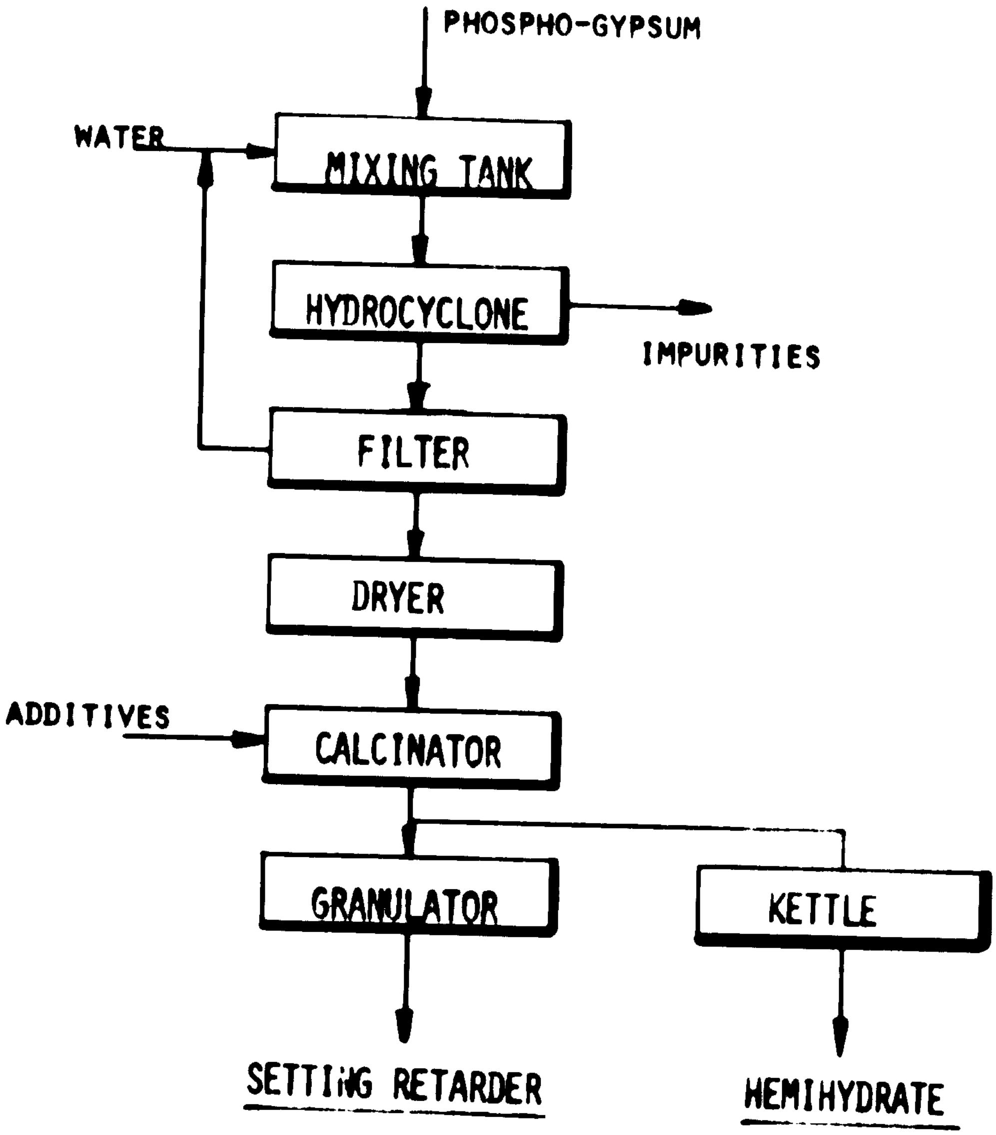


FIG 2 CALCINATION PROCESS FOR SETTING RETARDER AND HEMIHYDRATE



Messrs. Babcock-BSH, Federal Republic of Germany
Messrs. Donau Chemie, Austria
Messrs. Charbonnage de France-Air Industrie, France
Messrs. Knauf Engineering, Federal Republic of Germany
and others.

3.1.? 2 Plaster

Plaster is used in large quantities to cover the walls and ceilings of buildings by manual methods. Its main component is calcium sulfate-hemihydrate (plaster of Paris)+), which is also the intermediate material for the production of building blocks, wall board, decorative panels, and other products.

The manufacture of plaster of Paris from phospho-gypsum is in principle the same as that of setting-retarder, figs. 1 and 2. In the Giulini process the hemihydrate is formed in the autoclave, so it has only to be recovered by filtration and dried. In the calcination process the purified, dried, and precalcinated product is completely transformed into hemihydrate in a second calcination step, e.g. in a gypsum kettle.

Two types of plaster are usually produced from gypsum:

Light weight plaster is made from calcium sulfate hemihydrate and a light weight component, such as vermicullite, expanded perlite, etc., and a small amount of additives. It is mixed with water at the building site and is applied one layer to walls and ceilings.

Wall plaster is a mixture of about one third calcium sulfate

+) There are two modifications of calcium sulfate hemihydrate, called the alpha and the beta form. The alpha modification is not normally used in building materials, so in this review the term hemihydrate will always mean the beta modification.

hemihydrate and two thirds calcium sulfate anhydrite. The particle size distribution of the product is also important, 20 % have to be coarser than 200 microns.

Although natural gypsum is used for the greatest part of the plaster production, phospho-gypsum can be substituted by using suitable technology. The hemihydrate for the light weight plaster is produced by repulping the phospho-gypsum with water, removing the fine particles, and refiltering the gypsum, fig. 3. The filter cake is dried, dehydrated to the hemihydrate, and ground to the proper particle size. This hemihydrate is mixed with the light weight component, which has to be of the proper particle size too, and with the additives, and bagged into 50 kg bags.

Wall plaster is more difficult to produce from phospho-gypsum, as the particle size of it is too small and the form of the particles is not suitable. So the phospho-gypsum has first to be purified by repulping with water and refiltering, fig. 4. After the filtration the gypsum is dried and is partially dehydrated to the hemihydrate. This material is then granulated by the addition of a small amount of water containing calcium hydroxide. The granules obtained have to age for some time, then they are calcined to a mixture of hemihydrate and anhydrite, which is finally ground to the proper particle size, and bagged.

A similar type of plaster can be used for the bonding of plaster board and plaster blocks.

Economic data for the processes mentioned are as follows:

FIG. 3 PRODUCTION OF LEIGHT WEIGHT PLASTER

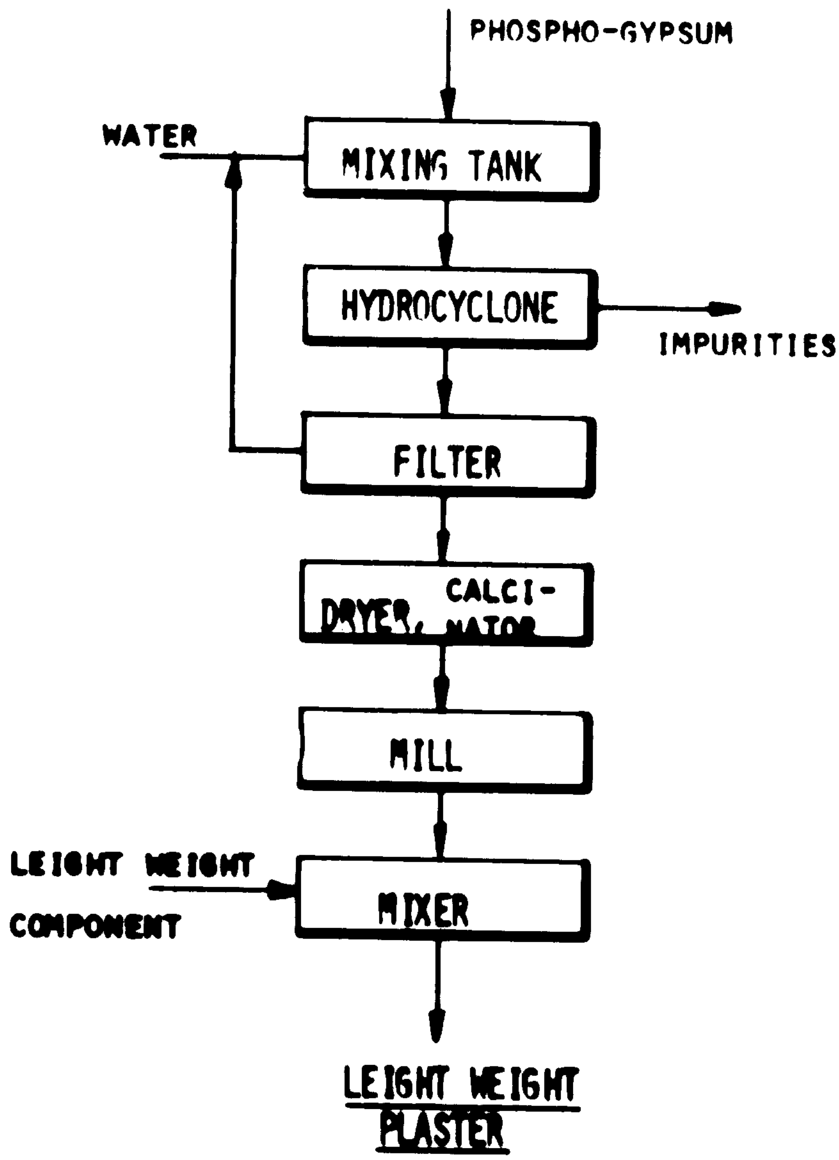
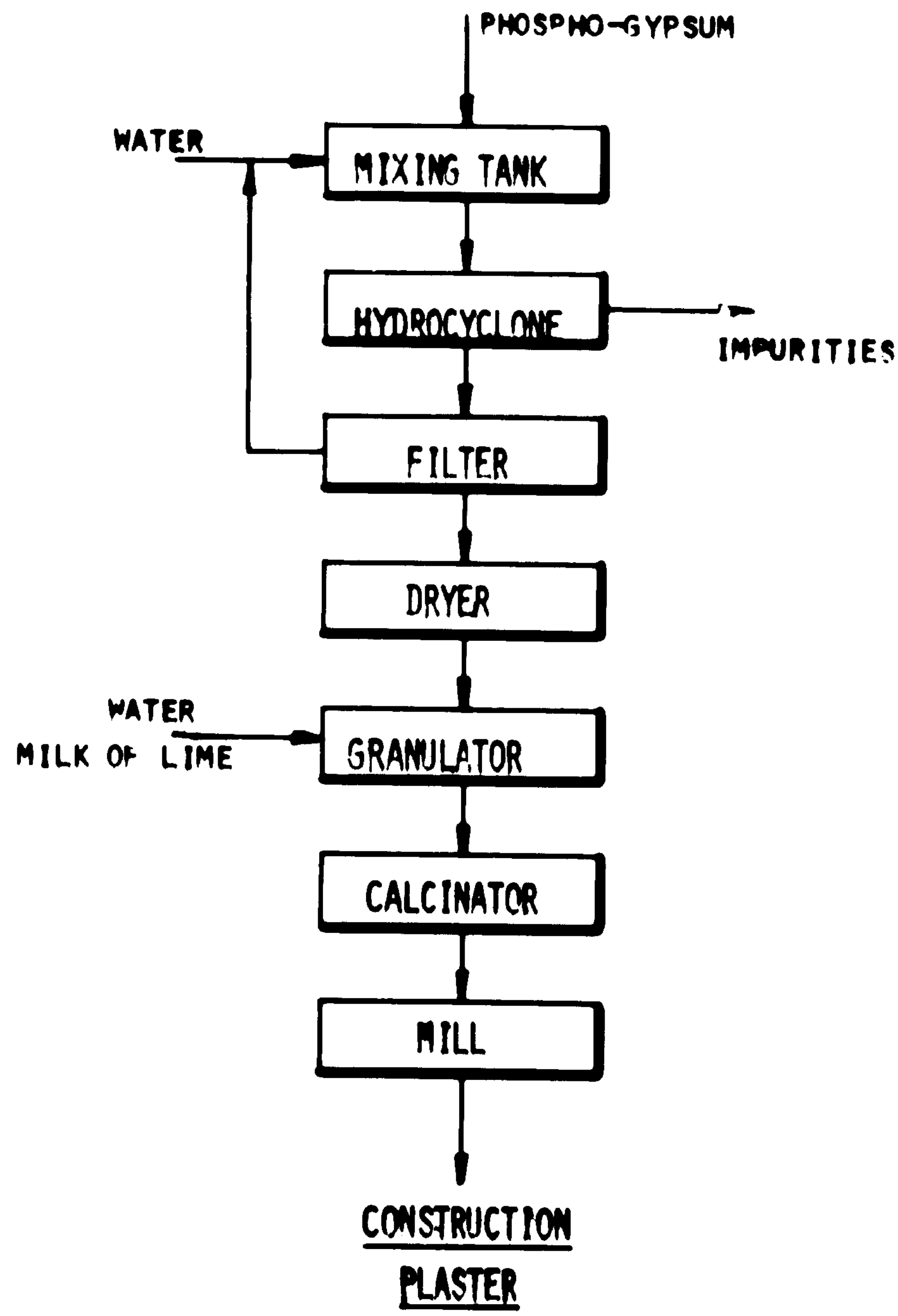


FIG. 4 PRODUCTION OF CONSTRUCTION PLASTER



GIULINI process

Consumption figures (per t of hemihydrate)

Phospho-gypsum	1.4	t
steam	0.6	t
water	4	m3
power	20	kWh
fuel oil	0.020	t
additives	2	SP

Calcination Process

Consumption figures (per t of hemihydrate)

	purification	drying	calcination
Phospho-gypsum	1.4 t	-	-
water	3 - 5 m3	-	-
power	20 kWh	20 kWh	20 kWh
fuel oil	-	0.033 t	0.029 t
calcium hydroxide	-	-	0.005 t

Technology and know-how for the production of plaster from phospho-gypsum are available from:

Messrs. Knauf Engineering, Germany
Messrs. Babcock-BSH, Germany
Messrs. Donau Chemie, Austria
Messrs. Charbonnage de France-Air Industrie, France
and others.

3.1.2.3 Gypsum building blocks

Building blocks made from natural gypsum have become an important product of the building materials industry in many countries within the last ten or fifteen years. They are widely used for non-bearing walls in buildings of all types. Their main advantage is that because of their smooth surface they do not need plastering but can be painted or covered with wall paper as such.

