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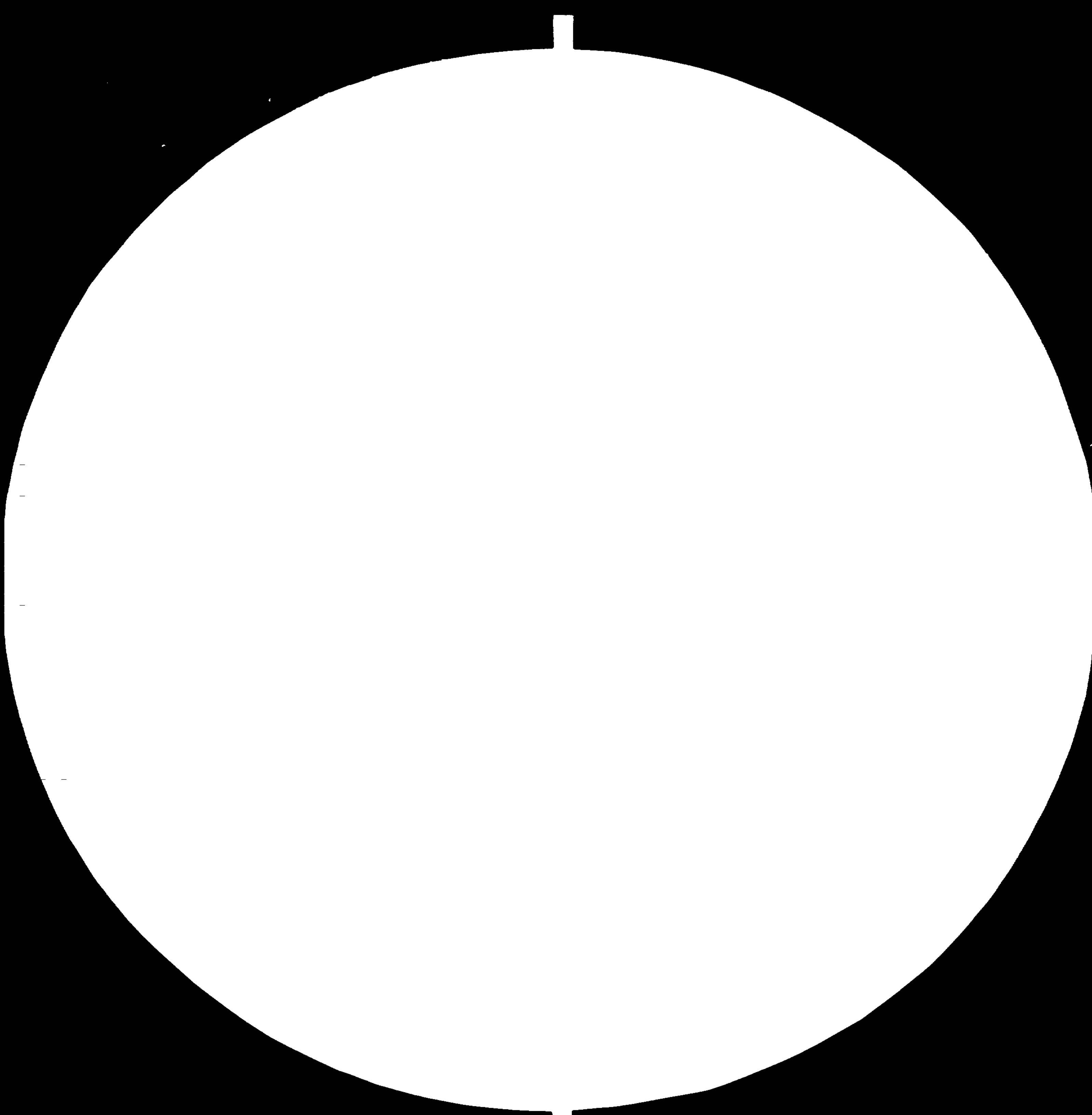

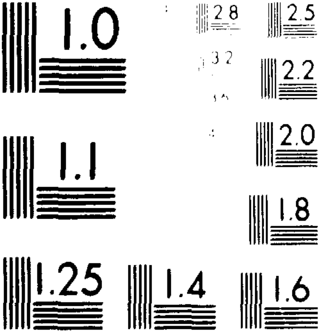
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BASIC CHEMICAL INDUSTRIES DEVELOPMENT
IN
BANGLADESH.

Part One
SUMMARY

FERTILIZER (PLANNING & DEVELOPMENT) INDIA LTD

SINDRI, INDIA, 828122

Job No. 3104

10139(1)

PART - I

SUMMARY OF FINDINGS & RECOMMENDATIONS

PART I

CONTENTS

<u>DRAWINGS</u>

ABBREVIATIONS

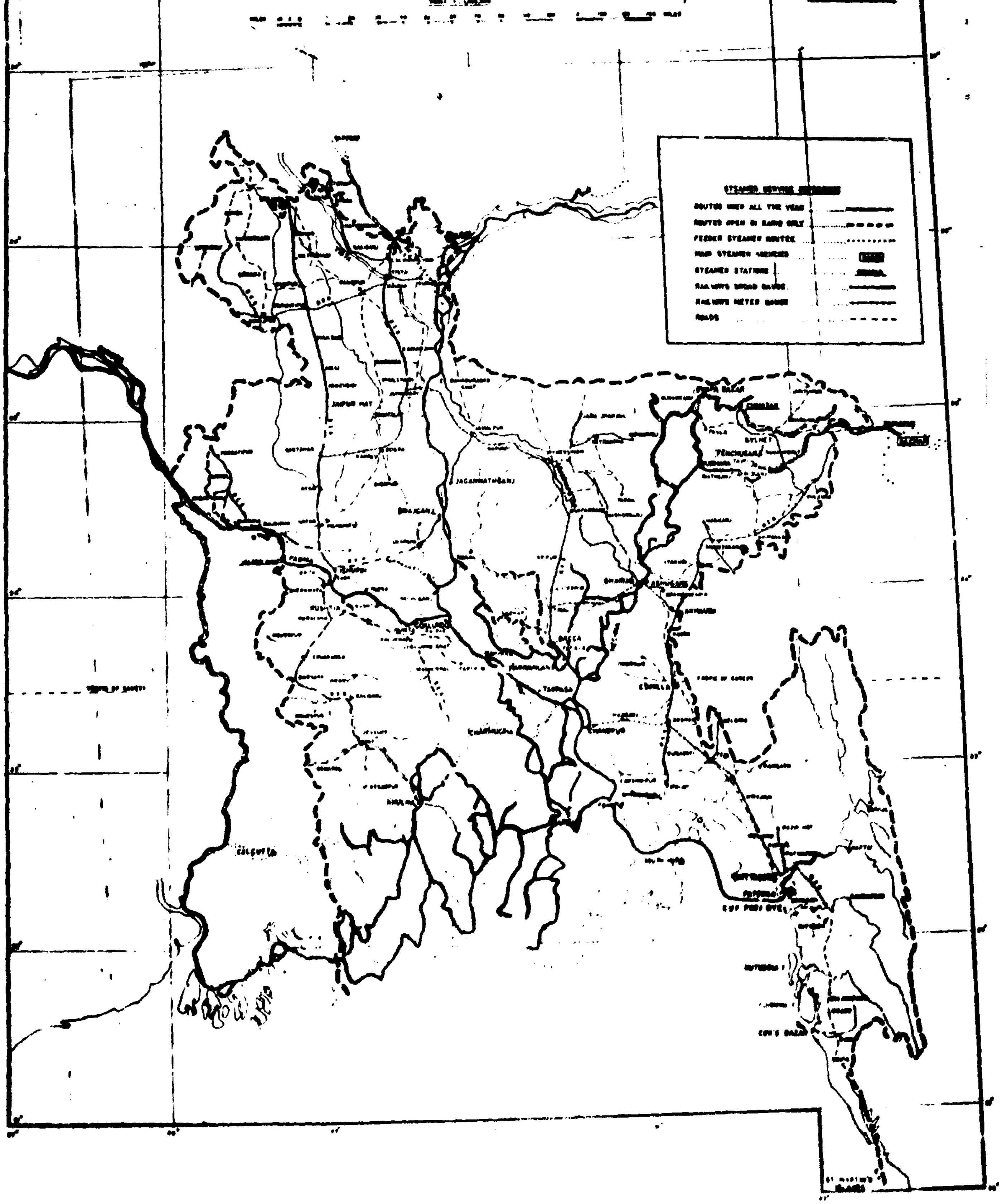
Consultant	(The) Fertilizer (Planning & Development) India Limited
UNIDO	United Nations Industrial Development Organisation
UNDP	United Nations Development Programme
ADB	Asian Development Bank
BCIC	Bangladesh Chemical Industries Corporation
PDB	Power Development Board, Bangladesh
WASA	Water and Sewerage Authority, Bangladesh
BMEDC	Bangladesh Mineral Exploration and Development Corporation
BIWTC	Bangladesh Inland Water Transport Corporation
BADC	Bangladesh Agricultural Development Corporation
TSP	Triple Superphosphate
CUFP	Chittagong Urea Fertilizer Project
NGFF	Natural Gas Fertilizer Factory, Fenchuganj
GUFF	Ghorasal Urea Fertilizer Factory, Ghorasal
PA-I	Phosphoric Acid Plant - I (TSP Complex, Chittagong)
PA-II	Phosphoric Acid Plant - II (TSP Complex, Chittagong)
SA-II	Sulphuric Acid Plant - II (TSP Complex, Chittagong)

(**Abbreviations Contd.**)

BCSIR	Bangladesh Council of Scientific and Industrial Research
HBRI	Housing & Building Research Institute
BBS	Bangladesh Bureau of Statistics
BSCIC	Bangladesh Small & Cottage Industries Corporation
TPD	Tonnes (Metric) per day
TPA	Tonnes per annum
TPY	Tonnes per year
Cft	Cubic Feet
Scft	Standard cubic feet
MWH	Mega Watt Hour
NM^3	Normal cubic metre
$	US $ (Assumed conversion rate $: TK 15)

BANGLADESH
COMMUNICATION NETWORK

DRG. NO.-1



Chapter - I

THE ASSIGNMENT

1.1 The Fertilizer (Planning & Development) India Ltd (FPDIL) a consultancy and engineering organisation based in India specialising in the field of fertilizer and chemical industries (hereinafter referred to as the Consultants), was retained by the United Nations Industrial Development Organisation (UNIDO) in August 1978 to undertake this project called the 'Basic Chemical Industries Development in Bangladesh'. The main objective of the Project, as visualised in the Terms of Reference, is "to find an economic means of utilising the phosphogypsum byproduct" produced in the country for the production of certain basic chemical industrial products needed by Bangladesh. UNIDO's Terms of Reference to the Consultants covered, besides statement of objectives, comprehensive guidelines on the Project's scope and indication of the activities expected of the Consultants in the execution of the Project.

Project's Scope

1.2 The principal end-uses in which byproduct gypsum could be economically utilised were envisaged to be :

- manufacture of cement clinker and sulphuric acid
- manufacture of ammonium sulphate, and
- manufacture of gypsum building materials.

1.3 In examining the question of utilising the by-product gypsum in the manufacture of these products, however, certain major inter-linkages occur. For instance, for the production of ammonium sulphate substantial quantities of anhydrous ammonia are required as input. If ammonium sulphate is produced, chalk (calcium carbonate) becomes available as a precipitate, which can support a soda ash plant, if availability of industrial grade common salt can be ensured. Alternatively, soda ash needed by Bangladesh in substantial quantities can be produced by another process-route, if salt and ammonia supply can be assured, in which ammonium chloride, a useful nitrogenous fertilizer, is obtained as a co-product. If the cement clinker route were to be chosen from among the alternatives, a plan for the utilisation of sulphur dioxide gas produced concurrently will need to be evolved alongside. Hence, in the interest of evolving an optimised development scheme covering the major products as well as inputs, the scope of the Project was spelt out for the Consultants as follows :

> "The aim of the project is to provide the Bangladesh Chemical Industries Corporation (A Government Enterprise) with technical and economic information to facilitate the implementation in the Project Area of the following industrial activities :
>
> (a) expansion of solar salt production;
>
> (b) manufacture of soda ash;

(c) expansion of ammonia production facilities;

(d) production of phosphogypsum based cement or ammonium sulphate; and

(e) conversion of phosphogypsum by-products into building materials".

In the course of discussions with UNIDO on the Work Plan submitted by the Consultants, it was agreed that the Consultants should also make an evaluation of the salt production method through industrial evaporation and refining techniques as supplement to solar salt production.

Project Team

1.4 The Project Team for the assignment comprised of the following :

1. P.A. Bhaskara Rao : Industrial Economist & Marketing Expert
2. D.M. Thakre : Expert on Phosphogypsum Reprocessing
3. M.A. Khan : Expert on Manufacture of Ammonia
4. H.C.P. Sinha : Expert on Manufacture of Soda Ash
5. G.B. Rathod : Expert on Solar Salt Production

6.	A.S. Mehta	:	Expert on Salt Production based on Industrial Evaporation
7.	C.A. Taneja	:	Expert on Gypsum Building Materials

Summary of Work Performed by the Team

1.5 The Project work commenced with the arrival in Bangladesh of the Team Leader on September 20,1978. The other members of the Project Team reached the Project Area in the next few weeks in accordance with a pre-determined work plan and spent varying periods from six weeks to twenty eight weeks between September 1978 and April 1979 on data collection and field study. The Team worked throughout in close association with a Counterpart Team of local experts nominated by the Bangladesh Chemical Industries Corporation (BCIC) - the counterpart agency concerned with the Project in Bangladesh (Appendix - I). The Team Members in the course of the field study, also had benefit of discussions with a large number of other technical experts within the country. They included specialists from organisations like the BCSIR, HBRI, Planning Commission, BMEDC, Geological Survey of Bangladesh, Bangladesh University of Engineering Technology, BADC, Bangladesh Rice Research Institute, Bangladesh Bureau of Statistics, BSCIC, Petro-Bangla, Soil Fertility & Soil Testing Institute, PDB, WASA, BIWTC, BRTC, etc., besides officials from the Government and the BCIC.

1.6 The Team visited Chittagong, where the TSP units are located, and toured, individually and in groups, several other parts of the country primarily with a view to (i) ascertaining the availability and conditions of supply of the raw materials needed for the schemes under consideration within the country (ii) study of present production conditions of materials involved in the Project's scope (iii)assessment of the suitability of possible sites for location of projects (iv) evaluation of actual conditions under which the products concerned are expected to be used (v) assessment of the facilities available within the country for fabrication of needed equipment and (vi) an overview assessment of the facilities for the transport and handling of raw materials and end-products. With the assistance of local Counterparts, the Team also made a survey of the demand conditions within the country for the products covered in the study.

1.7 Since the Project revolved around the utilisation of byproduct gypsum being produced by the two phosphoric acid plants of the TSP Complex owned by the BCIC, the Team Members made a close study of the actual working of the TSP Complex at Chittagong and the general conditions governing the supply of phosphogypsum. The Team made, in consultation with the plants' technical managers, an assessment of the projected rates of accretion of byproduct gypsum on long-term basis from each of the plants and submitted its recommendations on the minimum plant modifications and operational improvements considered necessary to ensure uninterrupted availability of phosphogypsum at the projected rates.

1.8 In view of the critical importance of the phosphogypsum's composition for formulating its recommendations, the Team arranged for the conducting of scientific analyses of the byproduct gypsum from the two phosphoric acid plants, in Bangladesh as well as, independently, in the Consultants' own laboratory. Similarly, in the case of other critical inputs, as far as possible, the Consultants tried to ensure that the locally available products were compatible with the requirements of the processes concerned. This involved the testing of, for instance, the sand locally available for use as additive in the cement kiln and the useability of different types of jute fibres to impregnate cast gypsum boards for use as building materials. Since coke is a critical and high-cost input in the cement clinker - sulphuric acid scheme, the Consultants organised a laboratory-scale study of the possibility of use of low volatile matter anthracite, (which is far cheaper and more easily available) as a substitute for coke in the phophogypsum-based cement clinker unit.

Basis of Estimating

1.9 At the end of the Team's field study, a resume of the major findings and conclusions of the Team was submitted to the Counterparts for their comments, if any. Their broad acceptance of the conclusions thus obtained, the Team proceeded to elaborate the proposals into specific project schemes in the Home Office. In formulating the projects, the Consultants made preliminary designs of the relevant plants and related facilities on the basis of data collected during field study. Thereafter, based on the preliminary sizing and specifications of equipment, competitive quotations were sought from reputed firms, wherever feasible. Where such budgetary quotations were not available, the cost files of the Consultants were made use of to arrive at the most likely costs. Assessment of the extent of local procurement of supplies was based on the Project Team's conclusions after visits to the various fabrication shops in Bangladesh. The basic project cost estimates have been computed on the basis of July '79 prices.

Review of Findings

1.10 The draft of the Project Report, containing the alternative basic schemes and the Consultants' recommendations, was presented to BCIC in September 1979 for the comments of concerned agencies in Bangladesh. The BCIC appointed a representative 'Evaluation Committee' of local experts to examine the study and offer comments. The Team Leader independently met a number of experts and sought their reactions. This Final Report incorporates the relevant comments received from such experts. The opportunity has also been made use of to update some of the critical data.

Chapter - 2

EXECUTIVE SUMMARY

2.1 The chemical industries sector in Bangladesh is still in an incipient stage of development. Inspite of a sizeable and growing market potential, almost all the basic chemicals needed by the country are presently being imported owing to inadequate local production base. Insufficient imports due to balance of payments problems have generally tended to restrict supplies.

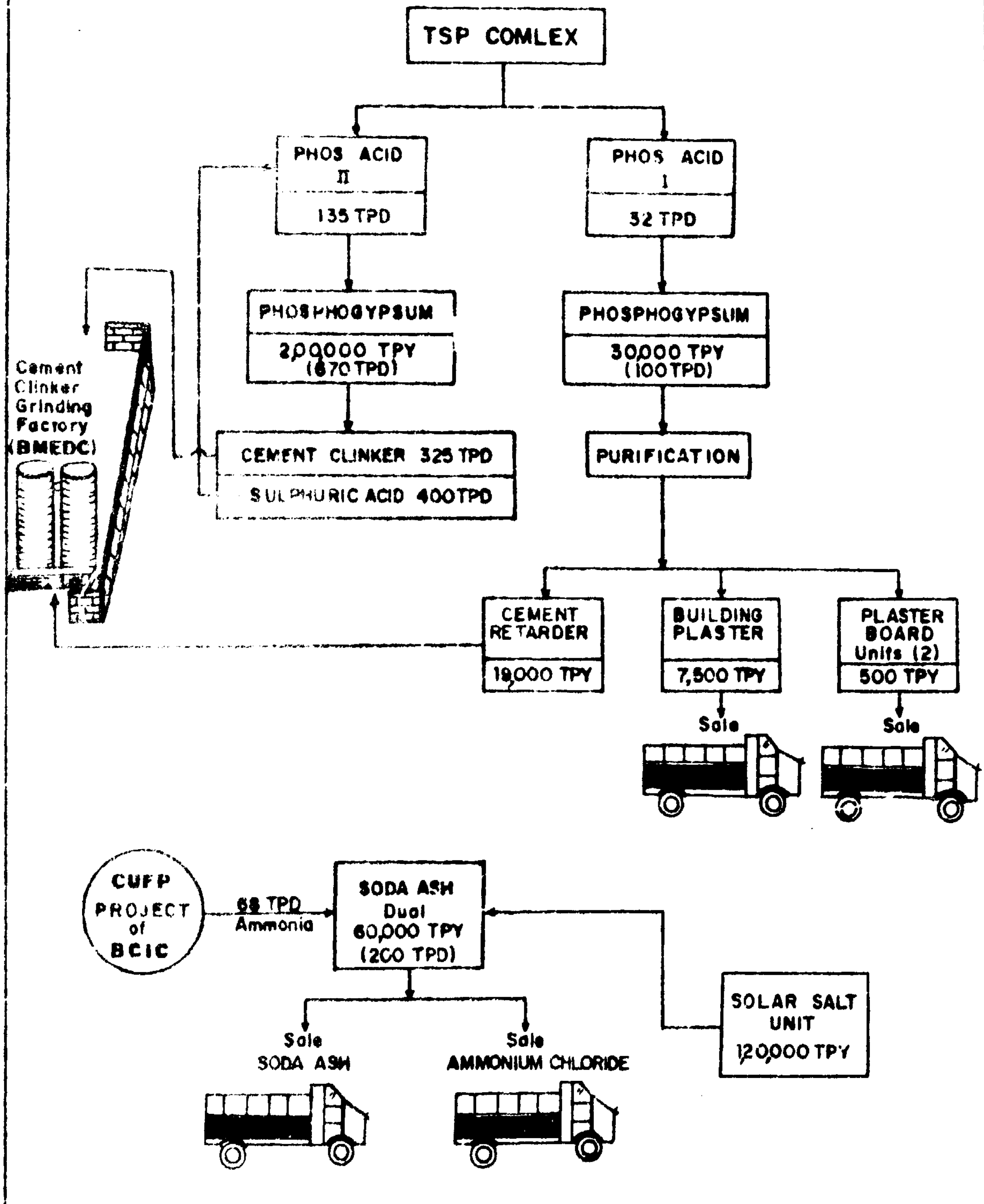
2.2 One of the critical problems involved in the development of chemical industries in the country is the dearth of industrial raw materials and minerals in general, natural gas being the only major natural resource found in ample measure in the country. The availability of natural gas has enabled the establishment of three nitrogen fertilizer factories-with two more in the planning stage. However, the present utilisation rate of the gas is still low owing to inadequate pipeline distribution network. The plan for piping the gas to Chittagong, the second largest city and the major industrial centre of Bangladesh, is still in the formulation stage.

2.3 The Basic Chemical Industries Development Project in Bangladesh is primarily concerned with examining the techno-economic feasibility of production of some specified basic chemical industrial products in the country and finding economic uses for the locally available phosphogypsum in the manufacture of these products. The products considered are : ammonia, ammonium sulphate, cement clinker and sulphuric acid, soda ash, common salt and gypsum building materials. Of these, phosphogypsum can find end-uses in the manufacture of ammonium sulphate, cement clinker and gypsum building materials. However, the production of ammonium sulphate will require substantial supplies of ammonia. If ammonium sulphate is produced, chalk (calcium carbonate) becomes available as a by-product, which can be utilised in the manufacture of soda ash, if the availability of adequate quantities of industrial grade common salt can be ensured. Soda ash, needed by Bangladesh, can also be manufactured through another process-route if the supply of ammonia and salt can be assured - where ammonium chloride, a nitrogenous fertilizer, is obtained as a co-product. If phosphogypsum were to be used in the cement clinker production, the sulphur dioxide gas produced concurrently will require to be converted into sulphuric acid. The Project thus involved evolving an optimised development scheme covering the major products as well as inter-linkage of inputs.

2.4 The phosphogypsum is produced in the two wet process phosphoric acid plants laid out in parallel streams in the Tiple Superphosphate Complex at Chittagong. The larger of the two streams, designed and erected by Hitachi Zosen in 1970, comprises of a 400 tpd sulphuric acid, 135 tpd (P2O5) phosphoric acid and a 450 tpd TSP plants. The phosphoric acid plant is based on the New Nissan (hemihydrate-dihydrate) process. It is expected to produce annually around 200,000 tonnes/year (approximately 667 tpd) of waste phosphogypsum per year under the planned improved operating conditions. The smaller stream, comprising of a 100 tpd sulphuric acid, 32 tpd (P_2O_5) phosphoric acid and a 100 tpd TSP plants, constructed in 1969, is expected to generate annually around 30,000 tonnes (100 tpd) of phosphogypsum. This phosphoric acid plant is based on the dihydrate process.

2.5 As seen above, ammonia supply is crucial to the choice of the product route. A close study of the operating and 'under-construction' ammonia fertilizer plants in Bangladesh established that none of them could be depended upon for making available, on a continuous basis, any significant

BASIC CHEMICAL INDUSTRIES DEVELOPMENT IN BANGLADESH
Recommended Schemes



FERTILIZER (P&D) INDIA LTD.

Drawing No. I - 1

quantities of ammonia for use as input in other industries. The establishment of a separate captive ammonia plant for the purpose is found to be uneconomic on account of the high cost of production in a sub-optimal sized plant. However, investigations indicated that ammonia upto a limit of 72 tpd could be available from the planned Chittagong Urea Fertilizer Project, if the requirement could be incorporated in the design of the plant before implementation.

2.6 With this constraint in the availability of ammonia, utilising the phosphogypsum in the production of ammonium sulphate becomes possible only with a captive ammonia plant to make available the required quantity (133 tpd) of ammonia. However, the high cost of supply of ammonia contributes considerably to making the scheme uneconomic.

2.7 Among theother alternatives to make use of the phosphogypsum, the cement clinker - sulphuric acid route has been recommended to utilise the phosphogypsum (200,000 tonnes/year) from the larger Nissan process phosphoric acid plant. The annual availability of phosphogypsum can support a clinker plant of 325 tpd capacity, which is considered a viable size. The sulphurous gases produced in the kiln during the process of clinker production can be processed into sulphuric acid in the existing sulphuric acid plant, with some marginal modifications. However, the volume of gas available can yield only 325 tpd of sulphuric acid, while the requirement of the downstream phosphoric acid plant will be about 400 tpd. In order to maintain the sulphuric acid production, the burning of elemental sulphur in the kiln to raise the concentration of SO_2 gas has been recommended.

2.8 In view of the presence, beyond permissible limits, of critical impurities in the phosphogypsum produced by the other (dihydrate) plant, it cannot be made use of in the cement clinker scheme without an elaborate and expensive purification step. The Consultants, therefore, recommend that phosphogypsum from this plant (30,000 tonnes/year) be purified and the major part (19,000 tonnes/year) utilised as setting retarder (cement additive) in the cement grinding plants. The balance of 8000 tonnes/year (net of processing losses) can find use as building materials,-7500 tonnes as building plaster and 500 tonnes in the manufacture of plaster boards in two small scale units to be sponsored for the purpose.

2.9 For soda ash production, the Study recommends the setting up of a 200 tpd (60,000 tonnes/year) plant based on the Dual Process - in which ammonium chloride is obtained as co-product. Ammonia required for the scheme (68 tpd) can be procured from the Chittagong Urea Fertilizer Project. The co-product ammonium chloride can be utilised as a nitrogenous fertilizer in the non-acidic soil region of Bangladesh. To make available the required quantity of industrial grade salt, a captive solar salt production unit organised on scientific lines is recommended on an area of 2000 hectares in the Chittagong district, to produce annually around 120,000 tonnes of high purity salt. The Study also recommends that technical expertise in the field of solar salt production be made available to Bangladesh to make up the existing deficiency.

2.10 To sum-up, the Study recommends the following projects :

1. A cement clinker plant based on phosphogypsum
2. A plant for the purification of phosphogypsum for use as building materials, including plaster boards
3. A Dual-Process soda ash plant, and
4. A viable scale solar salt production unit.

The total capital investment on these four projects is estimated at $ (US) 122.40 million, of which the foreign exchange component is estimated at $ 67.31 million.

Chapter - 3

CONCLUSIONS AND RECOMMENDATIONS

3.1 The central theme of the present project is the economic utilisation of thephosphogypsum by-product for the production of certain basic chemical industrial products needed in Bangladesh. Among the alternatives considered to accomplish this objective, the Consultants feel, on the basis of the detailed studies carried out in the ensuing volumes, that -

(i) the phosphogypsum produced in the larger phosphoric acid plant (PA-II), assessed at 200,000 tonnes/year on sustained basis, is best utilised for the manufacture of cement clinker and sulphuric acid;

(ii) the byproduct gypsum available from the smaller phosphoric acid plant, expected around 30,000 tonnes/year, is best used, after purification, partly as setting retarder for cement (cement additive) and the balance as building materials such as building plaster.

For the manufacture of soda ash, the Consultants recommend a Dual Process plant with ammonia procured from the planned Chittagong Urea Fertilizer Project and the salt supplied from a captive solar process unit to be set up for the purpose.

Cement Clinker Route

3.2 The byproduct gypsum available from the larger phosphoric acid plant (200,000 tonnes/year) can support a cement clinker production unit of 325 tonnes per day capacity. In the opinion of the Consultants this capacity is within the economic size-range. The SO_2 gas produced in the kiln can be processed in the existing sulphuric acid plant (SA-II) but in order to match the capacity of the sulphuric acid plant (400 tpd), some elemental sulphur will be required to be burnt in the kiln to improve the gas concentration. It has been confirmed that the existing plant can handle the volume of gas involved in this route. The effective plant capacities recommended, thus are :

- Cement Clinker (new) : 325 tonnes/day
- Sulphuric Acid (existing) : 400 tonnes/day

Know-how

3.3 The Consultants are convinced that the basic process scheme has relevance to the particular conditions obtaining in Bangladesh and that proven technology and experience is available for exploiting the process. Chemie Linz of Austria have the best experience for process know-how. The incorporation of a counter-current heat exchanger in the Chemie-Linz process scheme by Krupp-Koppers has given a decisive edge to this process over other available schemes in terms of energy economy. In view of these considerations, the Consultants recommend the Chemie-Linz (OSW) - Krupps 'know-how' for the proposed cement clinker route plants.

Location

3.4 In view of the close linkages with the TSP plant complex, including gypsum supply and the return of sulphur dioxide gas involved, the clinker plant will need to be located within the TSP Complex itself. The Consultants recommend that the plant be set up in the plot of vacant land lying next to the existing gypsum pond in the TSP Complex, with marginal encroachment on the existing gypsum pond. The clinker produced in the plant may be delivered to the existing clinker grinding factory of BMEDC, located within close distance from the TSP Complex, so that fresh investment on a grinding unit is avoided.

Inputs

3.5 In view of the firm indications of a plan to carry natural gas from Bakhrabad field to Chittagong being taken up for implementation shortly, and considering the fact that Bangladesh has ample reserves of natural gas, the Consultants recommend the use of natural gas as fuel in the cement clinker plant. For use as reducing agent in the kiln, the Consultants recommend that the possibilities of securing supplies of coke fines from India might be explored, in order to reduce the input-cost. Simultaneously, the possibility of using low volatile matter anthracite from Assam in the place of coke may also be pursued with the process licensors, in view of the promise indicated in early tests. The availability of anthracite may be easier and the cost substantially lower compared to both coke and coke breeze, especially since coal supply from Assam to Bangladesh is governed by an agreement with India. Other raw material inputs such as sand and clay are locally available.

Utilisation of Balance of Gypsum

3.6 The byproduct gypsum available from the smaller Phosphoric Acid Plant (PA-I), being derived from the conventional dihydrate process, contains a higher percentage of P_2O_5 and Fluorine than prescribed by the established process licensors as tolerance limits in the cement clinker-sulphuric acid route, and therefore it cannot be directly used in cement clinker production without a somewhat expensive purification step. Considering the inherent condition of the plant and the likely operational problems, the Consultants assess the availability of gypsum from this plant on sustained basis at around 30,000 tonnes (dry basis) per year. Since Bangladesh has no known deposits of natural gypsum, byproduct gypsum will be needed for use in the country as substitute for natural gypsum, after suitable treatment. In most applications the quantities needed are small (e.g. as plaster of Paris), and therefore, the products can readily absorb the processing cost; in any case the cost of the processed product will still be lower than the cost ofthe alternative, viz. imports.

Cement Additive Production

3.7 Among the several possible alternatives, one of the most promising and high priority uses of phosphogypsum in Bangladesh is as additive (setting retarder) to cement clinker in the manufacture of Portland cement. The Consultants, therefore, recommend that the phosphogypsum available from this Phosphoric Acid (PA-I) plant should be primarily made use of, after necessary purification, as cement additive, and any surplus left after this use, should be utilised for manufacture of building materials, such as building plaster and plaster products.

3.8 The Consultants envisage that the cement industry's off-take of phosphogypsum will reach around 19,000 tonnes in the next few years, leaving a balance (after processing) of around 10,000 tonnes for other uses. This quantity can be usefully utilised for manufacture of (i) building plaster and (ii) fibre-reinforced prefabricated plaster boards in small scale units. The manufacture of gypsum building blocks (precast slabs) is not recommended in Bangladesh owing to the facts that -

(i) in a high rainfall country they have limited application since they are not damp-proof,

(ii) they cannot be used in load-bearing walls, and

(iii) cannot compete with locally produced bricks in cost.

Location of Units

3.9 The Consultants further recommend that the TSP Complex should concern itself only with the purification of phosphogypsum and making available the 'cleansed' phosphogypsum to the cement plants or to other users. The plant for the purification of the phosphogypsum should be located within the TSP Complex for which the necessary plot of land has been identified. The establishment of two plaster board manufacturing units - one each in Chittagong and Dacca - with an annual capacity for the production of 240,000 sq. ft. of fibre-reinforced gypsum boards is recommended, either in the private sector or in the joint sector. Since the process of manufacture of plaster boards is simple, capital requirement low and the scope for expression of individual skills high, the Consultants feel that the industry is ideally suited for being promoted as small-scale units.

Other Industrial Chemicals

3.10 Among the other industrial chemical products being considered for manufacture in this Study, the Consultants recommend that facilities be established at the earliest for the production of soda ash and common salt in Bangladesh. The necessary conditions, including adequacy of demand and the availability of the required principal raw material inputs within the country, exist for the purpose. The Consultants do not foresee any major technical problems in establishing these manufacturing facilities. In the opinion of the Consultants, there are clear economic benefits to be derived in embarking on their local production, instead of continuing the imports.

Production of Soda Ash

3.11 The most economical route for soda ash production under the prevailing conditions in Bangladesh is the Dual Process. This conclusion is based on the firm indication that the required (68 tpd) quantity of ammonia for a 200 tonnes per day soda ash plant can be made available from the planned Chittagong Urea Fertilizer Project's facilities. The ammonium chloride, which becomes available as a co-product in the process, can be utilised readily as a nitrogenous fertilizer, since there are large tracts of well-drained alkaline soils in the country where ammonium chloride could be used with equally good results as urea. The plant capacity recommended (200 tonnes per day) is based on the size of the demand within the country as well as the technological considerations relating to minimum viable size.

3.12 The plant's location on a site adjacent to the proposed Chittagong Urea Fertilizer Project site is recommended. The plant should have provision for producing both dense and light soda ash. The Consultants recommend the use of the Central Glass - TEC process. The establishment of the soda ash unit should, however, be contingent upon the development of a modern solar salt works for the supply of industrial grade salt to the unit.

Manufacture of Solar Salt

3.13 Despite a fairly long tradition, the salt manufacturing industry in Bangladesh has so far hardly developed on sound lines on account of certain critical shortcomings. The Consultants hold that it would be imprudent and risky to build a salt based chemical industry of any sizeable capacity on a rather tenuous raw material supply base of the kind obtaining in Bangladesh. The Consultants, therefore, recommend the setting up of a modern large-scale solar salt producing unit at Chakaria - Sundarban, in the Chakaria 'thana' of Chittagong district - about 30 Km away from Cox's Bazar town for captive production of salt for industrial use in Bangladesh. The unit should cover an area of 2000 ha (5000 acres) to produce on an average about 120,000 tonnes per annum (minimum of 100,000 tpy in a lean year) of high grade salt suitable for industrial use.

Development of Local Salt Industry

3.14 Considering the ample scope for undertaking salt production through the solar evaporation method and the cost of commercial energy input, the establishment of any unit based on forced evaporation for salt production in Bangladesh is not recommended for the early future. Instead, the Consultants feel that efforts be directed to bring about qualitative and organisational improvements in the solar salt industry in the country. To plan, coordinate and oversee the development of the solar salt industry on efficient lines, the Consultants recommend the creation of a Salt Development Corporation. The Consultants propose that broadly, the functions of the proposed Corporation should cover :

(i) Leasing of all land for salt production in economic sized units

(ii) Development of new areas for salt production

(iii) Research and development on the improvement of techniques of salt production appropriate to Bangladesh conditions and on the extraction of useful chemicals from waste bittern

(iv) Provision of loans and credit and equipment and instruments for salt production

(v) Buffer stock operations and public distribution of salt, and

(vi) Import and export of salt.

3.15 The Consultants also propose the establishment of a Salt and Marine Chemicals Research Institute in Bangladesh under the Salt Development Corporation to evolve techniques of salt production best suited to the conditions in the country, to lay down the norms for the design of salt farms and extraction of marine chemicals, etc.

Technical Assistance

3.16 In the opinion of the Consultants, Bangladesh also initially needs external technical support to train its extension and research personnel in the field of solar salt technology and to advise the Government of Bangladesh on the optimal lines of development of the industry. Hence, it is recommended that the Government of Bangladesh should secure the services of an outside expert in the solar salt technology preferably with adequate field experience in a developing country working under labour intensive techniques and in relatively small units - to advise it on the development of the salt industry in the country and to train the local personnel. The Consultants also recommend that a nucleus of trained technical manpower in the relevant solar salt technology should be formed by deputing every year two persons concerned with overseeing the salt development in the country over a period of three years for the study of the modern solar salt production methods in countries whose experience could be relevant. The training could be covered under an appropriate technical assistance programme of UNDP/UNIDO.

Projects Not Recommended

3.17 The setting up of new facilities for the production of ammonia and ammonium sulphate in the country is not recommended. In the case of ammonia, in view of the significant economies of scale, production in a sub-optimal sized unit for the purpose of only meeting the industrial requirement is not advisable on account of the disproportionate production costs and the high investment requirement. The present industrial demand for anhydrous ammonia in the country is not large enough to warrant a new exclusive economically sized unit.

3.18 The establishment of a new ammonium sulphate unit for utilisation of byproduct gypsum has not been recommended because the proposal is economically unattractive. The principal reasons for it are :

(i) the problems involved in handling and transporting gypsum to a site where ammonia and carbon dioxide are available

(ii) non-availability of surplus ammonia and carbon dioxide to the needed extent from any of the existing ammonia units and the planned Chittagong Urea Fertilizer Project, and the high cost of producing them in a separate captive unit, and

(iii) the low selling price of ammonium sulphate within the country

Total Investment

3.19 The aggregate capital investment requirement for the projects recommended above works out as follows :

Capital Investment

($ Million)

Scheme	Capital Outlay		
	Foreign Exchange	Local currency	Total
1. Cement Clinker Sulphuric Acid	26.85	17.64	44.49
2. Gypsum Building Material*	2.11	1.84	3.95
3. Soda Ash	37.50	33.30	70.80
4. Solar Salt	0.85	2.31	3.16
Total :	67.31	55.09	122.40

*excluding investment on plaster board units ($ 25,170 each)

Phasing of Investment

3.20 The Consultants envisage, on the basis of scheduling of work proposed in the respective Parts (III, V, VI & VII) that the phasing of expenditure will be as follows :

Phasing of Expenditure

($ Million)

Year	Foreign Exchange	Local Currency	Total
First Year	8.2	6.2	14.4
Second Year	43.7	36.1	79.8
Third Year	15.0	12.8	27.8
Fourth Year	0.4	-	0.4
Total :	67.3	55.1	122.4

Cost of Technical Assistance

3.21 The cost of the technical assistance programme for salt works development recommended in para 3.16 above is estimated as follows :

Estimated Outlay on Technical Assistance

($ '000)

Phasing	Foreign Exchange	Local Currency	Total
First Year	85.6	4.4	90.0
Second Year	81.6	4.4	86.0
Third Year	81.6	4.4	86.0
Total :	248.8	13.2	262.0

Chapter - 4

PROJECT BACKGROUND

4.1 The Project essentially centres, as mentioned earlier, around the concept of economic utilisation of byproduct gypsum being produced by the Triple Superphosphate (TSP) Fertilizer Complex of the BCIC. The byproduct gypsum is obtained during the process of production of phosphoric acid in the two parallel wet process phosphoric acid plants of the Complex located adjacently. When the phosphate rock is attacked by sulphuric acid, the calcium values in the rock are converted into insoluble calcium sulphate, which is then separated out by filtration. For the most part, the phosphogypsum so obtained is treated as a waste material (See Part III); at present it is dumped as slurry into a waste-pond located within the factory campus, with some quantities being occasionally sold for use as cement additive and other minor uses.Both the phosphate rock and the sulphur needed by the plant complex are imported, since Bangladesh has no known reserves of either.

Location

4.2 The TSP Complex is located about 4 Km south of Chittagong on the west bank of the river Karnaphuli in an industrial estate called North Patenga - just south of the Chittagong port on the same side of the river. A cement clinker grinding plant is located approximately about 600 yards from the complex. An oil refinery is also located close by. The Karnaphuli river serves as shipping lane to the port. The Complex has its own jetty in front of the works site along the river front, with a closed conveyer system to unload and transport both rock phosphate and sulphur to the factory storage. The works proper are located about 500 ft inland, with a highway (connecting the local aerodrome) intervening between the jetty and the factory site. The Complex is connected by a metre gauge track to the Bangladesh railway system.

4.3 The factory complex comprises of two TSP Plants (TSP-I and TSP-II) with common off-site and supportive facilities such as water treatment and power supply, raw material unloading and storage, maintenance, administration and related facilities. Each of the TSP plants is laid out in parallel process trains. Thus the TSP-I plant group comprises of a 100 tpd (98%) sulphuric acid (SA-I), a 32 tpd P_2O_5 phosphoric acid (PA-I) and a 100 tpd ROP triple superphosphate plants. This group of plants was completed in 1969. The TSP-II plant group consists of a sulphuric acid (SA-II) plant of 400 tpd (98%) capacity, a phosphoric acid (PA-II) plant of 132 tpd P_2O_5 capacity and a ROP triple superphosphate plant (TSP-II) of 450 tpd capacity. This group of plants was completed in 1970.

TSP-I Group

4.4 The TSP-I series of plants was constructed by a French - US joint venture company. It was originally meant to be a single superphosphate plant, but after the bid was won by a U.S. company, it was decided to change the project into a TSP unit for which French aid funds had become available. The plants were designed by Pan-American Consultants. The SA-I is a Monsanto type contact acid plant with an attached oleum tower, permitting the production of around 10 per cent of the output as oleum. The phosphoric acid (PA-I) Plant is based on the conventional dihydrate process, Dorr-Oliver Single Tank type design, equipped with a single tank reacter, vacuum slurry cooler, Prayon tilting pan filter and a single stage vacuum evaporator. Rock grinding is done in a Poittee Mill-an air-swept ring roll mill provided with hot-air furnace. The TSP production is done in a Broadfield den, but no drying is provided for.

4.5 These plants hardly worked for about 4 weeks after the start-up in 1969 and had to be closed down due to severe corrosion problem in the phosphoric acid plant equipment caused by the high chloride content (0.5%) in the rock phosphate. The plant had been designed to use either Floridan or Moroccan rock but when it was commissioned the rock in fact used was Jordanian. Besides, the cargo was said to have been contaminated in transit with chlorides.

4.6 The PA-I plant remained out of operation until early 1977 owing to a legal dispute with the suppliers on contractual liabilities, when attempts were again made to operate the plant. The sulphuric acid (SA-I) plant was, in the meantime, in operation intermittently, partly for making oleum and partly for sale of acid, but was shut down in 1976 for overhaul after a total of about 30 months of intermittent operation since 1969. Thereafter, its boiler and furnace were being used for production of steam by oil-firing. The plants were recommissioned in 1978, but had to close down again in 1979 owing to raw material shortage.

TSP-II Group

4.7 The TSP-II corpus of plants was designed and erected by Hitachi Zosen on turn-key basis, financed by Japanese suppliers'credits. The SA-II plant also is of Monsanto type and the acid is produced (as in SA-I) from elemental sulphur. The molten sulphur is fed by pump to a burner feeding a furnace. The furnace is fed with air dried by sulphuric acid and heated by gases from the later conversion stages. The gases from the burning of sulphur are fed to a waste heat boiler to reduce their temperature to around 400/420°C. The waste-heat boiler generates steam which is used as the principal source of energy in the entire process. From the waste-heat boiler the gases pass to a hot gas filter where impurities are filtered out by graded layers of crushed brick, which protects the catalysts from contamination and prevents the building-up of pressure across the beds of granular catalyst. The conversion of SO_2 to SO_3 takes place in a converter when SO_2 and air is passed over a granular Vanadium Pentoxide catalyst bed and the conversion is accomplished in four stages.

4.8 After the conversion, the gas containing about 7 per cent SO_3 is cooled first in a heat exchanger and then in an economiser, which preheats the water feed to the waste-heat boiler to reach the optimum temperature for absorption in strong sulphuric acid and reaction with water. The cooled gases pass counter-current up the absorption tower to a flow of 98.5% sulphuric acid. The 98.5% acid is passed to the drying tower to remove moisture from the air passing to furnace and converters - where it is duluted to around 94 per cent H_2SO_4 and bled off as product.

4.9 The PA-II plant is based on Nissan's hemihydrate-dihydrate process. It is designed to use phosphate rock of low chloride, fluoride and silica content, which rules out rock of Jordanian origin. The process arrangement followed is conventional. The rock, ground in an airswept ball mill, is attacked by sulphuric acid at around 90°C in the first of the two digestion tanks, into which is also fed the recycled phosphoric acid. The slurry of phosphoric acid and calcium sulphate is then passed on the crystallizers where the slurry is cooled and seeded with gypsum by a slurry recycle. Here the calcium sulphate hemihydrate is recrystallised as calcium sulphate (gypsum) dihydrate, thus removing the water from the system. This results in a slurry with good filtering characteristics and high purity gypsum with a liquid phase consisting of phosphoric acid of around 30 per cent P_2O_5 strength. Eventually the slurry is filtered to remove gypsum which is reslurried with water and pumped to the waste pond, after being washed to ensure recovery of P_2O_5, the washing being returned to the first digestion tank with a portion of the product acid. The acid (30% P_2O_5) is concentrated in two forced circulation Struthers Wells vacuum evaporators. The condensate from these evaporators is partly used as the wash water in the phosphoric acid plant.

4.10 The equipment used for TSP manufacture in the TSP-II plant is similar to the Broadfield den, comprising of a slow moving steel slat conveyor with slowly reciprocating vertical sides. The phosphoric acid and ground rock are metered and mixed in a ribbon type mixer at a temperature of 50-70°C. This results in a fairly thick rapidly reacting slurry, which is then passed on to the den. This train is provided with a dryer.

4.11 Though the TSP-II group of plants was completed in 1970, their commissioning was delayed because Hitachi would not agree to it being started with Jordanian rock. The plants lay idle for a time when the Liberation War intervened. The plants were finally commissioned in 1974 with Moroccan rock. Since then it has been operating intermittently, partly due to operational problems and early teething troubles, and partly due to extraneous factors such as raw material shortages and power interruptions. Thus, between September 1974 and July 1977, the sulphuric acid (SA-II) plant is said to have operated only for 499 days at an average rate of 221 tpd. In the same period, the phosphoric acid (PA-II) plant operated for 436 days with an average capacity utilisation rate of 85 tpd. The major causes of down time during this period were said to be :

	Causes	Approximate Share of Downtime (Percent)
1.	Normal teething problem	20
2.	Electrical and mechanical breakdowns (within the factory)	34
3.	Electrical supply failures	16
4.	Raw material shortage	30

Present State of Plants

4.12 A number of expert groups who have studied the working of the plants in recent period have confirmed that both the TSP-I and TSP-II groups of plants are intrinsically sound in design and except for wear and tear caused by intermittent operations and some severe corrosion spots, the plants are reasonably in good shape. They are, however, incapable of being operated at rated capacity levels in the existing state, and need extensive overhauling and replacement/repair of some major critical equipment damaged in maloperations. A firm of technical consultants - Bresler and Associates, New York - were recently engaged by the BCIC under a World Bank's IDA Technical Assistance Credit to make an end-to-end survey of the plants, identify equipment items requiring replacement, locate bottlenecks and suggest measures for improving the plants' operation in general. The implementation of these recommendations - for revamping both the production trains - is presently covered by another UNIDO assistance project.

External Constraints

4.13 Apart from these internal problems, the Complex is faced with some bottlenecks adversely affecting fuller utilisation of installed capacity. One of the acutest problems faced by the management in recent period has been the shortage of experienced and qualified personnel to operate the plants. The turnover rate of skilled operators and supervisors in the unit, mainly due to emigration to the Middle East, has been quite high, as in most public sector industrial units in Bangladesh. As a result, both plant maintenance and operation have suffered in quality.

4.14 Another production bottleneck faced by the Complex has been in the field of power supply interruptions. The problem is directly attributable to the grid-supply and has been recognised as 'serious'. PDB has been making efforts to stabilise the supply by setting up more sub stations in the area. The management of the TSP Complex has also taken some corrective steps to cushion the impact of the problem. Two diesel generators have been installed to provide emergency power supply to keep the vital plant units (e.g. the agitators in the phosphoric acid reaction vessel) in operation.

4.15 Yet another serious problem faced by the unit is the deterioration in its water supply system.The Complex has three water supply sources : deep tube wells, the river Karnaphuli and the Water and Sewerage Authority (WASA). When the factory was constructed, tube wells were assumed to be the principal source of supply of fresh water. At that time the salinity of the water was low. But in due course, the supply from each well continued to decrease and salinity showed a steady rise. Sinking new wells did not provide much relief. Process water containing high chloride content probably accounts for part of the severe damage to equipment.

4.16 To meet the problem, a combination of well water and river water is being tried now by installing pumps to draw water from the Kamaphuli river, close to the factory jetty. However, reliance on river water is also beset with problems because composition of Kamaphuli water varies widely with level of river flow as well as the tides. At present, the quality of river water is being controlled by carefully choosing the appropriate time of the day, when the chloride content is the lowest, for drawing water, and then storing the water in a storage reservoir.

4.17 Recently (at the beginning of 1978), the Chittagong WASA constructed a pipeline and a metering station to bring water from the city supply system to the factory, and possibly this can take care of most of the pressing needs of the unit for process water. It is understodd that in due course WASA plans to augment the water supply capacity to the entire industrial estate of North Patenga with the construction of a large capacity loop pipeline with which the existing system will be integrated. This plan is expected to be completed by 1984.

Gypsum Disposal

4.18 Currently byproduct gypsum is pumped in slurry form into a pond of roughly about 11.5 acres, where it is allowed to drain off. At the expected accretion rate of approximately about 770 tpd (230,000 t/yr), the storage area presently available can be stretched to accommodate the gypsum for some 2-3 years at the most. Several proposals to tackle the problem of gypsum disposal on long term basis have been made. Among them are -

(i) Construction of a pipeline to pump gypsum slurry to the Bay of Bengal, about 3 KM away from the coast, or alternatively, use of barges for the same purpose

Though this is a widely practised method of disposal, especially in Western Europe, the USA and North Africa, it is not considered safe enough for Bangladesh besides being expensive. There have been objections on environmental grounds - especially on account of its possible injurious effect on marine fish life. In Tunisia, all fish and lobster in the Gulf of Gabes are said to have disappeared as a consequence of phosphogypsum disposal. There is also objection to wasting a useful product with a high sulphur content since Bangladesh has no deposits of natural gypsum.

(ii) Stockpile the gypsum in dry form initially in the factory area, but later in a suitable site within reasonable distance outside by transporting the dry gypsum by road. The gypsum so stacked can be reclaimed if necessary.

This proposal has the advantage of lower capital investment and possibly less intense objection by conservationists, since gypsum is not totally wasted. But it will require extensive land in an area where land prices are very high. It will also involve modifications in the plants to change-over from slurry discharge to dry discharge from the filters. Besides, the method is not quite safe as assumed, since there are chances of highly acidic leach liquids from these deposits (containing also fluorides) percolating into ground water and rendering it unsuitable for agricultural use or human and animal consumption. The contaminated water may also attack concrete foundations and steel reinforcements in the concrete.

(iii) Utilisation of phosphogypsum in the manufacture of a chemical product needed by Bangladesh

This study covers, in essence, the third proposal. The possible use of phosphogypsum as a soil conditioner is not discussed, since the total quantity potentially needed is small, and will account for only a small fraction of the total supply.

Gypsum Supply

4.19 In view of the intermittent and sub-optimal working of both the TSP trains in the past, a realistic assessment of the long-term availability of phosphogypsum is a pre-requisite before consideration of any schemes for its utilisation. In the light of the close study made by the Project Team and in the light of its discussions with the plants' technical staff the following broad conclusions were arrived at with the concurrence of the management of the Complex at the very outset :

(i) The byproduct gypsum availability that can be assumed from TSP Plant II (Hitachi) on assured long-term basis is about 200,000 tonnes/year.

(ii) The TSP-I set of plants cannot be expected to yield more than 30,000 tonnes/year of phosphogypsum on sustained basis in the long run.

These assessments are, however, based on the understanding that atleast the minimum of plant modifications and operational improvements suggested by the Team are carried out without further delay. This Study proceeds on the gypsum supply indications given above.

Chapter - 5

SUMMARY OF FINDINGS

5.1 Among the alternative proposals (Para 1.2) proposed for study for the economic utilisation of phosphogypsum, two schemes involve the use of ammonia in significant quantities, viz -

(i) Ammonium Sulphate

(ii) Soda Ash

In the conditions prevailing in Bangladesh, the availability of ammonia could be critical to the choice of either of these two schemes. Hence, confirmation of the possible availability in adequate quantities, and the likely sources of supply, of ammonia will be necessary before a study of the schemes proper.

5.2 Ammonia Requirement & Supply

5.2.1 Bangladesh has at present two nitrogenous fertilizer factories in operation and another one is in an advance stage of implementation. Two more plants, one small by modern standards, and another of large capacity are in the planning stage. Natural gas, of which Bangladesh has ample reserves, is the feedstock for all ammonia plants, existing and new. The location, capacities and the stage of implementation of plants is shown in Table 5.1.

Table - 5.1

Ammonia Plant Capacities in Bangladesh

S. No.	Location	Ammonia plant capacity (tpd)	Product	Stage of implementation
1.	Fenchuganj	204	Urea Ammonium Sulphate	In operation, being renovated
2.	Ghorasal-I	660	Urea	In operation
3.	Ashuganj	925	Urea	Due for commissioning in 1980.
4.	Ghorasal-II	180	Urea	Firmed up for implementation
5.	Chittagong	986	Urea	In advance stage of planning

5.2.2 Apparently, there are three possible sources from which ammonia needed for the manufacture of ammonium sulphate and soda ash can be met viz.-

(a) existing nitrogen fertilizer units at Fenchuganj and Ghorasal or the Ashuganj Urea Fertilizer Project, presently under implementation

(b) from one of the two new ammonia - urea projects (Ghorasal-II, CUFP) under planning, and

(c) an independent captive ammonia plant of requisite capacity based on natural gas available within the country.

The import of ammonia as a possible alternative is not considered, since ammonia requires special tankers for transport and special handling equipment and storage facilities at the ports, which are costly to install and uneconomic to operate if the quantities involved in import are not sizeable. The ammonia requirements of the schemes under discussion are too small to make this alternative viable.

5.2.3 Manufacture of ammonium sulphate and soda ash requires, alongwith ammonia, fairly large volumes of carbon dioxide. Normally, carbon dioxide is concurrently produced in the process of manufacture of ammonia. It is used in urea production if urea is the end-product, as in Bangladesh plants. In certain situations, however, depending on the composition of the feed gas, the ammonia plant complex may be operating on the basis of a close balance in the carbon dioxide supply. In such an event, even if ammonia were available, separate facilities for the production of carbon dioxide may be needed.

Ammonia Requirement

5.2.4 When ammonium sulphate is produced through the gypsum route, chalk ($CaCO_3$) is obtained as a byproduct, which, in turn can be utilised for the manufacture of soda ash through the classical Solvay process. The combined requirement of ammonia for both ammonium sulphate and soda ash through this route for an optimal sized plant (involving the utilisation of 200,000 tpy of phosphogypsum) is assessed at 133 te/day. Alternatively, if soda ash is produced through the Dual Process route, the minimum ammonia requirement is reduced to about half. The requirement of ammonia and carbon dioxide in the different alternatives will be as shown in Table 5.2.

Table - 5.2

Ammonia and Carbondioxide Requirement

(Tonnes/day)

	Product	Plant Capacity	Ammonia	Carbon dioxide
1.	Ammonium Sulphate (gypsum route)	480	132	197
2.	Soda Ash (Conventional route)	200	1	104
3.	Soda Ash (Dual process)	200	68	94

Ammonia Availability

5.2.5 The ammonia production facilities at Fenchuganj and Ghorasal, which are in operation, have been designed for complete utilisation of ammonia in the downstream product plants and as such they do not have provisions for excess production of ammonia. In fact, both the units have been experiencing constraints in ammonia production in recent past. The scope for increasing ammonia production through say, renovation of the plants (as in Fenchuganj) or improvements in operating techniques, even if exists, is assessed to be not on a substantial scale. Besides, the managements of the respective plants have revealed clear preference for utilising any increase in ammonia production in the downstream product plants, which currently suffer due to ammonia shortage, rather than divert the additional supplies for use elsewhere. In view of this, the Consultants consider that it will not be possible to secure the needed quantities of ammonia, or even a major part of it, from the operating plants in Bangladesh. The possibilities of augmenting ammonia production of these units by expansion of the ammonia plants say, by the addition of another train, are remote in view of the constraints experienced in utilities and the off-site facilities.

5.2.6 The Ashuganj plant, now in the final stages of execution, also has a urea plant matching with the ammonia production capacity and therefore, in the ordinary course there will be no surplus ammonia available for transfer. However, conceptually, ammonia synthesis gas equivalent to about 50 tonnes per day of ammonia might become available if the plant functioned normally after commissioning on account of the design construction in the synthesis section, but separate facilities would need to be established to convert this synthesis gas into ammonia. But assurance of the availability of surplus synthesis gas can be confirmed only after the plant is commissioned and stabilised - say, in about 3 years, and therefore, it may be premature to bank on this source at the present stage for ammonia supply.

5.2.7 Among the new plants under consideration, the China-aided Ghorasal - II project will also have a matching urea plant, and BCIC has clearly indicated that its location as well as the plant capacities are 'frozen', since the offer from China is a 'package' offer. There is, therefore, no possibility of ammonia from this source being made available for any other purpose. The other, the Chittagong Urea Fertilizer Project (CUFP) is also planned to have a urea plant downstream to match the ammonia plant capacity (986 tpd). The project authorities were disinclined to consider any proposal for lowering the urea plant capacity for the purpose of making available excess ammonia for the proposed schemes. However, assurance has been given that ammonia upto 72 tonnes per day can be made available with marginal modifications in the design of the project, to be incorporated before its implementation. The project, however, will not be in a position to spare any carbon dioxide and therefore, new facilities for the supply of carbon dioxide will need to be installed - by drawing on the flue gas of the steam generation plant of CUFP.

5.2.8 In the light of this assessment of the ammonia supply possibilities, the options available narrow down to two alternatives, viz.

(1) A captive ammonia plant of requisite capacity will need to be set up if the ammonium sulphate-soda ash (conventional) scheme is preferred for byproduct gypsum utilisation, since its total requirement of ammonia (133 tpd) is beyond the supply capability of the CUFP.

(2) For the manufacture of soda ash alone, the required ammonia can be drawn from the CUFP, even if the Dual Process route, with its high ammonia requirement, is adopted.

Locational Considerations

5.2.9 In view of the significant interaction between the source of ammonia supply and the location of the user industries due to the high costs of transport of ammonia, the production as well as use of ammonia in the proposed schemes needs to be considered integrally to arrive at the most economical choice. Locational studies undertaken by the Consultants (Parts IV and V) establish that for logistical reasons, any ammonium sulphate plant involving the use of phosphogypsum will need to be set up in Chittagong, in order to minimise the cost of raw phosphogypsum transport, which has a material impact on the cost of production of ammonium sulphate. It follows for the same reason that the soda ash unit based on the chalk available as byproduct in the ammonium sulphate process will also need to be set up in the vicinity of the ammonium sulphate unit in Chittagong. Since, as indicated above (Para 5.2.8), the required quantity of ammonia (133 tonnes) for this route cannot be met from any of the existing or planned ammonia plant facilities and a new captive ammonia unit is a pre-requisite, the production facilities for this scheme will entail the setting up of 3 main plants viz. -

(i) ammonium sulphate

(ii) soda ash (byproduct - chalk) and

(iii) ammonia plant (captive)

with necessary off-site and related facilities.

5.2.10 The vacant land available in the TSP complex area in Chittagong is not adequate to accommodate these plants, and no other suitable site is available in the vicinity. Hence the plants will have to be located at a site across the Karnaphuli river from North Patenga, adjoining the site proposed for the Chittagong Urea Fertilizer Project. Though this is a 'green-field' site at present, it will have the advantage of the area being 'opened up' by the planned CUF Project with which it can share several common facilities, including water and power. Considering the fact that the CUF Project is in a position to make available upto 72 tpd of surplus ammonia from its facilities, the Consultants envisage that this scheme will require the setting up of a captive ammonia plant of only 100 tpd; the balance could be procured from the adjacently located CUF Project. (since the cost of this ammonia, as will be seen later, cheaper).

Options for Soda Ash Plant Location

5.2.11 In addition to the above discussed byproduct chalk route, soda ash can be manufactured
(i) either based on limestone through the adoption of the conventional Solvay process or
(ii) through the Dual process, in which chalk or limestone is not used. These plants can be set up independently of the ammonium sulphate facilities and therefore, are relatively more 'footloose' for location purposes. The Consultants found (Part V) that Ghorasal offered itself as an alternative site for locating the Dual process soda ash plant. Thus, in all in addition to the byproduct chalk route, three alternative projects for indigenous manufacture of soda ash could be envisaged, viz. -

(i)	Chittagong location	-	based on classical solvay process using indigenous limestone
(ii)	Chittagong location	-	based on Dual process.

(iii) Ghorasal location - based on Dual process

5.2.12 The ammonia requirement of these 'independent' (i.e., not attached to the ammonium sulphate unit) soda ash units located in Chittagong could be met from the offer made by the Chittagong Urea Fertilizer Project Authorities. In case the project is located in Ghorasal, two alternatives for ammonia supply are possible ;

(i) by transporting ammonia from the CUF Project; and

(ii) by setting up a captive ammonia unit in Ghorasal itself to feed the soda ash plant

The choice will depend primarily on the delivered cost of ammonia from the alternative sources.

5.2.13 Thus, the alternative project proposals considered above and the identified sources of supply of ammonia for each of the schemes are tabulated in Table 5.3.

Table - 5.3

Sources of Supply of Ammonia

Alternative	Location	Production Scheme	Qty.of Ammonia Reqd. (Te/day)	Source of Supply of Ammonia
Alt.I	Chittagong	Ammonium Sulphate & Soda Ash (Solvay Process)byproduct chalk based	133	100 te from new captive plant & 33 te from CUF project
Alt.II	Chittagong	Soda Ash (Solvay Process) 'based on use of natural limestone	1	Total from CUF Project
Alt.III	Chittagong	Soda Ash (Dual Process)	68	--do--
Alt.IV	Ghorasal	--do--	68	From new captive plant to be set up in Ghorasal
Alt.V	Ghorasal	--do--	68	*

*Total from CUF Project with arrangement for ammonia transport to site.

Capital Cost of Captive Ammonia Plant

5.2.14 As seen in Table 5.3, two of the alternatives considered involve the installation of new captive ammonia facilities - in one case in Chittagong and in the other case, at Ghorasal. For purpose of study of relative costs and economics, in both the cases, the capacity of the plant is taken to be 100 tonnes/day and natural gas is assumed to be the feedstock. In Chittagong, as mentioned above, a site close to the CUF Project has been identified to locate the plant, and some of the facilities are assumed to be shared in common with the CUF Project and the plant is assumed to be closely integrated for power, water and other facilities with the related ammonium sulphate and soda ash plants constituting the complex. In Ghorasal, a site adjacent to the existing Ghorasal Urea Fertilizer Factory and contiguous to the site earmarked for the China-assisted Ghorasal II Project has been identified as suitable for setting up the proposed captive ammonia and related soda ash plants. The estimated capital cost of the ammonia plant and the related facilities respectively at the Chittagong and Ghorasal locations have been shown in Table 5.4. The scope of the project and the basis of estimate have been explained in Part - II.

Table - 5.4

Ammonia Plant Cost Estimates
(Capacity : 100 tpd)

(In $ Million)

	Item	Chittagong		Ghorasal	
		FC	Total	FC	Total
1.	Total Manufacturing Facilities	22.52	30.83	23.40	34.90
2.	Township & Public Buildings	1.90	3.40	1.90	3.40
3.	Spares	2.26	2.43	2.40	3.10
4.	Contingency	1.34	1.84	1.40	2.10
5.	Commissioning Expenses (Net)	-	0.60	-	
6.	Escalation	7.26	11.73	7.50	13.40
7.	Financing Charges	-	4.96	-	5.20
	Total :	35.28	55.79	36.60	62.10

FC = Foreign Exchange Cost

Cost of Ammonia Supply

5.2.15 Based on the above capital cost estimates, the cost of production of ammonia in the two plants has been worked out below :

	(In $/tonne)
Chittagong	303
Ghorasal	325

In comparison, the derived supply price of the additional 72 tonnes of ammonia in the Chittagong Urea Fertilizer Project, including a 12 per cent return on total capital, works out to $ 151 per tonne, - thus reflecting the high cost of production of ammonia in a sub-optimal sized plant. Even when ammonia from the CUF Project is transported to Ghorasal, the delivered cost of ammonia has been calculated at $ 154.33 per tonne - which is less than half of the cost of production in a locally established captive plant.

5.2.16 Since ammonia is only an intermediate input in the linked ammonium sulphate/soda ash plants, a comparison of capital estimates and production costs of ammonia plants alone may not conclusively indicate the most economical choice. A proper comparison to make, therefore, would be the total investment requirement of all the related plants together. The total investment requirements estimated for the alternative schemes discussed in Para 5.2.13 are given in Table 5.5.

Table - 5.5

Total Capital Cost Estimates of Ammonium Sulphate/Soda Ash Projects

(In $ Million)

Alternative	Location	Plants - Production Scheme	Estimated Total Capital Investment
Alt I	Chittagong	Ammonia/Ammonium Sulphate/Soda Ash	159 70
Alt II	Chittagong	Soda Ash(Limestone)	66.30
Alt III	Chittagong	Soda Ash (Dual) 1/	70.80
Alt IV	Ghorasal	Ammonia/Soda Ash (Dual)	143.10
Alt V	Ghorasal	Soda Ash (Dual) 2/	90.00

1/ Ammonia procured from CUF Project

2/ Ammonia transported from CUF Project

Conclusion

5.2.17 To sum up, the following conclusions emerge from the study :

A If the ammonium sulphate route is chosen for phosphogypsum utilisation, then a captive ammonia plant will become necessary to supplement (after procuring part of the needs from the CUF Project) the ammonia requirements of the process.

The entire complex is best located in the site adjoining the planned Chittagong Urea Fertilizer Project in the Middle Island area of Chittagong and share with it the possible common facilities.

B The ammonia requirement of the soda ash project considered alone is most economically met by drawing on the surplus available from the planned Chittagong Urea Fertilizer Project, which is adequate for an economical sized plant considered in the study.

C In case the choice of location of the soda ash plant falls on Ghorasal, it will still be cheaper to transport ammonia from the CUF Project for meeting its needs, compared to local production in a captive plant.

5.3 Production of Cement Clinker From Phosphogypsum

5.3.1 Phosphogypsum is produced in the wet process phosphoric acid plants, when the calcium values in the rock are converted into insoluble calcium sulphate for facility of removal by simple filtration. Nearabout 4 to 5 tonnes of byproduct gypsum are obtained per tonne of P_2O_5 produced, depending on the source and characteristics of the phosphate rock used. This byproduct gypsum is considered, for the most part, a waste product, and presently, only an insignificant proportion of the 80-100 million tonnes being produced annually in the world is put to any commercial use. One major reason for this is that most of the 50-odd impurities that could be present in the rock are carried on into the phosphogypsum, which profoundly affect its crystalline properties as well as the characteristics of the products made out of it. The need for a purification step generally renders the use of byproduct gypsum unattractive in competition with natural gypsum.

Principal Industrial Uses of Phosphogypsum

5.3.2 Once purified to rid of the injurious impurities 'inherited' from the phosphate rock, phosphogypsum can be used as a substitute for natural gypsum in nearly all its applications. In particular, under current state of commercial technology, there are three principal uses in which its utilisation can be considered, viz. -

(i) Production of cement clinker & sulphuric acid

(ii) Manufacture of ammonium sulphate, and

(iii) Conversion into plaster and plaster products.

The last two alternatives are discussed in the subsequent sections.

Merit of the Cement Clinker Route

5.3.3 The cement clinker - sulphuric acid route has the merit of regenerating a major proportion of the sulphuric acid used in the digestion of the phosphate rock in the phosphoric acid production process, besides finding a solution to the problem of waste gypsum disposal. The reduction in the sulphur requirement of the sulphuric acid plant from the use of the process could be as high as around 80 per cent. The process however, has not attracted worldwide application - despite having been commercialised many years ago (Para 5.3.6) - primarily due to two reasons : First, the route was essentially seen as a sulphuric acid process and seldom did the acid producers develop interest in cement manufacture and vice versa. Purely as a sulphuric acid process, it was not attractive since it required a considerably more expensive plant and involved high energy consumption. In a normal sulphur-based sulphuric acid plant, for instance, the energy required to operate the plant is largely derived from sulphur burning, while in any gypsum-based plant, a large input of external energy is required for drying, calcining and decomposing gypsum, etc. Secondly, the relatively low ruling world prices of cement and sulphur did not offer much incentive to build plants on this process. Historically, the fortunes of this process, therefore, tended to move directly with the trend of world sulphur prices.

Relevance to Bangladesh

5.3.4 For a country like Bangladesh, however, the process route still holds attraction in view of the exceptional circumstances in its favour viz.-

(i) Bangladesh has no indigenous deposits of sulphur or pyrites ores and, therefore, sulphur needs require to be met by imports only. The use of this technology can result in a major import substitution of the sulphur requirement of the existing sulphuric acid plant. The consequent reduction in annual sulphur import is assessed at 32,500 tonnes. With the sharp rise in the world sulphur prices in recent months, the reduction in import bill could be significant.

(ii) Bangladesh is heavily deficit in cement production. The country has limited resources of easily mineable limestone deposits and, therefore, does not have a firm base for the development of cement industry. The choice of this process-route can increase the indigenous production capacity of cement clinker.

(iii) The location of a cement clinker grinding factory close to the gypsum source - the TSP Complex - based on imported clinker obviates the need for investment on a clinker grinding plant. The adoption of this process can help reduce the cement clinker imports by about one-third.

(iv) The domestic prices of cement in Bangladesh are high enough (around $ 93 per tonne ex-factory) to provide a reasonably attractive base-price for the cement clinker produced.

(v) Reasonably cheap fuel in the form of low priced natural gas from the Bakhrabad field is expected to be available for the project, since plans for carrying the gas to Chittagong are being firmed up. Low priced fuel by keeping down the cost of energy input, improves significantly the projects attractiveness. Alternatively, domestically produced furnace oil, which is surplus to the country or refinery off-gas from the adjoining oil refinery (being largely flared now) can be made use of at reasonably low fuel costs.

Considering these favourable factors, the cement clinker sulphuric acid route projects itself as one of the attractive methods of economic utilisation of phosphogypsum.

5.3.5 That there are not many plants round the world based on the process need not be a cause for undue worry for Bangladesh, since as will be seen later (Part III), the process is well-proven and a commercial plant of identical size is already working successfully at Phalaborwa in South Africa, besides the Chemie Linz Plant at Linz. Bangladesh could very well draw on the experience of these plants in the execution of the project.

The Process Selection

5.3.6 The basic process, popularly known as the Muller-Kuhne process, was originally developed with natural gypsum/anhydrite feed during World War I in Germany. A number of plants based on this process route came into operation in the subsequent decades. Efforts to adopt the process for use of phosphogypsum was made in late sixties and was stimulated by the high levels of world sulphur prices. Most of the research work in this area was done in UK by the Building Research Establishment, in Austria by OSW AG (Now Chemie-Linz AG) and in GDR by VEB Chemiewerk Coswig. Both OSW (Now Chemie-Linz) and Coswig have now licensable knowhow for the process. Of the two, the Consultants feel that Chemie Linz (OSW Process) has better experience, since there is one full scale commercial plant exclusively using phosphogypsum and based on the Chemie Linz process operating satisfactorily at Phalaborwa in South Africa (Part III Annexure III-4). The plant has been designed by K. .pps Chemieanlagenbau (now Krupp-Koppers) and was commissioned in 1972. Krupps have carried out some design modifications (e.g. a counter current heat exchanger at the feed-end of the rotary kiln), a feature unique to Krupps design, in the process scheme in the interest of improving its energy efficiency. In view of these considerations, the Consultants recommend Chemie-Linz (OSW) process for Bangladesh.

Quality of Phosphogypsum

5.3.7 The principal snag in the use of phosphogypsum in lieu of natural gypsum in the process has been that the byproduct gypsum obtained from the wet process phosphoric acid plants contain a wide range of impurities, which are not normally found in the natural calcium sulphate. However, while most of the impurities present in the phosphogypsum either do not produce any definable adverse effects or are present in too low concentrations to cause any hindrance in the cement-sulphuric acid process, three constituents cause concern, viz.-

(i) moisture

(ii) residual phosphate, and

(iii) residual fluoride.

Problem of Moisture

5.3.8 In the Muller-Kuhne process, raw materials have to be dried if moist, before feeding into the kiln. The byproduct gypsum generally contains substantially high moisture and as a result the amount of thermal energy requirement increases with the use of phosphogypsum. Except for this, the higher moisture content has no adverse effect on the process. However, the phosphoric acid processes which give waste gypsum with lower water of crystallisation are inherently more suitable for being linked to the cement-sulphuric acid plant than the conventional dihydrate process plants.

Influence of Phosphate

5.3.9 The phosphate content in the byproduct gypsum remains in three forms :

(i) in the form of unreacted particles of phosphate rock

(ii) in the form of free phosphoric acid, and

(iii) in the soluble form in the interstices of the gypsum filter cake or co-crystallised and occluded in the agglomerates of crystals.

The exact amount of phosphate content can vary widely depending on the composition and reactivity of the phosphate rock on the one hand and the type of phosphoric acid process and its operative conditions, on the other. Since very little of the phosphate in the phosphogypsum is volatalised in the kiln, it is passed on to the cement clinker and thence, to cement. Phosphate in cement tends to lower the initial strength of cement (Part III,Table 4.1). Generally, phosphogypsum from the hemihydrate - dihydrate phosphoric acid process (e.g. New Nissan) or the dihydrate - hemihydrate (e.g. Central Prayon) process contains considerably less phosphate (because of better P_2O_5 recovery) than the waste gypsum from the conventional dihydrate (e.g. PA-I) type of process.

Effect of Fluorine

5.3.10 The exact proportion of fluorine residue in the phosphogypsum varies according to the origin of the phosphate rock. However, unlike phosphate, the fluorine content of phosphogypsum is lowered during calcination. It is estimated that, depending on the operating conditions, upto 40 per cent of the F is released as gaseous fluorine compounds and mixes with the sulphur dioxide kiln gas. Fluorine is extremely damaging to contact sulphuric acid plant catalysts, attacking both the silica support and the active vanadium component and has the effect of lowering the melting point of the materials in the kiln. There is also a possibility that F may cause the protective coating on the kiln to be eroded with consequent reduction in refractory life. Besides, the residual fluoride and sulphate content in the clinker together is believed to adversely affect the hydraulicity of the cement in a rather unpredictable way. For these reasons it is considered desirable to restrict the fluorine content in the phosphogypsum feed to safe levels - of about 0.15 per cent.

Useability of Phosphogypsum

5.3.11 Of the two wet process phosphoric acid plants (PA-I & PA-II) operating at the TSP Complex in Chittagong, phosphoric acid plant II (PA-II) is a New Nissan hemihydrate-dihydrate plant. As mentioned earlier, the phosphogypsum produced in a hemihydrate-dihydrate plant is less contaminated with 'injurious' impurities such as phosphates and fluorine due to the better P_2O_5 recovery, recrystallisation of calcium sulphate, etc. in the process. The other phosphoric acid plant (PA-I) is based on the conventional dihydrate process and the gypsum obtained in the plant has a higher percentage of phosphates and fluorides. It cannot, therefore, be directly used in the cement clinker kiln without purification. The analysis of samples of phosphogypsum obtained from both PA-I and PA-II plants with a feed of Jordan rock of fairly high fluoride content (around 3.5 per cent) is shown in Table 5.6.

Table - 5.6

Chemical Composition of Phosphogypsum

Constitutents		Per cent	
		PA - I	PA - II
1		2	3
Total P_2O_5		0.65	0.38
Water Soluble	P_2O_5	0.25	0.15
	CaO	31.26	31.69
	SO_3	44.75	45.32
	SiO_2	1.30	0.64
Fe_2O_3		0.012	0.10
Al_2O_3		0.008	0.008
MgO		-	-
CO_2		-	-
F		0.40	0.32
Water of Crystallization		18.82	19.29
Acidity (as $CaCO_3$)		0.53	0.26
Organic matter		0.96	1.02
Water Soluble Chloride		0.015	0.013
Size of Crystals:	Length	0.01 - 0.10 mm	0.01 - 0.40 mm
	Breadth	0.01 - 0.03 mm	0.01 - 0.10 mm

P.S : Moisture content : 20 - 27 per cent as in the gyp. um yard.

5.3.12 As may be seen from the table, phosphogypsum from PA-II contains less than 0.40 per cent total P_2O_5 and around 0.30 per cent F - the permissible upper limits prescribed by reputed process licensors, such as Chemie Linz. Though the normal upper limit prescribed for F is 0.15 to 0.20 per cent, a limit upto 0.30 per cent is considered permissible, since F is partly removed during drying and calcination and can be treated by adding active silica during the rock digestion stage. Chemie Linz have also developed two procedures for the control of P_2O_5 and F in excess of the specified limits of 0.5 per cent and 0.15 per cent respectively. In the first, wet phosphogypsum is mixed before calcination with sulphuric acid and hydrated silica, which releases the fluorine and enables the phosphates to be washed out of the calcium sulphate with water. The second method controls only the F content and consists in adding active silica to the reaction system of the phosphoric acid plant.

Plant Capacities

5.3.13 It is mentioned earlier that the assessed availability of waste gypsum from PA-II plant from its expected normal operation on assured long term basis is 200,000 tonnes per year. In view of the fact that this phosphogypsum can be directly used (after simple washing) in the cement clinker-sulphuric acid process (without the need for an elaborate purification step), the Consultants propose that phosphogypsum from PA-II plant alone be considered for the production of cement clinker. The gypsum expected to be available can support a plant of 325 tpd cement clinker capacity - which is identical to the Phalaborwa plant. No major modifications to the PA-II plant is considered necessary to enable utilisation of this phosphogypsum for cement clinker - except for providing feeding devices to add active silica to the rock digestion vessel to bring down the F content to acceptable limits.

5.3.14 A cement clinker plant of 325 tpd capacity will yield sulphur dioxide gas equivalent to 325 tpd sulphuric acid (98 per cent), but the existing sulphuric acid plant, where the gas will be processed, has a capacity of 400 tpd - which is the requirement of the downstream phosphoric acid plant. Hence, in order to raise the sulphuric acid production to 400 tpd, it will be necessary to burn elemental sulphur in the kiln to raise the SO_2 concentration, so that the sulphuric acid production does not suffer. Only some marginal modifications in the sulphuric acid plant will be necessary to process the kiln gases, such as provision of heat exchangers to raise the temperature of inlet gas to converter and provision of a service boiler to supplement steam requirements.

5.3.15 Though a cement clinker plant of 325 tonnes per day capacity, for utilisation of 200,000 tonnes per year of phosphogypsum produced by the PA-II plant, will be a relatively small unit for cement clinker by the present day trend, the Consultants are of the opinion, and it is confirmed by other experts in the field, that the plant is within the economic-size range. The Phalaborwa plant in South Africa is of identical capacity, which allows the design and experience of that plant to be nearly duplicated in Bangladesh. In order to meet the full requirement of sulphuric acid plant, the sulphuric acid capacity will, however, have to be maintained at 400 tpd by burning, as discussed earlier, elemental sulphur in the kiln. Hence the effective plant capacities proposed are :

(i)	Cement clinker	:	325 te/day
(ii)	Sulphuric Acid	:	400 te/day

Raw Materials Supply

5.3.16 Nearly all the other important raw material inputs required for the scheme, except coke, are available indigenously in Bangladesh. Sand from the huge dunes found on the opposite side of the river Karnaphuli was found to be suitable. Clay is available in plenty around Chittagong itself. Laterite deposits have been located at a distance of about 40 Km north of Chittagong. Though no chemical analysis of the deposits have been made, the Consultants have been assured by the Geological Survey of Bangladesh that laterite supply of requisite analysis within Bangladesh to the extent of around 3000 te/year may not be a problem. Limestone, needed only in small quantities, can be procured from within Bangladesh from existing sources, such as the Baglibazar mines.

5.3.17 Coke, needed as a reducing agent to decompose calcium sulphate will, however, be required to be imported. The annual requirement is assessed at about 9400 tonnes. Even coke fines containing not more than 5 per cent volatiles can be used. Bangladesh is presently importing around 20,000 tonnes per year of mainly metallurgical coke from world sources and no difficulty is foreseen in importing the additional requirement for the proposed scheme. To minimise input cost,however, it may be worthwhile to explore thepossibility of procuring coke fines from a neighbouring country such as India, with which Bangladesh has an agreement for the supply of around 450,000 tonnes per year of coal. Chemie Linz have confirmed the Consultants' preliminary finding that it might be possible to use anthracite of less than 5 per cent volatile matter content in the process. This needs, however, to be 'confirmed by a comprehensive test'. The availability of anthracite coal is expected to be far easier, besides the cost being about one-fourth of that of coke.

Location

5.3.18 In view of the close linkages with the existing second (Hitachi) train of the TSP complex, the proposed cement clinker plant will require to be located within the TSP factory campus, close to both gypsum source and the Sulphuric Acid II plant for proper integration with existing facilities. This will also be close to the cement clinker grinding factory of BMEDC and facilitate delivery of the clinker produced to the grinding unit. The Consultants have identified a plot of vacant land of about 7.5 acres lying next to the gypsum pond in the TSP Complex, which will be adequate for the purpose - with some marginal encroachment on the existing gypsum pond. The plot is about 400 metres from the gypsum discharge point of the PA-II plant. The Sulphuric Acid - II plant will be almost adjacent to the plot. The details of location and accessibility are given in Part III (Drawing 11).

Capital Investment

5.3.19 The estimated capital cost of the project, as conceived above, is shown in Table 5.7.

Table - 5.7

Capital Cost Estimates of Cement Clinker - Sulphuric Acid Project

($ '000)

Item 1		F.C. 2	I.C. 3	Total 4
A.	Manufacturing Facilities			
(i)	Land Development	-	142.7	142.7
(ii)	Erected Cost of Main Plant	18966.0	8557.0	27523.0
(iii)	Off-sites & Auxiliaries	837.4	503.6	1341.0
(iv)	Project Management	-	400.0	400.0
(v)	Erection Tools & Tackles	-	40.0	40.0
B.	Other Fund Requirements			
(vi)	Working capital	-	854.0	854.0
(vii)	Spares	1235.9	413.7	1649.6
(viii)	Contingency	2104.9	1091.1	3196.0
(ix)	Escalation	3703.1	2880.5	6583.6
(x)	Financing charges	-	3367.2	3367.2
(xi)	Commissioning Expenses (Net)	-	(-)610.3	(-)610.3
Total Capital Outlay		26847.3	17639.5	44486.8

5.3.20 The financing charges are based on the assumption that the entire foreign component of the capital is to be treated as loan and the entire local currency expenditure will be treated as equity in accordance with the current practice in Bangladesh. The interest on loan capital is assumed to be 10 per cent.

Cost of Production of Clinker

5.3.21 The operating cost of the plant varies significantly on whether natural gas or an alternate fuel is used and whether coke or coke fine is used in the process. The costs of production of clinker under the different alternatives and after giving credit for SO_2 gas passed on to the sulphuric acid plant at roughly the equivalent of the price of sulphur required to produce the same volume of SO_2 gas in the existing facilities (with an allocated notional processing charge) is shown in Table 5.9.

Table 5.9

Cost of Production of Cement Clinker

		($ per tonne at 100 per cent production level)
A.	With use of natural gas and coke	44.00
B.	With use of natural gas and coke fines	31.20
C.	With use of fuel oil and coke	58.80
D.	With use of fuel oil and coke fines	46.60

Return on Capital

5.3.22 Cement and clinker prices have been rising quite sharply in recent period, mainly reflecting the higher fuel costs and the expansion of demand, besides the influence of world inflation. The Consultants estimate that the landed cost of cement clinker at Chittagong in future will not be lower than $ 65/tonne. If this is treated as the transfer priceof clinker produced to the grinding unit, the Project is expected to yield the following returns on the capital employed :

A.	Based on natural gas and coke	7.6 per cent
B.	Based on natural gas and coke fine	10.4 per cent
C.	Based on fuel oil and coke	4.4 per cent
D.	Based on fuel oil and coke fine	7.1 per cent

5.2.23 The Internal Rate of Return of the Project Works out as follows :

A.	Based on natural gas and coke	10.5 per cent
B.	Based on natural gas and coke fine	13.1 per cent
C.	Based on fuel oil and coke	7.1 per cent
D.	Based on fuel oil and coke fine	9.8 per cent

The Project's implementation will result, as indicated earlier, in a saving of around 32,500 tonnes of sulphur per year - roughly about 80 per cent of the present total requirement. The cement quality produced will conform to the internationally accepted standards for Portland cement.

5.3.24 To sum up, the cement clinker route offers itself as one of the viable and fairly attractive methods of utilising the bulk of the phosphogypsum produced. The process is established and proved. In particular, the Chemie Linz (OSW) process has been tested in commercial scale plants. In view of the significant economies available, the plant should be based on natural gas as fuel and, if available, on the use of coke fine as the reducing agent. Considering the experience and the improvements in design carried out at the Phalaborwa plant, Krupp-Koppers GmbH may be engaged to design, engineer erect and commission the plant.

5.4 Production of Ammonium Sulphate

5.4.1 Utilisation in the manufacture of ammonium sulphate - which, next to urea, is the most popular nitrogen fertilizer produced in the world - is one of the feasible, and under certain circumstances, attractive methods of phosphogypsum disposal in an ecologically satisfactory manner. There are already a number of plants in operation as well as under construction for the production of ammonium sulphate based on the phosphogypsum route. In countries where the need and favourable conditions exist, chalk ($CaCO_3$) available as byproduct in the sulphate process can be put to further use in the production of soda ash (through the Solvay process).

Problems of Location

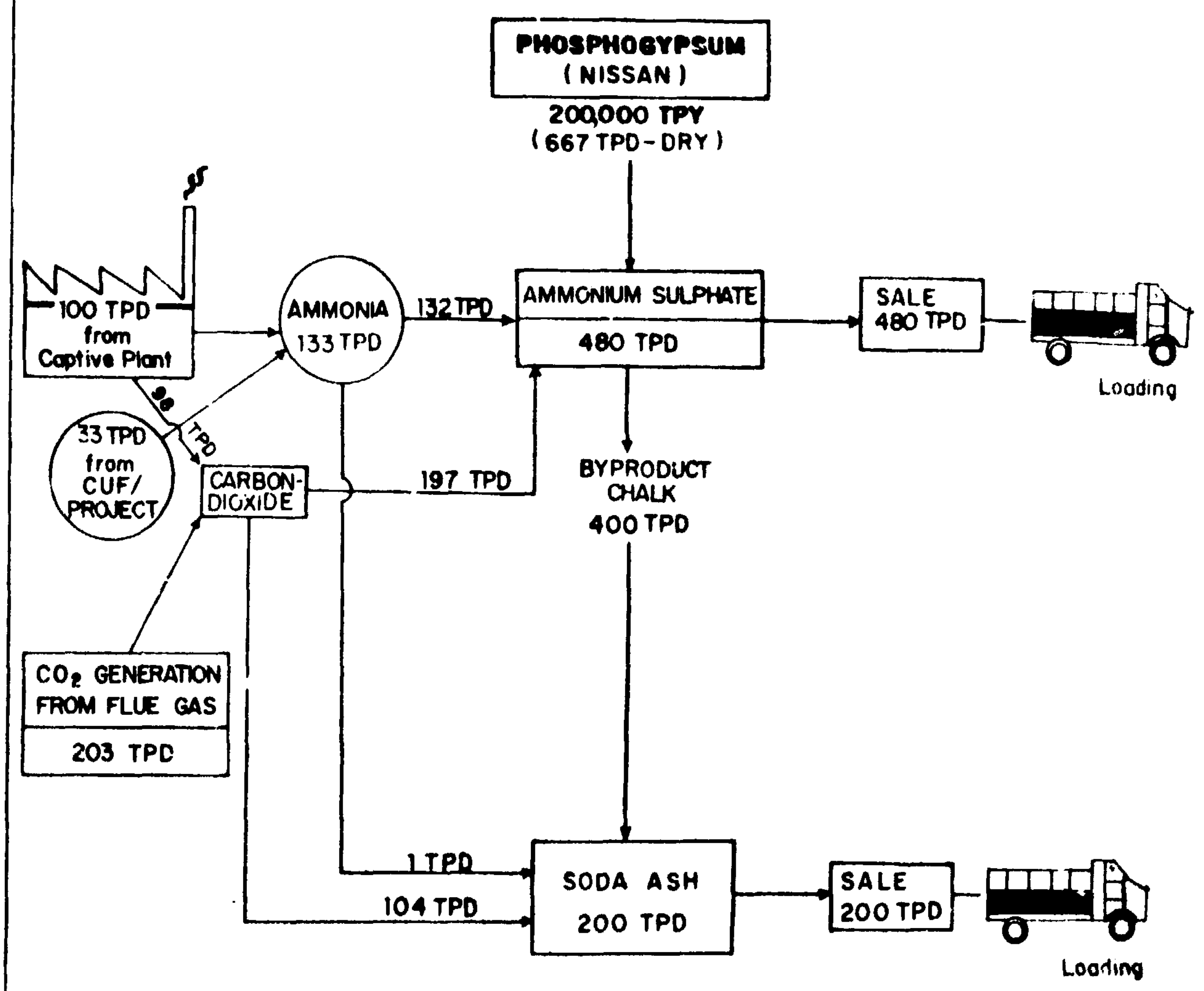
5.4.2 The ammonium sulphate route of gypsum disposal requires fairly sizeable quantities of ammonia and carbondioxide, which, for the scheme to be economical will need to come from an optimal sized plant. On account of the high material index - roughtly about 1.4 tonne of phosphogypsum per tonne of sulphate - and the problems involved in handling it, transport of phosphogypsum to another site, where ammonia and carbon dioxide may be available, is both inconvenient and expensive. For similar reasons, movement of ammonia and carbon dioxide over long distances to the gypsum source is either impractical or quite costly. It is for these reasons that the ammonium sulphate route can be conveniently put into operation only in locations where byproduct gypsum, ammonia and carbon dioxide are available within easy reach of each other.

5.4.3 The problem in Bangladesh is compounded by the fact that surplus ammonia - and carbon dioxide - in required quantities is not available for use in the ammonium sulphate process from any of the operating ammonia plants. As seen earlier, it is not easy to get supplies on assured basis from the planned new plants either, particularly since the requirements are fairly large. The utilisation of 200,000 tonnes/year of phosphogypsum from the Nissan process phosphoric acid plant (which alone can be directly used without an elaborate purification system to get rid of the interfering impurities such as P_2O_5, fluorine and organic matters beyond permissible limits) will involve an ammonium sulphate plant of 480 tonnes/day capacity. This capacity is too small to permit the setting up of an economic sized - by modern standards - captive ammonia plant to meet the ammonia needs of the process. The carbon dioxide availability is an even more difficult constraint due to composition of feedstock natural gas (over 95 per cent methane). For these reasons, the conditions for the adoption of this route for phosphogypsum utilisation in Bangladesh are not propitious. However, a project scheme based on the utilisation of 200,000 tpy of phosphogypsum in the ammonium sulphate manufacture has been worked out for providing a basis for comparative evaluation.

Input Supply

5.4.4 As seen earlier, the ammonia requirement of a sulphate plant of 480 tpd capacity is about 132 tpd (Para 5.2.4 above). If a soda ash plant is established to make use of the byproduct chalk (through Solvay process), one tpd of ammonia will be needed additionally, raising the total requirement to 133 tpd. The total carbon dioxide requirement will be 197 tpd. For

AMMONIUM SULPHATE - SODA ASH SCHEME



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DRAWING NO. I - 2

reasons explained earlier, it will be necessary to set up a separate ammonia plant to captively produce at least 100 tpd of ammonia for the purpose of feeding the sulphate plant. The balance of 32 tonnes can, however, be procured from the Chittagong Urea Fertilizer Project. The shortfall in carbon dioxide will, however, need to be obtained by recovering CO_2 from the gases of the steam generation unit of the CUF Project. The other major raw material, viz. sulphuric acid needed at the rate of about 16 tpd can be procured from the TSP Complex itself. Natural gas, which is expected to be available in Chittagong in the near future will be the most economical energy source.

Gypsum Transport

5.4.5 The entire complex covering the captive ammonia, ammonium sulphate and the byproduct chalk-based soda ash plants can be located in a site adjacent to the CUF Project site in the Chittagong Middle Island area. In that case, byproduct gypsum will need to be transported across the river Karnaphuli from the TSP Complex site at the rate of about 840 tonnes of wet gypsum per day. Since wet gypsum is not convenient to handle, and with a view to avoiding multiple handling, barge transport to move the gypsum is envisaged. Gypsum will be loaded on to 7 tonne trailers at the TSP Complex, which will then be hauled to the jetty, where it will be rolled on to a barge. Each barge will carry five such trailers to the opposite bank, from where the trailers will again be hauled to the factory gypsum yard and emptied. In the meantime, the empty trailers waiting at the jetty will be carried back by the barge on the return journey. This arrangement will require, however, construction of two new jetties - one (fresh) at the TSP Complex and the other at the proposed factory site.

Capital Investment Requirement

5.4.6 Since the ammonium sulphate project is envisaged to be part of a complex of several plants with common facilities, the investment requirement of the ammonium sulphate plant will consist of the capital needed for the plant proper and the allocated investment cost of the common facilities. The estimated total capital outlay needed for the Project on this basis is shown in Table 5.10.

Table - 5.10

Capital Investment For Ammonium Sulphate Plant

($ '000)

Details		FC	IC	Total
A.	Manufacturing Facilities			
	1. Main Plants	9100.0	2600.0	11700.0
	2. Off-sites and Jetty	9090.0	3390.0	12480.0
	3. Site Development	60.0	150.0	210.0
	4. Spares	1210.0	100.0	1310.0
	5. Project Management	730.0	2440.0	3170.0
	Sub Total :	20190.0	8680.0	28870.0
B.	Other Fund Requirements			
	6. Township & other Public Buildings	2000.0	1400.0	3400.0
	7. Working Capital	-	2200.0	2200.0
	8. Commissioning Expenses	-	100.0	100.0
	9. Contingency	1110.0	600.0	1710.0
	10. Escalation	5800.0	5250.0	11050.0
	11. Financing Charges	-	4090.0	4090.0
	Total Investment	29100.0	22320.0	51420.0

Production Cost

5.4.7 The cost of production of ammonium sulphate, worked out on the basis of the above investment estimates, 100 per cent production level and 300 operating days, works out to $ 158.00 per tonne. No credit is given for byproduct chalk. The cost includes notional allocated cost of common facilities such as utilities, overheads, depreciation of common plants, etc. as well as interest charges and selling expenses. The interest rate is assumed at 10 per cent and the plant is assumed to depreciate over a period of 12 years.

Profitability of the Project

5.4.8 The selling prices of all fertilizers, including ammonium sulphate are subsidised in Bangladesh, the subsidy element on the Fenchuganj's product being around TK 1085 ($ 72) per tonne in 1978-79. A fair basis to evaluate the project will be to determine the market price of ammonium sulphate. Taking into account the international prices at which sales of ammonium sulphate have been effected recently, the Consultants estimate that the landed cost of ammonium sulphate in Bangladesh will not be lower than $ 101 per tonne. On the basis of this price the project shows a negative return to the extent of around 13 per cent on the total capital employed.

5.4.9 The project is not financially viable primarily due to three factors, viz. -

(i) high cost of ammonia, particularly on account of captive generation in a small plant;

(ii) exclusive generation of carbon dioxide since no supply from an external source is possible and

(iii) the need for transport of gypsum across the river to the plant site, which adds to the processing costs.

5.5 Manufacture of Soda Ash

5.5.1 Soda ash - Sodium Carbonate - is one of the low-cost, reasonably pure soluble alkalies and its manufacture constitutes one of the largest basic chemical industries in the world. It is extensively used in a large number of industries. Indicative of its importance, the consumption of soda ash is often regarded, like sulphuric acid, as an index of a country's state of industrial development.

Demand for Soda Ash

5.5.2 Soda ash is used in the manufacture of a number of products in Bangladesh, such as low-priced soaps, glassware, silicates, and paper and pulp. Besides, a large proportion of it is used as a household cleaning agent and in non-powered laundering by the local washermen. Though the statistics available are scanty and not very reliable, the present demand in the country is estimated at around 30,000 tpy. Soda ash is not produced at present in Bangladesh and in the absence of local production, the consumption is being fed by imports entirely. The restrictive import policy followed by the Government has generally tended to prune demand and on the evidence of periodical scarcity conditions in the market, one can surmise the existence of substantial unsatisfied demand. Given in the freer supply, the demand is projected to increase to around 49,000 tpy by 1985 - adequate to support a viable sized plant.

Process Options

5.5.3 There are two major, technically distinct, process routes in commercial use for the manufacture of soda ash. Both are based on salt as principal raw material - though varying in the rate of consumption. The first one, the standard 'Ammonia-Solvay' process, or more popularly known as the classical Solvay process, was for a long time the only process commercially used throughout the world. The other, 'Dual Process' sometimes referred to as the 'Modified Solvay' was the result of vigorous development work done in Japan and came into commercial application fairly recently. The principal difference between the two processes lies in the fact that in the Dual Process, ammonium chloride, a nitrogenous fertilizer, is produced as a co-product with soda ash in equal quantities.

5.5.4 The principal raw materials required for the Solvay process are principally, salt, limestone (or chalk) and very small quantities of ammonia for 'make-up'. The Dual process does not require limestone (or chalk), but its ammonia requirements are high, since the ammonia used is 'fixed-up' as ammonium chloride and therefore is not available for recycling (Table 5.2). It also requires carbon dioxide in fairly ample proportions from an exogenous source. Technically, either of these process-route plants can be set up in Bangladesh, though some constraints exist in each case. However, as will be seen later, the expansion of salt production on modern lines within the country to ensure adequacy of supplies and production of industrial grade quality is an essential pre-requisite for the development of a viable soda ash industry within the country.

Constraint of Ammonia Supply

5.5.5 The process selection options are somewhat blurred in Bangladesh by the raw material supply constraints, principally with regard to ammonia. Normally, a plant based on the utilisation of by-product chalk available from the gypsum-based ammonium sulphate plant would have commended itself as an ideal scheme, since

(i) it would have taken care of the problem of phosphogypsum disposal (in sulphate production),

(ii) would have involved utilisation of a waste product (byproduct chalk) with no ecologically hazardous residue left,

(iii) would have required, as will be seen later, the least capital outlay, and

(iv) made no demands on the country's meagre limestone resources.

But the scheme suffers, as examined earlier (Para 5.2.8) from the infirmity that the ammonia requirements of the ammonium sulphate plant (needed to provide the byproduct chalk) are too large to be met from the surplus of any of the existing or proposed ammonia plants in the country. With captive ammonia production the ammonium sulphate scheme turns out to be non-viable. However, for comparison of overall viability, three schemes have been examined here, viz. -

(i) Byproduct chalk (Solvay Process)

(ii) Limestone route (Solvay Process)

(iii) Dual Process route.

Disposal of Ammonium Chloride

5.5.6 For a Dual process plant of minimum viable capacity, however, the ammonia supply promised by the Chittagong Urea Fertilizer Project Authorities would be adequate (Para 5.2.13). If the Dual process route is chosen, market will, however, have to be found for the ammonium chloride produced as co-product in equal quantities with soda ash. Study made by the Consultants, however, indicated that the use of ammonium chloride as nitrogenous fertilizer in Bangladesh will not pose any problem. Bangladesh has fairly extensive well-drained, alkaline as well as slightly acidic, soils with high lime content, where ammonium chloride could be used as efficaciously as any other nitrogenous fertilizer, including urea. The ammonium chloride likely to be available from the soda ash plant can hardly meet the nitrogen consumption of five districts with such alkaline type soils in Bangladesh.

Locations of Units

5.5.7 A detailed survey of five prospective locations viz. Chittagong, Chandpur (Shatnol), Ghorasal, Ashuganj and Fenchuganj was made by the Consultants for the choice of an optimal centre for the setting up of the soda ash plant. Their relative merits were evaluated chiefly in consideration of the following factors :

(i) Availability of and proximity to raw materials and scope for effluent disposal.

(ii) Situational advantages and infrastructures.

(iii) Construction costs

(iv) Expected cost of production

(v) Costs of distribution of finished products, and

(vi) Regional development and incentives.

The evaluation indicated that Chittagong was the most suitable location for both Solvay and Dual process plants, with Ghorasal ranking next in respect of the Dual process soda ash plant only. In Chittagong the project can be set up in the site adjacent to the Chittagong Urea Fertilizer Project - so that the required ammonia and flue gas for carbon dioxide generation can be drawn conveniently from the CUFP. In the case of Ghorasal a suitable site in the vicinity of the existing Ghorasal Urea Fertilizer Project has been identified as suitable.

Optimal Plant Capacity

5.5.8 In respect of both classical Solvay and Dual process routes, the technological limits to the stream size of a soda ash plant is generally set by the size of the carbonating towers, where the precipitation of sodium bicarbonate takes place. Its reaction rate is slow which requires large-sized towers. Since for higher capacities multiple units are used, no conspicuous advantages accrue from large capacity soda ash plants in terms of the economies of scale. Similarly, it has also not been possible to reduce below a minimum size the diameter of the carbonating towers and calciners for plants lower than 200 tpd capacity. Thus 200 tpd is generally considered the minimum viable capacity for a soda ash plant. A plant of this capacity does not suffer much in comparison to larger sized plants. The projected size of demand for soda ash within Bangladesh (Para 5.5.2) also indicates a plant of this capacity.

Alternatives Considered

5.5.9 Taking into account the process alternatives (Solvay - limestone/byproduct chalk and Dual), location alternatives (Chittagong, Ghorasal) and raw material supply (principaly ammonia) possibilities (captive, CUF Project), five different alternatives were studied in depth for arriving at the most economical choice viz.-

A. Chittagong Location

Alternative I	Solvay process - based on byproduct chalk
Alternative II	Solvay process - based on possible supply of indigenous limestone
Alternative III	Dual process - based on ammonia supply from CUF Project.

B. Ghorasal Location

Alternative IV	Dual process - based on inplant generation of ammonia
Alternative V	Dual process - based on transport of ammonia from CUF Project.

Capital Outlay

5.5.10 The investment requirements of the five alternatives discussed above are summarised in Table 5.11. As mentioned earlier, in two cases (Alternative I and IV) where the soda ash plant forms part of a larger complex, the capital costs in respect of common facilities have been somewhat arbitrarily allocated between the different plants involved in the schemes.

Table 5.11

Summary of Erected Soda Ash Plant Cost Estimates

(Cost $ Million)

			Capital Cost		
Alternative	Feature	Process	FC	LC	Total
Alt. I	Byproduct Chalk	Solvay	27.42	25.02	52.49
Alt. II	Limestone	Solvay	33.50	32.80	66.30
Alt. III	NH_3 from CUFP	Dual	37.50	33.30	70.80
Alt. IV	Captive NH_3	Dual	41.00	40.00	81.00
Alt. V	NH_3 from CUFP	Dual	46.30	43.70	90.00

FC : Foreign Exchange Cost

LC : Local Currency Expenditure

Cost of Production

5.5.11 The cost of production of soda ash under the different alternatives on the basis of 300 operating days per year and 100 per cent production level, works out as shown in Table 5.12.

Table - 5.12

Cost of Production of Soda Ash

		($/tonne)
Alt. I	(Byproduct Chalk - Solvay) Chittagong Location :	217
Alt.II	(Limestone - Solvay) Chittagong Location :	284
Alt.III	(Dual NH_3 from CUF) Chittagong Location :	202
Alt.IV	(Dual, Captive NH_3,- Ghorasal)	260
Alt.V	(Dual, NH_3 from CUFP, Ghorasal)	232

(Details are shown in Part-V)

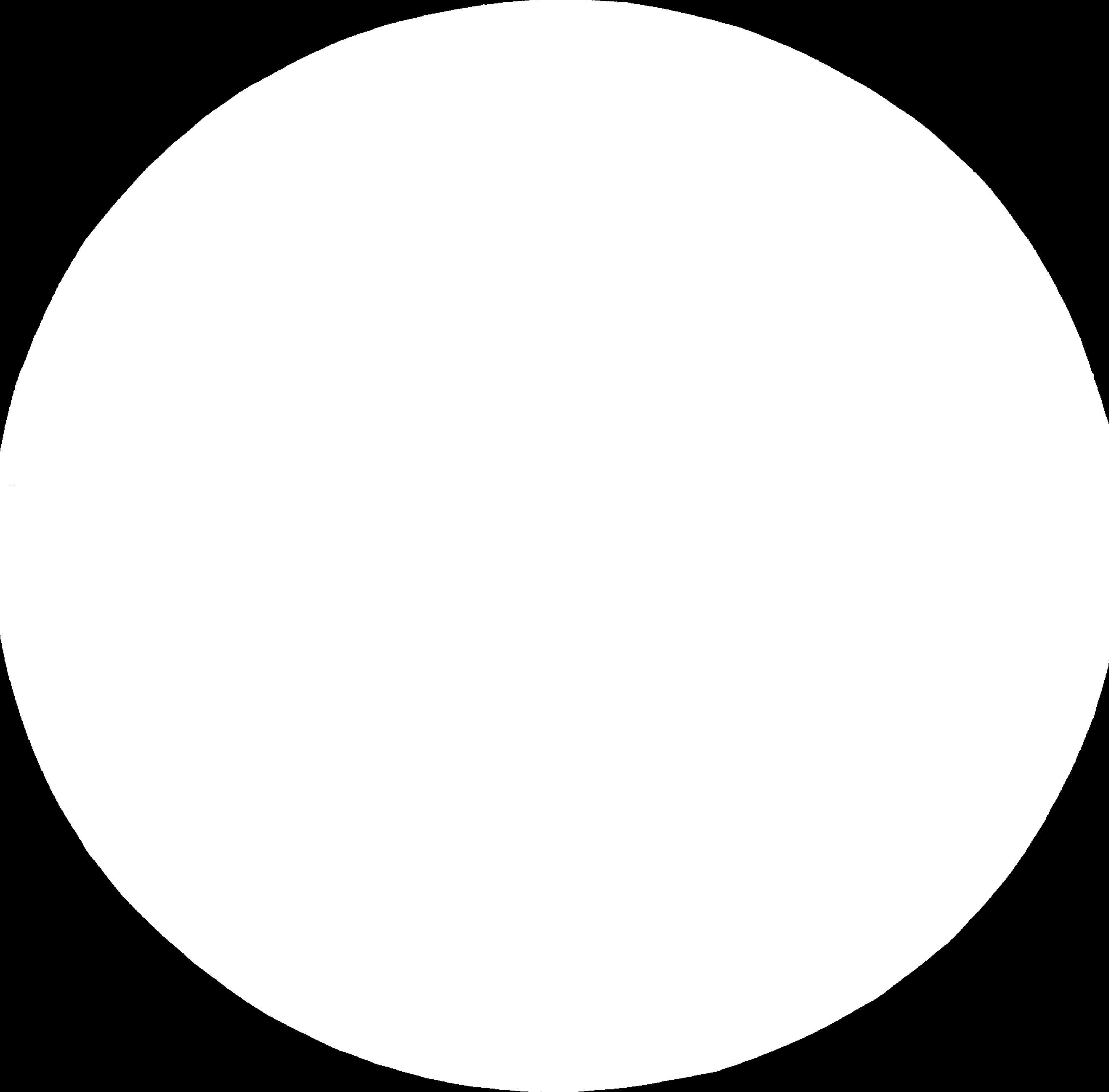
Choice of Scheme

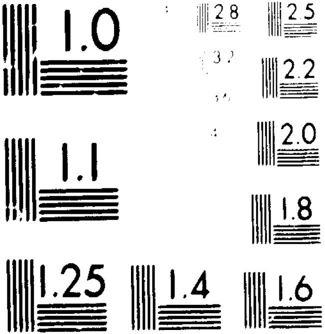
5.5.12 The cost of production of soda ash works out the lowest with a Dual process plant at Chittagong. In terms of investment capital and return on investment, however, the byproduct chalk route (Alt.I) in Chittagong projects itself as the most attractive. However, as seen earlier, the proposal can be implemented only if byproduct chalk becomes available from the ammonium sulphate plant, and the whole scheme involving the setting up of

(i) captive ammonia,

(ii) ammonium sulphate, and

(iii) soda ash plants




1.0
2.8
2.5
3.2
2.2
3.6
4
2.0
1.1
1.8
1.25
1.4
1.6

does not project itself as attractive owing to high investment and low return on total capital employed (Part - II). Hence, the Dual process alternative at the Chittagong location commends itself as the feasible least cost proposal for manufacture of soda ash in Bangladesh. The details of estimated capital outlay for the Dual process plant at Chittagong location is given in Table 5.13.

Table - 5.13

Estimated Capital Outlay for Dual Process Soda Ash Plant at Chittagong

($ '000)

Details		FC	LC	Total
A.	Manufacturing Facilities			
(i)	Site Development	130	350	480
(ii)	Main Plants	12700	5800	18500
(iii)	Offsites & Jetty	8750	3340	12090
(iv)	Spares	2600	200	2800
(v)	Project Management	1420	4310	5730
B.	Other Fund Requirements			
(vi)	Township & Buildings	2800	2200	5000
(vii)	Working Capital	-	3870	3870
(viii)	Commissioning Expenses (Net)	-	(-)1100	(-)1100
(ix)	Contingency	1400	1020	2420
(x)	Escalation	7700	8110	15810
(xi)	Financing Charges	-	5200	5200
	Total :	37500	33300	70800

Return on Capital

5.5.13 The annual production of soda ash and ammonium chloride from the proposed plant, on the basis of 300 stream days, will be 60,000 and 61,200 tonnes respectively. Keeping in view the projected demand shift in favour of industrial applications it is proposed that the soda ash section of the plant be designed to produce dense soda ash, with facility to withdraw 30 percent of the product as light soda ash. If the soda ash is priced at $ 323.30/tonne, - equivalent to the landed cost of imported dense soda ash at Chittagong at the prevailing international prices, - and credit is given to the ammonium chloride produced at $ 123 per tonne (equivalent to the current urea price in the international market adjusted for nitrogen content), the project is expected to yield a return of 13 per cent on the total capital employed.

Know-how for Dual Process

5.5.14 There are four commercial processes available for licence for the production of soda ash and ammonium chloride by the Dual process route, viz.-

(i) Central Glass - TEC, Japan

(ii) Tcyo-Soda (TSK), Japan

(iii) Ashai Glass, Japan, and

(iv) Sahu Jain, India.

Of these, the Ashai Glass process has not gained wide acceptance, compared to the others. The remaining three processes seem to be broadly on par technically. However, purely in terms of technological balance of advantage, the Central Glass - TEC process has a slight edge on the following grounds :

(a) The overall conversion efficiency of raw materials is marginally higher

(b) Requirement of utilities minimal, and

(c) Utilisation of comparatively lower grades of salt is possible because of the unique salt purification system.

5.6 Production of Solar Salt

5.6.1 Salt (Sodium Chloride) is an article of human consumption and is categorised as a 'basic food' item. But salt also forms one of the basis raw materials of the chemical industry. In some industries such as chlorine-caustic and soda ash, it forms the principal raw material but its non-edible applications cover a wide spectrum of industries such as soap and detergents, leather tanning, textile dyeing, dairy, rubber, fish curing and petroleum exploration.

Problems of Production

5.6.2 Bangladesh has no known deposits of rock salt (or underground brine wells) and, therefore, the country has to depend only on sea-source for salt production. Despite a long coastline of over 480 Km, however, the salt industry faces some basic handicaps ; first, the brine density along the coastline for a major part of the year goes down substantially on account of heavy discharge of sweet water by the mighty river systems draining the country. Secondly, owing to the rainfall distribution pattern, the country can have only a relatively shorter production 'season' congenial to solar evaporation - of about 180 days per year compared to 220-240 days in several 'dry' countries. Thirdly, owing to the pressure of population on available land resources- for its size of population, Bangladesh is the most densely populated country in the world[1] - the land suitable for salt 'cultivation' is in acute short supply. Most of the available land is in private hands, who prefer to farm it out to actual cultivators in tiny, wholly uneconomic-sized plots. The land still available with the Government ('Khas' land) competes for several uses, including forest development, shrimp cultivation and salt production.

Production Trend

5.6.3 Bangladesh had never been self-sufficient in salt until very recently. There was a marginal surplus only in 1977-78, mainly due to an exceptional production season (Table 5.14).

Table - 5.14

Production of Salt in Bangladesh

('000 tonnes)

Year	Production
1966-67	309
1970-71	322
1973-74	168
1974-75	762
1975-76	573
1976-77	452
1977-78	780

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[1] Just Faaland & J.R. Parkinson : Bangladesh, The Test Case of Development, C Hurst & Co., 1976.

However, statistics of production do not seem to make allowance for the large percentage (Upto 20 per cent) of impurities - some of them undesirable for human consumption in such high concentrations- contained in salt produced in the country. Production figures for the last few years show wild fluctuations, reflecting the uncertainties associated with the industry - but an underlying trend of improvement, mainly due to area increase, is recognizable.

Present State of Industry

5.6.4 Nearly the entire area presently devoted to salt production, around 11,000 hectares, is concentrated in just one district, Chittagong (including off-shore islands of Kutubdia and Maishkhal) along the eastern shores of the Bay of Bengal. A combination of more favourable climatological, physical and land availability conditions seem to explain this regional concentration, and for these very reasons, future expansion of solar salt production will have to be largely confined to this district, particularly to the Cox's Bazar sub-division.

5.6.5 Production of salt is mostly organised in small uneconomic-sized units; over two-thirds of the production units comprise of less than 2 acres (0.8 ha) of land each and only 5 per cent of units had 5 acres and above.

5.6.6 Solar salt production, being dependent on natural evaporation, is quite land intensive and a scientifically based layout of the salt farm is hardly possible on such small plots. According to a survey made by the University of Chittagong, the cost of production of crude salt declined by 50 per cent as the size of the plot increased from 1 to 5 acres. Much of the production inefficiency, including low yields, could be ultimately traced to the uneconomic holdings. In the opinion of the Consultants, the minimum economic size of the land for a solar salt unit should be about 20 hectares (50 acres) even under Bangladesh conditions and a unit of less than 10 hectares will be hardly tenable.

Production Methods

5.6.7 The method used for solar evaporation of brine is pretty crude by modern standards, which is mainly due to the defective design of the different components of the salt farm and the non-familiarity of the producers with even the basic requirements of the process. Science is an important input of the solar evaporation method involving as it does the fractional crystallisation of the different marine chemicals to extract sodium chloride in reasonably pure form, but the industry hardly gets the needed scientific and technological expertise, being based only on traditional experience. For instance, despite the fact that precision control of the density and flow of brine through successive ponds forms a critical element of the management of the process, even such a simple apparatus as the Baume hydrometer is not known to be used by any of the producers in the country. As a result, often weak brine is charged into the crystallizer pans and allowed to evaporate to dryness alongwith all impurities such as calcium and magnesium salts. In their anxiety to shortem the production cycle, only thin films, sometimes 3-5 mm, of salt in the crystallizer pans are harvested, resulting in largescale contamination of salt with clay and other impurities.

Yield

5.6.8 The general yield levels are low, the highest yield being around 75 tonnes/ha (of crude salt) in 1971-72 and the lowest, 22 tonnes/ha (1973-74). One of the important causes of low yield is that the producers do not generally make the best use of the 'dry' season period; thelack of security of lease for the land, the generally weak financial position and exploitation in marketing resulting in low prices for the produce often drive them to resort to production practices not conducive to obtaining best yields.

Need for New Unit

5.6.9 The Consultants hold that it would be imprudent and risky to build any salt-based chemical industry of any sizeable capacity, such as soda ash, on a raw material supply base of the kind obtaining in Bangladesh. The present supply-demand balance in the country is a tenuous one, and going strictly by the nutritional standards and making allowance for impurities in the salt produced and consumed, there might in fact be a marginal deficit even in 1977-78, - the year in which a surplus was reported. The prospects for obtaining any substantial production increase from the existing subsistence scale production units without a significant measure of nationalisation of the units and adoption of modern technology appears none-too-bright. Considering the large number of producers involved, the constraints to be expected and the types of measures required, the process of modernisation is bound to be slow and halting, atleast in the initial years. Under the circumstances, at best, the country can hope to meet, on average, the growing consumption demand for salt from out of the existing production units even that only if the country can initiate quick and determined measures for the improvement of the production structure.

5.6.10 It will, therefore, be imperative that BCIC develop its own captive production source for salt before establishing any large scale salt-based chemical plant, such as the soda ash unit considered in this study, if it is not to be cramped in working by uncertainties of supply, wide variations in quality, problems of transport from a large number of centres and possible restrictions on procurement in times of shortage from the civil supplies authorities. The development of a modern viable scale salt works, working on scientific lines, can be useful also in creating an impact on the entire gamut of the industry and in helping to generate the needed momentum for modernisation. In fact, as indicated above, the viability of the soda ash production unit is considerably dependent on the establishment of a modern solar salt unit for captive production of salt for industrial use.

The Project

5.6.11 The major bottleneck in the organisation of a large solar salt production unit in Bangladesh, is the availability of land of the proper type and in large enough contiguous blocks to permit scientific design of the works. Considering the minimal production needs in lean years and the land area required for storage godowns and other purposes, the total land requirement for a viable unit is assessed at 2000 hectares (5000 acres). A survey made by the Consultants with the local officials indicated the availability of such land under Government (Khas) ownership in the 'Thanas' of Chakaria, Maheshkhal and Cox's Bazar.

The Site

5.6.12 A preliminary evaluation of the three locations in terms of factors like soil conditions, gradient, brine density and proximity to source, facilities for rainwater discharge, proneness to floods, transport lead, etc. indicated that of these, the site at Chakaria-Sundarban in the Chakaria Thana of Chittagong district is the most suitable for the development of the salt works. The area is located approximately 75 Km from Chittagong and 40 Km from Cox's Bazar by road. The total area available at this location is understood to be about 4800 ha, of which 2000 ha could be marked out for salt works on the basis of a detailed survey. For this location, one of the feeder channels of the Maheshkhal Channel, - which is 200 m wide and is navigable by sail boats and small motor boats - could be conveniently developed as brine intake source. The land is flat with a gentle gradient, which will permit gravity flow of brine. The soil is formed of fine silt and clay with good plasticity, which will give the necessary imperviousness. In high tide water spreads on the catchment area and, therefore there are possibilities that lifting of brine through pumps may not become necessary. The Chittagong - Cox's Bazar arterial road is only an estimated 3 Km away from this site. There is no salt manufacture around this site at present.

The Layout

5.6.13 A proper layout of the salt works can be drawn up only after detailed contour survey and evaluation of site data such as wind directions, tide table, etc. but from a preliminary study the Consultants suggest that the works be organised into five blocks of about 400 ha (1000 acres) each. The advantages of arranging the works into identical smaller blocks (of economic size) lie in the fact that the production can start even when only one block has been readied and that expansion of the works can be undertaken by adding similar blocks successively, without further design calculations.

Purity of Salt

5.6.14 Even though the salt obtained from the crystallizer pans will be much purer than the salt marketed in Bangladesh at present, it will still contain minor impurities, as strict process control under solar evaporation is not possible. For industrial use, purer grade of salt will be needed, and therefore, provision has been made in the Project plan to give a thorough washing for the salt at the salt works itself - when the salt is still wet and fresh. The NaCl content of salt obtained after washing is expected to be between 98.50 and 98.60 per cent.

Capital Cost

5.6.15 The capital cost of the solar salt works project covering an area of about 2000 ha, is estimated to be around $ 3.16 million, as shown in Table 5.15.

Table - 5.15

Estimated Capital Cost of Salt Project

($ '000)

Details	F.C.	L.C.	Total
A. Manufacturing Facilities			
1. Civil Works	76.8	1998.5	2075.3
2. Plant, Equipment & Accessories	469.4	317.6	787.0
3. Know-how, Engineering, Supervision, Pre-operating Expenses	177.0	20.4	197.4
4. Project Management	-	71.1	71.1
5. Capitalised Land Lease Rent	-	40.0	40.0
B. Other Fund Requirements			
6. Residential Quarters	56.0	224.0	280.0
7. Spares	28.2	19.1	47.3
8. Working Capital	-	934.9	934.9
9. Contingency	40.4	185.3	221.7
10. Financing Charges	-	114.4	114.4
11. Credit for Product during construction Period	-	(-)1612.4	(-)1612.4
Net Project Cost	847.8	2308.9	3156.7

F.C. : Foreign Exchange Cost; L.C. : Local Cost

Cost of Production

5.6.16 The project is expected to produce, on average, around 120,000 tonnes of high grade (98.50%NaCl) salt per year. The actual annual production, of course, will vary in accordance with the climatic conditions, but even in a possible worst year, the outturn is not expected to slide below 100,000 tonnes. The cost of production of salt, on the basis of average yield, works out to $ 10.50 per tonne.

Project's Profitability

5.6.17 The profitability of the project depends on the pricing of salt. On the basis of existing price structure, with adequate adjustments for present price rigidities, but not for quality, the project is expected to yield close to 73 per cent return on the total capital employed. The IRR works out to 46.9 per cent. The pay back period will be 1.3 years after the full production stage. Even with a notional 10 per cent return on capital employed, the sale price can be fixed at $ 12.50 per tonne, which is, roughly, less than half of the price presently paid by BCIC for its salt requirements (for the caustic soda plant).

Improvement of Existing Works

5.6.18 Mention has been made earlier of the shortcomings of the salt industry as it operates at present in Bangladesh. The Consultants feel that it may not be difficult for Bangladesh to reorganise its solar salt industry if the Government of Bangladesh can take some hard policy decisions on the future growthlines of the industry and pursue it with determination. In particular, the Consultants that the following measures are urgently called for to re-orient the working of the industry and place it on a sound footing, from where it can expand on its own steam to meet the country's growting requirements of salt for human consumption :

(i) A recognition on the part of the Government that solar salt industry is not just a 'cottage' industry but an 'industry' and formulation of policies appropriate to such a concept : e.g. in terms of incentives, bank finance, priorities in the allotment of soarce land and resources, etc.

(ii) Legislative and other measures to conserve, develop and ensure proper utilisation of land identified to be suitable for salt production in the country. This will involve a balanced land utilisation policy between competing uses.

(iii) Consolidation of existing units into economic holdings, including those on private-owned lands; where possible, development of cooperative production systems with common infrastructural and auxiliary-owned facilities, but with individually-owned crystallizers. Pending implementation of these measures, regulation of lease of holdings by private land owners in accordance with these long term objectives.

(iv) Coordination between different Government agencies involved in the development and maintenance of sea-fronts, such as WAPDA in charge of protective embankments, Department of Fisheries in charge of shrimp cultivation, Revenue Authorities in charge of 'Khas' land, etc. to ensure that the interests of the salt industry are adequately safeguarded. In the WAPDA embankments, for instance, sluice gates for drawing brine into the salt reservoirs and rain water discharge outlets need to be provided for the benefit of the salt works located within. Embankments should be built where they do not exist at present to protect the salt units. The Department of Fisheries should consider the possibilities of using 'shrimp farms' for salt production in the off-season.

(v) Provision of necessary technical assistance to the salt producers to develop the salt works on more scientific lines, especially in regard to layout, control of brine strength and flow, use of required apparatus and equipment, etc. Also development and standardisation of optimal production practices (e.g. optimal brine depth in crystallizer pans) appropriate to the climate and production conditions of Bangladesh.

(vi) Creation of an appropriate institutional machinery to oversee the total optimal development of the salt industry in all aspects. The Consultants suggest the establishment of a Salt Development Corporation to be charged with all aspects of salt cultivation to research and development on improved techniques and byproduct use. It will also establish a Salt and Marine Chemicals Research Institute to provide the required scientific input to the industry.

Technical Assistance

5.6.19 The Consultants feel that Bangladesh needs external technical support to train its extension and research personnel in the field of solar salt technology and to advise it on the development of the industry. The engagement of an outside expert with adequate field experience in a developing country under labour intensive techniques, preferably through an appropriate UN agency, is recommended. In addition, the country should be enabled to depute, under a relevant technical assistance programme two persons engaged in the overseeing of the salt industry's development in the country per year for training to a suitable country abroad for one full season (8 months) each. The programme can initially cover a period of 3 years. The estimated cost of this technical assistance programme is shown in Table 5.16.

Table - 5.16

Estimated Cost of Technical Assistance

($ '000)

Details	FC	LC	Total
1. One Expert for 3 Years	180.0	-	180.0
2. Local Input for the Expert	34.0	13.2	47.2
3. Training of 6 persons in 3 years - including Travel	34.8	-	34.8
Total :	248.8	13.2	262.0

Scope for Forced Evaporation Process

5.6.20 The solar evaporation process is universally acknowledged as the cheapest method of production of salt from sea water in areas where climatic conditions are favourable and sunshine is abundant. The solar method has the added advantage of simplicity of operation and low capital intensity - except for land requirement. It is particularly suitable to regions where labour supply is ample and wage rates relatively low.

5.6.21 Salt manufacture from sea water essentially involves evaporation of brine to near solidity and therefore the process is highly energy intensive. It takes the evaporation of about 43,000 litres of 3.5 B e brine to get a tonne of salt and the energy input needed is equivalent to about 2.32×10^7 Kcal (approximately 4.2 tonne of coal replacement). The critical difference in any artificial evaporation system is that unlike solar heat, which is free, any form of commercial energy has a cost, and the energy intensive nature of the operation makes the process expensive in comparison.

5.6.22 The artificial evaporation system, for this reason, is sparingly used the world over for salt production, save in exceptional cases such as :

(i) where salt is priced very high and procurement by imports is not possible for any reason;

(ii) energy available is cheap;

(iii) purity of salt required is very high; and

(iv) where salt production is incidental to the main objective of producing water of high purity or in water scarce regions.

In Bangladesh, however, climate factors are not unfavourable, and none of these special conditions exist. As seen above, substantial scope exists for expanding salt production through solar evaporation.

5.6.23 The Consultants, therefore, do not recommend the establishment of a unit based on forced evaporation for salt production in Bangladesh. A study of the artificial system made by the Consultants (Part VI-B) indicate that the cost of production of salt, even with natural gas as possible energy source, works out to about $ 18.20 per tonne, compared to the cost of production of around $ 10.50 per tonne in the solar evaporation process.

5.7 Gypsum Building Materials

5.7.1 Gypsum one of the two naturally occuring forms of calcium sulphate, is extensively used as a building material in several countries of the world. The manufacture of plaster and plaster products for the building industry constitutes the single largest use of natural gypsum, accounting for an estimated 45 per cent of the total consumption. Several different types of gypsum plaster are manufactured with properties suited to different uses, but the most commonly known of these is plaster of Paris (calcium sulphate hemihydrate). The plasters based upon the hemihydrate form of calcium sulphate are preferred because they rehydrate more quickly than the anhydrite form, and are therefore quicker setting.

Setting Retarder for Cement

5.7.2 Gypsum is normally added to Portland cement at the rate of about 4 to 5 per cent during the clinker-grinding process to regulate the process of hydration (i.e. setting and hardening when mixed with water) of cement and to prevent 'flash-setting'. The moderating influence of gypsum is important not only because it maintains the mixture in a manageable state for long enough to work on but also because it helps to provide a stronger solid matrix by reducing the hydration of the aluminous species to below that of tricalcium silicate. The amount of gypsum added needs to be carefully controlled, however, because any excess may lead to side reactions which may bring about volume expansion in the element.

Use of Phosphogypsum

5.7.3 As seen earlier, phosphogypsum can be used as a substitute for natural gypsum in nearly all applications, including as construction plaster, prefabricated plaster products and as setting retarder in cement - in countries where there are no easily mineable natural gypsum deposits, provided the phosphogypsum is treated for removal of its undesirable impurities. The major injurious impurities are of two kinds : soluble and insoluble. Solube impurities, broadly, are of three types, viz. -

(i) Free phosphoric acid and sulphuric acid which

  (a) increase the corrosiveness of the plaster towards the structural elements in the building and the equipment used in conversion into prefabricated products, and

  (b) retard setting

(ii) Acid salts such as phosphates and fluosilicates which reduce the setting rate of plaster, and

(iii) Sodium and potassium salts which tend to floresce.

5.7.4 The insoluble impurities in the phosphogypsum consists of two groups :

(a) Those derived from the phosphate rock in an essentially unchanged form such as rock, silica and organic materials*; and

(b) Those formed in reactions during digestion of the rock such as co-crystallised $P_2 0_5$ and a number of other insoluble phosphate and fluoride compounds.

The first group, silica and unreacted rock particles, in particular do not adversely affect the quality of plaster as such, but being abrasive, increase the wear and tear of the equipment used for processing. The organic matter present may cause discolouration of the product, delay the setting and adversely affect the strength of the plaster. The second group, especially the co-crystallised P205 also affects the setting rate. Many of these impurities, especially the co-crystallised impurities such as the phosphate also affect adversely the hydration and the strength development characteristic of cement, particularly in the early periods of curing, if

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* Radium, present in the phosphate rock is another impurity which, although it has no effect on the properties of the plaster, may nevertheless be harmful on environmental grounds.

the phosphogypsum is used as cement additive. Hence processing of phosphogypsum to eliminate the injurious impurities or atleast keep them within safe limits is necessary before it can be used either for plaster manufacture or as cement additive (setting retarder).

Purification

5.7.5 Over time, attempts to overcome the problem of impurities in phosphogypsum have been made in two directions :

(i) by introducing process modifications, and

(ii) by developing purification processes.

As a result of the first, phosphogypsum from the hemihydrate - dihydrate (e.g. Nissan) and dihydrate-hemihydrate (e.g. Central Prayon) process plants has improved purity, since these processes involve recrystallisation of calcium sulphate, and usually it can be directly used in plaster manufacture or as cement additive after simple washing. In the second ·, several processes have been developed for the purification of gypsum from a conventional (dihydrate) type plant. Of those which have been developed and commercially exploited, the following are well known :

Rhone - Poulenc (France)

Gebruder Knauf (West Germany)

CdF Chemie - Air-Industrie (France)

Guilini (West Germany)

Cerphos (France)

Donau Chemie (Austria)

The purification method in most processes, in essence, consists of passing the phosphogypsum slurry either through hydrocyclones or through floatation cells to remove the solube impurities and organic matter and then passing it through a vacuum filter or centrifuge; the cake so obtained is then passed through an air dryer to get gypsum for use as cement additive or calcined further to get plaster. Calcination is done either in a specially designed fluidised bed furnace or in a rotary dryer fitted with cyclone (for details, see Part VII).

Demand for Plaster Products

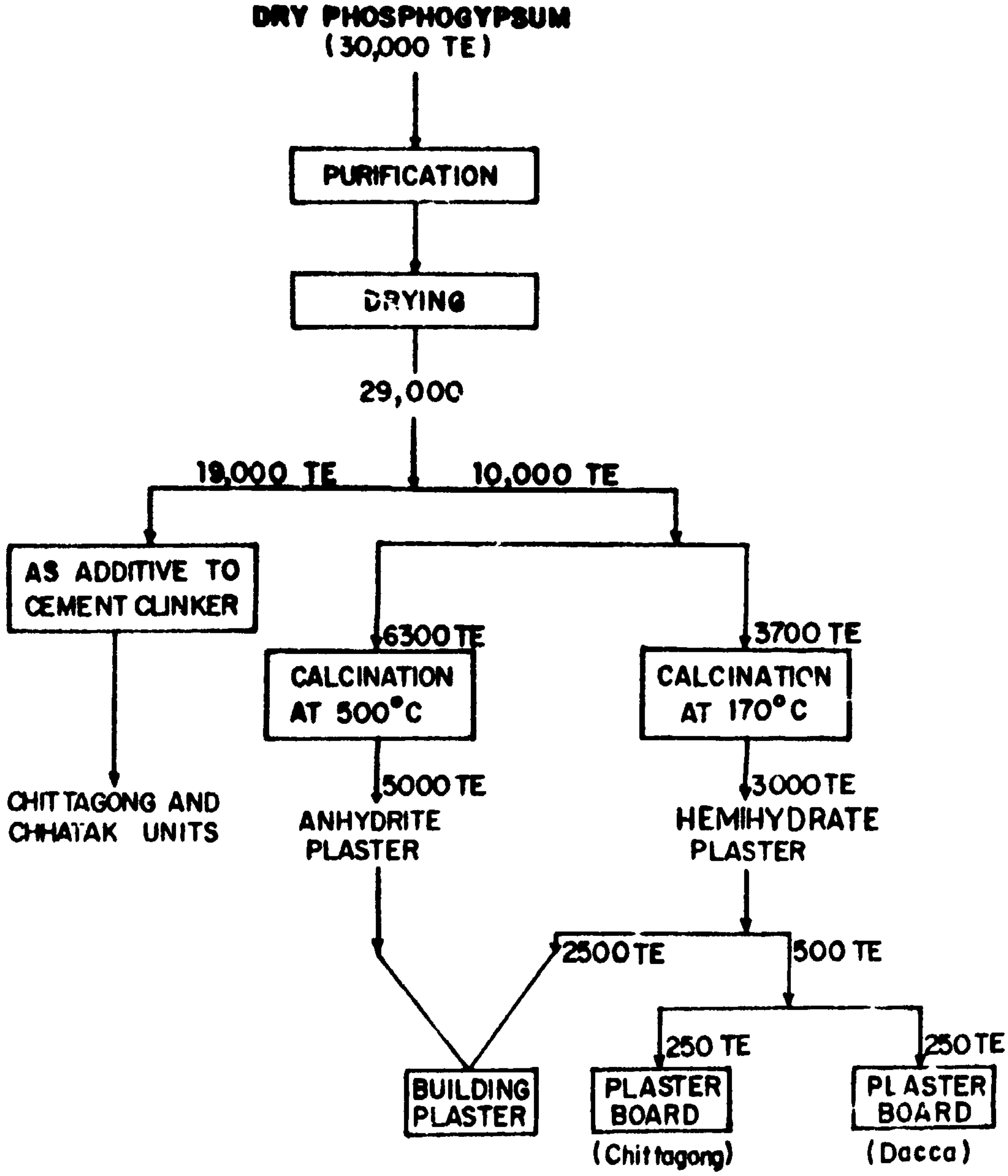
5.7.6 A wide range of building products based on purified and treated phosphogypsum have been developed and are being manufactured in several countries for use in construction, such as plaster boards, paper-surfaced plaster boards, panels, precast slabs, special types of acoustical and fire-resisting premixed plaster, acoustical tiles, blocks for partition walls, etc. However, the brittle characteristic of the gypsum set products prevent the effective utilisation of their high compressive strength in structural applications, though some improvements have been achieved by incorporating organic or glass fibres as reinforcement material. The gypsum building products suffer from another infirmity, which to some extent limit their applications. The slight solubility of gypsum in water prevents their use in situations where they may be exposed to dampness or rainfall. Hence in countries like Bangladesh, they can be used indoors only.

5.7.7 Though Bangladesh faces acute shortage of building materials in the face of sharply rising demand, arising both from population growth and expanding need for non-residential structures, the demand for gypsum building materials can only be limited, at least in the initial years. In the first place, as noted above, under the climatic conditions in Bangladesh, especially due to heavy rainfall, gypsum plaster and plaster products are not suitable for exterior use. Secondly, the country has not been exposed to gypsum building materials so far, and the construction industry being as conservative as anywhere else, its acceptance of a new product is bound to be slow. Thirdly, some types of materials such as the pre-fabricated plaster products may be too sophisticated for the construction industry in Bangladesh, especially considering the income levels of majority of population and the present types of construction within the country. The Consultants' market studies in Bangladesh also indicate only limited scope for utilisation of gypsum plaster and pre-fabricated plaster products in the country. In view of these, the demand for gypsum-based building materials is not likely to be high in the initial years and only a relatively small plant can be considered.

Gypsum Utilisation Plan

5.7.8 The two phosphoric acid plants (PA-I and PA-II) in Bangladesh are expected to produce about 230,000 tonnes (dry basis) of phosphogypsum per year on long term basis. Of these, 200,000 tonnes are expected from the Nissan process PA-II plant, and owing to the improved process, this gypsum contains less impurities compared to gypsum from PA-I plant (30,000 tpy), which is based on the conventional dihydrate process (Table 5.6). Ideally, the Nissan gypsum from PA-II is best suited for utilisation in the building materials

UTILISATION PLAN FOR PHOSPHOGYPSUM FROM PHOSPHORIC ACID PLANT- I (DIHYDRATE GYPSUM)



FERTILIZER (P & D) INDIA LTD.

Drawing No. I - 3

and cement additive outlets. However, considering the limitations on the use of gypsum building materials in a heavy rainfall country and the general demand situation in Bangladesh, the scheme cannot make use of the entire gypsum available from this plant. Besides, the problem of disposal of dihydrate gypsum from PA-I will remain to be solved. Since Nissan gypsum (PA-II) can be utilised with advantage in alternative applications (e.g. cement clinker) where tolerance limits for impurities are more rigorous, it is suggested that gypsum available from PA-I plant should be made use of primarily as cement additive after necessary purification and any surplus left should be utilised for manufacture of building plaster and plaster products.

Surplus Gypsum for Building Products

5.7.9 Of the total availability (30,000 tonnes) of phosphogypsum from PA-I plant, the processing loss would be about a thousand tonnes and about 29,000 tonnes can be expected to be recovered after purification. Of this, about 19,000 te could get utilised as additive to cement clinker on a firm basis - not taking to account the requirement likely to emanate from the implementation of the planned Jaipurhat project for the cement clinker production. This will leave a balance of roughly 10,000 tonnes - which can be considered available for manufacture of plaster of Paris, building plaster or plaster products for use in the building industry. In case the Jaipurhat project is taken up for immediate implementation, practically no surplus will be left, and the entire quantity will be needed as cement additive only.

Product-Mix

5.7.10 The plaster products that can be considered for manufacture in Bangladesh are somewhat limited, in view of the unfavourable climatic factors and the uncertain marketing situation. Products like pre-cast slabs (building blocks) can have only very limited application, since they cannot be used in walls exposed to dampness or in load-bearing walls. Some products such as glass fibre-reinforced panels and paper-coated gypsum boards are considered too sophisticated to find a market in Bangladesh. The Consultants, after a survey of the market conditions and in consultation with BCSIR and HBRI, which have been experimenting with the utilisation of phosphogypsum products for construction purposes, came to the conclusion that building plaster and jute fibre-reinforced plaster boards are the most suitable products for Bangladesh conditions.

Building Plaster

5.7.1' For internal plaster, it is common to use beta hemihydrate plaster (plaster of Paris) mixed with an additive such as glue or hydrolysed Keratin (about 0.1 per cent by weight)to prevent rapid hydration. This type of plaster is known as retarded hemihydrate plaster. The building plaster as distinct from the above plaster, used in France, Germany and several other countries consists of a mixture of one-third hemihydrate plaster and two thirds anhydrite overburnt plaster. Certain additives like oxymethyl cellulose in suitable proportion is added to retard the setting and thereby facilitate its application and at the same time increase its plasticity and make it hard, once set. These plasters have all the necessary properties : early initial setting,long final setting, a setting and workability behaviour which corresponds to the average working speed of a plasterer, smoothness, plasticity high coverage, rapid drying of the finished plastering, suitable density as well as good strength. The building plaster, when mixed with sand can replace currently used cement : sand or cement : lime : sand mortar for internal plaster of brick walling in residential and public buildings as well as in private construction in Bangladesh. Final finishing coat may be given with neat plaster. Gypsum plaster provides a neat smooth finish and being inert, is suitable for decorative use if desired. The use of this gypsum plaster can help to relieve the present-and foreseen-shortage of cement in the country to some extent. Though a quantitative assessment of the total requirement has not been possible, considering the practically universal use of bricks [illegible] for building construction, the Consultants estimate that the saving in cement from the substitution of cement by gypsum plaster could be sizeable, particularly with the expanding building activity. From a comparison of costs, the Consultants assess that the cost of plastering with the gypsum plaster will be substantially cheaper than the conventional cement : lime : sand plaster and at par with the cement : sand plaster work.

Plaster Board

5.7.12 Plaster Boards, manufactured out of beta hemihydrate plaster, are not presently used in Bangladesh, but the Consultants feel that there is considerable scope for developing a reasonably sizeable demand within the country. They can substitute, for instance flat asbestos cement sheets, and chipboards (locally known by the trade name 'Partex'), which are generally in short supply as well as the hard board sheets in uses like false ceiling materials in residential and public buildings as well as in shops and commercial establishments. Similarly, because of its fire-resistant, thermal insulation and acoustic properties, pre-fabricated plaster board can find ready acceptance for interior panelling of cinema houses and public halls as well as in office buildings designed for air-conditioning. Fibre reinforced plaster boards can be used even in residential buildings for non-load bearing partitions and panelling.

5.7.13 In view of the fact that the country is still unfamiliar with the use of gypsum plaster boards and that the building industry is generally conservative not much given to experimentation, the demand for the products is admittedly likely to grow only slowly in the initial years of introduction. Until, therefore, the consumer reaction for the product is established it may be prudent to manufacture the plaster boards within the country only on a pilot scale. It is, therefore, suggested that plaster boards should be produced initially in small scale unmechanised units.

Location of Units

5.7.14 Since it will be totally unrelated to its main activity, the Consultants do not feel that the TSP Complex should be directly involved in these products. However, since the gypsum is produced by a TSP unit, the involvement of the TSP Complex will be necessary at least upto a stage. The Consultants therefore envisage that the TSP Complex should process the phosphogypsum from PA-I plant and make it available in dried form to bulk consumers, such as the cement plants, packing units for building plaster and the proposed plaster board units. The actual manufacture of the plaster products should be left to be undertaken by new units to be set up for the purpose. Considering the advantages of integration, it is suggested that the plant for the processing of plaster should be set up within the TSP Complex. A vacant plot of land lying between the road alongside the jetty and the TSP plants, measuring about 2-3 acres in area, is available for the purpose and is considered suitable.

Plaster Board Units

5.7.15 The manufacture of plaster boards is recommended in two independent small scale units - one each at Chittagong and Dacca. Since the process of casting of boards is simple which does not require much technical skill, the capital requirement low and the scope for expression of individual skills high, the industry is ideally suitable for being set up as small scale units. Each of these units will have a capacity of about 240,000 sq. ft. per annum of jute reinforced pre-fabricated boards. There is already a proposal to set up a small production unit to process phosphogypsum for plaster of Paris under the joint auspices of BCSIR and BSCIC in Tongi near Dacca. The same unit may take up manufacture of plaster boards by way of diversification. The unit at Chittagong may be jointly set up by BSCIC and BCSIR or may be offered to a private entrepreneur.

Purification Process

5.7.16 In view of the higher percentage of impurities in PA-I plant (dihydrate) gypsum, slightly more elaborate processing techniques will be normally needed to make this gypsum suitable for use as additive to cement clinker. However, petrographic examination of samples of phosphogypsum from this plant suggests that washing could eliminate most of the soluble impurities, since the crystals are present in open packing with little agglomeration. The physical properties of an experimental cement sample using washed phosphogypsum as additive indicated results comparable to those of cement using natural gypsum. Hence, for use as cement additive, only thorough washing of phosphogypsum is considered adequate.

5.7.17 Since the know-how currently available for purification processes from established process licensors is for large capacity plants only, and does not quite fit in with the requirements of Bangladesh, the Consultants have indicated (Part VII) a simplified scheme of purification, based on the same principles. (Part VII - Drawing VII-5). In this, raw phosphogypsum from the vacuum filter of PA-I plant is suspended in a tank by means of water from a hydrocyclone. The suspension is cleaned of large particles of quartz, unreacted rock and any foreign bodies on a sifting screen. The sifted product is collected in a tank and then pumped to a hydrocyclone. The gypsum, collected at the downflow in the form of a thick pulp falls into another washing tank. Most of the liquid carrying away the soluble impurities and organic matter is collected at the upflow and sent on to the waste neutralisation plant. In the washing tank, gypsum pulp is neutralised using lime solution and then pumped to the hydrocyclone. The cyclone separates the liquid which is recycled to the first washing tank. Gypsum collected at the downflow in the form of a thick pulp is spin dried in a continuous centrifuge and the filtered liquid is sent to the washing tank. The filtered gypsum containing 10 per cent moisture is received by a conveyor belt and taken to the thermic treatment unit, where, in a rotary drier it meets current of air at a temperature of 110°C. The gypsum arrives at the other end of the drier in a dry condition. A part of the dry gypsum is stored in a silo for use as cement additive.

Plaster Manufacture

5.7.18 The rest of the gypsum is calcined in a rotary drier at 130-170°C. To neutralise any phosphoric acid occluded in the gypsum crystals, addition of about 0.2 per cent bases like $Ca(OH)_2$ or NaOH has been recommended. A part of the calcined hemihydrate plaster is taken out for the manufacture of fibre-reinforced plaster boards. The rest is calcined further at a temperature of 500°C in a rotary calciner. The calcined anhydrite plaster obtained is mixed with hemihydrate plaster in the ratio of 2:1 for use as building plaster.

Capital Estimate

5.7.19 The investment capital requirement of the project, involving the production of 19,000 tpy of cement additive and 8000 tpy (net of processing losses) of plaster-corresponding to the total utilisation of 30,000 tpy of raw dihydrate gypsum - has been estimated as shown in Table 5.17.

Table - 5.17

Capital Investment for Gypsum Processing

($ '000)

Item	FC	LC	Total
A. Manufacturing Facilities			
1. Land & Land Development	-	72	72
2. Cement Additive & Plaster Plants	1660	910	2570
3. Auxiliary Facilities	80	110	190
4. Project Management	-	140	140
5. Spares	100	40	140

Item		FC	LC	Total
B.	Other Fund Requirement			
6.	Contingency	90	60	150
7.	Escalation	180	120	300
8.	Working Capital	-	215	215
9.	Financing Charges	-	245	245
	Total :	2110	1840	3950

Cost of Production

5.7.20 The cost of production of cement additive, on the basis of the capital outlay estimated above, works out to $ 24 per tonne. The clinker grinding unit at Chittagong is understood to be presently paying a price of $ 10 per tonne of raw gypsum from the gypsum pond. In view of the present complaints about the cement quality due to use of raw phosphogypsum, the clinker grinding unit will now be forced to import natural gypsum for use as cement additive, and the landed cost of such imported gypsum is expected to be not less than around $ 40 per tonne and could be as high as $ 60 (depending on the source of import).

Profitability

5.7.21 In the absence of any reliable indications regarding the possible market prices of the cement additive and plaster, the selling prices are arrived at on the basis of a 12 per cent return on equity. The selling prices thus derived are :

- Cement Additive	: $ 32/te
- Plaster	: $ 60/te

The Consultants are convinced that these prices will be competitive in comparison with possible substitutes in Bangladesh.

Capital Cost of Plaster Board Units

5.7.22 The equipment required for the manufacture of plaster boards on a small scale are :

- Concrete casting table
- Steel frames, and
- Buckets, trays, towels, etc.

The capital investment required for a unit of 240,000 sq.ft./year capacity of jute fibre reinforced gypsum plaster board unit, including the cost of land and buildings ($ 13,850) is estimated at $ 25,170. The estimated cost of production of the plaster board, on the basis of single-shift working (300 working days) works out to $ 12.10 per 100 sq. ft. At the possible selling price of around Tk 2.04 ($ 0.14) per sq. ft. the gypsum board will be competitive with the 'Partex' boards currently in wide use and yield return of 14 per cent on the total capital employed.

Chapter - 6

FOLLOW-UP ACTION

6.1 The following follow-up action by the agencies concerned is visualised to initiate work on the implementation of the recommended (Chapter 3) schemes. Necessarily, the steps indicated here are only illustrative, rather than exhaustive. It is suggested that the Bangladesh Chemical Industries Corporation will initially entrust a senior executive, preferably of the level of General Manager, with the 'processing' of the Study and initiating action for the implementation of the recommendations made therein. Where inter-agency action is involved, he will coordinate the activities and pursue them through the successive stages. It will be necessary that, as a first step, he develop his own action-plan in keeping with the procedural requirements of the Government and related agencies.

A. Cement Clinker - Sulphuric Acid

(i) Ascertain that the modifications and operational improvements recommended for the TSP Complex are being implemented satisfactorily to ensure gypsum availability in accordance with the estimates made in this Study.

(ii) Secure concurrence from the BMEDC to the proposals regarding cement clinker utilisation made herein (so that if any adjustment is required in the BMEDC's plans for the domestic production of clinker and its utilisation in the clinker [illegible] Grinding Factory in Chittagong, it is made early).

(iii) Approach UNDP/UNIDO for assistance to get :

- (a) actual test runs of the hemihydrate gypsum from the Phosphoric Acid Plant II in the Chemie-Linz plant to make certain the suitability of gypsum for the Chemie-Linz process and generate data for design of the plant, and
- (b) to get a proper appraisal, including actual tests, made of the possibility of using anthracite instead of coke as a reducing agent.

(iv) In the meantime, explore the possibilities of obtaining coke breeze from India and work out the economics of using it in lieu of coke in the process.

(v) Initiate appropriate action (including approach to international aid agencies) to secure the services of Chemie-Linz to prepare a detailed project report for the execution of the project.

(vi) Explore the possibilities of sending an expert technical team to visit the Phalaborwa plant in South Africa to assess its working, if necessary through the assistance of Krupp-Koppers GmbH or alternatively, visit the Chemie-Linz plant at Linz(Austria).

(vii) Get a detailed and finer appraisal made of the indigenous raw material supply sources and firm up the supply lines.

(viii) Negotiate with the clinker grinding factory on the arrangements to be made for the transport of clinker to its clinker silos so that the scheme could be incorporated in the detailed project report.

(ix) Secure firm assurances of the availability of the required quantity of water from WASA Chittagong and power from PDB.

(x) Approach the Government for special exemption of all duties and taxes on import of capital equipment/raw materials for the project on the grounds of waste-utilisation and pollution control benefits to the economy in order to reduce the burden of investment cost on the project.

(xi) In the long term interest of obtaining byproduct gypsum of broadly consistent quality for processing, get the BCIC and the Government to commit to import rockphosphate from any single well defined source and within broad specifications, so that the design of the plants could be tailored to phosphogypsum of definite analysis.

B. Gypsum Building Materials

(xii) Secure from the BMEDC firm indication of the future requirement of purified gypsum for use as cement additive by the cement units.

(xiii) Initiate action to secure the services of an experienced consulting firm to prepare a detailed project report and implementation plan for the execution of the project.

(xiv) Firm up with the TSP Complex Management the availability of the land identified in the Study for the location of the project.

(xv) Get the BSCIC to formulate a proper project scheme for the utilisation of processed gypsum for the manufacture of fibre-reinforced plaster board in 2 small scale units - one at Chittagong and the other in Dacca, and approach the Housing and Building Research Institute to organise training of the workers.

(xvi) Approach BCSIR and the HBRI to provide extension work, including organisation of seminars and exhibitions, for popularising the use of gypsum building materials (including gypsum plaster) in building construction work in Bangladesh and provide expert guidance to the users. Approach the Government to amend the building byelaws to encourage the use of gypsum building materials and begin using it in Government construction work in appropriate places.

(xvii) Work out a proper arrangement, such as appointment of main dealers, for the marketing of gypsum building materials, particularly the building plaster.

C. Soda Ash

(xviii) Reconfirm the availability of ammonia from the Chittagong Urea Fertilizer Project and approach the project authorities for making necessary adjustments in the plant design for making available the agreed inputs (e.g. steam, fuel, gas, water, emergency power, etc.) to the soda ash plant and for sharing of the facilities.

(xix) Appoint an engineering consultant for preparing a detailed project report including selection of site, soil investigation, water supply arrangement, etc. and recommend names for preparation of a short list of engineering contractors and the project consultant.

(xx) Firm up with the PDB the supply of power and negotiate with the Government, the release of necessary land, correspond with the Port Authorities regarding construction of jetty, etc.

(xxi) Approach BADC for undertaking an extensive 'seeding' programme for popularising the use of ammonium chloride in the areas identified as suitable on the basis of agronomic and soil conditions as well as cropping pattern.

(xxii) Confirm from the Government that concessional rate of customs duty will be available to the Middle Island location as an industrially backward area.

(xxiii) Develop an appropriate plan* for the marketing of soda ash from the proposed unit, including distribution scheme, market outlets, terms, etc.

(xxiv) Get a proper market survey done for assessing the demand for dense ash and for identifying the customers.

D. Solar Salt

(xxv) Arrange for an expert contour, topographical and soil survey of the land identified for establishing the salt works in the Chakaria-Sundarban area and secure release of the selected land from/through the Government.

(xxvi) Secure the services of an experienced consultant to design the layout of the salt works and supervise construction.

(xxvii) Initiate action for the preparation of a proper tide table at the Chakaria-Sundarban area and for borehole tests to be done for ascertaining availability of drinking water in the area.

(xxviii) Approach UNDP/UNIDO for getting the assistance of an expert on solar salt industry with experience of working in a developing country under labour intensive conditions and in relatively small units to :

(a) advise the Government on development of salt industry

(b) prepare a blue-print for the establishment of the Salt Development Corporation,

(c) prepare a plan for the training of technical personnel, and

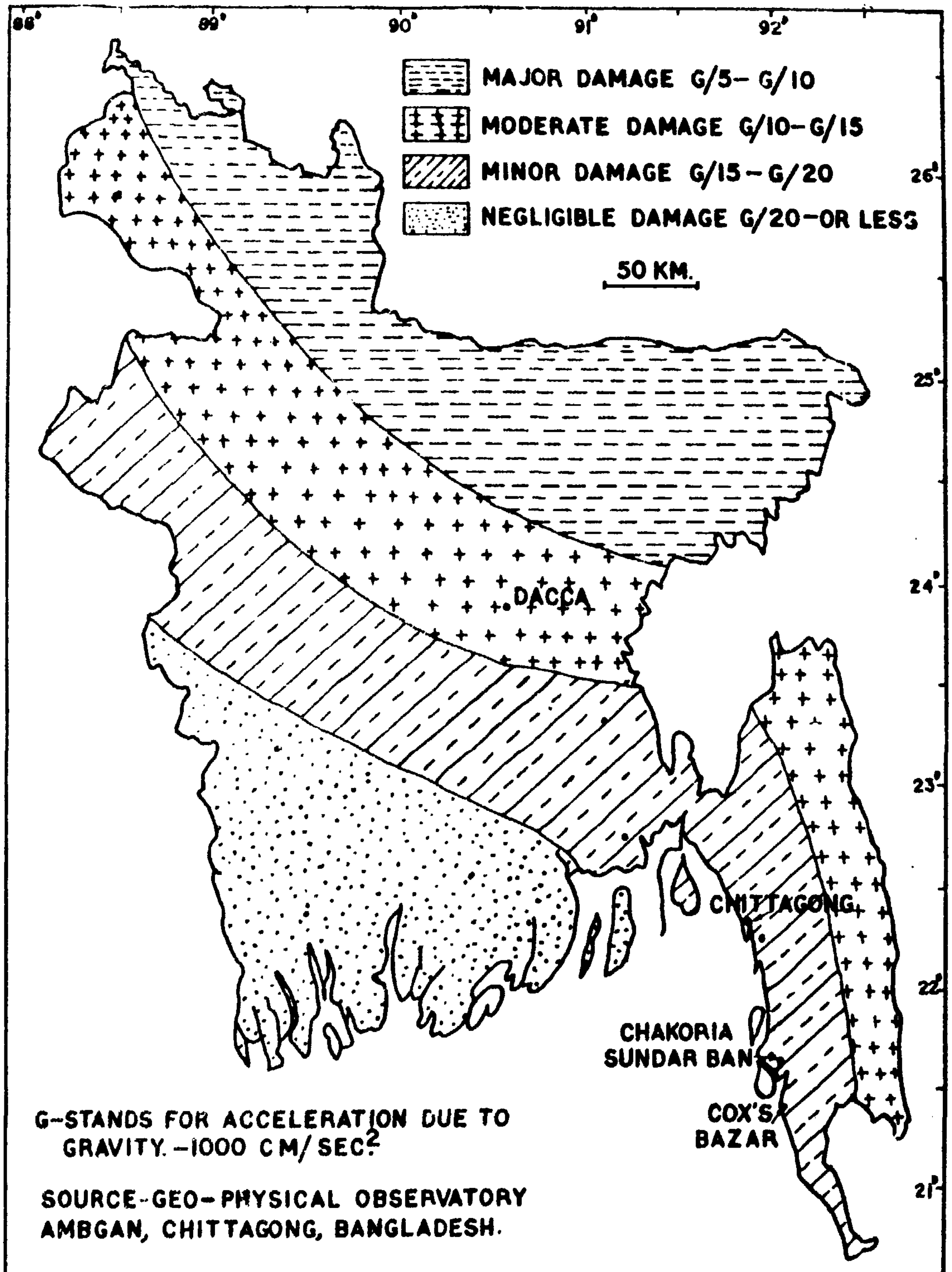
(d) work out a blue print for the establishment of a Salt and Marine Chemicals Research Institute.

(xxix) Approach UNDP/UNIDO for funding a training programme for deputing two trainees per year for 3 years to selected salt works in a country whose experience will be relevant.

APPENDIX - I

THE COUNTERPART TEAM

1.	Mr. E.R. Chaudhury, Team Leader	Chief, Chittagong Urea Fertilizer Project, Bangladesh Chemical Industries Corporation.
2.	Dr. Shameem J. Ahmed	Principal Scientific Officer, Bangladesh Council of Scientific Research.
3.	Dr. A.K.M.A. Quader	Associate Professor, Bangladesh University of Engineering & Technology.
4.	Mr. Akhtaruddin Ahmed	Research Officer, Housing & Building Research Institute.
5.	Mr. M.A. Latif	Process Engineer & Entrepreneur, Kismat Chemicals
6.	Mr. W.R. Chaudhury	Consultant & Chemist, Bikrampur Laboratory.
7.	Mr. F.H. Chowdhury	Chief Engineer, Ghorasal Urea Fertilizer Factory.
8.	Mr. Md. Solaiman Miah	Dy. General Manager, Triple Superphosphate Complex.
9.	Mr. Moinul Islam	Chief Chemist, Triple Superphosphate Complex.
10.	Mr. Zahirul Huq	Dy. General Manager, (Planning & Development) Bangladesh Chemical Industries Corporation.



G-STANDS FOR ACCELERATION DUE TO GRAVITY.-1000 CM/SEC^2

SOURCE-GEO-PHYSICAL OBSERVATORY
AMBGAN, CHITTAGONG, BANGLADESH.

FERTILIZER (P&D) INDIA LTD. SINDRI	
TITLE:- **SEISMIC ZONES OF BANGLADESH**	
PROJECT:- B.C.I.D.B	DRG. NO. 11

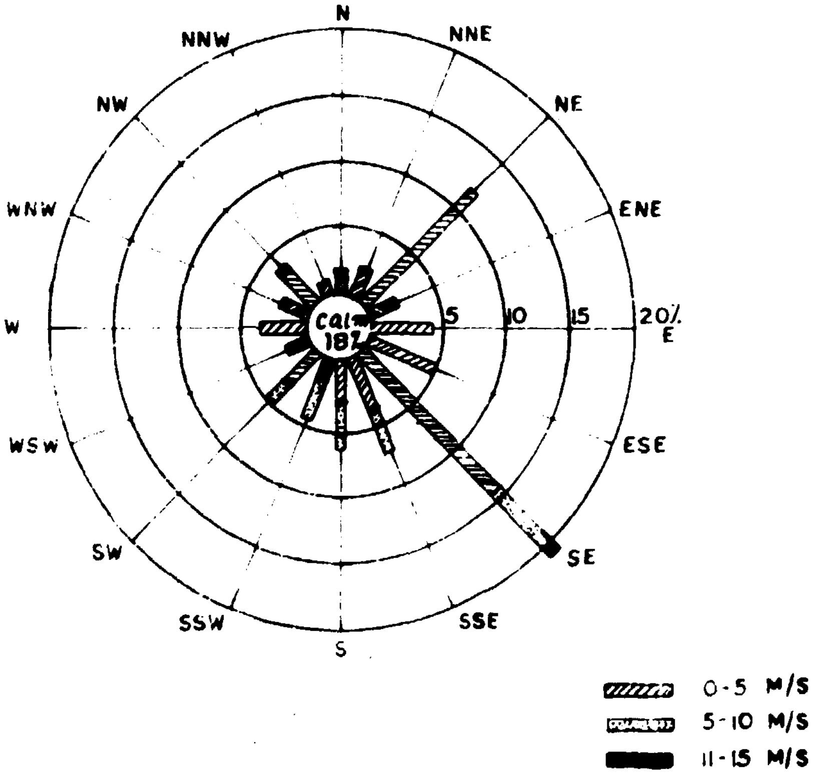


FIG-6.4

FERTILIZER (P. & D.) INDIA LTD., SINDRI

TITLE.
ANNUAL WIND ROSE
CHITTAGONG

PROJECT: B.C.I.D.B.
DRG. NO
REV

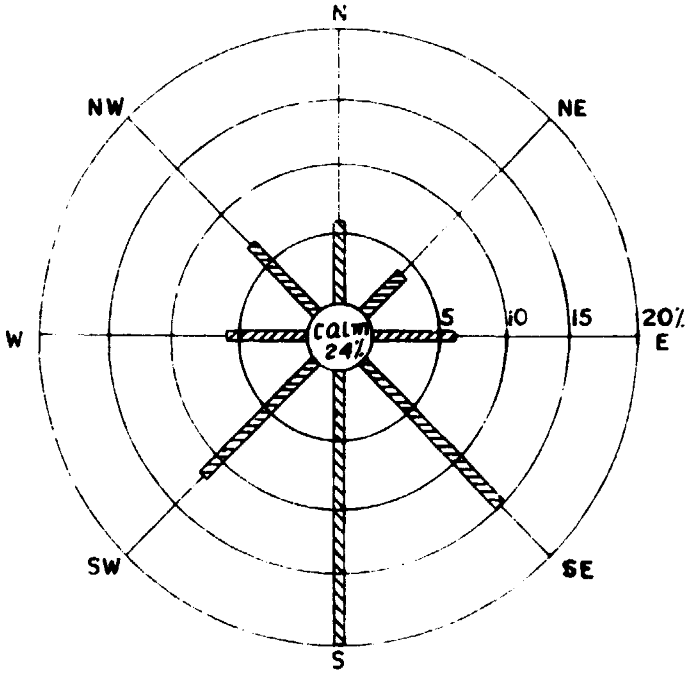
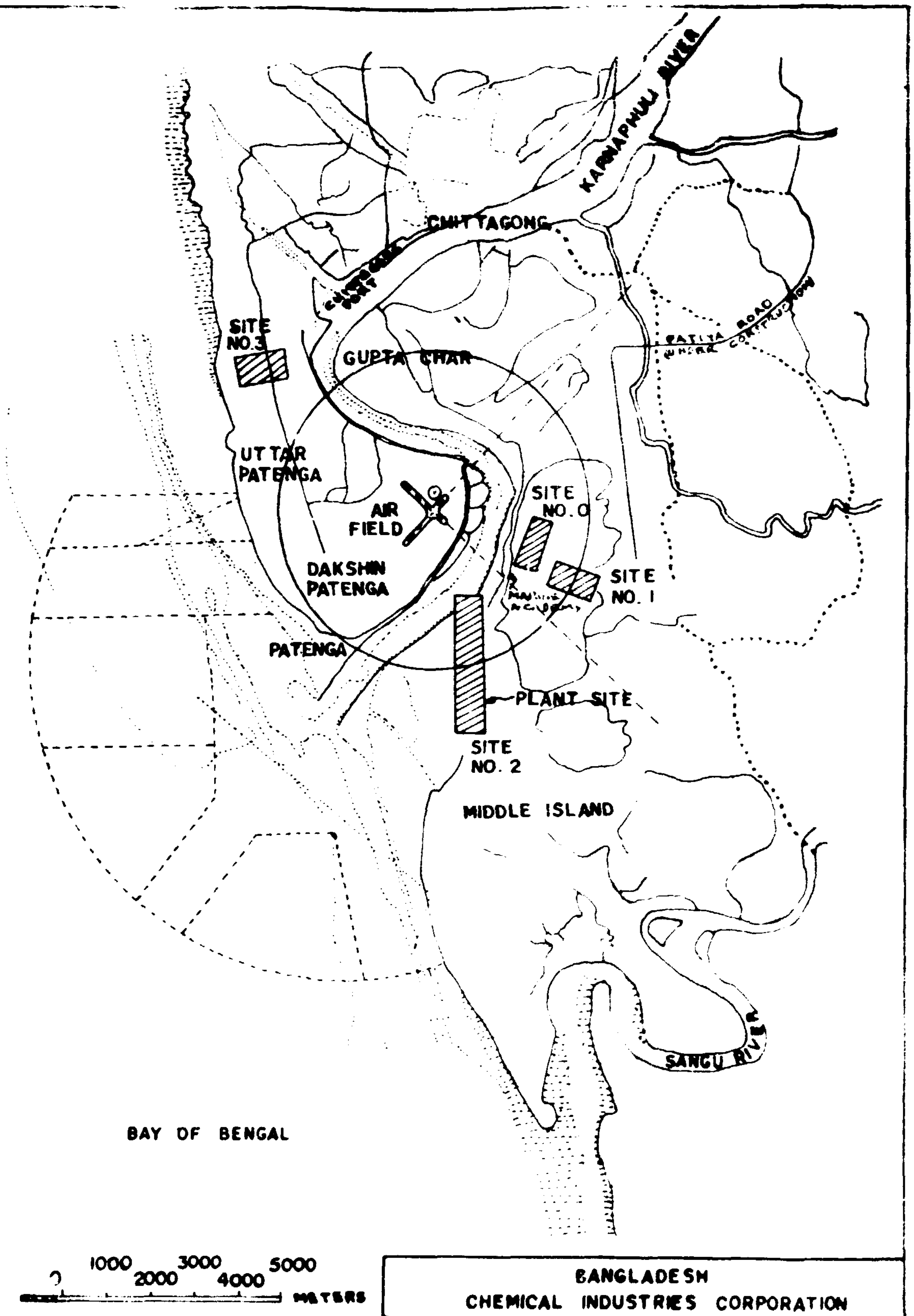


FIG.-65

FERTILIZER (P. & D.) INDIA LTD., SINDRI

TITLE:
ANNUAL WIND ROSE
GHORASAL

PROJECT : B.C.I.D.B | DRG. NO | /REV.



BANGLADESH
CHEMICAL INDUSTRIES CORPORATION

CHITTAGONG UREA FERTILIZER PROJECT

SITE LOCATION

UNICO INTERNATIONAL CORPORATION

DATE

FIG 1-1

BASIC CHEMICAL INDUSTRIES DEVELOPMENT
IN
BANGLADESH

Part Two
AMMONIA REQUIREMENT AND SUPPLY

FERTILIZER (PLANNING & DEVELOPMENT) INDIA LTD

SINDRI, INDIA, 828122

Job No. 3404

10139
(2)

PART II

AMMONIA REQUIPEMENT AND SUPPLY

PART II

AMMONIA REQUIREMENT AND SUPPLY

CONTENTS

ANNEXURES

DRAWINGS

PART II : AMMONIA REQUIREMENT & SUPPLY

Chapter - 1

INTRODUCTION

1.1 Ammonia (NH_3) is the principal form in which atmospheric nitrogen is 'fixed' for being made available as plant food. It is for this reason that ammonia production is generally associated with the nitrogenous fertilizer industry. Even though fertilizer manufacture may constitute its single largest use, anhydrous ammonia has several other industrial applications, - in the production of nitric acid, alkali industry, explosives, refrigeration of food and beverages and many others. Compared to the scale of world production, however, the free market supplies of ammonia are very much limited, accounting for only a small proportion of the total production, mainly due to the problems involved in its storage, transport and handling. Hence, the trend in ammonia plant construction in recent years, particularly in the nitrogen fertilizer industry, has been to put up down stream product plants of matching capacity. As a consequence, unless excess ammonia capacity is deliberately created through planned imbalance in the product stream, normally no surplus ammonia in significant quantities can be counted upon to be available from the fertilizer ammonia plants for other uses. Another factor of significance affecting the non-captive ammonia supply has been the technological break-throughs in favour of large capacity plants, which has rendered production in small scale plants increasingly uneconomic due to disproportionately high production costs. Non-availability of surpluses of ammonia from the modern large scale plants for free sale owing to the matching product plants, on the one hand, and the uncompetitive character of production through the small plants on the other, has unfavourably affected, in general, the climate for the setting up the ammonia-user industries, particularly if the total ammonia requirements are not large enough to need a minimum optimal-sized plant, in the developing countries in general, Bangladesh being no exception. Imports of tonnage supplies are equally difficult since they need special tankers for transport and special handling equipment and storage facilities at the ports, which are costly to install if the quantities involved in import are not sizeable.

