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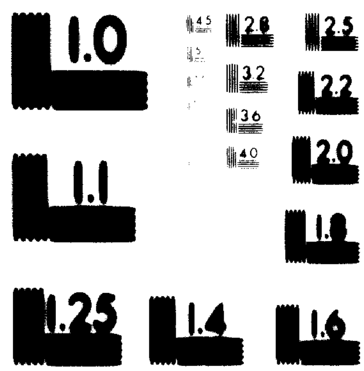

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HUMPHREYS & GLASGOW LIMITED

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANISATION

PRE-INVESTMENT STUDIES FOR THE PROMOTION OF FERTILISER AND PETROCHEMICAL INDUSTRIES IN PAKISTAN

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for

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANISATION

VOLUME IV

THE UTILISATION OF BY-PRODUCT GYPSUM FROM THE TSP PLANTS AT CHITTAGONG IN EAST PAKISTAN

July, 1970.

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UNIDO Vienna for Pakistan | Pre-Investment Studies for Fertiliser & Petrochemical Industries - Final Report | C.1669 July 1970

VOLUME IV

THE UTILISATION OF BY-PRODUCT GYPSUM FROM TSP PLANTS AT CHITTAGONG IN EAST PAKISTAN

CONTENTS

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VOLUME IV

THE UTILISATION OF BY-PRODUCT GYPSUM FROM TSP PLANTS AT CHITTAGONG IN EAST PAKISTAN

Summary of Report

The E.P.I.D.C. site at Chittagong, when completed, will comprise two streams for the production of TSP, via sulphuric and phosphoric acid, from sulphur and phosphate rock. The by-product gypsum has no sale as plasterboard, nor may it be converted to ammonium sulphate at Chittagong. As the disposal area is very limited in size, the only alternative, if no other use can be found for the gypsum, is to transport it from the site, to be dumped, either at sea by barge, or on waste land.

A cement grinding and blending plant is in the final stages of construction, very near to the TSP site, to operate using imported cement clinker. Consideration has therefore been given to the conversion of the gypsum to sulphuric acid and cement clinker using the Müller-Kühne process.

The two licensors for the process were contacted and gave adequate cost and operation data for a study to be prepared and costed. Hitachi-Zosen, who are currently constructing the sulphuric acid plant for the second TSP plant have prepared technical and cost data for their plant to convert gas from the Müller-Kühne process in sufficient quantity to produce 475 MTPD sulphuric acid (as 100% H_2SO_4).

Process flow diagrams and a layout have been prepared for the scheme. Cost comparisons have been made for the project considering it both as part of the overall Pakistan economy, and as part of E.P.I.D.C.'s investment programme. In the former case, a shadow rate of exchange, and in the latter, a return on investment have been calculated and presented for a higher and a lower sulphur price.

It is concluded that the scheme is technically viable. Economic viability is related to the forecasts of sulphur price during the life of the plant. The project would result in a reduction of the net outflow of foreign exchange even at the lowest assumed sulphur price ($40/MT). The Rupee expenditure required to achieve this saving may, however, be considered excessive. A significant improvement in the economic position of the project would result if means could be found for achieving a reduction in the capital cost of the project, or if more of the required equipment could be produced in Pakistan.

VOLUME IV

THE UTILISATION OF BY-PRODUCT GYPSUM FROM THE TSP PLANTS AT CHITTAGONG IN EAST PAKISTAN.

SECTION I

1.1 Introduction

The present TSP complex of East Pakistan Industrial Development Corporation (E.P.I.D.C.) at Chittagong produces, as an end-product, Triple Super Phosphate (TSP) from imported sulphur and imported phosphate rock. There are two complete TSP units of capacities:

Plant I - 32,000 MTPA TSP

Plant II - 120,000 MTPA TSP

Each TSP unit includes Sulphuric Acid, Phosphoric acid and TSP plants, together with associated off-site facilities.

One sulphuric acid plant of 100 MTPD capacity is currently operating, and a further plant of 400 MTPD capacity for the second TSP plant is under construction, and should be commissioned in mid 1971.

Two phosphoric acid plants will eventually be in operation, these are:

(i) Equivalent to 10,670 MTPA P_2O_5, using the Dorr-Oliver Single Tank Process. (33,345 MTPA H_2SO_4).

(ii) Equivalent to 40,000 MTPA P_2O_5, using the Nissan hemi-hydrate/di-hydrate process. (118,480 MTPA H_2SO_4).

The total sulphuric acid requirements are therefore 152,000 MTPA. On an annual operating life of 320 days, this amounts to 475 MTPD H_2SO_4 (as 100%).

As a byproduct, gypsum is produced by the phosphoric acid plants. This may be discarded as a waste either out to sea, which will be costly, or merely dumped on one side of the plant area. The latter will, of course, require a large amount of ground in an area where land is at a premium. The area at present allocated on the plant site for this purpose if totally inadequate on a long term basis.

1.1 Introduction - continued

The objective of the study, therefore, is to determine how the by-product gypsum may best be used. It is clear that a decision will then have to be taken either to implement a scheme such as that proposed in this study, or to make alternative provision for disposal of the gypsum being produced continuously from the TSP fertilizer plant operations. As the rate of production of gypsum from both plants when at full capacity is approximately 850 tons per day the problem of disposal becomes quite serious.

Useful products from this gypsum are limited to about three:

(a) Production of Plasterboard

There is no sale at all in East Pakistan for this material.

(b) Production of Ammonium Sulphate Fertiliser

This is carried out by double decomposition of $CaSO_4$ and $(NH_4)_2CO_3$ solution. The latter is produced by reaction of gaseous ammonia and CO_2 gas in a packed tower. It requires an on-site ammonia plant for the CO_2. Since this is not present at Chittagong, this will not be considered.

(c) Production of Sulphuric Acid and Cement Clinker

The third alternative is to make an SO_2 containing gas stream and Portland Cement Clinker using the well known Müller-Kühne process. In this process, the gypsum is roasted with additives in a rotary kiln. The off-gas containing SO_2 is cleaned, the required oxygen is added as air, the mixed gas is then dried and passed to the existing sulphuric acid plant. The solid residue is unground Portland cement clinker, which will be passed to a cement grinding and blending plant.

The third of the alternatives is ideally suited for Chittagong. A cement grinding and blending plant is currently being constructed some 600 metres distant from the existing TSP plants. The existing sulphuric acid plant for TSP II may be modified at a cost of approximately Rs 4,310,000 to produce the full quantity of H_2SO_4 from the clean dry kiln gas. The plant would show large savings in foreign exchange in that sulphur and cement clinker imports would be markedly reduced.

Since the overall efficiency of the sulphur cycle is only about 90%, a proportion of the sulphuric acid would still have to be made from sulphur. This may be achieved by burning sulphur in the kiln along with oil (or gas.)

It is proposed that the sulphuric acid plant for TSP I (100 MTPD H_2SO_4) be left unmodified, and that the new plant be sized at 475 MTPD H_2SO_4, thus satisfying the demand for H_2SO_4 on the site. In this way a standby or immediate increase in capacity of 100 MTPD H_2SO_4 is available.

1.2 Acknowledgements

Humphreys and Glasgow Limited wish to express their appreciation of the help and information given to them in their work on the project by:

The Government Project Representative in Rawalpindi, the U.N.I.D.O. Project Manager and Co-Project Manager, and U.N.I.D.O. Experts.

The Directors and Senior Executive (Planning) of W.P.I.D.C. head office Dacca, East Pakistan. The Manager, Head of Production and senior staff of the TSP Factory at Chittagong. The Manager of E.P.I.D.C. Branch Office in Chittagong, also the Deputy Director General of the Geological Survey of Pakistan - Eastern Division, Dacca.

SECTION 2

EXISTING TSP COMPLEX

2.1 Location of Plant

The plant is located at Chittagong, East Pakistan, in the Patenga Industrial Estate area.

It is connected to the railway network of Pakistan Eastern Railways and has its own jetty in Chittagong Port, adjacent to the plant, for the handling of raw materials and finished products.

The TSP complex is situated adjacent to other E.P.I.D.C. projects i.e. grain silos and steel mill. A cement grinding and blending plant is under construction approximately 600 metres from the TSP complex (see paragraph 2.4).

Pakistan Eastern Refinery is also located nearby.

2.2 Raw Materials

Sulphur and rock phosphate are the main raw materials for the TSP plants. Sulphur is imported by the Trading Corporation of Pakistan normally under cash-cum-bonus scheme, but sometimes under loans from various countries. Rock phosphate is imported from Jordan, although the plant design was based on the use of Morocco rock.

2.3 Existing Plant and Facilities

2.3.1 General

TSP plant number I was completed in 1969, has operated for three or four weeks, but has had to shut down due to corrosion troubles in the phosphoric acid section of the plant.

A small quantity of sulphuric acid is, however, being made (1000 tons at a time, this being the capacity of the storage tank) and sold to the steel mill and to private industry - e.g. tanneries.

TSP plant number I is expected to be back on stream later this year - as soon as the requisitioned replacement parts are available.

TSP plant number II is at present under construction and is expected to be commissioned by mid 1971.

2.3.2 Gypsum Disposal Area

A gypsum disposal area of about 46,600 m^2 (11.5 acres) is available on the present site. This is large enough to accommodate the by-product gypsum from TSP plants I and II at full output (at 2m depth) for about 150 days only. This area is shown on plot plan drawing number 1669-L51-1.

