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March 27, 1986

F I N A L   R E P O R T

for the

PROVISION OF SERVICES RELATING TO THE
PRE-FEASIBILITY STUDY FOR THE PRODUCTION OF CEMENT AND
SULPHURIC ACID FROM PHOSPHOR GYPSUM FOR
BANGLADESH CHEMICAL INDUSTRIES CORPORATION's
TRIPLE-SUPERPHOSPHATE PLANT; PHASE I
in the
PEOPLE's REPUBLIC OF BANGLADESH

15496

Contract No. 85/40
UNIDO Proj.No. DP/BGD/78/002
Activity Code: DP/02/32.1.A

ANNEX
OFFER FOR PHASE II

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Abbreviations

TSP	-	Triple Superphosphate
BCIC	-	Bangladesh Chemical Industries Corporation
MT	-	Metric tonnes
MTD	-	Metric tonnes per day
MTY	-	Metric tonnes per year

Abbreviations

P-Gypsum	-	A by-product of gypsum from a phosphoric acid plant
GS-Process	-	Process for the production of sulphuric acid and cement from gypsum
EPIDC	-	East Pakistan Industrial Development Corporation

I. EXECUTIVE SUMMARY AND CONCLUSIONS

The aim of this study is to establish whether the production of sulphuric acid and cement from P-Gypsum of phosphoric acid plant II at the TSP plant in Chittagong is technically possible and whether this undertaking is economically feasible or not.

The study will be carried out in two parts. In part I the technical feasibility of the project will be reviewed, whilst in part II the economic viability will likewise be investigated.

For the first part of the study, the raw materials under review, and especially the P-Gypsum were tested in terms of their suitability for the production of sulphuric acid and cement. The P-Gypsum yielded by phosphoric acid plant II is not suitable for the GS-Process owing to its high fluorine content.

In three experimental trials which were carried out at the Chittagong plant it was possible to confirm laboratory tests in which the content of fluorine in the P-Gypsum was reduced to below 0.15 % by utilizing a specific quantity of Kieselghur. Hence the tests showed that the P-Gypsum is suitable for the GS-Process provided it has undergone the appropriate pre-treatment.

The necessary additives such as clay, sand and iron residues which can be found in or in the (direct) vicinity of Chittagong were analysed. On the basis of the results of these analyses, the additives may be used for the GS-Process.

Coke breeze and Kieselghur are not available in Bangladesh and therefore need to be imported.

Natural gas in Bangladesh can be used to provide the fuel for the drying and calcination of the waste gypsum as well as to fire the cement kiln.

On the basis of the above results it can be stated that both the waste gypsum after the appropriate course of treatment as well as the additive materials are suitable for the production of sulphuric acid and ordinary Portland cement according to the British Cement Specification 12/1958 with the exception of the SO_3 content. In the British Cement Specification the content of SO_3 and S expressed as SO_3 is limited to a maximum of 3 %.

For various reasons the 3 % value cannot be maintained when cement is manufactured according to the GS-Process and must be raised to 3.5. %. However it should not be too difficult to push through this raise since a number of countries specify that the SO_3 content is limited to a maximum of 3.5 %.

As Part I of the study has proved that the production of sulphuric acid and cement from P-Gypsum of the phosphoric acid plant in Chittagong is technically possible, the subsequent Part II of the study shall examine whether production is feasible from an economic point of view.

II. INTRODUCTION

In order to produce TSP at the fertilizer plant of BCIC in Chittagong, phosphoric acid is required. The phosphoric acid can be produced at the plant from phosphate rock and sulphuric acid, in the course of which 4 - 5 MT of P-Gypsum accrue per MT of P_2O_5.

The P-Gypsum is stored on an 11.5 acre piece of dumping space which is directly adjacent to the plant itself. Since the dumping space can only house a maximum of 400,000 MT of P-Gypsum, storage possibilities will be exhausted in the near future.

In this case, it would seem necessary to set up a new dumping ground for the future amounts of P-Gypsum. However, it is now virtually impossible to acquire new areas of land bordering on the plant, and more distant dumping grounds would incur high transport costs.

A further option would be to pump the slurried P-Gypsum either directly into the sea or into the Karnafuly river which flows past the plant. Yet the damage that would be caused to the sea fauna by the impurities in the residuary plaster make this an untenable proposition.

Another approach towards solving the problem lies in the conversion of the residuary gypsum, for which there are, at present, four main processes:

1. Plaster and Plaster Board production
2. Retarder Gypsum
3. Ammonium Sulphate
4. Sulphuric Acid and Cement (GS-Process)

Ad 1.

Plaster and plaster board are not suitable for external use in the building trade owing to the specific climatic conditions in Bangladesh such as torrential rainfall and extreme humidity during the monsoon season. There is relatively little demand for plaster and plaster board in interior construction work and even where such demand exists, high freight costs caused by the transport of these products over long distances render this kind of operation an uneconomic undertaking.
For this reason it would only be possible to implement this process to convert a small amount of the P-Gypsum; the problem of storing the bulk of the P-Gypsum would remain unsolved.

Ad 2.

Since Bangladesh does not have any natural resources of gypsum, the P-Gypsum , once properly cleaned, could be used as retarder gypsum for the inland cement industry.
Assuming that 1,665,000 MTY of cement are produced by the end of 1986, and given that 4 % of retarder gypsum is required, the demand would equal 66,600 MTY, but even this rate of demand is too low to satisfactorily solve the residuary plaster storage problem.

Ad 3.

Large scale technical facilities already exist to produce ammonium sulphate from residuary plaster, but ammonia and carbon dioxide are needed for the process. Both of these raw materials could presumably be supplied by the Chittagong Urea plant which is being built in the vicinity of the main plant. Yet the by-product lime, which results from the production of ammonium sulphate, would also have to be utilized, as in a soda plant run on the solvay process, for example.
But since ammonium sulphate itself is a by-product of numerous chemical processes and is therefore relatively cheap on the world market, a new production plant in Chittagong under these conditions would prove uneconomic.

Ad 4.