1.2 Bangladesh has at present two nitrogen fertilizer factories in operation, one at Fenchuganj (NGFF) and the other at Ghorasal (GUFF). A project for a large capacity plant is in an advance stage of implementation at Ashuganj. These factories are owned by the Government through two public sector companies. Thus the total installed capacity for ammonia in the country is about 560,000 tpy (1790 tpd). However, all the three units have product plants matching with the ammonia capacity and therefore, there is no built-in surplus ammonia capacity within the country to cater to the requirements of other ammonia-based industries on regular basis. In the same way, in the new Chittagong Urea Fertilizer Project presently in the process of appraisal by the Government for investment decision, as well as in the proposed Ghorasal II Project (China-aided), the capacity proposed for the urea product plants will ordinarily leave no surplus of ammonia. Hence, any industrial need for sizeable quantities of ammonia on sustained basis can be met only by -

(i) either possible modifications in the operating plants to raise their ammonia production capacities or

(ii) by deliberately building excess capacity in the ammonia plants now under implementation or under consideration.

Alternatively,

(iii) an independent ammonia plant to be set up exclusively for the purpose.

In the event of ammonia being available from the already installed or planned capacity, the facilities and costs of transport and handling will need to be evaluated, since ammonia, being a volatile and hazardous cargo, requires special transport, handling as well as storage equipment.

1.3 Among the alternative schemes being evaluated for the economic utilisation of byproduct gypsum produced in the two wet-process phosphoric acid plants of the TSP Complex at Chittagong, two involve the use of ammonia viz,

(i) Ammonium Sulphate

(ii) Soda Ash

In the conditions prevailing in Bangladesh, the availability of ammonia could be critical to the choice of any of these schemes. The Consultants therefore, had to make an assessment whether the ammonia needed for these schemes could be made available from any of the operating units, including the project under implementation, and whether the needed supplies could be secured by building additional capacity into the ammonia-urea project now under consideration of the Government. In the alternative, the implications of obtaining the supplies from an independent captive plant of appropriate capacity on the economics of the scheme needed to be evaluated.

1.4 Along with ammonia, the above schemes would require carbondioxide in fairly large volumes. Normally, carbon dioxide is concurrently produced in the proeess of production of ammonia. It is used in the urea plant, if urea is the end-product, as in Fenchuganj, Ghorasal and Ashuganj. In certain situations, depending on the composition of the feedstock used, the ammonia-urea plant complex may be operating on the basis of a close balance in carbon dioxide supply. In such an event, even if ammonia is available, separate facilities for the production of carbon dioxide may have to be set up.

Chapter - 2

AMMONIA REQUIREMENT AND SUPPLY FROM EXISTING PLANTS

[illegible] Ammonia Requirement

2.1 Ammonia and carbondioxide are needed in the production of ammonium sulphate from gypsum so that ammonium carbonate, formed by combining ammonia with carbon dioxide could be reacted with gypsum to yield ammonium sulphate and calcium carbonate. Similarly, of the two soda ash processes (See Part V), ammonia is required in the Dual Process to ammoniate the brine, which is then 'carbonated' with carbon dioxide to yield sodium bicarbonate and ammonium chloride. In the conventional soda ash process also, ammonia is needed to 'ammoniate' the brine and carbon dioxide is used to get ammonium bicarbonate as precipitate. However, in this process much of ammonia and part of carbon dioxide can be recirculated so that recurrent supplies will be needed for 'make-up' only. The requirement of ammonia and carbondioxide in the different alternatives, and for the optimal plant capacities, as determined in subsequent Parts, will be as shown in Table 2.1.

Table - 2.1

Ammonia and Carbondioxide Requirement

(Figs. in tonnes/day)

Sl. No.	Product	Plant Capacity	Ammonia	Carbon-dioxide
1.	Ammonium Sulphate (gypsum route)	480	132	197
2.	Soda Ash (conventional route)	200	1	104
3.	Soda Ash (dual process)	200)	68	94
	Ammonium Chloride (Co-Product)	204)		

2.2 If the ammonium sulphate route is chosen for the utilization of waste gypsum, chalk ($CaCO_3$) will be produced as a byproduct, which in turn can be utilised for the production of soda ash through the classical Solvay process. In that case total ammonia requirement for the combined scheme of ammonium sulphate and soda ash production will be about 133 tonnes per day. Soda ash production through the Dual Process, where ammonium chloride is produced as a coproduct will require about 68 tonnes of ammonia per day. Therefore, the maximum requirement of ammonia for either of the two alternatives will be 133 tonnes per day.

<u>Ammonia Availability</u>

2.3 As indicated earlier, ammonia requirement of the various schemes could be met from one of the following sources :

(i) existing fertilizer units at Fenchuganj and Ghorasal or the Ashuganj project at present under implementation

(ii) proposed Chittagong Urea Fertilizer Project or the Ghorasal-II project.

(iii) as independent ammonia plant exclusively built for the purpose.

2.4 The present ammonia production facilities at Fenchuganj and Ghorasal as well as the one at Ashuganj under execution are designed for complete utilisation of ammonia in the downstream product plants and as such do not have provisions for excess production of ammonia. Possibilities of stepping up ammonia production in these units in relatively small quantities either through changes in plant efficiencies or manipulations in operating conditions cannot be ruled out altogether though no conclusive studies on these lines are available. However, it is difficult to establish this possibility at this stage, since the plants are either in the process of renovation as in Fenchuganj, or still in the process of overcoming teething troubles, asin Ghorasal. A detailed note on performance of the operating fertilizer plants is enclosed at Annexure II-A.

Fenchuganj Fertilizer Factory

2.5 The Fenchuganj fertilizer factory was established in 1962 and is located in the Sylhet district of Bangladesh. It produces mainly urea with a small capacity for the manufacture of ammonium sulphate. Its ammonia plant was designed to produce annually about 65,000 tonnes of liquid ammonia. However, due to ageing and poor maintenance of plants and facilities, the condition of the factory in general has deteriorated and ammonia production in recent period has been restricted to about 40,000 tonnes (61% of the rated capacity) only. The plants and facilities are now being renovated and rehabilitated by Kobe Steel, the original supplier, with a view to increasing the life and efficiency of the plants. Kobe Steel is understand to have estimated that as a result of the rehabilitation programme, the life of the plant will be extended by a further period of 10 years and urea production may increase from around 60,000 tonnes to about 75,000 tonnes annually. Ammonium sulphate production is also expected to improve from an uncertain production level to around 8,000 tonnes. It is also expected that plant efficiencies will improve and ammonia consumption in end products will reduce to a reasonable level (Annexure II-A). Based on the projected production and efficiency figures, the ammonia production is expected to be 49,000 tonnes, which works out to about 75% of the rated capacity and which the plant will be in a position to use up entirely. Any further improvement from an old, renovated plant, on a sustained basis will be unrealistic to expect.

2.6 Any proposal for securing supplies of ammonia by expansion of the unit say, by adding another stream, is also considered unrealistic. Apart from the problems relating to site, such as availability of land, utilities and other offsite facilities, the following factors weigh against the proposal :

(a) ammonia will have to be transported to Chittagong or Ghorasal, - the proposed sites for ammonium sulphate/soda ash plants - either by rail or road· waterway is ruled out since the facility from Fenchuganj cannot be relied upon. The delivered cost of ammonia will be prohibitive, besides the proposal being operationally cumbersome

(b) carbon dioxide generated as process waste in the ammonia plant cannot be made use of due to location of plants at different sites

Location of the soda ash plant at Fenchuganj to take advantage of possible ammonia and carbondioxide (and lime stone) supply will be equally unrealistic as it will involve movement of large quantities of salt required for the process and movement of the soda ash produced to potential consumers, primarily in and around Dacca and Chittagong. Apart from the two-way freight burden, the traffic generated will overstrain the transport system which is not in a fine state even at present.

2.7 In view of these overriding considerations, the Consultant did not make a 'in-depth' study of the possibilities of producing ammonia at Fenchuganj through possible expansion of capacity of ammonia plant.

Ghorasal Fertilizer Factory

2.8 The Ghorasal factory is located at a distance of about 50 Kilometers from Dacca City. The complex consists of an ammonia and a urea plant. These process plants are rated to produce annually 217,800 and 340,000 tonnes of ammonia and urea respectively. The performance of the production units has not been satisfactory from the very start due to several factors, including power failures and equipment failures. Most of the problems seem to be confined to the ammonia plant, and the urea plant has not faced any major problem except gland leaks in H.P. pumps and compressors, which has resulted in heavy consumption of ammonia and carbondioxide. As a result of these problems, the annual urea production has dropped to below 200,000 tonnes. Many shutdowns were planned and used to overhaul the plants and facilities but it has not made any significant improvement. A consulting firm, Bresler & Associates, appointed through the World Bank Group to suggest remedial measures has recommended certain modifications/additions in the plant and related facilities to improve production. The consulting firm is said to be of the opinion that with the suggested modifications, the plant can achieve a production level of 280,000 tonnes (82% of rated capacity) of urea. This is based on assumption that the specific consumption of ammonia will improve to 0.60-0.61 tonne per tonne of urea and ammonia production will average 168,000 tonnes per annum. At this level the ammonia plant will operate, on the average, at 85% of the rated capacity, which may be considered reasonably good. Detailed discussions with the Plant Management in the light of the technical inspection and analysis carried out by the consulting firm indicated that the plant is in no position to give a better performance in ammonia production on sustained basis. In the Managements view, even if the plant can be made to operate at higher efficiency, the extra ammonia available will be preferably diverted to raise urea production rather than disposed of an anhydrous ammonia. Hence the possibility of securing the required quantities of ammonia, or even a major part of it, from the Ghorasal plant's existing facilities are not assured. For the same reasons, the scope for expanding production of ammonia say, by adding another stream is not high owing to the limitations on the utilities and auxiliary plants. This is very much evident from the fact that the Ghorasal II, the Chinese-aided package fertiliser plant to be located adjacent to the existing fertilizer unit, has planned its own utilities and auxiliary facilities.

Ashuganj Fertilizer Project

2.9 The Ashuganj fertilizer project is located at a distance of about 60 kilometers from Dacca. The project is rated to produce annually about 275,000 tonnes of ammonia (925 te/day) and 475,000 tonnes of urea (1600 te/day) (Annexure II-A). Hence in the ordinary course, with the urea plant functioning normally, there will be no surplus ammonia available for disposal. However, during discussions with project authorities it was pointed out that ammonia synthesis gas equivalent to about 50 tonnes of ammonia might be theoretically available, if the plant functioned normally as anticipated, after commissioning. Due to constraints in the synthesis section, however, separate facilities will need to be established for converting the synthesis gas into ammonia. But assured supply of synthesis gas can be confirmed only after the plant goes into operation and production stabilises, say, in about 3 years of commissioning. In view of the fact that modern largescale ammonia plants involve highly sophisticated technology with several delicately balanced features, there are instances when in operation the plants failed to perform in accordance with expectations owing to unforeseen technical problems. Therefore, the availability of ammonia from the project cannot now be taken as assured.

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2.10 The possibility of expansion of the project to meet the requirement of ammonia for the proposed ammonium sulphate/soda ash scheme is ruled out, since the project itself is in the implementation stage and is not expected to be commissioned till 1980. Besides, the availability of land and other utilities like water etc. can be properly assessed only after the plant starts operating at full load.

Chapter - 3

AMMONIA SUPPLY FROM NEW PLANTS

3.1 Bangladesh is planning to set up two new nitrogen fertilizer plants, based on natural gas available within the country, for the production of urea. One of these is proposed to be located at Chittagong and the other at Ghorasal adjoining the existing ammonia-urea plant. Both these projects are in an advance stage of formulation and planning. As such, if conditions otherwise permit, it may be useful and easier to integrate the ammonia requirements of the schemes under consideration into these projects at the present project formulation stage itself, so that the necessary flexibility could be built-in and the costs of needed modifications could be minimised. Such integration in the 'pre-project' stage will also help to avoid any constraints that might arise at a later stage in operation.

Chittagong Urea Fertilizer Project

3.2 A consulting firm engaged by the Government of Bangladesh has recently (December '78) submitted the feasibility report for the Chittagong Urea Fertilizer (CUF) project. On the basis of this report, the Government has approved the project in principle and is seeking international financial assistance for its execution. The project is proposed to be located at Chittagong, across the river Karnaphuli from North Patenga (where the TSP Complex is located) and will have an ammonia-urea complex along with associated auxiliary plants. The complex is to be based on natural gas which, under another project will be made available from the Bakhrabad fields by a pipeline. As proposed (Annexure II-B) the ammonia plant will be rated to produce annually about 298,500 tonnes (986 te/day), which will be wholly converted into 510,000 tonnes of urea per year (1700 te/day). As formulated now, the project will have no excess ammonia and therefore, it apparently there would be no possibility of securing the required quantities of ammonia from the plant unless the requirement is dovetailed into the project before the start of execution.

3.3 Discussions with the consulting firm UNICO (which prepared the feasibility study) and the project authorities, however indicated (Annexure III-C), that even though the proposed project had balanced capacities for ammonia and urea, by increasing the ammonia synthesis loop pressure and reducing the loop purges, it will be possible to increase the production of ammonia from the planned ammonia facility by about 70 to 72 tonnes per day. An increase in ammonia production upto 50 tonnes/day may not require any modifications in the proposed system, but any production exceeding 50 tonnes may require some minor modifications downstream of the Methanator. The project authorities assured that the cost of such modifications, being not very significant at this stage, will be borne by the project itself. The supply of 133 tonnes of ammonia to meet the full requirement of the ammonium sulphate-soda ash scheme, however, will not be possible without enlargement of ammonia plant capacity. This will necessitate reworking of the Chittagong project study, both in terms of input-output balances and cost estimates by the consulting firm. Investment requirements will clearly increase if the ammonia plant capacity were to be increased, though the magnitude of additional investment could not be ascertained from the consulting firm. For these reasons, though it was not expressly stated, the project authorities did not seem to favour this proposal of raising the ammonia plant capacity. Alternatively, it could be possible to draw the full requirement of ammonia by keeping the ammonia capacity fixed at the proposed level, but by curtailing urea production capacity. Since the Chittagong urea project is meant to be an export-oriented unit (on account of the insufficient absorbtive capacity for urea produced within the country), there could possibly be a case for diverting the ammonia from the production of urea to the manufacture of ammonium sulphate/soda ash, since nearly the entire ammonia gets fixed as fertilizer nitrogen in any case. This might not need any additional investment; there might in fact be a marginal reduction in the urea plant cost. However, acceptance of this proposal will be worth its while only if the ammonia so diverted could bring in better returns than in urea production[1] so that the project's overall viability is not adversely affected. The project as conceived, however will not have any surplus of carbondioxide due to the high methane content of the Bakhrabad gas. The carbon dioxide needed, however, can be generated by drawing the requisite amount of flue gas from the steam generation plant. For this purpose, the project owners will have to maintain the oxygen content in the flue gas within 1.5 per cent by volume, which they have agreed to do (Annexure III-C).

Ghorasal II Project

3.4 The other project which is under the active consideration of Bangladesh Government is a relatively smaller 180 tpd ammonia/300 tpd urea (100,000 tpy urea) project being put up at Ghorasal, next to the existing plant. Both the ammonia and urea plants are being supplied on turn-key basis by China as part of development assistance. Like the Ghorasal-I complex, this unit will also be based on natural gas from the same source. Preliminary designs for the plants and

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[1] This alternative has not been discussed since on a preliminary analysis it was found that urea brought better returns compared to ammonium sulphate.

related facilities have already been completed and they are in the process of being firmed up. With a planned matching urea plant, the project is not likely to have any significant surplus of ammonia left over. Discussions with BCIC clearly established that the site as well as plant capacities of this project are 'frozen' and since the offer from China is a package offer, there are no possibilities of ammonia from this project being made available for any other purpose.

New Captive Plant

3.5 From the assessment made above, it is apparent that any requirement of ammonia upwards of 72 te/day can be secured only by (i) lowering marginally the capacity of the urea plant in relation to the ammonia plant capacity in the Chittagong Urea Fertilizer Project or (ii) by setting up an independent captive ammonia plant. In the event of the larger quantities of ammonia being required at any location farther from Chittagong, the case for a captive plant gets strengthened, in view of the expected high delivery (transport and handling) costs of ammonia in Bangladesh due to lack of developed facilities. However, it is a well known fact that production cost of ammonia in a small plant is disproportionately high due to the constraints of process technology. The case for recommending a large capacity plant to permit the use of centrifugal compressor technology is weak, since Bangladesh is expected to be substantially surplus in fertilizer nitrogen (principally urea) production, when the Ashuganj project and the proposed two new projects (Ghorasal II and Chittagong) go into stream. It is for this reason that the Chittagong Urea project is being conceived essentially an export-oriented project.

The prospects for ammonia user-industries being set up in the country in near future on such scale as to make use of the entire production of ammonia from a modern largescale plant are not bright, in view of the present state of the economy.

Chapter - 4

ALTERNATIVE PLANS FOR AMMONIA SUPPLY

Location of Projects

4.1 It has been established in Part IV that the ammonium sulphate plant involving the utilisation of byproduct gypsum will need to be located at Chittagong in order to minimise the cost of raw phosphogypsum transport, which has a material impact on the cost of production of ammonium sulphate. Since the available land in the TSP Complex area is not adequate to accommodate the ammonium sulphate plant and no suitable area is available in the vicinity, the site chosen to locate the plant is on the other side of the Karnaphuli river, adjoining the site proposed for the Chittagong Urea Fertilizer Project (Drawing in Part V). The soda ash unit, making use of the chalk available as a by-product in the ammonium sulphate process (through the gypsum route), based on Solvay process, can also be located in the same site (Part V). In that case, the ammonia source should be available close to the ammonium sulphate/soda ash plants in order to minimise the cost of ammonia handling, transportation and storage and to make use of the carbon dioxide, to the extent available. The ammonia needed can be made available, as discussed earlier, by setting up an independent ammonia plant of 100 te/day capacity with supplemental ammonia obtained from the Chittagong Urea Fertilizer Project, since the urea project cannot make available more than 72 or 73 te/day from its planned facility.

4.2 If, however, the scheme recommended for utilisation of phosphogypsum does not involve the prodction of ammonium sulphate, the soda ash unit will have to be based on the Dual Process in view of the non-availability of chalk. In that case the ammonia required will be only 68 te/day for the optimal plant size proposed in Part V. Two alternate sites have been considered for the Dual Process soda ash plant in Part V, viz. Chittagong and Ghorasal.

It the location chosen is Chittagong then also the site proposed will be next to the site selected for the Chittagong Urea Fertilizer Project, in which case the needed ammonia can be secured from the adjoining Urea Project, as discussed earlier. In case the site gets shitted to Ghorasal for reasons discussed in Part V, the ammonia supply can be made available from two sources (i) from the Chittagong Urea Fertilizer Project - with arrangements for transport ot ammonia or (ii) from a new captive ammonia plant with a capacity of 100 te/day located in Ghorasal. The different alternatives considered are shown in Table 4.1.

4.3 Based on the preliminary investigations, a suitable site adjacent to the area earmarked for the proposed Chittagong Urea Fertilizer Project has been identified, in case the establishment of an independent ammonia plant of 100 tpd capacity becomes necessary. Similarly, if the project gets shifted to Ghorasal, a site close to the proposed Ghorasal II project and adjacent to the site identitied for the soda ash plant at Ghorasal can be used for the ammonia plant. Ammonia balance based on the above proposed schemes for supply ot ammonia has been presented in Table 4.1.

Chittagong Site

4.4 The site identitied in Chittagong for the ammonium sulphate/soda ash unit with captive ammonia plant is across the river Karnaphuli from North Patenga where the TSP Complex is located. It is a 'greenfield' site with poor communication facilities. An old rail-cum-road bridge at Kalughat at a distance of about 25 kilometers from Chittagong is the only possible land link between the site and North Patenga. Normally ferry is used for transportation of material from Chittagong. Sufficient Government land is available in the area for locating all the proposed facilities viz the ammonia-urea complex

Table 4.1

Ammonia Balance

(Te/day)

Sl.No.	Location		Production Schemes	Ammonia	
				Quantity required	Source of supply
1.	**Chittagong**				
	Alternative I	a)	Ammonium Sulphate and Soda Ash (Solvay Process)	133	100 tonnes from new captive plant and 33 tonnes from Chittagong Urea Fertilizer Project.
	Alternative II	b)	Soda Ash (Solvay Process) by use of natural limestone	1	Total from Chittagong Urea Fertilizer Project
	Alternative III	c)	Soda Ash (Dual Process)	68	-do-
2.	**Ghorasal**				
	Alternative I	a)	Soda Ash (Dual Process)	68	New Captive Plant
	Alternative II	b)	Soda Ash (Dual Process)	68	Total from Chittagong Urea Fertilizer Project (with arrangements for ammonia transport to site)

(of Chittagong Urea Fertilizer Project), ammonium sulphate/soda ash complex as well as the proposed ammonia plant. The area is free from vegetation or dwellings. In general, the soil bearing strength of the area is good, though piling will be required for heavy foundations. The entire area is prone to storms and flooding; therefore the site will have to be raised above the highest flood level (8 metres above MSL). Normally, monsoon in the area lasts for about 6 months. The extreme meteorological conditions of the area as reported. is given below :

Maximum temperature : 39°C (May)

Minimum temperature : 9°C (January)

Maximum rainfall (Monthly average) : 760 mm (July)

Humidity : 89%

Wind velocity (Max.) : 70 meters/sec.

Natural gas supply to the project will be made from the gas line to be laid for the Chittagong Urea Fertilizer Project. Water in the river Karnaphuli near the proposed site is saline and therefore sweet water supply to the project will have to be drawn either from Bahakhal stream at a distance of about 10 kilometers or upstream of Karnaphuli river at a distance of about 20 kilometers as suggested for Chittagong Urea Fertilizer Project. Discussions with the project authorities of the Chittagong Urea Project indicated that the water requirement can be integrated with the urea project. Alternatively, the Water and Sewerage Authority (WASA) of Bangladesh has agreed to supply process water to the area in required quantities at the battery limits of the project. Power Supply will be made by Power Development Board (PDB) at 33 KV.

Ghorasal

4.5 The site selected is located on the bank of river Sitalakhya and adjacent to Ghorasal fertilizer factory. Part of this land will be taken up by the Ghorasal II project, but the Consultants feel that enough land will still be available for locating a 100 te/day ammonia plant with requisite handling and other facilities as well as the proposed soda ash plant (Part V). Most of the land has already been levelled and filled. Soil bearing condition is understood to be good but will require piling for heavy foundations. The metereological information for the proposed site is given below as :

Maximum temperature : 42°C (May)

Minimum temperature : 5°C (January)

Maximum rainfall (Monthly average) : 350 mm (August)

Humidity : 87%

Wind Velocity : 20 metres/sec.

Natural gas supply to the project will be made from the existing gas line already in use by the Ghorasal Plant. The natural gas supply is made from Titas gas fields. Ghorasal is on one of the main trunk routes of riverine traffic, with a minimum draft of about 5 ft. throughout the year. Therefore, waterway is a popular mode of communication though the site is reasonably well-connected by road (except for a short distance, which is being improved) and rail. Water supply to the project will be made by drawing on the river Sitalakhya, which is perennial and water is of acceptable quality, as evidenced by the fact that the Ghorasal plant is presently drawing water from this source. A PDB power plant of 110 MW generation capacity is located close to the site. Power supply to the project will be made from PDB grid at 33 KV.

4.6 Construction materials such as cement, sand, stone aggregate etc. are not available in the locality and hence these have to be transported from outside. Similarly skilled construction labour will have to be brought from Dacca - Narayanganj area.

Plot Plan

4.7 A tentative plot plan showing the location of different plants and offsites for two locations (Chittagong and Ghorasal) is enclosed at Drawings II-1 and II-2. Based on the preliminary layout of plants and facilities, the land requirement for factory and township is shown below in Table 4.2.

Table 4.2

Land Requirement

(Acres)

Land	Chittagong		Ghorasal	
	Alt. I	Alt. II & III	Alt. I	Alt. II
1. Factory	40	20	25	20
2. Township	40	20	20	20
Total	80	40	45	40

Note :

Chittagong : Alternative I - Ammonium Sulphate and Soda Ash (Solvay) with captive ammonia plant

Alternative II - Soda Ash (Solvay) plant (with purchased ammonia)

Alternative III - Soda Ash (Dual) plant (with purchased ammonia).

Ghorasal : Alternative I - Soda Ash (Dual) plant (with captive ammonia plant)

Alternative II - Soda Ash (Dual) plant (with purchased ammonia).

Chapter - 5

PROCESS SELECTION

5.1 If the proposed ammonium sulphate or soda ash plants are required to be dupported by an independent ammonia plant as discussed in the preceding chapter, the feedstock for the plant will evidently be natural gas. Process schemes for gas-based ammonia plants have been standardised over years, recent innovations being largely confined to the methods and extent of energy recovery so that the energy consumption is minimised. Most of the recent technological developments are, however, confined to the large capacity plants. In fact, with the significant economies of scale emerging from large capacity plants, interest on small plants has been steadily languishing and as a result no major break-through has occurred in the technology of small plants.

5.2 Since the ammonia plant discussed here is of small capacity the centrifugal compressor technology cannot be made use of. The compressors are, therefore, motor driven and of reciprocating type. The process described below is typical and proven; actual selection can be done from among several processes offered by reputed companies in USA, Europe and Asia. The processes are proven and backed by experience.

5.3 The process scheme (represented in Drawing No.II-3) forms the typical route for the natural gas based ammonia plants viz. desulphurisation, primary and secondary reformation, HT and LT shift conversion, carbon dioxide removal, compression, synthesis and liquid ammonia storage.

Gas Metering and Desulphurisation

5.4 Natural gas is assumed to be available at the battery limits of the plant at 20 Kg/cm^{2}a. The gas after passing through the metering station will be divided into two parts. The first part will be used as process feed and the other part after thorttling to 6 kg/cm^{2}a will be utilised for fuel in the primary reformer furnace and other uses. The process gas will be compressed to about 40 kg/cm^2 and passed through desulphurisation step for removal of sulphur, if any. Although no sulphur or its compounds are reported in the analysis of natural gas, a zinc oxide desulphurisation unit has been envisaged as a precautionary measure against any sulphur contamination of catalysts, since the Petro-Bangla reportedly is not ready to guarantee supply of completely sulphur-free gas.

Reformation : Primary

5.5 The feed gas exit desulphuriser is mixed with process steam to maintain a steam carbon ratio of 3.6 in the reformer feed mixture. The mixed gas is preheated to 500°C in the flue gas convection section of the primary reformer before it enters the primary reformer tubes. In the primary reformer the endothermic reformation reaction is carried out in the tubes packed with nickel catalyst. The tubes are heated externally by gas burners located on the top or side of the primary reformer furnace. The primary 'reformed' gas outlet temperature is kept at about 800°C. The outlet pressure from the primary reformer is maintained at 30 kg/cm^{2}a. Heat available in the flue gas from the primary reformer furnace is recovered by placing different coils in the convection section as per the process requirements. The flue gas leaves the convection section at about 180°C and vented to the atmosphere through an induced draft fan and chimney.

Secondary Reformer

5.6 The primary 'reformed' gas at 800°C is passed to the secondary reformer where pre-heated air at 500°C is also added. Two numbers of reciprocating type process air compressors have been envisaged, - one of them will be a standby. Air from the process air compressor is heated to 500°C in the flue gas convection section and then sent to secondary reformer, the methane effluent from the primary reformed gas is reduced to 0.28% by vol. (dry) in the presence of nickel catalyst. The outlet temperature of the secondary reformed gas will be maintained at 977°C, and the gas will be cooled to 360°C in the reformed gas boiler before it enters the high temperature shift converter. The reformed gas boiler will be split into two portions laid out in series with an extemal by-pass for the low temperature portion in order to have a better and easier control of gas temperature at the inlet of H.T. shift converter. Steam will be generated in the reformer gas boiler and flue gas waste heat boiler at 40 kg/cm^2a.

Shift Conversion

5.7 Carbon monoxide is converted from 12.66 percent by vol (dry) to 3 percent by vol (dry) in the high temperature (HT) shift converter in the presence of iron oxide catalyst. The outlet temperature is maintained at 425°C. The partially converted gas is cooled to 200°C in a trim heater and a boiler-feed water heater before it enters the low temperature LT shift converter. Carbon monoxide leakage in the converted gas at the outlet of the LT converter will be about 0.3 percent by vol (dry) and the temperature will be about 222°C. The converted gas supplies the regeneration heat to Benfield solution and enters the CO_2 absorber.

CO_2 Removal

5.8 The Benfield system has been assumed for the carbon dioxide removal scheme. A split stream absorption and single stage regeneration has been assumed to be employed here. The lean solution from the regenerator is pumped by the solution circulation pump to the absorber in two parts. A portion of total solution is fed to the top of the absorber, after it is cooled to 70°C in a solution cooler by the cooling water. The other portion, is fed at the middle of the absorber without cooling. Carbon dioxide gas and steam coming out of the regenerator is first cooled indirectly by demineralised (DM) water and subsequently by cooling water. Carbon dioxide gas is sent to gas holder of 3000 m^3 capacity. The hot converted gas at 222°C supplies the major portion of the heat required for regeneration of Benfield solution. The feed gas first passes through a condensate reboiler to raise steam at 4.5 Kg/cm^2a and then passed through a solution reboiler for indirect boiling of Benfield solution. The gas is further cooled in a gas cooler to 116°C before entering the absorber. Carbon dioxide leakage in the decarbonated gas at the outlet of the absorber will be about 0.1 per cent vol (dry).

Methanation

5.9 Decarbonated gas coming out from Benfield absorber at 70°C is heated to 296°C in the methanator gas heat exchanger and subsequently to 315°C in the trim heater of the shift conversion section before it enters the methanator. CO and CO_2 present in the decarbonated gas is converted to CH_4 in the presence of a nickel catalyst. The temperature of the gas rises to 348°C in the methanator due to exothermic heat of reactions. Methanated gas is first cooled in the methanator heat exchanger and then in the methanated gas cooler. The methanated gas at the outlet of gas cooler contains less than 10 ppm of CO + CO_2 and will be available at the suction of the synthesis gas compressor at 25 ata and 45°C.

Compression, Synthesis and Recovery

5.10 The make-up synthesis gas is compressed to about 1315 Kg/cm^2 in a reciprocating gas compressor driven by electric motor. The make-up gas is mixed with the circulating gas at outlet of the oil filter. Reciprocating recirculating compressors have been considered for the duty. The make-up gas is cooled in the after cooler of the synthesis gas compressor before going to cold exchanger. The synthesis loop will be operating at about 300 Kg/cm^{2}a. The mixed gas is cooled in the cold exchanger to 23°C and further cooled to 0°C in the ammonia cooled condenser. One level of refrigeration (-10°C) has been adopted for ease of operation. About half of the total ammonia production is collected in the cold ammonia separator after the ammonia cooled condenser. The cold gas at 0°C is heated first in cold exchanger to 40°C and subsequently in the hot exchanger to 185°C before entering the synthesis converter. An axial quench type converter has been assumed. The converter consists of a pressure shell and a basket. The basket is divided into a lower heat exchanger and a catalyst section consisting of three beds. The synthesis gas is introduced into the converter from the top and passes downwards through the annular space between the basket and pressure shell, keeping the latter cool. At the bottom of the converter the gas goes to the shell side of the lower exchanger, in which it is heated by heat exchanger with the gas leaving the converter. The temperature may be adjusted by means of a cold gas by-pass introduced through the bottom of the converter. The gas then enters the catalyst bed from top to bottom. After passing through the first bed of catalyst the gases get heated due to formation of ammonia. Just below the first catalyst bed grate, a gas distributer is provided. Here cold inlet gas is mixed with the hot gas and the temperature is brought down. After passing through the third bed at a temperature of about 490°C the gas goes to the tube side of the lower exchanger. It leaves the converter through the bottom of the pressure shell at a temperature of 380°C. The content of ammonia at the inlet and outlet of the converter are 3.3 and 16.8 percent respectively. A considerable part of the heat content in the gas leaving the converter is utilised in generating steam at

40 Kg/cm^{2}a in an external waste heat boiler and at as a result the recirculation gas temperature is reduced to 280°C. The recirculation gas is further cooled to 126°C in the hot exchanger and then cooled to 40°C in the water-cooled condenser. About half of the total ammonia produced is condensed in the water cooled condenser and collected in the hot ammonia separator. The gas from the ammonia separator is recycled back to recirculating compressor to complete the cycle. Hot and cold ammonia collected in the two separators are sent to the let-down tank which is maintained at 40 Kg/cm^{2}a. Liquid ammonia from let down tank is further depressurised to about 4 Kg/cm^{2}a and sent to down stream plants and/or ammonia storage tank.

5.11 In order to prevent accumulation of inert gases (CH_4&A) in the loop, a certain quantity of circulating gas is purged from the synthesis loop after the hot ammonia separator. The purge gas is cooled to 0°C in the purge gas cooler to recover ammonia in the gas. The purge gas is mixed with the flash gas from the flash gas cooler which is put at the top of the let-down tank. The mixed gas is washed with water in a scrubber to bring down the ammonia content in the gas to 100 ppm. The purge gas mixture has fuel value and hence will be utilised for supplementing the fuel req-uirement in the primary reformer furnace. Aqueous ammonia produced in the ammonia scrubber is distilled in the ammonia stripper to get pure ammonia which will be sent to ammonia storage tank. The ammonia vapour arising from the flash vessel and storage tank is passed through a reciprocating motor driven refrigeration unit where ammonia is condensed and the recovered ammonia is pumped back to the system.

Plant Efficiency and Production

5.12 The selection of process steps and the design philosophy have been made on the assumption that the plants will be operating, on an average, for 330 days in a year at rated production level (33,000 tonnes/year). However it is expected that the minimum annual production would not fall below 30,000 metric tons (90% of rated capacity). Ammonia and carbondioxide production capacities are given below :

(i) Ammonia production

a) Daily : 100 metric tons

b) Annual : 30,000 metric tons

c) Stream days : 300

(ii) Carbondioxide (by product)

a) Daily : 98 metric tons

b) Annual : 29,400 metric tons

Product Specifications

5.13 The ammonia produced from the plant will be conforming to following specifications :

(by weight)

Liquid ammonia : 99.8% min.
Moisture : 0.2% max.
Oil : 10 ppm max.

Chapter - 6

RAW MATERIAL AND UTILITIES

6.1 The estimated requirements of raw materials and utilities for a battery-limit 100 metric tons per day ammonia plant has been tabulated in Table 7.1. The figures are based on normal operation of the plant :

Table 6.1

Requirement of Raw Materials and Utilities

(a)	Natural gas	:	91200	Nm^3/day
(b)	Power	:	82	MWH/day
(c)	Process water (make up)	:	1680	m^3/day
(d)	Boiler feed water	:	432	m^3/day
(e)	Cooling water (circulation)	:	33600	m^3/day

6.2 Since ammonia production forms part of the larger scheme, wherein soda ash and ammonium sulphate are produced, the overall estimated requirement of raw materials and utilities is shown in Drg. No. II-4 and II-5. The requirements of raw materials and utilities exclusively required for the production of ammonium sulphate and soda ash are dealtwith in detail in the respective Parts.

Natural Gas

6.3 Bangladesh has large reserves of natural gas and a number of proven and commercially rich fields have been located (Table 6.2). All the gas deposits discovered so far have more or less similar gas composition (methane over 95% by volume), with practically no sulphur and only traces of impurities.

6.4 The pace of utilisation of gas has been rather slow (Table 6.3), the major industrial users at present being the Fenchuganj Fertilizer Factory the Chhatak Cement Factory and the Ghorasal Fertilizer Factory The reserves are, therefore expected to last several decades at the current trend of utilisation. Hence, for the Ghorasal location, supply of gas from Titas field, from where the Ghorasal Fertilizer Factory is presently drawing the natural gas, is assumed. The pipeline system has sufficient capacity to supply natural gas to the plants (including soda ash) if located at Ghorasal.

Table 6.2

Gas Reserves in Bangladesh

Gas Fields	Proven Reserves (10^{12}cft)	Methane (Vol.%)	Condensate Recovery (BBL/10 cft)	Calorific value gross (Btu/cft)	Year ot dis-covery
1. Sylhet	0.28-0.43	95.49	3.7	1 052	1955
2. Chhatak	0.04	99.05	Traces	1,007	1959
3. Rashidpur	1.06	98.02	0.30	1,014	1960
4. Kailas Tila	0.60	95.70	10.00	1,050	1962
5. Titas	2.25	96.90	1.70	1,036	1962
6. Habibganj	1.28	97.80	0.05	1,020	1962
7. Bakhrabad	4.16	94.03	2.00	1,022	1968
8. Semutag	0.03	96.94	Traces	-	1969
9. Katubdia	Over 1.00	95.72	Traces	1,043	1977

Table - 6.3

Production of Natural Gas in Bangladesh

(Figs. in 10^6 Scft.)

Year	Chhatak	Sylhet	Titas	Habibganj	Total
1973	385	3,420	17,327	3,159	24,291
1974	903	4,488	14,592	2,598	22,581
1975	1,036	4,898	14,546	2,232	22,712
1976	965	5,262	22,875	2,189	31,291
1977	1,468	5,895	21,803	2,800	31,966

(Source : Petro Bangla)

6.5 At Chittagong location, as mentioned earlier, the natural gas will be supplied from Bakhrabad fields. A project to transmit gas from Bakhrabad to the Chittagong area through a 24 inches, 200 kilometer pipeline is actively under study. The pipeline will also serve the proposed Chittagong Urea Fertilizer Project. The same gas line can meet the requirements of the other plants proposed to be located in the adjoining sites.

Water

6.6 The requirement of water for process, utilities and services in different alternative schemes is shown in Drawing No. II-4 & II-5. The maximum water requirement at Chittagong and Ghorasal locations for the ammonia production scheme is 670 M^3/h of process water and 570 M^3/h of raw water.

6.7 As explained elsewhere, river Karnaphuli cannot supply water to the plants at the Chittagong location because of salinity, Water for the proposed projects, therefore, will have to be piped either from Sikal Bahakhal at a distance of about 10 kilometers or from a suitable location in upstream of river Karnaphuli, where water is perennial and sweet. An investigation conducted for water supply to the Chittagong Urea Fertilizer Project indicated that good quality water is available near Kalurghat bridge, at distance of about 25 kilometers from the site. The analysis of water from river Karnaphuli and Sikal Bahakhal is shown in Table 6.4

Table 6.4

Water Analysis (Average)
(March 1978)

	Karnaphuli river at Kalurghat	Sikal Bahakhal at Kalapul
Alkalinity (as $CaCO_3$)	55-60 mgm/lit.	50-60 mgm/lit.
Total hardness as $CaCO_3$	50-70 ppm	75-90 ppm.
Dissolved solids	70-85 ppm	100-130 ppm.
Suspended solids	10-20 ppm	20-50 ppm
Conductivity (in micro mhos/cm)	80-100	100-200
pH	7-7.5	6.8-7.3
Turbidity	15-30	30-70
Calcium ++	8-10 ppm	8-10 ppm
Iron	0.5 ppm	2-5 ppm
Chloride$^-$	3-6 ppm	8-25
Silica	100-200 ppm	100-250 ppm

6.8 The WASA is also planning to extend the city water supply facilities to the other side of the rive: Kamaphuli in case of assured demand and it will be possible to get the required water supply from this source. This will, however, be contingent on the plan for expansion of city water supply being taken up for execution. The delivered cost of filtered water was estimated at TK 2.08 per cu. meter. The scheme is expected to be ready by 1982. The analysis of water to be supplied by WASA is given in Table 6.5.

Table 6.5

WASA Water Analysis

Total alkalinity as $CaCO_3$	118 mgm/litre
Total hardness "	45 "
Calcium hardness "	25 "
Iron after treatment	0.5 ppm
Residue	259 mgm/litre
Chloride	NIL

6.9 The water supply to the proposed schemes, if located at Chittagong, can be integrated with the facilities that will be built for the Chittagong Urea Fertilizer Project. This has been agreed to by the project authorities, in view ot the marginal cost involved in increasing the water supply capacity. However, in the absence any cost indications of water supplied, for estimate purposes, the cost of sweet water supply has been assumed TK 2.08 per cu. metre i.e. the cost indicated for WASA supply.

6.10 At Ghorasal, the water will be drawn from river Sitalakhya and treated as per requirement. A typical analysis of water from the river is given below in Table 6.6.

Table 6.6

Analysis of Sitalakhya River Water

A. As given by Japanese consultants - 1969 :

Water temperature	31°C
Turbidity	25-8 (Japanese Ind.Std).
Total Hardness as $CaCO_3$	160 ppm.
Alkalinity as $CaCO_3$	178 ppm.
Silica	30.1 ppm.
Chloride ion	6.1 ppm
Sulfate ion	6 ppm
Calcium	43.6 ppm

B. As analysed by Bresler and Associates - 1978 :

	Dry Season (as $CaCO_3$)	Rainy Season (as $CaCO_3$)
Calcium	108	41
Magnesium	52	17
Sodium	Not Reported	9
Potassium	Not Reported	5
	160	72

	Dry Season	Rainy Season
HCO_3	178	51
SO_4	6	7
Cl	8	5
SiO_2	21	4
	213	67
Dissolved Solids	360	

Power

6.11 Power supply in Bangladesh is controlled by the Power Development Board (PDB). All power stations west of Jamuna are connected to a common grid system called the Western grid; similarly a common grid system (Eastern grid) connects all power stations east of Jamuna. A project to connect these two regional grids into a national grid is under execution. Mostly the grid supply is at 132 KV, but power supply to industries is made at 33 KV through 132/33 KV substation located at different points.

6.12 Power supply to the Chittagong Urea Project will be made by PDB at 33 KV from their substation located nearby. The CUF Project authorities have agreed that the power requirement of the new schemes may be met from the same source (Annexure II-C). Similarly at Ghorasal, the fertilizer factory which is receiving 12 MW power from the PDB grid at 33 KV has extra capacity to cater to the possible needs of the new projects, in case it is decided to locate the ammonia-soda ash complex at Ghorasal.

6.13 The present* power tariff for high voltage supply to industries drawing power above 50 KW is as follows :

(a)	Fixed charges	TK 42.0 per KVA of billing demand per month
(b)	Energy charges :	
(i)	Monthly consumption upto 200 KWh per KVA of billing demand	36 poisa per KWh
(ii)	Monthly consumption in excess of 200 KWh per KVA of billing demand	31 poisa per KWh

(c) Minimum charge in any month not to be less than the fixed charge.

(d) Interest @ 1% per month on the total billed amount for payment beyond due date.

(e) Power factor for supply 0.85.

6.14 During discussions with PDB, the power supply to proposed schemes both at Chittagong and Ghorasal was confirmed. On the question of reliability of power supply, PDB assured that measures including direct supply of power to Chittagong from Karnaphuli hydroelectric system and to Ghorasal from the Thermal Power Plant located nearby with tie-up with grid for emergency power supply to improve the efficiency of power supply were under consideration. Power supply to proposed schemes, therefore, is assumed to be through PDB supply system.

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*April 1979.

Steam Generation

6.15 The steam generation system envisaged for CUF Project provides for 3 boilers (2+1), each with a capacity of 80 metric tons per hour steam at 102 Kg/cm^{2}a. Normally 2 boilers will be operating to meet the steam requirements of the project. During discussions with the project authorities as well as consultants (Annexure II-C), it was indicated that if required, steam upto 80 metric tons per hour may be made available from the CUF Project by operating the spare unit. The steam requirement of the proposed scheme will in no case be more than 50-60 te per hour. Therefore, it is assumed that steam supply can be integrated with CUF Project.

6.16 At Ghorasal, steam will have to be generated to meet the requirements of soda ash and ammonia plants. It is estimated that during normal operations of soda ash plant about 30 tonnes per hour of steam at 40 Kgh/cm^2(g) pressure will be required. A provision of (1+1) boiler rated for 35 metric ton per hr steam production has been made in the estimate.

Chapter - 7

PROJECT SCOPE : COMMON FACILITIES

7.1 The project scope at either of the locations (Chittagong or Ghorasal) will include, besides the respective process plants and facilities, the following common facilities which will be shared by all plants covered under this project :

Natural Gas Supply

7.2 The gas is assumed to be available at the battery limits of the respective site. The project's scope will, therefore, include only the metering facilities and piping necessary to connect the gas supply to different gas utilisation points.

Water Supply and Distribution

7.3 As described in the earlier chapter, the requirement of water at the Chittagong location will be met through a common pipeline with CUF Project and at Ghorasal, by drawing water from the river Sitalakhya. The provisions at Chittagong include the facilities for process water distribution, boiler feed water preparation, condensate recovery and distribution etc. At Ghorasal location, the facilities will include, raw water pumping system and storage pond, process water treatment plant, boiler feed water preparation unit, sanitary water unit and water distribution system.

Power Supply and Distribution

7.4 Power at both the sites will be received at 33 KV from the PDB system. The facilities at site will include step down transformers (33/3.3 KV), switch boards, circuit breakers, protective devices and power distribution cables etc. Further step down to desired voltages will be done in individual plants.

Steam Generation

7.5 The steam requirement at Chittagong is assumed to be met through the Chittagong Urea Project. Hence no separate installations are needed at Chittagong. However, at Ghorasal, 35 tonnes capacity boilers (1+1) generating steam at 40 Kg/ cm^2 will be provided.

Cooling Towers

7.6 Cooling water requirement for process plants are :

(a)	Ammonia Plant	:	1400 m^3/hr
(b)	Soda Ash Plant	:	3200 "
(c)	Ammonium Sulphate Plant	:	400 "

The provision under this head includes closed cycle induced draft type towers, tower basin, pumping system and inter-connecting pipelines.

Effluent Treatment and Disposal

7.7 Liquid effluents generated in the process plants and other facilities include oil drippings, floor washings, chemical drains, cooling tower purges etc. These effluents are collected and treated to render them free of ammonia, oil and other toxic material. The resultant effluent is then diluted with normal water drains and flushed into the river. The provision under the effluent treatment facilities include a tower for distillation of ammonia, chemical dosing unit, effluent collection tank and a channel to dispose off the liquid effluents. Adequate safeguards have been taken to minimise atmospheric pollution.

Auxiliary Services

7.8 The facilities under this head include :

- Workshops (mechanical, electrical and instrument)
- Fire fighting and safety
- Laboratories
- Telephone and telecommunication
- Drawing office equipment
- Warehouse equipment
- Technical library
- First aid equipment
- Canteen and general welfare facilities

To optimise the cost of the project, it is assumed that the workshop and other facilities of Chittagong Urea Fertilizer Project or Ghorasal Fertilizer Factory will be available for the new plants. Therefore, only marginal provisions have been made for these facilities in the project cost estimates.

Non-Plant Buildings

7.9 The scope under this head includes the following main buildings :

		Area (M^2)
1.	Security House	60
2.	Time Office	50
3.	Administrative Building including Canteen and Laboratory	1000
4.	Fire Station and First Aid	250
5.	Garage	400
6.	Warehouse and Workshop	3000
7.	Electrical Substation	200
		4960
	Say =	5000

In the alternative involving only soda ash production, the covered area under non-plant buildings is estimatedat about 2500 square meters.

Transport Facilities

7.10 Transportation of bagged products (soda ash and ammonium sulphate) from the bagging plant to jetty (for inland transportation by barges) is assumed to be by trucks. The provision of transport vehicles, therefore, include sufficient number of trucks required for the purpose.

Jetty

7.11 By-product gypsum movement to the proposed site across the river Kamaphuli will be made through river barges (Part IV). The truck-trolleys loaded with the material will be mounted on barges and carried to the otherside of the river and the

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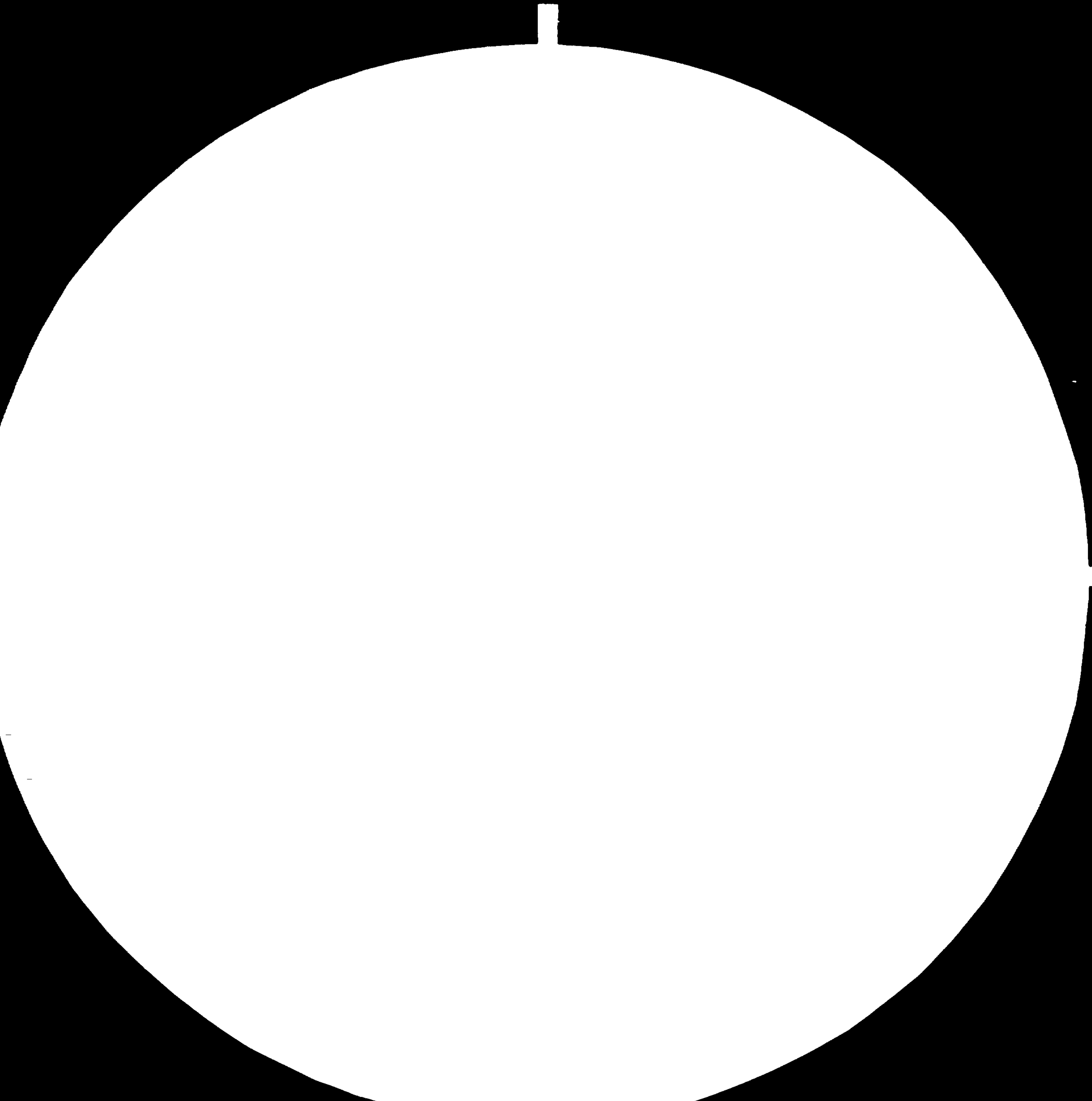

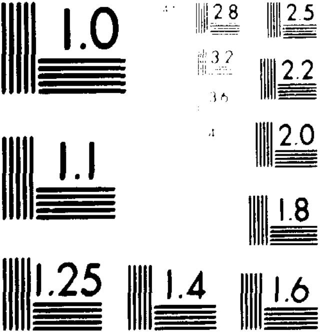

MICROCOPY RESOLUTION TEST CHART

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empties will be brought back for reloading. The proposed mode of transportation will require a jetty on either side of the river. Details of the scheme are explained in Part IV. Another jetty with terminal facilities for loading of bagged products on barges will be provided.

Construction Equipment and Facilities

7.12 It is assumed that the construction equipment needed during project execution will normally be available with the contractors. However, provision of a few cranes, road rollers, dumpers and special tools and tackles has been included in the scope of the project. Normally, the construction facilities available with the CUF Project, including the construction jetty could be shared. At Ghorasal, the existing facilities of the fertilizer factory can be made use of.

Township and Public Buildings

7.13 A colony to house the permanent staff, based on the estimated manpower requirements under alternative schemes at Chittagong and Ghorasal, has been provided. The number of residential houses is based on the guidelines given by BCIC in accordance with present practice. Under this, housing accommodation is provided for all but the lowest category staff, for whom the 'satisfaction' limit will be 20%. The details are given in Table 7.1.

Table 7.1

Residential Accommodation

Category	Plinth Area (Sq.ft.)	No. of houses				% Satisfaction
		Chittagong		Ghorasal		
		Alt.I	Alt.II & III	Alt. I	Alt.II	
1	2200	8	8	8	8	100
2	2000	14	12	13	12	100
3	1800	73	36	62	36	100
4	1300	192	77	144	77	100
5	760	431	210	324	210	100
6	480	210	107	108	107	100
7	220	70	50	60	50	20

Besides the residential buildings, some public utility buildings such as Trainee's Hostel and a Guest House are also included in the scope of the project.

Ammonia Transportation

7.14 In the two schemes under discussion, special arrangements will be needed to transport/receive ammonia. In the first case, if ammonia is made available from the CUF Project, arrangements to receive it at plant site will be needed. It has been assumed that ammonia will be transported from the ammonia plant storage facilities (atmospheric ammonia storage) through a pipeline. Therefore, the scope under the scheme will include ammonia transfer pumps, pipeline, ammonia measuring instruments and a day tank located near the process plants. In case ammonia is required to be transported to Ghorasal from the Chittagong Urea Project, an elaborate arrangement will be needed to transport ammonia through specially designed river barges.

7.15 The scheme to transport liquid ammonia to Ghorasal will include the following facilities :

(i) a 600 te capacity river barge/tanker where two cylindrical tanks each of 300 tonnes capacity will be placed parallel to each other in the hold. The tanks will be insulated and designed for 30 $kg/cm^2(g)$ pressure. These tanks will be fitted with temperature and pressure measuring and recording devices. Since the tanks will be filled with ammonia at about - 20°C and the temperature rise during the 3 days' journey to Ghorasal (400 Km) may not be more than 10°C, the tanker will be operating very much within safe operating limits. Hence no refrigeration unit on board the tanker will be provided. However, safety valves and emergency vents etc. will be provided on the tanks. The barge/tanker is assumed to be owned by the Bangladesh Inland Water Transport Corporation (BIWTC) and hired to the project.

(ii) terminal facilities for loading liquid ammonia at Chittagong and unloading at Ghorasal including ammonia pumps and package refrigeration units.

(iii) 2.5 kilometer and 1.5 kilometer pipeline at Chittagong and Ghorasal ends respectively. Beside liquid ammonia line, a boil-off vapour ammonia-line to withdraw vapours generated during initial cooling operation of the system will also be provided.

Loading/Unloading Procedure

7.16 The tanks and the connecting pipeline will first be cooled to about -20°C by slowly injecting liquid ammonia through the system and withdrawing the ammonia vapour thus generated through vapour line running parallel to the main line and insulated together to optimise cold losses. The vapour received at the plant site will be compressed, condensed and liquid ammonia recycled back to the system. After the system stabilises at -20°C the liquid will be pumped into the tanks. Similarly, at Ghorasal the system will be cooled to Hortonsphere temperature (0°C) and then ammonia will be unloaded. The Hortonsphere normally operates at 0°C temperature and 4.5 Kg/cm^2 pressure.

7.17 The hiring charges of the barge have been estimated on the basis of the information furnished by BIWTC as shown below :

(i)	Barge charter rate	: Tk 5 per te per day
(ii)	Tug charges	: Tk 250 per day
(iii)	Rebate in tug charges during loading and unloading	: TK 250 per day

Transportation Cost

7.18 For transportation of ammonia from Chittagong to Ghorasal through river barges the following turn-round cycle has been assumed :

		(days per cycle)
1.	Ammonia loading operation at Chittagong	1
2.	Journey to Ghorasal	3
3.	Ammonia unloading operation	1
4.	Return journey to Chittagong	2
5.	Inspection, maintenance and rest etc.	1
		8

The above cycle is assumed to be operative till the annual shutdown of plants (30 days on the average) for inspection and maintenance. During this period the barge will also be overhauled and painted. The annual shutdown of plants at Ghorasal will be matched with the shutdown of CUF Project to avoid imbalance in ammonia availability and consumption.

7.19 Based on the above mentioned hiring charges and hiring period of the barge the cost of ammonia transportation through inland waterways have been estimated as shown in Table 7.2.

Table - 7.2

Ammonia Transportation Charges

		Taka
1.	Barge charter rate (5 x 600 x 8) (Rate x load x days)	24,000
2.	Tug charges (250 x 7)	1,750
3.	Rebate on tug charges (250 x 2)	(-) 500
		25,250
4.	Escalation @ 20%	5,050
	Total Charges	30,300
5.	Ammonia transferred per trip	600 tonnes
6.	Cost per metric ton of ammonia	Tk 50.5
	Say	Tk 50.0

After evaluation of alternatives, such as road and rail transport, it has been assessed that transportation of ammonia through barges will be the cheapest and therefore barge transport is assumed here.

Chapter - 8

IMPLEMENTATION AND TIME SCHEDULE

8.1 Bangladesh does not have adequate expertise for executing large industrial projects, involving specialised skills. Almost all the major projects such as the TSP Complex, Ghorasal and Ashuganj projects executed so far have been done on turn-key basis. The country also has an acute shortage of skilled and experienced personnel required for construction management, monitoring, design-engineering, procurement and inspection, erection and other activities connected with the execution of a project. The problem is compounded by the migration of available skilled manpower. A note on contracting system is enclosed at Annexure II-D.

8.2 Considering these conditions and the fact that conditions are not expected to materially improve in the next few years - it is proposed that the project may be contracted out on 'turn-key' basis, except for some specified functions (para 9.4), to an experienced engineering firm on the basis of international bids. An illustrative list of such firms is enclosed (Annexure II-E). It is suggested that in accordance with the standard practice followed now in the case of internationally-aided projects, initially applications may be invited from the firm for being considered for the job and after a pre-qualifying scrutiny, a short list of firms may be drawn up, to whom bid documents could be issued for quotations. The proposals received from the bidders will then be scrutinised and evaluated for technical soundness and financial competitiveness, culminating in the selection of one engineering contractor. Association of local personnel in the project management/monitoring services can be made a precondition to the award of the contract, depending on the extent of skills available in the country.

8.3 Broadly, the role of the selected Engineering Contractor will be as listed below :

(i) licensing arrangements for the processes

(ii) design, engineer and specify the plant and equipment for the process plants for obtaining bids

(iii) specify the requirements of utilities and the related facilities for the operation of the main process plants for normal as well as emergency periods

(iv) suggest reputed parties for plant and equipment supplies

(v) assist owner/or his representative (e.g. a consultant) during bids evaluation and selection of parties

(vi) provide inspection assistance

(vii) supervise construction jobs

(viii) render commissioning, supervision and demonstrate process and performance guarantees

(ix) arrange for the training of operation and maintenance personnel

(x) provide technical assistance in the operation of the plants in the initial period.

8.4 Other activities of the project, which can be taken up by local personnel, e.g. land acquisition and preparation, civil construction, procurement of indigenous items etc. will be executed by a Project Management Team formed by the owner. A Project Consultant may be appointed to assist the owner in the execution ot the project.

Broadly, the Project Consultant will perform the following activities :

(i) prepare tender documents for site preparation, plant civil works, erection etc.

(ii) prepare bid invitations for the selection of an Engineering Contractor for main process plant and other contractors for off-sites and utilities

(iii) prepare bid documents, invite quotations and select suppliers for procurement of plant and equipment

(iv) evaluate the bids and recommend parties for the award of contracts

(v) carryout inspection/appoint inspection agents, expedite and follow-up during procurement ot plant and equipment

(vi) ensure shipping arrangements and delivery of supplies at site; ensure proper arrangements for receipt, storage and issue of materials and supplies during construction stage

(vii) oversee construction jobs carried by the contractors

(viii) monitor and schedule project activities and costs

Project Schedule

8.5 The time schedule for completion of a project will depend on several factors like mode of financing, selection of equipment suppliers, procurement procedures, freedom given to Engineering Contractor and the ability of the local suppliers to deliver local supplies in reasonable time. In this project it is assumed that the project will be financed by international financial and development institutions or by a consortium of commercial banks. It is expected that after a review of the feasibility report by the Government of Bangladesh it will be submitted to the probable financing agencies for financial arrangement. It is assumed that this procedure will take about 10 months. In the meantime, depending on the response shown by financing agencies, a qualified and experienced Project Consultant may be appointed if necessary, in consultation with the financing agencies concerned.

8.6 After the selection of the Project Consultant and finalisation of financing arrangement for the project, Engineering Contractor may be selected from the pre-qualified list of engineering contractors. It is expected all these pre-project activities will be completed within about 16 months. It is anticipated that the project can be mechanically complete within 30 months from the 'zero date', the date when the contract to the Engineering

Contractor is awarded. The trial run and commissioning of plants may take about 6 months from the mechanical completion date. A bar chart indicating various project activities on time scale has been shown in Drawing No. II-6.

Chapter - 9

ORGANISATION, MANAGEMENT AND STAFFING

9.1 The proposed project (both ammonia and down stream plants) is assumed to be owned and operated by a company to be formed in Bangladesh, possibly under BCIC. The Board of Directors of the company will be responsible for the general administration, financial and policy matters. A Project Management Team headed by a Project Manager appointed for the project implementation will be responsible for the direct supervision of the project during construction.

9.2 Though the project will largely be executed by the Engineering Contractor and the Project Manager will possibly be assisted by the Project Consultant, the role of the Project Management Team in project implementation needs to be emphasized. It is envisaged that the Project Management Team will eventually form part of the permanent work-force responsible for the operation of the plants. The continuity of personnel from the implementation stage to the operational stage will be a great advantage in the plant operation. Thus the Project Manager could in due course take over as General Manager.

9.3 The total man-power requirement of the project, recruited in a phased manner, will vary between 700 and 1280 depending on the schemes proposed to be implemented. A tentative phasing of staff recruitment for various phases of project implementation has been shown in Table 9.1. Care has been taken to keep in position the operation and maintenance staff in advance of the plant commissioning stage.

9.4 Present generation chemical plants involve highly sophisticated machinery and control systems. Hence, a well knit organisation with a core of highly skilled specialists is a prerequisite for smooth implementation and operation of a project. It may, therefore, be advisable to continue to engage the services of a few foreign specialists in key areas (preferably personnel from the Engineering Contractor) for a year or so after the plants are handed over to the owners to help stabilise the plants' operating and also to train the local staff more thoroughly in operation and maintenance techniques. This may, however, be decided by the owners in due course on the basis of advice from Engineering Contractor/Project Consultant.

Table 9.1

Phasing of Project Staff

(in position at the end of year)

Year	Chittagong Location Alternatives		Ghorasal Location Alternatives		Remarks
	I	II & III	I	II	
1st	23	23	23	23	Pre-Project Stage
2nd	392	220	349	220	
3rd	783	359	666	359	
4th	1280	700	1060	700	Commissioning Stage

Note : The explanation of Alternatives, see Table 4.2 ante.

Staffing :

9.5 A suggested pattern for the permanent staff is shown at Annexure No. II. Under this pattern of staffing, the entire operation of the complex will be the responsibility of a single General Manager. The General Manager will under him have Manager (Production), Manager (Maintenance), Manager (Technical Services), Manager (Finance) and Manager (Administration & Personnel). Each Manager will be assisted by an Assistant Manager.

9.6 Manager (Production) will be responsible for overall production activities whereas the individual sections will be headed by Plant Superintendents. The Superintendents will be assisted by Shift Engineers and other supporting staff. The Maintenance Department will be headed by a Manager as shown in Annexure No. II-0. In this department stress has been given on preventive maintenance. A small workshop to handle day to day maintenance will be organised, whereas for any special problem the facilities available with the respective fertilizer plants will be made use of.

9.7 The Manager (Technical Services) will control the following departments :

(i) Industrial Engineering

(ii) Efficiency and production statistics

(iii) Training

(iv) Laboratory

The Manager (Administration & Personnel) will be responsible for :

(i) Safety and fire

(ii) General administration

(iii) Publicity

(iv) Medical

(v) Welfare & public relations

(vi) Personnel

The above pattern of organisation has been proposed in the light of the Consultant's experience and discussions with knowledgeable persons in Bangladesh. The pattern can, however, be varied within broad limits, if necessary. The assistance of the Project Consultant may be sought to scrutinise the staff requirement more closely.

Chapter - 10

CAPITAL OUTLAY

10.1 The total investment on the proposed schemes including the infrastructure facilities and the working capital requirements for alternative locations has been estimated as shown in Annexures J&K and summarised below in Table 10.1.

Table - 10.1

Capital Investment

(In $ million)

Sl. No.	Items	Chittagong Alternatives* I	Chittagong Alternatives* II	Chittagong Alternatives* III	Ghorasal Alternatives* I	Ghorasal Alternatives* II
A.	Total investment					
	a) Foreign Exch Component	91.80	33.50	37.50	77.60	46.30
	b) Local Component	67.90	32.80	33.30	65.50	43.70
	Total Cost	159.70	66.30	70.80	143.10	90.00
B.	Investment Allocated to Ammonia Production					
	a) Foreign Component	35.28	-	-	36.60	-
	b) Local Component	20.51	-	-	25.50	-
	Total Cost	55.79	-	-	62.10	-

*For explanation see Table 4 .2 ante

10.2 The details of the costs allocated to ammonia production at Chittagong and Ghorasal are presented in Table 10.2.

Table 10.2

Ammonia Plant Cost

A = Allocated
E = Estimated

(In $ million)

Sl. No.	Location Item	Chittagong F.C.	 Total	Ghorasal F.C.	 Total	Remarks
A.	<u>Manufacturing Facilities</u>					
1.	Land & Land Development	0.14	0.54	-	0.05	A
2.	Construction Equipment	0.78	0.84	1.00	1.23	A
3.	Ammonia Plant	17.00	21.80	17.00	24.00	E
4.	Yard Piping	0.06	0.13	0.01	0.02	A
5.	Water Supply, Storage & Distribution	0.15	0.23	0.60	0.90	A
6.	Power Supply and Distribution	0.50	0.60	0.40	0.55	A
7.	Cooling Tower	0.18	0.22	0.20	0.25	E
8.	Ammonia Storage & Handling	1.25	1.50	1.23	1.65	E
9.	Effluent Treatment	0.21	0.28	0.35	0.50	A
10.	Non-plant Buildings	0.13	0.19	9.15	0.25	A
11.	Auxiliary Services	0.72	0.85	0.82	1.23	A
12.	Transport Facilities	0.07	0.09	0.07	0.10	A
13.	Temporary Construction Facilities	0.07	0.12	0.11	0.20	A
14.	Project Management Charges	1.26	3.44	1.46	3.97	A
	Total Manufacturing Facilities	22.52	30.83	23.40	34.90	

Table 10.2 (contd.)

Sl. No.	Location / Item	Chittagong F.C.	Chittagong Total	Ghorasal F.C.	Ghorasal Total	Remarks
B.	Township & Public Buildings	1.90	3.40	1.90	3.40	A
C.	Spares incl. Spare Charges of Catalyst & Chemicals	2.26	2.43	2.40	3.10	E
D.	Working Capital	-	-	-	-	
E.	Contingency	1.34	1.84	1.40	2.10	E
F.	Expenses during Commissioning & Trial Run	-	0.60	-	0.60	E
G.	Escalation	7.26	11.73	7.50	13.40	E
H.	Financing charges	-	4.96	-	5.20	E
	TOTAL CAPITAL	35.28	55.79	36.60	62.10	

Basis of Estimates

10.3 The basic estimates of supplies have been computed on the basis of preliminary design of plants and facilities and sizing of equipment (Annexure II-F). Budgetary quotations from suppliers and engineering organisations have been obtained, where possible. Data from the cost files of the Consultants has been extensively used where quotations were not available. The foreign exchange component of the project cost has been computed on the assumption that the freedom of procurement from the cheapest source will be available. In estimating the local supplies, Consultant's conclusions after visits to the major fabrication shops in Bangladesh formed the basis. In the Consultant's opinion, engineering workshops in Bangladesh can fabricate tanks, low pressure vessels, piping, light duty small heat exchangers, cast pumps and relatively simple welding work. For more sophisticated fabrication, however, the engineering shops will need to be equipped with marginal facilities, especially radiographic and other non-destructive testing facilities.

10.4 Practically all electrical equipment and facilities, instruments and instrument erection material, civil construction equipment and structural steel will have to be imported. Other construction material such as cement, stone aggregates and wood are, however, available. The current prices of indigenously available materials are shown in Table 10.3.

Table 10.3

Cost of Indigenous Materials

1)	Structural Steel	: Tk.8000-10,000 per tonne
2)	Stone Aggregate	: Tk.800-1200 per cft.
3)	Cement	: Tk. 70 per bag (50 Kg.)
4)	Sand	: Tk. 150 per 100 cft.
5)	Bricks	: Tk. 850 per 1000 nos.
6) a)	Timber for Scaffolding	: Tk. 60 per cft.
b)	Timber for Structural use	: Tk. 100-200 per cft.
7)	Glass Sheets	: Tk. 10 per sq.ft.
8)	Asbestos Sheet	: Tk. 300 per sheet
9)	G.I.Pipe 2" Size	: Tk. 20 per Rft.

10.5 The provision of 'on shelf' spares, components and machinery is based on the recommendations of suppliers and experience of the Consultants. These spares are presumed to be sufficient for 2 years of normal operation of the plants.

Ocean Freight

10.6 Ocean freight has been calculated at 10% of the FOB cost of supplies. This is a generalised average figure and generally corresponds to imports from European ports. However, in case of imports from Japan the figures may be about 6%. It is expected that equipment unloading facilities of the Chittagong Urea Fertilizer Project will be available for the project. A provision of insurance at a rate of 0.6% of FOB cost has been made in the estimates.

Import Duty

10.7 Normally, import duty for fertilizer and chemical projects is charged at the rate of 20% of CIF cost. However, the Middle Island area of Chittagong (across the river Karnaphuli) is likely to be declared as backward area, and therefore, a concessional rate of duty at 2.5% of CIF cost is expected to be levied for Chittagong location. At Ghorasal location duty will have to be paid at normal rates.

Clearing and Forwarding Charges

10.8 Imported materials inside port area are generally handled by authorised agents, who assist the consignee to clear the port dues, inspection of consignments etc. The agent's fees for services work out to about 1% of the FOB cost of imported supplies.

Inland Handling

10.9 In Bangladesh, most of the equipment and supplies will have to be transported to site through waterways and from jetty to plant site by specially designed truck trailers. Total inland handling charges are estimated at 3% and 5% of the cost of supplies for Chittagong and Ghorasal locations respectively.

Insurance

10.10 The supplies are covered under comprehensive insurance scheme for inland handling, site storage and erection etc. A provision at a rate of 1% of the cost of total supplies has been made in the estimates towards these charges.

Sales Tax

10.11 Indigenous supplies attract sales tax at a rate of 20% of the value of the supplies as per the prevailing tax structure of Bangladesh. The tax is also payable on the duty paid value of imports as specified rates.

Licence Fee, Engineering and Procurement Charges

10.12 As explained in Chapter 8, the Engineering Contractor will arrange process licences and basic know-how for various process steps, based on which the detailed engineering will be developed. Therefore, the cost estimates include the licence and basic engineering fees payable to the licensors and fees for detailed engineering work done by the Engineering Contractor. A provision of 5% of the cost of equipment and other supplies has also been made in the estimates to cover the cost incurred towards procurement and inspection of supplies. For inspection of equipment, a reputed agency like Lloyds will have to be engaged. The process licence required under alternative schemes will depend on theprocess finally chosen. However, for this study, purely as an illustration, the following processes have been assumed.

Process Licences & Knowhow

			Licensor
a)	Ammonia Plant		
i)	Primary Reformation	:	TOPSOE - Denmark
ii)	Decarbonation	:	BENFIELD - USA
iii)	Ammonia Synthesis	:	TOPSOE - Denmark
b)	Soda Ash		
i)	Solvay Process (Byproduct chalk)	:	POLIMEX - Poland
ii)	Dual Process	:	CENTRAL GLASS/TEC-Japan

Civil Works

10.13 The civil works cost for plants has been estimated on the basis of preliminary information on site and soil conditions collected during the visits by the Consultants and cost data made available by the Chittagong Urea Fertilizer Project authorities. At Ghorasal, the data was made available by the fertilizer factory, The extent of piling required etc. will, however, be known only after detailed site investigation and completion of detailed engineering.

Erection Charges

10.14 The estimates for erection charges have been computed on the basis of preliminary equipment specifications (Annexure II-F), the erection rates provided by BCIC for similar projects in Bangladesh and data from the Consultants' cost files. In many cases, like steam generation, water supply and distribution, power supply, material handling, cooling tower etc., the erection responsibility could be given to the suppliers themselves. The typical erection rates for various categories of mechanical equipment and machinery assumed in this study are summarised below in Table 10.4.

Table 10.4

(US $ per tonne)

Sl.No.	Item	Rate
1.	Compressors and pumps (moving machinery)	175
2.	Static equipment	150
3.	Waste heat boilers or package boilers	500
4.	Structurals	100
6.	Tower packing	70 per M^3
6.	Refractory	140
7.	Internals	380

Erection costs for electrical items and instruments work out to about 15-20% of the cost of supplies.

Erection and Commissioning Supervision

10.15 The selected Engineering Contractor, besides rendering design engineering job, will supervise the erection and commissioning work. If required, expatriate personnel of process licensors will also be made available during erection and commissioning of plants to ensure satisfactory erection work and to demonstrate process and performance guarantees. This can be settled only at the time of licence agreement. For erection of complicated equipment and machinery, specialist assistance from vendors will need to be made use of. The provision under this head therefore, includes the Engineering Contractor's fees and estimated charges for expatriate personnel.

Building and Residential Houses

10.16 The essential buildings inside the factory compound will mostly have asbestos roofing and the residential and other public buildings in the township will have concrete slab roofing with multi-storied structures. Estimates for these facilities are based on the prevailing schedule of rates in Bangladesh for such civil constructions as shown in Table 10.5 and material costs as given in Table 10.3 above.

Table 10.5

Schedule of Rates for Buildings

(1)	Ordinary buildings/shed with reinforced structure	Tk. 150/sq.ft.
(2)	A - class residential building	Tk. 200/sq.ft.
(3)	B - class "	Tk. 150/sq.ft.
(4)	C - class " (Barrack with asbestos roofing).	Tk. 100-120/sq.ft.

Land & Land Development

10.17 The requirement of land as per preliminary plot plan has been shown in Chapter 6. The cost of land at Chittagong has been assumed at Tk 30,000 per acre whereas for Ghorasal site, it has been assumed at Tk 50,000 per acre, as indicated by local authorities.

The development charges for different sites provide for site preparation such as site clearing, filling, levelling, grading etc. and site development such as roads, sewers, external drains, trenches for underground piping and cabling and boundary wall for the factory. As per topographic data of the area, the sites require heavy filling (5-7 metres). The site at Ghorasal is already levelled and only marginal filling etc. will be required.

Project Management Charges

10.18 The suggested mode of implementation of the project envisages that the preproject activities and the most of the project implementation activities such as procurement of supplies, erection and commissioning etc. will be performed under the guidance of a Project Consultant assisted by the local staff. The provision, therefore, includes:

- Salaries of staff employed during construction period
- Pre-construction and overhead expenses such as site survey, soil testing, feasibility studies, running expenses on vehicles, electricity, water, stationery, telephone, liaison office expenses etc.
- Project Consultant's fees for supervision of implementation of the project on behalf of the owner and advisory works to owner.
- Provision for personnel training abroad and at factories in Bangladesh.

A broad break-up of the project management charges which will be capitalised, is shown in Table 10.6.

Table 10.6

Project Management Charges

(In $ Million)

Items	Chittagong Alternative						Ghorasal Alternative			
	I		II		III		I		II	
	F.C.	TOTAL	F.C.	TOTAL	F.C.	TOTAL	F.C.	TOTAL	F.C.	TOTAL
1. Salary of Project staff	-	2.70	-	1.34	-	1.34	-	2.20	-	1.34
2. Project Consultant (fixed fee)	2.49	2.49	0.81	0.81	0.92	0.92	2.17	2.17	0.92	0.92
3. Other Facilities including Training	0.50	4.15	0.50	3.22	0.50	3.14	0.50	3.74	0.50	3.14
4. Bank charges	-	0.85	-	0.28	-	0.33	-	0.70	-	0.33
Total	2.99	10.17	1.31	5.65	1.42	5.73	2.67	8.81	1.42	5.73

Working Capital

10.19 The details of working capital for different Alternatives are shown in Annexures II - G to H respectively. The provision for working capital includes an inventory of raw material and packing material equivalent to one month's requirement. However, inventory for salt is taken equivalent to 3 months' requirement, for reasons explained in Part VI Section A. The product inventory includes bulk storage of 23 days' production equivalent and bagged storage of 7 days' production. The entire provision of working capital like spare has been capitalised in keeping with the standard practice followed in Bangladesh.

Contingency

10.20 A contingency provision of 5% of manufacturing facilities including the cost of jetty has been made in the estimates to cover possible changes in scope etc.

Testing and Commissioning Expenses

10.21 The project is assumed to take about 6 months for testing and commissioning the plants. During testing and commissioning the plants do not run continuously and are estabilised section by section. Therefore, the consumption of raw material, utilities and other consumable items are much above the normal requirements. Normally, when the plants are stabilised, they are put to performance tests for sustained production for about a month. The provision under this head is the expenses net of the earnings from the sale of the produce during commissioning.

Escalation

10.22 The cost estimates are based on current (July 1979) price levels and wherever recent costs were not available the estimates are suitably modified to bring them to current price level to make the base project cost valid upto July 1979.

As discussed in Chapter 8 the pre-project activities are expected to take about 16 months from the submission of this study and the project will take about 30 months for mechanical completion. Assuming, that delivery of bulk of supplies will be completed and erection activities sufficiently advanced by the 20th month from zero date (say, January 1981), the price escalation for supplies and facilities are computed for 3 years from the validity date of the base estimates. Based on the Consultant's assessment of the possible rise inprice index for material and labour for West European countries and Bangladesh a price escalation at a rate of 8% and 12% per annum respectively has been assumed for the project. Therefore a provision of price escalation at a rate of 25.9% on foreign costs and 40.4% on local cost of the project is made in the cost estimates to make the project cost valid upto project execution stage (Say, December 1983).

Financing Charges

10.23 The mode of financing of the proposed project is not yet decided. However, for the limited purpose of financial analysis, the financial plan assumes that the total foreign exchange requirements of the project would be met through Government loans and the local currency portion of investment would be financed through equity. The loans will be charged interest at the rate of 10% per annum and the interest will be payable in local currency.

Based on the time schedule of the project as shown in Drg. No. II-6, the investment of the proposed project would be phased for the 3 years of implementation as given below in Table 10.7.

Table 10.7

Phasing of Expenditure

(In percentage)

Year of Implementation	Fund Disbursement
I	10
II	70
III	20

The financing charges of the project is calculated on the basis of above assumption and on the stipulation that the fund withdrawal will be made as and when required throughout the year. Therefore, interest on loan has been charged on the basis of average drawal.

Chapter 11

COST OF PRODUCTION

11.1 Ammonia and soda ash plants are normally rated to operate for 330 days in a year, whereas the stream efficiency of the ammonium sulphate plant is ordinarily taken at 300 days. For financial analysis however, it is assumed that all the plants will be operating annually for 300 days (which means the ammonia and soda ash plants will be operating at about 90% of the rated capacity). Therefore, cost of production of ammonia has been worked out at 90% capacity (30,000 tonnes/year) level of operation.

11.2 The raw material, utilities and consumables required for ammonia production are priced as given below. The basis for other calculations are also indicated in the following sections.

(i) Natural Gas :

In the light of discussions with concerned authorities, the following rates for natural gas use has been assumed :

(i) Chittagong : Tk 9 per 1000 cft.
(0.6 US $/1000 cft.)

(ii) Ghorasal : Tk 5 per 1000 cft.
(0.34 US $/1000 cft.)

(ii) Water :

As stated earlier, water supply at Chittagong location is assumed to be priced at Tk 2.08 per cubic meter. However, at Ghorasal, the project will have its own arrangements to draw the required raw water from the river Sitalakhya and therefore its cost is included in the project estimates.

(iii) Power :

Power is assumed to be priced at a fixed rate of Tk 485/MWh. The details are shown in Table 11.1.

Table 11.1

Power Tariff

1. Power consumption (Alt. I Chittagong location) - 12.7 MW
2. Installed power - 15 MW
3. Power factor - 0.85
4. Power in KVA - 17,700 KVA
5. Annual power consumption - 91,500 Mwh
6. Total Kwh/KVA/month - 440

Power Tariff Calculations

a. Annual fixed charges - Tk 8.90 million
b. Annual energy charges - Tk 31.10 "
c. Escalation @ 10% on (a&b) - Tk 4.00 "
Total Charge Tk 44.0 million

d. Power rate per MW (44 x 106/91500) - Tk 481

Say - Tk 485/Mwh ($ 32.33/Mwh).

(iv) Steam :

The steam requirements of ammonia plant will normally be met through internal generations in waste heat boilers in reformation and ammonia synthesis sections. However, the steam requirements during start-up operations may either be generated in an auxiliary boiler or imported. At Chittagong location 40 Kg/cm^2 pressure steam upto 80 metric tons per hour will be available from the proposed Chittagong fertilizer project. Therefore, there will be no need for provision of a start-up boiler. At Ghorasal location the required steam will have to be generated endogenously. The cost of imported steam for the ammonia plant has been worked out on the basis of allocated costs of plants and facilities and with a 12 percent return on investment. The unit cost of steam works out to Tk 95/tonne ($ 6.33/te).

(v) Consumable Stores

The consumable stores include the catalyst, chemicals and other materials required for normal operation of plants. The yearly catalyst requirement for ammonia production has been calculated on the basis of average life of catalyst as shown below :

Catalyst	Life
1. Primary reformation	2-3 years
2. Secondary reformation	3-4 years
3. H.T. shift	2-3 years
4. L.T. shift	1-2 years
5. Methanation	4-5 years
6. Ammonia synthesis	4-5 years

(vi) Labour and Overhead

The labour and overhead cost has been calculated on the basis of staffing pattern indicated earlier and on the basis of the scales of pay and benefits currently in force in the country.

(vii) Maintenance

The cost of maintenance material is taken at 5% of the landed costs of supplies and 1.5% of the cost of jetty, residential and other buildings.

(viii) Insurance

A provisionof 0.3% of the total capital is made in the operation cost of the complex to cover the risks of fire etc.

(ix) Contingency

To take care of any variation over assumed consumption figures and any unforeseen expenditure a contingency of 5% of works cost has been provided in the cost of production calculations.

(x) Depreciation

For the purpose of this study, straight line depreciation, on the basis of 12 years' life for the plants and 30 years' life for jetty and township has been considered.

(xi) Interest on Term Loan

Interest at the rate of 10% per annum has been adopted on outstanding loans as suggested by BCIC. As the loan is repaid in instalments, interest burden will also get gradually reduced; therefore in the cost of production calculations, average interest payable during the life of the project has been assumed.

11.3 Based on the above assumptions, the allocated processing cost of ammonia has been worked out in Annexure - II L&M and summarised below in Table 11.2.

Table 11.2

Processing Cost of Ammonia

(Plant Capacity : 100 metric tonnes/day)

(E = Estimated
A = Allocated)

(Cost in $ '000)

Sl. No.	Items	Chittagong Annual Cost	Ghorasal Annual Cost	Remarks
1.	Raw Material Natural Gas	613	337	E
2.	Utilities	1148	1113	A
3.	Chemicals & Consumables	160	207	E
4.	Labour & Overheads	373	413	A
5.	Maintenance Material	973	1220	E
6.	Insurance	167	186	E
7.	Contingency	172	174	E
	Annual Works Cost	3606	3650	
8.	Depreciation	3707	4245	A
9.	Selling Expenses	-	-	
10.	Average Interest on Loan	1764	1830	E
	Annual Processing Cost	9077	9725	
11.	Annual Production (tonnes/year)	30,000	30,000	
12.	Unit Cost of Production (US $/tonne)	$ 303	$ 325	

Cost of Purchased Ammonia

11.4 In the other alternatives, as explained earlier, the ammonia requirements of the process schemes will be met through 'import' of ammonia from the proposed Chittagong Urea Fertilizer Project. The project authorities have not given any indication of the likely price. However, the purposes of calculating the viability of the different schemes, an attempt has been made to arrive at a transfer price based on a return of 12 per cent on the allocated investment.

11.5 The cost of production of additional 72 tonnes of ammonia per day, which the CUF Project authorities have agreed to make available from the projects proposed facilities has been worked out as shown in Table 11.3, where it is assumed that the ammonia plant capacity has been enlarged to produce the additional 72 tonnes of ammonia.

Table 11.3

Cost of Additional Production of Ammonia in C.U.F. Project

1. Allocated Investment for Ammonia Production : $ 172 million

2. Annual Production of Ammonia : 0.317 million tonnes

(Cost in $ Million)

Sl.No.	Items	Annual Cost
1.	Natural Gas	7.69
2.	Chemicals and Consumables	1.80
3.	Labour & Overheads	1.06
4.	Maintenance Material	3.35
5.	Insurance	0.56
6.	Depreciation	12.67
7.	Return on Total Capital @ 12%	20.70
8.	Total Annual Cost of Production	47.83
9.	Annual Ammonia Production (tonnes/year)	317,000
10.	Expected Transfer Price ($/tonne)	151
	In Taka	2265

11.6 Based on the estimated transfer price of ammonia as worked out above, the delivered cost of ammonia has been computed as shown in Table 11.4. For Chittagong location, the 'imported' ammonia will be transported to plant site through a pipeline, whereas in the case of Ghorasal, ammonia from Chittagong will be carried through river barges. The cost of pipeline and pumps etc. needed to deliver ammonia to the processing plants at either of the locations is included in project costs and the cost of ammonia transportation through barges has been worked out as discussed earlier.

Table 11.4

Delivered Cost of Ammonia

(Cost per tonne of Ammonia)

Sl. No.	Items	Chittagong Taka	Chittagong $	Ghorasal Taka	Ghorasal $
1.	Ex-factory Price of Ammonia	2265	151.0	2265	151.0
2.	Transportation Cost	-	-	50	3.33
	Total Cost	2265	151.0	2315	154.33

11.7 Compared with the delivered cost of ammonia from the Chittagong Urea Fertilizer Project, the cost of production in an independent ammonia plant works out to be very unfavourable as expected, - almost 2 to 2.3 times costlier. Hence, the Consultants do not recommend the setting up of a separate plant for the supply of ammonia, but suggest that the commitment from the CUF Project authorities for the supply of ammonia be firmed up. The high cost of ammonia supply from an independent plant will have an adverse impact on the ammonium sulphate-soda ash schemes as can be seen in the subsequent Parts.

ANNEXURE II-A

Existing Fertilizer Units in Bangladesh
(including projects under implementation)

1. Fenchuganj Fertilizer Factory :

1.1 The first nitrogenous fertilizer producing unit in Bangladesh was set up at Fenchuganj in Sylhet district (about 20 Kilometers south of Sylhet and near Kusiyara river) in 1962. The factory has a rated capacity of 106,000 metric tons per year (MTPY) of urea based on 312 stream days operation. The plants and facilities were supplied, erected and commissioned by Ms. Kobe Steel Ltd., Japan on turnkey basis. The main plants, the ammonia and urea, are laid in multistreams (Ammonia - 2x102 MTPD and Urea - 3x113 MTPD). Later on, in 1969 small ammonium sulphate production facility with annual production of about 12,000 metric tons of crystalline sulphate (40 MTPD) based on direct neutralisation route were added to the complex, keeping in view the utilisation of ammonia surplus created from operation of the ammonia and urea plants having different stream-days efficiencies (ammonia : 320 streamdays and urea : 312 streamdays). The production of ammonium sulphate at Fenchuganj was taken up mainly to cater to the needs of the Sylhet tea gardens. Besides other off-site and utility facilities power generation (24 MW) to meet the power requirements of the complex were also included in the scope of the unit.

1.2 The ammonia production at Fenchuganj is based on a process route designed by Chemical Construction Corporation of USA where natural gas from Sylhet (Haripur) fields is steam-reformed at about 20 Kg/cm^2 to get the required quantities of carbon monoxide and hydrogen. Carbon monoxide is

HT-shift converted, carbon dioxide removed by Hot Potash Wash and final purification of synthesis gas is done by copper liquor wash system. Ammonia synthesis is carried out at about 350 Kg/cm^2 pressure. Multifunctional reciprocating compressor is used to perform compression duties. A 1000 metric tons ammonia storage facilities for flexibility in downstream plant operations is also provided.

1.3 The urea plant supplied by Ms. Kobe Steel Ltd., Japan is based on partial recycle technology where recovered gaseous carbon dioxide and ammonia from unconverted carbamate solution are separately compressed, condensed and recycled back to the reactor along with the fresh makeup.

1.4 The performance of Fenchuganj plant was at a satisfactory level from the start (1962) upto the time of the Liberation War (1970) and production achieved was on an average at 87% of the rated capacity. Although suffering no damage during the war, the production in postwar years had fallen to just a little over 50 per cent level. This could mainly be attributed to equipment failures due to the lack of proper and planned maintenance, mal-operation of the plants and non-availability of adequate spare parts. The yearly production figures from 1962-63 through 1977-78 are presented in Table IIA.1 below :

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Table IIA.1

Yearwise Production Figures

(Tonnes/year)

Year	Urea	Amm. Sulphate
A. Pre-Independence Period		
1962-63	72,600	-
63-64	101,100	-
64-65	77,400	-
65-66	92,900	-
66-67	95,100	-
67-68	111,000	-
68-69	88,000	-
69-70	95,900	4,700
B. Post-Independence Period		
1970-71	56,100	6,200
71-72	47,000	3,100
72-73	39,200	6,000
73-74	60,600	10,200
74-75	58,400	4,900
75-76	53,200	6,200
76-77	77,400	-
77-78	62,000	-
Installed Capacity	106,000	12,000

1.5 Experts from Ms. Kobe Steel, Asian Development Bank (ADB) and Tennessee Valley Authority (TVA) visited the factory during the period 1972-75 to assess the condition of the plant and reported that the plants and facilities required major renovation. Keeping in view the seriousness of the problem, BCIC appointed a Technical Committee in 1976 to scrutinise the recommendations of the various experts, which also confirmed the deteriorated condition of the plants.

1.6 An assessment made jointly by Kobe Steel and the Technical Committee indicated that with proper rehabilitation, the operational life of the plants could be extended by a further period of about 10 years and the rate of production could be improved to a figure of 75,000 tonnes per year against the existing achievable level of 60,000 metric tonnes. Specific consumption figures were also expected to be improved as shown in Table IIA.2 below.

Table IIA.2

Ammonia Consumption

Items	Specified	Present	Expected after Rehabilitation
1. Urea	0.60	0.65	0.62
2. Ammonium Sulphate	0.30	0.35	0.32

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1.7 Accordingly, a scheme for rehabilitation of plants and facilities at an estimated cost of $ 17.40 Million as shown in Table IIA.3 was drawn up. Its implementation was in progress when the Consultants visited the factory. It was then expected that the plants would be put on stream by mid-1979.

Table IIA.3

Cost of Rehabilitation

(Cost in $ 000)

Item	F.C.	L.C.	Total
1. Total supplies (FOB)	8100	-	8100
2. Ocean freight and insurance @ 8.5%	689	-	689
3. Duty and taxes @ 25%	-	2197	2197
4. Inland handling @ 5.5% incl. insurance	-	439	439
5. Design and Engineering	1333	-	1333
6. Erection charges and commissioning	560	438	998
7. Civil works including jetty and cooling tower etc.	-	1567	1567
8. Contingency and miscellaneous items	572	303	875
9. Interest during construction	936	262	1198
Total Fund Requirement	12190	5206	17396
Say (Million US $)	12.20	5.20	17.40

Source : BCIC

1.8 The cost of production of urea at yearly production levels of 60,000 metric tons (before the plants were rehabilitated) and 75,000 metric tons (after the rehabilitation scheme) have been worked out based on the consumption figures shown below in Table IIA.4.

Table IIA.4

Cost of Production of Urea

(Cost in $ Million)

Items	Level of Production	
	60,000 MTPY	75,000 MTPY
1. Natural gas	1.003	1.140
2. Fuel and Power	0.274	0.274
3. Catalyst, Chemicals and Consumables	0.476	0.541
4. Packing Material	0,929	1.161
5. Maintenance Material	1.098	0.629
6. Labour and Overheads	1.697	1.697
7. Insurance and Taxes	0.091	0.119
8. Contingency	0.278	0.278
9. Selling Expenses	0.012	0.015
10. Annual Works Cost	5.858	5.854
11. Depreciation	0.907	1.885
12. Interest on Investment	0.212	1.126
13. Total Annual Cost of Production	6.977	8.865
14. Annual Production (MTPY)	60,000	75,000
15. Unit Cost of production (US $/te)	116.28	118.20
(Say)	117	119

1.9 Though the estimated cost of production of urea from the rehabilitated plant work out marginally higher in comparison to the non-renovated plant, the investment decision on the rehabilitation scheme was taken, it is understood, mainly on the following considerations :

(i) the life of the plant will increase by 10 years from the presently assessed life of 2 to 3 years.

(ii) natural gas reserves of Sylhet will be exploited usefully.

(iii) manpower resources of the area will be employed gainfully.

(iv) general uplift of the area

1.10 During the visit to the factory, the Consultants felt that though the rehabilitation scheme may increase the life of the plants, their overall performance will, to a great extent, depend on the following important factors :

(i) availability of adequate spares (plants being of old generation, spare parts are not easily available).

(ii) effective plant maintenance.

(iii) availability of trained personnel for operation and maintenance.

2. Ghorasal Urea Fertilizer Factory

2.1 The fertilizer complex at Ghorasal is located at a distance of about 50 kilometers from the Dacca city on the bank of Sitalakhya river in the district of Dacca. The plant site is well connected with rail (meter gauge), road and waterways. However, the bulk of the material movement of the factory is done through waterways. The fertilizer complex at Ghorasal is designed to produce 375,000 tonnes of urea annually, on the basis of annual streamdays efficiency of 330 days from the facilities producing daily 660 te and 1137 te of ammonia and urea respectively. However, the plants are derated to produce, on average, about 340,000 tonnes of urea annually. The electrical energy requirements of the complex are met through inplant captive power generation (16 MW/gas-turbines).

2.2 The complex was constructed by Ms. Toyo Engg. Co. of Japan on turnkey basis. The work on the factory was started in 1967 and completed on schedule in May 1970. The ammonia and the urea plants were designed on the concept of large single stream units and the use of centrifugal machines wherever possible.

2.3 The ammonia plant at the complex is laid out in single stream and is based on the use of natural gas from the Titas gas field located at about 30 miles from the plant site across the Meghna river. The gas is brought to the site through a 14-inch pipelines at about 30 Kg/cm^2 pressure. At factory site the natural gas is compressed to an operating pressure of 35 kg/cm^2 before passing through a desulphurisation unit to reduce the sulphur content (the gas is reported to be normally free from sulphur compounds). The desulphurised natural gas is first steam reformed and then partially oxidised by air to get the required carbon monoxide, hydrogen and nitrogen. The reformed gas is then subjected to HT & LT shift conversion steps. Carbon dioxide from the gas mixture is recovered by Vetrocoke (GV) Process. Final polishing of synthesis gas is done by converting the objectionable residual oxides of carbon ($CO + CO_2$) to methane, which acts as an inert gas in the ammonia synthesis loop. The purified gas mixture containing mainly hydrogen and nitrogen in proper ratio (3:1) is compressed to about 150 Kg/cm^2 in a centrifugal synthesis gas compressor and finally converted to ammonia in a synthesis reactor. The product ammonia is separated from the unconverted constituents and balance gas is recycled back to the synthesis loop. The liquified ammonis is either stored in spheres (1500 metric tons capacity) or processed to urea in downstream plant.

2.4 The conventional Toyo-Koatsu Total Recycle process (with urea crystallisation, remelting and prilling) is adopted for the synthesis of urea. The plant is laid in two streams with reciprocating compressors used for carbon dioxide compression. In this process the carbon dioxide gas, preheated ammonia and recycled carbamate solution are fed into the reactors where urea synthesis is carried out at 230 Kg/cm^2 pressure and 190°C temperature. Unconverted ammonia and carbon dioxide from the decomposers are separated from the urea solution and fixed as carbamate solution. The carbamate solution thus formed is recycled back to the urea reactor. Excess ammonia separated in the process is recycled to the reactor alongwith ammonia make-up. The 70% urea solution is sent to vacuum evaporator crystalliser unit where urea crystals are formed. The centrifuged urea crystals are remelted and prilled to get low biurate urea prills. The bagged product is transported to consumption centres mostly through river barges. The barges loading facilities including river-side jetty included in the scope of the complex. Steam requirement of the urea plant is generated separately in auxiliary boilers. Recently a unit for making polythene lining for jute bags used for product bagging has also been added to the complex.

2.5 The performance of the plants at Ghorasal had a chequered history. Since the commissioning of the complex in 1970 it suffered an abnormally high number of shutdowns, besides the two major ones (one during Libration War and the other in 1974 following an explosion in the main control room), when the plants were practically stopped for the whole year. Even after the general overhaul of the plants in 1974-75, there were more than 77 shutdowns from 1975 to 1977 (Table IIA.5) resulting in a down time of about 366 days. About 50% of these shutdowns were due to major equipment and process control failures. Considering the deteriorating conditions of the plants, another general overhaul of equipment was planned in 1978 (May-June).

Table IIA.5

Causes of Plant Downtime with Period

Causes of downtime	Downtime period (days/year) 1975	1976	1977
1. Ammonia Plant			
a) Gas supply reduced	22	-	1
b) Power failures	8	-	-
c) Gas turbine filure failures (power generation)	1	7	7
d) Mechanical failures			
i. CO_2 removal	-	-	40
ii. Other equipments	-	12	1
iii. Pipe and flanges	-	8	-
iv. General overhaul	20	33	73
e) Electrical equipment failure	14	5	-
f) Instrument failure	-	13	15
g) Operational problems (Electrical & Mechanical)	5	-	44
Total	70	78	181

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Causes of downtime	Downtime period (days/year) 1975	1976	1977
2. Urea Plant			
a) CO_2 compressors	6	8	8
b) Recycle pumps and piping	1	3	1
c) Others	1	4	5
	8	15	14

Source : 'Fertilizer Works Operation Improvement Programme'.

2.6 Although the plants were overhauled during the 1978 planned shutdown, the average production from the plants could not be improved above 50% of the rated capacity. Main reasons for this low level of production could be attributed to either frequent shutdowns due to power system failure or the supply of poor quality cooling water, besides the deficiencies in equipment/ machines.

2.7 It has been reported by plant authorities that in general the performance of ammonia plant and utility supply system is poor and urea plant operation is smooth. However, the gland leaks from HP pumps and compressors and frequent power failures due to faulty operation of machines reduce the production capabilities of urea plant.

Although alternative arrangements have been made to draw 12 MW of power from PDB grids, frequent voltage dips make the power supply unreliable.

2.8 As mentioned earlier, a consultant - Bresler & Associates Inc., New York, has been appointed to recommend measures for the overall improvement of the performance of the plant. The Consultant has already submitted an "Inception Report" and it is under the consideration of BCIC, Based on recommendations of the Consultant, and the suggestions made by plant operation staff, BCIC has estimated that the total investment requirement for executing the improvement programme of the factory at $ 21 million, which covers itemwise cost besides the ammonia and urea plants, water treatment, cooling tower, power plant, effluent disposal, maintenance tools and laboratory appliances. The scheme was still under consideration during the Consultants' visit to Bangladesh.

2.9 Bangladesh depends mostly on imports for spare parts and machinery supply, which has turned out to be a major constraint. Similarly, non-availability of trained operation/maintenance personnel is proving to be another major problem. Therefore assumption of higher rate of production than 85% level will be quite unrealistic.

3. Ashuganj Fertilizer Project

3.1 The Ashuganj Fertilizer Project is owned by the Ashuganj Fertilizer and Chemical Company (AFCC) andis located on the eastern bank of the Meghna River at a distance of about 60 kilometers from Dacca city. The project is based on low sulphur natural gas to be supplied from the Titas fields through Titas - Habibganj pipeline. The project is in advanced stage of implementation. The main plants (ammonia and urea) are laid in single stream and are designed to produce daily 925 metric tons of ammonia and 1600 metric tons of prilled urea operating on an average 330 days in a year. However the plants are expected to operate at 90% of rated capacity to produce annually about 275,000 & 475,000 tonnes of ammonia and urea respectively. Ms. Foster Wheeler Limited (FWL) of U.K. has been appointed to execute the project. The project's scope includes in plant power generation facility of 13.5 MW to meet the normal power requirement of the plants. However, power supply to colony will be drawn from the PDB supply system.

3.2 The ammonia production will be based on conventional two stage medium pressure reformation-H.T. - L.T. Shift conversion and methanation steps. Carbon dioxide generated in the process will be recovered by giving the crude gas Benfield solution wash. The final purified gas compressed in a centrifugal compressor will be pushed into the ammonia synthesis loop to produce liquid ammonia. A 10,000 metric tons atmospheric storage facility will be included for smooth operation of the down stream plant. The urea production will be based on Stamicarbon-CO_2 stripping process.

3.3 The Ashuganj project was approved by the Government of Bangladesh in 1975 at a estimated cost of $ 243.2 million, including a foreign exchange component of $ 144.16 million. The project was planned to be completed by March 1979.

3.4 The progress of the project has been behind schedule due to various reasons. The problems connected with site preparation and changes in design parameters (site falling under seismic zone with factor ranging G/10 to G/15) had been among the major reasons which contributed to slippages in time as well as increase in project costs. In April 1978, the revised estimated cost of the project was placed at $ 407.88 million with foreign exchange component of $ 229.22 million. The estimate indicated the project completion date as 30th September, 1980.

Cost of Production

3.5 The cost of production of urea based on the figures furnished in the revised estimates of April 1978 works out to $ 172/te, including depreciation and interest.

ANNEXURE II-B

NEW FERTILIZER PROJECTS IN BANGLADESH

1. Among the various proposals for the utilisation of the natural gas reserves of the country, high priority is being given in Bangladesh to nitrogen fertilizer projects. Two new projects are presently under active consideration of the Government of Bangladesh, viz.

i.	Ghorasal-II Project	: 100,000 tonnes/ year Urea
ii.	Chittagong Urea Fertilizer Project	: 510,000 tonnes/ year Urea

Ghorasal - II Project

2. In pursuance of an agreement on economic and technical cooperation signed between the Government of Bangladesh and the People's Republic of China in March 1978, the China National Complete Plant Export Corporation has offered to set up an ammonia/urea plant in Bangladesh, producing annually 100,000 tonnes of prilled urea. A suitable site adjacent to the Ghorasal fertilizer unit has been selected for the purpose. The preliminary design for the plant has already been completed and is under review. The project is expected to be completed within 36 months at an estimated cost of about $ 54 million, with a foreign exchange component of about $ 34 million. According to the present schedule, the project will start commercial production in 1983.

Chittagong Urea Fertilizer Project

3. The project is proposed to be set-up at Chittagong and is planned to draw gas from Bakhrabad fields

located at about 50 kilometers south east of Dacca. Since the Chittagong region is industrially the most developed area of the country, a master plan to convey gas to this region is being planned and the proposed Chittagong fertilizer project will form part of this gas-utilisation plan. In fact, this project will be the largest user of gas if and when the pipeline is laid.

4. A technoeconomic feasibility study for the proposed project has been prepared by UNICO of Japan. The proposed project at Chittagong will have facilities rated for the production of 510,000 tonnes of urea based on 300 stream days efficiency for ammonia and urea plants. The main plants will be designed to produce daily about 1000 tonnes of ammonia and 1700 tonnes of prilled urea and will be laid in single stream, based on extensive use of centrifugal machines.

5. Since a significant proportion of the production from the project is meant for export the project will be located close to the Chittagong port across the river Karnaphuli. The area selected for the location of the project is about 3 Km South-West of the Marine Academy and away from the Chittagong aerodrome circuit. Meteorologically the region is difficult and is prone to heavy storms and rain. Hence the site will require extensive land preparation to raise the level to about 8 meters above Mean Sea Level, and a protective bund etc. to guard the area from tides. As per the soil investigation, the soil bearing capacity of the area is moderately good and below 10 meters from MSL sandy strata exists.

6. The water for the project (24 x 10^3 m^3/day) will be drawn from Sikal Bahakhal, a tributary of Karnaphuli river at Kaygram located at a distance of about 10 Km from the proposed site, where fresh water is always available and intrusion of saline water during high tides does not take place. Electricity supply (15 MW) to the project will be made through inplant power generation (2 x 12 MW sets). However power supply to colony, water intake station and product bagging station will be made through PDB Power grids.

7. The project is expected to be commissioned within four years from the date of appointment of the general contractor and release of funds. It was initially expected that the project would commence in October 1979 and completed by June 1983.

8. According to the analysis presented in the Consultants' report, the production of urea from the proposed project will be surplus to the requirements of the country in the near future due to the slow growth in the country's fertilizer absorption capacity. The present demand can be met substantially from existing operating units and the Ashuganj project which is already at an advance stage of implementation, besides the proposed Chinese-aided Ghorasal-II project. Hence, the proposed Chittagong Urea Fertilizer Project will basically be meant for export only.

9. According to the feasibility report the proposed CUF project is estimated to cost about \$ 353 million (Table II B.1) with a foreign exchange component of about \$241 million. The estimated

ANNEXURE II-B
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cost of production of urea based on annual production at 510,000 tonnes on a typical year of operation, works out to about $ 160 per tonne (Table II B.1).

Table II B.1

Estimated CUF Project Cost

	Items	Foreign	Local	Total
		($ million)		
1.	Cost of land & site development	3.090	4.430	7.520
2.	Cost of equipment and supplies	104.980	-	104.980
3.	Building, structurals and jetty	16.370	6.650	23.020
4.	Construction & Erection	3.740	10.170	13.910
5.	Services and management assistance	31.800	1.730	33.530
6.	Pre-operational expenses	2.600	3.770	6.370
7.	Freight, insurance and duties	12.710	5.560	18.27
	Total manufacturing facilities (as on mid'78)	175.290	32.310	207.60
8.	Working Capital	2.770	6.620	9.390
9.	Colony	1.000	10.000	11.000
10.	Contingency & escalation	61.390	20.340	81.730
11.	Interest during construction	-	43.370	43.370
	Total Capital Outlay	240.450	112.640	353.090

Table II B.2

Cost of Production of Urea in CUF Project

S.No.	Item	($ million) Annual Cost
1.	Natural gas	9.318
2.	Catalyst and Chemicals	1.932
3.	Bags	11.104
4.	Maintenance Cost	6.710
5.	Labour and overhead	2.637
6.	Insurance	1.111
7.	Sales Expenses	1.632
8.	Works Cost	34.597
9.	Depreciation	25.343
10.	Interest on Loan	21.640
11.	Total Annual Cost of Production	81580
12.	Annual Production (te/yr)	510,000
13.	Cost of Production of Urea (US $/tonne)	160

ANNEXURE II-C

Gist of Discussions of the Meeting held on 23 January 1979 in the Office of the Chief, Chittagong Urea Fertilizer Project regarding the supply of Liquid Ammonia, gaseous Carbon Dioxide, Steam, Process Water and Power from CUF Project to Basic Chemical Industries Development Project at an adjacent site

Participating :

1.	Mr. E.R. Chaudhury	Chief	Chittagong U.F. Project
2.	Mr. S. Huq	Chemical Engineer	
3.	Mr. Y. Ichiki		Ms. UNICO International Corpn.,Japan
4.	Mr. P.A. Bhaskara Rao	Project Leader	Basic Chemical Industries Development Project ; Bangladesh
5.	Mr. H.C.P. Sinha	Soda Ash Expert	

In the meeting, the desired supply of Liquid Ammonia, gaseous carbon Dioxide, Steam, Water and Power from Chittagong U.F. Project to Soda Ash Complex as stated in the Memorandum dated 1 January, 1979 was discussed and the following agreements were arrived at :

Liquid Ammonia :

1. With the built-in provision in CUF Project, it is possible to produce an additional quantity of 50 te/day of Ammonia without any modification.

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To produce even an additional quantity of 72 te/day of Ammonia instead of 50 te/day, there is no limitation upto Methanator, but the equipment downstream of Methanator may have to be marginally modified.

Hence the supply of liquid Ammonia amounting to only 72 te/day from CUF Project to Soda Ash Complex can be assured, and the necessary modifications for the same will be taken care of by Ms. UNICO. This amount of Ammonia is adequate for Scheme I of Soda Ash Complex. Hence supply of ammonia upto 72 te/day will not involve any direct additional investment.

Carbon Dioxide :

2. No Carbon dioxide gas can be spared from Ammonia Plant for the Soda Ash Complex. With the system provided, it will be also not feasible to generate additional quantity of carbon dioxide corresponding to the extra production of 72 te/day of ammonia.

Hence it was suggested that use be made of the flue gas of Steam Generation Plant of CUF Project for recovering CO_2 gas for Soda Ash Complex. Accordingly Soda Ash Complex shall draw the requisite amount of flue gas from S.G. Plant for recovery of CO_2 gas. For this purpose, the oxygen content in the flue gas shall be maintained within 1.5% by volume.

Ms. UNICO advised that the Soda Ash Complex should provide in the Carbon Dioxide recovery unit another 20-25% additional capacity over design so as to supplement CO_2 - gas supply to Urea Plant, if required.

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3. Steam :

The provision in the Steam Generation Plant of CUF Project is for 3 boilers - 2 in operation and 1 standby, each rated for 80 te/hr of steam generation. The requirement of steam for Soda Ash Complex (45 te/hr for Scheme-I or 80 te/hr for Scheme-II) is assured to be met by operating all the three boilers at corresponding reduced load. It was however observed that in such a case the annual shutdown for maintenance of Soda Ash Plant may be required to be matched with the annual shutdown of any boiler taken for annual inspection/maintenance. No difficulty is anticipated in this.

Steam to Soda Ash Complex will be supplied at 40 ata either as extraction steam from turbine or from Steam Reducing Station. Adjustment in Extraction Turbine for this, if any, shall be reviewed and provided by Ms. UNICO in the design.

4. Water :

Supply of adequate quantity of process water for cooling tower make-up and other process use in Soda Ash Complex (both Schemes) is assured from the existing provision of CUF Project. The CUF Project shall also provide Sanitary and Fire Hydrant water for Soda Ash Complex (both Schemes). Small quantity of D.M. Water, if required for process use in Soda Ash Complex, can be met from CUF Project.

5. Power :

(i) Normal Power : Keeping in view theoritical operating condition of Ammonia Plant, the supply of normal power from the existing Turbo-Alternator system of CUF Project to Soda Ash Complex is considered not feasible. However 7 (seven) MW power can be supplied to Soda Ash Complex from the main Sub-station of CUF Project from the mains connected to PDB Supply Station.

Hence Soda Ash Complex may include the cost of a 7 MW Turbo-Alternator set to be installed by the side of the T.A. sets of CUF Project. CUF Project shall, however, provide arrangement for 7 MW Power supply from PDB source through their Sub-station.

(ii) Emergency Power : The supply of emergency power to Soda Ash Complex (both Schemes) is assured from 3 MW Emergency set provided for CUF Project.

6. Urea Plant :

The capacity of Urea plant shall remain unaltered. Then normal level of Ammonia and Carbon Dioxide supply to this Plant shall not be affected in any way by any one of the above consideration/modification.

7. Natural Gas :

Natural Gas shall be supplied to Soda Ash Complex (both Schemes) from the N.G. pipeline at CUF Project site.

8. Jetty

For transportation of equipment and other erection materials, the service jetty to be built by CUF Project can be used by Soda Ash Complex also.

For products disposal however, Soda Ash Complex may have to provide its own jetty, if required.

ANNEXURE II-D

CONTRACTING SYSTEM IN PROJECT IMPLEMENTATION

1. Since the project passes from the initial stages of project formulation to the execution stages of engineering, procurement, construction and commissioning and finally into commercial operation, when commercial production is established, the project execution contracting system should aim in achieving the following :

   - The contract shall conform to the requirements of the local government and related financing agencies.
   - The construction of plants will be made to the best of industrial standards which will maintain designed capacity during the expected project life and follow the standard maintenance practices.
   - The plant will be constructed within optimum time and at minimum costs.
   - Secure the best services during construction and afterwards from the contractors.
   - Utilisation of local potential in the best interest of the project/country.

2. There are many contracting systems which can be adopted for project execution, depending on the situation under which the scheme has to operate. Broadly the contracting system or the mode of implementation may be classified as :

(i) On the basis of responsibilities of the parties

(ii) On the basis of payment procedures

3. The Contracting system for implementation of projects which fall under the first classification include :

(i) Full turnkey contract

Where all responsibility of implementing the project starting from site levelling through engineering, procurement, shipment, construction and commissioning the plants lie with the contractor. In this system technical capability of the contractor may be utilised to the maximum extent but optimisation of the project from owner's view point is difficult. However, if the owner has inadequate number of experienced staff to handle the workload this system may be useful

(ii) Semi turnkey contract

Where the responsibilities for project implementation are shared between the owner and the Contractor and both the parties are allowed to show their skill and capabilities. Main drawback in the system is the coordination of work, where both the parties perform their responsibilities independently where any shortcomings occur, each may try to hold the other party responsible.

(iii) Sub-contracting system

Where owner takes the full responsibility and sub-contracts segments of activities to other contractors. This system is most suited for a project where owner has in his command sufficient experienced personnel to control the project activities. This system require a large contingent of personnel to supervise and coordinate the multi-contract activities and extract the best out of contractors.

4. The contracting system under the other classification will include :

(i) Lumpsum contract

Where the contractor gets a fixed money and all the risks of unforeseen costs are borne by the contractor. Therefore the contracted costs normally contain certain cushions to cover the risks. The quantum of cushion will depend on the location of project (developed site/difficult site) or the technology to be adopted (proven/new).

(ii) Cost-plus-fee with maximum price ceiling

Where the contractor receives the payment against actual invoice, so long as the aggregate cost does not exceed a predetermined sum mutually agreed upon. In this type of contract, the contractor does not have much incentive for the cost reduction. The ceiling price can in fact be the real target. The contractor will have a higher incentive if the cost figures are reasonable and a bonus clause for cost saving is included in the contract.

(ii) Cost-plus-fee contract :

Where the contractor receives payment against actual invoice value. In this system all the risk is taken by the owner and the contractor expects to recover all the expenses and manpower costs from the owner. This system diminishes the incentive for cost reduction and the efficiency of construction on the part of the contractor. Therefore, the owner must supervise all of the contractor's work. The advantage of this type of contract is the minimisation of extra payment to the contractor to cover the risk.

5. In general the lumpsum turnkey contract where in a reputed general contractor is selected and entrusted with the total responsibility is considered the most suitable mode of implementation of a project for a developing country like Bangladesh, where adequate experienced personnel are not available to take up the desired responsibilities. Though this type of contracting may lessen owner's burdens, the obvious disadvantages are that the owner will have no direct involvement in the project activities and valuable construction experience to be gained for future use is lost. Costwise also this mode may not be advantageous.

ANNEXURE II-E

LIST OF ENGINEERING CONTRACTORS AND SUPPLIERS

A. Engineering Contractors

1. Pullman Kellogg Ltd
The Pullman Kellogg Buildings
Stadiumway Wembley
Middlesex, HA-90EE
LONDON, U.K.

2. Toyo Engineering Corporation
Kasumigasaki Buildings
2-5, 3-Chome
Kasumigasaki, CHIYODA-KU
TOKYO

3. Fredrich Uhde GmbH
46-Dortmond
Deggingstrasse 10-12
Federal Republic of West Germany

4. Humphrey & Glasgow (Overseas Ltd)
22, Carlisle Place
London SWIP 1 JA
U.K.

5. Technimont
Piazza-Turr-3
Casella Postale 3268
201493 Milano
ITALY.

6. Haldor Topsoe A/s
Nymollevej-55
DK-2800, Lyngby
Copenhagen
DENMARK.

ANNEXURE II-E
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7. C.F. Braun & Co.
Alhambra
California 91802
U.S.A.

8. Fertilizer (Planning & Development) India Ltd.
C.I.F.T. Buildings
P.O. Sindri
Dhanbad - 828122
INDIA.

Ammonium Sulphate

1. Fertilizer (Planning & Development) India Ltd.
C.I.F.T. Buildings
Sindri - 828122
INDIA.

2. FACT Engineering & Design Organisation
P.O. Udyogmandal
Alwaye,
Kerala
INDIA.

3. Davy Powergas Inc.
P.O. Drawer 5000
Lakeland
Florida
USA 33803

B. List of Suppliers

1. Voest Alpine A.G.
P.O. Box No. 2
A-4010 Linz/Donau
Muldenstrasse 5
Osterriech
AUSTRIA

ANNEXURE II-E
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2. Bignier - Schmid - Laurent
25, Quai Marcel Boyer
F-94, Ivry Surseine
FRANCE.

3. Bronswerk PCES
P.O. Box 28
Brabantsestraat 10
Amersfoort
NETHERLAND.

4. Nuovo Pignone
Direzione Generale
Firenze
ITALY.

5. Borsig GmbH
Berliner Strasse 19-37
1-Berlin-27
WEST GERMANY.

6. Larsen & Toubro Ltd.
Powai Works
Saki Vihar Road
BOMBAY - 72

7. Fried Krupp GmbH
Krupp Maschinen Fabriken
43 Essen 1, Postfach 963
Helenen Strasse 149
WEST GERMANY.

8. Linde A.G.
Werks Gruppe Munchen
8023, Hollriegelskrenth
Carn-von-Linde-Strasse 6-14
WEST GERMANY.

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9. Maunesmann Export A.G.
4, Dusseldorf-1
Breite Strasse 29/31
WEST GERMANY.

10. Dodsal (P) Ltd
2, Brabourne Road
P.B. No.2646
Calcutta
INDIA.

11. Rheinstahl Maschinenban
581, Witten Arinen, Postfach 3
Stockumer Strause 28
WEST GERMANY.

12. Bharat Heavy Plate & Vessel Ltd.
P.O. BHPV
Visakhapatnam
INDIA.

13. Bharat Heavy Electricals Ltd.
New Delhi House-27
Barakhamba Road
P.O. Box No. 72
NEW DELHI-110001
INDIA.

14. Bharat Pumps & Compressors
First Floor, Chanakya Bhawan
Vinay Marg
Chanakya Puri
New Delhi-110021
INDIA.

15. Testeels Ltd
Navdeep, Ashram Road
AHMEDABAD, INDIA

ANNEXURE II-E
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16. Hayward Tyler & Co. Ltd
24, Crawley
Greem Road
Inton, Prods,
U.K.

17. Pompe Gabionetta SpA
20131, Milan
Via Paisiello 10,
ITALY.

18. Deutsche Worthington GmbH
2, Hamburg - Braunfield 1
Wandsbekerstr 21-23
WEST GERMANY.

19. Mitsubishi Corporation
Mitsubishi Shoji Buildings
6-3 Marunsuchi
2, Chome
Chiyoda - Ku - Tokyo
JAPAN.

20. Torishima Pump Mfg. Co. Ltd
1-1-8, Miyato-Cho
Takat Suki City
Osaka
JAPAN.

21. Copper Bressemer
People's Gas Building
122 South Michigan Avenue
Chicago-3
Illinois
U.S.A.

ANNEXURE II-F

SPECIFICATIONS OF MAJOR EQUIPMENT
(Ammonia Plant)

Sl. No.	Items	Number reqd.	Brief Specifications		Material of Construction
1.	2.	3.	4.	5.	6.
1.	Desulphuriser	1+1	I.D.	1750 mm	Alloy Steel (AS)
			Ht.	6000 mm	
			Catalyst Volume	10.5 Cu.m.	
2.	Primary Reformer	1	No. of tubes	45	Tubes : HK-40
			OD/ID	125/95 mm	Outlet
			Heated length	10,500 mm	Header : Incoloy
			Heat absorbed	6x10^6Kcal/hr	
3.	Secondary Reformer	1	O.D.	1100/1970 mm	Alloy Steel
			Ht.	5750 mm	
			Catalyst Volume	3 Cu.m.	
4.	Reformed Gas Boiler	2[1]	Type	Shell & Tube	Shell : Alloy Steel
			Shell side	Reformed gas	
			Pressure	29.5 Kg/Cm^2	Tube : Carbon Steel
			Tube side	Water	
			Pressure	40 Kg/Cm^2	
			Duty	4.7x10^6Kcal/hr	
5.	Mixed Gas Heater[2]	1	Type	Hairpin coil	Tube : S.S. 321
			Tubeside pres.	35 Kg/Cm^{2}g	
			Surface	11 Sq.meter	
			Heat duty	1.5 x 10^6Kcal/hr	

[1] Two boilers in series; provision for gas bypass for the second boiler to control gas temperature to H.T. shift converter.

[2] Flue gas convection side.

ANNEXURE II-F
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1	2	3	3	4	5	6
6.	Process Air Heater[2]		1	Type	Hairpin coil	Tube : Alloy Steel
				Tubeside press.	33 Kg/cm^{2}g	
				Surface	21 Sq.meter	
				Heat duty	0.42 x 10^6Kcal/hr	
7.	Natural Gas Heater[2]		1	Type	Hairpin coil	
				Tubeside press.	35 Kg/cm^{2}g	Tube : Carbon Steel
				Surface	21 Sq.meter	
				Heat duty	0.46x10^6Kcal/hr	
8.	Flue gas Waste Heat[2] Boiler		1	Type	Evaporation coils	
				Tubeside press.	40 Kg/Cm^2	Tube : Carbon Steel
				Surface Area	155 Sq.meter	
				Heat duty	1.50x10^6Kcal/hr	
9.	Combustion Air Heater[2]		1	Type	Shell & tube	Shell : Carbon Steel
				Surface	140 Sq.meter	Tube : Carbon Steel
				Heat duty	0.60x10^6Kcal/hr	
10.	Flue Gas Stack		1	I.D.	1.150 mm	Carbon Steel
				Ht.	40,000 mm	Top (5000 mm) S.S.
11.	Process Air Compressor		1+1	Type	Reciprocating	
				Suc/Disch.	Atm/40 Kg /Cm^{2}g	
				Capacity(max.)	6000 Nm^3/hr	
12.	Startup Nitrogen Compressor		1	Type	Reciprocating	
				Suc/Disch.	Atm/35 Kg/Cm^{2}g	
				Capacity (max.)	200 Nm^3/hr	

1	2	3	4	5	6
13.	Nitrogen Circulation Compressor	1	Type	Reciprocating	
			Suc/Disch.	20/35 Kg/Cm^{2}g	
			Capacity (max.)	2000 Nm^3/hr	
14.	I.D. Fan	1	Type	Centrifugal	
			Capacity(max.)	20,000 Nm^3/hr	
15.	F.D. Fan	1	Type	Centrifugal	
			Capacity(max.)	20,000 Nm^3/hr	
16.	H.T. Shift Converter	1	Type	Vertical cylindrical packed with catalyst	
			I.D.	1500 mm	A.S.
			H.T.	6000 mm	
			Catalyst volume	6.5 Cu meters	
17.	L.T. Shift Converter	1	Type	Vertical cylindrical packed with catalyst	A.S.
			I.D.	1500 mm	
			Ht.	7500 mm	
			Catalyst volume	9 Cu meters	
18.	Boiler Feed Water Heater	1	Type	Shell & Tube	Shell : A.S.
			Service(Shell/tube)	Partially converted gas/BFW	Tubes: S.S.-321
			Pr.(shell/tube)	29/40 Kg/Cm^2	
			Surface	50 Sq.meter	
			Heat duty	1.7 x 10^6 Kcal/hr	

1	2	3	4	5	6
19.	Benfield Absorber	1	Type	Packed Tower	C.S.
			Pressure	26.5 Kg/Cm^2	
			O.D.	875/1100 mm	
			Ht.	42500 mm	
20.	Benfield Regenerator	1	Type	Packed Tower	C.S.
			Pressure	Atmospheric	
			O.D.	1670 mm	
			Ht.	28,400 mm	
21.	Converted Gas Cooler	1	Type	Shell & Tube	Shell : A.S.
			Service (shell/tube)	Conv.gas/C.Water	Tubes: SS-304
			Pressure(shell/tube)	26.5/3.5 Kg/Cm^2	
			Surface	9 sq.meters	
			Heat duty	0.26 x 10^6 Kcal/hr	
22.	Condensate Boiler	1	Type	Kettle type	Shell : SS-304
			Service (shell/tube)	Cond./Conv.Gas	Tubes: SS-321
			Pressure (shell/tube)	4.5/27.3 Kg/Cm^2	
			Surface	93 Sq.meter	
			Heat duty	1.3 x 10^6 Kcal/hr	
23.	Solution Reboiler	1	Type	Kettle Type	Shell : SS-304
			Service (shell/tube)	Rich Solution/Conv. gas	Tubes: SS-321
			Pressure (shell/tube)	1.5/27 Kg/Cm^2	
			Surface	115 Sq.meter	
			Heat duty	1.5 x 10^6 Kcal/hr	

1	2	3	4	5	6
24.	D.M. Water Heater	1	Type	Shell & Tube	Shell : SS-304
			Service (shell/tube)	CO_2 gas/D.M.Water	Tubes: SS-304
			Pressure (shell/tube)	1.35/1.5 Kg/Cm^2	
			Surface	60 Sq.meter	
			Heat duty	0.9 x 10^6 Kcal/hr	
25.	CO_2 Cooler	1	Type	Shell & Tube	Shell : C.S.
			Service (shell/tube)	CO_2 gas/C.Water	Tubes: C.S.
			Pressure (shell/tube)	Atm./3.6 Kg/Cm^2	
			Surface	200 sq.meters	
			Heat duty	2.1 x 10^6 Kcal/hr	
26.	Solution Cooler	1	Type	Shell & Tube	Shell : C.S.
			Service (shell/tube)	Benfield solution/ Cooling water	Tubes: C.S.
			Pressure (shell/tube)	30/3.6 Kg/Cm^2 .	
			Surface	30 Sq.meter	
			Heat duty	0.8 x 10^6 Kcal/hr	
27.	Benfield Solution Circulation Pumps	1+1	Capacity	110 Cu meter/hr	SS-304
			Suc./Dis. Pressure	1.04/35 Kg/Cm^2	

1.	2.	3.	4.	5.	6.
28.	Carbon Dioxide Gas Holder	1	Type	Wet Seal Type	C.S.
			Capacity	1000 Cu meter	
29.	Trim Heater	1	Type	Shell & Tube	Shell : A.S.
			Service (shell/tube)	Decarbonated gas/ Conv. gas	Tubes: A.S
			Pressure (shell/tube)	26.1/28.5 Kg/Cm^2	
			Surface	23 Sq. meter	
			Heat duty	0.10 x 10^6 Kcal/hr	
30.	Methanator	1	Type	Vertical cylindrical packed with catalyst	A.S.
			O.D.	1275 mm	
			Ht.	3450 mm	
			Catalyst volume	2.70 Cu meters	
31.	Methanated Gas Heat Exchanger	1	Type	Shell & Tube	Shell : A.S.
			Service (shell/tube)	Decarbonated gas/ Methanated gas	Tubes: A.S.
			pressure (shell/tube)	26.5/25.5 Kg/Cm^2	
			Surface	150 Sq.meter	
			Heat duty	0.90 Kcal/hr	
32.	Methanated Gas Cooler	1	Type	Shell & Tube	Shell : C.S.
			Service (shell/tube)	Methanated gas/ Cooling water	Tubes: C.S.
			Pressure (shell/tube)	25.5/3.5 Kg/Cm^2	
			Surface	50 Sq.meter	
			Heat duty	0.4 x 10^6 Kcal/hr	

1	2	3	4	5	6
33.	**Synthesis Gas Compressor**	1+1	Type	Reciprocating	
			Service	Synthesis gas (H_2:N_2) (= 3:1)	
			Pressure (Suc./disch.)	24/300 Kg/Cm^2	
			Gas flow(max.)	13500 Nm^3/hr	
34.	**Start-up Furnace** [3]	1	Heat capacity	0.5 x 10^6 Kcal/hr	
			Tubes	Coil type	Coil : SS-321
			Pressure	70-300 Kg/Cm^2	
			Start up gas	In coils	
35.	**Ammonia Synthesis Converter**	1	Type	Axial quench type	Shell : A.S.
			I.D.	1050 mm	Catalyst
			Ht.	9500 mm	Basket : SS-304
			Catalyst	5 Cu meter	
36.	Waste Heat Boiler	1	Type	Kettle type	Shell : Boiler grade CS
			Service	Conv.gas/BFW	
			Pressure	300/40 Kg/Cm^2	Tube : Boiler grade CS
			Surface	60 Sq.meter	
			Heat duty	1.6 x 10^6 Kcal/hr	
37.	Heat **Exchanger**	1	Type	Shell & Tube	Shell : C.S.
			Service	Converted syn.gas	Tubes: A.S.
			Pressure (shell/tube)	294/284 Kg/Cm^2	
			Surface	50 Sq.meter	
			Heat duty	2.5 x 10^6 Kcal/hr	

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[3] Refractory lined.

1.	2.	3.	4.
38.	Water Cooled Condenser	1	Type Service (shell/tube) Pressure (shell/tube) Surface Heat duty
39.	Cold Exchanger	1	Type Service Pressure (shell/tube) Surface Heat duty
40.	Ammonia Cooled	1	Type Service (shell/tube) Pressure (shell/tube) Surface Heat duty
41.	Flash Gas Cooler	1	Type I.D. Ht.
42.	Purge Gas Cooler	1	Type Service (shell/tube) Pressure (shell/tube) Surface Heat load

5.	6
U.Tube type C.Water/Amm.Syn. gas 3.6/283 Kg/Cm^2 100 Sq.meter 2.0 x 10^6 Kcal/hr	Shell : C.S. Tubes: C.S.
Shell & Tube Sy.gas 296/284 Kg/Cm^2 75 Sq.meter 0.7 x 10^6Kcal/hr.	Shell : C.S. Tubes: C.S.
Kettle Ammonia/Ammonia Synthesis gas 2.35/298 Kg/cm^2 65 Sq.meter 0.8 x 10^6 Kcal/hr.	Shell : Low Temp. CS Tubes: Low Temp. CS
Packed Column 215 mm 1500 mm	Shell : Low Temp. CS Demister:SS-304
Kettle type Ammonia/Purge gas 2.35/282 Kg/Cm^2 2.0 Sq.meter 15000 Kcal/hr.	Shell: Low Temp. Temp. CS Tubes: C.S.

1	2	3	4	5	6
43.	Hot Ammonia Separator	1	Type	Vertical cylindrical	Shell : C.S.
			Service	Liquid ammonia	Demister : SS-304
			Pressure	281 Kg/Cm^2	
			I.D.	760 mm	
			Ht.	2300 mm	
44.	Cold Ammonia Separator	1	Type	Vertical cylindrical	Shell : C.S.
			Service	Liquid ammonia	Demister : SS-304
			Pressure	297 Kg/Cm^2	
			I.D.	700 mm	
			Ht.	1750 mm	
45.	Recirculating Gas Compressor	1+1	Type	Reciprocating	
			Service	Synthesis gas	
			Pressure (Suc./Disch.)	280/300 Kg/Cm^2	
			Gas Flow(max.)	44,500 Nm^3/hr	
46.	Process Refrigeration Compressor	1+1	Type	Reciprocating	
			Service	Ammonia gas	
			Pressure (Suc./Disch.)	2.35/19 Kg/Cm^2	
			Gas Flow	3.4 metric tons/hour	
47.	Let-down Tank	1	Type	Vertical cylindrical	C.S.
			Service	Ammonia, Syn. gas	
			Pressure	40 Kg/Cm^2	
			I.D.	850 mm	
			Ht.	3400 mm	

1	2	3	4	5	6
48.	Ammonia Scrubber	1	Type	Bubble Cap.tray column	Shell : C.S.
			Service	Ammonia vapour	Demister:SS-304
			Pressure	39 Kg/Cm^2	Trays : C.S.
			I.D.	400/700 mm	
			Ht.	8000 mm	
			No. of Trays	20	
49.	Ammonia Stripper	1	Type	Tray Column with Reboiler	C.S.
			Service	Ammonia	
			Pressure	39 Kg/Cm^2	
			I.D.	350/650 mm	
			Ht.	7000 mm	
			No. of Trays	17	
50.	Ammonia Storage Tank	1	Type	Spherical insulated	Low Temp.: C.S.
			Service	Ammonia vessel	
			Pressure	4.5 Kg/Cm^2	
			I.D.	17000 mm	
			Capacity	1500 metric tons	
51.	Ammonia Storage 4/	1+1	Unit complete with compressor, condenser and receiver Capacity : 600 Kg/hr ammonia vapour Compressor Suc. Pressure : 2.8-3.3 Kg/Cm^2		

4/ Spare unit for emergency refrigeration driven by diesel set.

ANNEXURE II-G

WORKING CAPITAL
(Alternative-I)

CHITTAGONG LOCATION
(Ammonia-Ammonium Sulphate-Soda Ash)

Sl.No.	Item	Total Cost (In $ '000)
1.	Accounts Receivable One month sales @ 5000 Taka/te for soda ash & @ 1600 Taka/te for amm. sulphate	3540
2.	Operating Supplies Bags (one month) @ 7 Taka/no. for soda ash & @ 12 Taka/no. for amm.chloride Chemicals & Consumables (3 months)	380
3.	Raw Material Inventories - Salt (Avg. Storage 30,000 te @ Taka 247/te) - Coke (one month) - Sod. sulphide (one month) - Sulphuric acid (15 days)	610
4.	Product Inventories - 23 days bulk soda ash & ammonium sulphate - 7 days bagged soda ash & ammonium sulphate	2510
5.	Goods in Process (one day)	70
6.	Accounts Payables (one month)	(1427)
7.	Deposits & Advances	(350)
8.	Cash in Hand	67
		5400

ANNEXURE II-H

WORKING CAPITAL
(Alternative-I)*

GHORASAL LOCATION
(Ammonia - Soda Ash - Ammonium Chloride)

Sl.No.	Item	Total Cost (In $ '000)
1.	Accounts Receivable One month Sales @ 5000 Taka/te for Soda Ash & @ 2000 Taka/te for Ammonium Chloride for Ammonia @ 2315 Take/te	2970
2.	Operating Supplies a) Bags (one month) @ 7 Taka for Soda Ash @12 Taka for Ammonia Chloride b) Chemicals & Consumables (3 months)	285
3.	Raw Material Inventories - Salt (2500 te Avg. @ 247 Taka/te) - Lime (one month) - Sod. Sulphide (one month)	620
4.	Product Inventories - 23 days bulk storage for Soda Ash & Ammonium Chloride - 7 days bagged storage for Soda Ash & Ammonium Chloride	2400
5.	Goods in Process (one day)	40
6.	Accounts Payable (one month Bill)	(782)
7.	Deposits & Advances	(300)
8.	Cash in Hand	67
		5300

*Alt. IV in Part V

ANNEXURE II-I

CAPITAL OUTLAY

AMMONIA - AMMONIUM SULPHATE - SODA ASH:CHITTAGONG LOCATION (Alternative-I)

(Cost in $ million)

		F.C.	L.C.	TOTAL
1.	Land & Land Development	0.260	0.700	0.960
2.	Main Plant : Equipment & Material			
i)	Ammonia	10.900	1.200	12.100
ii)	Soda Ash	7.100	2.400	9.500
iii)	Ammonium Sulphate	6.000	0.670	6.670
	Sub-total (2)	24.000	4.270	28.270
3.	Off site : Equipment & Material			
i)	Yard Piping	0.330	0.220	0.550
ii)	Water Supply, Storage & Distribution	0.430	0.070	0.500
iii)	Power Supply & Distribution	0.820	-	0.820
iv)	Cooling Tower	0.840	-	0.840
v)	Raw Material Handling & Storage	1.620	0.120	1.740
vi)	Product Handling, Bagging & Storage	0.970	0.130	1.100
vii)	Ammonia Storage & Handling	0.840	-	0.840
viii)	CO_2 Recovery Plant	1.900	0.250	2.150
ix)	Effluent Treatment Plant	0.240	0.030	0.270
x)	Auxiliary Services	1.450	0.200	1.650
xi)	Transport Facilities	0.240	0.060	0.300
xii)	Temporary Construction Facilities	0.150	0.070	0.220
	Sub-total (3)	9.830	1.150	10.980

ANNEXURE II-J
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		F.C.	L.C.	Total
4.	Spares	5.200	0.400	5.600
5.	Jetty, Non Plant Building & Plant Civil Works	5.360	3.370	8.730
6.	Construction Equipment	1.800	0.130	1.930
7.	Township & Public Buildings	5.800	4.400	10.200
8.	Freight, Insurance, Handling, Duties & Taxes	3.600	4.100	7.700
9.	Licence, Knowhow, Design, Engineering and Procurement	7.040	-	7.040
10.	Erection & Erection Supervision Charges	3.720	5.780	9.500
11.	Project Management Charges	2.990	7.200	10.190
12.	Working Capital	-	5.400	5.400
13.	Contingency	3.500	1.900	5.400
14.	Expenses during Commissioning	-	0.400	0.400
15.	Escalation	18.700	15.800	34.500
16.	Financing Charges	-	12.900	12.900
	TOTAL CAPITAL	91.800	67.900	159.700

ANNEXURE II-K

CAPITAL OUTLAY

AMMONIA - SODA ASH : GHORASAL LOCATION
(Alternative-I)*

(Cost in $ million)

	F.C.	L.C.	TOTAL
1. Land & Land Development	-	0.100	0.100
2. Main Plants : Equipment & Material			
i) Ammonia	10.900	1.200	12.100
ii) Soda Ash	7.600	2.500	10.100
Sub-total (2)	18.500	3.700	22.200
3. Offsites : Equipment & Material			
i) Yard Piping	0.060	0.040	0.100
ii) Steam Generation	1.230	-	1.230
iii) Water Supply, Treatment and Distribution	1.090	-	1.090
iv) Power Supply & Distribution	0.850	-	0.850
v) Cooling Tower	0.510	-	0.510
vi) Raw Material Handling	2.700	-	2.700
and Storage	0.800	0.100	0.900
vii) Product Handling, Bagging and Storage	0.800	0.100	0.900
viii) Ammonia Storage & Handling	0.840	-	0.840
ix) Effluent Treatment Plant	0.240	0.030	0.270
x) Auxiliary Services	1.300	0.200	1.500
xi) Transport Facilities	0.180	0.020	0.200
xii) Temporary Construction Facilities	0.150	0.070	0.220
Sub-total (3)	9.950	0.460	10.410

*Alt. IV in Part V

ANNEXURE II-K
pp.2

		F.C.	L.C.	TOTAL
4.	Spares	4.700	1.400	6.100
5.	Jetty, Non Plant Building & Plant Civil Works	3.450	2.220	5.670
6.	Construction Equipment	1.800	0.430	2.230
7.	Township & Public Buildings	4.800	3.700	8.500
8.	Freight, Insurance, Handling, Taxes & Duties	3.050	9.350	12.400
9.	Licence, Knowhow, Design, Engg. & Procurement	6.750	-	6.750
10.	Erection & Erection Supervision	3.030	4.700	7.730
11.	Project Management Charges	2.670	6.140	8.810
12.	Working Capital	-	5.300	5.300
13.	Contingency	2,900	1.900	4.800
14.	Expenses during Commissioning	-	0.600	0.600
15.	Escalation	16.000	15.700	31.700
16.	Financing Charges	-	11.000	11.000
	TOTAL CAPITAL	77.600	65.500	143.100

ANNEXURE II-L

COST OF PRODUCTION
(Alternative-I)

CHITTAGONG LOCATION
(Ammonia - Ammonium Sulphate - Soda Ash)

Sl. No.	Item	Unit	Unit Rate $	Annual Quantity	Annual Cost	Allocated Cost (In $ '000)		
						Ammonia	Soda Ash	Ammonium Sulphate
1	2	3	4	5	6	7	8	9
1.	Raw Material							
	a) Natural Gas	1000cft	0.60	$1021x10^3$	613	613	-	-
	b) Salt	Te	16.48	102336	1687	-	1687	-
	c) Coke	Te	113.00	8232	930	-	930	-
	d) Sodium Sulphate	Te	504 .67	204	103	-	103	-
	e) Sulphuric Acid	Te	63.30	4610	293	-	-	293
	f) Ammonia							
	i) Own Production	Te	302.6	30,000	-	-	-	9077
	ii) Imported	Te	151.00	9900	1495	-	45	1450
2.	Utilities							
	a) Natural Gas	1000cft	0.60	$516x10^3$	310	40	240	30
	b) Power	MWH	32.33	91440	2956	1000	747	1209
	c) Water	M^3	0.14	5537000	775	108	243	424
	d) Steam	Te	6.33	333000	2108	-	1367	741
	e) Fuel Oil	Te	88.20	900	79	-	-	79
3.	Consumable Stores	-	-	-	367	160	33	174

1	2	3	4	5	6	7	8	9
4.	Bags							
	a) Soda Ash	No	0.47	1200000	564	-	564	-
	b) Ammonium Sulphate	No	0.80	2880000	2304	-	-	2304
5.	Labour and Overheads	-	-	-	1540	373	613	554
6.	Maintenance Material	-	-	-	2693	973	847	873
7.	Insurance	-	-	-	479	167	158	154
8.	Contingency	-	-	-	965	172	379	414
	Annual Works Cost	-	-	-	20261	3606	7956	17776
9.	Depreciation	-	-	-	10610	3707	3487	3416
10.	Selling Expenses	-	-	-	220	-	200	20
11.	Average Interest on Loan	-	-	-	4590	1764	1371	1455
12.	Annual Cost of Production	-	-	-	35681	9077	13014	22667
13.	<u>Annual Production</u>							
	a) Ammonia	Te				30,000		
	b) Soda Ash	Te					60,000	
	c) Ammonium Sulphate	Te						144,000
14.	<u>Unit Cost of Production</u>							
	a) Ammonia ($/Te)					302.60 = 303		
	b) Soda Ash ($/Te)						216.50 = 217	
	c) Ammonium Sulphate ($/Te)							157.40 = 158

ANNEXURE II-M

COST OF PRODUCTION
(Alternative - I)
GHORASAL LOCATION
(Ammonia - Soda Ash)

Item	Unit	Unit Rate $	Annual Quantity	Annual Cost	Allocated Cost (In $ '000) Ammonia	Allocated Cost (In $ '000) Soda Ash
1	2	3	4	5	6	7
1. Raw Material						
a) Natural Gas	1000cft	0.33	1021000	337	337	-
b) Salt	Te	20.00	76020	1520	-	1520
c) Lime	Te	60.00	4800	288	-	288
d) Sodium Sulphate	Te	504.67	204	103	-	103
2. Intermediate Product						
Ammonia	Te	324.16	20196	6547	-	6547
3. Utilities						
a) Natural Gas	1000cft	0.33	926000	306	20	286
b) Power	MWH	32.33	100100	3236	1093	2143
4. Consumable Stores	-	-	-	440	207	233
5. Bags						
a) Soda Ash	No	0.47	1200000	564	-	564
b) Ammonium Chloride	No	0.80	1224000	979	-	979
6. Labour & Overheads	-	-	-	1033	413	620
7. Maintenance Material	-	-	-	2567	1220	1347
8. Insurance	-	-	-	429	186	243
9. Contingency	-	-	-	590	174	416
Annual Works Cost	-	-	-	12392	3650	15289

ANNEXURE II-M
pp.2

1	2	3	4	5	6	7
10. Depreciation	-	-	-	9783	4245	5538
11. Selling Expenses	-	-	-	210	-	210
12. Average Interest on Loan	-	-	-	3880	1830	2050
13. Annual Cost of Production	-	-	-	26265	9725	23087
14. Credit from Ammonium Chloride Sales @ $ 95/Te	-	-	61200 Te	7528	-	7528
15. Net Annual Cost of Production	-	-	-	18737	9725	15559
16. Annual Production						
a) Ammonia					30,000Te	
b) Soda Ash						60,000Te
17. Unit Cost of Production						
a) Ammonia ($/Te)					324.16 = 325	
b) Soda Ash ($/Te)						259.32 = 260

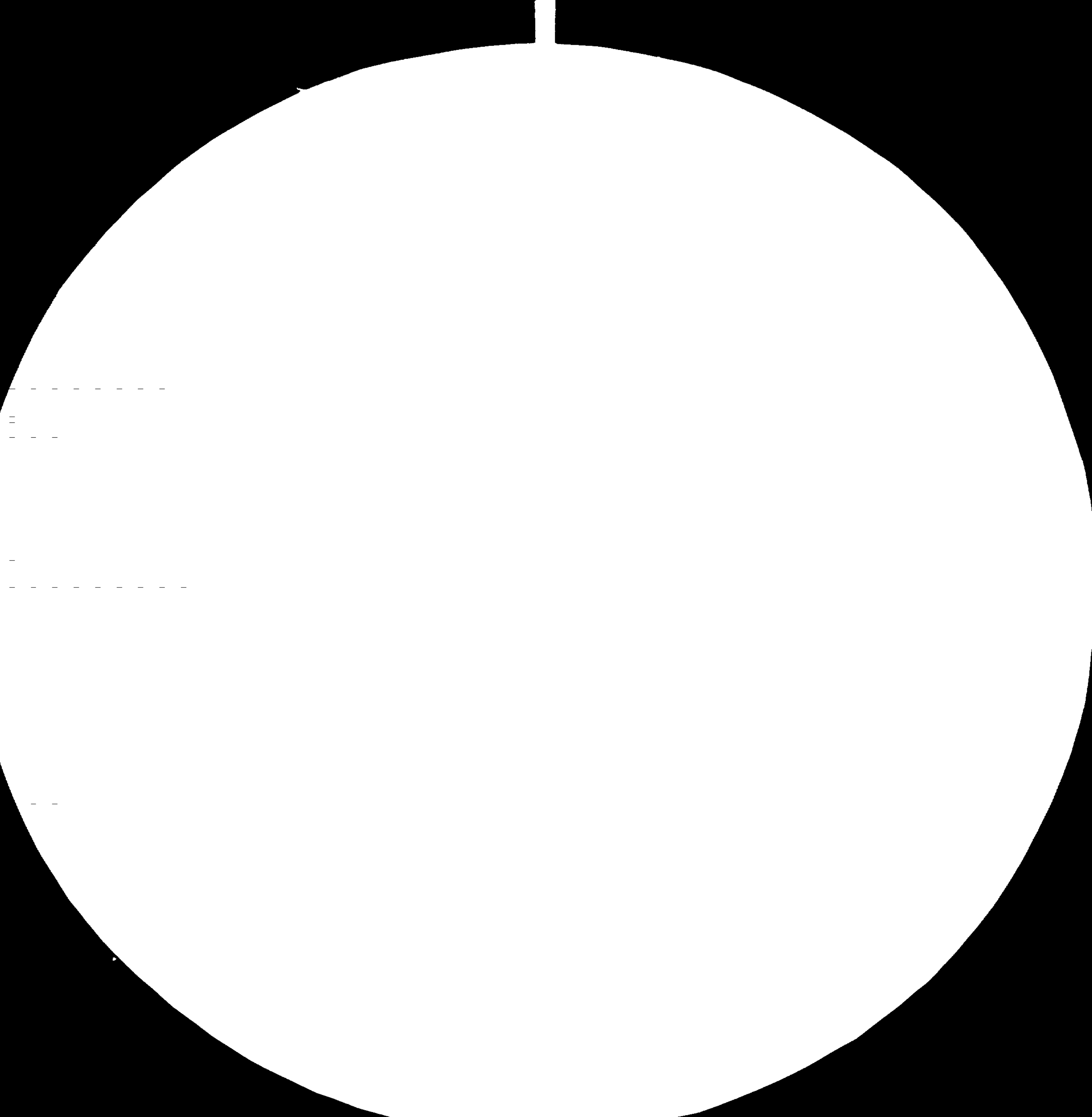
ANNEXURE II-N

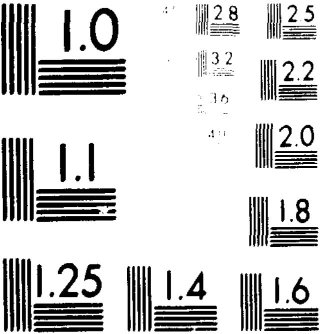
PROFITABILITY ANALYSIS
(Alternative-I)

Chittagong Location : Ammonia - Ammonium Sulphate Soda Ash*
Ghorasal Location : Ammonia - Soda Ash@

($ '000)

	Chittagong	Ghorasal
1. Sale Price (Taka/Te)		
i) Soda Ash	4850	4850
ii) Ammonium Sulphate	1515	-
iii) Ammonium Chloride	1845	1845
iv) Ammonia	-	2315
2. Annual Production (Te)		
i) Soda Ash	60,000	60,000
ii) Ammonium Sulphate	144,000	-
iii) Ammonium Chloride	-	612,00
iv) Ammonia (for Sale)	-	9804
3. Annual Realisation		
i) Soda Ash	19400	19400
ii) Ammonium Sulphate	14544	-
iii) Ammonium Chloride	-	7528
iv) Ammonia	-	1513
Total Realisation	33944	28441





MICROCOPY RESOLUTION TEST CHART

[illegible]

ANNEXURE II-N
pp.2

		Chittagong	Ghorasal
4.	Annual Works Cost	20261	12392
5.	Depreciation	10610	9783
6.	Selling Expenses	220	210
	Sub Total 4 to 6	31091	22385
7.	Gross Profit	2853	6056
8.	Total Capital Employed	159700	143100
9.	Equity Capital	67900	65500
10.	Borrowing	91800	77600
11.	Avg. interest on borrowing	4590	3880
12.	Profit after interest	(1737)	2176
13.	Return on		
	i) Total Capital (%)	1.8	4.2
	ii) Equity (%)	(2.6)	3.3

(Bracket indicates negative figures)

*Solvay Process

@Dual Process

ANNEXURE II-0

STAFF ING PATTERN & STRENGTH

Category/Designation		Location	
		Chittagong (No)	Ghorasal (No)
A.	General Management		
	General Manager	1	1
	Dy General Manager*	4	4
	Asst General Manager @	3	3
	Supporting Staff	23	23
B.	Production		
	Plant Supdt	5	4
	Process Engineer	28	17
	Shift Supervisor	82	50
	Operator	241	177
	Workers (Unskilled)	135	123
	Others	7	4
C.	Maintenance		
	Supdt Maintenance	3	3
	Maintenance Engineer	10	10

* Production - 1 Maintenance - 1 Tech Services - 1 Fin/Admn/Pers-1

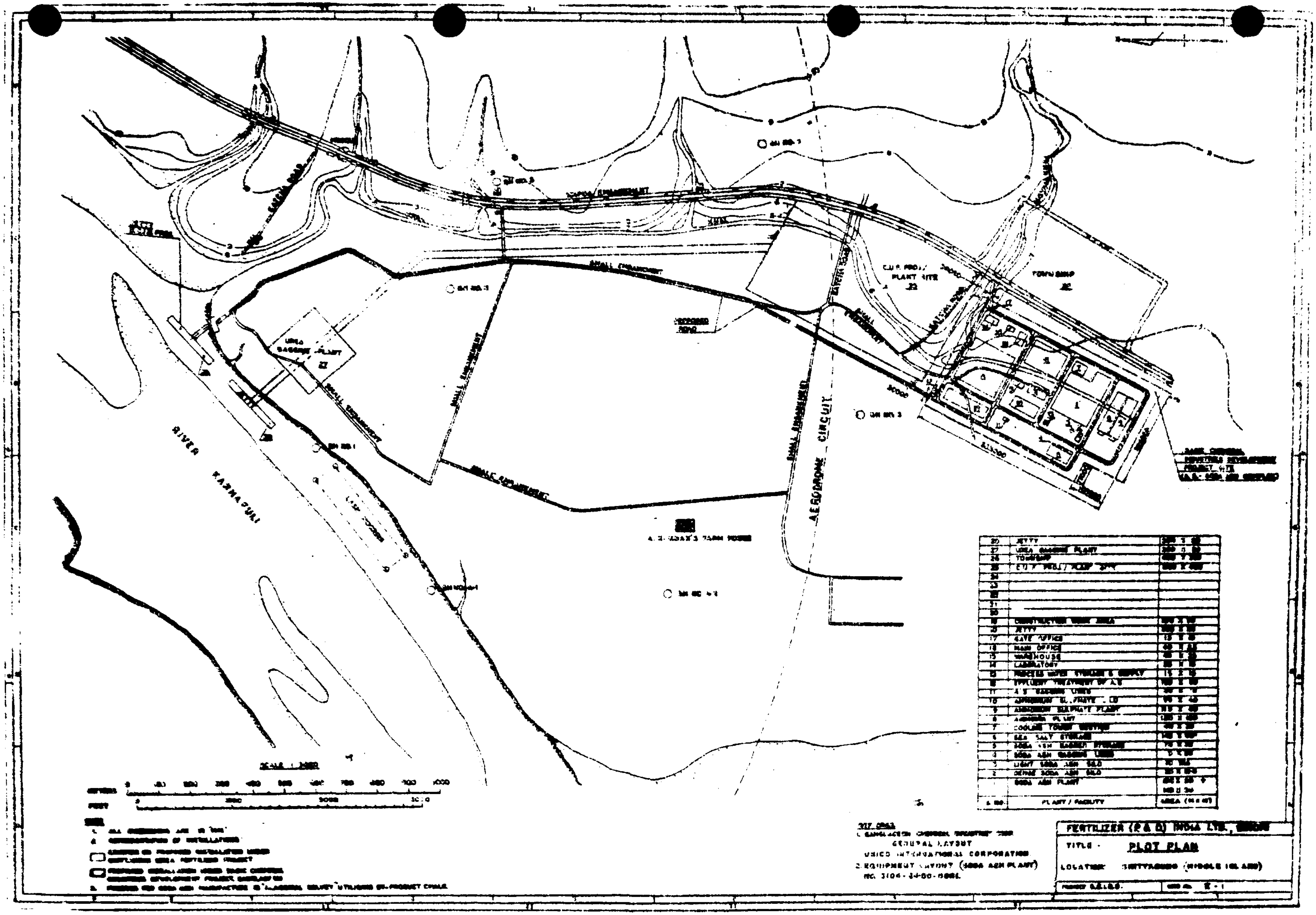
@ Production - 1 Maintenance - 1 Tech Servicies - 1

ANNEXURE II-0
(p.p. 2)

	Shift Supervisor	73	57
	Technician	169	126
	Workers (unskilled)	87	86
	Others	6	4
D.	Technical Services Training/Laboratory		
	Superintendent/Senior Chemist	3	3
	Engineer/Trg Officer/Chemist	23	23
	Technical Asst/Technician/Analyst	35	35
	Sampler	35	35
	Draughtsman	2	2
	Workers (unskilled)	12	12
	Others	6	6
E.	Administration		
	Administrative Officer	1	1
	Asst. A.O/Publicity Officer/ Doctors/Safety & Fire Officer	8	8
	Asst Safety/Fire Officer	1	1
	Supervisor (Canteen/Transport/ Security) Office Supdt	7	7
	Telephone Operator/Receptionist Office Asst/Compounder/Nurse/Asst Security Supervisor	30	30

ANNEXURE II-0
(p.p. 3)

	Fireman/Driver/Cook	102	72
	Worker/Guard	86	81
F.	Personnel		
	Personnel Manager	1	1
	Peronnel Officer	2	2
	Office Supdt	2	2
	Office Asst	15	15
	Worker	5	5
G.	Finance		
	Asst Finance Manager	1	1
	Sr Accountant	2	2
	Accountant	5	5
	Office Asst	15	15
	Worker	4	4
	TOTAL	1280	1060

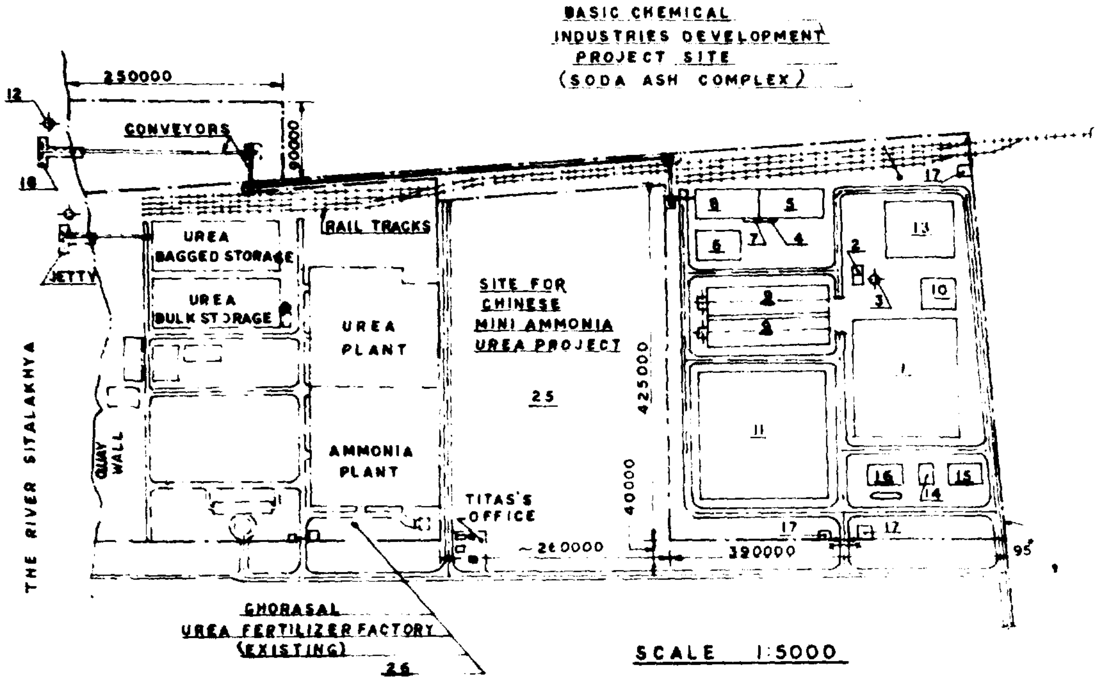


S. NO.	PLANT / FACILITY	AREA (M X M)
28	JETTY	[illegible]
27	UREA BAGGING PLANT	[illegible]
26	TOWNSHIP	[illegible]
25	C.U.F. PROJ./ PLANT SITE	[illegible]
24		
23		
22		
21		
20		
19	CONSTRUCTION WORK AREA	[illegible]
18	JETTY	[illegible]
17	GATE OFFICE	[illegible]
16	MAIN OFFICE	[illegible]
15	WAREHOUSE	[illegible]
14	LABORATORY	[illegible]
13	PROCESS WATER STORAGE & SUPPLY	[illegible]
12	EFFLUENT TREATMENT OF A.S.	[illegible]
11	A S BAGGING UNITS	[illegible]
10	AMMONIUM SULPHATE [illegible]	[illegible]
9	AMMONIUM SULPHATE PLANT	[illegible]
8	AMMONIA PLANT	[illegible]
7	COOLING TOWER SECTION	[illegible]
6	SEA SALT STORAGE	[illegible]
5	SODA ASH BAGGED STORAGE	[illegible]
4	SODA ASH BAGGING UNIT	[illegible]
3	LIGHT SODA ASH SILO	[illegible]
2	DENSE SODA ASH SILO	[illegible]
1	SODA ASH PLANT	[illegible]

NOTES
1. ALL DIMENSIONS ARE IN [illegible]
2. [illegible] OF INSTALLATIONS
☐ [illegible]
☐ [illegible]
3. [illegible] SODA ASH MANUFACTURE [illegible] UTILISING BY-PRODUCT CHALK

REF. DWGS.
1. [illegible]
GENERAL LAYOUT
UNICO INTERNATIONAL CORPORATION
2. EQUIPMENT LAYOUT (SODA ASH PLANT)
NO. 3104-34-00-0001

FERTILIZER (P & D) INDIA LTD., [illegible]
TITLE - PLOT PLAN
LOCATION [illegible] (MIDDLE ISLAND)
[illegible] | [illegible] E-1



S.NO	PLANT / FACILITY	AREA(MXM)
26	GHORASAL U.F. FACTORY	EXISTING
25	CHINESE MINI AU PROJECT	425 X 260
24		
23		
22		
21		
20		
19		
18	JETTY	40X 10
17	GATE OFFICE	15X 15
16	MAIN OFFICE	40X 25
15	WAREHOUSE	40X 25
14	LABORATORY	25 X 15
13	WATER TREATMENT AND D.M WATER PLANT	80X65
12	RAW WATER INTAKE TOWER	8 DIA.
11	AMMONIA PLANT	150X 150
10	COOLING WATER SECTION	40X 35
9	SEA SALT STORAGE	145 X 66
8	A.C BAGGED STORAGE	75 X 32
7	A.C. BAGGING LINES	5 X 20
6	AMMONIUM CHLORIDE STORAGE	49 X 35
5	SODA ASH BAGGED STORAGE	75 X 32
4	SODA ASH BAGGING LINES	5 X 20
3	LIGHT SODA ASH SILO	10 DIA
2	DENSE SODA ASH SILO	25X 12.5
1	SODA ASH PLANT	140 X 122°

NOTE

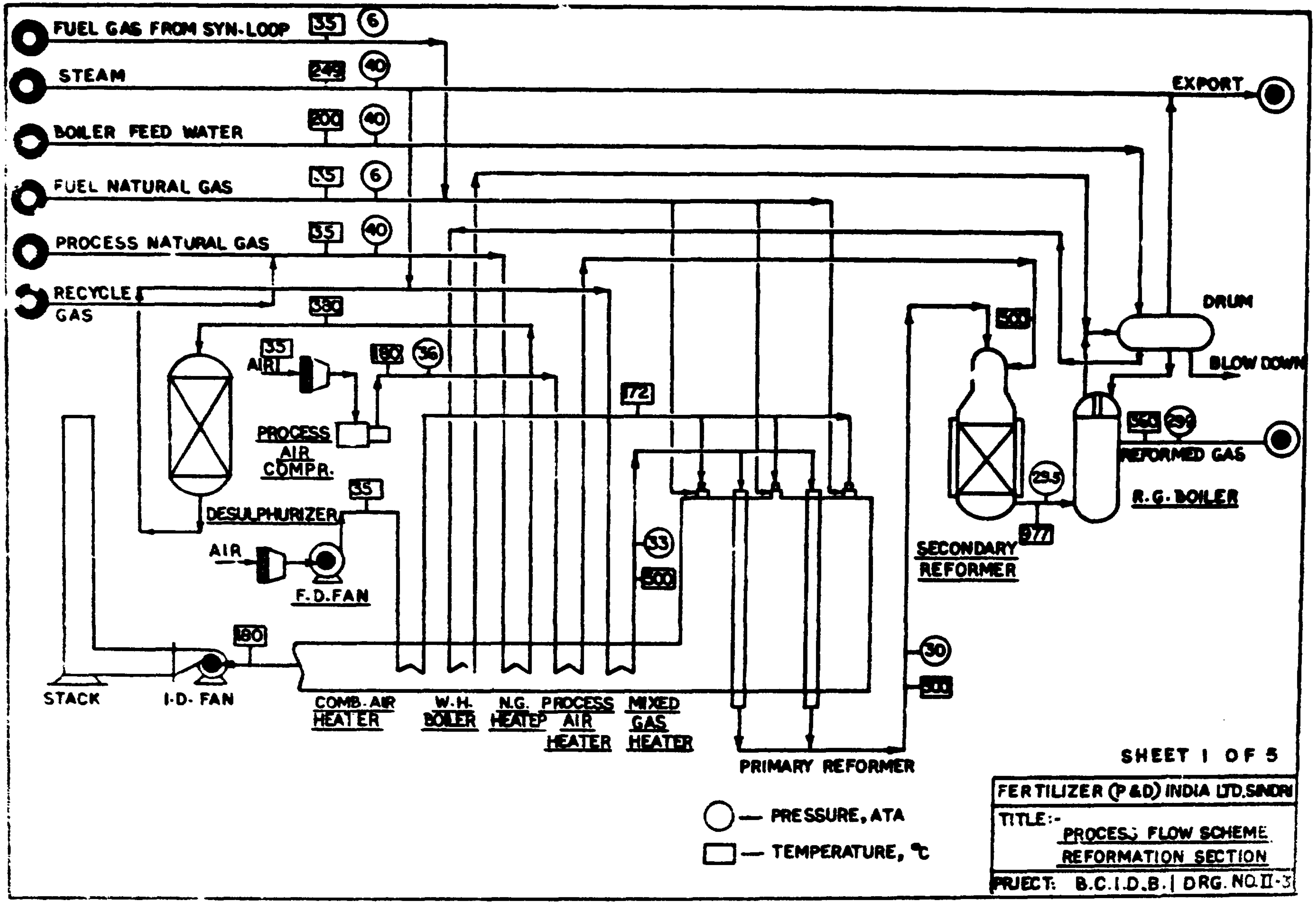
1. ALL DIMENSIONS ARE IN 'MM' *UNLESS OTHERWISE INDICATED*
2. REPRESENTATION OF INSTALLATIONS -
   - ┅┅ *EXISTING* INSTALLATIONS UNDER GHORASAL UREA FERTILIZER FACTORY
   - ▭ PROPOSED INSTALLATIONS UNDER BASIC CHEMICAL INDUSTRIES DEVELOPMENT PROJECT, BANGLADESH
3. PROCESS FOR SODA ASH MANUFACTURE IS 'DUAL (CENTRAL GLASS-TEC PROCESS)'.
4. REF DRGS -
   (i) BFCPC UREA FERTILIZER FACTORY, GHORASAL
   DRG NO UFF/55 B. DATED 8.5.69.
5. EQUIPMENT LAYOUT (SODA ASH PLANT)
   DRG NO : 3104 - 2400 - 0002

FERTILIZER (P&D) INDIA LTD.,SINDRI.