A spot analysis of the by-product gypsum from the TSP I plant gave:

CaO	39.5	% w/w
$CaSO_4$	96.07	
P_2O_5	1.3	
free H_3PO_4	0.247	
H_2SO_4	0.11	
CO_2	0.08	

No data for fluorine.

This analysis is not representative since the product has been washed by several rainfalls. (The rock was Jordan rock - 34.6% P_2O_5, 3.93 % F, 0.06% Cl).

2.3.3 Water - (Tubewells)

At present, 8 tubewells are installed, of which two give saline water and are thus unuseable. Wells at Chittagong are normally 350-400 ft. depth, and a single well can be expected to give 30,000 igph.

The capacity of the tube wells will now all be used when the two TSP plants are both in operation, but two more may be installed. After that a limit is reached on the river frontage.

Water - (River)

River water may be taken from the Karnaphuli river during low water since it is saline during high water periods. Hence settling and storage facilities are required.

2.3.4 Electrical Power

Power for the complex is provided by E.P.W.A.P.D.A. (East Pakistan Water and Power Development Authority) but at present the supply is very unreliable - 3 or 4 breakdowns per day are not uncommon. It is understood that this is due largely to overloaded transmission lines. Plans are being considered, at long term, to install power generation equipment for the entire E.P.I.D.C. complex (including the TSP complex) E.P.W.A.P.D.A. will not permit installation of private power supply since they have considerable excess capacity. However, they are installing further loop lines to ensure reliability of supply.

An emergency power supply of 900 kWh is being installed to deal with essential power requirements for the TSP plants i.e. for moving the digestors.

2.4 Cement Factory

Adjacent to the TSP factory site, E.P.I.D.C. are at present constructing a cement grinding and blending plant to produce cement for use in East Pakistan.

The plant will ultimately be able to produce 300,000 tons per year of cement, but at the first stage will only be capable of producing half this capacity.

Cement clinker will initially be imported, but the plant is conveniently situated to take cement clinker from the cement clinker/sulphuric acid plant described in this study.

The cement plant has its own wharf up-stream of the TSP plant wharf, and is capable of taking vessels of up to about 10,000 tons.

The plant will have three storage silos, each of 5,000 tons capacity for cement clinker and three silos of the same size for cement product.

The first shipments of cement clinker to the new plant are expected in December 1970.

SECTION 3

ANALYSIS OF PROCESS STATUS

3.1 Licensors

Four manufacturing companies license know-how for their processes using byproduct gypsum.

These are:-

a) Osterreichische Stickstoffwerke, (O.S.W.) of Linz-Austria

O.S.W. license through four contractors:

M.W. Kellog Company, New York.
Fried, Krupp GmbH Chemieanlagenbau, Essen.
Vereinigte Osterreichische Eisen und Stahlwerke A.G. Linz
Engineering and Industrial Corporation, S.A. Luxembourg.

b) V.E.B. Chemiewerk Coswig D.D.R.

The process is licensed through Simon Carves Chemical Engineering Limited.

c) Marchon Division, Albright & Wilson Ltd. (U.K.)

The process is licensed through the Power-Gas Corporation.

d) Polimex - Poland

N.B. The data used in this report have been supplied by O.S.W. and Coswig.

3.2 Process Experience (OSW & Coswig)

a) O.S.W.

The company has a cement/sulphuric acid plant at Linz in Austria. They have one kiln of approx 200 MTPD H_2SO_4 capacity, which was constructed in 1953 to produce sulphuric acid and cement from mixed anhydrite. O.S.W. have a phosphoric acid plant on the same site, so a mixture of anhydrite and byproduct gypsum is normally used.

Experimental work on byproduct gypsum is limited to runs of 7-10 days by the lack of feedstock, the phosphoric acid capacity being inadequate to produce sufficient gypsum to satisfy the sulphuric acid need. A number of these tests have been carried out, and to date some 40,000 MT of byproduct gypsum have been processed.

Fried. Krupp have been awarded a contract in South Africa for a plant of 1000 short tons/day H_2SO_4 from byproduct gypsum from Phalaborwa rock. This plant is in two stages, the first being 350 tons/day. A full scale test at Linz was successfully carried out on byproduct gypsum shipped from the South African site.

3.2 Process Experience - continued

b) Coswig D.D.R.

Coswig have four kilns with a total capacity of 800 MTPD H_2SO_4, built in 1938, and a further four kilns built in 1955 of 680 MTPD H_2SO_4 total. All kilns operate on mixed anhydrite. During the period March 1966 to December 1968, five full-scale experiments were carried out using byproduct gypsum in place of the natural anhydrite. As with O.S.W., limitations of supply of the byproduct gypsum eventually terminated the individual test runs, but Coswig were satisfied with the experience gained during these runs. The cement quality improved after each run. (Data on the cement produced is given in Section 3.4).

3.3 General Experience

Both licensors have devoted much time and effort to minimising the effects of impurities, particularly P_2O_5 and F, on cement quality and the process. The effects of these are as follows:

P_2O_5

This will stabilise the dicalcium silicate phase in the cement clinker to the detriment of tricalcium silicate. Dicalcium silicate is slow setting whereas tricalcium silicate is fast, so the effect of P_2O_5 will be to reduce the early strength of the cement, which is the characteristic which determines the acceptability of the cement.

F

The presence of fluorine in the kiln can lower the melting points of the materials in the kiln and may cause ring formation. Any fluorine which does pass to the converter will shorten the life of the SO_2 oxidation catalyst, but may be easily removed. In addition, the fluorine may cause the protective coating on the kiln brickwork to be eroded with consequent reduction in refractory life.

Licensors experience of P_2O_5 and F in the gypsum is:

O.S.W. P_2O_5 a maximum of 2.0% w/w.
F a maximum of 0.15% w/w.

Coswig P_2O_5 a maximum of 2.0% w/w.
F a maximum of 0.2% w/w.

It is generally expected that an increase in fluorine up to 0.3% in gypsum will be permissible since much of the fluorine is removed during drying and calcination.

3.3 General Experience - continued

Other limitations on impurities include:

(i) Alkali (as Na_2O & K_2O) 1.5% in clinker (0.7-0.8% in raw mix)

(ii) Chlorine 0.1% in raw mix.

3.4 Cement Quality

The cement clinker produced will be of adequate quality to use for the manufacture of cement to BS 12 or equivalent (ASTM C150; DDR STANDARD TGL 10573; GERMAN DIN STANDARD 1164).

The average composition of the cement will be approximately as follows: (% w/w)

CaO	SiO_2	Al_2O_3	Fe_2O_3	MgO	Alkali	SO_3
63.85	21.08	5.79	[illegible]	2.47	1.40	2.7

It will, of course, vary within fine limits due to the exact composition of the feed gypsum and additives.

Tests carried out by O.S.W. at Linz indicate that the cement quality is dependent upon the P_2O_5 content of the clinker.

P_2O_5 in clinker	2.0%	1.0%	0.0%
F in clinker	0.10-0.15%	0.10-0.15%	0.10-0.15%
Specific Surface (Blaine, cm^2/g)		3000-3200	
Bending Strength (kg/cm^2) (to DIN 1164)			
After 3 days	45	50	60
7 days	60	65	70
28 days	80	85	85
Compressive Strength (kg/cm^2) (to DIN 1164)			
After 3 days	190	200	220
7 days	290	320	320
28 days	420	490	400

3.4 Cement Quality - continued

Comparing the above with DIN 1164:

Strength class	Compressive Strength (kg/cm^2) 7 days	28 days
275	min 100	min 275
375	min 175	min 375

and BS 12 for Ordinary Portland Cement,

3 days	7 days
min 154 kg/cm^2	239 kg/cm^2

it may be seen that the quality as regards compressive strength is adequate.

Similarly, Coswig have carried out determinations on cement produced during their test in 1967. Results of this are as follows: (Tested according to TGL 10573)

3 days	7 days	28 days
202	365	507
219	361	507
202	343	524
216	361	517
250	375	582
202	365	532

A British Portland cement tested to the same Standard gave

203	332	432
216	300	455

3.5 Conclusions Concerning Process Status

It would appear that the better experience, in terms of quantity of byproduct gypsum processed is held by O.S.W. They have carried out a number of test runs on their own byproduct gypsum, and also a full scale plant test on material from South Africa. Fried. Krupp have obtained a contract to build a unit in South Africa using the O.S.W. process, and this should be operating well before the plant proposed for Chittagong. The benefit of the experience obtained at the Krupp plant would then be available via the licensor, O.S.W.

3.5 Conclusions Concerning Process Status - continued

Coswig, on the other hand have produced excellent quality cement during a relatively short plant run. They have eight kilns in operation against O.S.W.'s single unit. They have, at present, better experience on minimising the effect of fluorine in the gypsum, although it is expected that O.S.W. will at least match this.

It may therefore be seen that there is adequate experience and confidence that the scheme and process is viable. It is, however strongly recommended that reliable geological surveys are carried out to determine the availability and analyses of suitable additives (clay & sand), and also that accurate analyses of byproduct gypsum be made.

The only real problem facing the project is that of fluorine disposal. This will be released during calcination and wet gas cleaning and will appear as a liquid effluent, roughly equivalent to the fluorine content of the gypsum.

The remainder of this report is concerned with analysis of the financial and engineering viability of the proposed scheme.

