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INTERNATIONAL COOPERATION ADMINISTRATION

TUDOR ENGINEERING COMPANY, WASHINGTON, D. C.

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INTERNATIONAL COOPERATION ADMINISTRATION

REPORT ON

[illegible] FERTILIZER FACTORY

DAUD KHEL, PAKISTAN

[illegible] ENGINEERING COMPANY, WASHINGTON, D.C.

[illegible] 1957

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International Cooperation Administration
815 Connecticut Avenue, N. W.
Washington 25, D. C.

November 20, 1957
Reference: TEC-44

SUBJECT: FERTILIZER FACTORY - DAUD KHEL, PAKISTAN

Gentlemen:

Pursuant to Task Order No. 44, Dr. John van der Valk, chemical consultant, was assigned to make a field inspection of the ammonium sulphate fertilizer factory now nearing completion at Daud Khel in West Pakistan.

Dr. van der Valk left New York on July 1, 1957, called at the USOM office in Karachi on July 5, 1957, and spent the period from July 15 to August 25 at the fertilizer factory and the nearby Makarwal coal mining area. Within the time available, he studied the present condition of the factory and the steps required to bring it into efficient production at an early date. He also investigated the supply of raw materials and examined the present development of the housing colony for factory employees. Many conferences were held with the engineers on the job and officials of the Pakistan government.

On his return trip from Pakistan, Dr. van der Valk called again at Karachi, stopped at Teheran for a conference with ICA officials and spent two days in Brussels in conference with the Union Chimique Belge, the Belgian firm which has the contract for design and construction of the factory. He returned to New York on September 8, 1957.

Dr. van der Valk's report in summary form is submitted herewith. It will be followed at a later date by a supplemental report containing supporting and supplementary material, which will be of interest to those most directly concerned with the plant and its future operation and development.

CONCLUSIONS

The major conclusions of Dr. van der Valk's report are as follows:

1. The plant processes employed are well suited to the raw materials available and the end product desired.

2. The site of the factory is satisfactory so far as topography, availability of raw materials and accessibility to markets are concerned.

3. Soil conditions at the site were not sufficiently explored in advance of construction and some of the structure foundations were not adequately designed.

4. The factory is well designed and laid out. Equipment used is good and, apart from the foundations, structures are well built, although some inferior concrete was used. The factory is now ready for operation tests.

5. Serious settlement of several structures has occurred. Immediate corrective measures are necessary.

6. Completion of the factory has been delayed for about 15 months beyond the period of construction specified in the contract. Many factors contributed to the delay, most of which were beyond the control of the contractor.

7. Auxiliary facilities at the factory are generally satisfactory excepting the first aid room, the store room and the condition of the internal road system.

8. Living facilities for factory personnel are below acceptable standards and have contributed to low morale of employees and construction and erection personnel and consequently delay of construction work.

9. Raw materials for factory use are available in adequate quantity but production and transportation facilities for coal and by-product must be improved to ensure full and continuous delivery to the factory.

10. Competent Pakistani personnel to take over operation of the factory at conclusion of the testing period are not now available and will only gradually become available in the years to come through training under qualified foreign supervisors.

11. The cost of the factory has exceeded the 1952 estimates by about $3,500,000 or 20 per cent. The principal increases were in land, freight and insurance, transport, structure foundations, wages of European labor, administrative expense, trainee expense and customs duties.

12. Authorized ICA contributions to the project have included $13,064,970 for the factory and $1,093,000 for coal mining improvements.

13. Yearly ammonium sulphate production can almost certainly be increased from the guaranteed amount of 50,000 metric tons per year to 55,000 and may possibly reach 60,750.

14. With adequate factory management and an output of 50,000 metric tons of ammonium sulphate a year the cost of production including depreciation charges will be about 409 Rs per metric ton. This figure will drop to about Rs 382 per metric ton if 55,000 metric tons are produced. With less than full production the cost will be greater than Rs. 409. The price of imported ammonium sulphate delivered at Lahore is Rs 361.

15. Additional fertilizer production in West Pakistan is needed. It is estimated that the Daud Khel factory can be expanded to twice its present capacity for about 38,000,000. This figure includes 10 per cent for unforeseen contingencies and an adequate amount of spare parts. After such enlargement, the cost of production would be about Rs 280, or nearly Rs 100 less than the probable cost at the present factory.

RECOMMENDATIONS

The principal recommendations contained in the report, particularly those requiring immediate consideration, are summarized as follows:

1. A further investigation of soil and foundation conditions at factory structures should be undertaken at once. Employment of the Soil Mechanics Laboratory of Delft, Holland for this purpose is recommended. The corrective steps to halt foundation settlement should be undertaken as soon as the soils condition survey indicates what is necessary.

2. A minimum of 30 foreign experts in factory management and operation should be obtained by means of a contract with a company experienced in operation of ammonia plants and should be retained until Pakistani personnel have been adequately trained. A contract with Union Chemique Belge is recommended.

3. The Government of Pakistan should assign at least three additional Pakistani chemical engineers for factory operation and a number of chemical, mechanical and electrical engineers for training. Some of these should be offered training abroad after they have gained enough knowledge and experience to warrant the expense.

4. Consideration should be given to the addition of a compressor for gas discharged from the sulphation plant and to the provision of additional storage facilities for ammonia.

5. An improved first aid room should be provided at the factory.

6. A foreign currency credit in favor of the factory management should be established on a revolving fund basis in Europe or the United States so that equipment parts and replacements can be ordered and obtained with minimum delay.

7. The factory should be enlarged to at least twice its present capacity as soon as possible and prior to undertaking a second fertilizer plant in West Pakistan. As a first step to this end a comparative study of available alternate processes of ammonia and fertilizer production with either coal or natural gas should be authorized immediately.

8. Living and recreation facilities should be improved by:

   a. Providing a modern 20-bed hospital.

   b. Equipping all poorer type houses with electricity, running cold water and flush toilets. Equipping the present W.P.C. bungalows and bachelor quarters with running hot water, air conditioning units in all occupied bedrooms and decent kitchens with electric ranges.

   c. Improving the mess-hall.

   d. Providing additional bungalows.

   e. Providing additional recreation and cultural facilities.

   f. Employing a doctor, a registered nurse, a mess steward and a welfare officer.

   g. Providing better roads and transportation.

9. The supply of coal should be increased and made more dependable by:

a. Providing additional mining equipment.

b. Providing equipment needed for the development of new mining areas.

c. Replacing generators in the mine power station.

d. Providing additional coal cars or heavier locomotives.

10. Gypsum mining should be improved and accelerated by:

a. Providing a rock crusher.

b. Providing additional development and handling equipment.

c. Employing a qualified foreign supervisor.

ACKNOWLEDGMENTS

We are extremely grateful to all the various officials who gave us valuable documentary material, information and suggestions for this report, including particularly the staff of the ICA Industrial Engineering Division in Washington, representatives of ICA in Pakistan and officials of agencies of the Government of Pakistan.

Very truly yours,

TUDOR ENGINEERING COMPANY

(sgd) John G. Marr

RGW:bb

John G. Marr
Project Manager

Map of West Pakistan

Plate I

REPORT ON

A FERTILIZER FACTORY

DAUD KHEL, PAKISTAN

By John van der Valk, Chemical Consultant

1. Initiation of Project

The idea of erecting a fertilizer factory in Pakistan had been discussed and studied even before partition of the Indian sub-continent in 1947. The location intended for this factory was probably in the Punjab Province east of the Indus River, somewhere between Mianwali and Mari Indus. (See Plate I.) About 25 to 30 miles to the west were the coal deposits in the Makarwal, Mallakhel and Gullakhel mines, then the property of Indians. Gypsum deposits were known to exist some five miles southeast of Mari Indus and a few miles north of a mud-hut village called Daud Khel. This early project was deferred in favor of a similar one for the erection of a fertilizer factory at Sindri in India, also based on the use of coal and gypsum. Since neither India nor Pakistan had any known sources of natural gas at that time, it was logical to rely on indigenous coal both for the production of hydrogen required for the synthesis of ammonia and for the production of power and steam.

The Sindri project was started before partition. The designers, engineers and constructors of this project were the Power Gas Company

of Stockton-on-Tees, England, assisted by the Chemical Construction Corporation of New York City.

After partition, insufficient production of food crops to adequately feed the Pakistan population, caused largely by lack of water and lack of fertilizers, induced the Government of Pakistan (GOP) to consider the immediate erection of a fertilizer factory in the Mari Indus area along the lines of the pre-partition project.