TITLE **PLOT PLAN**

LOCATION GHORASAL

PROJECT BCIDB | DRG NO 3104 0000-000[illegible]

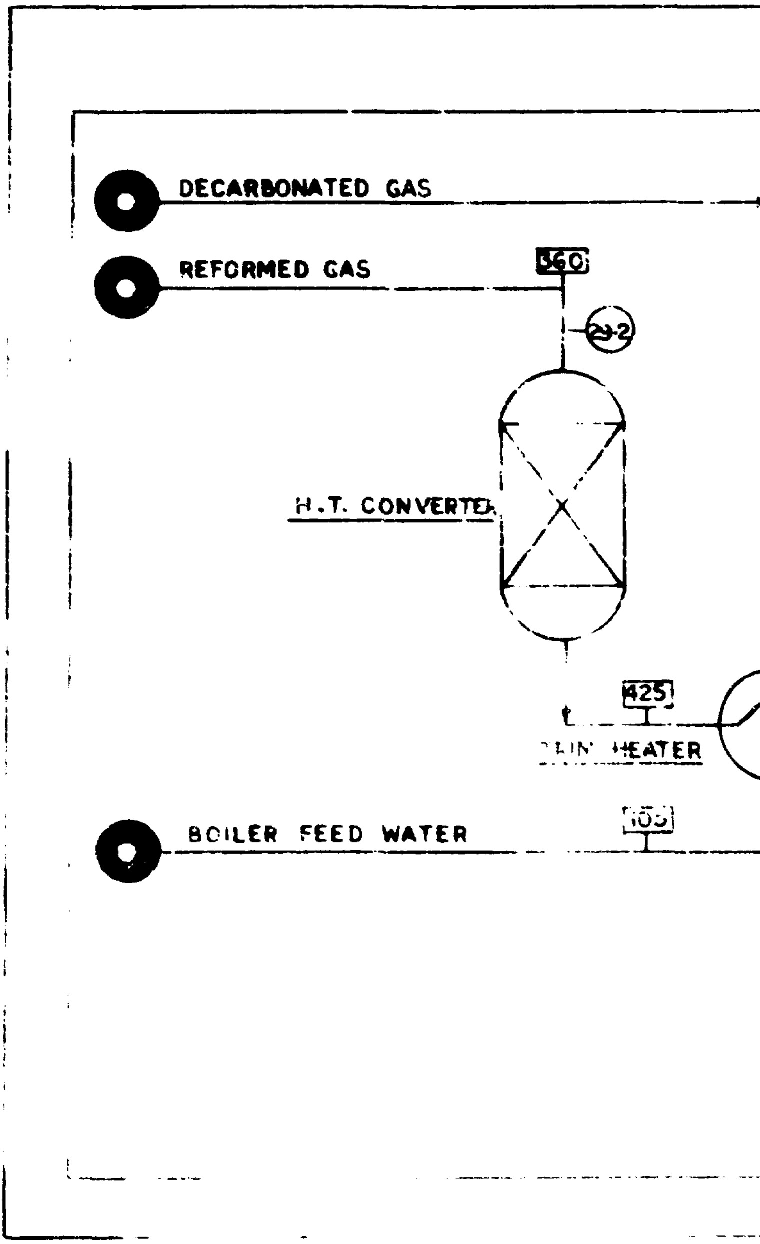


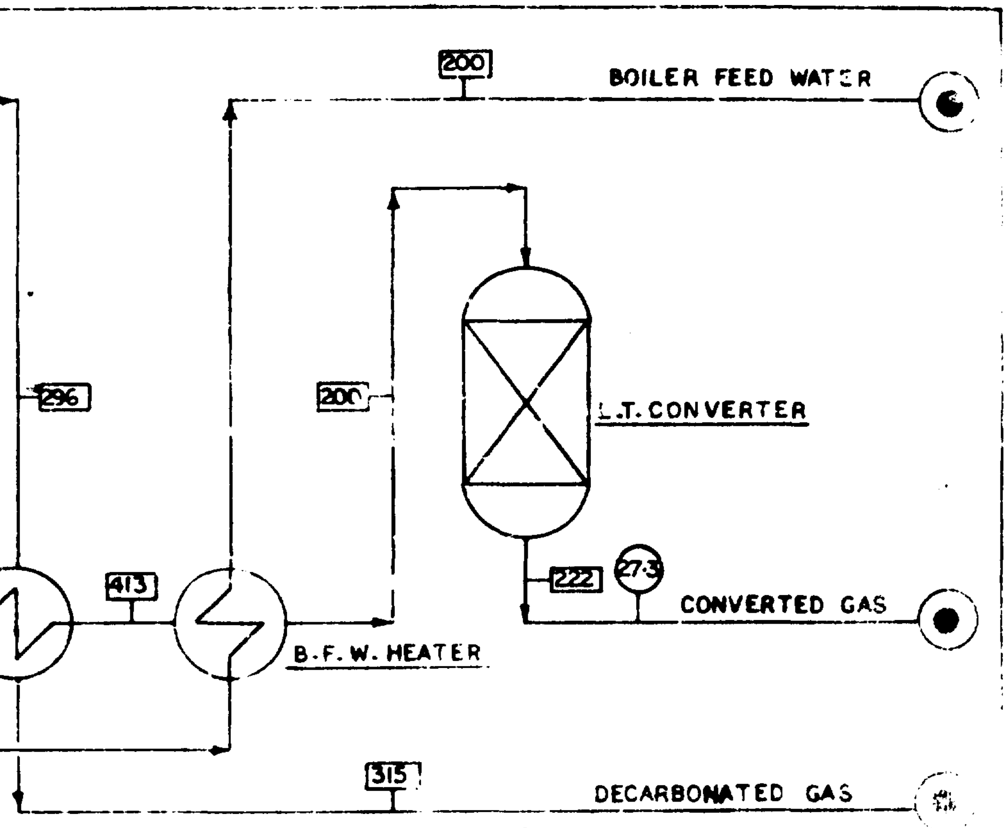
SHEET 1 OF 5

FERTILIZER (P&D) INDIA LTD. SINDRI

TITLE:- PROCESS FLOW SCHEME
REFORMATION SECTION

PROJECT: B.C.I.D.B. | DRG. NO. II-3


DECARBONATED GAS
REFORMED GAS
360
23-2
H.T. CONVERTER
425
TRIM HEATER
BOILER FEED WATER
105



○ — PRESSURE, ATA

▭ — TEMPERATURE C

SHEET 2 OF 5

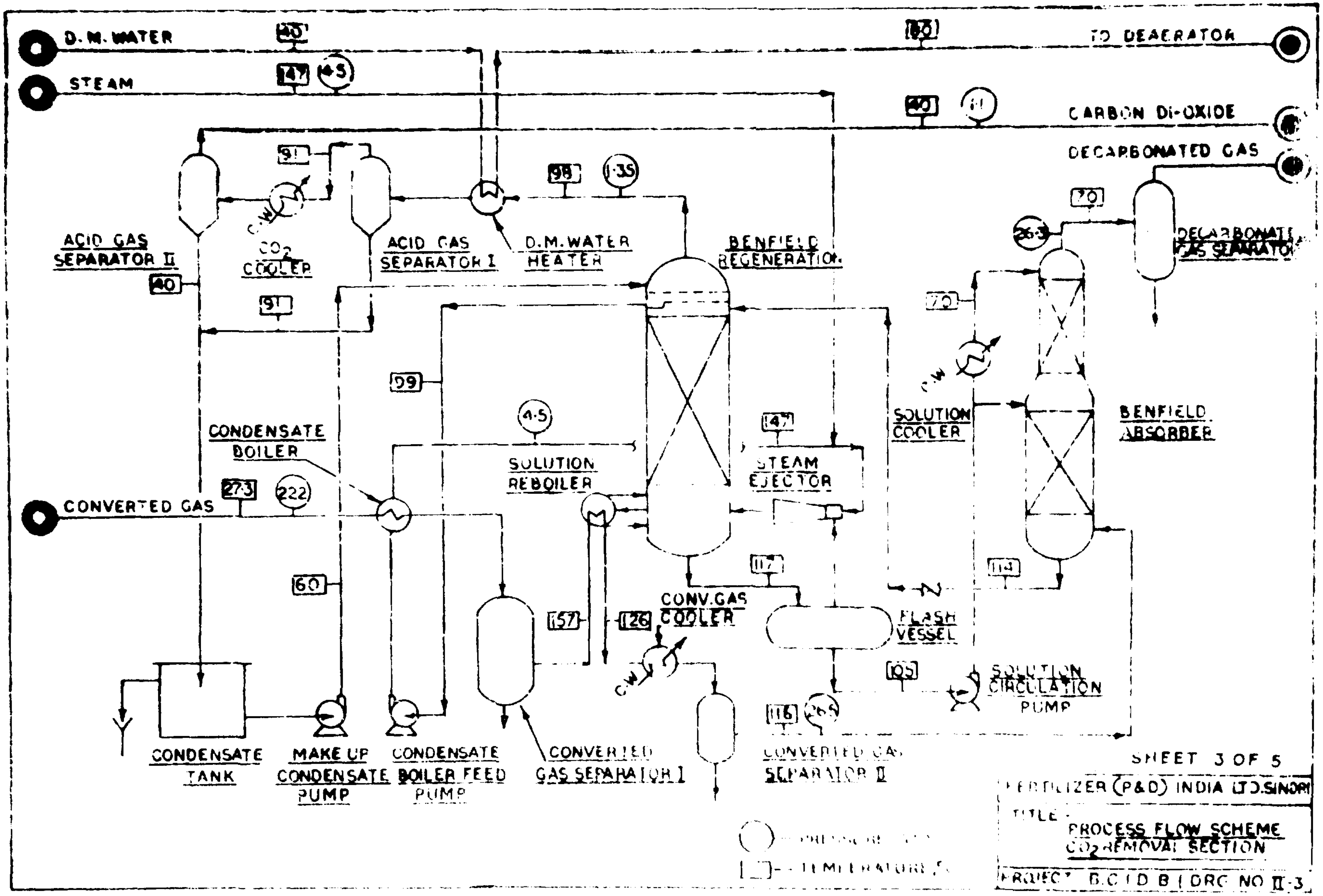
FERTILIZER (P & D) INDIA LTD. SIN

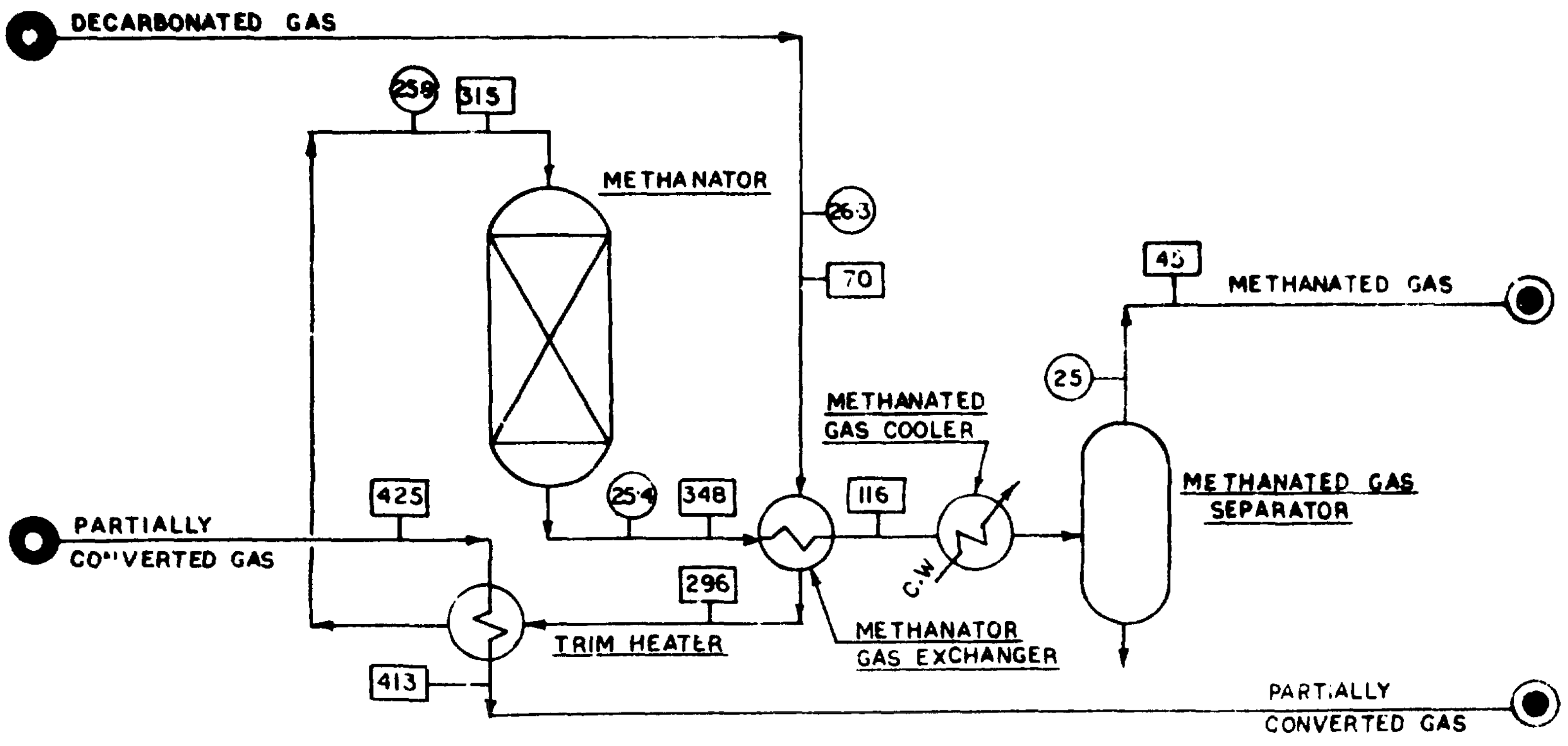
TITLE -

PROCESS FLOW SCHEM

CO-CONVERTION SECTIO

PROJECT: B.C.I.D.B. | DRG NO


D.M. WATER
STEAM
TO DEAERATOR
CARBON Di-OXIDE
DECARBONATED GAS
ACID GAS SEPARATOR II
CO2 COOLER
C.W.
ACID GAS SEPARATOR I
D.M. WATER HEATER
BENFIELD REGENERATION
DECARBONATED GAS SEPARATOR
SOLUTION COOLER
BENFIELD ABSORBER
CONDENSATE BOILER
SOLUTION REBOILER
STEAM EJECTOR
CONVERTED GAS
CONV. GAS COOLER
FLASH VESSEL
SOLUTION CIRCULATION PUMP
CONDENSATE TANK
MAKE UP CONDENSATE PUMP
CONDENSATE BOILER FEED PUMP
CONVERTED GAS SEPARATOR I
CONVERTED GAS SEPARATOR II
40
147
4.5
80
40
91
91
98
1.35
70
26.3
70
40
91
99
4.5
147
273
222
60
157
126
117
114
105
116
26.5
PRESSURE
TEMPERATURE
SHEET 3 OF 5
FERTILIZER (P&D) INDIA LTD. SINDRI
TITLE :
PROCESS FLOW SCHEME
CO2 REMOVAL SECTION
PROJECT B.C.I.D.B.I DRG NO II-3



SHEET 4 OF 5

○— PRESSURE, ATA
□— TEMPERATURE, °C

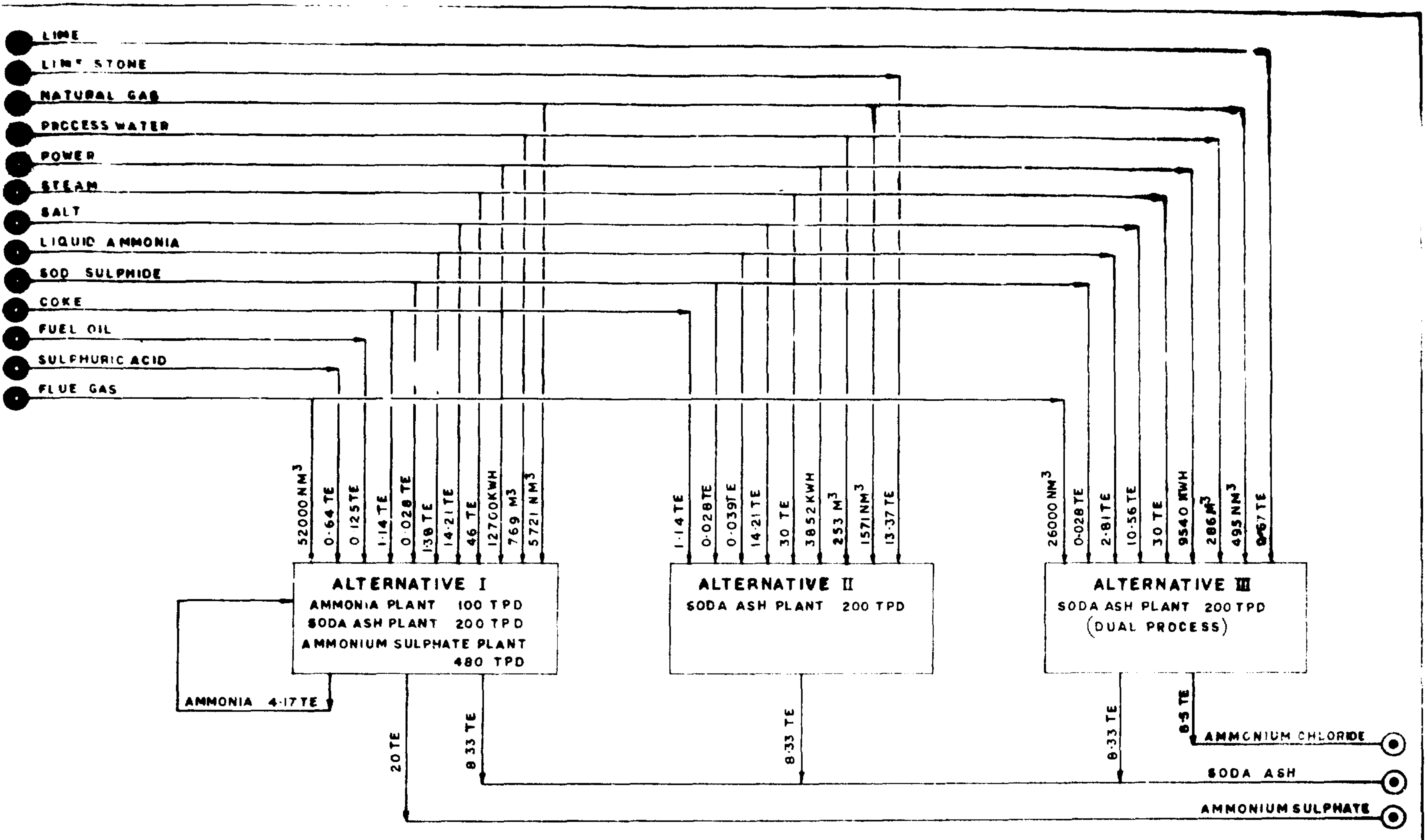
FERTILIZER (P & D) INDIA LTD. SINDRI

TITLE :-

PROCESS FLOW SCHEME
METHANATION SECTION

PROJ. B.C.I.D.B

DRG. NO. II 3

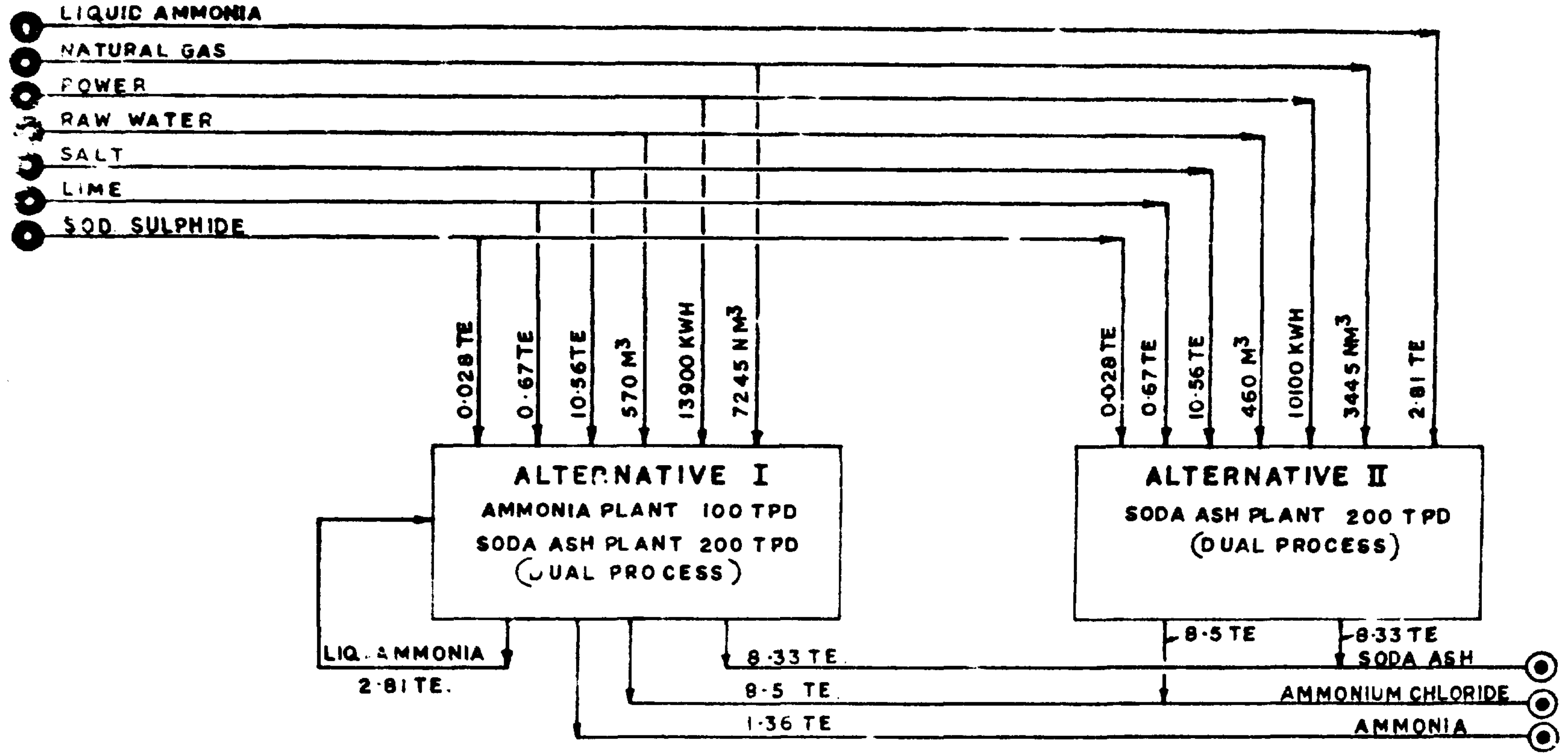


FERTILIZER (P&D) INDIA LTD SINDRI

TITLE - **HOURLY MATERIAL & UTILITY BALANCE**

SITE - CHITTAGONG LOCATION

PROJECT BC 108 | DRG NO II 4



FERTILIZER (P&D) INDIA LTD SINDRI

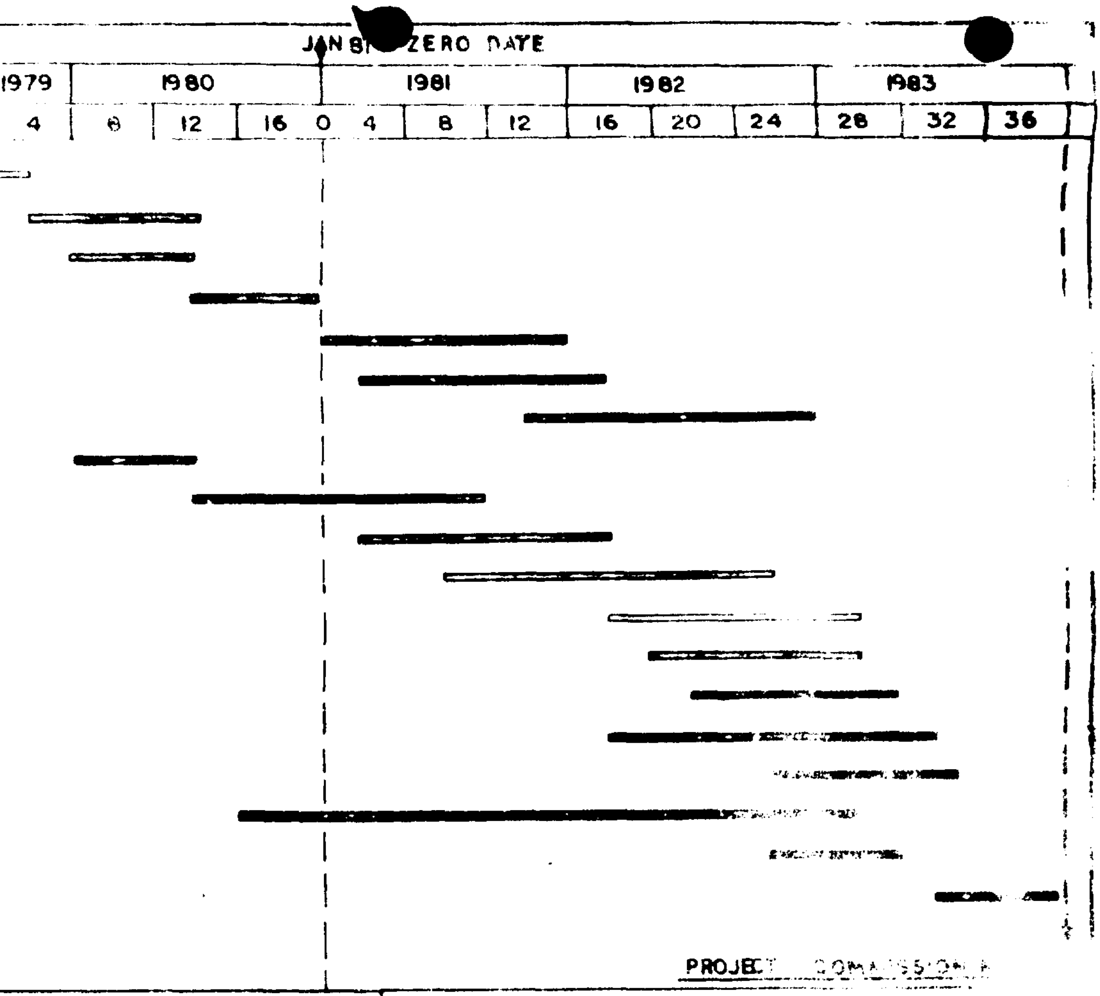
TITLE:- **HOURLY MATERIAL & UTILITY BALANCE**

SITE:- GHORASAL LOCATION

PROJECT:- B.C.I.D.B. | DRG NO. II 5

FINANCIAL YEAR | SEPT 1979

		YEAR
S. NO	ACTIVITY	MONTH
	SCRUTINY OF PROJECT REPORT	
	FINANCIAL ARRANGEMENT	
	SELECTION OF PROJECT CONSULTANT	
	SELECTION OF ENGG. CONTRACTOR	
	DGN & ENGG. OF PLANTS & FACILITIES	
	ORDERING OF EQPTS & SUPPLIES	
	DELY OF EQPTS & SUPPLIES	
	LAND ACQUISITION	
	SITE PREPARATION	
	CIVIL - WORKS DESIGN	
	CIVIL - WORKS EXECUTION	
	ERECTION MECHANICAL	
	—DO— ELECTRICAL	
	—DO— INSTRUMENTS	
	—DO— PIPING	
	INSULATION & PAINTING	
	OFF-SITE FACILITIES	
	TRIAL RUNS & COMMISSIONING OF OFF SITE FACILITIES	
	TRIAL RUNS FOR MAIN PLANTS & COMMISSIONING OF PROJECT	



FERTILIZER (P & D) INDIA LTD. SINDRI

TITLE.

TENTATIVE TIME SCHEDULE

PROJECT :- B.C.I.D.B. | DRG.NO :- II - 6

BASIC CHEMICAL INDUSTRIES DEVELOPMENT
IN
BANGLADESH

10139 (3)

Part Three
PRODUCTION OF CEMENT CLINKER FROM PHOSPHOGYPSUM

FERTILIZER (PLANNING & DEVELOPMENT) INDIA LTD

SINDRI, INDIA, 828122

Job No. 3104

PART III

PRODUCTION OF CEMENT CLINKER FROM PHOSPHOGYPSUM

PART III

PRODUCTION OF CEMENT CLINKER FROM PHOSPHOGYPSUM

CONTENTS

DRAWINGS

PART III

PRODUCTION OF CEMENT CLINKER FROM PHOSPHOGYPSUM

Chapter 1

INTRODUCTION

1.1 Phosphogypsum is produced as 'by-product' in fairly ample proportions in the wet-process phosphoric acid (nearabout 4 to 5 tonnes per te of P_2O_5) when the calcium values are converted into calcium sulphate for facility of removal by simple filtration. This byproduct gypsum is, for the most part, considered a waste product: only an insignificant proportion of the 80-100 million tonnes currently being produced in the phosphoric acid plants round the world is put to any commercial use. One reason for this is that most of the 50-odd impurities that could be present in the rock are carried on into phosphogypsum and therefore, profoundly affect its crystalline properties as well as the characteristics of the products made out of it. The need for a purification step, therefore, generally renders use of byproduct gypsum unattractive in competition with natural gypsum.

1.2 With the growing awareness of the environmental problems created by industrial wastes, the disposal of phosphogypsum is posing a problem for most producers of phosphoric acid in several countries, including Bangladesh. The normal method of disposal of waste gypsum has been either by discharging it into the sea or the inland waters, or by dumping it on land in disposal ponds. Though dumping waste gypsum into the sea has probably the least ill-effect, to minimise the pollution problem, the gypsum will have to be carried far into the sea, - atleast about 3-4 Km. - where the action of currents and waves can reduce its acidity and dissolve the gypsum itself so that fluorides and other toxic substances are quickly diluted and dispersed. The cost of such disposal in a country like Bangladesh would be quite high. Even then, there have been doubts that such disposal may have harmful effect on marine life, esepcially on account of Bangladesh's considerable dependence on the marine fish catch. Discharging into the Karnaphuli river flowing just outside the phosphoric acid (TSP) complex, though probably the cheapest method, has been held to be even more dangerous due to the inadequacy of water, especially during the summer months, to dilute and carry away the pollutants. The waste gypsum disposal pond of the complex, covering an area of about 11.5 acres has been found to be too small to serve the purpose for long. Due to the pressure on land and the high cost, it has not been found easy to find adequate land in the neighbourhood for dumping the waste gypsum.

1.3 Phosphogypsum can, however, be used as substitute for natural gypsum after suitable treatment to rid of the injurious impurities, especially in countries lacking in mineable deposits, such as Bangladesh. There are three principal uses to which phosphogypsum can be put within the current state of technology and the prevailing conditions in Bangladesh, viz. -

i) Production of plaster and plaster products

ii) Production of ammonium sulphate, and

iii) Production of cement clinker and sulphuric acid.

The first two alternatives are discussed in the subsequent Parts.

1.4 Since the cement clinker-sulphuric acid route results in the regeneration of a major proportion of the sulphuric acid used for the digestion of the phosphate rock, the process also helps to reduce the input of sulphur substantially, besides finding a solution to the problem of waste gypsum disposal. The process , however, has not attracted world wide application for two reasons : first, the route was essentially seen as a sulphuric acid process and seldom did the acid producers develop interest in cement manufacture and vice versa. The relatively low ruling world prices of cement and sulphur also did not offer much incentive to build plants on this process. Secondly, purely as a sulphuric acid process, it was not attractive, since it required a considerably more expensive plant and involved high energy consumption. In a normal sulphur-based sulphuric acid plant, for instance, the energy required to operate the plant is largely derived from sulphur burning, while in a gypsum-based plant, a large amount of external energy will be required for drying, calcining and decomposing gypsum, etc. Thus, historically, the fortunes of this process tended to move directly with the trend of sulphur prices.

1.5 For a country like Bangladesh, however, the process still holds attraction in view of the exceptional circumstances in its favour. First, 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. Secondly, the country is heavily deficit in cement, and the prospects are that Bangladesh will continue to have to depend for considerable years to come on imports of cement to meet the growing internal demand (Chapter 2) in view of the dearth of easily mineable limestone deposits. Thirdly, the location of a cement clinker grinding unit adjacent to the phosphoric acid (TSP) complex, based on import of clinker for grinding into cement, obviates the need for investment on a grinding plant to convert clinker into cement. Fourthly, under the prevailing price structure of cement, the product from this scheme can compare favourably in price with the landed cost of imported cement. Fifthly, the TSP Complex faces difficulty in disposing of phosphogypsum in an environmentally satisfactory way and this can provide a solution. Sixthly with the prospect of supply of natural gas, of which Bangladesh has ample reserves (Part II), to Chittagong, supply of the needed fuel at a reasonable cost can be ensured. Alternatively fuel oil from the adjacently located refinery, which is surplus to Bangladesh's requirements or the off-gas from the refinery can be used for the purpose. Considering these factors the cement clinker - sulphuric acid route projects itself as one of the attractive methods of economic utilisation of phosphogypsum. That there are not many plants round the world based on this process need not be a cause for undue worry, since each country has factor endowments and social needs unique to itself and the country with the most urgent needs takes upon itself the burden of being the pioneer in the field. That the process is well proven with a commercial scale plant (of identical size as proposed for Bangladesh) already working successfully at Phalaborwa (and another one of slightly smaller size at Linz) should be enough gurantee to dispel any hesitations in this regard. The recent spurt in sulphur and cement prices has generated a new interest in the process and a number of proposals (e.g. in India) are understood to be on the anvil.

Chapter 2

CEMENT INDUSTRY IN BANGLADESH

Local Production

2.1 Bangladesh presently relies on imports for the major proportion of her domestic requirements of Portland cement. In 1977-78, the indigenous supplies accounted for only around 17 percent of the apparent consumption. There is at present only one integrated cement manufacturing unit in the country–atChhatak in the north-east corner of the country – for a population of over 85 million. The only other production unit – at Chittagong – is just a grinding complex which relies on imported clinker.

2.2 The production unit at Chhatak is a small one by present day standards. The first cement unit to be set up in the area now constituting Bangladesh between 1938 and 1941, about 25 miles north-west of the district town of Sylhet, it had originally a rated capacity of 200 tonnes of cement per day (60,000 te/year) only. The unit was supplied and commissioned by Polysius AG. In 1958-59 the production capacity was expanded by the addition of another (3x120m) kiln, along with another raw mill for wet grinding, which raised the capacity by another 300 tonnes/day (90,000 tonnes/year). The equipment for the second stream was supplied by F.L. Smidth & Co. Both the kilns were designed for the wet process. In 1961, both were converted from coal firing to gas firing. The unit draws the gas, exclusively from a well near Sylhet over a 12 mile 4" pipeline. Limestone, the principal raw material, is obtained substantially from the Indian side of the border over a 10 mile ropeway, from a rich limestone deposit about 1.2 miles inland of the border. These imports are supplemented by local limestones from Takerghat, about 70 km from Sylhet.

2.3 Ever since the installation of the second kiln, the first kiln had not been in regular use. It was used mostly as a standby in the initial years. But with the steady deterioration setting in, the use of the kiln had been given up even before 1971. For many years now, therefore, the effective installed capacity of the Chhatak unit has been only 90,000 tonnes/year, against the 'name-plate' capacity of 150,000 tonnes.

2.4 The Chittagong Cement Grinding Factory was set up in 1974 with a grinding capacity of 1000 tonnes/day (300,000 te/year). Originally planned to make use of clinker from West Pakistan, the unit now imports clinker by open world-wide tender. Even though the unit has faced no major mechanical problem, power supply interruptions and clinker supply problems have been adversely affecting its operation, and the capacity utilisation in 1977-78, the best year since its commissioning in 1974-75, has been only around 78 percent, a substantial improvement nevertheless compared to the 69 percent of the previous(1976-77) year.
The total cement production in the country in recent years is given in Table 2.1 below.

Table 2.1

Cement Production in Bangladesh

(Tonnes)

Year	Chhatak Unit	Chittagong Unit*	Total
1974-75	92,614	54,410	147,024
1975-76	90,132	69,365	159,497
1976-77	100,038	207,808	307,846
1977-78	103,332	235,291	338,623
1978-79	126,629	193,044	319,673

Source : BMEDC. * Clinker grinding unit

Consumption Demand

2.5 There are no reliable estimates of cement consumption in Bangladesh, much less credible projections for future years. Most of the consumption estimates appear to have been computed on the basis of supplies but even here available figures, from different sources, differ substantially. The table below (Table 2.2) gives supply and consumption figures for recent years, as reconstructed from different sources :

Table 2.2

Apparent Consumption of Cement in Bangladesh

(In '000 tonnes)

Year	Indigenous Production (excluding from clinker grinding) @ (1)	Imports including clinker (2)	Total Supplies (3)=(1)+(2)	Consumption (4)
1968-69	63			795
1969-70	53			748
1970-71	66			398
1971-72	23			165
1972-73	31			339
1973-74	52	118	170	167
1974-75	93	439	532	480
1975-76	90	174	264	381
1976-77	100	247	347	519
1977-78	103	501 (Est)	604	559
1978-79	127*	578(Proj)	705 (Est)	NA

Source : 1. Monthly Statistical Bulletin of Bangladesh, July 1978

See next page

2.6 It is, however, clear even from these 'raw figures' that consumption of cement had begun gradually shrinking compared to 1968-69, presumably due to restricted supplies as a sequel to progressive curtailment of imports. Thus the total consumption came down from close to 800 thousand tonnes in 1968-69 to about 165 thousand tonnes in 1971-72. Despite the fact that consumption has tended to look up since then due to improved supplies, partly as a result of the commissioning of the Chittagong clinker grinding unit in 1974 and partly owing to more libteral imports, the total consumption is still below the 1968-69 level. Primarily the consumption seems to be circumscribed by import constraints and the consequent availability, since domestic capacity is practically stagnant. There is little doubt that the present demand is considerably restrained due to lack of free supplies but the extent of unsatisfied 'latent' demand can only be guessed.

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2. Bangladesh Bureau of Statistics (Communication dated 24.11.1978).

3. BMEDC, Final Report of the Committee for Utilisation of Indigenous Natural Resources of Bangladesh 1977, and BBS.

@ The production of clinker grinding unit excluded since it is included in the import figures. Bangladesh has no separate figures for clinker imports. Actual cement production may be slightly more than the weight of clinker used, to the extent of additives used.

* Actual

Projection of Demand

2.7 Demand projections for cement under Bangladesh's present conditions might be a somewhat difficult exercise for want of any reliable estimate of the existing unsatisfied demand. But it appears reasonable to assume that the demand would have been atleast about 20 percent higher if the supplies had been freely available and the consumers had the freedom to lift any quantities they cared from the distributors. The Government's rigidly enforced price control on retail prices of cement and a carefully structured distribution machinery covering the entire national market and reaching right upto the major rural centres are adequate indications of the pressure of demand on the available supplies.

2.8 The two year (1978-80) Plan estimated, on the basis of the past trend of cement consumption per unit of investment and the projected level of investment under the Plan, the requirement of cement for the two Plan years as follows :

	(Tonnes)
1978-79	705,493
1979-80	843,053

The actual availability during 1978-79, however, appeared to have been substantially lower, estimated at 519 thousand tonnes, owing to lower imports. The Committee for Utilisation of Indigenous Natural Resources of Bangladesh appointed by the Government, which inter-alia went into the question of utilisation of indigenous limestone deposits for cement production, quoted in its report (1977) the following (Table 2.3)demand projections for cement made by BMEDC.

Table 2.3

Projected Demand for Cement upto 1990

Year	Projected Demand (million tonnes)
1978	1.14
1979	1.20
1980	1.28
1981	1.32
1982	1.39
1983	1.46
1984	1.56
1985	1.67
1986	1.79
1987	1.92
1988	2.05
1989	2.19
1990	2.34

Source : Report of the Committee for Utilisation of Indigenous Natural Resources of Bangladesh (August 1977).

2.9 These projections appear to be quite optimistic and do not seem to take into account some of the basic constraints in the economy, especially from the supply side. Subsequently, the BMEDC appeared to have revised these projections, mainly because of the shortfall in base level figures of consumption (in 1977-78). Assuming a 14% compound growth rate in consumption, the BMEDC projected the demand to rise from 0.59 million tonnes in 1977-78 to 1.5 million tonnes in 1984-85. The yearwise details are given in Table 2.4.

Table 2.4

BMEDC's Projection of Cement Demand : 1984-85

(Million Tonnes)

Year	Projected Demand at a compound growth rate of 14%
1977-78	0.59
1978-79	0.67
1979-80	0.77
1980-81	0.88
1981-82	1.00
1982-83	1.14
1983-84	1.30
1984-85	1.50
1989-90	2.25

2.10 The growth of demand for cement in future will undoubtedly depend upon the liberalisation of imports - atleast in the near future, - which will permit expansion of consumption. There is, however, a clear and close relationship between investment on development activities and the demand for cement. In most developing countries, in the earlier stages of planning for growth, development involves considerable expansion of construction activities in roads and bridges, buildings, housing, airfields, water and sewage, factories etc and as a result usually the requirement of cement goes up sharply. Particularly in a country like Bangladesh, with widespread destruction caused during the Liberation War, the cement that will be needed for building just the basic physical infra-structure will be tremendously large and reconstruction of a large number of such facilities in a matter of great urgency to sustain the growing economic activities. Assuming that supplies will continue to be regulated through imports and the imports will progressively be expanded to keep pace with growth in demand , the BMEDC's projections appear realistic and the demand projection of 1.5 million tonnes will be the minimum requirement of the country by 1985. Even with this projected consumption, the per capital consumption of cement in Bangladesh will be just around 15 Kg compared to the present 29 Kg in the neighbouring India and to world average of around 155 Kg.

Projection of Supply

2.11 As at present, there is only one concrete proposal under implementation for expanding cement production capacity in the country. This relates to restoring effectively the original capacity of the Chhatak cement plant, presently crippled by the shut-down of a kiln. Called the 'BMR' (Balancing Modernisation and Rehabilitation)

Chhatak Cement Factory', the project envisages principally (i) the substitution of the old Polysius kiln of 200 tons/day by a new kiln of 250 tons per day capacity and (ii) the expansion of the storage and the packing plant capacities. It is understood that the contract for the execution of the work - tenders for which had been called in January 1976, - has now been awarded and the project is expected to be completed by 1982. With the commissioning of the new kiln, the country's production of cement is anticipated to rise by another 75 thousand tonnes. To that extent, the gap between indigenous production and requirement will narrow down.

Limestone Availability Position

2.12 Bangladesh is not fortunately placed in the matter of raw material resources for the largescale expansion of the cement industry. A particularly severe limitation is the sparsity in the occurrence of limestone deposits in the country. Most of Bangladesh is underlain by the fine silts deposited by the Ganga-Brahmaputra river systems upto a thickness varying from approximately 500 ft to an estimated 5000 ft and above in the sourth of the delta, - silts originally derived from the erosional material originating from the north and south flanks of the Himalayas. Hence, most mineral resources, even when their occurrences are identified, are found to be too deeply situated to be economically mined. Sustained geological investigations have been able to identify only three principal limestone deposits in the country. The richest of these is in the Jaipurhat area of Bogra district in the north-west part of the country. The consulting firm of Krupps Rohs toffe assessed in 1966 the mineable reserves from the extractable

23 ft limestone bed in an area of 2.7 square miles at over 100 million tons; the total reserves including in the surrounding area are estimated at several thousand million tons. But the deposits coccur at a depth of 1400 to 1700 ft fromthe surface, overlain by unconsolidated or weakly consolidated alluviums, silt, sand, stone, shell etc. of younger age, necessitating adoption of the freezing methods (of surrounding ground) for sinking shafts. Besides the mines will have to be continuously dewatered at the rate of about 1 cu meter per te of limestone mined. Though technically considered feasible and economical, mining the deposits at the depth where they have been discovered is a major undertaking, beset with high investment content, - a large proportion of it in foreign exchange. Despite the assurances of technical feasibility,the job is considered a challenging one and some unexpected technical snags in the execution of the project could not be altogether ruled out, contributing to the risk element of the project. The limestone is said to contain about 97.98% $CaCO_3$.

2.13 The other two deposits of any significance occur at Takerghat - Baglibazar area of Sylhet district and in St Martin's Island, off the Chittagong coast, respectively. The Takerghat - Baglibazar deposits are located close to the Bangladesh-Meghalaya (India) border in the Sunamganj sub-division of Sylhet district. The deposits extend over a 12 mile long narrow strip of piedmont plain with Takerghat on the east-end and Baglibazar village on the west. The thickness of the limestone bed is said to vary from a few feet to over 700 feet. The deposit is, however, covered with an overburden from 0 to 500 ft.[1/] The exposed quantity,

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[1/] Report of the Indigenous Natural Resources Committee (Ibid) however, is understood to be quite small. Estimates of total mineable reserves vary, but according to BMEDC, the reserves in Ba glibazar alone might run around 40 million tons. But the location itself is an island between two streams and the Indian border. The island, while being normally above the water level, could be submerged for short periods during heavy rains. The development of the mine for largescale quarrying, therefore, required further detailed technical investigations including geological and geomorphological investigations, as well as study of the possibility of protecting the mines against inflow of ground water, flood and rain. A current UNDP - aided project 2/ covers deep drilling and other studiesto establish the techno-economic feasibility of the project. Some small scale mining, however, is undertaken at present in the area and production in 1977-78 was estimated at 61,000 tons, which meets about 50 percent of the limestone needs of the Chhatak cement unit (after meeting the needs of other users such as the Steel Mill).

2.14 The third find, viz. St Martin's Island, of limestone deposits consists of nearly 3 million tonnes of shelly and coraline limestone. The exploitation of it has to be necessarily restricted for fear of submerging the island underwater. Besides, this limestone is not considered suitable for Portland cement manufacture.

Development of Limestone Mines

2.15 Bangladesh has an ambitious scheme for the exploitation of the Jaipurhat limestone deposits for use in cement

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2/ The First Phase of which has been completed.

production. The project is conceived for execution in three, somewhat extended, phases : the first phase covers only the limestone mining and the mines are planned to be developed to yield a supply of 1.7 million tonnes of limestone per year. The project, however, has along history and was first approved in 1969 by the then Government of Bangladesh territory. Subsequently, after Independence, the Government of Bangladesh approved it again in 1974. But it was only in 1978-end that tender documents were issued to pre-qualified bidders. There was probably a reissue of tenders again in early 1979, no formal decision had been taken on the award of the contract till 1979 end. One major hitch causing delay in the execution of the project appeared to be lack of adequate response on the part of the prospective donor countries to commit loan assistance to the project[3]. Lately, however, there has been some improvement in the climate for the project aid, especially with the promise of US $ 30 million from the Saudi Development Fund. Hence, though the BMEDC is still officially committed to the time schedule of full development of the limestone mines by 1982 with an annual output of 1.7 million tons of limestone per year, it appears reasonably certain that this schedule cannot be maintained even if full project assistance for the foreign exchange part were readily forthcoming[4]. Reasonably, it can also be anticipated that the cost of production of limestone will be substantially higher than the figure estimated by BMEDC viz. Tk 150/ton.

3/ Thus, The Two Year Plan 1978-80 document says : "....... implementation of major projects like Jaipurhat limestone ..... remained unimplemented for want of foreign aid".

4/ During discussions in September-October 1979, it was indicated to the Consultants that the required funds had been tied up and the bids received were being evaluated.

2.16 The second and the third phases of the project relates to setting up cement clinker and integrated cement plants for the eventual use of the mined limestone from the Jaipurhat mines. The second phase envisaged the establishment of a 2000 tons/day cement clinker producing unit to feed the existing clinker grinding factory at Chittagong, which now relies on imports, and another one planned to be set up in the meantime at Khulna. In the third phase, another integrated cement factory complete with grinding and bagging plants with a daily output capacity of 1000 tons of ground cement is proposed to be set up at Jaipurhat itself, utilising the Jaipurhat limestone. The execution of both the second and third phases is however contingent on (i) the development of the mines as envisaged and (ii) the availability of the requisite foreign aid to cover atleast the foreign exchange cost of the project. Though initially BMEDC had assumed that work on the second phase would commence in 1978 and completed in 1983. and the third phase would be completed in 1984, considering the delays that have occurred in the mining part of the project itself (Phase I), and the uncertainties regarding the foreign assistance to finance the subsequent phases of the project, the prospects for early completion of these projects do not seem to be bright. An optimistic assessment is that the second phase will be completed by about the mid-80's. The third phase will appear to bestill farther away by atleast another 2-3 years.

Other Projects

2.17 The BMEDC has an ambitious, if somewhat unrealistic, plan to develop the cement industry in the country on the basis of exploitation of limestone deposits found in the country. The projects formulated for implementation include, in addition to the Jaipurhat projects mentioned above, the following :

i) Khulna Cement Clinker Grinding Factory :

Formulated more or less on the pattern of the existing Chittagong Cement Clinker Grinding Factory, the unit will initially import the required clinker from world sources but eventually switchover, like the Chittagong unit, to the clinker produced by the Jaipurhat project Phase II. A consulting firm has been retained to select a site and prepare a feasibility report. No reliable programme of execution is available.

ii) Surma Cement Factory :

Proposed to be located at Chhatak close to the existing cement unit, with a capacity of 275 thousand tonnes of cement per year, the unit is to be based on limestone and part of gypsum to be imported from India. A feasibility study was carried out in 1975, when the total cost of the unit was estimated at $ 30.54 million. No further progress, apart from Governments' approval in principle, has been reported since.

iii) Baglibazar Cement Factory :

The establishment of this unit based on the Baglibazar limestone deposits will depend on the outcome of the techno-economic feasibility of limestone mining, presently being covered by a UNDP project.

Supply Imbalance

2.18 From the foregoing it may be seen that the prospect of Bangladesh attaining self-sufficiency in cement in the near future is not quite assuring. It is apparent that the country will have to continue to depend on imports for meeting the domestic requirements, growing at a fairly high rate, in the foreseeable future. The execution of the Jaipurhat project, the only concrete and firm project (apart from Chhatak BMR) now available for providing net addition to the cement production capacity in the country, can at best alleviate the magnitude of imports marginally by about the middle 80's. The extent of deficit, on quite optimistic assumptions, will be as follows (Table 2.5).

Table 2.5

Projected Supply-Deficit of Cement in Bangladesh

('000 tonnes)

	Anticipated supply				
Year	Existing Capacity	Additional Capacity	Total	Projected Demand	Deficit
1980	390	-	390	770	380
1981	390	-	390	880	490
1982	390	75 *	465	1000	535
1983	390	75	465	1140	675
1984	390	375 +	765	1300	535
1985	390	375	765	1500	735

* BMR Chhatak

\+ Cement clinker production at Jaipurhat, to be ground into cement at Khulna

Marketing & Pricing

2.19 Cement distribution is controlled by the Government in Bangladesh. The Government not only fixes the retail price for the consumers in the case of indigenous production, but also the ex-factory price of the producing unit and the distributors' margin. Indigenous production is marketed by the BMEDC through the appointment of private retail dealers. Retail prices are uniform throughout the country and they include, besides excise duty levied by the Government at the rate of Tk 203 per tonne, a distribution margin of Tk 5 per bag (or Tk 100 per tonne). The BMEDC maintains buffer godowns in most regions for facilitating distribution. As a matter of general policy, the producing units at Chittagong and Chhatak sell cement to the public sector consumers on 'ex-factory' terms only and allow them to make their own arrangements for transport, while private consumers have to buy on 'ex-godown' terms. The retail prices for cement, including excise duty in March '79 was Tk 1370 per tonne, which has since been raised to Tk 1420/te (Tk 71 per bag). At this price, cement is being heavily subsidised indirectly by the Government, both on a major proportion of the indigenous production and on import supplies. The cost of production of cement at the Chittagong Clinker Grinding Factory, during the Consultant's visit, at the then prevailing landed cost of clinkers, was found to be around Tk 1200/-, while the ex-factory realisation was only around Tk 1150/- per tonne. Only in Chhatak, the cost of production was sufficiently low (around Tk 660 per te) to allow a fair margin. The landed cost of imported cement, corresponding to the prevailing c & f price of around $ 85/te is substantially higher than the selling price.

Imports

2.20 Imports, for the most part, were canalised through the Trading Corporation of Bangladesh (TCB), though relatively smaller quantities were said to have been permitted for private imports under the "Wage Earners' Scheme" . Though reliable figures of the imports under the Wage Earners' Scheme are not available, an estimate placed such imports by private importers at around 30,000 tonnes/year. The extent of private import largely depends on the market situation, principally, the extent of scarcity and the TCB's planned schedule of imports. The TCB's imports, on the other hand, depend on the foreign exchange allocation (in value terms) made by the Government and the level of import prices. The following table (Table 2.6) gives the annual imports made by TCB in recent years.

Table 2.6 - Cement Imports by T.C.B. (Tonnes)

Year	Imports
1976-77 (July-June)	205,500
1977-78 "	540,300
1978-79 "	290,000

Source : TCB

2.21 The Phillippines, South Korea and Burma are the main countries from which TCB has been importing cement in recent period, though occasionally other countries such as Japan, Taiwan, China and North Korea also figured in the imports. A substantial proportion of the imports, both in 1977-78 and the next year, were covered by credits or barter agreements; in the earlier year viz. 1976-77, the imports were mostly against cash.

2.22 TCB has been complaining of having losses in the import and distribution of cement in recent years and the annual loss in 1978-79 was estimated by TCB officials at around Tk 100 million mainly on account of the sharp rise in the international prices of cement vis-a-vis almost stagnant domestic prices. For instance, the TCB's purchase prices C&F - Chalna, which were around $ 43-46 (Tk 645 - 690) in the first half of 1977 went up to around $ 63 (Tk 945) per tonne in the beginning of 1979, but TCB's selling prices had remained stagnant. It was raised to Tk 1170 per te only in 1979.

2.23 Cement attracts an import duty of Tk 40/tonne when imported into Bangladesh and a sales tax at the rate of 20 percent of the duty paid value, which together (Tk 228/ton) came to about 25 percent of the C&F value, assumed at $ 60 (Tk 900) for tonne. With various other charges, levies and imposts (See Appendix A) built upon this, the landed cost comes to about Tk 1327 per tonne, a build-up of 47 percent on the C&F price (Tk 900). There has been, therefore, a steadily growing pressure on the Government for upward revision of the prices both by the demestic manufacturers (primarily Chittagong Clinker Unit) as well as the TCB on the strength of losses sustained in marketing at the present controlled prices. The TCB has been particularly urging the Government to revise the internal price structure appropriately to reflect the new international prices as the losses sustained by it had mounted to huge figures. It was as a result that the retail selling price of cement was raised from Tk 1370 per te to Tk 1420 per tonne and the TCB's selling price was appropriately adjusted upwards. Most of the imports of cement, almost 80% of the total import, - arrive in Chalna, and only about a fifth, at the other port, Chittagong.

APPENDIX 'A'

PRICE BUILD-UP OF IMPORTED CEMENT
(CHALNA PORT)

March 1979

		Taka Per tonne
1.	C&F price, say $ 60/te	900.00
2.	Marine insurance @ 1.25%	11.25
3.	Customs duty @ Tk 40/te	40.00
4.	Sales tax @ 20% of duty paid value	188.00
5.	L/C charges @ 0.25% of C&F Price	2.25
6.	a/ Landing charges @ 6.20x1.20	6.32
	b/ River dues @ 4.55/te	4.55
7.	Stevedoring at jetty	6.80
8.	Shipping agency charges @ 0.50/te	0.50
9.	Survey, sampling & inspection charges	1.00
10.	Weighment charges	2.00

11.	Handling charges :		
	i/	agency commissioning unloading/loading etc.	9.18
	ii/	carrying charges	33.00
	iii/	Addl. carrying charges from Chalna to Khulna	40.00
	iv/	Delivery ex-godown	8.16
12.	Storage (12 weeks avaerage)		32.30
13.	Octroi		1.00
14.	Unforeseen expenses		1.60
		Sub-total	1287.91
		TCB's commission @ 3%	38.64
		Landed cost	1326.55
		Selling Price	1170.00

Chapter 3

AVAILABILITY OF PHOSPHOGYPSUM

3.1 Bangladesh has two wet process phosphoric acid plants, both located in Chittagong, within the same factory campus of the Triple Super Phosphate Fertilizer Complex in North Patenga, on the bank of the river Karnaphuli, The first of these plants, known as the Phosphoric Acid Plant I (PA-I) is a 32-te P_2O_5/day conventional dihydrate type of plant. The production train of this plant consists of a 100 tpd sulphuric acid plant based on Monsanto contact process and 100 tpd ROP triple superphosphate product plant. The sulphuric acid plant has an oleum tower attached to it permitting the production of around 10 per cent of the output as oleum. The plant-group was commissioned in 1969 but the phosphoric acid plant (PA-I) was shutdown almost immediately thereafter due to severe corrosion caused by high chloride content of phosphate rock. PA-I remained out of operation until early 1977, but the sulphuric acid plant was operated intermittently, chiefly for oleum. In March 1977 the plant was restarted, but is facing several operational problems. As a result, it has been working at a very low stream efficiency (Annexure III-1).

3.2 The second phosphoric acid plant (PA-II) is a New Nissan hemihydrate - dihydrate, 135 te P_2O_5/day, plant built as 'turn-key' project by Hitachi-Zosen in 1970, along-with a 400 tpd sulphuric acid and 450 tpd TSP plant. The plant was however, commissioned only in September 1974. Since then the plant has been operating at less than about half of its rated capacity (Annexure III-1) mainly due to some equipment problems in the upstream sulphuric acid plant.

3.3 Both the phosphoric acid plants, along with other plants and related facilities, have been the subjects of an end-to-end study by a firm of consultants, Bresler & Associates, under the World Bank Group assisted "Fertilizer Works Operation Improvement Programme", with the object of identifying bottlenecks and suggesting modifications for improving their overall performance. The follow-up viz. revamping of both the production trains is presently covered by another UNIDO assistance programme. The 'Inception Report' of Bresler and Associates has come up with the finding that the plants' designs are basically sound with most of the equipment intact in spite of some hard use, and that the plants can meet 'design production goals' with the implementation of its recommendations.

3.4 The Consultants also made a close study of the working of both the phosphoric acid plants and related facilities in association with the technical staff of the TSP Complex, besides going over the findings of the study made by Bresler & Associates, with a view to ascertaining the general conditions governing the supply of the phosphogypsum. In the light of this study, the following conclusions in regard to the future supply of phosphogypsum have been arrived at jointly with the Management of the TSP Complex :

i) Considering the inherent difficulties of operating under Bangladesh conditions the PA-I plant cannot be expected to yield, on sustained basis, more than 30,000 tonnes of phosphogypsum (dry basis) per year.

ii) The availability of waste sgypsum from PA-II plant from its normal operation on assured, long term basis can be assessed at 200,000 tonnes/year (dry basis).

These conclusions have been based on the understanding that both the TSP trains will be revamped in accordance with the recommendations of Bresier & Associates. However the Consultants have separately submitted a note to the BCIC on the minimum plant modifications and operational improvements necessary to be carried out 'without further delay', to ensure that the plants are operated at levels, where the availability of byproduct gypsum at the figures mentioned above could be assured.

Gypsum Quality

3.5 Gypsum obtained as byproduct in the wet process phosphoric acid plants generally contain two types of impurities : (i) those which are present in the phosphate rock (rock, silica, organic materials) and which are passed on essentially in unchanged form to gypsum and (ii) those formed in secondary reactions during digestion of the rock, e.g. co-crystallysed P_2C_5 and a number of insoluble phosphate and fluoride compounds. As indicated earlier, PA-I plant is based on the conventional dihydrate process and therefore the waste gypsum obtained contains a number of impurities attributable to the (acid) process used. The PA-II plant, however, is based on Nissan hemihydrate-dihydrate process and therefore the gypsum produced is less contaminated with injurious impurities due to the better P_2O_5 recovery and the recrystallisation of calcium sulphate in the process. The Consultants obtained analyses of fresh samples of phosphogypsum from both PA-I and PA-II plants (Table 3.1) and also made a comparison with the analyses of samples from the gypsum pond made available by the TSP Complex.

3.6 As seen in the Table 3.1, the phosphogypsum obtained from PA-I contains higher percentage of P_2O_5 and fluorine and cannot be directly used in the kiln without an intermediate purification treatment step, in view of the adverse effects of high concentration of P_2O_5

Table 3.1

Chemical Composition of Phosphogypsum

Constituents	Per cent	
	PA-I	PA-II
Total P_2O_5	0.65	0.38
of which Water Soluble P_2O_5	0.25	0.15
CaO	31.26	31.69
SO_3	44.75	45.32
SiO_2	1.30	0.64
Fe_2O_3	0.012	0.10
Al_2O_3	0.008	0.008
MgO	-	-
CO_2	-	-
F	0.40	0.32
Water of Crystallization	18.82	19.29
Acidity (as $CaCO_3$)	0.53	0.26
Organic matter	0.96	1.02
Water Solube Chloride	0.015	0.013
Size of Crystals : Length	0.01 - 0.10 mm	0.01 - 0.40 mm
Breadth	0.01 - 0.03 mm	0.01 - 0.10 mm

P.S. : Moisture content : 20 - 27 per cent
as in the gypsum yard.

on the setting properties, and therefore early strength, of cement. Similar y, the presence of F above the permissible limit has the effect of lowering the melting point of the materials in the kiln and may result in shortening the life of the SO_2 oxidation catalyst. Besides, there is a possibility that fluorine may cause the protective coating on the kiln to be eroded, with consequent reduction in refractory life. The waste gypsum from PA-II, however, contains less than 0.4 per cent P_2O_5 (total)and around 0.3 percent F,-the permissible upper limits prescribed by reputed process licensors such as Chemie Linz[5/]. In view of this, the phosphogysum from PA-II, accounting for an estimated annual output of around 200,000 tonnes can be directly used in the process after simple washing. No major modifications in the PA-II plant appear to necessary to enable utilisation of waste gypsum from the plant for cement clinker/sulphuric acid production, in view of the quality of gypsum obtained, except for providing feeding devices to add active silica (Annexure-III-3) to the rock digestion vessel to bring down the F content to acceptable limits. The vent gases can very well be washed in the existing gas scrubber of PA-II plant.

3.7 The Consultants, therefore, propose that the phosphogypsum from the PA-II plant alone be considered for the production of cement clinker/sulphuric acid in view of the fact that gypsum is qualitatively suitable for the process. Alternate uses can be found for the by-product gypsum of PA-I in the production of cement additive and building plaster, after necessary purification, as explained later in Part VII.

[5/] The normal upper limit prescribed for F is 0.15 to 0.20 percent. However, it has been stated that an increase in fluorine upto 0.30 percent in phosphogypsum will be permissible, since F is removed during drying and calcination and can be treated by adding active silica during the rock digestion stage (Annexure-III-3)

Chapter 4

CHOICE OF PROCESS

History of the Process

4.1 The basic Muller-Kuhne process for the production of SO_2 containing gas stream and Portland cement clinker from gypsum is an old established process, originally developed in Germany during World War I by W.J. Muller and H.Kuhne in the laboratories of Farbenfabriken Bayer. The pioneering work was established in a semi-commercial plant of 40 tpd built at Leverkusen, which was in operation till 1931. Muller himself later joined ICI to set up a 300 tpd plant based on anhydrite at Billingham in 1929. After some initial difficulties, the plant reached full production in 1935 and was expanded in 1954 by another 200 tpd. The plant with both kilns, continued to be in production till 1972.

4.2 In the meantime, Bayer designed plants were erected at Mirmas near Marseilles (70 tpd) in 1937, at Wolfen in GDR (400 tpd) in 1938 and at Coswig , also in GDR (850 tpd). Between 1945 and 1956 three plants were built in Poland and one in Austria, at Linz. Of these, a few plants such as the one at Wolfen (rebuilt in 1952-54) in GDR, one in Poland at Wizow (520 tpd) and the one at Linz (later expanded to 230 tpd) are said to be still in operation. Two more plants were built in the U.K. during the early 1950's, when severe sulphur shortage was experienced : the one at Widnes was opened in 1955 with an eventual capacity of 580 tpd but closed down during 1973, while that at Whitehaven (Solway Chemicals Ltd - later Albright & Wilson Ltd), which opened in the same year was expanded from its original capacity of 300 tpd to 500 tpd in 1962, and again to 1,075tpd in 1967, before being converted to bnm sulphur partly in 1973 and completely, late in 1975.

4.3 All the plants mentioned above were based on either natural gypsum or anhydrite : phosphogypsum was never tried in these first generation plants. The main stimulus for the development of the process based on phosphogypsum was said to have been provided by the high levels of world sulphur prices between 1967 and 1969. Most of the research work in this area was done in the United Kingdom at the Building Research Establishment (BRE), in Austria by OSW AG (now Chemie Linz AG) and in the GDR by VEB Chemiewerk Coswig. Thus between March 1966 and December 1968, Coswig carried out five full scale experiments using byproduct gypsum instead of natural anhydrite in one of their kilns. Though the durations of individual test runs were only a few days each due to limitations on the supply of byproduct gypsum and the fact that the mechanical handling system was not designed to handle this meal, the experience gathered was found to be adequate to convince that the process could be adapted to use phosphogypsum on full scale. Similar results were obtained at other centres.

4.4 The principal snag in the use of phosphogypsum in lieu of natural gypsum in the process was that byproduct gypsum obtained in the wet process phosphoric acid contains a wide range of impurities which are not normally found in natural calcium sulphate. However, mostof the impurities either do not produce any definable adverse effects or are present in too low concentrations to be of any importance in the cement/ sulphuric acid process. The principal causes of concern in the use of phosphogypsum, however, are : (i) moisture (ii) residual phosphate (iii) residual fluoride.

Influence of Moisture

4.5 In the Muller-Kuhne process, raw materials have to be dried, if moist, before feeding into the kiln. Even natural gypsum must be calcined first to remove water of crystallisation. Phosphogypsum from wet process phosphoric acid plants contains substantially high moisture and as a result, the amount of thermal energy requirement increases with the use of phosphogypsum. Except for this, the higher moisture content has no adverse effect on the process. The phosphoric acid processes which give waste gypsum with lower water of crystallisation are, therefore, inherently moresuitable for being linked to the cement/sulphuric acid plant than the conventional dihydrate process plants.

Inflence of Residual Phosphate

4.6 The phosphate content in byproduct gypsum remains in three forms : (i) in the form of unreacted particles of phosphate rock (ii) in the form of free phosphoric acid and (iii) in the soluble form in the interstices of the gypsum filter cake or co-crystallised and occluded in the agglomerates of crystals. The exact amount of phosphate content can vary widely depending on the composition and reactivity of the phosphate rock on the one hand and on the type of phosphoric acid process and its operative conditions, on the other. Phosphogypsum from hemihydrate-dihydrate type of phosphoric acid process (e.g. Nissan, PA-II) contains considerably less phosphate than the waste gypsum from the conventional dihydrate type of process (Table 3.1). Since very little of the phosphate content of phosphogypsum is volatalized in the kiln, it is passed on to cement clinker and thence to cement. Phosphate in cement tends to lower the initial strength of cement by suppressing the formation of tricalcium silicate, - the cement constituent mainly responsible for initial setting and hardening - and by forming a dicalcium silicate/tricalcium phosphate solid solution; besides it also tends to stabilize dicalcium silicate (Table 4.1). It is said that for every 1 percent P_2O_5 present, the tricalcium silicate level in cement is reduced by approximately 10 percent. It is for this reason that phosphogypsum from improved processes such as the Nissan's hemihydrate-dihydrate process and Central Prayon (dihydrate-hemihydrate) process is preferred for use in cement clinker production on account of the low phosphate values in such gypsum. Significantly, however, it seems that low phosphate content (a few tenths of a per cent P_2O_5), with little effect on the initial strength, can in fact enhance the 28 days' strength to such an extent that addition of phosphogypsum in small proportions to natural anhydrite used in the cement/sulphuric acid process has actually been recommended to improve the final strength fof the cement produced.

Table 4.1

Effect of Phosphogypsum on Compressive Strength of Portland Cement

Feed to Process	Phosphogypsum	Phosphogypsum	Anhydrite
P_2O_5 in clinker percent	2	1	0
Fluorine	0.10-0.15	0.10-0.15	0
Compressive strength (kg/cm^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

Source : Chemie Linz AG, quoted in Phosphorus & Potassium May-June 1977, British Sulphur Corporation

Effect of Flurine

4.7 The fluorine content of phosphogypsum is lowered during calcination, unlike phosphate. The exact proportion varies according to the origin of the phosphate rock and the operating conditions in the phosphoric acid plant. But it has been observed that upto 40 percent of F is released as gaseous fluorine compounds and mixes with the sulphur dioxide kiln gas. Since fluorine is extremely damaging to contact sulphuric acid plant catalysts, attacking both the silica support and the active vanadium component, fluorine has to be removed as completely as possible by wet scrubbing in the gas cleaning section.

4.8 To a certain extent, however, the fluorine remaining in the clinker is said to have a beneficial effect since it counteracts the effect of the phosphate by providing an alternative route by which tricalcium silicate can be formed by way of fluosilicates. Some correlation however, seems to exist between the fluorine content and the residual sulphate content of the clinker: the fluoride and sulphate together appear to be capable of adversely affecting the hydraulicity of the cement in a rather unpredictable way. For this reason it is considered desirable to restrict fluorine in the phosphogypsum feed to safe levels - about 0.15 per cent.

4.9 As mentioned earlier, despite the flurry of interest shown in the late 1960's in the byproduct gypsum based cement clinker/sulphuric acid process, mainly due to the then gyrating sulphur prices, few commercial plants embodying this process have been set up in recent period. The principal reasons for this have been indicated in Chapter 1. There is, however, one major commercial plant of 350 tpd (H_2SO_4) capacity which has been set up in South Africa - in 1972*. It is reported to be operating successfully (Annexure III-4)

4.10 A number of firms, however, have now licensable process know-how for the production of cement clinker-sulphuric acid based on the use of phosphogypsum. Of these two

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* The Chemie Linz plant is also reported to be operating on phosphogypsum now.

firms, viz. OSW of Linz (now Chemie Linz), Austria and VEB Chemiewerk, Coswig of GDR are the more important. According to the Consultants' information, the OSW process is being licensed through 3 contractors :

i) Krupp-Koppers, Postfach 8, D-4300. Essen BRD (W. G)

ii) Voest Alpine AG, A-4010 Linz Postfach 2, Austria

iii) Swindell - Dressler Co., 441 Smithfield Street
Pittsburg Pa 15222 (USA)

OSW and OSW-Krupp Process

4.11 Chemie Linz has been in the forefront of process development in this field from the beginning. The firm has a cement/sulphuric acid plant (80,000 tpy) as well as a phosphoric acid plant at Linz. Formerly mixed anhydrite was used, but now the plant is said to be using byproduct gypsum only. However from 1966, the company has been running experiments, at first using simulated phosphogypsum prepared from mixtures of natural anhydrite with rock phosphate, fluorespar and sodium fluosilicate and later (after the company's phosphoric acid plant was commissioned) on samples of real phosphogypsum. From 1969, the company is understood to be operating its cement/sulphuric acid plant on phosphogypsum, being the first plant in the world to do so. In December 1968, the South African Federale Kunsmis group is also understood to have successfully run a one week trial in the Chemie Linz plant making use of phosphogypsum from the Prayon process plant. As a result of this trial, a 350 short tpd plant based on the Chemie Linz process was built at Phalaborwa in South Africa, and commissioned in 1972. The plant was engineered by Krupp Chemieanlagenbau (now Krupp-Koppers GmbH). Possibly this plant is intended to be the first stage of a 1000 short tonnes/day capacity complex eventually proposed to be built at the site.

4.12 In the interest of improving the energy efficiency of the process, a Krupp countercurrent heat exchanger has been incorporated at the feed-end of the rotary kiln by Chemie Linz at their plant at Linz. It became operative in December 1972. This is a feature unique to the OSW-Krupps process. Though this kind of heat exchanger is used in the cement industry, fairly extensive modifications had to be carried out before it could be used in the cement/sulphuric acid process. The raw meal passing downwards through the heat exchanger takes up the heat of the hot gas rising from the upper end of the rotary kiln. In this way, the heat consumption has been reduced by about 15-20%. With the optimised design of heat exchanger as well as the kiln that may be built for future plants, it has been claimed that this energy saving could possibly be improved considerably.

4.13 In the OSW-Krupp process scheme, with the incorporation of the double absorption system, which they recommend instead of the conventional contact acid plant, the guaranteed conversion efficiency of sulphur dioxide to sulphur trioxide is claimed to be 99.5%. The maximum emission rate for particulates is claimed to be 50 ppm. The sulphuric acid product is of 94-98% concentration, with a maximum of 0.01% SO_2 and 0.0035% Fe content. Portland cement produced in the process is said to conform to DIN 1164 standard. Since Chemie Linz specifies a maximum of 0.5 percent of P_2O_5 and 0.15 percent of F in the phosphogypsum, some treatment of the gypsum may be required before it is introduced into the plant. Chemie Linz has developed two procedures for the control of these impurities. The first, in which the wet phosphogypsum is mixed, before calcination, with sulphuric acid and hydrated silica, releases the fluorine and enables the phosphates to be washed out of the calcium sulphate with water. The second controls only the fluorine content and consists in adding active silica to the reaction system of the phosphoric acid plant.

Coswig Process

4.14 VEB Chemiewerk[6] has a large 900 tpd plant located at Coswig, which was originally built to operate on mixed anhydrite. Between 1966 and 1968, full scale experiments were said to have been conducted at the works with phosphogypsum and Coswig is said to be fully satisfied with the process and the experience gained during these trial runs. The quantity of cement produced is said to be 'excellent'. Coswig is also credited with better experience on the effect of fluorine in phosphogypsum.

4.15 Not much information is available on other processes, though substantial experience seems to exist in the East European countries, particularly Poland in addition to GDR (Coswig). The Chemical Construction Corporation (now defunct) appeared to have entered into licence agreement with OKC Corporation of Dallas (Texas) some years ago to offer a cement sulphuric acid process specifically intended for use with phosphogypsum. However, no plant was ever built on this process.

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[6] Now reconstituted as Dungemittelkombinat veb Skickstoffwerk.

4.16 The Consultants and the Associated Cement Companies of India also conducted some experimental runs with phosphogypsum in the experimental kiln of ACC. The cement clinker produced was of IS-296-1958 standard for ordinary Portland cement (Table 4.2). The kiln being small, vent gases were diluted and the SO_2 concentration in vent gases was around 2.5-3%. The trials were satisfactory in establishing that quality cement clinker could be produced from byproduct gypsum . However, no commercial plant has been designed so far on the data gathered from these experiments, primarily because the process route did not hold out promise of being economically attractive under the prevailing (controlled) price structure of cement - the permitted "retention" price of cement in India being about $ 38/te compared to about $ 77/te in Bangladesh. Besides, India has plentiful resources of limestone - unlike Bangladesh - though lacking in sulphur deposits.

4.17 Itis apparent from the above review that proven technology and experience is available for the production of cement clinker/sulphuric acid from phosphogypsum (in lieu of anhydrite or natural gypsum). Of all the firms, Chemie Linz (in combination with Krupp) has the best experience for process and engineering know-how. The Krupp heat exchanger appears to have provided a decisive edge over the other processes so far as energy consumption is concerned. A Krupp designed large sized full commercial (105,000 tpy) plant is already operating satisfactorily (Annexure III-4) in South Africa. Hence in this study, the Chemie Linz (former OSW) process has been adopted as the basis for evaluation and estimation.

Table 4.2

Chemical Analysis of the Raw Materials & Clinker Produced in the EPDIL-ACC Trial Runs

Material	Gypsum	Coke Breeze Ash %	Clay No.1 %	Clay No.2 %	Macmatic	Sand	Clinker Produced
SiO_2	0.95	56.54	65.20	46.95	4.5	99.0	21.70
Al_2O_3	0.25	28.85	15.50	15.00	1.5	-	7.55
Fe_2O_3	0.20	6.75	5.80	13.00	90.8	0.5	4.50
P_2O_5	0.35	-	-	-	-	-	1.45
CaO	31.70	3.95	3.70	3.35	-	-	63.00
MgO	-	-	0.85	-	-	-	0.90
SO_3	44.50	0.57	-	-	-	-	-
F	0.4	-	-	-	-	-	0.80
Loss	21.85	-	8.90	18.8	1.5	-	-

Note: 1) Coke Breeze - VM. - 7.3%, Ash - 23.1% Fixed carbon 69.8%.

2) The clinker was mixed with 5% gypsum (natural) and the resulting cement was tested for compressive strengths and other physical characteristics according to Indian Standard 269-1958.

Chapter 5

PROCESS ARRANGEMENT

5.1 As mentioned earlier, this study follows broadly the Chemie Linz (OSW) - Krupp process arrangement. Already there is one full scale commercial plant exclusively operating on this process with phosphogypsum. Besides, the Krupp heat exchanger, unique to the process, promises to bring about substantial economies in energy consumption.

5.2 Portland cement is obtained by sintering an intimate mixture of finely pulversied limestone (or chalk) with silica, alumina and iron oxide containing materials and grinding the resultant clinker. In theory, in the production of cement, clacium sulphate can be substituted for limestone even in the eonventional process. However, because of its greater chemical stability, calcium sulphate cannot be decomposed by thermolysis alone, and requires a reducing agent. The basic chemistry of the process involves reduction of calcium sulphate by carbon to give SO_2, CO_2 and CO which then combine with other components to form cement clinker, as in the conventional cement process. In the case of natural gypsum, however, the production of intermediate calcium sulphide is virtually complete before evolu-tion of SO_2, but in the case of byproduct gypsum, which is more reactive, the two zones seem to overlap considerably.

Chemistry and Reaction Kinetics

5.3 In the OSW-Krupp process, calcium sulphate is reduced with coke carbon to calcium oxide with formation of sulphur dioxide. The calcium oxide combines with the additives to form cement clinker and the sulphur dioxide formed is used for making sulphuric acid.

Decomposition of $CaSO_4$

5.4 In order to decompose calcium sulphate, part of it is first reduced with carbon to form calcium sulphide as follows :

$$CaSO_4 + 2C = CaS + 2CO_2 \qquad (1)$$

This reaction starts at about 700°C. The carbon required for the reduction is added in the form of coke. In practice, excess of carbon amounting to about 20% is required. It is assumed that the reaction does not take place between solids, but via intermediately formed carbon monoxide. The calcium sulphide as formed above reacts with more calcium sulphate to form calcium oxide and sulphur dioxide according to the following reaction :

$$3CaSO_4 + CaS = 4\ CaO + 4\ SO_4 \qquad (2)$$

This reaction starts at about 900°C. The reaction temperature can however, be decreased by adding SiO_2, Al_2O_3 and Fe_2O_3.

Reaction of CaO to Cement Clinker

5.5 The calcium oxide formed according to reaction (2) then reacts exothermically in the sintering zone with the additives SiO_2, Al_2O_3 and Fe_2O_3 contained in the kiln feed meal to form the cement clinker.

Reaction of SO_2 to Sulphuric Acid

5.6 The SO_2 containing gas mixture evolved during reaction (2) is sent to the sulphuric acid plant. Sulphuric acid is manufactured in a contact reactor by catalytic oxidation of SO_2 and SO_3, followed by the absorption of SO_3 in concentrated sulphuric acid to combine with the water present in acid to form sulphuric acid.

Side Reactions in the Process

5.7 In case of byproduct gypsum, which is more reactive than natural calcium sulphate, other side reactions also take place, such as

$$4CaS + 2SO_2 = 4CaO + 3S_2 \quad (3)$$

$$CaS + 2SO_2 = CaSO_4 + S_2 \quad (4)$$

$$4CaO + 6SO_2 = 4CaSO_4 + S_2 \quad (5)$$

The results is that another reaction effectively takes place.

$$3CaS + CaSO_4 = 4CaO + 2S_2 \quad (6)$$

This reaction uses three molecules of calcium sulphide per molecule of calcium sulphate, while the main reaction uses one molecule of calcium sulphide to three molecules of calcium sulphate. Appreciable amount of free sulphur is also produced, accompanied by carbon disulphide, carbon oxysulphide and hydrogen sulphide due to other side reactions. In order to oxidize these compounds to sulphur dioxide, it is necessary to inject further air into the kiln at an appropriate point. It is very essential to oxidize this sulphur, as it will cause blockage in the purification system of acid plant.

Description of the Process (Drawing No. III-1)

5.8 The successive steps of the process using phosphogypsum for the production of sulphuric acid and cement clinker are -

1) Washing, filtration, drying and calcining of byproduct gypsum
2) Preparation of kiln feed meal
3) Grinding of additives
4) Production of cement clinker and kiln gases containing sulphur dioxide
5) Production of sulphuric acid from SO_2 in hot gases (by processing the gas in the existing sulphuric acid section of the TSP-II plant with some additional equipment to handle higher volume of gas)

Grinding of Cement Clinker

5.9 Cement clinker produced in the plant will be carried to the existing cement clinker grinding unit located adjacent to the TSP Complex. The clinker grinding factory has capacity to handle 1000 tonnes per day of clinker for grinding. Hence no extra facilities are needed for grinding of cement clinker.

Filtration, Drying and Calcining of Phosphogypsum

5.10 Byproduct gypsum from PA-II plant will be pumped by the existing slurry pump (20 percent solids) through a pipe to an agitated tank at the new plant site. The slurry will be filtered and the cake is washed with water. Washed cake is dried and calcined. Each calciner is a vertical shaft turbo-drier with a rotary shelving system, the hot gases passing upwards, assisted by axial rotors, while the solid material is transported from shelf to shelf by means of fixed scraper arms. On reaching the floor of the calciner, the calcined material will be discharged into a screw conveyor, which will discharge it into the gypsum receiving hoppers. The hot gas will be produced by burning gas or oil in a combustion chamber; combustion air is provided from the primary air fan, the gases being mainly induced by exhaust gas fan. A proportion of the hot gas will be recirculated by the recirculating fan and fed into the gas inlet of the calciner.

Gas Scrubbing

5.11 The remainder of the waste gases will be passed through an electrostatic precipitator to remove major part of the dust particles. The gases will be then wet-scrubbed in gas scrubbers for removal of fluorine and traces of dust. Lime storage and mixing vessels will be provided to permit lime addition to the scrubber circulating liquor. The scrubbed gas will pass through mist separators before being exhausted to atmosphere through the stack via exhaust gas fans.

The dust extracted by the precipitator will be conveyed to the gypsum receiving hopper.

Calcined gypsum will be conveyed from the hopper by means of a pneumatic conveying system whicn assists in cooling the material before storage. The calcined gypsum will be stored in two concrete silos. The silos' vent system will be linked together and the exhaust gases will be dedusted in silo vent filter.

The gypsum will be discharged from the silos using low pressure air and screw conveyors. It will then be conveyed and elevated into the mixed feed bunker from which it will be proportionately fed into the raw meal mixer.

Raw Material Storage

5.12 Coke : The coke is assumed to be delivered in rail wagon, from which it can be partially discharged by gravity and the remainder extracted using manual labour. Two wagons at a time will be unloaded at the coke wharf, the material being discharged on to the wharf side belt conveyor via a concrete ramp. The coke will then be conveyed to the coke storage pile using the conveyor. It will be distributed on the pile by a travelling belt tripper.

Laterite : Laterite will also be stored and reclaimed in the same manner.

Clay : Clay will be delivered in tippling type road vehicles, which will unload the clay into a collection hopper mounted at the feed-end of mobile stacker conveyor, which will produce a stock pile about 5 metre high.

Sand : Sand will be delivered in a similar manner. The sand will also beunloaded and stacked out in the same way, using mobile stacker conveyor.

Reclamation of Raw Materials

5.13 Coke will be reclaimed by means of mobile shovels and deposited into hoppers from which it will be conveyed on to a scalping screen. Prior to this there will be a magnetic separator to remove any tramp iron. The oversize coke will be crushed in a roll crusher and will return the undersize material on belt conveyor which feeds the dryer feed hopper. The dried coke is discharged on to conveyor and then through elevator feeding to coke bunker.

Laterite will be reclaimed using the same mobile shovel, like the coke, but it will be delivered direct onto belt conveyor, which feeds the iron oxide bunker.

Clay will be reclaimed from the stockpile by means of a mobile shovel which will feed the clay into hopper. The clay will be conveyed from this hopper and discharged into the clay shredder, prior to which there will be a magnetic separator to remove any large loose tramp iron. The shredder will discharge into belt conveyor, which feeds the dryer feed hopper.

The dryer will be fed by a screw conveyor. The dryer will be a rotary drum, cocurrent gas type, the hot gases being produced in an oil-fired combustion chamber. The combustion chamber will be of the double shell construction, the outer casing being cooled by secondary air from the fan, the primary air being supplied by the primary air fan. The oil pumping and heating set will be provided in duplicate. The main hot gases will be drawn through the dryer by induced draughts fan before passing to the electrostatic precipitator for dust removal, the dust being discharged into the same scrapper conveyor as the dry clay.

The hot gases leaving the precipitator will be discharged into atmosphere via an exhaust stack. The dry clay will be conveyed and elevated into either of two clay bunkers by means of elevators and can be recycled to assist in homogenisation via scraper conveyors. Clay dust will be collected at all transfer points and bunker exhaust vents, the dust laden air being passed through bag filter; the dust extracted will be returned to the bunkers and the air vented to atmosphere via the clay dust fan.

Sand will be reclaimed from the stockpile with the same mechanical shovel as the clay, but as it will not require shredding, the shovel will discharge sand on to belt conveyor after the shredder and the sand will be dried in the same manner as the clay. The dry sand will be dischargedon the same conveyor but will be tran ferred to elevator for delivery into the sand bunker. The dust from this bunker and the coke and iron oxide bunkers together with material from transfer point will be collected by the bag filter system.

Raw Material Proportioning

5.14 The dry coke, sand and iron oxide will all be extracted from their respective bunkers by constant weigh band conveyor feeder controls by a variable speed rotary volumetric feeder to control the discharge from the bunkers. The coke, being more easily controllable, can be fed direct on to the weighband conveyor. The correct proportion of these raw materials will be maintained by these weighbands.

The proportioned materials are delivered into the component mill feed bunker, the level in this bunker controlling the operation of the four weighband conveyors.

Component Milling

5.15 The proportioned raw materials will be milled in a tube mill to the necessary fineness, the mill being fed by a constant weighband conveyor. The mill will be under suction thus avoiding a dusty atmosphere. The dust laden air will be passed through an electrostatic precipitator , the dust extracted being returned to the milled component conveyor. The cleaned air will be exhausted to atmosphere via the component mill dust fan. The milled component will be conveyed and elevated to the mixer feed bunker.

Raw Meal Mixing

5.16 The calcined gypsum and milled component will be mixed together in a once through rotary mixer thus giving a continuous mix. The two materials will be extracted from their respective bunkers by volumetric feeders coupled to constant weighband conveyors.

The operation of these two proportioning feeders will be controlled by the level in the mixer feed bunkers. The mixer will be under suction to prevent escape of dust into the atmosphere, the dust laden air from the mixer and adjacent conveyor transfer points will be passed through a bag filter, the dust being discharged into the raw meal scraper-conveyor together with the mixed meal prior to being elevated and distributed into the raw meal scraper-conveyor, together with the mixed meal prior to being elevated and distributed into the raw meal silos.

Raw Meal Silos

5.17 Raw meal will be stored in three concrete silos having a total scapacity equivalent to 2 days' kiln feed. Thus when these and the calcined gypsum silos are full, there will be 7 days' kiln feed betweenthe phosphoric acid unit and the cement unit, giving adequate buffer storage for normal maintenance of all mechanical handling equipment prior to these silos.

All mechanical handling equipment between the raw meal silos and the clinker stockpile will be duplicated, or in the case of kiln feeders, alternative methods of feeding will be provided.

Kiln Feeding

5.18 The raw meal will be extracted fromthe silo outlets by rotary volumetric feeders. There will be four outlets per silo, two for each conveying system, one working and one standby. Porous air piping will be located at the flanks of the outlets to aerate the meal, should it be necessary to assist the flow.

The conveyor system will be provided such that each can collectefrom all the three raw meal silos. The raw meal will be distributed into the two kiln feed silos by scrappers, the first kiln feed silo being kept constantly full and the surplus material being conveyed forward to the second feed silos. The level in ths this silo will control the rotary feeders beneath the raw meal silo.

The kilns will normally be fed by a volumetric feeder and constant weighband system as previously described. This will be augmented by a hand controlled variable speed volumetric rotary feeder, should maintenance be required on the weighband system.

Cement Kiln and Coolers

5.19 Cement kiln having a I.D. of 4.27 meter and length of 103.5 meter, capable of producing 325 tonnes per day of cement clinker is provided. The kiln will be supported on rollers and will be provided with a variable speed drive. The kiln will be lined with refractory and basic bricks. Tertiary air will be admitted to the kiln by means of a blower installed on the kiln. The air will be injected by means of air annulus and air inlet pipe through the shell and meal bed.

The cement clinker will be cooled in grate cooler at the discharge end.

The kiln gases will flow countercurrent to the material, the hot gases being produced by burning gas or fuel oil and molten sulphur directly within the kiln shell. Combustion air is being provided by combustion air fan. A fuel oil pumping and heating set with standby will be provided. The existing sulphur melting pit of the

TSP Complex will be used for melting sulphur and will be pumped to the rotary kiln. The steam required for melting sulphur will be supplied from the proposed boiler or from existing facilities, - the quantity needed being only around 5 te/day. The hot gases will pass to suspension type heat exchanger, where it will exchange heat with raw meal (kiln feed) and will be processed in acid section. The outlet gas temperature from the suspension heat exchanger will be around 150°C. The SO_2 gas concentration will be around 8.65% by vol. The cooled clinker will be discharged into a hammer mill and from there, into one of a pair of elevating scraper conveyors.

Clinker Storage

5.20 The cooled clinker will be discharged into store by means of scraper conveyor; one of these conveyors will also discharge the clinker into spoilt clinker pile if it becomes necessary. The clinker is to be protected from rain water. The storage is a large trough partially excavated into the ground. The bottom of the trough is a specially designed opening from which the clinker will be reclaimed by travelling rotary ploughs, one plough being used as a standby and will be used when the spoilt clinker can be reintroduced with the normal clinker at a reduced rate. The reclaimed clinker will be conveyed to the existing cement clinker grinding plant of BMEDC in Chittagong.

Sulphuric Acid Plant

5.21 Sulphur Melting : The stored sulphur is charged to the feeding conveyor by a shovel loader and thrown in the sulphur melting pit, which is equipped with steam coils to melt the sulphur. The molten sulphur overflows a baffle wall to a skimming section to permit separation of low density impurities. The molten sulphur is pumped to the rotary kiln.

Acid Preparation

5.22 The SO_2 gases from cement plant pass through cyclones, dust precipitator, gas scrubber and mist separator, in which the dust and mist are eliminated and the gas is cooled down. In the gas scrubber, fluorine content gets removed. The clean gas is mixed with air, which is necessary for oxidation of SO_2. However the gas containing considerable moisture is washed with sulphuric acid to eliminate the moisture, which is harmful not only to the catalyst but construction material as well. The gas is sent to exchange heat in conversion section for raising the required temperature. Extra heat exchangers (two numbers) are provided over and above the existing heat exchangers in the Sulphuric Acid Plant II to raise sufficiently the temperature of the inlet gas to the converter. The gas contains about 6.8 percent of SO_2 (on dry basis). Gas further goes to converter containing vanadium pentoxide catalyst in four layers. The sulphur dioxide gas is oxidized with oxygen to sulphur trioxide in the converter. Since the gas leaving the first layer is at elevated temperature, cold dilution gas from the drying tower is introduced to outlet of the first layer, to reduce the gas temperature to an adequate level. The gas leaving the second and third layers flow into first and second heat exchangers respectively, where the gas temperature is adjusted to get the highest conversion rate in the third and fourth layer. In the first and second heat exchanger, the gas is cooled by unconverted gas from D.T. and air respectively. The SO_3 gas from the converter goes into an absorbing tower through third heat exchanger and fourth heat exchanger cools the converted gas to the desired unconverted gas temperature before entering the absorption tower. The acid is further cooled in product acid cooler and stored in the existing storage tank. Existing acid coolers are being used for this purpose. Part of the prdduct acid is used for drying the gases in drying tower.

5.23 It has been confirmed from Hitachi Zosen, the original designers of the sulphuric acid plant (II) that in their opinion that "gas ofaverage 7 vol % SO_2 (after dilution in the converter) content and volume of approximately 64000 Nm^3/h could be handled in the existing converter and absorption tower". The only major modifications required to the acid plant as a consequence of this scheme will be the addition of two heat exchangers. The equipment list with specifications is given as Annexure III-6. The Plot Plant is indicated as Drawing No. III-11 The proposed plant will be independent upto SO_2 generation, cleaning and purification. Once the gas generation section is stabilised, SO_2 gas header will be connected to the SO main gas header of the existing plant after the filter. This will also be synchronised with the annual shut down of the sulphuric acid plant to minimise the plant's downtime.

Chapter 6

RAW MATERIALS AND UTILITIES SUPPLY

6.1 All the raw materials required for the scheme*, except coke and sulphur, are indigenously available in Bangladesh. In the case of sulphur also, there will be no addition to existing imports, since sulphur needed for enriching the lean SO_2 gas will only replace sulphur burning in the existing sulphuric acid plant. Indded, the scheme will result in reducing the overall sulphur import requirement, since it makes use of the sulphur value in phosphogypsum for the same purpose.

Coke

6.2 As mentioned earlier, coke will be needed as a source of carbon, - to act as a reducing agent to decompose calcium sulphate. In fact, even coke fines (coke breeze) containing not more than 5 per cent volatiles will be adequate. Bangladesh however, has no deposits of coking coals. The only significant coal deposits identified in the country are in the Jamalganj-Paharpur area of Bogra - Rajshahi districts, but the deposits lie in depths of about 3000 to 3600 ft. below surface. The coal quality is understood to be non-coking to weakly coking bituminious, with an ash content of 25 per cent and average calorific value of 11000 Btu/lb. In view of the technical problems and the huge investments involved, there are no prospects of coal mining being undertaken in the near future. At the moment,

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* The requirements of raw materials and utilities upto the stage of SO_2 generation, cleaning and purification only are consideredin this Study. The subsequent stages in the sulphuric acid production are deemed to be part of the existing facilities.

both coal and coke are imported into Bangladesh, - coal from India and coke from any world source, the last consignment (Feb. 1979) being from France,

6.3 The annual coke requirement of the proposed scheme has been estimated at about 9400 tonnes. The coke will be required to be imported. Since India has been importing metallurgical coke herself in recent years, Bangladesh may have to depend on other world sources such as Australia, Japan and South Korea, or the European countries (Poland, for instance) for meeting this requirement, despite the high freight costs involved. Since the quantity involved is not large, no difficulty in procurement is envisaged. Besides, despite her problems with coking coal shortage India might be in position to spare about 10,000 tonnes of coke breeze from the Eastern region, which as mentioned above, can serve the purpose of the process. This will require, however, extension of the present agreement for coal supply (about 450 thousand te/year) between Bangladesh and India to coke fines. On a very rough basis, coke breeze might be available in India at a delivered price of around Tk.700/Te ($ 46.70/te) or about $ 57.0/te c&f, compared to the prevailing coke price of around $ 140.00/te c&f. The coke is presently sold by the Coal Controller in Bangladesh at Tk 2510 ($ 167.33) per tonne - Chittagong. The chemical analysis of coke assumed to be used in this study is given as Annexure III-2.

6.4 Bench scale experiments conducted in the Consultants' laboratory, however, indicated the possibility of using anthracite/coal in the process, instead of coke Chemie Linz have also confirmed that the "utilisation of anthracite instead of coke is probably possible, if the content of volatile parts amounts less than 5%. However, this must be confirmed by a comprehensive test.

Higher contents of volatile parts get for the most part to the sulphuric acid plant and burn at the catalyst. The (hydrocarbons) in the volatile parts including hydrogen gets by burning to water vapour, whence with SO_3 sulphuric acid smoke will arise. This sulphuric acid smoke causes corrosions and intensive acid mist in the tail gas....."

It will, however, be necessary, as pointed out by Chemie Linz to confirm those findings on pilot plant scale. In the event it is confirmed, low volatile anthracite/coal can be obtained from the Assam coalfields [3] in India, and the cost of the reducing agent input can be brought down substantially. The Consultants, therefore, recommend that as soon as an investment decision on this scheme is made, Bangladesh should get pilot plant tests on this aspect: undertaken with Assam coals of the appropriate quality at Linz or any other centre recommended by Chemie Linz.

Sand

6.5 Ample sand deposits are available within Bangladesh. sand dunes found on the opposite side of the Karnaphuli river, close to the proposed Chittagong Urea Fertilizer Project site were analysed (Annexure III-2) and found suitable for the purpose. The total sand requirement of the plant is estimated at 2064 te/yr. Even though no estimate of the quantity of sand available in the dunes has been made, the deposits are found to be

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[3] Presently, Bangladesh imports about 75000 Tonnes of Assam coals per year.

large enough to keep the plant served for many years. Alternatively, sand deposits are indicated to be available at a distance of about 40 Km. to the north of Chittagong. The delivered cost of sand has been assessed at Tk. 18/te.

Clay

6.6 There is no dearth of clay in Bangladesh; in fact clay is available in the North Patenga area of Chittagong itself. The clay sample, as analysed in the TSP Complex laboratory (Annexure III-2) is suitable. The annual requirement of clay will be about 25,560 tonnes. The delivered cost has been assumed at Tk. 18/te.

Laterite

6.7 Laterite deposits have been located by the Geological Survey of Bangladesh at a distance of about 40 Km to the north of Chittagong (Drawing III-12), but the total deposits have not yet been assessed. No chemical analysis of the laterite deposit is available either. However, discussions with the geologists in Bangladesh showed that availability of laterite will not be a problem, especially since the annual requirement will be only around 3000 te. The specification of laterite assumed to be used in this study is shown in Annexure III-2. Price assumed is Tk. 300/te. At the worst, it should be possible to import laterite at this price from the Indian sources across the border.

Limestone

6.8 Limestone is presently available indigenously in Bangladesh, though in small quantities. Fairly large deposits. however, have been located at Jaipurhat and Baglibazar areas. The requirement of the project is small - around 1240 te per year - and it can be locally purchased. Price assumed is Tk. 900/te at site.

Sulphur

6.9 Sulphur will need to be burnt in the rotary kiln along with phosphogypsum to obtain higher concentration of SO_2 in the gases, and to reduce the volume of gas handled in the sulphuric acid plant. This will also result in the required 400 tpd of acid being produced in the sulphuric acid plant. The annual requirement is assessed at 7700 tonnes. This will, however, only replace the sulphur burnt in the sulphuric acid plant, and therefore, will not involve additional import. Sulphur is at present costed by the TSP Complex at Tk. 1700/te.

Furnace Oil

6.10 In case fuel oil is to be used for burning in the kiln, the requirement, estimated at about 116 te/day (34,770 te/year), will be obtained from the Eastern Refinery, located by the side of the TSP Complex. Bangladesh is at present surplus in fuel oil, and with the proposed extension of natural gas supply, which will substitute fuel oil in several industrial units in Chittagong, the quantum of surplus, currently estimated at over 100 thousand tonnes is expected to further expand. Alternatively, natural gas, which is expected to be made available to Chittagong within the next few years (or refinery offgases, which are available from the Eastern Refinery) can very well be used in the kiln. Chemie Linz have actually recommended the use of furnace oil only if 'cheap oil with a high sulphur content' is available. Gas, alternately fuel oil, is assumed to be used in this Study. The delivered price of natural gas has been assumed to be Tk 9 per 1000 cft. The price furnace oil has been assumed at Tk. 990/te, which is higher than the export price obtained at present. The analysis of the furnace oil is given in Annexure III-2.

Water

6.11 The total quantum of cooling water required for circulation will be 13,500 M^3 per day, ot which 5 per cent (i.e. 675 M^3) will only be needed as make-up water. The process water requirement has been worked out at 543 M^3/day. The TSP Complex is at present beset with water supply problems due to the change in the characteristics of the water obtained by it from the tube wells sunk in the neighbourhood. As a result of the rising chloride content, water has become increasingly unacceptable. The use of river water for washing gypsum is not recommended. Presently, however, the Complex is obtaining river water during the low tide hours after carefully checking the chloride content, and a new storage tank has been constructed for storing this water. Recently (1978), however, the Water & Sewerage Authority (WASA) of Chittagong has constructed a pipeline to supply water from the city water supply scheme and the factory has started drawing WASA water to supplement its requirements. The Consultants' discussions with WASA showed that an active scheme to augment the water supply capacity to the entire industrial area of North Patenga, with the construction of a large capacity loop pipeline - with which the existing system will be integrated - is under consideration of WASA. The Consultants were assured that the entire water requirements of theproposed projects can be met by WASA supply by 1984-85. The water lines in the plant area are considered in the scope of work. Provision for connecting the WASA header with battery limit water header has been included in the scheme. In the meantime, the water requirements can be met by the fuller utilisation of the existing pipeline. Since the water requirement is not large, the Consultants feel that water supply may not pose any serious problem and can be adjusted within the existing provisions of the TSP Complex. The supply price has been assumed at Tk. 2.00 per M^3.

6.12 The power requirement of the scheme will be 31 Mwh/day 1.3 MW/hr). The Power Development Board (PDB) has assured supply of this additional power to the project Though power interruptions are fairly frequent at present, the remedial measures taken by PDB are expected to resolve this problem soon. Power will be supplied at 33 KV and a new substation has been provided in the estimates. Power rates in Bangladesh are given elsewhere in this report (Part II). For this scheme, power is assumed to be available at Tk. 400.50/Mwh(Part II).

Chapter 7

PLANT LOCATION AND CAPACITY

Plant Capacity

7.1 As discussed earlier, the scheme proposed here envisages theutilisation of 200,000 te/year of phosphogypsum produced by PA-II plant of the TSP Complex, for reasons explained earlier (Chapter 3). Corresponding to this annual supply, the cement clinker plant to be set up will be of 325 tonnes/day capacity. Though with this capacity, it will be a relatively small plant for cement clinker by present day standards, the Consultants are of the opinion, and it is confirmed by other experts in the field, that the plant is within the economic-size range. The full scale commercial plant based on Chemie Linz process operating in South Africa is of 318 tpd (i.e. about 350 short tons/day) capacity, and therefore, the design and experience of that plant can be nearly duplicated in Bangladesh.

7.2 The SO_2 gas produced in the kiln in the process of manufacture of cement clinker will be lean gas and can produce the equivalent of 325 tpd of sulphuric acid (98.5 per cent) only. The existing sulphuric acid plant has a capacity of 400 tpd, which is the requirement of PA-II plant to produce TSP at full capacity. Hence, in order to raise the sulphuric acid production to 400 tpd, it is proposed to burn elemental sulphur in the kiln to raise the SO_2 concentration to around 7 per cent by volume, which will also help the processing of this gas. It has been confirmed, as indicated earlier, that the existing sulphuric acid plant can handle the volume of gas involved viz. 64,000 NM^3/hr, without any major modifications (Annexure III-5). Hence, the effective plant capacities after the implementation of this scheme will be :

i)	Cement clinker	:	325 tonnes/day
ii)	Sulphuric acid	:	400 tonnes/day

Location

7.3 In view of the close linkages with the existing second (Hitachi) train of the TSP Complex, the proposed cement clinker plant will require to be located within the TSP factory campus, close to both gypsum source and the Sulphuric Acid II plant, for proper integration with the existing facilities. This will also help in the delivery of the cement clinker produced to the existing cement grinding factory of BMEDC, which is located at a distance of about 1500 meters from the TSP Complex site, with a grain silo yard intervening between the two factory compounds. A belt conveyor or ropeway can easily carry the material across to the cement grinding unit's existing clinker silos. Subject to further investigation, the Consultants suggest a ropeway to carry the clinker to the grinding unit.

7.4 The Consultants have identified, during the field visit, a plot of vacant land lying next to the gypsum pondin the TSP Complex, which, in the opinion of the Consultants, will be adequate and suitable for the purpose of setting up the cement clinker unit with related facilities (Drawing No. III-11). The Management of the TSP Complex indicated that this area was meant to be utilised for the eventual expansion of the facilities, including the possible expansion of the waste gypsum pond. This area could be utilised for the Scheme, with marginal encroachment on the existing gypsum pond, if theneed for expansion of the disposal pond is rendered superfluous by the gypsum utilisation scheme. The area of the plot is understood to be about 8 acres. The plot will require filling in some places, roughly to the extent of about 50,000 M^3

total. The plot is close to the gypsum pond, and about 400 meters from the gypsum discharge point of PA-II plant. The Sulphuric Acid Plant II (Hitachi) will be almost adjacent to the plot. Gypsum slurry can be transported to the site directly by pipeline.

7.5 Since the land is reclaimed and filled, piling will be necessary for heavy foundations. The proposed site is close to the main express road, freshly developed, on the southern side and the relocated railway line. It is understood that the present approach road along the riverfront will eventually be restricted to the use of the Navy. Since the site is easily accessible from the proposed arterial approach road, the traffic resulting from raw materials supply will not choke the traffic line. Details of location of the proposed facilities are shown in Drawing No. III-11.

Chapter 8

CAPITAL INVESTMENT AND COST OF PRODUCTION

8.1 It is assumed that the scope of this Project is broadly limited to gypsum washing/purification, production of cement clinker and arrangements for delivery to the Cement Clinker Grinding Factory, delivery of SO_2 gas of suitable analysis to the existing Sulphuric Acid Plant II and the modifications required to the sulphuric acid plant to handle the larger volume of slightly leaner gas. The related provisions such as water supply, power transmission, and effluent disposal are also included in the Project's scope. It is assumed that the Cement Clinker Grinding unit will make arrangements best suited to its requirements for carrying clinker from the Project's storage yard, and therefore, no provision has been made towards the cost of the ropeway, but a credit is given in the clinker price towards the cost of carriage. On this basis, the estimated total investment requirement of the project is indicated in Table 8.1. Details are given in Annexure III-7.

Basis of Estimation

8.2 The capital cost has been estimated on the basis of 1979 prices, and assuming the prevailing exchange rate of US $ = Taka 15. The detailed engineering of the project has not been carried out (which is normally done after the investment decision is taken) and the project estimates have been based on the basis of the preliminary designs and specifications worked out by the Consultants and on the basis of budgetary quotations received for vendor equipment from the suppliers. Freedom of procure-

Table 8.1

Summary of Capital Cost Estimates

($ '000)

	Item	F.C.	L.C.	TOTAL
A.	Manufacturing Facilities			
1.	Land & Land Development	-	142.7	142.7
2.	Erected cost of Main Plant	18966.0	8557.0	27523.0
3.	Off-site Facilities and Auxiliaries	837.4	503.6	1341.0
4.	Project Management Charges	-	400.0	400.0
5.	Erection Tools & Tackles	-	40.0	40.0
	Sub-Total	19803.4	9643.3	29446.7
B.	Other Fund Requirement			
6.	Working Capital	-	854.0	854.0
7.	Spares	1235.9	413.7	1649.6
8.	Contingency	2104.9	1091.1	3196.0
9.	Commissioning Expenses	-	1004.1	1004.1
10.	Escalation	3703.1	2880.5	6583.6
11.	Financing charges	-	3367.2	3367.2
	Sub-Total	7043.9	9610.6	16654.5
12.	Realisation from Product during Commissioning	-	(-) 1614.4	1614.4
		26847.3	17639.5	44486.8

ment from any cheapest source for the project has been assumed in computing the cost estimates.

8.3 The estimate also assumes maximum utilisation of indigenous services and equipment (e.g. tanks and vessels) from within Bangladesh. The estimates for locally procured items and services are based on the information collected by the Consultants during the field visit to Bangladesh.

8.4 Escalation during the construction period over the base (mid-1979) cost has been provided at the following rates :

- Local component of capital investment : 12 % year
- Foreign component of capital investment : 8 % year

8.5 Land and Land Development : It is assumed that land will be available free of cost to the Project in view of the fact that the Project will form part of the TSP Complex. In any case, no use is being made of this land at present; but for this Project possibly it might have been used for dumping the waste gypsum since no other land is available for the purpose. Land development costs cover mainly filling, levelling, laying of roads, sewers, drains etc. Construction equipment for the purpose is assumed to be provided by the contractors themselves.

8.6 In view of the presumption that the project will form part of the TSP Complex on account of the close interlinkages involved, no separate provision has been made in the cost estimates towards workshop facilities (except for supporting equipment), laboratory, workers' canteen, transport vehicles, fire station, administrative offices, telephones and such other facilities as already exist on the campus. A small provision, however, has been made for non-plant buildings in view of the substantial augmentation of staff under this project, which the existing facilities may not be able to accommodate. For water supply, electricity and other utilities, only marginal additions required (e.g. electric substation) for the new plant have been provided.

8.7 Care has been taken to ensure that the Project does not cause environmental pollution. Electrostatic precipitators will control the possible dust pollution, Liquor effluent from the plant will consist mainly of wash water, which may contain traces of P_2O_5 and fluorine. It will be treated before being drained to the effluent pond for settling and from there to the Karnaphuli river. The flow in the river is adequate to dilute and disperse the treated effluent. The water from the river at this point (or downstream) is not used for drinking purposes.

8.8 No separate employee housing has been provided since the TSP Complex shares the facilities with other industrial unit in a common pool of the industrial housing estate. No additional provision for stocking of sulphur will be necessary. The silos of the Clinker Grinding Factory can be used for storage of clinker; hence only a marginal provision equivalent to 7 days' production is made for clinker storage within the factory area.

8.9 The following taxes, duties, levies and other charges have been assumed in working out the total fund requirement :

Customs duty	-	20.0 % (cif price)
Sales tax	-	20.0 %
Ocean freight & marine insurance	-	10.6 %
Inland handling, insurance, etc.	-	3.0 %

8.10 Project Management Charges : Provision under this head include fees to be paid to any consultant for assisting the owners to implement this project, preliminary and preconstruction expenses such as site investigation, temporary construction facilities such as storage sheds, construction power etc., salaries and allowances of the project management team (to be capitalised) during the construction period, and other overheads such as training, travelling, stationery,legal expenses if any, etc. Also included are such other preoperating expenses as training of operating and maintenance staff.

8.11 Working Capital : The requirement of working capital has been worked out as shown in Annexure III-8. In accordance with the current practice in Bangladesh and the guidelines given to the Consultants, the entire working capital requirement has been capitalised.

8.12 Spares : Provision for spares has been made at an adhoc rate of 8 per cent of the equipment and machinery cost.

8.13 Contingency and Escalation : Since the estimates are based on preliminary design, and without all the required data on site etc., an element of tentativeness about them is natural. Hence, a contingency provision of 10 percent on the total estimated cost of manufacturing facilities has been made towards unforeseen expenditure.

The provision made for escalation, which will cover possible price increases over a period of 2 years over the base (1979) years' estimates is made as indicated in para 8.4 above. The period of 2 years is considered adequate to carry the project through all the stages of the investment decision-making process. Other broad assumptions have been mentioned in Part II.

Financial Plan

8.14 In accordance with the present official practice in Bangladesh and the guidelines given to the Consultants, the entire foreign component of the capital is treated as loan and the entire local currency expenditure has been treated as equity. Under the present estimates, the debt:equity ratio works out 1.5:1. The financing charges are based on this financial plan. For loan capital, the interest is assumed to be 10 per cent.

8.15 The phasing of expenditure, under the scheduling of work proposed in Drawing No. III-13 will be as follows :

($ '000)

Years	1	2	3	TOTAL
Foreign Component	4027.1	16108.4	6711.8	26847.3
Local Component	2584.4	10740.1	5929.4	19253.9
Total Expenditure	6611.5	26848.5	12641.2	46101.2

Cost of Production

8.16 The cost of production of cement clinker, on the basis of capital cost estimates given above, and after taking credit for the SO_2 gas passed on to the sulphuric acid plant works out to $ 58.80/tonne (Taka 882/te) in case fuel oil and coke are used in the process (Alternative I), and $ 44.00 (Taka 660) if natural gas is used as energy source with coke (Alternative II), as

Table 8.2

Cost of Production of Clinker
(Production Level 100%)

	Item	Annual Cost ($ '000)			
		Alternative			
		I (Oil & Coke)	II (Gas & Coke)	III (Oil & Breeze)	IV (Gas & Breeze)
1.	Raw Materials	2908.1	3022.1	1773.3	1891.3
2.	Utilities	2594.6	1108.5	2594.6	1108.5
3.	Consumables	133.4	133.4	133.4	133.4
4.	Labour & Overheads	133.3	133.3	133.3	133.3
5.	Maintenance Materials	1177.9	1177.9	1177.9	1177.9
6.	Insurance & Taxes	221.7	221.7	221.7	221.7
7.	Contingency	358.5	289.9	301.9	233.3
	Annual Works Cost	7527.5	6086.7	6340.1	4839.4
8.	Depreciation	3436.7	3436.7	3436.7	3436.7
9.	Average Interest	1342.4	1342.4	1342.4	1342.4
	Annual Cost of Production	12306.6	10865.8	11119.2	9618.5
	Credit for SO_2	(-) 6576.0	(-) 6576.0	(-) 6576.0	(-) 6576.0
	Net Annual Cost of Production of Clinker	5730.06	4289.8	4543.2	3042.5
	Annual Production (Tonnes)	97500	97500	97500	97500
	Cost of Production ($/tonne)	58.80	44.00	46.60	31.20
	(In Takas/tonne)	882	660	669	468

Alternative I : Fuel Oil & Coke
Alternative II : Natural Gas and Coke
Alternative III : Fuel Oil & Coke Breeze
Alternative IV : Natural Gas & Coke Breeze

shown in Table 8.2. If, however, coke breeze, instead of coke, is used in the process, the cost of production of cement clinker will come down to $ 46.60/te when fuel oil is used and $ 31.20 if natural gas is used in the place of fuel oil. Details are given in Annexure III-9.

8.17 Credit for SO_2 gas has been determined on the basis of the cost of additional sulphur required to produce the same volume of SO_2 gas in the existing facilities, with an allocated notional processing charge. Credit for the steam generated in the sulphuric acid plant and used in phosphoric acid production has been given in arriving at the notional transfer price of gas. This steam supply will be discontinued when the scheme is implemented, since vent gases will be utilised in preheating the kiln feed. The installation of a new boiler will therefore become necessary and its cost has been included in the estimates.

8.18 The cost of production includes the operating cost, maintenance of the plant and equipment, depreciation and average interest on loan. Coke, alternatively coke breeze, is assumed to be used as reducing agent in the kiln and furnace oil, alternatively natural gas, as the fuel. The requirements and costs of raw materials have been indicated earlier. Maintenance material has been assessed at 4 per cent of the cost of manufacturing facilities which is the normal figure for this type of plants. Insurance is assumed 0.5 percent of the total capital excluding land development. Depreciation has been worked out on a straight line basis over a period of 12 years.

8.19 The cost of labour and overheads has been calculated on the basis of estimated personnel requirements as shown in Drawing No. III-14 using the current wage levels for different categories of employees in Bangladesh.

Chapter 9

PRICING AND PROFITABILITY

9.1 The clinker produced by the project will be sold to the Cement Clinker Grinding Factory of BMEDC, located close to the TSP Complex. This clinker will partly replace the clinker required to be imported by the grinding unit at present. Since qualitatively the clinker produced by the scheme will be equivalent to international standards - cement produced from this clinker has been found to conform to DIN or BS or IS standards for Portland cement - the clinker grinding unit need have no hesitation in paying a price equivalent to what it pays for the imported clinker delivered at its jetty i.e., the landed cost of imported clinker. Since cement is subject to excise duty, it is assumed there will be no duty payable on clinker production. In any case, the Consultants feel that as a waste utilisation and pollution control project, the scheme would deserve duty exemption at the Government's hands both in respect of equipment procurement and production.

9.2 The Clinker Grinding Factory has been paying a price ranging from $ 28.50 to $ 43.35 per tonne during the last 2-3 years. The consignment received in December 1978 had been negotiated at $ 43.35/te C&F. The landed cost of the clinker worked out to Take 788.18 per te ($ 52.55/te) after payment of customs duty, and port and other charges. Prices of cement have risen sharply in the last few months - from around $ 50/te to around $ 85.00/te (C&F). In sympathy, clinker prices have also followed suit, though the market for clinker is more restricted. The current quotations are understood to be around $ 65-70 (c & f). On the strength of opinion from knowledgeable importers, it is assumed that the international commercial market price of cement clinker will not be less than around \$ 55/te in the near future. Assuming this price, the landed cost of clinker at the Chittagong jetty of the grinding unit will work out to approximately Taka 975/te (\$ 65/te). This will be treated as the sale price of clinker produced by the Project.

9.3 Pricing of SO_2 gas is a more difficult exercise since it is only an intermediate coproduct, and as such has no price in the normal course (unless liquified). It is therefore priced on the basis of sulphur substitution that the process will bring about to produce the same amount of (400 tpd) sulphuric acid. Sulphur requirement of the existing Sulphuric Acid Plant II will be reduced by 108 te/day as a result of the gypsum utilisation. Recently, sulphur prices in the international market have risen sharply; compared to a price of around \$ 55-60/te only a few months ago, the present (Sept 1979) f.o.b. prices are understood to be around \$ 93/te. Very recently, India is reported to have negotiated a large consignment at around \$ 137 for spot. Another large deal for future delivery is reported to have been struck at around \$ 125/te. Assuming a c & f cost of \$ 122/te, the price of sulphur locally (i.e. landed cost and other charges) works out to around Taka 2280/te (\$ 152/te). The reduction in sulphur use will give a credit for Taka 350,000 (\$ 23,300) for the SO_2 gas produced per day.

9.4 Based on this pricing method, the Project's profitability will be as shown in Table 9.1.

Table 9.1

Profitability of the Project

(Level of Production 100%)

($ '000)

	Item	I Fuel Oil & Coke	II Gas & Coke	III Fuel Oil & Breeze	IV Gas & Breeze
1.	Annual Realisation from sale				
	- Clinker	6337.5	6337.5	6337.5	6337.5
	- SO_2	6576.0	6576.0	6576.0	6576.0
	Total	12913.5	12913.5	12913.5	12913.5
2.	Annual Cost of Production (Excl. interest)	10964.2	9523.4	9776.8	8276.1
3.	Gross profit before interest	1949.3	3390.1	3136.7	4637.4
4.	Interest on long term loan (Average)	1342.4	1342.4	1342.4	1342.4
5.	Profit after interest (before taxes)	606.9	2047.7	1794.3	3295.0
6.	Total Capital Employed	44486.8	44486.8	44486.8	44486.8
7.	Return on Total Capital (Percent)	4.4	7.6	7.1	10.4
8.	Equity Capital	16432.4	16432.4	16432.4	16432.4
9.	Average Return on Equity (Percent)	3.7	12.5	10.9	20.1

9.5 Considering the fact that this project has been primarily conceived as a pollution control measure aimed at disposal of phosphogypsum in an environmentally satisfactory way, the Return on Investment is quite satisfactory and the project is viable, even with coke, particularly if natural gas is used as fuel. The project's attractiveness improves considerably if the fact is taken into account that it saves cost: it obviates the need for incurring large investments on alternative non-commercial methods of gypsum disposal, such as dumping into the sea, which would bring no return at all.

9.6 As discussed earlier, one of the expensive inputs in the process is coke, required as a reducing agent in the kiln. In the delivered price of coke, a major element is freight, since the sources of import are located at considerable freight distance. If, however, coke breeze could be imported from the Eastern India , which, given the goodwill between the neighbouring countries, Bangladesh might be able to negotiate by extending the present agreement for supply of coal from India, it can be substituted for coakwith substantial economy in cost. If it can be substituted for coke, and natural gas is used as fuel, the Return on Capital Employed improves considerably to 10.4 percent. Similarly, there are indications of possibilities, as discussed in para 6.4 of using low volatile anthracite/coal in the process If the project authorities could get the necessary pilot plant tests done at an early stage, the possible use of anthractie/coal could probably be incorporated in the kiln's design itself. In that case, if the import of such coal from the Assam sources could be firmed up, the Project's financial viability will be enhanced further.

Pay Back Period

9.7 The annual cash accruals including depreciation and profit before interest would enable the project to pay back the fixed investment in the following years after the plant goes into production.

Alternative I	(Fuel OIL & Coke)	8.7
Alternative II	(Nat. Gas & Coke)	7.0
Alternative III	(Fuel Oil & Coke Breeze)	7.3
Alternative IV	(Nat. Gas & Coke Breeze)	6.0

Break-Even Point

9. 8 The profit break-even point, i.e. the lowest production level at which the unit can operate without incurring any loss, as percentage of rated capacity, has been found to be at -

Alternative I	70.7 %
Alternative II	58.6 %
Alternative III	60.4 %
Alternative IV	51.4 %

Internal Rate of Return

9. 9 The Internal Rate of Return indicates the rate at which the discounted total of the annual cash in-flows over the period of operation of the plant equals the discounted current worth of initial investment. The IRR of the project works out to be -

Alternative I	7.1 %
Alternative II	10.5 %
Alternative III	9.8 %
Alternative IV	13.1 %

Details are given in Annexure III-10

Sensitivity of the Project

9.10 The sensitiveness of the project is financial returns due to deviations in the major assumptions made in the study are shown in Table 9.2.

Table 9.2

Sensitivity Analysis

A. Production

Production Level (Percent)	Return on Capital Employed			
	Alternative			
	I	II	III	IV
Base Case 100 %	4.4	7.6	7.1	10.6
90 %	2.2	5.4	4.6	7.8
80 %	1.5	4.2	3.5	6.2

B. Increase in Project Cost

Increase in Cost over Base Case (Percent)	Return on Capital Employed, %			
	Alternative			
	I	II	III	IV
Base Case	4.4	7.6	7.1	10.4
10 %	3.3	6.2	5.7	8.8
20%	2.4	5.1	4.6	7.4

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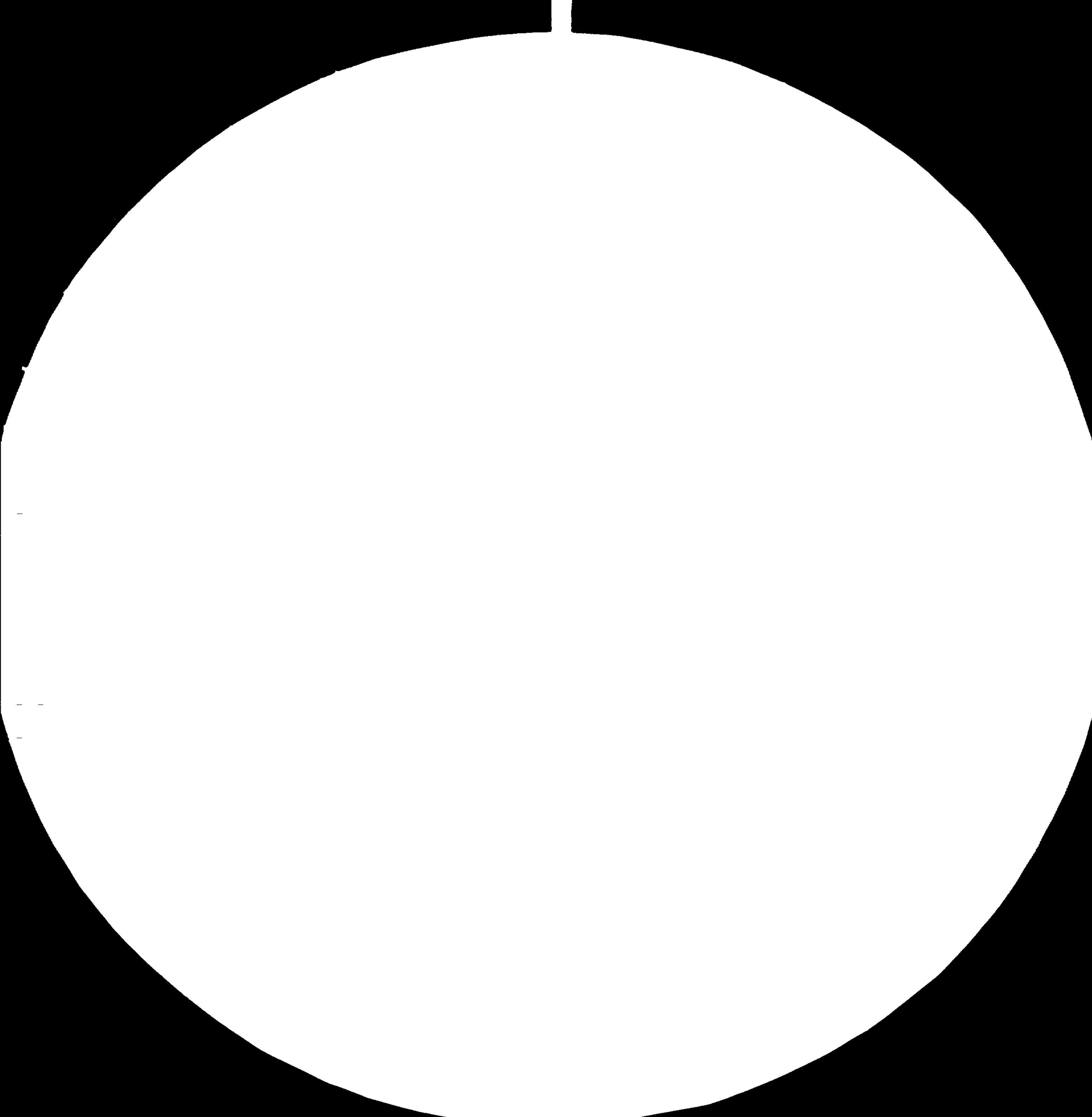
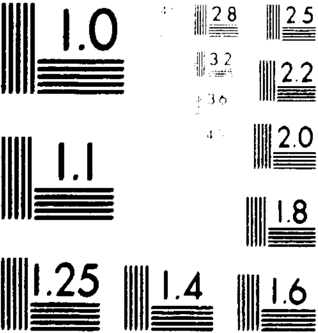




MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS-1963-A

C. Increase in Clinker Price

Variation in Selling Price of	Return on Capital Employed, %			
	Alternative			
	I	II	III	IV
Base Case @ $ 65.00/te	4.4	7.6	7.1	10.4
Increase of 10% (i.e. $ 71.50/te)	5.8	9.0	8.5	11.8
Fall of 10% (i.e. $ 58.50/te)	3.0	6.2	5.6	9.0

Chapter 10

IMPLEMENTATION AND TIME SCHEDULE

10.1 The production of cement clinker/sulphur dioxide from the waste gypsum involves use of sophisticated technology of which Bangladesh has little experience. It is, therefore, expected that the entire project will be executed through an experienced engineering contractor on 'turn-key' terms. The Consultants recommend the appointment of Krupp -Koppers GmbH, Essen, West Germany for the purpose, for reasons indicated earlier, viz. their experience in building a successful commercial plant in South Africa and the process improvement in the form of incorporation of heat-exchanger in the design for economising on energy consumption. The process recommended is, as mentioned earlier, the Chemie Linz (former OSW) process. In view of the fact that it will virtually be a single-party bid, the Consultants recommend the appointment of a Technical Consultant to assist the project owners in monitoring the project and watch the owners' interest.

10.2 The TSP Complex Management will, however, provide back-up support to the contractor by constituting a Project Management Group headed by a Group Leader who will be atleast of the rank of a Dy. General Manager. The Group will liaise with the contractor, if necessary through the Technical Consultant, and the TSP Complex Management and provide the needed local assistance, including assistance in the appointment of local contractors, identification of equipment that can be locally procured, liaison with the PDB, WASA and the Port Authorities etc. It is envisaged that eventually the Group will be placed in charge of the operation of the clinker plant.

10.3 It is expected that the project's execution from the 'zero date' to commencement of commercial production will be completed in about 34 months. The 'zero date' will be the date when the formal contract to the selected engineering contractor is awarded. Prior to this, after the investment decision is taken, financial arrangements will have to be tied up, a Technical Consultant will have to be appointed, and selection and terms of the engineering contractor will need to be settled. On a reasonably optimistic basis, it is estimated that process will require about 12 to 14 months after taking the investment decision. In the meantime, the civil works and work on off-site facilities can commence. About 6 months' time will reasonably be required to commission and stabilise the Plant. A bar chart indicating the tentative time schedule is enclosed as Drawing No. III-13. It is assumed that during the first year of operation, the plant will yield production equivalent to 50 per cent of capacity and in the second year, 75 per cent. From the third year onwards, 100 per cent production is assumed. For the shortfall in sulphur dioxide, the existing sulphur burning facilities will be used.

10.4 It is expected that the kiln will be a long delivery item. Therefore it will be necessary to place firm order for it sufficiently in advance to ensure that the delay in its delivery does not hold up the project.

Chapter 11

MANPOWER REQUIREMENT

11.1 The Project will be deemed to be a part of the TSP Complex, as indicated earlier, and therefore, the overall management of the plant will vest in the Chief Executive (presently, a General Manager) of the TSP Complex. Under him there will be a Deputy General Manager (or Plant Superintendent) to be directly in charge of the plant, who will supervise its day to day operations. The total additional manpower requirement for the operation of the plant has been tentatively estimated at 200, as shown in Table 11.1 (For details, Drawing No. III-14). This will include the additional staff required by the TSP Complex's common pool, such as administrative staff, accountants, drivers etc. as a consequence of increase in the activity level and turn-over due to the cement clinker plant. The staff requirement, however, may need to be scrutinised closely in consultation with the Management of the TSP Complex, after the Project is launched, just prior to starting the recruitment process. Advice of the Engineering Contractor, in the light of their experience, on this matter may also be available at this stage.

Table 11.1

Manpower Requirement of the Project

	Category	Number
1.	Dy. General Manager	1
2.	Engineers/Dy. Chief Chemist	5
3.	Shift Supervisors	7
4.	Operators/Technicians/Shift Chemists etc.	86
5.	Unskilled Workers	82
6.	Office Staff	19

11.2 The assessment of personnel requirement has been made rather liberally considering the fact that a large number of operations will be needed to be done manually in view of the nature and number of raw materials (mainly solids) involved and the type of product planned. In a plant of this type maintenance work will also be fairly widespread. Continuous monitoring by the laboratory of the analysis of the raw materials procured and used will be needed to ensure rigorous enforcement of the process requirements. All the same, the number indicated above may be treated as the outside limit and has been shown here only to assess the impact of the maximum work force on the plant's operational results.

11.3 The salary scales of the employees as well as the fringe benefits have been computed on the basis of the existing standard grades of the public sector employees, as practised in the BCIC units. No housing is envisaged to be provided, since Chittagong is a developed city and a common industrial housing estate provides housing facilities to industrial employees.

11.4 The operation and maintenance of the cement clinker unit will involve deployment of sophisticated and experienced skills. For instance, maintenance of the optimal conditions in the kiln, particularly in the clinkering zone is of crucial importance for the operation; any excess or deficiency of oxygen can, for example, give rise to serious operational troubles, - such as formation of fused calcium sulphate on the brick lining, - or result in the cement clinker acquiring undesirable characteristics. Exceedingly intensive training of the operating personnel is, therefore, necessary to ensure skilled trouble free operation of the plant. It is assumed that this training will be provided by the Engineering Contractors, more particularly during the commissioning period. For this purpose, the required staff will have to be recruited sufficiently in advance of the Project's mechanical completion date. The Project Management Group should ensure that in the later stages of the Project's execution, the recruited operating personnel are effectively involved in the construction work as well in some useful manner. The Consultants also feel that training of key operating personnel such as those in charge of the kiln operation outside the country will be necessary, since adequate exprienced personnel within the country will not be available. It is, therefore, envisaged that 3 persons will be trained by the engineering contractor either at the Chemie Linz or the Phalaborwa plant. Other supervisory and operating personnel can be trained at the existing cement plants and given necessary orientation.

ANNEXURE III-1

CAPACITY UTILIZATION IN TSP PLANTS

(In tonnes)

	Products	Production Unit TSP-I	Production Unit TSP-II	Total Production	Year
1.	Dry TSP	-	32,851	32,851	1974-75
2.	Bagged TSP	-	26,043	26,043	"
3.	50% Phos. Acid	-	22,276	22,276	"
4.	Sulphuric Acid	-	35,942	35,942	"
5.	By-product gypsum	-	52,561	52,561	"
1.	Dry TSP	-	40,690	40,690	1975-76
2.	Bagged TSP	-	39,209	39,209	"
3.	50% Phos. Acid	-	26,902	26,902	"
4.	Sulphuric Acid	-	39,216	39,216	"
5.	By-product gypsum	-	65,104	65,104	"
1.	Dry TSP	924	37,094	38,018	1976-77
2.	Bagged TSP	433	44,733	45,166	"
3.	50% Phos. Acid	-	25,723	25,723	"
4.	Sulphuric Acid	-	35,049	35,049	"
5.	By-product gypsum	14,744	59,348	74,092	"
1.	Dry TSP	3,428	37,846	41,274	1977-78
2.	Bagged TSP	3,259	34,983	38,242	"
3.	50% Phos. Acid	2,398	23,496	25,894	"
4.	Sulphuric Acid	2,456	43,554	46,010	"
5.	By-product gypsum	5,483	60,552	66,035	"
6.	Oleum	1,003	-	1,003	"

Source : BCIC Triple Superphosphate Fertilizer Complex

ANNEXURE III-2(i)

CHEMICAL ANALYSES OF RAW MATERIAL INPUTS

A. Raw Materials

Items	Gypsum	Sand	Clay	Coke
CaO	31.69	0.60	1.80	1.30
SiO_2	0.64	91.66	62.940	6.90
Al_2O_3	0.008	3.56	22.16	4.40
Fe_2O_3	0.010	1.68	3.36	2.00
MgO	-	0.10	1.23	0.40
SO_3	45.32	0.10	0.08	-
Total P_2O_5	0.38	-	-	-
Water Soluble P_2O_5	0.15	-	-	-
Fluoride	0.32	-	-	-
Acidity	0.26	-	-	-
Carbon	-	-	-	85.00
Organic Matter	1.02	-	-	-
Water of Crystallisation	19.29	-	-	-
Water Soluble Chloride	0.013	-	-	-
Remainder	-	2.30	-	-
Loss	-	-	8.43	-

ANNEXURE III-2(ii)

B. Fuel

(i) Fuel Oil

Carbon	88%
Hydrogen	8%
Sulphur	2%
Ash	0%
Cal. Value	9970 Kcal/Kg.

(ii) Natural Gas

Methane	94.3%
Ethane	3.4%
Propane	0.8%
Butane	0.6%
Nitrogen	0.4%
Carbon dioxide	0.5%
Cal. Value	9095 Kcal/NM^3

ANNEXURE III-2(iii)

C. Others

(i) Laterite

SiO_2	0.54%
Al_2O_3	27.00%
Fe_2O_3	44.50%
CaO	9.70%
Others	1.26%
Loss	17.00%

(ii) Sulphur (Dry basis)

Sulphur	99.0 - 99.9%
Ash	0.05 - 0.8%
Moisture	0.5% max.

ANNEXURE III-3

CHEMIE LINZ AG

The Fertilizer (Planning & Development) India Ltd
Attn. Mr. D.M. Thkare
Addl. Chief Engineer (PP)
C.I.F.T. Buildings
P.O. Sindri
Pin 828122
Dist. Dhanbad (Bihar)
India

Your ref	Your letter of	Our ref	Extension	Linz,
PPD/26/365	79 02 02	IVL/Bi/L	2226	Austria, St.Peter- StraSe 25 79 02 27

Ref :

Sulphuric Acid/Cement Clinker from Byproduct Gypsum (GS-Plant)	Referee Dr. Binder

Dear Mr. Thakre,

Thank you very much for your letter of February 2, 1979 in above matter. We would like to inform you thereto, that we have worked at the Project in Chittangong already in 1969 with the companies VOEST and Krupp.

We are glad that the work at this project is activated again and hope for a realization this time.

According to the raw material analysis mentioned by you, the raw materials (except the gypsum) for the production of cement clinker are suitable. The gypsum has a too high P_2O_5 - and F-content of 0.65% the water soluble part is 0.25%, it should be possible to lower the

ANNEXURE III-3
pp.2

P_2O_5 content to the wanted value of 0.5% by washing the gypsum. The F-content of 0.4% is also too high. It should be tried, how much fluorine could be removed by washing with water. In case the F content of the washed gypsum is higher than the wanted value of 0.15%, it has to be tried to lower the F-content by addition of active SiO2 in the phosphoric acid plant. Whether this is possible, had to be tested in the production plant. If you would send us a test sample of 5 kg byproduct gypsum and 5 kg of the corresponding phosphoric acid, we could carry out a preliminary laboratory test to be able to find out, whether it is useful to perform a test in the production plant.

Concerning the fuels, fuel oil as well as liquefied petroleum gas and natural gas can be used. We would, however, recommend fuel oil, where a cheap oil with a high sulphur content can be taken.

We hope we could help you wtth our statement and are readily prepared to provide you with further informations if wanted.

With kind regards

CHEMIE LINZ AG

Sd. Sd.
Steininger Binder

ANNEXURE III-4

FEDMIS (PTY) LTD.

9 WEST STREET, JOHANNESBURG 2001

WRS/mh File 09-15 Pc
1978-11-08

The Fertilizer (Planning & Development) India Ltd.
C.I.F.T. Buildings
P.O. Sindri, Pin 828122
Dist. Dhanbad
Bihar, INDIA

Attention : Mr. D.M. Thakre

Dear Sirs,

Sulphuric Acid from Phospho Gypsum

Thank you for your letter of 20th October 1978, reference PPD/1/3077. We can enumerate the main operating problem we have had with our plant as follows :

1. Upto the middle of 1977 we had insufficient anhydrite (produced from phospho gypsum by calcining) available to keep the kiln plant fully supplied. This was due to control problems in the phosphoric acid (hemihydrate process) plant and various problems were thus encountered in the operation of the drier/calciner. There were also some disabilities associated with the transporting of anhydrite from the drier to the kiln which was at that time done by road tankers. By adding a crystal modifying agent to the hemihydrate process and converting to a

pneumatic anhydrite transport system these problems were overcome and we now have just sufficient anhydrite available to run the kiln at its designed rate.

2. The life of the refractory lining in the burning zone of the kiln has been very short resulting in frequent stoppages for replacement of these bricks. This is due to our inexperience in kiln operation, which is steadily improving. We now have to stop for relining about twice per year. This could be improved by the use of more expensive imported bricks but we consider that we must achieve longer life with the locally available bricks before changing to a better quality.

3. Much downtime of the kiln has been caused by leaks in the acid coolers of the sulphuric acid plant. This plant is older than the kiln and is equipped with the old-fashioned cast iron serpentine coolers. We do not believe that these leaks are anything to do with the production of acid from kiln gas, and will be changing the coolers to the modern stainless steel shell and tube type in the future.

4. The Fuller clinker cooler has been a high maintenance cost item, due to overheating and failure of the grate plates and the supporting beams. We are investigating the causes of this at this time and we presently believe that maloperation and changes that we have made to the grate pattern have been contributing causes.

ANNEXURE III-4
pp.3

As far as costs of production are concerned, it depends on what you have to pay for fuel oil calcining and kiln operation, coke and clay. Therefore our costs would not be applicable to your situation. We can say That by crediting the acid at the value of equivalent imported sulphur and selling the cement at the current controlled market price for the conventionally produced product, the plant now shows a modest profit under our conditions.

We trust this information is of value to you.

Yours faithfully,

Sd. WR SCURR
Technical Director

ANNEXURE III-5

HITACHI ZOSEN
HITACHI SHIPBUILDING & ENGINEERING CO.LTD.

Mr. D.M. Thakre
Addl. Chief Engineer (PP)
The Fertilizer (Planning & Development)
India Ltd.
C.I.F.T. Buildings,
P.O. Sindri Pin 828122
Dist. Dhanbad (Bihar)
India

OSAKA 2nd March 1979

Dear Sir,

Sub : Sulphuric Acid Plant T.S.P.
Complex Chittagong, Bangladesh

In reply to your letter of PPD/26/439 dated 08.02.1979, we are pleased to inform you our opinion as follows.

The design capacity of existing sulphuric acid plant is 400 T/D and the plant uses 11 vol% SO_2 gas to the converter in which it is diluted to average SO_2 content of approximately 6.6 vol.%. Therefore, rated gas volume after dilution is approximately 58,000 Nm^3/h.

In view of a margin for the production capacity the plant has a record production of 470 T/D, which equals to approx. 15%.

Therefore, we consider the gas of average 7 vol.% SO_2 (after dilution in the converter) content and volume of approximately 64,000 Nm^3/h could be handled in the existing converter and absorption tower.

ANNEXURE III-5
pp.2

We hope our above opinion will be satisfactory to you and we thank you very much for writing to us.

Yours faithfully,

Sd,

M.Akiyama
General Manager
No. 1 Plant Design Development

ANNEXURE III-6

SPECIFICATIONS OF EQUIPMENT

Sl. No.	Items	No. Reqd.	Brief Specification	Material of Construction
A.	<u>Gypsum Calcination and Storage Section</u>			
1.	Gypsum belt conveyor	One	Cap : 60 Te/hr. Dimension : Width = 500 Length= 100,000	Rubber Band M.S.
2.	Turbo-calciner	One	Cap:38 Te/hr. Dimension : Height = 10.8 m Dia = 5.2 m No.of Trays = 51	M.S.
3.	Flue gas recirculation blower	One	Cap: 55000 Nm^3/hr at 80°C.	M.S.
4.	Air Blower	One	Cap:64,000 Nm^3/hr	M.S.
5.	Furnace including (1) Two numbers of pumps (2) Two numbers of oil burner set.	One	Heat duty: 13×10^6 Kcal/hr	M.S. and refractory bricks
6.	Screw conveyor for dried gypsum	One	Cap: 30 Te/hr Dimension : Dia = 0.6 m Length= 15 m	M.S.
7.	Screw conveyor for cyclone separator.	One	Cap : 5 Te/hr. Dimension Dia = 250 m Length= 20 m	M.S.

1.	2	3
8.	Star valve	One
9.	Spray tower for gas washing	One
10.	Recirculation pump	Two
11.	Lime solution tank with agitator	One
12.	Lime storage	One
13.	Lime feeder	One
14.	Entrainment separator	One
15.	Exhauster blower Diff. press : 200 mm W.G.	One
16.	Stack	One

ANNEXURE III-6
(p.p.2)

4	5
Cap : 5 Te/hr.	M.S.
Cap: 99851 M^3/hr gas rate Dimension : Dia = 4850 mm Packed ht = 0,5 m Total ht = 6,5 m	M.S.
Cap : 20 m^3/hr to 24 m^3/hr.	M.S. & C.I.
Cap : 5.5 m^3 Dimension : Height = 1.75 m Dia = 2.00 m	M.S.
Cap : 5,2 m^3 Dimension : Height = 2.0 m Dia = 1,8 m	M.S.
Cap : 100-500 Kg/hr	M.S.
Cap : Gas rate = 100,000 M^3/hr at 80°C	M.S.
Cap : 100,000 M^3/hr. at 75°C	M.S.
Cap : 100,000 M^3/hr at 75°C	M.S.

1	2	3
17.	Electrostatic precipitator	One
18.	Screw conveyor for electrostatic precipitator.	One
19.	Star valve	One
20.	Hopper	One
21.	Star feeder	One
22.	Pneumatic conveyor system including the following items : 1) Two no. air compressors 2) Blow tank 3) Aeration nozzle 4) Bag filter with necessary air blower.	One
23.	Silos for gypsum	Two
24.	Air slides with necessary air blower.	Two

ANNEXURE III-6
(p.p. 3)

4	5
Cap : Gas rate = 100,000 M^3/hr.	M.S.
Cap : 1 Te/hr. Dimension : Dia = 200 mm Length = 20 m	M.S.
Cap : 1 Te/hr	M.S.
Cap : 30 Te storage Dimension : Dia = 3.30 m Height = 3.5 m	M.S.
Cap : 30 Te/hr	M.S.
Cap: 30 Te/hr dried gypsum	M.S.
Cap : 1530 m^3 Dimension : Height = 15 m Dia = 11.5 m	Concrete
Cap : 30 Te/hr.	M.S.

1	2	3
25.	Star valve	Two
26.	Screw conveyor	One
27.	Bucket elevator	One
28.	Mixer feed bunker	One
29.	Star feeder, variable speed, range 25 Te/hr to 40 Te/hr.	One
30.	Weigh belt	One

ANNEXURE III-6
(p.p. 4)

4	5
Cap : 30 Te/hr	M.S.
Cap : 30 Te/hr Dimension : Dia = 500 mm Length = 15 m	M.S.
Cap : 30 Te/hr Dimension : Height = 15 m	M.S.
Cap : 30 m^3 Dimension : Dia = 2.75 m Height = 5 m	M.S.
Cap : 30 Te/hr.	M.S.
Cap : 25-40 Te/hr.	Rubber & M.S.

ANNEXURE III-6
(p.p. 5)

Sl.	Items	No.	Brief Specification	Material of Construction
1	2	3	4	5
B.	Raw Material Handling Section			
1.	Dryer exhauster fan	One	Cap : 7862 M^3/hr at 80°C	M.S.
2.	Clay dust collection system for silo including : 1) Bag filters (2) silo dust fan (3) Clay silo scavanger fan.	One Set	Cap : 150 m^3/Min.	M.S.
3.	Coke silo dust collection system including following items : 1) Bag filters (2) Coke silo dust fan (3) Coke silo scavenger fan.	Oneset	Cap : 150 M^3/hr	M.S.
4.	Mixer dust collection system including (1) Bag filters (2) Mixer dust fan (3) Mixer dust scavenger fan.	One set	Cap :150M^3/ Min	M.S.
5.	Raw mill dust fan Diff. press. 150 mm W.G.	One	Cap : 10,000 M^3/hr	M.S.
6.	Secondary air fan Diff. press.: 150 mm W.G.	One	Cap : 5150 M^3/hr.	M.S.

1	2	3
7.	Primary air fan for dryer Diff. Press : 200 mm W.G.	One
8.	Combustion chamber	One
9.	Fuel Oil Heater	Two
10.	Magnetic separator for clay	One
11.	Electrostatic dust precipitator	One
12.	Magnetic separator for coke	One
13.	Coke screen	One
14.	Ball mill dust precipitator electrostatic type.	One

ANNEXURE III-6
(p.p. 6)

4	5
Cap : 1000 Nm^3/hr.	M.S.
Cap: 84×10^4 Kcal/hr. Dimension : Dia = 2.2 m Ht = 2 m	M.S.
Cap: 1150 Kcal/hr. 5 KW.	
	Electro-magnet
Cap : 7300 M^3/hr at 80°C	M.S.
	Electro-magnet
Cap : 10 Te/hr. Dimension : Screen opening = 15 mm.	M.S.
Cap : 10,000 M^3/hr. at 80°C	M.S.

1	2	3
15.	Clay dryer vent stack	One
16.	Clay dryer fuel oil pump gear type.	One One
17.	Mobile belt sand stacker	One
18.	Sand reclaim conveyor	One
19.	Mobile clay stacker	One
20.	Clay reclaim conveyor	One
21.	Clay dryer feed conveyor	One

ANNEXURE III-6
(p.p.7)

4	5
Cap: 6300 M^3/hr. at 80°C Dimension : Height = 30 m Dia = 835 mm	M.S.
Cap : 500 Kg/hr at 3 Kg/cm2 press.	M.S.
Cap: 10 Te/hr. Dimension : Width = 0.400m Length = 10m	M.S. and Rubber
Cap : 5 Te/hr. Dimension : Width = 0.400mm Length = 15 m	M.S.and Rubber
Cap : 10 Te/hr. Dimension : Width = 0.400 mm Length = 10 m	M.S.and Rubber
Cap : 5 Te/hr Dimension : Width = 0.400 m Length = 15 m	M.S. and Rubber
Cap : 5 Te/hr Dimension : Width = 0.400 m Length = 15 m	M.S. and Rubber

1	2	3
22.	Clay dryer screw feeder	One
23.	Dry clay/sand/coke Conveyor	One
24.	Dry sand bucket elevator	One
25.	Dry coke bucket elevator	One
26.	Sand proportioner weigh belt	One
27.	Dry clay bucket elevator	One
28.	Clay bunker discharge table feeder type.	One
29.	Clay recycle conveyor (belt)	One
30.	Clay proportion (weigh belt)	One

ANNEXURE III-6
(p.p.8)

4	5
Cap : 15 Te/hr.	M.S.
Cap : 5 Te/hr Dimension : Width = 0.40 m Length = 20 m	M.S. and Rubber
Cap : 10 Te/hr Height = 20 m	M.S.
Cap : 10 Te/hr Height = 20 m	M.S.
Cap : 2 Te/hr variable	M.S. and Rubber
Cap : 10 Te/hr Ht.=20M	M.S.
Cap : 5 Te/hr variable	M.S.
Cap : 5 Te/hr Length = 5 m Width = 0.400m	M.S. and Rubber
Cap : 5 Te/hr	M.S.and Rubber

1	2	3	
31.	Component collection belt conveyor	One	Cap:
32.	Coke/iron stocking out conveyor	One	Cap:
33.	Coke stocking out conveyor	One	Cap:
34.	Coke reclaim conveyor	One	Cap:
35.	Coke/iron conveyor	One	Cap:
36.	Coke proportioner (weigh belt)	One	Cap:
37.	Iron Proportioner (weigh belt)	One	Cap:
38.	Component elevator	One	Cap:

ANNEXURE III-6
(p.p. 9)

4	5
10 Te/hr Width = 0.400 m Length = 25 m	M.S. and Rubber
10 Te/hr Width = 0.40 m Length = 50 m Lift = 3 m	M.S. and Rubber
10 Te/hr Width = 0.500 m Length = 25 m	M.S. and Rubber
5 Te/hr Width = 400 mm Length = 15 mm	M.S. and Rubber
10Te /hr Width = 500 mm Length = 40 mm	M.S. and Rubber
5 Te/hr variable	M.S. and Rubber
2 Te/hr variable	M.S.
10 Te/hr Height = 25 m	M.S.

1	2	3
39.	Mill feed conveyor (scrapper conveyor)	One
40.	Mill component conveyor (scrapper conveyor)	One
41.	Mill component elevator (bucket elevator)	One
42.	Weigh belt component proportioner	One
43.	Scrapper conveyor for raw meal	One
44.	Weight belt for component proportioning	One
45.	Clay/sand/coke dryer	One
46.	Clay mill (shredder) (hammer crusher for sticky raw material).	One

ANNEXURE III-6
(p.p. 10)

4	5
Cap : 10 Te/hr Length : 5 m	M.S.
Cap : 10 Te/hr Dimension : Length = 15 m	M.S.
Cap : 10 Te/hr Dimension : Height = 25 m	M.S.
Cap : 10 Te/hr variable	M.S. and Rubber
Cap : 40 Te/hr Dimension : Length = 10 m	M.S. and Rubber
Cap : 10 Te/hr variable	M.S. and Rubber
Cap : 5.2 Te/hr Dimension : Dia = 2.0 m Length= 20 m	M.S. and Rubber
Cap : 5 Te/hr	M.S.

1	2	3
47.	Mobile shovel diesel powered	Two
48.	Roll crusher for coke	One
49.	Tube mill for components	One
50.	Raw meal mixer (Rotary drum type)	One
51.	Sand intake hopper	One
52.	Clay intake hopper	One
53.	Clay dryer feed hopper	One
54.	Dry sand bunker	One
55.	Dry clay bunker	Two

ANNEXURE III-6

(p.p. 11)

4	5
Cap : Bucket cap = 0.6 m^3	M.S.
Cap : 5 Te/hr Feed size = 70 mm Product size = 20 mm	C.S. & C.I.
Cap : 5 Te/hr Feed size = 20 mm Product size = 85 % passing through 170 mesh.	C.S.
Cap : 40 Te/hr	M.S.
Cap : 5 M^3	Concrete
Cap : 5 M^3	Concrete
Cap : 1.5 M^3	M.S.
Cap : 15 M^3 Height = 3 m Dia = 2.5 m	Concrete
Cap : 27 M^3 Height = 3.5 m Dia = 3.2 m	Concrete

1	2	3
56.	Clay preweigher hopper	One
57.	Coke intake hopper	One
58.	Coke finer hopper	One
59.	Coke bunker	One
60.	Laterite bunker	One
61.	Mixer feed bunker	One
62.	Mill feed bunker	One

ANNEXURE III-6
(p.p. 12)

4	5
Cap : 1.5 M^3 Dimension : Dia = 1330 mm Ht. = 1500 mm	M.S.
Cap : 5 M^3	Concrete
Cap : 5 M^3	M.S.
Cap : 62.5 M^3 Dimension : Height = 5 m Dia = 4 m	M.S.
Cap : 6.5 M^3 Dimension : Height = 2.5 m Dia = 1.85 m	M.S.
Cap : 5 M^3 Dimension : Height = 2 m Dia = 1780 mm	M.S.
Cap : 5 M^3 Dimension : Height = 2 m Dia = 1780 mm	M.S.

1	2	3
C.	<u>Raw Meal Storage and Kiln Feed Section</u>	
1.	Raw meal silo dust fan Diff Press : 150 mm WG.	One
2.	Scavenger fan, Diff. Press : 150 MM WG	One
3.	Kiln Silo dust fan Diff. Press : 150 mm WG.	One
4.	Scavenger Fan, Diff. Press : 150 mm WG	One
5.	Raw meal silo dust collector including dust discharge arrangement	One
6.	Kiln silo dust collector	One
7.	Raw meal silo elevator	One

ANNEXURE III-6
(p.p. 13)

4	5
Cap : 150 M^3/Min.	M.S.
Cap : 50 M^3/Min.	M.S.
Cap : 150 M^3/Min.	M.S.
Cap : 50 M^3/Min.	M.S.
Cap : 150 M^3/Min. Dimension : Filter Area =137M^2	M.S. & Cloth
Cap : 150 M^3/Min. Dimension : Filter Area = 137M^2	M.S. & Cloth
Cap : 40 Te/hr Dimension : Height = 20 m	M.S.

1	2	3
8.	Raw meal distributor Scrapper conveyor.	One
9.	Raw meal distributor scrapper conveyor.	One
10.	Rotary feeder (Air lock type)	Four
11.	Raw meal collection conveyor (scrapper conveyor)	Two
12.	Raw meal feed elevator	One
13.	Kiln feed conveyor (scrapper conveyor)	One
14.	Kiln feeder (weigh belt)	Two
15.	Rotary feeder (Air lock type)	Eight
16.	Raw meal silo with air flow inducers	Two

ANNEXURE III-6

(p.p. 14)

4	5
Cap : 40 Te/hr Dimension : Length = 25 m	M.S.
Cap : 40 Te/hr Dimension : Length = 20 m	M.S.
Cap : 40 Te/hr	M.S.
Cap : 40 Te/hr Dimension : Height = 25 m	M.S.
Cap : 40 Te/hr Dimension : Height = 30 m	M.S.
Cap : 40 Te/hr Dimension : Length = 10 m	M.S.
Cap : 40 Te/hr variable	M.S.& Rubber
Cap : 40 Te/hr	M.S.
Cap : 900 M^3 Dimension : Height = 12 m Dia = 10 m	M.S.

1	2	3
17.	Kiln feed silo with air flow inducers.	two
18.	Air compressor (Root's type) for inducing flow in raw meal silo of suitable capacity.	One
19.	Air compressor (Root's type) for kiln feed silo of suitable capacity.	One

ANNEXURE III-6
(p.p. 15)

4	5
Cap : 30 M^3 Dimensions : Height = 4 m Dia = 3.10 m	M.S.
-	M.S. & C.I.
-	M.S. & C.I.

Sl. No.	Items	No. Reqd.
D.	<u>Cement Kiln Section</u>	
1.	Tertiary air blower, centrifugal type.	One
2.	Combustion air fan (Primary air)	One
3.	Cement rotary kiln	One
4.	Cement cooler Type : Grate cooler	One
5.	Fan for grate cooler (Centrifugal) Diff. Press : 100 mm WG.	One
6.	Product breaker Type : Hammer crusher	One

ANNEXURE III-6

(p.p. 16)

Brief Specification	Material of Construction
Cap : 5000 Nm^3/hr at 150 mm WG.	M.S.
Cap : 13000 Nm^3/hr at 100 mm WG.	M.S.
Cap : 325 Te/day cement clinker. Dimension : Inside dia = 3.87 m O.D. = 4.27 m Length = 103.50 m Linging = 200 mm Refractory	M.S. & Refractory Lined.
Cap : 325 Te/day cement clinker. Dimension : Grate area = 14.0M^2	C.S.&C.I.
Cap : 41000 Nm^3/hr	C.S.
Cap : 20 Te/hr Dimention : Rotor Dia = 1200 mm No.of hammer= 8	C.S.& C.I.

1	2	3
7.	Fuel oil heater Type : Electrically heated.	Two
8.	Fuel oil pump Type : Gear	Two
9.	Supension preheater for raw meal complete in all respects. Gas Rate : 163000 M^3/hr at 900°C.	One

ANNEXURE III-6
(p.p. 17)

4	5
Cap ; heat duty = 50×10^3 Kcl/hr	M.S.
Cap : 5 M^3/hr at 3 Kg/cm^2 press.	M.S. & C.I.
Cap : 35 Te/hr. raw meal	M.S.

ANNEXURE III-6
(p.p. 18)

Sl. No.	Items	No. Reqd.	Brief specification	Material of Construction
1	2	3	4	5
E.	Clinker Handling & Storage			
1.	Reclaiming dust fan Suction Press: (-) 150 mmWG.	One	Cap : 150 M^3/Min.	M.S.
2.	Reclaiming dust filter including dust discharge arrangement.	One	Cap : 150 M^3/Min.	M.S. & Cloth
3.	Clinker collection conveyor scrapper conveyor.	Two	Cap : 20 Te/hr. Dimension : Length = 30 m Lift = 5 m	M.S.
4.	Clinker distribution conveyor Scrapper type	Two	Cap : 20 Te/hr. Dimension : Length = 20 m Lift = 3 m	M.S.
5.	Clinker reclaimer Type : Rotary ploughs	Two	Cap : 20 Te/hr	C.S.
6.	Clinker reclaim conveyor scrapper type	One	Cap : 20 Te/hr Dimension : Length = 30 m Lift = 3 m	M.S.
7.	Dust conveyor (Screw)	One	Cap : 0.5 Te/hr Dimension : Length = 5 m	M.S.

ANNEXURE III-6
(p.p. 19)

Sl. No.	Items	No. Reqd.	Brief Specification	Material of construction
1	2	3	4	5
F.	<u>Sulphuric Acid & Gas Washing</u>			
1.	Cyclone separator (Working in parallel)	Three	Cap : 90,000 M^3/hr at 150°C Total. Dimension : Dia = 1750 mm Height = 2650 mm	M.S.
2.	Star valve	Three	Cap : 200 Kg/hr Dimension : Dia = 380 mm Width = 300 mm	M.S.
3.	Dust transfer conveyor (Screw conveyor)	One	Cap : 1 Te/hr	M.S.
4.	Dust conveyor (Screw)	One	Cap : 200 Kg/hr	M.S.
5.	Dust precipitator Type : Electrostatic type.	One	Cap : 90,000 M^3/hr at 150°C	M.S.
6.	SO_2 gas scrubber Type : Spray	One	Cap : 90,000 M^3/hr Dimension : Dia = 4000 mm Height = 6500 mm	M.S. lead lined.
7.	Air fan for SO_2 gas scrubber with filter, centrifugal type	One	Cap : 1500 Nm^3/hr Diff. Press : 200 mmWG.	M.S.

1	2	3
8.	Dust Conveyor (Screw)	One
9.	Recirculation pump for SO_2 scrubber, Type : Centrifugal	One
10.	Seal pot	One
11.	Mist precipitator I Type : Electrostatic type	One
12.	Mist precipitator II Type : Electrostatic type	One
13.	Seal pot for mist precipitactor - I	One
14.	Seal pot for mist prepitator - II	One

ANNEXURE III-6

(p.p. 20)

4	5
Cap : 800 Kg/hr	M.S.
Cap : 18 M^3/hr with 10 meter head.	M.S.
	M.S. lead lined.
Cap : Flow Gas : 57600 Nm^3/hr	Shell : M.S. Tube : Lead
Cap : Flow Gas = 53037 Nm^3/hr Water = 191 M^3/hr Dimension : 208.87 M^2 Heat transfer area.	M.S. and lead
	M.S.lead lined.
	M.S. and lead lined.

1	2	3
15.	Drying tower for SO_2 gases* Type : packed column.	One
16.	Drying tower for air Type : Packed column	One
17.	Absorption tower*	One
18.	Converter 4 stage*	One

ANNEXURE III-6
(p.p. 21)

4	5
Cap : Flow Gas = 66622 Nm^3/hr H_2SO_4 = 543 Te/hr Dimension : I.D. = 6520 mm Height = 11,110 mm Packing = 50 x 50 mm Ceramic raschig ring.	M.S.& Acid proof brick and lead lined.
Cap : Flow Air = 16650 Nm^3/hr H_2SO_4 = 131 Te/hr Dimension : I.D. = 2830 mm Packed height = 12000mm Packing =50 x 50 mm Ceramic raschig ring.	Shell : M.S. Lining : Acid proof bricks and lead, Packing:Ceramic
Cap : Flow Gas = 61632 Nm^3/hr H_2SO_4 = 685 Te/hr Dimension : I.D. = 6520 mm Height = 11,110 mm	-do-
Cap : Flow Gas = 66622 Nm^3/hr Dia = 7950 mm	- do - Grate : C.I. Catalyst : Vanadiam Pentaoxide.

ANNEXURE III-6
(p.p. 22)

1	2	3	4	5
19.	Air dyring tower acid cooler*	One	Cap : Flow Tube side = 830Te/hr H_2SO_4 Out side = Water 1310 M^3/hr Dimension : 592 M^2	C.I.
20.	Drying tower acid cooler* Type : Trombone	One	Cap : Flow Tube side = 600 Te/hr H_2SO_4 Out side = Water 210 M^3/hr. Dimension : 1169 M^2	C.I.
21.	A.T. Pump Tank*	One	Cap : 77 M^3	Acid proof brick lined.
22.	D.T. pump tank*	One	Cap : 56 M^3	-do-
23.	A.T. circulation pump* Type : Centrifugal, Submerged.	One	Cap : 14.6 M^3/Min.	C.I. and M.S.
24.	D.T. circulation pump* Type : Centrifugal, submerged.	One	Cap : 14.7 M^3/Min.	C.I. and M.S.
25.	Cooling water return pump* Type : Centrifugal	Two	Cap : 1520 M^3/hr.	M.S. and C.I.

ANNEXURE III-6
(p.p. 23)

1	2	3	4	5
26.	Cooling water circulation pump*	Two	Cap : 1200 M^3/hr	M.S & C.I.
27.	Booster fan, centrifugal type@ Inlet press : 1.05 Kg/cm^2a Outlet press:1.4 Kg/cm^2a	-	Cap : 66622 Nm^3/hr at 55°C	M.S.
28.	Product acid storage tank*	One	Cap : 400 M^3 Dimension : Dia = 8 m Height = 8 m	M.S.
29.	Product transfer pump* centrifugal type	One+One	Cap : 12 M^3/hr	M.S.
30.	Stack*	One	Cap : 66650 Nm^3/hr at 80°C Dimension: Height = 30 m Dia = 2.76 m	
31.	Heat Exchanger, type* shell and tube vertical	One	Cap : Heat duty = 16×10^5 kcal/hr Dimension : Tube = 1135 Nos. O.D. = 50.8 mm Length = 4500 mm Area = 815.12 m^2	M.S.
32.	Heat Exchanger+ Tube : shell & tube vertial	One	Cap : 34×10^5 kcal/hr Dimension : Area = 2509.51 m^2	M.S.

@ Existing blower K 1201 may be used with new motor ; If steam is available existing system may be used.

ANNEXURE III-6
(p.p. 24)

1	2	3	4	5
33.	Heat Exchanger+ Type : Shell & Tube vertical	One	Cap : 1608x10^5 kcal/hr Dimension : Area 1223 M^2	M.S.
34.	Heat Exchanger* Type : Shell & tube vertical	One	Cap : 50 x 10^4 kcal/hr Dimension: Area 214.79 M^2	M.S.
35.	Air fan*, Dis.press:500 mmWG Type : Centrifugal	One	Cap : 20,000 Nm^3/hr.	M.S.
36.	Start up heater and accessories + of sulphuric acid plant including	One set	Cap : 63 x 10^5 kcal/hr	
	1. Oil storage		Cap 64 M^3	
	2. Oil burning furnace		Cap : 12 x 10^6 kcal/hr Dimension : 104.25 M^3	
	3. Oil pumping unit		Cap : 1500 kg/hr	
	4. Primary air blower		Cap : 10000 Nm^3/hr	
	5. Secondary air blower		Cap : 40000 Nm^3/hr	
	6. Oil heater (Electrically heated)	One	Cap : Temp.inlet = 30°C Outlet = 80°C	M.S.