SECTION 4

TECHNICAL PROJECT DATA

4.1 General

The following description applies in general detail to both the O.S.W. and Coswig processes. Some differences do appear between the actual flow schemes, but both follow the same principles.

4.2 Process Description (See Flow Diagram Figs. IV.4.1 and IV.4.2).

The process for manufacture of sulphuric acid and cement clinker from gypsum is based on the well established Müller-Kühne process. Wet gypsum filter cake is dried and calcined prior to passing to the gypsum silo.

The additives, coke, clay, sand (to provide carbon, aluminium, iron, and silica) are individually crushed as required, then dried and milled before passing to their respective silos by ganged batch weighers, and passed to the Raw Meal Mixer where thorough blending takes place. The mixed meal is then passed to the Raw Meal Silos prior to being fed to the Cement Kiln. The kiln is inclined at a small angle to the horizontal, thus assisting the passage of material through it. As the meal passes through the kiln, it contacts hot gases from the combustion of oil and sulphur

A series of reactions take place; the net results being:

$4\ CaSO_4 + 2C \longrightarrow CaS + 3CaSO_4 + 2CO_2$ 1

$CaS + 3CaSO_4 \longrightarrow 4CaO + 4SO_2$ 2

$CaO + Al_2O_3 + SiO_2 + Fe_2O_3 \longrightarrow$ Portland Cement Clinker 3

Reaction 1 begins at approximately 700°C; the product calcium sulphide is an intermediate product only. Reaction 2 begins at approximately 900°C. At temperatures up to 1400°C, the CaO reacts with SiO_2, Al_2O_3, and Fe_2O_3 producing cement clinker. The clinker leaves the kiln at the firing (lower) end, and is cooled by secondary air fed to the kiln in the Clinker Cooler.

The SO_2 containing gas passes from the upper end of the kiln to the first stage of gas cleaning, in which the bulk of the dust is removed by cyclones, then by dry electrostatic precipitation, and returned to the kiln. The gas is then washed by water or very dilute sulphuric acid (approx. 1%) to remove fluorine and to cool the gas. The gas then passes through a further set of electrostatic precipitators, and then to the existing modified sulphuric acid plant.

4.2 Process Description - continued

The gas is dried using the existing Drying Tower, and boosted by a new gas blower through a new Heat Exchanger in the modified Boiler System. A stream of dry air from a new Drying Tower is added and the mixture passed to the first bed of the existing converter. A further stream of air and gas is added after each of the first two beds, the gas then being cooled in an existing air-cooled Heat Exchanger, before passing to the fourth bed of catalyst. The gas is then split into two parts, one passing through a feed-water economiser, the other through a feed gas preheater.

The mixed gas is then put to an Absorbing Tower and finally to atmosphere via a new Demister.

The existing Sulphur Furnace is oil fired to give sufficient steam for use at present. A new Heat Exchanger is positioned in the flue gas stream to act as a Start-up Heater for the Converter.

4.3 Equipment Layout (See Site Plan 1669-L51-1)

The equipment has been laid out with the following objects in mind.

1. To minimise modifications to the existing plant, keep cross-connection distances to a minimum, and take advantage of the existing roadways.

2. To allow future extension of at least 100% on capacity.

Gypsum will be transported as a damp filter cake to the gypsum storage. From there, it is dried and calcined, and then passed to the gypsum silos. The additives are individually reclaimed, dried, milled and put to their respective silos prior to blending.

Cement clinker is stored under a simple roof at the firing end of the kiln and then transported by conveyor to the existing cement grinding/blending plant.

Kiln off-gas passes to the purification plant where it is dedusted and washed. Separated dust is returned to the kiln, whereas the acid washings are discarded.

Provision for future extension has been made by allowing for possible installation of third and fourth kilns alongside the first two. The SO_2 - containing gas would be purified in a parallel plant to that for the first and second kilns, and then passed to a new contact plant for conversion and absorption. This plant could be installed in the area marked "Sulphuric acid plant extension".

4.3 Equipment Layout - continued

Should it be required to add sulphuric acid capacity as a sulphur burning unit, then again adequate space is available within the same area.

The proposed railway line serving the TSP plant bagging and loading area, as shown on the site plan drawing given to H&G Limited, will require relocation. This could probably be arranged as indicated in site plan drawing 1669-L51-1.

4.4 Effect of Power Failure

An unfortunate feature of the Chittagong site is the frequency of power failures. It is only necessary to ensure that the kiln rotation is maintained during these periods, although efforts must, of course, be made to improve the power supply situation. A simple diesel drive will be adequate for kiln safety.

4.5 Consumption of Feedstocks and Utilities

The consumptions are based on the production of 475 MTPD sulphuric acid (as 100% H_2SO_4), of which it is assumed that 45 MTPD will be produced from elemental sulphur burnt in the kiln.

	Per MT H_2SO_4 (100%)
(1) Feedstocks	
Byproduct gypsum (as $CaSO_4.2H_2O$)	1.75 MT
Clay	0.224 MT
Coke	0.082 MT
Sand	0.018 MT
Sulphur	0.032 MT
(2) Utilities	
Electric Power	210 kWh
Cooling Water (32°C-45°C)	100 M^3
Fuel Oil (Net CV. 9,900 Kcal/kg)	0.37 MT
(3) Byproducts	
Cement Clinker	0.85 MT
(4) Effluents	
Acid Water (from wet gas cleaning)	0.2 M^3

4.5 Consumption of Feedstocks and Utilities - continued

(5) Feedstock Analyses

The consumptions in Section 4.5(1) above have been calculated on the following compositions (% wt dry)

	Gypsum	Sand	Clay	Coke
SiO_2	0.10	91.66	67.67	6.90
Al_2O_3	0.10	3.56	24.41	4.40
Fe_2O_3	0.10	1.68	7.07	2.00
CaO	41.40	0.60	0.43	1.30
MgO	0.12	0.10	0.00	0.40
SO_3	56.60	0.10	0.00	0.00
C	0.00	0.00	0.00	85.00
Remainder	1.58	2.30	0.42	0.00

F & P_2O_5 See Section 3.3.

Variation on the above analyses will, of course, alter the actual quantities of each constituent, but not the viability of the scheme.

4.6 Availability of Raw Materials

By-product Gypsum

This is produced by the phosphoric acid plants at Chittagong. It will exist as a wet filter cake containing approximately 40% total H_2O (both fixed and free).

Sulphur

This will be imported as at present.

Coke

This will have to be imported. Coke fines containing not more than 5% w/w volatiles will be adequate.

Clay

Indications are that this will be available in East Pakistan, in the locality of Chittagong. On the basis of the analysis in Section 4.5 (5), about 650,000 MT will be required for 20 years operation. The actual quantity will, of course, depend upon the analysis.

4.6 Availability of Raw Materials - continued

Sand

Again indications are that this will be available in East Pakistan, in the locality of Chittagong. On the basis of the analysis in Section 4.5(5), about 60,000 MT will be required for 20 years operation. The actual quantity will, of course,depend upon the analysis.

During the H&G engineers' visit to East Pakistan, contact was made with the Geological Survey of Pakistan - Eastern Division, in Dacca seeking information on the availability (reserves) and analysis of sand and clay in the locality and neighbouring areas of Chittagong.

In a letter Ref No. 4643/P&I-IX(14)/70 dated 9th May 1970 they replied as follows, - quote:

"A scrutiny of various reports of the Chittagong town and the adjacent areas indicates that there are fairly large deposits of clays and sands in the proximity of Chittagong town.

The most promising deposit of clay is known as Girujan clay. Its thickness is about 1150 feet. It is exposed all along the Eastern slope of the Chittagong anticline.

Unconformably underlying the Girunjan Clay is the Tipam Sandstone with an approximate thickness of 1530 feet. This bed is composed of massive and bedded yellowish brown fine to medium grained sandstones with irregular shale interbeddings. Sand is being quarried from this bed for use by various parties in Chittagong town.

The Girujan Clay and Tipam Sandstone formations will certainly meet the desired reserves of 250,000 tons and 500,000 tons respectively at any one spot selected by you for mining near Chittagong town.

Two chemical analyses carried out by the Geological Survey Dacca, of the Clay samples collected from the site of the Cement Factory which was to be built in Chittagong by the East Pakistan Industrial Development Corporation are as follows:-

	SiO_2	R_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$
Sample No. 65	68.00	22.80	-	2.13	1.80
Sample No. 66	59.48	24.80	4.60	3.92	2.20

In case you need any additional information please let us know and we shall endeavour to supply you the same.

Yours faithfully,

(S. Tayyab Ali
Deputy Director General)
Geological Survey of Pakistan,
Eastern Division,
DACCA. "

- end of quote".

4.6 Availability of Raw Materials - continued

It is recommended that if the project is to proceed, a survey be carried out in the locality of Chittagong with the object of determining availability and analyses of these raw materials. It would then be possible to carry out more accurate estimates of the requirements.

Fuel

Fuel oil for combustion in the kilns is currently available in adequate quantity from the E.P.I.D.C. refinery at Chittagong.