2. Construction Proposals

In 1949, the Government of Pakistan invited several engineering and construction firms of international reputation to consider the submittal of project proposals, as a result of which by the latter part of the year two prominent firms had started to make the necessary surveys. These firms were:

a. The Power Gas Corporation (PGC) in combination with the Chemical Construction Corporation (CCC)

b. Union Chimique Belge (UCB) in combination with the Lurgi Corporation of Frankfurt-am-Main, Germany (Lurgi).

Toward the end of 1951, both companies had submitted proposals.

The PGC bid was largely based on process steps similar to those adopted by them in the Sindri factory in India. For the production of gas from coal, they proposed to use a process whereby the coal was charged to a mechanical grate gas producer which was blown continuously with oxygen and steam. This process requires the use of lump coal. When it was learned that Pakistan could not supply the required size of coal

for this process, PGC proposed to use the dust gasification process of the Fauindus Company of Rouen, France. Subsequent pilot plant runs on this process indicated serious troubles with slag formation when operating on Pakistan coal.

UCB proposed the use of a process developed by Lurgi whereby coal is gasified at 220 lbs gauge by a mixture of steam and oxygen. This process, developed prior to World War II, was already commercially in operation in Germany on favorable coals and was planned for use in Australia and in South Africa, in the latter country for the production of a gas suitable to make synthetic gasoline.

Both proposals estimated the cost of a fertilizer factory with a yearly capacity of 50,000 metric tons (MT) ammonium sulphate erected in the Mari Indus-Daud Khel area at slightly more than $17,000,000. The U. S. dollar part of this total was between $11,000,000 and $14,000,000.

The two proposals were submitted to the Technical Cooperation Administration (TCA/Washington) for review and evaluation. The National Research Council (NRC), the U. S. Bureau of Mines (BOM) and the U. S. Department of Agriculture (USDA) were thereupon requested to comment on these bids

The NRC was asked to study the suitability of the processes outlined in both proposals. Two panels of experts were formed and the

conclusion of their investigation was that preference should be given to the proposal submitted by Union Chimique Belge

Dr. F. A. Parker and Mr. G. H. Jacob of the USDA were invited to express an opinion as regarded the suitability of ammonium sulphate as a fertilizer for use in Pakistan. They agreed that ammonium sulphate was a suitable fertilizer, to be preferred over ammonium nitrate or urea.

At the same time, the USDA and the BOM were requested to review the capital cost of these factories as estimated by FCC and UCB. The USDA estimated, in the light of experience in the United States, but without giving consideration to several of the unique problems which this project might encounter in Pakistan, that a factory of the proposed size, including all engineering fees and services and reasonable standby equipment, if erected in the United States, would cost $12,000,000. This, it was recognized, was to be regarded as a preliminary conclusion. In a similar manner, the BOM arrived at an estimate of $14,000,000 for a factory erected in this country. After making adjustments for the large amount of standby equipment needed in a country like Pakistan and also allowing for other factors applying to this particular project, they arrived at a final estimate which practically coincided with that of UCB.

As a result of the findings and conclusions of the various parties, it was decided that the GOP through its statutory corporation, the Pakistan Industrial Development Corporation (PIDC), which had been established in 1950, should enter into an agreement with UCB. This agreement was

drafted and discussed in the summer and fall of 1952 and executed in Karachi on November 1, 1952.

3. Contract with UCB - November 1, 1952

The contract executed on November 1, 1952, provides that UCB, acting as engineers for PIDC, will plan, lay out and supervise the construction of a fertilizer plant guaranteed to produce 50,000 MT of ammonium sulphate per year. UCB is permitted to assign a maximum of seven technicians to the project in the field. The PIDC agrees to employ all other personnel required for the work and pay their salaries and traveling and living expenses. Such personnel are to be at the disposal of UCB, which will have full authority to direct their work, including the authority to discharge them, if necessary. PIDC also undertakes to furnish quarters, transportation and living expenses for the personnel assigned to the project by UCB.

The contract is divided into four parts. Some of the significant provisions of each part are given in the following paragraphs.

PART A describes the services to be rendered by the UCB, including the following:

a. Furnish plans, layouts, flow diagrams, specifications and estimates.

b. Draft invitations for tenders covering procurement and subcontract work; review tenders received; and prepare orders and contracts for those accepted.

c. Coordinate and expedite the shipment, insurance, customs clearance, and handling of all equipment, materials and supplies.

d. Check all invoices against shipments and report shortages or damages.

e. Prepare a construction program indicating types of labor and supervision required and a schedule of anticipated expenditures.

f. Supervise and coordinate all phases of the undertaking, including planning, procurement, transportation, construction and training of supervisory and operational personnel.

g. Coordinate sequence of operations for starting the various units of the plant.

h. Provide consulting engineering services as may be required.

PART B provides that the fee for engineering services shall be $1,700,000 payable in installments at three months' intervals. In addition, the UCB is to be paid a daily rate for the services of a technical manager ($70 per day) and one administrative officer and five engineers ($50 per day). UCB is to be furnished with administrative facilities for its personnel at Karachi and at the plant site.

PART C entitled "Guarantees and Damages" provides that the factory is to be constructed and ready for operation within 42 months from the date of first payment under the contract. The guaranteed output of the factory (50,000 MT per year) is stated and a reduction in the UCB fee is specified in case of failure to meet the guarantee. The ammonium sulphate manufactured is required to contain at least 20.5 per cent nitrogen. It is stated that the estimated total cost of the factory, excluding UCB fees and expenses, will not exceed Rs. 49,854,000 (about $15,107,000 at the exchange rate of Rs. 3.30 to $1.00 prevailing at contract date).

PART D covers certain general terms and conditions including a provision that PIDC after consultation with UCB may perform such work at the plant as it desires to undertake on its own responsibility.

4. Plant Processes

The process proposed by UCD and accepted by PIDC with the advice of ICA/Washington's panels consists essentially of the following steps:

a. Coal of a size between 1/8" and 1-1/2" will be gasified at high temperature and a pressure of 220 lbs gauge by a mixture of steam and oxygen. The products resulting from the gasification process are ash and a gas, which contains limited amounts of tar, oil and benzene in gaseous form.

b. The gas will be cooled with water to condense and separate all products which are liquid at ordinary temperature, including the tar, oil and crude benzene. The gas, now free of liquid products, consists of:

(1) hydrogen, necessary to make ammonia
(2) carbon monoxide, which is converted in a subsequent step to produce more hydrogen
(3) some hydrocarbons, mainly methane
(4) carbon dioxide
(5) hydrogen sulphide (H_2S) and traces of organic sulphur compounds. The hydrocarbons, carbon dioxide and sulphur compounds are undesirable constituents which must be separated from the rest of the gas.

c. The first contaminant to be removed is H_2S. This is achieved by washing the gas with water under pressure, followed by contact with a solid absorption material.

d. The gas, free of H_2S, is now mixed with steam and brought in contact with a catalyst at high temperature. The carbon monoxide and the steam react to form hydrogen and carbon dioxide. Some carbon monoxide will remain unconverted.

e. In the reaction in Step d, the traces of organic sulphur compounds are converted into H_2S. This has to be removed, which is done by passing the gas once again through solid absorption material identical to that mentioned under Step c.

f The next contaminant to remove is carbon dioxide. This is achieved by first washing the gas with water under pressure, followed by a scrubbing of the gas with a dilute solution of sodium hydroxide (caustic soda).

g The gas is now free of H_2S and CO_2. The only residual undesirable contaminants left are methane and other hydrocarbons and the carbon monoxide not converted into hydrogen as mentioned under Step d above. By cooling the gas to very low temperatures, all constituents except hydrogen and carbon monoxide are liquified and removed. The carbon monoxide is absorbed by washing the gas with liquid nitrogen. The residual purified gas is a mixture of hydrogen and a small amount of nitrogen.

h. To this mixture of hydrogen and nitrogen, more nitrogen is added to obtain a mixture containing 75 per cent hydrogen and 25 per cent nitrogen.

i. This mixture, so-called synthesis gas, is now compressed (note that this is the first time the original gas has been compressed) and is then passed under high pressure and high temperature over a suitable catalyst for conversion into ammonia.

j. The ammonia is subsequently reacted with part of the CO_2 washed out of the gas as mentioned above under Step f to form ammonium carbonate dissolved in water. This solution is then reacted with gypsum in powder form to produce a solution of ammonium sulphate and solid calcium carbonate. The latter is removed by filtration and the solution of ammonium sulphate is concentrated by evaporation and then centrifuged. The solid ammonium sulphate is then dried and either stored in bulk or bagged immediately. It is now ready for sale.

k. Oxygen (used in Step a) and nitrogen (used in Steps g and h) are obtained by compressing and liquifying air, followed by fractionation into its major components, oxygen and nitrogen. The air must first be scrubbed with caustic soda for removal of carbon dioxide.

l. The various steps require steam and electricity. Steam is used in the Lurgi gasification process, in the conversion of carbon monoxide (Step d above) and in several other places.