Standard size of building blocks is 50 x 66 cm, which makes three blocks per square meter wall area. They are produced in various thicknesses from 5 to 12 cm. Perforated blocks can also be produced.

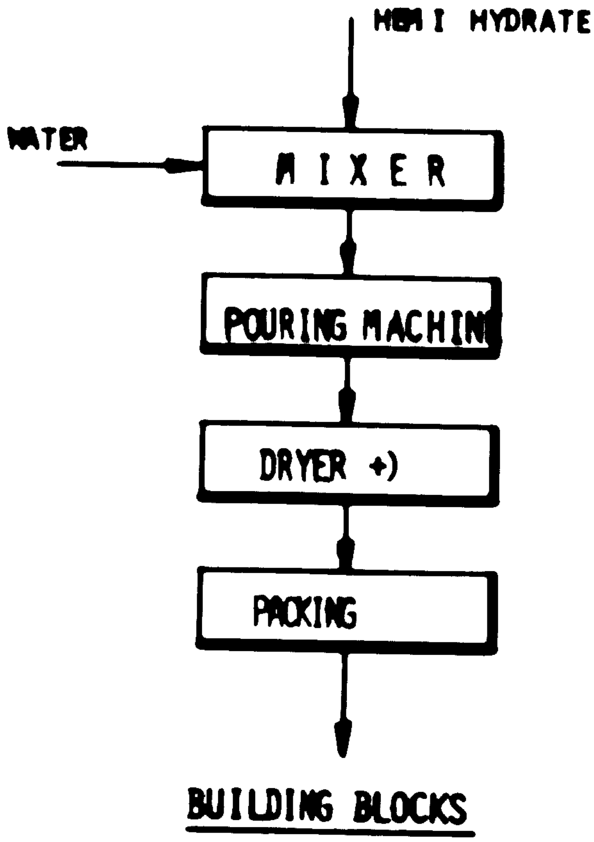
Building blocks are manufactured by mixing calcium sulfate hemihydrate with water and pouring the mixture into moulds of the proper size, fig. 5. After about ten minutes the hardened blocks are removed from the moulds and dried. This can be done in an oven, or under suitable climatic conditions by storage.

Phospho-gypsum is suitable for the production of building blocks, but the hemihydrate required has to be produced according to the processes described in the forgoing section. Large quantities of building blocks are produced from phospho-gypsum in Austria, Belgium, Federal Republic of Germany, Japan and other countries.

Technology and know-how for the production of building blocks is available from:

Messrs. Knauf Engineering, Federal Republic of Germany
Messrs. Donau Chemie, Austria
Messrs. Gerlach, Federal Republic of Germany
Messrs. Charbonnage de France-Air Industrie, France
and others.

FIG. 5 BUILDING BLOCKS PRODUCTION



+) OR NATURAL DRYING IN STORAGE AREA UNDER SUITABLE CLIMATIC CONDITIONS

3.1.2.4 Plaster board

Plaster board are rectangular plates, about 1 x 2 m in size and 1 to 2 cm in thickness. They consist of a layer of plaster sandwiched between two sheets of a special type of cardboard.

Plaster board is used for covering the inside walls of buildings instead of plastering, the main advantage being lower labor requirement for their application.

Plaster board is produced from calcium sulfate hemihydrate by continuously mixing it with water. A thin layer of plaster is applied to an endless cardboard sheet and covered with another sheet of cardboard. After shaping and hardening the board is cut to the desired size and dried, fig. 6.

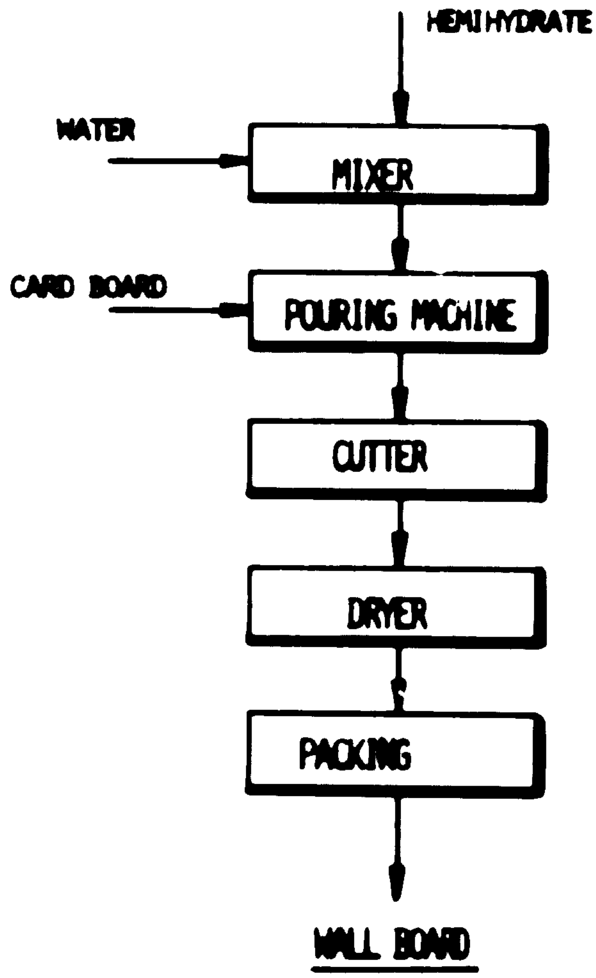
Phospho-gypsum is suitable for the production of plaster board after it has been purified, see sec. 3.1.2.2.

Technology and know-how for the production of plaster board is available from a large number of firms, e.g.:

Messrs. Knauf Engineering, Federal Republic of Germany
Messrs. Gerlach, Federal Republic of Germany
Messrs. Rigips, Federal Republic of Germany
Messrs. Donau Chemie, Austria

Fibre board is another type of board made from gypsum. For its production the hemihydrate is mixed with fibres (glass fibres, cotton, cellulosic fibres, etc.), and water. The resulting plaster is formed into an endless band 10 to 25 mm in thickness, allowed to harden, cut into shape, and dried. The uses of this type of board are similar to the ones of plaster board. For ceilings

FIG. 6 WALL BOARD PRODUCTION



certain types of decorative board and tiles are produced from the same material.

Technology is available from

Messrs. Knauf Engineering
and others.

3.1.2.5 Sulfuric acid and cement

Phospho-gypsum can be processed into sulfuric acid and portland cement clinker by a process which was originally developed in Germany for natural gypsum. From one ton of dry phospho-gypsum about 0.6 tons of sulfuric acid can be produced, and about the same quantity of cement is obtained at the same time. The sulfuric acid can be used in the production of the phosphoric acid, and the cement is a valuable by-product. The quality of both products is equal to products produced from conventional raw materials.

The calcium sulfate for sulfuric acid and cement manufacture will have to be free of moisture and of water of crystallisation. So the phospho-gypsum is dried to remove the moisture and calcined at 350 deg to remove the water of crystallisation.The quality of the phospho-gypsum used has to comply with a rigid specification as otherwise the cement quality will be impaired, and the cement kiln will have operating difficulties. From experience in operating plants the specifications for the phospho-gypsum are:

P2O5	max.	0.5 %)	in the dried gypsum (60 deg)
F	max.	0.15 %)	

This high purity will not normally be achieved in phosphoric acid plants; it is, therefore, necessary to include purification steps for the phospho-gypsum in the plant. Depending on the purity of the phospho-gypsum from the phosphoric acid plant one or several of the following purification processes can be used:

- repulping the phospho-gypsum with water and removing 10 to 15 % of the fines; this will remove the soluble part of the phosphate and part of the fluorine compounds;
- calcining the phospho-gypsum with addition of a small quantity of sulfuric acid; this will remove most of the fluorine compounds;
- recrystallising the phospho-gypsum from hot water under pressure; this will remove most of the phosphate from the phospho-gypsum.

The cost of operation and the necessary investment of the gypsum purification increase in the order shown.

Under normal conditions, i.e. the use of an average type of phosphate rock and a dihydrate type phosphoric acid plant properly operated, it can be expected that the phosphate content of the gypsum will - after repulping with water - comply with the specification mentioned above, but not with the fluorine specification.

If the phosphate contents of the phospho-gypsum after repulping does not comply with the specification, it will be necessary to recrystallise it from water under pressure; this will incur considerable additional cost, especially in investment.

The fluorine content of the phospho-gypsum can be reduced considerably by the addition of active silica (kieselgur) to the phosphate rock in the phosphoric acid plant. The co-crystallised phosphate contents can be reduced by proper adjustment of the sulfuric acid distribution in the reactor cascade. All these measures have to be tested for each phosphate rock and for each plant to find out optimum conditions. As all purification processes for the phospho-gypsum cause additional cost for the sulfuric acid and cement plant, these possibilities for the direct production of a gypsum complying with the specifications mentioned in the phosphoric acid plant are very important; they can only be ascertained after start-up of the phosphoric acid plant.

Besides the gypsum, further raw materials needed for the sulfuric acid and cement production are sand, clay, and coke. The exact quantities of sand and clay needed will depend on the composition of the phospho-gypsum and of these materials themselves, but they are normally in the range of a few percent of the sulfuric acid produced. The coke is needed for the reduction of the calcium sulfate in the kiln.

The sulfuric acid/cement process can be divided into three steps:

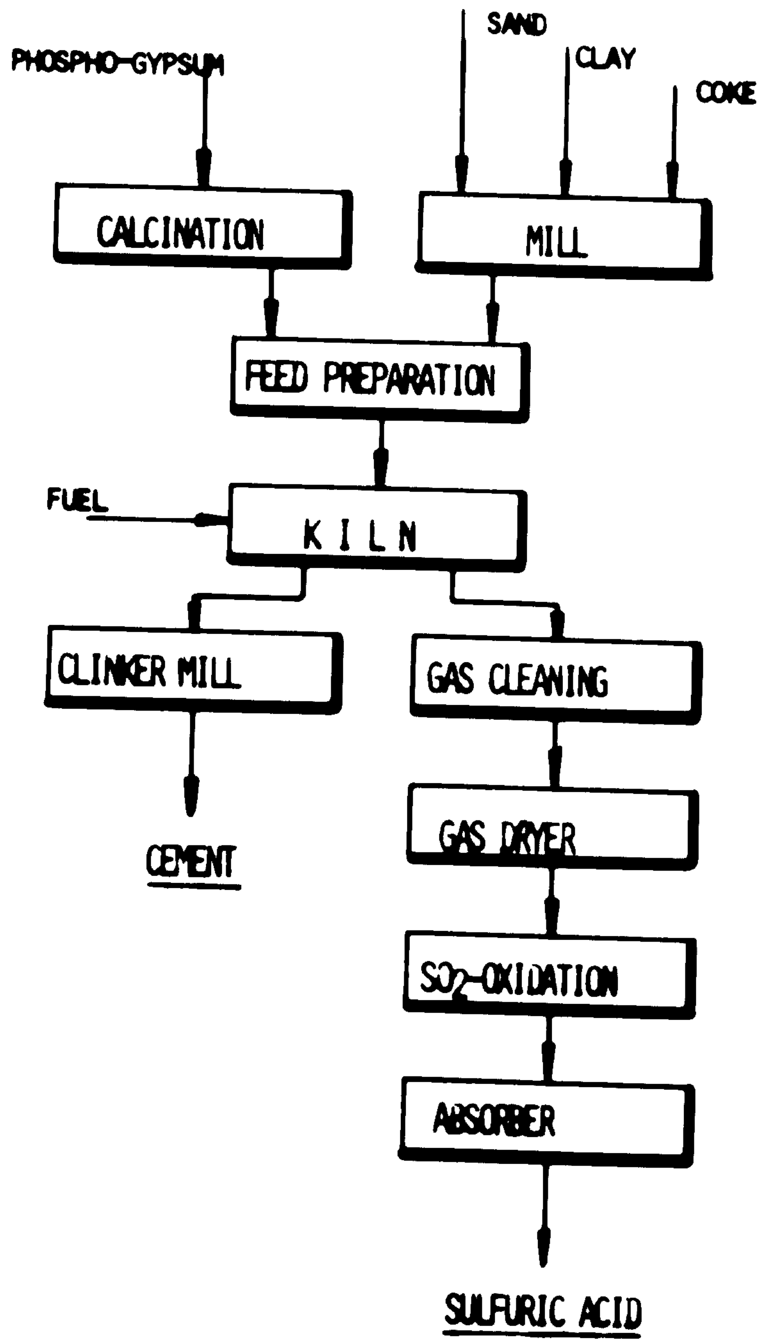
feed preparation, consisting of the phospho-gypsum purification and calcination; sand, clay, and coke milling; feed mixing;

clinker production, consisting of the cement kiln, clinker cooling, clinker storage, clinker milling, cement storage and bagging;

sulfuric acid production, consisting of the dust removal from the kiln gases, scrubbing with water, drying, catalytic conversion of the sulfur dioxide, and absorption of the sulfur trioxide, fig. 7.

The technology used in the process is the same as in conventional cement and in wet-gas sulfuric acid plants. The proper operation of the plant requires special attention to the kiln feed composition and to the operating variables of the kiln (draft, temperatures, oxygen content, etc.). Maximum capacity in one line is limited by the size of the kiln and is about 1000 t/d of sulfuric acid and cement each.

FIG. 7 SULFURIC ACID/CEMENT PRODUCTION



Corrosion conditions in the plant are about the same as in conventional sulfuric acid plants based on sulfur.

Consumption figures per ton of sulfuric acid (calcul. as 100 %) and cement each (including gypsum drying and calcination):

Phospho-gypsum (as dry dihydrate)	2.24	t
clay, approx. +)	0.07	t
sand, approx. +)	0.07	t
coke	0.10	t
cooling water	80	m3
power	230	kWh
fuel oil	0.28	t

+) exact quantities depending on the composition of these materials

Licenses and know-how for the production of sulfuric acid and cement from phospho-gypsum are available from Messrs. Chemie Linz, Austria, who have actual operating experience from their own plant (250 t/d sulfuric acid), and from a plant at Phalaborwa, South Africa, built by their license (320 t/d sulfuric acid).
Messrs. Chemie Linz have licensed
Messrs. VÖEST-Alpine, Austria
Messrs. Krupp-Koppers, Federal Republic of Germany
to engineer and build plants using their experience.