There are a number of schemes for pipelining natural gas into Chittagong and it is quite probable that such a line will be in operation at about the time of start-up of the project for conversion of gypsum to sulphuric acid. The anticipated costs of natural gas are :-

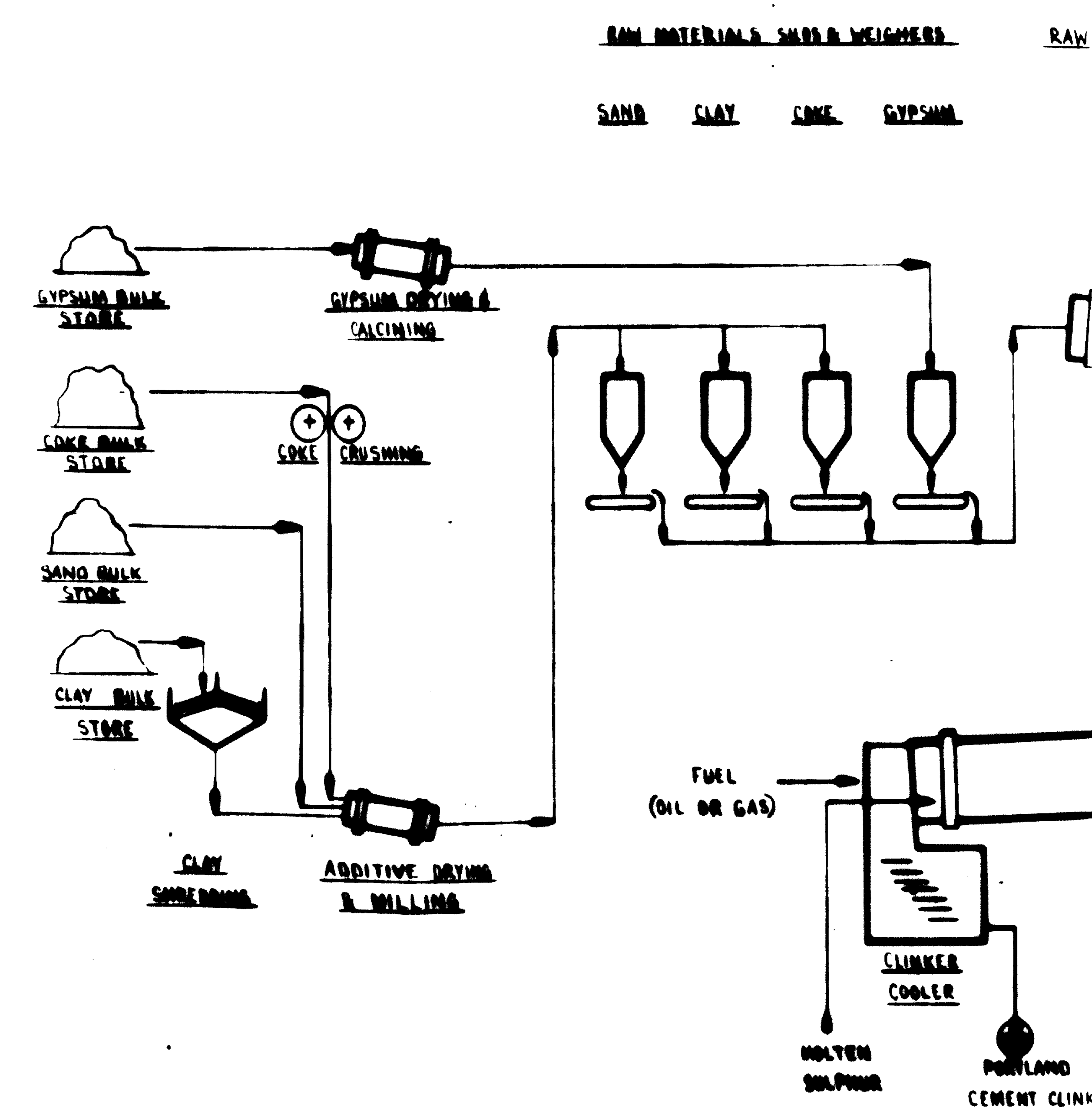
Rs 42.4 / 1000 Nm^3

plus Rs 14.1 / 1000 Nm^3 duty

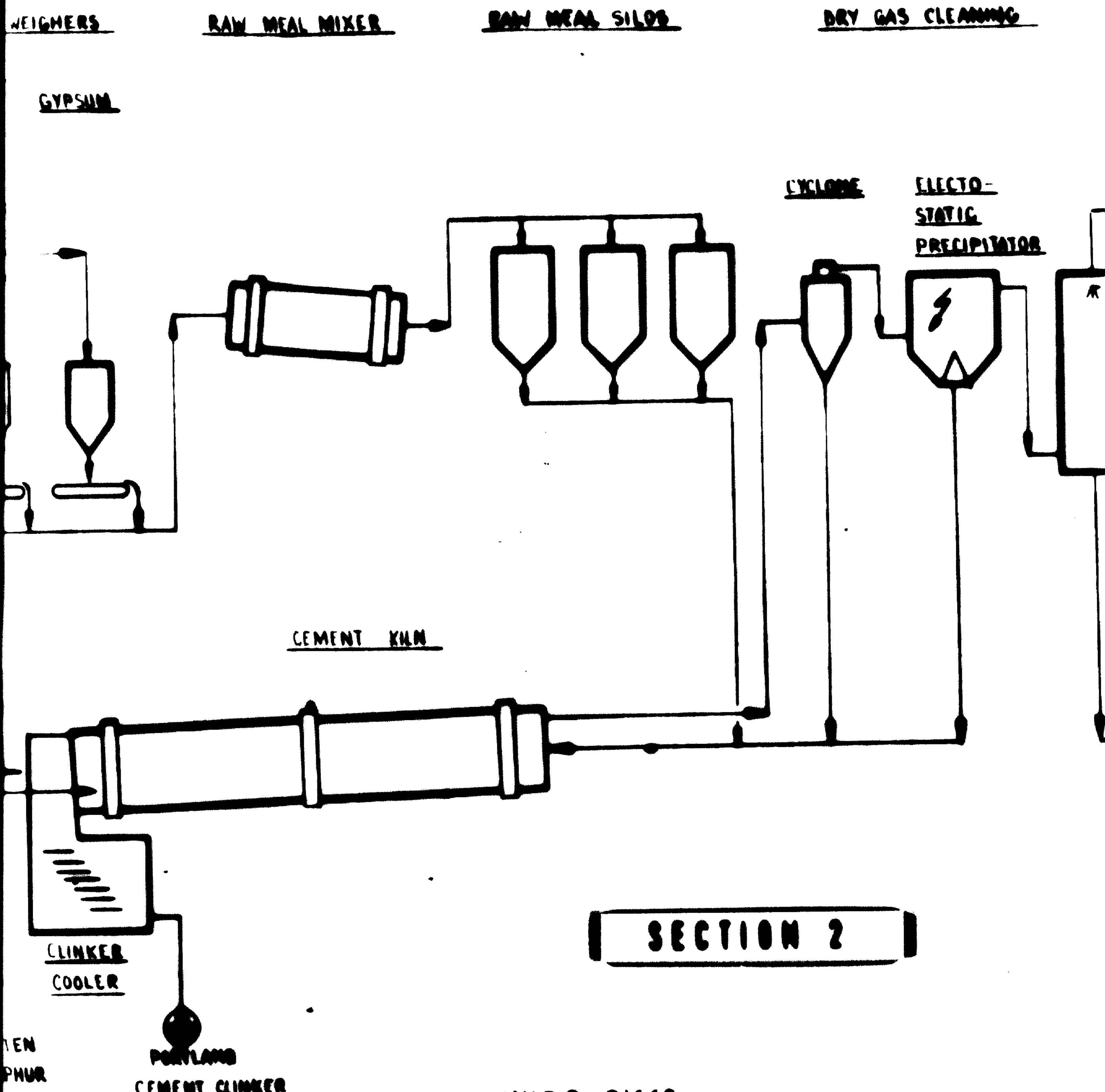
(Basis : delivered site at Chittagong)

4.7 Project Construction Programme

It is estimated that the project will take 30 months to implement from the date of signature of a contract for the supply of the plant until initial start-up. The commissioning programme will require an additional six months. A bar chart programme is attached on page 4.9.