\+ New * Existing

1	2	3
37.	Cooling tower * Induced draft type	One

* Existing

ANNEXURE III-6

(p.p. 25)

4	5
Cap : 2100 M^3/hr Temp. : Inlet 40°C Outlet 32°C Dimension : 237.87 M^2 area	Deodar cheer wodd

ANNEXURE III-7

CAPITAL COST ESTIMATES

(Figs. in $ '000)

Items	Estimated Cost		
	F.C.	L.C.	Total
I. Manufacturing Facilities			
1. Main Plant Equipment	12600.0	1400.0	14000.0
2. Off Sites -			
i) Power supply and Distribution	533.0	67.0	600.0
ii) Auxiliary Services	90.0	10.0	100.0
iii) Effluent Treatment & disposal	27.0	7.0	34.0
iv) Water Supply & Distribution	50.0	5.0	55.0
3. Project Management	-	400.0	400.0
4. License Fee, Design Engg. & Procurement	3549.0	-	3549.0
5. Civil Works	221.0	2132.7	2353.7
6. Erection, Supervision & Commissioning	1322.7	1886.3	3209.0
7. Freight, Insurance & Handling	1410.7	449.7	1860.4
8. Duties & Taxes	-	3245.6	3245.6
9. Erection Tools & Tackles	-	40.0	40.0
Total	19803.4	9643.3	29446.7

ANNEXURE III-7
(p.p. 2)

Items	Estimated Cost		
	F.C.	L.C.	Total
II. Other Fund Requirements			
10. Spares (landed cost)	1235.9	413.7	1649.6
11. Working Capital	-	854.0	854.0
12. Contingency	2104.9	1091.1	3196.0
13. Escalation	3703.1	2880.5	6583.6
14. Financing Charges	-	3367.2	3367.2
15. Commissioning Expenses	-	1004.1	1004.1
TOTAL FUND REQUIREMENT	26847.3	19253.9	46101.2
Credit for Production during Trial Runs	-	(1614.4)	(1614.4)
Net Project Cost	26847.3	17639.5	44486.8

ANNEXURE III-8

WORKING CAPITAL REQUIREMENT

	Item	Unit	Unit Rate $	Period/ Quantity	Total ($'000)
1.	Raw Materials				
	a) Coke/Coke Breeze	Te	167.33/46.67	2 months	261.00
	b) Lime	Te	60.00	1 month	6.00
	c) Sand	Te	1.20	1 week	-
	d) Clay	Te	1.20	1 week	2.50
	e) Laterite	Te	20.00	1 month	5.00
	f) Sulphur	Te	152.00	2 months	195.40
	Sub-total				469.90
2.	Utilities Fuel Oil	Te	66.00	15 days	96.00
3.	Chemical & Consumables			3 months	33.30
4.	Finished Product (Clinker)	Te	30.00	2000/te	60.00
5.	Goods in Process				20.80

ANNEXURE III-8
pp.2

	Item	Unit	Unit Rate $	Period/ Quantity	Total ($'000)
6.	Accounts Receivable (cement clinker)	Te	65.00	15 days	264.00
7.	Accounts Payable			15 days	(110.00)
8.	Cash in hand				20.00
	Total Working Capital				854.00

ANNEXURE III-9

COST OF PRODUCTION

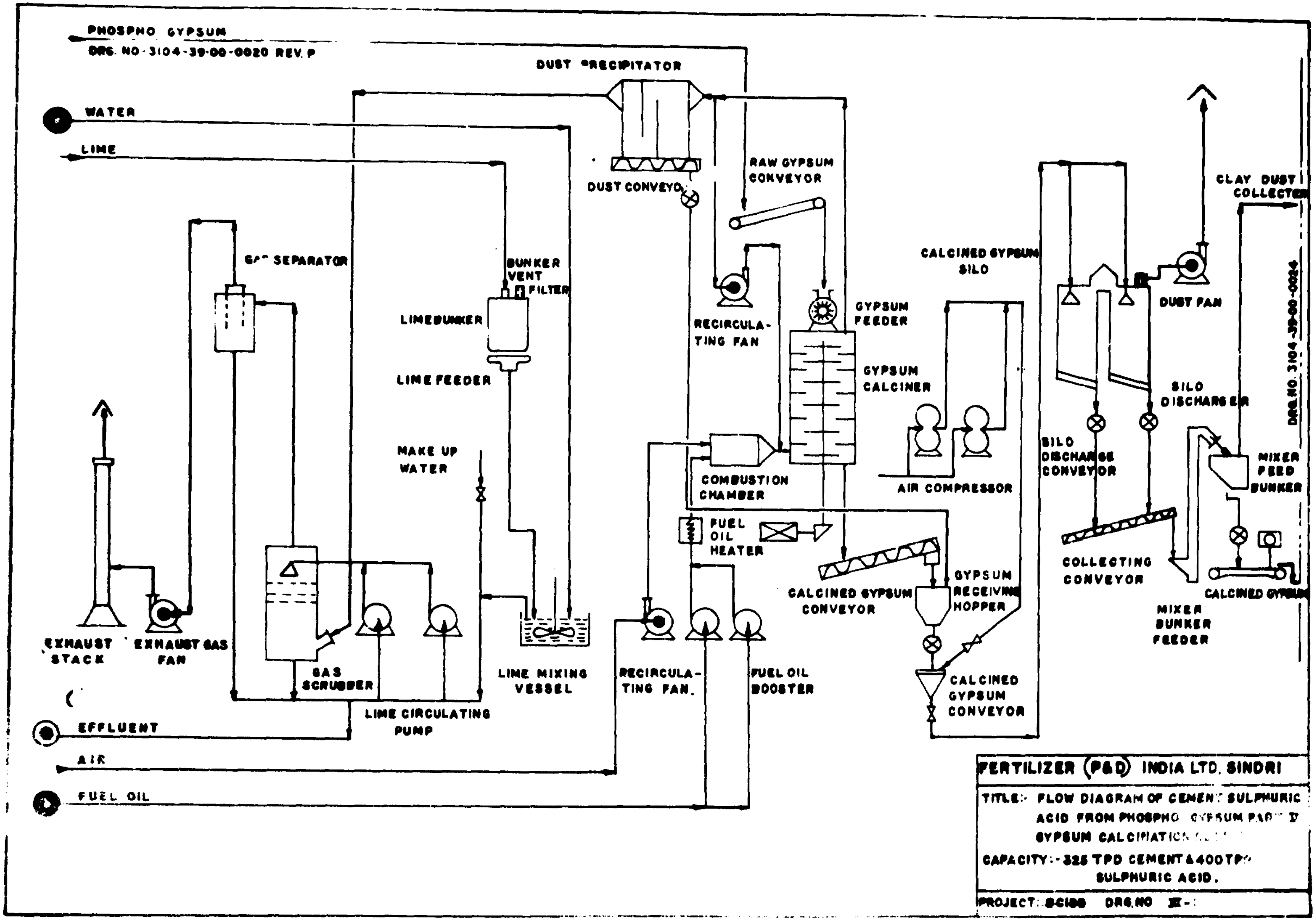
(Level of Production :100 percent)

Item	Unit	Unit Rate $	Annual Consumption	Annual Cost in $ 000			
				Alternative I	Alternative II	Alternative III	Alternative IV
1	2	3	4	5	6	7	8
1. Raw Materials							
i) Gypsum	Te	-	200,000	-	-	-	-
ii) Coke/Coke Breeze	Te	167.33/ 46.67	9372	1568.2	1568.2	437.4*	437.4*
iii) Lime	Te	60.00	1239	74.3	74.3	74.3	74.3
iv) Sand	Te	1.20	2064	2.5	2.5	2.5	2.5
v) Clay	Te	1.20	25560	30.7	30.7	30.7	30.7
vi) Laterite	Te	20.00	3000	60.0	60.0	60.0	60.0
vii) Sulphur -							
a) with Fuel Oil	Te	152.00	7713	1172.4	-	1172.4	-
b) with Nat.Gas	Te	152.00	8207	-	1286.4	-	1286.4
Sub-total				2908.1	3022.1	1777.3	1891.3
2. Utilities							
a) Fuel							
i) Fuel Oil	Te	66.00	34770	2294.8	-	2294.8	-
ii) Natural Gas	000 Nm^3	21.20	38148	-	808.7	-	808.7
b) Process Water	000 M^3	0.13	365.4	47.5	47.5	47.5	47.5
c) Steam	Te	2.67	1500	4.0	4.0	4.0	4.0
d) Power	Mwh	26.70	9300	248.3	248.3	248.3	248.3

ANNEXURE III-9
(p.p. 2)

1	2	3	4	5	6	7	8
3. Consumables	-	-	-	133.4	133.4	133.4	133.4
4. Labour & Overheads				133.3	133.3	133.3	133.3
5. Maintenance Materials				1177.9	1177.9	1177.9	1177.9
6. Insurance & Taxes				221.7	221.7	221.7	221.7
7. Contingency				358.5	289.8	301.9	233.3
Annual Works Cost				7527.5	6086.7	6340.1	4839.4
8. Depreciation				3436.7	3436.7	3436.7	3436.7
9. Average Interest on Term Loan				1342.4	1342.4	1342.4	1342.4
Annual Cost of Production				12306.6	10865.8	11119.2	9618.5
Credit for SO_2	000 Te	58.33	120	(6576.0)	(6576.0)	(6576.0)	(6576.0)
Net Annual cost of Production				5730.6	4289.8	4543.2	3042.5
Annual Production of Clinker	Te			97,500			
COST OF PRODUCTION	$/Te			58.80	44.00	46.60	31.20

* Coke Breeze



FERTILIZER (P&D) INDIA LTD. SINDRI

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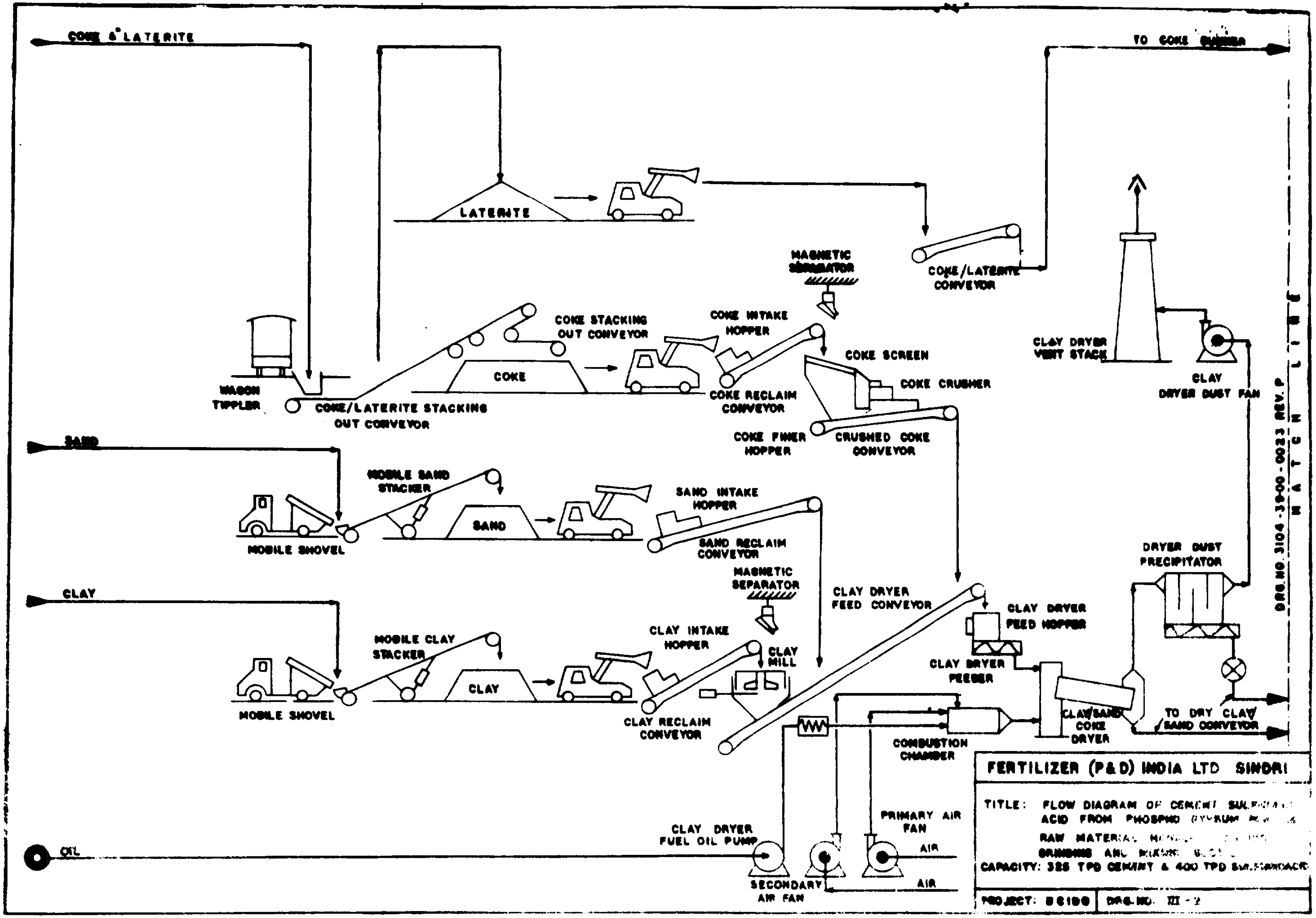
ACID FROM PHOSPHO GYPSUM PART V
GYPSUM CALCINATION [illegible]

CAPACITY:- 325 TPD CEMENT & 400 TPD
SULPHURIC ACID.

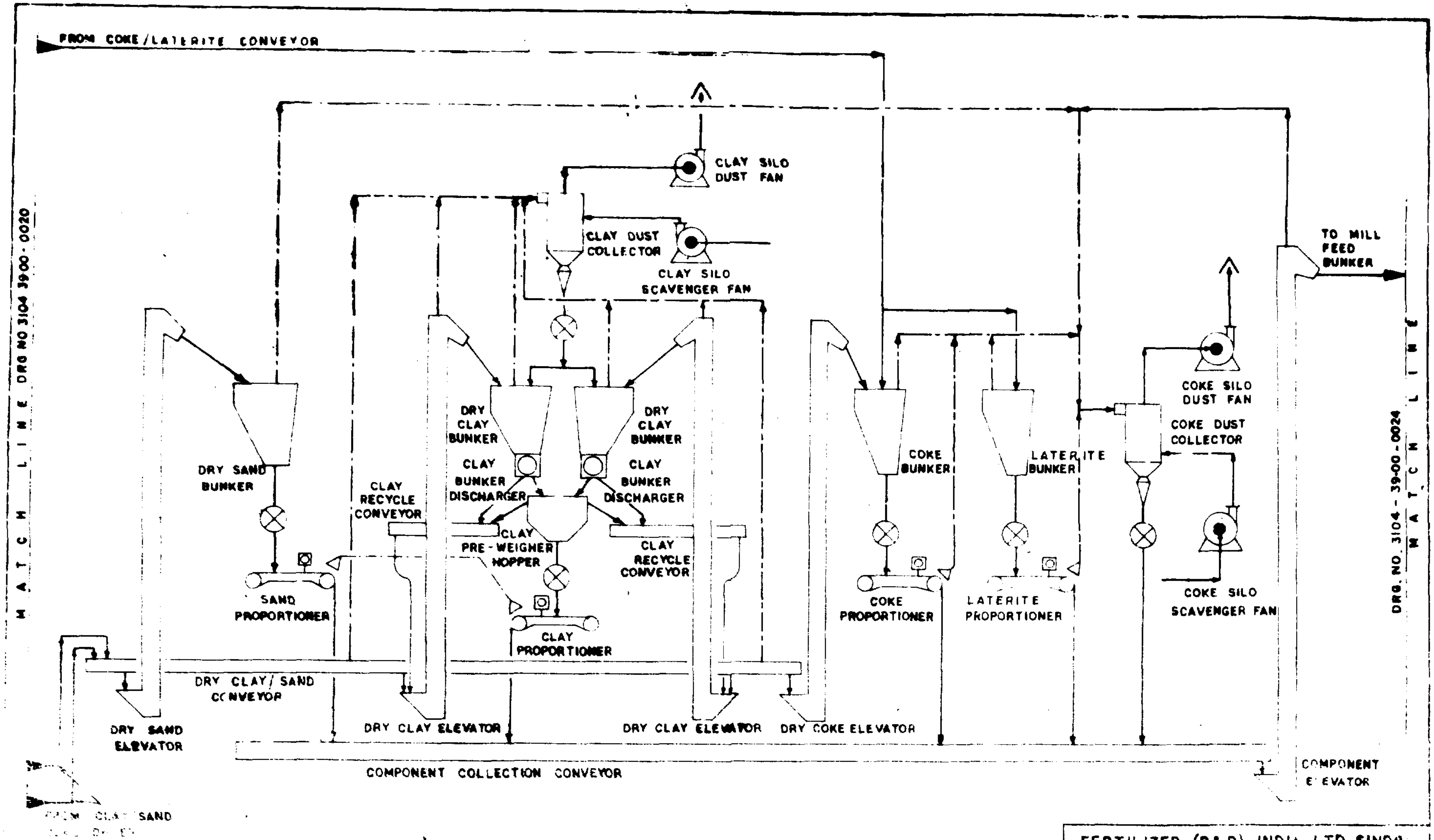
PROJECT: SC188 DRG.NO IV-



FERTILIZER (P&D) INDIA LTD SINDRI

TITLE: FLOW DIAGRAM OF CEMENT SUL[illegible]
ACID FROM PHOSPHO GYPSUM [illegible]
RAW MATERIAL H[illegible]
GRINDING AND MIXING [illegible]
CAPACITY: 325 TPD CEMENT & 400 TPD SULPHURIC

PROJECT: 86100 | DRG. NO. III - 2

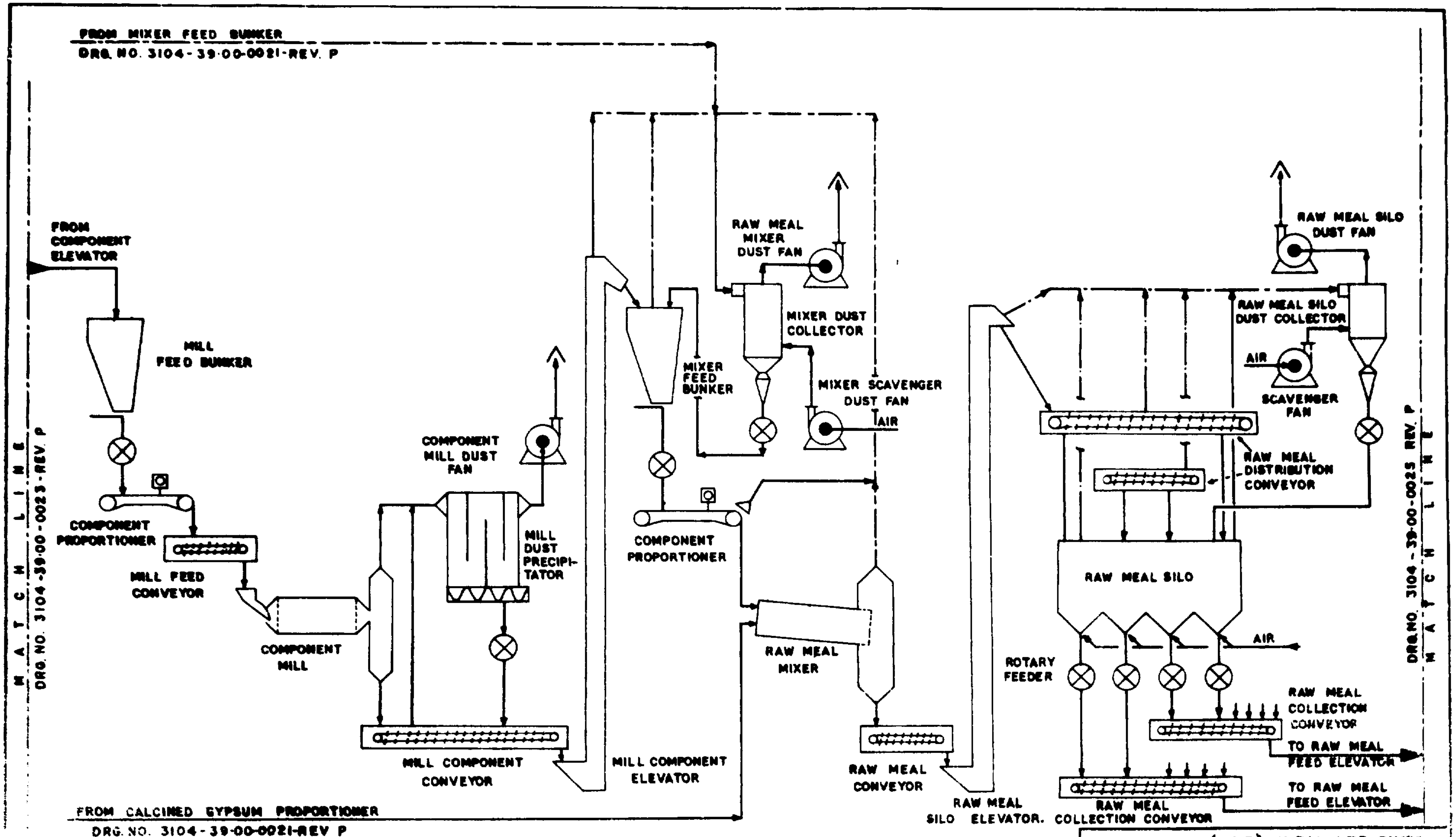


FERTILIZER (P&D) INDIA LTD. SINDRI

TITLE: FLOW DIAGRAM OF CEMENT SULFURIC
ACID FROM PHOSPHO GYPSUM PART
RAW MATERIAL HANDLING [illegible]
GRINDING AND MIXING SECTION

CAPACITY: 325 TPD CEMENT & 400 TPD SULFURIC ACID

PROJ. 8C1DB / DRG. NO. III-3

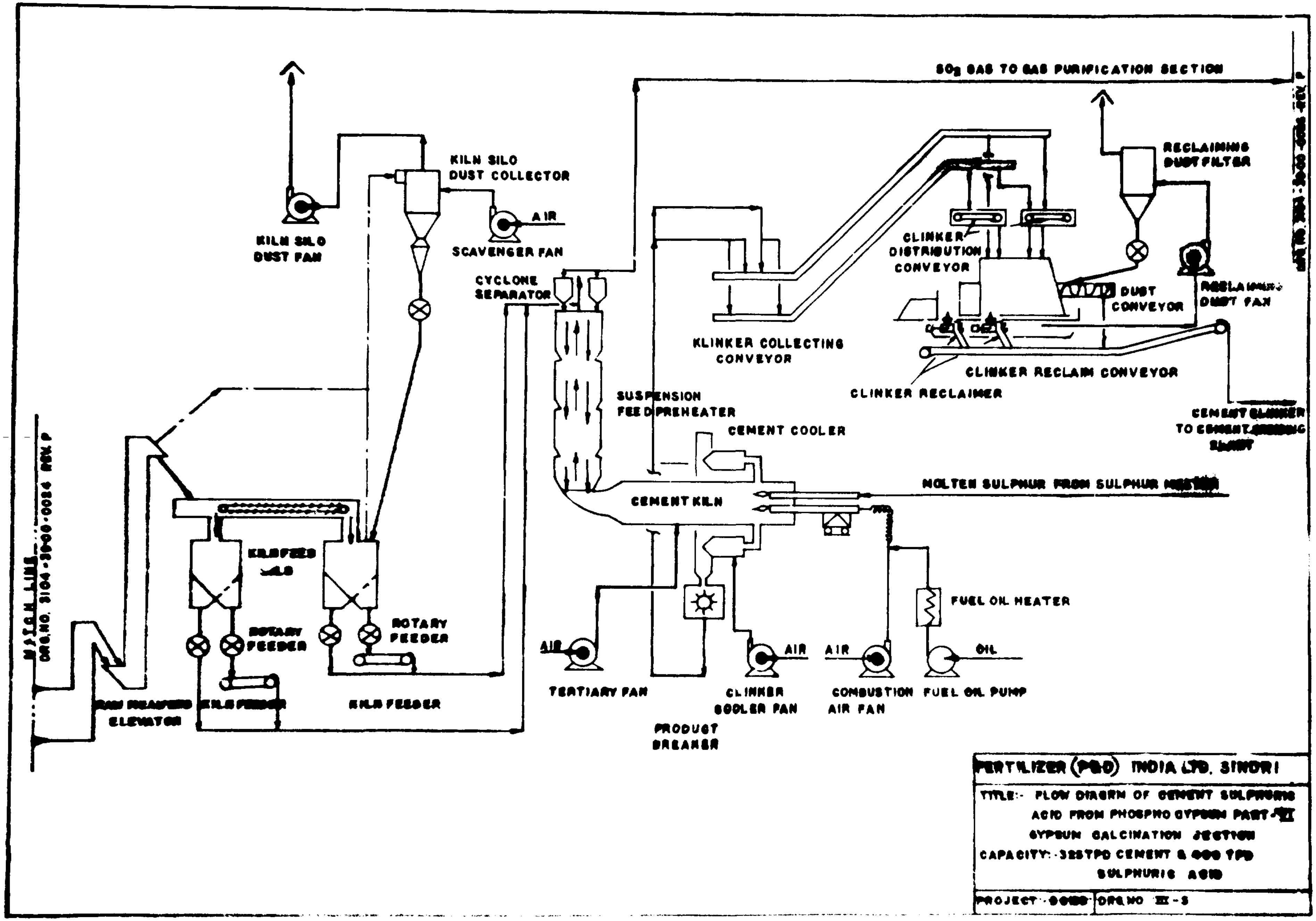


FERTILIZER (P&D) INDIA LTD. SINDRI

TITLE: FLOW DIAGRAM OF CEMENT SULPHURIC
ACID FROM PHOSPHO [illegible]
RAW MATERIAL HANDLING, DRYING,
GRINDING AND MIXING SECTION.

CAP : 325 TPD CEMENT & 400 TPD SULPHURIC ACID

PROJECT: 80108 | DRG. NO. III-4

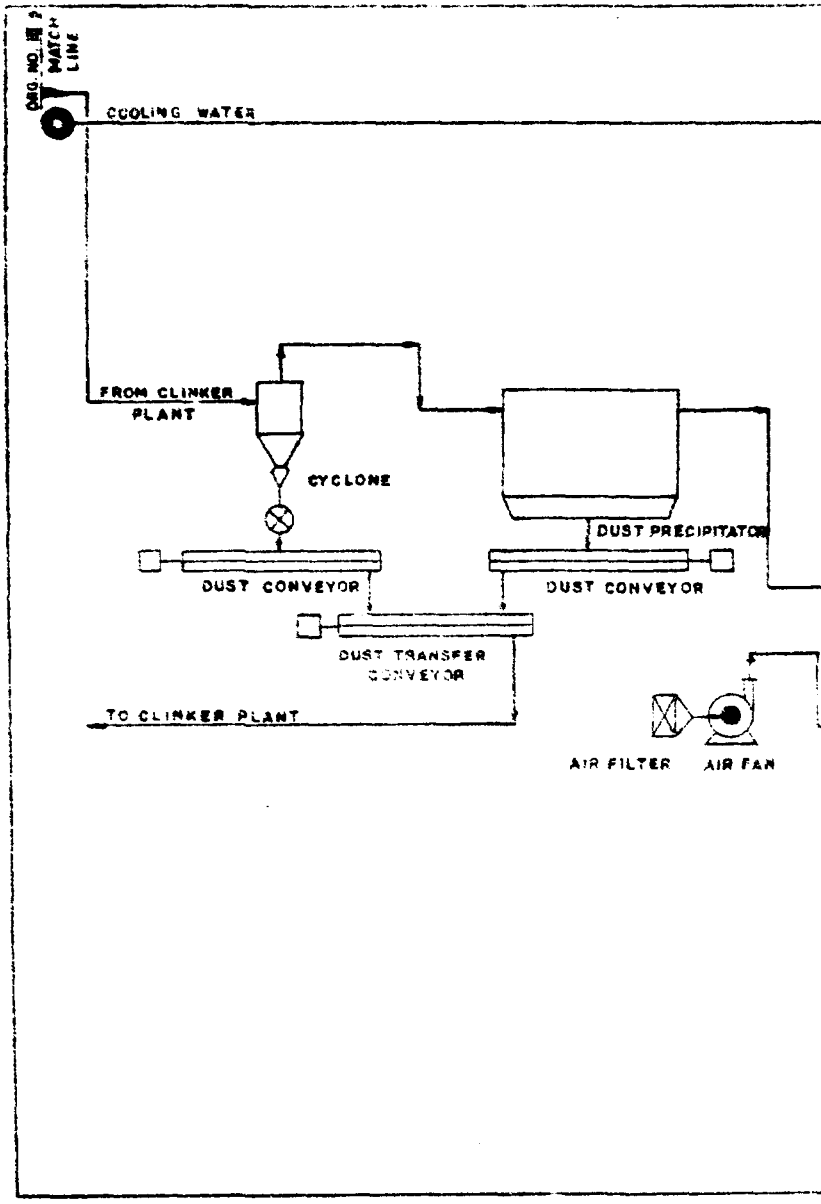


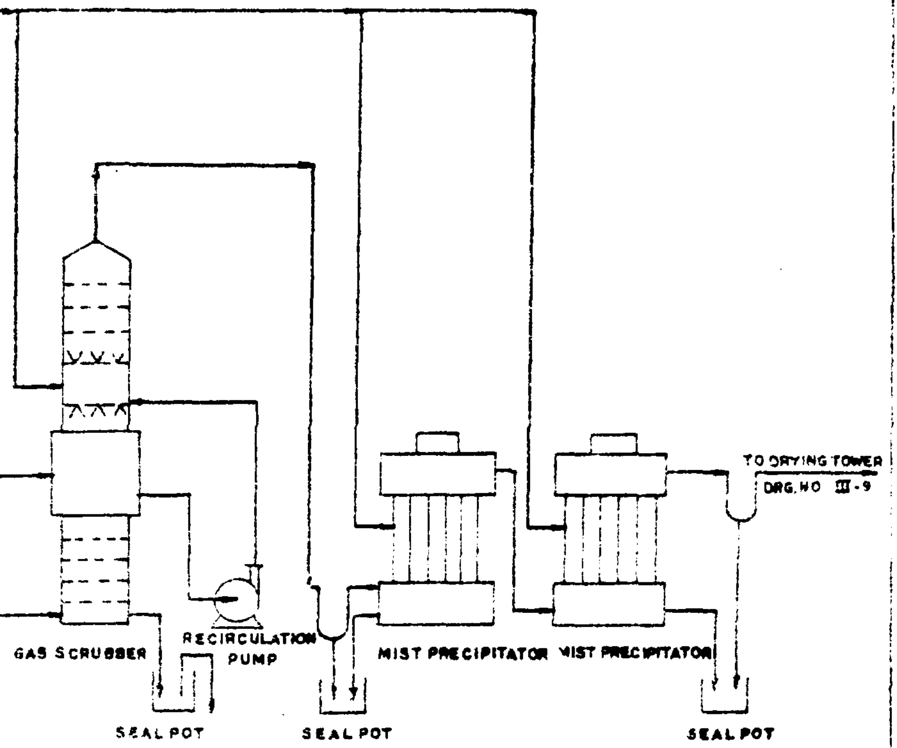
FERTILIZER (P&D) INDIA LTD, SINDRI

TITLE:- FLOW DIAGRAM OF CEMENT SULPHURIC ACID FROM PHOSPHO GYPSUM PART-II
GYPSUM CALCINATION SECTION

CAPACITY:- 325TPD CEMENT & [illegible] TPD SULPHURIC ACID

PROJECT [illegible]	DRG. NO. III - 5


DRG. NO. III 2
MATCH LINE
COOLING WATER
FROM CLINKER PLANT
CYCLONE
DUST PRECIPITATOR
DUST CONVEYOR
DUST CONVEYOR
DUST TRANSFER CONVEYOR
TO CLINKER PLANT
AIR FILTER
AIR FAN

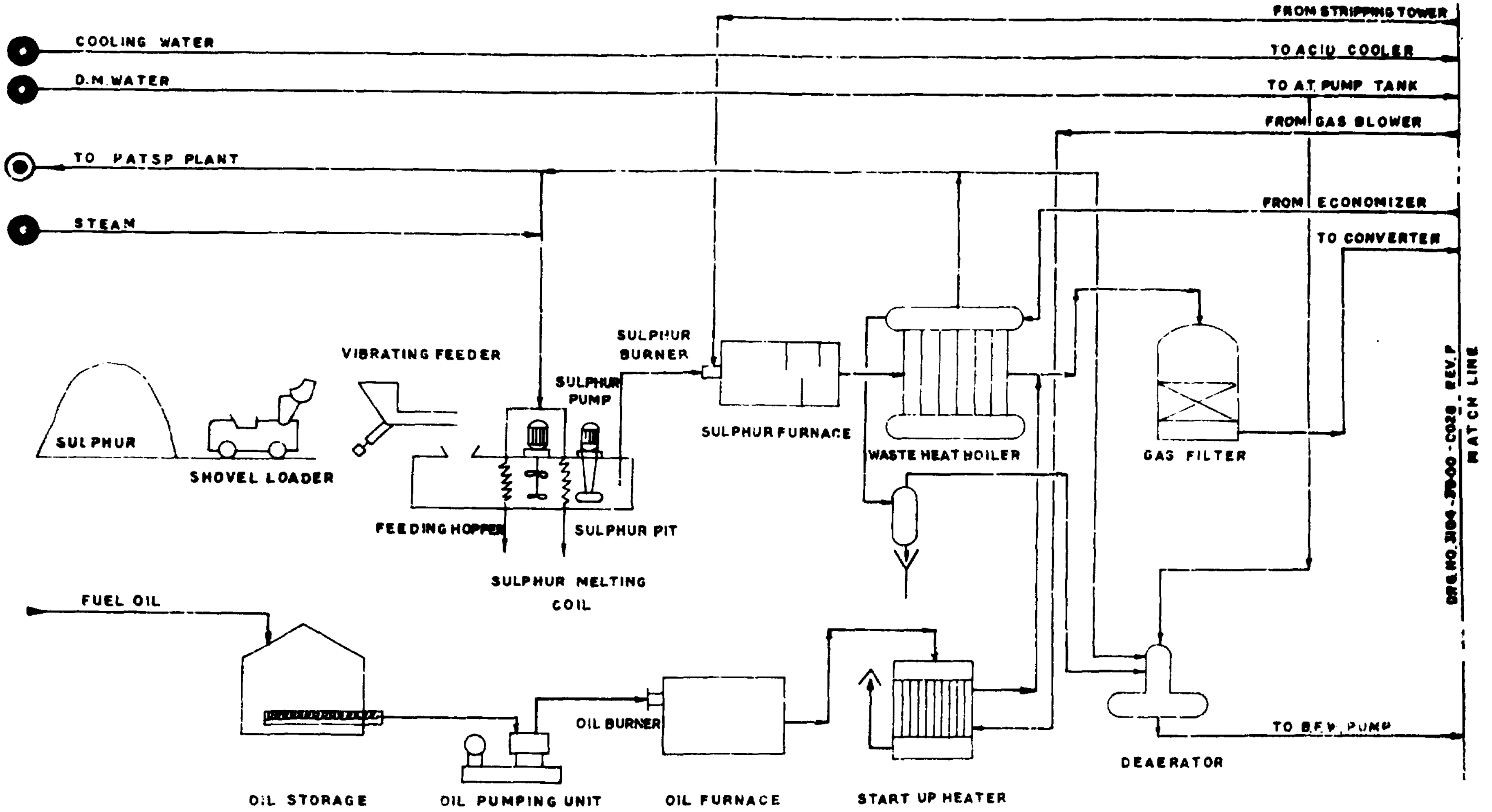


FERTILIZER (P&D) INDIA LTD. SINDRI

TITLE: FLOW DIAGRAM OF CEMENT SULPHURIC
ACID FROM PHOSPHOGYPSUM PART VII
GAS PURIFICATION SECTION

CAPACITY 325 TPD CEMENT & 400 TPD SULPHURIC ACID

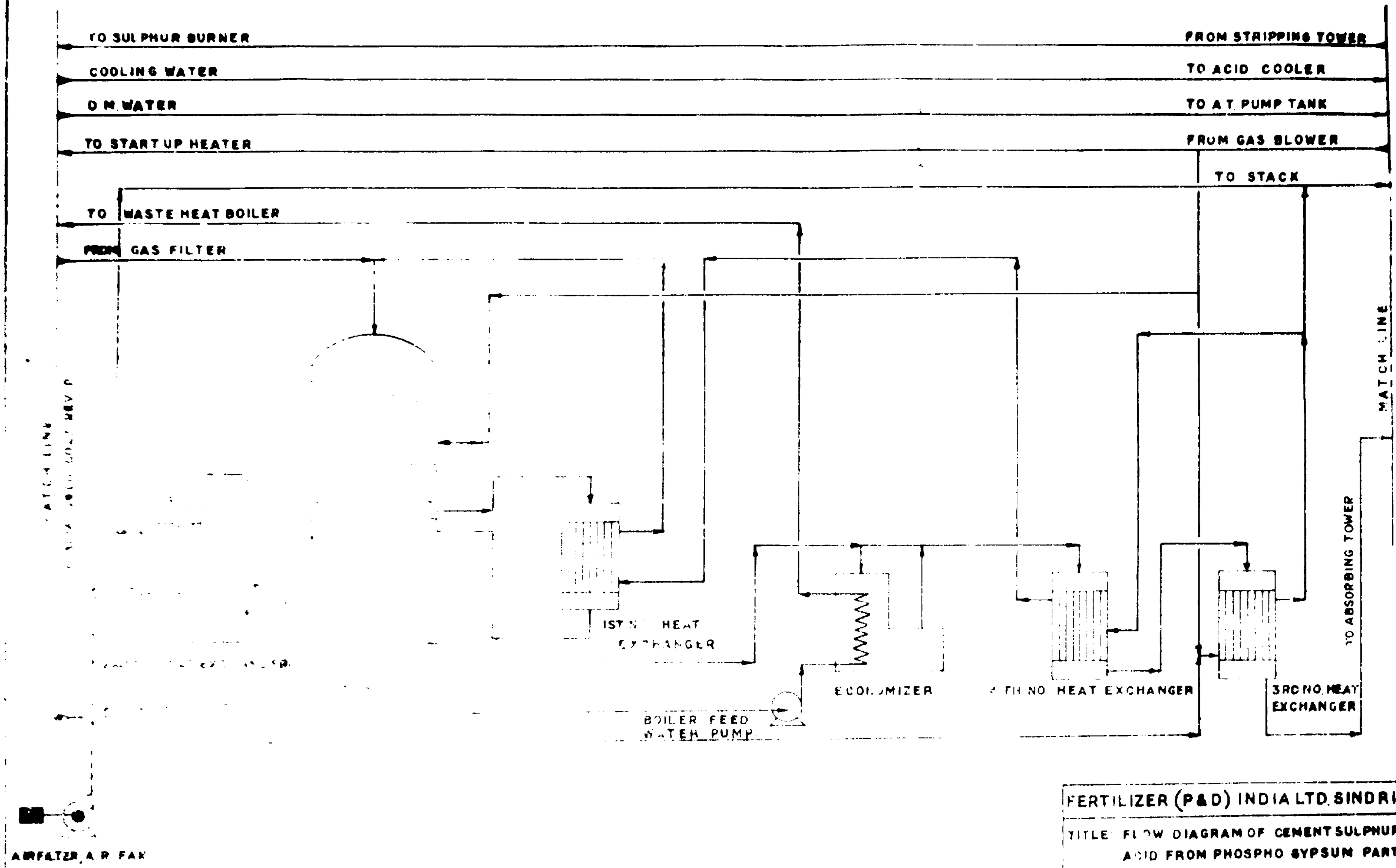
PROJECT 8610B | DRG NO III-6



FERTILIZER (P&D) INDIA LTD. SINDRI

TITLE: FLOW DIAGRAM OF CEMEN[illegible] SUL[illegible]
ACID FROM PHOSPH[illegible]
SULPHURIC ACID S[illegible]

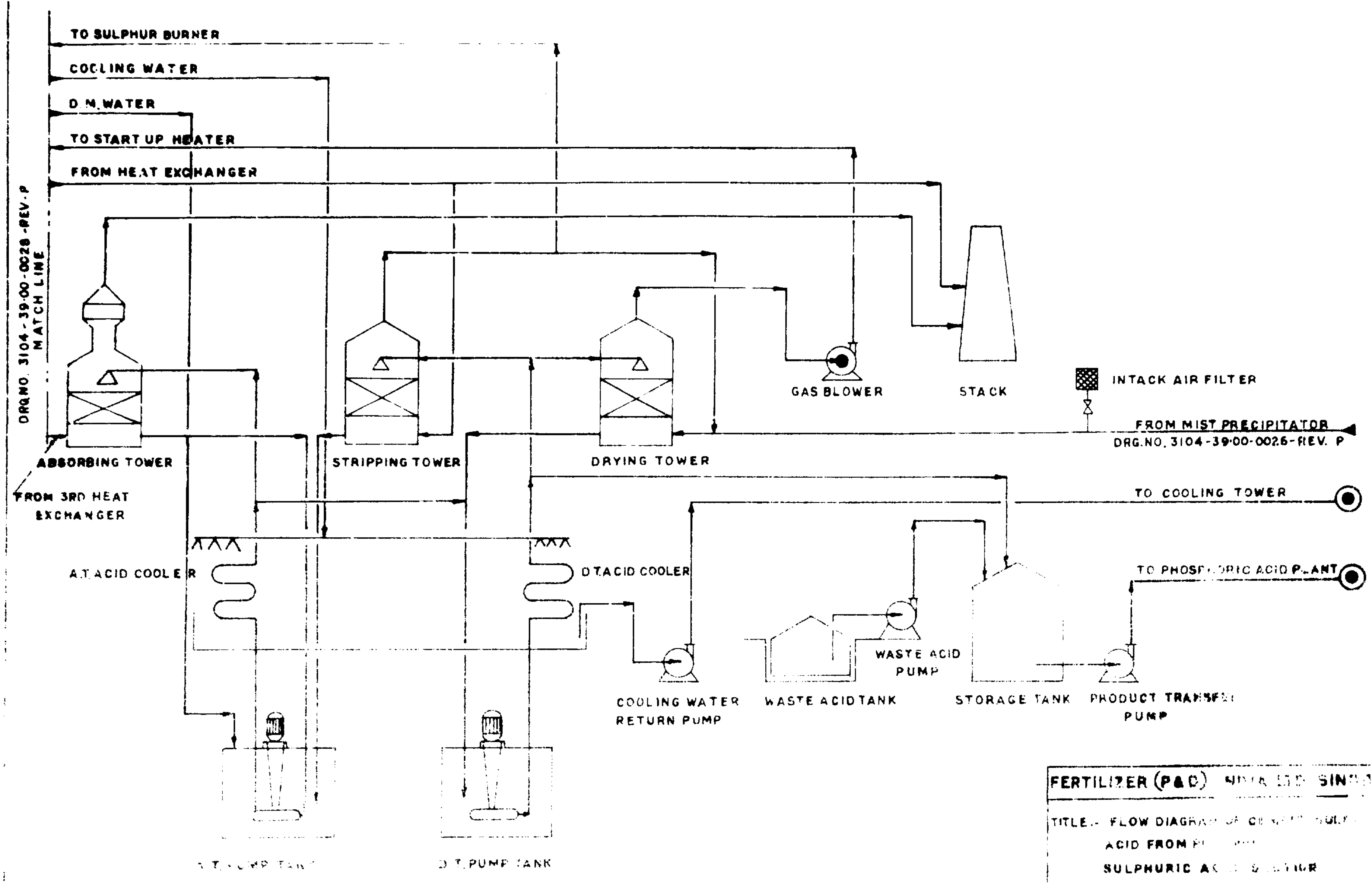
PROJECT BCIDB | DRG NO III-7



FERTILIZER (P&D) INDIA LTD. SINDRI

TITLE FLOW DIAGRAM OF CEMENT SULPHURIC
ACID FROM PHOSPHO GYPSUM PART-IX
SULPHURIC ACID SECTION

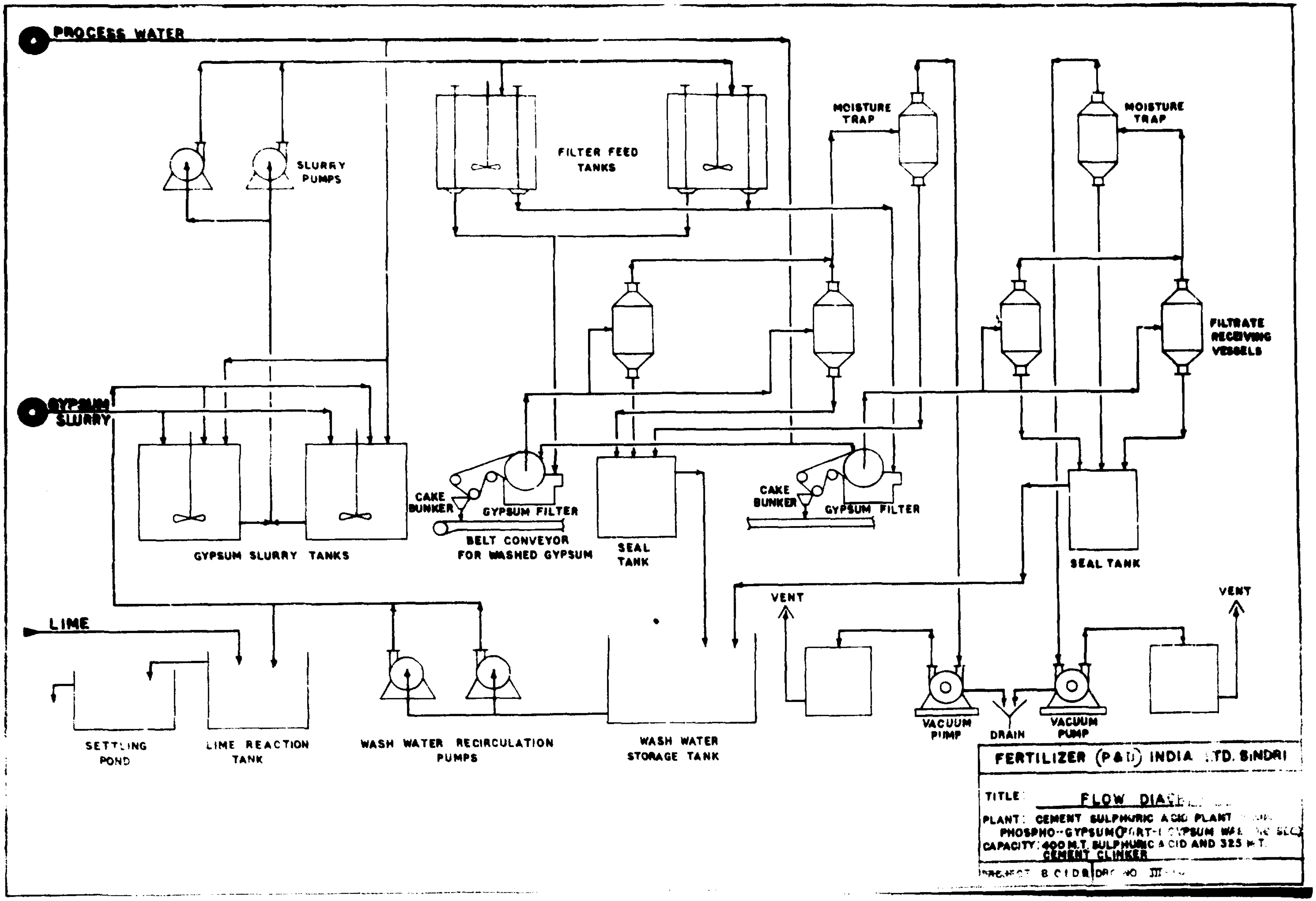
PROJECT-30108
DRG.NO III-8



FERTILIZER (P&C) SIN

TITLE.- FLOW DIAGRAM OF
ACID FROM
SULPHURIC AC

DRG.NO. III-5



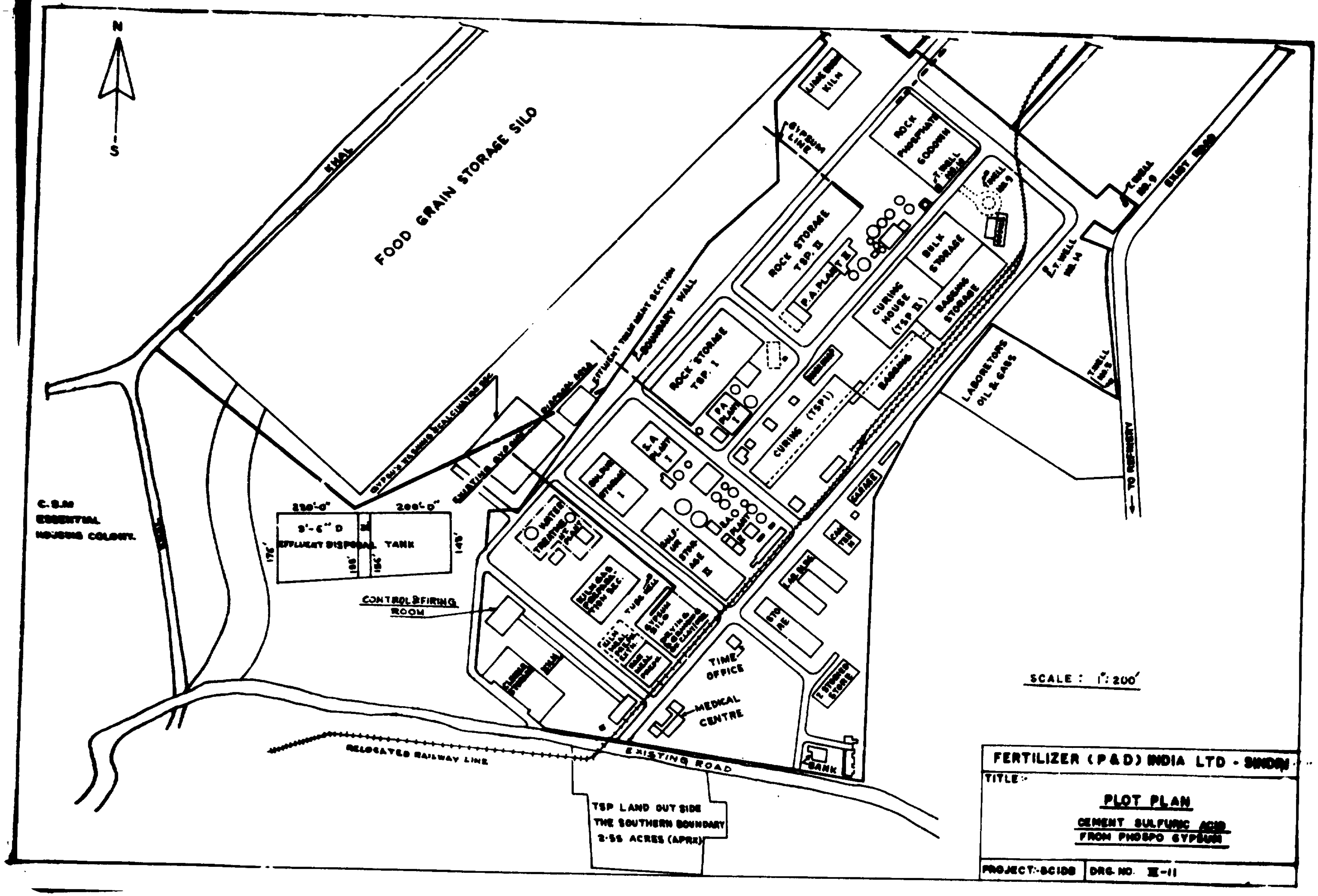
FERTILIZER (P&D) INDIA LTD. SINDRI

TITLE: FLOW DIAGRAM

PLANT: CEMENT SULPHURIC ACID PLANT FROM PHOSPHO-GYPSUM (PART-I GYPSUM WASHING SECTION)

CAPACITY: 400 M.T. SULPHURIC ACID AND 325 M.T. CEMENT CLINKER

PROJECT B C I D R | DRG NO III-



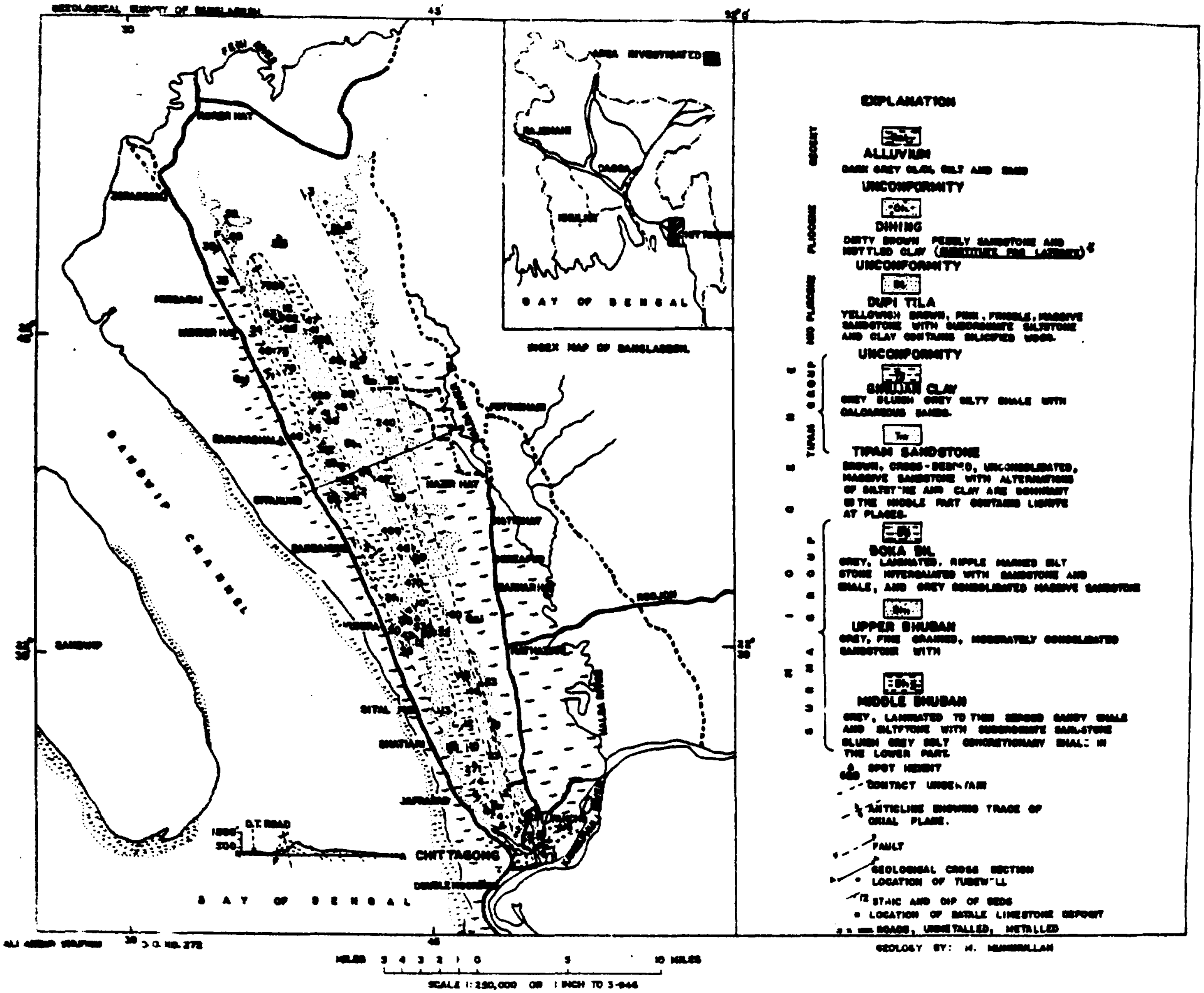
FERTILIZER (P&D) INDIA LTD - SINDRI

TITLE:-

PLOT PLAN

CEMENT SULFURIC ACID FROM PHOSPO GYPSUM

PROJECT:-SCIDS | DRG. NO. III-11

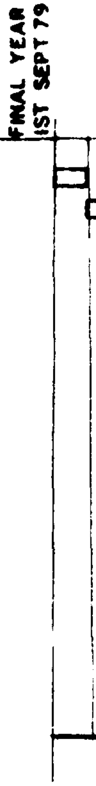


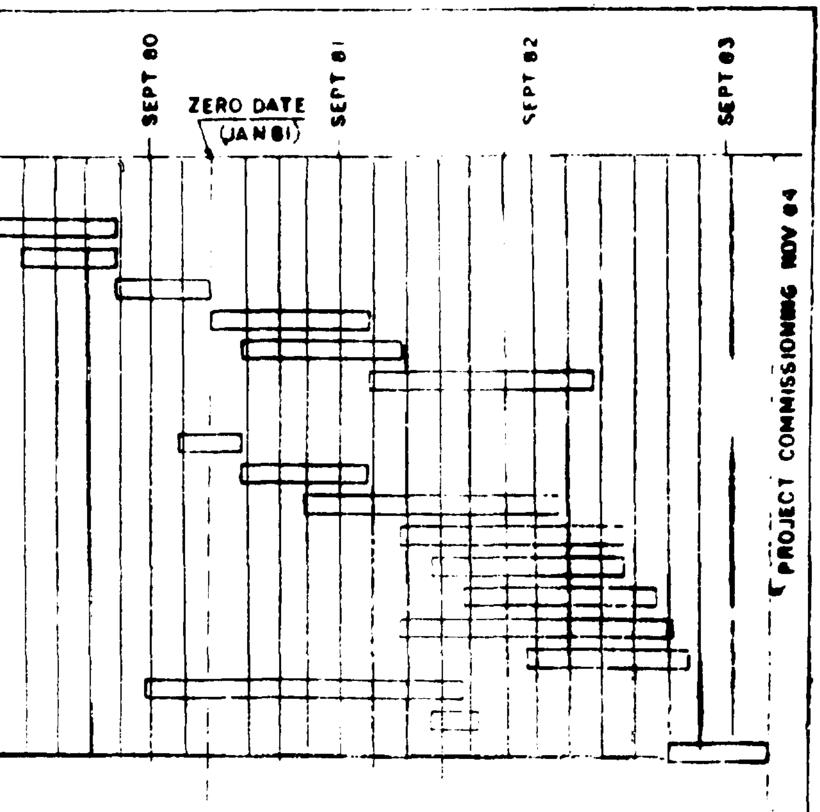
GEOLOGICAL MAP OF THE NORTHERN PART OF CHITTAGONG DISTRICT, BANGLADESH.

PROJECT ILC.D.8
DRG NO. II-12

1. SCRUTINY OF PROJECT REPORT
2. FINANCIAL ARRANGEMENT
3. SELECTION OF PROJECT CONSULTANT
4. SELECTION OF ENGINEERING CONTRACTOR
5. DESIGN AND ENGINEERING OF PLANTS AND FACILITIES
6. ORDERING OF EQUIPMENTS AND SUPPLIES
7. DELIVERY OF EQUIPMENTS AND SUPPLIES

8. SITE PREPARATION
9. CIVIL WORKS DESIGN
10. CIVIL WORKS EXECUTION
11. ERECTION (MECHANICAL)
12. ERECTION (ELECTRICALS)
13. ERECTION (INSTRUMENTS)
14. ERECTION (PIPING)
15. INSULATION AND PAINTING
16. OFF SITE FACILITIES AND UTLITIES
17. TRIAL AND COMMISSIONING OF OFFSITE FACILITIES
18. TRIAL RUNS FOR MAIN PLANT AND COMMISSIONING OF PROJECT

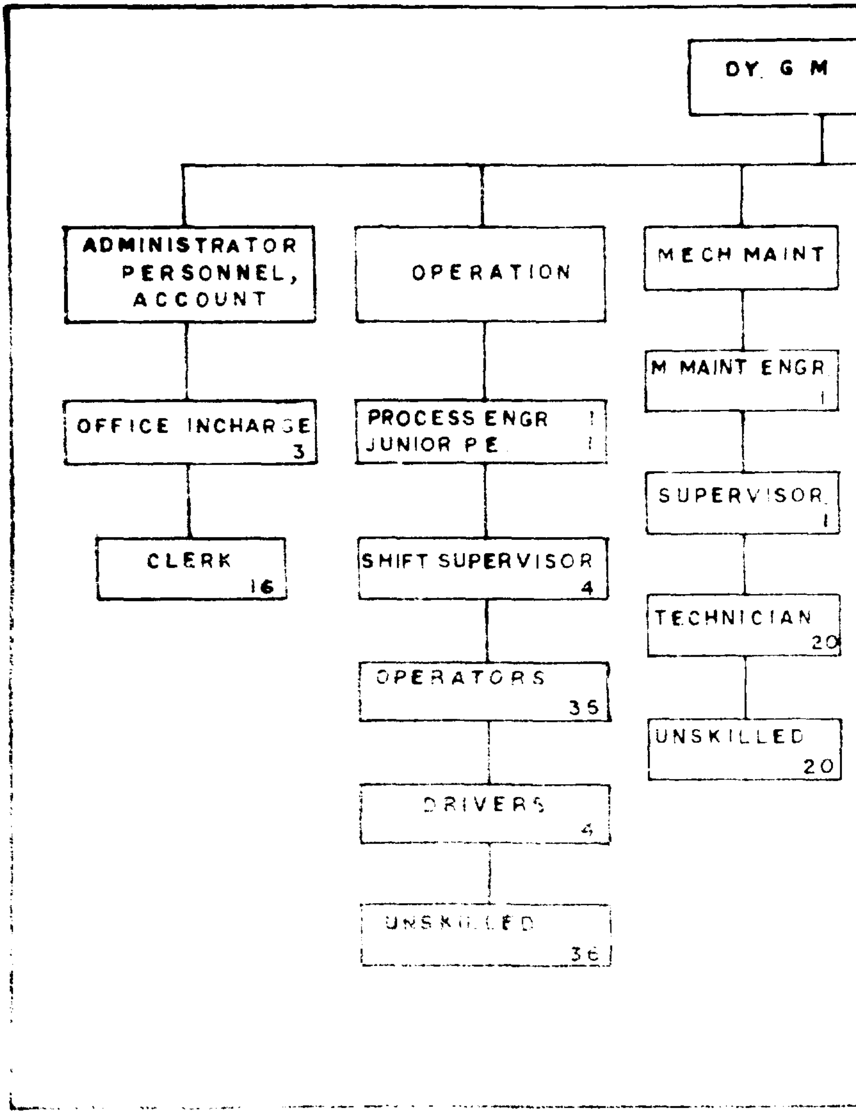


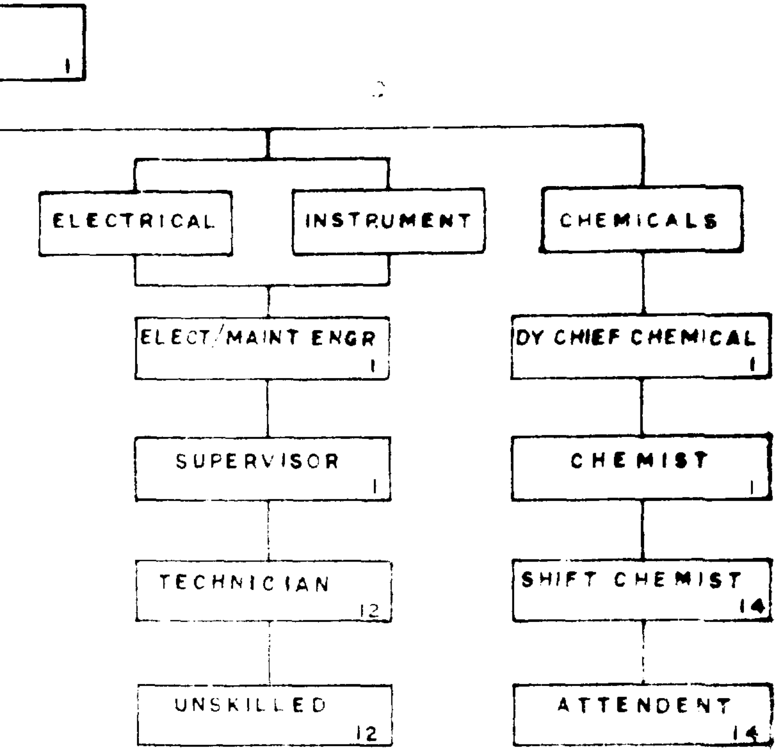


FERTILIZER (P&D) INDIA LTD SINDRI

TITLE: TENTATIVE TIME SCHEDULE
FOR CEMENT SULPHURIC
ACID PLANT

PROJECT [illegible] | DRG NO III [illegible]

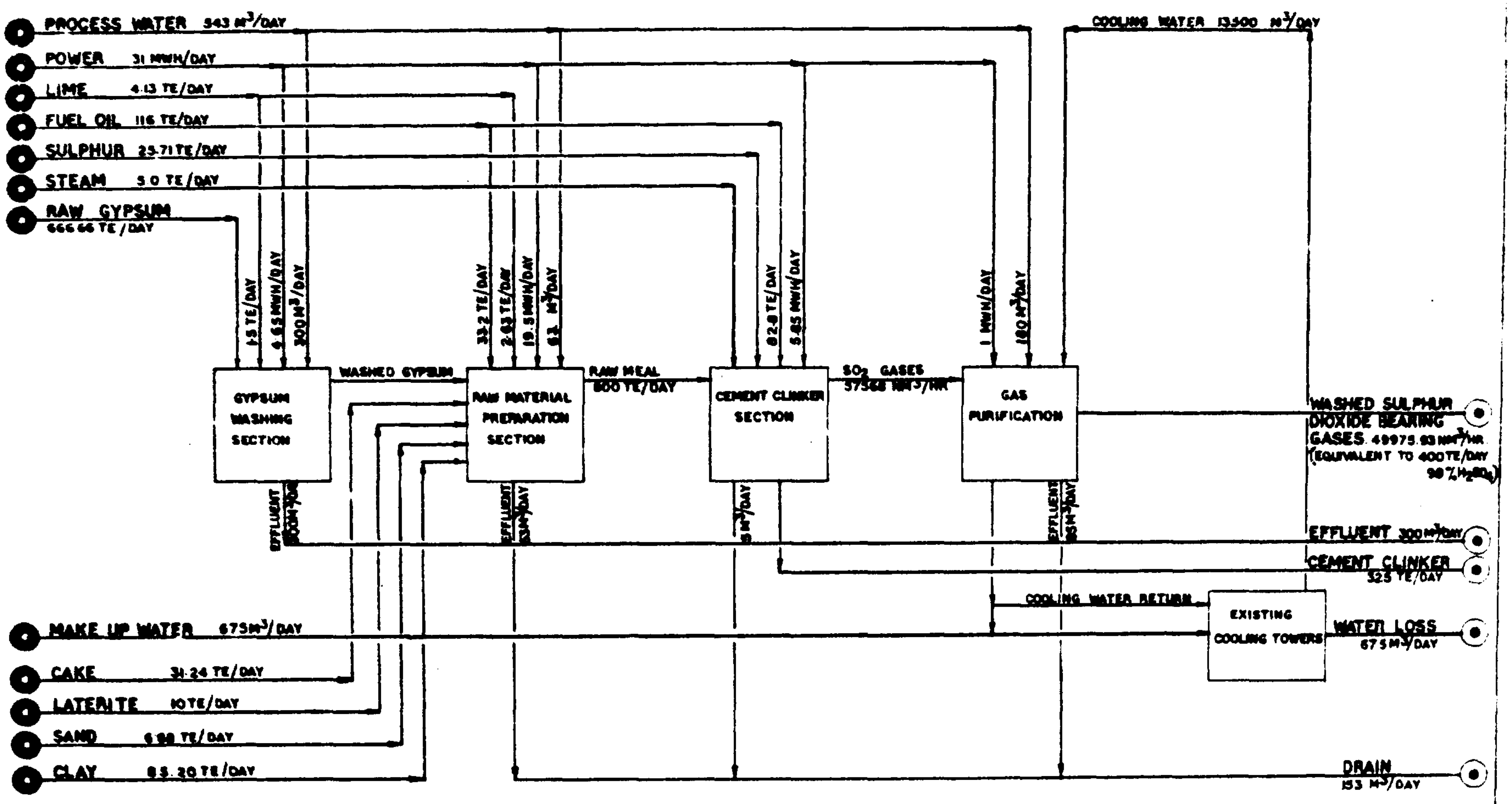

DY. G M
ADMINISTRATOR PERSONNEL, ACCOUNT
OFFICE INCHARGE 3
CLERK 16
OPERATION
PROCESS ENGR 1
JUNIOR P.E. 1
SHIFT SUPERVISOR 4
OPERATORS 35
DRIVERS 4
UNSKILLED 36
MECH MAINT
M MAINT ENGR 1
SUPERVISOR 1
TECHNICIAN 20
UNSKILLED 20



FERTILIZER (P & D) INDIA LTD SINDR

TITLE MANPOWER REQUIREMENT
TOTAL - 200

PROJECT 8 CIDB | DRG NO II-4



NOTE: —

* IF NATURAL GAS IS USED INSTEAD OF FUEL OIL QUANTITY OF N.G. WILL BE 127,160 NM³/DAY + 2.5 MT. OF S /DAY

** RAW GYPSUM IS CONSIDERED ON DRY BASIS IN THE ABOVE RAW MATERIAL & UTILITY REQUIREMENT SHEET. ACTUALLY WET GYPSUM CONTAINING 25% MOISTURE WILL BE AVAILABLE FOR WASHING & WASHED GYPSUM WILL ALSO CONTAIN 25% OF MOISTURE. AS SUCH WATER QUANTITY INVOLVED IS NOT SHOWN

FERTILIZER (P & D) INDIA LTD SINDRI

TITLE – RAW MATERIAL & UTILITIES REQUIREMENT

PLANT:- CEMENT SULPHURIC ACID PLANT FROM PHOSPHO GYPSUM (UP TO WASHED AND PURIFIED SO_2)

PROJECT:- B.C.I.D.B. | DRG. NO. III-15

BASIC CHEMICAL INDUSTRIES DEVELOPMENT
IN
BANGLADESH

10139
(4)

Part Four
PRODUCTION OF AMMONIUM SULPHATE

FERTILIZER (PLANNING & DEVELOPMENT) INDIA LTD

SINDRI, INDIA, 828122

Job No. [illegible]

PART IV

PRODUCTION OF AMMONIUM SULPHATE

PART IV

PRODUCTION OF AMMONIUM SULPHATE

CONTENTS

TEXT

ANNEXURES

DRAWINGS

IV (1-7)	Process Flow Diagrams
IV-8	Tentative Time Schedule
IV-9	Manpower Requirement & Staffing Pattern

PART IV : PRODUCTION OF AMMONIUM SULPHATE

Chapter 1

INTRODUCTION

1.1 One of the feasible, and under certain circumstances, attractive methods of phosphogypsum disposal is to make use of it for the manufacture of ammonium sulphate, which - next to urea - is the most popular nitrogen fertilizer produced in the world; in fact ammonium sulphate ranks higher than urea in some applications on account of its characteristics. There are already a number of plants for the production of ammonium sulphate based on the phosphogypsum route in operation as well as under construction. Some of them are in India, neighbouring Bangladesh. In fact, in one case in India (Sindri), a phosphoric acid plant was built, inter alia, to obtain phosphogypsum which could substitute for natural gypsum in an existing ammonium sulphate plant.

1.2 The ammonium sulphate route of gypsum disposal, however, is contingent on the easy availability of ammonia and carbon dioxide. It is for this reason that an ammonium sulphate plant is not rated quite 'foot-loose'. In view of the high material index - roughly about 1.4 te of phosphogypsum per tonne of sulphate - and the problems involved in handling it, transport of phosphogypsum to another site, where ammonia and carbon dioxide may be available is both inconvenient and expensive. For similar reasons, ammonia and carbon dioxide movement over long distances to the gypsum source is either impractical or quite costly. Hence, the scheme can be conveniently put into operation only where phosphogypsum, ammonia and carbon dioxide are available close to each other.

1.3 The problem in Bangladesh is compounded by the fact that surplus ammonia - and carbon dioxide - is not available for use in the ammonium sulphate process. The feasible ammonium sulphate plant capacity is too small to enable the setting up of an economic-sized, by modern standards, ammonia plant. Since the natural gas used as feedstock is nearly pure (over 95%) methane, the carbon dioxide availability in ammonia production also becomes a constraint. For these reasons, the conditions for the adoption of this route in Bangladesh are not quite propitious, even though the recent agronomic findings of sulphur deficiency in the soils in large areas emphasise the need for the application of sulphate to the crops.

Gypsum Availability

1.4 The total availability of phosphogypsum from the two phosphoric acid plants of the TSP Complex has been assessed, as mentioned in the earlier Part (III), at 230,000 tpy. Of this, the 200,000 tonnes expected to be available from the Phosphoric Acid Plant II (PA-II), which employs the Nissan process, is qualitatively suitable for being directly used in the ammonium sulphate process without the need for an elaborate purification step. Hence the capacity of the ammonium sulphate plant will be tailored to make use of the 200,000 tpy of Nissan gypsum. The gypsum available from the Phosphoric Acid Plant I (PA-I), being based on the conventional dihydrate route, has a high percentage of impurities, which interfere with the ammonium sulphate process. The P_2O_5 present in gypsum, for instance, converts itself in the course of reactions into tricalcium phosphate, which adversely affects the filtrability of the precipitate chalk. The fluorine and organic matters give rise to excessive foaming during reaction. For these reasons alternate uses have been recommended for the utilisation of this dihydrate gypsum as cement additive and gypsum plaster products (Part VII).

Chapter 2

PLANT CAPACITY AND REQUIREMENT OF RAW MATERIALS

Plant Capacity

2.1 The scheme for production of ammonium sulphate is based on the utilisation of entire quantities of phosphogypsum produced by the PA-II plant. The availability of 200,000 typ of dry gypsum will enable a plant with an annual capacity of 144,000 tpy of ammonium sulphate to be built. Assuming 300 stream days of operation, the daily rated capacity of the plant would be 480 tonnes. A plant of this capacity will produce 400 tpd of byproduct chalk ($CaCO3$) for use in the soda ash plant.

Availability of Ammonia

2.2 Besides gypsum, the other major input for ammonium sulphate manufacture is ammonia. As discussed in Part II, the ammonia requirement for the ammonium sulphate plant of 480 tpd capacity will be 39,600 tpy - or 132 tpd. It is seen in Part II (Chapter 4) that ammonia requirement of this order can be met only by captively producing ammonia to the extent of 100 tpd and drawing ammonia to the extent of 32 tpd from Chittagong Urea Fertilizer Project (CUF Project).

Carbon dioxide Availability

2.3 The gypsum based route for manufacture of ammonium sulphate requires carbon dioxide and the daily requirements will be 197 tonnes for a plant of 480 tpd capacity. In the absence of availability of any surplus carbon dioxide in the proposed CUF Project, the CO_2 requirements can be met by recovering from the flue gases of the steam generation plant of CUF Project. The flue gases will be piped to the proposed project complex and carbon dioxide recovered in a CO_2 recovery plant. The carbon dioxide available in the ammonia plant will be utilised in the soda ash plant.

2.4 No other major raw material is required for the manufacture of ammonium sulphate. A small quantity of sulphuric acid will be required and is assumed to be purchased from the TSP Complex, which can spare this quantity.

Chapter 3

PROCESS DESCRIPTION

Chemistry of the Process

3.1 The process adopted is the classical Merseberg process which is based on the reaction between gypsum and ammonium carbonate :

$$CaSO_4 + 2\ NH_3 + CO_2 + H_2O =$$

$$CaCO_3 + (NH_4)_2\ SO_4 + 2\ H_2O$$

The ammonium carbonate solution is prepared by the absorption of ammonia and carbon dioxide in water according to the reaction

$$CO_2 + 2\ NH_3 + H_2O = (NH_4)_2\ CO_3$$

The calcium carbonate (chalk) formed by the former reaction is filtered and the ammonium sulphate solution is concentrated by evaporation for production of crystals.

Plant Sections

3.2 The ammonium sulphate plant will have the following main sections :

1) Phosphogypsum washing (Drawing IV-1)
2) Carbliquor preparation (Drawing IV-2)
3) Reaction (Drawing IV-3)
4) Filtration (Drawing IV-3)
5) Evaporation and crystallisation of ammonium sulphate (Drawing IV-5)

6) Drying and cooling of ammonium sulphate crystals (Drawing IV-6)

7) Product handling (Drawing IV-7)

Phosphogypsum Washing

3.3 It will be necessary to wash the phosphogypsum first, as it contains impurities like P_2O_5, organic matters, fluorine, moisture and silica, which interfere with the main reaction. Free phosphoric acid present in the phosphogypsum reacts with ammonium carbonate to give ammonium phosphate, which in turn reacts with gypsum to ultimately yield insolube tricalcium phosphate. The tricalciumphosphate, due to its gelatinous state reduces the filtrability of the precipitate chalk. Organic matters with fluorine give rise to excessive foaming during the reaction stage. Silica present in phosphogypsum causes excessive erosion and interferes with filtration of chalk. Moisture in gypsum cake reduces the concentration of ammonium sulphate solution.

3.4 The 25% gypsum slurry prepared in the agitated tank will be pumped to a rotary drum filter. The flow will be controlled by manually operated pneumatic control valve. The rotary drum filter will be provided with polypropylene or terylene cloth. A vacuum of about 20 inches mercury will be applied for filtration with the help of a water ring vacuum pump. The gypsum cake formed on the filter will be thoroughly washed with filtrate from the filter. Washed gypsum cake will be discharged on gypsum belt conveyor, which in turn will feed to a mixer. Wash water, upto 10% of the total volume in circulation will be purged and sent for effluent treatment. Process water in equal amount will be added as make-up. The effluent water after treatment will be drained to a pond and let off to the sea.

3.5 The filtrate from gypsum filter containing washed P_2O_5 and some other soluble impurities will be sent to gypsum filter separator, and discharged through seal pot to a surge vessel from where it will bepumped back again for washing.

Carbliquor Preparation

3.6 The main equipment in this section are carbonation tower, carbliquor circulation pump, carbliquor coolers, carbonation tower balance tank and carbon dioxide compressor with accessories. Carbon dioxide (CO_2) gas will be compressed to 3 Kg/cm^2g pressure in a single stage reciprocating compressor. It will then be introduced to the carbonation tower through a flow recorder controller. Liquid ammonia will be introduced in the carbonation tower through flow recorder controller and flow integrator.

3.7 The carbonation tower will be operated at a pressure of 1.5 Kg/cm^2g. Provision will also be made to operate the tower at higher pressure upto 2.2 Kg/cm^2g. The carbon dioxide gas and ammonia react in the circulating carbliquor to form ammonium carbonate solution. The carbonation tower is packed with 50 mm resching rings. The carbliquor will be cooled in a plate type heat exchanger and will be recirculated back to the carbonation tower through carbliquor spray nozzle.

3.8 Any ammonia and carbon dioxide escaping over the main packing will become contacted with demineralised (D.M.) water, which will be sprayed over a packing of 25 mm reschig rings. Thus, a weak carbliquor is formed which will flow down to the main tower packing. There is a dry packing of (25 x 25) mm reschig rings which acts as a mist catcher. Carbliquor from carbonation tower will flow by gravity to the carbonation tower balance tank. It will be recirculated by carbliquor circulation pump via carbliquor cooler. A part of the carbliquor will be taken continuously to the mixer via a flow recorder controller.

Reaction

3.9 Gypsum cake from gypsum filter and carbliquor from carbonation section will be fed to the mixer in measured quantity. The mixer is a carbon steel tank with agitator. The overflow from the mixer will go to the reactors which are in four numbers. Reactors are also of carbon steel tanks with agitator. Overflow from one reactor goes to the next. Sufficient retention time is allowed for reaction for good reactivity and filtrability. Product magma from reactor will be pumped to the splitter box. To minimize ammonia loss from reactor and to keep the atmospheric pollution to the minimum, the mixer and the reactors' top will be connected with a reaction exhaust fan. Free ammonia which will be liberated due to the unreacted ammonium carbonate solution will be sucked alongwith carbon dioxide and water vapour and fed to the reaction scrubber. The reaction scrubber is a packed tower where 30-35% ammonium sulphate solution will be recirculated, 98% sulphuric acid will be mixed with circulating ammonium sulphate solution to neutralise free ammonia. The liquor from reaction scrubber will flow by gravity to the reaction and filtration scrubber balance tank. It will be cooled in a plate type scrubber liquor cooler and recirculated to the scrubber. A part of the solution will be fed to the S.F.L. pump tank as product.

Filtration

3.10 Product magma having ammonium sulphate solution, excess NH_3, CO_2, chalk etc. will be filtered in a tilting pan filter. Desired flow of magma to the filter is maintained by different orifice arrangement in the splitter box. The filter system is provided with 3 stages of washing, dirty filtrate removal, prewashing, air blowing for cake discharge, draining separator, cloth washing arrangement etc. Three stages of washing are adopted(for filtered chalk) to remove the entire adherent ammonium sulphate.

3.11 The product ammonium sulphate liquor, is collected in the first compartment of filtrate receiver seal tank, will be pumped to S.F.L. tank and further processed to produce product crystals.

3.12 The washed cake on the filter will be dried by air, sucked through the cake via draining separator, which is connected to a vacuum pump. The gases, released during filtration operations contain free ammonia, carbon dioxide and water vapour. A scrubber system is provided to fix free ammonia by neutralising with sulphuric acid (98% con.) injected into the circulating stream of ammonium sulphate. The rest of the non-condensible gases are washed with water and released to the atmosphere.

3.13 The chalk cake, discharged from the filter into the chalk hopper, is made into a slurry (48% by weight chalk) in an agitated tank and pumped to the soda ash plant.

Evaporation and Crystallisation

3.14 The ammonium sulphate solution will be doped with chemicals such as aluminium sulphate and arsenic as anticorrosive agent and evaporated in triple effect evaporator - crystalliser. Pressure and temperature maintained in 1st stage, 2nd stage and 3rd stage will be 1.02, 0.405, 0.13 Kg/cm^{2}abs and 109/99.6, 83/75.5, 58/51.5°C respectively. The material of construction of evaporators is AIS-316L stainless steel. Vacuum in the evaporator is maintained by barometric condensers. The concentrated slurry containing ammonium sulphate crystals will be pumped to the settler. Settled crystals will be filtered out. The mother liquor will be sent back to the evaporator feed tank and mixed with strong filter liquor (ammonium sulphate liquor) and processed again for the production of ammonium sulphate crystals. A small amount of enriched liquor will be required to be purged as and when necessary depending upon the concentration of the impurities in the liquor. Ammonium sulphate crystals will be dried in a rotary dryer. Hot gases from the fuel oil fired furnace will be used for heating the air and the ammonium sulphate crystals will be dried by this hot air. Hot crystals will be cooled in rotary cooler. Air from the dryer and cooler will be passed through the cyclone for collection of entrained dust and let off to atmosphere.

Product Handling

3.15 Product from the cooler will be conveyed by a belt conveyor, either to the bagging plant or storage silo. Normally, it will be conveyed to the bagging plant. The conveying system will incorporate arrangements to divert the product to storage silo. The bagging plant will be laid in 3 lines and each line will consist of a product hopper, weighing-cum-tripping machine, slat conveyor, bag stitching machine and discharge hopper. These will be laid out on the 1st floor and the filled stitched bags are discharged to a covered loading platform. The filled bags are loaded into trucks and transported to destinations or storage godowns.

The bagging will be done in polythene-lined jute bags of 900 mm (length) x 580 mm (width), which will hold 50 Kg material. The company's name, product brand name, details of net and gross weight, available 'N' content (%) etc will be printed on the bag. The bags are assumed to be purchased.

3.16 The bagging plant, as laid out, can handle 1.5 times of daily production in two shifts of operation. No bagging operations are envisaged in the night shift. The night shift production will be diverted to the silo. The product storage will consist of twin silos for 20,000 tonnes product in bulk to be stored. The silos will have overhead discharged conveyor with tripper arrangements to discharge material uniformly over the entire length of the silo. Two scrappers, each of 50 tph reclaiming capacity, moving on rails will reclaim material and load on the reclaiming conveyor inside the silo for conveying to the bagging plant.

Carbondioxide Recovery

3.17 The carbon dioxide requirement (197 te/day) will be obtained by scrubbing carbon dioxide from flue gases received by pipeline from the steam generation unit of Chittagong Urea Fertilizer Plant. The process adopted for CO_2 recovery is the monoethanol amine (MEA) process. Flue gases will be passed upward through an absorber, countercurrent to a stream of the amine solution. The rich solution from the bottom of the absorber will be heated by heat exchange with lean solution from the bottom of the regeneration column and then fed to the regenerator column at a point near the top of the tower. The lean solution after partial cooling in the heat exchanger will be further cooled by exchange with water or air and fed to top of the absorber to complete the cycle. Acid gas (CO_2) which will be removed from the solution in the regenerator will be cooled to condense a major portion of the water vapour. This condensate will be continuously fed back to the system to prevent amine solution from becoming progressively more concentrated.

The MEA process system is foreseen because of the advantages of high CO_2 loading capacity for the solution, ease of operation and commercially proven system. But a more detailed evaluation of the available processes may be done prior to final adoption in the scheme, at the time of implementation.

Chapter 4

RAW MATERIALS AND UTILITIES SUPPLY

4.1 The details on raw materials' supply - phosphogypsum, ammonia and carbon dioxide - have been already discussed in chapter 2. However, these are summarised in the following Table 4.1

Table 4.1

Raw Material Requirement

(Basis : 300 stream days of operation)

Items	Unit	Annual Requirement	Daily Requirement	Source
1. Phosphogypsum	te	200,000	667	Proposed PA-II plant cost free.
2. Ammonia	te	39,600	132	32 tpd from CUF Project @ Taka 2265 100 tpd captive plant @ Taka 4545
3. Carbon dioxide	te	59,100	197	From flue gases of steam generation plant of CUF Project free of cost.
4. Sulphuric acid	te	4,610	16	Purchased from TSP complex

4.2 The entire quantity of phosphogypsum is a by-product waste from the PA-II plant and hence no price has been assumed to be payable to TSP Complex authorities. The gypsum transport facilities will form part of the proposed project including conveyance upto the jetty.

4.3 The ammonia requirements, to the extent of 32 tpd will be obtained from the CUF Project by pipeline to be installed as part of the project scope. The purchase price assumed is Taka 2265 ($ 151) per tonne. The balance 100 tonnes will be obtained from the proposed captive ammonia plant of the scheme. The cost of production, as estimated, is Taka 4545 ($ 303) per tonne (Part II). The product costing is based on these two prices for ammonia.

Since carbon dioxide requirement will be met by recovering it from flue gases, which are let off to atmosphere, no cost (except for the utilities for recovering) is assumed for this.

4.4 The overall requirements of utilities and the prices assumed are as follows; the basis has been explained in Part II :

	Taka/Unit	Yearly Requirement
- Electricity (Mwh)	485	37.53×10^3
- Process water make-up (m^3)	2.08	3.03×10^6
- Steam (te)	95	0.117×10^6
- Fuel Oil (te)	1323	900
- Natural gas (1000 Nm^3)	32	1556

4.5 Electricity supply for the entire scheme will be met by the Power Development Board (PDB) at 33 KV, which will be stepped down to required voltages (11 KV/400 V/220V) for use in the various plants (see Part II). The sub-station arrangements will be common for all plants and hence the cost indicated is the allocated cost for the power consumed in the plant.

4.6 The process water supply to the proposed project cost possibly be obtained from the CUF Project, as explained earlier in Part II. However, since the cost of water cannot be ascertained at this stage, it is assumed that the process water supply will be made by the Water and Sewage Authority (WASA) and the cost indicated is the allocated cost for the amount of make-up water used in the plant. The Dimeneralised (D.M.) water requirements will be met from the common D.M. water treatment facilities of the project and the indicated cost here is the allocated cost.

4.7 Fuel oil and natural gas costs are the delivered prices. Fuel oil will be obtained from the Eastern Refinery across the river and gas will be piped to the site through a common pipeline and metered at the project.

4.8 The annual requirement of bags is 2.88×10^6 numbers and the current delivered price is Taka 12 per bag.

Chapter 5

LOCATION OF THE PROJECT

5.1 The process of manufacture of ammonium sulphate from gypsum requires as mentioned earlier, ammonia and carbon dioxide, among other inputs. Since there is no source of ammonia close the TSP Complex in North Patenga, Chittagong, and there is not enough land (as well as other facilities) available for setting up an ammonia plant close to the gypsum source, necessarily either ammonia or gypsum will have to be transported to the production site. It is obvious that between the two, it is easier - and cheaper - to transport gypsum compared to ammonia, which comes under the category of hazardous cargo and requires special tankers and facilities for loading, transport and unloading. Laying a pipeline for the purpose is considered impractical due to high costs and the risks involved during the dredging of the river. Transporting gypsum to the ammonia source has the added advantage of possible use of any carbon dioxide available as surplus in the ammonia complex. Since it is planned to make use of the chalk available as byproduct in the production of soda ash (Solvay process), chalk will need to be transported to the soda ash complex site, if ammonium sulphate were to be manufactured near the TSP Complex with a view to avoiding gypsum transport. There are some advantages, such as sharing common facilities, in establishing the ammonia, ammonium sulphate and soda ash (Solvay) units in a single complex compus, as explained in Part II.

5.2 It has therefore been proposed, in Part II, that the ammonium sulphate plant be located across the Karnaphuli river from North Patenga (TSP Complex) in the Middle Island area, close to the proposed site for the Chittagong Urea Fertilizer Project. A description of the site has been given in Part II alongwith a plot plan, which covers the ammonium sulphate plant as well. It will be close to the planned source of ammonia supply, and the required carbon dioxide can be generated from the flue gases of the steam generation plant of the CUF Project. Water, gas and power supply lines can be shared in common (Part II). The phosphogypsum, however, will have to be carried across the river to the proposed site as described elsewhere in this study.

Chapter 6

GYPSUM TRANSPORT

6.1 With the phosphogypsum source (TSP Complex) located on one side of the Karnaphuli river and the site for the ammonium sulphate plant on the other, one of the major problems of organising production is likely to be the transport of gypsum to the plant site. The gypsum being wet (25% moisture), its handling is not convenient. Besides, at the rate of production envisaged, about 840 tonnes of wet gypsum (about 35 te/hr) will need to be regularly delivered to the ammonium sulphate plant to feed the production line.

6.2 The rail and road transport are both ruled out on account of the new site being inaccessible. Though there are plans to lay a new road connecting the proposed Chittagong Urea Fertilizer Project site to the Kalurghat rail-cum-road bridge, no definite indications of its execution are available as yet. The proposal for a railway line is likely to be still further away. Preliminary discussions indicated that a ropeway across the river will be both expensive and difficult on account of the span as well as movement of ocean liners in the river. The only feasible method, therefore, seems to be to transport it through barges.

6.3 Different alternatives for carrying the gypsum in barges across the river were considered. The possibility of sun drying it before loading involves multiple handling, though it will be easier to transport a dry material than wet gypsum. If the wet cake is directly loaded into the hold of the barge, reclaiming the material at the other end will be cumbersome. Besides, since the gypsum yard of the plant will be some 2-3 Km away from the proposed jetty, the gypsum will require another handling and transport. Considering all these aspects, and in consultation with the Narayanganj dock yard authorities, the Consultants recommend tentatively trailers for the movement of gypsum. The gypsum will be loaded on 7-te trailers at the TSP Complex, which will be hauled to the jetty, where it will be rolled on to a barge. Each barge will carry five such trailers to the opposite bank. There, from the jetty, the trailers, will again be hauled to the gypsum yard and emptied. Empty trailers, waiting at the jetty will be loaded on the barges for the return journey. This arrangement will involve only one handling at each end, and will help to improve the turn-round time of the barges.

6.4 It is estimated, considering the likely turn-round period, that about 20 trailers will be needed to transport the gypsum, with two barges, each with capacity to carry on board five trailers at a time. New jetties for the purpose are envisaged on either side of the river and their estimated cost has been included in the project estimates. The draft in the river will be adequate for the purpose throughout the year. During the rainy season, the trailers will be covered with tarpaulin to prevent soaking.

Chapter 7

IMPLEMENTATION AND TIME SCHEDULE

7.1 The manufacture of ammonium sulphate through the gypsum route is not covered by any patented process and therefore, any engineering contractor with experience can build the plant. However, since ammonium sulphate forms part of the proposed larger complex covering ammonia production from natural gas, ammonium sulphate and soda ash (Solvay), it will be necessary to take an early decision on whether all the three plants and other off-site facilities should be entrusted to a single engineering contractor or whether the work should be split up on the lines of specialisation and different agencies should be engaged for the execution of particular works. On the basis of an overall view, the Consultants feel that the projects' execution could be contracted out to 4 agencies, each covering the following plants and related facilities :

(i) Ammonia Plant, Carbondioxide and other Utilities

(ii) Ammonium Sulphate

(iii) Soda Ash

(iv) Gypsum Transport Facilities, including the Jetties.

The total project work could be coordinated by an engineering consultant on behalf of the owners.

7.2 The possible modes of execution of the Complex have been discussed in Part II (Chapter 8) and as recommended therein, the engineering contractors may be engaged to erect and commission the respective plants and facilities on 'turn-key' terms. For this purpose, requests may be invited initially from a number of firms for being considered for the jobs and after a pre-qualifying scrutiny, a shorter list of firms may be drawn up for issue of bid documents. The selection of engineering contractor for each sector job could be done from the proposals received from the bidders, on the basis of technical soundness as well as financial competitiveness. A Project Management Team, constituted by the owners will coordinate the work with assistance from a Project Consultant to be appointed as mentioned in Part II.

Time Schedule

7.3 It is assumed, as indicated in Part II, that the project's execution will be mechanically complete within 30 months from the 'zero date', i.e. from the date of award of contract to the engineering contractor. Trial run and commissioning of the plant will take about 6 months. A bar chart indicating the various project activities and the estimated time for completion of each activity is shown as Drawing No. IV-8.

Chapter 8

MANPOWER REQUIREMENT AND STAFFING PATTERN

8.1 As proposed, the ammonium sulphate plant will form part of a larger complex including ammonia production facilities and a soda ash plant. Some of the facilities will be operated in a common pool. The staff-requirement indicated here relates only to the ammonium sulphate plant proper, to indicate the manpower needs of the plant alone. The total requirements have been discussed in Part II.

8.2 It has been assumed (Part II) that the complex as a whole will be the charge of a single General Manager under the BCIC, more or less on the pattern of other BCIC units. The ammonium sulphate plant will be charge of a Plant Superintendent, of the rank of a Dy. General Manager.

8.3 The total manpower requirement of the plant, excluding the common facilities but including the bagging plant has been assessed at 257, of which about 89 will be unskilled workers. The main categories and their number are indicated in Table 8.1.

Table 8.1

Manpower Requirement

Category	Number
1. Plant Superintendent	1
2. Process/Shift Engineers Dy. Chief Chemist	6
3. Supervisors/Chemists	34
4. Operators/Technicians/ Shift Chemists	127
5. Unskilled	89

8.4 This estimate of staff requirement may, however, be scrutinised more closely in consultation with the Project Consultant and the advice of the engineering contractors. In the meantime, the number indicated above may be treated as the outside limit,

8.5 The salary scales of the employees as well as the fringe benefits have been computed on the basis of the existing standard pay-scales of the public sector employees, as practised in the BCIC units. A common housing colony has been envisaged cost (allocated) included in the estimates.

Chapter 9

CAPITAL INVESTMENT AND COST OF PRODUCTION

9.1 Capital Investment

The estimated capital investment is $ 51.42 million (Taka 771 million), of which the foreign exchange component is US $ 29.10 million (Taka 437 million) (Annexure IV-A).

A summary of the capital investment estimate is given in Table 9.1.

Table 9.1

Summary of Capital Investment

(Figs. in $ 000)

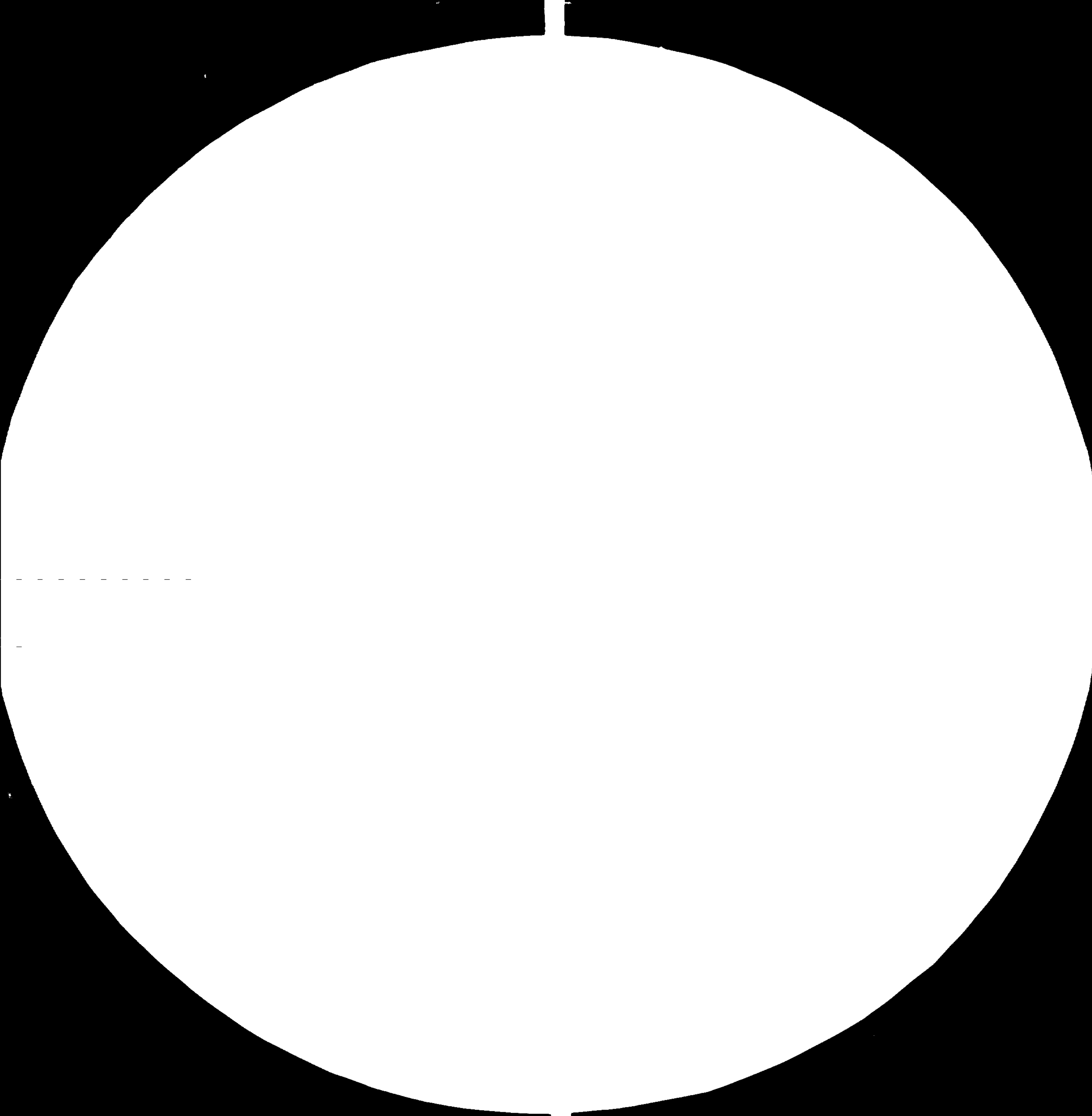
Item	FC	IC	Total
A. Manufacturing Facilities			
1. Main plants	9100.0	2600.0	11700.0
2. Offsite facilities and jetty	9090.0	3390.0	12480.0
3. Site development	60.0	150.0	210.0
4. Spares	1210.0	100.0	1310.0
5. Project management	730.0	2440.0	3170.0
Sub-total	20190.0	8680.0	28870.0

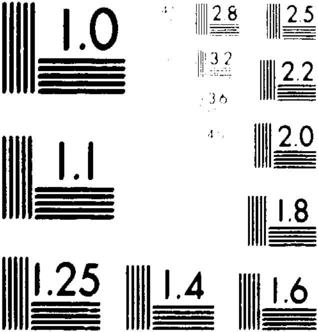
Table 9.1 (contd.)

Item	FC	IC	Total
B. Other Fund Requirement			
6. Township & public buildings	2000.0	1400.0	3460.0
7. Working capital	-	2200.0	2200.0
8. Commissioning Expenses (Net)	-	100.0	100.0
9. Contingency	1110.0	600.0	1710.0
10. Escalation	5800.0	5250.0	11050.0
11. Financing Charges	-	4090.0	4090.0
Sub-Total	8910.0	13640.0	22550.0
Total Investment	29100.0	22320.0	51420.0

9.2 The capital investment estimates include the allocated costs for common facilities consisting of water and power supply, effluent treatment, non-plant buildings, construction equipment etc. The cost allocation has been done on the basis of ratio of main plant requirements. Though a basis for estimating the share of common costs has been adopted, the allocation can be somewhat imprecise.

9.3 The costs of the main plants have been estimated by preliminary sizing of the equipment/machinery and using the in-house cost data of the Consultants, who as a premier design and engineering organisation,





MICROCOPY RESOLUTION TEST CHART

[illegible]

and by virtue of having designed and executed several fertilizer plants including the ammonium sulphate and the other plants under discussion, have a complilation of cost data.

9.4 The foreign exchange component of the cost estimates include the cost of imported supplies and services, whose requirements have been determined, based on an assessment of current situati 1 with regard to availability within Bangladesh.

9.5 Since the cost estimates are preliminary in nature and have not been based on any detailed engineering and quotations, provisions for contingency (at 10%) and escalation (8% for foreign component and 12% local costs) have been made.

9.6 In the current situation of uncertainties in international prices due to energy crisis and high inflation rates, precise prediction of prices in international market even under competitive tendering has become a difficult exercise. Therefore, the cost estimates are mid-1979 costs. Also the costs have been estimated on the basis of free foreign exchange cash mode of payment for supplies and services and no provision has been made for credit financing if resorted to.

Financial Plan

9.7 The foreign component cost has been assumed as debt while the local costs have been assumed as equity, in accordance with the standard practice in Bangladesh. Thus the term loans and equity will be

Loan - $ 29.10 million

Equity - $ 22.32 million

This corresponds to a debt : equity ratio of 1.3:1.

9.8 The financing charges have been calculated on the basis of phasing of loan disbursement, as indicated in Table 9.2 and assuming an interest rate at 10% per year :

Table 9.2

Loan Disbursement

Year	$ million	Taka million
1	2.91	43.65
2	20.37	305.55
3	5.82	87.30
Total :	29.10	436.50

Cost of Production

9.9 As mentioned in Part II, the stream efficiency of an ammonium sulphate plant is ordinarily assumed at 300 days per year. The cost of production of ammonium sulphate has been, therefore, worked out below on the basis of 100 percent production level and 300 operating days. Based on the capital estimates given above (Table 9 .1) and considering a normal year of operation, the cost of production of ammonium sulphate (with no credit for byproduct chalk) works out to $ 158/tonne (Taka 2370/te) as shown in Table 9.2. Details are given in Annexure IV-C.

Table 9.2

Cost of Production of Ammonium Sulphate

	Items	Annual Cost $ 000	Remarks
1.	Raw materials	10820	E*
2.	Utilities	2483	A
3.	Consumables	174	E
4.	Labour & Overheads	554	A
5.	Maintenance material	873	E
6.	Bags	2304	E
7.	Insurance	154	E
8.	Contingency	414	E
	Annual Works Cost	17776	
9.	Depreciation	3416	A
10.	Selling Expenses	20	E
11.	Average Interest on Term Loan	1455	E
	Annual Processing Cost	: 22667	
	Annual Production (Tonnes)	: 144000	
	Cost of Production ($/Tonne)	: 157.40 Say 158.00	

E = Estimated

A = Allocated (since some of the facilities are common between ammonia and soda ash plants)

*Ammonia price allocated.

9.10 The price of raw materials, utilities and consumables assumed for determining the cost of production have been indicated in para 4.1. The maintenance material cost has been assessed at 5 percent of the landed cost of supplies and 1.5 percent of the cost of jetty and buildings, including colony. Labour and overhead costs have been calculated on the basis of the estimated personnel requirements and staffing pattern as shown in Drawing No. IV-9, using the current salary scales and other benefits applicable to BCIC employees. The cost of insurance has been assessed at 0.3 percent of the fixed capital. Depreciation has been worked out on straight line basis over a period of 12 years. Interest on long term loan capital has been assumed, as mentioned earlier, at 10 percent per annum. The selling expenses have been assumed at Taka 2/Te only, since the fertilizer is distributed by another public sector corporation, viz. Bangladesh Agricultural Development Corporation (BADC) and lifted from factory premises. As indicated earlier, in the case of common facilies between ammonium sulphate, ammonia and soda ash plants, the costs have been allocated to the respective plants.

Chapter 10

PRICING AND PROFITABILITY

10.1 The selling prices of all fertilizers, both at wholesale and at retail levels are set by the Government of Bangladesh through the BADC which is responsible for domestic procurement and marketing of the fertilizers in the country. The retail prices are heavily subsidised. The subsidy element varied between 68 percent in 1970-71 and 27 percent in 1973-74, and covered, besides the difference between the procurement and retail prices, the cost of procurement, transport, distribution and sales administration. The subsidised retail price of ammonium sulphate in 1978-79 was Taka 544.40 per tonne, compared to the procurement price (Fenchuganj) of Taka 1630/te.

10.2 Since BADC is solely responsible for the marketing of all fertilizers in Bangladesh, it is assumed that the ammonium sulphate produced will be procured and distributed by BADC. The price at which it will be procured is rather hazardous to guess at this stage; in any case the price paid to Fenchuganj cannot provide a basis in view of the fact that Fenchuganj unit's installed capacity for ammonium sulphate is very small and the cost of production low, due to low gas price and, as an old plant, low capital charges. Since ammonium sulphate is also a nitrogen fertilizer and can substitute for urea, which is overwhelmingly the largest nitrogen fertilizer produced in the country, a fairer basis will be to fix a price corresponding to the price of urea, taking into account the nitrogen content of each. The Chittagong Urea Fertilizer Project assumes that the selling price of urea by the time the project is commissioned, will be around $ 175/te. The Consultants consider this to be an under estimate considering the present level of international prices and the long term trend. In the Consultants' opinion, the C&F Bangladesh price of urea will not be lower than $ 225/te by the time this scheme is implemented. The selling price of ammonium sulphate, corresponding to the urea price of $ 225/te, has been assumed to be Taka 1515 per tonne ($ 101/te) for the purpose of analysing the project's economics. The chalk produced in the process is treated as a waste product, and therefore no credit is taken for it.

On the basis of this pricing the projects profitability will be as shown in Table 10.1.

Table 10.1

Profitability of Project

		($ '000)
1.	Annual Realisation from Sale of Ammonium Sulphate	14544
2.	Annual Cost of Production (excluding interest)	21212
3.	Gross Profit before Interest	(6668)
4.	Average Interest on Term Loan	1455
5.	Profit after Interest (before Taxes)	(8123)
6.	Total Capital Employed	51420
7.	Return on Total Capital (Percent)	(12.97)
8.	Equity Capital	22320
9.	Average Return on Equity (Percent)	(36.39)

(Brackets indicate negative figures)

10.4 It is evident from the fact that since the cost of production of ammonium sulphate is higher than its presumed sale price, the project is not financially viable. As the table above shows, the returns are negative to the extent of 13.0 percent on total capital. There are 3 principal reasons for the negative financial returns:first , high cost of ammonia, particularly on account of captive generation in a small plant. As has been seen in Part II, the cost of production of ammonia in the captive plant worked out to \$ 303/te compared to less than \$ 151 in the Chittagong Urea Fertilizer Project, with its large scale (about 1000 tpd) ammonia plant. High cost of ammonia has a significant impact on the production cost of ammonia sulphate, since nearabout 0.28 te of ammonia is utilised per tonne of the sulphate. Secondly, the carbon dioxide needed for the process is required to be generated exclusively, since no supply from an external source is possible. The cost of the carbon dioxide plant, therefore, is additional to the normal investment on the ammonium sulphate facilities. It is for this reason that the present trend is to emphasise the manufacture of ammonium sulphate only if carbon dioxide from an external source is available, obviating the need for a CO_2 generation plant. Thirdly, the need for transport of gypsum across the river to the plant site adds substantially to the processing costs. Roughly the delivery cost of gypsum to the ammonium sulphate plant site works out to around Tk 14/tonne. To avoid this cost, the normal trend these days is to decide on an ammonium sulphate (gypsum route) plant only if it can be put up next to the gypsum source. Since these constraints from which the scheme basically suffers cannot be resolved, the project does not commend itself on the basis of financial returns.

10.5 However, the ammonium sulphate manufacture is being conceived primarily as a pollution control measure aimed at disposal of phosphogypsum in an environmentally satisfactory way. Seen in this light, the project can be acceptable, if the other proposals made in this study to utilise phosphogypsum, such as cement clinker manufacture, do not appeal, for some reason, to the Government of Bangladesh. In that case, in order to improve the project's economics, the Government might decide on the reduction of urea capacity of the CUF Project marginally to the extent of making available the entire 133 te of ammonia - and the available carbon dioxide- to this project and also raise the subsidy element, besides exempting the project imports from duties and taxes. Since large areas of Bangladesh have been found to suffer from sulphur deficiency, application of ammonium sulphate as nitrogen fertilizer has been recommended by Bangladesh Rice Research Institute (BRRI). The indigenous production of ammonium sulphate at Fenchuganj will not be adequate to meet the entire local demand, and therefore resort to import might be necessary. In that case, this scheme can be ranked as an import substitution project.

Chapter 11

USABILITY OF AMMONIUM SULPHATE

11.1 Ammonium Sulphate, with 20.5% N and 24.2% sulphur, is one of the oldest chemical sources of nitrogen for crops. It is also a good source of sulphur on soils deficient in this element. As a nitrogenous fertilizer, it is acknowledged to be pre-eminently suitable for neutral, calcareous, saline and alkaline soils. For acid soils, however, it was believed that, although its use may be very effective [1] in the short-term, being an acid forming fertilizer, continued use might result in degradation of such soils. This detrimental effect was believed to manifest itself only with long continued use in large doses. Recent expert opinion, however, does not support this view.[2] The Director of the Bangladesh Rice Research Institute (BRRI), for instance, disagreed with the theoretical concept that continued use of ammonium sulphate results in lowering of soil pH. He is of the opinion that irrespective of the type of fertilizer used, under a regime of water, the pH of the soil remains high, - at around 7. In any case, such a tendency can be arrested by the practice of periodical liming.

11.2 . Ammonium sulphate contains ammoniacal form of nitrogen, unlike urea which is an amide form. It can be safely applied to light as well as heavy

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[1] Handbook of Manures & Fertilizers, Indian Council of Agricultural Research, New Delhi.

[2] Bandyopadhya, Sahoo, Bhadrachalam & Patnaik : Effect of Continuous Application of Compost, Ammonium Sulphate and Lime on Some Physical and Chemical Properties of Rice Soils (Journal of Indian Soc. of Soil Sciences 17(3):369-374).

soils. When added to the soil, the ammonium ion is absorbed on the surface of clay and humus particles and is quite readily released for the use of plants. Its use can be equally effective in wet as well as dry lands. The loss of ammonium is very little in either of these conditions, compared to say, urea, which being highly soluble and non-solar in nature, runs the risk of being lost in run off leaching waters under flooded rice soil conditions[3]. Ammonium Sulphate is one of the most popular fertilizers in India under all agro-climatic situations, particularly in the highly leached condition of paddy farming. For urea well aerated dry soil conditions are necessary to decompose and get converted into ammoniacal nitrogen.

11.3 Experiments in several countries have shown that on wet lands under paddy, ammonium sulphate on equal nitrogen basis is more effective than all other nitrogen fertilizers. In the monograph on Rice Manuring (M. Comhaire) it has been stated that "nitrogen in the ammoniacal form is the most effective for application to paddy fields." The findings on relative efficiency of the various nitrogenous fertilizers by different authors are indicated below :

Author	Fertilizer	Relative Rating
i) De Geus	Sulphate of Ammonia	100
	Nitrate of Ammonia	92
	Phosphate of Ammonia	86
	Urea	82
	Calcium Cynamide	64
	Potassium Nitrate	44
	Sodium Nitrate	40

2/ Patnaik S : Urea - A Potential Fertilizer for Rice, Fertilizer News 11(6):29-30.

ii)	Lin, Taiwan	<u>First Crop</u>	
		Ammonium Sulphate	100
		Ammonium Chloride	98.9
		Urea	96.7
		Ammonium Nitrate	88.2
		<u>Second Crop</u>	
		Ammonium Sulphate	100
		Ammonium Chloride	96.9
		Urea	96.9
		Ammonium Nitrate	87.9
iii)	Authors of 'Rice in India'	Ammonium Sulphate	100
		Ammonium Phosphate	98
		Ammonium Nitrate	72
		Urea	65
		Cynamide	36
		Potassium Nitrate	33
		Sodium Nitrate	24
iv)	Vachani & Rao	Ammonium Sulphate	100
		Ammonium Phosphate	81.4
		Ammonium Chloride	85.8
		Urea	46.5
		Amm. Sulphate Nitrate	76.9
		Ammonium Nitrate	17.9
		Calcium Cynamide	6.1

11.4 Lately, application of ammonium sulphate has become imperative in Bangladesh due to sulfur deficiency in the soils notice in several parts, particularly with the cultivation of high yielding varieties of paddy and a steady rise in the fertilizer dosages applied. Several papers presented in a national workshop conducted at the BRRI in December 1978 indicated a fairly serious situation. In one of the papers

Roy et al[4] (Division of Soil Chemistry, BRRI) described the typical problem as follows :

> "Fertility experiments with (modern rice) varieties at BRRI headquarters, Joydebpur during the past few years revealed that under the experimental soil conditions at this research station, most modern varieties had limited response to nitrogen application. In many instances control plot yields were higher than those receiving 80 Kg N/ha. Use of either varied rates of phosphate or potash did not improve the situation. Under prolonged submerged condition, crop conditions were worse in many fields.Plants looked nitrogen starved with stunted growth, poor tillering and yellowish leaf colour, visual symptoms were close to those of nitrogen deficiency ...... we found that application of sulphate containing fertilizers recovered plant growth improved tillering and plant hight and grain yields to some extent .... "

Soil samples collected from the farmers' fields in the BRRI project area also showed low available sulphur values. Hoque and Hobbs (Division of Rice Cropping Systems) reported[5] that the "rice yield increased by 72 and 43 per cent due to sulfur application from ammonium sulphate and magnesium sulphate, respectively" and further "sulfur was equally important as nitrogen in bridging the yield gaps in farmers' fields". Islam[6] (Agronomy Division) found that "ammonium sulphate as a source of sulfur was significantly superior to gypsum" and reported

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[4] A.C. Roy, A.L. Shah, T. Aziz & .K. Biswas : Sulfur Requirements of Rice and Sulfur Status of Some Rice Soils and Plants of Selected Locations.

[5] M Zahidul Haque and Peter R Hobbs : Response of Rice Crops to Added Sulphur at BRRI Station and Project Area.

[6] Dr AJM Azizul Islam : Sulphur Deficiency Symptoms, Corrective Measures and Results Obtained.

further that" nitrogen from ammonium sulfate was found to be more efficient than urea under flooded rice culture". In view of these findings, the Bangladesh Soil Fertility and Soil Testing Institute has undertaken field experiments with the application of gypsum to paddy from August 1979. Under these circumstances, the marketing of ammonium sulphate in Bangladesh, if produced indigenously, will not pose any problem; indeed it may become necessary in due course to procure it through imports to correct the soil deficiency, which is bound to grow worse with continued cultivation.

ANNEXURE IV-A

CAPITAL OUTLAY

(Figures in $ '000)

Sl. No.	Item	F.C.	I.C.	Total
1.	Land and land development	60	150	210
2.	Construction equipment	420	30	450
3.	<u>Main Plants</u>			
	Ammonium sulphate	9,100	2,600	11,700
4.	Yard piping	570	570	1,140
5.	Water supply, storage and distribution	440	240	680
6.	Power supply and distribution	230	50	280
7.	Cooling tower	470	90	560
8.	Raw material handling and storage	1,200	350	1,550
9.	Product handling bagging	1,550	660	2,210
10.	CO_2 recovery plant	2,800	850	3,650
11.	Effluent treatment plant	150	40	190
12.	Auxiliary service facilities	600	220	820
13.	Non-plant building	120	50	170
14.	Transport facility	110	40	150
15.	Jetty	340	160	500
16.	Temporary construction facilities	90	40	130
17.	Project management charges	730	2,440	3,170
A.	Total manufacturing facilities	18,980	8,580	27,560

ANNEXURE IV-A
pp.2

Sl. No.	Item	FC	I.C.	Total
B.	Township and public buildings	2,000	1,400	3,400
C.	Spares	1,210	100	1,310
D.	Working Capital	-	2,200	2,200
E.	Contingency	1,110	600	1,710
F.	Expenses during commissioning and trial expenses (Net)	-	100	100
G.	Escalation	5,800	5,250	11,050
H.	Financing charges	-	4,090	4,090
	Total Capital	29,100	22,320	51,420

Note : Capital allocated in the case of common facilities.

ANNEXURE IV-B

WORKING CAPITAL

Sl. No.	Item	Total Cost ($ '000)
1.	Accounts Receivable One month's sale of ammonium sulphate @ Tk 1600/te	1540
2.	Operating Supplies - Bags (one month) @ Tk 12/piece - Chemicals & Consumables (3 months)	280
3.	Raw Material Inventory - Sulphuric acid (15 days)	20
4.	Product Inventory - 23 days' bulk product - 7 days' bagged product	1270
5.	Goods in Process (1 day)	60
6.	Accounts Payable (one month)	(837)
7.	Deposits & Advances	(150)
8.	Cash in Hand	17
		2200

ANNEXURE IV-C

COST OF PRODUCTION

	Item	Unit	Unit Rate $	Annual Consumption	Annual Cost ($ '000)
I.	Raw Materials				
	a) Sulphuric Acid	Te	63.30	4610	293
	b) Ammonia				
	i) Purchased	Te	151.00	9900	1450
	ii) Captive	Te	302.60	30,000	9077
II.	Utilities				
	a) Fuel Oil	Te	88.20	900	79
	b) Natural Gas	1000cft	0.60	50,000	30
	c) Steam	Te	6.33	11,710	741
	d) Power	Mwh	32.33	37,395	1209
	e) Water	$000M^3$	138.70	3029	424
III.	Others				
	a) Bags	000Nos	800.00	2880	2304
	b) Labour and Overheads	-	-	-	554
	c) Consumable stores	-	-	-	174
	d) Maintenance Material	-	-	-	873
	e) Insurance	-	-	-	154
	f) Contingency	-	-	-	414
	Annual Works Cost				17776

ANNEXURE IV-C
pp.2

	Item	Unit	Unit Rate $	Annual Consumption	Annual Cost ($ '000)
IV.	Depreciation				3416
V.	Selling Expenses				20
VI.	Average Interest on Loan				1455
	Annual Cost of Production				22667
	Annual Production (Te)				144000
	COST OF PRODUCTION ($/te)				157.40
				Say	158.00

ANNEXURE IV-D

SPECIFICATIONS OF MAJOR EQUIPMENT

Sl. No.	Items	No. reqd.	Brief Specification	Material of Construction
1	2	3	4	5
A.	Gypsum Washing and Wash Water Treatment Section			
1.	Gypsum belt conveyer	2	Cap : 25 M.T./hr	-
2.	Gypsum slurry tanks	2	-	C.S.rubber lined, wooden top.
3.	Slurry pumps	2	Cap : 200 m^3/hr	AISI - 316.
4.	Filter feed tanks	2	1600 mm dia x 2000mm ht.	C.S.rubber lined.
5.	Gypsum filter	2	Filter area : 30 m^2	Part in contact with slurry AISI-316.
6.	Chute for collecting gypsum cake	2	-	S.S.-316.
7.	Belt conveyor for washed gypsum	1	50 M.T./hr	-
8.	Filtrate receiving vessels	2+2	Dia : 1000 mm Height : 2000 mm	AISI - 316 L
9.	Moisture trap	1+1	Dia : 1000 mm Height : 2000 mm	AISI - 316 L
10.	Vacuum pump for gypsum filter	2	Vacuum : 508 mm Ht Capacity : 3000 m^3/hr	Casing :C.I. Impeller :C.S.

1.	2.	3.
11.	Seal tank for gypsum filter	2
12.	Wash water storage tank	1
13.	Wash water recirculation pump	2
14.	Lime reaction tank	1
15.	Settling pond	1
B.	<u>Carbonation and reaction, reaction and filtration gas scrubbing and filtration section</u>	
16.	Carbon dioxide compressor along with accessories	3
17.	Carbonation tower	1

ANNEXURE II-D
pp.2

4.	5.
Dia : 1500 mm Height : 1500 mm	AISI - 316 L
10000 mm lengthx5000 mm widthx3000 mm height.	R.C.C. with wooden cover.
200 M^3/hr	AISI-316
2500 mm dia x 2000 mm ht.	C.S.
40000 length x 25000 width x 1800 ht.	R.C.C.
Flow : 2750 Nm^3/hr. Suction pressure=1.2 Kg/ Cm^2g Discharge pressure = 4.0 Kg/Cm^2g	Cylinder:CI Gr.17 Piston : LM-13 BS - 1490 Piston ring-Teflon
Top portion : 850 Ø x 5350 mm ht. Bottom portion : 2100 Ø x 9500 mm ht.	Body : AISI-316 Frame & pressure Plate : C.S.

1.	2.	3.
18.	Carbliquor circulation pump	2
19.	Carbliquor cooler (plate type H.E.)	4
20.	Spray nozzle for carbonation tower	2
21.	Carbonation tower balance tank	1
22.	Vapour pocket	1
23.	Ammonia Injection nozzle	3
24.	Filter alongwith accessories	1
25.	Reaction exhaust fan	2

ANNEXURE IV-D
pp.3

4.	5.
Flow : 450 m ^{3}/hr Suction pressure : 1.7 Kg/cm ^{2}g Discharge pressure : 4.5 Kg/cm ^{2}g	Casing & Impeller: Incloy - 825 Shaft - AISI 318 Shaft sleeve : Inconel : 825
Flow through each cooler : 100 m ^{3}/hr.	Plate : AISI - 316 Pressure plate:C.S.
400 m ^{3}/hr	S.S. - 316
2000mm x 4000mm length	AISI - 316
200 mm x 400 mm ht.	C.S.
25NB seamless pipe with 16 nos. of 6 0 holes.	AISI-316
Effective filter area = 50 m ^{2}	Main filter body, all wetted parts filter pan, spray slurry and feed liquor distributor AISI - 321 Filter grid : Polypropylene.
3500 m ^{3}/hr Pressure = 1500 mm WG (-ve)	Casing : C.S. with rubber lining Impeller and shaft AISI-316.

1	2	3
26.	Product magma pump	2
27.	Portable pump	1
28.	Scrubber liquor circulation pump	2
9.	S.F.L. Pump	2
30.	Weak liquor pump	3
31.	S.F.L. transfer pump	2

4	5
100 m^3/hr Suction Pressure = 0.82 kg/cm^{2}g Discharge pressure = 4.0 kg/cm^{2}g	Casing Impeller : worthite or R-55 Shaft : ASTM-A314 Type : 316 Sleeve : R-55
70 m^3/hr Suction lift = 6 mlc Head developed = 25 mlc	Stator : AISI-316 Rotar : AISJ-316 Connecting rod : AISI-316
80 m^3/hr Suction pressure=0.2 kg/cm^{2}g Discharge pressure=1.84 kg/cm^{2}g	Casing & Impeller: ASTMA - 216 Gr.CF 8M Shaft and sleeve : ASTMA - 314 Type : 316
80 m^3/hr Suction pressure = 0.2 kg/cm^{2}g Discharge pressure = 2.0 kg/cm^2	Casing & Impeller: ASTM-A216 Gr.CF 8M Shaft and sleeve : ASTM-A314 Type : 316
25 m^3/hr	Casing & Impeller : ASTM - A314 Gr.CF 8M Shaft and sleeve : ASTM - A314 Type : 316
60 m^3/hr	--do--

1.	2.	3.
32.	Chalk slurry pump	2
33.	Floor pump pump	1
34.	Dirty filtrate pump	2
35.	Prewash circulation pump	2
36.	Scrubber liquor cooler (Plate type)	1
37.	Vacuum pump for primary and secondary condenser	2
38.	Vacuum pump for prewash separator	1
39.	Cake discharge blower	1
40.	Gypsum belt conveyer	1
41.	Mixer	1

4.	5.
43 m^3/hr	Casing & Impeller : CF 8 M Shaft & shaft sleeve AISI - 316
15 m^3/hr	--do--
25m ^{3}/hr	Casing & Impeller - CF 8 M
60 m^3/hr	--do--
70 m^3/hr	Plate : AISI 316 Frame & Pressure Plate : C.S.
2000 m^3/hr (max.)	Casing : C.I. Impeller : Bronze (10% Cu + 10% Sn)
2000 m^3/hr (max.)	--do--
2200 m^3/hr	Casing, Impeller : C.S.
50.0 M.T./hr	
Dia : 2500 mm Ht. : 3800 mm	C.S.

1.	2.	3.
42.	Agitator for mixer	1
43.	Seal pot for mixer	1
44.	Reactor	4
45.	Agitator for reactor	4
46.	Catch pot for reactor	
47.	Splitter box for filter feed	1
48.	Reaction scrubber	
49.	Vortex separator	1

4.	5.
Power consumed at shaft = 22 KW Speed : 60,85,100 RPM	AISI - 316
Dia : 650 mm Ht. : 1000mm	C.S. Rubber lined.
Dia : 4300 mm Height : 5000 mm Heating coil dia :3800 Ø Tube dia : 80 NB	C.S.Coil:AISI 316
Power consumed at shaft = 16 KW Speed : 20, 30 rpm.	C.S.
Dia : 1200 mm Height : 1200 mm	
Length : 1700 mm Width : 850 mm Height : 1650 mm	C.S. rubber lined.
Dia : 1400 mm Height : 4200 mm	Body : C.S. Rubber lined Grate : AISI 316 Packing : Ceramic raschig rings.
700 mm x 300 mm ends dia and 700 mm length	AISI - 316

1	2	3
50.	Reaction scrubber distributor with circulation loop.	1
51.	Acid injection nozzle for reaction scrubber.	1
52.	Reaction and filtration scrubber balance tank.	1
53.	Filtration scrubber distributor with circulation loop.	1
54.	Filtration scrubber	1
55.	Acid injection nozzle for filtration scrubber	1
56.	Dirty filtrate separator	1
57.	Filtrate separator	4
58.	Draining separator	1
59.	Prewash separator	1

4	5
	HV - 9A
15 mm 0i	Duriron
Dia : 2400 mm Height : 2400 mm	C.S.
-	HV - 9A
Dia : 1800 mm Height : 6300 mm Packed ht : 3200 mm	Body : C.S. rubber lined Grate : AISI-316 Packing : Ceramic RR
15 mm 0 i	Duriron
Dia top : 1000 mm Dia bottom : 500 mm Height : 2100 mm	Top : C.S. rubber lined Bottom : AISI-316
-do-	-do-
-do-	-do-
-do-	-do-

1	2	3
60.	Filtrate receiver seal tank	1
61.	Vacuum washer seal pot	1
62.	S.F.L. storage tank	2
63.	Prewash seal tank	
64.	Primary spray condenser	1
65.	Secondary spray condenser	1
66.	Chalk slurry tank	2
67.	Floor sump pit	1

ANNEXURE - IV-D

pp.8

4	5
Length : 5000 mm Width : 2400 mm Height : 2700 mm	Body : C.S. rubber lined Cover : Wooden.
Dia : 800 mm Height : 900 mm	C.S. rubber lined.
Dia : 6500 mm Height : 5000 mm	C.S. rubber lined.
Dia : 2000 mm Height : 1800 mm	C.S. rubber lined Barometric leg : H.D.P.
Dia : 1000mm Height : 3500 mm	Shell : C.S. rubber lined Spray nozzle AISI-316.
Dia : 1000 mm Ht. : 3500 mm	-do-
Dia : 3000 mm Height : 3000 mm	C.S.
Dia : 3200 mm Height : 1500 mm	C.S. [illegible]

1	2	3
68.	Dirty filtrate seal tank	1
69.	Agitator for chalk slurry tank	1
70.	Agitator for floor sump pit (paddle type)	1
71.	Agitator for dirty filtrate seal tank	1
72.	D.M. Water heater	1
73.	Chalk hopper	1
74.	Water hopper	1
75.	Chute for feeding gypsum to ET-1	1
76.	Chute for gypsum to mixer	1

4	5
Dia : 1500 mm Height : 1800 mm	C.S. rubber lined.
Power consumed at shaft : 7.0 kw. Speed : 12.5 rpm	C.S.
Power consumed at shaft : 5 kw Speed : 12.5 rpm	C.S.
Power consumed at shaft : 1 kw Speed : 48.5 rpm	Forged steel with rubber lining.
Shell : 400 mm Tube : OD 30 mm Tube length : 3000 mm No. of tubes: 45	S.S. - 316
Size : 3500x2500x3000mm	SS - 316
Size : 3300x2500x2500mm	SS - 316
	SS - 316
	SS - 316

1	2	3
77.	Chute for feeding chalk to chalk slurry tank	1
78.	After cooler for CO_2 compressor	3
C.	<u>Evaporation, Crystallisation, Drying and Cooling section</u> :	
79.	Dope mixing tank with agitator	1
80.	Chemical feed pump	2
81.	Sulphate solution storage tank	1
82.	Sulphate solution transfer pump	2

4	5
	CS rubber lined.
	C.S.
5 m^3 Dia : 2 m Height : 1.6 m HP of agitator -1 Vertical open top, conical bottom.	AISI - 316
Type : Positive displacement Cap : 0.18 m^3/hr Head : 3.5 kg/cm^{2}g HP - 0.25	AISI-316
200 m^3 Dia : 6 m Height : 7 m	AISI - 316
Type : Centrifugal Cap : 220 M^3/hr Head : 23 m	AISI - 316

1	2	3
83.	Evaporator feed head tank	1
84.	Evaporator feed tank	2
85.	Evaporator feed pump	2
86.	Evaporator heater	3
87.	Evaporator	3
88.	Liquor circulating pump	3
89.	Crystal regulating pump	3

4	5
18.2 m^3 Dia : 3 m Height : 3.5 m	AISI - 316
17.6 m^3 Dia : 2.6 m Height : 3.3 m	AISI - 316
Type : Centrifugal Cap : 190 m^3/hr Head : 14 m	AISI - 316
Type : Shell & Tube Vertical Area : 156 m^2	AISI - 316
Vaporizer Dia : 4.0 m Crystallizer dia : 4.8 m Overall Ht. : 12 M Downcomer Pipe Dia : 1 M Downcomer Pipe Ht. : 6 M	AISI - 316
Type : Screw volute Cap : 2400 m^3/hr Head : 21 m 45 HP x 3	AISI - 316
Type : Centrifugal Cap : 84 m^3/hr Head : 2.5 m HP - : 5 x 3	AISI - 316

1	2	3
90.	Salt slurry pump	3
91.	Ejector	3
92.	Jet condenser	1
93.	Seal pot	1
94.	Condensate extraction pump	1
95.	Condensate seal tank	1
96.	Hot condensate pump	2

4	5
Type : Centrifugal Cap : 32 m^3/hr HP - 15 x 3	AISI - 316
Type : Single stage, steam jet. Cap : 245 m^3/hr	AISI - 316
Vapour : 55°C Cooling temperature Inlet : 32°C Outlet : 45°C	M.S.
Pressure : 660 mm Hg vacuum Dia : 1.37 m Height : 1.83 m	M.S.
Type : Centrifugal Cap : 14.2 m^3/hr Head : 10.7 m Temp : 100°C HP - 2.5	Body : C.I. Impeller : AISI-316
Temp : 95°C Dia : 2.66 m Length : 6.7 m	M.S.
Type : Centrifugal Cap : 200 m^3/hr Head : 29 m Temp : 90°C HP - 30	Casing : C.I. Impeller : AISI-316

1	2	3	4	5
97.	Condensate head tank	1	Cap : 28.5 m^3 Temp : 90°C Press : atmospheric Dia : 2.66 m Length : 6.7 m	M.S.
98.	Condensate tank	1	Cap : 28.2 m^3 Press : atmospheric Temp : 90°C Dia : 2.66 m Length : 9.25 m	M.S.
99.	Salt slurry distributor	1	Temp : 50°C - 90°C	AISI - 316
100.	Salt settler	1	Type : Cone bottom Tube : 50-90°C Dia : 3.2 m Ht.(Total): 3.2 m	AISI - 316
101.	Salt filter liquor traps	1	Type : Cylindrical Press : 675 mm HgA Temp : 60-90°C Dia : 1.5 m Ht. : 2.5 m	AISI - 316
102.	Moisture trap	1	Type : Vortex Press : 675 mm Hg H20 Temp : 50-90°C	AISI - 316

1	2	3
103.	Salt filter	1
104.	Exhauster	1
105.	Salt filtrate tank	1
106.	Salt filtrate pump	1
107.	Rotary dryer Temp. : Salt Air Inlet 40°C 220°C Outlet 80° C 95° C	1

4	5
Type : Rotary vacuum Press : 675 mm Hg H_20 abs Temp : 50-90°C	AISI - 316
Type : Cyclodial Cap : 201 m^3/hr Press. suction: 675 mmHgabs Discharge : 200 mmHg abs. Temp. : 90°C H.P. : 150	C.I. & M.S.
Type : Vertical, Cylindrical Temp. : 50-90°C Dia : 2.0 m Height : 3 m	AISI - 316
Type : Centrifugal Cap : 93.5 m^3/hr Head : 24.4 m Temp : 50-90°C HP : 25	AISI - 316
Type : Rotary, counter current, horizontal shell with internal flights. Cap : 25 Te/hr. H.P. : 60	Shell : M.S. Lining : AISI-316

1	2	3
108.	Dryer furnace	1
109.	Dryer fan	1
110.	Rotary cooler	1
111.	Cooler fan	1
112.	Cyclone	2

4	5
Type : Vertical Cap : 350 m^3/hr Heat value : 9095 Kcal/kg. Temp. : 220°C Size : 1.8 x 1.8 x 5 m	M.S. & fire brick
Type : Centrifugal Cap : 44600 m^3 /hr Temp. : 70°C Head : 125 mm water gauge H.P. : 50	M.S. & C.I.
Type : Rotary Cap : 25 Te/hr. Temp. : Salt Air Inlet 80°C 30°C Outlet 50°C 58°C Dia : 2.8 m Length : 12.5 m H.P. : 60	Shell : M.S. Flights : M.S.
Type : Centrifugal Cap : 50000 m^3/hr Head : 125 mm H_2Og Temp : 50°C H.P. : 60	M.S.
Temp. : 70-80°C for dryer cyclone 60°C for cooler cyclone Dia : 3.2 m Cylindrical Ht.:4.8m cone Ht. : 8.0 m	M.S.

1	2	3
113.	Over flow extraction pump	1
114.	Jet condenser pump	1
D.	Ammonium Sulphate Bagging Section :	
115.	Ammonium sulphate stocking out conveyer	1
116.	Ammonium sulphate belt weigher	1
117.	Ammonium sulphate distribution conveyer	1

4	5
Type : Centrifugal Cap : 250 m^3/hr Head : 10 m H.P. : 75	AISI - 316
Type : Centrifugal Cap : 250 m^3/hr Head : 6.1 m Temp. : 32°C	M.S. & C.I.
Cap : 50 Te/hr (peak) Length : 45 m Lift : 9.5 m Angle of inclination - Horizontal and 18° Type : Belt H.P. : 7.5	Rubber & M.S.
Capacity : 25 Te/hr max. Type : Automatic and continuous conveyer weigher	-do-
Cap : 50 Te/hr (Peak) Length : 166 m Lift : 7 m Angle of inclination : 18° and horizontal Type : Belt H.P. : 12.5	-do-

1	2	3
118.	Ammonium sulphate stocking out tripper	1
119.	Ammonium sulphate mobile shovel	-
120.	Portable conveyer	1
121.	Reclaiming conveyer	1
122.	Outloading conveyer	1

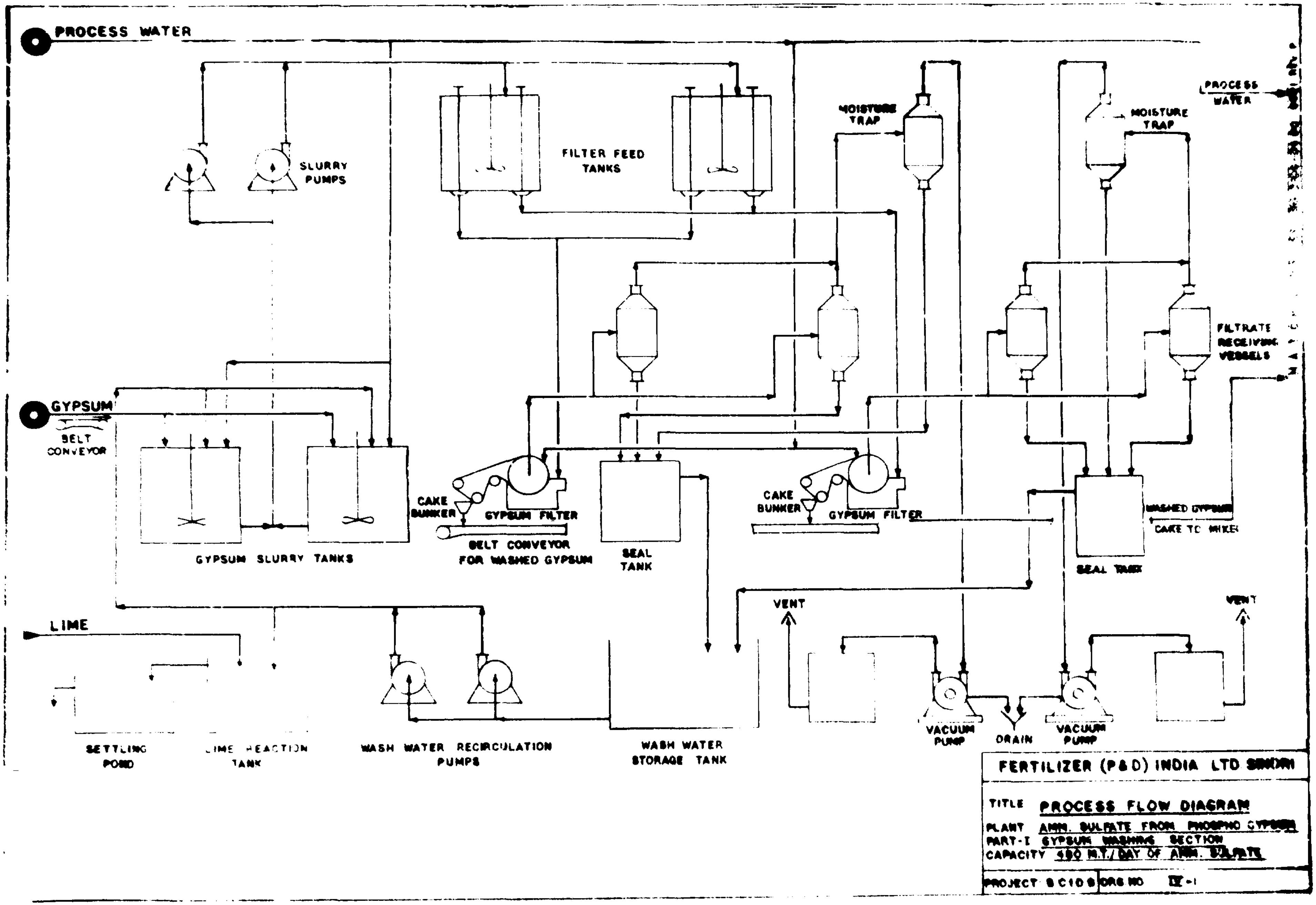
4	5
Fitted on ammonium sulphate distribution conveyer.	M.S.
Cap : 47 Te/hr (approx) Type : Positive crowed mechanical shovel. Diff. Cap: 0.67 cum. H.P. : 40	
Cap : 50 Te/hr Length : 9 m Lift : 2.5 m Angle of inclination 18° Type : Belt. H.P. : 8	M.S. and rubber
Cap : 50 Te/hr Angle of inclination : Horizontal and 18° Lift : 6.4 m Length : 180 m H.P. : 10	M.S. Rubber
Cap : 50 Te/hr Angle of inclination : 18° Lift : 5.4 m Length : 53 m Type : Belt H.P. : 7.5	M.S. & Rubber

1	2	3
123.	Bunker for ammonium sulphate	3
124.	Free flow mouthpiece	6
125.	Automatic weighing machine	6
126.	Bagging hopper	6
127.	Gravity conveyers for ammonium sulphate bags.	6
128.	Ammonium sulphate band conveyer	3
129.	Ammonium sulphate sack sewing machine	3

4	5
Cap : 25 Te	M.S.
Cap : To pass 50 Te/hr of ammonium sulphate crystal. Type : Small hopper fitted to bottom of bunker.	M.S.
Cap : To measure 50 kgs. crystals into each empty sack and each machine capable of 7 discharges of 50 kgs. in one minute. Type : Automatic preweigher.	-
Cap : 50 kg (min.)	M.S.
Type : Mild steel frame carrying tubular rollers.	M.S.
Cap : 50 Te/hr Lift : Nil Length : 6.5 m H.P. : 1	M.S.
Cap : 7 sacks per minute H.P. : 1	

1	2	3	4	5
130.	Ammonium sulphate retractable Bag Conveyor	1	Cap : 50 Te/hr 50 bags of ammonium sulphate. Horizontal length : 4.1 m H.P. : 2	M.S.
131.	Ammonium sulphate retractable bag conveyor	2	Cap : 50 Te/hr. 50 bags of ammonium sulphate. Horizontal Length : 8.1 m H.P. : 2	M.S.
132.	Ammonium sulphate feeder conveyor	1	Cap : 50 Te/hr Horizontal Length : 3.5 m H.P. : 2	M.S. & rubber

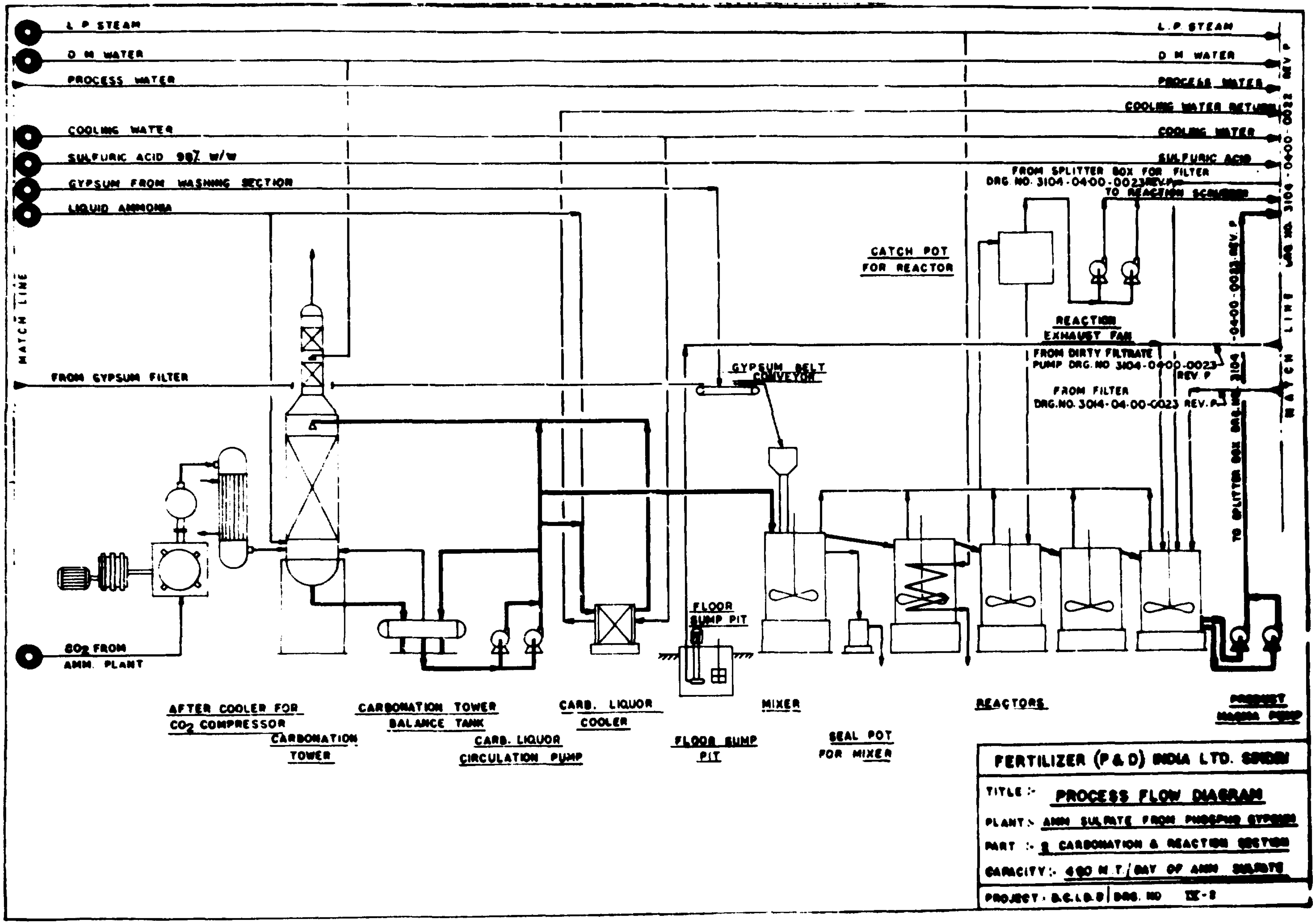
Silo size : 90 m x 38 m floor area.



FERTILIZER (P&D) INDIA LTD SINDRI

TITLE PROCESS FLOW DIAGRAM
PLANT AMM. SULFATE FROM PHOSPHO GYPSUM
PART-I GYPSUM WASHING SECTION
CAPACITY 450 M.T./DAY OF AMM. SULPHATE

PROJECT 8C108 DRG NO IX-1



FERTILIZER (P & D) INDIA LTD. SINDRI

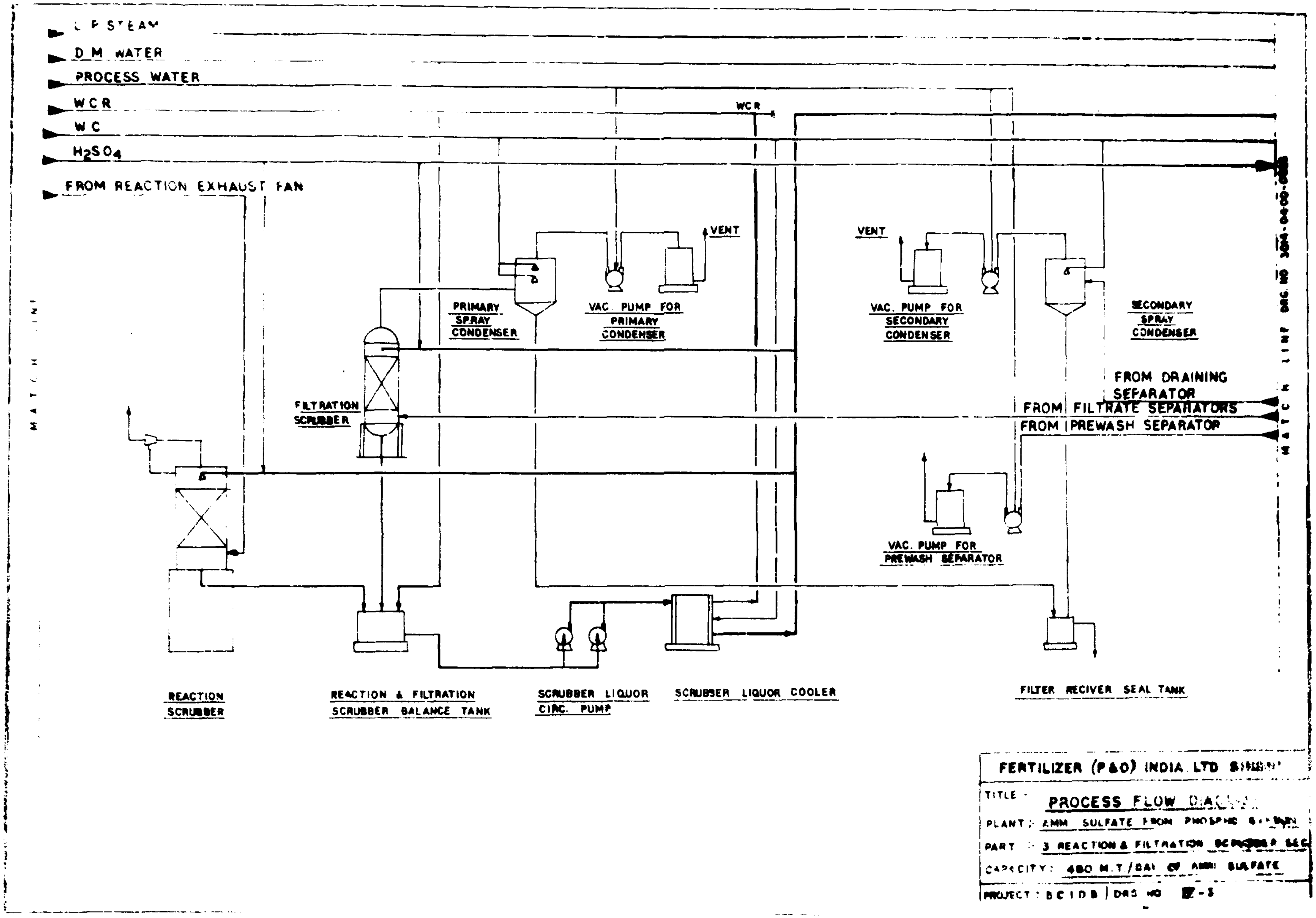
TITLE :- **PROCESS FLOW DIAGRAM**

PLANT :- AMM SULFATE FROM PHOSPHO GYPSUM

PART :- 2 CARBONATION & REACTION SECTION

CAPACITY :- 400 M.T./DAY OF AMM SULFATE

PROJECT : B.C.I.D.B | DRG. NO IX-2



FERTILIZER (P&D) INDIA LTD SINDRI

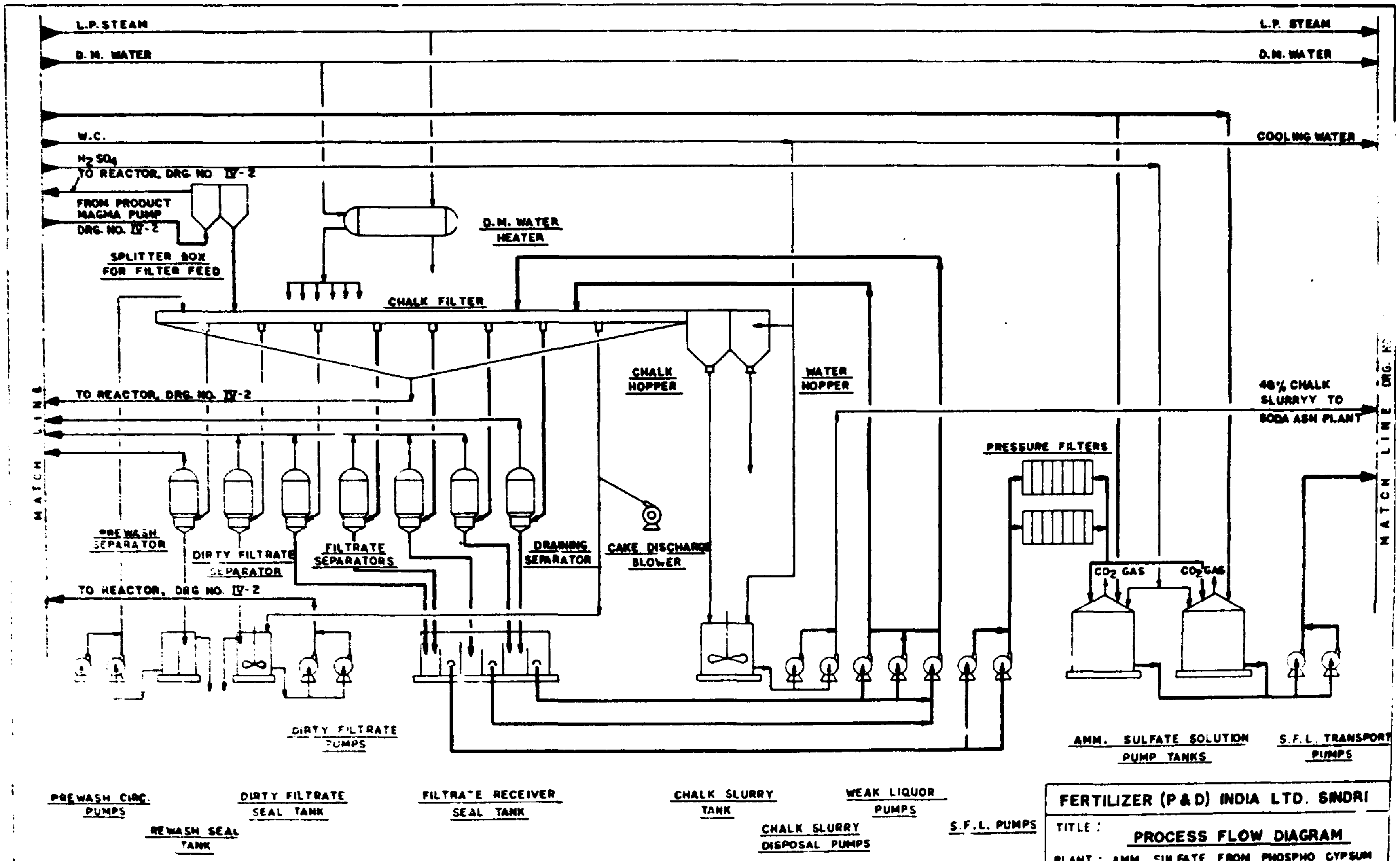
TITLE - PROCESS FLOW DIAGRAM

PLANT :- AMM SULFATE FROM PHOSPHO GYPSUM

PART :- 3 REACTION & FILTRATION SCRUBBER SEC

CAPACITY : 480 M.T./DAY OF AMM SULFATE

PROJECT : B C I D B | DRG NO IV-3



FERTILIZER (P & D) INDIA LTD. SINDRI

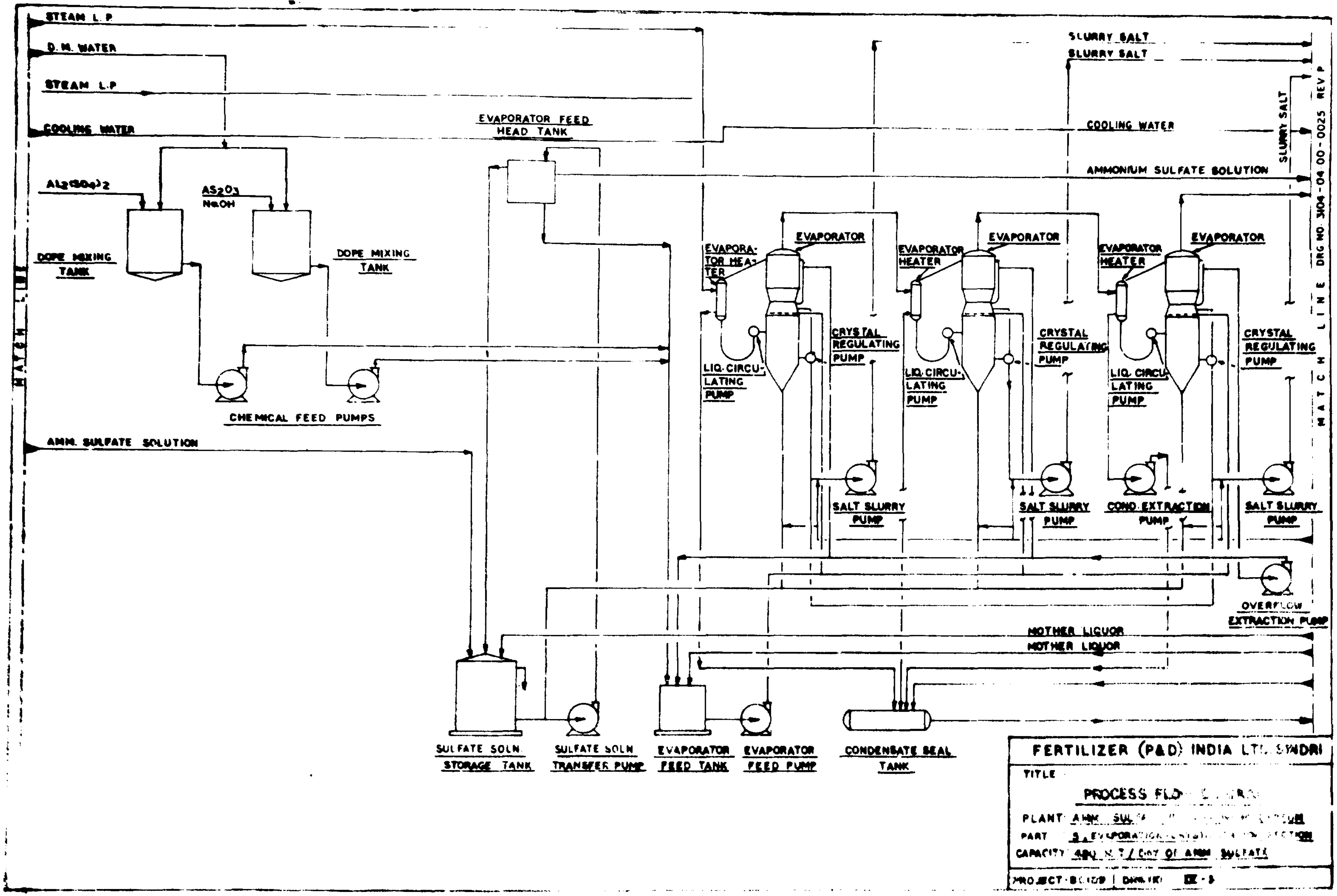
TITLE : PROCESS FLOW DIAGRAM

PLANT : AMM. SULFATE FROM PHOSPHO GYPSUM

PART : 4 FILTRATION SECTION

CAPACITY : 480 M.T./DAY OF AMM. SULFATE

PROJECT : B.C.I.D.B | DRG. NO IV-4



FERTILIZER (P&D) INDIA LTD. SINDRI

TITLE

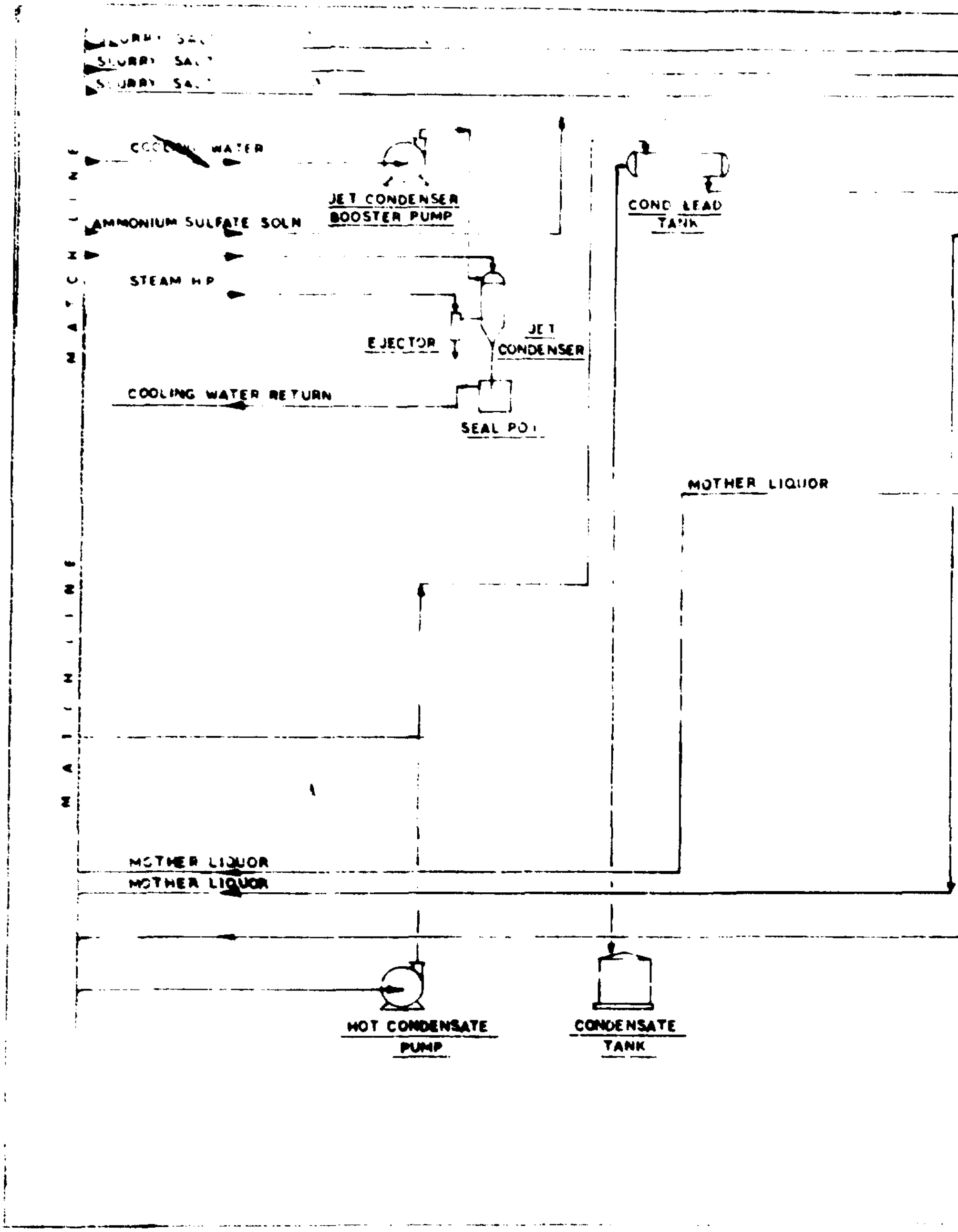
PROCESS FLO[illegible]

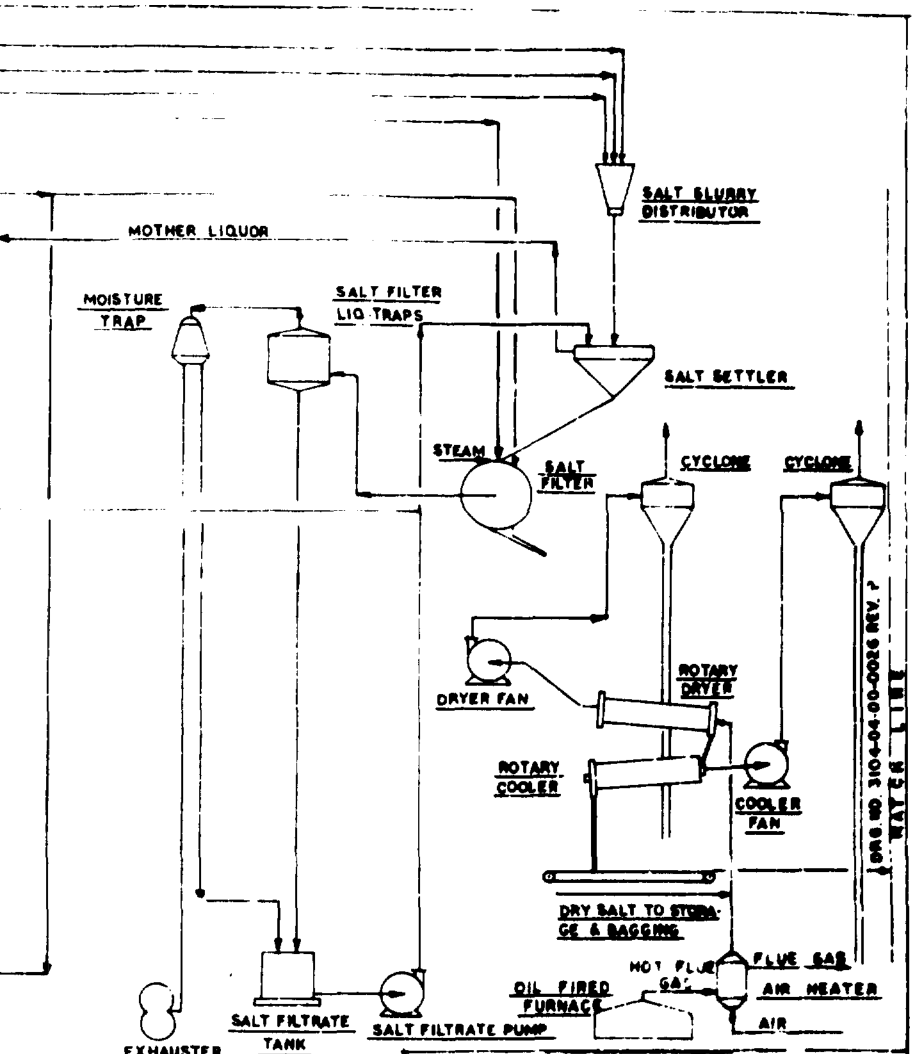
PLANT: AMM. SUL[illegible]

PART: 5. EVAPORATION [illegible] SECTION

CAPACITY: 400 M.T./DAY OF AMM. SULFATE

PROJECT · B[illegible] | DWG. NO. IX - 3


SLURRY SALT
SLURRY SALT
SLURRY SALT
COOLING WATER
JET CONDENSER BOOSTER PUMP
AMMONIUM SULFATE SOLN
STEAM HP
EJECTOR
JET CONDENSER
COOLING WATER RETURN
SEAL POT
COND LEAD TANK
MOTHER LIQUOR
MOTHER LIQUOR
MOTHER LIQUOR
HOT CONDENSATE PUMP
CONDENSATE TANK



FERTILIZER (P& D) INDIA LTD. SINDRI

TITLE :-

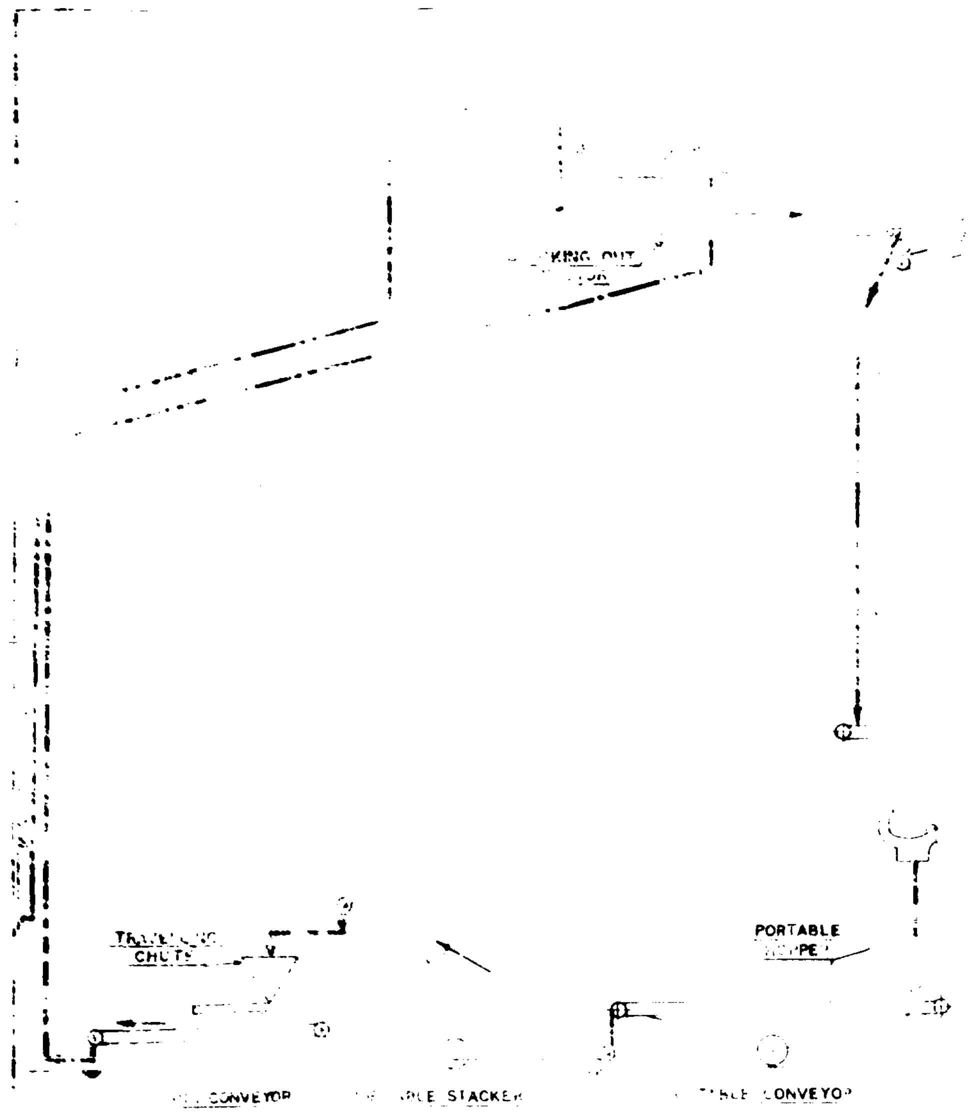
PROCESS FLOW DIAGRAM

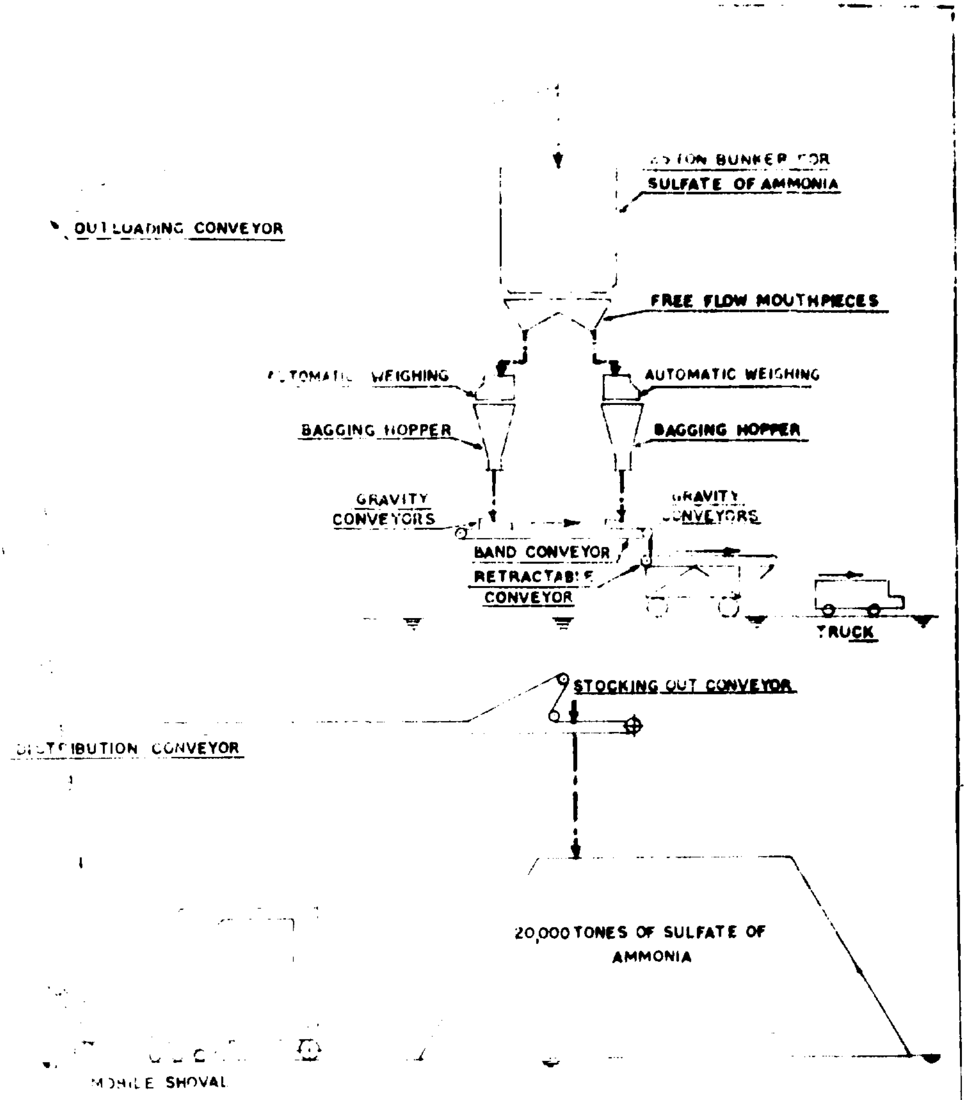
PLANT: AMM. SULFATE FROM PHOSPHO GYPSUM.