3.1.2.6 Ammonium sulfate

Ammonium sulfate is a nitrogen fertilizer containing 21 % nitrogen. It is especially suitable for alkaline soils and for certain crops, e.g. rice.

Ammonium sulfate is usually produced by the neutralisation of sulfuric acid with gaseous ammonia. This is a simple process technologically, but raw materials cost are high. Large quantities of ammonium sulfate are also produced as a by-product of the nylon and the acrylonitrile manufacture.

Ammonium sulfate can be produced by reacting gypsum with ammonium carbonate solution, which in turn is made from gaseous ammonia and carbon dioxide by absorption in water. Calcium carbonate is produced as a by-product, fig. 8.

The gypsum required is either natural gypsum or phospho-gypsum. There is no specification for the phospho-gypsum to be used, but the contents of phosphate and of organic matter should be low in order to prevent foaming in the evaporators. So the phospho-gypsum is usually repulped with water and classified in settlers or in hydrocyclones, whereby about 5 % of fines are removed.

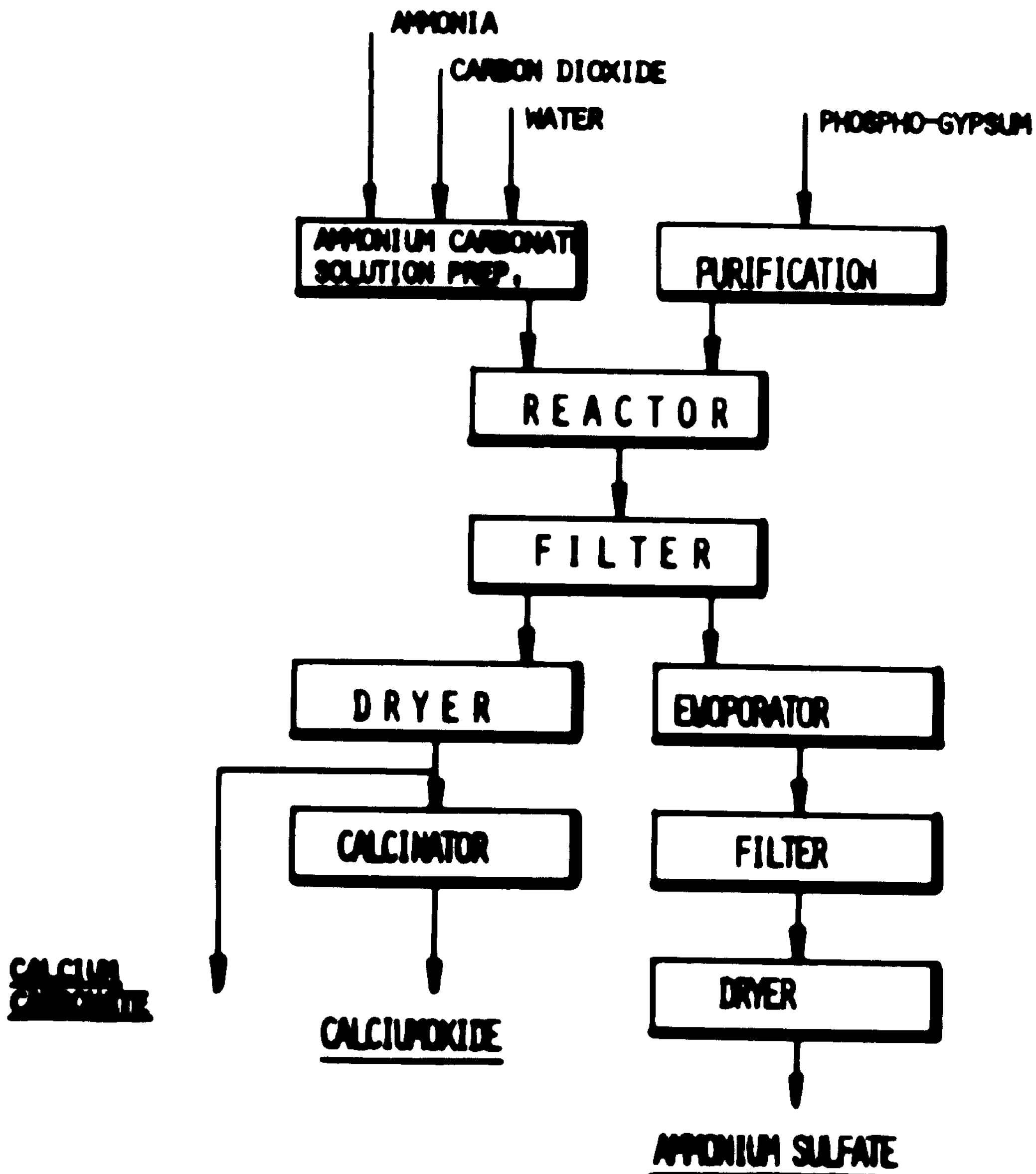
The calcium carbonate produced can be discarded either as it comes from the filter (15 to 20 % moisture), or repulped with water.

It is also possible to process the calcium carbonate after drying it, either for use in the calcium ammonium nitrate manufacture, or after calcination to calcium oxide for effluent neutralisation or as a building material.

Consumption figures for the production of ammonium sulfate from phospho-gypsum are per ton of product (excluding calcium carbonate drying and calcination):

Ammonia	0.270	t
sulfuric acid	0.06	t
gypsum, dry (60 deg)	1.50	t
carbon dioxide	0.35	t
calcium carbonate produced	0.84	t

FIG. 8 AMMONIUM SULFATE PRODUCTION



process water	1.5	m3
cooling water	50	m3
power	50	kWh
steam (6 bar)	0.65	t
fuel oil	0.0075	t

Technology and know-how is available from

Messrs. VÖEST-Alpine, Austria
Messrs. Davy-Powergas, the United Kingdom of Great Britain
Messrs. Didier Engineering Company, Federal Republic of Germany
and others.

3.1.2.7 Sodium sulfate

Sodium sulfate can be produced from gypsum in a similar way as ammonium sulfate by reacting sodium carbonate solution with gypsum. Calcium carbonate is precipitated and is filtered from the remaining sodium sulfate solution. From this solution sodium sulfate can be crystallised by cooling as the decahydrate, or by evaporation as the anhydrous product.

This process has not been used to any extent in industrialised countries as sodium sulfate is available in large quantities as a cheap by-product from the rayon and other manufactures. The price of sodium sulfate is, therefore, so low that there is no incentive to produce it from sodium carbonate.

As far as is known there is only one plant in operation in Rumania; licenses are said to be available from there. No process data are known.

3.1.2.8 Soil conditioner

In a number of countries large quantities of phospho-gypsum are used as soil conditioner for certain types of soil. Its effect is connected with the ion exchange equilibrium in the soil. In soils containing high levels of sodium the addition of calcium sulfate leads to a partial exchange of the sodium ions by calcium ions. The sodium can then be washed out of the soil by irrigation, which will lead to a considerable improvement of plant growth.

Phospho-gypsum is particularly suitable for this type of application as it has a much higher reactivity and dissolution velocity than natural gypsum. Its effectiveness will depend on the soil condition and is limited to the very special types of soil mentioned.

For use as soil conditioner phospho-gypsum can either be applied as the moist filter cake, or as a dried powder. No purification is necessary in either case.

3.2 Phospho-gypsum in the Syrian Arab Republic - technical aspects

3.2.1 Location

The town of Homs (140 000 inhabitants) is situated about halfway between Damascus and Aleppo at a distance of about 120 km from the coast of the Mediterranean sea. The nearest harbour is Tartous. The Orontes river passes nearby.

The location is favourable as towards the south the mountains of the Lebanon and the Antilebanon, and towards the north the mountains of the Ansariya form a natural barrier between the Syrian central plain and the coast, whereas between Homs and the Mediterranean there is a natural pathway, the Syrian gate.

Homs is, therefore, an important traffic crossing point. The main north-south road, the highway ME 5 from Aleppo to Damascus is crossed by an east-west road (ME 3) from the coastal area of Tripoli, Lattaquia, and Tartous to Palmyra and Deir-ez-zor on the al-Furat river. Another important road leads towards the south via Baalbeck to Beyrouth in the Lebanon.

Homs is connected by a railroad line with Aleppo and the Turkish railroad system. A new line now under construction will lead from the phosphate deposits near Palmyra via Homs to the harbour of Tartous; construction will be finished in 1980.

The town of Homs is fairly industrialised, major enterprises are a petroleum refinery, textiles industry, a cement plant, and a sugar plant, besides the fertilizer industry.

3.2.2 The site

The plant of the "General Fertilizers Company" is located in a wide plain about 10 km south of the town of Homs on the banks of an artificial lake formed by damming the Orontes river; the lake Katinê has an area of 60 km2.

At a distance of about 5 km there is a petroleum refinery, which processes crude oil from northern Syria; next to the fertilizer plant is a power station.

There is plenty of land available around the plant for future expansions.

Climatic conditions prevailing at the site are continental; temperature maximum in summer is 40 deg., minimum in winter is - 5 deg. Humidity is low, especially during the summer season. Average precipitation is 350 mm/year, but there is no rain from June to October. Westerly winds are prevailing all the year round.

Geological conditions at the plant site are normal, no recent seismic events are on record. Ground water level is between 1 and 2 m below surface.

The Homs plant of the General Fertilizers Company is the only fertilizer plant in Syria; it employs about 2000 people. At present it comprises:

Ammonia plant, 150 t/d, based on naphtha. Plant built by SNAM-Progetti on Humphreys-Glasgow design in 1972
Nitric acid plant, 270 t/d, Russian process and construction, 1972
Calcium ammonium nitrate, 550 t/d with 26 % nitrogen, Czech process and construction in 1972

Under construction are:

Ammonia plant, 1000 t/d from naphtha, design by Kellogg, construction by Creusot-Loire
Urea plant, 1050 t/d, Stamicarbon process, construction by Creusot-Loire
Sulfuric acid plant, 1700 t/d in two lines from sulfur, Romanian design and construction
Phosphoric acid plant, 533 t/d P205 in two lines including evaporators to 52 % P205 acid; Romanian design and construction
Triple superphosphate plant (or single superphosphate alternatively) 1500 t/d in three reactors, two granulators and two dryers;

Romanian design and construction

Aluminum fluoride, 9 t/d from fluosilicic acid, Chemie Linz process, Romanian design and construction.

All these plants are expected to start production late in 1979. The necessary raw materials are:

Sulfur: 30 000 t/a are available from the Homs and the Banyas refineries in Syria, the rest has to be imported. 100 000 t have been bought from the Iraq at a price of US $ 61.50 (single contract)

Phosphate rock: This will be supplied from the deposits near Palmyra by railroad and trucks. Price LS 80.-/t based on 30 % P_2O_5; composition see app. 5.3.

Naphtha: supply from Syrian refineries, price LS 500.-/t

Natural gas: at present not available, but it is expected to be available in the future from newly discovered deposits in northern Syria.

At the plant a number of off-site facilities are available:

Transportation: road and rail connections available

Energies:

Power: 66 kV, 6 kV, 220/380 V, 50 cycle.

Fuel oil, 5 - 6 % sulfur, SP 280.-/t

Diesel oil		LS 0.25/1	
Naphtha		LS 500.-/t	
Natural gas		to be available in the future	
Steam:	10 bar	60 t/h	surplus from stand-by boilers
	16 bar	30 t/h	- " -
	40 bar	30 t/h	- " -

Fresh water 400 m3/h available, 20 deg max.,price LS 0.04/m3

Cooling water should be recycled

Emission standards: no government regulations existing, European standards to be used

Effluent standards:

Max. temp.	35 deg	
pH	6 - 9	
Cl	400	ppm
SO4	400	ppm
Susp. solids	80	ppm
oil	10	ppm
BOD5	20	ppm
COD	30	ppm
TDS	1000	ppm
ammonia	10	ppm
urea	10	ppm
NO3	30	ppm
F	8	ppm

Labor:

Unskilled workers	LS 500.-/month
Skilled workers	LS 800.-/month

4 shifts per working place

3.2.3 Estimation of the quantity and quality of the phosphogypsum to be expected at Homs

The bases of the following estimations are:

- the phosphate rock as given in annex III a mixture of Eastern A and B quality will be used for the phosphoric acid production
- the gypsum composition from laboratory tests in Romania, (see annex IV).

The capacity of the phosphoric acid plant is 533 t/d P_2O_5. For a

P205 concentration in the phosphate rock of 30 % and a P205 yield of 95 % this corresponds to a phosphate rock consumption of 1870 t/d.

This phosphate rock consumed contains a quantity of 916 t/d of calcium oxide. From this the corresponding quantity of calcium sulfate can be calculated, assuming a yield of 98 %: 2271 t/d of calcium sulfate or 2872 t/d of calcium sulfate dihydrate (gypsum) will be produced.

From the gypsum analysis, (annex IV) a gypsum purity to be expected of 95.2 % can be calculated. Allowing for this composition the quantity of dry phospho-gypsum will be 3016 t/d, or, at 300 days per year, 904 852 t/a.

Usually the moisture content of the phospho-gypsum from the filter in phosphoric acid plants is about 25 %, so the quantity of filter cake to be expected is 4022 t/d, or 1 206 469 t/a.

Taking into account the marges of this estimation the following quantities will be used in all further calculations:

	Quantities to be expected	
	t/d	t/a
filter cake	4000	1 200 000
dry filter cake (60 deg)	3000	900 000
gypsum in the filter cake	2850	855 000

The gypsum composition given in annex IV is based on laboratory experiments using Syrian phosphate rock. The actual quality of the phospho-gypsum to be expected at Homs will depend on the phosphate rock quality and on plant operation.

As is well known in the phosphate industry it is impossible to predict the gypsum quality from a given phosphate rock with certainty by laboratory experiments. The exact quality of the phospho-gypsum to be expected at Homs will, therefore, only be known after start-up of the plant and after reaching a steady production. The composition given in annex IV should be considered with caution only.

As the Syrian phosphate rock is similar to Tunesian phosphate rock (appr. 30 % P2O5, high silica) gypsum compositions from an operating phosphoric acid plant using this phosphate and a similar process are listed in annex V for comparison. From this it appears that higher phosphate levels are to be expected in the Homs plant than obtained in the laboratory experiments. The same is true for the fluorine content.