RAW MATERIALS SILOS & WEIGHERS
RAW
SAND
CLAY
COKE
GYPSUM
GYPSUM BULK STORE
GYPSUM DRYING & CALCINING
COKE BULK STORE
COKE CRUSHING
SAND BULK STORE
CLAY BULK STORE
CLAY SHREDDING
ADDITIVE DRYING & MILLING
FUEL (OIL OR GAS)
CLINKER COOLER
MOLTEN SULPHUR
PORTLAND CEMENT CLINK

SECTION 1



SECTION 2

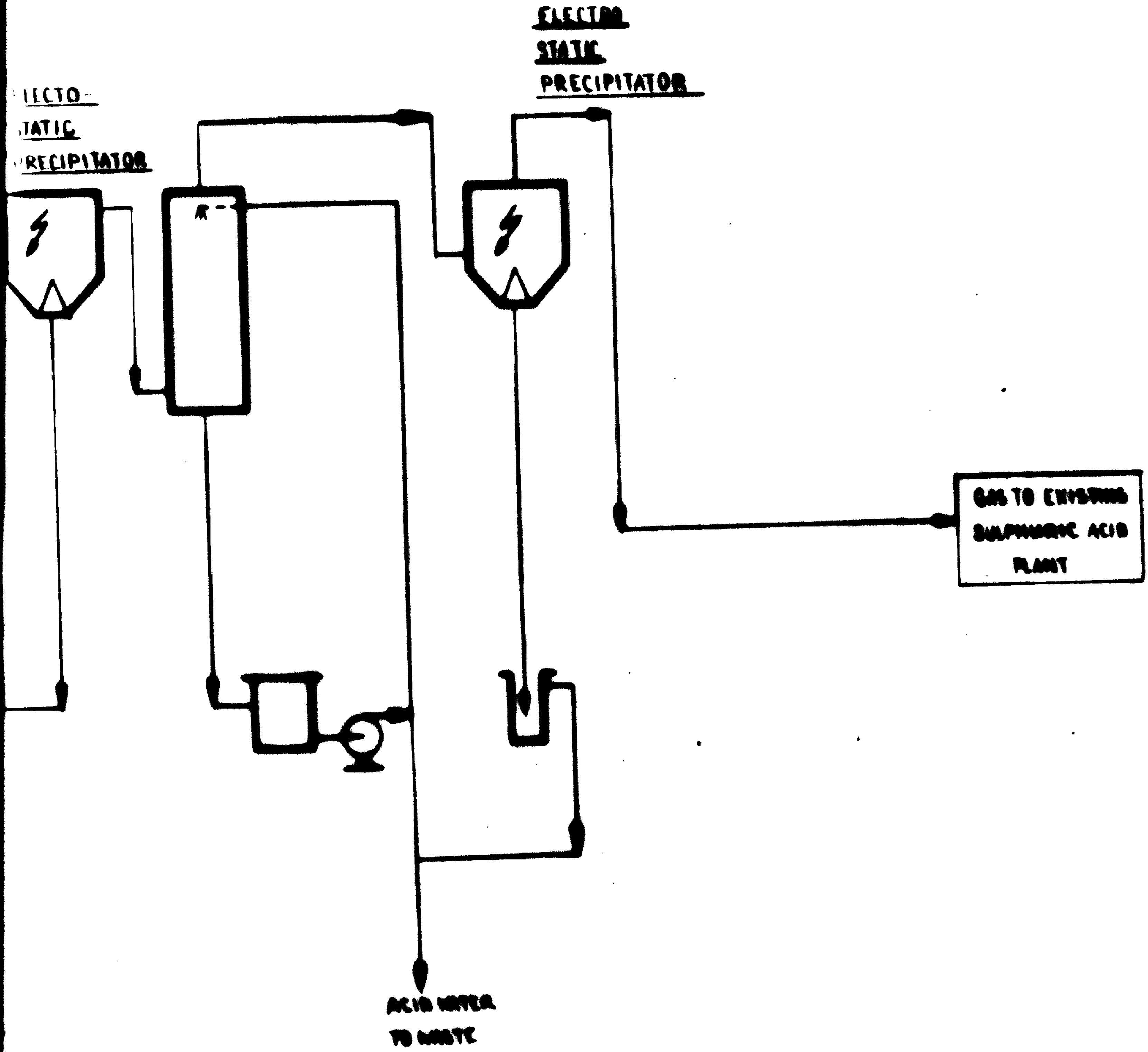
U.N.I.D.O. - C1669

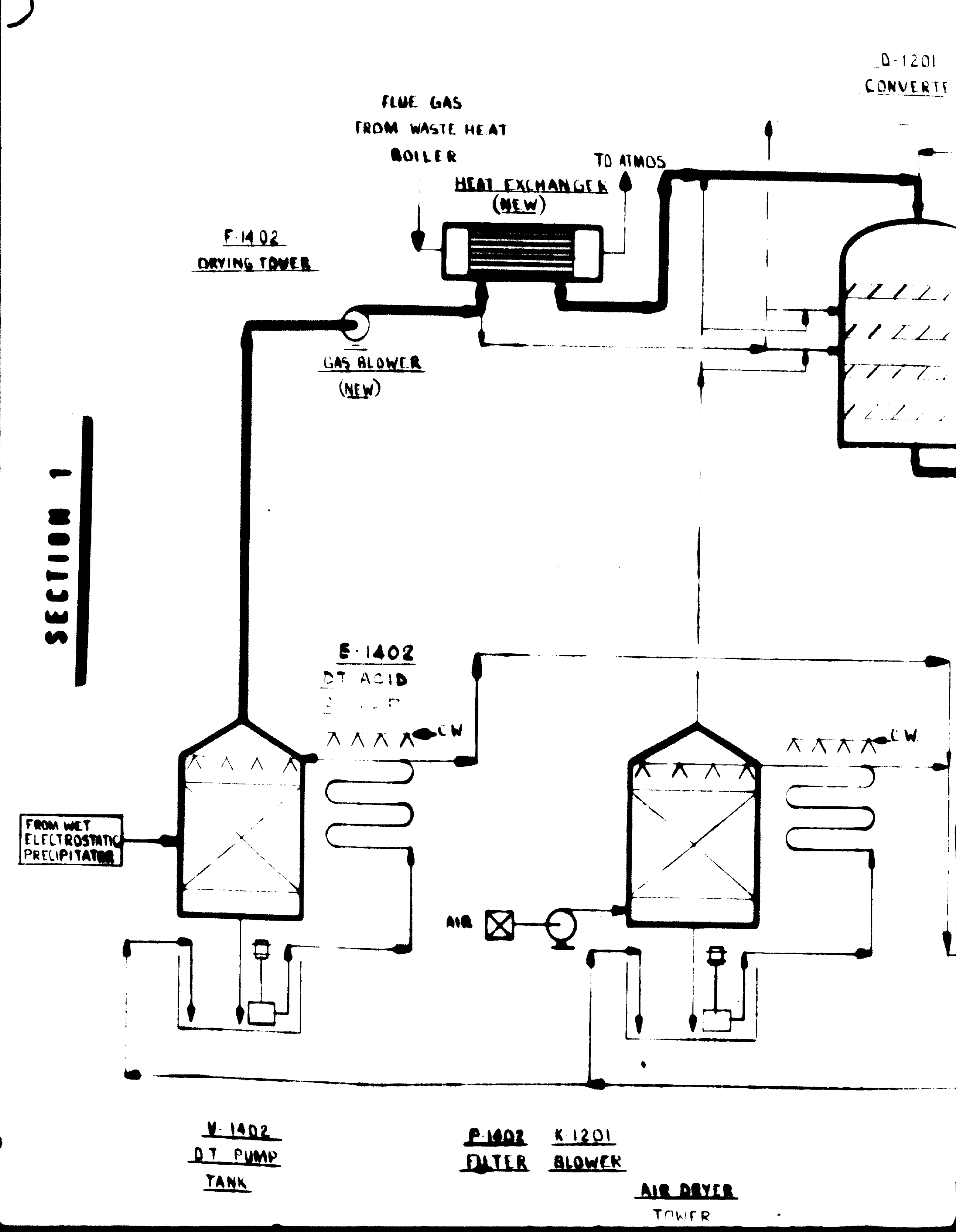
FLOW DIAGRAM - CEMENT CLINKER PLANT

FOR THE UTILISATION OF BY-PRODUCT GYPSUM FROM THE T.S.P. FERTILIZER FACTORY OF E.P.I.D.C., CHITTAGONG, EAST PAKISTAN.

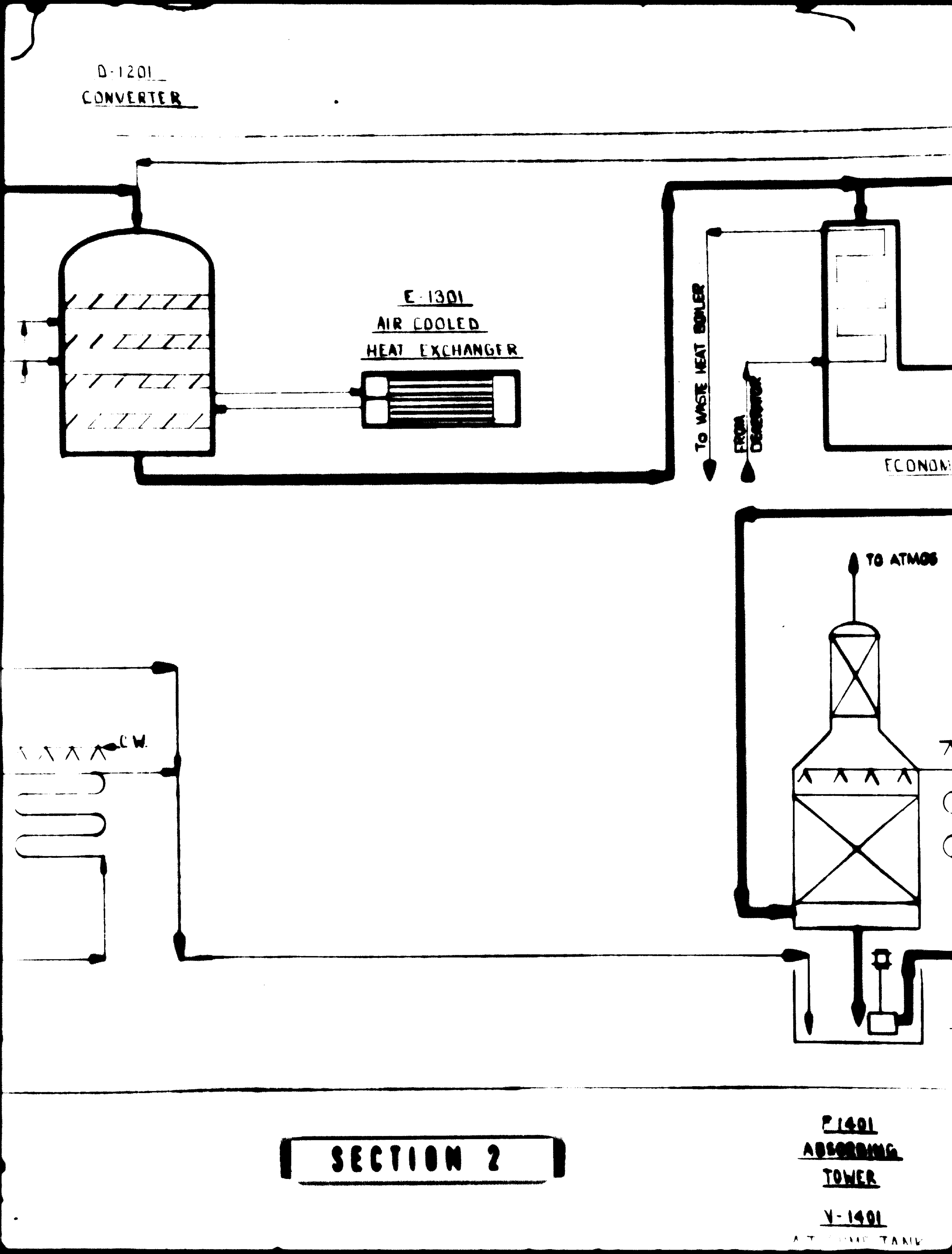
FIG. IV. 4.1.