PART: 6, FILTRATION, DRYING & COOLING SECTION

CAPACITY: 480 M.T./ DAY OF AMM. [illegible]

PROJECT BC108 DRG NO IV-6


KING OUT
TRAVELLING
CHUTES
PORTABLE
HOPPER
CONVEYOR
STACKER
CONVEYOR



FERTILIZER (P & D) INDIA LTD. - SINDRI

TITLE -

PROCESS FLOW DIAGRAM

PLANT: AMM SULFATE FROM PHOSPHO GYPSUM

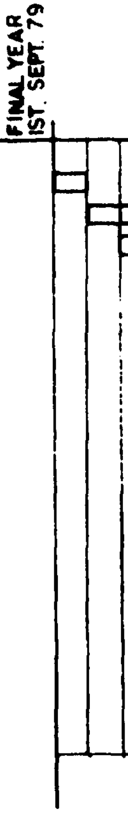
PART 7, AMM SULFATE HANDLING SECTION

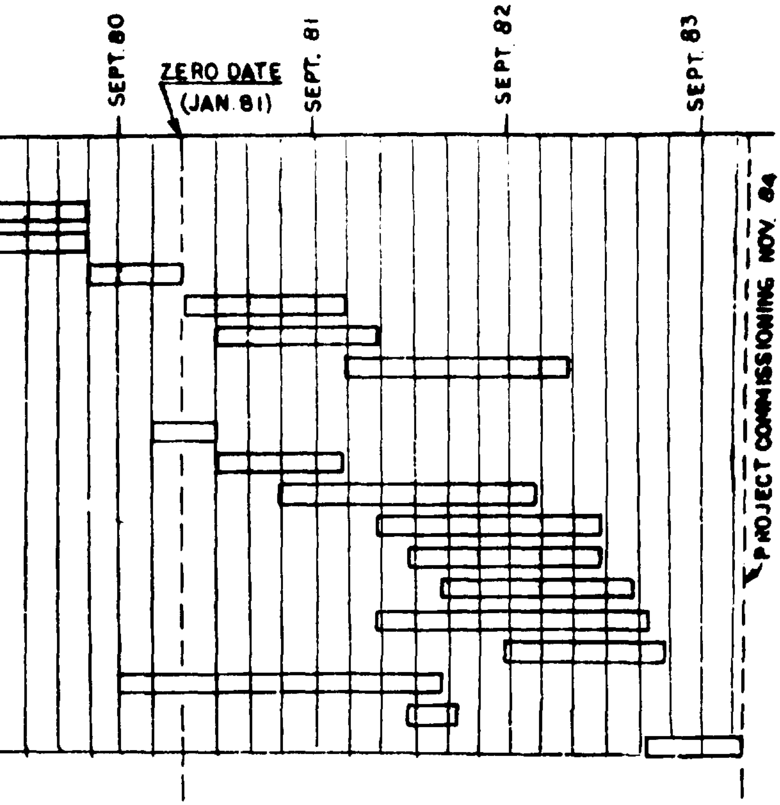
CAPACITY 480 M.T./DAY OF AMM SULFATE

PROJECT BCIDB DRG NO IV /

1. SCRUTINY OF PROJECT REPORT
2. FINANCIAL ARRANGEMENT
3. SELECTION OF PROJECT CONSULTANT
4. SELECTION OF ENGINEERING CONTRACTOR
5. DESIGN AND ENGINEERING OF PLANTS AND FACILITIES
6. ORDERING OF EQUIPMENTS AND SUPPLIES
7 DELIVERY OF EQUIPMENTS AND SUPPLIES

8. SITE PREPARATION
9. CIVIL WORKS DESIGN
10. CIVIL WORKS EXECUTION
11. ERECTION (MECHANICAL)
12. ERECTION (ELECTRICALS)
13. ERECTION (INSTRUMENTS)
14. ERECTION (PIPING)
15. INSULATION AND PAINTING
16. OFF SITE FACILITIES AND UTILITIES
17. TRIAL AND COMMISSIONING OF OFFSITE FACILITIES
18. TRIAL RUNS FOR MAIN PLANT AND COMMISSIONING OF PROJECT



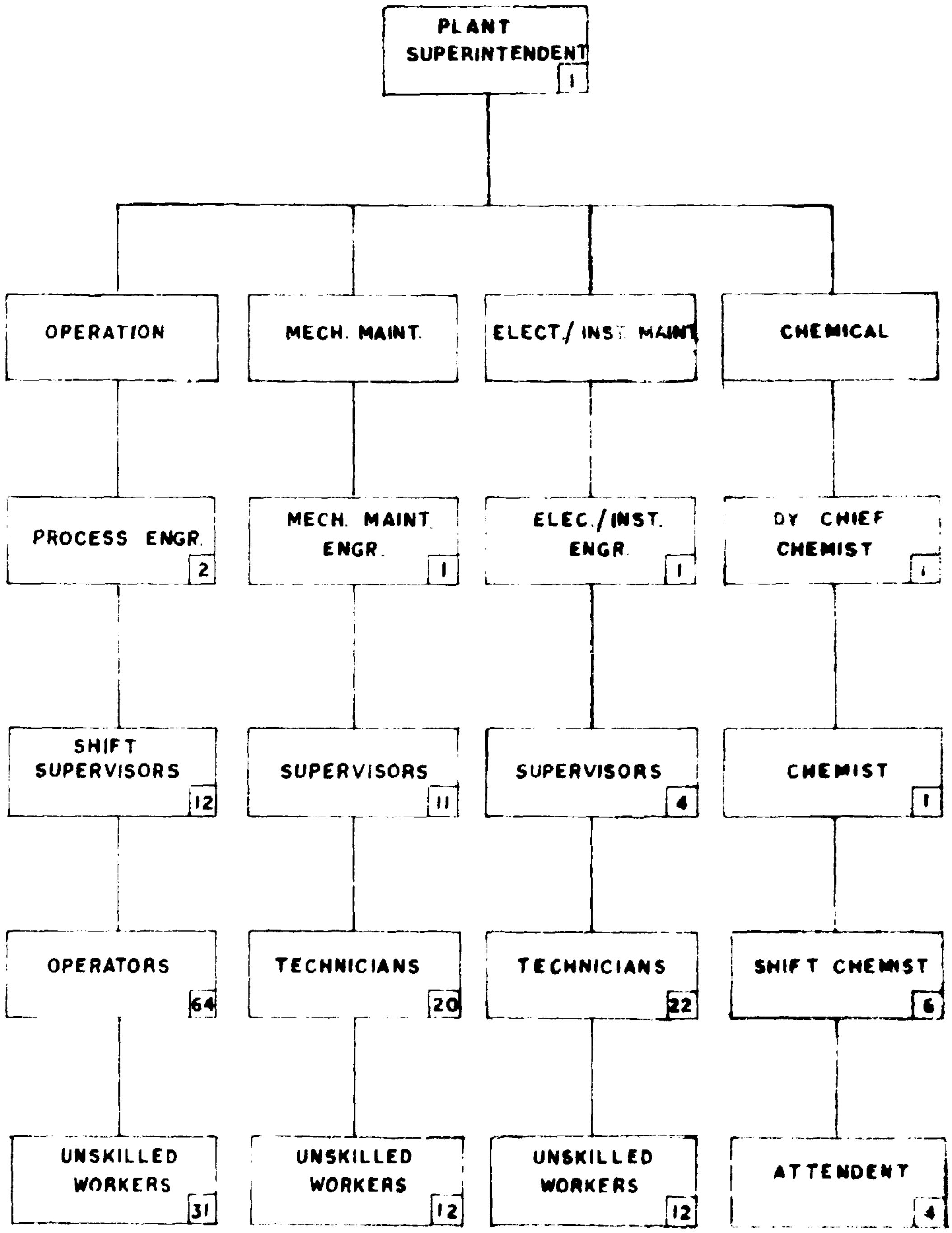


FERTILIZER (P&D) INDIA LTD. SINDRI

TITLE **TENTATIVE TIME SCHEDULE FOR AMMONIUM SULPHATE PLANT**

PROJECT - BCIC	DRG. NO. IV - 8

ANNE



BAGGING PLANT STAFF IS CONSIDERED ALONG WITH OFF SITE FACILITIES STAFF REQUIRED FOR BAGGING PLANT - TOTAL 52 NOS.

SUPERVISORS - 1 NO.
SHIFT SUPERVISORS - 3 NOS.
LOADING SUPERVISORS - 3 NOS
OPERATORS - 15 NOS.
HELPERS - 6 NOS.
LOADERS - 24 NOS.

FERTILIZER (P & D) INDIA LTD SINDRI

TITLE :

MANPOWER REQUIREMENT FOR AMMONIUM SULPHATE PLANT

TOTAL = 205

PROJECT : B.C.I.D.B | DRG NO. IV 3

BASIC CHEMICAL INDUSTRIES DEVELOPMENT
IN
BANGLADESH

10139
(5)

Part Five
MANUFACTURE OF SODA ASH

FERTILIZER (PLANNING & DEVELOPMENT) INDIA LTD

SINDRI, INDIA, 828122

Job No. 3104

PART V

MANUFACTURE OF SODA ASH

PART V

MANUFACTURE OF SODA ASH

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PART V : MANUFACTURE OF SODA ASH

Chapter 1

INTRODUCTION

1.1 Soda ash (technical grade sodium carbonate) is a white crystalline hygroscopic powder. It is one of the low cost alkalies widely in use throughout the world. Though a significant proportion of the supply is still obtained from natural sources, the manufacture of synthetic soda ash is one of the oldest and easily one of the largest basic chemical industries in the world - possibly the third largest in terms of world production.

1.2 By virtue of its being a relatively low-priced basic alkali chemical, soda ash is extensively used in a large number of industries - in fact, it is sometimes said that there is hardly any manufactured product which does not use soda ash or one of its derivatives at some stage of its production or other, Indicative of its importance, the consumption of soda ash (like sulphuric acid) is often regarded as an index of a country's industrial development.

1.3 There are two major,technically distinguishable, process routes in commercial use for the manufacture of soda ash. The first one, the standard Ammonia - Solvay Process (more popularly known as 'Classical Solvay Process', or simply 'Solvay Process') was originally evolved during the eighteenth century as Le Blanc process. For a long period, this was the only process commercially used throughout the world for soda ash production. In the 1960's however, as a result of the vigorous development work done in Japan, the Dual Process (sometimes referred to as Modified Solvay) came to be commercially estabilished with the setting up of a number of units based on this process. Unlike in the Classical Solvay

Process, the Dual Process produces two products almost in equal proportions : soda ash and ammonium chloride - which can be used as nitrogen fertilizer. As will be seen later, the Dual Process economises on the use of common salt, the principal raw material, and does not require limestone (another major raw material in the Classical Solvay process) for process-use, which makes the location of the plantrelatively more 'foot-loose'. However, the Dual Process requires large quantities of ammonia - which is fixed as ammonium chloride and therefore, is not available for recycling - and exogenous carbon dioxide. For this reason, the Dual Process soda ash plants are normally set up as adjuncts of largescale ammonia plants so that ammonia, and usually carbondioxide from the ammonia plants, can be made use of in the soda ash plants. Technically either of the process-route plants can be set up in Bangladesh, though some constraints exist in each case, the inadequacies of salt production within the country being applicable to both. The expansion of salt production on modern lines within the country to ensure adequacy of supplies and production of industrial grade quality is, therefore, a pre-requisite for the establishment of a viable soda ash industry within the country.

1.4 As mentioned earlier, this Study examines the feasibility of setting up manufacturing facilities based on either of the two established processes. However, in order to facilitate the economic disposal of phosphogypsum of the TSP Complex in Chittagong, the effect of using by-product chalk from an ammonium sulphate plant based on the phosphogypsum route, in lieu of limestone, has been examined (see also Part II) as an alternative, esepcially since the country does not have at present enough supplies of limestone and known deposits are not easy to mine. The availability of byproduct chalk is However, contingent on the setting up of an ammonium sulphate plant, for which arrangements for supply of ammonia and carbondioxide will need to be tied up. Principally, two locations have been discussed, Chittagong, and alternatively Ghorasal, near Dacca.

1.5 Bangladesh imports annually substantial quantities of soda ash both for industrial consumption and household use as a cleaning agent. There is at present no indigenous production. Compared to the pre-Independence (1970) period, however, the growth in consumption seems to have decelerated, though the statistics available are not very reliable (Chapter 2). The slow-down seems to be mainly due to import constraints, and the inadequacy of supplies of soda ash appears to have resulted in the neglect of a large number of user industries, besides lowering of the general standard of cleanliness in house-hold washing in the rural side. There is a reasonable prospect that indigenous production of soda ash, by relieving the uncertainties of supply and timing, might lead to a step-up in industrial activity in the country, partly by reviving the disused units and partly by promoting new industries. In several developing countries in the initial stages of industrialisation, the local production of a major input itself acts as a catalyst in promoting the growth of new user industries, and this is likely to happen in Bangladesh as well. Even without making allowance for these developments, as shown later. The projected demand in 1985 is expected to be around 49,000 tpy - adequate to support a viable-sized plant.

Chapter - 2

DEMAND FOR SODA ASH

2.1 Soda Ash is the commercial name for the technical grade sodium carbonate (Na_2CO_3). It is one of the widely available, low-cost and reasonably pure soluble alkalies in present day use. It is produced in several commercial forms, which vary in respect of size and shape of particles, bulk density etc. The standard forms are 'light' and 'dense' soda ash, graded according to bulk density. Though a significant proportion of the supply is still obtained from natural sources - according to an estimate, natural soda accounted for over 40 per cent of the total soda ash produced in the USA in a recent year, - the manufacture of synthetic soda ash is one of the oldest and easily one of the most important of the basic chemical industries in the world, in terms of number of units as well as magnitude of production. With over 20 million tonnes a year, it is the third largest chemical manufactured in modern times, possibly ranking next only to sulphuric acid and ammonia.

2.2 By virtue of its being a basic alkali chemical - a 'building block' in processing, - the quantum of consumption of soda ash is often regarded as an index of industrial development of a country. It finds uses in a large number of industries such as -

Glass
Soaps & detergents
Cleaners
Textiles
Water-softening
Petroleum refining
Aluminium production
Leather
Pulp and paper
Metal processing
Ceramics

and in the manufacture of a number of secondary chemicals such as caustic soda, silicates, sodium bicarbonate, boiler compounds, welding fluxes, etc. Its industrial uses are diverse; it is said that there is hardly any manufactured product which does not use soda ash or one of its derivatives at some stage of its production or other. Its single largest use in countries like Bangladesh, India and Pakistan, however, is in laundering and domestic washing where it serves as a cheaper substitute for soap.

Supply Source and Demand Trend in Bangladesh

2.3 There is nonindigenous manufacture of soda ash in Bangladesh and the entire demand is met by imports. A proposal for the establishment of a local unit for its manufacture had had a long and chequered history dating back to the late sixties. One of the principal reasons for the proposal not making much headway, apart from heavy capital requirements, appears to be the paucity in Bangladesh of the main raw materials viz. salt, limestone and ammonia needed for its production, Salt, in particular, is needed in relatively ample quantities - from 1.3 to 1.7 te per tonne of soda ash, depending on the process - and the indigenous production of salt in Bangladesh has been inadequate even for human consumption, necessitating regular imports. Besides the salt produced is qualitatively unsuitable for chemical processing, and its purification will add substantially to the costs of manufacture.

2.4 The data available for recent years on the imports of soda ash into the country, which as the sole source of supply could have given an indication of the demand trends within the country, - are quite sketchy and inadequate for any meaningful analysis. The published import statistics do not reveal the quantities, but only show the value of imports. The data specially collected from the Bangladesh Bureau of Statistics (BBS) do not seem to agree with the figures collected from the other equally reliable sources. The import figures, as given by BBS are shown in Table 2.1

Table 2.1

Imports of Soda Ash into Bangladesh

Year	Quantity (in tonnes)
1973-74	5,913
1974-75	14,205
1975-76	16,361
1976-77	8,993
1977-78 (July-Decr.)	3,946

These import figures do not agree with the data compiled from the Customs Bulletins (Table 2.2) for the Chittagong Port, where almost the entire quantity of soda ash is imported, for some past years.

Table 2.2

Soda Ash Imports acc. to Customs Bulletins

Year	Quantity (in tonnes)
1973-74	5,790
1974-75	12,510
1975-76	24,414

Besides, the records of the Trading Corporation of Bangladesh (TCB), a major State sector importer of light soda ash, show that TCB alone imported 12,085 tonnes of soda ash during 1973-74 (July-June), whereas the BBS figures indicate import of only 5913 tonnes during this period. Again, during the June-Dec.'77 (half-year) period, whereas the BBS figures show an import of 3,946 tonnes, the TCB is on record as having imported a single consignment of 5150 tonnes from Bulgaria. The figures made available by BBS show that the maximum import during the last five years (1973-78) was 16,361 tonnes and the average, less than 10,000 tonnes per year. However, an official committee of the Planning Commission on import substitution in the chemical process industries has estimated the average annual import of soda ash into the country at 30,000 tonnes.1/ The Consultants' discussion with knowledgeable officials in the Directorate-General of Industries, the TCB etc. and the limited market studies conducted among major consumers, importers and distributors in Bangladesh confirmed the view that the official statistics on soda ash imports are underestimates and that in all probability the annual imports average between 25,000 and 30,000 tonnes in recent years. Soda ash imports into Bangladesh averaged about 20,000 tonnes even during the sixties.

2.5 In the absence of reliable data, it is difficult to make any meaningful estimate of the present demand for consumption of soda ash in the country. It is, however, fairly certain that consumption has been severely curtailed by availability and the demand is substantially higher than is indicated by the import figures. The import policy in the post-Independence

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1/ Report of the Sub-Committee of Chemical Process Industries of Import Substitution (1978-79).

period has been fairly restrictive and has been effective in keeping down consumption. Though imports are allowed subject to quotas for the actual users, as well as the TCB (in the ratio of 70 : 30), the quotas, expressed in value terms, were until recently based on the 1973 prices of soda ash. The rise in the international prices since 1973 had the automatic effect of reducing the quantities imported. As a result, several industrial consumers found themselves starved of the product.

2.6 The quantities received in quite a number of cases were so small that the production units could be run only for short periods and the importers found it more profitable to sell the soda ash in the open market at high prices rather than use it in production. It was only in 1978 that the basis of quota values was updated to current prices. Considering, therefore, the considerable underutilization of capacity in a large number of user-industries, and the mark-up at which the product sells within the country, the Consultants feel that the unsatisfied demand could amount to atleast 20 per cent of the present actual consumption. Taking the recent average consumption conservatively at 25,000 tonnes, the present total demand for soda ash can be placed at about 30,000 tonnes/year.

Pattern of Consumption

2.7 Information on the end-uses of soda ash in Bangladesh is hard to get and the estimates therefore, have to be necessarily based on indirect evidence. Like other countries of the Indian sub-continent, a large proportion of the available supply, however, is understood to be used as a cleaning agent by 'dhobies' (washermen) and laundries (non-power) as well as by households especially in the rural areas, for washing of linen. Since soda ash is considerably cheaper than soap, and can be bought in small quantities, it holds considerable attraction as a washing agent for the semi-urban and rural families. In fact the Consultants observed that soda ash is sold in retail in practically every village grocer shop across the country. Estimates of actual total consumption by the 'washing sector', however, vary widely, based as they are on personal judgements rather than on any survey date. A consulting firm estimated in 1969 the total utilisation for this purpose at 13000 tons, when the population of Bangladesh was only 66.5 million, compared to 84.7 million at present (1978). Scarcity due to restricted imports, especially for non-industrial uses and high prices seem to have, however, acted as a drag on the natural growth in consumption in this sector with population rise, despite the void left by the practical non-expansion of the washing soap industry in the country. Based on discussions with the principal soda ash distributors in the country in regard to the off-take by upcountry centres in Bangladesh and a rough cross-check with the washermen and the village grocers in a few rural and semi-urban areas on the consumption norms etc. the Consultants estimate the present annual consumption for traditional-type washing by the 'dhobies', laundries and the households at about 14,000 tonnes.

Glass Industry

2.8 The glass industry is the next major consumer of soda ash in Bangladesh, and in the industrial application, it easily ranks as the biggest end-user. Even in advanced countries, the USA, for example, the glass industry accounts for about 40 to 50 per cent of the total demand for soda ash. On a world scale, the share of the glass industry in soda ash consumption is believed to be around 25 to 30 per cent. Bangladesh's consumption of soda ash for glass manufacture in 1968 itself was estimated at 11,000 tonnes. According to the Director General of Industries, there are at present on record 23 glass units in the country, including two in the public sector with a total nameplate capacity of 43, 850 tonnes of glassper year. On the norm of about 0.3 te of soda ash per tonne of glass, the total soda ash requirement of the industry should have been ordinarily around 13000 te/year. However, a number of units, mainly producing holloware and glass tumblers appear to have closed down. Almost all the remaining ones are understood to be working considerably below capacity. Someof them are, in fact, said to be working only nominally, both on account of raw material shortage and adverse marketing situation such as competition from imports[2]. According to the assessment made by the Consultants, the total quantity actually consumed by the glass industry in 1977-78 is about 5000 tonnes, of which light soda ash accounted for roughly 75 per cent. Except for one unit in the public sector producing sheet glass, almost all other units are said to be using light soda ash, though normally the glass industry prefers dense soda ash.

Silicates

2.9 Sodium silicate is the next important consumer of soda ash in the country with a substantial annual requirement. It is one of the oldest industries in Bangladesh and is fairly well established. There are at present in all 7 units including one in Chittagong with a total installed capacity of about 14800 tonnes/year. Except probably for one or two, none of the units are working

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2/ Under the existing taxation structure in Bangladesh certain categories of finished glass bottles (vials and ampoules) for instance attract only 10% import duty whereas the incidence of taxes and duties on locally produced bottles is said to be about 32%. Besides imported raw materials like soda ash used in its manufacture attract over 80% of duties, taxes and other imposts.

to full capacity and their actual consumption in 1977-78 is estimated at about 4000 tonnes. A large proportion of sodium silicate produced is understood to be used in low-priced washing soap production, mainly as a filler.

Paper & Pulp

2.10 Substantial quantities of soda ash are also understood to be used in the production of paper and pulp, particularly in the pulp mill at Sylhet and the newsprint mill at Khulna, both under the Bangladesh Chemical Industries Corporation (BCIC). The total annual requirement of the paper and pulp industry currently is estimated at 3500 tonnes.

Miscellaneous

2.11 Among other miscellaneous users, the 2 caustic soda unit use soda ash for brine purification (about 500 te/year) and it is used in the textile industry for scouring, (about 600 te/year). It is also used to some extent in leather (chrome) tanning in conjunction with lime for improving the action of liming and for making the chrome tanning liquor basic in order to facilitate absorption of chrome salts. Relatively small quantities are also used in refractrory units, in water treatment, vegetable oil processing, petroleum refining and rayon production. Thus, broadly, the present end-use pattern of soda ash in Bangladesh is as follows (Table 2.3).

Table 2.3

Present Pattern of Consumption of Soda Ash

	End -Use	Estimated consumption (Tonnes)
1.	As washing agent	14,000
2.	Glass industry	5,000
3.	Sodium silicate units	4,000
4.	Paper and pulp units	3,500
5.	Other miscellaneous uses	3,000
		29,500

Import and Distribution

2.12 Soda ash imports are subject to licensing restrictions and the quotas are usually expressed in value. Imports are allowed to major (industrial) actual users, as well as commercial importers besides the TCB which, in the latest import policy order (June 1978), has been allowed a 30 per cent share in the total import allocation for light soda ash. Except for the BCIC which imports small quantities of dense ash for its own units, almost the entire quantity imported is light soda ash. There are no restrictions on the distribution within the country and the mark-up at successive stages is quite high. The imports attract a customs duty of 55 per cent and a sales tax of 20 per cent on the duty paid value. Typically, the landed cost for TCB imports through the Chittagong Port works out as follows :

		Tk/Tonne
1.	C&F price (say, $ 82)	1230.00
2.	Import duty @ 55%	676.50
3.	Sales tax @ 20% of d.p.v.	381.30
4.	L/C charges	0.25
5.	Landing charges and river dues	10.82
6.	Shipping agency charges	2.50
7.	Stevedoring	9.85
8.	Survey, sampling and inspection	1.00
9.	Weighment charges	16.00

10.	Agency commission etc.	7.33
11.	Handling charges	18.00
12.	Removal from jetty to godown	37.00
13.	Storage	86.70
14.	Delivery ex-godown	8.16
15.	Octroi @ Tk 2/md	54.00
16.	Unforeseen expense 1%	25.40
17.	Commission @ 5%	128.27
		2693.67

Inclusive of interest charges, insurance, etc., the TCB's ex-godown selling price worked to around Tk 3000/- per te., a mark-up of about 245 per cent over the C&F value. However in retail the price went as high as Tk 4000 to 4500, depending on the quantity involved and the area.

Projected Demand : 1985

2.13 As mentioned earlier, the data available on the consumption of soda ash by the different sectors of industries in Bangladesh is meagre and imprecise, having been generally derived indirectly. A major proportion of the present demand, as shown earlier, emanates from the unorganised and household sectors, for which no data has ever been compiled. No reliable information is available on the extent of unsatisfied demand in the country caused by restricted imports, though it is known to be substantial. Whether the large number of soda ash consuming units presently closed will ever be reopened depends not only on the availability of supplies but also on several other factors including the industrial development policy of the Government. In view of these factors, any projection of future demand is bound to contain a certain element of conjecture.

2.14 The future growth in demand for washing purposes from 'dhobies', laundries and the household sector will determine to a large extent the size of demand for soda ash as a whole in the country. As seen earlier, the present consumption of this sector accounts for nearabout 47 per cent of the total use in the country. Ordinarily, with the high rate of growth of population growth in urbanisation and the spread of urban habits and improvement s in the standard of living due to economic development generally, the requirement of cleaning agents may be expected to grow fairly rapidly. However, the urbanisation process also tends to bring about a shift in favour of improved products for washing such as soaps and detergents. The changes in clothing materials with a manifest trend in favour of synthetic and blended textiles, which require lighter washing, are also expected to favour this trends. As a result, normally, the growth rate in soda ash consumption for washing purposes may be expected to slow down in future. However, to what extent this substituion process will manifest itself under Bangladesh conditions will depend to a considerable extent on the growth pattern and pricing levels of the soaps and detergents industry.

2.15 The detergents industry is still in a nascent stage of growth in Bangladesh, with only one manufacturing unit (600 te capacity) in production. The washing soap industty has not shown itself as a dynamic growth sector in the post-Independence period; in fact most of the units, in the non-mechanised sector particularly, seem to be

languishing though the total 'nameplate' capacity is estimated at over 100,000 te. The utilisation of even the organised sector's installed capacity - estimated at 13,400 tons in the mechanised units- is quite low; in 1976-77, it was only about 60 per cent. In the case of non-mechanised units it was possibly less than 15 per cent. The soap industry in Bangladesh suffers, among others, from the basic infirmity that almost all raw materials, including oil/tallow are required to be imported and the imports have never been quite free. There is also a fairly high excise duty (Tk 540/te) on soap production, which adds substantially to the mark-up over the already high cost of production resulting from duties and taxes on the imported raw materials. Under these circumstances, the Consultants do not expect the soap industry to expand further substantially with installation of new capacity by 1985. At best, only a marginal addition to effective capacity, through reopening some of the units presently closed, might take place. Soap prices are also unlikely to come down to any significant extent, considering the hardening trend of raw material prices, especially prices of oils and fats, unless the Government withdraws the duties and taxes on imported raw materials. With the available capacity, and even with optimistic improvement in capacity utilisation, the soap and detergents industry is, therefore, not likely to make a major dent in the demand for soda ash for washing purposes.
Keeping these constraints in view, therefore, the Consultants feel that a growth rate of 3 per cent per annum in the demand for soda ash for washing purposes may be reasonable to assume. This will give a demand of 17,000 tonnes in 1985.

Glass

2.16 In the glass industry, there are reasonably bright prospects for erection of additional capacity in sheet glass, since the present production is hardly adequate to meet the internal demand. Substantial quantities of sheet glass especially in 2 mm and above thickness are presently being imported. In view of the shortage of timber in the country, the use of glass sheets in the construction industry, among others, is expected to gain ground further. The present unit, a public sector undertaking, already has plans to expand production by the addition to new furnances. Since the major raw material for the industry, viz. glass sand, is indigenously available, the scope for capacity expansion is wide. Hence, on the basis of indications given to the Consultants, it is assumed that the capacity of the sheet glass industry will expand by another 10,000 tonnes by 1985.

2.17 The capacity in the glassware (bottles and other hollow-ware) sector of the industry is not likely to expand to any significant extent in view of the substantial under utilisation of capacity among the existing units. The demand for glass bottles and other containers is no doubt likely to record a discontinuous jump with the growth of the pharamaceutical and other (processed food, for instance) user industries, but the demand for the most part can be met from the available idle capacity. The capacity utilisation is, therefore, likely to improve. No doubt, some of the units may need to modernise production lines to meet the demand for more sophisticated products, but any increase in capacity incidental to such rationalisation will only tend to off-set the non-activated idle capacity and as such net addition to the total installed capacity in the country is unlikely. Similarly, though the glass bangles industry is likely to show improved performance, the production increase is likely to come from better utilisation of available capacity rather than through setting up of any new units. Assuming that as a combined result of these factors, the capacity utilisation of the industry as a whole - excluding sheet glass - will rise from the present 32 per cent or thereabout to about 70 per cent and that the production of the sheet glass industry (including new capacity) will be equivalent to about 80 per cent of the total capacity the soda ash requirement of the glass industry in 1985 is expected to be around 12,000 tonnes.

Silicate Industry

2.18 Future expansion of the sodium silicate industry will largely depend on the expansion of washing and laundry soap manufacturing, particularly in the non-mechanised and cottage industry sectors. The proportion of sodium silicate in washing soap varies widely from one manufacturer to another and also on the prices of oils and fats. While in the case of mechanised units, the prportion of silicate used in the laundry soap is about 5 per cent, the normal percentage in the case of non-mechanised units is around 15 per cent of the weight of soap but it is understood that the proportion may go up to as high as 50 per cent in some cases particularly when the oil prices are high. Though as a matter of official policy, the Bangladesh Government has been encouraging the expansion of the mechanised soap units even at the cost of the units in the decentralised sector, it is unlikely that role of the non-mechanised and cottage industry units will be curtailed greatly, since they have certain advantages such as cheaper prices, larger use of domestic materials , local market and lower selling and other overheads. Few of the units seem to pay, in practice, the excise duty. Considering the constraints under which the mechanised units operate, especially in regard to imported raw materials and their prices, there is in fact an even chance for the non-mechanised units to increase production to the extent of 80% of present installed capacity.

2.19 Sodium silicate has several other uses, besides in soap production. It has uses in textile industry and as an adhesive. It is also said to be used in USA "with remarkable effect" to harden and consolidate the surface of concrete. It is used in products like silica gel, in the lining of casks, ceramics, fireproofing of wood, paints and inks etc. Hence the demand for silicate for other uses is likely to increase in future. However, considering the fact that spare capacity available at present is not large and that the manufacture of sodium silicate is less dependent on imports, additional capacity to the extent of 6000 tonnes by 1985 is envisaged. Assuming that the average capacity utilisation of the industry will be around 90 per cent, the soda ash requirement of the industry in 1985 is estimated at 5,600 tonnes.

Miscellaneous Uses

2.20 New industries based on a high rate of consumption of soda ash such as bichromates are not expected to be set up in Bangladesh so long as the country is dependent solely on imports. However, its consumption in the several existing industries and end-uses is likely to be enlarged further with the step-up in [illegible] industrial activities. Thus it has been estimated that the textile industry will need about 1500 tonnes per year, when the existing and the planned new capacity is optimally utilised. The demand from the tanning industry is likely to grow in view of the likely expansion of the chrome leather industry and shift towards liquor tanning. The requirement of soda ash for brine purification, water treatment and in other relatively minor uses will also increase with the growth of capacity and higher levels of industrial activity. The increase in demand from the paper and pulp sector, however, is not likely to be significant, in view of the change in process technology adopted for the newer plants. Miscellaneous chemical industries such as bicarbonate of soda that are likely to come up in the next few years are also expected to require, on a conservative estimate, between 2000-2500 tonnes of soda ash per year. Thus, on the basis of these considerations, the total anticipated demand for soda ash in 1985 by end-uses is set out in Table 2.4.

Table 2.4

Projected Demand for Soda Ash : 1985

	End-Use	Anticipated Demand (Tonnes)
1.	Dhobies, Laundries and Household Washing	17000
2.	Glass Industry	12000
3.	Silicate Industry	5600
4.	Textile Industry	1500
5.	Paper & Pulp	4000
6.	Leather Tanning	1000
7.	Chemical Industries	2500
8.	Miscellaneous Uses	5500
		49,100

2.21 These demand estimates are, however, contingent on the assumption of free availability of supply and normal prices which are not out of step with the prices of manufacture. It will also depend to some extent on the prices of caustic soda, since over a sector of demand, the two are substitutable. In a majority of applications of caustic soda or soda ash, for instance, only Na_2O is required. While one gram molecule of soda ash is equivalent to one gram molecule of Na_2O, two gram molecules of caustic soda are equivalent to the same amount of Na_2O. Thus 80 gm of caustic soda are equivalent to 62 gr of Na_2O. It is obvious therefore that a price ratio of 1.325 : 1 is neutral between caustic soda and soda ash in such uses, and a higher ratio is favourable to soda ash. Hence the pricing of soda ash in relation to caustic soda can induce a substitution process away from caustic soda atleast in some uses. It is difficult at this stage to estimate the extent of such possible substitution in Bangladesh, but on a rough guess it can be placed around 5000 tonnes.

Effect of Local Production

2.22 It is not easy at this stage to foresee the effect of indigenous production of soda ash on the consumption demand within the country. However, soda ash being a basic chemical - a building block - can in turn support a large number of alkali-based industries, especially in the small and medium scale sector, which are now deterred by lack of assured supplies. Often it has happened in practice that assured supply from a local source itself has tended to stimulate the growth of user-industries, besides improving the efficiency of existing user-units. In the case of any surplus, export opportunities exist in the neighbouring countries of India, Burma and Nepal. India's present deficit of over 100,000 tonnes is not likely to narrow down significantly in the near future. Burma and Nepal do not have producing units and Bangladesh will have advantage of freight compared to competing sources. The surplus is not likely to be more than what these markets can absorb easily.

Chapter 3

PLANT CAPACITY

Economic Plant Size

3.1 Several factors, both technical economic, have a bearing on the optimum size of a soda ash plant. Among them, the size and nature of demand in the economic marketing zone, technological considerations, capital intensity and availability of raw materials are important. However, unlike in the nitrogen fertilizer industry, no outstanding developments - comparable to the concept of large single train amonia plants based on the centrifugal compressor technology-resulting in significant reduction in production costs have taken place in the soda ash manufacturing technology till the present, Though the size of soda ash production units has increased in the course of the last decade or two, the producers have not been able to reap real advantages from the increase in size of plants. For both of the competing commercial processes, i.e. Classical Solvay and Dual (Modified Solvay), the stream size of soda ash plant is generally guided by the size of the carbonating towers, where precipitation of sodium dicarbonate takes place. The reaction rate is slow and hence requires large sized carbonating towers. In Japan, a 600 tpd capacity soda ash plant is understood to be using as many as 19 carbonating towers, whereas a plant having capacity of 200 tpd or lower requires a minimum of 3 such towers. Similarly multiple units are used for ammonium chloride crystallization. It has also not been possible to reduce below a minimum size the diameter of carbonating towers and calciners for plants lower than 200 tpd. A 200 tpd capacity plant has an advantage over smaller sizes but does not suffer much in comparison to larger-sized plants.

3.2 The large diameter castings for vessels in the carbonation section act as the technological limitations in adopting larger size plants. In practice, the number of carbonating towers in a large capacity soda ash plant becomes a multiple of 200-300 tpd plant, and does not give any cost advantage. Where soda ash production is based on in-plant generation of ammonia, equally the economics of scale in ammonia production technology does not become available. Only in a large plant, the proportionate cost of some of the indivisible overheads will be lower, A large-sized soda ash plant with Dual Process will be advantageous only when ammonia is available from separate large-sized ammonia plant located nearby at attractive transfer prices, and not much because of the soda ash plant-size.

3.3 As indicated earlier, there are technologically two distinct processes for the manufacture of soda ash. A technical comparison of the two processes has been made elsewhere in this Study. Depending on the process route selected, the following finished products will be obtained :

	Process	Products
i)	Classical Solvay	a) Light soda ash b) Dense soda ash
ii)	Dual (Modified Solvay)	a) Light soda ash b) Dense soda ash c) Ammonium chloride (Fertilizer grade)

3.4 It has been shown in Chapter 2 that the demand for soda ash within Bangladesh by 1985 is not likely to exceed 50,000 tonnes per annum. Ammonium chloride as a fertilizer is hardly used within the country and its use will need to be actively promoted. Consistent with the above demand for the products and keeping in view (i) the indigenous availability of the major raw materials as well as (ii) technologically the economic size-range of plants, the Consultants consider that the most appropriate capacity of the plant for Bangladesh will be 60,000 tpy of soda ash. A plant of this capacity will have, as mentioned above the benefits of minimum optimal scale and at the same time broadly correspond to the size of demand within the country. The projected consumption pattern indicates that in most of the industrial applications, dense soda ash will be preferred, though for domestic washing, light soda ash will be adequate. Keeping in view the possible future demand, the plant will be designed to produce totally dense soda ash, but will have facility to withdraw 30% of the product as light soda ash. If the process adopted for manufacture is the Dual Process, about 61,200 tpy of ammonium chloride will be available as co-product.

Stream Days

3.5 Generally the achievable 'on-stream' days of the soda ash plant is 330 in a year. However to achieve this, the plant needs specially skilled operation as well as timely maintenance. Further, the plant is required to be provided with comparatively more standby and warehouse spare equipment/parts, which add to the investment. Considering the limited maintenance facilities available in the country and the severity of climatic conditions (e.g. monsoon) for a substantial part of the year, stream efficiency of 300 days a year would be reckoned as the likely achieveable figure. Based on this assessment the daily rated capacity of the plant has been arrived at as given in Table 3.1

Table 3.1

Daily Rated Capacity of Soda Ash Plant

Sl.	Manufacturing Process	Rated Capacity of Plant (tpd)		
		Light soda ash	Dense soda ash	Ammonium Chloride (Ferti. grade)
1.	Classical Solvay			
	I. Normal	60	140	-
	II. Provision	0	200	-
2.	Dual (Modified Solvay)			
	I. Normal	60	140	204
	II. Provision	0	200	204

The built-in rated capacity of the plant will be , as mentioned above, 200 tpd of dense soda ash. Normally the plant will be rated to produce 60 tpd of light soda ash and 140 MT/day of dense soda ash.

Chapter 4

RAW MATERIAL AVAILABILITY

4.1 Salt (NaCl) is the basic raw material for the soda ash industry. The precondition for setting up an economic unit is, therefore, the availability of high purity industrial grade salt. The other major raw materials required are ammonia and carbon dioxide. Depending on the manufacturing process, the raw materials required are :

Classical Solvay : (Sea) salt, ammonia, carbon dioxide, by-product chalk/natural limestone and coke.

(Carbon dioxide is needed when processing by-product chalk)

Dual Process : (Sea) salt, ammonia, carbon dioxide, lime (requirement of lime depends on the process licensor)

Annual Requirement of Raw Materials

4.2 The annual requirement s of major raw materials and their availability in Bangladesh for manufacturing 60,000 tpy of dense soda ash or 60,000 tpy of dense soda ash and 61,200 tpy of ammonium chloride are presented in Table 4.1.

4.3 The position about availability of salt for industrial consumption has been discussed in detail in Part VI. As indicated therein, the present supply position in regard to salt within Bangladesh is rather tenuous and indigenous production is being supplemented by imports. Besides, the quality of salt produced within the country is substandard, having been produced in a rather crude way by a large number of small producers,

Table 4.1

Annual Requirement of Major Raw Materials and their Availability

....

Process - I	Production of 60,000 tpy of dense soda ash by Classical Solvay process.
Process - II	Production of 60,000 tpy of dense soda ash and 61,200 tpy of ammonium chloride (fertilizer grade) as co-product, by Dual Process.

Sl. No.	Raw Material	Requirement tpy	
		Process I	Process II
1.	Sea Salt (98.5% NaCl)	1,02,236	76,020
2.	By-product chalk (100% $CaCO_3$)	91,200	-
3.	Limestone (100% $CaCO_3$)	96,240	-
4.	Liquid Ammonia	297	20,196
5.	Carbon-dioxide (100% CO_2)	31,200 (For by-product chalk only)	28,200

and contains several impurities, making it unsuitable for chemical industries. The typical analyses of sea salt (after washing) being produced in the country now are given in Table 4.2 and 4.3.

Table 4.2

Analysis of Sea Salt Produced in Bangladesh

Composition	% by wt.*
$NaCl$	93.0
Calcium as $CaCl_2$	0.5
Magnesium as $MgCl_2$	0.8
Sulphate as $CaSO_4$	1.2
Water Insoluble Matter	0.8
Moisture	3.7

* Analysis made by the Kamaphuli Complex of BCIC.

Table 4.3

Analysis of Sea Salt Produced in Bangladesh

Composition	% by wt. (dry basis)**	
	Sample-I	Sample-II
NaCl	94.61	92.31
KCl	0.13	0.12
$CaSO_4$	0.28	0.70
$MgSO_4$	0.95	0.83
$MgCl_2$	1.20	1.84
Insolubles	Rest	Rest

** Analysed by the Consultants from samples collected during field visit.

4.4 The above analysis indicate that the quality of salt presently produced is too poor to be acceptable for use in the soda ash industry directly. Though theoretically it is possible to manufacture soda ash from low grade salt, there has been a continuous trend in recent years in favour of rigid quality control on salt used, specially with regard to tolerances for total sulphates, magnesium, calcium and other impurities. In particulars, the sulphate content should be below 1%. Ca++ and Mg++ are, however, precipitated in the brine purification section by reaction with lime milk and soda solution, but their presence adds to the operating cost. To keep the impurities within permissible limits, it will be necessary to put up a salt washery. During washing, there will be a loss of about 10%, besides causing an additional problem of effluent disposal.

4.5 The quality of salt generally desired by soda ash manufacturers is given in Table 4.4 and can be compared with the analyses of salt actually available (Table 4.3).

Table 4.4

Desired Analysis of Sea Salt For Soda Ash Industry

.....

Composition	% by wt.
NaCl (min)	98.50 - 98.60*
Calcium as 'Ca'	0.10 - 0.60
Magnesium as 'Mg'	0.10 - 0.08
Sulphate as 'SO_4'	0.17 - 0.15*
Insolubles	0.13 - 0.11

* Soda ash plant is normally designed with the flexibility to process occasional deterioration in salt quality with respect to NaCl varying from 95-98% and SO_4 varying from 0.5-1%.

4.6 Hence, for reasons of quality as well as possible problems in procurement, as discussed in Part VI, the development of a capitive salt farm to produce annually around 100-120,000 tonnes of high grade salt has been recommended elsewhere in this Study. Apart from ensuring supplies and providing quality salt, the development of a captive unit, for which facilities in the country exist, is expected to bring down the procurement price of salt substantially compared to the prevailing prices.

By-product Chalk

4.7 For the adoption of the Solvay Process by-product chalk (calcium carbonate) of suitable grade will be available in adequate quantities in case utilisation of the phospho-gypsum available from the TSP complex for the production of ammonium sulphate is decided upon. As discussed in Part IV, the availability of by-product will be about 400 tpd, corresponding to the ammonium sulphate plant capacity of 480 tpd. The composition of by-product chalk expected to be available is given in Table 4.5. The chalk available is adequate for a soda ash plant of 60,000 tpy capacity as indicated earlier. Hence, it is considered as raw material for the Classical Solvay process-route.

Limestone

4.3 Substantial deposits of natural limestone have been discovered in Bangladesh but the quantity mined now is small and supplements the requirements of the Chhatak Cement Factory and the Chittagong

Table 4.5

Composition of By-product Chalk from the Proposed Ammonium Sulphate Plant

Characteristic of Chalk	Wet Basis % W/W	Dry Basis % W/W
Unreacted Gypsum	1,970	4.28
$CaCO_3$	41,110	89.18
$(NH_4)_2SO_4$	1,320	2.88
SiO_2	0.490	1.05
P_2O_5	0.175	0.38
F	0.243	0.52
Al_2O_3	0.006)	0.03
Fe_2O_3	0.008)	
Organic Matters	0.773	1.68
Water	53.905	-
	100.0	100.00

Steel Mills (Table 4.7), - the major proportion of the cement factory's needs being imported. The problem with the deposits discovered so far has been that they are not easily mineable. The principal limestone areas in the country are Jaipurhat area of Bogra district, and the Bhangerghat - Takerghat - Bagli Bazar area of Sylhet district. The estimated reserves of limestone in the various deposits are indicated in Table 4.6.

Table 4.6

Limestone Reserves in Bangladesh

District		Limestone Deposit Area	Reserves in Million	Mining Situation
1. Bogra	(1)	Jaipurhat	100*	Not yet mined
2. Sylhet	(i)	Bhangerghat-Takerghat	3	Being mined
	(ii)	Baglibazar	25	Not yet mined
	(iii)	Jaflong	0.04	Not yet mined
3. Chittagong	(i)	St.Martin's Island	3	Not recommended for mining
	(ii)	Sitakund	0.015	Not yet mined

* Mineable reserves.

Table 4.7

Demand for Limestone in Bangladesh

Consumer	Demand in Million Tonnes	
	1976-77	1980
Cement Industry	*	2.0
Others (e.g. sugar mills, steel mill etc.	*	0.5
Total	0.82	2.5

Source : 1. BMEDC

2. The Committee for Utilisation of Indigenous Natural Resources of Bangladesh, February, 1977.

4.9 Of these known deposits, the Jaflong and Sitakund deposits are considered too small to be of much economic significance and cannot sustain any large limestone-based industry. Similarly, the deposits of St. Martin's Island are shelly and coraline limestone, and mining from this deposit has not been recommended because of the fear that largescale extraction of limestone might put a large part of the island under water.

4.10 Though there are proposals to undertake mining of limestone in the Jaipurhat area, the project has not yet got off the ground so far. A major part of the limestone produced is planned for utilisation in cement clinker units to be set up in the area. Limestone mining in the Baglibazar area is beset with some technical problems and upto now only experimental drilling has been carried out/with UNDP assistance. Thus the only deposits presently mined are in the Bhangerghat - Takerghat area. However, the infrastructure for the mining operation is not yet well developed resulting in poor rate of mining. Composition of this limestone given in Table 4.8 shows that its quality is good for cement and other industries. The quality of limestone expected to be available from Jaipurhat area is better suited for the soda ash industry.

4.11 Thus, limestone in required quantities for the soda ash unit of the size proposed above can be met only if the Jaipurhat or Baglibazar deposits are commercially exploited. However, considering the cement needs of the country and the urgency for providing a firm base for the cement industry's development, the Government might assign higher priority for the cement industry requirement rather than that of soda ash. Moreover, the mines are yet to be developed and in the circumstances, the avail-

Table 4.8

Composition of Limestone Available in Bangladesh

***

S. No.	Deposit	Composition	% by wt.
1.	Jaipurhat	$CaCO_3$	97.98 (Min.)
		MgO	0.05-0.03
		Mn	0.0003
		SiO_2	0.03-0.05
2.	Bhangerghat - Takerghat - Baglibazar	$CaCO_3$	93.50
		$MgCO_3$	1.04
		R_2O_3	2.04
		Insolubles	2.84
		Moisture	0.15

bility of limestone for soda ash manufacture must be reckoned for the present as uncertain. No firm plan for the production of soda ash based on limestone can therefore be envisaged. However, limestone is being considered a raw material, is alternative to by-product chalk in this study for the purpose of assessing the comparative economics of the two raw materials.

Ammonia

4.12 The requirement of anhydrous ammonia for the production of 60,000 tpy of soda ash is around 20196 tpy in the case of Dualprocess and 297 tpy in the case of Classical Solvay process. The requirement and availability of ammonia for alternative schemes under consideration have been discussed in Part II. As summarised therein, the ammonia requirements of the soda ash (Dual) plant cannot be met from the two existing nitrogen fertilizer plants at Fenchuganj and Ghora sal. In the case of the Ashuganj project, presently under construction, the possibility can only be conjectural, since the project has a matching urea plant and any surplus production in the ammonia plant can be confirmed only after the plant goes on stream and production stabilises, - which might take 3-4 years. Of the two new plants under consideration, there is no prospect of getting ammonia from the China - assisted Ghorasal-II project; the Chittagong Urea Fertilizer Project is in a position to make available only a maximum of 72 tpd of ammonia with some marginal modifications in the design, without making any consequential change in the urea capacity. As a result, the following options are available in regard to ammonia supply. :

I. : Classical Solvay Process

i) With byproduct chalk :
Including the ammonia needs of the ammonium sulphate plant, the total requirement of 133 tpd of ammonia can be met only from a captive ammonia unit of requisite capacity, or alternatively partly from a captive unit and partly from the CUF Project.

ii) With natural limestone :
From any of the existing or planned units, since the requirement is small (297 te/yr).

II. : Dual Process :

Either from the CUF Project or from captive generation, depending on the location and the cost of transport of ammonia.

For various reasons, including the problem of gypsum transport, the location of the ammonium sulphate plant will need to be confined to Chittagong, and a site adjacent to the CUF Project site has been identified for the purpose (Part IV). In that case, the soda ash plant based on by-product chalk can also be located in the same complex to avoid handling of chalk and for taking advantage of the external economics by sharing common facilities. Hence for this scheme, it is envisaged (Part II) that ammonia to the extent of 100 tpd will be generated in a captive unit and the balance (33 tpd) obtained from CUF Project. Similarly, for the Dual process, if the location is Chittagong, ammonia supply is assumed to be tied up with CUF Project, while for any other location, the alternatives of local production in a captive unit vis-a-vis procurement and transport from CUF Project will be evaluated.

Carbon dioxide

4.13 As indicated earlier, (Table 4.1) the requirement of carbon dioxide for the manufacture of 60,000 tpy of soda ash is around 31,200 tpy in the case of Classical Solvay process using by-product chalk as raw material, and 28,200 tpy in case of Dual process. In the event of use of natural limestone as raw material (instead of by-product chalk) the soda ash plant does not need any external supply of CO_2 gas but the prospect for use of limestone for soda ash production in Bangladesh is not bright, as discussed earlier.

4.14 All the ammonia facilities under operation/implementation in the country are based on natural gas as feed stock where carbon dioxide available from the ammonia plant is always in deficit and cannot meet the full requirement of the respective urea plants as discussed in Part II. Therefore, each of the urea fertilizer units including new projects has facilities for supplementary generation of carbon dioxide either in a separate CO_2 gas recovery plant using boiler flue gas as source or in the main gas reformation/purification section (of ammonia plant) by marginal overdesign of the streams and subsequent burning of the additional gas in the reformer itself. Hence, free carbon dioxide is not available in any of the existing or planned ammonia plants. Depending on the manufacturing process and plant location, the soda ash manufacturing facility will require to be provided with its own generation facilities for carbon dioxide. Where captive ammonia plant has been planned for the supply of ammonia to the schemes under consideration, carbon dioxide available from the syn gas purification system has been considered for use in the manufacture of soda ash.

Chapter 5

LOCATION OF PLANT

5.1 Selection of an optimal location for the soda ash manufacturing facilities depends on certain basic decisions on the plant features and assignment of proper weightage to some of the special characteristics of the process. For a project that envisages the purchase of ammonia from an external source, it would be necessary, as mentioned in Part II, to locate the soda ash plant adjacent to the main ammonia complex so as to minimise the cost of transportation and bulk storage of liquid ammonia, and utilise any by-product carbon dioxide available from the ammonia plant, besides sharing the common facilities with the ammonia complex to the extent of availability. However, if the proposal involves captive ammonia production, an entirely different set of considerations need to be applied, such as the availability of feestock and needed utilities. In addition, since the process entails the utilisation of large quantities of salt and since, given the conversion charges, the working results of a soda ash plant are sensitive to the input costs of salt, adequate consideration will need to be given to the source of salt supply so as to minimise the cost of transportation and handling. The end products, soda ash and ammonium chloride, are both bulky in relation to their price, thus imposing another constraint on locating the plant away from their primary marketing areas. Besides, the availability of sweet water and energy source and the disposal of plant effluents are some of other factors which have a bearing on the selection on the sites for the plant.

5.2 Against the background of these broad considerations, an initial list of possible locations in Bangladesh were drawn up in consultation with the local experts, taking into account the specific requirements of the project. After preliminary scrutiny, the list was shortened to the five locations, viz., Chittagong, Chandpur (Shatnol) [illegible],,Ashuganj and Fenchuganj - chiefly on consideration of the following factors :

a) Availability of raw materials and prospect of effluent disposal.

b) Situational advantages and infrastructures

c) Cost of construction

d) Cost of production

e) Cost of distribution of finished products

f) Regional development and incentives

5.3 These five prospective locations were subjected to detailed investigations and based on the findings, the Consultants arrived at the following conclusions :

i) Chittagong emerges as the most suitable location for the setting up of a soda ash plant both in respect of Classical Solvay process and Dual Process;

ii) Chittagong is the only optimal location for a unit (Solvay) based on by-product chalk obtained from the ammonium sulphate plant, recommended for location in Chittagong (Part IV).

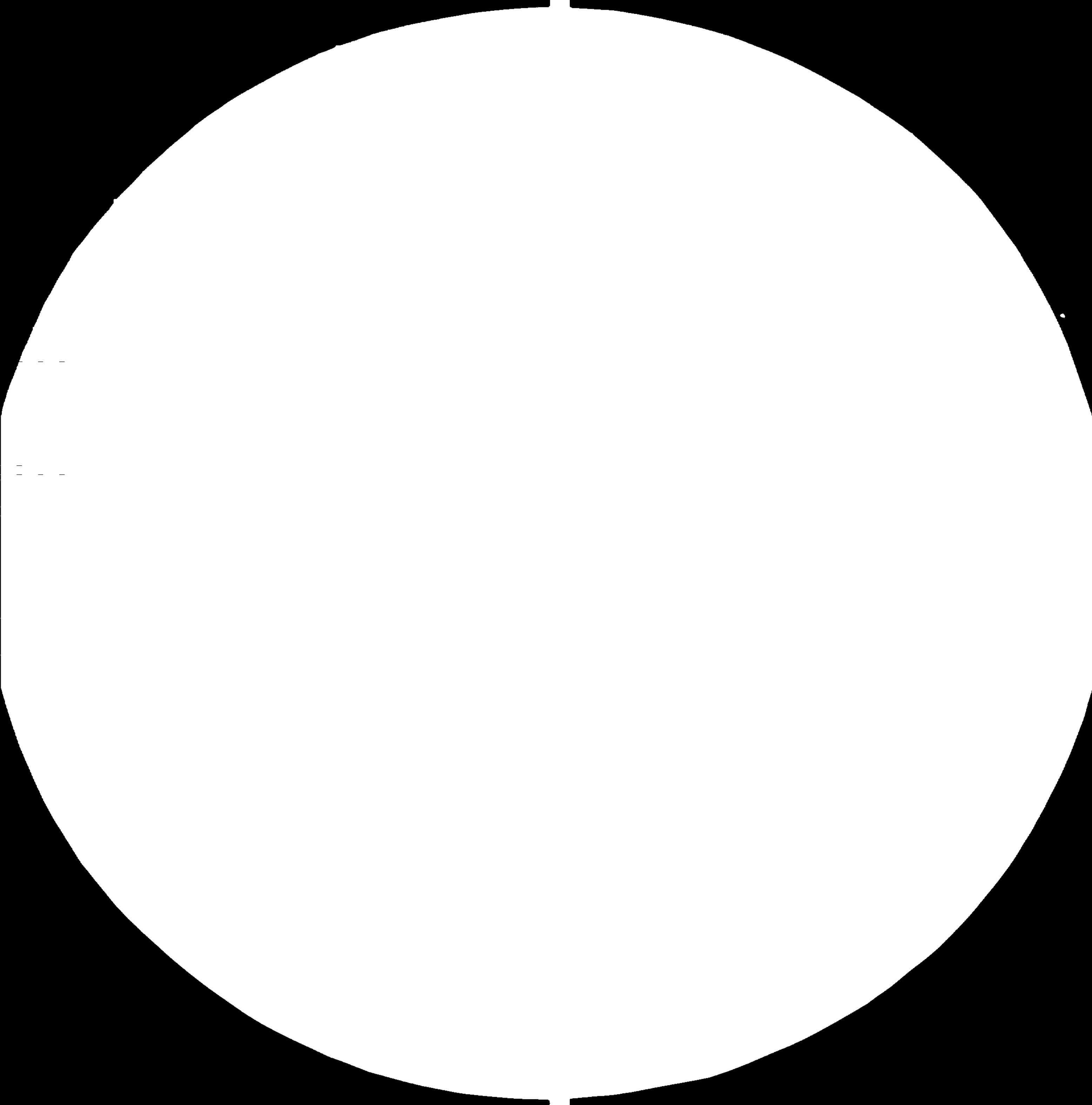
iii) Chittagong is comparatively a better site even for a unit based on indigenous natural limestone from Jaipurhat area through the Classical Solvay process. This is mainly due to the proximity to salt supply centres as well as product demand centres, and the assured availability of ammonia and steam from the CUF Project.

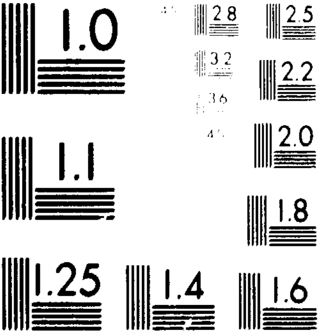
iv) Ghorasal stands out as an alternative prospective centre for locating the Dual Process soda ash plant.

In view of these findings, further studies have been confined only to the two locations, viz Chittagong and Ghorasal.

5.4 In Chittagong, a site adjacent to the CUF Project site has been considered suitable, as mentioned in Part II, for locating an entire complex consisting of the captive ammonia plant, ammonium sulphate plant and the byproduct chalk-based soda ash plant, in case the ammonium sulphate scheme is accepted. The site is also suitable, in case the Dual Process soda ash plant alone is set up. In that case, the ammonia required for the unit can be directly drawn from the CUF Project, without the need for handling. Besides, supply of steam and process water sufficient for Dual Process have also been assured from CUF Project, vide : Annexure II-C, Part II. If the project is located adjacent to the CUF Project, there are, in addition, fair prospects of some of the facilities such as roads and public services being shared in common.

5.5 In the Ghorasal area, as explained in Part II, the site considered most suitable is the one adjacent to the main factory itself and lying next to the proposed site for the Ghorasal II ammonia - urea complex.





MICROCOPY RESOLUTION TEST CHART

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Chapter 6

UTILITIES AND OTHER FACILITIES

6.1 For either of the two processes, viz. Classical Solvay and Dual process, process water/raw water, steam, fuel and power are needed. While common salt, ammonia and carbon dioxide are the chief raw materials common for both the processes, Classical Solvay needs coke and limestone or calcium carbonate, in addition.

6.2 Adequate facilities need to be provided for the intake, storage, distribution/handling and offtake of all the utilities, raw materials and products,. The facilities covered within the scope of this project at each of the two selected locations, i.e. Chittagong and Ghorasal, are specified below.

Steam

6.3 At Chittagong, the planned soda ash complex's site is close to the proposed CUF Project site. The supply of adequate quantity of steam (45 te per hour) at the required 40 ata pressure from the CUF Project to the soda ash plant has been assured (vide : Part II). Accordingly, the provision of a steam header for purposes of distribution alone is considered for steam supply to this project and no provision is envisaged towards generation of steam. At Ghorasal, there will be no external source of assured steam supply. Hence, the provision of steam generation facility with a capacity of 30 te/hr for the soda ash plant has been included inthe scope. Natural gas is taken as the fuel for steam generation.

Water

6.4 At Chittagong, supply of process water in adequate quantity is possible either from WASA or by integrating the project's requirements with the CUF Project's supply scheme, as discussed in Part II. Hence no provision for either the raw water intake station and water treatment plant or the demineralised water plant is required. However, provision has been made for process water receiving header, a common storage and for its distribution.

6.5 At Ghorasal, water required for the soda ash plant will have to be arranged, as the fertilizer plant is not in a position to make available the needed supply from the existing facilities. However, sweet water is available round the year from the nearby river Sitalakhya, from which the existing Ghorasal fertilizer factory is also drawing the raw water supply. Hence, considering this river water as the feed-source, the provision of the following facilities for the soda ash plant has been considered :

i)	Water intake pumping station	400 m^3/hr
ii)	Water treatment plant	330 m^3/hr
iii)	Demineralised water plant	38 m^3/hr

Fuel

6.6 Natural gas, of which Bangladesh is richly endowed (Part II) is assumed to be used in the process as fuel. However, it is not yet available in Chittagong, But the development of facilities for laying a supply line from the Bakhrabad gas field to Chittagong for distribution to, inter alia, the industrial consumers is under active consideration of the Government. The proposed CUF Project has been assumed to be based on this natural gas supply. Gas required for the soda ash complex will be tapped from the pipeline to the CUF Project as discussed in Part II. The provision towards a gas header has been included in the scope.

6.7 At the Ghorasal location also, the unit being proposed to be based on Dual Process, natural gas will be used. As explained in Part II, the existing Urea Fertilizer Factory of BCIC gets its supply of gas from Titas gas field and the receiving station is within the factory's battery limit. The gas for the soda ash unit also can be tapped from downstream of this station. Accordingly, the provision towards a gas header has been included.

Power

6.8 For safe and continuous operation of the proposed soda ash plant, using electric power as the main energy source, the following conditions are needed :

i) Voltage fluctuation : Within ± 5% of rated voltage

ii) Cycle change : Less than 0.5 Hz.

iii) Elec. power failure : Less than 2 to 3 in a year.

Power generation and distribution in Bangladesh is vested in the Power Development Board (PDB). The Board uses 132 KV and 66 KV for transmission and 33 KV, 11 KV, and 0.415/0.24 KV for distribution. Both Chittagong and Ghorasal come under the Eastern Power Grid of PDB.

6.9 The power position in Bangladesh at present is not very satisfactory, particularly in regard to the reliability and quality of supply. In fact, one of the major problems presently being faced both by the TSP Complex and the Ghorasal Urea Fertilizer Factory of BCIC is the frequency of power interruptions (Table 6.1)

Table 6.1

Power Interruptions* Recorded by the TSP Complex, Chittagong.

Year	Power Failure		No. of Interruptions
	Hrs.	Mins.	
1974-75	240	48	101
1975-76	156	32	136
1976-77	164	13	102
1977-78	49	58	36

* Excluding scheduled power interruptions.

It was however, gathered that adequate steps are being taken by PDB to ensure stability of power grids and to bring the reliability and quality of power supply within the acceptable norms of industrial consumers by 1983-84. Supply of required power to the soda ash units at both the locations has also been assured. Hence the soda ash plant will only receive power at 11 KV, step it down to the required level and distribute it within the plant sections. The supply of emergency power at Chittagong has been assured from CUF Project,

Storage and Handling of Raw Materials

6.10 Because of the general climatic conditions, in particular, the long wet season, - which affects the movement/transportation especially of the solid materials, - large storage facilities will need to be provided for certain raw materials. Salt production for instance, being strictly seasonal, large stocks will have to be procured/stored during the production season to meet the year-round demand. Since movement of salt during monsoon is particularly difficult, the factory storage will need to be large enough to meet the consumption demand of the entire wet period. The facilities for storage of the raw materials considered are given in Table 6.2.

6.11 Movement of salt from the salt works, proposed (Part VI) near Chakaria-Sunderban area, to the salt storage building at the Chittagong plant site is envisaged through a fleet of trucks. Salt will be unloaded close to the storage building and then stacked inside the building by means of stacking/overhead distribution conveyor. Salt will be reclaimed from the storage building by payloader and transported to the plant by belt conveyor having around 25 te/hr capacity.

Table 6.2

Planned Storage Capacities for Raw Materials

Process/ Location	Raw Material	Storage Capacity Provided	Remarks
1. Classical Solvay Chittagong	Salt	60,000 te	Equivalent to 6 months' requirement, covered storage.
	By-product chalk	Nil	Only buffer capacity in raw sludge tank provided.
	Limestone (Alternative to chalk)	9,650 te	One month's requirement, covered storage.
	Ammonia	Nil	Only buffer capacity in tank.
	Coke	400 te	15 days' requirement.
	Sodium Sulphide	10 te	One month's requirement, covered storage.

Table 6.2 (contd)

Process/ Location	Raw Material	Storage Capacity provided	Remarks
2. Dual			
Chittagong/ Ghorasal	Salt	60,000 te	Six month's requirement, covered storage.
	Ammonia	Nil	Only buffer capacity in tank provided, since supply is from CUF Project or from captive ammonia plant.
	Lime	480 te	Onemonth's requirement, covered storage
	Sodium Sulphide	20te	One month's requirement, covered storage.

6.12 For transportation of salt from the salt works to the plant site at Ghorasal, the movement is envisaged to be by road upto the Chittagong Port and threafter by barges right upto Ghorasal. Provision of a jetty at Ghorasal on the project side of the river Sitalakhya has been made, to facilitate unloading the salt on to a belt conveyor of 500 te/hr capacity running right upto the salt storage building. Salt from this storage building will be reclaimed by a pay-loader and transported to the plant by belt conveyor having 25 te/hr capacity. This arrangement, however, needs a buffer salt storage building of substantial capacity near the Chittagong port.

6.13 Transportation of by-product chalk from the proposed ammonium sulphate plant to the soda ash plant is envisaged to be done in the form of 48% slurry by pumping. Movement of limestone from the mines to the project area at Chittagong is assumed to be by road, rail and waterways. At Chittagong, on the project side of the river Karnaphuli, provision has been made for a jetty to facilitate unloading of material on to a belt conveyor of 500 te/hr capacity running right upto the limestone storage building. Limestone will be reclaimed from its storage building by payloader and transported to the soda ash plant by belt conveyor, having capacity of around 25 te/hr.

6.14 Liquid ammonia will be pumped to soda ash plant from CUF Project if the location decided upon is Chittagong. If Ghorasal is the project location, ammonia will be supplied either from a captive plant by pumping or from the CUF Project transported by barges, depending on the alternative selected. Hence, the necessary transportation pipes have been provided. Coke is envisaged to be brought to the soda ash plant from Chittagong by trucks or boats. Likewise, the movement of sodium sulphide and lime to the project area is envisaged to be generally by roadway or water transport. They will be unloaded and stored in the warehouse manually. The movement of stores from the warehouse to the plant will be by motorised trolleys.

Storage and Handling of Products

6.15 Keeping in view the climate and the problems of transport in Bangladesh, the provision for both bulk and bagged storage of products is considered essential. The facilities for storage of the products, viz., dense and light soda ash and ammonium chloride, planned to be provided at the factory site are indicated in Table 6.3.

6.16 The products-soda ash as well as ammonium chloride (in the case of Dual Process plants) - will be delivered to their respective silo/storage building by transportation conveyor system, Each of these products is envisaged to be bagged in 50 kg bags. Ammonium chloride as well as light soda ash will be bagged in polyethelene-lined jute bags whereas dense ash will be bagged in ordinary B-T will bags.

6.17 The bagging plant is expected to operate normally in 2 shifts only. No bagging in the night shift is envisaged. The number of bagging trains provided will be as follows :

Soda ash (dense/light)	1 (running) + 1 (standby)
Ammonium chloride (Dual process plant only)	1 (running) + 1 (standby)

Table 6.3

Product Storage Capacities

Process/ Location	Product	Storage Capacity provided	Remarks
1. Classical Solvay Chittagong	Soda ash dense		RCC silo
	Bulk	3450 te	Equivalent to 23 days' production.
	Bagged	1050 te	7'days production
	Light soda ash		RCC silo
	Bulk	1150 te	23 days' production.
	Bagged	350 te	7 days' production
2. Dual Chittagong/ Ghorasal	Dense soda ash		RCC silo.
	Bulk	3450 te	23 days' production
	Bagged	1050 te	7 days' production.
	Light soda ash		RCC silo.
	Bulk	1150 te	23 days' production.
	Bagged	350 te	7 days' production.
	Ammonium Chloride	-	Covered storage with air-conditioning
	Bulk	4700 te	23 days' production.
	Bagged	1400 te	7 days' production.

6.18 The capacity of the bagging train will be 30 te/hr for soda ash as well as for ammonium chloride. With the system envisaged, the bagging rate can be stepped up when needed. The location of the bagging plant will be close to the main soda ash plant.

6.19 The off-take of the bagged products will be either by road or, mainly, by waterways at Chittagong and by rail/waterways at Ghorasal. Accordingly, facilities for truck loading at Chittagong and wagon loading at Ghorasal have been considered, besides the product jetties with loading facilities at both Chittagong and Ghorasal. At Chittagong the jetty will be over two kms away from the bagging plant. Hence, the transporation of the bagged products from the bagging plant to the jetty will have to be done by trucks. At Ghorasal, jetty being close to the bagging plant, the transportation of the bagged product by belt conveyor is envisaged.

Instrument Air System

6.20 The provision of a centralised instrument air system having the desired capacity of clean dry air at 7 Kg/cm^2 abs pressure has been considered. The facilities considered include air compression, filteration, cooling, drying, storage and distribution. The requirement of instrument air for soda ash plant under various alternatives has been indicated in the "Raw Material and Utility Balance" (Diagram Nos. 0040 to 45).

Chapter 7

SELECTION OF PROCESS

Manufacturing Process

7.1 For the manufacture of soda ash, as already indicated, two established and commercially proven manufacturing process

i) Classical Solvay

ii) Modified Solvay, or popularly known as Dual Process.

The Dual Process has certain definite advantages over the Classical Solvay, in respect of process efficiency, operational performance and flexibility (Annexure V-J). The Dual Process gives a useful co-product ammonium chloride which is considered a good fertilizer, particularly for paddy crop. The improved process efficiency coupled with the utility of the co-product brings down considerably the cost of production of soda ash manufactured by Dual Process compared to that manufactured by Classical Solvay process. However, the need for large quantities of ammonia could sometimes act major constraint in adopting this process.

7.2 Nevertheless, the Classical Solvay process still retains its formidable position in competition with Dual Process because of its versatility in applications, rugged operational sequence and comparatively less dependence on the costliest raw material, ammonia. This process is of particular interest in regions where its chief raw materials, salt and limestone (or calcium carbonate), are available locally at relatively low prices.

7.3 Investigations conducted in Bangladesh indicate, as explained earlier, that from the point of view of availability of raw materials either of processes can be adopted for the manufacture of soda ash. In addition, the Classical Solvay process may, in particular, indirectly help solve the disposal problem of phosphogypsum produced in the TSP factory, through its conversion into ammonium sulphate (Part IV) and utilisation of the byproduct chalk as a substitute for limestone.

Know-how for Classical Solvay Process

7.4 The process available for licensing for the production of soda ash by the Classical Solvay route are available mainly from -

i) Polimex, Poland
ii) Tata Chemicals, India
iii) Humphreys & Glasgow Consultants, India.

Of the three firms, the first two are equally competant,technically established. Polimex, however, has a slight edge because of the recent special experience gained (in collaboration with Fertilizer (P&D) India Ltd., India) in processing the proposal for a soda ash plant based on byproduct chalk produced in the process of ammonium sulphate production through the phosphogypsum route (Haldia, India). Also a number of large-sized soda ash plants, designed and supplied by Polimex are under satisfactory operation in Latin America, Poland and some other countries. The largest soda ash plant built by Polimex is an export-oriented plant in operation at Janikowo, Poland, and has a capacity of 1400 tpd, with a stream efficiency of 360 days per year.

Data available on the Humphreys and Glasgow know-how and on their experience are too meagre for an objective appraisal. However, they seem to be less experienced compared to the other two, Hence the process license and know-how offered by Polimex, Poland has been taken as the basis for detailed analysis in this study. It is assumed that a proper analysis of the different processes will be made prior to implementation of the Project.

Process Licence and Know-how for Modified Solvay Process

7.5 The processes available for licence and know-how transfer for the production of soda ash and ammonium chloride by the Dual Process route are :

i) Central Glass - TEC, Japan

ii) Toyo - Soda, (TSK), Japan

iii) Ashai Glass, Japan

iv) Sahu-Jain, India

While the first three processes have been developed and commercially established in Japan, the fourth one has been developed in India.

Japanese Processes

7.6 In 1938, a 50 tpd soda ash-ammonium chloride plant was put up in Korea. After the second World War, the process was further developed and perfected. Several plants, based on the Dual Process, were subsequently built in 1950's. At present, some five major units are in operation in Japan on Dual Process, with a total installed capacity of over 700,000 tpy each of soda ash and ammonium chloride.

Table 7.1 below gives the list of factories, their location and installed capacities.

Table 7.1

Dual Process Factories in Japan

Sl. No.	Name of Company		Location	AnnualInstalled Capacity in Tonnes Soda Ash	AnnualInstalled Capacity in Tonnes Ammonium Chloride
1.	Ashai Glass Co.	i)	Makiyama	40,000	40,000
		ii)	Chiba	1,08,000	1,15,000
2.	Tokuyama Soda Industries Co.,		Tokuyama	1,80,000	1,80,000
3.	Toyo Soda Industries Co.,		Tonda	1,80,000	1,58,000
4.	Central Glass Co.,		Ube	1,80,000	1,80,00

7.7 Of the Japanese processes, the Ashai Glass process does not seem to have gained as wide an acceptance as the other two Japanese processes, Besides, the data available on this process are too meagre to consider this process for this Study.

7.8 The first plant on Toyo-Soda process (TSK) was built in 1959 and later it was expanded. Toyo-Soda now have a plant with capacity of 180,000 tpy of soda ash. The basic engineering and know-how for the TSK process is supplied by Toyo-Soda Company, Japan. The detailed engineering, supply, erection and start-up/commissioning services are offered by Hitachi Zosen, Japan.

7.9 The Central Glass - TEC process has been developed and perfected by Central Glass Company, Japan, Based on this process, a plant is under successful operation at Ube with a capacity of 180,000 tpy of dual products. On the basis of the technical know-how obtained from the construction of this plant and its operation, TEC provide the complete know-how and engineering in co-operation with Central Glass, claiming to offer the most economical plant.

Indian Process

7.10 The Sahu-Jain process is based on the development work initially done in Holland by Stamicarbon and later perfected in India by Sahu-Jain on a commercial scale plant. The New Central Jute Mills, a company belonging to the Sahu-Jain Group of industries, established this plant at varanasi, India with an installed capacity of 40,000 tpy each of soda ash and ammonium chloride. Basic engineering for this process and technical know-how are supplied by the New Central Jute Mills Company. The detailed engineering, supply, erection and start-up/commissioning services are being offered by Humphreys and Glasgow Consultants Private Limited, Bombay, India. They have the exclusive licence for this process.

Selection

7.11 A comparison of the salient features of the three technically acceptable processes, viz Central Glass-TEC, Toyo-Soda and Sahu-Jain (Annexure V-K), indicates that, by and large, no significant or outstanding advantage can be claimed for any of the processes, and in their totality, all the three processes are broadly on par. However, the following features give a slight edge to Central Glass - TEC, purely in terms of technological balance of advantage.

a) Overall requirements of raw materials are marginally lower in the case of Central Glass-TEC process.

b) Requirements of utilities, particularly of steam and water, are minimal for Central Glass - TEC process.

c) Utilisation of comparatively lower grades of salt is possible because of the provision of a unique salt purification system.

Hence for the Dual Process technology, the Central Glas-TEC process has been taken as the basis for detailed analysis.

Chapter 8

PROCESS ARRANGEMENT

A. Classical Solvay Process of Polimex :

8.1 A typical Polimex plant is broadly divided into six sections :

i) Lime preparation & carbon-dioxide recovery

ii) Brine preparation & purification

iii) Crude soda

iv) Dense soda

v) Steam-jet water refrigeration

vi) Cooling tower

i) Lime Preparation & Carbon-dioxide Recovery (Drawing No. 0030-I & II)

8.2 This section is used to produce milk of lime in the desired concentration for brine purification and ammonia recovery, and also to utilise kiln gases for CO_2 - gas recovery or for direct use in carbonation.

By-product chalk in the form of about 48% slurry is received in raw sludge tank, to which compressed air is injected in the bottom part by air compressor. This provides agitation in the tank and helps to keep solids in suspension.

8.3 Coke is used as a reducing agent. Coke slurry is obtained by subjecting coke to wet grinding in a ball mill where controlled amount of water is also fed. Coke slurry is fed to the raw sludge tank at the top by coke slurry pump where it is thoroughly mixed with chalk slurry. Chalk slurry having about 48% solids is fed to a rotary lime kiln by raw sludge feed pump through feed tankwhere it is subjected to thermal decomposition resulting in the formation of quick lime and kiln gases containing carbon-dioxide as per the following reaction :

$$CaCO_3 = CaO + CO_2$$

Natural gas or furnace oil is used as the heat source, and is supplied to a special burner in the lime kiln. Air blower supplies air to the burner.

8.4 Addition of coke in a predetermined quantity is extremely important for reducing the calcium sulphate present, particularly in by-product chalk. In the case of processing by-product chalk, the following reactions also take place in the kiln.

$$(NH_4)_2SO_4 = 2NH_3 + H_2O + SO_3$$

$$SO_3 + H_2O = H_2SO_4$$

$$H_2SO_4 + CaCO_3 = CaSO_4 + CO_2 + H_2O$$

$$CaSO_4 + 4C = CaS + 4\,CO$$

$$CaS + 3CaSO_4 = 4\,CaO + 4\,SO_2$$

$$CaCO_3 = CaO + CO_2$$

8.5 Hot quick lime is cooled down rapidly at the kiln outlet by controlled water spray and then slowly in a rotary lime cooler. Cooled lime from cooler outlet is transported by skip conveyor to quick lime bin which serves as buffer storage.

8.6 Unlike the processing technique of by-product chalk in the form of slurry, natural limestone (if used as alternative raw material) is fed in proper size as solid to the rotary lime kiln (Drg. No. 0030-II). The reducing agent coke is also added to the feed as dry solid in proper size.

8.7 Slaking of lime is done in a lime mill-slaker unit where the desired milk of lime containing about 190 gm CaO per litre is produced for specific use in brine purification and ammonia recovery in the subsequent sections. For this purpose, a rotary hydrator mill is used as a slaker unit. Quick lime is fed from bin to hydrator mill where controlled amount of water is also fed. Lime milk is stored in a buffer tank., from where it is pumped by lime milk pump to consumer equipment.

8.8 Kiln gases containing about 18-20% CO_2 by vol. when processing by-product chalk are cleaned of dust in acyclone before being subjected to CO_2 -gas recovery in M.E.A. unit, or being vented to atmosphere. The recovered carbon-dioxide gas along with calciner gas is utilised in crude soda section for carbonation of ammoniated brine.

8.9 When processing natural limestone, kiln gases contain about 35-40% CO_2 and hence, after removal of dust and mist, are used as lean CO_2 gas [illegible] for carbonation. In this case, a CO_2-gas recovery unit is not required unless, the natural limestone itself is of poor quality.

(ii) Brine Preparation & Purification (Drawing No. 0031)

8.10 This section is meant to prepare saturated brine from sea salt and to remove the impurities contained in the process liquor.

8.11 The raw sea salt is fed by belt conveyors to the salt dissolving tank where adequate amount of process water is added to dissolve it. The dissolution of salt is accelerated by intense agitation created in the tank by circulating weak brine using the brine circulation pump. Saturated brine is withdrawn from salt dissolving tank and stored in a huge crude brine tank.

8.12 The saturated brine is then freed of its impurities of Ca and Mg salts by treatment with lime milk and soda solution. Purification of saturated brine is an essential step to avoid crust formation within the equipment and pipelines during its further processing in crude soda section - thus avoiding disturbances in operation.

8.13 Crude brine pump feeds raw brine from crude brine tank to brine mixer through a batcher, to which soda solution and diluted lime milk are also added from soda solution tank and lime milk tank-II. For this purpose, concentrated lime milk received from lime preparation section is diluted with purified brine solution in a dilution tank provided with agitator. Mixed with reagents in brine mixer, the brine flows to reactor where under intense agitation the following reactions take place :

$$\begin{aligned}
MgCl_2 + Ca(OH)_2 = \quad &= \quad Mg(OH)_2 + CaCl_2 \\
MgSO_4 + Ca(OH)_2 \quad &= \quad Mg(OH)_2 + CaSO_4 \\
CaCl_2 + Na_2CO_3 \quad &= \quad CaCO_3 + 2NaCl \\
CaSO_4 + Na_2CO_3 \quad &= \quad CaCO_3 + Na_2SO_4
\end{aligned}$$

8.14 From reactor, the solution flows to brine clarifier where the insoluble magnesium hydroxide and calcium carbonate are allowed to settle. To accelerate setting, solution of flocculating agent is also added. From the brine clarifier, purified brine flows by over-flow to huge purified brine tank provided as storage tank. From this tank,purified brine pump supplies purified brine to ammonia absorbers incrude section.

8.15 The sludge settling at the bottom of brine clarifier is scraped out by a mechanical device and is allowed to flow to sludge washer. In this equipment, sludge is diluted and washed with large quantity of water. Weak salt solution is obtained from sludge washer as overflow liquor and is taken to a saline water tank from where it is pumped by saline water pump to salt dissolving tank. Recovery of this salt solution increases salt utilisation efficiency in this process.

The washed sludge that settles at the bottom of sludge washer, is scraped out by mechanical scraper and is taken through sludge tank and pump to the centralised waste sludge tank in crude soda section for disposal.

(iii) Crude Soda (Drawing No. 0032)

8.16 This section is to produce crude sodium bicarbonate by absorption of CO_2 - gas into ammoniated brine. It also recovers ammonia which may escape from the plant as effluent.

8.17 The section involves broadly the process steps of ammonia absorpotion, carbonation, bicarbonate filteration, ammonia distillation and CO_2 -gas compression. To reduce the ammonia and partially CO_2-losses in off-gases, the purified brine received from brine purification section is fed in parallel to three scrubbers, viz. tower gas washer, absorber gas washer and filter gas washer. Pre-ammoniated brine from these three scrubbers flows subsequently to ammonia absorber from the top where the cooled gases containing NH_3 and CO_2 from distiller are introduced at a lower zone. Make-up liquid ammonia is also introduced to this absorber. Here again, nearly the entire amount of escaping ammonia and limited amount of carbon-dioxide are absorbed in counter currently flowing preammoniated brine. This results in the formation of ammonium hydroxide and carbonate as represented below :

$$NH_3 + H_2O \quad = \quad NH_4OH$$

$$2NH_4OH + CO_2 \quad = \quad (NH_4)_2CO_3 + H_2O$$

Since the absorption reactions are highly exothermic, the scarcely carbonated ammoniated brine is cooled in the cooler provided at the lower part of ammonia absorber before it is stored in ammoniated brine tank. Another trombone type brine cooler cools it to the temperature desired for carbonating tower.

8.18 To reduce the iron oxide contamination in the process liquor, adequate amount of sodium sulphide solution is added to ammoniated brine tank. This provides passivation for the inner surface of the downstream equipment. For dozing sodium sulphide solution, a tank with agitator and sodium sulphide pump are provided.

8.19 The system of carbonation consists of three carbonating towers. These are cylindrical cast iron towers having several trays and bubble caps inside and several cooling boxes at lower part. One of the these three towers is a standby to cover internals for cleaning (known as 'cleaning' tower), while others are in operation (known as 'making' towers).

8.20 The scarcely carbonated ammoniated brine is further saturated gradually with carbon-dioxide in carbonating tower. During carbonation, essentially the following reactions take place :

$$2NH_4OH + CO_2 \quad = \quad (NH_4)_2\, CO_3 + H_2O$$

$$(NH_4)_2\, CO_3 + CO_2 + H_2O \quad = \quad 2\, NH_4\, H\, CO_3$$

$$2NH_4HCO_3 + 2\, NaCl \quad = \quad 2NaHCO_3 + 2NH_4Cl$$

As a result of carbonation, the crystals of sodium bicarbonate ($NaHCO_3$) are precipitated in 'making' tower. In general one of the 'making' towers, whose inside is covered with bicarbonate crust during a working period of precipitation, is put on standby as 'cleaning' tower. The scarcely carbonated ammoniated brine is first fed into the top of 'cleaning' tower and lean CO_2-gas is fed from the bottom. The deposited bicarbonate crust is dissolved and most of CO_2 is absorbed.

8.21 Liquor from 'cleaning' tower (precarbonated brine) is directed to the top of 'making' tower, to which rich CO_2 is fed from the bottom. Then, the aforesaid carbonation reactions take place. Since the reactions are exothermic, internal cooling is applied at the lower part of tower. For high yield and better crystal growth of sodium bicarbonate, chilled water having temperature of 18-20^{o}C is used in the cooling boxes. Chilled water is obtained from the steam jet water refrigeration section.

8.22 Gases escaping from carbonating towers are passed through tower gas washer mainly for recovery of ammonia before venting to atmosphere. Tower magma containing suspended sodium bicarbonate is fed to rotary drum type vacuum filter through tower magma tank for separation of bicarbonate from mother liquor. The cake is also washed with condensate over the filter to remove trapped NaCl and ammonium salt.

Bicarbonate cake separated from filter is conveyed to dense soda section for calcination and densification.

8.23 The mother liquor flows from filter- separator to M.L. tank. For the purpose of passivation, sodium sulphide solution is added to this tank also. Most of ammonia used formerly in the absorption process is retained in mother liquor as $(NH_4)_2CO_3$, NH_4HCO_3 and NH_4Cl. Ammonia fixed in these forms is recovered for its reprocessing in the production line. This is achieved by their thermal decomposition in specially designed distiller and by decomposition with lime milk in 'Prelimer' - another piece of special equipment. Decomposition reactions take place as represented below :

$$NH_4HCO_3 = NH_3 + CO_2 + H_2O$$

$$(NH_4)_2CO_3 = 2NH_3 + CO_2 + H_2O$$

$$2NH_4Cl + Ca(OH)_2 = 2NH_3 + CaCl_2 + 2H_2O$$

8.24 To carry out the above reactions, mother liquor is fed to the top of distiller preheater by M.L. pump where hot vapour rising from distiller strips off free NH_3 and CO_2. From preheater, liquor flows to 'Ptelimer' where it comes under intense mixing with concentrated lime milk. The liberated gases including NH_3 are fed to distiller preheater, but the liquid flows to the top of distiller proper. Low pressure steam is introduced to the distiller from bottom. Gases from distiller pass through preheater - thus helping in stripping off NH_3 & CO_2. The recovered gases from distiller preheater alongwith those from condensate distiller are cooled in gas cooler and then routed to filter gas washer for absorption again - thus completing the ammonia cycle in the process. Condensate obtained from gas cooler is fed to condensate distiller for recovery of ammonia. Hot sludge from distiller containing $CaCl_2$, unreacted $NaCl$, SiO_2, and other solid impurities is subjected to two stage flashing in sludge flash tank for heat economy. It is then collected in the central waste sludge tank for its ultimate disposal in the sea.

8.25 The CO_2 - gas for carbonation comes from ammonia plant or CO_2 -gas recovery plant (called Holder Gas), lime kiln, boiler flue gas and calciner gas. In order to get better carbonation, these gases are mixed to make up two kinds of CO_2-gas mixture, i.e. rich gas and lean gas. The rich gas, containing 70% CO_2 or more, is compressed by steam driven rich CO_2 -gas compressor, cooled by gas after cooler and fed to the bottom of 'making' tower. The lean gas, containing 40% or less, is compressed by steam driven lean CO_2-gas compressor and delivered to the bottom and middle part of 'cleaning' tower after cooling. Since the concentration of CO_2 -gas affects greatly the quality and yield of bicarbonate, the recovered gases are to be as rich in CO_2 as possible. Besides, from the view point of corrosive property, oxygen content in the CO_2-gas is required to be as low as possible. Standard condition of CO_2 gases are as follows :

Holder gas : approx. 99.0%

Calciner CO_2-gas : : 80-90%

Boiler flue gas : approx. 14%

(iv) Dense Soda (Drawing No. 0033)

8.26 This section provides for the production of light soda ash by calcination of sodium bicarbonate, the production of dense soda ash by densification of light soda ash and recuperation of NH_3 and CO_2 contained in calciner off-gases.

8.27 The filter cake from crude soda section, called crude soda or sodium bicarbonate, is calcined in a rotary steam tube calciner which yields light soda ash as per the following endothermic decomposition reaction.

$$2NaHCO_3 = Na_2CO_3 + H_2O + CO_2$$

As the crude bicarbonate contains also minor quantities of such ammonium compounds as NH_4HCO_3 and $(NH_4)_2CO_3$, they get decomposed to produce NH_3 gas, also as per the following reactions :

$$NH_4HCO_3 = NH_3 + CO_2 + H_2O$$

$$(NH_4)_2 CO_3 = 2NH_3 + CO_2 + H_2O$$

for the above calcination reactions, crude bicarbonate is weighed and then fed to calciner through a mixer alongwith recycle soda ash from calciner. To avoid crust formation on the heating surface of the calciner, it is essential to limit the moisture content in the calciner feed to within 7%. Only this necessitates the recycle of part of calciner products back to calciner feed through mixer.

8.28 Calciner is fed with steam at 33 Kg/cm^2abs in saturated condition, i.e., 270^oC. Condensate leaves it through a cut-off tank, is flashed in two stages, and then pumped by condensate transfer pump partly to steam generation plant. Steam from first stage expander is directed to 7 Kg/cm^2 steam header in the plant for utilisation in steam jet water refrigeration section and steam pressure boosting station. Low pressure from second stage expander is used in distillers in crude soda section after its pressure is boosted to the desired level by steamejector using steam at 7 Kg/cm^2.

8.29 Off-gas from calciner laden with soda ash dust is passed through cyclones where bulk of the dusts get separated and then fed back to calciner mixer. The gas from cyclines flows to gas cooler through a gas header inside which condensate is sprayed at various sections to remove its remaining dust. Soda solution, thus obtained, is taken to soda solution tank for brine purification. Cooled gas leaving gas cooler is directed to calciner gas washed where its NH_3 is scrubbed off by counter-currently flowing purified brine. Condensate obtained from gas cooler is mainly utilised for spraying in gas header as mentioned above. Unutilised condesnate is fed by soda solution pump to condensate distiller in crude soda section. Purified brine leaving calciner gas washer is collected in brine tank, and is then fed by brine pump to ammonia absorber in crude soda section.

8.30 Light soda ash produced in calciner is conveyed to the distribution screw conveyor which feeds part or whole of soda ash to light soda ash bin.

8.31 Light soda ash, if desired as product, is reclaimed from light soda ash bin and is fed to cooler where it is cooled to temperature below 80°C. From cooler outlet, it is weighed by light soda ash weigher before being sent to soda ash bagging station.

8.32 From distribution screw conveyor, the predetermined amount of light soda ash is batched through a feeder and taken to an agitated soda solution tank. Condensate is added to this tank in a controlled way to make soda solution which is subsequently transferred by soda solution pump to brine mixer in brine purification section.

8.33 To manufacture dense soda ash, light soda ash from calciner outlet and/or reclaimed from light soda ash bin is fed to a rotary monohydrator through distribution screw conveyor and feeder. Controlled amount of condensate available from dust scrubber is also fed to monohydrator. Thus, the light soda ash mixed with strictly controlled amount of condensate recrystallizes into monohydrate $Na_2CO_3.H_2O$ of more compact crystal structure in this equipment. The reaction, that takes place, is as follows :

$$Na_2CO_3 + H_2O = Na_2CO_3.H_2O$$

Water of crystallisation of soda ash monohydrate is then removed in a direct fired rotary dryer called dense soda ash dryer. Dryer exit product is dense soda ash. Dense soda ash is then cooled in a rotary cooler to around 50°C, weighed in a dense soda ash wei weigher, and finally sent to storage silo or bagging plant. Hot gas containing soda ash dusts from dense soda ash dryer passes to cyclones where bulk of dusts get separated. While separated soda ash dusts from cyclone are fed to cooler alongwith product dense soda ash, gas is routed through a dust scrubber where its dust is scrubbed off by condensate being circulated by circulation pump. Clean gas from scrubber is vented to atmosphere.

(v) Steam-Jet Water Refrigeration (Drg.No.0034)

8.34 This section provides refrigerated water at 18-20°C for use as cooling medium at lower part of carbonating tower. The method adopted for chilling water is a simple, conventional and versatile one, i.e. spraying water in cooling chamber under the desired vacuum created by steam-jet ejector and condenser system.

8.35 For the above, the water (at 33°C) to be refrigerated is directed to a 6-chamber vacuum evaporator where, by evaporation under high vacuum conditions the temperature of this water is successively lowered in each chamber and finally to 18-20°C. The vacuum in the vevaporator is created bv main ejectors fed with motive steam at 7 Kg/cm^2. The discharge of main ejectors is connected to vacuum condenser whose vacuum is supported by an auxiliary ejector & auxiliary condenser system. Vacuum in auxiliary condenser is maintained by a water ring vacuum pump. Normal cooling water is fed to the main and auxiliary condensers. Hot water from both the condensers and separator of vacuum pump is collected in hot water tank before being sent to cooling tower section. Chilled or refrigerated water from vacuum evaporator is taken to chilled water storage tank through a cut-off tank. Chilled water pump supplies this chilled water to the cooling boxes of carbonating towers.

(vi) Cooling Tower (Drawing No. 0030)

8.36 An induced-draft cross flow cooling tower is foreseen to supply circulating cooling water to the various coolers in all sections of the plant.

Equipment List

8.37 Annexure V-H gives a list of equipment for the plant, based on Classical Solvay process (Polimex arrangement).

B. Dual Process of Central Glass - TEC

8.38 The main plant is broadly divided into three units, namely :

- (a) Soda ash unit
- (b) Ammonium chloride unit
- (c) Cooling tower

(a) Soda Ash Unit

8.39 This unit is divided into the following five sections :

- i) Salt and brine purification
- ii) Carbonation and ammonia recovery
- iii) Bicarbonate calcination
- iv) Carbon-dioxide gas compression
- v) Monohydrate drying

i) Salt and Brine Purification (Drawing No. 0035)

This section is for preparing the purified salt powder to be charged into the salt adding tank at ammonium chloride cyrstallization section and to remove impurities contained in process liquors.

8.40 Raw sea salt of size 6 mm or less is stored in the raw salt hopper of about an hour's capacity. It is fed to the bottom end of inclined salt washer through weigher, while the purified saturated brine is sprayed from the top end of washer. In operation, the salt is transferred upward along the washer, being washed and stirred by the brine. From the washer, the salt is charged to the salt crusher where fresh brine is added. Here the salt is crushed and washed again after mixing with the same brine, It is then introduced to salt slurry tank via the salt screen. The over-size is returned to the crusher. The purpose of this procedure is to accelerate salt dissolution in the ammoniated solution in the salt adding tank and to eliminate the impurities contained within the raw salt crystals.

8.41 The purified salt is centrifuged and separated from the brine and supplied to ammonium chloride crystallization section. As the dirty brine discharged from the above equipment contains a small amount of salt particles, this is introduced to the M.L. tank to recover the salt particles which are then returned to the washer. The overflow from the tank is sent to the lower part of crude brine reacting tank wherein milk of lime is added with vigorous agitation. The impurities in the raw salt, especially Mg compounds, are precipitated in the said tank by following reactions :

$$MgCl_2 + Ca(OH)_2 = Mg(OH)_2 + CaCl_2 \quad (1)$$

$$MgSO_4 + Ca(OH)_2 = Mg(OH)_2 + CaSO_4 \quad (2)$$

$$CaSO_4 + 2\,H_2O = CaSO_4 . 2\,H_2O \quad (3)$$

$MgCl_2$ contained in raw salt increases $CaCl_2$ concentration in the recycled brine and consequently reduces the product quality and disturbs the operation. Therefore it is necessary to add some soda solution after the above reactions into the upper part of the tank.

$$CaCl_2 + Na_2CO_3 = 2NaCl + CaCO_3 \quad (4)$$

The liquor leaving the reaction tank is sent to the crude brine clarifier after adding a flocculent. After settlement of the precipitates, it is reused in the salt washing system. The under flow of the clarifier is withdrawn from the system as a mud slurry waste, which has approx, 200 g/l solid content. This mud is discharged into the mud sewerage in the auxiliary unit.

8.42 The liquor remaining after separation of ammonium chloride crystals (Drg. No. 0039) is passed through the ammonia absorber at ammonium chloride unit (A.C. Unit) to enhance its free ammonia concentration (called F.NH_3) and temperature as carbonator feed (ammoniated brine).

8.43 The ammoniated brine contains various impurities from the salt and is purified by adding milk of lime and flocculating reagent. The impurities in the brine are coprecipitated with $CaCO_3$ in the reaction tank and settles in the bottom of ammoniated brine clarifier. The mud slurry withdrawn from the bottom is fed to the mud filter. The filtrate is returned to the ammoniated brine clarifier via the filtrate tank, while the mud cake is taken out directly. The purified ammoniated brine from the clarifier is charged to carbonators by ammoniated brine transfer pump.

8.44 As the raw lime may contain lumps and sand in relatively high proportions, the milk of lime is prepared in a lime slaker of the rotary drum type, then stored in the lime milk tank after passing through the lime milk screen. The storage should cover one shift's requirements. Oversize on the screen is discharged to the floor and accumulations taken out together with the mud cake above mentioned. The soda solution is prepared at the calcination section, then stored in the soda solution tank in the following section to the extentof one shift's requirement.

(ii) Carbonation & Ammonia Recovery (Drawing No. 0036)

8.45 This section is meant to precipitate crude bicarbonate by the absorpotion of CO_2 gas into ammoniated brine. It also recovers NH_3 which may escape from overall plant as effluents.

8.46 The system of carbonation consists of four carbonators. These are cylindrical towers having several trays and bubble caps inside and several cooling boxes at lower part. One of these is a standby to covery internals for cleaning while others are 'making' towers in operation. Main reactions taking place in the carbonator are as follows :

$$NH_3 + CO_2 + H_2O = NH_4HCO_3 \quad (1)$$

$$NH_4HCO_3 + NaCl = NaHCO_3 + NH_4Cl \quad (2)$$

In the 'making' tower, bicarbonate crystals are precipitated by carbonation. In general one of the 'making' towers, whose inside is covered with bicarbonate crust during a working period of precipitation, is put on standby as 'cleaning' tower. Overflow from the ammoniated brine clarifier is fed into the top of 'cleaning' tower and low concentration CO_2 gas if fed from the bottom. Thus deposited bicarbonate crust is dissolved and most of the CO_2 absorbed.

8.47 The liquor from 'cleaning' tower (precarbonated brine) is introduced into the top of 'making' towers, after being stored in the precarbonated brine tank. High concentration CO_2 is fed from the bottom. Then the reaction (1) and (2) aforementioned take place. As these reactions are exothermic, internal cooling is applied at the lower part of tower. In order to increase the yield of bicarbonate and to obtain good crystals, it is necessary to keep appropriate density of CO_2 and control the liquid temperature in the tower by adequate cooling. To maintain proper conditions, the towers are cleaned of bicarbonate crust periodically in rotation.

8.48 The slurry of crude bicarbonate drawn out from the bottom of the 'making' tower is delivered to a feed tank which is followed by the bicarbonate filter where crude bicarbonate is separated from process liquor. For this duty, vacuum type drum filter is adopted, because a vacuum filter can treat large amount of bicarbonate and is economical in the case of a large-scale unit. The moisture content of the separated bicarbonate is kept less than 15% at normal condition.

8.49 Separated crude bicarbonate is sent to the calcination section. The filtrate discharged from the bicarbonate filter is sent to ammonia recovery tower No. 1

and No. 2 where the liquor absorbs NH_3 gas contained in off-gases from carbonator scrubber, and ammonia distiller. The ammonia enriched liquor is then stored in the mother liquor tank. Mother liquor is sent from here to ammonium chloride unit.

8.50 As off-gases from carbonators contain residual carbon dioxide and stripped ammonia, it is firstly washed in the carbonator scrubber by ammoniated brine to recover CO_2 gas, then sent to ammonia recovery tower. Recovery of ammonia is one of the important steps in this process. At the various sections of aforementioned operations, the formation of ammonia and carbonate containing solutions which cannot be returned directly to carbonation and ammonium chloride crystallization sections are unavoidable and these solutions are collected in recovery liquor tank and sent to the ammonia distiller to recover ammonia and carbon-dioxide. The recovery liquors generally are as follows :

Calciner gas cooler drain;

Wash liquors from ammonium chloride scrubber ;

Liquors of recovery pits in each section, etc.
(excluding salt purification section)

Ammonia distiller consists of two parts, upper part is a preheating section (called preheater) and lower part is stripping section (called stripper).

9.51 Recovery liquor contains two kinds of ammonia, one of which is free ammonia, another is combined ammonia. Free ammonia can be isolated only by heating, whereas combined ammonia cannot be recovered by heat only.

Therefore, decomposition by lime milk is necessary before heating.

8.52 Firstly, the liquor is charged into the top of the ammonia distiller, which is subsequently taken to the 'Prelimer' wherein the lime milk is added to decompose combined ammonia as follows :

$$2NH_4Cl + CaCO_3 = 2NH_3 + CaCl_2 + 2H_2O$$

From the bottom of distiller, low pressure steam is blowndirectly to strip ammonia and carbon dioxide gas off. The off-gas from the top of distiller is supplied to the ammonia recovery tower No. 2 via the condenser. Condensate from the condenser is fed back into the ditiller. Ammonia in the gas is absorbed by the filtrate of bicarbonate filter in the tower. As carbon-dioxide amount in the off-gas of this tower is large, it is returned to rich carbon-dioxide compressor. Outlet gas from carbonator scrubber contains ammonia as aforementioned. Hence, it is recovered in the recovery tower No. 1 by ammoniated brine firstly, and then by treated water in series. The remaining is vented into the atmosphere.

(iii) Bicarbonate Calcination (Drawing No. 0037)

8.53 This section is designed to produce light soda ash by calcination of crude sodium bicarbonate cake obtained from bicarbonate filter. The section also provides for the recovery of carbon dioxide and ammonia contained in the calciner off-gases.

8.54 In this plant, a conventional steam tube dryer is used as calciner. The equipment contains adequately designed number of steam heating tubes through which high pressure (30 $Kg/cm^2.g$) steam flows in order to decompose crude sodium bicarbonate cake according to the following reaction into light soda ash, water and carbon dioxide.

$$2NaHCO_3 \longrightarrow Na_2CO_3 + H_2O + CO_2$$

The crude bicarbonate contains moisture of approximately 15% and small amount of ammonia compounds such as ammonium bicarbonate $NaCO_2$ NH_2 etc. After being mixed with recycled soda ash, the crude bicarbonate is fed to steam tube dryer and calcined at the temperature of over 200°C to produce light soda ash.

8.55 During calcination, decomposition of the bicarbonate gives rise to carbon dioxide, ammonia and moisture. As these gases contain soda ash dust also, they are sent to a gas washing system consisting of calciner gas washer and the cooler after passing through the calciner cyclone to separate dust, moisture and ammonia. Soda ash dust collected by cyclone is sent back to steam tube dryer with recycle soda ash. Condensate drained from the gas washing system containing ammonia, carbon-dioxide and soda ash are sent to ammonia recovery section. The rich CO_2-gas from the system is fed to carbonation process by rich carbon dioxide compressor, as the recovered carbon dioxide will be having a purity of 80-90%. The upper part of the gas cooler acts as a heat exchanger, between the gas and the ammoniated brine from the ammoniated brine clarifier. The brine which gets warmed up to the correct temperature required to wash the inside of cleaning tower, is fed to the carbonation section.

8.56 In the bicarbonate calcination, it is desired to reduce moisture content in the calciner feed so as to avoid forming hard deposits of bicarbonate on the inner wall and heating surfaces of the steam tube dryer. For this purpose, a certain amount of hot soda ash is recycled from outlet ofthe steam tube dryer to be mixed with the crude bicarbonate to keep the moisture content of the feed mixture less than 7%. Thus, from light soda ash discharged from the calciner, a part is recycled as return soda ash, while other parts are the feed stock to make dense soda ash and soda solution to purify raw salt and raw water etc. The remainder is sent to the storage unit after being cooled until below 80°C by light soda ash cooler followed by light soda ash weigher. The product light soda ash meant for sale is sent to soda ash bagging station.

8.57 Steam condensate from calciner is flashed to low pressure steam in flash tanks. This is used as process steam mainly for ammonia distiller. After flashing, the low pressure condensate is sent to the auxiliary unit for its utilisation.

(iv) Carbon Dioxide Gas Compression & Water Refrigeration (Drawing No. 0037)

8.58 This section is intended to receive various grades of CO_2-gases and then prepare the CO_2-gases to be fed to carbonators in accordance with the process requirements. The section also provides the facility for water refrigeration so as to supply chilled water to cool carbonators ('making' towers).

8.59 The grades of CO_2-gases available for utilisation in carbonation section are as follows :

- The make-up pure CO_2-gas either from ammonia plant or CO_2-gas recovery plant stored in CO_2-gas holder (called holder gas).
- The off-gases from ammonia recovery tower No. 2 (called recovery CO_2-gas).
- Calciner CO_2-gas containing 80-90%CO_2.
- Boiler flue gas containing 10.5-14% CO_2.

In order to get better carbonation, these gases are mixed to make up two kinds of CO_2 containing gases, rich gas and lean gas. The rich gas containing 70% or more CO_2 is compressed by the rich CO_2-gas compressor, cooled by gas after-cooler and is fed to the bottom of making tower. The lean CO_2 gas containing 40% or less, is compressed by lean CO_2-gas compressor and delivered to the bottom and middle part of cleaning tower after cooling. As the concentration of CO_2 gas affects greatly the quality and yield of bicarbonate, the recovered gases need to be as rich in CO_2 as possible. Besides, from the view point of corrosive property, oxygen content in the CO_2 gas is required to be as low as possible.

8.60 Standard concentrations of CO_2 gases are as follows :

Holder gas	:	approx. 99.0%
Recovery CO_2 gas and calciner CO_2 gas	:	80 - 90%
Boiler flue gas	:	approx. 14%

In this process, cooling water temperature is also important, especially that used in making towers (carbonators) is required to be less than 25°C. Therefore chilled water apparatus is necessary, which consists of suitable refrigerator and water cooler. As the coolant in chilled water appratus, freon is utilised.

(v) Monohydrate Dry ing (Drawing No. 0037)

8.61 The purpose of this section is to produce dense soda ash by drying of monohydrated soda ash prepared by hydration of light soda ash in a compressing mill.

8.62 To manufacture dense soda ash, an equivalent amount of light soda ash is fed to the monohydrator through an inverted gravity-type feed hopper, where the feed is mixed with a sufficient amount of hot alkali liquour that has been recovered at the scrubber system of this section. A compressing mill is utilised as monohydrator in this process. Smooth faced press rolls pick up the feed, apply a rolling pressure, and produce continuous sheet (full width of rolls) of soda ash monohydrate which is formed according to the following reaction.

$$Na_2CO_3 + H_2O = Na_2CO_3.H_2O$$

As the sheet of soda ash monohydrate comes from the compressing mill, it is broken by flake breaker part of the mill into pieces to provide suitable feed for the dense soda ash dryer.

8.63 Dense soda ash monohydrates are then fed to dryer via screen. Over-size from the screen is crushed in crusher before feeding to the dryer. Water of crystallisation from monohydrates is removed in this dense soda ash dryer where the feed is heated to over 150°C. A typical steam tube dryer is used for this purpose where steam at 12 kg/cm^{2}g is used.

8.64 Dried product from dense soda ash dryer is taken to a classifying screen which separates standard sized powdery granular product of dense soda ash. Product dense soda ash is subsequently cooled in a cooler to around 50°C, and weighed in dense soda ash weigher,then sent to the storage silo or bagging plant for bagging and subsequent shipment. Undersize obtained from classifying screen is returned to dense soda ash dryer as recycle. Vapour from dense soda ash dryer containing fine dusts of soda ash is taken to a dust scrubber where it is scrubbed with water fed from top. The alkali solution obtained from this scrubber is mainly fed to monohydrator and partly to the miscellaneous dust scrubber. Vapour after scrubbing is vented to the atmosphere.

8.65 Generally in these dry solid handling sections, dust emission from various equipment is unavoidable - for instance from dense soda ash screens, light soda ash cooler, conveyors, chutes,etc. Hence, exhaust fans and dust scrubbers are provided to arrest these dusts and prevent air pollution. Dusty air surrounding these equipment/parts are collected by exhaust fan and blown to the bottom of miscellaneous dust scrubber where water is fed from top. The scrubber liquor with dissolved alkali dusts is sent to the soda solution pit for recovery.

(b) Ammonium Chloride Unit

8.66 This unit is divided into the following two sections :

(i) Ammonium chloride crystallisation

(ii) Crude ammonium chloride drying

The functions of each section is described below :

(i) Ammonium chloride crystallization
(Drawing No. 0039)

8.67 This section is meant to crystallize crude ammonium chloride from mother liquor and to separate it.

The liquor from ammonia recovery tower (Drg.No.0036) is controlled to get adequate free ammonia concentration by injecting more fresh ammonia through the ammonia absorber. The object of this step is to prevent co-precipitation of sodium bicarbonate into ammonium chloride crystal, that causes deterioration of the product and increment of sodium-losses. The resultant liqour (ammoniated brine solution) is stored in the ammoniated solution tank, then cooled countercurrently in solution heat exchanger by cold filtrate from which ammonium chloride has been separated.

8.68 The plate type solution heat exchanger used is operated at a temperature range at which ammonium chloride is not crystallized out and only heat exchanger between the ammoniated solution and the ammonium chloride filtrate is performed. Outlet from the heat exchanger is fed first to the salt adding tank wherein the purified solid salt is mixed, and crystallization of ammonium chloride is promoted by vigorous agitation with dissolution of the salt. In this case, accurate ratio of flow rate on both salt and solution is required. So the salt is charged through the purified salt weigher with constant feeder. Outlet slurry of the tank is fed to ammonium chloride crystallizers wherein crystallization is accomplished. The crystallisers have vertical forced circulation type heat exchangers where heat of vaporization of ammonia liquid from the ammonia storage tank is utilized as coolant. The ammonia liquid is fed into the shell bottom of crystallizers. A part of vaporised gaseous ammonia is sent to ammonia absorber as feedstock and the other is sent to the ammonia refrigerator where it is liquefied again. The refrigeration unit consists of ammonia compressor and ammonia condenser.

8.69 As ammonium chloride crystal deposits on inner walls of ammonium chloride crystallizer and the salt adding tank and lowers operational efficiencies, their periodical cleaning by washing liquor is necessary. Besides, impurities from the salt deposit on the cooling surfaces of solution heat exchangers and crystallizers as a scale. Therefore, cleaning by acid solution is required occasionally. A separate ammonia tank is used for temporary storage to tide over maintenance periods of the crystallizer.

8.70 Ammonium chloride slurry cooled down to require low temperature on the crystallizer, is conveyed and concentrated in the ammonium chloride thickener, and fed via the feed tank to the ammonium chloride centrifuge where crude ammonium chloride is separated from mother liquor. As the filtrate from centrifuge still contains a little amount of ammonium chloride crystals, it is returned to the thickener. Overflow from the thicknener is passed through solution heat exchanger and ammonium absorber, after warming and adjusting of free ammonia content and is stored in the ammoniated brine receiver, wherefrom it is transported to the brine purification section of soda ash unit.

(ii) Crude ammonium chloride drying (Drawing No. 0039)

8.71 This section produces fertiliser grade ammonium chloride from the crude ammonium chloride crystals by granulation and then drying.

8.72 Crude wet ammonium chloride from centrifuge is mixed in ammonium chloride mixer with dry powder of ammonium chloride returned from ammonium chloride classifying screen. The mixed material is then fed to specially designed granulator where the mixture is pressed to sheet, then cut to proper size, and charged to a rotary drum type ammonium chloride dryer. The dryer is a direct fired one using natural gas as the heating source. Sufficient care is required for the operation and maintenance of this hot equipment because of the corrosive property of ammonium chloride and its tendency for sublimation at low temperature.

8.73 Temperature of hot flue gas entering ammonium chloride dryer is kept generally lower than 180°C.

Ammonium chloride discharged from dryer is classified into three fractions by classifying screen. Oversize crusher, undersize is returned to the mixer, and the intermediate size fraction is taken as product. The product ammonium chloride is then cooled to about 50°C in the ammonium chloride cooler, weighed in ammonium chloride weigher, and then sent to the storage silo or the bagging plant for bagging and shipment.

8.74 The exhaust gas from ammonium chloride dryer is introduced to the dryer cyclone for dedusting and then blown to a dust scrubber for final removal of dust where water is introduced from the top. The recovered ammonium chloride dust from cyclone is routed to mixer, while the scrubbed liquor is sent to the recovery liquor tank at soda ash unit. Clean gas from dust scrubber is vented to atmosphere.

(c) Cooling Tower Unit (Drawing No. 75.20-0030)

8.75 An induced-draft, cross-flow cooling tower is foreseen to supply circulating cooling water for the various coolers in all sections of the plant.

Equipment List

8.76 Annexure V-H gives a list of equipment for plant based on Dual Process (Central Glass - TEC arrangement).

Equipment Layout and Plot Plan

8.77 The detailed equipment layout of the soda ash plant, based on the two selected processes, has been shown in Drawing Nos. 0001 (Polimex) and 0002(Central) Glass - TEC). The layout shown is generally in accordance with the details made available by the process licensors. The arrangement has the flexibility normally required in the operation of plants. Expansion space has been provided to accommodate certain critical equipment in each section. The layout also provides adequate space for in-plant mobility, maintenance and other essential requisites.

8.78 For the selected locations and processes, plot plan has been shown in the following drawings :

		Location & Process
i.	Drawing No. 0001	Chittagong, Classical Solvay (Polimex), based on by-product chalk.
ii.	Drawing No. 0002	Chittagong Dual (Central Glass - TEC) with ammonia from CUF Project.
iii.	Drawing No. 0003	Ghorasal Dual (Central Glass - TEC) with captive ammonia production.

These indicate the facilities considered for computation of investment required for the project and used in the estimation of production cost.

8.79 While developing the plot plan for the Chittagong site, statutory requirements of the civil aviation regulatory authority have been complied with. All the facilities have been located close to the proposed site of CUF Project because of the close linkages with this project. Keeping in view the problems involved in handling soda ash, which is characteristically different from urea prills, the bagging plant has been kept close to the main production plant. For operational convenience, the jetty of the project has been shown close to the proposed location of the CUF Project's jetty. This has, however, resulted in the jetty being about 2 Km away from the bagging plant.

8.80 At Ghorasal due consideration has been given to the possible area requirement of the proposed Chorasal II plant in allocating the available land area. In developing the plot plan, however constraint is experienced in accommodating yet another ammonia plant for captive product of ammonia for the soda ash unit within the available plain land of the existing UF Factory. Hence, the plot plan shown (Drawing No.0003 indicates the need for acquiring some private owned land.

Chapter 9

CAPITAL OUTLAY AND COST OF PRODUCTION

9.1 The erected cost of the soda ash plant based on the byproduct chalk, including the investment requirements of related facilities such as ammonia and ammonium sulphate, at Chittagong has been shown in Part II. Similarly, the total investment requirement of the ammonia - soda ash (Dual Process) facilities at Ghorasal location has been shown there, For purposes of comparison, however, the estimated capital outlay required for the different soda ash schemes under discussion is summarised in Table 9.1. As mentioned earlier, in the case of common facilities, the capital cost has been somewhat arbitrarily allocated between the different plants involved in the schemes.

Table 9.1

Summary of Erected Cost Estimates for the Soda Ash Facilities

(Cost in $ million)

Alt.	Location	Feature	Process	Erected Cost FC	Erected Cost LC	Erected Cost Total
I.	Chittagong	Byproduct chalk route	Solvay	27.42	25.07	52.49
II.	-do-	Limestone route	-do-	33.50	32.80	66.30
III.	-do-	Ammonia from CUF Project	Dual	37.50	33.30	70.80
IV.	Ghorasal	Captive ammonia	-do-	41.00	40.00	81.00
V.	-do-	Ammonia from CUF project'	-do-	46.30	43.70	90.00

FC : Foreign exchange cost, LC : Cost in local currency

9.2 As seen from 9.1, the erected cost of the soda ash plant based on byproduct chalk and employing the Classical Solvay process is the lowest even in comparison with the plant using natural limestone as the raw material. This is mainly because of the fact that use of natural limestone needs an additional facility for cleaning the CO_2 - bearing gases from lime kiln for usein carbonation. The cost of an independent CO_2 - recovery unit required to supply CO_2- gas for carbonation for use of by-product chalk is allocated between the sulphate and soda ash plants. Though the erected cost of soda ash plant based on Dual Process (Central Glass - TEC) is almost the same whether located at Chittagong or at Ghorasal, the investment on providing off-site facilities is comparatively higher at Ghorasal. As indicated, the off-site facilities required at Ghorasal include the provision of river water intake station, water treatment plant, D.M. water plant and steam generation plant, whereas none of these is needed at Chittagong.

9.3 The details of investment in respect of the different schemes for Chittagong and Ghorasal locations are given in Table 9.2

TABLE - 9.2

Capital Outlay for Soda Ash Plants

($ million)

Details	Alternative I		Alternative II		Alternative III		Alternative IV		Alternative V	
	F.C.	Total	F.C.	Total	F.C.	Total	F.C.	Total	F.C.	Total
A. Manufacturing Facilities										
i) Main plants	11.10	16.70	11.50	17.20	12.70	18.50	12.60	20.00	12.60	20.00
ii) Offsites & jetty	4.94	6.42	6.96	9.77	8.75	12.09	11.99	16.51	15.60	22.26
iii) Site development	0.06	0.21	0.13	0.48	0.13	0.48	-	0.05	-	0.09
iv) Spares	1.73	1.86	2.60	2.80	2 60	2.80	2.30	3.00	2.60	3.30
v) Project management	1.00	3.58	1.31	5.65	1.42	5.73	1.21	4.84	1.42	5.73
Sub-total	18.83	28.77	22.50	35.90	25.60	39.60	28.10	44.40	32.22	51.38
B. Other Fund Requirement										
i) Township & buildings	1.90	3.40	2.80	5.00	2.80	5.00	2.90	5.10	2.80	5.00
ii) Working capital	-	3.20	-	3.35	-	3.87	-	5.30	-	4.56
iii) Commissioning expenses (Net)	-	(0.30)	-	(0.10)	-	(1.10)	-	(0.60)	-	(0.70)
iv) Contingency	1.05	1.85	1.30	2.25	1.40	2.42	1.50	2.70	1.78	3.06
v) Escalation	5.64	11.72	6.90	15.00	7.70	15.81	8.50	18.30	9.50	20.20
vi) Financing charges	-	3.85	-	4.70	-	5.20	-	5.80	-	6.50
Sub-total	8.59	23.72	11.00	30.40	11.90	31.20	12.90	36.60	14.08	38.62
Total Outlay	27.42	52.49	33.50	66.30	37.50	70.80	41.00	81.00	46.30	90.00

Note : Alt. I : Byproduct chalk (Chittagong) - Solvay
Alt. II : Limestone (Chittagong) - Solvay
Alt. III : NH_3 from CUF Project (Chittagong) - Dual
Alt. IV : Captive NH_3 (Ghorasal) - Dual
Alt. V : NH_3 from CUF Project (Ghorasal) - Dual

(Brackets indicate negative figures).

Basis of Estimates

9.4 The basis for the estimates and the assumptions made have been explained in detail in Part II. The cost of plants and facilities have been made, as explained earlier, from preliminary designs and budgetary quotations from suppliers and process licensors, where available. Data from the Consultants' cost files have been utilised, sometimes using an escalation factor, where fresh quotations could not be obtained. The Consultants have made an extensive survey of the fabrication facilities available in Bangladesh and have identified the equipment that can be locally procured (Annexure V H), which formed the basis for estimates of local supplies. The prices assumed for procurement of indigenous materials, fabrication charges etc have been indicated in Part II.

9.5 The provision of 'on shelf' spares etc is based on the normal recommendations of the suppliers and the experience of the Consultants. The spares are adequate in the ordinary course for 2 years' operation of the plants.

9.6 Ocean freight has been assumed at 10 percent of the fob cost of supplies and marine insurance at 0.6 per cent. Since the equipment are not over-dimensional, no special provision at the Chittagong port will be necessary. In most cases, equipment can be unloaded directly from the ship to the construction jetty of the CUF Project using the ship's derrick for the Chittagong site. But for Ghorasal, barges will have to be used for unloading and movement to site. No special difficulty is anticipated in this arrangement, since this mode is already in use in respect of equipment for the Ashuganj fertilizer (1000 tpd ammonia - 1700 tpd urea) project. The inland handling charges have been assumed at 3% of cost of supplies for Chittagong and 5% for Ghorasal.

9.7 The cost estimates include the license and basic engineering fees payable to the process licensors. A provision of 5 percent of the cost of equipment has been included to cover the cost of procurement and inspection. The basis for computation of erection charges has been spelt out in Part II. It is assumed that for erection of complicated equipment and machinery, specialist assistance from the vendors will be available. The provision for payment towards Project Consultant's fees etc are adhoc, since these are negotiable and depend considerably on the scope of services.

9.8 The civil works costs are largely based on secondary data about site conditions, and no detailed and in depth investigations, necessary for actual design, have been carried out. A housing complex for the staff is envisaged, as explained in Part II.

9.9 Customs duty for project imports at a concessional rate of 2.5 percent for the Chittagong site has been assumed as an industrially backward area, on the basis of preliminary indications given to the Consultants, Sales tax has been assumed at 20 percent of the landed cost. The concessional rate of customs duty will not however be available for Ghorasal, and the rate assumed is 25 percent.

9.10 As indicated in the earlier parts the estimates include a contingency provision equivalent to 5 percent of cost of manufacturing facilities. The cost estimates correspond to mid - 1979 prices and to validate the estimates upto the period of implementation, an escalation of 25.9 percent of foreign cost and 40.4 percent of local cost of the project has been incorporated. The interest on longterm loan has been assumed at 10 percent. It is also assumed that the entire foreign cost will be treated as loan and local cost as equity since this is the normal practice in Bangladesh.

Working Capital

9.11 The basis for calculation of working capital requirements is indicated in Annexure V-0. In accordance with the standard practice in Bangladesh, the entire working capital requirement has been capitalised.

Financial Plan

9.12 On the understanding that the entire foreign exchange cost will be treated as loan, the debt-equity ratio for the different schemes works out, roughly, around 1 : 1. Based on the implementation scheme indicated elsewhere, the phasing of the investment will broadly be 10% in the first year, 70% in the second year and the balance in the third year. The financing charges are based on these assumptions - interest being counted on the average period of drawal of funds during the year.

Cost of Production

9.13 As mentioned earlier, the stream efficiency of a soda ash plant under Bangladesh conditions cannot ordinarily be more than 300. The cost of production of soda ash under the different schemes of production has been worked out, therefore, on the basis of 300 operating days and 100 percent level of production The capital charges are derived from the investment estimates given above. The production cost works out as shown in Table 9.3.

Table 9.3

Cost of Production of Soda Ash

	Particulars	Annual Cost $ '000				
		Alt. I	Alt. II	Alt. III	Alt. IV	Alt V
1.	Raw materials	2765	5040	4694	8458	5028
2.	Utilities	2597	2772	3920	2429	2656
3.	Consumables	33	34	34	233	233
4.	Labour & overheads	613	807	807	620	807
5.	Maintenance materials	847	914	1049	1347	1560
6.	Bags (Packing)	564	564	1543	1543	1543
7.	Insurance	158	199	212	243	270
8.	Contingency	379	517	613	416	605
	Annual Works Cost	7956	10847	12872	15289	12702
9.	Depreciation	3487	4300	4661	5538	6184
10.	Selling expenses	200	200	210	210	210
11.	Average interest on term loan	1371	1675	1875	2050	2315
12.	Annual Processing Cost	13014	17022	19618	23087	21411
	Less					
13.	Credit for amm.chloride@	-	-	(7528)	(7528)	(7528)
14.	Net Annual Processing Cost (Soda Ash)	13014	17022	12090	15559	13883
	Annual Production (Te)	60000	60000	60000	60000	60000
15.	Cost of Production	216.90	283.70	201.50	259.30	231.40
	Say.	217	284	202	260	232

@ $ 123/te

Notes : Please see Table 9.2

9.14 In some of the schemes discussed above, the soda ash plant forms only one of the production units in the complex. For instance, in Alt. I, the production complex envisaged covers (i) a captive ammonia plant of 100 tpd capacity (Part II), (ii) an ammonium sulphate plant of 480 tpd capacity (Part IV) which would yield byproduct chalk for use in the soda ash plant and (iii) a soda ash plant employing the Solvay process and making use of the byproduct chalk. Similarly Alt. IV cover both captive ammonia plant and the soda ash plant. For purposes of external economics, several facilities such as carbon dioxide, power and water etc serving all the units have been laid in common wherever the scheme covered more than one unit. Necessarily, therefore, the costs had to be allocated to the different production units somewhat arbitrarily.

9.15 As seen in the Table 9.3, the cost of production soda ash works out the lowest in Dual Process Plant with ammonia procured from CUF Project (Alt III). The route (Alt I) where by products chalk is utilised as the raw material ranks next. The attractiveness of the Dual Process alternative (Alt III) is mainly due to the external supply source for ammonia - thus eliminating the need for a captive ammonia - plant - with its high cost ammonia supply. The credit for ammonium chloride the co-product in the Dual Process for outweights the higher capital charges of the process scheme compared to the byproduct chalk (Alt I) route.

9.16 The general assumptions relating to the computation of the cost of production above have been set out in Part II. Likewise, the prices of inputs and utilities assumed for the purpose of these calculations have been indicated there. The price of salt (delivered at site) has been assumed at Tk 247/te. The labour and overhead cost has been calculated on the basis of the staffing pattern indicated in Chapter 12. The payscales and fringe benefits assumed are those currently applicable to public sector employees in Bangladesh, as practised in BCIC. Maintenance material has been assumed at 5 percent of the landed cost of supplies and 1.5 percent of the cost of jetty and buildings. Consumable stores, covering chemicals and other materials required for normal operation of the plant have been assessed on the basis of presumed consumption. The contingency meant to provide for any unforeseen expenditure is assumed at 5 percent of works cost. The cost of insurance has been assessed at 0.3 percent of total capital. Depreciation has been worked out on a straight line basis over a period of 12 years, except for the colony and the jetty, where a life of 30 years has been assumed. Interest on long term capital has been assumed, as mentioned earlier, at 10 percent. The selling expenses for ammonium chloride has been assumed at Tk 2/te, since the fertilizer is assumed to be lifted from factory premises by the Bangladesh Agricultural Development Corporation (BADC), which is the sole authority for distribution of agricultural inputs in the country. The selling expenses for soda ash are assumed at Tk 50/te.

Chapter 10

PRICING AND PROFITABILITY

10.1 Apart from the cost of production which, given the conditions in Bangladesh, will tend to be inveterate to a substantial extent, the commercial attractiveness of the project will be considerably influenced by the sale prices for the products, - ammonium chloride and soda ash. Ammonium chloride will be largely sold as a nitrogen fertilizer, - and its suitability for Bangladesh soils has been discussed later - though a small proportion of the production can be converted into technical grade product for sale to industrial consumers (e.g. battery manufacturers, galvanising, and tanneries) and to that extent, substitute the imports. The present annual import of ammonium chloride (technical grade) is understood to be around 1500 te, though given free supply, the consumption is expected to rise sharply. Since ammonium chloride is not at present produced or sold as fertilizer within the country, its possible selling price can only be derived from urea price, since both are essentially nitrogen fertilizers and can substitute for each other as agricultural inputs in large tracts of the country. The study on the Chittagong Urea Fertilizer Project projects a selling price of $ 175 per tonne for urea produced by the new unit. The Consultants feel this to be a somewhat pressimistic projection, especially considering the recent escalation in the world fertilizer prices and the future outlook for petroleum products in the world in general. The Consultants feel that the international prices of Urea by 1983 will not be lower than $ 225/te. In fact considering the recent escalations in project costs, the cost of production Urea in any new plant in Bangladesh is not likely to be lower than this figure.

Making allowance for the nitrogen content of each, the ex-factory price for ammonium chloride corresponding to the urea price of $ 225 works out to $ 123/te. The actual selling price to the farmers may however be lower, since all fertilizers are heavily subsidised in Bangladesh.

10.2 For purposes of pricing, the entire production of soda ash from the proposed new unit will be assumed to be dense soda ash. The current international prices of soda ash c&f Chittagong are well above $ 200/te*. Though the present prices are lower compared to the peak levels of 1974, the indications are that the downward trend had been long halted and the prices are poised for a further firming tendency in future, partly reflecting the inflationary conditions and partly the hike in the cost of processing in general. Considering the heavy investment requirements and the rather difficult conditions - due to inadequate development of the industrial infrastructure - under which the project will have to be executed in Bangladesh, leading to cost escalation, it may be over - optimistic to expect a locally established soda ash unit to be able to sell its products below international prices. Since the product is primarily meant for domestic consumption, a fair basis for price fixation will be the present landed cost of the import. In order to assess the project's vaiability under rather pessimistic conditions, the import price (c&f Chittagong) of dense soda ash is conservatively assumed to be $ 200/te - while the actual price is closer to $ 300/te. Corresponding to the c&f price of $ 200/te,

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* In February 1980, the import price of 7000 te of light soda ash c&f Chittagong was $ 250/te.

the landed cost works out to around $ 340 (Tk 5100/te). However, making allowance for the fact about one-third of the production might be in the form of light soda ash, and reflecting a cautious approach, the average ex-factory selling price is assumed for purposes of calculation to be $ 323.30 (Tk 4850) - which is in fact significantly lower than the actual landed cost of light soda ash at Chittagong at present. The Consultants estimate that by 1983-84 the dense soda ash prices (landed) are likely to be well above Tk6000/te, assuming the existing level of customs duties and other charges.

10.3 On the basis of the pricing assumed above, the projects' profitability under different schemes will be as shown in Table 10.1.

Table 10.1

Profitability of the Soda Ash Project

(Figs. in $ '000)

Particulars	Alt.I	Alt.II	Alt.III	Alt.IV	Alt.V
1. Annual realisation from sale					
i. Soda ash	19400	19400	19400	19400	19400
ii. Amm.chloride	-	-	7528	7528	7528
Total	19400	19400	26928	26928	26928
2. Annual works cost	7656	10847	12872	15289	12702
3. Depreciation	3487	4300	4661	5538	6184
4. Selling Expenses	200	200	210	210	210
5. Gross profit before interest	7757	4053	9185	5891	7832
6. Average interest on term loan	1371	1675	1875	2050	2315
7. Profit after interest (before taxes)	6386	2378	7310	3841	5517
8. Total capital employed	52490	66300	70800	81000	90000
9. Return on total capital (percent)	14.8	6.1	13.0	7.3	8.7
10.Equity capital	25070	22800	33300	40000	43700
11.Average return on equity (percent)	25.5	7.3	22.0	9.6	12.6

(brackets indicate negative figures). For notes see Table 9.2

Consultants' Recommendation

10.4 Apparently, it is seen from the figures in Table 10.1, that the most attractive proposal would be to establish the soda plant on the basis of utilisation of byproduct chalk (Alternative-I). However, as discussed earlier, the proposal involves the setting up of an ammonium sulphate plant to yield the required byproduct chalk, and at the assumed level of ammonium sulphate prices (based on urea price) the ammonium sulphate unit will be incurring heavy loss, as the sale price will be only around two-thirds the cost of production (Part IV). The overall return on the entire scheme, involving captive ammonia plant, ammonium sulphate and soda ash (Solvay) - is unattractive, being around 1.8 percent on the total capital employed. Closely behind in the ranking of profitability is the Alternative III, which with a projected return of 13 percent on total capital, compares favourably with the first alternative. Hence, considered as a whole, a Dual Process plant located at Chittagong appears to be the most attractive proposal among all the five alternatives - primarily because of the tie-up for ammonia with the CUF Project. The Consultants, therefore, recommend selection of the Dual Process and location of the plant at Chittagong, next to the CUF Project site with arrangement for ammonia supply from the CUF Project as discussed earlier. In the subsequent paras, discussion is confirmed to this Alternative.

Sensitivity

10.5 Though with the above shown return of about 13 percent on the capital employed, the recommended (Alt III) project does commend itslef as an investment proposition, yet, as mentioned earlier, this could be possibly a conservative view of the project's profitability, since the selling price for soda ash assumed is based on a pessimistic projection. If the selling price is increased to more realistic levels, the emerging profitability position works out as follows (Table 10.2) :

Table 10.2

Sensitivity of Price Changes

(Percent)

Selling Price	Return on Capital Employed	Return on Equity
Base (Taka 4850)*	13.0	22.0
Price increase by 5%	14.9	26.0
Price Increase by 10%	16.8	30.0
Price Decline by 10%	9.2	13.9

* Ammonium Chloride : TK 1845/te

10.6 The effect of the capital cost increase on the project's economics may be seen in Table 10.3. The project looks viable even if there should be a substantial escalation in capital costs.

Table 10.3

Sensitivity of Capital Cost Increase

(Percent)

Capital Cost	Return on Capital Employed	Return on Equity
Base ($ 70.8 m)	13.0	22.0
10% higher	11.0	17.8
15% higher	10.2	16.0
20% higher	9.4	14.4

10.7 As may be noticed from Table 10.4, the project's viability is not materially affected by escalations in raw material prices either.

Table 10.4

Sensitivity to Raw Material Prices

Raw Material Prices	Return on Capital Employed	Return on Equity
Base ($ 4.69 m)	13.0	22.0
Increase by 10%	12.3	20.5
Increase by 15%	11.9	19.7
Increase by 20%	11.6	19.0

Internal Rate of Return

10.8 The Internal Rate of Return, which indicates the rate at which the discounted total of the annual cash inflows over the life of the project equals the discounted current worth of initial investment, is usually regarded as an acceptable guide to a project's attractiveness to the investor. The IRR of the recommended alternative viz. the Dual Process scheme at Chittagong (Alt III) is around 18 percent.

Chapter 11

MODE OF IMPLEMENTATION AND TIME SCHEDULE

11.1 The mode of implementation of the project complex including the upstream plants - ammonia and ammonium sulphate, where required - has been discussed in detail in Part II . The different contracting methods for implementation of projects through third parties (e.g. engineering contractors) and their salient features have also been discussed in that section, UNIDO is presently understood to be engaged in evolving a set of model contracts for fertilizer plants and they can provide some general guidelines for soda ash plants as well.

11.2 As mentioned in Part II, Bangladesh does not have at present adequate expertise for executing large industrial projects involving specialised skills of design engineering, project management, supervision and monitoring. The normal run of execution of such projects hitherto has been to entrust the projects to a suitable engineering contractor on 'turn-key' terms. Though the needed skills are building up through increasing participation in project activities, the country may continue to have to depend for some more years on foreign contractors for the execution of complex chemicals plants, such as the soda ash plant, especially owing to the dearth of qualified and competent personnel at the middle and lower levels and inadequate design-engineering experience, It will, therefore, be necessary, both in the interest of minimising costs and ensuring trouble-free operation of plants to entrust the soda ash projects implementation to a suitable engineering contractor on turn-key basis. An illustrative list of such firms is given in Annexure V-G.

11.3 The engineering contractor may be chosen on the basis of international competitive bidding, as indicated in Part II. In the interest of developing indigenous skills, the engineering contractor may be advised to associate the local staff in selected functions, It is visualised that some of the facilities such as steam generation, water supply and treatment, product handling etc. will be sub-contracted to firms specialising in these lines.

11.4 As mentioned in Part IV, the project owners (assumed to be BC IC) may have to decide at the very outset whetheran engineering contractor should be engaged to execute the entire complex or whether different plants should be farmed out to different firms on the basis of their specialisations. In the latter case the soda ash plant alone might be contracted to one of the firms (Annexure V-G) experienced in the line.

11.5 It has been recommended in Part II that to assist the project owners in the implementation of the project, a Project Consultant may be appointed to prepare bid documents, invite offers and quotations, evaluate the offers, carry out inspection, expediting and follow-up functions, ensure arrangements for receipt and issue of materials, coordinate between different contractors and generally monitor the various project activities. A project management team may be appointed by the owners to liaise with the Project Consultant and undertake specific local functions involving liaison with the government agencies and local manufacturers. It is envisaged that the Project Management Team will be eventually involved in appropriate operating functions of the plants concerned, after the commissioning.

Project Time Schedule

11.6 The time schedule for completing a project will dependon several factors, as indicated in Part II including mode of financing of the needed external resource. It is assumed that the foreign exchange credit will be available from one of the international development agencies or from a consortium of banks, and that freedom to procure equipment from any cheapest source is available.

11.7 Implementation of the soda ash plant at both the selected sites, viz. Chittagong and Ghorasal, has been shown along with necessary upstream plants as a single project, and the tentative time schedule has been shown in Part II. It has been assumed that the projected time for the implementation of the project (up to commercial production) will be about 36 months from the award of contract (the "zero date") to successful engineering contractor. The expected time for implementing the project will be about the same for both the manufacturing processes of soda ash, but the source of ammonia supply (e.g. from the proposed CUF Project vs a captive plant) will have a bearing on the time schedule.

11.8 Another factor of critical importance to the soda ash plant particularly is the salt works development project (Part VI), since the primary raw material for the soda ash plant is assumed to come from this source. Similarly the project's execution is tied up wit the plan for extension of natural gas supply to the Chittagong city and the CUF Project. For the Solvay process, another factor of critical importance will be the limestone mining programme and its availability for the manufacture of soda ash.

Chapter 12

MANPOWER REQUIREMENT AND STAFFING

12.1 As indicated in Part II, the soda ash Plant alongwith its upstream and ancillary plants is assumed to be owned by BCIC, in view of its large soda ash requirements and other linkages. The proposed management pattern for the complex as a whole has been discussed in Part II. It is assumed that the complex will function as a unit of BCIC under a General Manager. The soda ash unit's operational management will also be controlled through functional heads covering production, maintenance and technical services, to be headed by respective managers. The recommended staffing pattern for the operation and maintenance of the soda ash plant alongwith its associated facilities have been shown for both the processes in the Drawing No. V-24.

12.2 The requirement of operating staff have been decided on the basis of suggestions obtained from the process licensors. The general staffing pattern broadly follows the present system in the operating fertilizer plants in Bangladesh. It is assumed that besides the day-to-day maintenance, the annual maintenance work will be done by the regular staff and not by any contractor. During the field survey in Bangladesh, the Consultants found that reliable contractor capable of undertaking annual maintenance of chemical plants, such as the soda ash plant, were not locally available.

12.3 The proposed phasing of staff recruitment has been indicated in Part II. It is assumed that some of the staff recruited in the early stages will be trained and engaged in supervising project construction work.

Since Bangladesh at present does not have any soda ash plant, training of the recruited staff at appropriate levels is considered essential. Some of the key operation/maintenance personnel should, therefore, be trained in operating plants designed by the process licensors/contractors selected for this project, outside the country. This should form part of the contractor's responsibility. At an appropriate stage, the question of engaging some expatriate operating staff in one or two critical areas of operation until production stabilises and to train adequately the local staff until they gain experience may be considered.

Chapter 13

MARKETABILITY OF AMMONIUM CHLORIDE

13.1 Ammonium Chloride, sometimes, known as muriate of ammonia, is a salt of ammonia with hydrochloric acid. It has two prominent uses ; as a fertilizer and as an industeial chemical. As a straight nitrogenous fertilizer, it resembles ammonium sulphate but with 25.5% N, has a higher nutrient content than ammonium sulphate (20.5%). Like ammonium sulphate, all its nitrogen is in ammonical form and is similarly absorbed and retained by the soil colloids. It is subsequently made available to the plants by conversion to nitrate form though some crops take up part of the nitrogen directly in the ammoniacal form.

13.2 So far as the nitrification process is concerned, ammonium chloride is found to be slightly slower in the earlier stages than ammonium sulphate, but in both the cases it reaches the maximum within about a month or so. Both ammonium chloride and ammonium sulphate, on application, combine with the calcium content of the soil and remove it by degrees, thus producing an acidulating effect. Ammonium chloride is thus an acid forming fertilizer and 100 lbs. of the fertilizer is said to produce acid equivalent to 128 lbs. of calcium carbonate. This figure is, however, higher than ammonium sulphate, when considered in terms of N-applied (110 lbs).

13.3 Though from the point of view of the stability of nitrogen content and its availability to crops, ammonium chloride is comparable to a mmonium sulphate, the different nature of acidic radical in the two fertilizers makes for a marked difference in behaviour between the two. The Cl_2 ions in ammonium chloride are more mobile than the SO_4 ions of ammonium sulphate and hence, are more quickly leached out than the latter. A large quantity of chlorine is therefore, believed to be washed out rapidly carrying with it equivalent quantities of Ca.

13.4 However, while for most crops the range of maximum availability of primary (N,P & K) as well as secondary nutrients (S, Ca and Mg) is at a range of 6.5 to 7.5, rice can tolerate a fairly acidic reaction (pH 5.0). It is also observed that in soils with pH higher than 6.5, the Mg in the soil becomes unavailable. Hence in such alkaline soils (e.g. Gangetic Alluvium), ammonium chloride has a higher manurial effect than other nitrogen fertilizers. However, for crops which are susceptible to chlorine toxicity, ammonium chloride could prove harm ful when applied in high does. Chlorine is however one of the elements indispensable for vegetation and ammonium chloride is found to be especially suited for fibrous crops like jute and cotton.

Crop Responses

13.5 The use of ammonium chloride as a fertilizer, though it contains 25.5% nitrogen, is not very widespread because of the two important unfavourable reactions on the soil mentioned above, viz (i) it makes the soil acidic and (ii) increases the chloride ion concentration. However, it has been used extensively in Japan, Thailand, Taiwan and India. For paddy, it is claimed by some to be a better source of nitrogen than ammonium sulphate. In the degraded paddy soils (poor in iron) of Japan, ammonium chloride in preferred to ammonium sulphate. In the recent years the highest yields of paddy are understood to have been obtained by the Japanese farmers who used ammonium chloride rather than ammonium sulphate.

13.6 It is sometimes belived that extensive use of ammonium chloride for crop production may lead to chlorine toxicity.

But experiments and opinions from reputed agronomists (e.g. Yamaguchi Prefectural Agriculture. Experimental station) show that this fear is baseless. Besides, the accumulation of chlorine in the soils of Bangladesh with high annual precipitation is not possible because of its susceptibility to leakage. Ammonium chloride has been used fairly in large quantieies in some countries and encouraging results have been obtained with its application. Rusell[1] reported that ammonium sulphate is superior to ammonium chloride as a source of nitrogen for potatoes but less effective for barley. Skinner and Buie[2] have found both to be equally effective in the production of cotton. Brown et al[3] studied the sources of nitgrogen for potato fertilizers and found that ammonium chloride compared favourably with ammonium sulphate. Gardner[4] has shown that the effect of ammonium chloride on the growth of oat is better than ammonium sulphate or urea. Mikhalovski et al[45] graded the various nitrogenous fertilizers according to their effect on the yield and quality of sugar beets. According to the authors, ammonium sulphate is the most effective, followed by urea, ammonium chloride and Leuna saltpeter. Harada[6] found ammonium sulphate and ammonium chloride to be equally effective, in increasing the yield of paddy. A review of fertilizer industry in Japan (Fertilizer Industry in Japan - 1954), reported that on equal nitrogen basis the average effect of ammonium chloride to paddy is better than ammonium sulphate. Vachani & Rao, as well as Lin (Taiwan) give to ammonium chloride a relative rating next only to ammonium sulphate (See Part IV : Ammonium Sulphate).

13.7 A large number of experiments conducted in India with ammonium chloride under different agroclimatic conditions confirm its suitability. Reviewing the results of several experiments, Desai[7] reported that ammonium chloride is as good as ammonium sulphate on equal nitrogen basis. While working on sugarcane in Bihar, Khanna et al[8] observed better results with ammonium chloride in noncalcarious soils while opposite trend was found in calcarious soils. Jain[9] conducted experiments with wheat in U.P. and found that the comparative efficiency of ammonium chloride varied between 93 to 110 as against 100 for ammonium sulphate.

13.8 In the complex trials carried out under the fertilizer use project during 1953-56, ammonium sulphate, ammonium chloride and ammonium chloride and ammonium sulphate nitrate were compared at three centres. At Aduthurai (Madras State), ammonium chloride was found to be superior to ammonium sulphate at all levels. At Sahaspur, ammonium sulphate, however, proved superior to ammonium chloride. The results were not very conclusive at the third centre.

13.9 In simple trials conducted under the same project on wheat, equal effectivness with regard to yield was obtained in ammonium sulphate and ammonium chloride at 20 and 40 lbs/acre levels. In complex trials on wheat carried out during 1954-55, 1955-56, almost a similar trend was obtained in equal levels of fertilizer application.

13.10 Experiments carried out at the Central Rice Research Institute, Cuttack, have shown that the differences in yield of paddy due to the application of ammonium chloride, ammonium sulphate, ammonium sulphate nitrate, ammonium phosphate and sodium nitrate were not statistically significant (Ghosh et al[10]), Non-significant yield differences were found in paddy, Kharif Jowar, cotton and wheat with ammonium chloride, ammonium sulphate and ammonium sulphate nitrate in the experiments conducted in the former Hyderabad State in 1952-53. Mukherjee and Ghosh[11] carried out pot culture experiments on jute at the Central Jute Research Institute, Barrackpore and found that ammonium chloride is superior to ammonium sulphate.

13.11 Gho sh et al[12] working in alluvial soils of Karnal found ammonium chloride to be comparable to ammonium sulphate with respect to yield of paddy and wheat. The uptake of chloride was increased by using ammonium chloride. Sinha[13] also working in Bihar with maize and Marua found ammonium chloride to be superior to ammonium sulphate in alluvial soils whereas reverse results were met with in laterite soils. Ghosh[14] reported the relative response of ammonium chloride and other nitrogenous fertilizers for different crops under varying agroclimatic oconditions of West Bengal. From the results of these experiments on wheat, Aman and Aus paddy and sugarcane, it was seen that in most cases ammonium chloride was better than the ammonium sulphate or chilean nitrate. When fertilizers like ammonium sulphate or ammonium chloride are added to the soil the ammonium radical is absorbed by the soil complex releasing an equivalent quality of potassium, calcium or hydrogen ions.

13.12 Thus the available information indicates clearly that there is considerable scope for use of ammonium chloride as a fertilizer. On equal nitrogen basis, ammonium chloride is as effective as ammonium sulphate for many crops under different soil and climatic conditions, except for crops which are susceptible to chlorine injury such as potato, tobacco and certain fruits and vegetables*

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* In a communication to the Consultants, Dr. S. Patnaik, Head of the Crops & Soils Division, Central Rice Research Institute, Cuttack, (India) also indicated that "ammonium chloride has been found to be as efficient as ammonium sulphate and has almost similar effect on the soil properties".

13.13 There is no reason to be scared about aggravating the acidity of the soils as a result of the use of ammonium chloride because all N-carriers (except sodium nitrate) leave a residual acidity in soils, though the hypothesis that it affects the crop under flooded conditions is now disputed. In case of lateric soils and those of high rainfall areas, even the application of ammonium sulphate would require a progrmme of liming. Being similar to ammonium sulphate in most of its properties, ammonium chloride is also a fertilizer of all-round utility. Ammonium chloride is equally effective both for basal application as well as for top dressing. As it is more effective under the conditions of abundant water supply, it is especially suitable for wet land crops like paddy, jute and sugarcane.

Ammonium Chloride as Fertilizer

13.14 The use of ammonium chloride as a fertilizer started as early as 1918 in Europe when BASF produced ammonium chloride for the first time. Its use received a boost from 1950 in Japan, with the setting up of Daul Process soda ash plants where ammonium chloride is produced as coproduct. Ammonium chloride also proved more advantageous compared to ammonium sulphate in the cultivation of paddy. There are at present atleast 6 units manufacturing ammonium chloride in Japan, with a total capacity of 670,000 tonnes. China used to be a major importer of ammonium chloride. India has 2 units producing ammonium chloride, with a total capacity of 65,000 tonnes/year. Two more plants with an annual capacity of 86000 tonnes are under implementation. India also used to import ammonium chloride, the peak imports being 51,000 tonnes (1967-68), the imports in 1975-76 were 30,000 te.

Suitability for Bangladesh Conditions

13.15 Soil Characteristics : Bangladesh is mostly a deltaic region of a number of major rivers. About 87% of the area of Bangladesh is alluvial plain. On the basis of geological origin and properties, the soils of Bangladesh have been broadly classified into sevel tracts. The soil analysis of these tracts is shown in Table 13.1. The characteristics of each tract is discussed below :

i) The Red Soil Tract of Madhupur Tract :

Comprises parts of Dacca and Mymensingh districts and extends through isolated tracts in Comilla and Noakhali, towards south in Chittagong. The total area is about 4,000 sq.miles. The soils are very clayey containing numrous ferroginous concretions. They have low base exchange capacity and high phosphate fixing capacity. The pH lies between 5.5 and 6.0.

ii) Barind Tract :

Comprises of parts of Rajshahi, Dinajpur and Bogra districts. This tract covers an area of about 5,000 sq. miles. The soil of this tract belongs to an old alluvial formation which is usually composed of massive argillaceous beds of pale reddish brown, often turns yellow ish on weathering. The pH varies from 5.0 to 6.5.

iii) Gangetic Alluvium :

Comprises of parts of Rajashahi, Pabna, Kushtia, Jessore, Faridpur and Dacca districts . The total area is about 10,600 sq.miles. The texture of the soil varies from clay loam to light sandy loam according to its formation from the silt of the various tributaries of the Ganges. The soil is characterised by high lime content and pH varies from 7.0 to 8.4.

iv) Teesta Silt Tract :

Comprises parts of Dinajpur, Rangpur, Bogra and Pabna districts. The area covered by this soil is about 6,500 sq. miles. The tract represents a sandy loam similar to the ordinary silt soil of Bangladesh. The pH ranges from 6.0 to 6.5.

v) Brahamputra Alluvium :

Comprises of the district of Comilla, Noakhali, parts of Mymensing, Dacca, Chittagong and Sylhet districts. The total area covered by this soil is about 16,000 sq. miles. This soil is sand loam with a pH range of 5.5 to 6.8.

vi) Saline Tract :

The comprises Satkhira and Bagerhat sub-divisions of the Khulna district, Pirojpur, Patuakhali and Bhola sub-divisions of the Barisal district, and the islands and coastal areas of Noakhali and Chittagong districts. The soil is saline and salt efflorescence occurs in many places. The saline tract **covers an** area of roughly 6,000 square miles.

vii) Hill Tracks :

The Chittagong Hill Tract and the Garo Hills in Mymensingh district mainly constitute this tract. It covers an area of about 7,000 sq.miles. The soil consists of hard red clay with a mixture of fine sand of the same colour and nodules containing a large percentage of the sesquioxide.

13.16 No field experiments with ammonium chloride seem to have been conducted in Bangladesh. Pot culture experiments were said to have been conducted once in Dacca University, but the results could not be ascertained. However, discussions with the officials of the Soil Fertility and Soil Testing Institute as well as the concerned experts of the Bangladesh Rice Research Institute indicated that in the well drained alkaline soils of Bangladesh such as Gangetic alluvium or slightly acidic soils of Teesta tract, - covering the districts of Pabna, Faridpur, Rajashahi, Kushtia and Khulna, - with a high lime (CaO) content in soils (Table 13.2), ammonium chloride could be used with advantage. Some experts were of the opinion that in these districts, on equal nitrogen basis, ammonium chloride might yield better results than urea.

Table 13.1

Bangladesh - Average Soil Analysis

		Surface Soil						Sub-soil				
		N2%	P_2O_5%	K_2O%	CaO%	Loss on ign %	pH	N2%	P2O5%	K2O%	CaO%	Loss on ign %
Madhupur	I	0.08	0.08	0.74	0.48	3.77	5.5-6.0	0.06	0.06	0.84	0.44	3.47
Barind	II	0.07	0.07	0.90	0.34	3.33	5.0-6.5	0.06	0.08	1.03	1.28	3.29
Gangetic	III	0.10	0.13	1.18	2.66	4.42	7.0-8.4	0.06	0.13	1.21	3.32	3.68
Teesta	IV	0.10	0.11	0.96	0.25	4.15	6.0-6.5	0.06	0.10	0.97	0.36	3.19
Brahmaputra	V	0.12	0.09	1.05	0.62	4.61	5.5-6.8	0.08	0.08	1.11	0.64	4.10
Coastal	VI	0.11	0.12	1.40	1.00	5.44	Acid Saline to neutral	0.07	0.12	1.59	0.98	4.24
Tentative Average	E.P.	0.10	0.10	1.03	1.16	4.42	-	-	-	-	-	-

Table 13.2

Bangladesh : Soil Analysis of Different Districts

Name of District	N_2%	P_2O5%	K_2O%	CaO%	Loss on ign %	PpH
Dacca	0.09	0.08	0.86	0.51	4.01	5.5-6.9
Mymensingh	1.10	0.10	0.89	0.83	5.39	3.8-7.2
Barisal	0.13	0.15	1.60	1.45	4.54	6.0-7.0
Faridpur	0.12	0.15	1.24	3.71	4.81	6.0-8.5
Chittagong	0,10	0.07	0.93	0.28	4.88	3.1-7.0
Chittagong Hill Tracts	0.11	0.08	0.80	0.17	4.34	4.5-7.0
Noakhali	0.12	0.10	0.93	0.25	4.31	5.0-8.2
Comilla	0.12	0.07	0.84	0.25	4.83	5.0-8.0
Sylhet	0.19	0.09	1.54	0.28	6.98	5.0-8.2
Rajshahi	0.09	0.13	1.17	2.99	4.17	7.0-9.5
Pabna	0.08	0.10	1.31	3.88	5.08	6.0-7.5
Bogra	0.07	0.04	0.79	0.25	3.26	5.4-6.7
Dinajpur	0.10	0.09	0.89	0.26	4.17	4.5-6.5
Rangpur	0.10	0.11	0.95	0.29	3.88	-
Kushtia	0.07	0.12	0.93	1.74	3.17	7.0-9.0
Jessore	0.08	0.10	0.99	0.92	3.76	6.5-7.5
Khulna	0.09	0.12	0.89	1.66	3.59	7.0-7.5
Mean	0.10	0.10	1.03	1.16	4.42	-

Some were of the opinion that ammonium chloride could also be used in the districts of Barisal and Jessore and parts of Dacca, Dinajpur, Rangpur and Bogra districts without harmful side effects. Any increase in acidity in these soils can be checked by the application of triple superphosphate (TSP). The nitrogen consumption of the five districts with alkaline type soils in the recent years is given below (Table 13.3)

Table 13.3

Potential Demand for Ammonium Chloride

(Tonnes)

Districts	Urea		N-Nutrient	
	1976-77	1977-78	1976-77	1977-78
Faridpur	6443	8773	2964	4036
Pabna	13049	21371	6003	9831
Rajshahi	17218	25238	7920	11609
Kushtia	11114	16346	5112	7519
Khulna	6970	8294	3206	3815
Total	54794	80022	25205	36810

Equivalent ammonium chloride (25.5% N) 144353 tonnes in (1977-78).

These five districts alone can thus consume the entire 61,000 tonnes of ammonium chloride likely to be produced in Bangladesh in case the proposal for setting up a Dual Process soda ash plant in the country is implemented.

13.17 To sum up, ammonium chloride can be used in Bangladesh provided its price is comparable to that of urea. However, should any problem arises in marketing it as a straight fertilizer, a NPK granulation unit can be set up. As a component of NPK granulated fertilizer in different formulations, the usefulness of ammonium chloride is beyond any doubt. TVA has stressed the compatibility of ammonium chloride as granulated and bulk blended fertilizer. NPK complex are bound to be increasingly used for basal dressing of most crops in Bangladesh. In Japan also high analysis NPK fertilizers containing ammonium chloride have grown in popularity in recent years.

13.18 The following grades of compound fertilizers containing ammonium chloride can be formulated :

N-P-K	15-15-15
	14-14-14
	12-18-14
	15-15-06
	12-12-12
N - P	18-22-0
	16-20-0
N - K	16-0-18
	17-0-17
	16-0-20

13.19 Industrial Grade Product

The industrial grade ammonium chloride has a wide range of uses. e.g. in dry cells, soldering, galvanising and tinning, and cosmetics. There is no reliable estimate of the total demand for industrial grade ammonium chloride, but with the expansion in indigenous production of dry cells it may grow fast. It is apparent that demand for other uses will also grow with the expanding industrial activity.