The GS-Process would solve the problem of the P-Gypsum inasmuch as there is a definite need for the resultant products- sulphuric acid and cement - on the home market and imports of sulphur and cement clinker could at least partially be reduced. Since the sulphuric acid can be re-used in the phosphoric acid plant, the production of sulphuric acid from imported sulphur can also be cut back by the corresponding amount.
In the case of cement, there is an equally large demand on the home market. Because Bangladesh does not have any large scale suitable limestone deposits of its own, cement clinker production within Bangladesh is too low to satisfy internal demand, with the result that cement clinker must be imported. Yet at least part of these imports could be covered by producing cement clinker from P-Gypsum.
The raw materials necessary for production are readily available in Bangladesh with the exceptions of coke breeze and Kieselghur.

III. PROJECT BACKGROUND

Even before the first TSP-plant was started up in 1969, the EPIDC of that time had recognized the problem of disposing of the P - Gypsum and was contemplating the production of sulphuric acid and cement.

For this purpose Krupp Chemieanlagenbau and VÖEST-Klöckner INA-Chemiebau had been invited to submit a tender for a GS-plant. These firms worked out preliminary tenders which were subsequently forwarded to EPIPC. Political disturbances then caused the project work to be interrupted until 1980.

The UNIDO commissioned a study entitled "Basic Chemical Industrial Development in Bangladesh" which was carried out by an Indian Company, called Fertilizer (Planning and Development) India Ltd. The study included proposals for a GS plant to make use of the residuary plaster from the GSP plant in Chittagong and demonstrated the economic viability of operating such a plant in Banlgadesh. The study foresaw the best internal rate of return as being 13.1 %, given a capacity of 325 MTD cement clinker, with natural gas being used for heating material and coke breeze for the reduction phase.

The World Bank promised to provide financial backing for the project on condition that the assumptions on which the above mentioned study is based are verified.
The study's conclusions were based on the following assumptions:

- that the P-Gypsum and other raw materials are suitable for the GS-Process
- that the rough estimated investment costs are not very different from the real one

Since any divergence from the above mentioned assumptions might be the construction of the plant impossible or jeopardize the economy at least, it will be the purpose of the present study to review and if necessary correct these assumptions.

The present study will be carried out in two parts. In the first part, the raw materials will be analysed to ascertain whether they are suitable for the GS-Process. The second part will work out the capacity, investment costs and operational costs of a GS-Plant based on the results of the first part of the study. On the basis of the raw-material, energy, investment and wage costs as well as the market yields from the final products, a financial analyses will then be carried out to show whether a GS-Plant in Chittagong can be operated economically or not.

IV. PROCESS AND HISTORY

The GS-Process was developed during the first World War in the Farbenwerke Bayer in Leverkusen by Müller und Kühne, to a commercial scale.

Natural anhydrite was used as raw material. On the basis of this process a number of plants were built of which the following are still in operation today:

Year of Starting up	Company	Location	Country
1954	Chemie Linz AG	Linz	Austria
1954	VEB Chemiekombinat	Wolfen	GDR
1955	Düngemittelkombinat VEB Stickstoff	Coswig	GDR
1955	Zakladny Chemizne	Wizow	Poland
1972	Fedmis	Phalaborwa	South Africa

Of these plants, Chemie Linz AG and Fedmis use P-Gypsum, the other three use natural anhydrite (apart from operational trials). The Chemie Linz AG plant is unique in that since 1972 it also operates a raw meal preheater which accounts for a 20 % reduction in heat requirements.

The majority of the above-mentioned plants have been in operation since the mid-Fifties so that the process may be regarded as being tried and tested. The Chemie Linz AG plant switched from natural anhydrite to P-Gypsum in 1966 so that twenty years of experience have already gone into the use of this raw material.

The major reason why world-wide only two GS-Plants process P-Gypsum, even though 100,000.000 MTY of this material are produced from phosphoric acid plants all over the world lies in the fact that investment costs for such plants are high. Energy consumption is just as high too because the P-Gypsum contains about 40 - 50 % water and must be dried and calcined before being passed into the rotary kiln.

In addition to this, the GS-Process requires about twice as much heat as the limestone-cement process. This is due to the fact that the decomposition of gypsum (instead of limestone) needs a much higher heat of reaction.

Evidently, there is little incentive to build a GS-Plant unless there are problems with dealing with P-Gypsum and importing raw materials. The circumstances at Chittagong are, however, so different as to justify a more optimistic outlook.

Crucial factors are:

- problems of dealing with P-Gypsum
- lowering of the investment costs for a GS-Plant if it seems possible to adapt the existing sulphuric acid plant to the GS-Process (this will be investigated in Part II of the study) and because a grinding + bagging plant for cement already exists at Chittagong
- savings of about 30,000 MTY imported sulphur
- savings of about 80,000 MTY imported cement clinker
- no problems in selling the final products
- own natural gas available as source of energy
- low wage costs.

Once these factors are taken into account it may be said that a GS-Plant in Chittagong may prospectively be operated economically and could help to save foreign exchange reserves that would otherwise be used to finance a large amount of the sulphur and cement clinker imports.

The GS-Process using P-Gypsum and a raw meal preheater was developed by Chemie Linz and Krupp-Koppers and is called "Chemie Linz-Krupp Process". According to this process dried and partially calcined P-Gypsum is carefully mixed in the right proportions with the necessary (dried and finely ground) additives sand, clay and iron residues and coke breeze. This raw meal is preheated to about 600 °C in a raw meal preheater and enters the rotary kiln at this temperature. At 700 - 1100 °C the gypsum decomposes in two stages to form calcium oxide and sulphur dioxide according to the following equation.

$$2\ CaSO_4 + C = 2\ CaO + 2\ SO_2 + CO_2$$

The CaO and additives SiO_2, A_2O_3, Fe_2O_3 combine at about 1.450 °C in the hottest part of the rotary kiln to form cement clinker. The SO_2 together with the kiln gases is then fed through to the sulphuric acid plant, where the gas is cooled, dried and freed from dust. The gas is passed over a vanadium catalyst, where the sulphur dioxide together with the oxygen contained in the gas is combined to form sulphur trioxide, which, combined with water, forms sulphuric acid.

V. BODY

- Aim of this study

The aim of this study is to examine whether the additive materials which occur in Chittagong or in the vicinity are suitable for use in the GS-Process.

In addition to this, tests carried out in the phosphoric acid plant II should establish whether the F-content of P-Gypsum can be reduced to a level suitable for implementation in the GS-Process.

- Evaluation of the additives

The composition of the additives clay, sand and iron residues must be such that together with the P-Gypsum a raw meal can be mixed which, after treatment in the rotary kiln, produces a clinker possessing the qualities demanded by the standard.