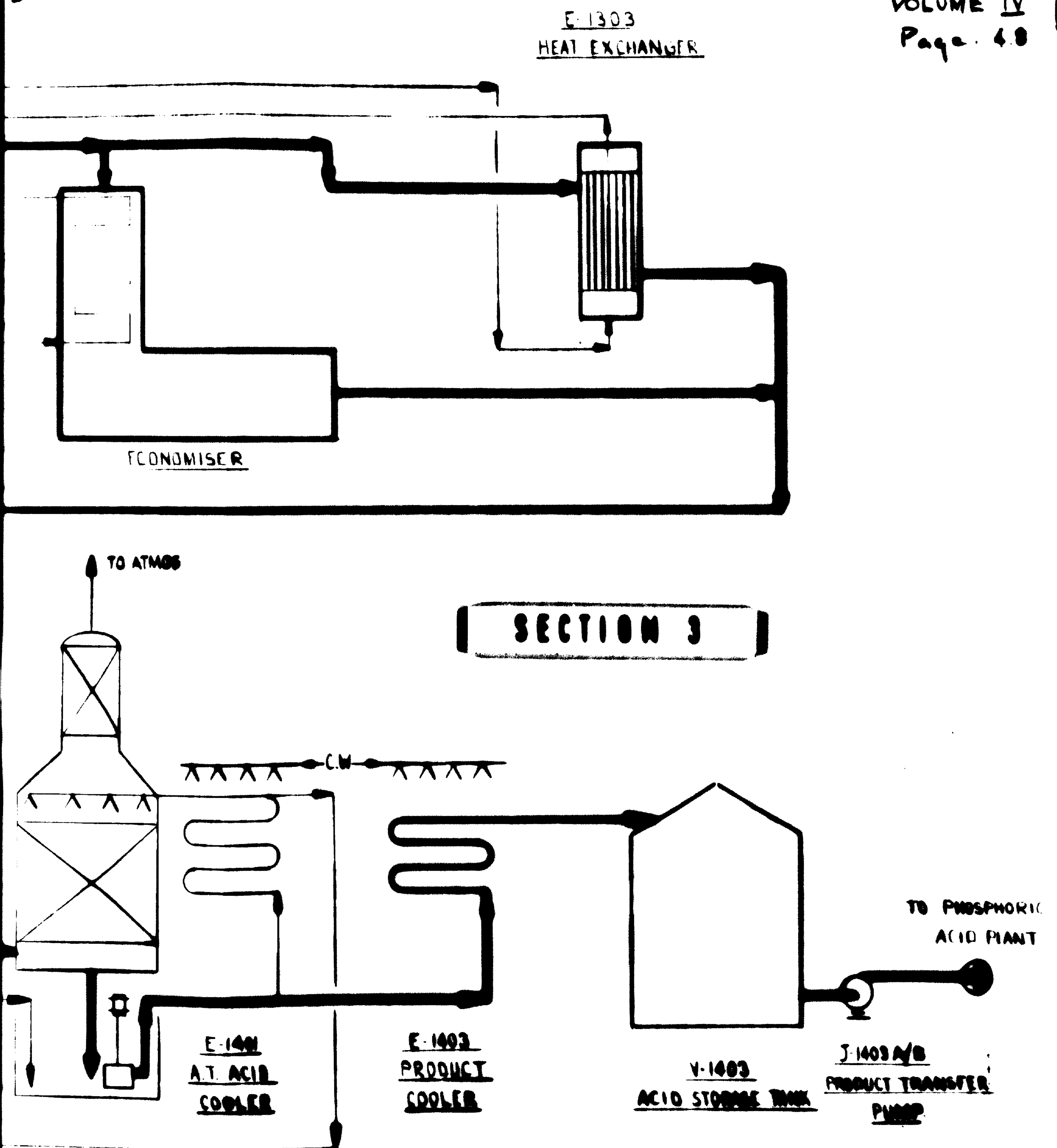
CLEANING WET GAS CLEANING





SECTION 1
FLUE GAS
FROM WASTE HEAT
BOILER
TO ATMOS
HEAT EXCHANGER
(NEW)
D-1201
F-1402
DRYING TOWER
GAS BLOWER
(NEW)
E-1402
ACID
CW
C.W.
FROM WET ELECTROSTATIC PRECIPITATOR
AIR
V-1402
DT PUMP
TANK
P-1402
FILTER
K-1201
BLOWER
AIR DRYER
TOWER


D-1201
CONVERTER
E-1301
AIR COOLED
HEAT EXCHANGER
To WASTE HEAT BOILER
FROM DEAERATOR
TO ATMOS
C.W.
SECTION 2
ABSORBING
TOWER
V-1401



U.N.I.D.O. C 1669

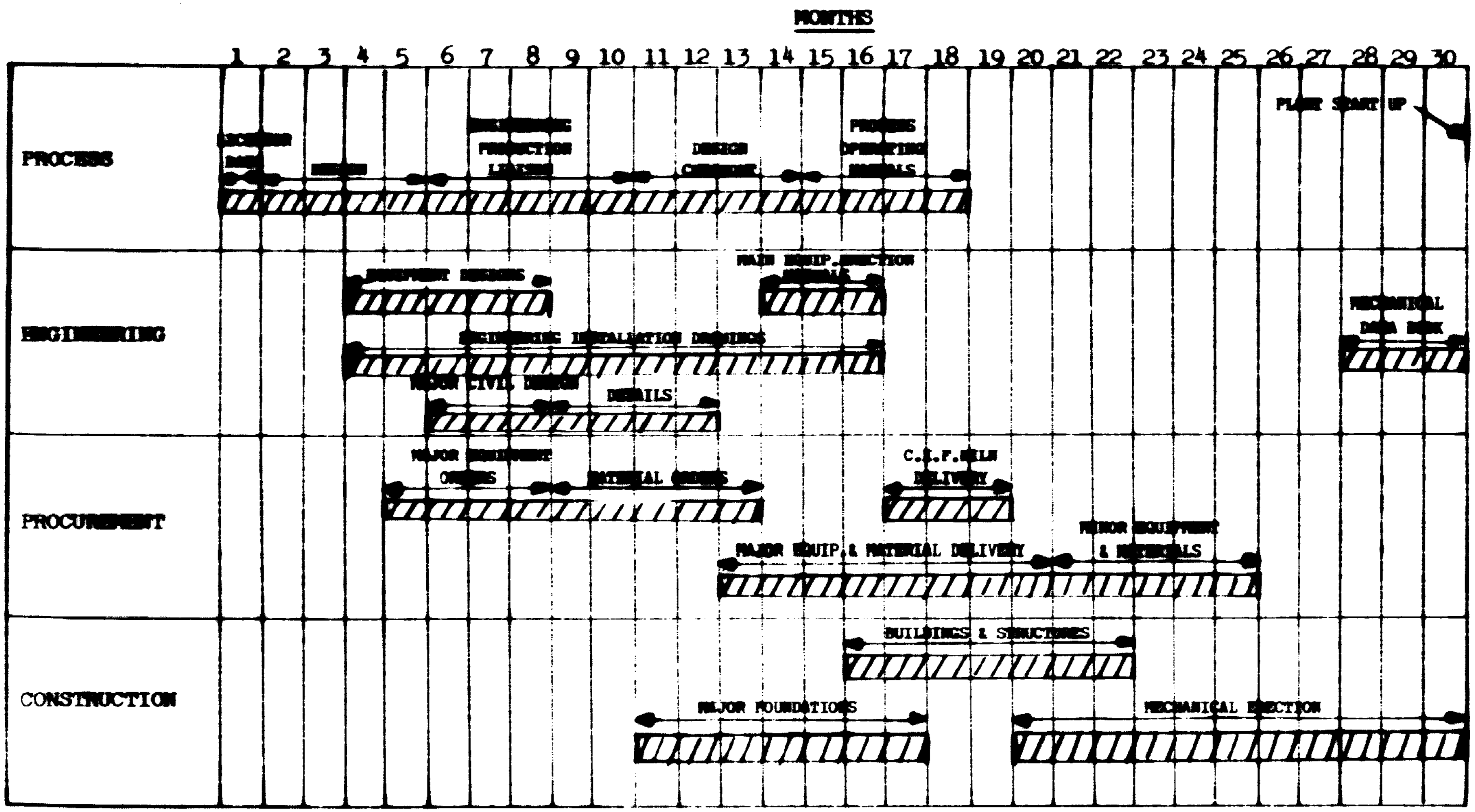
FLOW DIAGRAM OF MODIFIED
HITACHI SULPHURIC ACID PLANT,
FACTORY OF E.P.I.D.C. CHITTAGONG E. PAKISTAN