Block Diagram

Plate II

Electricity is needed to drive the motors of the compressors and most of the pumps. A power plant has therefore been built to produce steam from either coal, oil or gas (gaseous hydrocarbons) for process use and for transmission, under a maximum pressure of 665 psi, to turbo-generators for production of electric power.

m. The caustic soda (sodium hydroxide) used in steps f and k is converted by these processes into sodium carbonate. A unit has been provided to re-convert the sodium carbonate into sodium hydroxide by the use of calcium oxide (burned lime) which is produced by another unit from locally obtained lime.

The major units comprising the fertilizer factory are shown by the block diagram on Plate II.

5. Factory Site

The fertilizer factory is located about two miles east of the Indus River approximately 75 miles south of Peshawar and mid-way between Mari Indus and Daud Khel. (See Plate III.) It occupies a portion of a tract of land about one mile wide by three miles long extending northerly along the east side of the North Western Railway's broad gauge branch-line from Daud Khel to Mari Indus. The tract was acquired by PIDC for industrial purposes and provides for a cement factory, a dye factory, a penicillin factory and a housing colony, in addition to the fertilizer factory.

The site lies on the alluvial plain of the Indus River and the topography is generally flat. It has been subject in the past to flooding by runoff from the hills to the east. A dry wash called Jabba Nalah, which bisects the industrial tract, carries occasional torrential flows.

Transportation service is provided by the broad gauge railroad mentioned and by a recently extended narrow gauge railroad which is used to bring in coal from the mines lying to the west. A road connection has been made to the Works department highway serving the neighboring communities and two service roads run easterly, one to the lime quarry and the other to the gypsum quarry.

6. Soil Conditions

Immediately after the contract with PIDC was signed, UCB gave explicit advice and instructions regarding the necessary soil investigation and the testing equipment which should be procured. Unfortunately, PIDC did not approve purchase of the particular equipment recommended by UCB, but late in February 1953 signed a contract for a soil investigation with Swissboring Company of Switzerland. The company had an office in Karachi and some soil testing equipment in Pakistan.

It is now quite evident that there was no adequate equipment of the required kind anywhere in Pakistan at the time. Five years after partition, Pakistan still lacked modern equipment in almost every field and foreign companies, operating in Pakistan, understandably did not consider it necessary or advisable to send their better equipment and better personnel to that country.

Swissboring did a fair to poor job. Fifteen borings were made over a wide area spaced nearly 1000 ft. apart, too wide a spacing for a

thorough investigation. Instead of going approximately 60 ft. deep, as contracted for, most of the borings went only 40 ft. deep. They did not live up to their contractual obligations, and only a preliminary report was issued, followed by two or three letters, but, so far as could be ascertained, no final report giving full and pertinent foundation advice was ever rendered. Swissboring's main conclusions were:

a. The subsoil consists of rather recent deposits of medium fine to fine sand, clay and silt.

b. More or less solid sand strata exist below a depth of 80 ft. (This conclusion was based on the result of one boring which went down 90 ft.)

c. In view of possible earthquake tremors, it is advisable to support the heavier pieces of equipment on piles.

UCD was not satisfied with Swissboring's conclusions and advice, which, according to them, were based on insufficient borings made with inadequate equipment and on insufficient soil data.

In the meantime, it had been decided to place a number of piles under cement factory structures then under construction. A British firm, Cementation Ltd., had been entrusted with this work. They proposed sinking piles 15 inches in diameter and 40 ft. long, each good for a 47-ton load. Swissboring had advised 22-inch piles also 40 ft. long, but having a bearing capacity of 100 tons. PIOC favored the Cementation piles because they were cheaper.

UCB finally, but reluctantly, agreed to the sinking of piles for the fertilizer factory and to Cementation as the contractor. They would have preferred a completely new investigation made by soils specialists with modern equipment. This, however, would have delayed the factory, possibly by as much as the better part of a year, and would have cost additional money which PIJC probably would not have been willing to spend. Under the Cementation Ltd. contract, more than 1000 piles were placed.

Somewhat over a year ago, when major units of the factory were in place, it became apparent that the soil was settling under buildings and structures in both the fertilizer factory and the cement factory. Cracks in walls appeared, two gasholders and a tank started to tilt, and one ash bunker and the feed water pumps in the boiler plant settled. Then, some time in the second half of July 1957, the tall, 5 stories high structure supporting the Lurgi gasifiers began to tilt. (See Photograph No. 1) This structure rests on piles and measurement showed that some of these piles had sunk as much as 3 inches. This settlement has been corrected by the use of jacks on at least two occasions.

The writer then suggested that a top expert in the field of soil mechanics be employed to make a thorough investigation, and PIJC agreed. In view of the fact that the Dutch have probably had more experience with clayey and silty soils than any other people, and that a large part of Western Holland is built on piles, it was suggested that

the Shell Company in Holland be asked to recommend a first rate man and PCG fully supported the idea. Subsequently, the Shell Company suggested the Soil Mechanics Laboratory in Delft, headed by Mr. ... C. van Nierlo.

In the meantime, PCG, through their Paris agent, had retained Professor Combefort of Ecole des Travaux Publics in Paris. He visited Haut Chelat early in August 1957 for 3 days. His main conclusions were:

> a. UCB's idea that water is the main cause of the trouble is correct. He therefore was in full agreement with the protective work which UCB had already started, namely, the digging of trenches around the main buildings of the factory to remove all collecting rain water and all process water which is spilled accidentally.
>
> b. He suggested laying a waterproof blanket around all buildings, say 5 m. wide, to prevent percolation.
>
> c. A stable foundation can be obtained with piles bearing on the clean sand layer some 100 ft. deep, but he did not suggest the driving of new piles.
>
> d. It may be possible to consolidate the structure of the soil by injection with chemicals, clay or bentonite. He recognized that this might be dangerous because water would be introduced at the same time.

Recently Professor Combefort suggested that a series of tests with chemical injections be undertaken. He warned that this is a difficult operation requiring specialized knowledge and experience. UCB apparently has decided to follow Professor Combefort's suggestion and to entrust Swissboring with its execution, since they have done similar work for the Canadians at the Beersak dam.

The proposed method of solving the soil problem may well be the best one under the circumstances. However, before starting on this course, it is strongly recommended that a second expert opinion be obtained. Since the Soil Mechanics Laboratory itself seems to have an international reputation - a number of oil companies, including large U. S. oil companies, are among their clients - it is suggested that this laboratory be retained without delay to make a complete investigation and recommend methods of treatment. They have already been contacted by UCB and have submitted an attractive offer, amounting to an estimated $3000 to $4000, exclusive of traveling expenses.

It is furthermore recommended that the execution of the chemical injection plan, if approved by the second expert, be entrusted to one of the best firms obtainable in this field of work. Swissboring's past record at Qaud Khel is far from confidence-inspiring.

7. Progress to date and present status

The factory is well designed and well laid out. (See Plate IV.) All materials and equipment above ground are good, although some inferior concrete work was observed. The layout is such that the capacity of the factory can be doubled by installing additional equipment and extending existing structures without disturbing facilities already built. Apart from the foundations, all structural work is good, except that a considerable part of the concrete work is of poor quality.

At the end of August of this year, all units of the factory, except the lime kiln, were completed, and should now be ready to be put into operations. (See Photographs 1 to 4 taken in August 1957.) In doing so, some bugs will undoubtedly be encountered which will require correction The Lurgi gasifier is reported to have been placed in operation on September 1, 1957

Very little roadway or yard paving had been completed by that time, but this work was underway and progressing slowly Some of the paving may have to be left unfinished to allow adequate access to the soil should further piling, injection of chemicals or other steps be required to improve the structure foundations.