For this purpose the raw meal must fulfil the following criteria:

$$\text{Lime saturation factor (LSF)} = \frac{CaO - 0.7\ SO_3}{2.8\ SiO_2 + 1.2\ Al_2O_3 + 0.65\ Fe_2O_3} = 0.98\text{-}1.02$$

$$\text{Silica ratio (SR)} = \frac{SiO_2}{Al_2O_3 + Fe_2O_3} = 2.3\text{-}2.7$$

$$\text{Aluminia ratio (AR)} = \frac{Al_2O_3}{Fe_2O_3} = 2.5\text{-}3.5$$

Two sand samples, thirteen clay samples and three iron residues samples were taken in Bangladesh and analysed in Linz.

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The analyses were carried out according to the gravimetric, except the K_2O and Na_2O flame photometry methods respectively.

The results of the analyses are listed in Appendix I. The calculations carried out with these analytical values derived from the listed raw materials and P-Gypsum show that with these a suitable raw meal can be produced which fulfil the above demands with reference to LSF, SR and AR. The additives are therefore suitable for the process.

The aim of the second part of the study is to attempt optimization through an economic selection of additives.

- Evaluation of the coke

A material with carbon content is necessary for the reduction of the gypsum. Coke breeze proved to be an economic material which, however, is not produced domestically and must therefore be imported.

For the GS-Process it is important that the volatile parts of the coke are under 5 %, and this is generally the case. This must be taken into account when importing coke. A sample of imported coke from the neighbouring steelworks was analysed. The analytical values can also be seen in Appendix I. According to these values the volatile parts of the coke amount to 1.8 %. This coke would, therefore, be suitable for the GS-Process.

- Evaluation of the P-Gypsum

The main impurities contained in the P-Gypsum yielded by the phosphoric acid plant are P_2O_5 and F.

Both impurities have a negative effect on the GS-Process. Thus interfere with clinker production as well as affecting the qualities of the cement. In order to guarantee trouble free operation of the rotary kiln and to produce a high quality cement, these impurities should not exceed certain values. These maximum values are, with reference to dry dihydrate, 0.5 % for P_2O_5 and 0.15 % for F.

If the P_2O_5-content exceeds 0.5 %, which would correspond to about 1 % in the clinker, the strength of the cement suffers. The initial strength (of 1 to 3 days) is especially affected. The strength after 7 days is affected only minimally or not at all.

The P_2O_5-content of the waste gypsum of the phosphoric acid plant II (Nissan process), which is investigated in the study, is under 0.5 % because of the process, whereby a recrystallization of the gypsum from hemihydrate is affected. This P-Gypsum is thereby suitable for the GS-process with reference to the P_2O_5-content.

Concerning the F-content, it must be said that a higher F-content in the gypsum lowers the sintering temperature. This could quite possibly be welcomed in cement process based on limestone. In some cases fluorspar is added to the raw meal in order to increase the melting phase for the production of high quality cement.

However, in the GS-Process the clinker already contains enough substance which increase the melting phase part. This is due to the different reduction stages of the gypsum.

A further increase brought about by a high F-content in the P-Gypsum is undesirable because rings could thus be formed in the coldest parts of the rotary kiln and the coating removed from the sintering-zone which drastically reduces the operational life of the lining.

The F-content of the P-Gypsum yielded by the phosphoric acid plant II is variable. However, it is considerably higher than the required limit of 0.15 % and must therefore be reduced in order to make it suitable for the GS-Process.

This can be achieved by the addition of active silica for instance in the form of Kieselghur, at a suitable stage in the phosphoric acid plant.

However, due to the fact that the success of the above mentioned measure is dependent upon not only the process but also the type of phosphate rock employed, a laboratory trial can only serve as a guideline and cannot be seen as a definitive statement as to whether a reduction of the F-content is actually possible in the existing plant.

For these reasons it was necessary to carry out a field test in the phosphoric acid plant II in Chittagong.

- Laboratory investigation

P-Gypsum from the phosphoric acid plant II in Chittagong was used in the test.
The plant was operated with phosphate rock from Jordan.
With reference to dihydrate, the F-content of this gypsum was 0.22 %.

30 grammes of this gypsum were stirred with 70 grammes of phosphoric acid (24.2 % P_2O_5) produced by Chemie Linz AG and 0.15 grammes of Kieselghur for one hour at a temperature of 72 °C. The gypsum was then filtered off on a buchner funnel and washed with 70 ml of water.

After this treatment the F-content of the gypsum with reference to dry dihydrate was only 0.05 %.
This trail shows that it was possible to reduce the F-content substantially even with relatively small amounts of siliceous earth under laboratory conditions.
Confirmation or correction of these laboratory results should arise out of the following field test.

- Field investigation

The field tests were carried out between February 24 - March 3, 1986 at phosphoric acid plant II in Chittagong under the supervision and surveillance of a Chemserv team.

During this period phosphate rock from Jordan was processed in the phosphoric acid plant. The analyses of the phosphate rock are to be found in Appendix III. The necessary Kieselghur for the tests was imported from Hungary since Kieselghur is not found in Bangladesh. During the tests the Kieselghur was added to the phosphate rock before the belt weigher in the form of manual proportioning which were monitored exactly.

In each of the three experimental tests the plant was operated under constant conditions as far as possible for 24 hours after the addition of the Kieselghur. Samples were subsequently taken at intervals of 3 hours over a further period of 24 hours.

The samples were taken from the pre-washed gypsum on the gypsum filter in the phosphoric acid plant and divided into two parts. In one part the P_2O_5- and F-content was directly determined. 100 g of the other part was slurried in 150 g water and manually stirred for 10 minutes at the laboratory of BCIC. Afterwards the gypsum was filtered off using a suction filter. The P_2O_5- and F-content was likewise determined in the gypsum thus treated. All samples were taken in the laboratories of Chemie Linz AG, Austria as well to determine the P_2O_5- and F-content.

The Chemserv team also carried out measurement of the F-content of the gypsum samples in Chittagong. These analyses however were only carried out to give approximate values and acted as part of the management and surveillance of the tests.

Three tests were carried out according to the method described above. Each time, different amounts of Kieselghur were added, namely 0.5 - 1.0 - 2.0 % related to the P_2O_5 load of the phosphoric acid plant.