3.2.4 Phospho-gypsum disposal

Beginning with the start-up of the phosphoric acid plant at Homs in autumn 1979, phospho-gypsum will be produced in increasing quantities. As at that time no reprocessing plant will be available, the gypsum will have to be discarded.

At a distance of about 4 km from the plant a large area is available for the deposition of the phospho-gypsum. This area is at present neither inhabited nor used by agriculture.

An inspection of this area showed (fig. 9 to 12) that the ground water level is only in about 1.5 m depth, as the area is near the lake Katinê. The river Orontes and various irrigation canals pass nearby.

The proposed dumping area is not utilised at present, but the lake Katinê has a high potential as a recreational area for the

FIG.9 General view of the proposed dumping area near the General Fertilizers Co. at Homs

FIG. 10 Road to the proposed dumping area

FIG. 11 Permeable soil in the dumping area

FIG. 12 Ground water level in the dumping area

population as well as for tourists in the future. Any development in this respect would be made impossible by allowing the phospho-gypsum to be deposited in the vicinity of it, as the existing industry in the area - the power plant, the refinery, and the fertilizer plant - are already serious handicaps.

Besides this, pollution of the ground water is to be feared on a long range as the phospho-gypsum contains phosphoric acid and fluorine compounds and is itself somewhat soluble in water. So precipitations during the winter months will form an acid, fluorine compounds-containing solution, which will finally find its way into the ground water stream as the soil in this area is very permeable. As water from this ground water stream is used further down the Orontes valley by the population and for agriculture this could lead to serious consequences.

Another problem to be considered are the medium to strong westerly winds prevailing at the site nearly all the year round. It is probable that the dumped gypsum will lead to a dust and an emission problem during the hot and dry summer season.

As a consequence the proposed area near the plant cannot be considered to be suitable for dumping the phospho-gypsum.

Search for a suitable dumping area near the plant at least as a short term solution to the phospho-gypsum problem at Homs should be initiated immediately under the direction of a geologist and an ecologist. The new area should preferably be a depression, i.e. an area which has no connection to the general ground water streams and be remote from the banks of the lake Katiné.

For economic reasons the investments for this preliminary dumping area should be kept as low as possible at the expense of higher operating cost, as a permanent solution of the phospho-gypsum problem, either development of a permanent dumping system or a reprocessing plant, should be sought.

As a long-range solution to the dumping problem a permanently usable dumping area will have to be outside the inhabited and agriculturally used zones of the Orontes valley in desert land because of environmental reasons. The nearest distance to such an area is 40 to 45 km in easterly direction.

The transport of 1.2 million tons of wet phospho-gypsum over a distance of 45 km would require the erection of a special transportation system, such as e.g. cable cars. The investment for this system would be well over LS 100 million, which seems prohibitive.

As an alternative the existing railroad line could be used to transport the phospho-gypsum back to the phosphate mines area and to deposit it there. The railroad cars bringing in the phosphate rock would, after being emptied, thus be filled with phospho-gypsum and sent back to the phosphate mines area in the desert, fig. 13 - 16. Additional railroad cars will be needed as the quantity of phospho-gypsum is larger than that of the phosphate rock, and the bulk density is lower as well (phosphate rock 1.5 t/m3, phospho-gypsum 1.25 t/m3). Because of the acidity of the phospho-gypsum a small quantity of milk of lime should be added as a precaution to prevent possible corrosion of the railroad cars.

It seems preferable to transport the filter cake back to the mines area and not to the nearest suitable point of desert area although this involves a longer distance of transportation as in the mines area there is already a suitable infrastructure available. At a new site facilities for the workers and their supervision would have

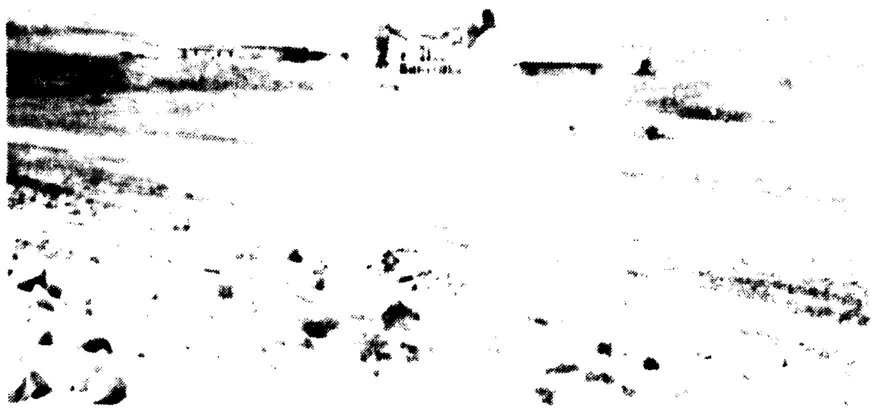


FIG. 13 View of the area of the phosphate mine at Kneiffis

FIG. 14 Mining operation at Kneiffis showing the overburden

FIG. 15, 16 Dumping area for the overburden at Kneiffis

to be newly created.

The equipment necessary for the disposal of the phospho-gypsum would consist of:

at the Homs plant, a loading station, including an intermediate hopper for the filter cake, and a feeder for the quick lime;

at the mine area, an unloading station for the railroad cars, and a distribution system for the gypsum (one fixed and one movable conveyor, one caterpillar).

The transport of the phospho-gypsum from the plant at Homs to the dumping area in the desert by trucks would involve investment for 30 trucks (25 t carrying capacity) and require about 150 men as drivers and for loading and emptying the trucks. So this possibility was not adopted.

3.2.5 Phospho-gypsum reprocessing at Homs

As shown in sec. 3.1.2 the following products can be manufactured from phospho-gypsum:

- setting retarder for cement
- plaster
- plaster board
- building blocks
- sulfuric acid and cement
- ammonium sulfate
- sodium sulfate
- soil conditioner

It will now be investigated which products and what capacities appear suitable for phospho-gypsum reprocessing at Homs from the technical and the marketing points of view. The economic situation of these products will be considered in sec. 3.3.

3.2.5.1 Setting retarder

Gypsum is used as a setting retarder in all existing cement plants in Syria, and it will be used in those under construction now.

Location	Capacity cement t/d	Gypsum consumption t/d	Distance from source of natural gypsum deposit km		Distance from Homs km
Aleppo	6000	300	160 (tr)	Lattaquia	200 (r)
Hama	1300	65	140 (tr)	Djeroud	40 (r)
Homs	250	12.5	100 (tr)	Djeroud	20 (r)
Lattaquia	150	7.5	20 (tr)	Lattaquia	220 (tr)
Tartous	6700	335	140 (tr)	Lattaquia	100 (r)
Damascus	2800	140	60 (tr)	Djeroud	100 (tr)
Export Lebanon (Tripoli)		200	190 (tr)	Lattaquia	100 (tr)

(tr) Transport by truck

(r) Transport by rail

The total quantity of gypsum used for this application is about 1000 t/d. With the exception of Damascus all cement plants are situated at about the same or even nearer distances than from the natural gypsum deposits. So all could be supplied in principle from Homs.

The quality of the setting retarder produced from phospho-gypsum should be the same as from natural gypsum as the existing cement factories are used to this quality. The setting retarder will have to be granulated, as most of the cement plants, except Hama and

Damascus, are equipped for this type of material.

As shown in sec. 3.1.2.1 the consumption of fuel oil per ton of setting retarder produced is 0.033 t; this constitutes an appreciable part of the cost of production. Petrocoke from the refinery at Homs is available at a much cheaper cost than fuel oil, but has a sulfur contents of about 9 % compared with 5 - 6 % of the fuel oil. Still the use of petrocoke as fuel for the gypsum-dryer can be advocated as the total consumption for this purpose would be about one ton per hour only.

3.2.5.2 Plaster, building blocks, and wall board

Plaster, building blocks, and wall board will be considered together as all of them use calcium sulfate hemihydrate as intermediate. Hemihydrate should be produced from phospho-gypsum by the General Fertilizer Company at Homs, whereas the finished products, such as the various kinds of plaster, building blocks, wall board, etc. should be produced by the building materials industry from this intermediate at suitable locations.

The advantages of the products mentioned for the Syrian building industry have been examined in detail in the reports of

Dr. Yahya A. Abohussein, Feasibility Study for Gypsum Projects,
Dr. A. Bozanovic, Building materials industry in the Syrian Arab Republic, present situation and future possibilities.

Following their suggestions a capacity of 100 to 200 t/d of hemihydrate seems suitable for Homs.

It is not suggested that plaster board should be produced in Syria in the near future as this would necessitate the import of the special type of cardboard required. Furthermore it offers no advantages over plastering by hand and would require a long period of introduction on the Syrian market.

As it can be seen from fig. 2 it is possible to integrate the production of setting retarder and of hemihydrate up to the dryer. Part of the dried and precalcinated product can be granulated to produce setting retarder, part of it can be completely calcinated to produce hemihydrate. This will give a considerable saving in investment cost.

3.2.5.3 Sulfuric acid and cement

The production of sulfuric acid and cement from phospho-gypsum is in principle a recycle process whereby part of the sulfuric acid needed in the phosphoric acid plant is regenerated. This is an advantage as another valuable product, cement, is produced at the same time.

Syria produces at present sulfur in the two refineries at Homs and Banyas (100 t/d) and will produce more in the future from natural gas desulfuration. It is estimated that this would add up to approx. 250 t/d of sulfur. This quantity should be utilised for the production of sulfuric acid at Homs in any case. As the total consumption of sulfur for the sulfuric acid production from sulfur will be 570 t/d, 320 t/d will have to be imported in the long run.

It is suggested that this import should be substituted by using phospho-gypsum for the sulfuric acid manufacture.

There are two possible capacities for sulfuric acid production from phospho-gypsum at Homs:

It is estimated that about one third of the sulfur dioxide in the existing sulfuric acid plants can be substituted by kiln gas from a sulfuric acid/cement plant without complete change of the converter, absorber, and heat exchangers. This would set the capacity of the sulfuric acid/cement plant at about 570 t/d sulfuric acid and cement each.

As an alternative one line of the existing sulfuric acid plant could be substituted by a sulfuric acid/cement plant based on phospho-gypsum; this line could be kept as a stand-by. In this case the capacity of the new plant would have to be 850 t/d sulfuric acid and cement each.

A decision between the two capacities proposed can be found by an economic analysis only, see sec. 3.3.

As can be seen from the figures given in sec. 3.1.2.5, 0.1 tons of coke are required per ton of sulfuric acid produced. Coke is not produced in Syria at the moment, so it would have to be imported at considerable cost. On the other hand petrocoke is available from the Homs refinery, so the question comes up, if it can be used to substitute the coke.

The composition of the petrocoke is given in annex VIII According to it the contents of volatile matter can be up to 12 %, which is too high for the cement/sulfuric acid process.

In this process the coke is required for the reduction of the calcium sulfate. The coke is mixed with the feed of the kiln and will be heated up slowly in the kiln. During this period the volatile matter of the petrocoke will be volatilised, but will be burnt only partially. So part of it will be in the gases leaving the kiln, will pass through the gas scrubbing section and will finally be oxidised on the vanadium catalyst of the sulfuric acid plant. In this reaction water vapor will be formed which will combine with the sulfur trioxide present to sulfuric acid mist. This mist will cause corrosion in the down-stream equipment and noxious emissions.

The contents of volatile matter in the petrocoke can be reduced by calcination in a simple rotary kiln. The vapors from the calcinator can be introduced into the large cement kiln and need not be cleaned otherwise. The cost of this additional equipment will have to be included in the cost of the sulfuric acid/cement plant.

The utilisation of the petrocoke available at Homs for the manufacture of sulfuric acid and cement should not be limited to the substitution of the coke, but should be extended to the substitution of the fuel oil also.

Up to now no utilisation of the petrocoke has been found in which the sulfur dioxide formed when it is burnt is not emitted into the atmosphere; this is a serious handicap. In this respect the utilisation of the petrocoke for firing the cement kiln would be an exception, as the sulfur dioxide would not be emitted, but used for the production of sulfuric acid.

The low cost of the petrocoke as compared with fuel oil is an economic advantage for the sulfuric acid/cement process.

For the production of one ton of sulfuric acid 0.28 tons of fuel oil are required; which corresponds to 0.32 t of petrocoke. So the total consumption of petrocoke per ton of sulfuric acid would be 0.11 t for the substitution of the coke (prior to calcination), and 0.32 t for the substitution of the fuel oil, all together

0.43 t petrocoke per ton of sulfuric acid; of this quantity 0.13 t will be needed for the drying and the calcination of the gypsum and 0.3 t in the kiln. The sulfur contents of this quantity of petrocoke is equivalent to 0.08 t of sulfuric acid, or about 8 % of the production.

In the design of this sulfuric acid/cement plant it should be attempted to have the phospho-gypsum drying, or at least the calcination integrated into the cement kiln in order to include the sulfur dioxide from the fuel used for these operations into the kiln gases going to the sulfuric acid plant, even at the expense of higher fuel consumption. It is advisable to discuss this situation in detail with the engineering firms involved.

The petrocoke used for the substitution of the fuel oil need not be calcined, but can be used as it comes from the refinery, so no additional cost are involved.

The use of petrocoke instead of fuel oil and coke in the production of sulfuric acid and cement from gypsum leads to a change in the relation of the two products produced. Whereas normally about one ton of cement is produced for each ton of sulfuric acid, in this case about 0.9 t of cement per ton of sulfuric acid will be produced only.

The main difficulty for the decision on a sulfuric acid/cement plant is the still unknown quality of the phospho-gypsum to be processed, see sec. 3.2.3. If the phospho-gypsum produced does not comply with the specification (0.5 % P205 max., 0.15 % F max.) additional purification steps will have to be included in the plant as described in sec. 3.1.2.5.

For the economic evaluation it will be assumed that no additional equipment for the purification of the phospho-gypsum will be necessary, but that the addition of kieselgur to the phosphate rock and optimal operation of the phosphoric acid plant will produce a gypsum complying with the specifications mentioned.

This assumption is justified by experience from operating phosphoric acid plants. On the other hand the necessity of additional purification steps would mean by all probability that the production of sulfuric acid and cement from the phospho-gypsum would be uneconomic.