UCB is constructing temporary ditches around most of the buildings and structures. They are intended to collect and remove from the site any water spilled or drained in the various factory units, as well as any surface runoff following rain. This should help to prevent the penetration of water into the ground where it may be the cause of soil movement and foundation settlement

8. Causes of Delay

The contract for construction of the factory provides that it will be erected and ready for operation within 42 months from the date of the first payment to UCB. This payment was received on December 17, 1952, and UCB was therefore under obligation to have the factory ready for operation on or before June 17, 1956 That this has not been realized is

Lurgi Gasifier

Photograph No. 1

Photograph No. 2 - Power House, Coal Silos, Spur Track

Photograph No. 3 - Cooling Towers From South Hill

Photograph No. 4 - Compressor Floor LCC Building

Photographs Nos. 2, 3, and 4

due to a large number of circumstances, most of which, it is believed, were beyond the control of UCB.

As far as can be ascertained, UCB, immediately after the contract with PIDC was signed, started with diligence on their assignment. Throughout the past five years they have been trying hard to discharge their responsibilities and to provide Pakistan and PIDC with a factory of which they themselves and Pakistan could be justifiably proud. Naturally, mistakes have been made and UCB is not entirely blameless, but they have been operating under severe handicaps and, taking this into consideration, the results as of today can be termed quite satisfactory.

If foundation conditions had been more satisfactory, the factory could probably have been put gradually into operation sometime late last Spring, say, between April and June of 1957. This means that the factory might have started not more, and possibly less than, one year after the date originally guaranteed. In view of the various hindrances and handicaps which developed, this delay would have been entirely acceptable.

Some of the principal factors which caused delay are the following:

a. A slow start by PIDC, after the contract was signed, with respect to the necessary soil investigation.

b. The fact that PIDC did not have a staff capable of handling many of the specialized phases of a complicated project.

c. A clause in the contract limited UCB to a maximum of seven of their own personnel in Pakistan. This limitation should never have been accepted by UCB.

The maximum of seven included personnel required in Karachi for liaison with PIDC and to expedite customs clearance and forwarding to Daud Khel, as well as supervision at the site. It is apparent that it was impossible to complete all of these tasks with so few responsible employees. Eventually, 10 persons were authorized, but the number was always inadequate.

d. The fact that PIDC lacked the modern equipment needed for development of the site and for construction purposes.

e. Delay by PIDC in authorizing the first UCB engineers to come to Pakistan to supervise development of the site. The first two engineers arrived in the Fall of 1953.

f. Delay in the clearing of equipment through customs at the Karachi docks.

g. Delay in transportation from Karachi to Daud Khel mainly on account of shortage of railroad rolling stock.

h. Lack of sufficient UCB personnel at Karachi to expedite inland transport and give priority to equipment most urgently needed.

i. Frequent delays in opening credits for payment for equipment and for the services at Daud Khel of suppliers' personnel.

j. Delays in shipment of equipment by a number of European and U. S. suppliers. The Bailey Meter Co. of Cleveland, Ohio, for instance, was about one year behind in its delivery schedule.

k. A year went by before a decision was reached as to whether Ingersoll Rand or the European firm of Burckhardt, Switzerland, would be given the contract for the major part of the compressors.

This list is far from complete, but the above enumeration should suffice to indicate that a year's delay in the erection of this factory is not surprising. Fortunately, most of the delays overlapped.

Photograph No. 5 - Main Office

Photograph No. 6 - Laboratory

Photographs Nos. 5 and 6

There is one reason for delay, not listed above, which is quite important and which warrants special mention, namely, the prevailing low morale of suppliers' personnel caused by the below-par living conditions provided, the often below-par and monotonous food, lack of sufficient transportation as promised the suppliers by UCC, and the long waiting period for most of the foreign erectors between the time of their arrival at Paul Shel and the arrival of their equipment. These conditions were certainly not conducive to speedy erection work.

9. Auxiliary Facilities

The auxiliary and general facilities and services of the factory such as operators' mess hall, change room, the main office, etc., are generally adequate. The main office is anything but luxurious and is not overly large, but has been built so that it can easily be extended (Photograph No. 5.) The washroom for foreign personnel is below par and UCC should correct this situation immediately.

A room in the main office is being used as a first aid room, but it is unhygienic, under-equipped and understaffed. Until the end of August of this year, the factory had no facilities or personnel to care for serious accidents which can happen in a factory of this kind. Plans prepared at one time by UCC for an adequate infirmary were disapproved by PIDC on the grounds of economy.

The laboratory is well built, of adequate size, as can be seen on Photograph No. 6, and reasonably well equipped.

Photograph No. 7 - Central Road through Plant

Photograph No. 7

The workshop is large and well equipped. As a result of training by UCB's and some suppliers' personnel, several of the machinists, fitters, welders, etc have by now a fair to good ability in their fields. Due to low pay and below-par housing and recreational facilities, the tendency is for the better trained ones to leave and seek employment in more attractive communities at better remuneration

The carpenter shop is quite large, well staffed and fairly well equipped. Carpentry is an art in Pakistan, passed on from generation to generation.

The roads through the plant and around the various units are unpaved and in poor condition, as can be seen on Photograph No. 7. Early in July, a Pakistani contractor started the placing of a concrete pavement on the Central Road. Nearly two months later, only about 700 feet had been completed This is a typical indication of the rate at which Pakistani contractors and labor work.

The storeroom is badly arranged and managed Once put to rights, it may prove to be of adequate size, but it gives the impression of being overcrowded and badly organized What is needed is a first class storekeeper who can put this building in order and who can set up a foolproof system of checking at any time as to what is on hand and what should be ordered

10. Personnel Facilities

Daud Khel is 5 hours by car, or 15 hours by train, from Lahore and 4 hours by car from Rawalpindi. It is located in a desert, far from any place of entertainment or culture. Anybody going there to work for any length of time is entitled to be compensated financially, or in better housing, or in reasonable recreation facilities. PIDC has failed to provide any one of these incentives Pay apparently is low and certainly not better than in more attractive places such as Karachi, Lahore, Peshawar or Rawalpindi Housing is below par and recreational facilities are practically non-existent Transport, even to and from the factory, is at best barely sufficient

The first group of houses, built soon after construction of the factory started, is called the Provisional Housing Colony. It is about 2 to 2-1/2 miles from the factory and consists of a number of bungalows and a rest house, all built of mud The present condition of these buildings is such that this colony must be condemned as a living quarters for European and American engineers. As temporary shelter, it will do

A second housing development built later on PIDC property is now the main housing colony. (Plate V.) It is about 4 miles from the factory, as shown on Plate III. A location closer to the factory would have been better so that, in emergencies, operators could run from their homes to the plant in the shortest possible time. It was reported that the location

Housing Colony Map

Plate V

chosen was a compromise between UCB and PLUL. UCB apparently suggested a location still further away from the factory in view of possible nuisances which might be caused by obnoxious fumes.

The colony consists of D-type bungalows occupied by senior engineers, C-type bungalows occupied by some senior but mostly junior engineers, and a large number of type B, A, and T quarters where skilled workmen and the more important operators of the factory are living. There are also some bachelor quarters. Other buildings include a mess hall, two schools, and a shopping center.

The housing colony facilities fail to meet ordinary minimum standards. The houses are built of bricks laid in mud rather than mortar. The best houses (types B and C) lack a decently equipped kitchen and have no running hot water. The poorest one-room houses, built for single families, are now mostly occupied by 4 to 6 male factory operators. They have no flush toilets and most of them are without electricity. Water is obtained from a single faucet for a block of 10 houses. It is understood that eventually all C-type houses will have electricity and separate water taps.

There is no hospital building, but one of the two school buildings has been converted for hospital use. It lacks the most modest type of equipment, has no hot water, no sterilization equipment, and no examination room, is unhygienic and below the minimum standards one might expect of even the poorest type hospital.

The electric distribution lines in the colony consist of wires that are too small on spans that are too long, so that moderate wind or rain storms frequently cause short circuits

Recreational facilities consist of a single tennis court The ends of the court are enclosed by wire netting in poor condition with gaping, man-sized holes which are not being repaired, notwithstanding frequent requests.

The housing colony as a whole is badly in need of improvement, but FIOG's lack of finances or pressing demands for funds elsewhere have thus far, and certainly in the last two years, prevented any steps to make living there more agreeable.