The F- and P_2O_5-values for the gypsum samples analysed in the laboratories of the Chemie Linz AG are given in Appendices IV, V and VI.
A reason why the values deviate so much lies in the fact that the phosphoric acid plant was not evenly operated, as can be seen from the strong fluctuations of the SO_4 values shown in Appendix VII. The reason for these fluctuations can be found in the irregular dosage of raw phosphate and sulphuric acid. An improvement in dosage techniques would be desirable.

As the analyses in Appendices IV, V and VI indicate, it is possible to reduce the F-content from an average of 0.31 % to an average of 0.12 % by adding 0.5 % Kieselghur (in relation to P_2O_5) and subsequently washing the gypsum, which means that P-Gypsum as a raw material is suitable for the GS-Process.

Raising the amount of Kieselghur to 1 % and 2 % respectively did not produce any considerable improvement so that an addition of more than 0.5 % Kieselghur is unnecessary.

VI. QUALITY OF CEMENT

In relation to clinker from limestone, the cement clinker produced from P-Gypsum in the GS-Process displays the following chemical differences, which could affect the qualities of the resulting cement.

- content of F
- content of P_2O_5
- content of SO_3
- content of S

F-content

The F-content influences the setting time of the cement, which can be substantially reduced or increased depending on the F-content.

If the F-content of the P-Gypsum is below 0.15 %, then the setting times will lie within the values demanded by the standard.

P_2O_5-content

The P_2O_5-content of the cement clinker reduces the tricalciumsilicate content (C_3S).

However, C_3S is largely responsible for the strengthness of the cement, especially the initial strengthness.

As can be seen from the table in Appendix II, the initial strengthness (1 to 3 days) decreases with increasing P_2O_5 content, whereas the strengthness after 7 days is not changed by a P_2O_5-content of 1 %.

Due to the fact that the P_2O_5-content of the P-Gypsum is under the required limit of 0.5 %, the hardness values of the cement are also within the standard.

SO_3-content

The optimal SO_3-content in clinker produced by the GS-process lies at around 2 %. A lower value can be attained by more intensive burning. However, this has a negative effect on the strengthness of the clinker and increases the heat requirement of the rotary kiln. It is, therefore, not worthwhile to reduce the SO_3-content of the clinker below 2 %.

Under consideration of the addition of the gypsum for the regulation of setting time, the SO_3-content limit of 3 % in cement as required by the British specification cannot be met.

Therefore, the specification governing the maximum SO_3-content should be changed in order to increase the maximum to 3.5 %.

In the standards of many countries the SO_3-content is limited to 3.5 %.

S-content

If the GS-Plant is operated correctly, the S-content of the clinker can be kept low enough so as not to have any negative effects on the qualities of the cement.

Under consideration of the above points and using the raw materials listed in Appendix I a cement can be produced by the GS-Process which, with reference to ordinary Portland Cement, corresponds to the British Cement Specification 12/1958.

The only exception is the SO_3-content, which cannot be met. The norm should be changed so that the maximum SO_3-content is increased to 3.5 %.

A different possibility would be to grind the clinker of the GS-Plant together with that of another cement plant, whereby a maximum SO_3-content of 3 % could be met, since the clinker from a limestone cement plant possesses a low SO_3-value.

Cement from P-Gypsum is produced in the plant of Chemie Linz AG (Austria) since 20 years. This cement is used for all high rise and low level constructions and fulfilled all the requirements needed by the construction companies since 20 years.

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Project Manager

Appendices I to VII

March 27, 1986

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APPENDIX I

LIST OF RAW MATERIALS WHICH WERE ANALYSED

- Sand sample No. 1	Silhet
- Sand sample No. 2	Comilla

As there is no boiler asn or shale available several samples of clay were analysed.

- Clay sample No. 1	Kalurghat
- Clay sample No. 2	Kalurghat
- Clay sample No. 3	CUFL
- Clay sample No. 4	CUFL
- Clay sample No. 5	KPM
- Clay sample No. 6	Watertank
- Clay sample No. 7	CUFL
- Clay sample No. 8	KPM gate
- Clay sample No. 9	Bhatiavia
- Clay sample No. 10	Brickfield
- Clay sample No. 11	Play ground
- Clay sample No. 12	Play ground
- Clay sample No. 13	School area

- Phosphogypsum sample	TSP-Complex
- Iron residue, blowing mill	Steel Mill
- Iron residue, furnace	Steel Mill
- Iron residue, after rolling	Steel Mill
- Coke uncrashed	Steel Mill

APPENDIX I

Results of Analysis

	loss of ignition %	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	CaO %	MgO %	Na_2O %	K_2O %	TiO_2 %	F %	Cl %	H_2O %	SO_3
Clay No.1	6,5	60,4	18,0	6,8	1,0	2,5	1,0	3,2	1,2	0,07	0,01	14,1	
Clay No.2	6,5	60,7	18,4	6,6	0,8	2,2	1,0	3,1	1,2	0,07	0,008	23,1	
Clay No.3	4,1	68,0	14,2	5,2	1,3	2,1			1,1	0,06	0,12	0,8	
Clay No.4	[illegible],6	61,5	19,1	4,3	1,4	3,0	1,2	3,3	1,1	0,07	0,022	1,1	
Clay No.5	4,3	66,4	14,5	5,5	1,4	2,3			1,1	0,06	0,008	0,5	
Clay No.6	7,8	56,3	20,5	4,6	1,4	2,5	1,4	2,8	1,1	0,16	0,13	3,0	
Clay No.7	6,0	58,6	18,5	7,1	1,5	3,1			1,1	0,08	0,011	18,7	
Clay No.8	4,8	66,2	16,8	4,1	1,4	2,5	1,2	2,1	1,0	0,06	0,008	12,0	
Clay No.9	5,8	58,8	18,6	6,9	1,4	3,0	1,1	3,4	1,1	0,08	0,006	14,1	
Clay No.10	4,2	67,2	14,6	5,6	1,5	2,3	1,0	2,3	1,1	0,05		1,1	
Clay No.11	5,6	61,7	17,8	6,6	1,0	2,5	1,0	2,7	1,2	0,06		14,8	
Clay No.12	5,4	64,3	16,0	6,2	1,1	2,5	1,0	2,7	1,1	0,06		5,5	
Clay No.13	5,5	62,0	17,4	6,4	1,3	2,7			1,0	0,06		1,5	
Sand 1	0,5	93,8	2,6	0,4	0,7	1,0	0,12	1,0	0,5	< 0,01	0,005	0	
Sand 2	0,3	95,1	0,6	1,2	0,1	0,1	0,12	0,8	0,2		0,004	6,7	
Gypsum	20,8	0,5	0,03	0,01	32,5	0,6	0,03	< 0,01	0,03	0,22	0,013	$60^{o}C$;9,1	44.4
Mill-Scale 1	+ 5,3			103,3									
Mill-Scale 2	+ 6,6			109,5									
Mill-Scale 3	+ 5,8			103,3									
Coke	87,9	5,9	4,2	1,2	0,3	0,2	85,9	1,8	7130 cal/g	0,01		14,2	

						MgO	S	C	volatile	heat value	F	11,0
Coke	87,9	5,9	4,2	1,2	0,3	0_2	0.4	85,9	1,8	7130 cal/g	0,01	14,2

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APPENDIX II

Effect of by-product gypsum on compressive strength of Portland Cement.