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ANNEXURE V-A

TEMPERATURE AT CHITTAGONG

Month	Temperature, °C			
	Extreme maxi	Mean Monthly maxi.	Extreme Mini.	Mean Monthly Mini.
Jan	30.6	25.8	8.9	13.8
Feb.	32.8	27.6	10.6	15.9
Mar.	35.6	30.5	12.2	20.3
April	37.8	32.0	14.4	23.6
May	39.4	32.2	20.0	24.9
June	35.0	31.0	21.0	25.2
July	35.0	30.5	21.7	24.9
Aug.	35.6	30.3	22.2	24.8
Sept.	35.0	31.1	21.1	25.0
Oct.	35.0	30.7	18.3	23.7
Nov.	33.3	29.1	13.3	18.9
Dec.	31.7	26.3	10.6	15.4

Source :

1. Agro-Climatic Survey of Bangladesh (BRRI & IRRI)
2. The Statistical Year-Book of Bangladesh, 1975 (Bangladesh Bureau of Statistics)

ANNEXURE V-B

TEMPERATURE AT DACCA (GHORASAL)

	Temperature, °C			
	Extreme Maxi.	Mean Monthly Maxi.	Extreme Mini.	Mean Monthly Mini.
Jan.	30.6	25.3	5.6	11.9
Feb.	35.0	28.3	7.2	14.1
Mar.	39.4	32.8	12.8	19.3
April	42.2	34.4	15.6	23.3
May	42.2	33.5	18.9	25.1
June	37.2	31.5	21.1	25.8
July	35.0	30.1	22.8	26.1
Aug.	36.1	30.9	23.3	26.2
Sept.	35.0	31.3	21.7	25.8
Oct.	33.9	30.7	17.2	23.6
Nov.	32.2	28.7	11.7	17.7
Dec.	30.6	25.9	6.7	12.8

Sources :

1. Agro-Climatic Survey of Bangladesh
2. The Statistical Year-Book of Bangladesh, 1975.

ANNEXURE V-C

RELATIVE HUMIDITY

(Percent)

Month	Chittagong		Dacca/Ghorasal	
	9 AM	6PM	9AM	6 PM
Jan.	72	65	74	61
Feb.	87	63	65	48
March	70	67	64	44
April	73	73	70	54
May	75	77	78	75
June	82	84	84	81
July	85	86	87	82
Aug.	85	86	86	83
Sept.	83	81	84	83
Oct.	89	81	78	79
Nov.	76	73	73	71
Dec.	77	69	78	70

Source : Agro-Climatic Survey of Bangladesh

ANNEXURE V-D

MEAN MONTHLY & ANNUAL RAINFALL

Month	Rainfall (mm)	
	Chittagong	Dacca/Ghorasal
Jan.	14.3	5.6
Feb.	15.4	5.3
March	41.1	46.5
April	131.3	89.9
May	224.6	247.9
June	569.8	328.6
July	758.6	334.0
Aug.	602.9	339.8
Sept.	270.2	235.1
Oct.	202.7	152.3
Nov.	61.7	108.8
Dec.	21.8	34.4
Annual	2914.4	1928.2

Source : Agro-Climatic Survey of Bangladesh

ANNEXURE V-E

CYCLOGENESIS OVER THE BAY OF BENGAL (1948-1970)

Year	Number				
	Number of Depressions	Moderate Storms	Severe Storms	Total	Crossed near Bangladesh Coast
1948	9	3	None	12	2
1949	4	1	None	5	1
1950	7	2	2	11	2
1951	10	2	None	12	1
1952	6	2	None	8	None
1953	6	1	None	7	None
1954	6	1	None	7	None
1955	12	3	None	15	2
1956	10	2	None	12	None
1957	7	1	None	8	None
1958	9	4	None	13	1
1959	9	1	1	11	2
1960	7	1	2	10	4
1961	7	1	1	9	4
1962	5	5	None	10	1
1963	4	2	1	7	3
1964	7	2	2	11	2
1965	7	1	2	10	4
1966	7	8	1	16	3
1967	7	4	2	13	1
1968	8	3	3	14	3
1969	10	6	None	16	1
1970	2	1	2	5	5
Total :-	166	57	19	242	42

Source : Agro-Climatic Survey of Bangladesh

ANNEXURE V-F

FREQUENCY DISTRIBUTION OF TROPICAL CYCLONES FORMING IN THE BAY OF BENGAL

1948-1970

Cyclonic Intensity	Cyclones (Number)											
	Jan.	Feb.	Mar.	Apr.	May	June	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
Depression	1	1	None	3	8	25	31	32	37	21	6	5
Moderate Storm	2	None	None	None	11	2	1	3	6	15	14	4
Severe Storm	None	None	None	None	6	None	None	None	1	5	3	4
Total	3	1	None	3	25	27	32	35	44	41	23	13

Source : Agro-Climatic Survey of Bangladesh

ANNEXURE V-G

LIST OF PROCESS LICENSORS/CONTRACTORS FOR SODA ASH

A : Process Licensors

(i) Classical Solvay Process

1. Polimex, Poland
2. Tata Chemicals, India
3. Humphreys & Glasglow Consultants, India

(ii) Dual Process

1. Central Glass - T.E.C., Japan
2. Toyo-Soda (TSK), Japan
3. Ashai Glass, Japan
4. Sahu-Jain/Humphreys & Glasglow Consultants, India

B : Engineering Contractors

1. Fertilizer (P&D) India Ltd., India
2. Humphreys & Glasglow Consultants Pvt. Limited, India
3. Polimex, Poland
4. Toyo Engineering Corporation, Japan
5. Hitachi Zosen, Japan

ANNEXURE V-H(i)

LIST OF EQUIPMENT

A : Classical Solvay Process (Polimex)

Sl. No.	Equipment	Number Required	Possible Source of Supply*
(i)	Lime Preparation Section		
1.	Raw Sludge Tank	3	I
2.	Coke Hopper	1	I
3.	Coke Slurry Tub	1	I
4.	Lime Kiln	1	F
5.	Lime Cooler	1	F
6.	Cyclones	2	I
7.	Stack	1	I
8.	Oil Buffer Tank	1	F
9.	Quicklime Bin	1	F
10.	Lime Milk Tank	1	I
11.	Ball Mill (For Wet Coke)	1	F
12.	Coke Slurry Pump	1+1	F

* I = Indigenous; F = Foreign

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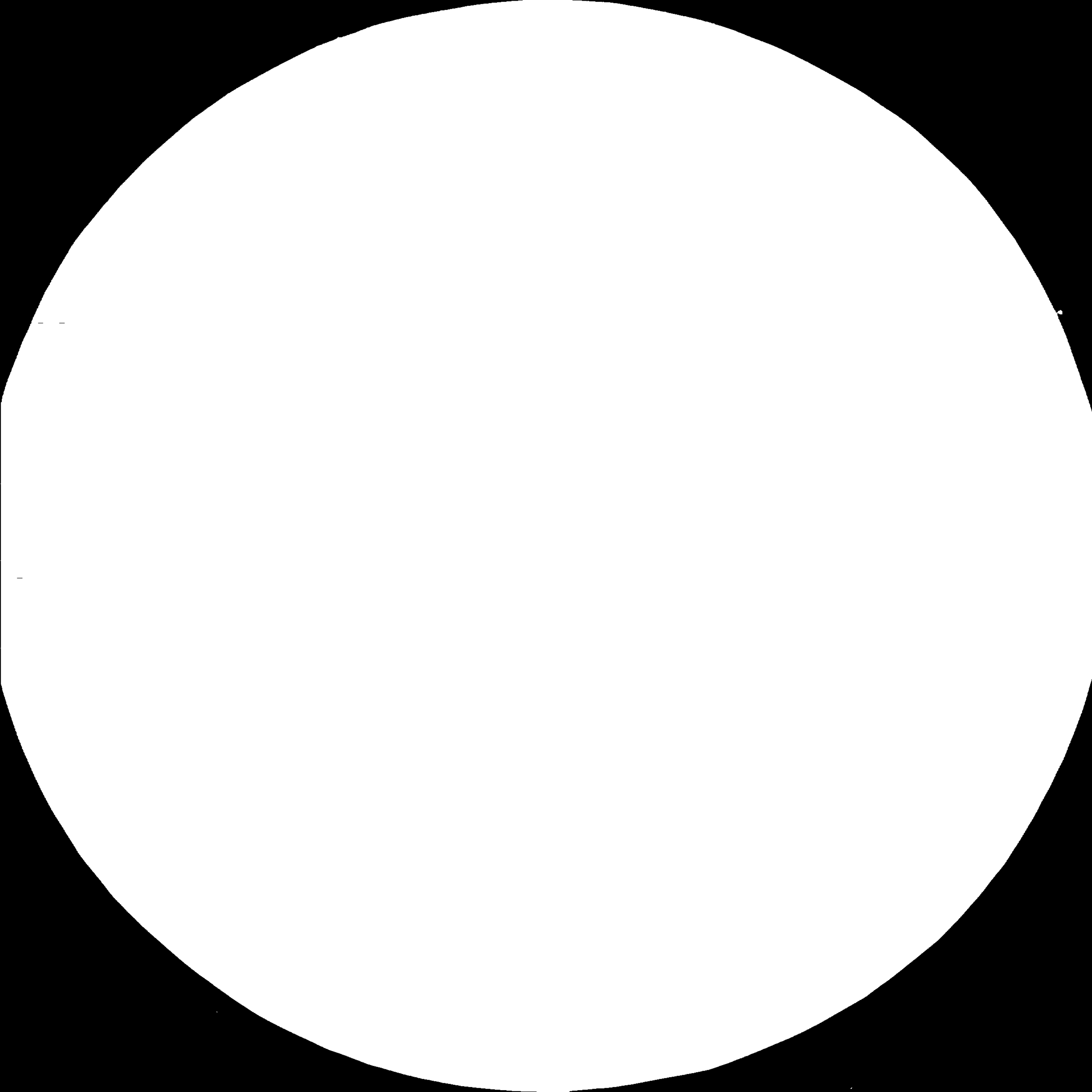
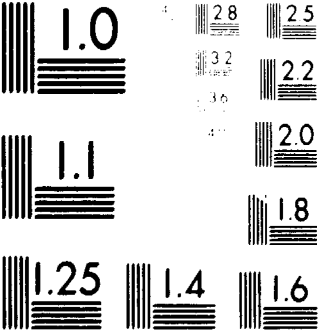




MICROCOPY RESOLUTION TEST CHART

ANNEXURE V-H(ii)

Sl. No.	Equipment	Number Required	Possible Source of Supply
13.	Raw Sludge Feed Pump	1+1	F
14.	Sludge Feeder	1	F
15.	Exhaust Fan	1	F
16.	Air Compressor	1+1	F
17.	Oil Pump	1+1	F
18.	Oil Burner Assembly for Lime Kiln	1+1	F
19.	Skip Elevator (For Quick Lime)	1	F
20.	Exhaust Fan (For Hydrator Mill Waste Gases)	1	F
21.	Lime Milk Pump	1+1	F
22.	Lime Milk Transfer Pump	1+1	F
(ii)	<u>Brine Preparation/Purification Section</u>		
23.	Salt Dissolving Tank	1	I
24.	Weak Brine Tank	1	I

ANNEXURE V-H(iii)

Sl. No.	Equipment	Number Required	Possible Source of Supply
25.	Brine Tank	1	I
26.	Crude Brine Tank	1	F
27.	Soda Solution Feed Tank	1	I
28.	Lime Milk Tank-I	1	I
29.	Lime Milk Tank-II	1	I
30.	Brine Mixer	1	I
31.	Reactor	1	F
32.	Brine Clarifier	1	F
33.	Purified Brine Tank	1	F
34.	Dilution Tank	1	F
35.	Slurry Washer	1	F
36.	Saline Water Tank	1	I
37.	Slurry Tank	1	F
38.	Slurry Dilution Tank	1	F

ANNEXURE V-H(iv)

Sl. No.	Equipment	Number Required	Possible Source of Supply
39.	Flocculent Tank	1	F
40.	Flocculent Storage Tank	1	I
41.	Effluent Tank	1	F
42.	Salt Conveyor	2	F
43.	Brine Circulation Pump	1+1	F
44.	Crude Brine Pump	1+1	F
45.	Crude Brine Pump	1+1	F
46.	Lime Milk Pump	1+1	F
47.	Lime Milk Pump	1+1	F
48.	Purified Brine Pump	1+1	F
49.	Saline Water Pump	1+1	F
50.	Slurry Pump	1+1	F
51.	Diluted Slurry Pump	1+1	F
52.	Effluent Pump	1+1	F
53.	Flocculent Soln. Pump	1	F

ANNEXURE V-H(v)

Sl. No.	Equipment	Number Required	Possible Source of Supply
(iii)	<u>Crude Soda Section</u>		
54.	Tower Gas Washer	1	F
55.	Ammonia Absorber	1	F
56.	Absorber Gas Washer	1	F
57.	Filter Gas Washer	1	F
58.	Absorber Cooler	1	F
59.	Ammoniated Brine Cooler	1	F
60.	Ammoniated Brine Tank	1	F
61.	Carbonating Tower	3	F
62.	Precarbonated Brine Tank	1	F
63.	Tower Magma Tank	1	F
64.	Condensate Tank	1	F
65.	Mother Liquor Tank	1	F
66.	Filter Overflow Tank	1	F
67.	Filter Separator	2	F

ANNEXURE V-H(vi)

Sl. No.	Equipment	Number Required	Possible Source of Supply
68.	Effluent Tank	1	F
69.	Distiller Preheater	1	F
70.	Distiller	1+1	F
71.	Pre-limer	1+1	F
72.	Flash Tank	1+1	I
73.	Lime Milk Tank	1	I
74.	Gas Cooler	1	F
75.	Condensate Distiller	2	F
76.	Condensate Cooler	2	F
77.	Hot Condensate Tank	1	I
78.	Cooled Condensate Tank	1	F
79.	Waste Sludge Tank	1	F
80.	Sodium Sulphide Tank	1	F
81.	Ammonia Brine Pump	1+1	F

ANNEXURE V-H(vii)

Sl No	Equipment	Number Required	Possible Source of Supply
82.	Sodium Sulphide Pump	1+1	F
83.	Ammoniated Brine Pump	1+1	F
84.	Precarbonated Brine Pump	1+1	F
85.	Tower Magma Pump	1+1	F
86.	Filter Overflow Pump	1+1	F
87.	Effluent Pump	1	F
88.	Mother Liquor Pump	1+1	F
89.	Waste Sludge Pump	1+1	F
90.	Condensate Pump	1+1	F
91.	Cold Condensate Pump	1+1	F
92.	Hot Condensate Pump	1	F
93.	Effluent Pump	1	F
94.	Prelimer Liquor Pump	1+1	F
95.	Lift	1	F

ANNEXURE V-H(viii)

Sl No	Equipment	Number Required	Possible Source of Supply
96.	Vacuum Pump	3+1	F
97.	Bicarbonate Fliter	1+1	F
98.	BiCarbonate Conveyor	1	F
99.	BiCarbonate Conveyor	1	F
100.	Cake Blower	1+1	F
101.	Rich CO_2-Gas Compressor	1	F
102.	Gas Cooler	1	F
103.	Lean CO_2-Gas Compressor	1+1	F
104.	Gas Cooler	1+1	F
(iv)	<u>Dense Soda Section</u>		
105.	Calciner Gas Washer	1	F
106.	Ammonia Stripper	1	F
107.	Dust Scrubber	1	F & I

ANNEXURE V-H(ix)

Sl No	Equipment	Number Required	Possible Source of Supply
108.	Monohydrator	1	F
109.	Gas Cooler	1	F
110.	Cooler for Light Soda Ash	1	F
111.	Cooler for Dense Soda Ash	1	F
112.	Soda Solution Tank	1	F
113.	Cut-Off Tank (For Condensate from Calciner)	1	F
114.	Brine Feed Tank	1	F
115.	Brine Tank	1	F
116.	Condensate Feed Tank (For Monohydrator)	1	I
117.	Water Circulation Tank	1	F
118.	Cyclone (For Calciner Gas)	2	I

ANNEXURE V-H(x)

Sl No	Equipment	Number Required	Possible Source of Supply
119.	Vibrating Screen	1	F
120.	Light Soda Ash Bin	1	F
121.	Calciner	1	F
122.	Dense Soda Ash Dryer	1	F
123.	Combustion Chamber	1	F
124.	Cyclone (For Dense Soda Dryer Gas)	1	I
125.	Oversize Soda Crusher	1	F
126.	Combustion Air Fan	1+1	F
127.	Exhaust Fan	1+1	F
128.	Calciner Gas Exhauster	1+1	F
129.	Soda Solution Pump	1+1	F
130.	Brine Pump	1+1	F
131.	Soda Solution Pump	1+1	F

ANNEXURE V-H(xi)

Sl No	Equipment	Number Required	Possible Source of Supply
132.	Scrubber Circulation Pump	1+1	F
133.	Soda Solution Pump	1+1	F
134.	Condensate Pump	1+1	F
135.	Mechanical Shovel for Bicarbonate	1	F
136.	Bicarbonate Weigher	1	F
137.	Soda Ash Conveyor (From Cyclone)	1	F
138.	Soda Ash Feeder (From Calciner)	1+1	F
139.	Soda Ash Conveyor	1+1	F
140.	Return Soda Conveyor	1+1	F
141.	Return Soda Feeder	1+1	F
142.	Soda Conveyor (For Monohydrator)	1+1	F
143.	Start-Up Soda Ash Conveyor	1	F

ANNEXURE V-H(xii)

Sl No	Equipment	Number Required	Possible Source of Supply
144.	Soda Ash Feeder (For Soda Solution Tank)	1	F
145.	Soda Ash Feeder (For Monohydrator)	1	F
146.	Soda Ash Feeder (To Dryer)	1	F
147.	Soda Ash Conveyor (To Dense Soda Cooler)	1	F
148.	Dense Soda Ash Weigher	1	F
149.	Dense Soda Ash Elevator	1	F
150.	Dense Soda Ash Product Conveyor	1	F
151.	Soda Ash Conveyor (From Light Soda Ash Bin)	1	F
152.	Soda Ash Elevator	1	F
153.	Soda Ash Feeder (For Light Soda Ash Cooler)	1	F

ANNEXURE V-H(Xiii)

Sl No	Equipment	Number Required	Possible Source of Supply
154.	Light Soda Ash Weigher	1	F
155.	Light Soda Ash Elevator	1	F
156.	Light Soda Ash Product Conveyor	1	F
157.	Condensate Flash Tank-I	1	F
158.	Condensate Flash Tank-II	1	F
159.	Condensate Flash Tank (For Start-up)	1	F
160.	Steam Desuperheater	1	F
161.	Steam Desuperheater	1	F
162.	Condensate Injection Pump	1+1	F
163.	Condensate Transfer Pump	1+1	F
(v)	<u>Steam Jet Water Refrigeration Section</u>		
164.	Vacuum Evaporator	1	F

ANNEXURE V-H(xiv)

Sl No	Equipment	Number Required	Possible Source of Supply
166.	Main Ejector	6	F
167.	Auxiliary Ejector	1	F
168.	Auxiliary Condenser	1	F
169.	Vacuum Pump	1	F
170.	Cut-Off Tank	1	F
171.	Chilled Water Tank	1	F
172.	Chilled Water Pump	1+1	F
173.	Hot Water Tank	1	I
(vi)	<u>Cooling Tower</u>		
174.	Cooling Tower	1	F
175.	Cold Water Pump	2+1	F
176.	Hot Water Pump	2+1	F
(vii)	Electricals		
(viii)	Instruments		
	B : <u>Dual Process (Central Glass - TEC)</u>		
	(i) Soda Ash		
A.	<u>Tower</u>		
	1. Ammonia Recovery Tower No. 1	1	F

ANNEXURE V-H(xv)

Sl No	Equipment	Number Required	Possible Source of Supply
	2. Ammonia Recovery Tower No.2	1	F
	3. Ammonia Distiller	1 Set	F
	4. Carbonator Scrubber	1	F
	5. Dust Scrubber	1	F&I
	6. Calciner Gas Washer	1	F
	7. Carbonator	4	F
B.	<u>Heat Exchanger</u>		
	8. Condenser	1	F
	9. Calciner Gas Cooler	1	F
	10. Light Soda Ash Cooler	1	F
	11. Dense Soda Ash Cooler	1	F

ANNEXURE V-H(xvi)

Sl No	Equipment	Number Required	Possible Source of Supply
C.	Tank, Separator, Cyclone, Filter, Hopper & Crusher		
12.	Salt Slurry Tank	2	I
13.	Reacting Tank No.1	2	I
14.	Reacting Tank No.2	1	I
15.	Lime Milk Tank	2	I
16.	Reagent Dissolver	1	I
17.	Reagent Tank	1	I
18.	Filtrate Tank	1	F
19.	Precarbonated Brine Tank	1	F
20.	Solid Separator	1	F
21.	Bicarbonate Feed Tank Screen	1	F
22.	Circulating Liquor Tank	1	F
23.	Water Head Tank	1	I
24.	Mother Liquor Head Tank	1	F

ANNEXURE V-H(xvii)

Sl No	Equipment	Number Required	Possible Source of Supply
25.	Mother Liquor Tank	1	F
26.	Recovery Liquor Tank	1	I
27.	Recovery Liquor Head Tank	1	I
28.	Decomposer	1	F
29.	Soda Solution Tank	1	I
30.	Flash Tank	1	I
31.	Washed Salt Storage Bin	1	I
32.	CO_2-Gas Holder	1	F
33.	Calciner Cyclone	1	F
34.	Light Soda Ash Cooler Cyclone	1	I
35.	Dense Soda Ash Cooler Cyclone	1	I
36.	Salt Washer	1	I
37.	Salt Settler	1	F
38.	Salt Screen	1	F

ANNEXURE V-H(xviii)

Sl No	Equipment	Number Required	Possible Source of Supply
39.	Crude Brine Clarifier	1	F
40.	Ammoniated Brine Clarifier	1	F
41.	Mud Filter	1	F
42.	Lime Milk Screen	1	F
43.	Bicarbonate Filter	1	F
44.	Dense Soda Ash 1st Screen	1	F
45.	Dense Soda Ash 2nd Screen	1	F
46.	Dense Soda Ash 3rd Screen	1	F
47.	Lime Hopper	1	I
48.	Bicarbonate Hopper	1	I

ANNEXURE V-H(xix)

Sl No	Equipment	Number Required	Possible Source of Supply
49.	Calciner	1	F
50.	Salt Crusher	1+1	F
51.	Dense Soda Ash 1st Crusher	1+1	F
52.	Dense Soda Ash 2nd Crusher	1	F
D.	<u>Rotating Machine</u>		
53.	Salt Slurry Pump	1+1	F
54.	Crude Brine Pump	1+1	F
55.	Purified Brine Pump	1	F
56.	Recovery Pump	1	F
57.	Salt Settler Pump	1	F
58.	Lime Milk Pump	1+1	F
59.	Mud Filter Feed Pump	1	F
60.	Filtrate Pump	1	F

ANNEXURE V-H(xx)

Sl No	Equipment	Number Required	Possible Source of Supply
61.	Drain Pump	1	F
62.	Ammoniated Brine Transfer Pump	1	F
63.	Precarbonated Brine Pump	1+1	F
64.	Bicarbonate Filtrate Pump	1+1	F
65.	Mother Liquor Pump	1+1	F
66.	Circulating Liquor Pump	1	F
67.	Recovery Liquor Pump	1+1	F
68.	Chilled Water Pump	1+1	F
69.	Gas Cooler Pump	1	F
70.	Soda Solution Pump	1	F
71.	Dust Scrubber Pump	1	F
72.	Gas Washer Pump	1+1	F

ANNEXURE V-H(xxi)

Sl No	Equipment	Number Required	Possible Source of Supply
73.	Air Blower	1	F
74.	Lean CO_2-Gas Compressor	1	F
75.	Rich CO_2-Gas Compressor	1	F
76.	Vacuum Pump	1	F
77.	Cooling Air Fan	1	F
78.	Dust Blower	1	F
79.	Light Soda Ash Cooler Blower	1	F
80.	Chilled Water Apparatus Freon (1st Charge)	1 Set	F

ANNEXURE V-H (xxii)

Sl. No.	Equipment	Number Required	Possible source of Supply
81	Agitator	2	F
82	Agitator No.1	2	F
83.	Agitator No. 2	2	F
84.	Agitator	1	F
85	Agitator	2	F
86	Agitator	1	F
87.	Agitator	1	F
88.	Agitator	1	F
89.	Agitator	1	F
90.	Agitator	1	F
91	Agitator	1	F
92.	Agitator	1	F
93.	Agitator	1	F
94.	Agitator	1	F
95.	Salt Centrifuge	1+1	F

ANNEXURE V-H(xxiii)

Sl. No.	Equipment	Number Required	Possible Source of Supply
E.	<u>Transportation Equipment</u>		
96.	Raw Salt Conveyor	1 Set	F&I
97.	Salt Feeder	1	F
98.	Salt Conveyor	1	F&I
99.	Purified Salt Conveyor	1 Set	F&I
100.	Calciner Discharger	1	F
101	Light Soda Ash Return Conveyor	1 Set	F
102	Light Soda Ash Conveyor	1 Set	F
103	Dense Soda Ash Conveyor No. 1	1	F
104	Dense Soda Ash Conveyor No. 2	1	F
105	Dense Soda Ash Conveyor No. 3	1	F
106	Dense Soda Ash Conveyor No. 4	1	F
107	Dense Soda Ash Cooler Feeder	1	F
108	Crane for CO_2-Gas Compressor Room	1	F
109	Salt Weigher	1	F

ANNEXURE V-H (xxiv)

Sl. No.	Equipment	Number Required	Possible Source of Supply
110	Table Feeder	1	F
111	Light Soda Ash Weigher	1	F
112	Dense Soda Ash Weigher	1	F
	(ii) Ammonium Chloride		
A.	**Furnace**		
113	Furnace with Burner Apparatus	1 set	F
114	Stack	1	I
B.	**Scrubber**		
115	A.C. Dust Scrubber	1 Set	
	- Screen & Spray Nozzle		F
	- Others		I
C.	**Heat Exchanger**		
116	Solution Heat Exchanger	3	F
117	Ammonium Chloride Crystalizer	6	F
118	Ammonium Chloride Cooler	1 Set	F

ANNEXURE V-H (xxiv)

Sl No.	Equipment	Number Required	Possible source of Supply
D.	Tank, Separators, Cyclone, Hopper, Dryer, and Crusher		
119.	Ammoniated Solution Tank	1	I
120	Salt Adding Tank	1	I
121	Centrifuge Feed Tank	1	I
122	Absorber Head Tank	1	I
123	Ammoniated Brine Receiver	1	I
124	A.C. Slurry Tank	1	F
125	Washing Liquor Tank	1	F
126	Acid Tank	1	F
127	Ammonia Temporary Tank	1	I
128	Nitric Acid Tank	1	F
129	Ammonia Storage	1	F
130	Fuel Oil Tank	1	I
131	Ammonia Mist Separator	5	F
132	Dryer Cyclone	1	I
133	Dust Cyclone	1	I

ANNEXURE V-H (xxvi)

Sl.	Equipment	Number Required	Possible Source of Supply
134	Ammonium Chloride Cooler Cyclone	1	I
135	Ammonium Chloride Thickener	1	F
136	Ammonium Chloride Classifying Screen	1	F
137	Purified Salt Hopper	1	I
138	Crude Ammonium Chloride Hopper	1	I
139	Ammonium Chloride Dryer	1	F
140	Ammonium Chloride Crusher	1	F
E.	Rotating Machines		
141	Ammoniated Solution Pump	1	F
142	Ammoniated Brine Pump	1+1	F
143	A.C. Crystallizer Feed Pump	1+1	F
144.	A.C. Thickener Pump	1+1	F
145	Clear Liquor Pump	1+1	F
146	A.C. Slurry Pump	1	F

ANNEXURE V-H (xxvii)

Sl. No.	Equipment	Number Required	Possible Source of Supply
147	Washing Liquor Pump	1	F
148	Cake Washing Pump	1	F
149	Acid Pump	1	F
150	Nitric Acid Pump	1	F
151	Recovery Pump	1	F
152	Centrifuge Feed Pump	1+1	F
153	A.C. Scrubber Pump	1	F
154	Recovery Pump	1	F
155	Air Compressor	1	F
156	Furnace Air Fan	1	F
157	Dryer Induced Fan	1	F
158	Dust Fan	1	F
159	Ventilator	1	F
160	A.C. Cooler Blower	1	F
161	Ammonia Refrigerator	1 Set	F
162	Agitator	2	F
163	Agitator	1	F
164	Agitator	1	F

ANNEXURE V-H (xxviii)

Sl. No.	Equipment	Number Required	Possible Source of Supply
165	A.C. Mixer	1	F
166	Agitator	1	F
167	A.C. Centrifuge	1+1	F
	(iii) Cooling Tower		
168	Cooling Tower	1	F
169	Cold Water Pump	2+1	F
170	Hot Water Pump	2+1	F
	(iv) Electricals		
	(v) Instruments		

ANNEXURE V-J

SPECIAL FEATURES OF DUAL PROCESS

In comparison with the Classical Solvay Process, the Dual Process has in brief the following characteristics and advantages :

a) While in the Classifical ammonia - soda process, only about 70% of common salt is effectively used, in Dual process both Na and Cl are more efficiently fixed as Na_2CO_3 and NH_4Cl except, of course, for a small quantity of loss. As a result, the raw salt requirement per tonne of soda ash is reduced. The salt (100% NaCl) required per tonne of soda ash in the Classical Solvay process is 1.7 to 1.8 te, but in the Dual process it is only about 1.25 to 1.3 te.

b) The Dual process is a total recycle system of process solution. So nothing is lost except product crystals of sodium bicarbonate and ammonium chloride taken out of the system. Hence the use rates of each raw material is comparatively high.

c) Compared to the Classical Solvay process, in Dual process the quantity of process waste liquor is small - thereby minimising the problem of effluent disposal. This is a major advantage, specially for plants situated in an inland location.

d) In the case of Dual process, the consumption of steam for process is comparatively low. This process generally does not needthe process of recovery and recycle of ammonia by heating and distillation of the co-product ammonium chloride solution with milk of lime.

e) No limestone is required for the Dual process. This makes the location of soda ash plant relatively more "foot-loose".

f) Requirements of utilities are significantly lower in the case of the Dual process, compared to the Classical Solvay.

g) The Dual process is claimed to require less capital on overall basis.

ANNEXURE V-K

TECHNICAL COMPARISON OF DUAL PROCESSES

Sl. No.	Description			Central Glass - T.E.C.	Toyo -Soda	Sahu - Jain
1	2			3	4	5
1.	Plant Capacity					
	. Maxi. as Dense Soda ash			200 tpd	200 tpd	200 tpd
	. Ammonium Chloride (Fertilizer grade)			204 tpd	200 tpd	200 tpd
2.	On Stream Days/Year			330	330	330
3.	Product Quality					
	a) Soda Ash					
		i) Light	Na_2CO_3 (dry basis)	99% Min.	99% min.	98.5% min.
			NaCl (dry basis)	0.5% max.	0.5% max.	1.0% max.
			Na_2SO_4	0.08% max.	0.05% max.	0.3% max.
			Iron as Fe_2O_3	0.007% max.	-	0.007% max.
			Water Insolubles	0.15% max.	0.1% max.	0.15% max.
			Bulk Density	465-700 gm/lit.	600 gm/lit.	750 gm//lit.
		ii) Dense		Mechanical densification by compaction.	Chemical densification by steam in monohydrator and subsequent dehydration.	Mechanical densification.

1	2	3	4	5
		Compacted soda ash as inferior in quality to chemical densified soda ash.	Superior in quality to compacted soda ash.	Inferior in quality to chemically densified soda ash.
b) Ammonium Chloride				
	N-content (wet basis)	25.2% min.	95.5% min. NH_4Cl	98% min. NH_4Cl
	H_2O (dry basis)	0.4%	-	-
		Product is in granular form suitable for use as fertilizer	Product is fertilizer grade	Product crystalline in structure (size range of 1-2 mm); suitable as fertilizer.
		Fine crystals can be produced for industrial use.	-	Technical grade product can be also produced.
4. Raw Material Quality i) Raw salt				
	NaCl (dry basis)	95-98%	95-98%	95.05% min.
	$MgCl_2$	0.42% max.	0.4%	1.0% max.
	$MgSO_4$	0.40% max.	0.4%	1.0% max.
	$CaSO_4$	0.58% max.	0.58%	-

1	2	3
	Water Insolube	0.89% max.
	Moisture	10.38%
	Size : 3-6 mm.	99%
5. Requirements of Raw Materials and Utilities		
i)	Sea Salt Kg. (100% NaCl)	1250 per te of light soda ash
ii)	Ammonia Kg. (100% NH_3)	325 per te of NH_4Cl (F)
iii)	Carbon-dioxide Nm^3 (100% CO_2)	285 per te of light soda ash
iv)	Lime Kg.	80 per te of light soda ash
v)	Sodium Sulphide Kg.	3.4 per te of light soda ash
vi)	Natural Gas Nm^3	22.8 per te of NH_4Cl (F)
vii)	Steam (te/dual) Kg.	1630 (Steam at 30 kg/cm^2)
viii)	Process Water m^3 (te/dual)	1.6

ANNEXURE V-K
(p.p. 3)

4	5
0.1%	0.17% max.
10.8%	3.75% max.
	Any size
1300 per te of light soda ash	1300 per te of light soda ash
340 per te of NH_4Cl (F)	335 per te of NH_4Cl (F)
300 per te of light soda ash	310 per te of light soda ash.
150 per te of light soda ash	-
-	2 per te of light soda ash.
15.5 per te of NH_4Cl (F)	8.3 per te of NH_4Cl (F)
2500 (steam at 39 kg/cm^2)	4812 (steam at 28.2 Kg/cm^2)
6	8.5

1	2	3
ix)	Cooling Water m^3 in Circulation (te/dual)	210
x)	Raw Water m^3	-
xi)	Power (te/dual) Kwh	400
	<u>Remarks</u>	
	Salt consumption	Lowest
	Ammonia consumption	Lowest
	CO_2 consumption	Lowest
	Steam consuption	Lowest
	C.W. circulation	Lowest
	Power consumption	Lower
6.	Technical Features	
	a) Salt Dissolving and Purification	A unique salt/brine purification system similar to that of Classical Solvay. Pufified salt after centrifuging is used in amm.chloride unit. The Ca- and Mg-impurities almost completely removed

ANNEXURE V-K
(p.p. 4)

4	5
300	400
-	32 per te of dual
500	250
Lower	Lower
Highest	Lower
Lower	Highest
Lower	Highest
Lower	Highest
Highest	Lowest
Inclined moving screw type two stage salt washers and dissolver provided. Salt crushing, washing and purification sections provided.	Static salt dissolver of patented design incorporated. Impurities from salt separate and disposed off to sludge-sump by slurry pumps. The sludge is pumped by sump pump to filter process. Raw salt of varying grades and size added to salt dissolver where process

1	2	3
b)	Crystallisation of Ammonium Chloride.	Mechanical refrigeration used and vapour ammonia is used as fresh feed. Fine crystals are produced and are granulated for use as fertilizer. Recrystallisation of ammonium chloride could be achieved for production of industrial and technical grade ammonium chloride.
c)	Effect of salt impurities.	Facilities provided for periodic cleaning of cooling surfaces of heat exchangers and crystalliser by acid circulation.

ANNEXURE V-K
(p.p. 5)

4	5
	process liquoris continuously added. The outflow from dissolver is analysed for chloride and entire process control depends. on chloride content.
Vacuum crystallisation with vacuum pump is used. The process of mechanical refrigeration system is in successful operation in the plants supplied by TSK. The vapour ammonia produced is used for feed to absober. The crystals formed are of 1.2 mm size and of proper hardness suitable for direct use as fertilizer.	Evaporative cooling by steam-jet refrigeration is used in evaporator and crystallizer under vacuum for crystallizing ammonium chloride to ensure optimum liquor concentration with simultaneous desired degree of cooling to produce bigger crystals. Crystals of 1-2 mm size produced-suitable for direct application as fertilizer.
Not known.	Not clear.

ANNEXURE V-K
(p.p. 6)

1	2	3	4	5
d)	Carbonation	Carbonators and the process adopted in the TEC process are suitable to Toyo-Soda process. Only the towers are provided with several trays and bubble caps. L.p. steam is fed to distiller for recovery of NH_3 & CO_2 which are recycled back to the system.	In the TSK process, carbonating towers are of conventional Solvay towers (Passette Towers) with cooling base of special C.I. construction.	Carbonating towers are simple in construction and easy to clean, CO_2 of 95% purity and higher concentration can be directly used in this process with a single CO_2 compressor. The vessels are of mild steel lined with bricks and are arranged one on top of other for gravity flow of liquor. Carbonation towers are stopped for periodic cleaning.
e)	Ammoniation	Liq. ammonia utilised for refrigeration in crystallizer and used for ammoniaation as vapour.	The system same as in Central Glass - TEC process.	Liq. ammonia used for water chilling and vapours obtained is used. Ammonia vaporiser is provided to vaporise additional amount of ammonia required.

1	2	3	4	5
7.	Instrumentation	Adequate indicating, measuring and controlling instruments for generally automatic operation.	N.A.	Less sophistication in instruments.
8.	Mechanical Maintenance & Operational.	The process sequence involves quite large number of moving mechinery like compressors, pumps and agitators. All have their own inherent maintenance problems resulting in downtime in operation with consequential cost implication.	Same as Central Glass - TEC.	In this respect,this process enjoys distinct advantage. The construction of equipment in salt dissolution section, Carbonating towers, and crystallisation units are simple in construction & operation. owing to comparatively less number of equipment-particularly the moving ones, maintenance problem is less, resulting in downtime.
9.	Air Pollution Control	Measures for air pollution control are adequately considered. Recovery units, cyclones, dust scrubbers and exhausters provided.	Appears to lack in adequate provision.	Appears to lack in adequate provision

1	2	3
10.	Experience	Central glass have own plant in operation at Ube, (capacity 180,000 tpy). A number of plants with this process under negotiation. Wide experience in processing salts of ranging composition and from different sources.
11.	N-P-K Complex Fertilizer using NH_4Cl as Nitrogen Source.	Process provides a granulator for granulating product ammonium chloride, Dedusting equipment are also provided in the system. With marginal modification in the existing equipment, and NPK complex fertilisers in various grades may be made in the same granulator. With ammonium chloride as nitrogen source, possible to make a range of N-P & N-P-K grade fertilizers.

ANNEXURE V-K
(p.p. 8)

4	5
Toyo-Soda have their own plant in operation at Tonda (capacity 180,000 tpy).	Sahu-Jain have own plant in operation at Varanasi, India (capacity 40,000 tpy). Expansion scheme to secure additional capacity of 109,360 tpy under implementation.
Experience in processing salts of wide range in composition and from different sources similar to those of Central Glass - TEC.	
No provision in the main process as such, but can be provided at additional cost to manufacture any one of the several grades.	No provision in the main process as such, but can be provided at additional cost to manufacture any one of the several grades.

ANNEXURE V-K
(p.p.9)

1	2	3		4		5	
12.	Economic Analysis (based on unit cost at Chittagong)	Specific consumption	Cost/te prod. (TK)	Specific consumption	Cost/te Prod. (TK)	Specific consumption	Cost/te Prod. (TK)
	a) Raw Materials						
	i) Salt (te)	1.25	308.75	1.30	321.1	1.30	321.1
	ii) Liq.Ammonia (te)	0.325	892.13	0.34	933.3	0.335	919.58
	iii) CO_2 Gas (Nm^3)	285		300		310	
	iv) Lime (te)	0.08	72	0.15	135	-	0
	b) Utilities						
	i) Natural Gas (Nm^3)	22.8	7.64	15.5	5.2	8.3	2.78
	ii) Steam (te*)	1.63	154.85	2.5	237.5	4.812	457.14
	iii) Process Water (m^3)	1.6	3.33	6	12.48	8.5	17.68
	iv) Power (Mwh)	0.4	194	0.5	242.5	0.25	121.25
	c) Chemicals						
	i) Sodium Sulphide Kg.	3.4	25.74	Not known	-	2	15.14
	ii) Flocculent, Kg.	0.9	6.75	Not known	-	Not known	-

* excl. enthalpy adjustment

ANNEXURE V-L

CAPITAL OUTLAY

(Alternative-I)

Classical Solvay Process: Byproduct Chalk Route
CHITTAGONG LOCATION

Capital Outlay - Allocated for Soda Ash

($ '000)

S.No.	Item	FC	LC	Total
1.	Land & Land Development	60	150	210
2.	Soda Ash Plant	11100	5600	16700
3.	Off-site facilities			
i.	Yard piping	30	20	50
ii.	Water Supply, Storage and Distribution	350	180	530
iii.	Power Supply & Distribution	450	90	540
iv.	Cooling Tower	580	120	700
v.	Raw material Handling and Storage	1300	350	1650
vi.	Products handling, Bagging and Storage	670	280	950
vii.	Auxiliary services	600	230	830
viii.	Non Plant Building & Jetty	190	90	280
ix.	Transport Facilities	100	30	130
x.	Temp. Construction Facilities	70	50	120
	Sub Total (3)	4340	1440	5780
4.	Project Management Charges	1000	2580	3580
5.	Spares	1730	130	1860
6.	Construction Equipment	600	40	640
7.	Township & Public Buildings	1900	1500	3400
8.	Working Capital	-	3200	3200
9.	Contingency	1050	800	1850
10.	Expenses during Commissioning and Trial run	-	(300)	(300)
11.	Escalation	5640	6080	11720
12.	Financing charges	-	3850	3850
	Total Capital :	27420	25070	52490

(Bracket indicates negative figures)

ANNEXURE V M

CAPITAL OUTLAY

(Alternative-II)

Classical Solvay Process -Limestone Route

CHITTAGONG LOCATION

(Cost in $ '000)

S.No.	Item	FC	LC	Total
1.	Land & land development	130	350	480
2.	Soda ash plant :equipment and material	7,300	2,400	9,700
3.	Off Sites : Equipment and Material			
i.	Yard piping	60	-	60
ii.	Water supply storage and distribution	30	20	50
iii.	Power supply and distribution	550	-	550
iv.	Cooling tower	310	-	310
v.	Raw material handling and storage	1,130	-	1,130
vi.	Product handling, bagging & storage	400	40	440
vii.	Ammonia storage & handling	60	-	60
viii.	Effluent treatment plant	40	20	60
ix.	Auxiliary services	750	100	850
x.	Transport facilities	140	20	160
xi.	Temporary construction facilities	100	50	150
	Sub-total (3)	3,570	250	3,820
4.	Spares	2,600	200	2,800
5.	Jetty, non plant building and plant civil works	3,180	2,160	5,340
6.	Construction equipment (hiring)	-	200	200
7.	Township & Pub. buildings	2,800	2,200	5,000
8.	Freight, insruance, handling, duties & taxes	1,150	1,530	2,680
9.	License, knowhow, design engineering & procurement charges	1,940	-	1,940
10.	Erection & erection supervn.	1,320	1,970	3,290
11.	Project management charges	1,310	4,340	5,650
12.	Working capital	-	3,350	3,350
13.	Contingency	1,300	950	2,250
14.	Expenses during commissioning & trial run	-	100	100
15.	Escalation	6,900	8,100	15,000
16.	Financing charges	-	4,700	4,700
	TOTAL CAPITAL	33,500	32,800	66,300

ANNEXURE V-N

CAPITAL OUTLAY

(Alternative-III)
Dual Process

CHITTAGONG LOCATION

(Cost in $ '000)

S.No.	Item	FC	LC	Total
1.	Land & Land Development	130	350	480
2.	Soda ash plant : equipment & material	7,600	2,500	10,100
3.	Off-Sites : Equipment & Material			
i.	Yard piping	220	130	350
ii.	Water supply & storage	30	20	50
iii.	Power supply & distribution	720	-	720
iv.	Cooling tower	380	-	380
v.	Raw material handling & storage	700	-	700
vi.	Product handling, bagging & storage	800	100	900
vii.	Ammonia handling & storage	60	-	60
viii.	CO_2 recovery plant	1,100	130	1,230
ix.	Effluent treatment plant	40	20	60
x.	Auxiliary services	750	100	850
xi.	Transport facilities	180	20	200
xii.	Temporary construction facilities	100	50	150
	Sub-total (3)	5,080	570	5,650
4.	Spares	2,600	200	2,800
5.	Jetty, non-plant building & Plant civil works	2,880	1,800	4,680
6.	Construction equipment (hiring)	-	200	200
7.	Township & public buildings	2,800	2,200	5,000
8.	Freight, insurance, handling, taxes & duties	1,350	1,710	3,060
9.	Licence, know-how, design, engineering & procurement	3,050	-	3,050
10.	Erection & erection supervision	1,490	2,360	3,850
11.	Project management charges	1,420	4,310	5,730
12.	Working capital	-	3,870	3,870
13.	Contingency	1,400	1,020	2,420
14.	Expenses during commissioning & trial runs	-	(1,100)	(1,100)
15.	Escalation	7,700	8,110	15,810
16.	Financing charges	-	5,200	5,200
	Total Capital	37,500	33,300	70,800

(Brackets indicate negative figures)

ANNEXURE V 0

CAPITAL OUTLAY

Dual Process
GHORASAL LOCATION
(Alternative IV :with Captive Ammonia)

Capital Outlay-Allocated for Soda Ash

(Cost in $ '000)

S.No.	Item	FC	LC	Total
1.	Land & Land Development	-	50	50
2.	Soda Ash Plant	12,600	7,400	20,000
3.	Off-Site Facilities			
	i. Yard Piping	110	130	240
	ii. Water Supply, Treatment Storage & Dist.	1,300	500	1,800
	iii. Power Supply & Distribution	850	250	1,100
	iv. Steam Generation	1,750	550	2,300
	v. Cooling Tower	550	200	750
	vi. Raw Material Handling & Storage	4,050	1,400	5,450
	vii. Product Handing & Storage	1,150	500	1,650
	viii. Auxiliary Services	820	420	1,240
	ix. Non-plant Building & Jetty	350	250	600
	x. Transport Facilities	140	40	180
	xi. Temporary Construction Facilities	120	80	200
	Sub-total (3)	11,190	4,320	15,510
4.	Project Management Charges	1,210	3,630	4,840
5.	Spares	2,300	700	3,000
6.	Township & Public Buildings	2,900	2,200	5,100
7.	Construction Equipment	800	200	1,000
8.	Working Capital	-	5,300	5,300
9.	Contingency	1,500	1,200	2,700
10.	Expenses During Commissioning & Trial-run	-	(600)	(600)
11.	Escalation	8,500	9,800	18,300
12.	Financing Charges	-	5,800	5,800
	TOTAL CAPITAL	41,000	40,000	81,000

(Brackets indicate negative figures)

ANNEXURE V-P

CAPITAL OUTLAY

(Alternative - V)
Dual Process

GHORASAL LOCATION

(Cost in $ '000)

S.No.	Item	FC	LC	Total
1.	Land & land development	-	90	90
2.	Soda ash plant:equipment & material	7,600	2,500	10,100
3.	Off-Sites:Equipment & Material			
i.	Yard piping	60	40	100
ii.	Steam generation plant	1,230	-	1,230
iii.	Water supply, treatment & distribution	1,010	-	1,010
iv.	Power supply & distribution	720	-	720
v.	Cooling tower	380	-	380
vi.	Raw material handling & storage	2,700	-	2,700
vii.	Product handling, bagging & storage	800	100	900
viii.	Ammonia handling & storage	1,200	-	1,200
ix.	CO_2 recovery plant	1,100	130	1,230
x.	Auxiliary services	750	100	850
xi.	Effluent treatment plant	40	20	60
xii.	Transport facilities	180	20	200
xiii.	Temporary construction facilities	100	50	150
	Sub-Total (3)	10,270	460	10,730
4.	Spares	2,600	700	3,300
5.	Jetty, non-plant building & plant civil works	2,580	1,670	4,250
6.	Construction equipment (hiring)	-	200	200
7.	Township & public buildings	2,800	2,200	5,000
8.	Freight, insurance, handling, duties & taxes	1,910	5,960	7,870
9.	Licence, know-how, design engineering & procurement	3,860	-	3,860
10.	Erection & erection supervision	1,980	3,270	5,250
11.	Project management charges	1,420	4,310	5,730
12.	Working capital	-	4,560	4,560
13.	Contingency	1,780	1,280	3,060
14.	Expenses during commissioning	-	(700)	(700)
15.	Escalation	9,500	10,700	20,200
16.	Financing charges	-	6,500	6,500
	Total Capital	46,300	43,700	90,000

(Brackets indicate negative figures)

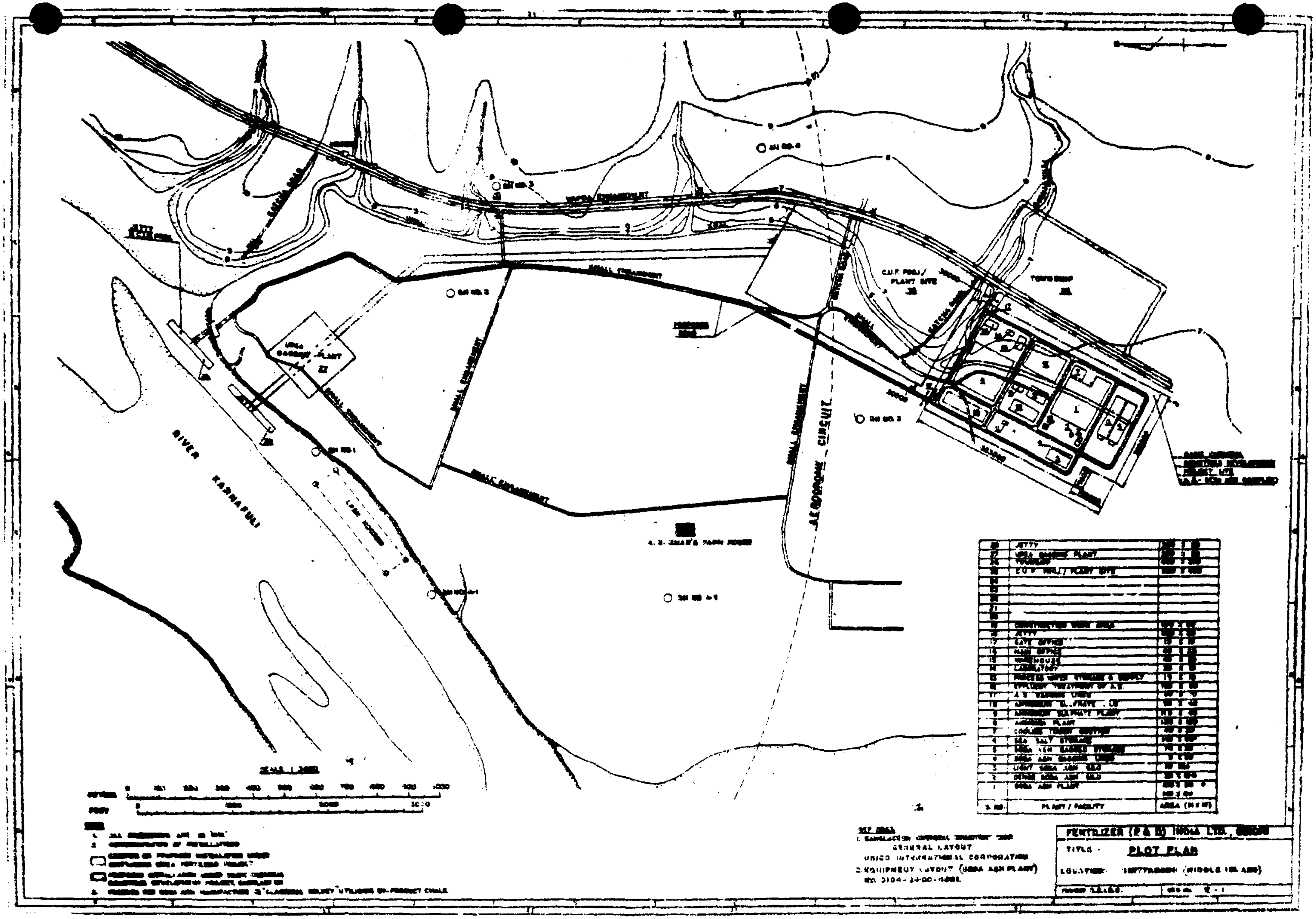
ANNEXURE V Q

WORKING CAPITAL

(Cost in $ '000)

	Particulars	Alt.I	Alt.II	Alt.III	Alt.IV	Alt.V
1.	**Accounts Receivables** One month's sales @ TK 5000/te for soda ash @ TK 1600/te for ammonium sulphate @ TK 2000/te for ammonium chloride	2000	2000	2820	2820	2820
2.	**Operating Supplies** (a) Bags (one month's requirements) Soda ash:Tk 7/piece Amm.sul.:Tk 12 " Amm.Chl.:Tk 12 " (b) Chemicals & consumables (one month)	100	60	167	246	246
3.	**Raw Material Inventories** i) Salt (one month) ii) Coke (one month) iii) Sodium sulphide (one month) iv) Lime (one month) v) Ammonia (for V only 750 te)	590	820	450	640	640
4.	**Product Inventories** 23 day's bulk storage 7 day's bagged storage	1240	1650	1866	2400	2030
5.	**Goods in Process**	30	33	47	50	42
6.	**Accounts Payable** (one month)	(600)	(1080)	(1267)	(643)	(1005)
7.	**Deposits & Advances**	(200)	(200)	(280)	(280)	(280)
8.	**Cash in Hand**	40	67	67	67	67
	Total Requirement	3200	3350	3870	5300	4560

For explanation of alternatives, see Table 9.2



28	JETTY	[illegible]
27	UREA BAGGING PLANT	[illegible]
26	TOWNSHIP	[illegible]
25	C.U.F. PROJ./ PLANT SITE	[illegible]
24		
23		
22		
21		
20		
19	CONSTRUCTION WORK AREA	[illegible]
18	JETTY	[illegible]
17	GATE OFFICE	[illegible]
16	MAIN OFFICE	[illegible]
15	WAREHOUSE	[illegible]
14	LABORATORY	[illegible]
13	PROCESS WATER STORAGE & SUPPLY	[illegible]
12	EFFLUENT TREATMENT OF A.S.	[illegible]
11	A.S. BAGGING UNITS	[illegible]
10	[illegible]	[illegible]
9	AMMONIUM SULPHATE PLANT	[illegible]
8	AMMONIA PLANT	[illegible]
7	COOLING TOWER [illegible]	[illegible]
6	SEA SALT STORAGE	[illegible]
5	SODA ASH BAGGED STORAGE	[illegible]
4	SODA ASH BAGGING UNITS	[illegible]
3	LIGHT SODA ASH SILO	[illegible]
2	DENSE SODA ASH SILO	[illegible]
1	SODA ASH PLANT	[illegible]
S. NO.	PLANT / FACILITY	AREA (M X M)

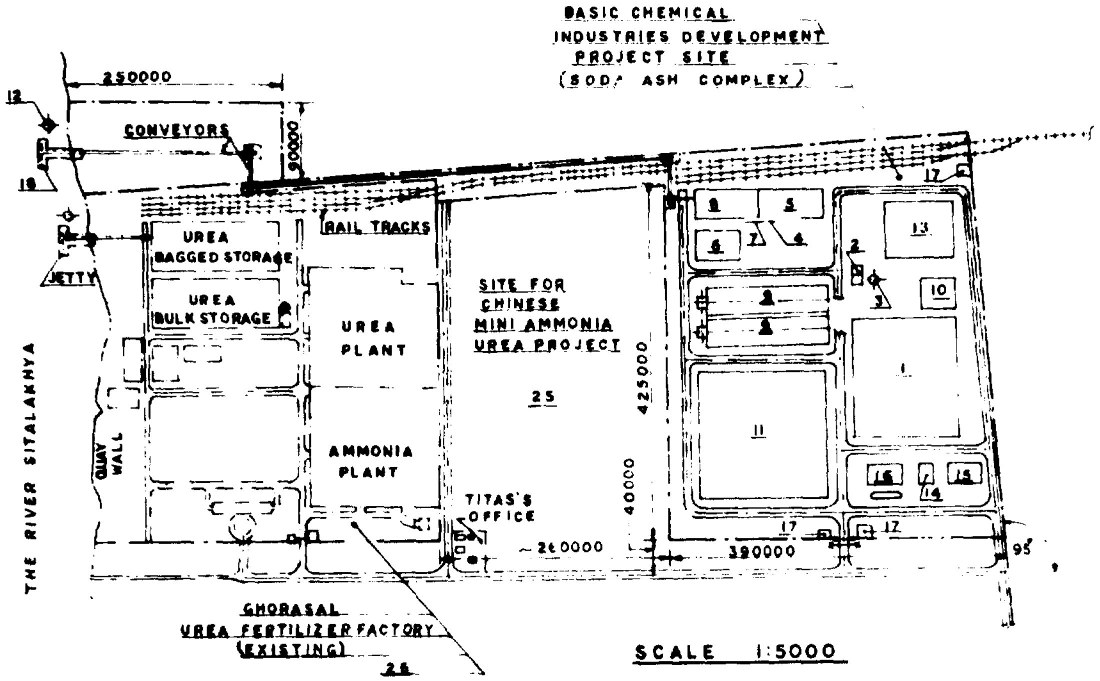
REF. DWG.
1. BANGLADESH CHEMICAL INDUSTRY CORP. GENERAL LAYOUT
UNICO INTERNATIONAL CORPORATION.
2. EQUIPMENT LAYOUT (SODA ASH PLANT) NO. 3104-34-00-1001.

FERTILIZER (P & D) INDIA LTD., [illegible]

TITLE: **PLOT PLAN**

LOCATION: [illegible] (MIDDLE ISLAND)

[illegible] S.S.A.B.C. | DWG. NO. E-1



SCALE 1:5000

26	GHORASAL U F FACTORY	EXISTING
25	CHINESE MINI AU PROJECT	425 X 260
24		
23		
22		
21		
20		
19		
18	JETTY	40X 10
17	GATE OFFICE	15X 15
16	MAIN OFFICE	40X 25
15	WAREHOUSE	40X 25
14	LABORATORY	25 X 15
13	WATER TREATMENT AND D M WATER PLANT	80X65
12	RAW WATER INTAKE TOWER	9 DIA
11	AMMONIA PLANT	150X 150
10	COOLING WATER SECTION	40X 35
9	SEA SALT STORAGE	145 X 68
8	A.C. BAGGED STORAGE	75 X 32
7	A.C. BAGGING LINES	5 X 20
6	AMMONIUM CHLORIDE STORAGE	49 X 35
5	SODA ASH BAGGED STORAGE	75 X 32
4	SODA ASH BAGGING LINES	5 X 20
3	LIGHT SODA ASH SILO	10 DIA
2	DENSE SODA ASH SILO	25X 12.5
1	SODA ASH PLANT	140 X 122.5
S NO	PLANT / FACILITY	AREA(M X M)

NOTE

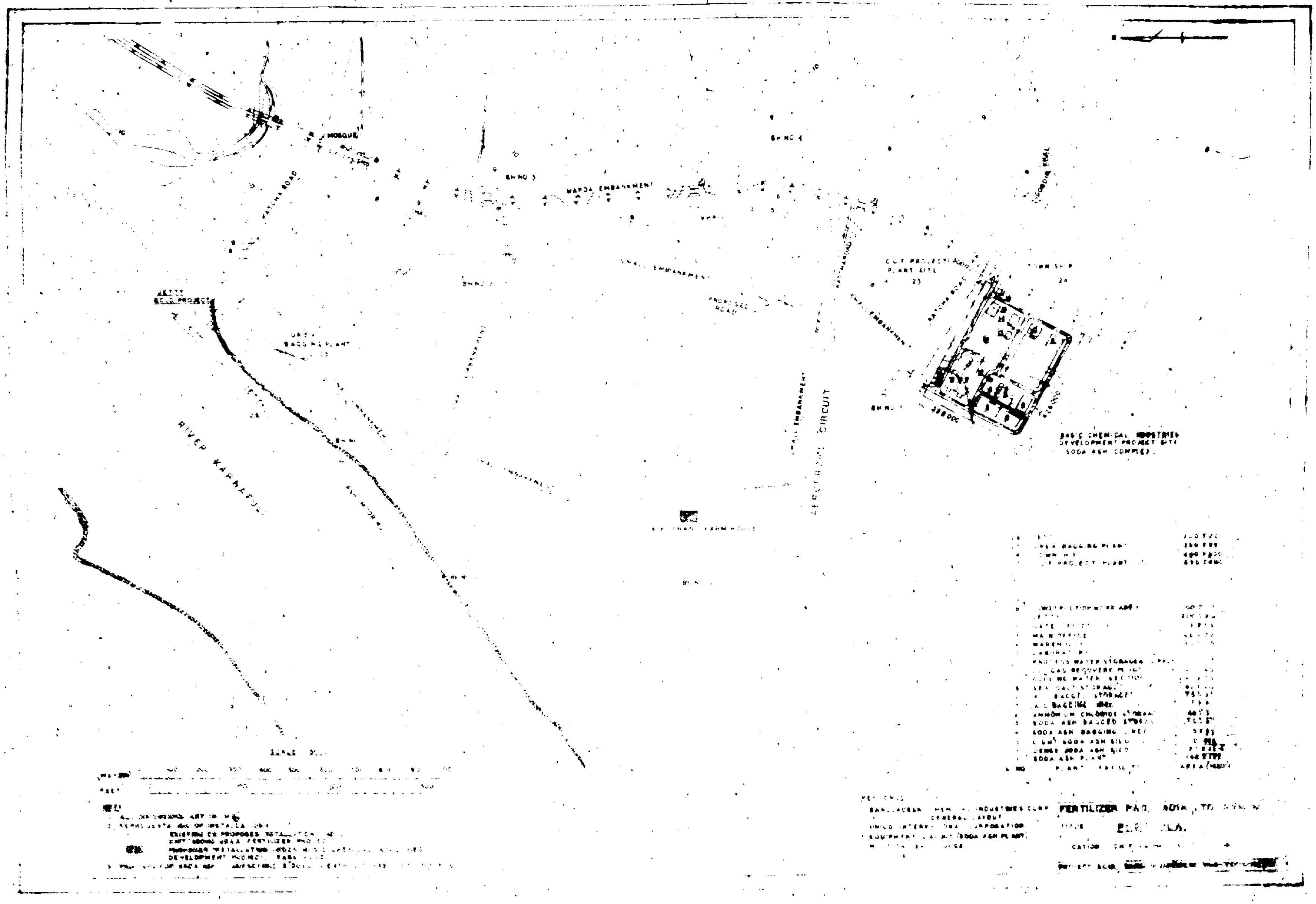
1. ALL DIMENSIONS ARE IN 'MM' UNLESS OTHERWISE INDICATED
2. REPRESENTATION OF INSTALLATIONS -
   - ⬚ EXISTING INSTALLATIONS UNDER GHORASAL UREA FERTILIZER FACTORY
   - ▭ PROPOSED INSTALLATIONS UNDER BASIC CHEMICAL INDUSTRIES DEVELOPMENT PROJECT, BANGLADESH
3. PROCESS FOR SODA ASH MANUFACTURE IS DUAL (CENTRAL GLASS-TEC PROCESS).
4. REF DRGS -
   (i) BFCPC UREA FERTILIZER FACTORY, GHORASAL
   DRG NO UFF/35 B, DATED 8.5.69.
5. EQUIPMENT LAYOUT (SODA ASH PLANT)
   DRG NO: 3104 - 2400 - 0002.

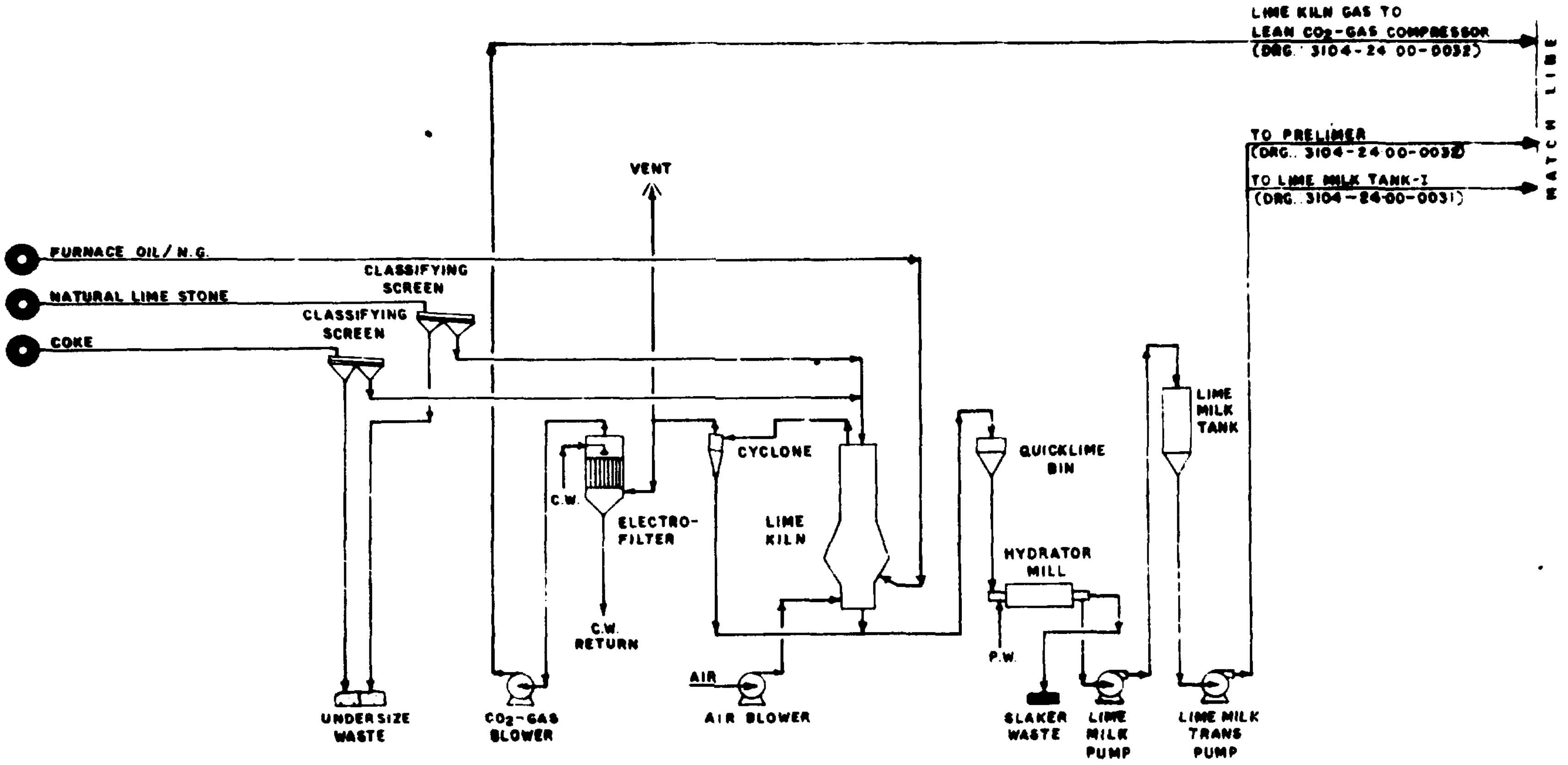
FERTILIZER (P&D) INDIA LTD., SINDRI.

TITLE **PLOT PLAN**

LOCATION GHORASAL

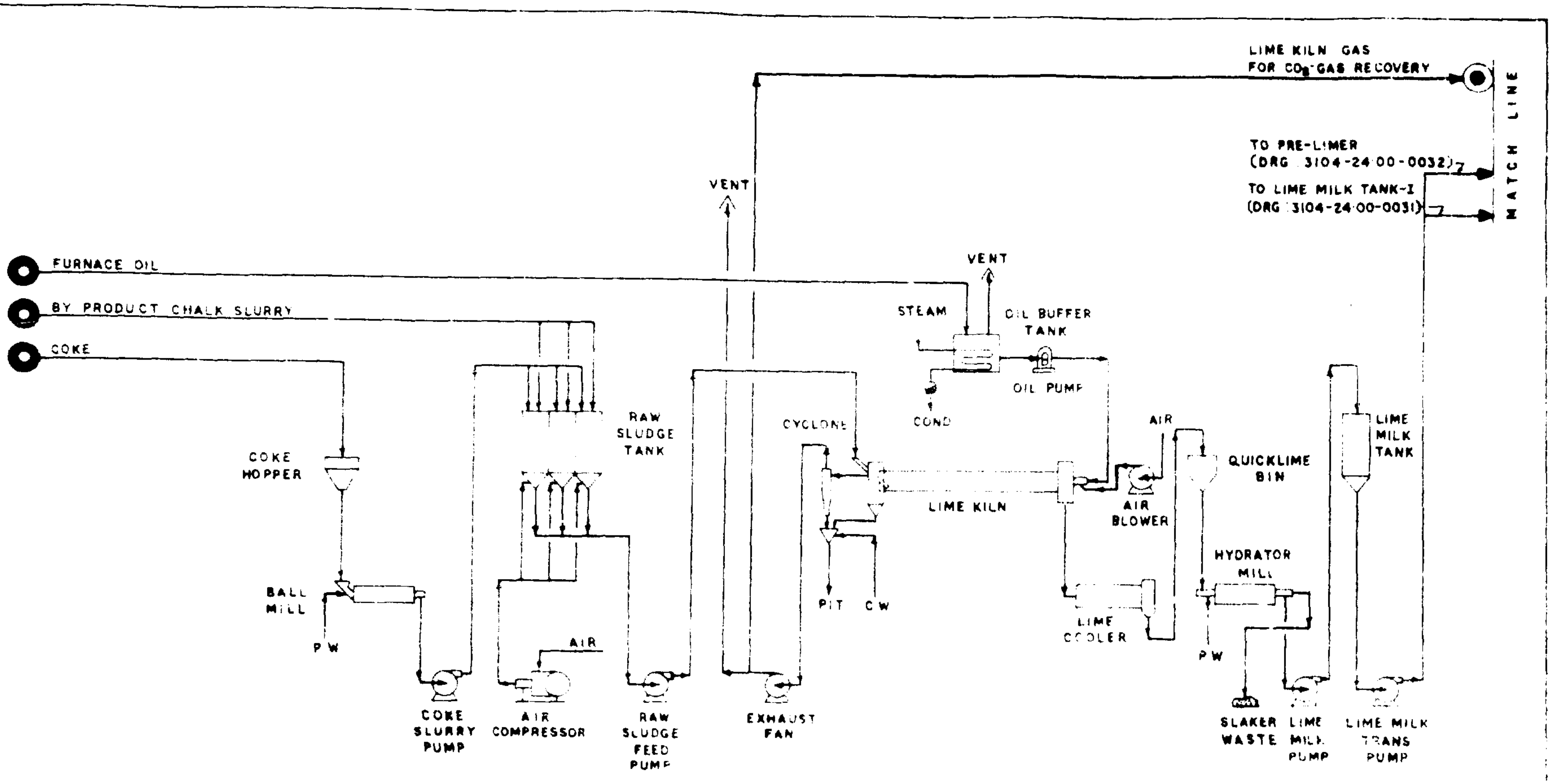
PROJECT BCIDB | DRG NO 3104 0000-0003


MOSQUE
BH NO 3
BH NO 4
MARDA EMBANKMENT
JETTY
B.C.I.D. PROJECT
UREA BAGGING PLANT
RIVER KARNAFULI
PROPOSED ROAD
CIRCUIT
EMBANKMENT
C.U.F. PROJECT PLANT SITE
TOWN SHIP
BASIC CHEMICAL INDUSTRIES DEVELOPMENT PROJECT SITE SODA AX COMPLEX
UREA BAGGING PLANT
CONSTRUCTION WORK AREA
MAIN OFFICE
GAS RECOVERY PLANT
COOLING WATER SECTION
SEA SALT STORAGE
AMMONIUM CHLORIDE STORAGE
SODA ASH BAGGED STORAGE
SODA ASH BAGGING LINE
LIGHT SODA ASH SILO
DENSE SODA ASH SILO
SODA ASH PLANT
PLANT FACILITY
AREA
SCALE
FEET
GENERAL LAYOUT
CORPORATION
FERTILIZER



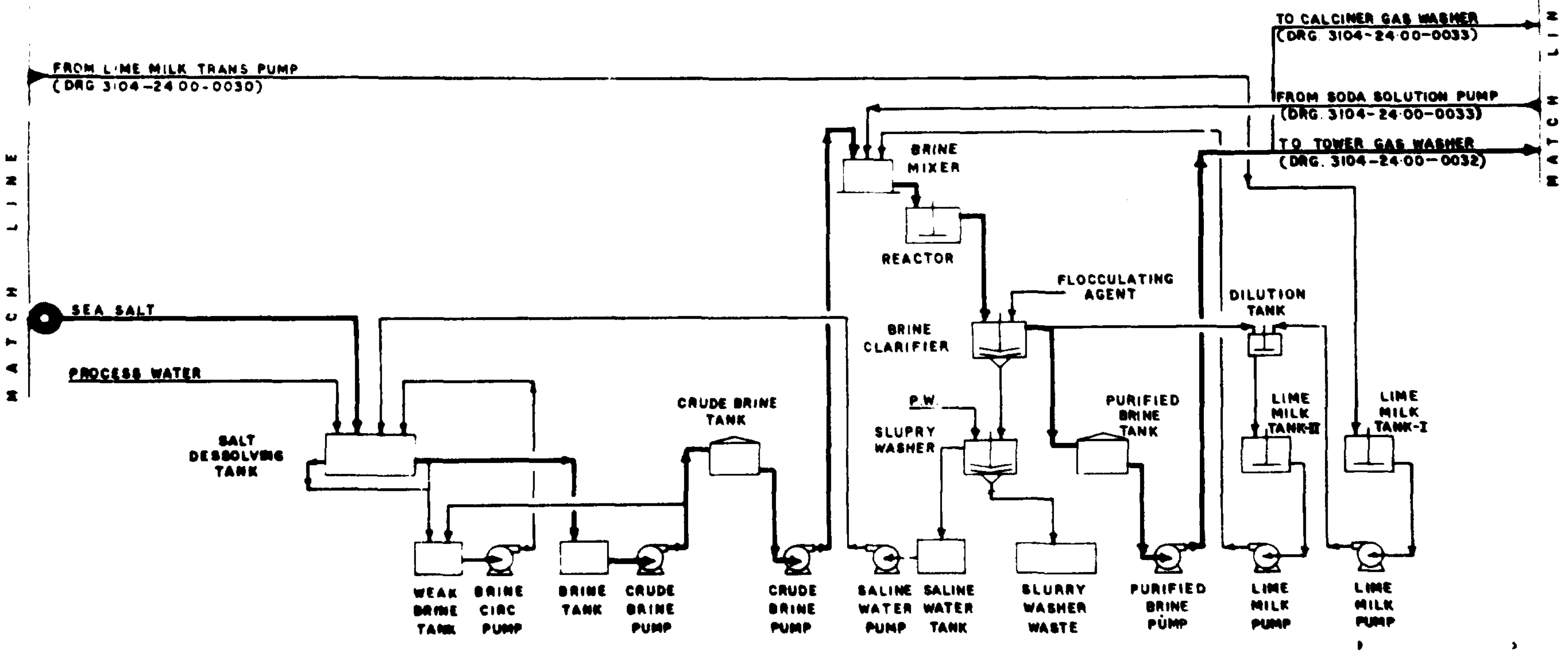
FERTILIZER (P&D) INDIA LTD., SINDRI

TITLE: **PROCESS FLOW DIAGRAM**
SECTION: LIME PREPARATION
PLANT: SODA ASH
PROCESS: CLASSICAL SOLVEY (POLIMEX)
PROJ: B.C.I.D.B. | DRG. NO. 3104-24-00-0030 | REV



FERTILIZER (P&D) INDIA LTD., SINDRI

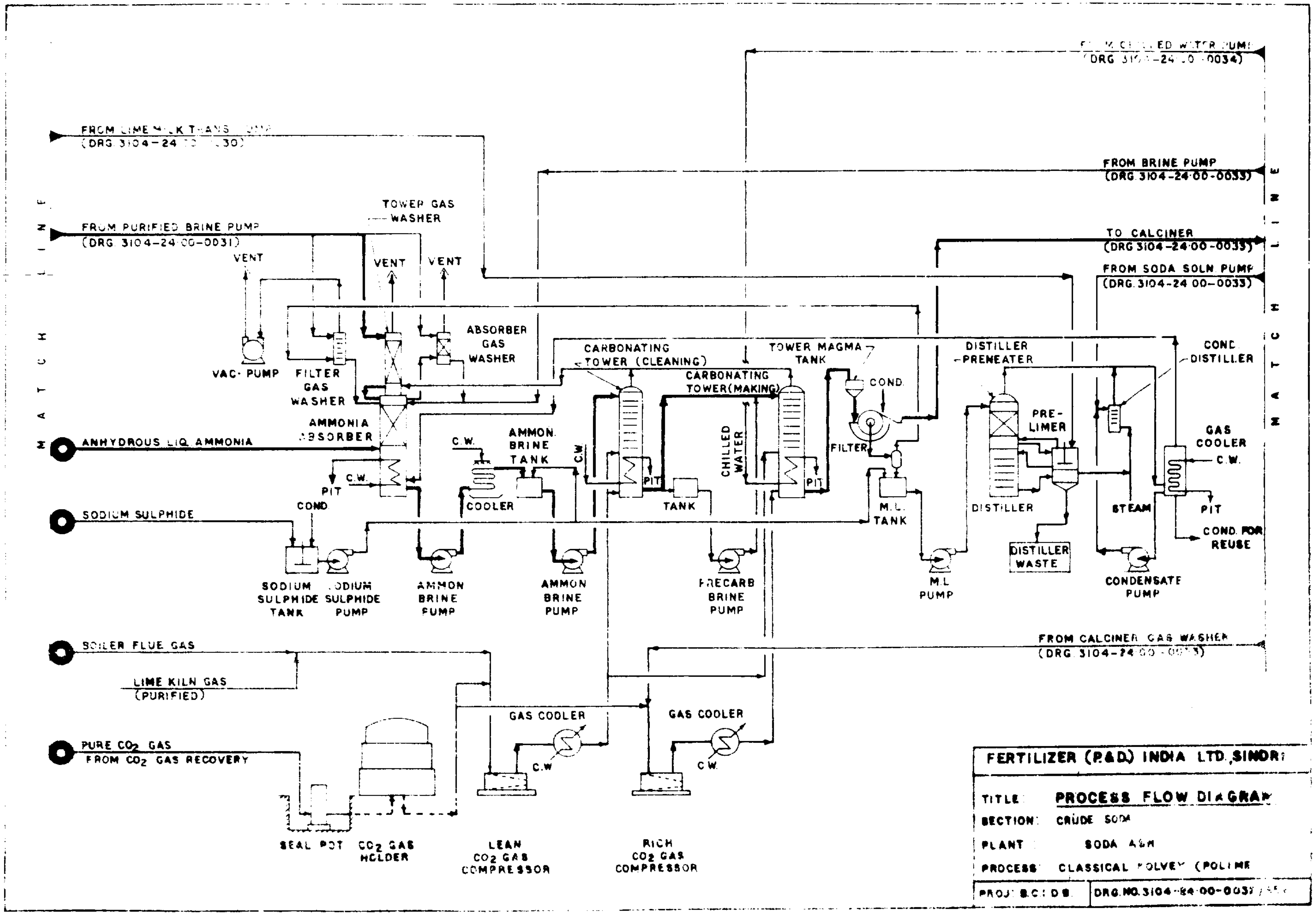
TITLE PROCESS FLOW [illegible]
SECTION LIME PREPARATION
PLANT SODA ASH
PROCESS CLASSICAL SOLVAY (POLI[illegible]
PROJ. [illegible] DRG. [illegible] 24-00-003[illegible] REV



FERTILIZER (P&D) INDIA LTD SINDRI

TITLE: **PROCESS FLOW DIAGRAM**
SECTION BRINE PREPARATION/PURIFICATION
PLANT SODA ASH
PROCESS CLASSICAL SOLVAY [illegible]

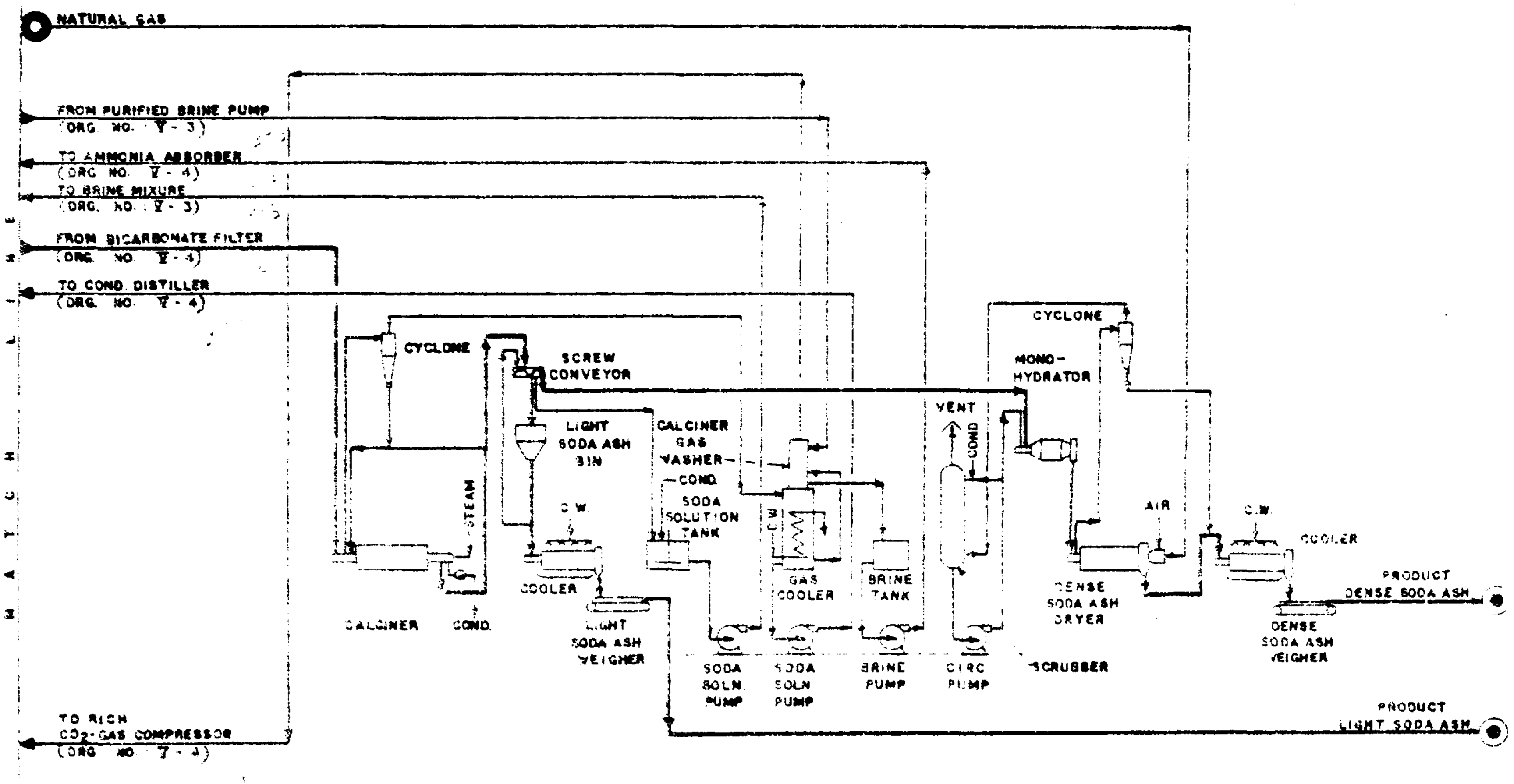
PROJ B.C.I.D.S	DRG. NO. 3104-24 00-0031	REV



FERTILIZER (P&D) INDIA LTD, SINDRI

TITLE: **PROCESS FLOW DIAGRAM**
SECTION: CRUDE SODA
PLANT: SODA ASH
PROCESS: CLASSICAL SOLVEY (POLIME

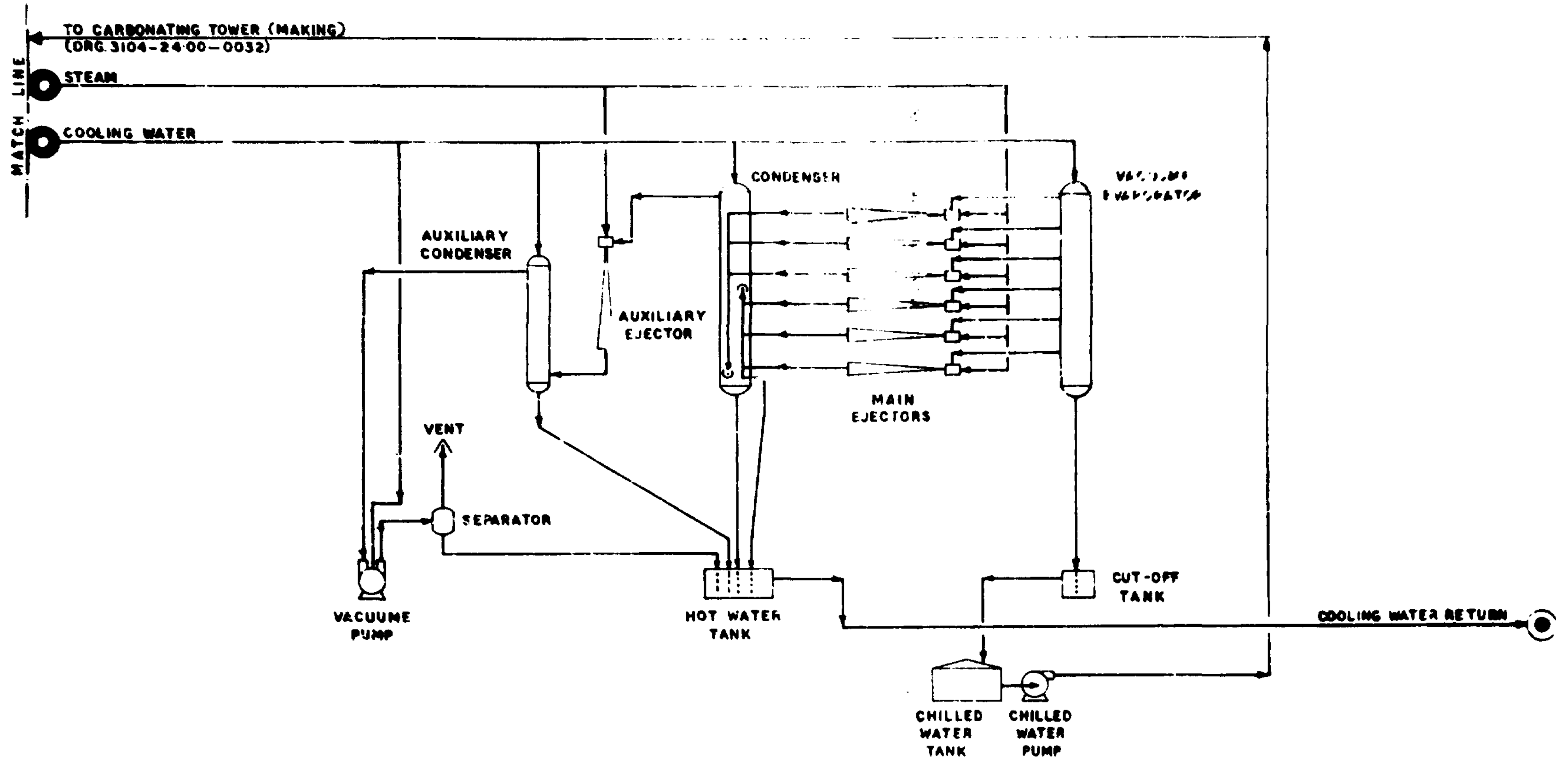
PROJ: B.C.: D.B.	DRG. NO. 3104-24-00-0037 / [illegible]



FERTILIZER (P&D) INDIA LTD. SINDRI

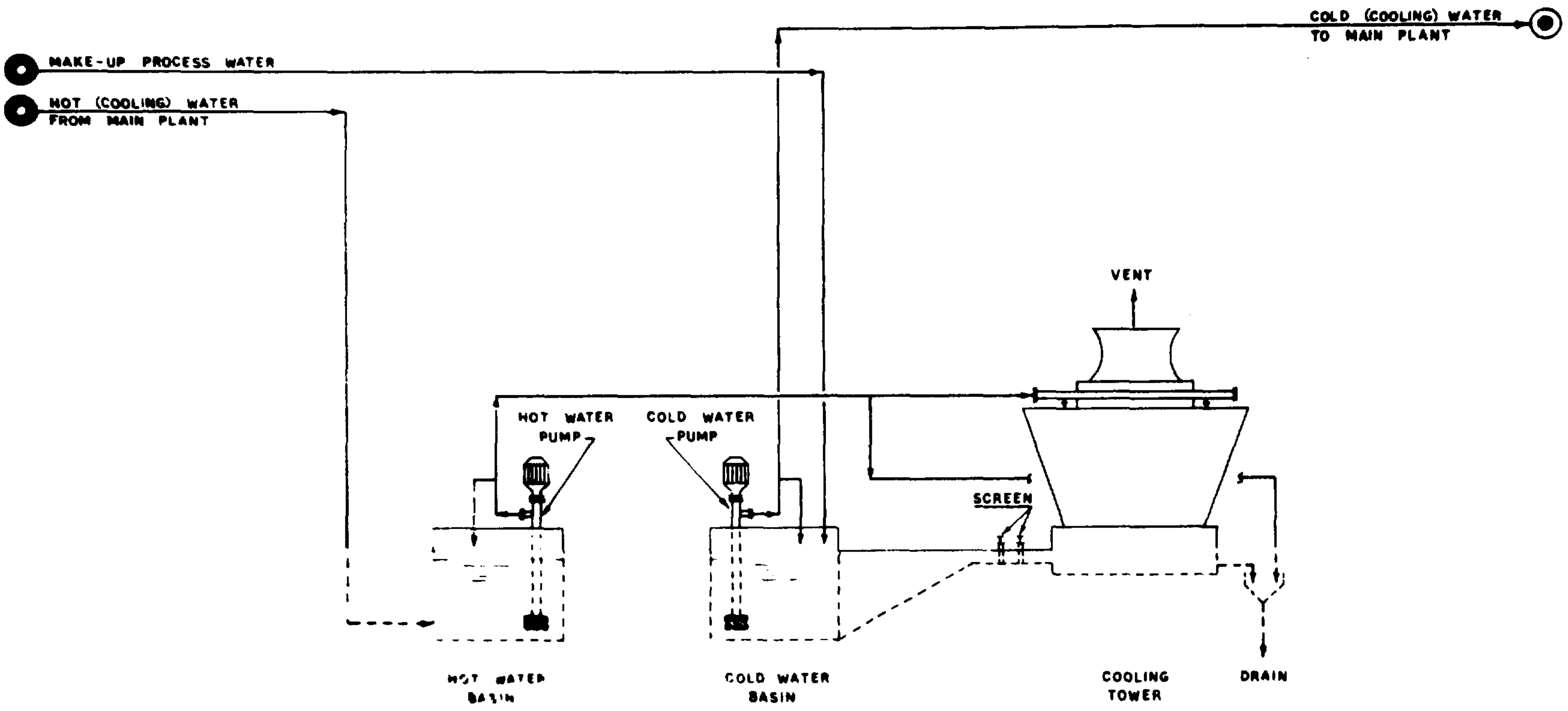
TITLE PROCESS FLOW DIAGRAM
SECTION DENSE SODA
PLANT SODA ASH
PROCESS CLASSICAL SOLVAY (POLIMEX)

PROJ. [illegible]	DRG. NO. V - 5 [illegible]



FERTILIZER (P.&D.) INDIA LTD, SINDRI

TITLE	**PROCESS FLOW DIACRAM**
SECTION	STEAM JET WATER REFRIGERATION
PLANT	SODA ASH
PROCESS	CLASSICAL SOLVEY (POLIMEX)
PROJ. 8 C I D 8	DRG NO 3104-24-00-0034 / REV



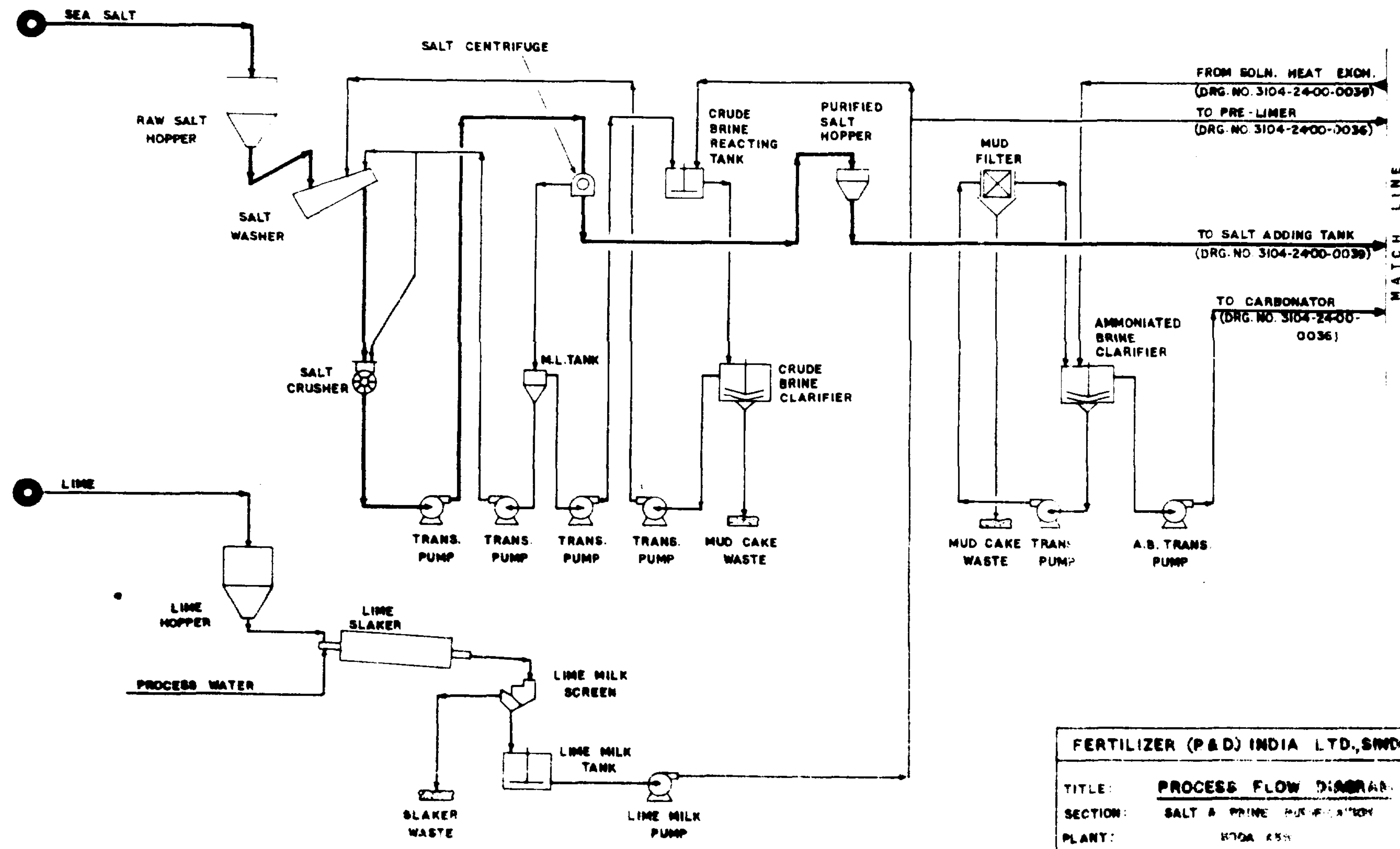
FERTILIZE (P & D) INDIA LTD., SINDRI

TITLE: **PROCESS FLOW DIAGRAM**

SECT COOLING TOWER

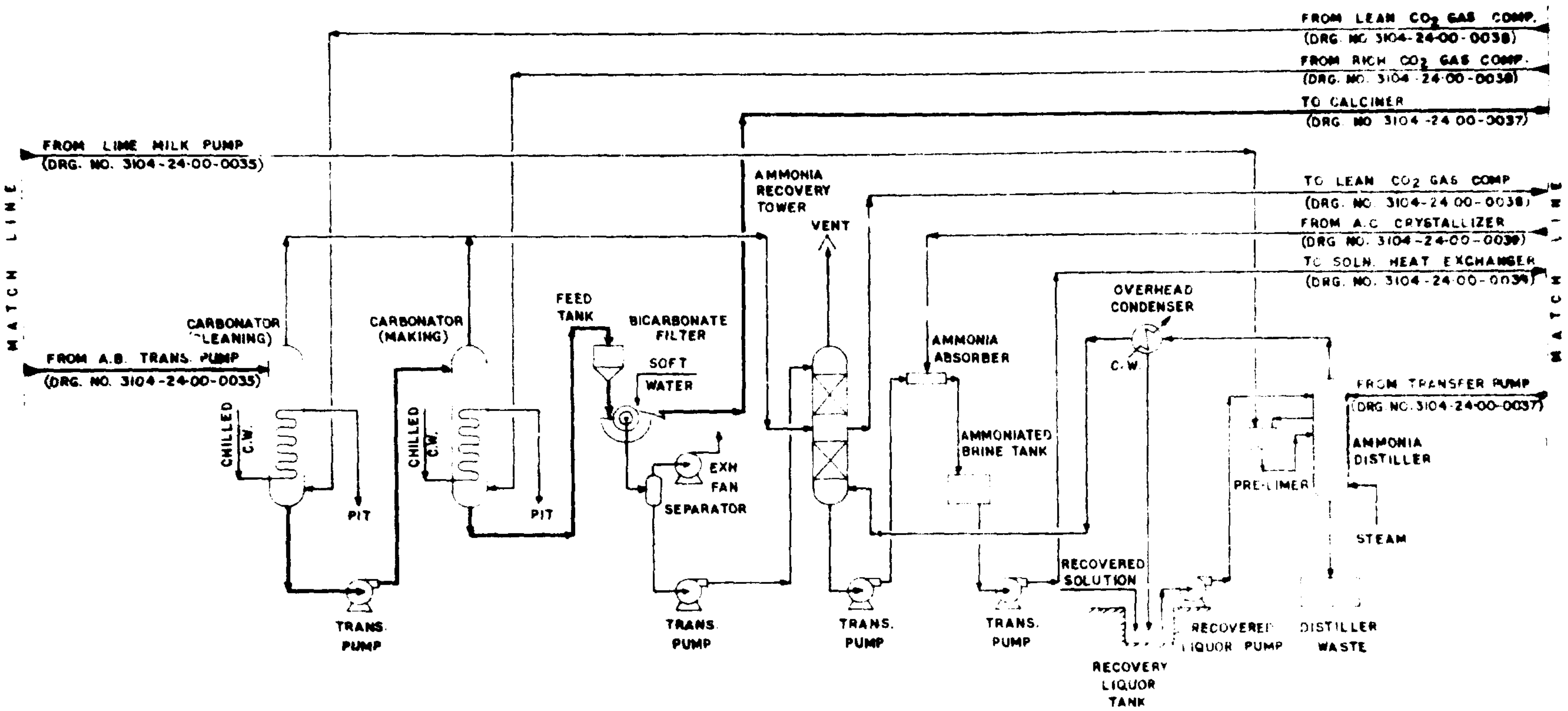
PLANT SODA ASH

PROJECT B C I D B | DRG NO 3104-75-20-0030 /REV



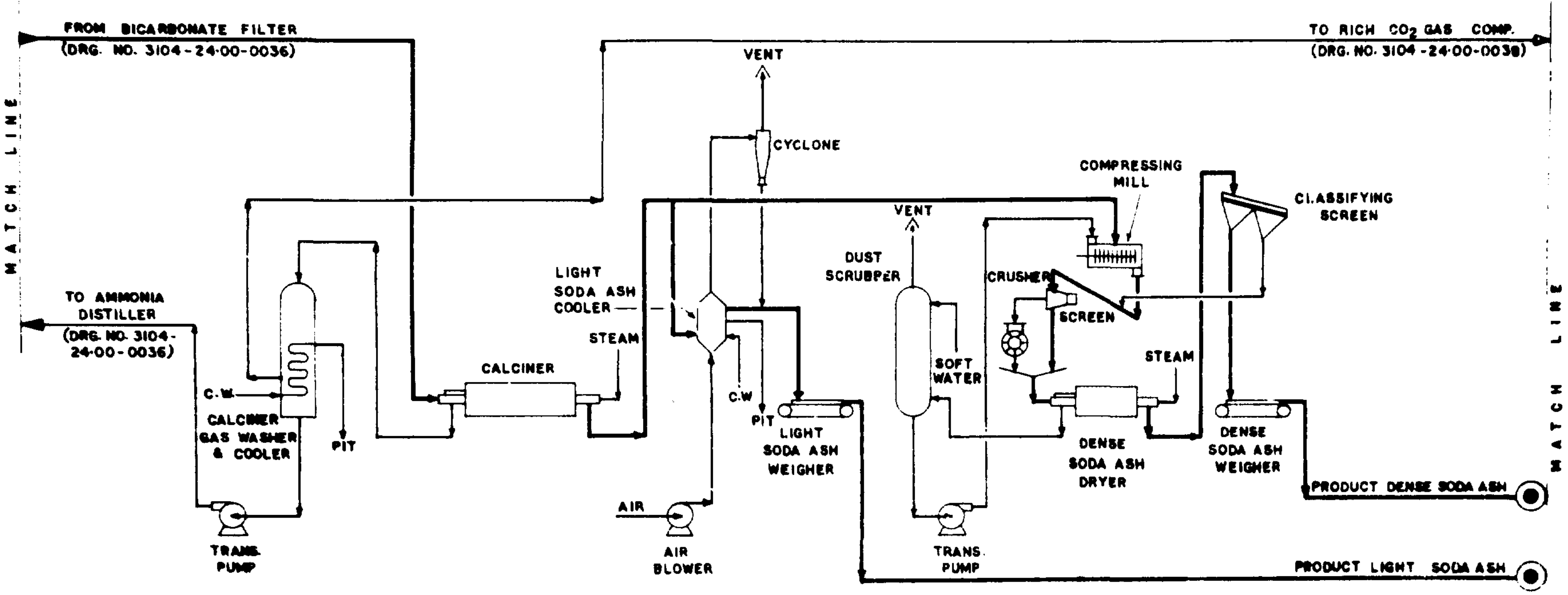
FERTILIZER (P&D) INDIA LTD., SINDRI

TITLE: PROCESS FLOW DIAGRAM
SECTION: SALT & BRINE PURIFICATION
PLANT: SODA ASH
PROCESS: DUAL (CENTRAL GLASS T.[illegible]
PROJ: S C.I.D.B. | DRG NO. 3104-24-00-0035 | REV.



FERTILIZER (P&D) INDIA LTD., SINDRI

TITLE: **PROCESS FLOW DIAGRAM**
SECTION CARBONATION & AMMONIA RECOVERY
PLANT SODA ASH
PROCESS DUAL (CENTRAL GLASS T.E.C.)
PROJ. B C I D B | DRG. NO. 3104-24-00-0036 | REV



FERTILIZER (P & D) INDIA LTD., SINDRI

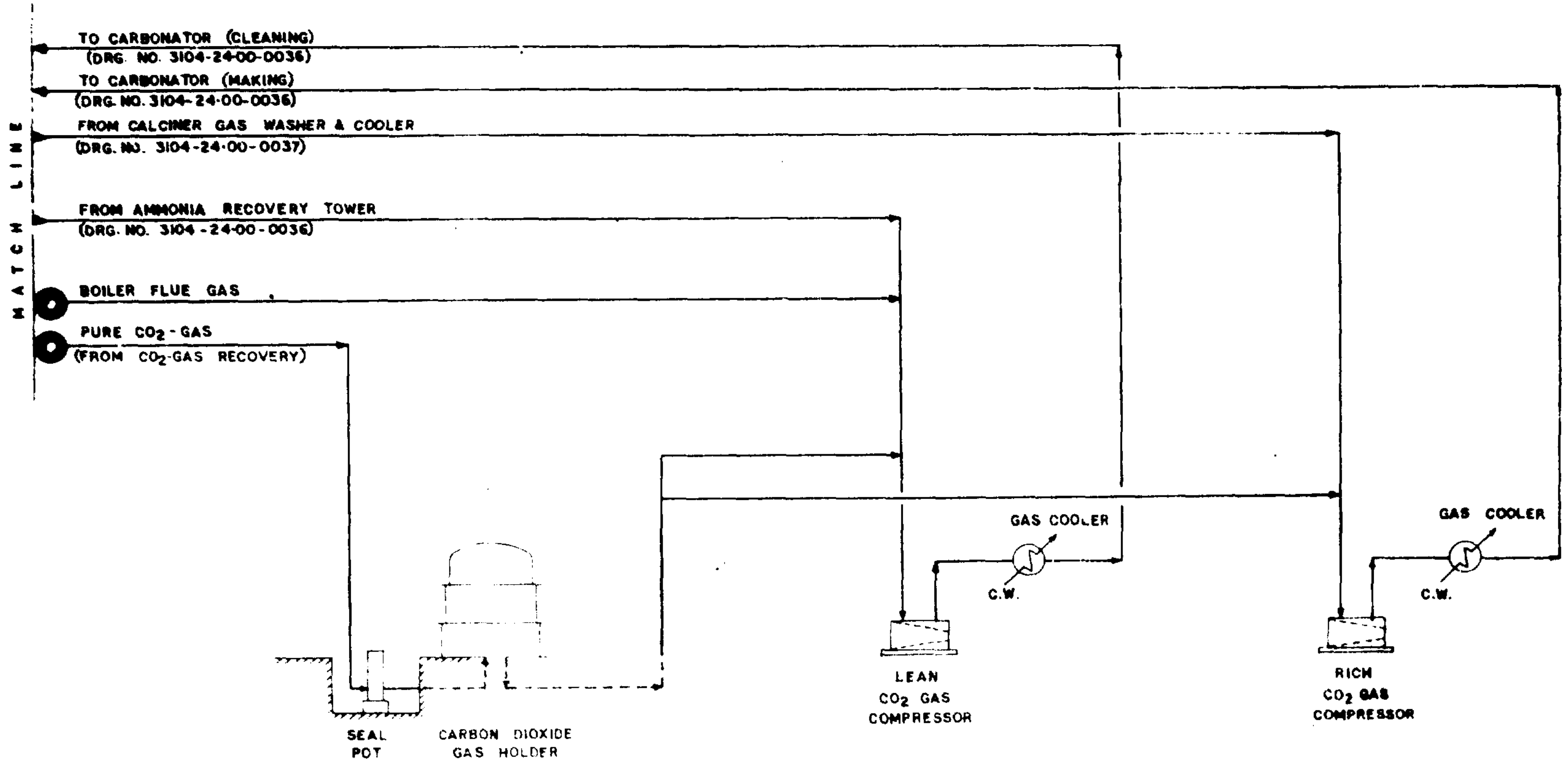
TITLE: **PROCESS FLOW DIAGRAM**

SECTION: CALCINATION & DENSIFICATION

PLANT: SODA ASH

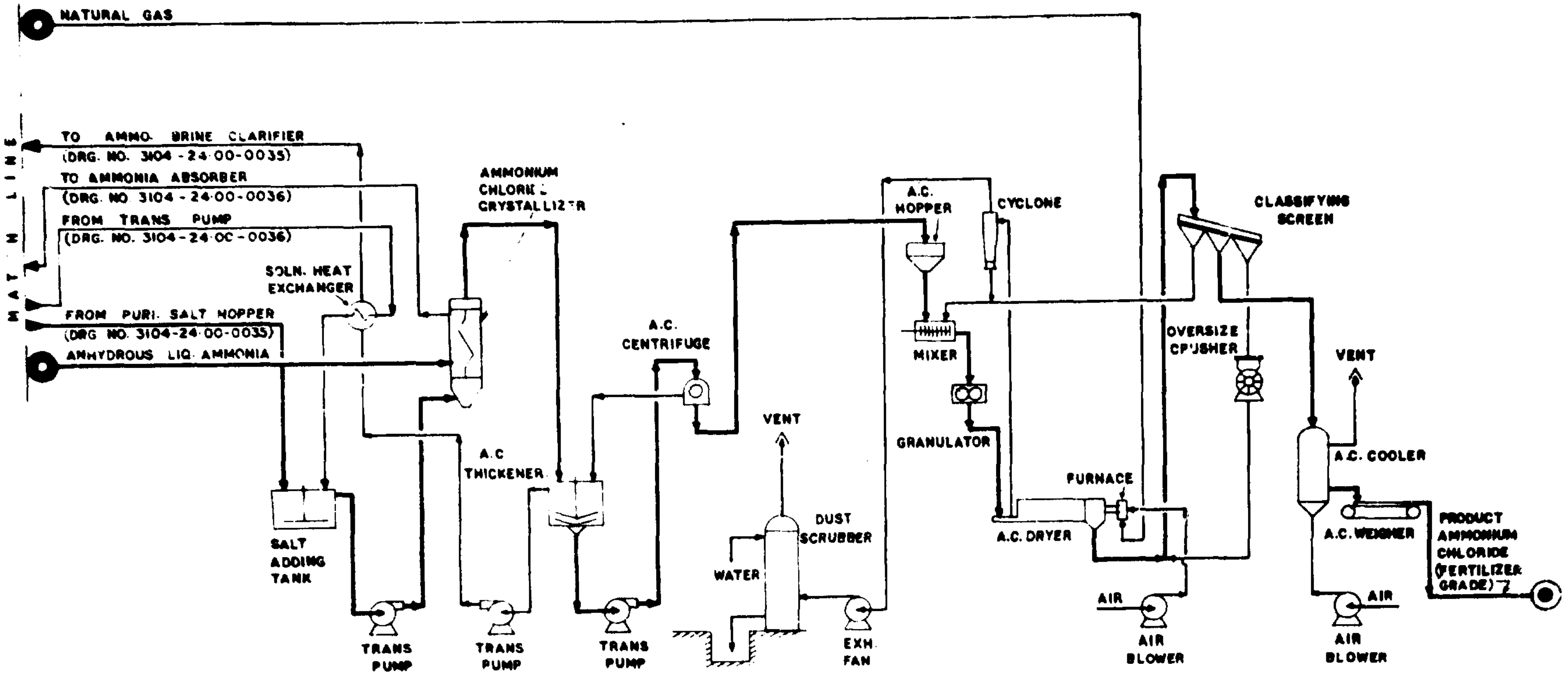
PROCESS: DUAL (CENTRAL GLASS T.E.

PROJ: B.C.I.D.B. | DRG NO 3104-24-00-0037 REV.



FERTILIZER (P.& D.) INDIA LTD., SINDRI

TITLE. PROCESS FLOW DIAGRAM
SECTION. CARBON DIOXIDE GAS COMPRN.
PLANT: SODA ASH
PROCESS DUAL (CENTRAL GLASS T.E.C.)
PROJ: B.C.I.D.B. | DRG. NO 3104-24-00-0038 | REV.



FERTILIZER (P&D) INDIA LTD., SINDRI

TITLE: PROCESS FLOW DIAGRAM

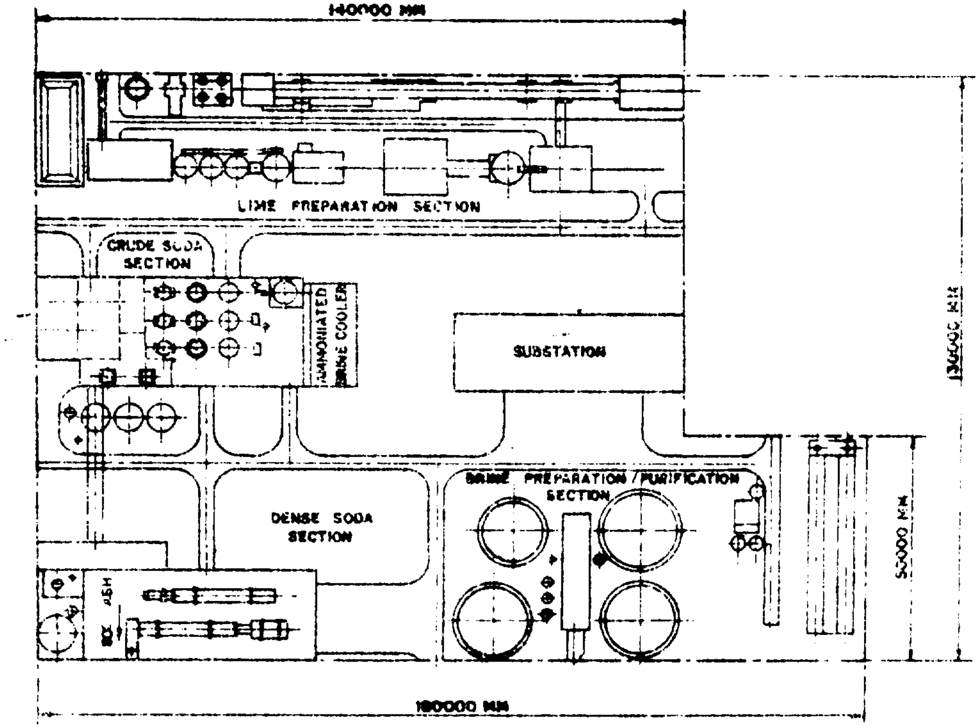
SECTION: AMMONIUM CHLORIDE

PLANT: SODA ASH

PROCESS: DUAL (CENTRAL GLASS T.E.C.)

PROJ: S.C.L.D.S

DRG. NO. 3104-24.00-0039 / REV.



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FERTILIZER (P. & D) INDIA LTD., SINDRI.

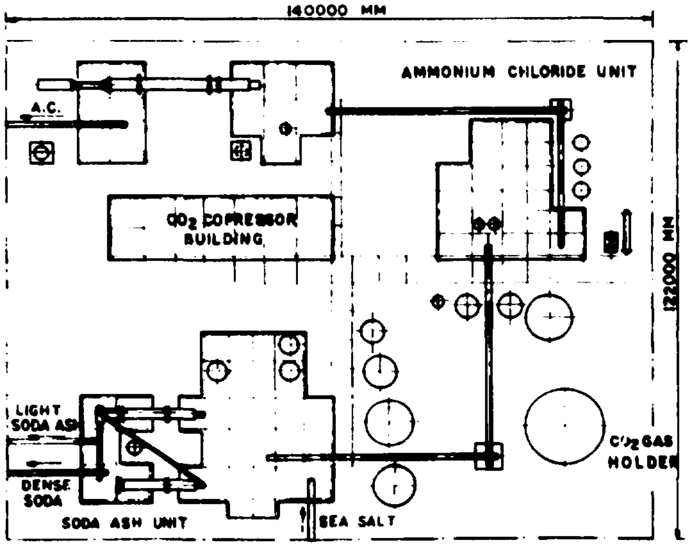
TITLE: **EQUIPMENT LAYOUT**
(PLAN)

PLANT SODA ASH

PROCESS CLASSICAL SOLVAY (POLIMEX)

PROJECT: S.C.I.D.S. | DRG. NO. : V - 13 (0001)

V-13



SCALE - 1:1000

FERTILIZER (P&D) INDIA LTD. SINDRI

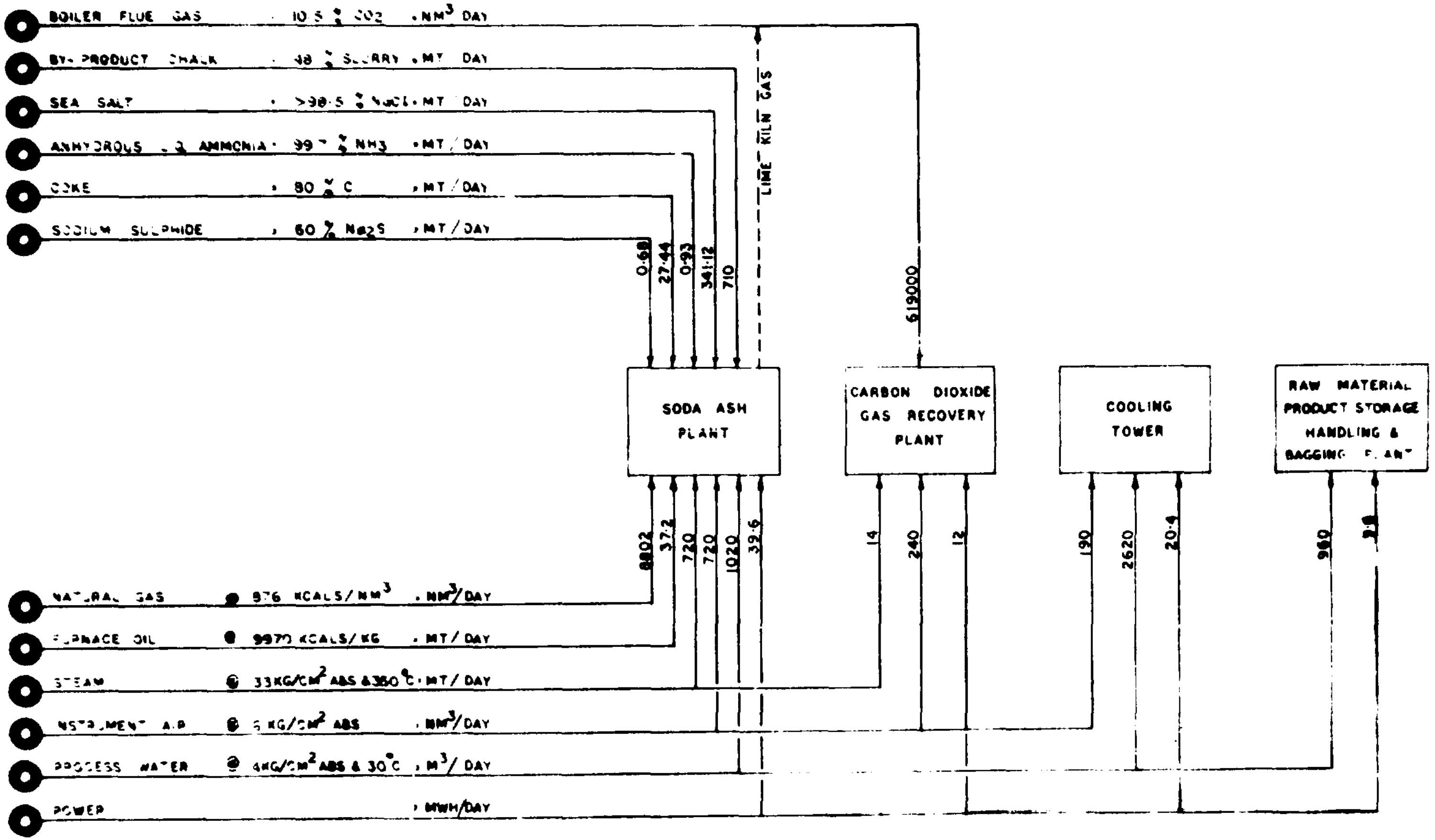
TITLE : EQUIPMENT LAYOUT (PLAN)

PLANT SODA ASH

PROCESS DUAL (CENTRAL GLASS-TEC)

PROJ B C I D.B

DRG NO 3104-24 00-0002 REV.



NOTE

1. THE BALANCE CORRESPONDS TO THE RATED 100% CAPACITY OF PLANT / PLANTS
2. THE RATED CAPACITY OF SODA ASH PLANT IS 200 MT/DAY OF DENSE SODA ASH
3. CARBON DIOXIDE GAS RECOVERY PLANT IS FORESEEN ONLY WHEN SODA ASH COMPLEX DOES NOT HAVE CAPTIVE AMMONIA PLANT.

FERTILIZER (P & D) INDIA LTD., SINDRI

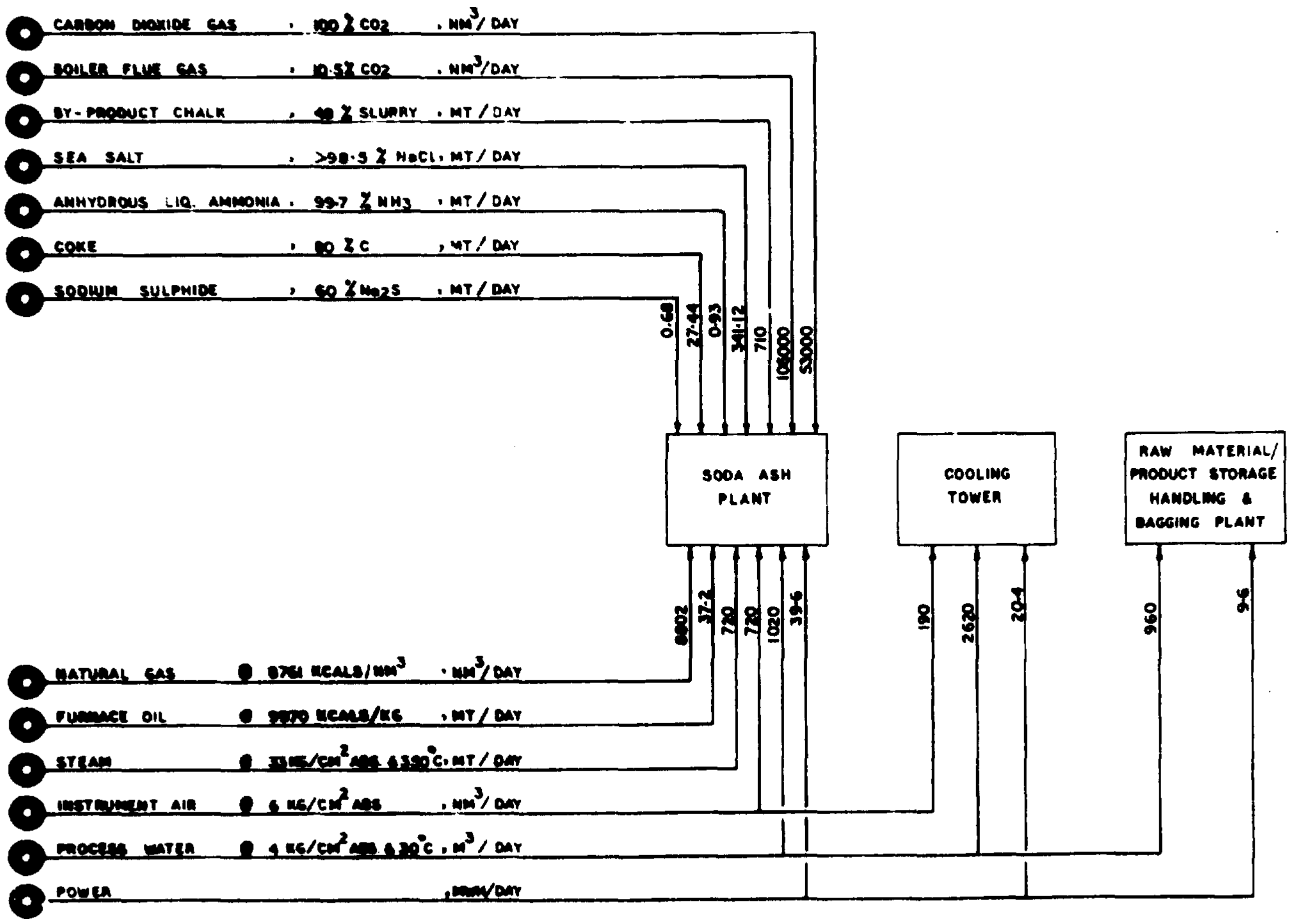
TITLE **RAW MATERIAL & UTILITY BALANCE**

PLANT SODA ASH

PROCESS CLASSICAL SOLVEY (POLIMEX)

SITE CHITTAGONG

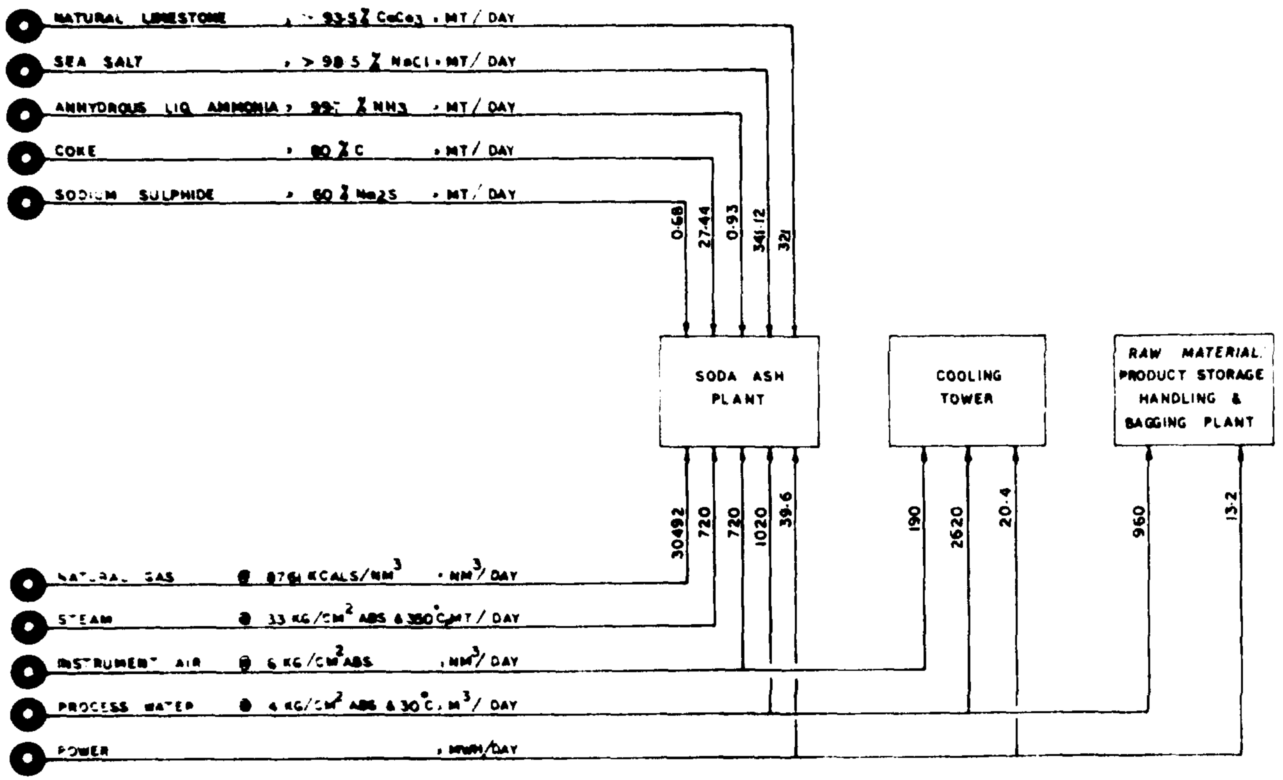
PROJECT B C I 0 0 | DRG NO 3104-24.00-0040 /REV



NOTE

1. THE BALANCE CORRESPONDS TO THE RATED 100% CAPACITY OF PLANT / PLANTS
2. THE RATED CAPACITY OF SODA ASH PLANT IS 200 MT/DAY OF DENSE SODA ASH
3. CARBON DIOXIDE GAS FROM CAPTIVE AMMONIA PLANT CONSIDERED AS AN ALTERNATIVE IS UTILISED FOR SODA ASH PLANT WHICH DISPENSES WITH SEPARATE CO_2 GAS RECOVERY PLANT

FERTILIZER (P. & D.) INDIA LTD., SINDRI	
TITLE: RAW MATERIAL & UTILITY BALANCE	
PLANT : SODA ASH	
PROCESS : CLASSICAL SOLVEY [illegible]	
SITE : CHITTAGONG	
PROJECT: B.C.I.D.B.	DRG. NO. 3104-24-00-0041 /REV



NOTE

1 THE BALANCE CORRESPONDS TO THE RATED 100% CAPACITY OF PLANT/PLANTS

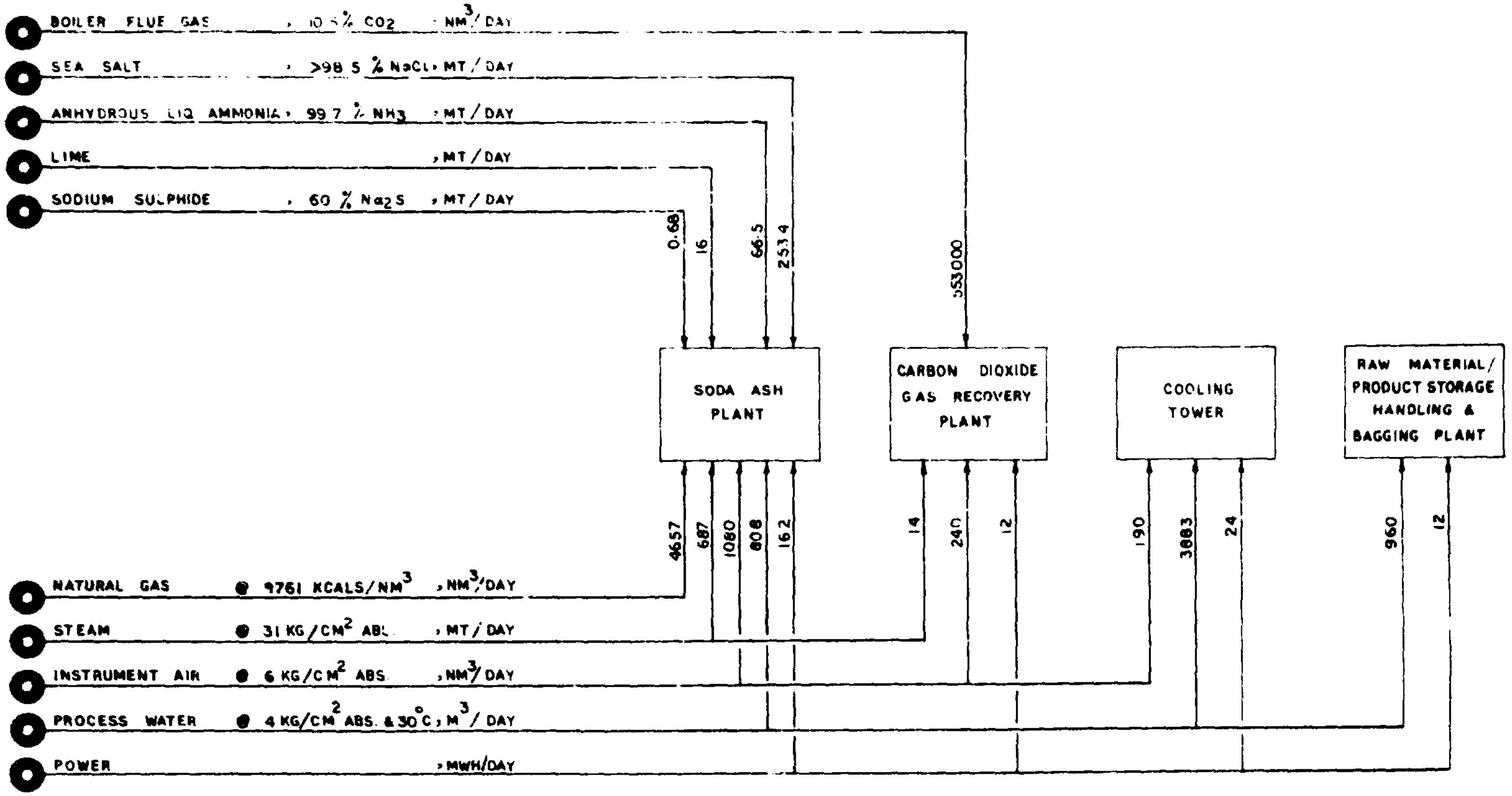
2 THE RATED CAPACITY OF SODA ASH PLANT IS 200 MT DAY OF DENSE SODA ASH

FERTILIZER (P & D) INDIA LTD, SINDRI

TITLE **RAW MATERIAL & UTILITY BALANCE**

PLANT SODA ASH
PROCESS CLASSICAL SOLVEY (POLIMEX)
SITE CHITTAGONG

PROJECT: B C I D B | DRG NO 3104-24-00-0048 | REV.



NOTE

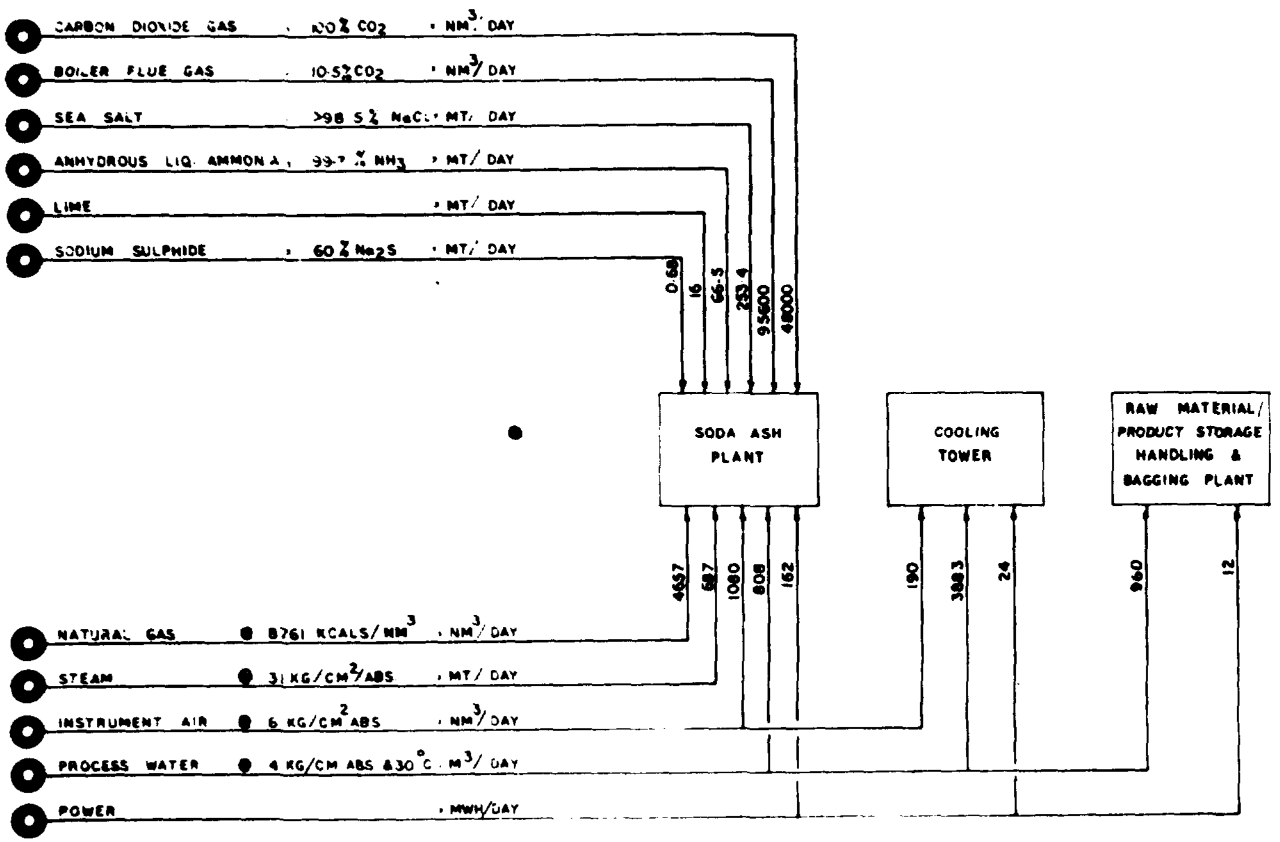
1. THE BALANCE CORRESPONDS TO THE RATED 100% CAPACITY OF PLANT / PLANTS.
2. THE RATED CAPACITY OF SODA ASH PLANT IS 200 MT/DAY OF DENSE SODA ASH AND 204 MT / DAY OF AMMONIUM CHLORIDE (FERTILIZER GRADE) AS CO-PRODUCT
3. CARBON DIOXIDE GAS RECOVERY PLANT IS FORESEEN ONLY WHEN SODA ASH COMPLEX DOES NOT HAVE CAPTIVE AMMONIA PLANT

FERTILIZER (P & D) INDIA LTD., SINDRI

TITLE : **RAW MATERIAL & UTILITY BALANCE**

PLANT : SODA ASH
PROCESS : DUAL (CENTRAL GLAS [illegible]
SITE : CHITTAGONG

PROJECT B C I O B. | DRG NO 3104-24-00-0043 | REV.



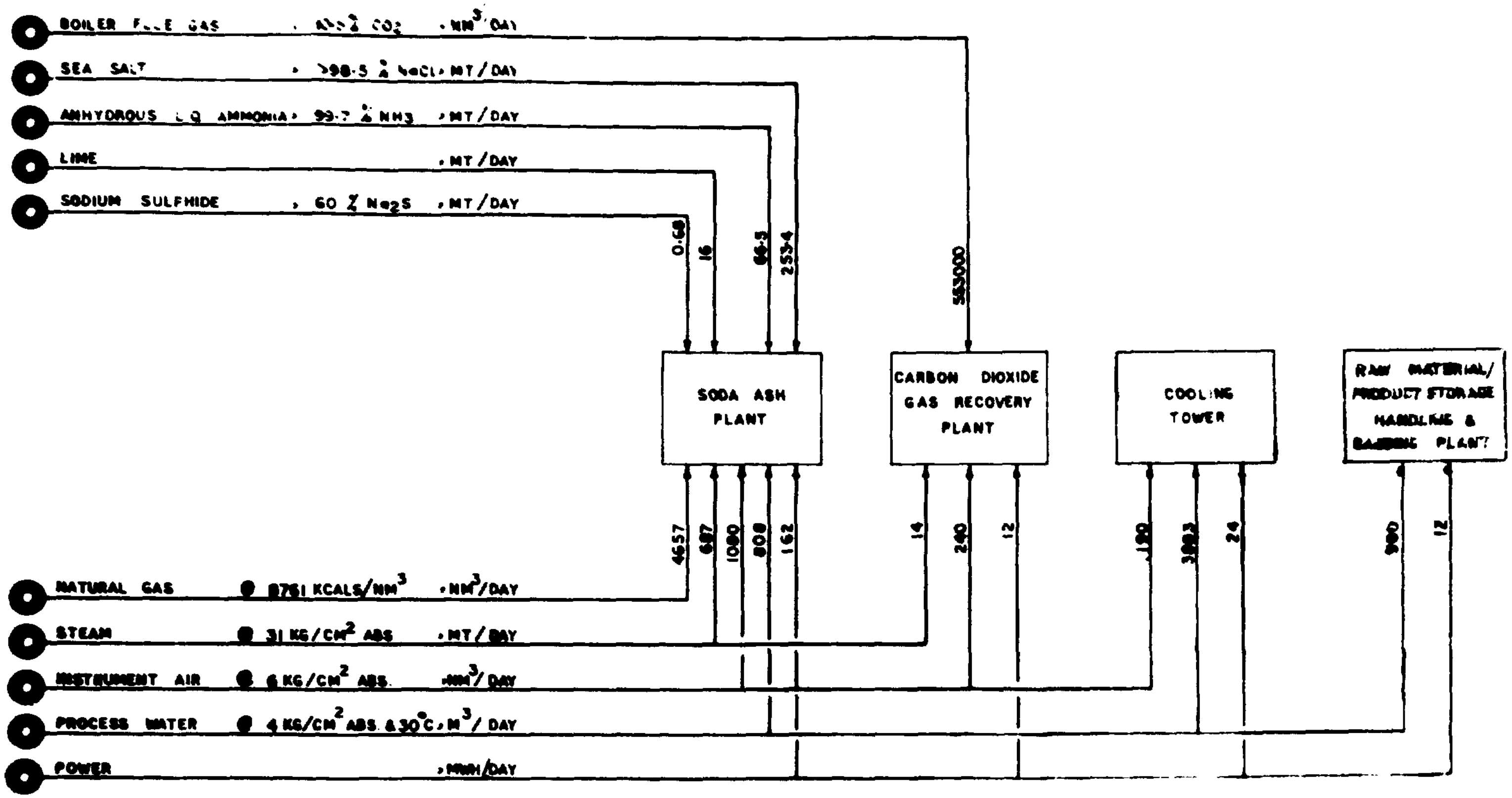
NOTE

1. THE BALANCE CORRESPONDS TO THE RATED 100% CAPACITY OF PLANT/PLANTS
2. THE RATED CAPACITY OF SODA ASH PLANT IS 200 MT/DAY OF DENSE SODA ASH AND 204 MT/DAY OF AMMONIUM CHLORIDE (FERTILIZER GRADE) AS CO-PRODUCT
3. CARBON DIOXIDE GAS FROM CAPTIVE AMMONIA PLANT CONSIDERED FOR SODA ASH COMPLEX AT THIS SITE IS UTILISED FOR SODA ASH PLANT WHICH DISPENSES WITH SEPARATE CO_2 GAS RECOVERY PLANT

FERTILIZER (P & D) INDIA LTD, SINDRI

TITLE: **RAW MATERIAL & UTILITY BALANCE**

PLANT	SODA ASH
PROCESS	DUAL (CENTRAL GLASS - T.E.C.)
SITE	GHORASAL
PROJECT: B.C.I.D.S.	DRG NO. 3104-84-00-0044 / REV.



NOTE

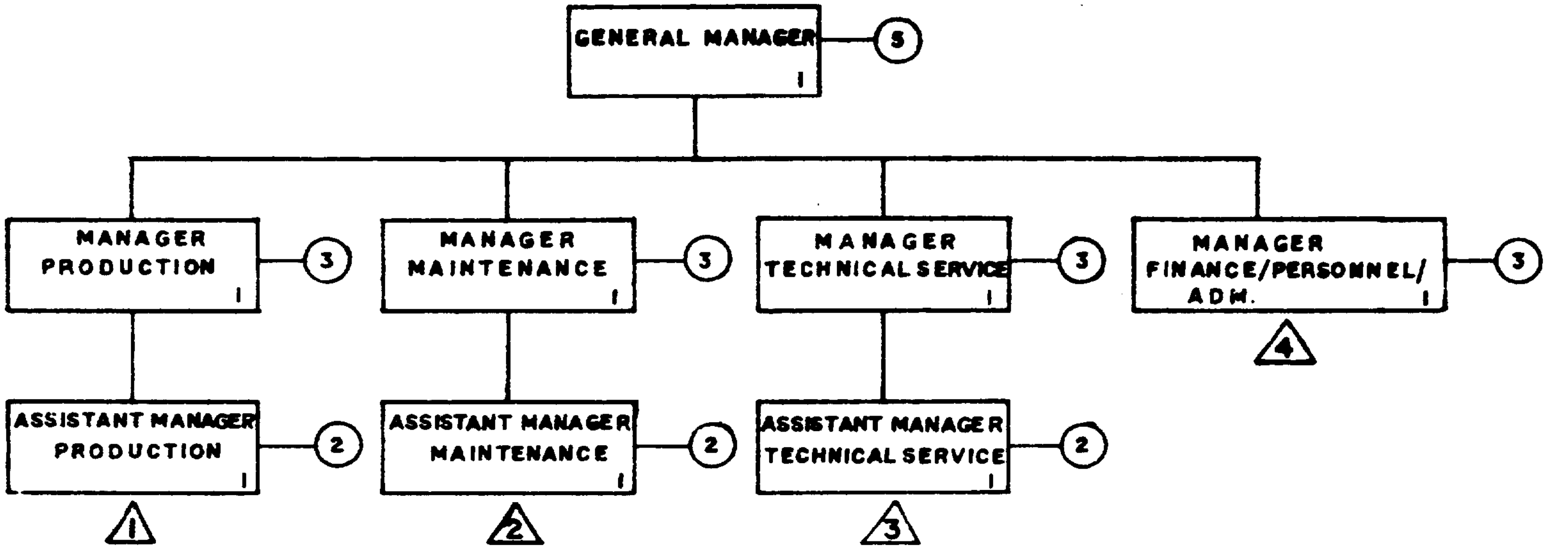
1. THE BALANCE CORRESPONDS TO THE RATED 100% CAPACITY OF PLANT/ PLANTS
2. THE RATED CAPACITY OF SODA ASH PLANT IS 200 MT/ DAY OF DENSE SODA ASH AND 204 MT / DAY OF AMMONIUM CHLORIDE (FERTILIZER GRADE) AS CO-PRODUCT
3. CARBON DIOXIDE GAS RECOVERY PLANT IS FORESEEN ONLY WHEN SODA ASH COMPLEX DOES NOT HAVE CAPTIVE AMMONIA PLANT

FERTILIZER (P & D) INDIA LTD, SINDRI

TITLE: **RAW MATERIAL & UTILITY BALANCE**

PLANT SODA ASH
PROCESS DUAL (CENTRAL GLA[illegible]
SITE GHORASAL

PROJECT UCIDB | DRG NO. 3104-24 00-0046 /REV.



—○ INDICATES NOS. OF SUPPORTING & MINISTERIAL STAFF.

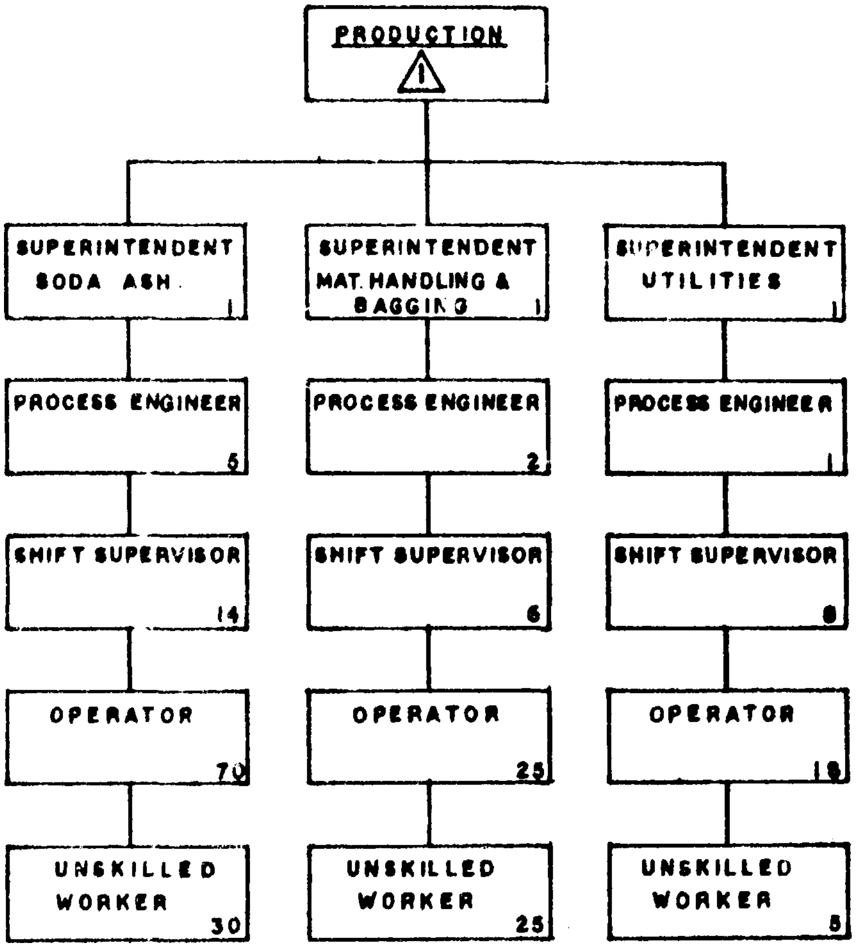
TOTAL MAN POWER = 700

FERTILIZER (P& D) INDIA LTD. SINDRI.

TITLE :- **MAN POWER CHART**

LOCATION:- CHITTAGONG / GHORASAL

PROJECT: B.C.I.D.B. | DRG. NO. V 24 (SHEET 1 OF 6)

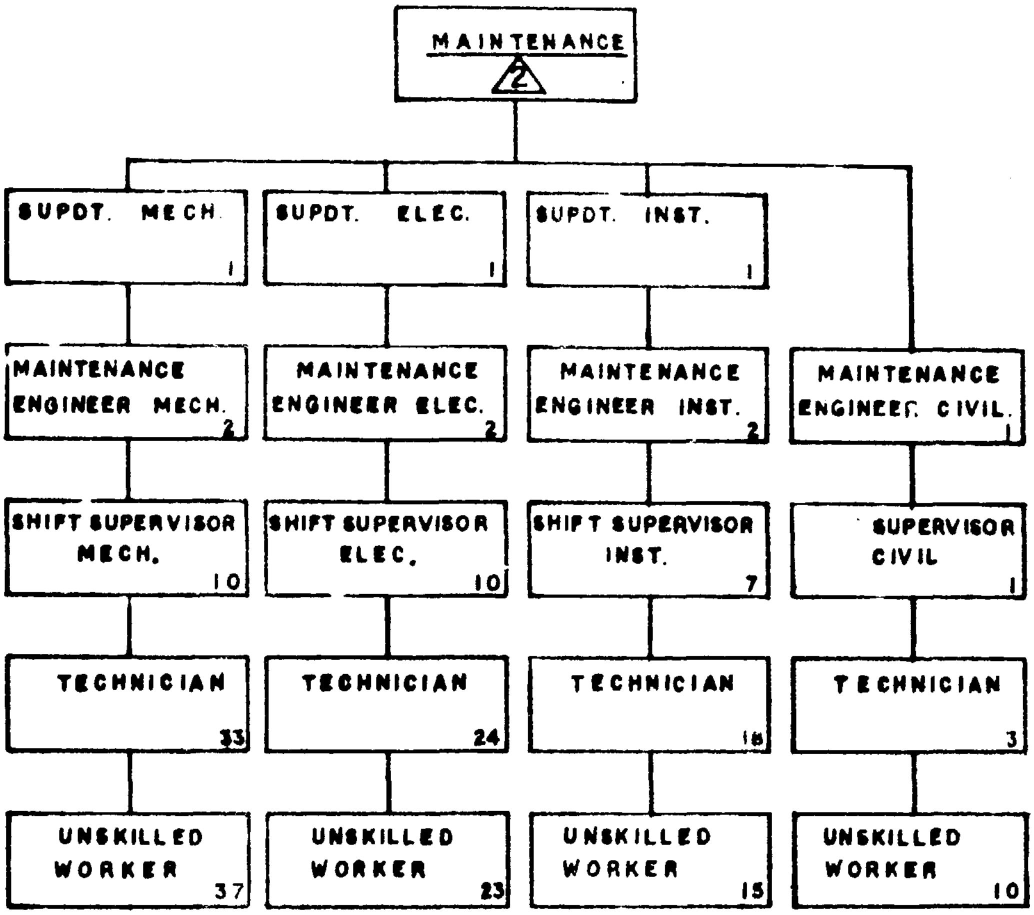


FERTILIZER (P& D) INDIA LTD, SINDRI.

TITLE :- **MANPOWER CHART**

LOCATION :- CHITTAGONG/GHORASAL

PROJECT B.C.I.D.B. | DRG NO. V-24 (SH. 2 OF 6)

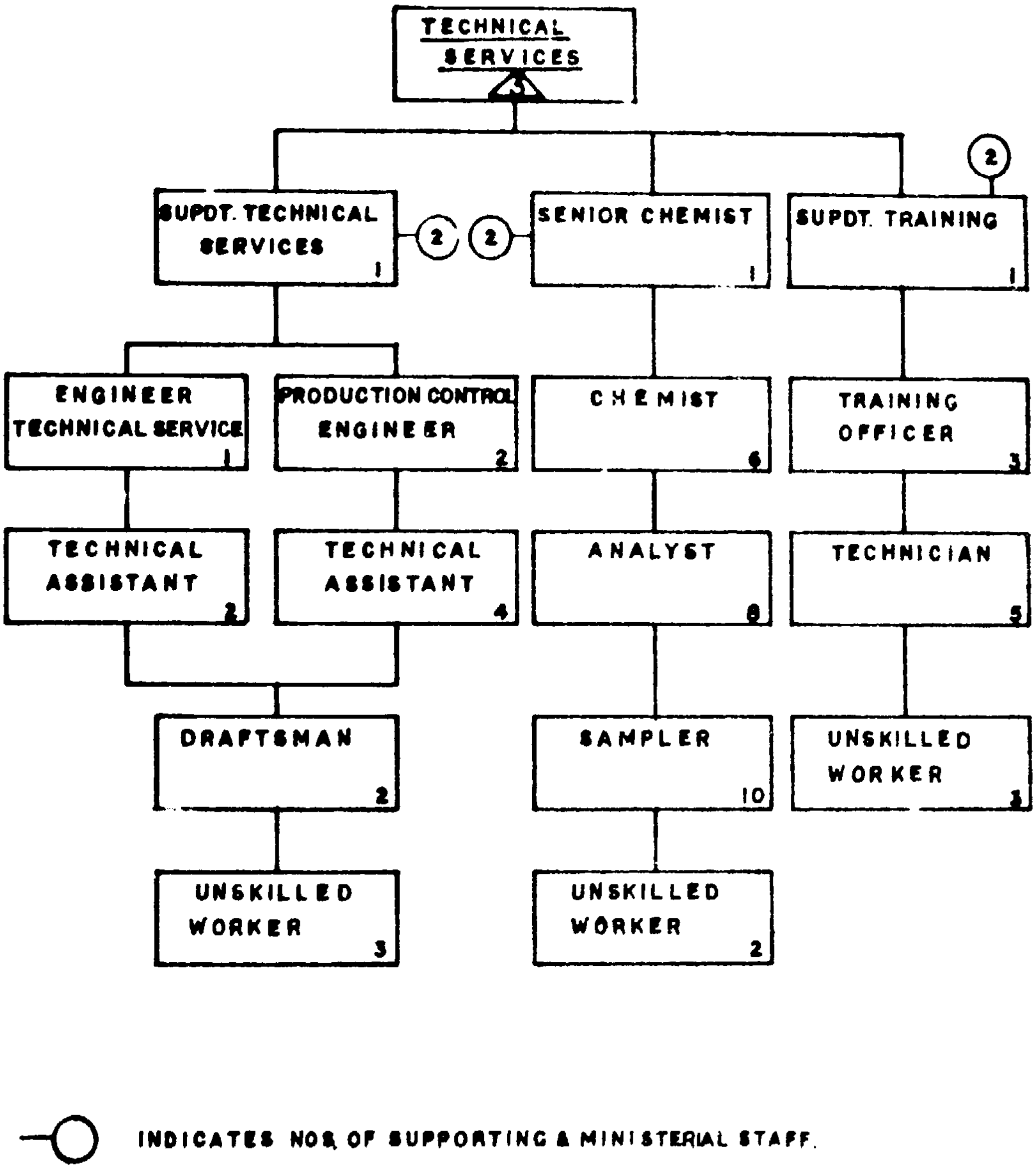


FERTILIZER (P&D) INDIA LTD. SINDRI

TITLE :- **MANPOWER CHART**

LOCATION CHITTAGONG / GHORASAL

PROJECT:- B.C.I.D.B. | DRG. NO. V-24 (SH. 3 OF

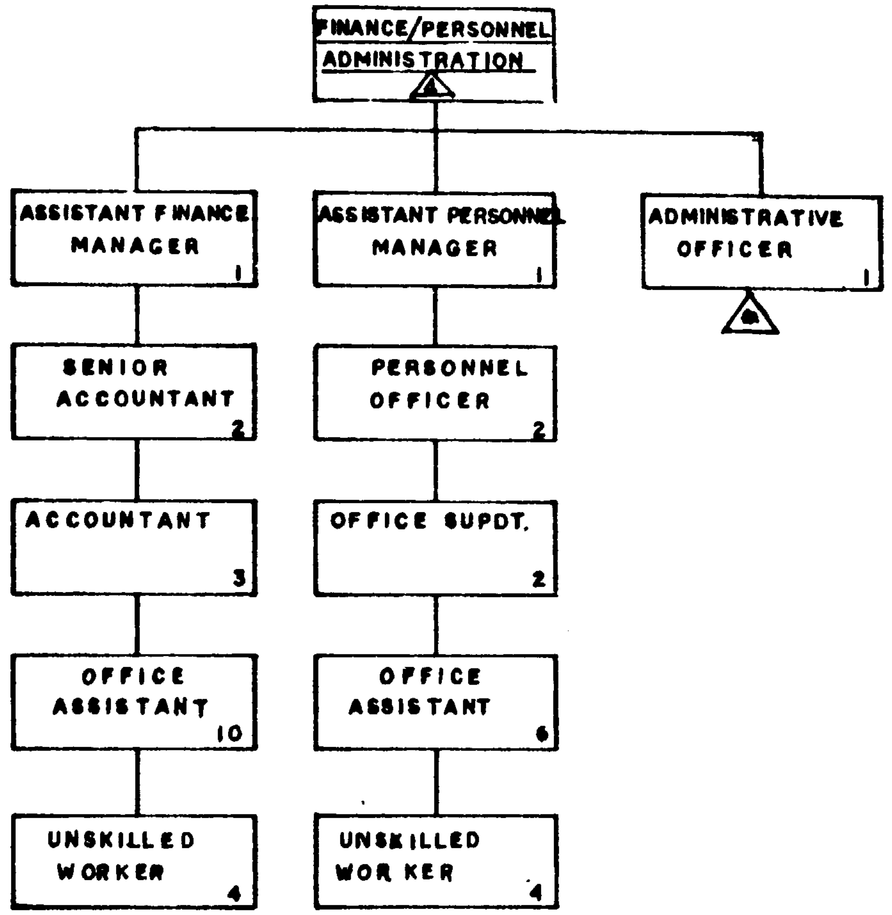


FERTILIZER (P& D) INDIA LTD. SINDRI

TITLE :- **MANPOWER CHART**

LOCATION :- CHITTAGONG / GHORASAL

PROJECT :- B.C.I.D.B DRG. NO. V 24 (SH. 4 OF 6)

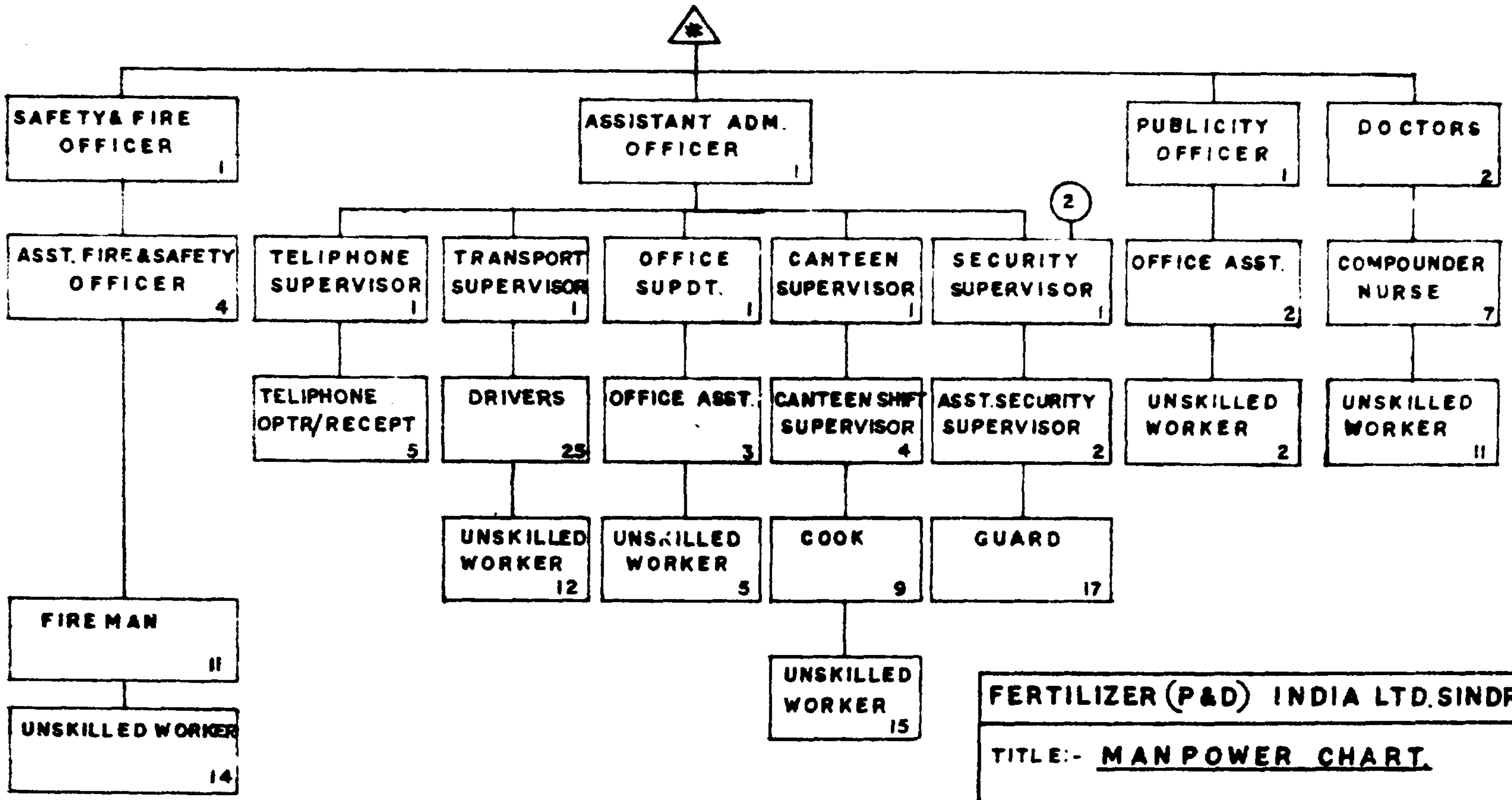


FERTILIZER (P&D) INDIA LTD. SINDRI.

TITLE:- **MAN POWER CHART**

LOCATION:- CHITTAGONG/GHORASAL

PROJECT:- B.C.I.D.B. | DRG NO. V 24 (SH.5 OF 6)



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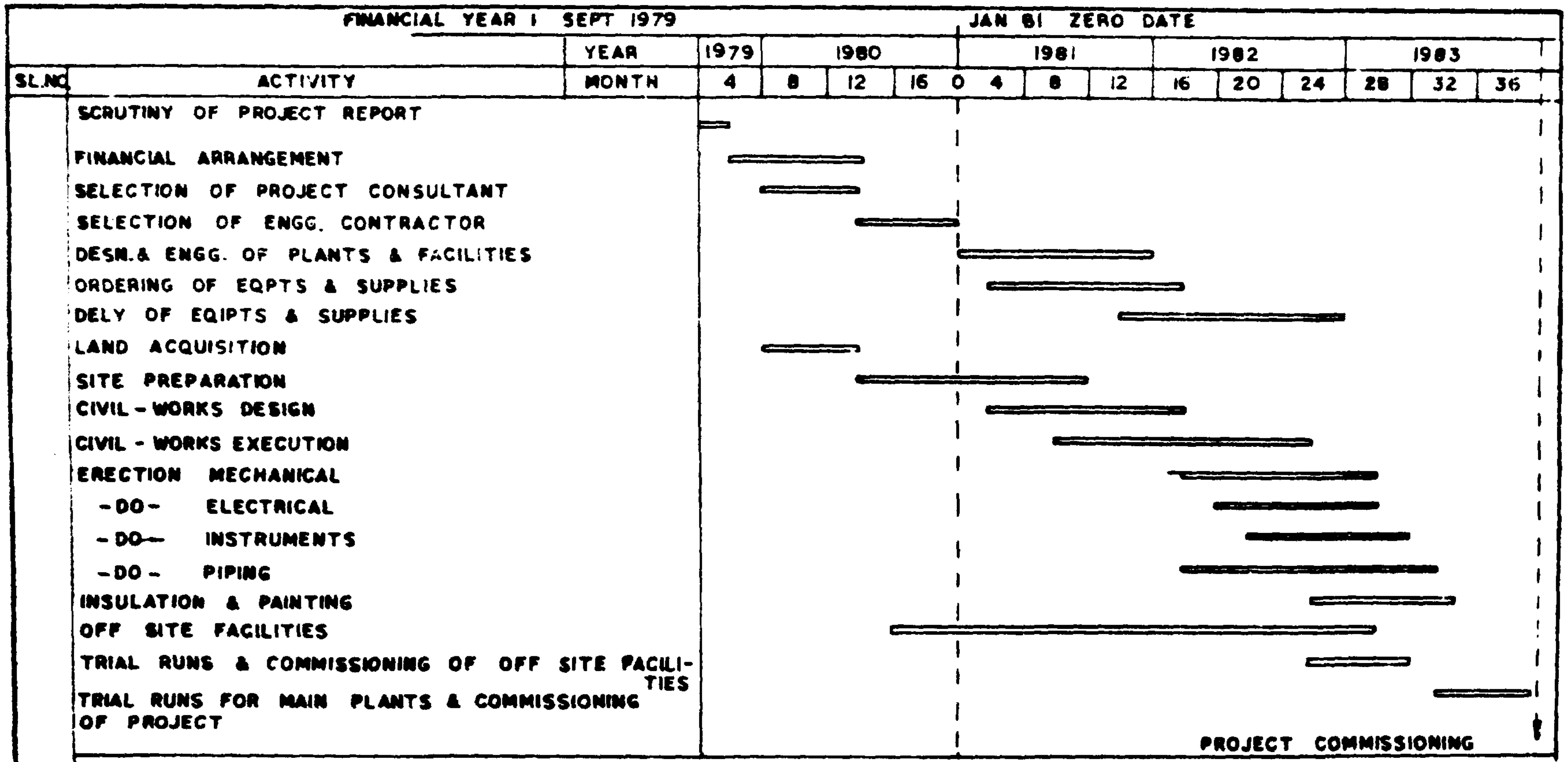

FERTILIZER (P & D) INDIA LTD. SINDRI

TITLE

TENTATIVE TIME SCHEDULE

PROJECT : B.C.I.D.B. | DRG NO. V-23

BASIC CHEMICAL INDUSTRIES DEVELOPMENT
IN
BANGLADESH

10139
(6)

Part Six
PRODUCTION OF SALT

FERTILIZER (PLANNING & DEVELOPMENT) INDIA LTD

SINDRI, INDIA, 828122

Job No. 3104

PART VI

PRODUCTION OF SALT

PART VI

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SECTION A : PRODUCTION OF SOLAR SALT

Chapter - 1

INTRODUCTION

1.1 Salt or Sodium Chloride, as it is chemically known in its pure form is an article of human consumption and comes in the category of basic food needed to provide the body's requirements of sodium and chlorides. In countries where a large proportion of the population lives below the "poverty line", as in Bangladesh, adequate supply of salt in atleast a fairly pure form and at a reasonably low price, commensurate with the general purchasing power of the population, could become critical to maintaining the minimum health and nutrition standards. Besides, salt has literally thousands of other uses (Table 1.1), and forms one of the basic raw materials of the chemical industry, particularly the chlorine-caustic and soda ash industries. Its non-edible applications cover, besides chlorine, caustic soda and soda ash, where it forms the principal raw material, such a wide-spectrum of the industrial field as soap and detergents (to separate soap from water and glycerine), textile dying, meat canning, fish curing, refrigeration, metals (descaling, fluxes and fused salt bath), leather tanning (preventing bacterial decomposition of hides), dairy, rubber (for salting out rubber from latex) and petroleum exploration (inhibiting fermentation of starch in drilling mud) etc. One of its growing new uses in recent period has been in the regeneration of ion-exchange resins in 'soft' water production. Its importance to industrial growth can be gauged from the fact that a close correlation between salt production and the general industrial production indices has been observed in several industrial countries, such as the United States. Its consumption is also historically correlated closely with the gross national product in most economically advanced countries. The establishment of a sound and

Table 1.1

Uses of Salt

Edible		
Human (direct)	Human (Indirect)	Cattle
Edible Common salt Table salt Iodized salt Refined salt Medicinal	Butter & Cheese Preservation Fish curing Fish canning	Mineralised salt for cattle Cattle lick blocks

Industrial

Chemical
Industry

Soda Ash
Caustic Soda
Sodium Metal Manufacture
Sodium Chlorate
Sodium Hydrosulphate
Soap Industry
Fertilizers
Water Softening
Refrigeration
Textiles
Paper & Pulp
Hide Curing
Ice Removal & Road Making
Glass &
Ceramics
Rubber
Petroleum Exploration
etc. etc.

vigorous salt production industry can possibly provide stimulus to the growth of a wide range of industrial products even in developing countries.

1.2 This Report covers production of salt from sea water, both by solar evaporation (Section A) and artificial energy-induced evaporation in a modern plant (Section B). While recognizing the need for development of the industry in Bangladesh to manufacture salt for both human consumption and industrial use, this study lays particular emphasis on the industrial need, both qualitatively and quantitatively since a principal objective of this Project is to examine the scope and spell out the implications involved in the development of a viable soda ash industry. The Consultants feel that while salt for human consumption will continue to be primarily obtained from the existing "minuscule type" works with modifications suggested herein, nc modern large scale salt-based chemical industry can be established on the basis of presumed supplies from the existing salt works, without facing the prospect of crippling uncertainties of production and supply, high supply prices and indifferent, widely, varying qualities of supplied salt. At the same time, it is envisaged that reorganisation and rationalisation of the existing salt works, however urgent, is necessarily a long drawn process and considering the constraints and the large number of people involved, it may be necessary to adopt a policy of *festina lente* and allow the reform to move forward largely on its own steam.

Basis of the Industry

1.3 Most of the world's salt is in the oceans, and sea water, therefore, is an important source of salt manufacture, particularly in countries not favourably endowed with rock salt mines. Sea water contains an average of 3.3 per cent of salt, but the concentration varies from 2.90 per cent in the polar seas to upwards of 3.55 per cent near the equator. Much of the salt throughout the world occurs as sylvinite which is a mixture of sodium and potassium chlorides. Typically, at an average concentration of 3.5° Be[1] a litre of sea water may contain about 35 grams of solids and its probable composition could be as given in Table 1.2.

Table 1.2

Average Analysis of Sea Water
(At 3.5° Be)

	Grams/litre
$CaCO_3$	0.12
$CaSO_4$	1.44
NaCl	29.11
$MgSO_4$	2.34
KCl	0.72
$MgCl_2$	3.58
$MgBr_2$	0.05

1.4 World salt production has been steadily rising in recent years, though data on the production of solar salt separately is not available. The world's total production in 1977 was around 173 million tonnes compared to less than 100 million tonnes in 1964. The

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1/ Baume' hydrometer to measure density

Table 1.3

World Production of Salt

(Million tonnes of product)

	Production in			
	1964	1970	1973	1977*
U.S.A.	28.7	41.6	39.8	39.0
China	10.0	15.6	18.1	30.0
USSR	10.0	12.4	12.9	14.3
West Germany	6.4	10.5	8.7	12.6
East Germany	2.1	2.2	2.3	2.6
United Kingdom	6.7	9.2	8.4	8.2
France	4.0	5.7	4.8	5.8
India	4.7	5.6	6.9	5.3
Mexico	1.8	4.1	4.3	4.9
Italy	2.9	9.4	3.7	4.0
Brazil	0.7	1.8	1.9	2.5
Australia	0.6	2.1	3.7	5.0
Canada	3.6	4.9	4.8	5.9
Colombia	0.3	0.5	1.3	0.6
Netherlands	1.6	2.9	3.1	3.1
Poland	2.2	2.9	3.1	4.4
Rumania	1.8	2.9	3.3	4.5
Spain	1.9	2.1	2.0	3.2
TOTAL WORLD	99.3	134.6	147.7	172.5

Source : Statistical Yearbook,
United Nations, New York, 1977

*Estimated

U.S. is by far the largest producer of salt in the world (Table 1.3), accounting for about 23 per cent of the production, followed by China, the USSR, West Germany,U.K and India. China and India are believed to be the principal leaders in solar salt production. Despite large production bases, salt hardly accounts for any significant volume of international trade, - its bulk in relation to price being one of major deterring factors militating against transport over long distances. Besides, being a very basic need, every country has been, understandably, seeking to achieve atleast a measure of self-sufficiency in salt supplies.

Chapter - 2

BANGLADESH'S REQUIREMENT OF SALT

2.1 Salt is essential to life-of both human beings and animals - and, as mentioned earlier, provides the body's requirements of sodium as well as chloride. Apart from the dietary requirement, it adds taste to food and usually the total consumption of salt is much in excess of the body's real needs. The human body has a unique method of excreting (within broad limits) the excess salt consumed from the system and maintaining the concentration of salt in the body fluids to an equivalent of about 0.9 per cent solution of sodium chloride. There is thus a definite relationship between salt content and water balance of the body - a low intake of salt, for instance, causing loss of water. In hot and humid countries like Bangladesh, however, substantial quantities of salt are lost through the skin by sweating and therefore, the minimal intake of salt has to be higher than in the cold and temperate zone countries.

2.2 No scientific data on the minimum dietary requirement of salt for human consumption in Bangladesh is available. A household expenditure survey conducted by the Bangladesh Bureau of Statistics in 1973-74 indicated an average per capita consumption of 0.6 seer (or 1.2 lbs) for the country as a whole. Discussions with the Food Department of the Government of Bangladesh and the BSCIC, however, revealed that the civil supplies authorities in Bangladesh work on the assumption of a minimum per capital requirement of 6 seer (5.4 kg) per year. This probably covers consumption in all forms direct as well as indirect by way of seasoning, preservative etc. - and appears amply adequate from the point of view of nutritional standards. The actual per capital consumption worked out by the BBS, however, appears to be substantially higher, as may be seen from Table 2.1

Table 2.1

Estimated Per Capital Consumption of Salt

Year	Estimated Population (Million)	Salt availability for human consumption('000 te)	Per Capita consumption (kg)
1972-73	74.3	627	8.44
1975-76	79.9	677	8.49
1976-77	81.8	669	8.17
1977-78	83.7	706	8.44

Source : Bangladesh Bureau of Statistics

Though the figure of per capital consumption has been indirectly derived from 'total disappearance' of available supplies - assuming trade inventory to be constant - there is reason to believe that the apparent consumption as given above is fairly close to the actual consumption, since all through the country has been known to be 'passing through the experience of marginal scarcity rather than abundance of supplies in salt', and therefore, the 'disappearance' of supplies must have been due to actual consumption. In fact, the steady rise in the retail prices of salt between 1972-73 and 1977-78 from Tk. 8.39 to Tk. 1.61 per seer (1.72 to 3.55 per Kg) is said to reflect this feeling of scarcity, necessitating the maintenance of a public distribution system. Besides, since salt is fairly hygroscopic in humid climate, large stocks are not carried over from season to season except by the government agencies or other organised stockists. The most plausible explanation of the discrepancy appears to be that the BBS figures include consumption on account of livestock as well, since no separate figures of utilisation as cattlefeed are indicated.

2.3 The consumption of salt, as one of the basic necessities of life and accounting for an insignificant fraction of the household expenditure, is generally assumed to be highly inelastic in relation to both price and income changes. However, the Household Expenditure Survey 1973-74 of the BBS reveals that at very low income brackets salt consumption does rise significantly with income (Table 2.2). For instance, there is a significant jump in the per capita consumption of households as the income bracket jumps from 'less than Tk 50 per month' to the next (Tk 100 - 149) from about 0.36 seers to 0.58 seers. However, since this group accounts for less than 1 per cent in the sample, the impact of any income rise in this group on the total demand for salt is not expected to be material. For the major proportion of the households in the sample, however, the per capital consumption is nearly constant, and tends to rise only at top income levels, - reflecting probably the increase in the use of salt in non-direct consumption such as in preservative (e.g. pickles).

Table 2.2

Consumption of Salt by Different Expenditure Groups 1973-74

Expenditure Group by Monthly Income	No. of Household Members (Av)	Salt Consumption of per Household (Seer)	Per Capita Consumption (Seer)
Less than 50	2.55	0.93	0.36
50 - 99	2.79	1.42	0.51
100 - 149	3.37	1.95	0.58
150 - 199	3.86	2.16	0.56
200 - 249	4.22	2.37	0.56
250 - 299	4.71	2.89	0.61
300 - 399	5.25	3.12	0.59
400 - 499	5.98	3.56	0.60
500 - 749	6.87	4.27	0.62
750 - 999	8.23	4.92	0.60
1000 - 1499	9.98	5.87	0.59
1500 - 1999	10.91	6.72	0.62
2000 & above	10.80	7.21	0.67
All Groups	5.83	3.48	0.60

Source : Bangladesh Bureau of Statistics

2.4 Broadly, therefore, the per capital consumption of salt may be expected to remain fairly constant at the present levels in the reasonably near future though some slow rise on account of the general improvement in the standard of living is not unlikely, especially if the consumer prices of salt do not show any significant jumps. On this assumption, the total consumption demand for salt becomes directly linked to the population growth. The demand projections made by BBS (i) on the assumption of constant growth and (ii) with the adjustments for elasticity of demand are given in Table 2.3.

Table 2.3

Projected Consumption Demand for Salt

Year	Assumed Per Capital Consumption (constant) (kg)	Total Requirement on the basis of Constant Per-capita Consumption ('000 te)	Per capita Consumption allowing for Elasticity of Demand (Kg)	Total Requirement on the basis of Elastic Consumption ('000 te)
1977-78	8.44	706	8.44	706
1980-81	8.44	756	8.86	793
1985-86	8.44	840	9.49	943

Since, as mentioned earlier, the per capita consumption is assumed to include all consumption requirements including livestock feed, the figures given above may be assumed to represent the total consumption requirement for the country.

2.5 The projection of industrial demand for salt can only be very approximate, since it will depend on the assumptions regarding possible development of salt-based industries. But the very development of such industries may in turn depend on the assured availability of industrial grade salt. As discussed elsewhere in this section, the present supply base for meeting the industrial demand is not quite reliable; besides the salt quality is unsuitable and involves costly purification before use. The present industrial demand, according to the best estimates is around 93,000 tonnes.

2.6 The most important single user of salt for industrial purposes seems to be the BCIC - in the several industrial units controlled by it, e.g. the Karnaphuli Complex, Chemical Industries of Bangladesh, Sylhet Paper Mills, Crescent Paper Mills etc. Among the other principal users are : (i) the leather industries (ii) ice factories (iii) fish-curing industry and (iv) the soap factories. Though the industrial demand is likely to receive greater emphasis than hitherto in future, it will still constitute only a fraction of the demand for consumption. There are at present only 2 major proposals for industrial units involving large use of salt; the first is the soda ash plant discussed in this study. The other is a PVC production project where salt will be needed to produce chlorine. Taking into account the likely demand from these projects and the expansion of demand from the existing user industries the total industrial demand for salt is likely to be around 1,50,000 tonnes in 1980-81 and 3,00,000 tonnes in 1985-86. Thus, the total demand for salt in Bangladesh by 1985-86 is expected to be as under (Table 2.4).

Table 2.4

Projected Demand for Salt ('000 te)

Year	Consumption demand	Industrial demand	Total
1980-81	793	150	943
1985-86	943	300	1243

Chapter - 3

PRESENT STATE OF INDUSTRY

3.1 Bangladesh has a long tradition of salt manufacture from sea water and in the absence of any deposits of rock salt, the country has been dependent only on sea source in the early years. A combination of solar evaporation and forced evaporation processes, pretty crude by present day methods, known as 'lixiviation'[2] was practised in the coastal areas of Chittagong, Noakhali, Barisal and Khulna from time immemorial. While lixiviation has been largely replaced by the more economical solar evaporation process in the districtof Chittagong - the lixiviation method is still being practicsed in the districts of Barisal, Khulaa and Noakhali. Even in Chittagong, by far the most important solar salt producing district in the country, about 10 per cent of salt production is accounted for by this process (e.g. Taknaf and Ramu). The lixiviation process is a rather primitive production method, involving the use of high cost and scarce fuel and can at best produce small quantities of salt to meet the domestic requirements of the producers. Since the process involves separating the entire dissolved salts in sea water, it contains large percentages of impurities such as calcium and magnesium salts - considered unfit for human consumption in such large concentrations. That the lixiviation process is still practised on such a wide scale alongside solar evaporation in the face of growing shortages of traditional fuels

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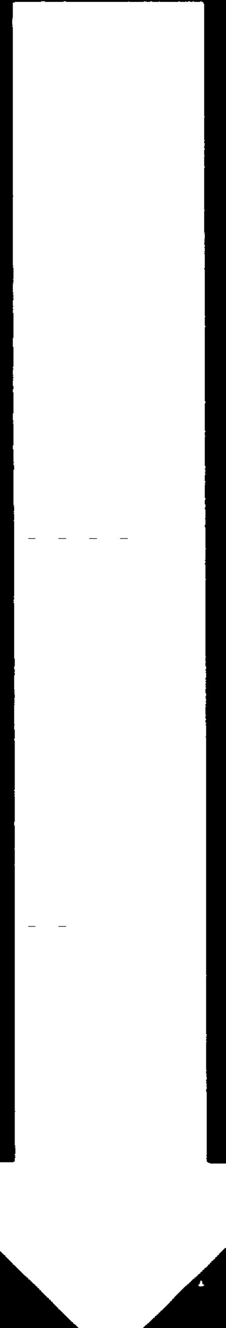
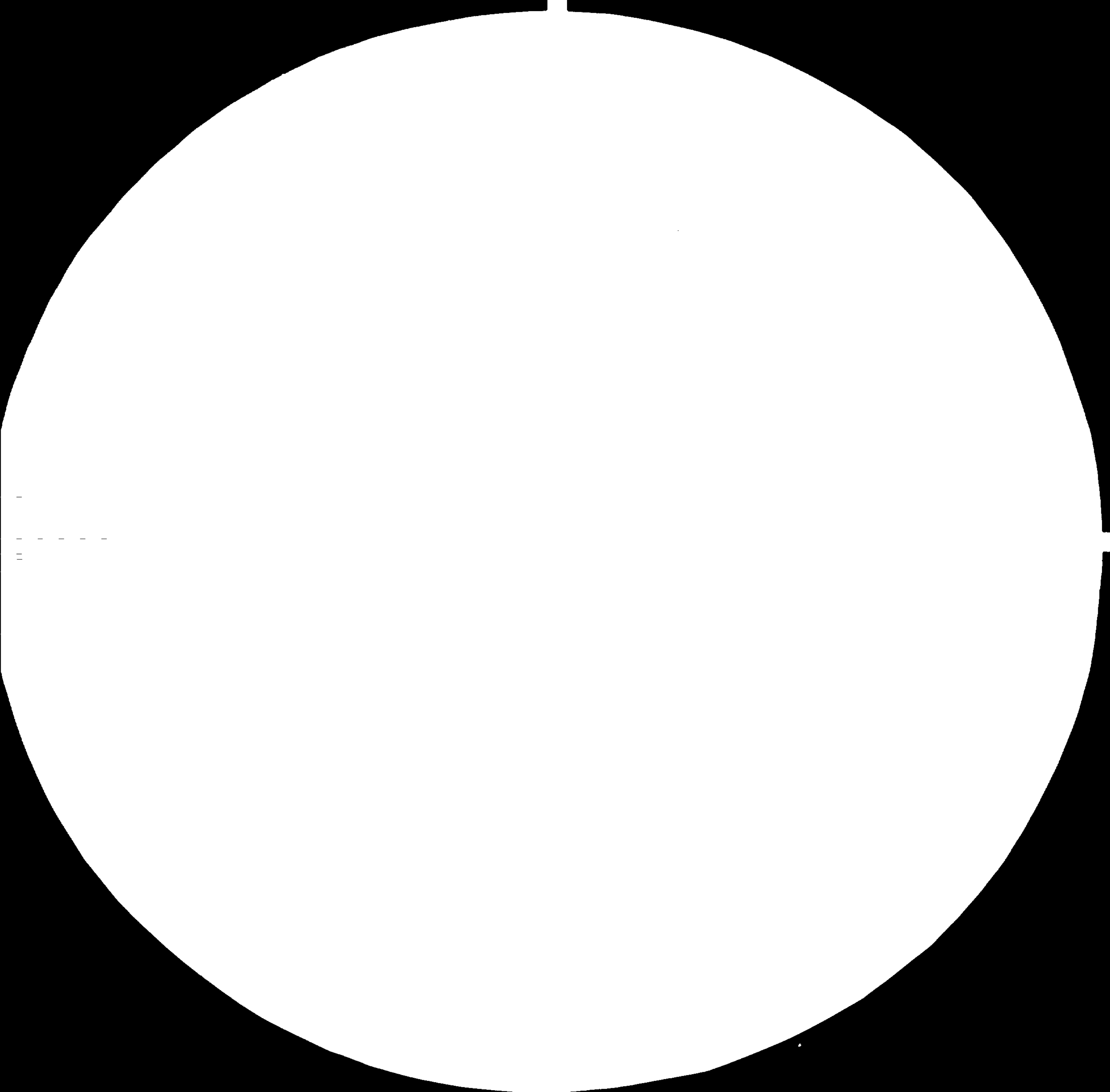
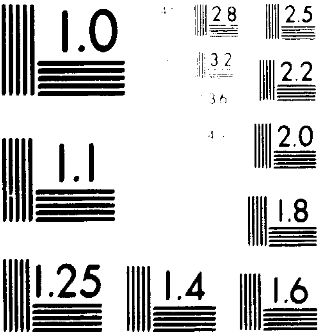
2/ The process involves scraping of the soil, on which high tides and subsequent evaporation had left a thin crust of salt, in the coastal areas and leach with fresh water until a clear solution is obtained by filtration. The solution is then evaporated by boiling to obtain salt crystals.