3.2.5.4 Ammonium sulfate

The advantages of ammonium sulfate as a fertilizer in irrigated areas as compared with urea favour a production of this material in Syria. For this production part of the excess ammonia from the plant at Homs (approx. 400 t/d) could be used.

The ammonium sulfate would compete in the Syrian market with the urea also produced at Homs. But as part of the urea will have to be exported anyway, this would not matter much: It will be preferable to export more urea than to export the excess liquid ammonia, as for this a liquid ammonia sea terminal would have to be erected at Tartous.

Ammonium sulfate could also be exported to a certain, but limited extent; Egypt, Greece and Turkey being importing countries in the eastern Mediterranean.

It is thus suggested that 400 t/d of ammonium sulfate should be produced from phospho-gypsum at Homs, this capacity being at the lower end of the economic size of such plants. It would utilise about 600 t/d of phospho-gypsum and 105 t/d of ammonia.

As a by-product about 340 t/d of calcium carbonate would be produced. Of this quantity 140 t/d should be used in the calcium-ammonium nitrate plant at Homs, substituting natural limestone, the rest for the production of burnt lime (approx. 100 t/d calcium oxide)[x]. The burnt lime would be used for the effluent neutralisation of the TSP plant. So this by-product would cause no special problems and could be utilised without creating another ecological problem.

3.2.5.5 Sodium Sulfate

Sodium sulfate is not produced in the Syrian Arab Republic at present, but major quantities will be consumed by the detergent and the pulp and paper industries. As these quantities will have to be imported, a production of sodium sulfate in Syria would be desirable. It is thus suggested that a certain quantity of phosphogypsum is reserved for this purpose pending further information on the process.

3.2.5.6 Soil conditioner

As already mentioned in sec. 3.1.2.8, favorable effects of the application of phospho-gypsum as soil conditioner require a special type of soil condition. According to information from the Soil Science Department of the Arab Institute For The Study Of Arid Zones And Dry Lands (ACSAD), Damascus, such types of soil do not exist in Syria to any extent.

The effect of the gypsum in the soil is caused by a shift of the ion-exchange equilibrium from sodium to calcium; the ion-exchanging

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x) For the calcination of the precipitated calcium carbonate special types of furnaces (multiple-hearth) have to be used because of the small particle size.

substance in this case is the clay in the soil, so the usefulness of the gypsum depends on the clay contents of the soil. Soils in Syria have very low clay contents as they are mainly based on calcium carbonate.

It so appears that there is no market for phospho-gypsum for use as a soil conditioner in the Syrian Arab Republic.

3.3 Phospho-gypsum in the Syrian Arab Republic - economic aspects

3.3.1 General remarks

In sec. 3.2 the problem of reprocessing the phospho-gypsum in Syria was investigated from a technical point of view. This section will deal with the economic aspects of the problem.

The study is based on actual cost data relevant in the Syrian Arab Republic in mid-1979.

General assumptions made are:

Days of operation per year: 300
Cost of labor: SP 8000 per worker per year
Overhead (administration, supervision, etc.): 150 % of labor
Maintenance: 2 % of total investment per year for materials, labor to be included in the labor force
Amortisation: 10 years
Interest: 9 % of the falling capital p.a.

Amortisation and interest on capital have been recalculated to give equal annual installments for the periods of amortisation. Interest during the time of construction has been assumed to be

7 % of the total investment and has been included to give total fixed cost of 16.67 % of the total investment per year.

All calculations have been made in Syrian Pounds at a current rate of exchange of

1 US \$ = LS 3.90

Other cost data used are:

Power	LS 0.05/kWh
Fuel oil	LS 288.-/t
Petrocoke	LS 70.-/t
Steam	LS 30.-/t
Water	LS 0.04/m^3
Demin. water	LS 2.-/m^3

3.3.2 Cost of dumping the phospho-gypsum

Following the technical description given in sec. 3.2.4 the cost of dumping the phospho-gypsum produced at Homs can be estimated:

Investment:	
Additional equipment at the Homs plant:	LS 3 500 000.-
Equipment at the dumping area:	LS 5 500 000.-
Total investment	LS 9 000 000.-

Cost of dumping (1 250 000 t moist filter cake annually):

Lime	3125 t	LS 275.-/t	LS	860 000.-/a
Railroad freight	1250000 t	7.80/t		9 750 000.-
Labor, incl. overh.	50 worker	20 000.-/w.		1 000 000.-
Maintenance	2 %			180 000.-
Fixed cost	16.67 %			1 500 000.-
			LS	13 290 000.-

Cost per ton of filter cake (25 % moisture): LS 10.63
Cost per ton of dry gypsum: LS 14.17

So the cost of dumping the phospho-gypsum will be about LS 14.-/t in the long range.

A credit of LS 14.- per ton of dry phospho-gypsum will be used in all further calculations if dumping is avoided,as it represents the expected cost of dumping the gypsum without detrimental effects to the environment.

3.3.3 General comparison between the cost of production of natural gypsum and of purified and dried phospho-gypsum

Before going into the various uses of phospho-gypsum and their relative economics, the competitive situation between natural gypsum and purified and dried phospho-gypsum will be compared in a general way.

Cost for natural gypsum in Syria are about LS 7.- at the mine, about LS 12.- for the crushed product ex works, and about LS 18.- for the ground product.

The cost of production of purified and dried phospho-gypsum are shown in fig. 17. The upper curve shows the cost of production if fuel oil is used for the drying of the phospho-gypsum, the lower curve the cost when using petrocoke as fuel.

A comparison of the production cost of purified and dried phospho-gypsum with that of natural gypsum shows that the cost of production of the phospho-gypsum approach those of the natural gypsum ex mine at high capacities; but if they are compared with ground natural gypsum, the break-even point is at lower capacities already.

It can be concluded that purified and dried phospho-gypsum will be competitive with natural gypsum in Syria in most cases.

3.3.4 Cost of production of setting retarder

Cost of production of setting retarder from phospho-gypsum as a function of plant capacity is shown in fig. 18 for the Giulini and the calcination process. As can be seen from this graph cost of production of setting retarder are:

Capacity of plant, t/d	500	1000
Giulini process	LS 55.98/t	LS 47.01/t
Calcination process	LS 23.69/t	LS 19.49/t

Because of its higher cost the Giulini process is not considered further.

The cost of production of setting retarder by the calcination process have to be compared with the cost of natural gypsum. The crushed product sells at about LS 12.-/t ex works, so it is

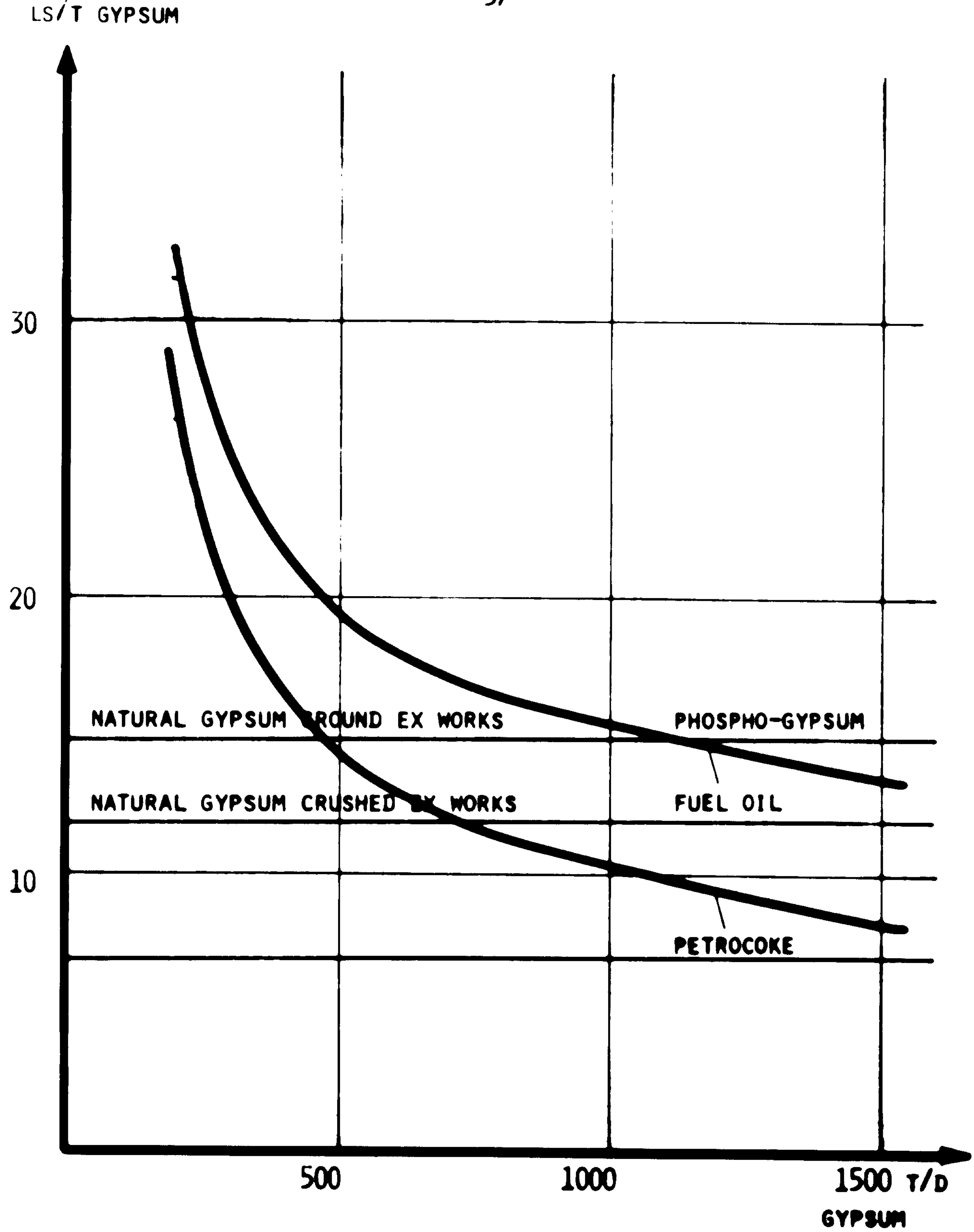

FIG. 17: COMPARISON BETWEEN COST OF NATURAL GYPSUM AND PURIFIED AND DRIED PHOSPHO-GYPSUM

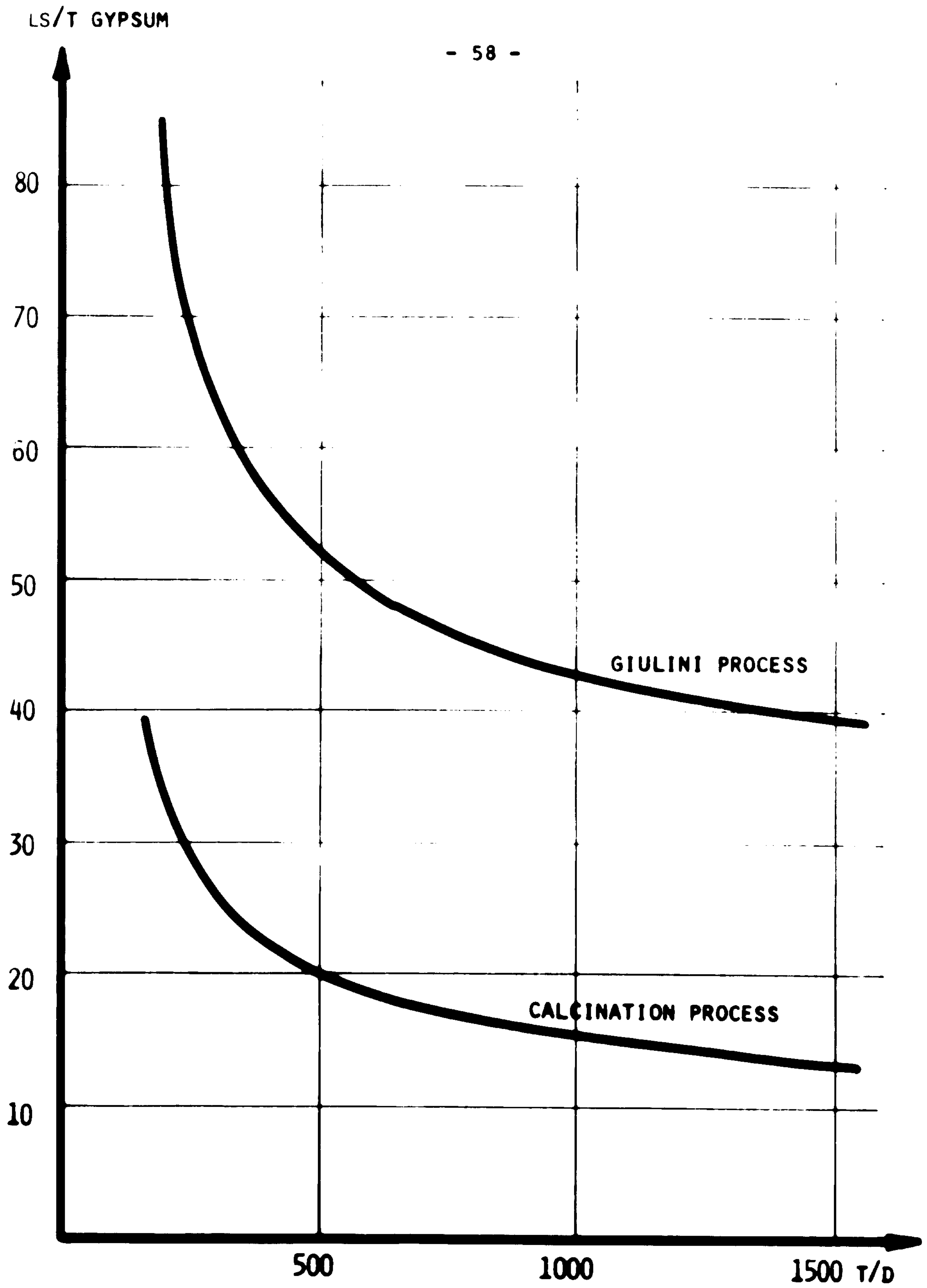

FIG. 18: COST OF PRODUCTION OF SETTING RETARDER

cheaper than the product prepared from phospho-gypsum.

The exact comparison has to include the cost of transportation to the users, i.e. the cement plants.

The cost of transportation will be calculated using the distances given in sec. 3.2.5.1 and the milage cost given in app. 5.7, i.e. LS 7.- per ton and per 100 km by rail, and LS 14.- per ton and per 100 km by truck.