Feed to Process	By-product gypsum	By-product gypsum	Natural anhydrite
% P_2O_5 in clinker	2	1	0
% F in clinker	0.40- 0.15	0.10- 0.15	0
Comprehensive strength (kg/m^2)			
After 1 day	70	100	120
After 3 days	190	200	220
After 7 days	250	320	320
After 28 days	420	450	400

APPENDIX III

Jordanien Phosphate Rock

	Sample 1	Sample 2
CaO	52,0 %	52,0 %
P_2O_5	33,4 %	33,5 %
SiO_2	2,8 %	2,8 %
F	3,6 %	3,7 %
MgO	0,24 %	0,24 %
Cl	0,03 %	0,03 %
H_2O	0,89 %	0,86 %
Sieve analysis		
$>$ 60 μ	60,2	59,5
60 - 75 μ	5,2	6,1
75 - 90 μ	7,2	6,4
90 - 100 μ	4,6	5,0
100 - 120 μ	6,2	4,8
120 - 150 μ	5,6	6,6
150 - 200 μ	7,6	8,8
$<$ 200 μ	3,0	2,8

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APPENDIX IV

Test 1 — 0.5 % Kieselghur

Date	Time	Gypsum from filter % F	Gypsum from filter % P_2O_5	Gypsum after treatment % F	Gypsum after treatment % P_2O_5
1.3.86	6,00	0,38	0,12	prior to the addition of Kieselgur	
	7,00	0,39	0,12		
2.3.86	7,00	0,22	0,17	0,13	0,16
	10,00	0,29	0,18	0,14	0,18
	13,00	0,16	0,21	0,13	0,19
	16,00	0,11	0,17	0,10	0,17
	19,00	0,33	0,23	0,11	0,22
	22,00	0,46	0,24	0,17	0,22
3.3.86	1,00	0,44	0,22	0,12	0,22
	4,00	0,39	0,22	0,11	0,22
	7,00	0,44	0,41	0,10	0,19

F- and P_2O_5-contents are related to dry dihydrate

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APPENDIX V

Test 2 1.0 % Kieselghur

Date	Time	Gypsum from filter		Gypsum after treatment	
		% F	% P_2O_5	% F	% P_2O_5
24.2.86	10,00	0,39	0,22	prior to the addition of Kieselgur	
	12,00	0,33	0,20		
25.2.86	10,00	0,43	0,14	0,18	0,12
	13,00	0,37	0,28	0,13	0,12
	16,00	0,40	0,16	0,17	0.12
	19,00	0,19	0,11	0,14	0,11
	22,00	0,39	0,14	0,15	0,13
26.2.86	1,00	0,18	0,15	0,12	0,14
	4,00	0,13	0,25	0,12	0,16
	7,00	0,32	0,19	0,15	0,18
	10,00	0,34	0,22	0,13	0,21

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APPENDIX VI

Test 3 2.0 % Kieselghur

Date	Time	Gypsum from filter		Gypsum after treatment	
		% F	% P_2O_5	% F	% P_2O_5
27.2.86	7,00	0,16	0,21	0,13	0,20
	10,00	0,16	0,18	0,15	0,14
	13,00	0,24	0,16	0,17	0,15
	16,00	0,18	0,16	0,16	0,16
	19,00	0,16	0,16	0,16	0,14
	22,00	0,23	0,15	0,19	0,14
28.2.86	1,00	0,29	0,14	0,18	0,14
	4,00	0,26	0,16	0,17	0,12
	7,00	0,18	0,15	0,16	0,11

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APPENDIX VII

Date	Shift	Digestor % SO_4 (shift average)
24. 2. 1986	morning	5,80
	midday	4,22
	night	---
25. 2. 1986	morning	5,82
	midday	3,64
	night	4,80
26. 2. 1986	morning	3,16
	midday	---
	night	2,81
27. 2. 1986	morning	4,84
	midday	4,54
	night	3,76
28. 2. 1986	morning	6,84
	midday	4,34
	night	---
1. 3. 1986	morning	4,66
	midday	4,77
	night	4,27
2. 3. 1986	morning	2,28
	midday	---
	night	5,39

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1986 04 07

O F F E R

F O R

FEASIBILITY STUDY FOR THE PRODUCTION OF CEMENT AND SULPHURIC ACID FROM PHOSPHOR GYPSUM FOR BANGLADESH CHEMICAL INDUSTRIES CORPORATIONS's TRIPLE-SUPERPHOSPHATE PLANT in the PEOPLE's REPUBLIC OF BANGLADESH

PHASE II

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TABLE OF CONTENTS

A) BACKGROUND AND DESCRIPTION OF TASK

The project in hand covers a study for a plant to make sulphuric acid and cement from by-product gypsum from Bangladesh Chemical Industries Corporation's Triple Superphosphate plant at Chittagong.

The study will be implemented to two phases. In phase I it is planned to investigate whether the by-product gypsum and the raw materials available in Bangladesh are suitable for the above process, and whether the project is technically feasible.

The aim in phase II is to determine whether implementing this project is advisable from the economic point of view.

Phase I (UNIDO Project No. DP/BGD/78/002, Activity Code: DP/02/32.1.A) has already been carried out, with positive results; in other words, making sulphuric acid and cement from the gypsum from the Chittagong plant and the additives available in Bangladesh (sand, clay, iron residues) is technically feasible. Only coke breeze and Kieselghur need be imported.

Starting from these findings, phase II should now be implemented; here the issue is whether the project makes economic sense.