In order to attract more foreign experts, which is necessary if the factory is to be operated at full capacity, more houses, a better hospital, more recreational facilities and adequate transport should be provided. Specifically, the following are needed:

a. At least one, and possibly two, B-type bungalows, one for the technical manager of the factory.

b. Depending on the number of married people among the required foreign personnel, several additional B-type bungalows. Seven B-type bungalows are now occupied by fertilizer factory engineers At least 10, and possibly 15, more of these bungalows will be required to accommodate the needed European experts and their families for possibly 3 to 4 years.

c. A properly equipped hospital should be built

d. More recreational facilities should be provided, such as one or two more tennis courts and a swimming pool.

e. Sufficient transport should be made available so that each of the senior engineers will be able to reach the factory on short notice at any time of the day or night. Moreover, PLUC in their personnel contracts have promised to provide transport for recreational purposes as well.

f. The bachelors' mess hall should be improved.

All B- and C-type bungalows, the hospital, the bachelor quarters and the mess hall should be equipped with an adequate number of air conditioning units. The Canadians at Kemsak provide air conditioning units for every bedroom occupied.

Serious consideration should be given to the hiring of the following personnel to be stationed at the housing colony:

a. 1 European medical doctor

b. 1 European graduate nurse.

c. 1 mess steward, to supervise the bachelor mess hall, the boiling of drinking water, washing of the vegetables, etc.

d. 1 welfare officer.

It is undoubtedly correct to say that if a mess steward and a welfare officer had been engaged during the construction period, a considerable amount of time would have been saved and the morale of the European employees would have been very much higher.

11. Water Supply

The supply of water for the fertilizer factory, as well as for the cement factory and the housing colony, is now fairly well secured, but

this has been true for only the last year or less. During the construction period, there were several months when the supply of water to the housing colony was limited to three hours per day. At times, the only supply for all purposes was obtained by pumping from the river with a diesel pump intended for fire fighting use.

The original intention was to pump all water from the Indus River, but this plan was abandoned when it was learned that the weir used to maintain the river level (see Plate III) was opened for a period of three weeks each year and that the bed of the river had a tendency to shift away from the bank on the side near the fertilizer plant. For much the same reason, it was found impractical to take water from the canal which diverts water from the river at the weir site. After several unsuccessful efforts by local contractors to produce satisfactory wells, UCB constructed a pit 35 feet deep with concrete and masonry lining, which served as the principal source of supply during the construction period.

In the following years, four different contractors were employed to drill wells with steel casings and perforated inner shells to provide a permanent water supply. There were numerous failures, partly because depths were restricted by boulders and partly due to plugging up because of inadequate strainers. All of these wells were drilled close to the bank of the Indus River.

At the present time, four completed wells can operate with a combined capacity of 7.5 to 8 cubic feet per second (cfs). Two additional

wells are being deepened and it is conservately estimated that, when finished, they will increase the supply by at least an additional 6 cfs Another well, if repaired and finished as intended, may add another 2.5 to 3 cfs. Together, these seven wells should have a total capacity of about 17 cfs. This is more than ample to cover the 5 5 cfs needed for the fertilizer factory and about 2 cfs each required for the cement plant and the housing colony.

12. Coal Supply

Coal is mined on the easterly slope of the Surghar Mountain Range located about 25 to 30 miles west and northwest of Daud Khel in a zone roughly 5 miles long called the Makarwal Mining Area. (Plate VI.) There are four principal groups of mines. The Lamshiwal and Simpson groups, containing 6 important mines in the vicinity of the town of Makarwal are the largest producers. The Mallakhel and Gullakhel groups, several miles to the north, contain 4 important mines.

Lamshiwal and Simpson Groups.

Coal from the Lamshiwal and Simpson groups is transported by donkeys, ropeways and camels to loading points on a 24-inch gauge mine railway which takes it to Makarwal station, where it is transferred to coal cars on a 30-inch gauge branch line of the North Western Railway for shipment to Mari Indus and the fertilizer factory. The present production capacity is nearly 500 MT per mining day, or almost 3000 MT per week.

Makarwal Mining Area

Plate VI

Temporarily, it may be possible to reach a production capacity of 600 MT per mining day by working some small discontinued mines where old pillars were left.

A number of improvements have been provided or are contemplated, including a power station to provide additional electricity, new and improved ropeways, a 5000 foot tunnel to open up new mining areas, additional mine cars and locomotives, and other equipment. A number of these improvements are underway, with ICA assistance, including the tunnel, but this will not be completed until late 1959. Thereafter, it should be possible to increase production capacity of the mines in the Lamshiwal and Simpson groups from the present 500 to about 825 MT per mining day, or approximately 5000 MT per week. Quality of the coal should also be improved as a result of the reduction in number of transfer points contemplated, which will decrease the degradation of the coal into particles below minimum allowable sizes now caused by frequent handling. The increased output can only be reached if PIDC orders the necessary equipment for development of the mines. If purchased well in advance, it will still take four years from now to reach the increased production figure mentioned.

Mallakhel and Gullakhel Groups.

The present production capacity of the Mallakhel and Gullakhel groups is about 50 MT per mining day. Coal from these mines is transported by donkeys and ropeways to concentration points, loaded onto camels or trucks and then transported 10 or 12 miles to Kamar Mushani on the

North Western Railway line to Mari Indus. The installation of new mining and electrical equipment now on order or planned could increase the production capacity of these mines to about 140 MT per mining day. By purchasing additional equipment needed for development work, the output could be increased to about 415 MT per mining day.

Combined Production Capacity.

The present combined production capacity of both groups of mines is nearly 500 MT per mining day. Actual maximum working capacity is about 20 per cent higher, but the lower figure given for production capacity must be used in order to allow for equipment spares and for time lost in development work and opening up new working faces. The mines are worked 6 days per week or about 290 days per year. Since the fertilizer factory will work 365 days per year, the present production capacity of nearly 550 MT per mining day will be equivalent to about 420 MT per calendar day. This is insufficient to meet the requirements of the fertilizer factory and the cement factory when both are in full production, estimated at 500 MT per calendar day. (See Plate VII.)

The future combined production capacity of the mines, after contemplated improvements are completed, can reach 1240 MT per mining day or 1000 MT per calendar day. The total increased output capacity will not be reached for about 4 years. In the meantime, the only obtainable increase in production must come from the Mallakhel and Lullakhel mines.

Coal Production and Requirement

Plate VII

Transportation bottleneck

Before the increased amounts can be delivered to Gullakhel, an existing bottleneck in the transportation system must be removed. With the presently available open railway cars, the maximum coal carrying capacity of the railway system from the Makarwal Mining Area is between 450 and 500 MT per day, or 2700 to 3000 MT per week. This quantity is barely sufficient for the fertilizer and cement factories, but leaves practically nothing for other consumers of coal. The need of additional coal cars has been brought to the attention of officials of PIDC.

Additional Equipment Needed.

The foregoing analysis clearly indicates that the equipment should be ordered for the following purposes:

a. To increase the present low capacity of the Mallakhel and Gullakhel mines to a production capacity of 170 MT per mining day. This is electrical equipment.

b. To increase the production capacity of the Mallakhel and Gullakhel again from 170 to 415 MT per mining day. All of this equipment has still to be ordered.

c. To develop the Lanchhiwal and Simpson mines after the tunnel has been completed.

In addition, it is necessary that PIDC order equipment for a better workshop at Makarwal station.

It is further are suggested that a new diesel generator be ordered of ample capacity to replace the two old ones located in the expanded power station near Makarwal station.

PIDC has been slow in taking the necessary steps to increase production from these mines and to improve the transportation from Makarwal

to Mari Indus. Requests for more equipment urgently required were sent to PIDC headquarters in Karachi late last January, but no action had been taken by the end of August. Neither had these requests been discussed with IGS/Karachi's project engineer for the Pakistan collieries.

13. Gypsum Supply

Gypsum is obtained from deposits about a mile east of the fertilizer plant. Proven reserves are said to be 20 million MT. The fertilizer factory will require about 300 MT per mining day of good quality gypsum.

The mining program and mining methods used to date are greatly in need of improvement. The gypsum is mined by blasting, but unfortunately this is being done in a rather unorganized and ineffective manner. Holes for explosives are not drilled as deep as they should be, and are placed too far apart, and not always in the correct pattern. Consequently, the result of the blasting is rather unsatisfactory. The gypsum is generally only loosed and not broken clean away from the hillside. As a result, a considerable crew of laborers is required to push the gypsum fragments downhill with the aid of crowbars.