MICROCOPY RESOLUTION TEST CHART

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reflects in a way the state of the salt industry in Bangladesh. Since the total production by this process is not large,- around 16,000 tonnes or about less than 3 per cent of the total salt production in the country, and since its economic significance is negligibly small, this study does not take into account production by this method.

3.2 There is some evidence to indicate that the long tradition of imports of salt into the Bangladesh region deflected from adequate attention being paid to the organisation of salt industry on more efficient lines with the object of achievement of self-sufficiency. Until the partition of India in 1947 (when the territory now constituting Bangladesh was separated out as a wing of Pakistan), substantial quantities of salt used to be imported, initially from UK, but later on from Bombay and Madras (through Calcutta) and the local industry, with its low efficiency and high cost of production could not stand upto this competition. After 1947, Karachi largely replaced Calcutta as the major source of supply[3/] and if some attention was paid during this period to the reorganisation and development of salt industry in the Bangladesh region, it was only because West Pakistan itself periodically faced shortages and there were fairly frequent disruptions in supply lines due to the long haulage involved. With the growing awareness of the wastefulness of the lixiviation process and the cessation of firewood supplies for the purpose by the Forest Department, the solar evaporation process received a measure of support, especially since 1949, when some modern

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[3/] Salt Economy, a Study on the Economics of Production of Crude Salt in the Cox's Bazar Thana, by Kazi Ahmed Nabi and Dipak Kanti Dutta, University of Chittagong.

solar salt works were organised at Gomatali Mauza (Cox's Bazar Thana) of Chittagong district, with the help of an expert from India. The success of this pioneering effort led to the gradual spread of the solar evaporation process in Bangladesh and gave a boost to salt production. However, a serious attempt to attain self-sufficiency was made only after the country's Independence and several development measures, including withdrawal of excise duty, were initiated for the expansion of the industry.

Present Production Trends

3.3 Bangladesh presently (1977-78) has about 11,000 hectares (27,300 acres) of land under salt production (Table 3.1). The area has been showing some fluctuations - the lowest being 7600 ha (18,800 acres) in 1973-74 - primarily due to climatic conditions, but in recent years, generally there has been a steady expansion of the area, an acknowledgement that the Government's efforts to step up production within the country is yielding some results. The entire area devoted to the solar evaporation process is concentrated in just one district - Chittagong, along the eastern shores of the Bay of Bengal. A combination of more favourable climatological, physical and land availability conditions seem to explain this phenomenon - and for these reasons, future expansion of solar salt production will have to be largely confined to the Chittagong district. Even within Chittagong district, the Cox's Bazar sub-division accounts for the major proportion of the producing area.

Table 3.1

Area under and Production of Salt in Bangladesh

Year	Area (Hectares)	Actual Production (In Tonnes)	Yield (Tonnes/ Hectare)
1966-67	7,833	3,08,884	39.4
1967-68	8,318	4,40,462	53.0
1968-69	9,782	5,67,126	58.0
1969-70	9,591	5,58,463	58.2
1970-71	NA	3,21,720	-
1971-72	10,643	7,97,013	74.9
1972-73	10,634	7,11,758	66.9
1973-74	7,597	1,67,973	22.1
1974-75	10,793	7,61,797	70.6
1975-76	9,890	5,72,534	57.9
1976-77	10,623	4,51,661	42.5
1977-78	11,040	7,80,141	70.7

Source : BSCIC Salt Project Officer, Chittagong.

3.4 Despite the long coastline of over 480 Km (300 miles) the area suitable for solar salt production in Bangladesh is rather restricted on account of the heavy discharge of sweet water by the mighty river systems during a major part of the year, which brings down the brine density along the coast substantially. Along the deltaic region, the coast line is rather shallow, the average depth being not more than 5 fathoms (30 ft) at a distance of 5 to 10 miles from the shore. During the period Aug-Sept the Gangetic system alone is said to discharge about 5 million cft per second (about 88 cubic miles/month) of fresh water into the Bay of Benga[4/]. Then there are other rivers draining the Assam and Burma Hills which also discharge considerable volumes of water. Though the peak flow abates after the rainy season, the flow is still high enough to continue to keep the dilution high. By way of illustration, Table 3.2 gives the brine densities on select dates in the Noakhali and Barisal districts which form part of the Ganges - Brahmaputra delta. Little authentic data, however, is available on variations in brine densities between regions and seasons, but it appears from available information that dilution by and large is a localised phenomena extending to some distance from the mouths of the rivers.

Table 3.2

Brine Densities in Noakhali & Barisal Districts-1949

	Area	Date	Density in Be'
1.	Noakhali (Meghna mouth)	Feb 6	1.5
2.	Barisal steamer-route between -		
	a) Chandpur - Barisal	Feb 15	0.0
	b) Patuakhali-Gala Chifa	Feb 28	1.5
	c) Galachifa - Kalapora	Feb 1	1.5
3.	Bolligerkhal	March 1	0.0
4.	Shibbarca	March 3	1.0
5.	Kuakata (Bay of Bengal)	March 3	1.5

[4/] Salt & Related Chemicals in East Pakistan; W.L. Badger Associates Inc.; 1965

3.5 The Chittagong coastline from the mouth of the Karnaphuli river upto Teknaf is, however, relatively free from this "dilution effect" caused by river flows and by and large the sea water densities have been found to be fairly stable except during about 4 months of peak rainy season.

Data indicates that from November onwards, the density starts rising from about 2°Be' to 3.5°Be' (Tabie 3.3).

Table 3.3

Seasonal Brine Density Variations in Cox's Bazar

Month	Density ($^{\circ}$Be')
15th November	2.0
1st December	2.2
15th December	2.4
1st January	2.7
15th January	3.0
1st February	3.3
After 15 February	3.5

Likewise, the major off-shore islands of Kutubdia and Maishkhal are not particularly affected by the dilution caused by sweet water discharges of the rivers and therefore only the rainfall causes the major disturbance. Hence, from the point of view of brine density, the areas most suitable for solar salt production are Banshkhali, Chakaria, Cox's Bazar Thana areas along the coast and the offshore islands of Maishkhal and Kutubdia. These sub-regions in fact account for almost the entire area under salt production in the country.

3.6 As mentioned earlier, Bangladesh had never been self-sufficient in salt and imports had been practically a regular feature. Table 3.1 shows the yearwise production for recent years and Table 3.4 gives the imports.

Table 3.4

Import of Salt into Bangladesh

Year	Imports (In '000 tonnes)
1972-73	26
1973-74	-
1974-75	77
1975-76	22
1976-77	55
1977-78	60

Source : Bangladesh Bureau of Statistics

Only in a very recent year, a kind of 'notional' balance between production and demand has been established and imports have been largely used for building a bufferstock, which is intended to even out the effects of the year-to-year fluctuations in output, caused primarily by the yields. The flucutations in yield sand production are principally due to climatic factors. In a sense, salt 'cultivation' in Bangladesh, like crop production, is a gamble on weather. The effect of unseasonal rains could be disastrous for production, as it happened in 1973-74, when heavy rains in March resulted in production declining by about 76 per cent. Extension of monsoon could also lead to reduction in the length of the production season. Cyclones and tidal forces could equally cause havoc with production and the infrastructures built for the purpose. As the Table shows, the best year's production so far has been in 1971-72, when about 10,600 hectares of salt lands produced nearly 800 thousand tonnes of salt 5/ giving a yield rate of about 75 tonnes per hectare. During the last five years (preceding 1977-78), a comparable, though lower marginally, volume of production has been achieved only in 2 years out of five and in three the production was substantially lower. In the best among the 3 bad years, vis. 1975-76, production was as low as 573 thousand tonnes - a decline of about 28 per cent compared to the peak of 1971-72.

Scale of Production

3.7 Salt manufacture is presently undertaken on a very tiny scale, which can hardly permit efficient production operation even under Bangladesh conditions

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5/ Strictly speaking, production statistics of salt as given in Bangladesh are somewhat misleading. Though the figures are said to relate to crushed and washed salt, it has been seen that they contain quite a high percentage of clay and other marine salts, such as calcium sulphate, magnesium sulphate, potassium salts etc., which are allowed to crystallise out with sodium chloride. The best quality of salt purchased by Karnaphuli Paper Mills had only 95 per cent of NaCl.

A survey conducted by the University of Chittagong[6], sometime ago in the Cox's Bazar Thana revealed that about 65 per cent of the producers had less than 2 acres (0.8 ha) each and only 5 per cent had 5 acres and above. A scientifically based design and layout of a salt farm is hardly possible on such tiny plots and to a large extent low yields and the general production inefficiency could be ultimately traced to this factor. The survey also revealed that the average cost of production of crude salt declined by 50 per cent as the size of the plot increased from 1 acre to 5 acres. The Consultants are of the opinion that even for a country like Bangladesh, the minimum economic size of land required for a salt unit should be about 20 hectares (50 acres).

3.8 The tiny scale of salt fields in Bangladesh might have something to do with the land - ownership pattern, but possibly it might also have been due to the fact that salt manufacture was visualised essentially as a 'cottage' industry, rather than as an 'industry'. Most of the available land developed for salt cultivation (such as those with protective embankments) is said to be in private hands and there seems to be a ceiling on land holdings by private owners. A survey report of the BSCIC showed that of the total land of 2650 acres (1073 ha) available for salt cultivation in theGomatali area, 2078 acres were in private hands Similarly, in the Chaufuldandi Thana in the same year out of 1736 acres about 1600 acres were private holdings. On a rough basis, it is estimated that private lands accounted for about 84 per cent of the total salt area. Private owners preferred to lease out their lands in small plots, since generally the producers did not command adequate capital to organise production on a bigger scale and therefore the risk element involved in realizing the extortionist rent was lower. The availability of land in small manageable plots also

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[6] Salt Economy : Ibid.

created keener competition among the prospective producers to bid for land and permitted the land owner to get a higher rent. The average rent demanded is said to be presently around Tk 4000 per acre/season[7/], compared to around Tk 1000 in 1970-71 and the lease rent of Tk 30 per acre charged by the Government for its 'Khas' land. Probably for fear of attracting the provisions of the land tenurial regulations, the land owners often did not allow the producers to lease the same plots for a long period, and as a result, the producers did not get an opportunity to develop the field even on semi-permanent basis. In the case of Government 'Khas' lands also, the present system allows leases only on an annual basis and as such no long term development of the plots is possible. On a rough estimate, only about a third of the producers are believed to be owners of the land they use. The exorbitent rent charged for most of the land, combined with the small scale of production appeared to account for the rather high cost of production of crude salt in the country, with the rent alone accounting for close to 40%. Since the organisation of production was severely limited by the scale of operation and the general lack of capital for investment, the producers have little holding power, and therefore, they are often victims of exploitation in marketing as well. The 'Dadan' system (money lending against promised delivery of produce) is said to be widespread.

Existing Process

3.9 Essentially, the method followed in Bangladesh for solar salt production is about the same as in the solar evaporation process practised the world over

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[7/] BSCIC : Production of salt under supervision of BSCIC and by Food Department during 1977-78: Mimeographed.

At the time of high tide brine spreads over a low area and then enters a distribution canal which is used as reservoir by individual producers. From the reservoir canal, brine is bucketed manually, usually by two men using a sling type container ("Shichayin") or lifted with a counter balanced wooden trough ("Donkin") into the first concentrating ponds. (Drg No VI A-2) Generally, there are four concentrating ponds, the size of each pond being roughly about 20m x 10m though there are no standard sizes, and each individual producer uses his own experience. At this stage, the density of brine in concentrating ponds may be around 2.0° to 2.5° Be'. The brine remains stagnant for 3 to 4 days in each pond in a shallow depth of less than 5 cm, the brine being transferred from one pond to the next either by gravity flow or by manual lifting, depending on the topography. In these concentrating ponds the brine is exposed to evaporating action of the sun and wind until the density gradually increases in successive ponds. An important aspect of the management of the process involves the control of the flow of brine through successive ponds so that concentration rises in stages. After passing through the concentrating ponds brine is led to a row of crystalliser pans called "salt ponds", which is again devided into 4 compartments each of about 5 m x 10 m approximately Prior to each charge, the bed of the crystallizer pan is consolidated by rolling a light wooden roller of about 100 kg weight. The concentration of brine in the successive ponds is achieved by allowing the brine to remain stagnant for 3 to 4 days depending on the weather and checked at the end visually. The Consultants did not come across, during field visits, a single instance where the producers used a Baume' hydrometer for measuring the density of brine, even though it is one of the inexpensive instruments which can make a decisive difference to the manufacturing process. In the solar evaporation process, precision control of brine strength at different stages is essential to separate out the other salts e.g. Ca and Mg, and therefore, the Baume' hydrometer constitutes an essential equipment. During the visits to the production centres, the Consultants noticed that often weak brine of less than 20° Be' was charged into the crystallizer pans, which results in $CaSO_4$ crystallizing out along with NaCl in the crystallizer pans themselves, instead of separating out in the last concentrating pond. The producers themselves did not seem to care much for separating out calcium sulphate, since it added to the weight of the crude salt and gave them an advantage.

The depth of the concentrated brine in crystallizer pans is kept less than 3 cm and brine is evaporated in the pans to complete dryness, instead of the bittern being discharged at 29° Be'. After drying, the thin film of salt (less than 5 mm thick) is harvested. The total production cycle takes about a week. The harvested salt is very dull in colour and contains all the impurities. The preparation of the pans, harvesting etc. are done entirely manually.

Marketing

3.10 The salt harvested in the farms is not directly edible and contains, apart from other crystallised impurities, some 20 per cent or so of silt, though some farms, more scientifically worked, produce much better qualities. There is thus another important link in the chain between producers and consumers, viz. the salt crushers, whose function it is to clean this salt. The crude salt collected from the field by the producers generally is sold either to the buying agents of the salt crushing units or to the middle men who specialise in buying crude salt from the producers and selling to the crushing units for a difference, often carrying the product in their own boats. Occasionally, the producers transport the salt themselves and sell to the crushing units directly. Transport of crude salt is done invariably in sail boats (sampan). Loading and unloading is done manually in bamboo baskets. Storing till the produce is disposed of is usually done in shallow ditches situated near the crystallising pond, where it is exposed to the hazards of rain. There are hardly any proper godowns for storage of crude salt, and partly on account of their weak holding capacity and partly due to lack of proper storage facilities, the producers are often in a hurry to dispose of their production. This makes them vulnerable to exploitation by the buyers, and as a result, the producer prices are usually only a fraction of the price the salt finally gets in the wholesale market.

3.11 The crushing units, as pointed out above form an important link in the marketing chain. They buy salt from the producers, wash them and crush them to get clarified salt, and sell to the wholesalers. This washing and crushing involves washing witn brine in a rotating cage once or twice and piling for draining. The dry salt is then crushed along with brine for further breaking the large crystals and washing out the dirt lodged within. The washed salt is dumped into a heap for storage till disposal. The crusher consists of two mild steel rollers moved by a motor or an oil engine. The equipment used is pretty primitive and investment is low. The entire operation appears crude and unhygenic. The brine drained out is used again and again, and sometimes carried over to the next season in tanks covered with wooden planks. Periodically the settled dirt in wash-brine is drained out. With the washing, the salt acquires a dull white colour and the purity substantially improves. But the co-crystallised impurities such as Ca and Mg salts largely remain. The loss in washing and crushing is estimated at 20 per cent, mainly due to removal of clay. The crushing units are mostly located in Chittagong city and neighbourhood (e.g. Indrapole, about 10 miles from Chittagong) and near Dacca. There are an estimated 150 crushers in the country, each with annual "capacities" varying from about 500 tonnes/year to 5000 tonnes/year.

3.12 Solar salt production evidently can be carried on only in the dry season. The length of the production season, therefore, is largely determined by the length of rainy season, which is Bangladesh generally extends from middle of May to end of Sept. On an average, the salt producers can count on about 180 dry days per year only. However, under the existing system of production, the producers do not seem to be able to make the best use of the dry season, which explains to some extent the low yields. During the field visits to the salt farms, the Consultants were informed that the production generally started in late December or early January, though the weather is generally favourable from early November. The major difficulty in the way of early commencement appeared to be that most of the ponds are still under water in November and land preparation takes quite some time. For instance, the low dikes around the ponds usually are practically completely destroyed during rainy season, and the first job of the producer, each season, is therefore, to rebuild these earthen embankments and dikes, besides levelling the ponds, digging the channel,drying the crystallizer beds etc and rebuilding the field layout generally. Most producers do not get lease of lands until the season actually starts, as the land owners prefer to lease land only on an annual basis and try to hold back until the very last to secure the best possible terms. Usually, negotiation of loans and advance rent demanded by the land owners (usually 50 per cent) also involves wastage of production time.

Most of these construction activities involves considerable coordination with other producers in the same area, since some of the facilities are enjoyed in common and therefore normally no individual producer can start production until all are ready. Table 3.5 below gives average actual production season in Bangladesh for some recent years and the length of the season that could have been worked, in the opinion of the Consultants.

Table 3.5

Actual and Possible Length of Production Season

Year	Avg. no.of days actually worked	No. of days could have worked	Possible increase in production
1973-74	130 days	160 days	20%
1974-75	160 days	180 days	15%
1975-76	140 days	170 days	20%
1976-77	140 days	180 days	25%

Labour Requirements

3.13 The entire salt industry, as practised in Bangladesh is highly labour intensive, and involves little capital investment. As such, it is particularly suited to the country with surplus manpower and few opportunities of employment. Except for the initial investment on physical infrastructure such as dikes, embankments and shelters and for some simple implements such as troughs for lifting water and implements used for earth work, hardly any capital investment is involved in the manufacturing process. Even brine density is measured, albeit quite roughly with the help of a bamboo implement locally developed by the producers themselves, or, more widely, by the 'rice-floatation' test. Though no reliable statistics are available, on a rough basis, it is estimated that the total number of about 30,000 solar salt units in the country engage in all about 130-140 thousand persons per season in production alone.

3.14 The only segment of the industry which is somewhat mechanised albeit crudely, and therefore involves some capital investment, is the 'crushing' industry. Though for the most part housed in thatched sheds and practically the entire range of work such as feeding, straining, heaping, weighing and packing in jute bags is carried on manually with the help of only bamboo baskets, a unit nonetheless involves the installation of a motor (if power is available) or a diesel engine (eg Indrapole) as impellers and a set of roller-crushers to crush the salt. Some of the bigger units are also housed in masonry structures. Since the industry is operated seasonally, for near-about half the year the establishment is entirely closed.

Pricing

3.15 Salt, being an article of food, is presently covered in the public distribution system, like food-grains and sugar. However, it is also simultaneously traded freely in the market, where the prices may be higher than in the ration shops. The Government procures and stocks salt from the producers/crushers for feeding the public distribution system and for replenishing its buffer-stock. The Government also uses imports for procuring supplies when the indigenous production fell short of the demand.

3.16 As a measure of encouragement to producers, the Government fixes, prior to the commencement of every season, the minimum support prices for salt, as in the case of paddy. The Food Department undertakes to purchase any quantity offered by the producers at its storage godwons at this support price. Presently (1978-79), the support price is fixed at Tk 30 per md of washed salt (Tk 810/- per tonne) and Tk 15 per md (Tk 405/te) for crude salt. In practice, however, the support price is not quite effective and salt was found to be selling freely at prices much below the minimum support prices. It appears the crushers have become the greatest beneficiaries of the support price. Earlier, the Government is said to have tried to procure crude salt directly from the producers but the experiment seems to have failed. Now the Government has found it easier to procure the washed salt from the crushers at fixed prices, though in the process, the concept of extending price support at the producers' level seems to have become a victim. The crushers purchase crude salt generally at prices substantially below the minimum and sell to the Government washed salt corresponding to the support prices of Tk 30 per md.

Finance

3.17 Apart from land, finance appears to be the biggest bottleneck in the organisation of production. Being largely an unorganised industry, the producers hardly receive any assistance either for investment or working capital from the banking sector. The role of cooperatives is even smaller. Few producers own adequate capital on their own to finance production. Since initial capital requirements to start production - for payment of advance rent, advance wages to labour, renovation of layout, erecting temporary huts etc., - is proportionately quite high, almost all producers resort to borrowing from money - lenders or potential buyers at exorbitant interest rates. The survey conducted by the University of Chittagong in the Cox's Bazar Thana area in 1976 showed that the interest rate during the season averaged 121 per cent per annum. Near about 60 per cent of the producers are presumed to take advances under the 'Dadan' system, contracting to deliver the produce at predetermined prices on harvesting. The Government through the BSCIC has been making attempts to make available loans, but the scheme has turned out to be largely ineffective, since few producers are covered under the existing procedures and the loan is too small to be effective (Tk 500/- per acre). More often than not, it is not available in time. The financial stringency often drives the producers to resort to sub-optimal production methods to expedite harvesting and marketing, leading to an overall reduction in yield. It is thus said that in some cases, the producers lower the brine depth in the concentrating and crystallizing ponds in order to shorten the production cycle and expedite harvesting.

Government's Role

3.18 Salt industry has been a charge of the Bangladesh Small Industries Corporation (later Small and Cottage Industries Corporation - BSCIC) right from the early 1960's, which naturally tried to organise the units on a 'cottage' industry scale. This probably explains the lack of any serious effort to reorganise production on more economic lines, which would have involved larger, commercially viable, units. Even as late as in 1976-77, the

BSCIC was distributing Government 'Khas' lands in plots too small to be worked viably on modern lines. Apart from distribution of Government lands for salt production for some years and distribution of production loans, the main development effort of BSCIC consists in running a model demonstration salt farm at Lemshikhali on the Kutubdia island, off the Chittagong coast. The farm extends over a 100 acres, of which 80 acres have been developed for salt production. This is the only salt unit in Bangladesh where a pump is used to draw brine to the reservoir, thus avoiding the need for dependence on tides for replenishing the brine supply. However, judging from the production record, the unit can hardly have much 'demonstration' effect on the industry; with a production of 1000 tonnes in 80 acres during 1977-78, the yield was lower than what some private producers could obtain. In fact BSCIC itself cannot claim to have much of expertise on solar salt manufacturing industry and what expetise it has acquired over the years appears to be from countries with totally different climatic and production conditions and therefore, not of much relevance to Bangladesh. In the Consultant's view, both the design and working of the demonstration unit leaves much to be desired. The ratio between the area of crystallizers and the area of the reservoir plus the condensers is not quite appropriate, being less than 1 : 5, whereas for Bangladesh conditions, the ratio should have been at least 1 : 8. No data appears to be available with the unit on the reduction of the volume of brine at different stages of concentration, which is necessary for determining an optimal layout for the farm. It is found that the unit's reservoir is filled to a depth of 50 cm, which will hardly permit proper brine concentration through evaporation. The circulation given to the brine in the concentrating ponds is also straight rather than in zig-zag curves to give it more travel length and scope for more rapid evaporation (See Drawing No. VIA-3). The concentrated brine is allowed to evaporate to dryness in the crystallizer pans, instead of bitterns of 29°-30° Be' being discharged out to prevent contamination of salt with impurities of Mg etc. The farm layout does not provide for roads for approach and transport of salt economically. The unit seems to have tried the 'accretion' system of Australia without much success and now appears to be experimenting with alternative methods.

Chapter - 4

IMPROVEMENT OF EXISTING WORKS

4.1 Evaporation is the chief activity involved in solar salt manufacture. As is well known, evaporation is influenced by several factors such as temperature, rainfall, humidity, wind-velocity, the size and shape of water surface and the density of brine. The temperature best suited for solar evaporation is above 10°C and is Table 4.1 shows Bangladesh (Chittagong) has a temperature range of between 7.2°C and 38.9°C. For only 3 months in a year (Jan-Mar) the minimum temperature goes below 10°C, but even in those months the maximum is above 31°C. Except for about 5 months in a year, the duration of bright sunshine hours exceeds 8 hours per day going upto 9.5 hours. Hence the salt producing areas in Bangladesh have a climate suited to the solar evaporation process. Ideally, the industry is best suited to a country with little rainfall and with most of it concentrated in a brief period as the rain interferes with the production, not only by raising the humidity (thus decreasing the rate of evaporation) but also by diluting the concentrated brine and washing out the earthen embankments in thefields. As mentioned earlier, the Chittagong district (Drawing No. VIA-4) of Bangladesh (Cox's Bazar) has an average annual rainfall of around 110 inches (2800 mm), but it is spread over nearly five months between mid-May and mid-October (Tables 4.2 and 4.3 & Drg. No. VIA-5). On the basis that occasional showers not exceeding 20 mm (0.8 inches) per day will not interefere with the manufacturing operation materially, the number of days that solar salt manufacture can be undertaken in Bangladesh is about 180. Regions of low humidity are ideal for the location of solar salt

Table 4.1

Temperature Range in Chittagong District

Month	Temperature in °C		
	Maximum	Minimum	Average
January	31.6	7.2	19.9
February	33.9	7.8	23.6
March	37.2	10.5	25.6
April	38.9	15.0	27.7
May	36.6	18.3	28.3
June	36.6	20.0	27.8
July	34.4	19.4	27.5
August	33.9	22.2	27.6
September	35.0	21.6	27.8
October	34.4	16.6	27.3
November	33.9	11.1	24.1
December	31.1	8.3	20.7

Source : i) Climate of Asia

ii) Report on Chittagong Urea Fertilizer Project Vol. III, 1978.

Table 4.2

Rainfall Data (District Chittagong)
(1966.4 - 1977.12)

Months	Monthly Rainfall (mm)		
	Maximum	Minimum	Average
January	29.2	0.0	6.6
February	56.4	0.0	14.5
March	107.7	0.0	26.9
April	535.4	44.2	177.5
May	466.1	64.8	220.2
June	1472.2	209.3	577.1
July	1009.1	372.6	712.5
August	1086.9	130.6	516.1
September	403.6	54.4	259.1
October	351.5	45.0	185.2
November	252.7	0.0	96.8
December	79.8	0.0	12.2
			280.47

Source : Hydrological Year-book of Bangladesh
(for Data of 1966.1 - 1975.3) ;
TECON (for 1975-1977).

Table 4.3

Rainy Days - Chittagong District
(1966.4 - 1977.12)

Month	Numbers of Rainy Days, Average (mm)				
	2.5	10.0	25.0	50.0	100.0
January	0.5	0.3	0.1	0.0	0.0
February	0.8	0.6	0.1	0.1	0.0
March	1.7	1.0	0.3	0.0	0.0
April	6.4	4.5	2.4	1.0	0.2
May	8.7	6.5	3.2	0.9	0.1
June	14.7	10.8	6.9	3.1	1.2
July	18.5	12.7	8.2	5.5	1.5
August	17.6	11.6	6.8	2.8	0.7
September	11.7	7.0	3.6	1.5	0.3
October	6.6	5.2	2.6	1.2	0.2
November	2.9	2.2	0.9	0.7	0.3
December	0.5	0.4	0.2	0.1	0.0

Source : Hydrological Year Book of Bangladesh
(For data of 1966.4 - 1975.3) and
TECON (for 1975-1977).

Table 4.4

Humidity Range (Chittagong District)

Month	Humidity % age	
	8.00 hrs.	17.30 hrs
January	81	58
February	76	58
March	76	65
April	78	71
May	79	71
June	84	83
July	87	85
August	87	85
September	86	84
October	85	78
November	84	71
December	85	68

Source : Climate of Asia

Report on Chittagong Urea Fertilizer Project, Vol. III, Nov. 1978.

works, and evaporation practically ceases to take place when the relative humidity exceeds 80 per cent. The Cox's Bazar meteorological observations indicate (Table 4.4) that except for the five months period May to September, the mean humidity remains fairly below 80 per cent. Evaporation rate increase with windspeed upto a certain value and the wind velocity in the coastal region of Chittagong districtis quite high - between 39 Km and 4.5 Km per hour (Table 4.5). The areas exposed to evaporation can be manipulated in the design of the brine evaporating system. As already seen, the density of the brine in the coastal region along Cox's Bazar generally remains high. Thus, the major conditions required for successful practice of the process generally exist in the main salt producing region of Bangladesh.

4.2 Next to climate, the most important factor to be considered for the viable operation of the industry is the availability of adequate land with impermeable soil and suitable location. As the process involves the use entirely of solar energy for the evaporation, a large surface area is required to expose the brine to the sun for concentrating. Hence the solar salt process is necessarily land intensive. Normally, however, it uses land not preferred for other uses on account of high salinity. The land has to be reasonably flat to permit a proper layout which will allow the brine to move by gravity flow from one section of the field to another. Proximity to the brine source is another consideration which needs to be given

Table 4.5

Average Wind Velocity Chittagong District

Month	Average Wind Velocity in Km/hour	
	Maximum	Minimum
January	10.5	5.4
February	12.5	6.4
March	21.6	11.1
April	34.2	17.6
May	23.3	15.7
June	35.6	18.3
July	39.6	20.4
August	35.1	18.1
September	25.5	13.1
October	10.7	5.5
November	12.1	6.2
December	8.7	4.4

Source : Climate of Asia.

weight. The soil should preferably consist of fine particles of silt and clay, so that the bed becomes impervious and holds the brine without seepage losses. Experience has shown that for crystallizer beds the permeability should be below 10^{-3} cm/hour. The Consultants' study in Bangladesh has convinced them that large areas of present salt lands conform to these specifications.

4.3 If in spite of these favourable conditions, the salt manufacture in Bangladesh has not developed on sound lines or displayed a vigorous growth, the fault seems to lie in some of the critical short-comings of the industry. Starting from practically the same base, the solar salt industry has made conspicuous progress in the neighbouring country of India and the expansion of the industry in India's east coast, where the physical conditions are nearly identical to that of Bangladesh has been fairly vigorous. Apart from the State undertakings, many private units are also reported to be working , on sound commercial lines in this region. The average yield is reported to be between 30 and 35 tonnes per acre, compared to about 20 in Bangladesh. In the Consultant's view it will not be a difficult task for Bangladesh to reorganize its solar salt industry and place it on a sound footing, where it can expand to meet the country's growing demand for salt, if the Government of Bangladesh could take some hard policy decisions on the future growth lines of the industry and pursue it with determination. Unless these decisions are taken, the industry will tend to languish at the existing level and the country's hope of self-reliance in salt may largely remain, considering the growth in population and demand for salt in industry, a fond hope.

4.4 The most striking problem of the industry, in the Consultant's view, is the organisation of salt units in uneconomic holdings. As shown earlier, nearly about half the numberof units are of less than one hectare each and only one per cent had plots of more than 2 hectares (5 acres) each. Whatever be the strength of the case for small units in the country in other sectors, in salt production the working of the independent 'tiny' units has been pretty disastrous from thepoint of view of production as well as the long-term viability of the industry. Salt production has most of the featuresof cultivation with some features of a modern industry and the economic case for minimum holdings as well as the technological case for minimum size both are applicable. As emphasised earlier, the solar salt process is land-intensive, and it will be impossible to develop a scientifically based lay-out on such minuscule plots as half to one hectare in size. To be able to evaporate the brine to proper viscosity a minimum surface flow needs to be ensured and to obtain the salt crystals by natural evaporation a certain minimum area for crystallisation to take place is required. A certain optimal ratio also needs to be maintained between the different components of the salt farm such as reservoir, condensers and crystallizers. The farm needs to incorporate provisions for discharing out the bittern, without which the injurious impurities cannot be separated out. In a small unit, a significantly higher proportion of the area is devoted to embankments and bunds separating the different compartments and the area effectively available for production proper will be smaller still. With the uneconomic rate of production and subsistance level of operation, a salt producer is in no position to adopt the experience of science or introduce even well-established improvements in technology. Mention has already been made of the unfamiliarity among nearly all the producers with such inexpensive tools as Baume' hydrometers for density check. In nearly all salt works, brine is lifted manually and the producers are in no position to install pumps for the purpose. In fact, several expert committees of the predecessor government of Bangladesh have pointed out that the salt produced in the country was unfit for human consumption, and if over the years no improvement in salt quality has taken place, the explanation lies in the size of units and the producers' inability to implement even badly needed improvements in their holdings and manufacturing methods.

4.5 The first step in the direction of reorganisation of the industry on economically sound lines will involve a recognition on the part of the government that salt manufacture is not a "cottage" industry, but an 'industry' subject to the technological laws of indivisibility like any other industrial unit and the formulation of policies appropriate to such a concept. This will bring about in its train a complete change in the Government's approach to the industry eg. as regards incentives, provision of bank finance and priorities in allotment of land and other scarce resources. An impression appears to have gained ground in the country as a consequence of some Government measures in recent period that salt manufacture is less important compared to say, an export-oriented industry such as shrimp cultivation; on the contrary, one would expect that as a basic food industry as well as in terms of import substitution effort, salt industry should normally enjoy high priority, and it appears necessary, therefore, that the Government correct this impression at the earliest to ensure proper attention being paid to salt manufacture.

4.6 A second major step will involve Government's land use policies, both in regard to the use of land in private hands and the allocation of 'Khas' lands. Most of the land suitable for salt cultivation in the Chittagong district's coastal line seems to be in private hands and not all such lands have been developed for salt cultivation. Even the land presently used for salt production appears to have been indifferently developed in most areas, to the detriment of production as a whole. It was found in many areas that protective embankments do not have sluice-gates to let in brine during tides and salt fields do not have proper drainage systems. Levelling and layout is not based on a proper contour survey to make maximum use of gravity flow, necessitating lifting of brine from one section to another with manual labour. No tide tables are available in relation to even major salt production areas. The practice of private land owners parcelling out the land in uneconomic plots for short-term (annual) leases is probably the worst feature of the present system.

4.7 The Government, therefore, will have to take steps to ensure, if necessary, through legislative measures, that land suitable for salt cultivation is really put to salt production and that best use is made of such land. As the consumption of salt picks up in future, both as a consequence of the rise in population and as a result of increasing industrial demand, the requirement of land for salt production will tend to increase even if allowance is made for a rise in per acre yields, if the objective of self-sufficiency is to be sustained. In a country where the pressure on available land is severe, it may be necessary to conserve suitable areas for salt production more or less on the lines of reservation of areas for forests by the Forest

Department. The Consultants are of the opinion that under Bangladesh conditions, this is best secured through the establishment of a Salt Development Corporation (SDC), the details of which are given later in this Study. All land considered suitable for salt production in the Chittagong district and related islands, identified through proper survey, should vest in this Corporation, which should acquire even private lands falling in this category. The acquisition of private lands will be necessary for two reasons; first, most land identified as suitable is already privately-owned, and according to indications, available Government 'Khas' land for salt production is not substantial.. Thus a BSCIC report says that out of the 12,000 acres of unused 'Khas' land in the Cox's Bazar Sub-Division, identified as being suitable for development of salt cultivation, about 7000 acres were with the Forest Department under forest reserves and a part of the balance is being allotted for shrimp cultivation. Secondly, in some areas, where the entire land may be needed to be developed as a single unit, a part of the land might be in private hands and part in Government, and the area development approach may not be possible without single ownership. It will be responsibility of the SDC to develop the areas on scientific lines and keeping for itself some suitable plots for establishing model demonstration-cum-commercial farms, lease out the rest of the land in appropriate economic units for private cultivation, the existing landholders/cultivators being given preference in such allotment. While what constitutes an economic unit should be the subject matter of an expert study with adequate data-base drawn from Bangladesh, the Consultants feel that it should not be less than ten hectares. In India, 20 hectares is considered the minimum holding for viable operation, and there are salt works as large as 2000 hectares. The SDC should also have the powers of supervision to ensure that salt cultivation takes place in accordance with the model guidelines framed by it, e.g. preventing fragmentation of land, keeping the area fallow without valid reason, sub-leasing etc. Pending development of this machinery, the least the government can do is to regulat the leasing of land by private owners in accordance with the best interests of long term production and restrict the rent charged from the leaseholders to reasonable levels.

4.8 The Consultants recognize the dislocation that the proposed reorganisation into larger, economic, units might cause to existing producers. But the effect of such dislocation could easily be exaggerated. In any case, most of the existing producers live from season-to-season with no security regarding allotment of land under the present system, which remains entirely at the discretion of the landowners. As indicated earlier, more often than not, the landowners do not engage the same producers for long. The net return of the producers, after payment of extortionist rent and wages, interest, etc. is not strikingly different from that of the labourers. According to one study, the average cost of production of salt on private land in 1976 worked out to Tk 12.69 per md, whereas the average selling price was around Tk 13.66 per md. Thus with a yield of 633 mds/acre, and a holding of 12 acres, a producer could earn a return of Tk 1308, compared to a labourer's cash wages of around Tk 1700 per season. With the development of new salt areas, the SDC might able to resettle most of the displaced producers in new areas. In any area where the problem appears specially acute, a cooperative farming system-with most of the infrastructural facilities such as reservoirs and concentrating ponds commonly owned, but with crystallizers individually owned - could be evolved.

Production Methods

4.9 Mention has already been made of the several aspects of the production process which, by modern standards, are considered sub-optimal. The WAPDA has constructed embankments along the sea-shore in most areas of Bangladesh to prevent soil erosion. (Table 4.6 and Drawing No . VIA-6). Wherever the WAPDA embankments exist, they help the salt works located within from getting flooded during high tides and cyclones. But these embankments rarely provide for sluice gates for facilitating intake of brine by the saltworks into the reservoir or rainwater discharge outlets. As a result, the producers do not get assured brine supply throughout the season and in many cases brine may have to be lifted from canals. Some of the canals have been badly silted and do not hold adequate brine. Similarly, the fields close to the embankments get flooded after heavy rains due to lack of enough rainwater discharge outlets, and this often results in the start of the season being delayed until the area dries up. These will need to be urgently provided by WAPDA in the interest of the industry.

4.10 Not much of study seems to have been made in Bangladesh to develop layout plans appropriate to local conditions. The layout for a salt work, no doubt, is specific to the location, as it depends on the topography, soil structure climate etc. However, there are certain general principles of universal application which need to be adapted

Table 4.6

Details of The Embankment Constructed By Water And Power Development Authority (WAPDA), Cox's Bazar

Polder No.	Length of Embankment	Type	Area coverd
64/1C	5.90 miles	Sea Dike	4,400 Acres
	8.10 miles	Interior Dike	
	14.00 miles		
64/2A	6.00 miles	Interior Dike	15,300 Acres
	15.50 miles	Marginal Dike	
	21.50 miles		
64/2B	40.18 miles	Interior Dike	17,200 Acres
	8.82 miles	Sea Dike	
	9.52 miles	Marginal Dike	
	58.52 miles		
65	29.00 miles	Interior Dike	15,600 Acres
66/1	3.50 miles	Sea Dike	6,400 Acres
	8.50 miles	Marginal Dike	
	12,00 miles		
66/2	12.00 miles	Marginal Dike	4,700 Acres
66/3	5.00 miles	Sea Dike	5,500 Acres
	1.60 miles	Interior Dike	
	3.00 miles	Marginal Dike	
	9.60 miles		
67	8.00 miles	Interior Dike	4,200 Acres
68	10.00 miles	Sea Dike	8,700 Acres
	5.50 miles	Interior Dike	
	0.50 miles	Marginal Dike	
	16.00 miles		

Table 4.6 (contd)

Polder No.	Length of Embankment	Type	Area Covered
69	6.50 miles 1.50 miles 8.00 miles	Sea Dike Interior Dike	4,400 Acres
70	16.00 miles 5.00 miles 21.00 miles	Sea Dike Interior Dike	7,500 Acres
71	20.50 miles 10.50 miles 31.00 miles	Sea Dike Interior Dike	16,600 Acres

for a particular region and then modified to suit the requirements of particular farms based on physical and contour survey. Generally, the layout should ensure gravity flow of brine into the reservoir during high tide and then from reservoir to crystallizers to minimise use of external energy. The relative proportions of areas needed by the different components of a salt work will have to be evolved in terms of changes in the volume of brine taking place with progressive evaporation and the rate of evaporation in the locality. The design of the condensers should permit zig-zag movement of the current flow to allow maximum exposure to the evaporation process. The siting of the condensers and crystallizers in relation to wind current should allow the wind blowing from the land direction to cross the pans rather than go along them, so that wind does not get saturated with vapour until it has crossed the pans. The brine depths to be maintained in the different pans during different parts of the season has to be correctly worked out for maximum yield. Proper standards for consilidation of crystallizer beds have to be evolved. The density control at the different compartments to ensure separation of impurities like $CaSO_4$ and $CaCO_3$ should be laid down as also the removal of bittern from the crystallizers at the right stage into a drainage channel (Table 4.7 and Drawing Nos. VIA - 7 & VIA-8). The standard practices in relation to all such matters need to be evolved on the basis of relevant local data and then disseminated to the producers. Considering the fact that the present salt works are for the most part improperly designed, there can be little doubt that improved layout of the works alone will considerably help in raising production and reducing the cost of production, in addition to conspicuous improvement in the quality of salt produced.

The quality improvement will secure a higher price for salt in the market.

4.11 The present practice of crude salt being transported to the crushing centres for washing and bagging apears wasteful, both economically and in terms of production. The carrying of silt alongwith salt over long distances, just to be discarded, involves wasteful transport and it is found that the crushers take more than proportionate share of the price for the operation at the cost of the producers, on account of the producers' weak bargaining position, In general, on account of the high impurity of the salt the producers do not get a proper price for their produce (Table 4.8).

Table 4.8

Market Prices for Crude Salt in the Coastal Belt of Chittagong

Year	Annual Average Price (Tk)*
1968	3.19
1969	2.26
1970	1.29
1971	3.13
1972	2.99
1973	2.19
1974	7.79
1975	10.25
1976	13.66

Sources : Salt Economy (Ibid)

* Per md.

Table 4.7

Stages in the Evaporation of Sea Water

No.	Stage	Separated salt (major underlined)	Identification in salt industry	Volume residual % (V/V)	Condition of liquor saturated
1.	3.5° Be to 10.0°Be	$CaCO_3$	-	36.7	$CaCO_3$
2.	10.0 to 17.0° Be	$CaCO_3$	-	19.8	-do-+ $CaSO_4$
3.	17.8 to 24.5° Be	$CaSO_4 2H_2O$	Gypsum	12.78	$CaSO_4$
4.	24.5° to 29°Be	NaCl	Edible Common Salt Bittern Evaporation	2.4	-do- + NaCl
5.	29.0° to 32°Be	NaCl $MgSO_4\ 7H_2O$	Impure salt refined by washing to edible salt	1.5	NaCl
6.	32° to 34° Be	NaCl $MgSO_4$ $7H_2O\ 7H_2O$	Crude salt Liq. for Bromine	1.26	-do- + $MgSO_4$
7.	34° to 36° Be	NaCl + $MgSO_4$	Sels Mixts Epsom Salts & Sodium Sulphate	1.02	-do- + KCl
8.	36° to 38° Be	KCl+$MgSO_4\ 7H_2O$ +NaCl	Mixed salt for Potash	0.86	-do- + KCl
9.	38° Be solidification	$MgCl_2 6H_2O$	Processed to fused magnesium chloride	-	-do- + $MgCl_2$

Data obtained from Dr. D. Seshadri, Central Salt & Marine Chemicals Research Institution, Bhavnagar, India.

The normal practice in other countries such as India is to get the salt washed in the crystallizer pan itself, after draining out the bittern, with a fresh charge of 25° Be' saturated brine from the last condenser, as the harvesting is done. This gives salt of near purity and the loss of salt in washing is minimised, since the drained brine remains in the pan itself, - besides being more hygenic. This practice requires to be disseminated widely.

4.12 The density control in different compartments as practised at present by the producers is never accurate since they do not use even Baume hydrometers. The result is that dissolved mineral impurities are not separated out stagewise, but remain with the salt, making it unfit for human consumption in the strictest sense. The practice of allowing brine to evaporate to dryness, instead of the bittern being drained out needs to be desisted in the interest of consumers in general, as the bitterns are rich in epsom salts. The producers also normally tend to harvest the salt every week, and in order to get this rapid production cycle, they let in only a thin layer of brine for evaporation in the crystallizers. This appears to be a wasteful practice, as the crude salt layer is only about 5 mm thick and considerable labour and skill is required to harvest such a thin layer. While the optimal brine depth required to be kept under the conditions in Bangladesh needs to be studied by experts, it appears that the minimum brine depth in the crystallizer pans could be more than 10 cm and harvesting should be done less frequently, say, after 2 successive charges of brine, so that a thicker bed of atleast about 5 cm of salt is available for scrapping. Harvesting a thicker bed has less chances of contamination from silt and the salt quality improves.

4.13 Most salt producers do not have any storage facilities for salt and in the event of sudden rain, the harvested salt is washed out. To overcome this problem, theproducers tend to market the salt immediately on harvest, irrespective of price. If the support price policy of the government is to be maaningful, theholding power of the producers needs to be strengthened. In pursuance of this the government should undertake to build buffer godowns in all important salt producing centres, which could be rented out to the producers for nominal charge. The banks should be encouraged to advance funds to the producers against hypothecation of salt in these godowns. Such availability of funds will improve the economic position of the producers and permit them to adopt scientific methods of cultivation.

Possible Production Increase

4.14 According to the BSCIC statistics, the area under solar salt production in the country at present (1977-78) is around 11 thousand hectares (27000 acres). The production of crude salt has been estimated at 780 thousand tonnes. Deducting from this the washing losses estimated at 20%, the washed salt production is around 624 thousand tonnes. The average yield per hectare of washed salt works out to around 57 tonnes per ha. Even this, of course, is an inflated figure, since under the existing manufacturing process, the mineral impurities are not removed but get crystallised with salt. If this salt is to be used for industrial purposes, these impurities will have to be removed, which, apart from cost of such removal, results in substantial loss on purification - roughly to the extent of about 8 per cent.

4.15 The year 1977-78 was a better-than-average year for salt production in Bangladesh. Normally in a span of 10 years, the country experience normal production conditions in 4 years, while three years turn out to be adverse and three favourable. The average yield per hectare over the period of last 10 years is about 55 tonnes of crude salt or about 44 tonnes/ha of cleaned salt. While the effect of weather on salt production acannot be eliminated as the production process is entirely dependent on climatic factors, the effect of adverse weather on production could be cushioned to some extent.

4.16 The Consultants are of the opinion that if the industry is remodelled on the lines indicated above, it may be possible to get an average yield of about 60 tonnes per hectare (24 te/acre) compared to the present yield in Bangladesh of about 44 tonnes/ha (18 te/acre) of washed salt or effectively about 40 tonnes of comparable pure salt. The yield under favourable conditions could go as far upto 75 tonnes/ha (31 te/acre) compared to the best year's production of around 55 tonnes of pure salt (i.e. 60 tonnes of washed salt) achieved in Bangladesh. Under severely adverse conditions, as during 1973-74, the yield might go down to 43 tonnes/ha (17 te/acre). Thus under normal conditions, the present acreage under salt can give an annual production of about 660 thousand tonnes, on the basis of 10 year's expected average yield. The salt quality will be much better, comparable to the international grade.

4.17 The implementation of the measures for improvement of the salt production, as proposed above, will not obviously be a quick affair. Considerable pre-planning will need to be done before some of the measures could be enforced. An adequate machinery, such as the proposed Salt Development Corporation will have to be evolved for implementing the measures. Adequate expertise will need to be built up. Since a large number of producers and other functionaries are involved, the process cannot be hustled through, and the implementation will necessarily be slow. Any large industrial demand for salt in the meantime can be met only through development of a new large salt work rather from the existing production units.

Chapter 5

THE PROJECT

5.1 References have been made earlier to the fact the present supply-demand balance for salt in Bangladesh is rather a tenuous one, and even at the existing level of consumption, the supply may fall short of consumption if the climatic conditions in any one year should turn out to be unfavourable. In fact, going strictly by the nutritional standards and making allowance for impurities in the salt presently consumed throughout the country, there may be a marginal deficit even in a normal year. As described in the earlier chapter, the possibilities of increasing production substantially from the existing units in the short run do not appear too bright, considering the large number of subsistence scale production units involved and the gap in technology requiring to be bridged through development and dissemination. Even with the best possible results, the country can only hope to meet, on average, the growing consumption demand for salt from out of the existing area under salt cultivation. It will be risky and imprudent to try to superimpose any future large scale industrial demand for salt on the existing production structure. It is the Consultant's firm opinion, therefore, that any salt-based chemical plant, such as the Soda Ash unit being considered as part of this Project, should develop its own source of production if it is not to be cramped in working by uncertainties of supply, wide variations in quality and problems of transport from a large number of centres, apart from possible administrative interferences in times of short supply. Besides, the development of a modern salt works, working on scientific lines and producing salt of a superior grade at a substantially lower cost can creat a tremendous impact on the entire gamut of industry and help attract to it the new entrepreneurial class. For the unit, it will ensure supply, subject only to the vicissitutes of climate, guarantee quality and result in a marked reduction in supply price.

5.2 The Soda Ash unit of capacities envisaged elsewhere in this Project (Part V) will need a salt requirement of roughly around 100 thousand tonnes (98% NaCl) per year. The Consultants are of the opinion that this requirement could be best met through the development of a new captive salt unit of required size based on the solar evaporation process. In the absence of any ready agency which can take up this work, it is only to be assumed that the Soda Ash unit will also own the new salt works*. In any case, under Bangladesh's present conditions, there is a strong case for such vertical integration.

Location

5.3 Since from the point of viewof cost of production, solar evaporation process is the obvious choice, climatic factors as well as brine density considerations will need to be given adequate weight in the location of the unit. As mentioned earlier, from both these considerations, the Chittagong district,

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* In this Study, the Soda Ash Unit has been assumed to be owned by BCIC - the Bangladesh Chemical Industries Corporation.

south-wards of the mouth of the Karnaphuli river, offers the best advantage. The solar evaporation process being highly land-intensive, the availability of suitable land close to the brine source should form another important criterion. Enquiries revealed that mostland along the coastal belt in the Thanas of Anwara, Banshkhali, Chakaria, Maishkhal, Kutubdia, Cox's Bazar, Ukhia and Teknaf, are privately owned and securing their release for the project might be a long-drawn process. Besides, Anwara is too close to the mouths of big rivers and therefore, brine density along its coast is likely to be low for a longer period. The soil conditions were found to be unsuitable in the southern most Thanas of Teknaf and Ukhia.

5.4 A survey made by the Consultants with the local officials indicated that suitable Government 'Khas' land is available in large enough blocks only in the Thanas of Chakaria, Maheskhal and Cox's Bazar. The details are given in Table 5.1 (See Drawing No. VI A 9-11).

Table 5.1

AVAILABILITY OF GOVERNMENT LAND

Location of the Site	Area Available and Suitable	Source
Chakaria Thana		
1. Chakaria Sundarban, near Bahaltali, Rampur, Badar-Khalighona, Palakata and Dulahazara Villages.	2800 hectares	Out of total area of about 4800 hectares, 2000 hectares, is alloted for shrimp cultivation and remaining 2800 hectares suitable for salt works. The land is with Forest Department
Cox's Bazar Thana		
2. Area between Gomatali and Napitkhali.	2000 hectares	Some land is with Government as Khas land, but most of the land is with private land owners.
Maheskhal Thana		
3. Maheskhal island-between Hatalia and Honak villages.	2500 hectares	From this area 2000 hectares of land can be developed. About 1000 hectares land is with Government as Khas land and remaining with private owners.

5.5 The total land requirement, taking into account, the production needs in lean years and the land area needed for related facilities such as storage godowns, is estimated at 2000 hectares. Thus in all the three locations, land available is adequate. A preliminary survey was then made of their relative merits in respect of transport-lead, soil conditions, gradient, brine density and availability, facilities for rain water discharge, proneness to floods etc. and the findings are tabulated in Table No. 5.2.

5.6 As may be seen from the comparative statement, the site in the Chakaria-Sundaraban appears the most suitable for locating the salt works. Its main advantage is that the land is already in Government possession. The total area available (shade area in the Drg.No. VIA 9) is around 4800 hectares, of which 2000 ha could be developed initially on the basis of detailed survey. One of the feeder channels of Maheshkhal Channel could be conveniently developed as brine intake point. The land is flat with a gentle natural gradient, which will permit gravity flow of brine. The soil is alluvial and is formed of silt and clay particles of less than 0.002 mm - which will give the necessary imperviousness. In high tide water spreads on the datchment area and therefore there are possibilities that lifting of brine through pumps may not become necessary. The main arterial Chittagong - Coz's Bazar road is only an estimated 3 Km away from this site. Boats can ply from the site in high tide through the Maheshkhal Channel. The area is however, covered by mangroves which will need to be cleared prior to site development. At present no salt is manufactured in closeby areas.

5.7 In comparison, the area between Gomatali and Napitkhali in the Cox's Bazar Thana (see shaded area : Drg. No. VI A-10) is already under salt production to some extent. Most of the site earmarked is presumably

Table 5.2

Comparative Advantages of the Three Plant Sites

Sl. No.	Factor	Proposed Plant Site		
		Chakaria Sundarban	Gomatali Napitkhali	Maheskhal Island
1.	Availability of 'Khas' land	E	N	M
2.	Availability of sea water at initial stage	E	M	E
3.	Nature of soil-impermeability etc.	E	E	M
4.	Required gradient and level of ground with reference to tidal mark	E	M	M
5.	Brine density	E	E	E
6.	Climatic condition	M	M	M
7.	Location for sluice gate for intake of sea water into reservoir	E	M	M
8.	Rain water discharge facilities	E	M	M
9.	Road and transport facilities	E	M	N
10.	Safety during rains, floods and storms	M	M	N
11.	Clear land without mangroves, creek disturbances etc.	N	E	M

E : Excellent M : Comparatively Good N : Unsuitable in private hands, though the picture is not clear due to disputes between those in actual possession of the land and the Government. The area is clear of mangroves. The site is also pretty close to the main arterial road and suitable in other respects. Brine can be taken in from one of the creeks along the Maheshkhal channel. The site is about 30 Km away from the Cox's Bazar town. The third site is on the Maheshkhal island and faces the sea directly (Drg. No. VI A-11). Heavy outter embankments to protect the works may, therefore, become necessary. In some spots, the soil did not appear suitable due to previous characteristic. Only a part of the land required is in Government possession and acquisition of private land may be necessary to get a contiguous block of 2000 ha. Besides, from the point of view of communication and transport, the island is rather poorly placed in relation to the first site. For these reasons, the Consultants recommend the location of the works at the Chakaria - Sundarban site.

The Site

5.8 The proposed site of Chakaria - Sundarban is located at about 75 Km from Chittagong and 40 Km from Cox's Bazar by road. The site is cut through by several creeks. The main channel, the Maheshkhal Channel skirting the site is more than 200 m wide and 10 m deep and is navigable by sail boats and small motor boats. The soil appeared to be of tight black clay and silt, with good plasticity. A shortage of drinking water in summer was reported by some of the villages around the site, but the wells used were found to be shallow and therefore susceptible to drying in summer. Enquiries indicated that the water table in the area is well below 10 metres from surface and there are fairly good prospects that adequate drinking water will be available if deep wells are sunk. This will, however, need to be confirmed before site development is undertaken. Power is not available at the place at present, but it will be possible to connect it to the powerline, as the transmission line passes only about 2-3 Km from the site. The site is surrounded by a number of villages such as Bahaltali, Rampur, Palakata, and Charandwip and labour supply will not therefore, be a problem. Several of the inhibitants had in fact worked at some time or the other in the saltfields and, therefore, had some elementary experience ofthe solar evaporation process.

Layout

5.9 A proper layout of theworks can be drawn up only after a detailed contour survey has been undertaken and other relevant local data such as wind direction, tide table, drainage discharge outlets etc. are evaluated. The location of brine intake point and the design of the sluice gate can only be determined on the basis of the survey data. Similarly, whether pumping of brine into the reservoir will be required or whether brine supply can be obtained by harnessing the tides cannot be determined at present for want of detailed data. However, a preliminary layout is given in Drg. No. VIA-12 on the basis of available data by way of illustration of a modern solar salt work.

5.10 The preliminary design is based on the reduction in volume of brine through evaporation at different stages of concentration worked out by theConsultants corresponding to the data for the Cox's Bazar region as a whole (Table Nos. 5.3 and 5.4). For effective control and management, it is assumed that works will be organised into 5 blocks of 1000 acres (403 ha) each; this is, however, basedon a preliminary assessment of the topography, and the final decision will have to await the contour survey. The preliminary layout shown in the Drawings Nos. VIA-12 & VIA-13 relate to the notional block of 1000 acres (403 ha). The advantage of arranging the works into identical smaller blocks lies in the fact that the expansion of the works can be undertaken by adding similar blocks successively without further design calculations and production can start even when only one block has been readied.

5.11 In the design of the layout for each block, the daily rate of evaporation and percolation is worked out on the assumption of 6 mm for 3° Be' brine and 4 mm for 25°Be' brine. As shown in the layout plan (Drg.No. VI A-12) reservoirs area will be 120 ha, corresponding to the reduction in volume of brine by 66.7% - from 22,940 kilolitres to 11,600 kilolitres. The rise of density in the reservoir will be from 3° Be to 6°Be'. Condenser No. I will have 94 hectares of land, to increase the density from 6° Be' to 10°Be', about 59% reduction of volume (i.e. from 11,600 kilolitres to 6485 kilolitres). To increase the density from 10°Be' to 17°Be' condenser No.II will require 69 hectares of area, corresponding to the volume reduction from 6485 kilolitres to 3155 kilolitres. The last condenser No. III has 34.5 hectares of land, where again 3,155 kilolitres of brine will be reduced to 1645 kilolitres and the density of brine will increase from 17° Be' to 25° Be'. The 25° Be' brine is to be charged into crystallizer pans, where the density is to be maintained from 25°Be' to 29°Be'. The crystallizer pans the reduction of volume will be 15.68%, which will reduce the volume of brine from 1,645 kilolitres to 240 kilolitres. The remaining balance of 240 kilolitres will be discharged out as bittern. Table 5.5 gives the area required for the different components of the works.

5.12 Table 5.4 shows the composition of sea water at different densities in solar salt works up to the crystallisation of sodium chloride stage. Different salts separating out at appropriate stages are worked out on percentage basis :

At the end of Condenser No. 1 at 10° Be'	$CaCO_3$ - 50%
At the end of Condenser No. II at 17° Be'	$CaCO_3$ - 95% 30% of $CaSO_4$
At the end of condenser No. III at 25° Be	$CaSO_4$ - 85%
At the end of crystalliser pan at 29° Be	NaCl - 85%

5.13 It is assumed in this Study on a conservative basis that only 15 percent of the brine requirement will be obtained through the sluice gates by tidal action and that the balance will be obtained by pumping.

Assuming an overall evaporation and percolation loss of 7 mm per day on average in the reservoir, the daily replenishment requirement will be around 31.2 million gallons, of which 26.5 million gallons will need to be supplied by pumping. On the assumption of an average 15 hour work-day for a pump, and a head of 10 metres, five pumps of 6000 gpm capacity will be needed - one for each block.

5.14 The brine depth in the reservoir (Drawing No. VIA-12 R1 to R6) will be maintained at about 20 cm, depending on its elevation. The brine strength in the reservoir will rise from 3° to 6° Be' in about 8-10 days, depending on the temperature. In the reservoir, the brine will be made to circulate in a zig-zag manner to raise the length of the flow and maximise exposure. The brine will be charged to condenser

No. I (C1A) at 6° Be' where it will rise to 10° by the time it reaches the last compartment (C1F) in about 8-10 days. The depth of the brine here will be between 15-18 cm. When it is charged to condenser No. II (C_2A), the brine depth will need to be reduced to 12 cm and the density will increase from 10° Be' to 17° Be' in about 12 days' time. In the last condenser (No. III-C3) the brine density will further rise to 25° Be', the brine depth being maintained at about 10 cm. The time required for this may be around 8 days. From the last condenser, brine at 25° Be' will be charged into the crystallizers for separating out the salt from the saturated brine. There will be 78 crystallizer pans of 150 m x 34 m each in every block. (Drawing No. VIA-13). The brine depth in the crystallizers should be maintained at about 10-15 cm, by recharging the saturated brine whenever the depth goes down. When the brine density goes beyond 29° Be', the bittern should be drained out immediately and a fresh charge of brine should be allowed. The process of draining out the bittern and charging the brine will be continued till a reasonably thick layer of atleast about 5 cm is obtainned, which may take between 40 to 50 days under normal conditions. Under ideal conditions, it may be possible to harvest salt 2-3 times a season with an average top layer of 1.5 to 2 each. Harvesting will, however, be continuous, since by the time the last pan is harvested, the first pan will be ready once again.

5.15 Initial washing of the salt will be done in the crystallizer pan itself while harvesting the salt, with fresh charge of concentrated brine. Harvesting will be done manually, but provision has been made in the layout plan for roads around the crystallizer pans. The harvested salt will be moved by tractor trailers to the washery where it will be dumped into a slurry pit of saturated brine. It will be agitated

Table 5.3

Calculations for Areas for Different Components of a Salt Works Unit : 403.3 Hectares (1000 acres)

Density Range	Volume Reduction	Percent loss due to evaporation	Daily rate of evaporation and percolation in metres	Areas in Hectares	Brine in Kiloliters				
					Input	Evaporation	Percolation	Total lose	Balance transferred to next stage
Reservoirs $3^{o}/3.5^{o}-6^{o}$Be'	100-66.7	33.30	0.00635	120	22,940	7,620	3,720	11,340	11,600
Condenser No.1 $6^{o}-10^{o}$Be'	100-58.95	41.05	0.00508	94	11,600	4,775	340	5,115	6,485
Condenser No.II $10^{o}-14^{o}$ Be'	100-67.84	32.16	0.004318	48.3	6,485	2,085	220	2,305	4,180
$14^{o}-17^{o}$ Be'	100-79.62	20.38	0.004064	21	4,180	855	170	1,025	3,155
Condenser No.III $17^{o}-23^{o}$ Be'	100-67.76	32.34	0.00381	27	3,155	1,029	106	1,135	2,020
$23^{o}-25.5^{o}$ Be'	100-86	14.00	0.00381	7.5	2,020	285	90	375	1,645
Crystalliser $25.5^{o}-29.5^{o}$ Be'	100-15.68	84.32	0.003556	39.0	1,645	1,387	18	1,405	240 Bittern above $29^{o}-5^{o}$Be'

Total Area for Crystallisers, Reservoirs & Condenser	356.8
Area for Salt Stage Platform, Bunds, Roads, Channel, Buildings etc.	46.5
	403.3

Table 5.4

Composition of Sea Water at Different Densities in Solar Salt Works (30-35°C) up to the Crystallisation of Sodium Chloride - Reference Data

Particulars	3.5° Be'	10° Be'	17° Be'	24° Be'	29° Be'	Particular	3.5° Be'	10° Be'	17° Be'	24° Be'	29° Be'
Volume reduction	100.00	26.720	19.830	12.780	3.0	Reduction in Weight	100.00	38.52	21.98	15.15	3.63
		(g/100 ml)						(g/100 g of soln.)			
$CaCO_3$	0.012	0.006	Trace	Trace	Trace	$CaCO_3$	0.012	0.005	-	-	-
$CaSO_4$	0.144	0.292	0.435	0.113	0.03	$CaSO_4$	0.141	0.363	0.383	0.094	0.027
$MgSO_4$	0.234	0.634	1.180	1.831	7.0	$MgSO_4$	0.228	0.587	1.038	1.526	5.6
$MgCl_2$	0.358	0.953	1.805	2.801	15.0	$MgCl_2$	0.350	0.882	1.589	2.334	12.0
KCl	0.072	0.196	0.363	0.563	2.6	KCl	0.070	0.181	0.319	0.469	2.1
NaCl	2.911	7.927	14.679	22.777	15.0	NaCl	2.840	7.339	12.921	18.980	12.0
$MgBr_2$	0.005	0.013	0.025	0.0391	0.23	$MgBr_2$	0.005	0.012	0.022	0.003	0.18

Total Salts 3.736

Data obtained from Dr. K.Seshadri, Central Salt & Marine Chemicals Research Institute, India.

Separation of salts :	10° Be'	$CaCO_3$	50%
	17° Be'	$CaCO_3$	95 + 30% $CaSO_4$
	24° Be'	$CaSO_4$	84%
	29° Be'	NaCl	84%

Practical recovery of common salt in salt works at 29° Be' under Indian conditions) 70 - 75 %

Table 5.5

Allocation of Land for Different Components of a Salt Work Unit 403.3 Hectares (1000 acres)

No.	Component of the Salt Works	Sign	Area Allotted in Hectares	Total area in Hectares
1.	Reservoirs (6 parts)	R1	20.00	
		R2	20.00	
		R3	20.00	120.00
		R4	20.00	
		R5	20.00	
		R6	20.00	
2.	Condenser No. 1 (6 parts)	C1A	15.66	
		C1B	15.66	
		C1C	15.66	94.00
		C1D	15.66	
		C1E	15.66	
		C1F	15.66	
3.	Condenser No. 2 (6 parts)	C2A	11.55	
		C2B	11.55	
		C2C	11.55	69.30
		C2D	11.55	
		C2E	11.55	
		C2F	11.55	
4.	Condenser No. 3 (6 parts)	C3A	5.75	
		C3B	5.75	
		C3C	5.75	34.50
		C3D	5.75	
		C3E	5.75	
		C3F	5.75	
5.	Net Crystalliser Pan Area 78x150x34	CRY	39.00	39.00
6.	Area for salt storage, bunds, roads, channel buildings, etc.		46.5	46.50
		Total Area of One Unit		403.30 Hectares

and pumped into a screw classifier (Drawing No. VIA-14) where it undergoes further agitation. It is then led into a vibrating screen where another wash is given with saturated brine. The washed salt will be discharged into a belt conveyor for heaping in the storage. The wash brine will be periodically discharged as bittern. The salt obtained is expected to have the following specifications :

	Percent by weight
NaCl	98.50 - 98.60
Calcium	0.10 - 0.60
Magnesium	0.10 - 0.08
Sulphate	0.17 - 0.15
Insoluble	0.13 - 0.11

5.16 Even though the salt obtained from the crystallizer pans will be much purer than the salt marketed in Bangladesh at present, it will still contain minor impurities, as strict process control under solar evaporation is not possible. Typicallly, the impurities will be as follows :

$CaSO_4$: 0.6 %

$MgSO_4$: 0.3 %

$MgCl_2$: 0.3 %

Insolubles : 0.2 %

Though for human consumption this salt will be normally adequate, for industrial use a still purer grade of salt will be needed as the impurities interfere with the process. Normally the cost of purification through neutralisation in a chemical plant will be costlier, and it will be more economical to wash the salt of the impurities at the salt works itself, since adequate brine can be easily obtained from the works and the washing is quite effective if carried out when the salt is fresh and wet i.e. soon after harvesting. Hence the provision for washing in the Project plan.

Preservation of left-over brine

5.17 Just before the rain starts, at the end of the season, the concentrated brine of 24-25° Be' left out in the last condenser and the crystallizers will be fed into one compartment of the last condenser and stored in a depth of about 0.5 m for next season. Over the surface of brine level outlet pipes will be provided to drain out the rain water from the top surface of conentrated brine. Preserved concentrated brine will be helpful in the early start of next season.

Chapter 6

PROJECT COST ESTIMATES AND FINANCIAL RETURNS

6.1 The solar salt works project, as envisaged in the preceding chapter, covering an area of 2000 ha of salt works is expected to cost around Tk 47.4 million, ($ 3.16 million) in capital investment with a foreign exchange component of Tk 12.7 million ($ 0.85 m), excluding land cost. But the actual total fund requirement will be about $ 4.8 million to complete the project, not taking into account the credit for salt produced during the project implementation period. The net project cost may vary slightly depending on the actual sale price of this product accruing during the Project's construction period. For the purpose of capital cost estimates the sale price is assumed at $ 29.30/te as explained later. Land is assumed to be available, being Government 'Khas' land, on long lease. The capital investment includes a washery, as explained in Chapter 5. Table 6.1 gives a summary of the capital estimates. Details of the estimates are given in Annexure VIA-I.

Basis of Estimates

6.2 As may be seen, the major part of the capital expenditure is covered under the following four heads :

Earthwork
Buildings
Plant & Equipment
Miscellaneous Accessories

Table 6.1

Project Cost Estimates

(Figs. in $ '000)

Sl. No.	Item	F.C.	L.C.	Total
1.	Plant & Equipment & Miscellaneous Accessories	469.4	317.6	787.0
2.	Civil Works			
	(i) Earthwork	-	1691.3	1691.3
	(ii) Building	76.8	307.2	384.0
3.	Know-how, Engineering Supervision, Pre-operating Expenses	177.0	20.4	197.4
4.	Project Management Charges	-	71.1	71.1
5.	Capitalised Land Lease Rent	-	40.0	40.0
	Total Manufacturing Facilities	723.2	2447.6	3170.8
6.	Residential Quarters	56.0	224.0	280.0
7.	Spares	28.2	19.1	47.3
8.	Working Capital	-	934.9	934.9
9.	Contingency 5%	40.4	181.3	221.7
10.	Financing Charges	-	114.4	114.4
	Total Fund Requirement for Completion of Project	847.8	3921.3	4769.1
11.	Credit for Sale of Product during Construction Period	-	(1612.4)	(1612.4)
12.	Net Project Cost	847.8	2308.9	3156.7
	Net Project Cost (in Tk. million)	12.7	34.7	47.4

F.C. : Foreign Exchange Cost
L.C. : Local Currency Cost

a) Earthwork

6.3 The solar salt process being essentially land intensive, a major proportion of the capital expenditure will be incurred on the land development and layout, which involves mainly earthwork. It includes the formation and construction of boundary bunds, cross bunds, brine channels, crystallisers, storage platforms and roads. The estimates of quantities and costs of earthwork have been made after a preliminary study of the field conditions at the site and the topography of the area. The cost has been principally based on the schedule of rates currently accepted by the Bangladesh Government.

b) Buildings

6.4 The buildings covered in the capital works include pump houses, works office, stores, rest sheds for workers, sheds for the washery, a godown for the storage of salt, a small laboratory for analysis of salt, vehicles shed and a maintenance workshop. The capacity of the storage godowns is assumed to be 35,000 tonnes, equivalent to about 30 per cent of the anticipated average annual production. Storage at the works of this order will be needed, since rains might interfere with transport at the close of the season's harvesting. The cost of the buildings have been estimated on the basis of the current cost of civil construction in Bangladesh. A foreign exchange component of 20 percent of building cost is assumed since many building materials are still imported. This figure has been arrived at on the basis of discussions with knowledgeable building contractors.

c) Plant & Equipment

6.5 Apart from the equipment for the washery, this head includes pumps and accessories, salt harvesting equipment, stackers and other weighing and handling equipment. The estimates for the different equipment have been worked out on the basis of the current rates obtained from the leading suppliers. Most estimates have been based on actual quotations received and adjusted for delivered cost. The estimates include an escalation of 20% to provide for possible price increases till actual ordering. The estimates include (i) ocean freight and insurance @ 10.6%, (ii) customs duty at 2.5%, (iii) inland handling at 5% and (iv) Sales tax of 20% on landed cost. Inland movement and storage insurance is assumed at 1%. Since the proposed site is considered an industrially undeveloped area, the concessional import duty offered by the Government for new project is assumed. Cost estimates for the washery have been derived on the basis of a preliminary design.

d) Miscellaneous Accessories

6.6 Provision has been made for obtaining high tension power supply at the salt works site and arrangements for the internal distribution of L.T. power for operating the equipment in the washery. A well equipped laboratory for analysis of salt samples for 'in-process quality control' will also form an essential part of the project. Provision has been made for the needed complement of motor vehicles such as cars, jeeps and motorcycles as well as bicycles for use by the supervisory and inspecting staff to ensure effective control of field operations. Provision for the supply of fresh water has been made on the assumption that it may be possible to get sweet water in the area through deep wells.

e) Technical Supervision

6.7 Provision has been made under Technical Fees and Supervision to cover expenses of engineering fees, technical direction and field supervision of the development operations through a four year period until the unit is fully commissioned. In view of the lack of necessary expertise, it has been assumed that a foreign consulting firm will be engaged to survey the land, prepare the layout, design and engineer the washery and provide general supervisory services for execution of the works, including erection of equipment /machinery. The work will be executed through local contractors. Necessary counterpart supervisory staff will be provided by the project owners and the cost thereof is included in the estimates.

f) Project Management Charges

6.8 The project management charges consist mainly of pre-construction expenses, pre-operating expenses, the wages and salaries of project management group and other expenses connected with the execution of the project. The basis for the estimate is given in Annexure VIA-II.

g) Capitalised Land Lease Rent

6.9 The rent for the land during the development period is assumed to be capitalised. Under the existing regulations of the Government, the rent for lease of 'Khas' land is Tk 30 per acre per year, which is assumed here.

h) Residential Quarters

6.10 A residential colony for the permanent staff, is provided in the estimates. The requirements of residential accommodation for different categories of management and operating personnel have been worked out and a total of 55 houses are assumed to be built for a total strength of 80. The financial provision under this head includes estimated lease rent for land, its development including sewerage, water and power supply etc. It has been assumed that 20% of the cost will be in foreign currency and 80% will be in local currency.

i) Spares

6.11 The spares requirement is assumed at 6% of the cost of plant and equipment miscellaneous accessories.

j) Working Capital

6.12 The details of working capital requirements are shown in Annexure VI A-III. The total fund requirement for working capital is $ 935 thousand, which includes provision for stocking of one month's requirement of fuel, product inventory of 42,500 te of salt (35,000 in storage godowns and about 7500 te in the open during the production season) has been provided. Provision of 30 days is kept for accounts receivable and 15 days for accounts payable. Adequate provision for cash in hand has been made. The total working capital is capitalised, in accordance with the practice followed in Bangladesh.

6.13 Financing Charges

In keeping with the guidelines for capital projects given by the Government of Bangladesh, the entire local currency expenditure is treated as equity and the foreign exchange component of the capital outlay is treated as loan. The loan capital is assumed to carry an interest of 10 per cent/annum. The financing charges have been calculated on the basis of actual drawal of funds over a four-year period of construction on the basis of planned schedule of construction

The overall debt-equity ratio for the project on the basis of the estimated outlay works out to 1 :3.

COST OF PRODUCTION

6.14 The estimated cost of production of pure washed salt has been worked out in Table 6.2. The cost of production of washed salt comes to $ 10.50 (Tk 157.50) per tonne, including depreciation and interest. This compares with the estimated average cost of production of around Tk 340 ($ 22.60) for crude salt and around Tk 700 ($ 46.70) per tonne of washed salt in the existing works in Bangladesh, not counting the much superior grade of salt produced in the new unit.

6.15 In working out the cost of production, labour and overheads have been taken on the basis of estimated personal requirements given in Table 8.1. Appointment of causual labour has been assumed for harvesting, transportation, washing of salt etc., since the work is seasonal.

6.16 Maintenance cost including materials has been assumed at 8% of the cost of total manufacturing facilities. This will include mainly the annual repairs to the bunds and salt pans, maintenance of pumps, tractors washery equipment etc. Insurance and local taxes have been assumed at 0.5% of the cost of total manufacturing facilities. Contingency is assumed at 5%.

6.17 Depreciation has been worked out on stright-line basis over a period of 15 years, except for the residential quarters, which is depreciated over a 30-year period. Lease rent on land is taken at Tk 30/acre per year. Interest on loan is assumed at 10%.

Table 6.2

Cost of Production of Salt (In $'000)

Sl. No.	Item	Annual cost
1.	Raw material	-
2.	Diesel oil etc.	240.0
3.	Power	10.0
4.	Labour and Overheads	160.0
5.	Maintenance material	253.7
6.	Insurance and taxes	16.0
7.	Contingency	34.0
	Annual Works Cost	713.7
8.	Depreciation	131.9
9.	Rent on land	10.0
10.	Selling & Admn. expenses	360.0
		1215.6
11.	Average interest on long term loan	42.4
	Annual Cost of Production *	1258.0
	Annual Production (Tonnes)**	120,000
	Unit Cost of Production (Per tonne)	$ 10.50

* including interest ** average of good and lean seasons

PRICING AND PROFITABILITY

6.18 As mentioned earlier, the Government of Bangladesh has fixed a minimum support price for salt at Tk 30/md for washed salt and Tk 15/- per md for crude salt at the crushing/production centres respectively, as a measure of incentive for increasing salt production in the country. This policy is expected to be continued in future since salt is recognised as an essential article of food and the country has not yet reached the position of assured self-sufficiency. Considering the growth in population and the likely demand for salt for other uses, including industrial consumption, the prospects for the production to increase to a level outstripping demand over a consistently long period is not too bright and therefore, the likelihood of the Government withdrawing the price support policy or reducing the support level appears remote.

6.19 The support price of Tk 30/md works out to Tk 810 per tonne at say, Chittagong. Though notionally the Government is expected to step in and offer to buy all the salt offered at this price, there are, in practice, periods when the market price drops below this level by a few Takas, albeit for relatively short periods in the thick of the season, due to over-supply position in relation to off-take. Hence, should a large unit try to off-load substantial quantities on the market on a regular basis, it is not unlikely that the prices may ease a little below the support level. This can, of course, be overcome by making over the salt directly to the public distribution system or through long term contracts with large consumers.

6.20 The planned salt works is assumed to be part of a proposed soda ash complex and therefore, the unit may not be free to sell its produce in the free market at open market prices except to the extent of surplus available. However, for a proper assessment of the project's work in terms of profit-earning capacity, the unit's production may be notionally valued at the market prices, and the possible returns on the investment made can be calculated to evaluate its attractiveness as an independent industrial venture. For this purpose, making allowance for the cost of transport between the project site and Chittagong and any possible unforeseen decline in prices, the price of salt at the factory gate is taken to be Tk 440 ($ 29.30) per tonne. This price, however, ignores the premium the salt from the new unit is likely to command on account of its superior analysis.

Return on Capital

6.21 On the basis of assumed selling price of Tk 440/tonne ($ 29.30) the project is expected to give a gross profit of 72.9 percent on the total capital employed (Table 6.3) and a return of 97.8 percent on the equity capital.

6.22 The annual cash accruals including depreciation and profit after interest and taxes would be adequate to pay-back the investment in 1.3 years after full production stage.

Break-Even Point

6.23 The break-even point, that is the lowest production level at which the unit can operate without incurring any loss, as per cent of the rated capacity, has been found to be at 29.3 per cent.

Table 6.3

Profitability of the Project Production Level - 100%

	In $ '000
Sales Realisation (120,000 te @$29.30)	3516.00
Annual cost of production (excluding interest)	1215.60
Annual cost of production (including Av. interest)	1258.00
Gross profit (before interest)	2300.40
Gross Profit (after average interest/before taxes)	2258.00
Total Capital	3156.70
Total Equity	2308.90
Return on Capital	72.9%
Return on Equity	97.8%

Internal Rate of Return

6.24 The Internal Rate of Return (IRR) indicates the rate at which the discounted total of the annual cash in-flows over the 15 years of operation equals the discounted current worth of initial investment.

Details are given in Table 6.4. The IRR of the project works out to be 46.9 per cent.

Table 6.4

Internal Rate of Return
Level of Production:100%

I.R.R. - 46.881%

(Figs. in $ '000)

Period	Gross Receipt	Discount Factor	Discounted Value
1.	- 106.20	0.680823	- 72.30
2.	-1046.00	0.463520	-484.84
3.	-1576.10	0.315575	-497.38
4.	- 314.00	0.214851	- 67.46
5.	2465.92	0.146276	360.70
6.	2461.12	0.099588	245.10
7.	2456.32	0.067802	166.54
8.	2451.52	0.046161	113.16
9.	2446.71	0.031427	76.89
10.	2441.91	0.021397	52.25
11.	2437.11	0.014567	35.50
12.	2432.32	0.009418	24.12
13.	2427.52	0.006752	16.39
14.	2422.72	0.004597	11.14
15.	2417.92	0.003130	7.57
16.	2413.11	0.002131	5.14
17.	2408.31	0.001451	3.49
18.	2403.51	0.000988	2.37
19.	2398.72	0.000672	1.61
			- 0.01

I.R.R. = 46.8810 %
Say = 46.9%

Sensitivity fof the Project

6.25 The sensitiveness of the project's financial returns are examined in Table 6.5.

Table 6.5

Sensitivity Analysis

A. : Production

Production level %		Return on capital employed (%)	Return on equity (%)
Base Case	100%	72.9	97.8
	90%	62.2	83.2
	75%	46.8	62.1

B : Increase in project cost

Increase in cost over base case		Return on capital employed (%)	Return on equity(%)
Base Case		72.9	97.8
	10%	61.2	80.5
	20%	52.6	68.0

C. : Variation in selling price

Variation in sale prices	Return on capital employed (%)	Return on equity(%)
Base case at $ 29.30/tonne	72.9	97.8
At $ 25/tonne	50.0	64.2
At $ 20/tonne	28.7	35.1

Actual Return

6.26 Since the proposed salt unit is likely to be treated as a captive unit for the soda ash plant, salt may be priced on the basis of cost of production with a reasonable return on capital. Allowing a 10 per cent return, - considered reasonable under Bangladesh conditions, - on the total capital employed (before interest), the transfer price works out to $ 12.50 per tonne (Tk 187.00), which is less than half of the price presently being paid by BCIC for its salt procurement, not counting the difference in salt grades.

Chapter 7

TIME SCHEDULE AND IMPLEMENTATION

7.1 It is expected that the execution of the project will be completed within 48 months from the zero date. Construction period of this length will be necessary since most of the work involved will be earth-work, and therefore, construction work can be undertaken only during the drier months. A bar chart indicating the typical types of activities and their phasing is enclosed as Drawing No. VIA-15.

7.2 Zero date is assumed to be the date when the contour survey work starts. This has to be necessarily after the rainy season. It is assumed that the survey of the site and the proceedings for transfer of land will be initiated before the zero date, as soon as the investment decision is formally taken. During the first year, prior to on-set of the rainly season, contour survey, site levelling and civil design will be completed and actual construction work will commence from the beginning of the second year. It will be possible to partly utilize the facilities created for the production of salt from the third year onwards, but full production can commence only from the beginning of the fifth year. For the purpose of time schedule, a year is taken to extend from November to October, corresponding to the salt season.

7.3 It is assumed, in working out the time schedule, that a foreign consulting firm will be engaged for the design, engineering and supervision of construction and the actual work will be executed by the project owners through experienced local contractors.

Chapter 8

MANAGEMENT AND STAFFING

8.1 The salt works is assumed to be managed as an autonomous unit and an independent profit centre even if it forms part of the proposed soda ash complex. It will be headed only by a General Manager, who will be responsible for tits day-to-day functioning and report to the Central Board. The staffing of the unit has been proposed on the assumption that, being a captive unit, higher directions of management will be provided by the Central Board.

8.2 The unit will require a staff strength of about 81, at full production point, including the General Manager, but excluding casual labour to be employed on a daily basis during the production season alone. An indicative staffing pattern is shown as Drawing No. VIA-1 6, and the different categories of staff and number in each is shown in Table 8.1. The staff includes technical staff for maintenance and workshop. No separate hospital facilities have been provided. The annual salary bill of the staff has been calculated on the basis of the average pay for a mid-point of the scale, as prevailing in Bangladesh at present. The annul salary bill for the staff, including the General Manager, works out to about Tk 960,000.

8.3 During the production season, casual labour will be recruited from the surrounding villages as helping hands in the production operations. When production is in full swing, about 800 such hands may be required for an average period of 6 months in a year - from mid-November to mid-May. Their average wage is assumed at Tk 15 per day. The requirement during the third and fourth year of construction, when only part operation of the created facilities is envisaged, will be lower, as shown in Table 8.2. During these first two years their engagement will be essentially seen as training for creating a hard core of experienced labour.

8.4 Training for the technical staff, especially the supervisory staff of the salt works proper will be essentially on the job. Since no fine sophistication in supervision is involved, no separate training facility is envisaged. However, during the third and fourth year, when salt production will be commenced on a limited scale, they will be trained to undertake the work independently with the help of the expatriate experts engaged by the consulting firm.

Table 8.1

Total Staff Requirement

Sl. No.	Designation	Number Required III year	IV year	V year and onwards
1.	General Manager	1	1	1
2.	Production Supdt.	1	1	1
3.	Assistant Supdt.	1	1	1
4.	Office Manager	1	1	1
5.	Accountant	1	1	1
6.	Office Asstt.	2	3	4
7.	Foreman	1	1	1
8.	Auto Mechanics	1	2	2
9.	Electricians	1	1	1
10.	Chemists	1	2	2
11.	Field Supervisors	4	4	6
12.	Store Keeper	1	1	2
13.	Vehicle Drivers	2	4	8
14.	Assts. Field Supervisor	4	4	6
15.	Field Clerks	2	3	4
16.	Fitters	2	3	4
17.	Mistries	2	4	6
18.	Pump Attenders	6	8	10
19.	Washery Attenders	Nil	6	12
20.	Watchman	4	6	8
	Total :	38	57	81

Table 8.2

Casual Labour Requirements

Months	Number of Labourers required					
	III Year		IV Year		V Year onwards	
	No.per day	Mandays/ month	No. per day	Mandays/ month	No.per day	Mandays/ month
November	25	750	50	1500	100	3000
December	50	1500	100	3000	200	6000
January	75	2250	150	4500	300	9000
February	100	3000	200	6000	400	12000
March	150	4500	300	9000	600	18000
April	200	6000	400	12000	800	24000
May	200	6000	400	12000	800	24000

Chapter 9

ORGANISATION FOR FUTURE DEVELOPMENT

9.1 For all the attention that salt demanded from the Government by virtue of its importance to the economy of Bangladesh and in pursuance of the national objective of self-sufficiency, the salt industry's development seems to have suffered through neglect even in the post-Independence period. By and large, it does not seem to have received the kind of promotional thrust that a priority industry of the kind deserved. Apart from the sizeable proportion of the population engaged in salt industry in various functions and its critical importance in terms of employment in the coastal areas, salt should rank as a major industry even in terms of value of output, roughly estimated at over Tk 50 crores ($ 33 m) on the basis of current minimum support prices. As a basic food item, the adequacy of production and healthy, continuous growth of the industry are of prime importance to the country, since imports are both expensive due to its bulk in relation to value and uncertain due to possible delays in arranging supplies, as the experience of 1974 amply indicated. The Government, however, does not seem to have evolved upto now a cogent, comprehensive plan for its development on modern lines or created an appropriate machinery for it.

9.2 Salt industry is a charge of the Bangladesh Small and Cottage Industries Corporation, a Bangladesh Government undertaking, which is concerned with the promotion and development of several industries, primarily the promotion of new industrial units in the small-scale sector. The Corporation has a department to deal with salt, located in Chittagong. The executive staff for overseeing the development of salt industry consists of a Deputy Director and a couple of Assistant Directors, in addition to some field staff at junior levels. Discussions with a number of senior officers of the Corporation gave the Consultants an impression that ordinarily salt received only a peripheral attention at the hands of the Corporation's governing Board.

BSCIC's Role

9.3 The BSCIC's major contributions to the development of salt industry till now cover (i) distribution of some 'Khas' (Government) land to the salt producers on annual leases during 2 or 3 years (ii) provision of production loans to the salt producers (iii) development of a model demonstration-cum-production unit on the Kutubdia island (iv) construction of some storage godowns at the producing centres (v) arrangements for procurement of salt for buffer stock operations and (vi) recently (Nov. 1978) development of a scheme for setting up some modern crushing units in the main producing areas of Cox's Bazar belt, which is yet to be implemented. Even in these mainly administrative measures, the BSCIC does not seem to have excelled itself as to create a major impact. During 1974-75 and 1975-76, when BSCIC was put in charge of distribution of 'Khas' land, only about 911 and 433 acres respectively were leased out to salt producers; of these several cases appeared to have landed in law courts. From 1976-77, again the function of distributing 'Khas' land has been taken over by the Revenue Department's Circle Officer from the BSCIC, though ordinarily the BSCIC would have been the appropriate agency for it. The Corporation has been distributing production loans at the rate of Tk 300 to 500 per acre to actual salt producers, but inevitably due to the Government's slow procedures, the loans invariably reached late, when the production season was well advanced, whereas, as seen earlier, the producers' primary requirement of cash was at the beginning of the season. During field visits in February 1979, the Consultants observed the BSCIC officials preoccupied with loan distribution in the Cox's Bazar area, almost in mid-season. The loan facility does not as yet seem to have made a significant dent, either in bringing down the interest rates or in the availability of funds. Most producers seem to be viewing it as a supplementary source of cash. As indicated earlier, the demonstration unit on Kutubdia is still far from being a 'demonstrable' unit. Though the BSCIC had plans to set up a number of such centres, only one has been set up till now, and that too on a somewhat remote island where its demonstration value may not be high. For providing storage, BSCIC seem to have constructed a number of storage godowns in the producing areas, which are being used for storing the crude salt procured from the producers. The total storage capacity now available with the BSCIC is understood to be of the order of 4.2 thousand tonnes. The salt producers, in general, however, do not seem to be making use of these godowns.

9.4 Although one of the primary functions of the BSCIC, in so far as salt is concerned, is given as promotional work involving extension services, technical guidance to the producers and improvement of the salt production techniques[9] to raise productivity, the Corporation does not seem to have particularly concerned itself with such matters. Whatever activities it organised in respect of these functions were only of an adhoc nature, confined to short durations, such as "production with improved beds". In fact it is this area, including experiments on improved techniques, with which BSCIC should have primarily concerned itself to bring about some modernity in the production methods. But then, basically, BSCIC itself does not have rich expertise in the technology of salt production, and its familiarity with the developments taking place elsewhere in the world in relevant areas does not appear to be adequate. It has only one officer trained in salt production abroad-in Australia- and it appears he has only a short service left with the Corporation. There is also a general reluctance on the part of the young BSCIC officials to accept charge of salt since salt is not rated 'high' in the scale of importance among industries under BSCIC. One reason why the demonstration unit at Kutubdia has not come up to expectations could be the reluctance of any of the promising executives to stay on in the island close to the works, on account of its poor communication facilities with the mainland.

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[9] A note circulated by the BSCIC says "BSCIC's activities have been confined mainly to demonstration of improved method, propagation of better techniques ... ..." etc.

Salt Development Corporation (SDC)

9.5 The Consultants, therefore, feel that in the overall interest of the industry, salt should be dissociated from the omnibus BSCIC, and a separate corporation should be charged with the responsibility for its overall development. The dimensions of the industry will justify the creation of a separate corporation. In the Consultant's view, only a corporation exclusively concerned with salt will be able to give the industry the close attention it needs. The proposed corporation, to be called the Salt Development Corporation (SDC) should be entrusted with all aspects of the salt industry from the leasing of land for salt cultivation to research and development on improved techniques and byproduct use. However difficult it might be found to be, in the interest of rationalised development of the industry and its future self-reliant growth, it will be necessary to entrust all land considered suitable for salt cultivation, including private land used at any time for salt manufacture in the last 10 years in the Chittagong district, to the care of the SDC to ensure its proper development and utilisation. While this proposal may not cause any problem in the case of the Government 'Khas' land, which can be identified through an expert survey, the transfer of land privately owned at present may cause difficulties and may need legislative support. The transfer of private land to the SDC could be either in the form of outright ownership transfer, which may require payment of compensation to the present owners, or it could be in the form of permanent lease. The proposal need not sound "revolutionary" as it may at first sight look, since very similar powers appear to be available to the Forest Department to 'reserve' specific areas for forest development and to regulate the development of forests in general in the public interest.

9.6 Broadly, the functions of the SDC will cover -

i) Leasing of all land for salt production in economic sized units

ii) Development of new areas for salt manufacture

iii) Research and Development on the improvement of techniques of salt production appropriate to Bangladesh conditions and on the extraction of useful chemicals from waste bittern.

iv) Provision of loans and credit, and equipment/instruments

v) Buffer stock operations and public distribution of salt

vi) Import and export of salt

Some of the functions presently exercised by other Government agencies may have to be transferred to the SDC in the interest of overall coordination of work and unified direction.

9.7 It is assumed that the SDC will be headed by a Chairman and three 'functional' Directors, - one in charge of R&D, one in charge of projects and the third in charge of operations covering leasing functions, loan operations, and buffer stock/public distribution. Finance, Personnel and Import/Export will be Chairman's direct responsibility, to be excercised through senior officers of thelevels of

General Managers. Lease-rent, profits from its own production of salt and profits from other commercial operations such as godown renting, public distribution and import/export will be the main income sources for the SDC. If necessary, a small cess may be levied on salt production to cover specific expenditures such as R&D. The headquarters of the SDC could be in Chittagong if that does not prove inconvenient from the point of view of coordination with the Government.

Research Institute

9.8 It will be necessary for the country to evolve techniques of salt production best suited to its specific conditions and to laydown the norms for design of salt farms. Borrowed experience can only be of limited help in these matters. Experimentation will also be needed on the minimum optimal size of the farms and on the methods of improving salt quality, cost reduction methods etc. Appropriate techniques for extracting marine chemicals from bitterns will have to be evolved. It is, therefore, recommended that a Salt and Marine Chemicals Research Institute should be established in Bangladesh, preferably under the aegis of the SDC. It could be located in one of the important salt producing centres, preferably close to the proposed project area in Chakaria-Sundarban and should have a farm of medium size attached to it. The Institute can possibly be modelled more or less on the lines of the Central Salt and Marine Chemicals Research Institute in India, as the conditions in India are possibly the closest to those of Bangladesh and the Institute has acquired considerable experience in the field (Appendix I).

Technical Assistance

9.9 The expertise available in Bangladesh at present in the field of solar salt technology appears totally inadequate to the needs, considering the dimensions of the problem involved. The Consultants feel that the country needs external technical support in the initial years to provide guidance in the development of the industry apposite to Bangladesh conditions and train the local staff. It is, therefore, recommended that the Government of Bangladesh should try to secure the services of an outside expert in the solar salt technology, preferably through an appropriate U.N. agency such as UNIDO/UNDP to advise it on the development of the salt industry in the country. The expert should preferably have acquired adequate field experience in a developing country working under labour intensive techniques and in relatively small units. His services could be made use of in organising the development work of the SDC, and evolving a suitable programme for demonstration and extension. The expert should also be required to train a group of atleast six local persons over a period of three years, who will form the nucleus of technical staff of SDC. In addition, the Government should depute, under a relevant technical assistance programme atleast 2 persons from the SDC over a period of 3 years for study of modern solar salt production methods in countries whose experience could be relevant. Their study should cover atleast one full season. The technical assistance programme as envisaged above is estimated to cost about $ 262 thousand, of which the foreign cost may be around $ 250 thousand (Table 9.1).

Table 9.1

Estimated Cost of Technical Assistance

(in $ '000)

Item	Ist Year		IInd Year		IIIrd Year	
	F.C.	L.C.	F.C.	L.C.	F.C.	L.C.
One expertfor 3 years period @ $ 5000/- per month	60.0	-	60.0	-	60.0	-
Expenses on accommodation etc. @ $ 300/- per month	-	3.6	-	3.6	-	3.6
Travel for expert	10.0	-	10.0	-	10.0	-
Vehicle	4.0	-	-	-	-	-
Driver	-	0.8	-	0.8	-	0.8
Training two persons abroad @ $ 600 p.m. for 8 months	9.6	-	9.6	-	9.6	-
Travel for trainees	2.0	-	2.0	-	2.0	-
Total :	85.6	4.4	81.6	4.4	81.6	4.4

APPENDIX - I

CENTRAL SALT AND MARINE CHEMICALS RESEARCH INSTITUTE
BHAVNAGAR, INDIA

1. The Central Salt & Marine Chemicals Research Institute, (CSMCRI), Bhavnagar, India is one of the several research institutes functioning under the aegis of the Council of Scientific and Industrial Research (CSIR). CSIR is an apex body under the Ministry of Science and Technology charged with overseeing the governance of a number of public-funded scientific research institutes in India. Located in Bhavnagar, one of the smaller port-towns some 350 Km north of Bombay on the Gulf of Khambat, CSMCRI was established in 1954 in pursuance of the recommendation of an expert committee which went into the question of the policy measures and back up facilities needed for the expansion of salt production in India. The main activity areas of the Institute are :

   i) Industrial research in the fields of salt and marine chemicals, desalination, marine algae and sea - water irriculture and solar energy utilisation.

   ii) Development work in the fields of sciencific design and layout of salt works, improvement in the yields through scientific management of the salt works and recovery of marine chemicals.

iii) Process development for manufacture of specialty salts and salt-based chemicals

iv) Technical assistance to industry.

2. The Institute claims to have acted as a catalyst in the rapid expansion of the solar salt industry in India - from around 3 million tonnes in 1955 to close to 6 million tonnes at present - by demonstrating the possibilities of improving yields and returns from solar salt works. The extension services of the Institute cover assistance to entrepreneurs in the selection of proper sites, design and layout of modern salt works appropriate to the local physico-environmental conditions and methods of yield-improvement through improved practices. CSMCRI maintains some experiment-cum-demonstration works.

3. CSMCRI has developed, inter alia, the following processes for the recovery of marine chemicals from waste-bittern of asalt-works

i) Potassium from sea bittern in the form of potassium-schoenite fertilizer (potassium and magnesium sulphates as double salt), which has been tested under field conditions. A plant to produce this fertilizer on commercial scale is in operation at Tuticorin, Tamilnadu (India).

ii) Recovery of basic magnesium salts from sea-bittern using soda ash. The magnesium salts (e.g. magnesium tricilicate) produced conform to pharmaceutical grade. Processes for the preparation of active and refractory grade magnesium oxide have also been standardised.

iii) Patented designs to produce 150-300 kg/day of bromine from bittern which is commercially exploited at present in India.

4. CSMCRI has a field station to study the economic utilisation of marine algae. It claims process know-how for the manufacture of alginic acid, alginates and agaragar from seaweeds. As an extension of its study of reverse osmosis technique, the Institute has been lately studying its applicability for concentration of textile dyes from the effluent for an industrial unit.

5. The Institute is headed by a Director who is assisted by Scientific Advisory Committees in the principal areas of research. An executive committee under the Chairmanship of the Director and comprising of outside experts and scientists from within the Institute supervise its functioning. Each of the research disciplines, viz.

i) Salt & Marine Chemicals

ii) Inorganic Chemicals

iii) Reverse Osmosis

iv) Ion exchange

v) Solar Energy

vi) Marine Algae

vii) Sea Water Irriculture

as well as the Planning and Technical Services Cell is headed by a 'Discipline Coordinator'. The total budget of CSMCRI in 1978-79 was around Rs. 75 lakhs (Approximately $ 1 million).

ANNEXURE - VIA-1

CAPITAL OUTLAY ESTIMATE

(In $'000)

Sl. No.	Item	1 Year			2 Year			3 Year			4 Year					
		F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total
1.	**FOB/FOR Supplies**															
	i/ Plant & Equipment	-	-	-	31.3	-	31.3	106.3	-	106.3	143.8	-	143.8	281.4	-	281.4
	ii/ Misc. Accessories	-	-	-	-	13.8	13.8	55.0	75.6	130.6	87.5	133.1	220.6	142.5	222.5	365.0
2.	Ocean freight & Marine Insurance	-	-	-	3.3	—	3.3	17.1	-	17.1	25.1	-	25.1	45.5	-	45.5
3.	Customs duty	-	-	-	-	0.9	0.9	-	4.5	4.5	-	6.4	6.4	-	11.8	11.8
4.	Inland Handling	-	-	-	-	2.3	2.3	-	11.8	11.8	-	18.2	18.2	-	32.3	32.3
5.	Sales Tax	-	-	-	-	2.8	2.8	-	15.1	15.1	-	26.6	26.6	-	44.5	44.5
6.	Insurance	-	-	-	-	0.5	0.5	-	2.4	2.4	-	3.6	3.6	-	6.5	6.5
7.	**Civil Works**															
	i/ Earth work	-	-	-	-	581.3	581.3	-	850.0	850.0	-	260.0	260.0	-	1691.3	1691.3
	ii/ Buildings	-	-	-	8.6	34.4	43.0	28.2	112.8	141.0	40.0	160.0	200.0	76.8	307.2	384.0
8.	Know-how, Engg. Sup. etc.	63.6	6.6	70.2	52.5	3.0	55.5	25.8	5.4	31.2	35.1	5.4	40.5	177.0	20.4	197.4
9.	Proj. Management Char.	-	20.9	20.9	-	17.4	17.4	-	16.4	16.4	-	16.4	16.4	-	71.1	71.1
10.	Capitalised land lease rent	-	10.0	10.0	-	10.0	10.0	-	10.0	10.0	-	10.0	10.0	-	40.0	40.0
	Tofal Mfg. Facilities	63.6	37.5	101.1	95.7	666.4	762.4	232.4	1104.0	1336.4	331.5	639.7	971.2	723.2	2447.6	3170.8
11.	Residential Quarters	-	-	-	14.0	56.0	70.0	28.0	112.0	140.0	14.0	56.0	70.0	56.0	224.0	280.0
12.	Spares	-	-	-	2.1	1.2	3.3	10.7	6.6	17.3	15.4	11.3	26.7	28.2	19.1	47.3
13.	Working Capital	-	-	-	-	160.8	160.8	-	333.9	333.9	-	440.2	440.2	-	934.9	934.9
14.	Escalation during implementation	-	-	-	INCLUDED IN THE RESPECTIVE ITEMS											
15.	Contingency 5%	3.2	1.9	5.1	5.6	44.2	49.8	13.6	77.8	91.4	18.0	67.4	75.4	40.4	181.3	221.7
16.	Financing Charges	-	3.3	3.3	-	12.6	12.6	-	32.7	32.7	-	65.8	65.8	-	114.4	114.4
	Total Capital Outlay	66.8	42.7	109.5	117.4	941.2	1058.6	284.7	1667.0	1951.7	378.9	1270.4	1649.3	847.8	3921.3	4769.1
17.	Credit for sale of product during construction period of Project	-	-	-	-	-	-	-	342.9	342.9	-	1269.5	1269.5	-	1612.4	1612.4
18.	Net Project Cost													847.8	2308.9	3156.7

ANNEXURE VI A-II

Project Management Charges

General Manager	1 No.
Project Engr. & Assistant	2 Nos.
Typist	1 No.
Driver	1 No.

			I	II	III	IV
GM	(1)	$	3,648	3,648	3,648	3,648
PE & Asst	(2)	$	4,640	4,640	4,640	4,640
Typist	(1)	$	600	600	600	600
Driver	(1)	$	540	540	540	540
Total Salary & Wages		$	9,428	9,428	9,428	9,428
Temp. const & c.		$	2,000	1,000	-	-
Printing & stationery		$	500	500	500	500
Postage		$	1,000	1,000	1,000	1,000
Travelling Exp.		$	2,000	2,000	2,000	2,000
Operation and maintenance of vehicles		$	1,000	1,000	1,000	1,000
Project activities		$	2,000	-	-	-
Legal expenses		$	500	500	500	500
Misc. expenses		$	1,500	1,000	1,000	1,000
			19,928	16428	15428	15,428
Contingency			1,000	1000	1000	1,000
Total :			20,928	17428	16428	16,428

ANNEXURE VIA-III

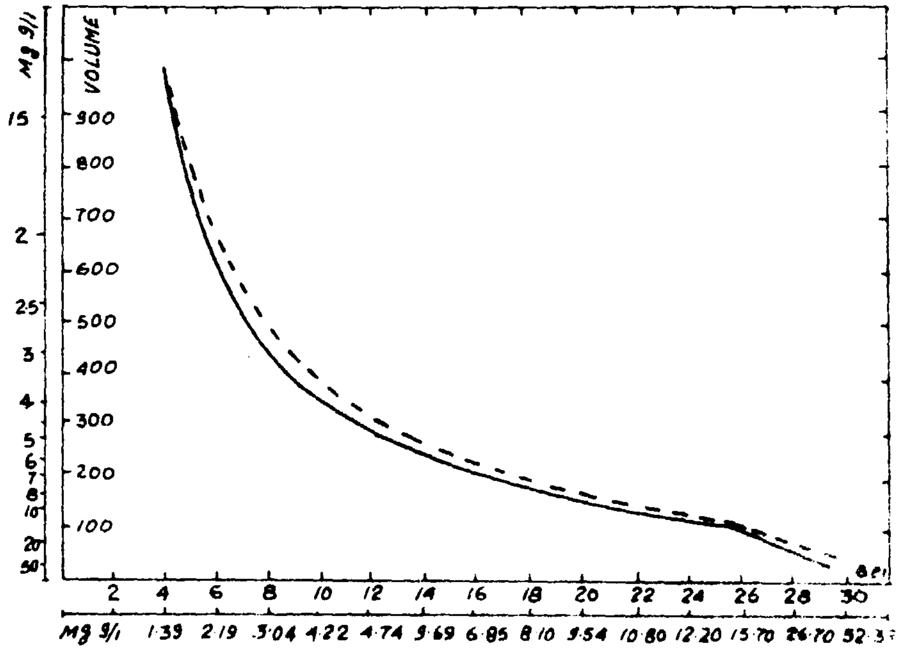
WORKING CAPITAL REQUIREMENT

(In $ '000)

Sl. No.	Particulars	Year II	Year III	Year IV
1.	Fuel : diesel oil etc. one month (total of 6 months)	6.7	21.7	40.0
2.	Goods in process	1.0	2.0	4.0
3.	Product inventory	50.7	152.1	304.2
4.	Accounts receivable (30 days)	97.8	317.7	586.7
5.	Account payable (15 days)	(3.4)	(10.8)	(20.0)
6.	Cash in hand	8.0	12.0	20.0
		160.8	494.7	934.9

(1) Figs. in brackets negative

(2) The total working capital is capitalised



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SEAWATER CONCENTRATION
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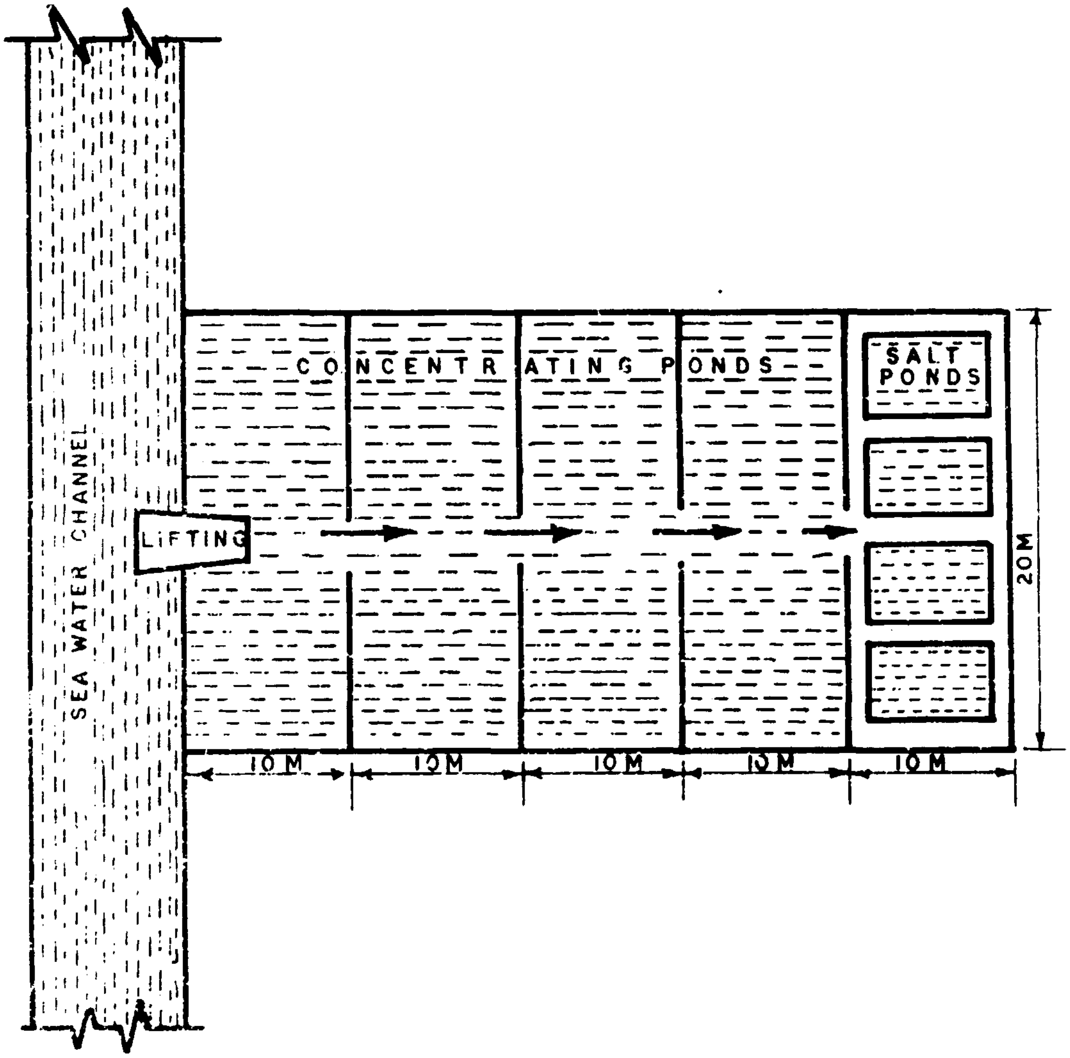

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EXISTING SALT FIELDS IN BANGLADESH

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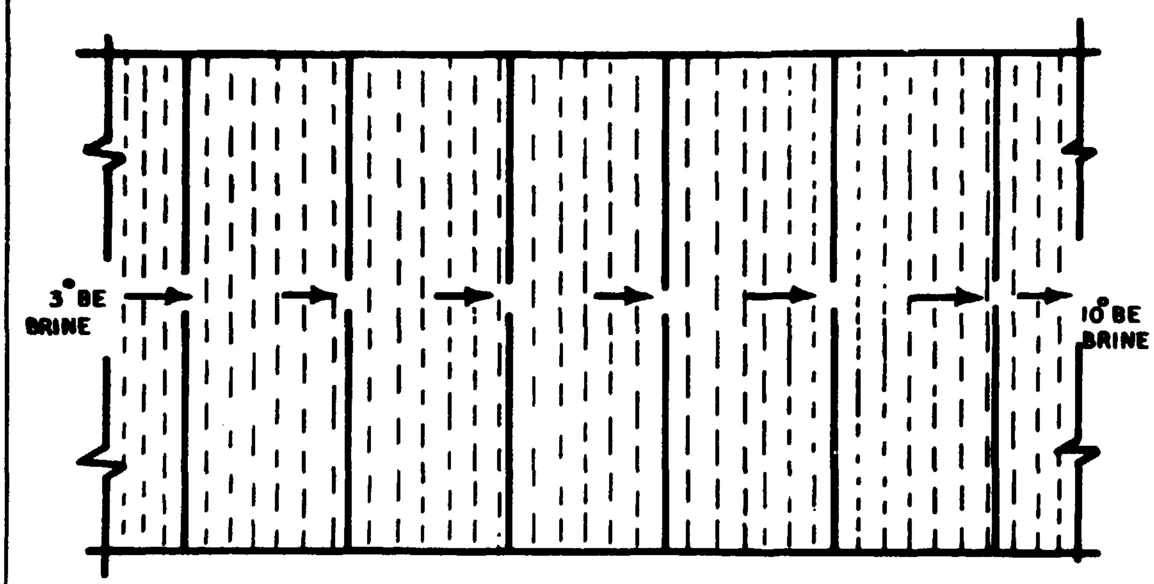

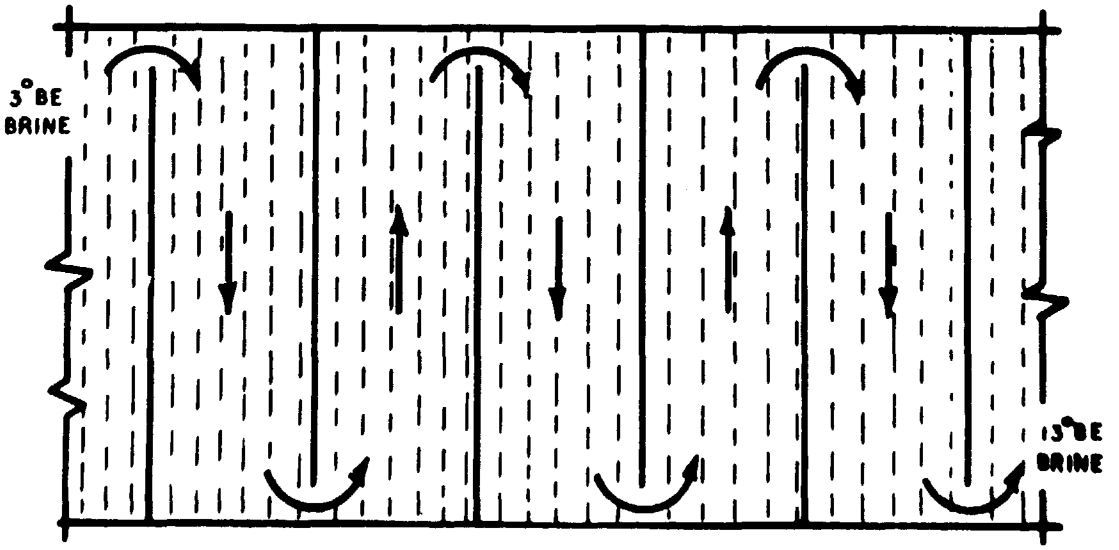

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EXISTING PRACTICE & RECOMMENDED METHOD OF BRINE CIRCN.

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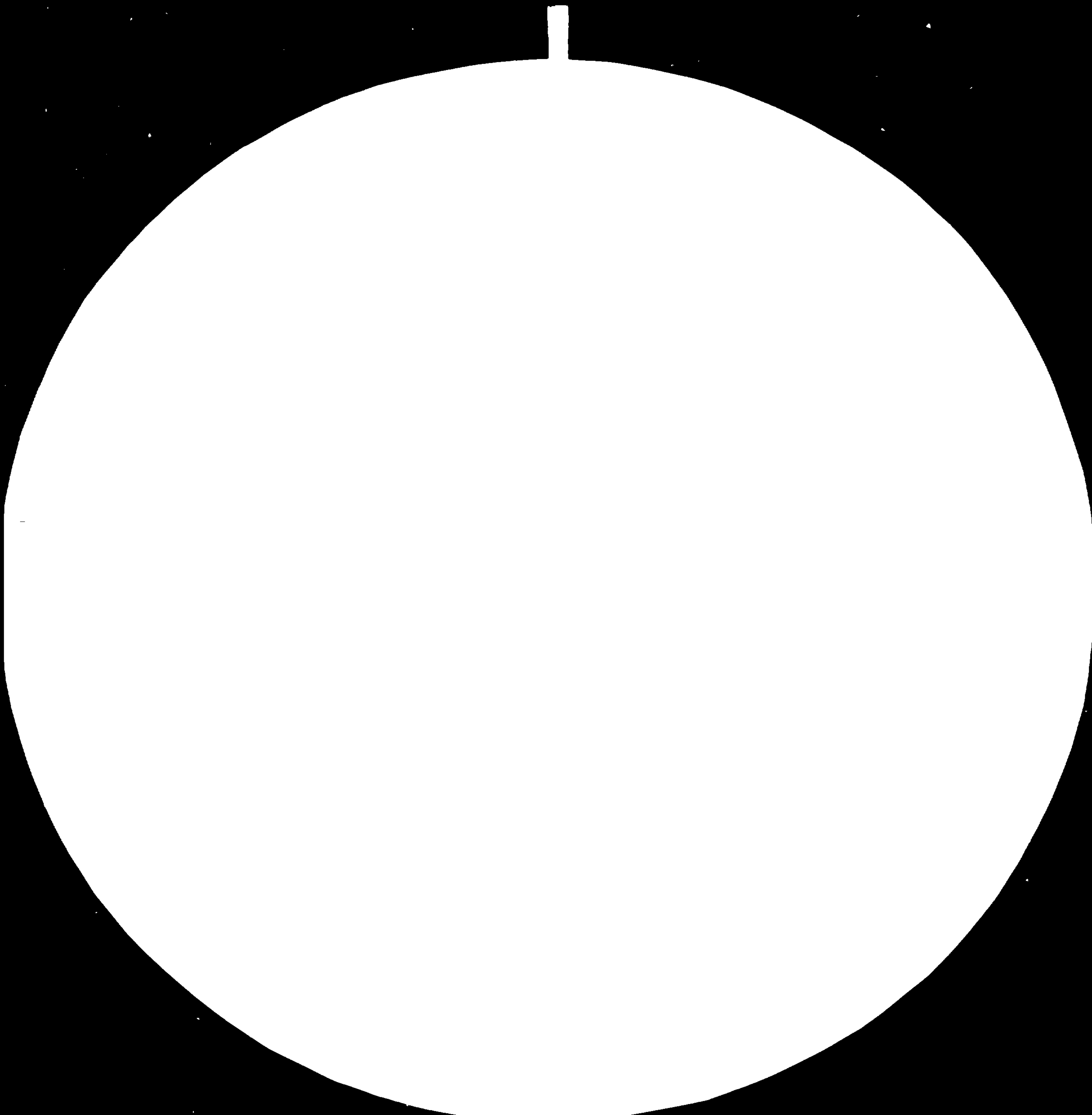

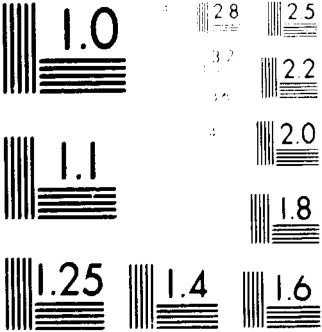
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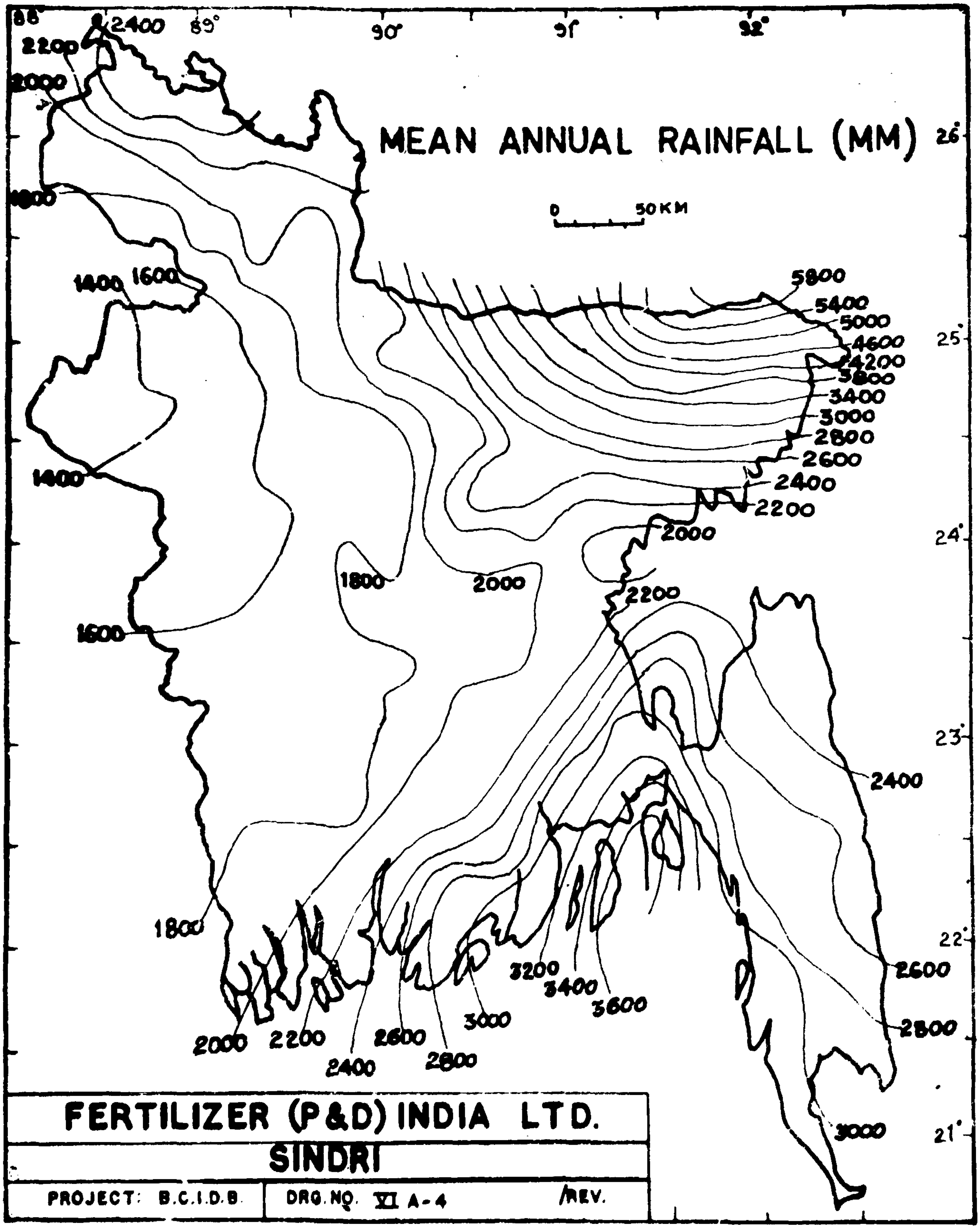

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SINDRI

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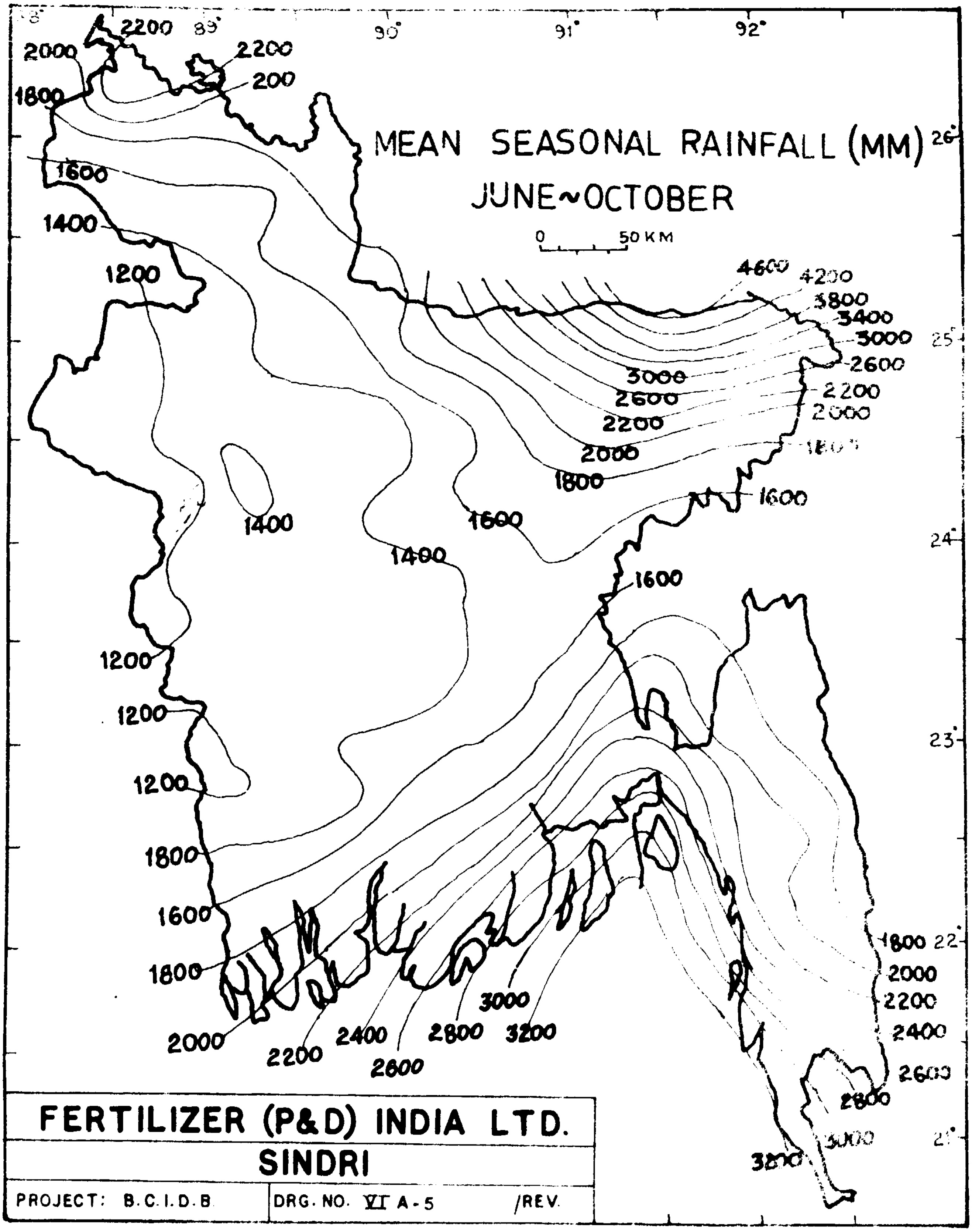

MEAN SEASONAL RAINFALL (MM)
JUNE~OCTOBER

FERTILIZER (P&D) INDIA LTD.

SINDRI

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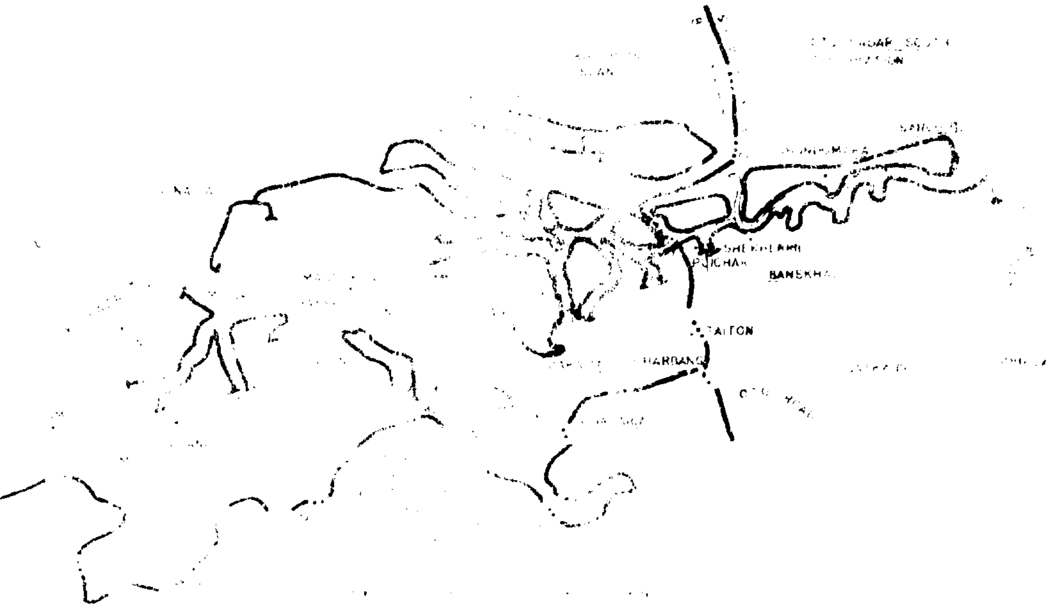

EMBANKMENT

ZER (P & S) INDIA LTD

MAP SHOWING THE COASTAL
EMBANKMENT UNDER COX'S
BAZAR POLICE STATION
CHITTAGONG

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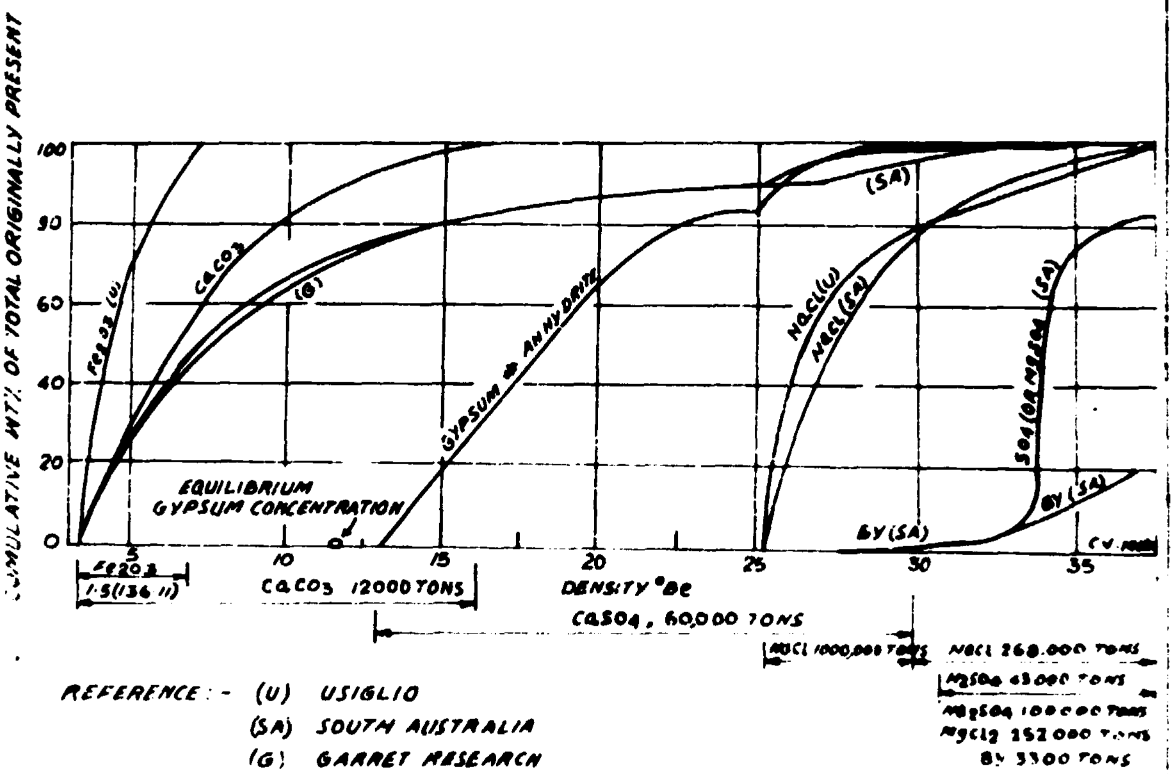

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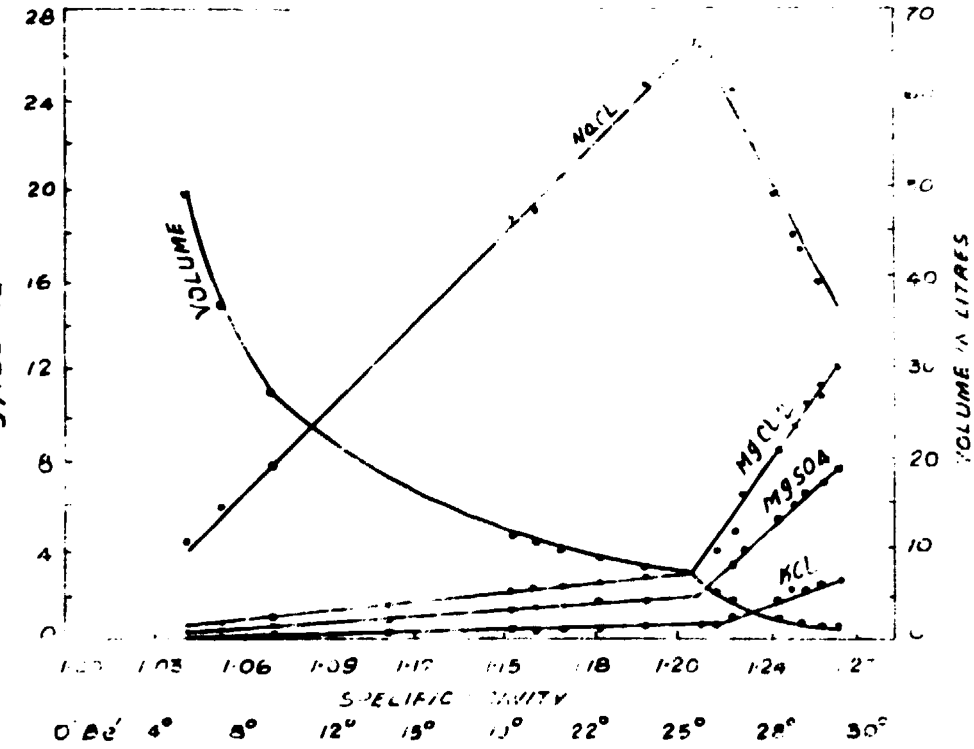
TITLE

DEPOSITION OF SALTS DURING THE EVAPORATION OF SEAWATER 25°C

PROJECT B C I D B	DRG NO VI A-7	REV

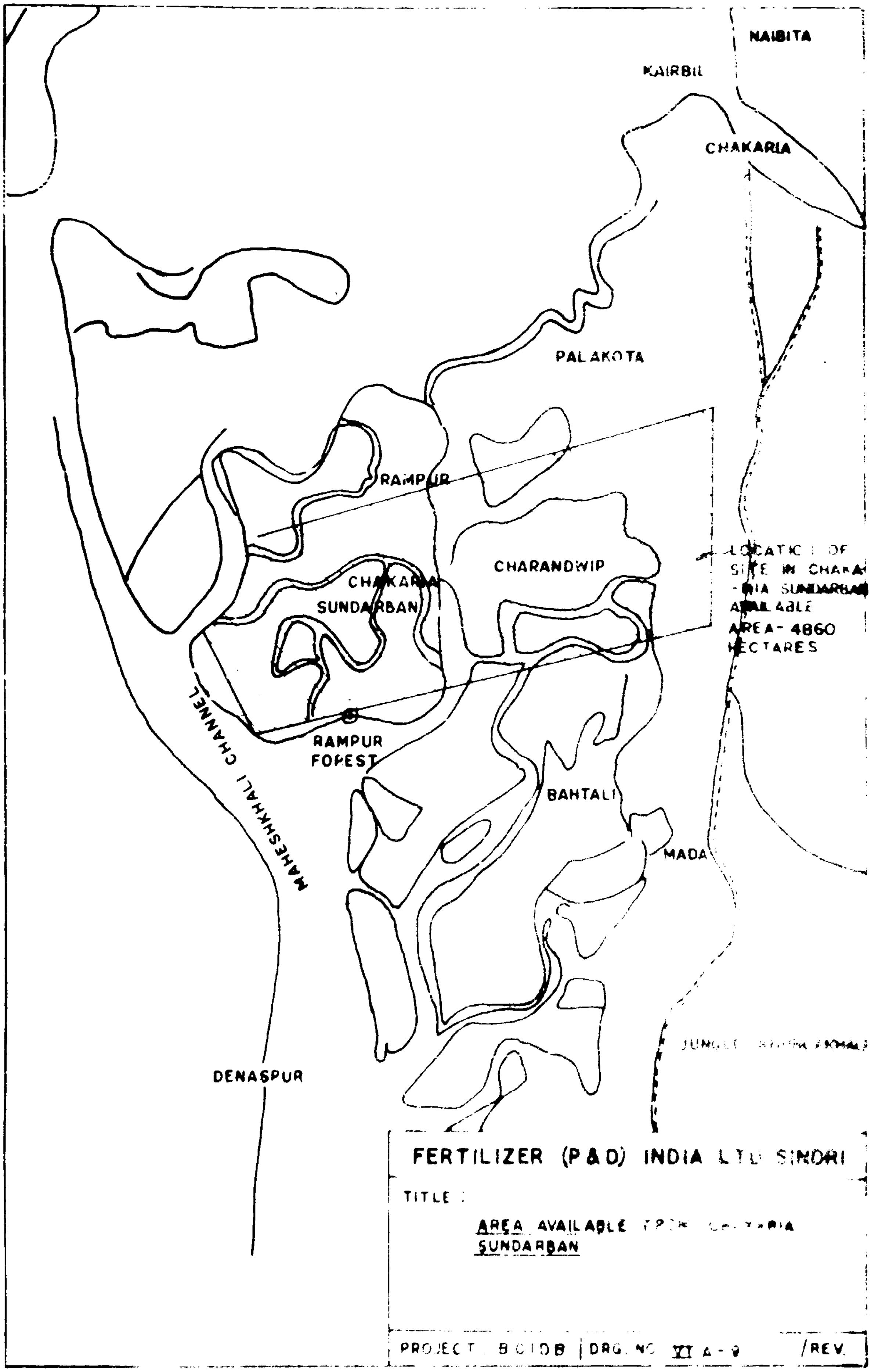


FERTILIZER (P&D) INDIA LTD. SINDRI

TITLE:

SEPARATION OF SODIUM CHLORIDE,
MAGNESIUM CHLORIDE, MAGNESIUM
SULPHATE AND POTASSIUM CHLO-
RIDE AND REDUCTION OF VOLUME
ON EVAPORATION OF SEA BITTERN

PROJECT [illegible]	DRG NO [illegible]	REV



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TITLE :

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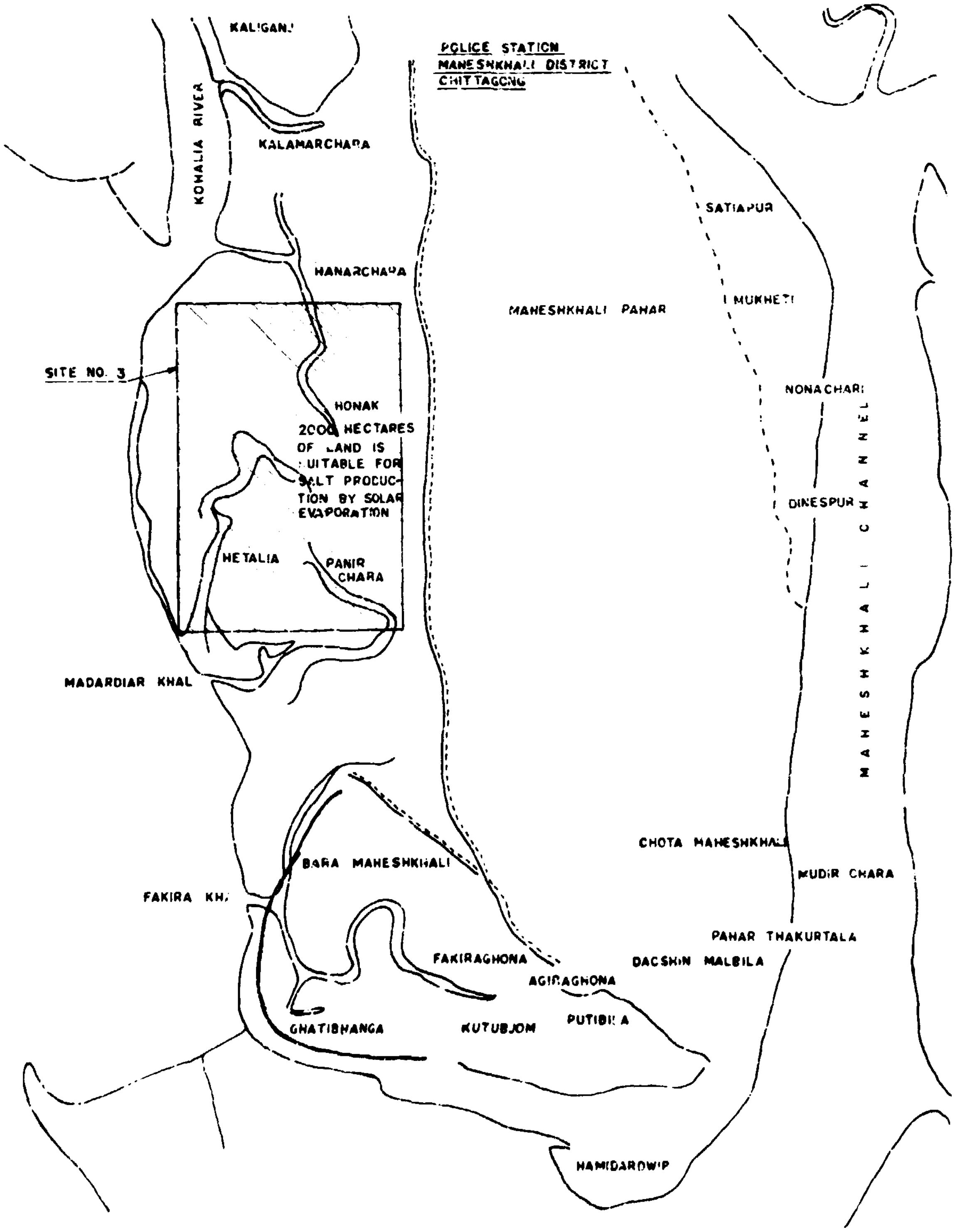
SUNDARBAN

PROJECT BC10B | DRG. NO XI A-9 | REV.

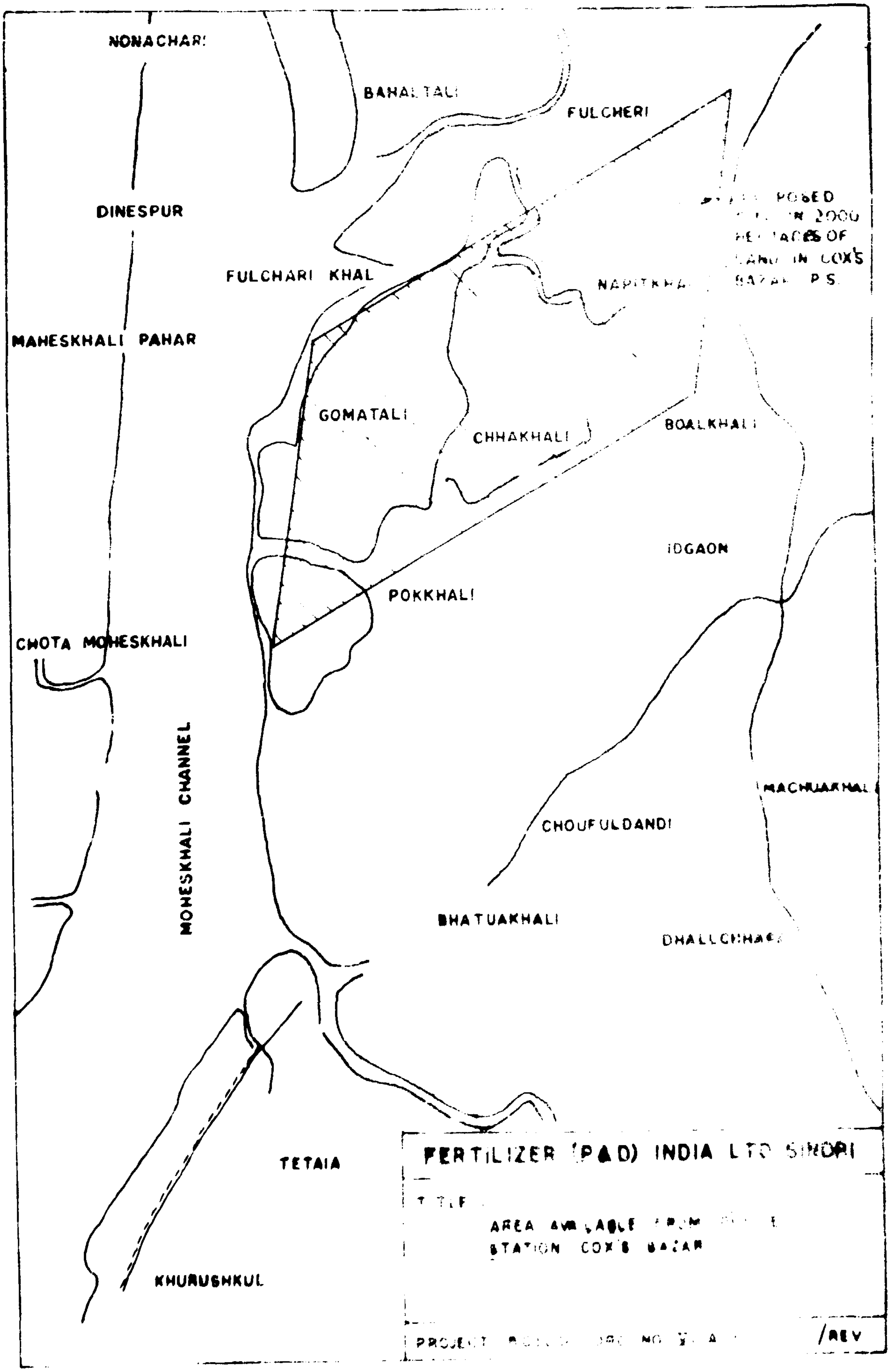


SCALE 1" : 1 MILE

FERTILIZER (P&D) INDIA LTD. SINDRI

TITLE :
AREA AVAILABLE FROM POLICE STATION
MAHESHKHALI DISTRICT CHITTAGONG

PROJECT : BCIDR | DRG NO V A-10 | /REV



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TITLE

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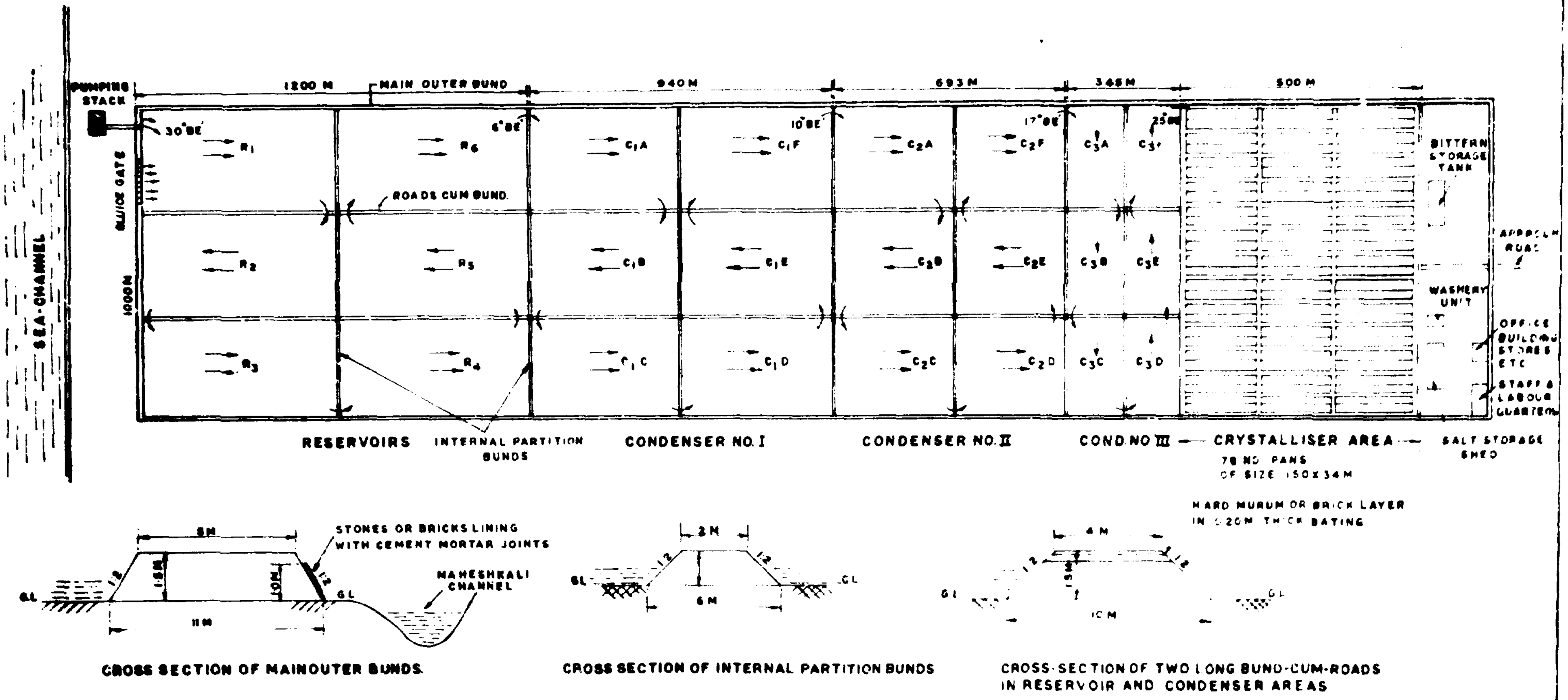
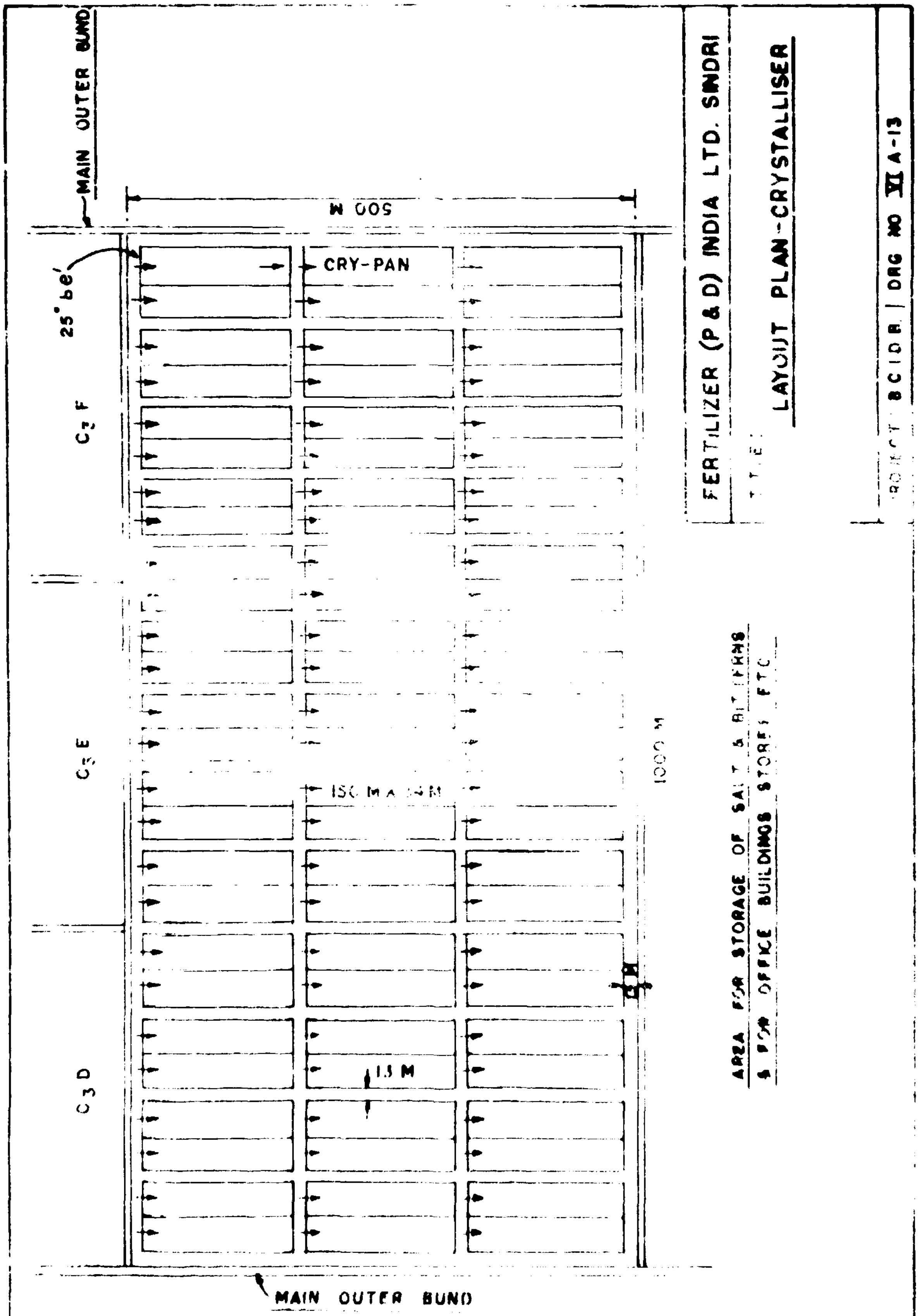


LAYOUT PLAN FOR 403.3 HECTARES (1000 ACRES) OF LAND
FOR LARGESCALE SOLAR SALT WORKS
ONE UNIT

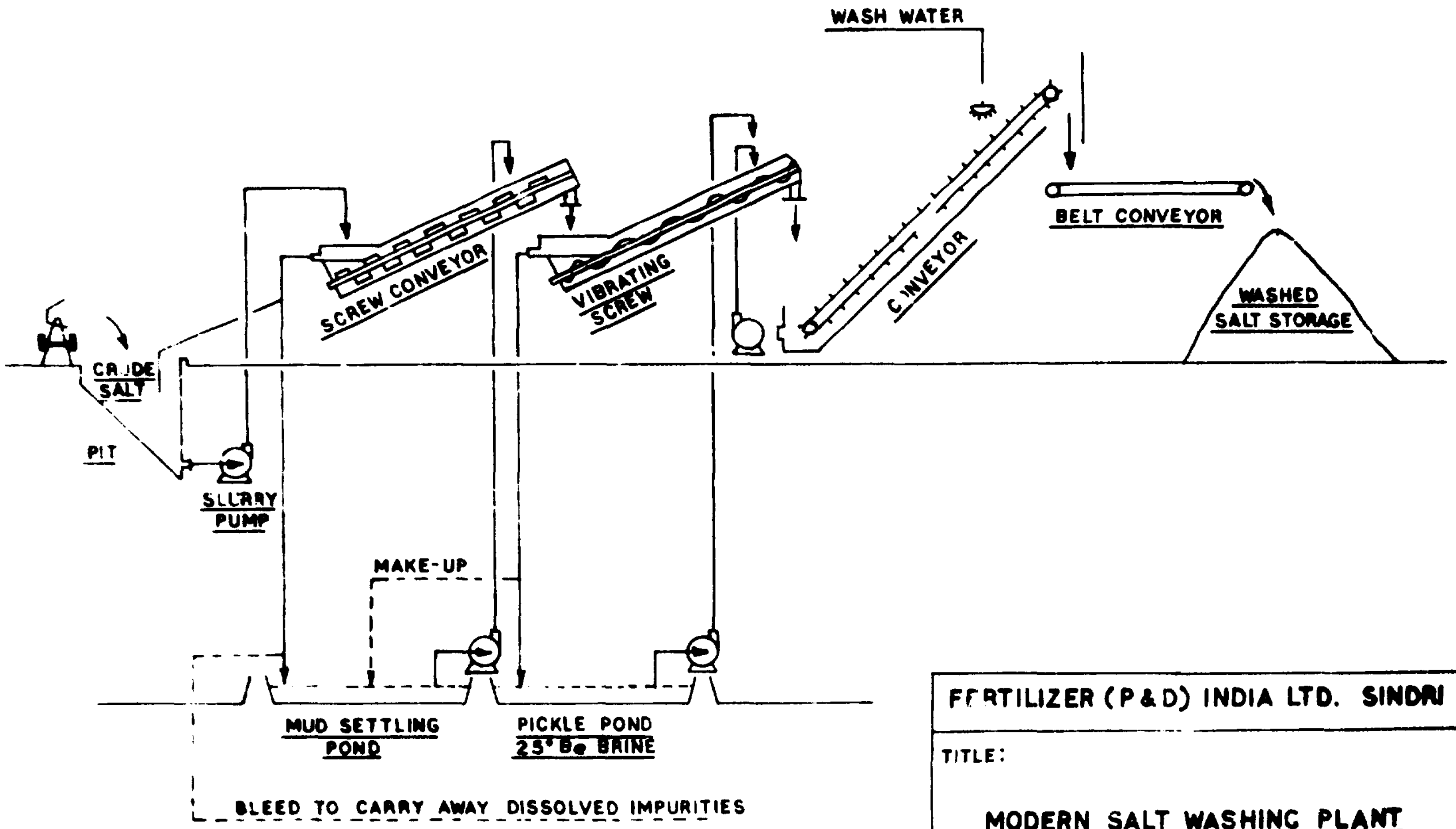
FERTILIZER (P&D) INDIA LTD SINDRI

TITLE - LAYOUT PLAN
FOR 403.3 HECTARES (1000 ACRES)
OF LAND FOR LARGE SCALE SOLAR
SALT WORKS

PR [illegible] | DRG NO [illegible] | REV



DETAILS OF CRYSTALLISER PANS 78 No OF SIZE 150 M X 34 M
WITH ROADS & CHANNEL PATHWAYS



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TITLE:

MODERN SALT WASHING PLANT

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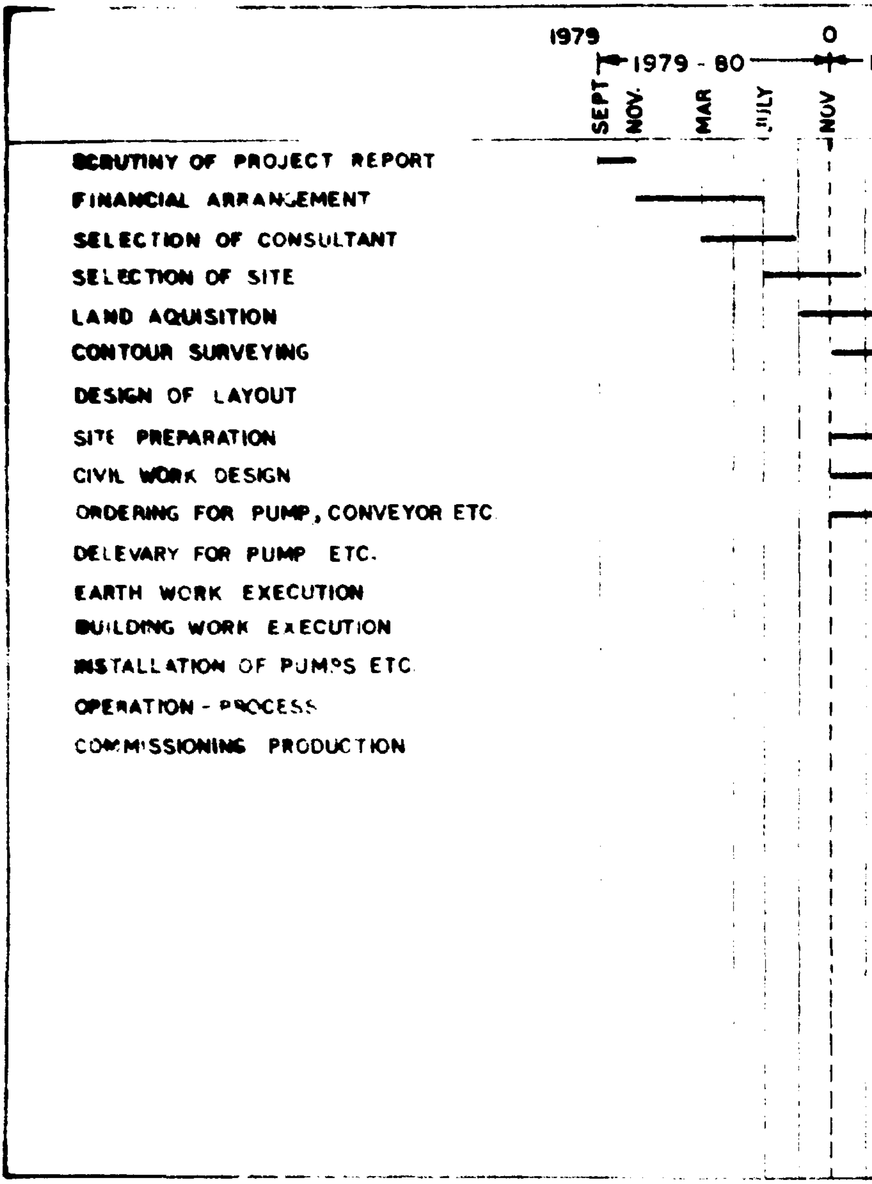
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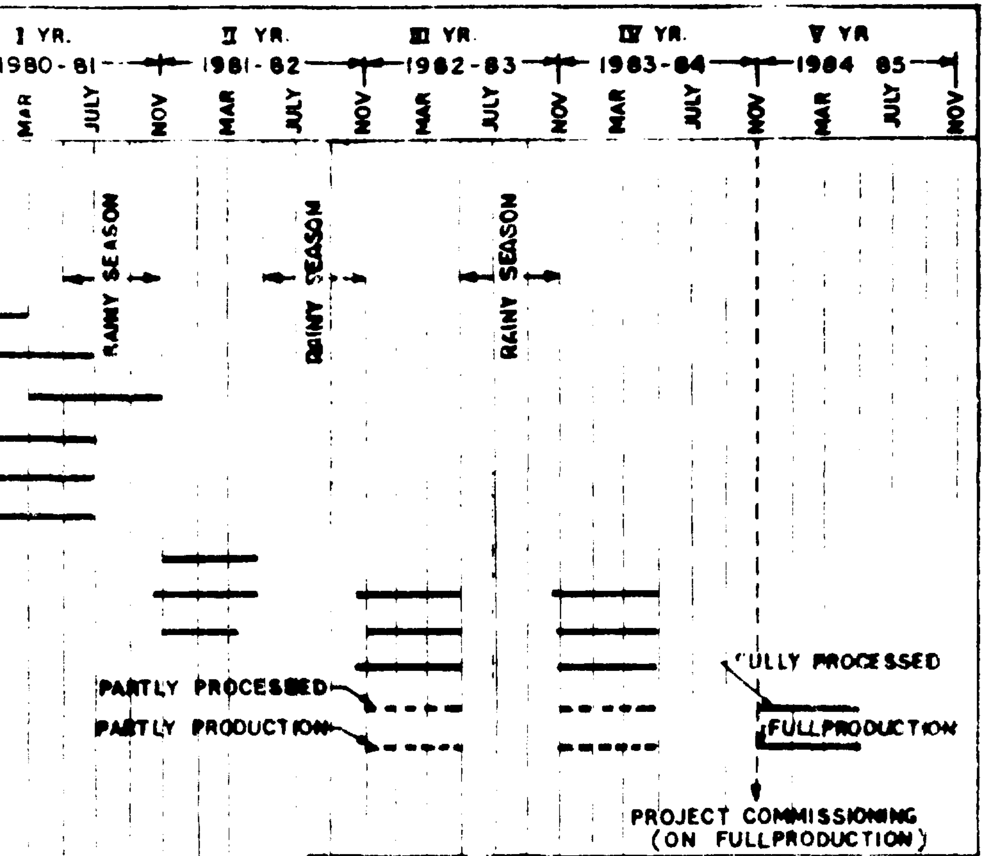
SELECTION OF CONSULTANT
SELECTION OF SITE
LAND AQUISITION
CONTOUR SURVEYING
DESIGN OF LAYOUT
SITE PREPARATION
CIVIL WORK DESIGN
ORDERING FOR PUMP, CONVEYOR ETC
DELEVARY FOR PUMP ETC.
EARTH WORK EXECUTION
BUILDING WORK EXECUTION
INSTALLATION OF PUMPS ETC
OPERATION - PROCESS
COMMISSIONING PRODUCTION



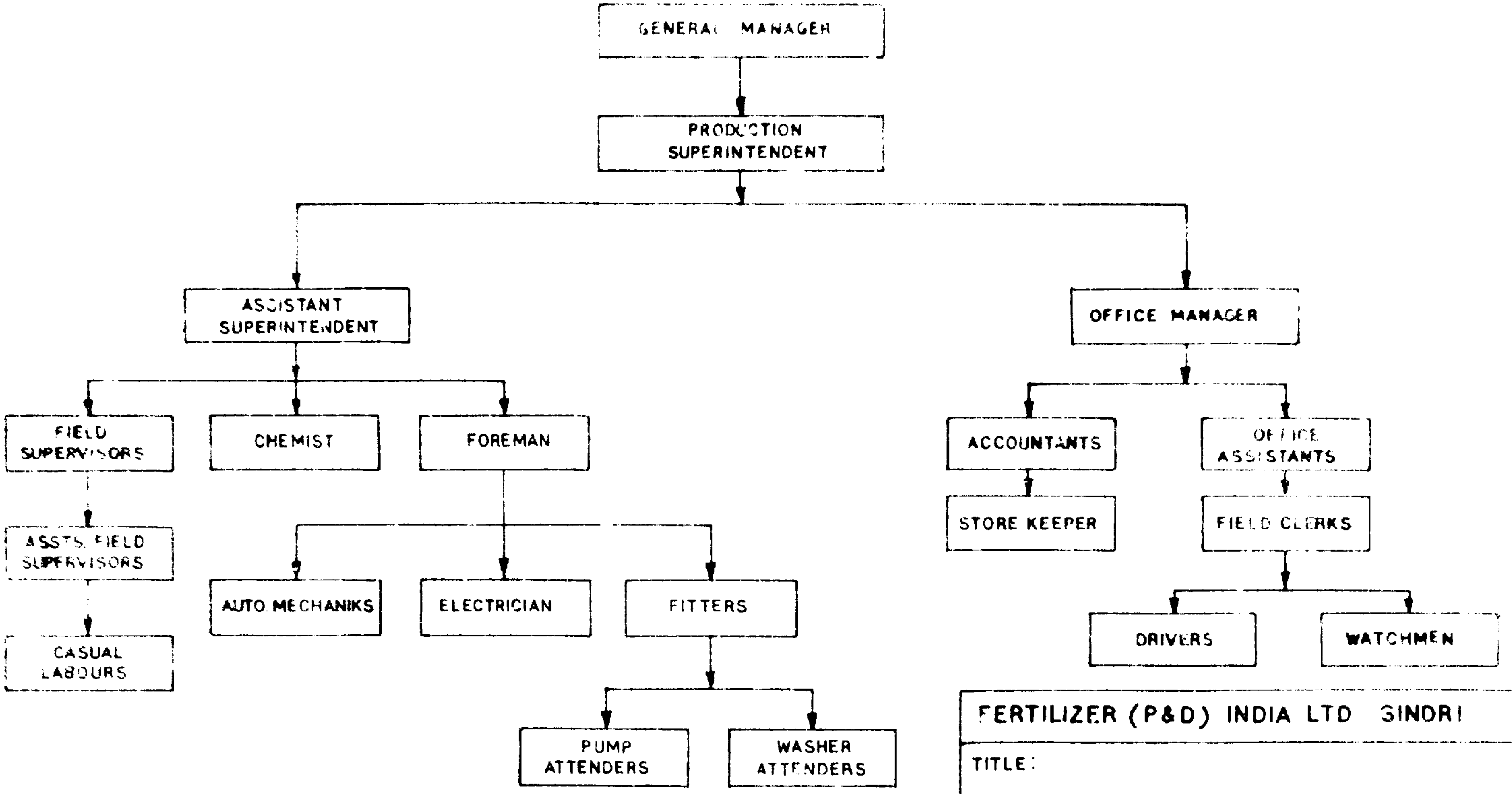
FERTILIZER (P& D) INDIA LTD. SINDRI

TITLE :

TENTATIVE TIME SCHEDULE

PROJECT B.C.I.D.B

DRG. NO. VI A-15



FERTILIZER (P&D) INDIA LTD SINDRI

TITLE:

STAFFING

PROJECT: B.C.I D.B

DRG. NO. VI A-16

PART VI

SECTION B

SALT PRODUCTION THROUGH FORCED EVAPORATION

SECTION B : SALT PRODUCTION THROUGH FORCED EVAPORATION

Chapter 10

SCOPE IN BANGLADESH

10.1 The Solar Evaporation Process is universally acknowledged as the cheapest method of production of salt from sea water in areas where climatic conditions are favourable and the sunshine is abundant. The solar method has the added advantage of simplicity of operation and low capital intensity, except for land. It is particularly suited to regions where labour supply is ample and wage rates relatively low. However, in countries where climatic conditions or land availability factors are not favourable, and reserves of rock salt do not exist or are considered inadequate, artificial techniques for manufacture of salt from sea water can be employed, provided other inexpensive sources of energy are available.