Disposing of by-product gypsum is currently a problem in the TSP production process at BCIC's Chittagong works.

At the moment the gypsum is stored on a dump adjacent to the works; but the dump has only limited capacity, and will be filled completely in the near future.

Environmental considerations and regulations rule out dumping the gypsum in the Bay of Bengal, as the effect on marine fauna would be deleterious.

Using gypsum to make sulphuric acid and cement will solve this problem. The project will thus make a significant contribution to conserving the environment of Chittagong, Bangladesh.

The bodies responsible for deciding whether the project for making sulphuric acid and cement from by-product gypsum makes sense in terms of Bangladesh's economic development need the results of this study.

The project offers the following main benefits:

1. Environmentally acceptable solution to the problem of how to dispose of by-product gypsum

2. Saving imports amounting to approx. 80 000 t/year of cement clinker.

   In 1984/85 about 1.04 million metric tons (mt) of cement was consumed in Bangladesh, of which about 70 per cent was imported. Cement demand in Bangladesh is projected to grow at an annual rate of 5.2 per cent, and will reach 1.99 million mt per year by 1995/96.

3. Saving imports amounting to approx. 30 000 t/year of sulphur.

   Bangladesh has no indigenous deposits of sulphur or pyrites and, therefore, sulphur needs will require to be met only by imports. The use of the process, therefore, can result in substantial import substitution of sulphur. Presently demand of sulphur is about 50 000 metric tons (mt per year with a tendency to grow by 4 % over the next 5 years.

4. Creating roughly 70 new jobs in the new plant to be constructed.

B) IMMEDIATE OBJECTIVE OF THE STUDY

The aim of the study is to draw up material on which to base a decision.

The material in question should enable the bodies concerned (UNIDO, Government of Bangladesh, BCIC, World Bank) to reach a decision on whether an installation to make sulphuric acid and cement from by-product gypsum should in fact be built in Chittagong.

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D) OFFERED SERVICES

Chemserv will carry out the work required for the study both in Linz/Austria and in Chittagong.

the following time investments are planned for this:

A) Project Area

Position Title		
1 Project Manager	2	manmonths
2 Process Engineers	1,5	manmonths
2 Technical Adviser	2	manmonths
1 Chemical Engineer	0,5	manmonths
total	6	manmonths

B) Home Office

Position Title		
1 Project Manager	3	manmonths
2 Process Engineers	7	manmonths
2 Technical Adviser	6	manmonths
1 Chemical Engineer	1	manmonths
*) Service of licensor	2	manmonths
	19	manmonths

*) The existing sulphuric acid plant was erected under licence from Nissan. To integrate the GS-process licence related services are required from Nissan, Japan.

E) INPUTS REQUIRED FROM THE COUNTERPARTS

The Cost of the study has been calculated on the assumption that BCIC TSP complex provides the following inputs free of charge:

1. All pertinent data and information concerning the project as available at BCIC
2. Composition and heat value of natural gas
3. Local safety and environmental regulations
4. All technical data of the existing sulphuric acid plant
5. Free access to all sites to be investigated as well as to documents and drawings essential to the project; to this purpose BCIC shall provide the project team with a suitable letter of introduction if necessary
6. Consult and help with regard to all legal matters affecting the project team in Bangladesh in connection with the execution of the study
7. Office and office facilities for the project team in Bangladesh
8. Telephone, telegraph, telex and mail services for communications between Bangladesh, Europe and Japan in connection with the execution of the study
9. Medical care of and assistance to the project team in the case of accidents or unforeseen illness
10. Transport of the project team from hotel to sites and back.

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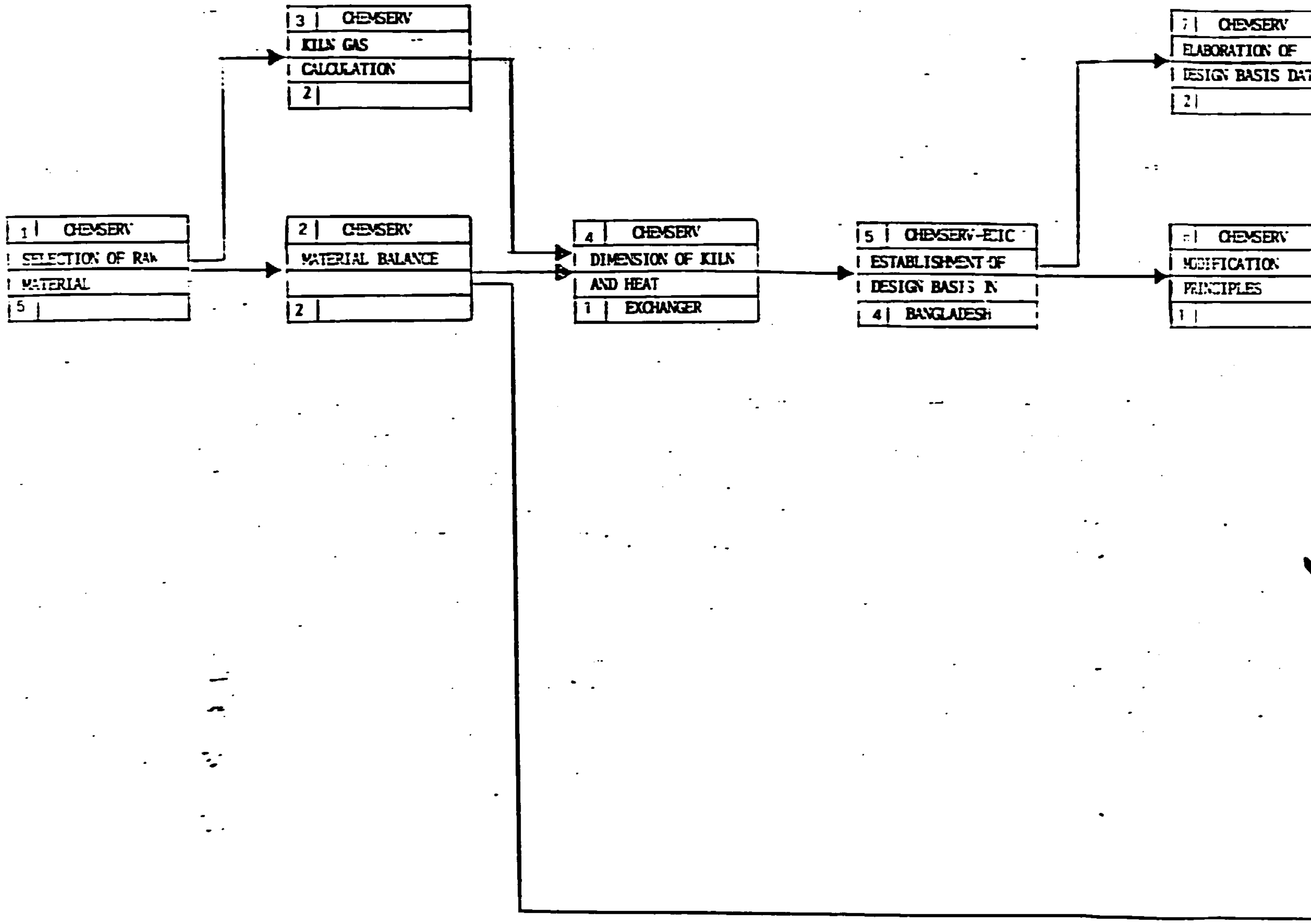
F) SUGGESTED WORK PLAN