At the present time, the gypsum, after blasting, is broken up by manual labor using ordinary hammers, which requires the continuous availability of a large number of laborers. As a substitute, a crusher was proposed for installation at the quarries as long ago as December 1955, and it is recommended that this equipment be purchased as soon as possible.

A serious problem encountered in the gypsum quarries is the existence of numerous seams of clay, which tend to cushion the effect of blasting and also to contaminate the gypsum supplied at the factory Appreciable amounts of clay in the gypsum will make the production of ammonium sulphate more difficult and costly Several truckloads have been rejected at the factory because of high clay content No economical means is available at the factory to separate the clay from the gypsum.

Expansion of gypsum mining operations on an economical basis will be dependant on competent supervision and direction of operations. It is recommended that an experienced gypsum mining engineer, or a general mining engineer familiar with explosives, by employed to ensure satisfactory and adequate output and also to train Pakistani personnel.

The transportation of the gypsum from the quarries to the factories can be taken care of satisfactorily, provided the existing road is repaired and improved and provided also that trucks are made available in adequate number. There is need of an additional factory truck which, in addition to general hauling, could transport gypsum from the quarry when necessary

14. Operating Personnel

The personnel situation at the factory is a matter of grave concern Article 22 of the contract between PIDC and UCB states that the starting up and operation of the factory is the responsibility of the assigned Pakistani personnel and will be done by them under the supervision and control of

UCB, assisted in this task by the suppliers' personnel. This seems to indicate that in 1952 PIDC believed and UCB agreed that the Pakistani staff would be able to perform as stated This assumption has proven to be a complete fallacy. As matters stand today, and notwithstanding the training given to Pakistani personnel in Europe, in the United States, and on the spot, PIDC lacks a staff of competent people capable of managing the operation of the factory even under supervision and control of UCB's full staff of technicians.

There is a shortage in Pakistan of capable trained engineers for chemical operation and mechanical maintenance in a plant like the Daud Khel fertilizer factory. Several young engineers have been engaged in PIDC for assignment to this factory Some 20 of these were given an 8 to 12 months training course in Europe with UCB and some of the equipment suppliers such as Lurgi, Linde and others Five were sent to the United States for additional training

The results of this effort on the part of ICA, UCB and the European suppliers is rather disappointing Complete lack of practical knowledge of the process, lack of experience in chemical engineering and operation in general, and language difficulties made it rather hard for these young men to avail themselves fully of the marvelous opportunities which were offered them. The sum total of all efforts is that not one of the assigned Pakistani engineers, as of August 1957, would be able to occupy a corresponding position in any ammonia plant in Europe or the United States

PUC unfortunately gave these young engineers, soon after their return from abroad, the title of "Junior Chemical Engineer". This was done before any of them had demonstrated what they could do. It may have raised their morale, but simultaneously had the effect of giving them an exaggerated feeling of importance. They now consider themselves above any real work on hands and knees, although this is the only way to learn and to gain practical experience. They now occupy positions where they are supposed to know the factory and to teach the operators. Because they are afraid to make mistakes and consequently lose face, they are inclined to shy away from their normal responsibilities.

Consequently, UCB will need more people to assist them during their guarantee test runs and PUC will need more people to run and manage the factory after UCB have completed the test runs and left the job. This serious state of affairs was brought to the attention of PUC officials at meetings held on August 29th and 31st of this year.

The number of foreign personnel required to operate the factory on a continuous basis at full capacity is at least 30. At least 7 people, urgently required, are lacking at this moment. This situation will become increasingly more serious when:

a. The suppliers' personnel starts to leave after their equipment has met the guarantees.

b. UCB withdraws after they have met their 91-day guarantee test run.

PUC will then be left with a complete vacuum.

Immediate steps should therefore be taken to correct this unsatisfactory condition. The best source for the additional personnel required is undoubtedly a company which has several ammonia plants in operation and which consequently is in a position to assemble a team of suitable people. Trying to engage a staff one by one through advertisements in technical journals, etc., as PIDC has heretofore attempted with little success, will at best lead, in view of the shortage of experienced men in Europe and the United States, to an incongruous collection of people with an average ability below required standards.

In view of the fact that UCB has several ammonia plants in operation, that they know the Daud Khel factory better than any other company, that they are fully acquainted with living and working conditions in Daud Khel, that they should know what can and cannot be expected of the Pakistani personnel, it was suggested to PIDC that UCB be asked to supply the people additionally required and take full responsibility for the operation of the factory until such time as the Pakistanis can take over. This suggestion was acceptable to PIDC officials at the above mentioned meeting of August 31 and was thereupon discussed in Brussels with UCB on September 4 and 5. UCB's reaction was favorable to the extent that they were willing to consider this proposition.

A note of warning should be sounded here. The writer's impression is, perhaps unjustly, that UCB is not fully convinced of the necessity of a complete around-the-clock shift supervision of all the units of the factory

by competent foreign engineers in order to obtain full production from the plant. Only by friendly persuasion did they decide to provide around-the-clock shift supervision in the powerhouse. It is the firm belief of the writer that this change will see the power plant operate smoothly and continuously.

Additional foreign personnel should be brought to Saudi Arabia only if adequate housing, adequate feeding, sufficient transportation both to and from the factory and for recreation, and all other facilities required for a minimum acceptable standard of living are provided by PIDC.

15. Capital Expenditures and U. S. Contributions

The estimated cost of the factory at the date of execution of the UCB contract (November 1, 1952) was approximately as follows:

Plant cost (as per Article 38 of contract)	Rs	43,854,000
Equivalent value at then current rate of exchange (Rs 3.30 = $1.00)	$	15,107,000
UCB fee, stated in contract		1,700,000
UCB personnel, travel and living expense 35 months @ $13,000 (estimated)		455,000
Total (approximate estimate)	$	17,264,000

The actual cost as of about August 1, 1957 was as follows:

Pakistan Government expenditures	Rs	38,442,000
Equivalent value at present rate of exchange (Rs 4.75 = $1.00)	$	8,093,000
U. S. Government expenditures	$	12,678,000
Total cost to date	$	20,771,000

The major reasons for the increase of about $3,500,000 in the cost of the project over the original estimate are increased cost for land, increased freight and insurance, increased cost of internal transport, increased cost of civil engineering structures (piling and railroad siding), increased cost of European labor, increased administrative expenses by PIDC, cost of trainees, cost of insurance during erection and the payment of customs duties. Originally it was assumed that the latter would not have to be paid because the foreign expenditure was a U.S. grant.

The total value in US dollars of orders placed in Europe and in the US up to the end of August 1957 was $9,438,872.27. This figure does not include the engineering fee to UCB, freight and insurance to Karachi or payment in foreign currency to suppliers' personnel. Neither does it include the cost of training given to Pakistan engineers in Europe and the United States.

On May 17, 1954, Operational Agreement No. 7 was signed between the Governments of Pakistan and the United States in which the latter agreed to contribute $4,000,000 to the foreign currency cost of the Mand'hel Fertilizer Project. In subsequent years, this agreement was amended and additional funds were put at the disposal of the Pakistan Government for foreign currency expenditures in connection with the project. A summary of US Government authorized financing is as follows:

Operation Agreement No. 7 dated May 17, 1954	$	4,000,000
Amendment No. 1 dated April 1953 US to furnish additional		5,000,000
Amendment No. 2 dated June 1954 US to furnish additional		3,500,000
PIA 091-43-007 FY 1955, Amendment No. 2, US to furnish additional		1,459,120
PIA 91-43-007 FY 1956		1,045,000
PIA 91-43-007 FY 1957		99,730
Total US Dollar Financing	$	13,054,970

In addition to the above, the U. S. Government has agreed to contribute toward the cost of developing the coal mines in the Makarwal Mining Area as follows:

Over fiscal year 1956	$	494,000
Toward payment of the cost of an inspection trip by a mining engineer		6,000
Over fiscal year 1957		593,000
Total		1,093,000

It is understood that an additional $96,000 has been requested by ICA/ Karachi which ICA/ Washington has not as yet approved

The amount contracted by July 19, 1957 was $480,948. This, it is believed, is exclusive of the $6,000 for services of a mining engineer.

16. Material Balance

A material balance of the factory has been calculated starting with the requirements of Makarwal coal and oxygen as stated by Lurgi, the amount of gas to be produced as guaranteed by Lurgi and the composition of the gas as provided by Lurgi and which is based on the experiments carried out with Makarwal coal in Lurgi's pilot plant. The capacities of the various units as guaranteed by the suppliers have been carefully checked against the amount of gas to be processed in each of these units.