10.2 Salt manufacture from sea water, since it essentially involves evaporation of brine to solidity, is highly energy intensive. It takes the evaporation of about 43,000 litres of water from a brine of 3.5^{o} Be' concentration to get a tonne of salt and the energy input needed is equivalent to about 2.32 x 10^{7} Kcal (about 4.2 tonnes of coal replacement). The critical difference in any artificial evaporation system is that unlike solar heat, which is free, any form of commercial energy has a cost, and the energy intensive nature of the operation makes the process expensive in comparison, unless the energy used is priced very low. Hence, the artificial evaporation system is sparingly used the world over for salt production, save in exceptional cases such as (i) where salt is priced very high and procurement by imports is uneconomic by comparison (ii) energy available is cheap (iii) purity of salt required is very high, which it is possible to produce in a controlled industrial unit, compared to the solar evaporation process where sophisticated controls are not feasible and (iv) where salt production is incidental to the main objective of producing high purity water for specialised applications or in water-scarce regions, from the available brine. As far as is known, there are hardly about a dozen units in the world producing salt, either as a main product or as coproduct, from sea water by this method. Among these, the plants in North Dakota (USA), Puerto Rico, Kuwait, Island of Aruba (Carribbean), Japan and India can be cited. The North Dakota plant is said to have a capacity of 300 tonnes of salt per day. In comparison, the Puerto Rico plant is a small one, with a capacity of only 16,000 te/year (about 50 tpd). The Indian plant has a capacity of 250 te/day, but essentially it is a facility for producing boiler feed water for the adjoining heavy chemicals complex. The units in Middle East are primarily meant for producing potable water.

10.3 Bangladesh is a tropical country, and as seen earlier in Section A, the climatic factors are not unfavourable to solar salt manufacture. Apart from the possibilities of raising output from the existing units, facilities exist for the expansion of area under salt production to a significant extent. Besides natural gas, no other commercial fuel source is available in ample quantities. In gas, though the total reserves are said to be quite high, the harnessing is in a development stage only and the present distribution system does not cover even the second largest city and the major industrial centre of Chittagong. Considering just the cost of gas transmission alone, the possible gas price cannot be so cheap as to make salt produced from an artificial evaporation unit competitive with solar salt. Hence for Bangladesh, the prime reliance will need to be placed on solar process only.

10.4 However, till very recently, Bangladesh has been importing substantial quantities of salt, and the present self-sufficiency is primarily due to a very favourable climate in 1977-78. The supply and demand equation being delicately balanced, adversity in climatic factors in any one year can again expose the country to deficits of large magnitude. Unfavourable climatic conditions are not uncommon. Experience has shown that in a cycle of 10 years, atleast 3-4 years will be abnormal from the point of view of salt production. The critical importance of the impact of weather on production and the supply-demand situation can only grow as the demand for salt increases. In the past, abnormal weather conditions have resulted in acute scarcity conditions in the market and though buffer stocks have now been built to tide over such crises, replenishments to the buffer stock will not be easy, except through imports, if the production falls short in successive years.

10.5 To meet such eventualities, there may be advantage in having a production system largely independent of the climate, and it is in this context that artificial evaporation salt plant can be considered, as a kind of insurance to meet the contingencies of acute scarcity. In addition, a salt based chemical plant, which wants to be assured of high grade salt and which is not sensitive to minor variations in the price of salt may consider the establishment of an artificial evaporation salt plant as a captive unit. In fact, as this Study will later show, the current market prices for salt in Bangladesh are not far below what a fairly large-sized artificial evaporation plant can produce and sell, taking into account the differences in salt purity.

10.6 The Consultants do not recommend the establishment of a unit based on forced evaporation for salt production in the early future. It may be more advantageous to concentrate on the improvements to the solar salt industry rather than expend scarce resources on a high-cost unit which may turnout to be a burden on the economy for long years to come, unless the production situation becomes really critical so as to leave no alternative. A study on the artificial system is presented in the following chapters only to provide a measure of the costs and investment magnitudes involved, so that a decision can be arrived at in the proper perspective. A fresh appraisal of the proposal can, however, be made, when gas supply at a convenient point becomes available at a reasonable cost.

Chapter 11

PROCESS DESCRIPTION

11.1 The process for the production of salt by artificial evaporation, considered suitable for Bangladesh, is a combination of solar evaporation for the initial concentration of brine and steam heated evaporation in the subsequent stages of salt recovery. This system has been proposed to economise on the commercial energy use. Complete dependence on the artificial evaporation method will involve considerably high use of commercial energy, since sea water has a low density of around 3° Be' along the Bangladesh coast. Use of the freely available solar energy for initial concentration can, therefore, result in significant economies in energy cost, since the evaporation rate in the early stages of brine concentration is significantly higher. Besides, the solar evaporation by stages can be used successfully with low cost to separate out bulk of the impurity of calcium sulphate (gypsum).

11.2 The process thus proposed is the same as the solar evaporation system upto the stage of concentration of brine to 25° Be', but from thereon, instead of the brine being led into the crystallisers it will be evaporated with steam heated evaporators. (Drawing No. VI B-1). The plant facilities, therefore, include solar concentration ponds with associated facilities, concentrated brine storage ponds, a steam heated multiple effect evaporator, boilers, centrifuge, dryer, a bagging plant and storage. The salt will crystallize in the evaporators as uniform cubes, almost similar to table salt. The salt crystals will then be washed with distilled water to remove any adhering impurities of calcium and magnesium salts in a centrifuge. The salt obtained from filtration will contain about 2 percent moisture, which it will not be necessary to remove if the salt is to be used for soda ash manufacture. A rotary dryer has, however, been provided in the facilities on the assumption that atleast a part of the salt will be sold for domestic consumption. Dry salt will be packed in jute bags in conformity with current practice in Bangladesh.

11.3 The use of an evaporator in the place of crystallising ponds has two distinct advantages : the first, it economises on the use of land, roughly by about 25 percent : Second since concentration of brine to 25° Be' results in a 90 percent reduction in volume, it becomes economically feasible to store the saturated brine in storage reservoirs and permit year-round production of salt, instead of its being confined to dry season alone. In addition, the scheme can count on the following merits :

i) closer control of brine densities, with resultant higher yield of salt

ii) continuous supply of bittern for byproducts recovery

iii) elimination of loss of costly brine through seepage etc. in crystalliser ponds

iv) less dependence on the vagaries of weather; saturated brine can in fact be carried from one season to another to cushion the effect of variations in climatic conditions

v) improved grade of salt due to closer process control

vi) economy of labour, harvesting being a labour intensive operation

Chapter 12

PLANT CAPACITY

12.1 Several factors will need to be considered in arriving at the optimal plant capacity, such as the demand for salt and the projected deficit, influence of climatic factors on production, land availability, the source of energy etc. Apart from these, however, one other important consideration is whether outlets exist for the sale of distilled water produced in the process at reasonably attractive prices. It is said that the viability of Tata's plant in India is due to the fact that water is priced at opportunity cost for supply to the adjoining chemical complex, which makes the process competitive with the solar evaporation method. In general, plants in the smaller capacity range are uneconomic due to the relatively heavy capital investment and maintenance costs, especially since salt is a very corrosive substance. Taking into account these factors, and the requirements of a minimum viable capacity soda ash plant (considered a part of this Project) and the country's requirement of high purity salt for special uses (about 30,000 tonnes/year), a plant of the capacity of 150 thousand tonnes/year (500 tpd) is proposed. This capacity is suggested in the light of experience of the owners of a similar type plant in India (with a plant capacity of 250 tpd) and the current plant costs. This capacity almost corresponds to the capacity of the solar evaporation process facility discussed in Section A, taking into account the saturated brine production capacity alone, and can therefore, be integrated with that unit any time. This will also permit direct comparison of the relative costs of production of salt by the two processes.

Chapter 13

SELECTION OF SITE

13.1 Two significant but somewhat mutually exclusive- under Bangladesh conditions, - considerations will need to be taken into account in the selection of sites for a salt plant based on artificial evaporation. First, since the feedstock for the plant is saturated brine, brine transport requires to be minimised; this factor tends to push the locations closer to the initial concentration ponds or closer to the brine source. Second, the prospects for finding a user for the distilled water, - which will substantially bring down the cost of production of salt - will be brighter if the plant is located in an industrial centre, say, close to the soda ash plant, which is presumed to be the main user of the salt produced. Under the prevailing conditions in the country, this will mean location away from the main solar brine source. Hence two alternative locations are considered in this study : first, location close to the brine source, viz next to the solar evaporation pond at Chakaria-Sundarban and the second, close to industrial centre, viz. Chittagong, next to the site for the proposed soda ash plant.

13.2 Location at Chakaria-Sundarban will involve no transportation of brine, and therefore, apart from the cost of transport, handling losses of brine will also be minimal. But this will mean, no proper use can be found for the distilled water produced, except perhaps in low value uses such as drinking water and wash water. Also, the possibility of use of natural gas as fuel is remote, since there is no likelihood of a gas transmission line to the area being laid in the near future, whereas there is already an active plan to feed Chittagong with natural gas from the Bakhrabad gas well. Necessarily, a plant at Chakaria-Sunderban will have to be based on furnace oil, which again will have to bear the additional burden of transport cost to the site, compared to Chittagong. Availability of skilled labour to operate the plant in Chakaria-Sunderban area will not be high, and, therefore, more intensive training of operating personnel will be required.

13.3 Chittagong location of the plant has the advantage that it might be possible to find users for the condensate water such as say, in boiler feed water or alternately find sources from where steam can be drawn at reasonable cost. It may also be possible to share some of the common infrastructural facilities such as roads and power with other salt-user units like the soda ash plant. In fact, since the site considered is adjacent to the proposed Chittagong Urea Fertilizer Project and the proposed soda ash plant sites in the Middle Island, the possibilities of sharing some of the utilities, including steam has been explored and it has been found possible to integrate this plant with the other two chemical plants in respect of steam generation, with a common steam generation unit. Hence, for the purpose of analysis, - and for the purpose of comparison of this process in its most favourable light with the solar salt process, - it has been assumed that steam will be purchased from a common generation plant at the cost of production viz. Tk 90 per tonne.

13.4 If the plant is to be located at Chittagong, brine transport arrangements will have to be considered, since there are no good facilities for developing solar evaporation ponds in the area, partly owing to land-scarcity and partly due to the low concentration of sea water for a major part of the year as a result of dilution from river flows. Two possible methods of brine transport from Chakaria-Sundarban are examined for evaluation : coastal tankers and pipeline.

13.5 Considering the volume of saturated brine that will need to be transported to the evaporator unit (500 te/day capacity), shipment by tankers will pose some acute problems of logistics. Theoretically, 4500 litres of 25° Be' brine will be needed to produce a tonne of salt, but considering seepage losses in storage pond and some handling losses, in practice, the requirement can be assessed at 5000 litres, which puts the daily intake for the 500 tpd capacity plant at 2.5 million litres. Again, assuming that brine transport will have to be arranged, on average, within 180 days in a year (corresponding to the production season at the solar works - so that a reservoir at production site is avoided), the quantity of brine which will have to be carried per day works out to around 5 million litres or about 6000 tonnes. The distance between Chakaria-Sundarban and Chittagong is about 75 Km and therefore, only one trip per day for a tanker of normal speed will be possible. Hence one tanker of about 6000 te capacity will be needed to move the brine. A tanker of this size will require proper berthing facilities both for loading and unloading at Chakaria-Sundarban and at Chittagong respectively.

13.6 A pipeline, on the other hand over a distance of nearly 100 Km will be both difficult to lay on a settled terrain criss-crossed by streams and rivers and expensive to maintain, especially since brine is highly corrosive. In view of the likely pressure drops, pumping stations will have to be provided at intermediate points. No industrial unit of the size considered here will be ordinarily in a position to take on the burden of costs involved. However, for purposes of comparison of the magnitude of values involved Table 13.1 gives a fairly rough indication of the additional cost of production of salt at Chittagong arising from transportation of brine either by tanker or by pipeline vis-a-vis the production cost of salt at brine source, viz Chakaria-Sundarban. As seen from the Table, transport of brine and manufacture of salt at Chittagong turns out to be prohibitive, compared to the production of salt at Chakaria-Sundarban and its transport to Chittagong. Therefore, the Chittagong location can be ruled out of consideration even at this stage.

Table 13.1

Comparison of Sites : Chakaria & Chittagong

(Figs. in US $ '000)

Sl. No.	Item	Site		
		Chakaria	Chittagong	
		Sundar-ban	Scheme-1 (Tanker)	Scheme-2 (Pipeline)
1.	Additional Investment			
	i) Tanker	-	2000	-
	ii) Pipeline	-	-	21688
	iii) Jetty	-	3000	-
	iv) Brine channel and brine reservoir for pumping brine into tanker	-	25	-
	v) Steam generation plant	950	-	-
	vi) Yard piping for steam	-	59	59
	Sub-total	950	5084	21747
2.	Extra Fixed Cost			
	i) Interest on investment	95	508	2175
	ii) Depreciation			
	a) Tanker-20 years' life	-	100	-
	b) Pipeline-10 years' life	-	-	2169
	c) Jetty-30 Years' life	-	100	-
	d) Brine channel, reservoir, steam generation plant and yard piping - 12 years' life	79	7	5
	iii) Maintenance			
	a) 5% on ship, pipeline, steam generation plant, and yard piping	48	104	1087
	b) 1.5% on jetty	-	45	-
	iv) Labour and Overheads	-	10	5
	v) Miscellaneous	-	2400	30
3.	Operating Cost			
	i) Furnace Oil	1125	-	-
	ii) Steam	-	1200	1200
	Sub-total	1347	4474	6671

Sl. No.	Item	Site		
		Chakaria	Chittagong	
		Sundarban	Scheme-1 (Tanker)	Scheme-2 (Pipeline)
4.	Extra cost per ton of salt produced, (US $)	8.98	29.82	44.47
5.	Credit for evaporator condensate per ton of salt produced	-	(1.55)	(1.55)
6.	Extra transportation charges of salt	5.00	-	-
7.	Net difference in cost per ton of salt produced, US $	13.98	28.27	42.92

Chapter 14

PROFILE OF THE PROJECT

14.1 The project that is being considered now will consist of two sections : the first will comprise solar ponds where sea water will be concentrated through solar evaporation upto saturation point and the second, where saturated brine will be evaporated through steam heated evaporators and salt recovered as crystals. The capacity proposed is 500 tonnes/day and the location : Chakaria-Sundarban in Cox's Bazar Thana.

14.2 The process of solar evaporation upto the stage of the concentration pond has been described in Section A (Chapter 5) and the proposed layout is given in Drawing No. VIA-12. Compared to the solar evaporation process dealt with in Section A, only the crystallizer beds will be eliminated, which will result in a reduction in the land area required for the works by about 1000 acres. Instead, saturated brine of 25^{o} Be' from the last concentration pond (C_3F) will be led into a reservoir, where brine will be stored for the year round operation of the evaporators. Three reservoirs, each of about 125 million litres capacity are contemplated. The reservoirs will be of 3 m depth but provision will be made at a depth of 0.5 m from the top for rainwater discharge outlets. Since brine has a higher density compared to rainwater, the water will tend to stay at the surface and therefore can be easily drained out. To minimise seepage losses, the reservoirs will be lined with polythelene sheets.

14.3 Saturated brine from the storage ponds will be pumped to the multiple effect evaporators, of which there will be five in number, four in operation and one standby (Drawing No. VIB-1). In the evaporators, brine is heated upto the boiling point with steam. In the first evaporator external steam at low pressure (20 psig) will be used as a heating media, but in the subsequent three 'effects', vapours generated in the preceding flash chambers will be used as heating media. The boiling brine will be flashed in the flash - chamber, (Evaporator-Body) where the reduction in pressure results in evaporation of water vapour, and formation of salt crystals which come out in the form of slurry alongwith unevaporated brine. A part of the slurry will be continuously removed from the evaporators but the rest will be recirculated to ensure that the density remains at around 29° Be'. With an elutriator leg attached to the bottom of each 'effect', the remaining impurity of calcium sulphate is also removed. Since calcium sulphate crystals are smaller than salt crystals, they settle down less rapidly and therefore can be separated out by making the crystals flow out through a rising column of feed brine. As mentioned earlier, water vapour (steam) from the flash chamber will be led into the next calandria wherein its latent heat will be used to heatup the brine. From the last flash chamber, the vapour will be led into steam jet ejector to maintain vacuum conditions in the last flash chamber. The slurry of brine and salt from each chamber is collected in a slurry tank from where it is led into a centrifuge to separate out the salt crystals. In the centrifuge itself, the the salt crystals will be simultaneously washed with a small volume of distilled water (condensate) to remove the impurities. The filtrate mother liquor will be led out as effluent and can be returned to the sea (till facilities are developed for recovery of marine chemicals). The steam for the process will be generated in a fire tube boiler.

14.4 The plant is quite simple and does not need much operational staff if proper instrumentation is provided. A very common problem of scaling is largely reduced through removal of calcium sulphate crystals in solution form. All the same, periodical descaling may become necessary to maintain the thermal efficiency of the 'effects'. Another common problem is 'combing', which results from layer-building of salt on the walls of the flash chamber, which may have to be periodically removed to prevent the pumps and tubes being choked when the layers peel off from the walls. The 'combing' effect itself can be considerably reduced through maintaining optimal operating conditions, especially when monel metal is used. Experience seem to indicate that with one spare 'effect' in a series of four, the plant can work on an average between 7500 and 8000 hours/year. However, on a conservative basis, 300 stream days are assumed in this study.

14.5 The 'effects' could be made of cast iron, but due to corrosion, the cast iron 'effects' require frequent maintenance. Recent trend, however, is for the use of monel-metal as the material of construction for the evaporator bodies. Though monel metal is more expensive, lower maintenance costs are said to compensate for the higher initial investment. Considering that the facilities for maintenance in the project site will not be good, monel metal is assumed to be used in this study.

14.6 The hourly material balance is shown in Drg. No. VIB-2. The fuel required for steam generation is assumed to be furnace oil. Power is assumed to be provided by the Power Development Board (PDB). A sub-station of 1 MW capacity is provided in the scheme. Power is assumed to be made available from the main transmission line at 33 KV and it will be stepped down to 440 V at site. Water requirement can be met for the most part from evaporator condensate. The make up water is assumed to be available from deep wells, as discussed in Section A. Furnace oil is assumed to be available from the Eastern Refinery at Chittagong, and the delivered cost, including freight has been taken as Tk 1290/tonne. The specific consumption of raw materials and utilities per tonne of salt produced in the process is given in Table 14.1.

14.7 An indicative lay-out for the plant is presented in Drawing No. VIB-3. The relative positioning of the various equipment and facilities in the layout plan have been chosen to facilitate smooth operation and minimise yard piping etc. An office and a small laboratory are included in the project.

Table 14.1

Specific Consumption of Raw Materials & Utilities

Sl No.	Item	Unit	Per tonne of salt	Per hour	Per day	Annual
1.	25°Be' sea brine	Mill. lit.	0.005	0.105	2.52	756
2.	Steam	Tonne	1.38	29.0	696.0	2,08,800
3.	Furnace oil	Tonne	0.0946	1.987	47.688	15,896
4.	Power	KWH.	23.8	500	12000	3.6x106

Chapter 15

ESTIMATES OF CAPITAL OUTLAY

15.1 The total capital outlay needed for the project has been estimated at US $ 20.55 million - equivalent to Tk 308.25 million. Detailed breakup showing the estimates under various cost heads is given in Annexure - VIB-2. A summary of the capital cost estimates is given in Table No.15.1.

Basis of Estimation

15.2 The capital cost has been computed on the basis of mid-1979 prices, and assuming the prevailing exchange rate between Tk and US Dollar (US $ = 15 Tk). The cost estimates have been prepared on the basis of preliminary design and sizing of various equipment. For vendors items such as centrifuges, evaporators and boilers, indicative quotations have been obtained from a few reputed manufacturers and the lowest of such quotations have been used. For erection cost, the data available with the Consultants have been used. The foreign exchange required is assumed to be available for procurement from any source. The estimates for locally procured services, namely civil and electrical works, have been based on the information collected during the Team's stay in Bangladesh.

15.3 Escalation during construction over the base cost (mid-1979) has been provided at the following rates :

- Local components of capital investment	- 12% / year
- Foreign component of capital investment	- 8% / year

Table 15.1

Sl. No.	Particulars	Capital Cost		
		Foreign Component	Local Component	Total
A.	<u>Manufacturing Facilities</u>			
1.	Land and Land Development including pond work	912	1678	2590
2.	Erected cost of the Main Plants	6969	1633	8602
3.	Off-site Facilities and Auxiliaries	742	198	940
4.	Project Management Charges	-	491	491
	Total Manufacturing Facilities	8623	4000	12623
B.	<u>Other Fund Requirements</u>			
5.	Township	802	534	1336
6.	Working Capital	-	1285	1286
7.	Spares	413	34	447
8.	Contingency	492	293	785
9.	Commissioning expenses	-	58	58
10.	Escalation (during construction)	1515	1365	2880
11.	Financing charges	-	1249	1249
	Total	11845	8818	20663
12.	Realisation from product during commissioning	-	110	110
	Net Project Cost	11845	8708	20553

15.4 In accordance with the present practice in Bangladesh, the foreign component of the capital has been taken as loan, while the entire local currency expenditure is treated as equity. Under the present estimates, the debt-equity ratio works out to 1.4:1. For loan capital, the interest rate assumed is 10 percent per annum.

The phasing of expenditure, under the scheduling of work proposed in Drawing Nc. VIB-4 will be as follows :

Table 15.2

Phasing of Expenditure

(Figs. in $ '000)

	Year			
	1	2	3	Total
Foreign component	592.25	3553.50	7699.25	11845.00
Local Component	756.90	3027.60	3784.50	7569.00
Total Expenditure	1349.15	6581.10	11483.75	19414.00

Note : Financing charges and realisation from sale of product during commissioning not considered.

15.5 The project cost estimates include provision for workshop, a small laboratory, transport vehicles, fire station, administrative office, first aid post, and canteen facilities. Storage for 35,000 tonnes of salt has been provided. Since the project is planned to be executed on turnkey basis, it is assumed that the contractor will make his own arrangements for construction equipment. A township for about 120 persons, including a Guest House has been provided. The area norms for the different categories of staff are those currently in use in Bangladesh.

15.6 The working capital provisions have been made on the following basis :

(i)	Accounts receivable	one month
(ii)	Inventories	
	- Bags	one month
	- Consumables	Three months
	- Furnace oil	one month
	Product :	
	- Salt	35,000 ton
(iii)	Accounts payable	One month

Details are given in Annexure VIB-3.

Cost of Production

15.7 The estimated cost of production of salt in terms of the capital estimates given above works out \$ 23.4 per tonne for loose salt. If, however, gas is used instead of furnace oil, other things remaining the same, and assuming the price for gas at Tk 9.00 per 1000 cft, the cost of production of salt works out \$ 18.20 per te approximately.

15.8 The details of estimated cost of production on the basis of use of furnace oil and on the basis of raw materials and utilities requirements mentioned earlier are given in Annexure VIB-4. The annual cost of production includes the operating cost of plant, depreciation, and maintenance of the plant but does not include selling expenses and interest on long term loan. Maintenance material has been assumed at 5% of the landed cost of equipment including procurement and 1.5 of the civil work and township. Insurance and local taxes have been assumed at 0.30 per cent of the total capital excluding land, land development and pond construction at Chakaria-Sundarban site.

15.9 Depreciation has been worked out on straight line basis over a period of twelve years except for township, which is depreciated over 30 years period. The average depreciation per year works out as follows :

Table 15.3

Depreciation

	Average Production ($ '000)
Plant and Services 8 1/3%	1383.0
Township 3 1/3%	57.0
Total	1440.0

15.10 Labour and overheads have been taken on the basis of estimated personnel requirements as given in Drawing No. VIB-5 using the current wage levels for different categories of personnel in Bangladesh.

Sale Price and Profitability

15.11 As explained in Part A, the current support prices for washed salt in crushing centres such as Chittagong is about Tk 810, ($ 54) per tonne. Making allowance for transport costs, selling expenses etc. and some possible decline in market prices (Section A . Ch. 6) the market price for unbagged salt at Chakaria-Sundarban works out to Tk 440/tonne ($ 29.30). If the transfer price to the soda ash unit is fixed at this level, the project's profitability will be as shown in Table 15.4.

Table 15.4

Project's Profitability

		($ '000)
1.	Annual realisation by sale	4395.0
2.	Annual cost of production (excluding interest)	3507.0
3.	Gross profit before interest and taxes	888.0
4.	Average interest on long term loan	592.5
5.	Profit after interest but before taxes	295.5
6.	Total capital employed	20553.0
7.	Equity capital	8708.0
8.	Return on total capital (percent)	4.32%
9.	Return (Av) on equity-(percent)	3.39%

15.12 The project will not, therefore, be commercially attractive under conditions spelt out here and cannot compete with the solar evaporation dealt with in Section A in terms of the cost of production. The principal contributions to the high production cost of the project are, as indicated earlier, made by (i) energy costs and (ii) high capital investment. The project can therefore, become commercially attractive only when the incidence of these factors on the cost of production could be lowered significantly. Alternately, the selling price of salt will have to be sufficiently high, since the prospects for finding outlets for the sale of condensate water are not likely to improve in the Chakaria-Sundarban area.

15.13 The energy costs account for near about 56 percent of the works cost and about 49 percent of the total cost of production of unbagged salt in the plant. If instead of fuel oil, the prices of which are unlikely to come down in the near future on account of the rising cost of imported crude,- natural gas could be used as the energy source, the cost of production can be brought down substantially. Assuming that the natural gas is charged at Tk 9 per 1000 cft, which is the price at which gas is expected to be made available from the Bakhrabad field to the industrial consumers at Chittagong the cost of production, as mentioned earlier, will be around $ 18.20 per tonne. At this cost, and the assumed transfer price of $ 29.30, the project can earn an overall return of 8.1 percent on capital employed, and about 12.3% (average) on equity.

15.14 Since the project's economics is also quite sensitive to the size of capital investment, one way of reducing the cost of production could, be to find ways of pruning the capital requirements by doing away with some of the frills, even if this meant compromising with the norms generally adopted for industrial projects. Thus a 20 per cent reduction in the capital investment can allow the project to earn a return of about 7.8 percent on the total capital employed. A reduction of about 20 percent is possible if, for instance, cast iron is used as material of construction in the 'effects' instead of monel metal and the provision for colony and some facilities like telephone, canteen and workshop are clipped to the bare minimum.

15.15 In the alternative, a higher price situation for salt than assumed in the study can provide a congenial environment for the project's commercial viability. A return of 10 percent on the capital employed will require the price to be fixed around $ 37.10/te, which is still reasonably below the current salt procurement prices of BCIC, if due weightage is given to the purity of salt.

15.16 Thus the essential conditions which must be fulfilled for the project to be seriously considered are (i) natural gas must be available for fuel at reasonably attractive cost and (ii) prices should be high enough to render the project's execution necessary. The project, under prevailing conditions, can therefore be considered only if the production through the solar evaporation cannot meet the demand or proves unreliable and the Government places high priority on the objectives of self-reliance even at the cost of high domestic prices.

Chapter 16

IMPLEMENTATION AND TIME SCHEDULE

16.1 The project's execution from the initial stages of planning to commissioning is expected to be completed in 38 months (Drg.No. VIB-4). The zero date is assumed to be the date of award of the contract. The work on the solar section as well as the evaporator section can begin simultaneously. The evaporator section can be commissioned within 28 months. By that time, however, the solar works would not have been completed, but a part of the facilities already developed can be used for feeding the saturated brine. However, in the initial years there is likely to be shortage of brine due to storage losses etc. Hence it is assumed that during the first year after the completion of the evaporator section, the facility will be working at 50 percent of capacity and in the second year it is expected to be operated at 75 percent of the capacity. From the third year, the plant will operate at full load.

16.2 In the opinion of the Consultants, the Project, if chosen for implementation, is best executed on turnkey basis, considering the general lack of experience within the country in implementing projects of this kind and the shortage of sophisticated skills of the kind required for industrial project construction. However, the key operating personnel for the plant can be selected in the early stages of execution of the Project itself and associated in all aspects of execution as the owner's representatives, as part of training. There will be no need for appointment of consultants to assist the owners to monitor the project, since the project is relatively unsophisticated and small. The selection of the contractor could be done on the basis of international competitive bidding. It is possible and probably desirable to split the work into two parts - one relating to the solar ponds upto the stage of brine reservoir and the other relating to design, engineering, erection and commissioning of the evaporation section, with the necessary auxiliary units. The design of the first part of the work can be assigned to an experienced consulting firm, but the work can be executed by a local contractor under the overall supervision of the consultant, as discussed in Section A.

Chapter 17

MANPOWER REQUIREMENTS

17.1 The manpower requirement as estimated by the Consultants, for the solar part of the works has already been discussed in Section A. Since evaporation in the crystalliser beds is excluded, the staff requirement will be reduced substantially, since it is the crystallizer beds of a solar salt works which require intensive supervision. In addition, the washing unit will not be necessary and therefore the staff requirement of the washery is excluded.

17.2 As can be seen from Drawing No. VIB-5, the total requirement of staff for the operation of the entire unit including the solar ponds is now estimated at 144. This works out to about one person per 1000 tonnes of salt production per year, which seems to accord generally with the output per person observed in other similar plants. Since the evaporation unit is a continuous processing plant, it will be necessary to provide for supervisory and operating staff for 3 shifts in a day. A high degree of technical skill will not be required for the operation of the plant and therefore the operating staff below the supervisory cadre (Process Engineers & equivalent) can be trained on the job during the commissioning period. The supervisory staff, however, will be recruited in advance such that most of them are in position during the erection/commissioning of the plant itself. They would also have a good training on the operating and maintenance manuals for the plant, which will be made available by the contractor. Since the works will operate as a captive unit for the soda ash project, as indicated in Section A, it is assumed that the higher directions of management will be provided by the Central Board.

ANNEXURE VIB-1

EQUIPMENT SPECIFICATIONS & SUPPLIES

1.0 Evaporator Plant

1.1 The entire plant, from boilers through dryer can be purchased from a single supplier. Some of the manufacturers with experience and reputation are :

(i) Escher Wyass Limited, Zurich, Switzerland
(ii) Swenson Evaporator Company, United States
(iii) Struthers Wells Corporation, United States
(iv) International Salt Co. Clarks Summit, Pennsylvania
(v) Larsen and Toubro, Bombay, India
(vi) Gladwyn and Company, Bombay, India.

2.2 Evaporator design, being a vendor's speciality, varies widely. Hence only a general specification is given here.

2.2.1	(a)	No. of Evaporator Effects	:	4+1
	(b)	Type of Evaporator	:	Forced circulation type with external, vertical, single pass calandria.
	(c)	Type of Steam Jet	:	Multistage, with surface condenser.
	(d)	Material of Construction	:	Evaporator bodies-Monel. Calandria Tubes-90/10 cupronickel, containing 1.25 per cent iron. Minimum thickness 17 gauge and first two feet at the bottom - 13 gauge. Calandria shell and piping-steel with a corrosion allowance of 0.01 inch.

(e)	Design Pressure	30 psig and full vacuum.
(f)	Flooding of Evaporator	The evaporator and its support must be able to withstand complete flooding with brine having a specific gravity at 1.25°.
(g)	Circulating Pumps	Propeller Type. No internal bearings. Mat. of constn. - 316 SS Replaceable shaft sleeves must be provided. Pumps are to be sealed with feed brine. Drive - belt, splash proof epoxy sealed motors. Temperature rise - 25°C in circulation through heaters is to be assumed. Slurry concentration 35 to 40 per cent by wt.
(h)	Evaporator Duty	Feed - 25° Be' brine Discarded slurry - 29° Be' bittern Both measured at 20°C temp. Evaporation rate 76.773 litre per hour with commercially clean heating surface. The above evaporation rate is based on 20 Psig steam pressures. Condenser cooling water supply of 2500 gpm at 30°C temperature.
(i)	Type of Feeding	Parallel feeding.

(j) Valves in Brine Service : Monel, rubber pinch type or rubber lined butterfly with aluminium bronze trim.

(k) Brine Piping : Brass except for fill and empty piping, which may be of steel.

2.2.2 Salt Slurry Pumps

No. of pumps required - 1 + 1

Material of construction - Alloy 20 stainless steel

Type of pumps - Centrifugal, self priming pump with open impellers and replaceable shaft sleeves.

Duty - To transfer slurry from the evaporator to the centrifuge or to centrifuge feed tank.

2.2.3 Filtrate Pump

No. of pumps required - 1 + 1

Duty - To pump filtrate from the centrifuge discharge to the disposal tank.

Details - Same as 2.2.2

2.2.4 Fill and Empty Pumps

No. of pumps required - 1 + 1

Type of Pump - Centrifugal self priming with an open impeller and replaceable shaft sleeve.

Material of construction - Cast iron

Duty - Capable of filling and emptying any effect within 15 minutes.

2.2.5 Condensate Discharge Pumps

Requirement - 2 + 2

Type of Pump - Centrifugal self priming with closed impeller

Mat. of const. - Brass

Duty - Discharge evaporator condensate, one for

- boiler make up water and another for disposal of condensate.

Conditions - should be capable of discharging from full vacuum to 30 psig.

2.2.6 Condensate Return pump

Requirement - 1 + 1

Type of pump - Centrifugal self priming with closed impeller

Material of Constn. - Steel

Duty - To pump the first effect condensate to the boilers at a rate 150 per cent of the evaporator's maximum steam consumption.

2.2.7 Sea Water Pumps

Requirement - 5 (No spare) interconnected to each other

Type of pump - Self priming centrifugal pump with open impeller. Diesel operated.

Duty - To pump sea brine from sea and to transfer sea brine in the solar ponds

Capacity - 5000 GPM.

2.2.8 Centrifuge

(a) Requirement - 4

(b) Type - Horizontal basket

(c) Service - To separate salt crystals from salt slurry continuously

(d) Operation - Fully automatic

(e) Capacity - i) Solid separation 21 te/hr.) (total)

ii) Solid in liquor 35 to 40% W/w

iii) Fluid characteristic

Specific Gravity - 1.25

Viscosity - 1.25 c.p.

Composition - gm/100 ml.

NaCl - 17.40

$MgCl_2$ - 10.50

$MgSO_4$ - 6.60

$CaSO_4$ - 0.027

KCl - 2.350

Temperature - 60 to 70 °C

Pressure - 4 meter of liquid column

iv) Washing Fluid - Distilled water

(f) Material of construction - All parts in contact with fluid - High nickel - Chrome alloy.

(g) Scope - Centrifuge complete with drive motor, lubrication and all instruments, base plate, foundation bolts etc., flexible connection for feed and discharge are to be provided.

2.2.9 Tanks

Material of construction - R.C.C.

1) Boiler feed - 20,000 litre capacity

2) Boiler make up - 50,000 litre capacity

3) Salt slurry tank - 8,000 litre capacity

4) Filtrate - 6,000 litre capacity

5) Boil outwater - 50,000 litre capacity

6) Boil out brine - 250,000 litre capacity provided with an air blower

7) Seal brine head tank - 1000 litre capacity

8) Wash water head tank - 4,000 litre capacity

2.2.10 Dryer

Requirement - One

Type - Rotary drier

Heating arrangement	-	Air is passed through steam coil
Capacity	-	10 te per hour
Moisture content	-	Feed salt 2 per cent Dry salt 0.1 per cent
Material of Const.	-	Alloy 304 stainless steel wherever salt is coming in contact.
Approximate Dimension	-	2000 mm Dia x 15000 mm long.
Revolutions per minute	-	3 to 5.

ANNEXURE VI B-2

CAPITAL OUTLAY

(Cost in $ '000)

S.No.	Item	FC	LC	Total
1.	Land Lease rent - 4000 Acre @ TK 30/Acre/Year	-	24	24
2.	Main Plant Equipment & Material	4122	-	4122
3.	Offsite Equipment & Material			
i.	Product Handling & Storage	250	-	250
ii.	Steam Generation	560	-	560
iii.	Power Supply and Distribution	150	-	150
iv.	Water Supply & Distribution	48	-	48
v.	Auxiliary Services	180	11	191
vi.	Transport Facilities	44	-	44
vii.	Temporary Construction Facilities	88	-	88
	Sub total (3)	1320	11	1331
4.	Spares	413	34	447
5.	Non-Plant Buildings, Plant Civil Works Incl. Brine Reservoir	1541	2329	3870
6.	Township	802	534	1336
7.	Freight, Insurance, Handling, Duties & Taxes	577	511	1088
8.	Erection including Supervision Charges	296	634	930
9.	Design, Engineering & Procurement	767	-	767
10.	Project Management Charges	-	491	491
11.	Working Capital	-	1285	1285
12.	Contingency	492	293	785
13.	Net Commissioning Expenses	-	(52)	(52)
14.	Escalation	1515	1365	2880
15.	Financing Charges	-	1249	1249
	Total Capital Requirement :	11845	8708	20553

(Brackets indicate negative figures)

Annexure VIB-3

WORKING CAPITAL

($ '000)

Sl. No.	Item	Unit	Unit Rate In Dollars	Quan- tity	Annual Cost
1.	Raw Material	-	-	-	-
2.	Consumables	-	-	-	13.0
3.	Operating Supply :				
	i) Bags	No.	0.33	$1x10^5$	33.0
	ii) Furnace Oil	Tonne	72.66	1290	94.0
4.	Product Inventory	Tonne	23.38	35000	818.0
5.	Accounts Receivable	Tonne	29.33	15000	439.0
6.	Goods in Process				8.0
7.	Cash in Hand				20.0
8.	Accounts Payable :				
	i) Bags	No.	0.33	$1x10^5$	(33.0)
	ii) Furnace Oil	Tonne	72.66	1290	(94.0)
9.	Deposits and Advances 10 percent of the accounts receivable for domestic salt only				(13.0)
10.	Total Working Capital				1285.0

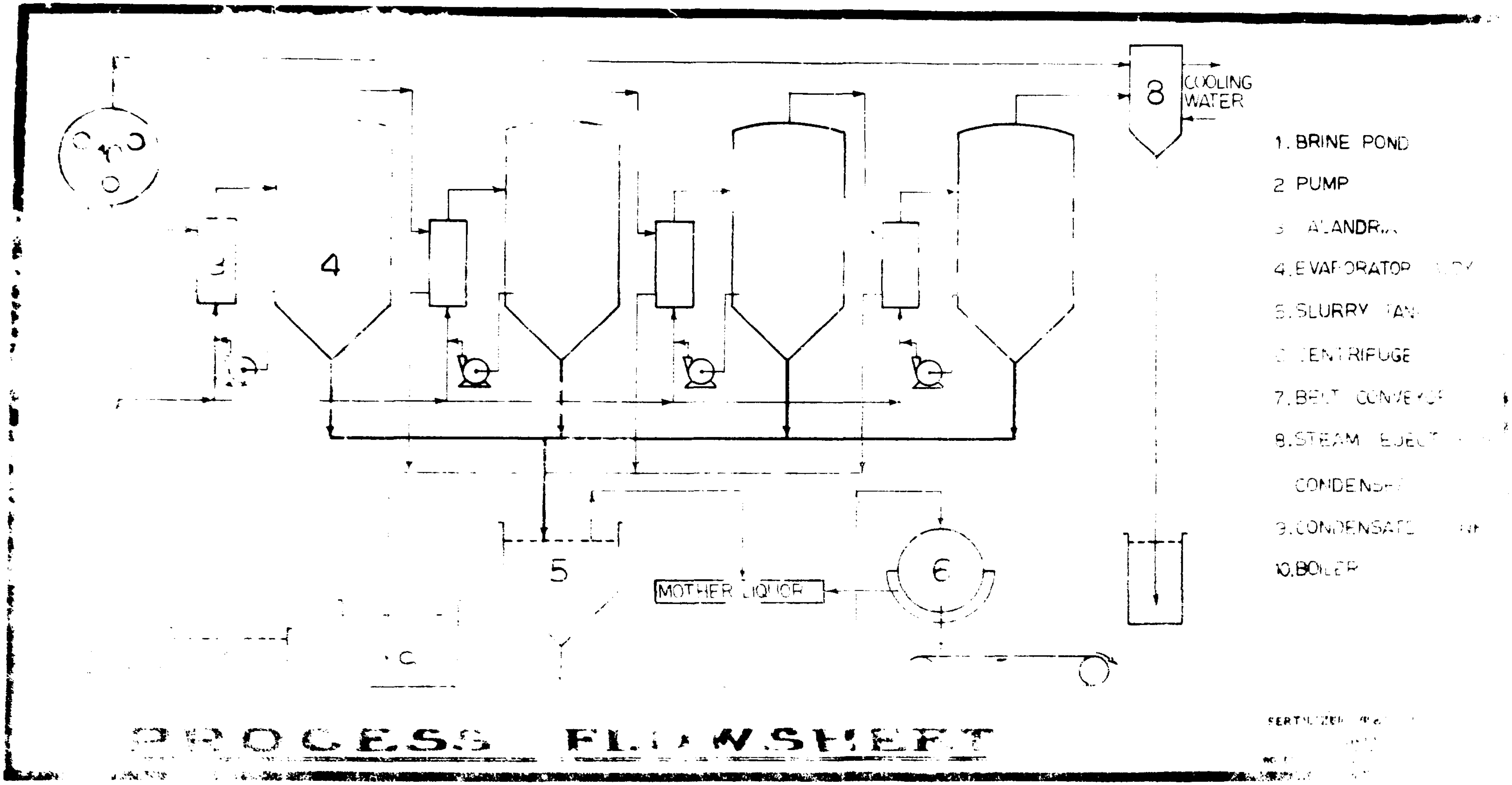
Note : ( ) indicates negative figures

Annexure VIB-4

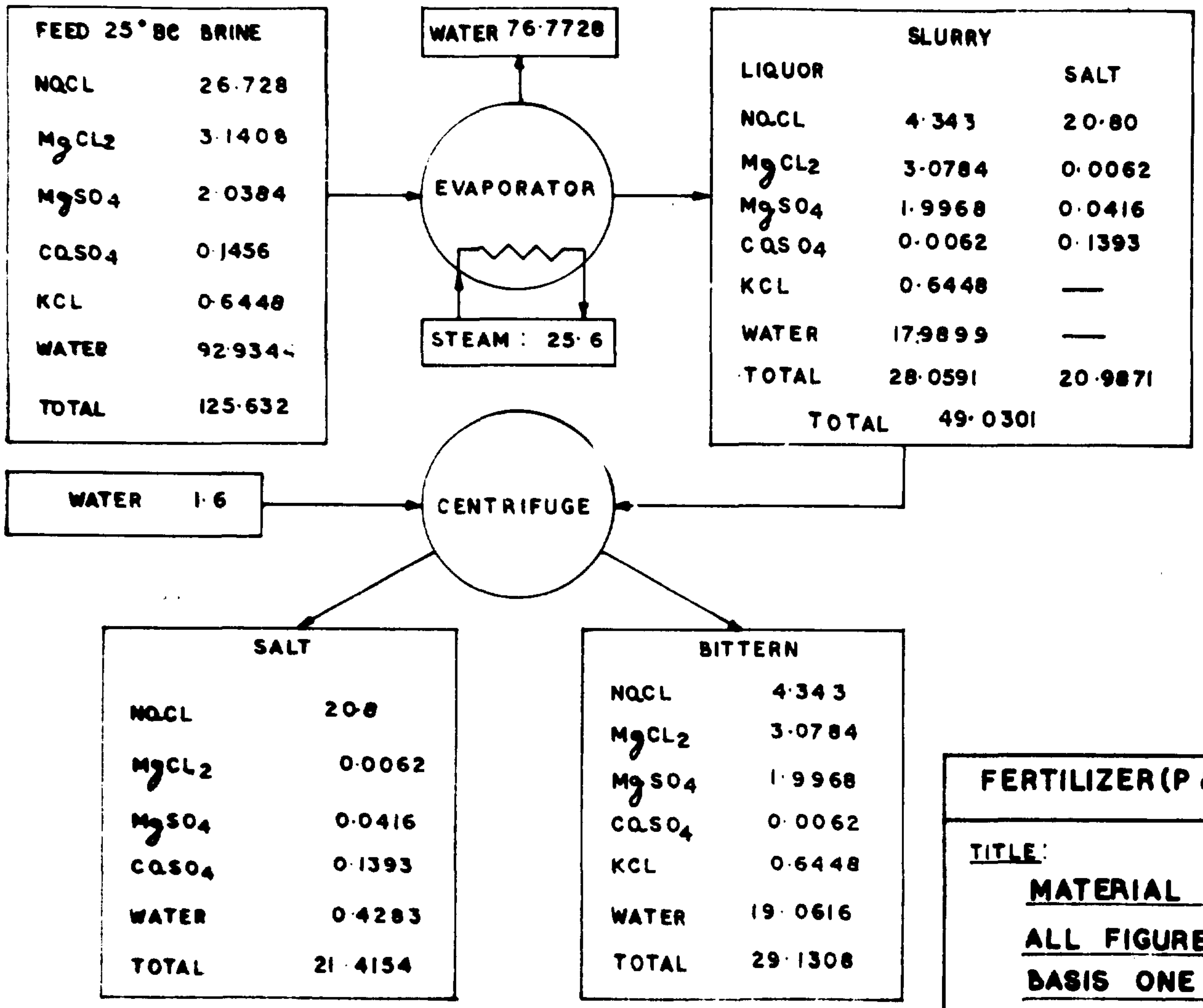
COST OF PRODUCTION

(All Figs. in $ '000)

Sl. No.	Item	Unit	Unit Rate in $	Quantity	Annual Cost
1.	Raw Material	-	-	-	-
2.	Utilities :				
	i) Power	KWH	0.026	3.6×10^6	96.0
	ii) Furnace Oil	Tonne	72.66	15.996	1155.0
3.	Consumables				80.0
4.	Labour and Overheads				146.0
5.	Maintenance Material				430.0
6.	Insurance and Taxes - 0.3% of capital investment, excluding land and earth work for solar ponds				54.0
7.	Contingency				98.0
8.	Annual Works Cost				2059.0
9.	Depreciation				1440.0
10.	Rent of the Land				8.0
11.	Total Cost of Production				3507.0
12.	Annual Production	Tonne			1,50,000
13.	Cost of Production per tonne of loose salt				23.38
				Say	23.40



PROCESS FLOWSHEET



FEED 25°BE BRINE	
NaCL	26·728
$MgCL_2$	3·1408
$MgSO_4$	2·0384
$CaSO_4$	0·1456
KCL	0·6448
WATER	92·9344
TOTAL	125·632

SLURRY	LIQUOR	SALT
NaCL	4·343	20·80
$MgCL_2$	3·0784	0·0062
$MgSO_4$	1·9968	0·0416
$CaSO_4$	0·0062	0·1393
KCL	0·6448	—
WATER	17·9899	—
TOTAL	28·0591	20·9871
TOTAL	49·0301	

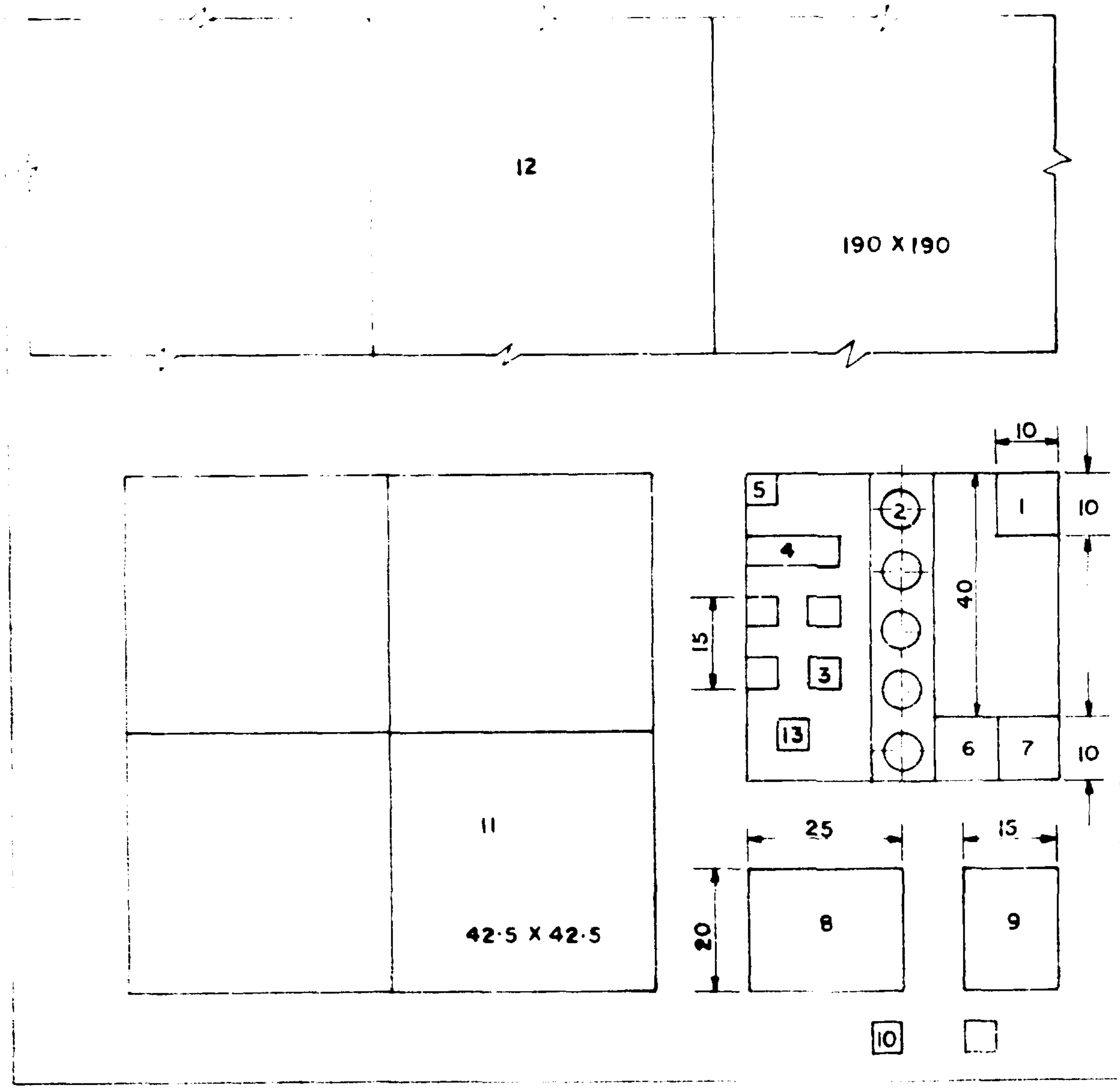
SALT	
NaCL	20·8
$MgCL_2$	0·0062
$MgSO_4$	0·0416
$CaSO_4$	0·1393
WATER	0·4283
TOTAL	21·4154

BITTERN	
NaCL	4·343
$MgCL_2$	3·0784
$MgSO_4$	1·9968
$CaSO_4$	0·0062
KCL	0·6448
WATER	19·0616
TOTAL	29·1308

FERTILIZER (P & D) INDIA LTD. SINDRI

TITLE:
MATERIAL BALANCE FLOW SHEET
ALL FIGURES ARE IN TON
BASIS ONE HOUR OPERATION

PROJECT : B.C.I.D.B. | DRG. NO VI B-2 | RE



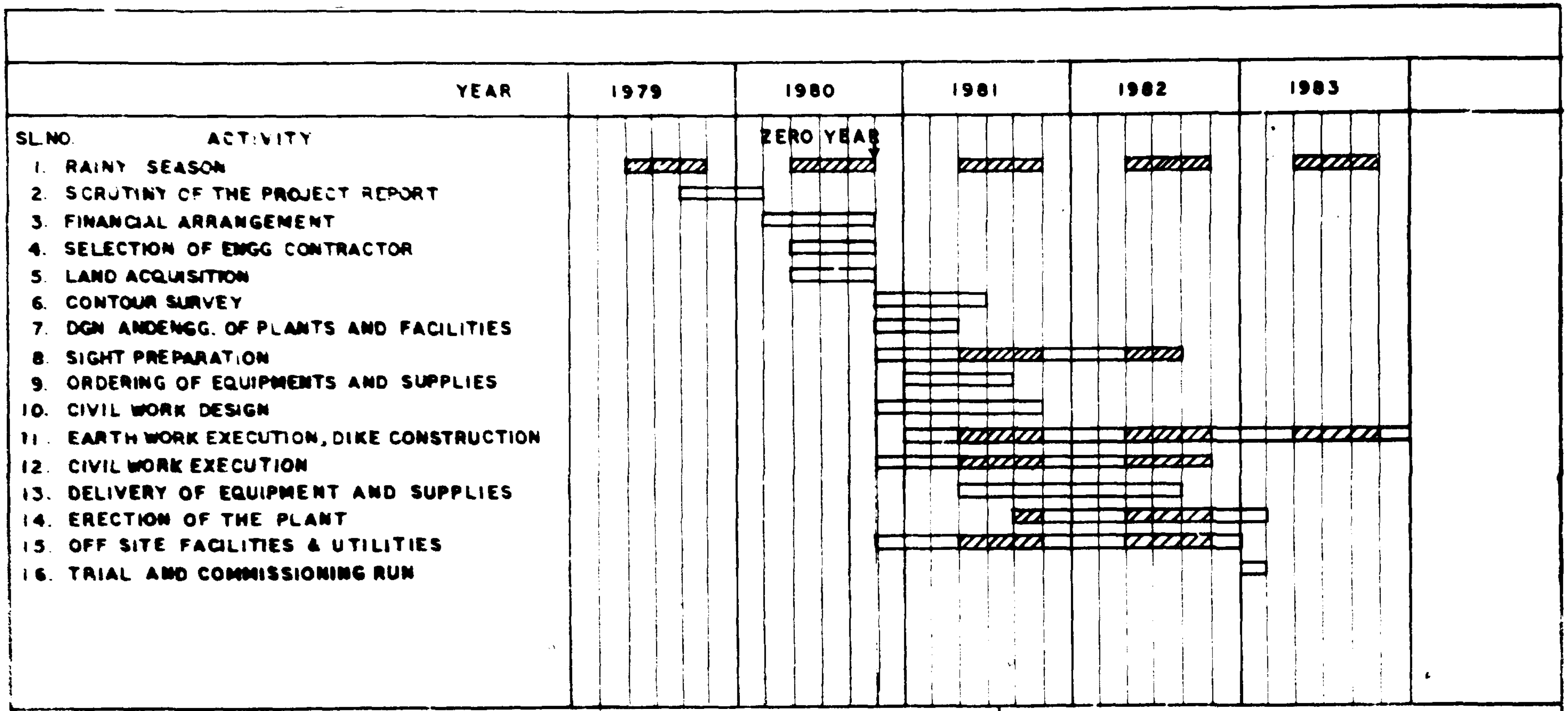
1	BOILER
2	EVAPORATOR
3	CENTRIFUGES
4	DRYER
5	DRY SALT STORAGE
6	CONTROL ROOM
7	PLANT OFFICE
8	ADMINISTRATIVE OFFICE
9.	WORK SHOP
10.	GATE OFFICE
11.	SALT STORAGE
12.	BRINE RESERVOIR
13.	SLURRY TANK

NOTE :- ALL FIGURES ARE IN METER.

FERTILIZER (P& D) INDIA LTD. SINDRI

TITLE :- **PLANT LAYOUT**

PROJECT :- B.C.I.D.B | DRG. NO. VI 5-3



FERTILIZER (P&D) INDIA LTD. SINDRI

TITLE:

TENTATIVE TIME SCHEDULE

PROJECT B.C.I.D.B. | DRG. NO. VI B-4 | /REV.

BASIC CHEMICAL INDUSTRIES DEVELOPMENT
IN
BANGLADESH

10139
(7)

Part Seven
GYPSUM BUILDING MATERIALS

FERTILIZER (PLANNING & DEVELOPMENT) INDIA LTD

SINDRI, INDIA, 828122

Job No. 3104

PART - VII

GYPSUM BUILDING MATERIALS

CONTENTS

ANNEXURES

DRAWINGS

VII GYPSUM BUILDING MATERIALS

Chapter-1

INTRODUCTION

1.1 Gypsum or calcium sulphate dihydrate ($CaSO_4.2H_2O$), one of the two naturally occurring forms of calcium sulphate, is extensively used as a building material in many countries of the world. Manufacture of plaster and plaster products for the building industry constitutes the single biggest use of natural gypsum accounting for an estimated about 45 per cent of the world production, and another 43 per cent is used as cement additive, - the rest being utilised for miscellaneous purposes[1]. There are several different types of gypsum plaster available, with properties suited to different uses. The most commonly known of these is plaster of Paris (Calcium Sulphate hemihydrate). The plasters most widely used in the building industry are based upon the hemihydrate form of calcium sulphate, since this rehydrates more quickly than the anhydrite form and is therefore quicker-setting. One of the major uses of these is in the manufacture of prefabricated plaster products.

Effect of Impurities

1.2 Phosphogypsum obtained as by product in the manufacture of wet-process phosphoric acid can, however, be used as

---

[1] Phosphorus and Potassium, British Sulphur Corporation No. 94, 1978. Extensive use has been made in this section of an excellent review on the problem of phosphogypsum disposal published in this issue, particularly the review of different processes.

substitute for natural gypsum in nearly all its applications, including as construction plaster and prefabricated plaster products, in countries where there are no natural gypsum deposits. Depending on the process conditions, phosphogypsum may crystallise either as calcium sulphate dihydrate ($CaSO_4.2H_2O$) or as the hemihydrate ($CaSO_4.\ 1/2\ H_2O$). These two forms can, however, be inter-converted through the loss or gain of water of crystallisation. Despite its close resemblance to natural gypsum, however, byproduct gypsum contains a number of soluble and insoluble impurities - attributable both to the type of rock used and to the particular acid process adopted - which have a detrimental effect on the properties of plaster. The soluble impurities are, broadly, of three major types :

(i) Free phosphoric and sulphuric acid, which (a) increases the corrosiveness of the plaster towards the structural elements in the building or the equipment used for converting it into pre-fabricated plaster products, and (b) retards setting ;

(ii) Acid salts including mono-calcium and di-calcium phosphates and fluosilicates which reduce the setting rate of plaster; and

(iii) Sodium and potassium salts which tend to effloresce.

Insoluble Impurities

1.3 Besides these soluble impurities, phosphogypsum may contain two groups of insoluble impurities :

(i) Those derived from the phosphate rock in an essentially unchanged form such as rock, silica and organic materials[2]; and

(ii) Those which are formed in secondary reaction during digestion of the rock such as co-crystallised P205 and a number of other insoluble phosphate and fluoride compounds.

The first group, silica and unreacted rock particles in particular, do not adversely affect the quality of plaster as such, but being abrasive, increase the wear and tear of equipment used for processing it. The organic matter may similarly discolour the product, delay the setting and adversely affect the strength of the plaster. The second group, especially the cocrystallised P205, also affects the setting rate. The utilisation of phosphogypsum in the manufacture of plaster and prefabricated plaster products, therefore, usually involves a treatment step, which inevitably increases its cost in comparison with natural gypsum. It is for this reason that phosphogypsum does not hold any attraction in countries which have adequate deposits of mineable gypsum.

Purification

1.4 Like natural gypsum, processing of phosphogypsum produced in hemihydrate-dihydrate (New Nissan) and dihydrate-hemihydrate (Central-Prayon) processes for plaster manufacture involves only heating to

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[2] Radium, present in the phosphate rock, is another impurity, which, although it has no effect on the properties of plaster, may nevertheless be harmful on environmental grounds. In the UK, use of phosphogypsum for plasters is permitted provided the concentration of radium in plaster product is below 25 picocuries per gm

remove the water of crystallisation, since the modifications incorporated in these processes result in better P205 recovery as well as (as a result of recrystallisation) in producing a less contaminated phosphogypsum. Dehydration can be effected either in dry condition or in aqueous solution (under pressure) in an autoclave. Calcination is more commonly used and by calcination, both hemihydrate and anhydrite plasters can be obtained. Processing of byproduct gypsum produced in the conventional dihydrate acid process however involves its purification in the first instance before thermal treatment. A number of processes have been developed to make use of the phosphogypsum produced in the conventional phosphoric acid plants for plaster manufacture.

Types of Building Materials

1.5 As mentioned earlier, once rid of interfering impurities, phosphogypsum can be almost a perfect substitute for natural gypsum in the manufacture of construction plaster as well as prefabricated plaster products. A wide range of building products based on purified and treated phosphogypsum have been developed and are being manufactured abroad for use in building construction, such as plaster-boards, panels, precast slabs, special types of accoustical and fire resisting premixed plasters, accoustical titles, blocks for partition walls etc. Their use in ceiling, partition-walling and flooring is popular on account of their lightness, fire resisting and thermal insulating properties, decorative effects, speedier construction and saving in labour cost on the site.

Disadvantages

1.6 The brittle characteristic of the gypsum-set products, however, prevent the effective utilisation of their high compressive strength in structural applications. Some improvement can be achieved by incorporating organic fibres. Large fibrous plasterboards, 11 mm thick, of storey height and upto 12 metre long are extensively used in Australia as the inner leaf in framed construction. A much greater improvement results from the use of glass fibre as reinforcement since they are stronger and their much higher modulus of elasticity allows more effective utilisation of the strength in a plaster composite. In this the development of glass-fibre reinforced gypsum by the British Building Research Establishment (BRE) is particularly noteworthy.

1.7 The gypsum building products suffer from another infirmity which, to some extent, limit their wider applications. The slight solubility of gypsum in water prevents their use in situations where they may be exposed to dampness or rainfall. Hence, in countries like Bangladesh, they can be used indoors only.

As Cement Additive

1.8 As shown earlier, gypsum finds a very wide use as additive to cement clinker during grinding for the production of cement. It regulates the setting properties of the Portland cement. Bangladesh has no deposits of natural gypsum, and therefore, gypsum has to be imported for use as cement additive. The indigenously available phosphogypsum can be safely substituted in its place, provided the byproduct gypsum is treated to remove its undesirable impurities, particularly the phosphates (unreacted, soluble as well as co-crystallized) and fluorine, which have a deleterious effect on the properties of cement. Phosphogypsum even from a conventional dihydrate plant can, however, directly be used as a soil-conditioner without any further treatment.

Scope for Gypsum Building Materials

1.9 Bangladesh faces acute shortage of building materials in the face of sharply rising demand, arising both from population growth and the expanding need for non-residential structurers. Only a very small proportion of the cement needed is produced within the country and on account of paucity of easily mineable limestone deposits, the prospects for self-sufficiency in cement production are not bright. Construction work is also hampered by shortage of stone and gravel for use as concrete aggregate. Any enlarged demand arising from stepped-up construction activities might necessitate imports, as in 1972-73 when 3 million cft of rock was imported. Though clay and sand are available indigenously, quality sands for construction (e.g. Sylhet sand) requires to be transported over long distances. Brick manufacture suffers from non-availability of cheap fuel for burning in the kilns. Fabricated building materials are produced only in limited quantities and are generally in short supply, often necessitating imports. In most cases, the principal raw materials are required to be imported in any case. Owing to the acute pressure on cultivable land, Bangladesh has one of the lowest forest to land-area ratios, combined with poor management, and as a result, timber for use as building material is both expensive and scarce. Hence, even though gypsum building materials cannot be looked upon as substitutes for ordinary cement material, yet they can help to relieve the pressure on availability of building materials in general and find uses in specialised applications where they can be used with advantage. To that extent, utilisation of an indigenously produced and waste material phosphogypsum for building materials deserves consideration.

Availability of Phosphogypsum

1.10 In the manufacture of wet process phosphoric acid, it is gypsum which is produced in the largest quantity; for every tonne of P205 produced, roughly about 4 to 5 tonnes of impure gypsum is precipitated and filtered out as waste material. Bangladesh has two wet process phosphoric acid plants, both located in Chittagong within the factory campus of the Triple Superphosphate Fertilizer Complex in North Patenga on the bank of the Karnaphuli river. The first of these plants, known as Phosphoric Acid Plant I (PA-I) is a 32 te P205 per day conventional dihydrate type of plant designed and constructed by Pan-American Consultants and Technic Chemie of France, along with the rest of the production train including a sulphuric acid plant (100 tpd) and a TSP Unit. The plant was started up in 1969, but was shut down almost immediately thereafter because of severe corrosion caused by high chloride in the rock. The plant remained out of operation until early 1977, when it was recommissioned (March '77). The plant is expected to yield, on sustained basis, about 30,000 tonnes dihydrate gypsum (on dry basis) per year. The second plant, known as Phosphoric Acid Plant II (PA-II) was erected by Hitachi - Zosen (Japan) under a turnkey contract for the entire second train of the TSP plant. The capacity of the plant is 135 te P205 per day. The process used is a Nissan hemihydrate-dihydrate process. The plant was completed in 1970 but was commissioned only in September 1974. It is estimated that this plant will yield annually, on average, about 200,000 tonnes of waste gypsum from its normal operation, - after the proposed revamping of both the TSP production-lines, presently covered by another UNIDO assistance programme. The estimates of gypsum availability have been arrived at in consultation with the Plants' Management, after a thorough study of the working of both the phosphoric acid plants and related facilities by the Consultants [3/] and study of other relevant expert reports on the plants' condition.

Gypsum Utilisation for Building Materials

1.11 As explained above, gypsum building materials, particularly the pre-fabricated plaster products, are sophisticated products and cannot be looked upon as simple substitutes for the conventional materials. Also, the marketing situation in Bangladesh is quite different from those of, say, the European countries, where such products are in extensive use. Under the climatic conditions in Bangladesh, especially due to heavy rainfall, gypsum plaster and plaster products are not suitable for exterior use. Moreover, the country is not yet exposed to gypsum building materials and in a conservative industry like the construction industry the acceptance of a new product, however desirable,

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[3/] A separate note on the minimum plant modifications and other operational improvements necessary to ensure this gypsum availability (i.e. to ensure this level of stream efficiency) has been separately transmitted by the Consultants to the Plant Management during the Team's stay in Bangladesh.

is bound to be slow. In view of these considerations demand for gypsum-based building materials is not expected to be high in the initial years. Hence only a relatively small plant is being considered in this Study. The use of phosphogypsum as soil-conditioner is not discussed on account of the relatively small quantities needed.

Chapter -2

PROCESSING OPTIONS

2.1 For a long time, the use of phospho-gypsum materials in building construction was considered prohibitive on account of the adverse effects of the impurities on the setting characteristics and strength development of cements or plasters produced from it. As indicated earlier, attempts to overcome this problem were made in two directions : first, by introducing process modifications and secondly, by developing purification processes. As a result of the first, phospho-gypsum from the hemihydrate - dihydrate (e.g. Nissan) and dihydrate - hemihydrate (Central Prayon) processes can be directly used in plaster manufacture due to the improved purity of gypsum, although these processes involving recrystallisation of calcium sulphate are more expensive than the conventional dihydrate process. In the second, several processes have been developed over time for the purification of the dihydrate gypsum. Serious attempts were first made in Japan (Onoda Chemical Ind.Co.) as early as in 1955 to make use of it for cement and plaster products to overcome the problem of non-availability of natural gypsum in the country. Methods for purification and inactivation of impurities were developed (Onoda Process) 4/ and patent taken. The Onoda Chemical Ind. Co. Ltd. erected a plant with capacity of 9,000 tons per month in 1959 to process phosphogypsum on commercial basis and increased its capacity to 18,000 tons per month in 1964. In 1971 Onoda erected a new plant with new calcination process and monthly capacity of 16,500

4/ Patent no. 249, 125, 488975 : Japan

tons. The Onoda process is licensed to several companies in Japan and outside as shown in Table 2.1.

Table 2.1

Plants Based on Onoda Process [5/]

Country	Company	Capacity	Date of Contract
Japan	Iahihara Sangyo	150 te/day	July 1964
	Nissan Chem. Ind	-do-	April 1965
	Nitto Chemical	-do-	June 1966
	Nissan Chem.Ind.	2000 te/month	Sept. 1966
	-do-	500 te/day	Feb. 1969
Philippines	Esso Standard Fertilizer & Agricultural Chemical Co.Inc.	350 te/day	Oct. 1966
Republic of Korea	Henil Cement Mfg. Co. Ltd.	350 te/day	Nov. 1967
		400 te/day	March 1971

[5/] Yamaguchi Taro : Phospho-gypsum Beneficiation Process : Chemical Age of India Vol 25 : No 3 (March '72)

Rhone-Poulenc Process[6]

2.2 Rhone-Poulenc of France has developed a method for converting phospho-gypsum into calcium sulphate beta-hemihydrate for use in the construction industry by passing it through a series of hydro-cyclones or floatation cells and then drying and calcining (Drawing No. VII-1). They have developed techniques for the initial purification by storing the gypsum as a suspension and removing the larger particles from it. As the main impurities in phosphogypsum are soluble, they are removed with water when the suspension is filtered or centrifuged before the calcination step. If the suspension is acidic, lime treatment is given to neutralize it. In this way, 80-90 per cent of the soluble impurities are removed. If further purification is considered necessary, depending on the properties of phospho-gypsum, either it is washed in hydrocyclones, when most of the remaining soluble impurities as well as organic matter are removed, or (if water is scarce) passed through floatation cells. With floatation method, extraction of organic matter is better, but removal of soluble impurities is only between 85-90 per cent compared to 95 per cent in hydrocyclones. The gypsum recovery in the second method, however, is between 90-96 per cent while in the hydrocyclone technique it is between 70-90 per cent. Filtering or centrifuging of suspension in either case needs to be done carefully to reduce the free water content to the lowest possible level to economise on fuel in the subsequent drying and calcination stages.

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[6] This description is based on review in the Phosphorus & Potassium, British Sulphur Corporation No. 94 (Mar/April 1978)

2.3 Rhone-Poulenc has developed two methods for drying and calcination. The first of these, used in the Rouen plant, comprises identifiable drying and calcination steps. Wet phospho-gypsum is directly fed into a pneumatic drier where it is contacted with cocurrent hot combustion gases. The gas leaving the drier is washed in a gas scrubber and emitted to the atmosphere. The partially dry gypsum is then calcined to beta-hemihydrate in a fluidised bed with most of the heat supplied by a steam heated heating coil immersed in the bed. The alternative method is a one-step process based on a specially designed direct-fired calciner operating at much higher temperatures. The gas product contact is also improved and thus the process can be more precisely controlled to prevent further dehydration of the hemihydrate. The exit gases from the calciner are scrubbed before being vented. The product is cooled by contact with the combustion air.

2.4 The first plant using the Rhone-Poulenc process came on stream in 1971 at Les Roches de Condrieu and has a capacity of 45,000 tpa of hemihydrate. The product is used in an adjacent plant to fabricate plaster boards. A second plaster production unit came on stream in 1975 at Rouen with a capacity of 250,000 tpa hemihydrate. The process is also licensed in a number of countries and plants are under construction. For instance, in Romania, a 100,000 tpa plant is being built at Becau. In Brazil, three phosphogypsum processing plants are coming up, at Sao Paulo, Juquia and Cajati with capacities between 1500 tpa, and 150,000 tpa. The Cajati plant (100,000 tpa) will produce hemihydrate pellets for use as a setting regulator in cement.

Knauf Processes

2.5 The West German firm of Gebruder Knauf, Iphofen, offers atleast three different processes, all of them commercialised, for phosphogypsum purification (Drawing No. VII-2). The first of these, known as Knauf S-I process, was developed to produce a beta-hemihydrate plaster for use in the manufacture of prefabricated plaster boards. In this process, wet gypsum from the acid filter is mashed and then purified by washing and floatation to remove the water soluble impurities and solids such as organic matter. This can be repeated as required, and the water recirculated to the phosphoric acid plant. Drying of the purified gypsum is carried out in directly heated units with vortex equipment and it is then dehydrated in kettles which can be operated continuously or in batches. The product, ground to powder, can be used to manufacture plaster boards as well as partition and ceiling panels. This process has the advantages of simplicity in operation and low energy consumption. Besides, the plaster obtained is of high purity and does not produce efflorescence.

2.6 The second, Knauf S-II process has been primarily developed to produce construction plaster. Unlike the plaster required for prefabricated products, where particles need to be relatively fine, construction plaster for wet application to interior walls and ceilings requires to be relatively coarse. Ideally it will have to be a mixture of one-third hemihydrate and two-thirds calcined anhydrite. It is usual for construction plaster to have atleast 20 per cent of particles in sizes above 0.2 mm, which requires to enlarge the gypsum crystals during processing. In the Knauf S-II process, the initial purification sequence is identical to the Knauf S-I process, but the amount of purification required may be lessened through the use of certain additives or, in some cases, eliminated altogether. After purification, the phosphogypsum is dried and partially dehydrated to the hemihydrate state. The grain size of the hemihydrate gypsum is then increased in a pelletizing process in which a certain amount of water is added to rehydrate some of the dehydrated phosphogypsum. Several additives are incorporated into the material to precipitate out the phosphates which otherwise would have influenced the setting time. Since this reaction is slow, phosphogypsum is stored in a reaction silo. On completion of the process of precipitation, the pellets are calcined to obtain construction plaster either in a rotary kiln or a roast band (conveyor kiln). The product is then ground to the required grain size. This process can also be used to produce specialty plasters such as projection plaster, bonding plaster and pre-mixed plaster, by the incorporation of various additives.

2.7 The third, Knauf S-III process is a development of the second and perhaps the simplest of the three. It was designed to process phosphogypsum which is obtained directly from the filter as hemihydrate (e.g. Central Prayon process) into construction plaster. Since the gypsum obtained in such processes is already of high purity, preliminary purification treatments used in S-I and S-II become superfluous. The drying and palletising units are also unnecessary since addition of small amounts of certain additives (to remove phosphate values) causes recrystallisation of gypsum into a pellet-like form. The calcining and grinding steps are identifical to those of S-I and S-II.

2.8 Up to now, there are three plants in operation using the Knauf processes. The first of these is at Castrop-Rauxel, West Germany and came into operation in 1963. It is operated by Knauf itself. It uses both S-I and S-II processes. The capacity of the plant is 70,000 tpa plaster and 0.5 million m^3 per year of gypsum partition blocks. A second plant was started in 1973-74 at Embsen, West Germany using S-II and S-III processes to produce construction plaster and specialty plasters. The plant is operated by Chemiegipswerke Embsen, jointly owned by Knauf and Veba-Chemie AG. The plant's capacity is 150,000 tpa. The third is located at Ehein, Belgium and has a capacity of 200,000 tpa of plaster. It uses S-III process and was commissioned in 1974. It produces special types of construction plasters.

CdF Chemie-Air Industrie Process

2.9 The CdF Chemie/Air Industrie process has been used in one commercial plant at the Chemie Works in Douvrin, France. The plant has a capacity of 130,000 tpa hemihydrate which is used mainly in the manufacture of plasterboards. The plant was brought into operation in 1975. The process consists essentially in converting the gypsum obtained from acid filter into a slurry with water obtained from another part of the processing plant (Drawing No. VII-3). After screening to remove the larger particles such as quartz and unreacted rock, the phosphogypsum is passed through a series of hydrocyclones, in which most of the liquid containing soluble impurities and organic contaminants is separated. The phosphogypsum pulp is again washed with clean water, which, after separation in hydrocyclones, is used to reslurry the gypsum obtained from acid filter. A lime solution is then added to neutralize the gypsum and the product is then vacuum filtered to produce a cake containing 15 to 20 per cent moisture. The filtrate is reused in the washing tanks. The thermal stage is carried out in three air driers, arranged in a series. Heated air is introduced into these driers and the gypsum is dispersed into the air stream and carried to the top of the column where it is collected in a cyclone. Each drier is used for a specific purpose - drying, calcining and rehydrating. In the first drier residual free moisture is removed and in the second air drier, gypsum gets dehydrated to a mixture of beta-hemihydrate and anhydrite III. From there, the material passes into the third drier, where all or part of the anhydrite III, depending on the product required, is rehydrated to the hemihydrate. The product is then pulverised to give a fine powder. Exhaust gases from the driers are partly recycled. Because of the conditions of operation, the processing can generally be done in temperatures lower than usually employed in the thermal stage and the residence time in each drier is very short (1 sec). The plaster obtained is particularly suited for use in prefabricated products which have good mechanical and physical properties. The CdF Chemie-AI process has the advantage of being capable of accommodating phosphogypsums of different compositions with modifications to the equipment used.

Giulini Process

2.10 The Giulini process developed in 1966 at the works of Gebruder Giulini in West Germany and advocated by Chemie-Linz of Germany for beneficiation involves the crystallisation of the dihydrate filter cake to alfa-hemihydrate form, which is then made suitable for casting plaster products. This is accomplished by passing the slurry through a series of flotation cells and then autoclaving at 120°C. The process has been adapted for the manufacture of building blocks, partition panels and jointing and moulding plasters. Work done on this process since 1966 is said to have made this process adaptable to phosphogypsum produced by different types of rock. In the Giulini factory in West Germany, 80 tpd of alfa plaster for lightweight and load bearing blocks of tongue and groove type are understood to be produced.

CERPHOS Process

2.11 Said to be the newest commercialised phosphogypsum processing technique, the CERPHOS process developed by the former Centre d'Etudes et de Recherches des Phosphates Mineraux has been used in a plant located at Dakar, Senegal. The plant has a capacity of 30,000 tpa and has been operating since 1976. Plaster from the plant is used for a number of building materials including plaster boards and internal wall and ceiling plaster. In this process only the purification section is specially designed - the drying and calcination units are standard equipment found in any plaster plant using natural gypsum. The purification treatment is based upon separation in hydrocyclones of the coarsest and finest crystals of phosphogypsum, in which many of the impurities are located, followed by washing and neutralisation. The purification is so organised that maximum quantity of water used is recycled to the phosphoric acid plant - which helps to improve phosphate recovery.

2.12 The impure gypsum from the acid plant is first reslurried to a pulp in the first stage of purification. It is then screened to remove coarse particles which contain impurities such as untreated rock and fluosilicates. Following this, floatation is done using alkyl aryl sulphonates to remove finer particles, largely contaminated with clay, organic materials etc. The pulp is then filtered and the filtrate into which most of the soluble P_2O_5 values and other soluble impurities have passed is returned to the acid plant. Washing is done in two stage : first with water and next with a solution of calcium carbonate to neutralize the product before it is dried and calcined. Because of the fineness of the phosphogypsum particles, the residual moisture in the product is removed by flash drying. Dry gypsum is then dehydrated by indirect heating in a kiln for a long period to obtain beta-hemihydrate as a fine powder.

Other Processes

2.13 There are two other processes which though established, are not much of commercial importance at present, particularly to Bangladesh. The ICI process, which was used in ICI plants at Severnside and Billingham for many years for producing both retarded plasters and plaster boards, is no longer used in any commercial plant at present. It seems there have been difficulties in operating this process, - though the purification treatment in the process itself was very simple, - which prompted ICI to give it up in favour of a new work based on wet-phase dehydration. The other process called Allied Chemical process, developed by the Allied Chemical Corpn of America is based on neutralisation of phosphogypsum with ammonia. The plaster produced in this process is particularly suited to manufacture of paper-lined plasterboards.

Chapter-3

UTILISATION PLAN FOR PHOSPHOGYPSUM

Additive to Cement Clinker

3.1 One of the most promising uses, and one with assured minimum demand, of phosphogypsum in Bangladesh appears to be as an additive to cement clinker (setting retarder) in the manufacture of Portland cement. As mentioned earlier, Bangladesh has no known deposits of natural gypsum. Addition of a small quantity of gypsum to cement during grinding of cooled clinker is necessary to regulate the process of hydration (i.e. setting and hardening when mixed with water) of cement and to prevent 'flash-setting' in which the cement mixture stiffens immediately. The gypsum reacts with tricalcium aluminate (3 CaO Al_2O_3) in the hydraulic cement to form insoluble calcium sulpho-aluminate. A similar reaction takes place between gypsum and tetracalcium alumino-ferrite of cement. It is from the added gypsum that the SO_3 content emanates. The moderating influence of gypsum is important not only because it maintains the mixture in a manageable state for long enough to work on but also because it reduces the hydration of the aluminous species to below that of tricalcium silicate, which is desirable since a much stronger solid matrix results from the hydration of tricalcium silicate than from the hydration of tricalcium aluminate. The amount of gypsum added, however, needs to be carefully controlled since any excess may lead to side reactions which may bring about volume expansion in the element at the cost of its strength. The British Standard Specifications limit the SO_3 content to 2.5 per cent when the tricalcium aluminate in clinker is less than 7 per cent and to 3.0 per cent when it exceeds 7 per cent. Addition of 4-5 per cent by weight of gypsum to clinker is, however, a standard practice followed in most developing countries, including Bangladesh.

3.2 Portland cement is being manufactured in Bangladesh in two units one located at Chhatak and other at Chittagong (Part III) Production of cement in the two plants in recent years is given in Table 3.1.

Table 3.1

Production of Cement in Bangladesh

(Tonnes)

Year	Chhatak	Chittagong	Total
1974-75	92,614	54,410	147,024
1975-76	90,132	69,365	159,497
1976-77	100,038	207,808	307,846
1977-78	103,332	235,291	338,623

3.3 The requirement of gypsum as additive for cement produced during 1977-78 is estimated to be around 13,545 tonnes at the rate of addition of 4 per cent by weight per tonne of cement. With the expansion of the Chhatak cement factory presently under execution and the fuller utilisation of the grinding capacity of the mill at Chittagong, production of cement is expected to go upto 465,000 tonnes in the next few years i.e. by 1982. The requirement of gypsum for this production capacity is expected correspondingly to go upto about 19,000 tonnes per annum. Since the import cost of mined gypsum is very high due to freight and handling, - the present landed cost (West German supply) is understood to be around Taka 3500 ($ 233)/tonne, it may be in national interest to use phosphogypsum for this purpose. Incidentally, this might relieve the problem of disposal of phosphogypsum.

3.4 The use of phosphogypsum in the place of natural gypsum as additive to cement clinker is possible, as seen earlier, if the phosphogypsum is cleared offthe harmful impurities, especially the phosphates which tend to reduce the initial strength of cement. Many phosphogypsums produced in the conventional dihydrateprocess contain anywhere between 0.45 per cent to 7.5 per cent of P2O5, depending on the rock composition, and this level is enough to cause a deleterious effect on cement's properties.

3.5 The chemical composition of representative samples of phosphogypsum of PA-I and PA-II plants taken from the disposal yards and dried at 45°C for 5 hours is shown in Table 3.2.

Table 3.2
Chemical Composition of Phosphogypsum

Constituents		PA-I	PA-II
Total P_2O_5		0.65	0.38
(Of which) Water soluble	P_2O_5	0.25	0.15
	CaO	31.26	31.69
	SO_3	44.75	45.32
	SiO_2	1.30	0.64
	Fe_2O_3	0.012	0.10
	Al_2O_3	0.008	0.008
	MgO	-	-
	CO_2	-	-
	F	0.40	0.32
Water of crystallisation		18.82	19.29
$Na_2 + K_2O$		Not * Reported	Not * Reported
Organic Matter		0.96	1.02
	Cl	0.015	0.013
Total		98.18	98.78

* Normally about 1%

CRYSTAL STRUCTURE OF PHOSPHOGYPSUM

SAMPLE FROM PA-I (DIHYDRATE GYPSUM)

SAMPLE FROM PA-II (HEMIHYDRATE-DIHYDRATE)

Purity of gypsum computed as $CaSO_4.2H_2O$ is 96.01% and 97.44% from PA-I and PA-II plants respectively.

3.6 Petrographic examinations of sample of phosphogypsum from PA-I plant showed prismatic lath, rhomb and a few needle shaped crystals (Illustration). A few twinned crystals were also seen. No agglomeration of crystals was observed. Samples from PA-II plant showed perfectly developed rhomb, lath-shaped and prismatic crystals. But no needles were seen. Impurities of phosphates, fluorides and organic matter were present in :

(a) soluble form absorbed on the surface of the gypsum crystals or occluded in the agglomerates of crystals.

(b) co-crystallised form when HPO4 or AlF5 group replaces SO4 in the crystal lattice of gypsum.

(c) soluble and insoluble form of decomposed organic matter.

(d) insoluble form consisting of undecomposed grains of phosphate rock.

As discussed, these impurities affect adversely the early strength characteristics of cement. Especially the co-crystallized impurities, in particular the phosphates which dissolve out slowly on hydration affect adversely the hydration and strength development characteristic of cement, particularly in the early periods of curing. Results of adverse effects of impurities in a sample of phosphogypsum used as additive to cement clinker on the physical characteristics of cement is reported in Table 3.3.

Table 3.3

Effect of Gypsum Additive on the Physical Properties of Portland Cement

Sl. No.	Gypsum used	SO3 Content on weight of of cement (%)	Fineness of cement Cm^2/g (bleino)	Setting time (minutes) (Initial	Final)	Compressive Strength([illegible]/Cm^2) 1 day	2 days	7 days	28 days	90 days
1.	Mineral	1.8	3300	79	254	80.5	196.8	280.0	308.0	436.0
2.	Phosphogypsum unreacted	1.8	3300	290	500	60.2	112.0	175.2	222.5	300.9
3.	Phosphogypsum passing 150 micron sieve, washed	1.8	3389	210	365	91.7	192.7	270.0	316.0	443.6

3.7 The results show poor strength development at early ages. Early strength is important for bonding of cement e.g. sand mortars/plasters to brick surfaces. It is learnt that for sometime the two cement units in Bangladesh have been using unprocessed phosphogypsum as additive in the place of natural gypsum because of non-availability. As a result, it appears problems of cracking and falling-off of plaster due to poor adhesion have already been noticed in some cases where this cement was used. Also incidence of pinholes in plasters has been observed which is presumably due to the evolution of gas by the attack of phosphoric acid released at a later date. Adequate early strength is also important for release of moulds in the precast concrete industry and for removal of shutterings of the in-situ concrete slabs and other building components. Hence processing of gypsum to eliminate much of the impurities and to keep them within safe limits is important before it can be put to use as cement additive.

3.8 The fluctuations in phosphate content in samples of phosphogypsum over a period of more than a month of running of these plants is shown in Table 3.4.

Table 3.4

Fluctuation in Phosphate Content
(Percent)

	PA-I		PA-II	
Phosphate	Range	Average	Range	Average
Total	0.26-0.84	0.61	0.23-0.73	0.45
Soluble	0.10-0.39	0.22	0.08-0.34	0.16

3.9 The impurity content in gypsum of PA-II plant (Nissan process) is comparatively low vis-a-vis that of PA-I (Dihydrate). Hence Nissan gypsum can be used, after simple washing to remove soluble impurities, as an additive to cement clinker, without appreciably affecting the setting or strength properties of cement produced. However, the quantity of gypsum required as cement additive in the near future is small-around 19,000 te/year and therefore a major proportion of it will remain unutilised. Besides, the problem of disposal of dihydrate gypsum from PA-I will remain to be solved. Since Nissan gypsum (PA-II) can be utilised with advantage in alternate applications such as cement clinker production, where the tolerance limits for impurities are more rigorous, and where gypsum from PA-I cannot be made use of without expensive purification, it is proposed that gypsum available from PA-I should be made use of as cement additive after necessary purification as explained later in this Study, and any surplus should be utilised for manufacture of building plaster and plaster products. Alternative schemes for the utilisation of the entire quantity of gypsum from PA-II (Nissan-hemihydrate) in cement clinker production through Muller-Kuhne process has been considered in Part III so that the total gypsum production of the plant can be put to use. About 0.25 million tonnes of gypsum presently lying in the disposal yard is also mainly from PA-II plant, and therefore, has comparatively lesser impurities. Hence it may be considered for use in the scheme evolved for utilisation of phosphogypsum from PA-II plant.

3.10 The gypsum of PA-I plant, which contains higher percentage of impurities requires slightly more elaborate processing to eliminate the soluble impurities to make it suitable as additive to cement clinker. Though no separate figures for co-crystallised phosphate content have been reported for samples of gypsum from

PA-I plant, the total figures for co-crystallised and unreacted phosphate when compared with the individual figures of samples from rock types of other sources (Table 3.5) show that the phosphate content in the samples of PA-I plant is considerably lower. Further, petrographic examination of samples of phosphogypsum of PA-I plant suggests that washing could eliminate most of the soluble impurities, since the crystals are present in open packing with little agglomeration. The co-crystallised impurities however, cannot be eliminated by these washing techniques. Flash-calcination techniques have been developed in Japan for inactivating these impurities at high temperatures. Autoclaving methods have also been developed for dissolving out the solid soluted impurities. These techniques are however, expensive and have been made use of for manufacture of specialty plasters only. For ordinary building plasters, such methods may not be necessary. The physical properties of an experimental cement sample using washed phosphogypsum as additive show results comparable to those of cement using mineral gypsum as additive. Hence only thorough washing of phosphogypsum is suggested to make it suitable for use as additive (cement retarder).

3.11 As indicated earlier, the PA-I plant, with the implementation of the measures recommended for improving its overall performance, is expected to throw annually about 40,000 tonnes of waste gypsum, containing about 25% of free moisture or about 30,000 tonnes of phosphogypsum on dry basis. On purification, about 97% or about 29,000 tonnes can be expected to be recovered. Of this, about 19,000 tonnes could get utilised as additive to cement clinker, thus leaving a balance of roughly, 10,000 tonnes. This quantity of

Table 3.5

Analysis of Phosphate Contained in Phosphogypsum from the Digestion of Different Phosphate Rock Types (weight) % (dry basis)

Contents	Chittagong PA-I	Florida	Morocco	Tunsia	Senegal	USSR
P205						
- Total	0.26- 0.96	0.8- 1.0	0.8- 1.2	0.9- 1.1	0.7- 0.9	1.0- 1.25
- Soluble	0.10- 0.39	0.2- 0.3	0.2- 0.4	0.15- 0.2	0.2- 0.25	0.15- 0.2
- Co-crystallised)	) 0.16-) 0.64	0.4- 0.5	0.5- 0.6	0.5- 0.6	0.4- 0.5	0.5- 0.6
- Unreacted)		0.2- 0.4	0.1- 0.2	0.25- 0.30	0.1- 0.15	0.35- 0.45

gypsum could be considered for manufacture of plaster of Paris, building plaster or plaster products for use in building industry (Drawing No. VII-4). This estimate of the requirement of cement additive does not take into account the need likely to emanate from the implementation of the planned Jaipurhat Project

(Part III Ch 2) for cement clinker production. In case this project is taken up for implementation in the immediate future, a fresh assessment of the surplus will be necessary - possibly the entire quantity may then be needed as cement additive only.

Chapter-4

SCOPE FOR MANUFACTURE OF BUILDING PLASTER AND PLASTER BOARDS

Building Plaster

4.1 The beta hemihydrate plaster or plaster of Paris, when mixed with water, sets and hydrates rapidly and, therefore, is unsuitable for plastering. Because of this, in USA, UK and Canada, it is usual to retard the set by adding materials such as glue or, hydrolysed Keratin about 0.1 per cent by weight. The plaster, so retarded is known as retarded hemihydrate plaster. This type is used as an internal plaster. It is applied by trowel at a consistency which is stiff. However, the addition of retarders brings about a lowering of strength of the plaster.

4.2 As distinct from the above plaster, building plaster, as used in Germany, France, Iran etc., consists of a mixture of one-third hemihydrate plaster and two-thirds calcined anhydrite overburnt plaster. Certain additives like oxymethyl cellu lose in suitable proportion may be added to retard the setting and thereby facilitate its application, which at the same time, increases its plasticity and makes it hard, once it has set. These plasters have all the necessary properties : early initial setting, long final setting, a setting and workability behaviour which corresponds to the average working speed of a plasterer, smoothness, plasticity and high coverage, rapid drying of the finished plastering, suitable density as well as good strength. The gypsum plasters are presently not used at all in Bangladesh though the Bangladesh Council of Scientific and Industrial Research (BCSIR) has a unit working on

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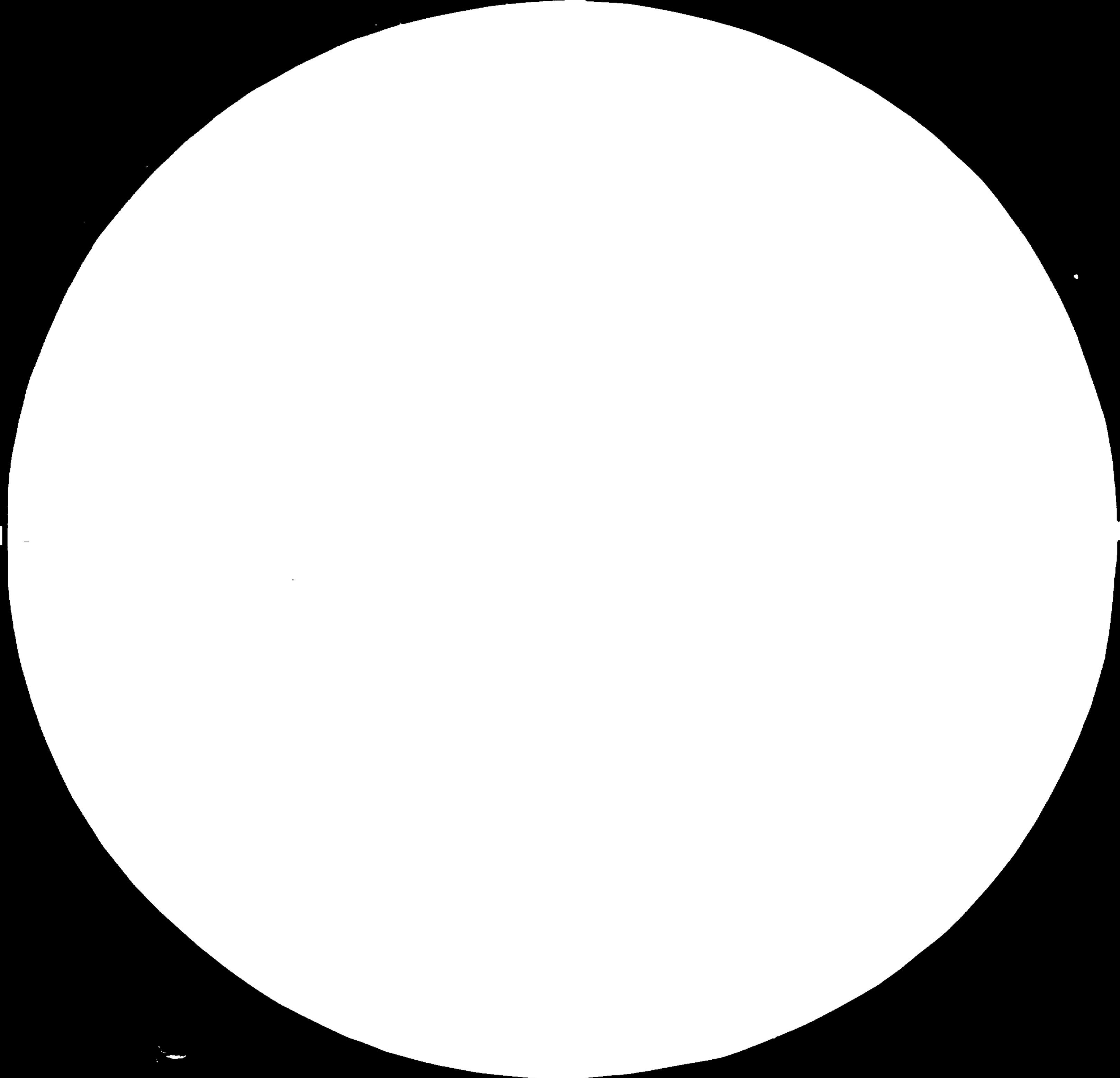

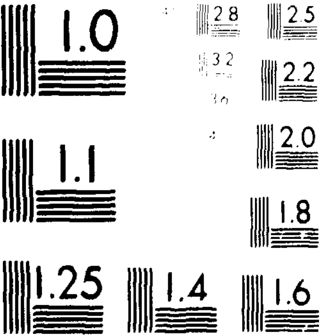
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the utilisation of phosphogypsum, and it manufactures, inter alia, plaster of Paris in small quantities for commercial sale. The BCSIR as well as the Housing & Building Research Institute (HBRI), which has also been experimenting with the utilisation of phosphogypsum building materials for construction purposes under Bangladesh conditions, can play an important role in developing gypsum based plasters appropriate to the conditions in the country and promoting their acceptance.

4.3 The building plaster, when mixed with sand, can replace currently used cement : sand or cement : lime : sand mortar for internal plaster of brick walling in residential and public buildings as well as in private construction. Final finishing coat may be given with neat plaster. The use of gypsum plaster can help to relieve the shortage of cement to some extent. Though it has not been possible to make a quantitative assessment of the cement which could be saved by substitution of gypsum plaster for cement-based plaster for internal plastering, the Consultants feel that the total amount involved could be fairly sizeable in terms of foreign exchange saving. Besides, with the expansion of construction activity, the cement requirement for plastering will tend to grow fairly rapidly and it may be desirable to find an equally good indigenous substitute for the purpose. Moreover, the gypsum plaster provides a neat smooth finish and being inert, is suitable for decorative use if desired.

4.4 The Consultants made a comparison of the costs of plastering with the above calcined gypsum plaster vis-a-vis that with the conventional cement : sand and cement : lime : sand plaster in Bangladesh with assistance from local experts (Table 4.1). The results indicate that gypsum plastering is at pat in terms of cost with cement : sand plaster work and is considerably cheaper compared to the cement : lime : sand plastering.

Table 4.1

Use of Different Plasters : Cost Comparison

The cost of plastering of 100 sq.ft. of brick masonry in Bangladesh with 1/2" thick plaster, reported in Dacca.

A. Gypsum Plaster : Sand
1:25 by weight on 1:1.25 by volume

(i) Materials

First coat 3/8" thick :	
100 lbs. of gypsum plaster at Tk 1000/te	Tk. 44.64
250 lbs. (2.8 cft) of sand at Tk 900/100 cft	Tk. 2.52
Second coat	
50 lbs. gypsum plaster at Tk 1000/te	Tk. 22.32
Sub-total	Tk. 69.48

(ii) Labour

(a) For preparation of mortar

Belder 0.125 at Tk 15/day	Tk. 1.88
Bhishti 0.0625 at Tk 15/day	Tk. 0.94
Sub-total	Tk. 2.82

(b) For Plastering

Mason 0.75 at Tk 30/day	Tk.22.50
Coolie 0.75 at Tk 15/day	Tk.11.25
Bhishti 0.25 at Tk 15/day	Tk. 3.75
Sub-total	Tk.37.50

Total cost/100 sq.ft. = Tk.69.48 + 2.82 + 37.50

= Tk.109.80

B. Cement : Sand Mortar
Ratio 1:6 by volume

(i) Materials

Cement 0.71 bag at Tk.71/bag	Tk.50.41
Sand(fine) 5.4 cft. at Tk. 90/100 cft.	Tk. 4.86
Sub-total	Tk.55.27

(ii) Labour

(a) For preparation of mortar

Belder 0.125 at Tk.15/day	Tk.	1.88
Bhishti 0.0625 at Tk.15/day	Tk.	0.94
Sub-total	Tk.	2.82

(b) For plastering

Mason 0.75 Tk. 30/day	Tk.	22.50
Coolie 0.75 at Tk. 15/day	Tk.	11.25
Belder 0.25 at Tk. 15/day	Tk.	3.75
Sub-total	Tk.	37.50

Cost for 100 sq.ft. = Tk. 55.27 + 2.82 + 37.50

= Tk. 95.59

Cost of white washsing (15%) = Tk. 14.34

Total cost/100 sq.ft. = Tk.109.93

C. <u>Cement : Lime : Sand</u>
Ratio 1:1:6 by volume

(i) <u>Materials</u>

Cement 0.71 bag at Tk.71/bag	Tk. 50.41
Lime 0.89 cft (13.2 kg) at Tk. 900/tonne	Tk. 11.88
Sand (fine) 5.4 cft. at Tk. 90/100 cft.	Tk. 4.86
Sub-total	Tk. 67.15

(ii) <u>Labour</u>

(a) <u>For preparation of mortar</u>

Belder 0.125 cft. at Tk. 15/day	Tk. 1.88
Bhishti 0.0625 at Tk. 15/day	Tk. 0.94
Sub-total	Tk. 2.82

(b) For plastering

Mason 0.75 at Tk. 30/day	Tk. 22.50
Coolie 0.75 at Tk. 15/day	Tk. 11.25
Belder 0.25 at Tk. 15/day	Tk. 3.75
Sub-total	Tk. 37.50

Cost/100 sq.ft. = Tk. 67.15 + 2.82 + 37.50

= Tk. 107.47

Cost of white washing (15%) = Tk. 16.12

Total cost/100 sq.ft. = Tk. 123.99

Plaster Board

4.5 The beta hemihydrate plaster can also find considerable scope for use in the manufacture of plaster boards, for which a reasonably sizeable demand can be developed in Bangladesh, though presently such plaster boards are not used at all. Gypsum plaster board is a commonly used false-ceiling material in residential and public buildings in several countries in the world. It has the properties of fire resistance and thermal insulation, besides providing a neat smooth finish. In Bangladesh, ceiling materials currently used in public and commercial buildings are flat asbestos cement sheets, chip boards made of jute sticks locally known by the brandname 'Partex', and hard-board supported by wooden frames. Asbestos cement sheets are rather expensive. Though indigenously manufactured, the available capacity is rather limited - around 7000 te annually for both flat and corrugated while the annual requirement is estimated at 15 to 20,000 tonnes. The import base of production for raw materials inhibits largescale expansion. Moreover, the thermal conductivity of A.C. sheets of density of 1700 - 1800 kg/m^3 (105 to 110 lbs/cft) is higher (0.25 Kcal/m/hr/^{o}C) than that of plaster-board of density of 900-1000 Kg/M^3 (55-60 lbs/cft), - being 0.14-0.17 Kcal/m/hr/^{o}C.

4.6 The annual indigenous production of chipboard 'Partex' is of the order of 4500 tons. It is manufactured in size of 8'x4' having thicknesses of 8, 12, 18, 25 and 36 mm and densities of 400, 500 and 600 Kg/m^3. Taking average thickness of 18 mm and density of 500 Kg/m^3, the total annual production in terms of area can be assumed to be a little over 5 million sq.ft. Except for jute sticks, most of the raw materials (mainly chemical compounds) such as urea formaldehyde (adhesive). and paraffin wax are imported. Hence there is substantial underutilisation of capacity. Particle boards are also exported in relatively small quantities. They are widely used in Bangladesh for false ceiling, partitioning (office buildings) as well as for special purpose applications such as exhibition stalls. In the absence of any indigenous better substitute, Partex also serves as accoustical material. In terms of price, it is even more expensive than asbestos sheet for comparable varieties.

4.7 The production of hardboard in 1976 was of the order of 13.4 million sq. ft. Enquiries showed that there was considerable demand for this material in the urban areas of Bangladesh for false ceiling and other decorative uses, esp. in cinema halls, shops and office establishments etc. However, there are some problems connected with its use, which make it not quite the suitable material : its life is rather short and it warps with absorption of moisture; also its thickness is limited to 1/4", requiring a more elaborate support frame. In the absence of any other substitute, however, demand for it is expected to increase with the new construction programmes for office buildings, cinema houses etc. In price, it is the cheapest material available in the country.

4.8 The Consultants' enquiries with architects, civil construction firms and other users, as well as with engineers of the Public Works Department of the Government gave a clear indication that prefabricated plaster board can easily replace the above materials to a considerable extent, besides meeting the new demand. It will find, for instance, ready acceptance for interior panelling of cinema houses and public halls- on account of its accoustical properties, thermal insulation and fire-resistance. Besides, it can be made to give a decorative finish. In fact, on account of its fire resistance properties, use of gypsum plaster boards in cinema halls and auditoriums can be made obligatory through an appropriate amendment of the building bylaws. For the same reasons, it can find use in office buildings designed for air conditioning or for insulating air-ducts. It can be used for false ceiling in shops and similar establishments. Once its utilitarian properties are established, it can offer serious competition to existing products. Fibre reinforced plaster boards can be used even in residential houses for non-load bearing partitions and panelling.

Promotional Requirement

4.9 The building industry, in general, is no doubt a conservative industry using traditional building materials and techniques, and is hardly given to experimentation. Gypsum plaster and plaster products, if produced, would be new to the industry. Acceptability of new materials assumes great importance from the point of view of cost, durability, comfort, appearance etc. Whatever the initial market survey done, in the final analysis the demand for the product will depend on the builders' reactions to the new products in actual performance. Most builders will also wait for someone else to use the product first and try to gain from others' experience. Hence, in all probability, whatever the promotion work done by the Government and related agencies like the HBRI and BCSIR, the demand will tend to grow only slowly in the initial years. Until, therefore, the consumer reaction to the product is confirmed and continued demand established, the products should be manufactured only on a pilot scale, so that investment risks are minimised. It is therefore suggested that the new materials, viz. plaster and plaster products should be produced in small units to start with and their use in buildings promoted through demonstrations to the practising engineers, building contractors, architects etc. and their performance studied over a period. Once the users are convinced about the suitability of these materials, production can be increased by multiplying the number of units. As mentioned above, there may also be need for amendments of the building by laws to the use of these materials. In the Government buildings, in the initial years atleast, the use of these products may be made mandatory to promote their use in national interest.

4.10 The Consultants, therefore, recommend that these products be manufactured on 'cottage industry' (unmechanised) basis. Since it will be totally a new field, unrelated to its main activity, the Consultants do not recommend that the TSP Complex should be directly involved in these products. However, since the gypsum is produced by the TSP complex, and it cannot altogether disown its responsibility to supply the needed phosphogypsum to the cement units, the involvement of the TSP unit will be necessary atleast upto a stage. The Consultants, therefore, envisage that the TSP Complex should process the gypsum from PA-I plant and make it available in dried form to actual consumers such as cement plants and the proposed plaster board units at a reasonably low price. The actual manufacture of boards and other products should be undertaken by new independent units to be set up for the purpose. Considering the transport modes and problems as well as local demand, it is suggested that the plaster unit should be set up in Chittagong within the TSP Complex by the BCIC as a sub-unit of TSP. Two units for the production of plaster boards may be set up, one in Chittagong and the other near Dacca promoted by the BCIC itself or by the Bangladesh Small & Cottage Industries Corporation (BSCIC). There is already a proposal to set up a small production unit to process phosphogypsum for plaster of Paris under the joint auspices of BCSIR and BSCIC in Tongi near Dacca. It is suggested that the same unit may be entrusted with the manufacture of plaster boards as well, as a diversified activity. In fact, if the proposed plaster of Paris unit comes up at the TSP Complex, this unit should confine its production line to manufacture of specialty plasters needed in small quantities, such as dental plasters. The unit in Chittagong can be entrusted to a private entrepreneur or can be set up as a joint venture by BCIC/BSCIC in a suitable locality. Each of these prefabricated plaster board units can have a capacity of 240,000 sq.ft. per year, which will be small enough to involve little risk of lack of demand. Casting of such boards does not require much technical skill and can be undertaken with some training provided by the HBRI. Since it is adaptable to labour intensive operations, the industry can provide employment opportunities and at the same time help to build skills of a sophisticated kind in the country.

Building Blocks

4.11 Due to climatic factors and the somewhat uncertain demand situation, the plaster products suitable for Bangladesh are limited: Products like pre-cast slabs (building blocks) can have only limited application since they cannot be used in walling exposed to dampness or in load-bearing walls. Besides, use of locally made bricks is likely to be cheaper in comparison with the likely cost of these products. Some products such as glass-fibre reinforced panels or paper coated gypsum boards are considered too sophisticated to find a market in Bangladesh. Hence the Consultants do not recommend the manufacture of these products in the country.

Chapter-5

PURIFICATION OF PHOSPHOGYPSUM

5.1 As discussed in detail earlier, impurities of phosphates, fluorides and organic matter adversely affect the early strength development characteristics of cement when untreated phosphogypsum is used as additive to cement clinker. These impurities also reduce the strength of plaster produced on calcination. Further, the impurities of organic matter impair the colour of the calcined plaster and the set products. Hence, purification of the phosphogypsum is essential before it can be made use of in construction and building materials.

Methods of Purification : Limitations

5.2 Several techniques of washing and purification are available and have been discussed in Chapter 2. Some of the licensors offering their processes for purification of phosphogypsum and production of plaster are :

1. Negai Consultant Co. Ltd., Japan
2. Rhone - Poulence, France
3. Gebruder Knauf, Iphofen, West Germany
4. CdF Chimie/Air Industrie, France
5. CERPHOS, France
6. Guilini, West Germany

However, the knowhow available from these licensors are generally for plants of large capacities only, not commensurate with the present requirements of Bangladesh, based on the quantity of gypsum available from PA-I plant or the demand for the products.

Several of the above firms recommend passing gypsum slurry through series of hydrocyclones or through floatation cells to wash off soluble impurities and organic matter, and drying and calcination in either specially designed fluidized bed or rotary driers in a current of hot air. On similar principles, a simplified scheme for processing of phosphogypsum is suggested below (Drawing No. VII-5) for a small 10,000 tpa capacity plant, based on the Consultant's own design.

Method Suggested

5.3 The raw phosphogypsum, coming from the vacuum filter in the phosphoric acid plant is suspended (Drawing No. VII-5) in a tank (T101) by means of water from a hydrocyclone (SC 102). The suspension is cleaned of large particles of quartz, unreacted rock and any foreign bodies on the sifting screen (SC 101). The sifted product consisting of phosphogypsum pulp is collected in tank (T102) and then pumped to hydrocyclone. The gypsum collected at the down flow in the form of a thick pulp falls into another washing tank (T 103). Most of the liquid carrying away the soluble impurities and organic matter is collected at the upflow and sent on to the waste neutralisation plant. In T 103 the gypsum is neutralised using lime solution and then pumped to the hydrocyclone. The cyclone separates the liquid which is recycled to the beginning of the treatment washing tank (T 101). The gypsum collected at the down flow in the form of a thick pulp is spin-dried in a continuous centrifuge and the filtered liquid is sent to the washing tank. The filtered gypsum containing 10% moisture received by a conveyor belt (ET 101) is taken to the thermic treatment unit. It is carried directly into a rotary drier (DR 101) where it meets current of air at a temperature of 110°C. The gypsum arrives at the other end of the drier in a dry condition. Part of the dry gypsum is stored in a silo (not shown) for use in cement plant as cement additive. Rest of the gypsum is calcined in a rotary calciner at 130-170°C. To neutralise any phosphoric acid occluded in the gypsum crystals, addition of about 0.2 percent bases like $Ca(OH)_2$ or NaOH is recommended. A part of the calcined hemihydrate plaster is taken out for the manufacture of fibre reinforced plasterboards. The rest of it is calcined further at a temperature of 500°C in a rotary calciner. The calcined anhydrite plaster obtained is mixed with hemihydrate plaster in the ratio of 2:1 for use as building plaster.

5.4 Specifications of the Equipment

1.	Washing Units :	Cylindrical
	Diameter	1.5 m
	Height	3 m
	Capacity	5 m^3
	Material of construction	Rubber lined mildsteel
	Shaft	Carbon steel or 316 stainless steel
	Impeller	Carbon steel

2.	<u>Pumps - Centrifugal</u> :	
	Capacity	300 L per minute
	Differential Pressure	2 Kg/cm^2
	Material of construction	Rubber lined carbon steel
	Motor	5 H.P.
3.	<u>Vibrating Screen</u> :	60 mesh mild steel
4.	<u>Hydrocyclones</u> :	Dorr Oliver
	Capacity	80 gallons per minute
5.	<u>Centrifuge</u> :	
	Capacity	4 tonnes of solids/hr for converting 50% concentration of slurry to 90% concentration
6.	<u>Belt Conveyor</u> :	Natural rubber/cotton fabric to handle 4 tonnes of cake (90% solid) per hr.
7.	<u>Rotary Dryer</u> :	To dry gypsum at 110°C
	Internal Diameter	3000 mm
	Diameter	15,000 mm
	No. of Guide Plates	16

No. of Lifters	20
Material of construction	Carbon steel
Shaft H.P.	15
Combustion Chamber for above	
Size	8' x 6' x 6'
Lining	9" Firebrick 2-1/2" Insulation brick
8. Rotary Calciner :	For operation at 170°C
Internal Diameter	900 mm
Length	4500 mm
No. of Lifters	6
Material of construction	Carbon steel
Shaft H.P.	2
Combustion Chamber for above	
Size	8' x 4' x 4'
Lining	9" Firebrick 2-1/2" Insulation brick

9. Rotary Caiciner : For operation at 500°C

Internal Diameter	600 mm
Length	3000 mm
Lining	Stainless steel - 4 mm
No. of Lifters	4
Material of construction	Carbon steel
Shaft H.P.	1

Combustion Chamber for above

Size	8' x 4' x 4'
Lining	9" Firebrick 2-1/2" Insulation brick

10. Blower :

Working temperature	30°C
Suction pressure	Atmospheric
Discharge pressure	2 kg/cm^2
Material of construction	Carbon steel

Raw Material

5.5 It is assumed that crude phosphogypsum will be supplied free of charge by the TSP Complex, the phosphoric acid producer, in the form of powder or an easily pumped aqueous suspension. In the latter case, the pump and the cost of pumping, as well as the piping leading to the raw material storage tank for the project, will be owned by the TSP unit as part of the gypsum disposal scheme.

Description of the Unit to be Supplied

5.6 (i) A three stage counter current gypsum washing system comprising three series of tanks of capacity of 5 m^3, each fitted with an agitator and a pump for the continuous evacuation of the contents into a-60 mesh screen to remove large particles, if any, and one of the hydrocyclones.

(ii) A hydrocyclone with a capacity of 80 gallon per minute for each of the two washing tanks.

(iii) A continuous centrifuge system comprising the centrifuge and, if required, washing of the residue on the filter.

(iv) A continuous rotary drier operating by parallel air flow and a temperature not exceeding 110°C with a capacity of 4 tonnes per hour of moist gypsum having moisture content of 10 per cent.

(v) A belt conveyor for conveying 4 tonnes of mist cake of gypsum per hour to the drying unit.

(vi) An air blower, with capacity in keeping with the performance required by the drier.

(vii) A combustion chamber with a heating capacity adjusted to heat the air supplied by the compressor to the temperature required to dry the gypsum without decomposing it.

(viii) A feed regulator for gypsum with a capacity of 30 tonnes per day leading to the calciner for plaster production.

(ix) A rotary gypsum calciner with a capacity of 400 kg per hour.

(x) An air blower for the above.

(xi) A combustion chamber to heat the air to 170^{0}C required for gypsum clacination to hemihydrate.

(xii) A storage silo for gypsum.

(xiii) A storage silo for hemihydrate plaster.

(xiv) A rotary gypsum calciner with a capacity of 800 kg per hour.

(xv) An air blower for the above.

(xvi) A combustion chamber to heat the air to 500^{0}C required for gypsum calcination to anhydrite.

(xvii) A storage silo for anhydrite.

(xviii) A settling tank for the waste water.

(xix) Underground connection

(xx) Overhead connection

(xxi) Electrical distribution

Chapter - 6

PLANT LOCATION, IMPLEMENTATION AND MANPOWER

Plant Location

6.1 A vacant plot of land lying between the road alongside the jetty and the TSP plants (Drawing No. VIII-6) along the railway line could be made use of for the purpose of putting up the proposed phosphogypsum purification facility. The land, about 2-3 acres in area, is adequate and is suitable. It is also close to the gypsum source. The Management of the TSP Complex has indicated that the land could be made available for the purpose. Utilities like electricity, water, fuel and infrastructural facilities are available from the TSP Complex. Since there is already an active proposal to connect Chittagong city with the Bakhrabad gas field by a pipeline, natural gas may very well be available for use as fuel in the next few years, say by 1984. In the meantime or if the gas distribution scheme is delayed for any reason, since the fuel requirement is not large, either fuel oil could be used in the thermic section, or if arrangements are finalised for making use of the refincry off-gases in the cement clinker/sulphuric acid project involving utilisation of gypsum (Nissan) from PA-II, then the same fuel source could be tapped for the plant. For purpose of deriving working results such as cost of production, natural gas is assumed to be used. As mentioned earlier, since the scheme is not energy intensive, the cost of production will not vary significantly - around 15 percent only - even if fuel oil is used.

Utilities

6.2 Power needed, about 1.5 MW - is assumed to be available from Bangladesh Power Development Board (PDB) through the TSP Complex sub-station. No separate substation will be required, since the requirement is low. Though presently supply interruptions to the TSP Complex are high, PDB has assured that the problem will be overcome shortly through the new grid system being implemented and that adequate power will be available for the new projects. The Consultants have also encured through the Counterparts that the power requirements for schemes involving utilisation of phosphogypsum, considered in this Study, have been incorporated in the PDB plan for power needs of the area.

Water

6.3 The TSP Complex is presently be deviled with the problem of water supply. The principal source of water to the complex till recently was a series of tube wells located close to the factory area. However, there has been a stady deterioration in the supply of water from most of the wells in recent years with the chloride content rising above the permissible limits. Lately, the complex has been drawing water mainly from the Karnaphuli river, flowing adjacent to the factory complex during specified periods of low tide, when the chloride content is low, on the basis of a close study of the analysis of river water during different hours of the day. However, it appears that even the use of river water is presenting some difficulties because the composition of water at the plant's intake station varies widely in terms of salinity, especially during the dry season when the flow is low. However, last year (1978), the Water and Sewerage Authority (WASA) of Chittagong has completed laying a pipeline for the supply of clean water from the city distribution system and this is expected to relieve considerably the problem of water supply at the TSP Complex. Discussions by the Consultants with the WASA authorities indicated that WASA has a plan to augment the water supply capacity to the industrial area of North Patenga with the construction of a larger capacity loop pipeline with which the existing system will be integrated. The WASA would then be able to meet the entire water requirements of the existing industries in the area, including the proposed new projects. The scheme has been planned to be completed by 1984-85 but during the interim period, the water supply from WASA sources can be stepped up by fuller utilisation of the existing pipeline. Since the total water requirement of the proposed purification system is only about 0.1 MGD, the Consultants feel that water supply may not pose any serious problem and can be adjusted within the existing facilities, including storage tanks, of the TSP Complex. The supply price of water has been assumed at Tk 10/1000 gallons (Tk 2/m^3), the price indicated by WASA.

Implementation

6.4 As mentioned earlier, it is assumed that the phosphogypsum processing facilities will be put up and owned by the TSP Complex (BCIC). Apart from purified gypsum to be sold to the cement units as additive, the facilities proposed will produce about 10,000 tonnes of plaster of Paris per year, which will be also sold by the TSP Complex to the plaster board manufacturing units to be established separately. This arrangement is proposed considering the scope and advantages of integrating the planned processing facility with the main complex. In the view of the Consultants, this will not create any problem or tax unduly the managerial resources of the TSPComplex.

6.5 The entire plant facilities for processing 30,000 tonnes of phosphogypsum can be erected and commissioned within a time-horizon of 30 months from zero date (Drg. No. VII-7). The zero date has been assumed to be the date when the investment decision is formally taken and the necessary contract awarded (whichever is later). Considering the facilities and expertise available for project execution in Bangladesh, the Consultants recommend that the contract for the erection and commissioning of the plant be given on 'turn-key' basis to an experienced engineering contractor, to be selected on the basis of worldwide tender to a preselected list of qualified firms. The selection list itself may be drawn up on the basis of requests from firms capable of executing, and interested in, the project. For this limited purpose of evaluation of offers, a consultant's services may be drawn upon. In the above suggested mode of implementation, the BCIC will provide an experienced engineer to act as a project coordinator and provide liaison between the owners and the prime contractor. The project coordinator will report to the General Manager of the TSP Complex and possibly takeover as the Dy. General Manager in charge of the plant, after it is handed over to the owners.

Manpower Requirements & Training

6.6 The proposed new facilities will be operated as a sub-unit of the TSP Complex and therefore, the higher levels of management will be provided by the TSP Complex. It is envisaged that the processing unit and the related facilities will be headed by Deputy General Manager, who will report directly to the General Manager of the TSP Complex. The total additional manpower requirements for the facilities will be about 38, including the Dy General Manager, and the strength of the different categories is shown in Table 6.1. This strength is based on the assumption that adequate laboratory and workshop facilities will be available in the TSP Complex and only supplementary staff need to provided.

Table 6.1

Manpower Requirement of the Project

	Level	Number
1.	Dy General Manager	1
2.	Shift Engineer	4
3.	Supervisors/Chemists	6
4.	Mechanics/Operators	16
5.	Helpers	11
	Total	38

6.7 The salary scales of the employees have been computed on the basis of the existing grades of the public sector employees as practised in the BCIC units. No housing is envisaged to be provided.

6.8 Since the operation of the unit is fairly simple, no specific training other than on-the-job training will be needed. It is however proposed that the skilled operating staff be recruited and placed in position atleast 6 months in advance of commissioning so that the operating personnel are properly trained by the prime contractor during the commissioning period of the plant.

Chapter 7

CAPITAL OUTLAY, PRODUCTION COST AND RETURNS

7.1 Project Cost

The investment capital requirement of the Project, on the basis of the proposed scheme for the production of 19,000 tpy of cement additive and 8065 tpy (net of processing losses) of plaster for use as building plaster and in plaster board manufacture (corresponding to 30,000 tpy of dry raw dihydrate gypsum of PA-I) is estimated at $ 3.95 million. Of this, $ 2.11 million will be in foreign exchange. A summary of estimates is given in Table 7.1.

Table 7.1

Estimated Capital Requirements

($ '000)

	Item	Foreign Currency	Local Currency	Total
1.	Land & land development	-	72	72
2.	Cement Additive and Plaster Plant	1660	910	2570
3.	Auxiliary facilities	80	110	190
4.	Project Management charges	-	140	140
5.	Spares	100	40	140
	Manufacturing Facilities	1840	1200	3040

Table 7.1 (contd)

	Item	Foreign Currency	Local Currency	Total
6.	Contingency	90	60	150
7.	Escalation	180	120	300
8.	Working Capital	-	215	215
9.	Financing Charges	-	245	245
	Total Capital outlay	2110	1840	3950

The details are given in Annexure VII-1

Basis of Estimates

7.2 Cement Additive and Plaster Plant : The cost of equipment, instruments, piping etc for the plant have been worked out on the basis of specification of various equipment proposed in a preliminary design developed by the Consultants. The major equipment like centrifuge, centrifugal dryer, combustion furnaces, calciners, belt conveyor etc are 'sized' and cost data available with the consultants is used to arrive at the cost. Cost of items like washing tanks and other locally manufactured equipment are estimated on the basis of unit rates for fabrication and material collected in Bangladesh. Spares are assumed to cost 10 per cent of the equipment supplies.

7.3 Ocean freight, duties, handling charges, taxes and insurance are estimated as percentages of supplies as indicated in Table 7.2.

Table 7.2

Ocean Freight, Duties, Handling Charges & Taxes in Project Cost

	Item	Basis
1.	Ocean freight	10% FOB
2.	Customs duty	20% C&F
3.	Inland Handling	3% (FOB + FOR)
4.	Sales Tax	20% Duty-paid Value/FOR
5.	Insurance - transit	1% (C&F+FOR)
	- erection	0.6% Landed Cost at Site

7.4 Construction Costs : Construction costs are estimated based on information collected in Bangladesh for cement, steel, aggregate, cost of land-filling, labour etc. for civil works and erection rates for erection charges.

7.5 Provision towards licese fee, design engineering, procurement and supervision is based on infroamtion furnished by CdF Chemie, France with correction factor applied for capacity.

7.6 Auxiliary Facilities : Laboratory and testing equipment, workshop facilities and other necessary offsites have been provided for under this head.

7.7 Project Management Charges : are estimated on the basis of 30 months' time schedule for the Project and a manpower requirement of 38. These charges cover salaries and wages during construction & commissioning period, preliminary investment charges, electricity & water charges and other pre-operating expenses.

7.8 Contigency & Escalation : The provision for unforeseen expenditure is assumed at 5% of the estimated cost of manufacturing facilities. A provision of 10% for escalation is covered in the estimates.

7.9 Working Capital : In accordance with the practice followed in Bangladesh, the entire working capital requirement is capitalised. The provision under the working capital covers -

1. Lime/limestone (2 months' requirement)
2. Product inventory (1 month)
3. Accounts receivable (1 month)
4. Cash in hand
5. Goods in process
6. Deposits & advances

7.10 Financing Charges : Following the investment guidelines given to the Consultants, the entire foreign exchange component is assumed to be borrowing and the local currency component as equity. Interest during the project construction period of 30 months estimated @ 10% per year is capitalised.

COST OF PRODUCTION

7.11 The estimated cost of production of cement additive and plaster of Paris are worked out in Table 7.3. The cost of production of gypsum for use as cement additive works out to $ 24 (Taka 360) per tonne, compared to the present procurement price of Tk 150 ($ 10) for raw (impure) gypsum-paid by the Cement Clinker Grinding Factory, Chittagong and the estimated landed cost of Tk 1500 ($ 100) per tonne of natural gypsum now proposed to be imported for cement additive (in view of the complaints about cement quality arising from the use of raw phosphogypsum). Since the permissible limit of gypsum addition to clinker is about 4 to 5 percent, an increase in the cost of procurement of say Tk 330 per tonne (Para 7.12) of additive will make only an insignificant difference of about 1 percent in the cost of cement.

Table 7.3

Cost of Production

($ '000)

	Item	Total	Cement Additive	Building Plaster
1.0	Variable Cost			
1.1	Phosphogypsum	-	-	-
1.2	Lime/Limestone	14	9	5
1.3	Fuel	67	37	30
1.4	Water	21	14	7
1.5	Power	33	20	13
1.6	Packing Material	94	-	94
1.7	Contingency	12	4	8
	Sub-Total	241	84	157
2.0	Fixed Cost			
2.1	Labour & Overhead	50	30	20
2.2	Maintenance Material	91	55	36
2.3	Insurance & Taxes	12	7	5
2.4	Contingency	8	5	3

Table 7.3 (contd)

($'000)

	Item	Total	Cement Additive	Building Plaster
2.5	Depreciation	294	177	117
2.6	Interest on Borrowing (avg)	106	64	42
2.7	Marketing & Selling Expenses	54	38	16
	Sub-Total	615	376	239
3.0	Total Annual Cost of Production	856	460	396
4.0	Annual Production (te)	-	19,000	8,065
5.0	Unit Cost of Production ($/te)	-	24	49

SALE PRICE & FINANCIAL RETURNS

7.12 The selling price of plaster in Bangladesh presently is around Tk 2800 (i.e. $ 186.70/te), but the amount of plaster sold is in small quantities for specialised minor applications and hence cannot be taken as the basis for pricing of the Project's output. In the absence of any other reliable indication the selling price is calculated based on a 12% return on equity. The selling prices thus arrived at are :

-	Cement Additive	:	$ 32 (Tk 480)/te
-	Plaster	:	$ 60 (Tk 900)/te

The Consultants feel that these prices will be competitive in comparison with possible substitutes in Bangladesh. As seen above in the case of cement additive, the landed cost of imported gypsum works out to $ 100/te (Tk 1500/te). In the case of building plaster the strength of competition is discussed elsewhere (Chapter 4). In actual market conditions, however, the prices may tend to settle between these two cases.

Return on Investment

7.13 The return on total capital employed works out to 8.7 percent if the sale price is fixed on the basis of cost of production plus 12 percent return on equity, and 34.5 percent if the sale price of plaster is assumed at Tk 2800/te i.e. the current market price (Table 7.4).

Table 7.4

Return Investment

($ '000)

Item	Sale Price of Plaster	
	@ $ 60/te	@ $ 186.70/te
1. Sales Realisation		
- Plaster	484	1 505
- Cement Additive @ 32/te	608	608
Total	1 092	2 113
2. Works Cost + Depreciation	750	750
3. Gross Profit	342	1 363
4. Total Capital Employed	3950	3950
5. Return on Investment	8.7%	34.5%

7.14 Pay Back Period : The pay-back period is around 6.2 years if the selling price is Tk 480 ($ 32)/te and Tk 900 ($ 60)/te for cement additive and plaster respectively and about 2.4 years if the possible market price for plaster is around Tk 2800/te.

7.15 The profit break-even point in the first case (Tk 480) is 54 percent and in the second case (Tk 2800), 24 percent.

Chapter 8

MANUFACTURE OF PLASTER BOARDS

8.1 Plaster boards are broadly of two types :

(i) Paper-surfaced plaster boards

(ii) Fibre reinforced plaster boards

Paper surfaced plaster boards consist of a set core of plaster of Paris sandwiched between paper lines. It is made by a highly mechanised factory-process and involves heavy capital investment. Manufacture of fibre reinforced plaster board, on the other hand, is feasible on small and cottage industry basis, and requires comparately small investment. It does not require high technical skill. The principal use for such plaster boards is as low cost substitute for plywood and particle boards of insulating type used for lightweight partitions and false ceiling. This may also be used as wall surfacing in place of plaster for dry and faster method of construction.

8.2 This section describes the process of preparation of the plaster boards as a small scale/cottage (i.e., non-mechanised) industry.

A. Raw Materials

(a) Gypsum plaster produced after purification and calcination of phosphogypsum.

(b) Organic fibre : sisal fibre is commonly used in Australia and New Zealand for the manufacture of plaster boards, In view of the non-availability of this fibre in Bangladesh, it can be substituted with 'A' grade jute fibre.

(c) A small quantity of oil for use as a stripping agent for plaster boards. Stearine or animal fat dissolved in mineral oil has been found to be satisfactory for this purpose.

B. Equipment

The equipment required for the manufacture of plaster boards on a small scale consists of -

(a) Concrete casting table about 9 ft. long, 4' 6" wide and 2' 8" high. The surface of the concrete table is trowelled to a high gloss so that it is perfectly smooth and truly level.

(b) Steel frames 4' x 2' having thickness of half an inch.

(c) Buckets, trays, trowels etc.

C. Method of Casting

A steel frame mould is laid over the concrete casting table having smooth trowelled surface. Calcined plaster is mixed with water to form think uniform slurry. The slurry is poured and evenly spread in the framed mould to 0.2" thickness. Fibre, about 25-30 grams per square foot, is then spread over the surface. The fibre near the edge is pressed into the plaster by hand. The remaining slurry is then poured, levelled and allowed to set. The set product is demoulded after two hours and dried in wooden racks in air.

D. Testing

A standard transverse bending test is performed by supporting 12" x 12" specimens of plaster board on 10" span. The specimen is centrally loaded with finished surface upwards, on two parallel supports 10 in apart and extending across the full width of the specimen. A load is applied to the specimen along a line parallel to and midway between the supports at a rate of 10 lbs per minute, by means of a steel roller 1/2" in diameter extending across the full width of the specimen, and supported so that the load is evenly distributed across the specimen. The deflection of the specimen is measured to the nearest 1/32". When subjected to a proof load of 75 lbs. the deflection of the specimen should not exceed 3/4". It should not deflect less than 1/4" before failure occurs.

8.3 The capital investment required for a small scale unit with an annual capacity 240,000 sq. ft. of fibre reinforced gypsum plaster board is given in Table 8.1.

8.4 An estimate of the cost of production of plaster boards for a plant capacity of 240,000 sq. ft. per annum is enclosed (Table 8.2). The cost works out to Tk. 1.82 per sq. ft. Selling price is estimated to be Tk. 2.04 per sq.ft. Selling price of 'Partex' 400/12, commonly used as a lining material in Bangladesh is Tk. 2.60 per sq.ft. Hence, plaster board would be quite competitive with 'Partex'.

Table 8.1

Predesign Estimate of Capital Investment

Project : Fibrous Gypsum Plasterboard

Capacity (a) per day (of one shift) - 800 sq.ft.

(b) per year (300 working days) - 240,000 sq.ft.

Capital Investment			Tk.
1.	**Land & Building**		
	(a)	Land - 5000 sq.ft. @ 50,000 Tk/acre	5,740
	(b)	Land improvement etc.	2,000
	(c)	Building - 2500 sq.ft. @ Tk. 80 sq.ft.	200,000
		Sub-total	207,740
2.	**Plant & Equipment**		
	(a)	**Equipment**	
		i) Concrete Casting Table - Five each 10' x 5'	10,000
		ii) Mild steel moulds - 25 each 4' x 2'	5,000

	Capital Investment	Tk.
iii)	Wooden racks for drying boards - 25	2,000
iv)	Buckets G.I. or Plastic - 20	500
v)	Flexural strength testing machine - one	10,000
vi)	Water services & drainage etc.	2,750
	Sub-total	30,250
3.	<u>Others</u>	
(a)	Laboratory, workshop etc.	2,750
(b)	Engineering & Supervision 30% of equipment cost	8,250
	Sub-total	10,900
4.	<u>Contingency</u>	
	Contingency - 15% of fixed capital on plant	6,172
	Total Fixed Capital	255,062
5.	Working capital @ 25% of Annuals Sales	122,500
	Total Capital Investment	377,562

8.5 The estimated cost of production of the plasterboard, on the basis of single-shift working and 300 working days is given in Table 8.2.

Table 8.2

Cost of Production

(No. of working days : 300)

(In Takas)

Item		Unit Cost	Qty. reqd. per unit of prodn.	Cost/ unit of Prodn.	Annual Cost
1.	Raw Materials				
a)	Gypsum Plaster (Tonne)	1000	2.2 lb	1.00	240,000
b)	Jute Fibre (Maund)	200	25 g	0.135	32,400
c)	Stripping Agent (Kg)	10	2 g	0.02	4,800
	Total				277,200

2. Labour and supervision

5 unskilled at Tk. 7/day	10,500
5 semi-skilled at Tk. 10/day	15,000

3.	Maintenance & repairs	
	a) Plant : 6% of fixed cost on plant facilities	2,839
	b) Building 2% of land & buildings cost	4,155
4.	Operating supplies - 15% of maintenance & repairs	1,049
5.	Taxes and insurance - 2% in total fixed capital	5,101
6.	Plant Overhead (includes cost of general plant overhead, payroll overhead, packing, storage facilities)	14,496
7.	Depreciation, plant @ 10%	2,750
	Building @ 2.5%	5,193
8.	Administrative Expenses at 2.5% of sales	12,250
9.	Distribution & selling costs at 5% of sales	24,500
10.	Interest on total capital investment at 15% per annum	56,634
	Total Cost of Production	436,667
11.	Annual Production of Plaster Board (Sq.ft.)	240,000
12.	Cost per sq. ft. of Plaster Board	1.82

Profitability

8.6 At the proposed selling price of Tk. 2.04 per sq. ft. (i.e. Tk. 16.32 per board of 4'x2'x1/2"), the project is expected to yield a return of 14.0 per cent on the total capital employed, as seen in Table 8.3

Table 8.3

Return on Investment

(Production : 240,000 sq.ft.
Selling price : Tk. 2.04/sq.ft.)

1.	Gross Annual Sales	Tk. 489,600
2.	Annual Cost of Production	Tk. 436,667
3.	Annual Return (1-2)	Tk. 52,933
4.	Return on Capital employed	14.0%

8.7 At the proposed sale price, the gypsum plaster board will be competitive with the 'Partex' board presently used widely for false ceiling, partitioning etc. as seen below :

1.	Present selling price of 'Partex'400/12	Tk. 2.60/ft^2
2.	Proposed selling price of gypsum plaster board	Tk. 2.04/ft^2

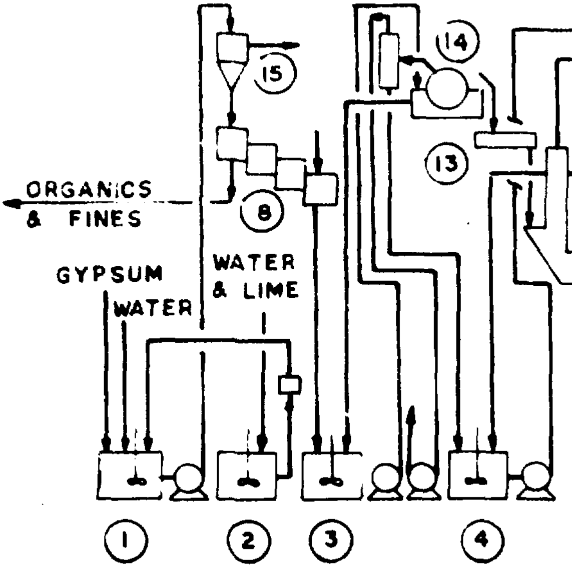
TOTAL CAPITAL OUTLAY

Cement Additive : 19,000 tpa
Plaster : 8,065 tpa

	Item	TAKA 1000			$ 1000		
		F.C.	L.C.	Total	F.C.	L.C.	Total
1.0	Land & Land Development	-	650	650	-	72	72
2.0	Cement Additive & Plaster Plant						
2.1	Equipment Supplies	13500	1500	15000	900	100	1000
2.2	Freight, Customs, Handling & Taxes & Insurance	1500	3975	5475	100	265	365
2.3	Construction Costs	1350	7650	9000	90	510	600
2.4	Supervision, Licence, Engg.& Procurement charges	8550	525	9075	570	35	605
	Sub-total (2)	24900	13650	38550	1660	910	2570
3,0	Auxiliary Facilities	1200	1650	2850	80	110	190
4.0	Project Management	-	2100	2100	-	140	140
5.0	Spares	1500	600	2100	100	40	140
	Manufacturing Facilities	27600	18000	45600	1840	1200	3040
6.0	Contingency @ 5%	1350	900	2250	90	60	150
7.0	Escalation @ 10%	2700	1800	4500	180	120	300
8.0	Working Capital	-	3225	3225	-	215	215
9.0	Financing Charges	-	3675	3675	-	245	245
	TOTAL CAPITAL OUTLAY	31650	27600	59250	2110	1840	3950

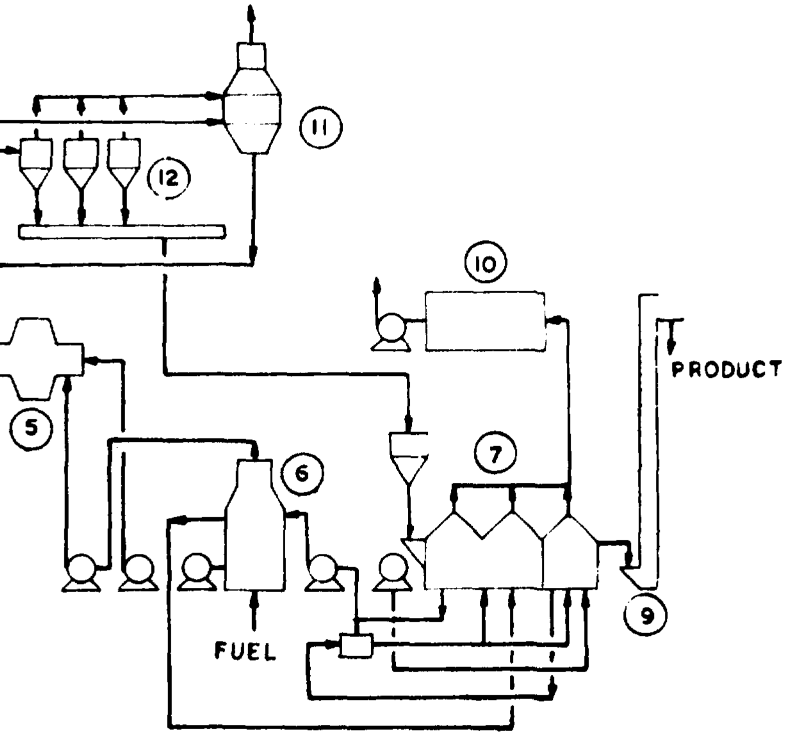
COST OF PRODUCTION OF CEMENT ADDITIVE AND PLASTER OF PARIS

	ITEM	Unit	Unit Rate Taka	Quantity	Taka 1000		
					Total	Cement Additive	Plaster
1.0	Variable Cost						
1.1	Phosphogypsum	Te	Nil	30,000	-	-	-
1.2	Lime	Te	470	450	210	135	75
1.3	Natural gas as fuel	$1000Nm^3$	315	3,168	1005	555	450
1.4	Water	M^3	2	$157x10^3$	315	210	105
1.5	Power	MWH	440	1,120	495	300	195
1.6	Packing Material	Nos	7	$201.7x10^3$	1410	-	1410
1.7	Contingency				180	60	120
	Sub-total (1)				3615	1260	2355
2.0	Fixed Cost						
2.1	Labour & Overheads				750	450	300
2.2	Maintenance Material				1365	825	540
2.3	Insurance & Taxes				180	105	75
2.4	Contingency				120	75	45
2.5	Depreciation				4410	2655	1755
2.6	Interest on Borrowings				1590	960	630
2.7	Marketing & Selling Expenses				810	570	240
	Sub-total (2)				9225	5640	3585
3.0	Annual Cost of Production				12840	6900	5940
4.0	Annual Production	Te				19000	8065
5.0	Unit cost of Production	Tk/te				Tk 360/ te	Tk 735/ te
		$/te				$ 24/te	$ 49/te



1. GYPSUM SLURRY DILUTION TANK
2. LIME WASH TANK
3. BUFFER TANK
4. WATER RECEIVER
5. GYPSUM DRIER
6. BOILER
7. CALCINER

8.
9.
10.
11.
12.
13.
14.
15.



FLOATION TYPE PURIFICATION FILTER

HEMIHYDRATE CONVEYOR

DUST FILTER

GAS SCRUBBER

HEMIHYDRATE CYCLONES

GYPSUM CONVEYOR

ROTARY FILTER

FILTER

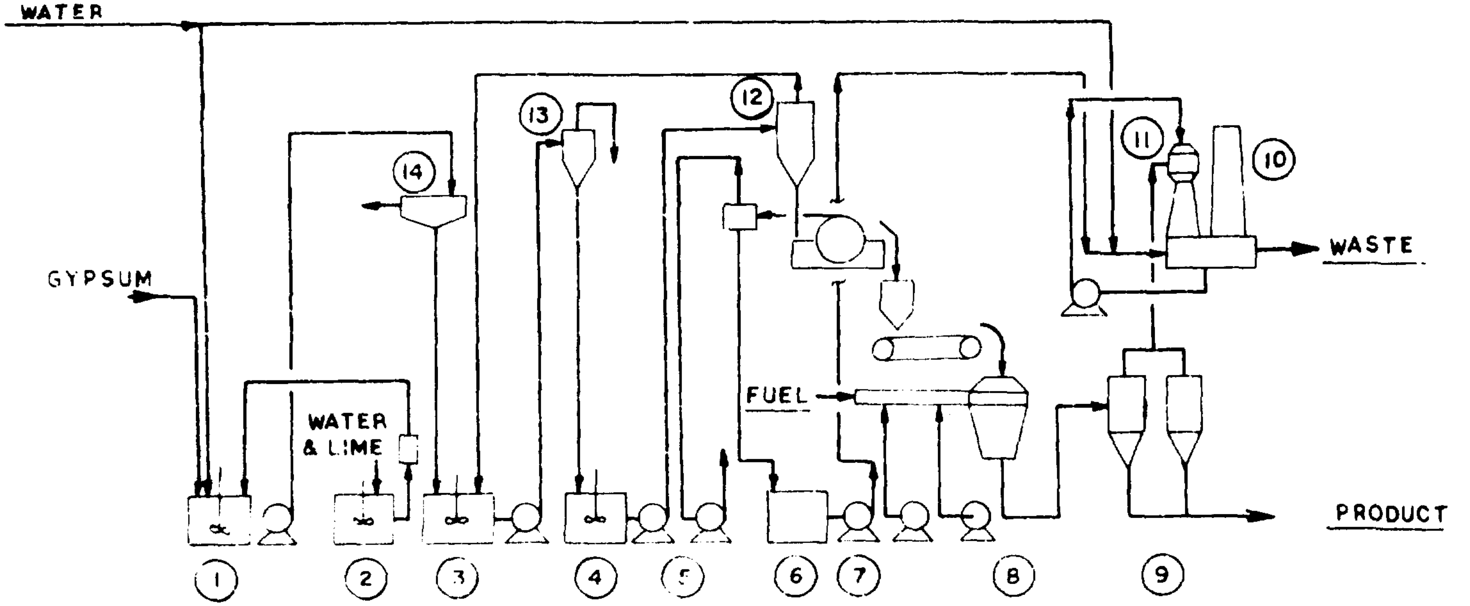
FERTILIZER (P & D) INDIA LTD. SINDRI

TITLE :

RHONE-POULENC PROCESS

INCORPORATING FLOTATION & A TWO-STEP CALCINATION

PROJECT : B.C.I.D.B | DRG NO. VII-1 (1 OF 2)



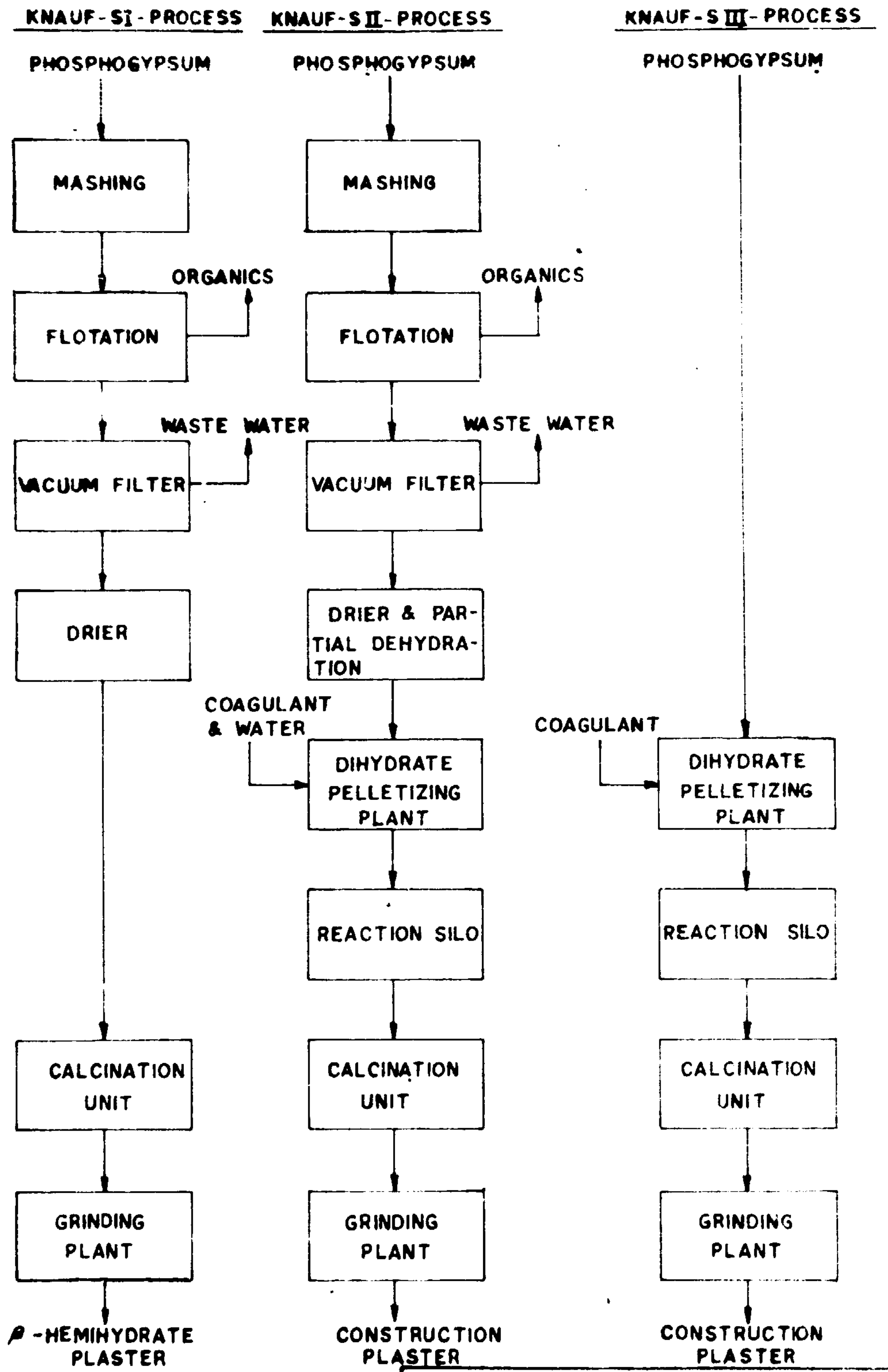
1. GYPSUM SLURRY DILUTION TANK
2 LIME WASH TANK
3 INTERMEDIATE TANK
4 FINAL WASHING TANK
5. VACUUM PUMP
6. WATER RECEIVER
7 ROTARY FILTER
8. L.E.A. CALCINER
9. HEMIHYDRATE CYCLONES
10 STACK
11 GAS SCRUBBER
12 HYDROCYCLONE
13 HYDROCYCLONE
14. FILTER

FERTILIZER (P & D) INDIA LTD. SINDRI

TITLE : RHONE - POULENC PROCESS
INCORPORATING A HYDROCYCLONE & A
ONE STEP CALCINATION

PLANT :

PROJECT : B.C.I.D.B. | DRG. NO. VII - 1 (2 OF 2)



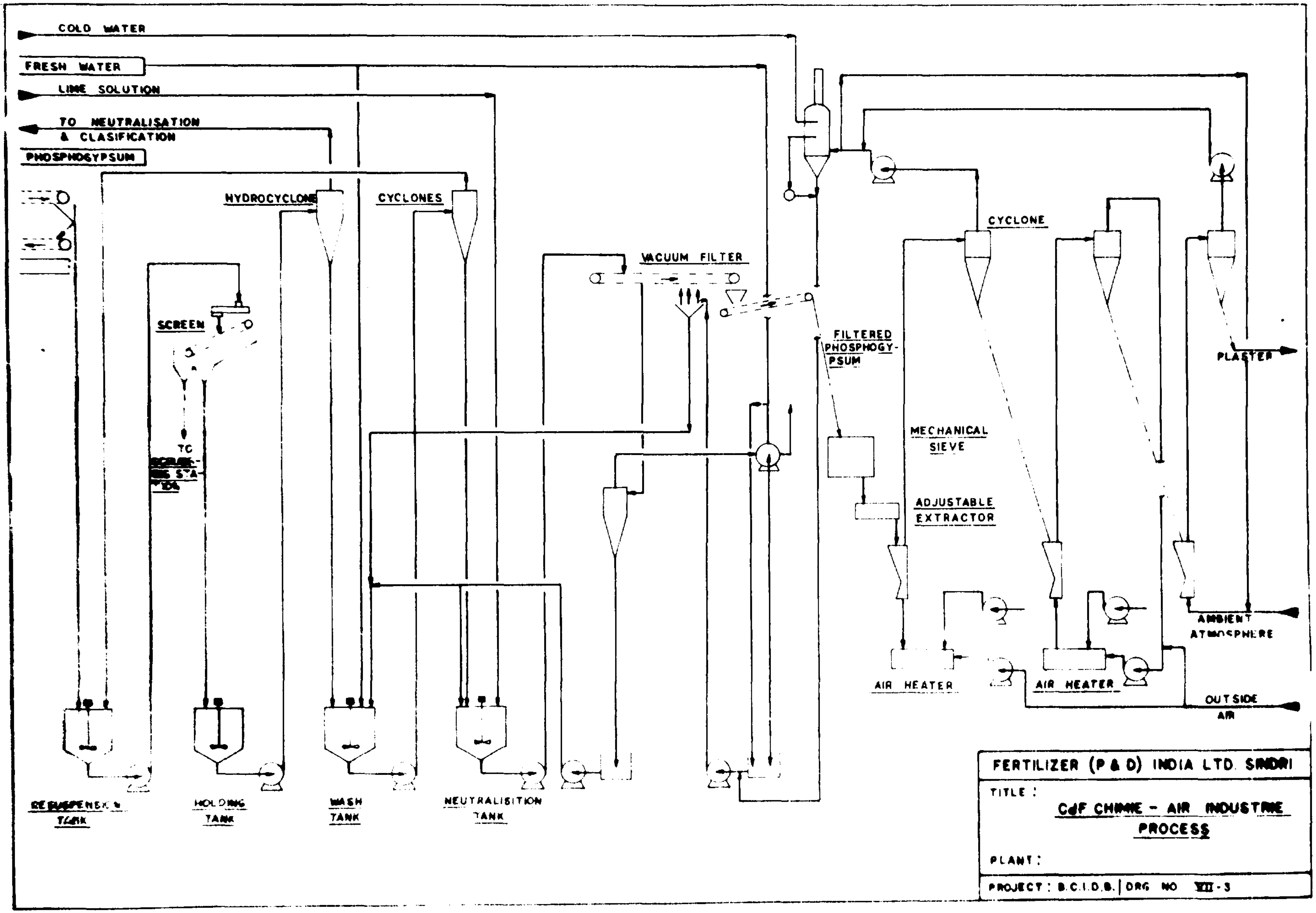
FERTILIZER (P & D) INDIA LTD. SINDRI

TITLE:

KNAUF PHOSPHOGYPSUM PROCESSES

PLANT :

PROJECT : B C I.D.B. | DRG. NO. VII-2 | REV.

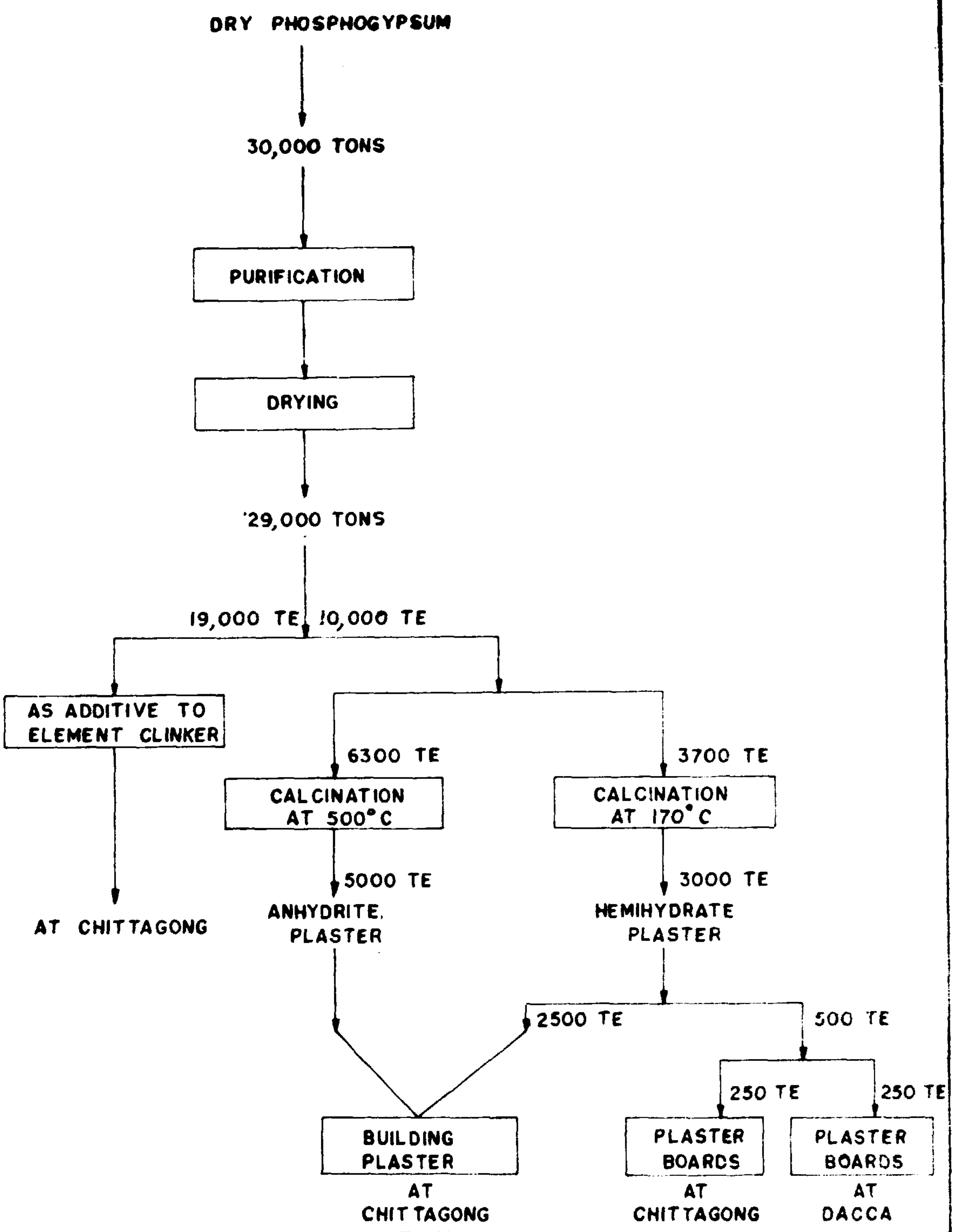


FERTILIZER (P & D) INDIA LTD. SINDRI

TITLE : **CdF CHIMIE - AIR INDUSTRIE PROCESS**

PLANT :

PROJECT : B.C.I.D.B. | DRG NO VII-3

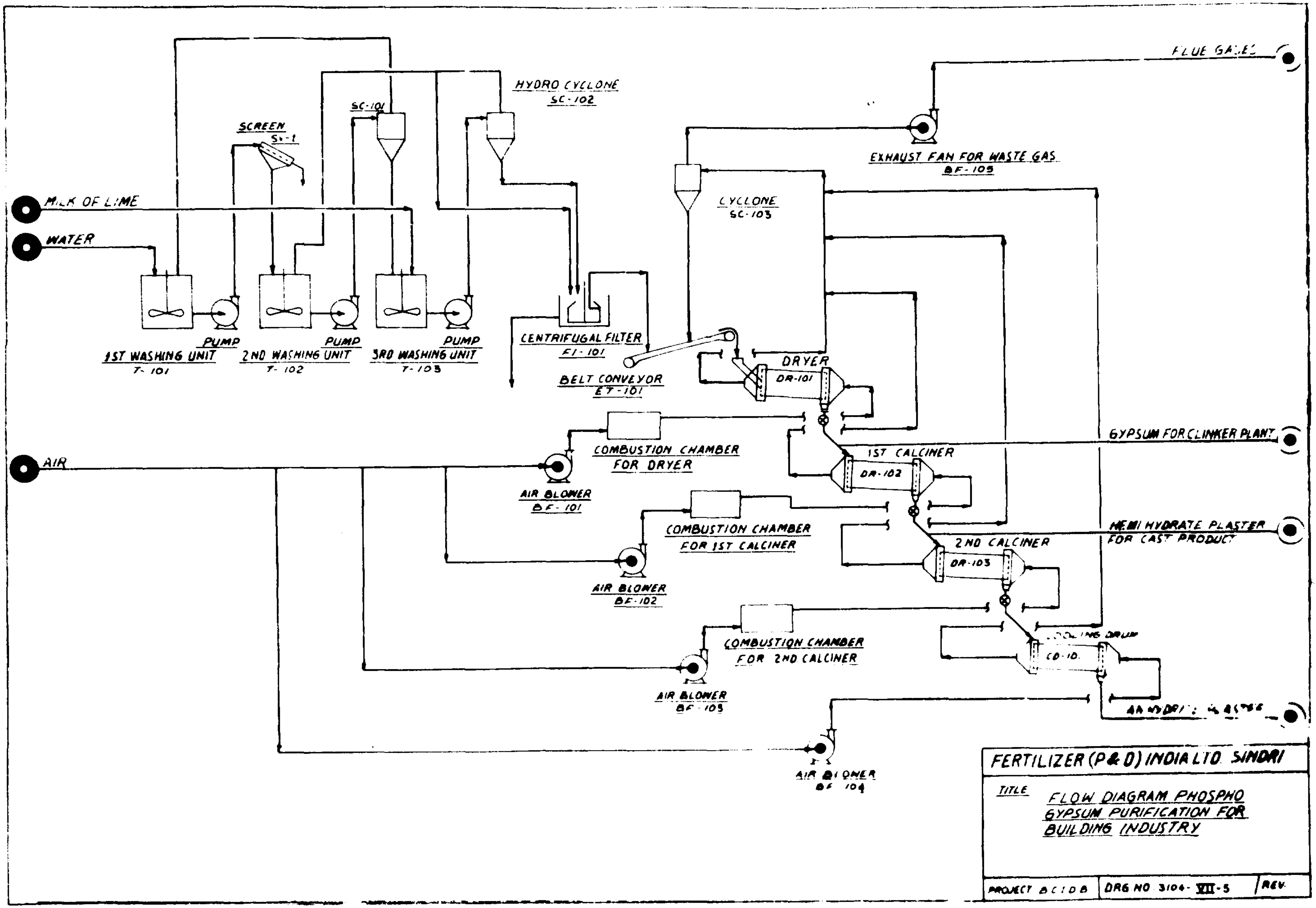


FERTILIZER (P & D) INDIA LTD. SINDRI

TITLE :

FLOW CHART FOR PROCESSING OF PHOSPHOGYPSUM OF PHOSPHORIC ACID -I PLANT

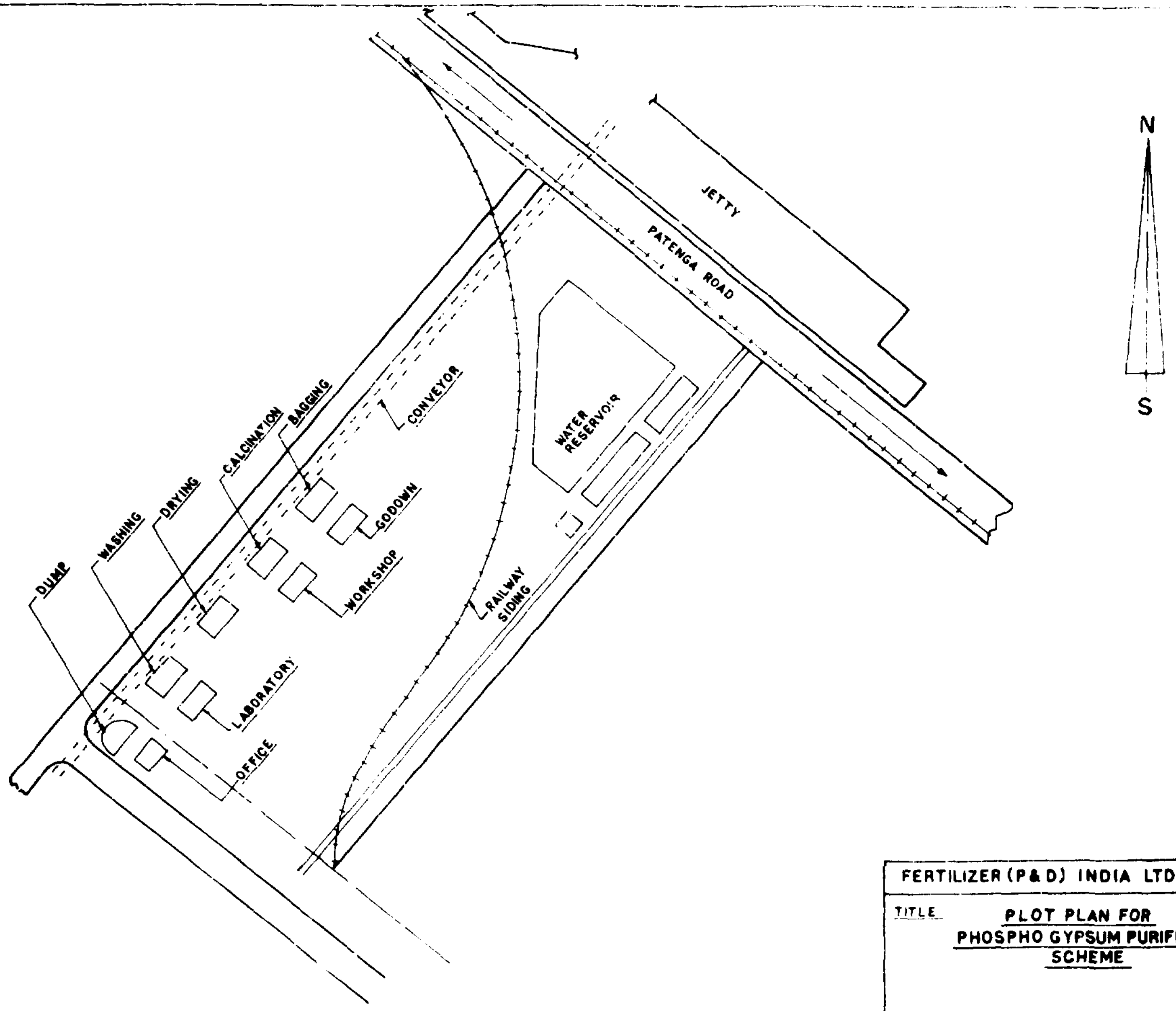
PROJECT : B.C.I.D.B | DRG NO. VII - 4



FERTILIZER (P&D) INDIA LTD. SINDRI

TITLE FLOW DIAGRAM PHOSPHO GYPSUM PURIFICATION FOR BUILDING INDUSTRY

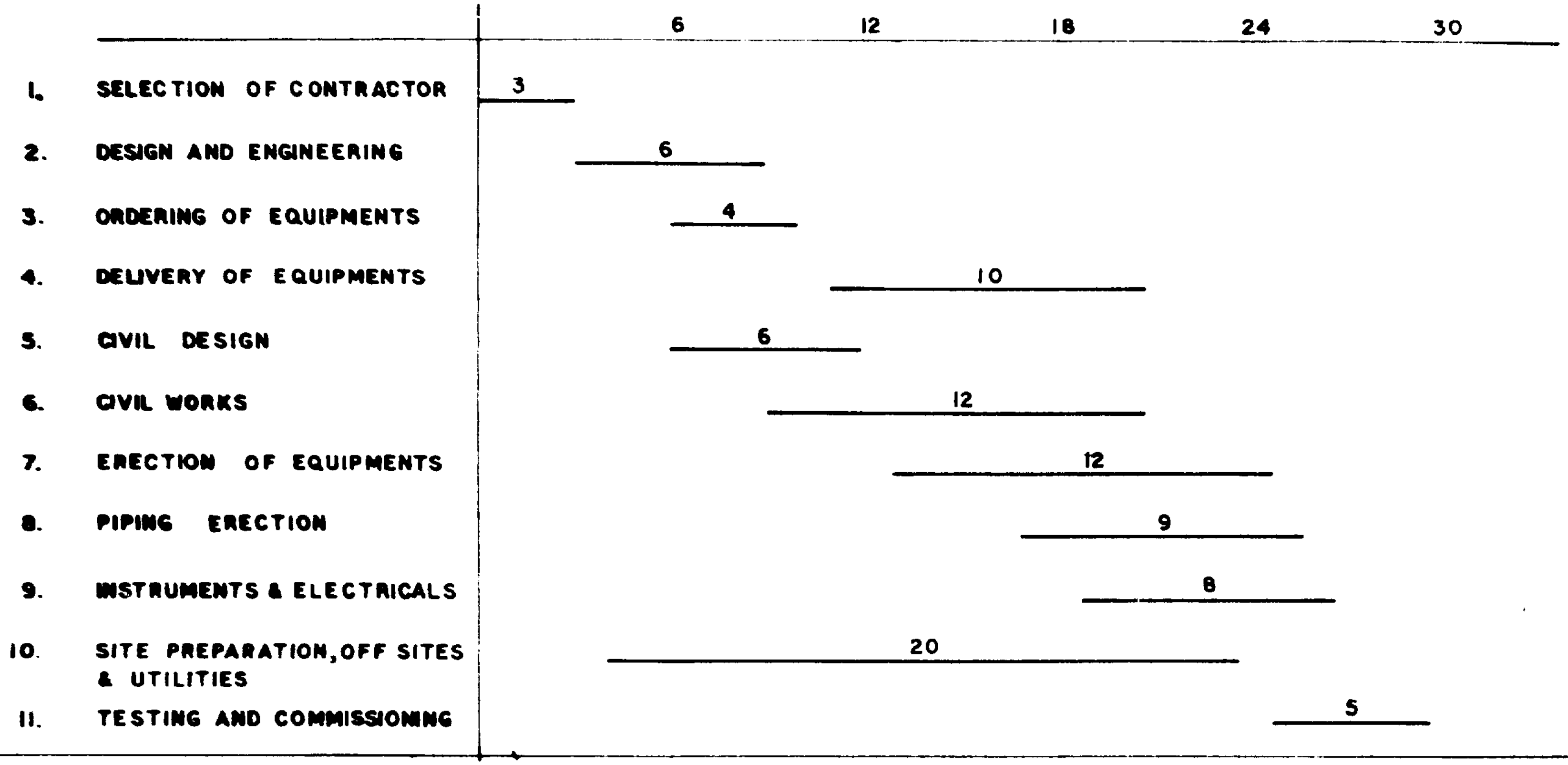
PROJECT BCIDB | DRG NO 3104-VII-5 | REV.



FERTILIZER (P& D) INDIA LTD. SINDRI

TITLE **PLOT PLAN FOR**
PHOSPHO GYPSUM PURIFICATION
SCHEME

PROJECT B.C.I.D.B. DRG NO. VII-6 / REV.



FERTILIZER (P&D) INDIA LTD. SINDRI

TITLE:

TENTATIVE TIME SCHEDULE

PROJECT: B.C.I.D.B. | DRG NO. VII - 7 | REV.