See attached page.



1 CHEMSERV
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3 CHEMSERV
KILN GAS
CALCULATION
2
2 CHEMSERV
MATERIAL BALANCE
2
4 CHEMSERV
DIMENSION OF KILN
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ESTABLISHMENT OF
DESIGN BASIS IN
4 BANGLADESH
CHEMSERV
ELABORATION OF
DESIGN BASIS DAT
2
CHEMSERV
MODIFICATION
PRINCIPLES
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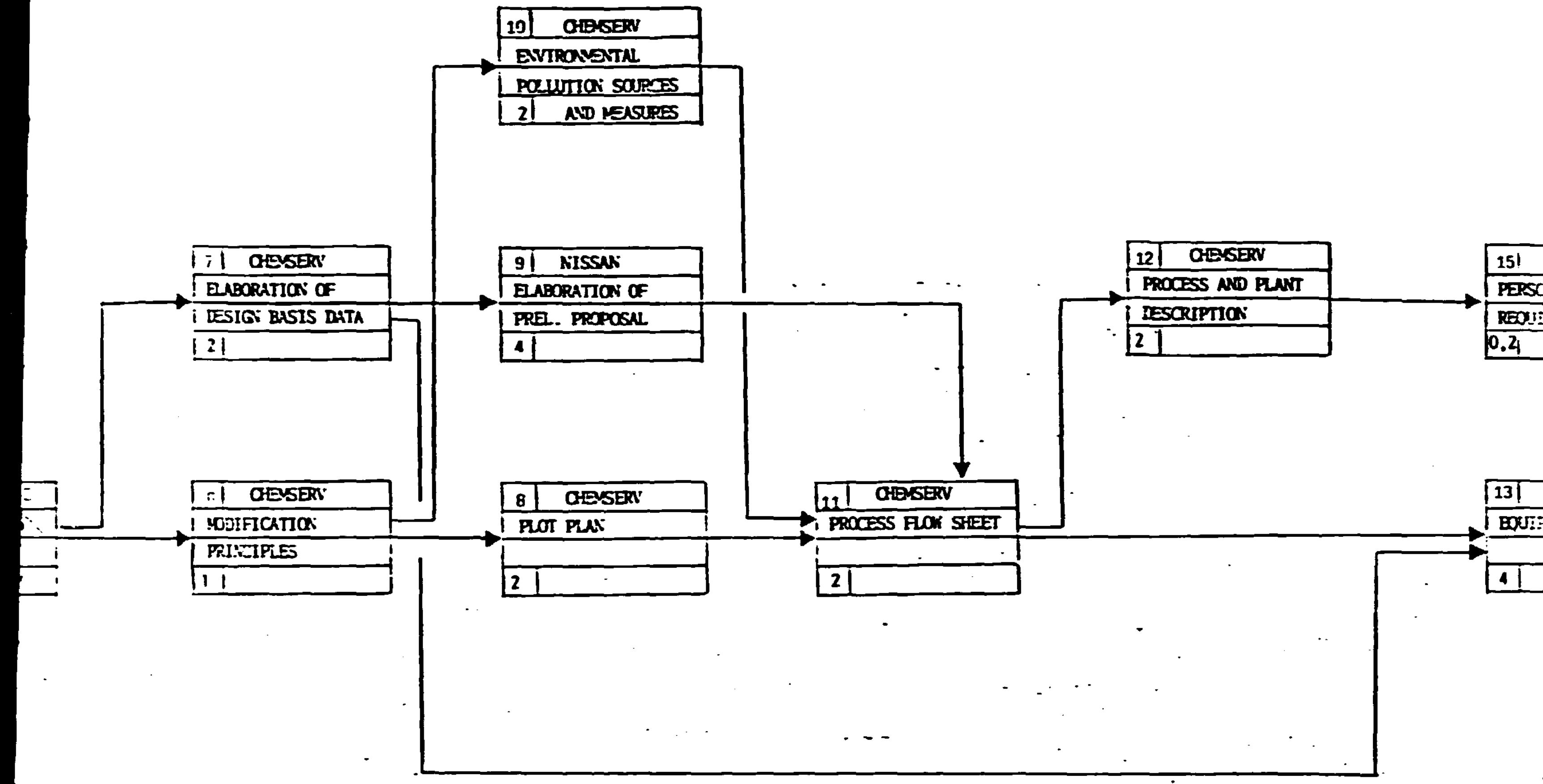
SECTION 1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PROCESS FLOW SHEET
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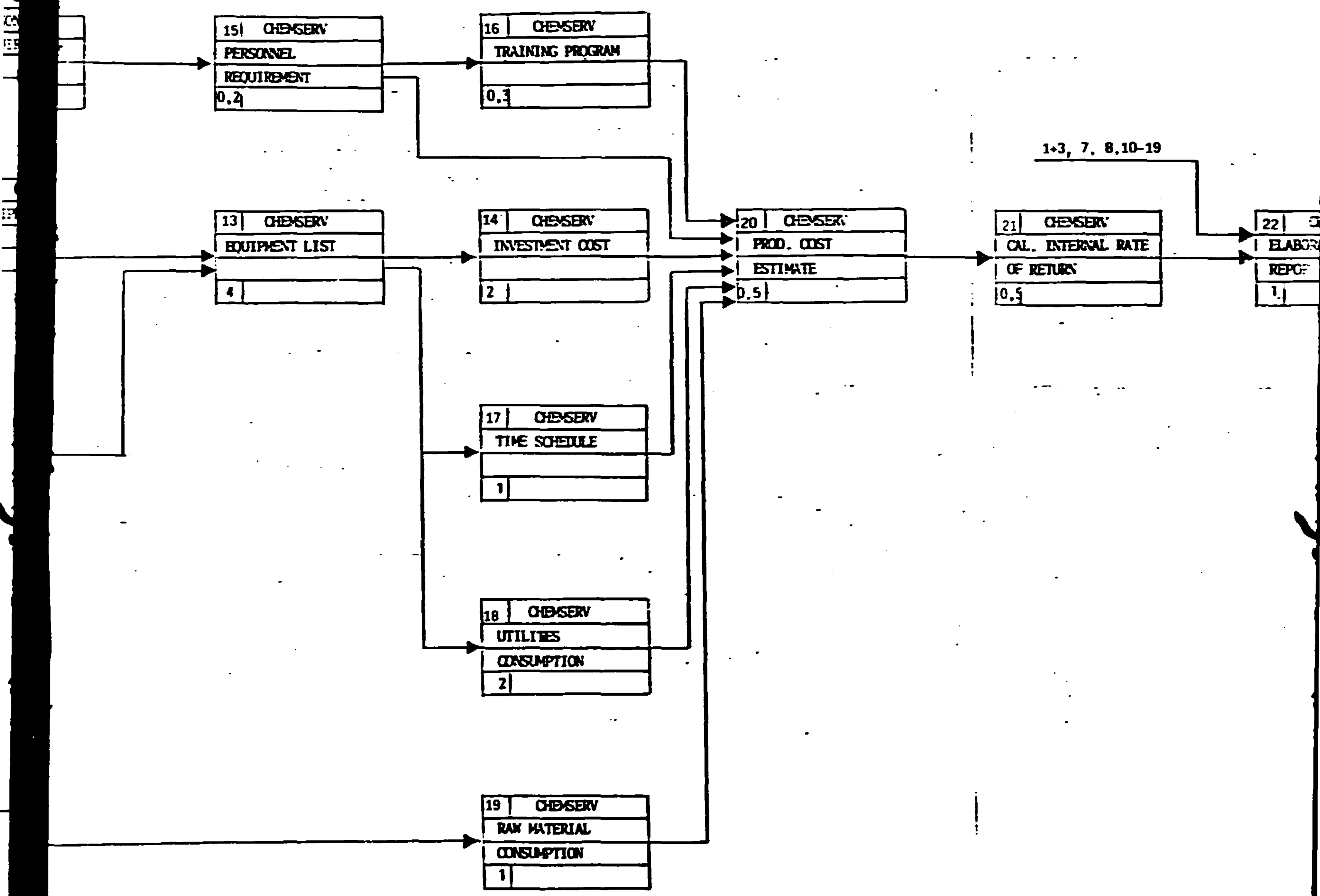
SECTION 2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14 CHEMSERV
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17 CHEMSERV
TIME SCHEDULE
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18 CHEMSERV
UTILITIES
CONSUMPTION
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19 CHEMSERV
RAW MATERIAL
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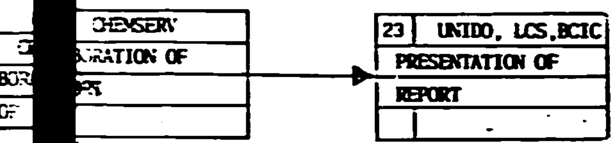
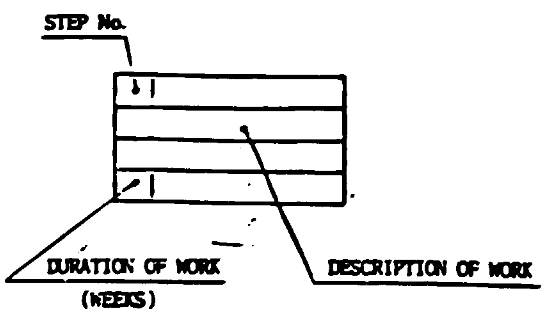
20 CHEMSERV
PROD. COST
ESTIMATE
0.5
1+3, 7, 8,10-19
21 CHEMSERV
CAL. INTERNAL RATE
OF RETURN
0.5
22
1