Using these values the following cost of crushed natural gypsum can be calculated:

Cement plant location	cost of gypsum LS/t	transportation cost LS /t	total cost LS/t
Homs	12.-	16.80	28.80
Hama	12.-	21.-	33.-
Aleppo	12.-	22.40	34.40
Lattaquia	12.-	2.80	14.80
Damascus	12.-	7.-	19.-
Tartous	12.-	19.60	31.60
Tripoli	12.-	26.60	38.60

This has to be compared with the cost of setting retarder produced from phospho-gypsum:

Cement plant location	cost of retarder LS/t	transportation cost LS/t	total cost LS/t
Homs	23.69	2.80	26.49
Hama	23.69	3.50	27.19
Aleppo	23.69	14.-	37.69
Lattaquia	23.69	33.60	57.29
Damascus	23.69	22.40	46.09
Tartous	23.69	7.-	30.69
Tripoli	23.69	14.-	37.69

By comparison it can be seen that the setting retarder produced in Homs would be cheaper for the cement plants in Homs, Hama, Tartous, and Tripoli. These plants add up to a consumption of approx. 600 t/d setting retarder.

So a production of about 600 t/d of setting retarder based on phospho-gypsum will be technically and economically feasible at Homs.

If the comparison is based on setting retarder production cost in a 1000 t/d plant, the total cost at Aleppo add up to LS 33.49/t, which is lower than the cost of natural gypsum at that location. So as an alternative, a plant for the production of 900 to 1000 tons per day of setting retarder could be contemplated, supplying the cement plants at Homs, Hama, Tartous, Aleppo, and Tripoli.

3.3.5 Cost of production of calcium sulfate hemihydrate (Plaster of Paris)

Production cost of hemihydrate (plaster of Paris) from phospho-gypsum are shown in fig. 19. The calcination process compares

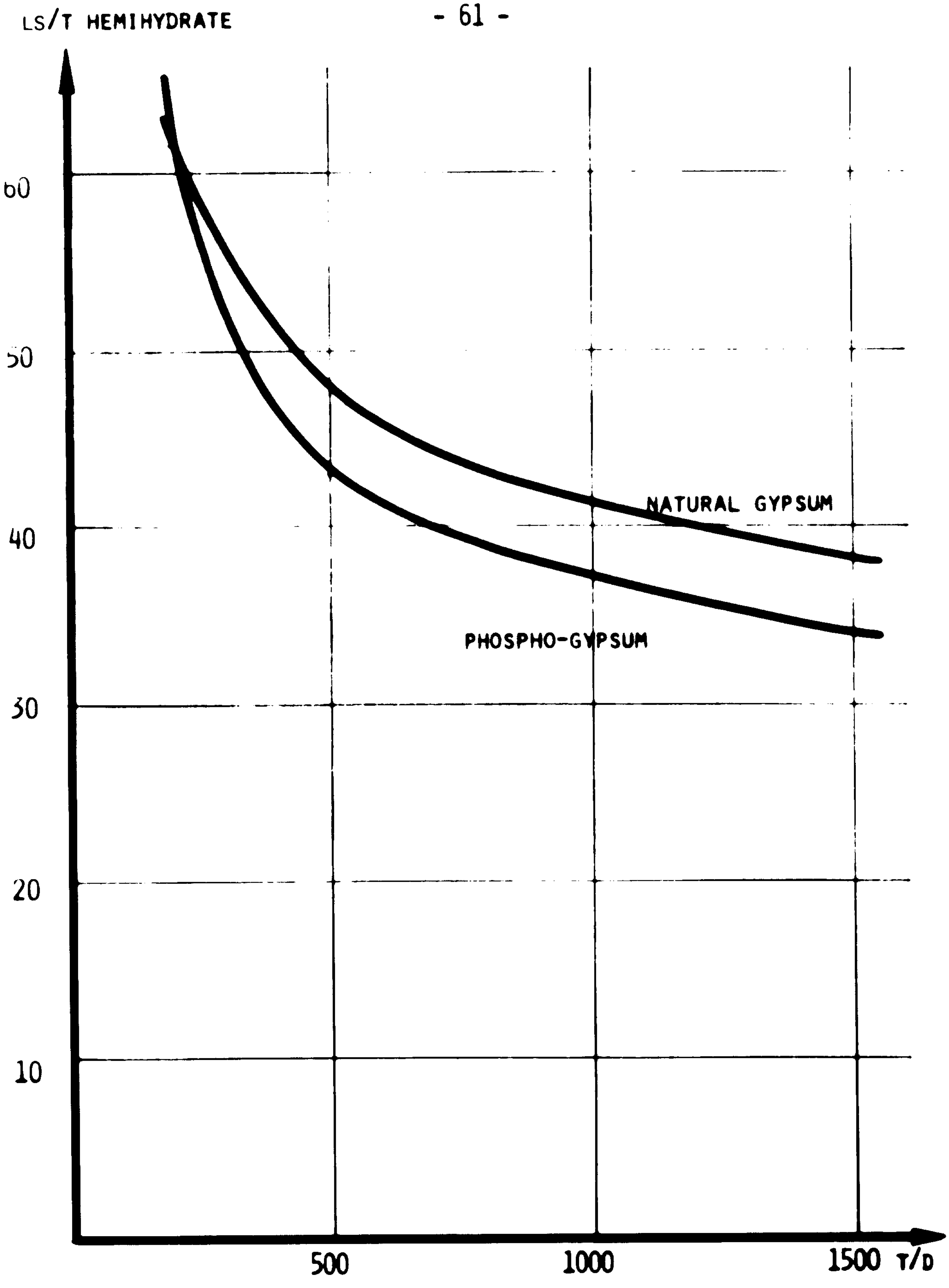

FIG. 19: COST OF PRODUCTION OF HEMIHYDRATE

favourably with the production of hemihydrate from natural gypsum. The use of petrocoke as a fuel for the drying of the phospho-gypsum would give an economic advantage here also, but is not possible because of technical difficulties.

As calcium sulfate hemihydrate is the base material for various types of plaster, for building blocks, wall board, fibre board, and decorative panels made from gypsum, this means that all these products can be made on a competitive basis from phospho-gypsum.

As the price of hemihydrate is fairly low, transportation cost play an important part in its economics. Marketing of it is limited to a rather restricted area around the site of its production. This means that the production capacities will not be very high, i.e. in the range of a few hundred tons per day maximum under present conditions in Syria.

The cost of production of hemihydrate can be reduced considerably by integrating its production with that of setting retarder up to the dryer and adding a final calcination step for part of the material. In this case the approximate cost of production should be read from fig. 19 at the total capacity of the two plants.

3.3.6 Cost of production of sulfuric acid and cement

The cost of production of sulfuric acid and cement from phospho-gypsum are shown in fig. 20. The production cost relate to one ton of sulfuric acid plus the equivalent quantity of cement.

As the maximum capacity per kiln is about 1000 t/d cement, minimum production cost are approx. LS 350.-. Taking into account that one ton of cement costs about LS 145.- when produced from standard raw

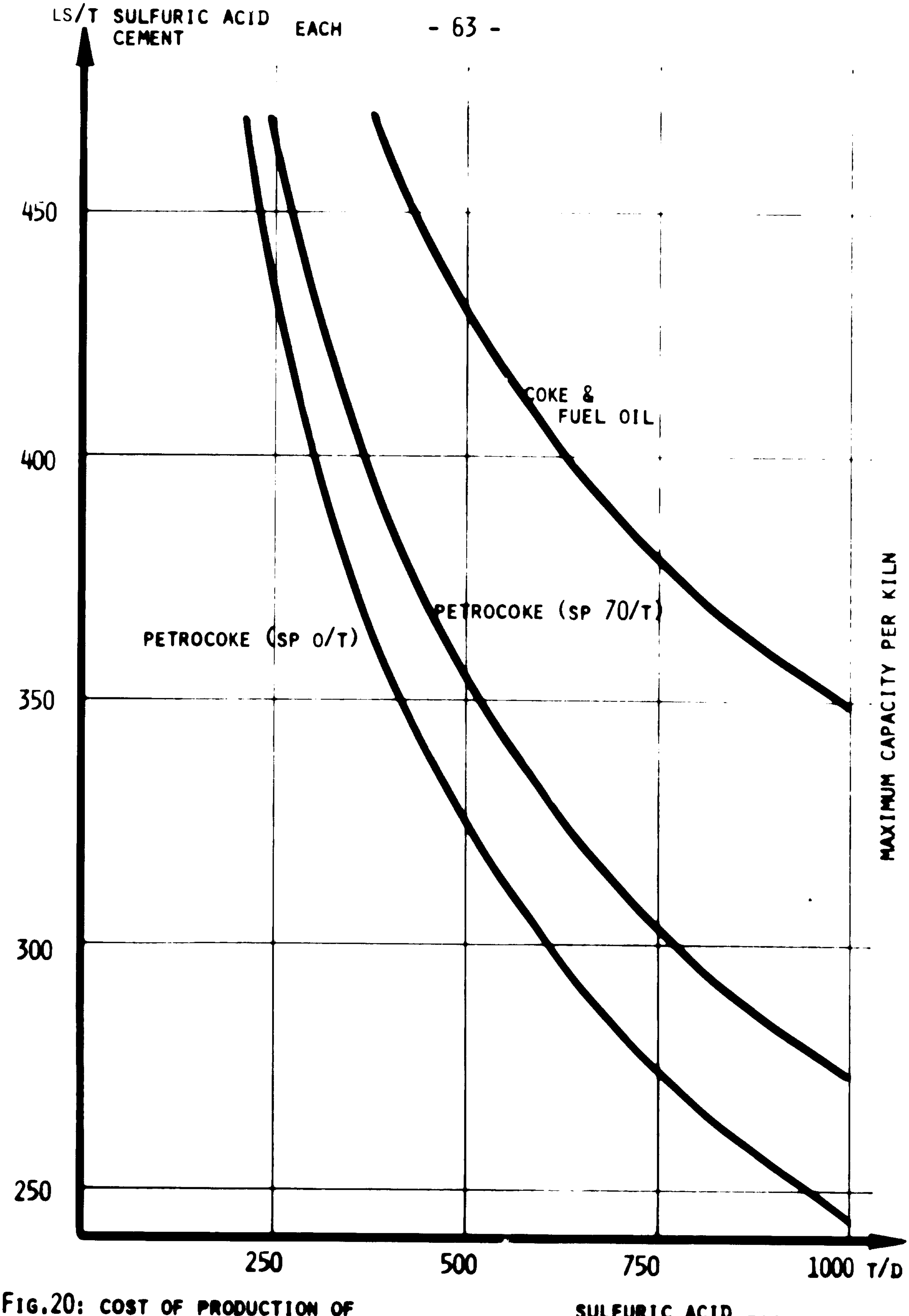

FIG.20: COST OF PRODUCTION OF SULFURIC ACID AND CEMENT

materials, this would give cost of production of about LS 205.- per ton of sulfuric acid when produced from gypsum. In fig. 21 cost of production of sulfuric acid from sulfur are shown as a function of sulfur cost for a plant capacity of 850 t/d of acid. Under these conditions sulfuric acid cost of LS 160.-/t would correspond to a sulfur price of LS 530.- or US $ 136.- per ton. As the price of sulfur cannot be expected to be as high in the future the production of sulfuric acid and cement from phosphogypsum would not be economic under these conditions.

As already mentioned in sec. 3.2.5.3 petrocoke available from the Homs refinery could be substituted for the coke of reduction and for the fuel used in the process. This would give a considerable reduction of the cost of production as shown by the lower curves of fig. 20. The cost shown refer in this case to 1 ton of cement plus 1.08 tons of sulfuric acid, as the sulfur contained in the petrocoke produces additional acid.

Two prices for the petrocoke have been assumed: LS 70.-/t and no cost. Part of the petrocoke was formerly exported at a price of LS 70.-, but as this is not possible any more and as it is not possible to use the petrocoke in any other way at the moment it can be argued that its value is really zero. So both prices have been included.

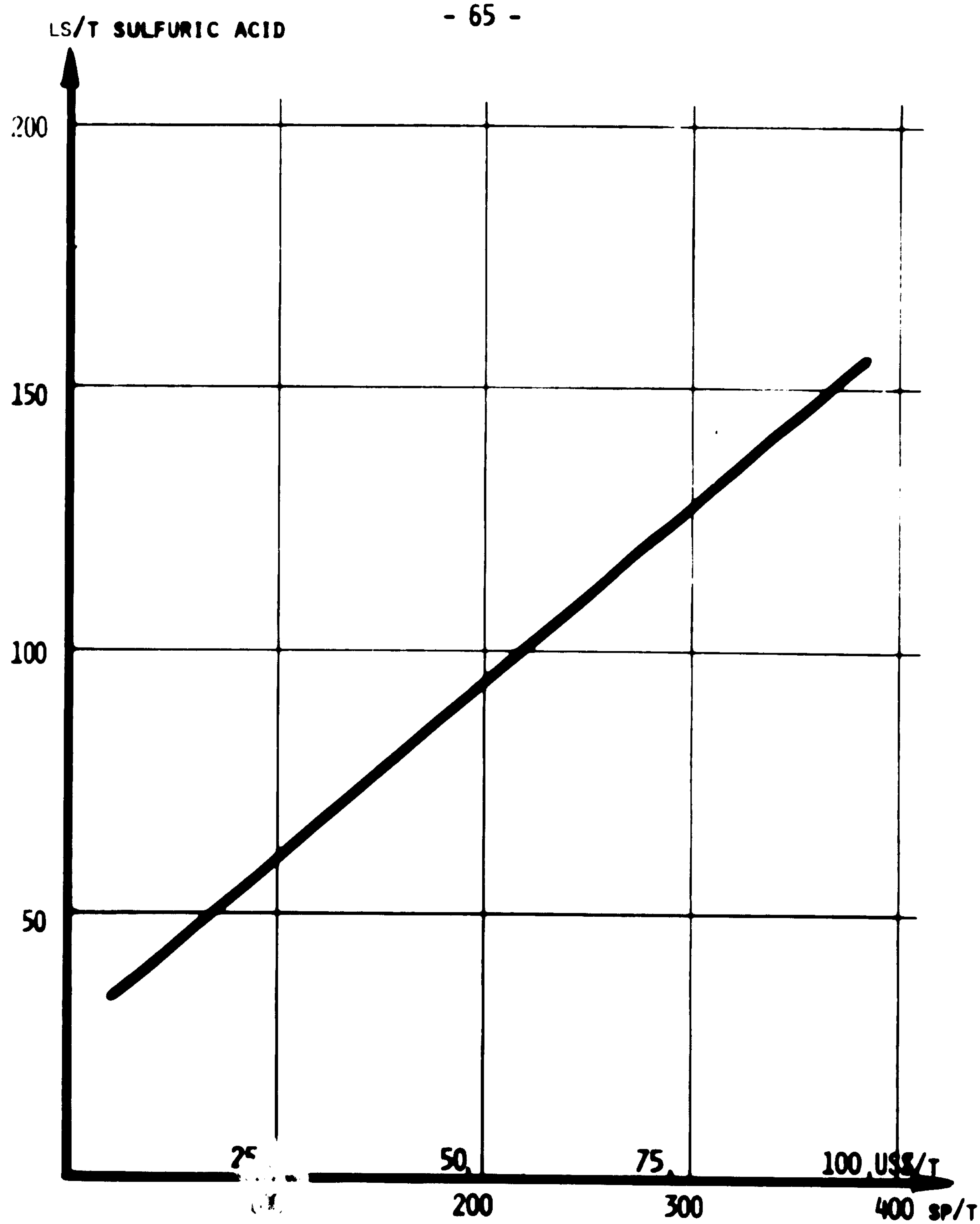

FIG. 21: COST OF PRODUCTION OF SULFURIC ACID FROM SULFUR; CAPACITY 850 T/D

The cost of production calculated are shown in the table:

Plant capacity 1000 t/d cement	fuel oil LS 280.-/t	petrocoke LS 70.-	LS 0.-
Total cost of production cement plus sulf. acid, LS	350.-	275.-	245.-
co. . of one ton of cem. from standard raw mater.,LS	145.-	145.-	145.-
cost of one ton of sulfuric acid, LS	205.-	118.-	91.-
this corresponds to a price of sulfur of US $	136.-	70.-	49.-

As sulfur can be expected to sell between US $ 70.- and 80.- in the future, these figures show a good economic situation of the process when using petrocoke.

As can be seen from fig. 20 the cost of production increase very much with a decrease in capacity of the plant. In sec. 3.2.5.3 it is argued that two different capacities are possible for such a plant at Homs from a technical point of view, either 570 t/d or 850 t/d of sulfuric acid. So from an economic point of view the capacity of 570 t/d seems not feasible; the plant should, therefore, have a capacity of 850 t/d of sulfuric acid. When using petrocoke for the reduction and as fuel this will correspond to a capacity of about 770 t/d of cement as explained in sec. 3.2.5.3.

3.3.7 Cost of production of ammonium sulfate

The cost of production of ammonium sulfate from phospho-gypsum as a function of the capacity is shown in fig. 22. Present world market price of ammonium sulfate and equivalent cost to urea+) are also shown. As can be seen from these graphs, world market prices can be reached at plant capacities higher than about 600 t/d, and equivalent urea prices can be reached at capacities larger than about 750 t/d of ammonium sulfate. For comparison cost of production of ammonium sulfate from ammonia and sulfuric acid are included.

One uncertainty in the calculation of the cost of production of ammonium sulfate is the credit for the calcium carbonate by-product. In this calculation a credit of LS 25.- per ton of calcium carbonate (15 % moisture) has been assumed. On this basis calcium oxide can be produced costing about LS 200.-. As the actual cost in Syria for this product is LS 275.-/t, a higher credit for the calcium carbonate seems possible. No higher credit has been adopted because of the competition of natural limestone possible in the future.

+) Equivalent cost to urea is the cost of ammonium sulfate, at which one ton of nitrogen in both compounds has the same price. Cost of production of urea have been calculated for the Homs plant under the standard set of assumptions of this study (see sec. 3.3.1)

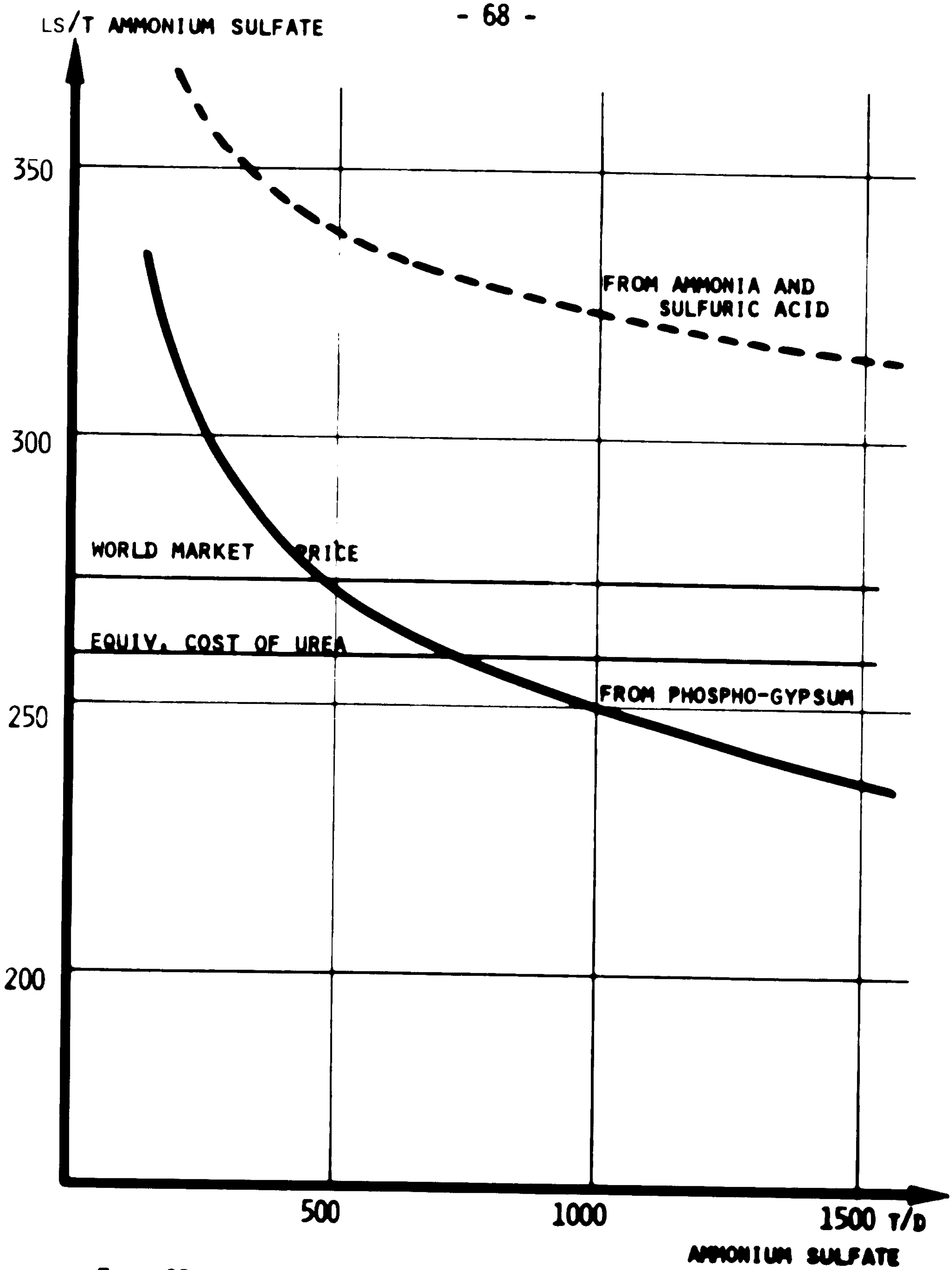

FIG. 22: COST OF PRODUCTION OF AMMONIUM SULFATE

3.4 Scheme for reprocessing the phospho-gypsum at Homs

3.4.1 Technical scheme

Summing up the results of the technical analysis of sec. 3.2 and of the economic analysis of sec. 3.3 the production of the following materials seems possible by reprocessing phospho-gypsum in Syria:

	capacity	phospho-gypsum consumption
	t/d	t/d
Setting retarder for cement	600 - 1000	660 - 1100
calcium sulfate hemihydrate (plaster of Paris)	200 - 300	280 - 420
Ammonium sulfate	400	600
Sulfuric acid/cement	850/770	1725

The consumptions of phospho-gypsum for the various products add up to 3265 t/d minimum to 3845 t/d maximum. As 3000 t/d are available only, not all the products can be manufactured in the quantities shown.

It is suggested that part of the dried and precalcined material from the setting retarder production is completely calcined in a kettle to yield calcium sulfate hemihydrate (plaster of Paris). As it can be expected that the production of the cement plants is not 100 % of capacity all the year round there will be a lower consumption of setting retarder also. So the excess product can be transformed into hemihydrate; the quantity is estimated to be approx. 100 t/d at the beginning.

This quantity of hemihydrate can be sold for the production of plaster or of building blocks. The production of hemihydrate can be increased as the market for this product develops in the following years, leaving the supply of setting retarder more and more to the natural gypsum quarries.

The economic analysis will be calculated under the assumption that no hemihydrate will be produced as this is the worst case.

So it is suggested that the following products should be manufactured by reprocessing phospho-gypsum at Homs:

	Capacity t/d	Consumption of phospho-gypsum t/d
Setting retarder for cement and hemihydrate	600	660
Ammonium sulfate	400	600
Sulfuric acid/cement	770/850	1725

In this way all of the phospho-gypsum produced at Homs can be reprocessed eventually.

As mentioned in sec. 3.2.[illegible].3 the quality of the phospho-gypsum cannot be assessed before the start-up of the phosphoric acid plant and after reaching continuous production in it; it is expected that this will be in the second half of 1980. So a decision on the sulfuric acid/cement plant will not be possible earlier than this date as a knowledge of the exact composition of the phospho-gypsum is essential for it.

If the quality of the phospho-gypsum produced at Homs proves suitable, the sulfuric acid/cement plant should be built, as this process would not only consume the phospho-gypsum but also approx. 330 t/d of petrocoke and so would at least partially solve another environmental problem in the Homs area. In addition it would save the import of about 85 000 t/a of sulfur and save about US $ 6 350 000.- of foreign exchange annually.

Decision on the production of setting retarder/hemihydrate and of ammonium sulfate can be reached immediately, as both processes are not so much depending on the quality of the phospho-gypsum.

Following this argument the proposed scheme for the reprocessing of the phospho-gypsum produced at Homs will be as follows:

First step:	Setting retarder/ hemihydrate	600 t/d
	Ammonium sulfate	400 t/d
Second step:	Sulfuric acid/cement	770/850 t/d

In case the phospho-gypsum produced at Homs will not prove suitable for the production of sulfuric acid and cement, the production of setting retarder could be increased to 1000 t/d, and a plant for the production of sodium sulfate should be erected.

3.4.2 Financial analysis

3.4.2.1 Setting retarder production

For the production of 600 t/d of setting retarder the investment cost will be LS 24 250 000.-. Pre-production cost and working capital will amount to LS 1 697 000.-.

The average price for the setting retarder will be approx. LS 25.- as shown in sec. 3.3.4 to give the same cost as natural gypsum at the cement plants. The plant will have an expected useful life of 20 years.

On the basis of these assumptions an

internal rate of return of 18.2 % p.a.

can be calculated.

3.4.2.2 Ammonium sulfate production

For the production of 400 t/d of ammonium sulfate, 140 t/d of calcium carbonate, and of 120 t/d of quick lime a total investment of LS 100 357 257.- is expected. Preproduction cost and working capital will be LS 7 025 000.-.

If the price of ammonium sulfate is set at the present world market price level (US $ 70.- per ton, equal to LS 273.- per ton) the

internal rate of return is 14.6 % p.a.

If the price of ammonium sulfate is set equivalent to the production cost of urea at Homs, calculated according to the set of assumptions of this study, i.e. at LS 258.90 per ton, the

internal rate of return is 12.7 % p.a.

If the ammonia used to produce the ammonium sulfate is priced at US $ 125.-, which is the return to be expected if the surplus ammonia produced at Homs is exported, and the ammonium sulfate is priced equivalent to urea as mentioned above, the

internal rate of return is 16.0 % p.a.

3.4.2.3 Sulfuric acid/cement production

A plant producing 850 t/d of sulfuric acid and 770 t/d of cement will have investment cost of LS 325 000 000.-. In addition pre-investment cost and working capital will be LS 22 750 000.-.

At a price of the sulfuric acid of LS 125.-, (which is the expected production cost of the acid in the existing plants at Homs at a price of sulfur of US $ 75.-), and a cement price of LS 145.- per ton, (which is the production cost of the existing cement plants when calculated according to the assumptions of this study), the expected

internal rate of return is 13.1 % p.a.

at a useful plant life of 20 years.

If the sulfuric acid price is set at LS 144.-, which is equivalent to a price of sulfur of US $ 90.-, the

internal rate of return is 15.0 % p.a.

If the petrocoke consumed in the plant is taken at zero cost, which seems reasonable, as this material cannot be utilised in any other way at present, and the sulfuric acid is priced at LS 125.- per ton, the

internal rate of return is 15.5 % p.a.

If the technological sophistication of the plant is taken into account and the plant production efficiency during the early years is reduced to

first year	50 %
second year	70 %
third year	90 %
fourth year and after	100 %,

the sulfuric acid is priced at LS 125.-/t, and the petrocoke is taken at zero cost, the

internal rate of return is 13.5 % p.a.

3.4.2.4 Commercial profitability and national economic evaluation

The internal rates of return calculated for the three plants proposed show good economic aspects for all of them.

The setting retarder/hemihydrate plant has low cost of investment, and a rather high return on the invested capital.

The ammonium sulfate plant will utilise another 100 t/d of ammonia, thus reducing the surplus ammonia available at Homs and producing additional solid fertiliser for export. The technology of it is fairly simple and unsophisticated. The return on investment to be expected is about average for good projects.

The sulfuric acid/cement plant will save imports of sulfur for more than US $ 6 million annually. It will produce in addition 770 t/d of cement, which will also substitute imports of this material. Furthermore it will utilise about one half of the petrocoke produced at the Homs refinery and so help to solve this problem, too. In view of these additional advantages its expected rate of return is also good.