FIG. IV 4·2

PRELIMINARY PROJECT PROGRAMME

Programme Notes

1. The Programme indicated below constitutes all major facets of Project Design, Procurement and Erection.
2. Plant Start-up will require a further six months of pre-commissioning and commissioning.
3. Overall Programme thirty six months from Effective Contract Date to Plant Handover.
4. Erection Programme based on achieved Labour productivity in Pakistan.



SECTION 5

ECONOMIC ANALYSIS OF PROJECT

5.1 General

The economic analysis of the project may be considered in two ways:-

(i) from the viewpoint of the Pakistan economy as a whole, the objective of the project being to eliminate foreign exchange expenditure on sulphur and cement clinker. Rupee costs per U.S. $ saved have, therefore, been calculated.

(ii) from the viewpoint of EPIDC. EPIDC's objective should be to obtain a reasonable return on their investment.

As will be seen later in this section, the long term sulphur price is an important factor in the analysis. The price of sulphur at Chittagong was quoted by EPIDC staff in April 1970 as Rs535/MT, which is equivalent to $57.8/MT (c&f). Current (July 1970) price in the Gulf of Mexico is down to about $27/MT, which would correspond to about $45/MT (c&f Chittagong). The problem of predicting long term prices is a very complex one and UNIDO have commissioned a study on this subject by the British Sulphur Corporation, but this is not yet released. A lower level of $40/MT was selected for study. The figure, with which the analysis is concerned, should be the mean level over the assumed life of the project 1974-1988. During this period, the price of sulphur is likely to undergo a number of fluctutations, as it has over the last 15 years, and limite of $40/MT and about $60/MT (c&f Chittagong) seem realistic, with a probability of the average price being near to the lower figure.

5.2 Capital Cost

Capital cost estimates for the gypsum conversion plant have been obtained from Fried. Krupp Chemieanlagenbau (O.S.W. process) and Simon Carves (Coswig Process). After adjustment to a comparable basis, these figures are in agreement within the accuracy of such budget estimates and so the mean price was used.

The cost of modifying the sulphuric acid plant supplied with TSP II, to take the kiln gas and produce 475 MTPD of acid was quoted by Hitachi.

5.2 Capital Costs - continued

These cost data have been assembled to give a total estimated cost for the development as follows:-

	Foreign Exchange (Rs Million)	Local (Rs Million)
Equipment, spares, freight and insurance, escalation	48.3	-
Engineering and fees, supervision of construction and commissioning	11.3	-
Construction, civils, local supply, services, freight, escalation		18.5
Import Duty		10.8
	59.6	29.3
Start up and Consultancy costs	4.3	4.4
Interest on F.E. loan during construction	6.7	-
TOTALS	70.6	33.7
OVERALL TOTAL	104.3	
Working Capital	2.5	

No allowance has been made for the production lost during connection of the new plant into the existing units. It would be possible to import phosphoric acid to keep the two TSP plants running during this period. In practice, the change-over period should be relatively short as the new plant facilities would be built alongside the running units and ready for connecting in.

The capital cost figures quoted above cover all direct expenditure associated with the modification of the plant for use of by-product gypsum and for production of cement clinker and its conveyance to the clinker grinding plant now under construction. The work covered is as follows:

1. Construction of plant for the production of SO_2 containing gas stream and cement clinker from byproduct gypsum.

2. Modification of the sulphuric acid plant (now being erected for TSP II) to use the SO_2- containing gases and produce 142,500 MTPA sulphuric acid.

5.2 Capital Costs - continued

3. Provision of gypsum and other raw material stores and handling facilities.

4. Facilities for conveying cement clinker to cement clinker grinding plant (now under construction).

5. Provision of interconnecting pipework, services etc.

6. New cooling tower facility for 2000 m^3/hr cooling water.

7. Facility for disposal of acid effluent from purification plant.

The working capital covers the provision of raw material inventories and storage capacity of cement clinker.

5.3 Unit Costs

In considering the two alternative cases, i.e. for the Pakistan economy and for EPIDC, the following unit costs have been used as listed in Table IV 5.1. In the cost analysis all cost figures have been assumed constant at 1970 levels.

5.3 Unit Costs - continued

Table IV.5.1 - Unit Costs

For Pakistan Economy

Sulphur	Rs 275.5/MT (c&f) $57.8/MT
Sulphur	Rs 190.9/MT (c&f) $40.0/MT
Fuel Oil	Rs 80 /MT (delivered site)
Coke	Rs 129 /MT (c&f)
Clinker	Rs 68 /MT (delivered site)
Clay	Rs 18 /MT (delivered site)
Sand	Rs 18 /MT (delivered site)
Power	Rs 0.13/kWh
Cooling Water	Rs 0.030/m^3 (circulated)
Gypsum Disposal (by barge to sea)	Rs 5.0/MT wet gypsum

For EPIDC

Sulphur	Rs 535/MT (delivered site)
Sulphur	Rs 370/MT (delivered site)
Fuel Oil	Rs 80/MT (delivered site)
Coke	Rs 250/MT (delivered site)
Clinker	Rs 68/MT (delivered site)
Clay	Rs 18/MT (delivered site)
Sand	Rs 18/MT (delivered site)
Power	Rs 0.13/kWh
Cooling Water	Rs 0.030/m^3 (circulated)
Gypsum Disposal (by barge to sea)	Rs 5.0/MT wet gypsum

5.3 Unit Costs - continued

Table IV.5.2

National Basis (i.e. no taxes)

Rupee costs - extra to costs for production of sulphuric acid from sulphur

		$Rs/MT\ H_2SO_4$
Cooling Water	$80\ m^3/MT\ H_2SO_4$	2.40
Clay	$0.224 MT/MT\ H_2SO_4$	4.03
Sand	$0.018\ MT/MT\ H_2SO_4$	0.32
Process Labour	(Extra 50 men)	2.30
Maintenance	(3.0% PA of investment)	16.09
Insurance	(0.3% PA of investment)	1.61
		26.75

= 26.75 x 142,500

= **Rs3.81 x 10^6/year**

Table IV.5.3

EPIDC Basis (i.e. with taxes)

Rupee costs - extra to costs for production of sulphuric acid from sulphur

Cooling Water	$80\ m^3/MT\ H_2SO_4$	2.40
Clay	$0.224\ MT/MT\ H_2SO_4$	4.03
Sand	$0.018\ MT/MT\ H_2SO_4$	0.32
Coke	$0.082\ MT/MT\ H_2SO_4$	20.50
Process Labour	(Extra 50 men)	2.30
Maintenance	(3.0% PA of investment)	16.09
Insurance	(0.3% PA of investment)	1.61
Power	$195\ kWh/MT\ H_2SO_4$	25.35
Fuel	$0.37\ MT/MT\ H_2SO_4$	29.60
		102.20

= 102.20 x 142,500

= **Rs14.56 x 10^6/year**

5.4 Impact of Project on Pakistan Economy

In table IV.5.4, foreign exchange and rupee costs of the project are calculated over a 15 year project life. In this table, all duties, taxes etc., payable in Pakistan, are excluded. Net foreign exchange savings are compared with rupee costs. A foreign exchange loan over 10 years is charged with interest at 8% and is repayable in equal installments. Table IV.5.2 lists the costs of raw materials and utilities and items included under the heading "Rupee costs - extra to costs for production of sulphuric acid from sulphur."

Thus, in the table IV.5.4, the new project is considered as an extension to existing facilities. The two cases of sulphur price of $57.8/MT and $40/MT are considered and the annual ratio of rupees expended/$ saved is calculated. This ratio has also been estimated by taking the sum of the net present worths of the annual figures for rupees expended and $s saved. A discount rate of 10% p.a. was used. The resulting two ratio figures of 6.53 (sulphur at $57.8) and 10.57 (sulphur at $40) are considered to give the most reliable assessment of the project from the viewpoint of the Pakistan economy. The conclusion drawn is that the project is acceptable at the higher level of sulphur cost, but not at the lower level.