SECTION 3



SECTION 4



CHEMIE LINZ AG	chemserv
P.O.B. 296 St. Peter-Straße 25 A-4021 LINZ AUSTRIA	

WORK PLAN

GS-STUDY CHITTAG…

Date 1986 04 07

ANNEX I

SECTION 5

CHEMIE LINZ AG	chemserv CONSULTING Ges.m.b.H.

P.O.B. 296 St.Peter-Straße 25 A-4021 LINZ AUSTRIA Tel: [illegible] Telex 02-1324

WORK PLAN

GS - STUDY CHITTAGONG PHASE II

Date 1986 04 07

COST FOR PHASE II OF THE STUDY

1. Professional Services

A) Project Area

Position Title	Manmonths	ATS per months	ATS Total
1 Project Manager	2	145.000,--	290.000,--
2 Process Engineers	1,5	135.000,--	202.500,--
2 Technical Advisers	2	135.000,--	270.000,--
1 Chemical Engineer	0,5	135.000,--	67.500,--
	6		830.000,--

B) Home Office

Position Title	Manmonths	ATS per months	ATS Total
1 Project Manager	3	135.000,--	405.000,--
2 Process Engineers	7	110.000,--	770.000,--
2 Technical Advisers	6	110.000,--	660.000,--
1 Chemical Engineer	1	110.000,--	110.000,--
*) Service of Licensor	2	200.000,--	400.000,--
	19		2,345.000,--

2. Subsistence

Project Area	
180 man/days at 2.100,-- per day	378.000,--
Briefing & De-briefing	
4 man/days at 500,-- per day	2.000,--
3. Travel & Transportation	
8 tickets Europe-Bangladesh-Europe	344.000,--
*) Contingency for travel to Japan within Europe	120.000,--
4. Reports	30.000,--
	4,049.000,--

Exchange rate 1 US $ = 17,-- ATS appr. US$ 238.180,00

*) The existing sulphuric acid plant was erected under licence from Nissan. To integrate the GS-process licence related services are required from Nissan, Japan.