The results of this calculation are the following:

a. The amount of gas guaranteed by Lurgi having a composition as stated by Lurgi will produce 41 MT of ammonia per day. This is 10 per cent more than the assumed capacity of the factory.

b. Based on the guaranteed capacity of each of the units, it is not impossible that the factory can manufacture 43.6 MT of ammonia per day. This quantity can be produced if the Lurgi gasifiers and the Lurgi H2S-wash unit have 10 per cent excess capacity. It is most probable that this is the case.

c. Whether the ammonium sulphate plant will be able to handle the increase from 41 to 41 or 43.6 MT of ammonia per day is still a question. Only actual operation of the factory can clarify this point. However, any ammonia which the sulphation plant cannot take should be sold as such and should fetch a price at least equal to the price of ammonia in ammonium sulphate.

d. The requirements of coal for a production of 41 and 43.6 MT of ammonia per day are as follows:

Quantities of Coal, 20% ash, required in MT

	44 MT ammonia per day	48.6 MT ammonia per day
For Lurgi gasifiers	122.5	135.5
For boilers when using all gaseous hydrocarbons as fuel	152.5	168.5
For boilers when using all gaseous and all liquid hydrocarbons as fuel	151.5	143.5
For whole factory:		
a. If only gaseous hydrocarbons fired	275.0	304.0
b. If gaseous and liquid hydrocarbons fired	354.0	431.0

v. The requirements of gypsum of the average quality now mined at the quarry and the corresponding expected daily and yearly production of ammonium sulphate are as follows in MT:

	Daily Ammonia Production		
	40 MT	44 MT	48.6 MT
Daily gypsum requirements at the factory	419	462	465
Daily amount of gypsum to be produced at the quarry	575	634	734
Daily ammonium sulphate production	150	165	182
Yearly ammonium sulphate production	50,000	55,000	60,750

17. Estimated Cost of Production

The Material Balance discussed in the previous section explains that the Maud Chel fertilizer factory under normal operating conditions will have an actual capacity of 44 MT of ammonia per day. 10 per cent

more than hitherto assumed. The ammonium sulphate unit proper, that is, the sulphation plant, is guaranteed to handle 40 MT of ammonia per day. It may well have 10 per cent excess capacity built in but, if this should not be the case, the daily excess of 4 MT ammonia can be sold as such

Production of 42 MT of ammonia and 150 MT or possibly 165 MT of ammonium sulphate per day (equivalent to 50,000 or 55,000 MT per year) can only be attained if an adequate staff of foreign personnel are brought to Iraq and kept to supervise and control the entire operation of the factory. Should for any reason the number of foreign engineers and technicians be less (this could happen if FICI were to adopt a "penny wise, pound foolish" policy), the production of the factory would certainly go down accordingly. At the Sindri plant in India, it was decided to dispense with the services of foreign engineers at an early date, probably in the expectation of saving money. The result is that even today the plant has not reached full capacity on a continuous day-to-day basis and has undoubtedly lost far more money that was saved by giving up the services of foreign experts too soon.

It might be assumed that the Pakistani staff will be able to manufacture some 50,000 MT ammonium sulphate per year without any foreign help and that the full production of 55,000 MT per year can be achieved with the aid of, say, 30 foreign engineers and technicians. Any number of foreign personnel between none and 30 (or 34, counting a doctor, nurse

mess steward and welfare officer as well) would probably result in a yearly production of ammonium sulphate increasing proportionally between 20,000 and 55,000 MT.

To show the effect of insufficient foreign staff on the cost of production of ammonium sulphate, the following table lists the calculated cost per MT for yearly outputs of 20,000, 25,000, 30,000, 40,000, 50,000 and 55,000 MT:

Output per year in MT	Cost per MT in Rupees
20,000	849.3
25,000	703.5
30,000	604.6
40,000	482.3
50,000	408.9
55,000	384.2

This calculation is based on the following basic figures:

a. Coal: 47 Rupees per MT at Makarwal, 51 Rupees per MT delivered to the factory.
b. Gypsum: 5.8 Rupees per MT delivered to the factory
c. Depreciation: 10% on ₹15,000,000 (equipment and structures)
2-1/2% on ₹6,000,000 (buildings and improvements)
The 10% depreciation figure on the major structures and pieces of equipment has been used in view of the status of training and experience of the Pakistani operating personnel
d. Maintenance: 2-1/2% on ₹12,000,000. This is not excessive, even for a similar factory in Europe or the United States
e. Fuel: The boiler house is fired with the minimum amount of coal, since the calculation is based on the use of all hydrocarbons, liquid and gaseous, as fuel.

The price of ammonium sulphate imported from the United States or Europe and delivered at Lahore depends, of course, on the F.O.B price in the country of origin An F.O.B. price of $40 per MT in jute bags, as required by Pakistan, is a fair average. This price is equivalent to 361 Rupees per MT laid down at Lahore.

It is evident that the Daud Khel factory, even when producing 44 MT of ammonia per day instead of 40 MT, cannot compete with imported sulphate There is a very good chance, however, that the factory will produce more than 44 MT per day. Calculations indicate that a production of 48.6 MT of ammonia per day is within the realm of possibility. This output is equivalent to 60,750 MT of ammonium sulphate per year If this quantity can be manufactured, the cost price of sulphate will decrease to Rs 360 per MT, or just about equivalent to the price of imported sulphate at Lahore.

FMCC may possibly try to do with less foreign personnel than recommended in this report This would definitely constitute false economy, a policy of keeping their fingers crossed , hoping that nothing serious will happen. A simple calculation shows that the saving on paper is definitely not worth the risk.

It is estimated that the total required staff of foreign experts can be engaged for some $750,000, maximum not over $1,000,000, or Rs 3,562,500 to Rs 4,750,000 per year. These figures are equivalent to Rs 65 to Rs 86.5 per MT ammonium sulphate when manufacturing 55,000 MT per year This production rate need only drop below 44,000 or 41,000 MT respectively to

reduce the value of the annual output by more than the entire cost of a complete foreign staff.

18 Proposed Enlargement of the Plant

The previous section clearly shows that the present capacity of the Sand Shel factory is too small for economical operation. This unsatisfactory situation would improve materially if the factory were to be doubled in size With this end in view, the plant was purposely laid out and built in such a way that its capacity can easily be increased Many parts of the factory now have 100 per cent standby capacity, such as:

All compressors, except the low pressure air compressor and the oxygen compressors. Proposals have already been made to install a second low pressure air compressor in any case There are two oxygen compressors, one of which is normally in operation. Only one additional would be required.

No increase in capacity of the powerhouse would be necessary since there is a 100 per cent spare in the boilers and a 100 per cent spare in the turbo-generators.

The sulphuric acid plant has sufficient capacity to manufacture and supply twice the presently required amount of sulphuric acid

The lime kiln is amply large

It is estimated that the total cost of increasing the factory to a capacity equivalent to a maximum yearly production of 150,000 MT of ammonium sulphate, using the present system of Lurgi-gasifiers and production of ammonium sulphate from gypsum, will be approximately $7,200,000.

Since the present factory's standby equipment will be fully utilized when capacity is doubled, more spare parts will be required. The aforementioned figure of $7,200,000 includes an adequate amount for such parts.

If the capacity of the plant is increased as suggested, the cost of ammonium sulphate would be reduced substantially as shown in the following table:

Yearly Production MT	Cost price in Rupees per MT
100,000	312.3
110,000	296.4
120,000	279.5

These figures show that the cost of ammonium sulphate can be reduced by roughly 100 rupees per MT. It can be shown that the 55,000 or 65,000 MT of additional ammonium sulphate would cost only Rs 206.7 or Rs 192.6 per MT respectively, inclusive of depreciation, etc. for a capital expenditure of $7,200,000, one-third of the cost of the present factory.

The question undoubtedly will arise whether the additional 55,000 to 65,000 MT of ammonium sulphate should be made at Daud Khel or at some other factory in Pakistan still to be erected. Plans have been developed for a second fertilizer factory at Multan, West Pakistan. With the expanding use of fertilizer in West Pakistan and the program to convert from foreign importation to domestic production, the full output of one or more new factories will undoubtedly be needed. The output contemplated for the factory at

Multan should be absorbed readily by the agricultural areas to the south and also northerly as far as Lyallpur and Lahore. Areas still further north, such as the upper Punjab, the Northwest Frontier Province and the Swat country, can best be supplied from Daud Khel and they should in the near future be able to absorb the full output of the Daud Khel factory even with double its present capacity. Doubled capacity at Daud Khel cannot possibly be achieved before, say, 1961.