As all of the plants mentioned will help to solve the serious environmental problem set by the production of the phospho-gypsum at Homs, their erection seems feasible from the commercial as well as from the national economic point of view. Furthermore, about 140 new working places would be created at Homs.

4. Conclusions and recommendations

1. After start-up of the phosphoric acid plant at Homs phospho-gypsum will be produced in a quantity of about 4000 t per day of moist filter cake. As no storage area is available in the plant and no reprocessing facilities will be available at that time, the phospho-gypsum will have to be discarded.

2. The proposed dumping area near the fertiliser plant at Homs is not suitable for environmental reasons. A new site should be found as quickly as possible by a team consisting of a geologist, an ecologist, and a plant engineer to provide a near-term solution of the dumping problem.

3. As a permanent solution for the dumping problem without detrimental effects to the environment, the phospho-gypsum could be transported back to the phosphate mines by rail and dumped nearby in the desert area at cost of approx. LS 14.-/t of dry matter.

4. Investment cost for the dumping operations should be kept as low as possible even at the expense of higher operating cost as reprocessing appears to be more economic in the long run.

5. A master plan for the reprocessing of the phospho-gypsum should be approved as soon as possible. This plan should include the following suggestions.

6. Reprocessing of the phospho-gypsum at Homs should consist of a number of processes as the quantity of the gypsum is too large for any single product.

7. Reprocessing capacity should be increased step by step in the future, starting as soon as possible and aiming at utilising all of the gypsum eventually. Processes with low investment cost and simple technology should be built first.

8. It is suggested that the final arrangement for the reprocessing of the phospho-gypsum should include the following products:

   setting retarder for cement
   hemihydrate (plaster of Paris)
   ammonium sulfate
   sulfuric acid/cement

   For all of these products well proven processes are available from plants operating on phospho-gypsum in various countries.

9. Setting retarder can be produced from phospho-gypsum by purification, drying, and granulation. The cement plants at Homs, Hama, Tartous, and Tripoli should be supplied from Homs; so a production capacity of 600 t/d should be provided; part of this quantity can be sold as calcium sulfate hemihydrate (plaster of Paris).

10. Ammonium sulfate can be produced from phospho-gypsum and ammonia. By using this process it would be possible to use part (100 t/d) of the excess ammonia available at Homs. Ammonium sulfate is a nitrogen fertiliser especially suitable for irrigated areas; so a production of 400 t/d mainly for consumption in Syria is suggested. The coproduced calcium

carbonate would be utilised in part in the existing calcium ammonium nitrate plant, in part be calcined to produce quicklime needed for effluent neutralisation at the Homs plant.

11. Phospho-gypsum should also be utilised to produce sulfuric acid and cement if its quality proves suitable for this process. This can be ascertained at the earliest after start-up of the phosphoric acid plant at Homs and after reaching continuous production in it. A capacity of 850 t/d of sulfuric acid and of 770 t/d of cement is suggested as this is equivalent to one line of the existing sulfuric acid plant, which should be kept as a stand-by facility. This process would use about 330 t/d of petrocoke from the Homs refinery for the reduction and as fuel without causing any detrimental effects to the environment, thus solving this problem, at least partially, too. The cement produced would be of standard quality and substitute imported product. The plant would also save the import of about 85 000 t/a of sulfur and so the expenditure of approx. US $ 6 million of foreign exchange annually.

12. The investment cost of the plants proposed are estimated to be:

setting retarder	600 t/d	LS	24 million
ammonium sulfate	400 t/d	LS	100 million
sulfuric acid/cement	850/770 t/d	LS	325 million

The expected internal rates of return for the projects are:

setting retarder	approx. 18 %	p.a.
ammonium sulfate	approx. 12 - 14 %	p.a.
sulfuric acid/cement	approx. 13 - 15 %	p.a.

The economic aspects of the proposed plants appear to be favourable, especially in view of the other advantages of the plants, i.e. in environmental and in foreign exchange respects.

13. If the phospho-gypsum produced at Homs does not prove suitable for the production of sulfuric acid and cement finally, the productions of setting retarder and of ammonium sulfate should be increased to 1000 t/d and 600 t/d respectively, and plants for the production of hemihydrate and of sodium sulfate should be erected.

14. Detailed feasibility studies for the production of setting retarder, ammonium sulfate, and sulfuric acid/cement with the capacities mentioned above should be executed by a competent engineering firm.

15. The building materials industry should be required to produce new types of building materials based on gypsum, as they are more economic. These productions should be based, in part, on hemihydrate produced from phospho-gypsum.

Annex I

JOB DESCRIPTION

The expert will work with the Government and with the assigned counterparts, and will specifically be expected to:

1. Assess the quantity and composition of by-product phospho-gypsum from the new plants coming on stream in 1980.

2. Assess the price of cement in the country, its marketability, transportation costs, etc.

3. Examine the requirements for the raw material inputs such as coke, natural gypsum etc., required for manufacture of cement from phospho-gypsum; identify energy requirements and its cost.

4. Assess the quantity of sulphur dioxide recoverable from phospho-gypsum for production of sulphuric acid and identify what modifications are required for adaptation of these units to process by-product sulphur dioxide of low concentration.

5. Prepare a review of phospho-gypsum reprocessing technology and recommend the most suitable process.

6. Work out a comparative techno-economic evaluation of the two basic processes for reprocessing of phospho-gypsum for manufacture of

   - cement and sulphur dioxide;
   - ammonium sulphate and its further processing to white and Portland cement;
   - lime and building materials.

   Estimate production costs of the final marketable products and compare these costs with production costs attainable in the country in case the same products would be manufactured by other methods.

7. Prepare the basic outline of the selected plants; provide description of processes, flow sheets, equipment lists and description of machinery, plot plans, requirements for off-site facilities and energy supply, consumption figures, labour requirements, description of buildings, and present other essential engineering data.

8. Estimate capital investment requirements and give breakdown of the total cost by specifying its major components as: license fees, engineering, procurement, and erection costs, etc.

9. Investigate requirements for transportation facilities for raw materials and finished products.

10. Review the environmental aspects of the project and any cost/benefit ratio derived from the same.

11. Suggest preselection of licensors, review the successful operation of plants in Austria, France and Germany and recommend experienced contractors and equipment suppliers for implementation of the project.

12. Prepare tender specifications for the given plants to be submitted for

    i) consulting companies;
    ii) engineering contractors.

13. Assess the capital investment and transportation costs for disposal of waste gypsum.

14. Provide advice on follow-up action as: Government decisions to be taken, contracting arrangements to be made by the Government, research on quality control and purification methods for phospho-gypsum, etc.

The expert will also be expected to prepare a final report, setting out the findings of his mission and his recommendations to the Government on further action which might be taken.

Annex' II

LIST OF COUNTERPARTS

The help of the following persons is gratefully acknowledged by the author of this report:

Chem. Eng. Salim Babil, adviser to H.E. the Minister of Industry
Dr. M. Seifuddin Atfeh, adviser to H.E. the Minister of Industry

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Mr. Asis Khalifa, director general
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Eng. E. Anhariri

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Mr. Mohammed A. Hussein, chief, ammonia and urea project
Mr. Abdallah H. Hassan, chief, triple superphosphate project
Mr. Hikmat Dalati, eng.

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Mr. Khaled Yassir, Resident Representative
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Industrial Testing, Research, and Development Center, Damascus

Dr. Zafer Sawaf, director general

Dr. H.C. Visvesvaraya, Project Manager

Annex III

THE SYRIAN PHOSPHATE ROCK

The phosphate rock to be used in the phosphoric acid and triple superphosphate plants at Homs is mined about 145 km east of Homs near Palmyra.

There are three mining areas, the respective phosphate rock qualities being called Kneiffis, Eastern A, and Eastern B. Whereas Eastern A and Eastern B have lower grade ores, the raw phosphate from Kneiffis ranges from 22 to 32 % P2O5 (as mined).

At the Kneiffis mine the phosphate rock strata has a depth of about 5 m, and is covered by an overburden of 7 to 25 m. One to three million tons of overburden have to be moved annually in the mine. The phosphate rock is crushed, sized, and dried at Kneiffis. At present it is transported by truck to the harbour of Tartous for export (about 250 km). A fleet of 180 trailers of 35 to 40 tons capacity each is used. Transportation cost are about SP 26.- per ton for this distance.

A new railroad line is under construction from the phosphate mines to Tartous via Homs and will be operational in 1980.

Average composition of the Syrian phosphate rock, % by weight

	Kneiffis	Eastern A	Eastern B	New sample+)
P2O5	31 - 33	29 - 30	29 - 30	26.46
CaO	45 - 51	47 - 51	47 - 51	45.9
SiO2	2.5 - 4	5 - 8	5 - 8	8.65
F	2 - 4	2 - 4	2 - 4	2.82
Cl	0.15 - 0.25	0.15 - 0.25	0.15 - 0.25	0.24
Fe2O3	0.2 - 0.5	0.2 - 0.5	0.2 - 0.5	0.14
Al2O3	0.1 - 0.6	0.1 - 0.6	0.1 - 0.6	0.28
MgO	0.2 - 0.5	0.2 - 0.5	0.2 - 0.5	2.07
Loss on ignition	7.5 - 11	7.5 - 11	7.5 - 11	-
H2O	2 max	2 max	2 max	3.44
Organic carbon				0.09
Size, mm	0 - 2	0 - 2	0 - 2	

Garantied phosphate contents 30 % minimum cn an average

+) Sample of the phosphate to be used in the phosphoric acid plant, sent to the author by the General Fertilizers Company, Homs, on 12 June 1979

Annex IV

PHOSPHO-GYPSUM COMPOSITION OF SYRIAN PHOSPHATE ROCK
(Result of laboratory tests made by the Romanian Contractors)

P_2O_5 total	0.85 %
P_2O_5 soluble	0.41
CaO	32.1
SO_3	44.29
SiO_2	3.76
F	0.475
Cl	nil
TiO_2	nil
Fe_2O_3	0.085
Al_2O_3	0.032
Na_2O	0.02
MgO	0.055
K_2O	nil
Water of crystallisation	18.8

Sample dried at 60 deg.

Annex V

PHOSPHO-GYPSUM COMPOSITIONS OF OTHER ROCK PHOSPHATE
(multi-tank dihydrate process)

Source of phosphate rock		Florida Agrico 72 BPL	Morocco Khouribga 73/75 BPL	Tunesia Gafsa 64/65 BPL	Senegal Taiba 80/82 BPL
P_2O_5	total	0.8 - 1	0.8 - 1.2	0.9 - 1.1	0.7 - 0.9
	soluble	0.2 - 0.3	0.2 - 0.4	0.15- 0.2	0.2 - 0.25
	cocrystallised	0.4 - 0.5	0.5 - 0.6	0.5 - 0.6	0.4 - 0.5
	unreacted	0.2 - 0.4	0.1 - 0.2	0.25- 0.3	0.1 - 0.2
F	total	0.7 - 0.9	0.8 - 1	0.7 - 0.8	0.5 - 0.8
	soluble	0.1 - 0.2	0.1 - 0.2	0.1 - 0.2	0.1 - 0.2
SiO_2		2 - 3	1 - 1.5	2 - 3	0.5 - 1
Al_2O_3		0.3 - 0.35	0.1 - 0.15	0.15- 0.2	0.2 - 0.4
Fe_2O_3		0.1 - 0.15	0.05- 0.1	0.1 - 0.15	0.1 - 0.2
Na_2O		0.25- 0.3	0.3 - 0.4	0.4 - 0.5	0.2 - 0.3
Organic carbon		0.1 - 0.2	0.05- 0.1	0.5 - 0.7	0.1 - 0.2

All figures weight percentage of dry gypsum (60 deg.)

Annex VI

NATURAL GYPSUM DEPOSITS IN THE SYRIAN ARAB REPULIC

There are three major deposits of natural gypsum in Syria:

Djeroud (70 km north of Damascus)
Lattaquia
Al-Raqqa (on the al-Furat river)

All three deposits hold reserves of more than 10 million tons each. The quality of the gypsum is good at all locations.

The Djeroud gypsum consists of fine crystals of eroded gypsum rock, which have been deposited by the wind. Gypsum purity is better than 90 %, 80 % is smaller than 0.16 mm in size. Gypsum is already recovered at the Djeroud site and used for the production of plaster and as a setting retarder in the Damascus and Hama cement plants.

At the Lattaquia site (about 24 km from Lattaquia on the road to Aleppo) the gypsum is quarried. The purity of the gypsum is better than 90 %, too. This gypsum is used as a setting retarder in the cement plants at Lattaquia, Aleppo, and Homs.

The gypsum from the deposit at a-Raqqa is not yet recovered. It consists of gypsum rock of pure white colour, and contains more than 96 % of gypsum.

Annex VII

COST OF TRANSPORTATION IN THE SYRIAN ARAB REPUBLIC

Most goods in the Syrian Arab Republic are shipped by truck, as only a few railroad lines are in operation.

Railroad tariffs differ according to the goods transported:

distance, km	freight LS/t		
	raw phosphate	fertiliser	building materials
100			8.0
150	7.80	8.40	10.40
200			12.00

Road transportation cost are more difficult to assess as they are open to negotiation, but at distances of 100 to 200 km LS 11.- per ton and 100 km appears to be an average figure for long term contracts. This cost will probably increase in the near future as the present price of Diesel oil is extremely low (0.25 LS/l) and will certainly be increased in the future.

For the economic evaluations in this study the following costs of transportation have been assumed:

rail	LS	7.-/ t . 100 km
road	LS	14.-/ t . 100 km

Annex VIII

COMPOSITION OF PETROCOKE FROM THE HOMS REFINERY

At the refinery at Homs petrocoke is produced in a quantity of about 700 t/d. The following composition and properties were given by the refinery:

density, apparent	1.2	-	1.3	kg/dm3
density, real	1.3	-	1.4	kg/dm3
moisture	0.3	-	0.4	%
volatile matter	6	-	12	%
sulfur	8.9	-	9.1	%
ash	0.6	-	0.8	%
calorific value	8300	-	8440	kcal/kg
vanadium		500		ppm
nickel		50		ppm
molybdenum		50		ppm

Analysis of a sample forwarded by the author:

C 86.9 % H 3.4 % S 7.9 %

The product was exported some time ago at a price of US $ 18.-/t.

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