Finally, the ratio was again calculated on a basis frequently adopted in Pakistan. This ratio is based on foreign exchange savings and rupee costs for a single year of operation. Net foreign exchange saved is calculated after allowing for 1 year's loan repayment and interest on the initial loan at a mean level of 5%. Rupee costs include all normal running costs, 10% annual depreciation but no interest on the rupee element. On this basis, the ratios are:-

Rupees expended/$ saved	7.18	(sulphur at $57.8/MT)
	13.07	(sulphur at $40/MT)

5.5 Return to EPIDC

In table IV.5.5, the project is considered from the point of view of EPIDC. The table includes savings in expenditure and costs, all in rupees. The Foreign Exchange loan repayable at 8% over 10 years is included and the annual cash flow for EPIDC is calculated. Table IV.5.3 lists the cost of raw materials and utilities and items included under the heading "Rupee cost - extra costs for production of sulphuric acid from sulphur".

The DCF rate of return on EPIDC's rupee investment has been calculated. A project life of 15 years is again assumed. The DCF rate of return for EPIDC is 22% (sulphur at $57.8/MT) but falls to 5% with sulphur at $40/MT. Similarly, at a sulphur price of about $34/MT, the return to EPIDC becomes zero.

[illegible]

Capacity:

Sulphuric Acid [illegible] MTPA (as 100% H_2SO_4)
Cement Clinker [illegible] MTPA

		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FOREIGN EXCHANGE COSTS (U.S.DOLLARS)											
CAPITAL REPAYMENT 10%		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
INTEREST [illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
F.E. Costs - extra to costs for production of Sulphuric Acid from Sulphur - [illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FOREIGN EXCHANGE SAVINGS (U.S. DOLLARS)											
Sulphur Case (A) [illegible]/MT		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Case (B) [illegible]/MT		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Cement Clinker at [illegible]/MT		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
NET FOREIGN EXCHANGE SAVINGS (U.S.DOLLARS)											
Case (A)		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Case (B)		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Net Present Worth of F.E. Savings	Case A $	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
discounting at 10% p.a.	Case B $	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
LOCAL COSTS (RUPEES) - [illegible]											
Fuel Oil Rs.[illegible]/MT		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Power Rs.[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Other Rupee Costs - extra to costs for production of Sulphuric Acid from Sulphur ([illegible])		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CAPITAL CHARGES ([illegible])											
Depreciation 10%		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Interest [illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Savings (Gypsum Disposal)		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Working Capital		[illegible]	-	-	-	-	-	-	-	-	-
Net Rupee Costs		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Net Present Worth of Net Rupee Costs discounting at 10% p.a.		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Yearly Ratio of Rupees expended per $ saved	Case A	N.A.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Case B	N.A.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Ratio of Net Present Worths of Rupees	Case A	-	-	-	-	-	-	-	-	-	-
expended per $ saved	Case B	-	-	-	-	-	-	-	-	-	-

SECTION 1

[illegible]

[illegible]

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	-	
83	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	-	
32	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
54	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
76	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
75	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
64	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
86	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
.25	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
.65	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
.22	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
.61	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
.01	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
.29	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	-	[illegible]
.20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	-	[illegible]
.51	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
-	-	-	-	-	-	-	-	-	-	-	[illegible]	
.70	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
.29	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
.37	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
.05	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
-	-	-	-	-	-	-	-	-	-	-	[illegible]	
-	-	-	-	-	-	-	-	-	-	-	[illegible]	

SECTION 2

[illegible] & [illegible] LIMITED

TABLE IV.[illegible] ANNUAL CASH FLOW FOR [illegible] ANALYSIS

[illegible] BASIS

Capacity:

Sulphuric Acid [illegible] MTPA (as 100% H_2SO_4)
Cement Clinker [illegible] MTPA

MILLION RUPEES

COSTS (RUPEES)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CAPITAL REPAYMENT - (P.B.) [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-7.65	-7.65
INTEREST - (P.B.) [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-0.56
OTHER COSTS (extra to same for H_2SO_4 from Sulphur Table IV.[illegible])	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
RUPEE INVESTMENT (TOTAL [illegible])	[illegible]	-	-	-	-	-	-	-	-	-
SAVINGS (RUPEES)										
Sulphur (A) Sulphur at [illegible] (Rs.[illegible] at site)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
(B) Sulphur at [illegible] (Rs.[illegible] at site)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Cement Clinker at Rs.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Gypsum Disposal	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Working Capital	[illegible]	-	-	-	-	-	-	-	-	-
TOTAL CASH FLOW ([illegible]) CASE (A)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CASE (B)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

SECTION 1

[illegible]

ABLE IV.5.5. [illegible]

[illegible]

[illegible]

[illegible]

1979	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7.05	-7.05	-7.05	-7.05	[illegible]	[illegible]	-	-	-	-	-
3.39	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	-
4.56	-14.56	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
-	-	-	-	-	-	-	-	-	-	-
23.40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6.84	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
.24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
.54	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
-	-	-	-	-	-	-	-	-	-	[illegible]
.22	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
.50	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

SECTION 2

5.6 Potential Use of Natural Gas

As indicated in Section 4.6, it is anticipated that natural gas will become available by pipeline at Chittagong. This is a cheaper fuel supply than the fuel oil assumed in the analysis of Sections 5.4 and 5.5. The use of natural gas in place of fuel oil would reduce the annual fuel costs by about Rs 1.2×10^6 (duty-free basis).

This reduction in rupee cost would reduce the ratio of rupees expended per $ saved to 6.0 (sulphur at $57.8/MT) and 9.7 (sulphur at $40/MT). The D.C F. rate of return to E.P.I.D.C is also calculated to be improved by about 2%.

Thus the use of natural gas has a beneficial effect on the overall economics of the process.

5.7 Discussion

The overall economic viability of the project must be viewed as marginal. Apart from the question of sulphur price forecasts, the major problem lies in the fact that the estimated capital cost of the project is high in relation to foreign exchange saved. If means can be found of reducing the project cost (both foreign exchange and Rupee elements) by 15to 20%, the economic position of the project would be markedly improved. This is true for both the National and E.P.I.D.C. basis. An alternative improvement from the National viewpoint would be an increase in proportion of the plant manufactured in Pakistan with corresponding reduction in the foreign exchange element of capital cost.

This project assessment has been concerned only with the effect on the Pakistan economy and EPIDC financial position of the extension. The detailed analysis of the viability of the complete site including both TSP plants and cement grinding plant will be possible when the units which are now under construction have been commissioned and operating performance is known. If these projects prove highly profitable then the lower DCF return on the gypsum conversion scheme may appear acceptable in view of the foreign exchange saving obtained.

Finally, attention should be focussed on a number of aspects of this project, which will require special consideration:

i) The construction of the new facilities must be undertaken while the existing plants are in operation. The contractor for the extensions will need to give special attention to the problems of connecting the new plant into existing equipment and to scheduling his work.

5.7 Discussion - continued

ii) Coke supplies are not available in Pakistan and the necessary authorisations for its import will be required. Coke specification must be prepared in collaboration with the process licensor.

iii) The supply to the plant of sand and clay available in East Pakistan must be assured and specifications prepared.

iv) In view of the small extent of full-scale operating experience of the use of byproduct gypsum it is important that proper trials are carried out using the raw materials which will be used at Chittagong. If inadequate supplies of byproduct gypsum are available at Chittagong, then the tests could be made using gypsum produced from the same phosphate rock in a similar design of phosphoric acid plant. Samples of local clay and sand should be made available for testing and these tests must include analysis of cement properties.

v) The long term supply ofphosphate rock of the grade used for test purposes must be assured. Phosphate rock type is known to influence design and operating conditions for the plant.

SECTION 6

CONCLUSIONS

6.1 Scheme Recommended

In view of the requirements for sulphuric acid and cement clinker, and the availability of by-product gypsum at Chittagong, it is recommended that the Müller-Kühne process is used for manufacture of sulphuric acid and cement clinker from by-product gypsum.

6.2 Technical Viability

The process has been operating for short periods with considerable success in both Austria and East Germany, the runs being terminated by lack of feedstock only. A contract has been placed for a plant in South Africa of comparable capacity to that for Chittagong. By the time that the Chittagong plant would be started, considerable operating experience would have been obtained from the South African plant. The quality of cement produced from the process meets all specifications for a normal Portland cement. The use of the Nissan phosphoric acid process enables the P_2O_5 content of the blended gypsum to be below a level where it has adverse effects on the setting time of the cement. Calcination of the gypsum removes sufficient fluorine to reduce its content to an acceptable level.

6.3 Economic Viability

Economic viability has been assessed on both a National and E.P.I.D.C. basis. This assessment indicates that the viability of the scheme is very sensitive to sulphur prices. The E.P.I.D.C. price ($57.8/MT-C & F) appears to be high in view of the present trend towards lower price. An alternative price of $40/MT C & F, at the lower end of the range of probable future price, has also been considered. The project shows a net foreign exchange saving at both sulphur price levels. At the higher price level, Rupee expenditure per $ saved 6.53 is reasonable. There is also a DCF rate of return of 22% to E.P.I.D.C. on the project at the higher level.

At the lower price of sulphur, however, the much higher rupee cost per dollar saved is likely to be unacceptable and DCF return on E.P.I.D.C's investment over the 15 year period is only 5%. The return to EPIDC falls to zero at a sulphur price of $34/MT.

6.4 General

It is recommended that means of reducing the capital cost of the project - both foreign exchange and Rupee - be investigated.

In any complex project of this type the skills of management and operating staff during construction, commissioning and subsequent operation are very important. They could be critical to the economic strength of this project. Emphasis must be laid on the importance of adequate training for management and operating personnel on comparable existing plant.

APPENDIX I

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