There is another reason why additional capacity should be placed at Daud Khel rather than adding an equivalent amount to the projected Multan factory. As long as the Daud Khel factory is not doubled in capacity, it will be an uneconomical plant, now and forever. Rather than starting with a second fertilizer factory in West Pakistan, the first one, which is well laid out and well constructed, should first be put on a paying basis. Since this can be done with reasonable capital expenditure, it is strongly recommended that the expansion of the Daud Khel factory be given priority over the erection of a second factory in West Pakistan, and possibly a third fertilizer factory in East Pakistan.

This recommendation in no way implies that erection of a second and possibly a third fertilizer factory should not be given serious consideration. It only means that first things should come first, and the first thing is to put the Daud Khel factory on a sound economical basis.

Doubling the capacity of the Daud Khel fertilizer factory involves more than mere capital expenditure. A study should be made as to how

this increase in capacity can best be achieved. There are various possibilities and each of these should be carefully considered. These possibilities are:

a. Increase of Lurgi gas by addition of a third Lurgi gasifier.

b. Conversion of the factory into one operating on natural gas, which is expected to be brought to Daud Khel in the next few years. If this is done, four processes should be carefully evaluated, namely:

(1) The conventional methane-steam process.
(2) The Texaco partial oxidation process of natural gas under pressure.
(3) The Shell partial oxidation process of natural gas under pressure
(4) The Montecatini partial oxidation process of natural gas at atmospheric pressure, utilizing a catalyst.

c. In addition, the Texaco partial oxidation process of coal under pressure should be evaluated as a possibility for Daud Khel.

d. Finally, the question should be studied whether all additional ammonia should be converted into ammonium sulphate by using gypsum or should be used in some other way, for instance, by the manufacture of ammonium nitrate or urea.

It is strongly recommended that this study be authorized now. This will save time and provide an urgently required answer which no doubt will be required sooner or later.

19. Conclusions:

PIDC in 1952 was a young organization, headed by some first-class men, but undoubtedly short of a sufficient number of able people capable of organizing and effecting the industrialization of a country left practically

without any industry after the partition in 1947. The Government of Pakistan and PIDC embarked on an ambitious program of industrialization which required far more capable people than available and more financial resources for local expenditures than they could obtain or provide. The result of this has been that whatever manpower was available and whatever money could be put at PIDC's disposal was spread too thinly. This conclusion was confirmed by PIDC in discussions held in their office late in August of this year. According to them, they had to follow this policy because they were pushed by the Government of Pakistan in its desire to industrialize the country.

In addition to this lack of manpower and financial resources, Pakistan in 1952 had far too little mechanical equipment, particularly modern mechanical equipment, to undertake speedily and efficiently all the necessary tasks required for the construction of a complicated factory, by far the most complicated factory in Pakistan. This means lack of rolling stock for inland transportation, lack of modern mechanical equipment for development of the site, lack of modern equipment for a thorough soil investigation, lack of adequate drilling equipment for water wells, etc.

Pakistan has a crying need for experienced chemical engineers. There are undoubtedly some, but not by far enough and it seems that the Government of Pakistan and PIDC have a tremendous task ahead of them in the education and training of promising young engineers.

Trained skilled workmen in the various crafts required for the construction of a chemical and high pressure factory, such as pipe fitters, welders for ordinary and stainless steel and for ordinary and high pressure equipment, machinists, electricians, etc were practically non-existent, at least not obtainable in Daud Khel. UCB and the suppliers' contractors had to train practically each and every skilled craftsman now employed at the factory. Here too is an enormous field for Pakistan and PIDC to develop

One of the items included in the cost price calculation discussed above is maintenance. This is not maintenance labor but rather the supply of necessary spare parts and equipment replacements. The estimated figure for Daud Khel is $300,000 per year. It is not an excessive figure and the actual expense for maintenance may well be higher. The exact amount is of less importance than the fact that practically all replacements have to be purchased abroad. Since the Daud Khel factory should at all times have sufficient repair material on hand to keep the factory going, a foolproof system of ordering parts and equipment should be installed. It is presently non-existent One of the recommendations listed later is concerned with this aspect of the factory operation

It is quite evident that lack of money or the necessity to spend it on supposedly more urgent and more important projects has resulted in too little money having been provided for anything beyond factory equipment proper This goes for everything: roads, houses, hospital, first aid room at the factory, transportation, education, cultural opportunities, recreational facilities, and the like. It is estimated that an additional one million

dollars would not only have been sufficient to create a center of which Pakistan and PIDC could have been justly proud, but would also have saved considerable money through higher morale of the foreign and local personnel. Less money would have been paid for overtime work and for foreign personnel expenses.

A craft which is of the utmost importance for a factory like Chaud Chel and which unfortunately is not known too well in Pakistan, or at least in the neighborhood of Chaud Chel, is concrete mixing and placing. This may seem surprising since a large amount of concrete work is going on all over the country. Most small jobs are done by local contractors. They apparently do not understand the great importance of good concrete work, as a result of which a considerable part of the concrete in the factory is of poor quality. The only way to prevent a similar occurance in the future is either to have all concrete work handled by reputable firms or to have sufficient foreign people supervising the proportioning, mixing, testing and pouring of the concrete.

Pakistan has a tremendous task ahead. With foreign aid they can make real progress in a comparatively short time. But it cannot be done overnight. This is one of the lessons learned. It takes time to train young technical engineers and it is completely unrealistic to expect that a year's training abroad in one or more factories will be sufficient. It is, therefore, important to staff the Chaud Chel factory with an adequate number of foreign experts who not only will be able to get the most out of the factory,

but who simultaneously can, and should, train the young Pakistan engineers in how to operate, how to maintain and how to manage such a complicated factory. PIDC should therefore employ at Daud Khel more young engineers than strictly necessary for the operation of the factory. This, admittedly, means more houses and an increase in the cost of production of ammonium sulphate. But it is an investment in the future, well worth the expense.

It has been reported that it is next to impossible to attract young Pakistani engineers to Daud Khel. The reason for this may seem quite obvious in view of what has been said above. At the same time, it is extremely disappointing, since the Daud Khel factory should offer extremely good opportunities for training and advancement when more factories are built. In order to entice young engineers to come to Daud Khel, it has been suggested that they be offered a year's stay in Europe or the United States. This seems quite wrong. It does not cure anything. They will still be dissatisfied after their return to Daud Khel.

The only way to change the present situation is to cure the seat of the trouble, and that is Daud Khel itself. A trip to Europe or the United States should be a reward and not a bribe. And last, but not least, it should be made only after these engineers have spent at least two years at the factory. They will then be able to profit from what they see and learn abroad.

Daud Khel itself should be made into a center which will entice people to work there. Action should be started now.

20. Recommendations

As a result of the on-the-spot study of the factory and subsequent discussions and calculations, a number of recommendations are submitted below. Some of them are not mentioned in the preceding report, but will be fully covered in the supplementary report which is to follow later. For clarity's sake, the recommendations are listed under the following sub-headings:

A. Factory Proper
B. Living and Recreational Facilities
C. Coal Supply
D. Water Supply
E. Gypsum Supply
F. General

A. Factory Proper

(1) The very first thing to do should be to invite a second opinion as regards steps to take for improvement, once and for all, of the soil conditions at the factory. In view of its international reputation and its recommendation by the Shell organization in The Hague, Holland, the Soil Mechanics Laboratory at Delft, Holland should immediately be retained for this purpose.

(2) Immediate efforts should be made to find a company which is operating ammonia plants and which is willing to enter into a contract to provide an adequate staff of people capable to manage, supervise and control the operation of the factory and to guarantee a minimum yearly production.

(3) A minimum of 30 foreign experts (engineers and technicians) should be engaged on such a contract for a minimum number of years.

(4) In view of UCB's knowledge of the factory and its experience with Pakistan conditions and Pakistan personnel, it is recommended that, if at all possible, the operating contract be made with this firm.

(5) In the future, any contract for work to be done in the factory should be awarded on the basis of ability and performance guarantee only and not on more availability in Pakistan. This may be more expensive in first cost, but cheaper in the long run.

(6) It is recommended that the factory be enlarged to twice its present capacity as soon as possible.

(7) Since enlargement of the factory can be done in a number of ways, both with coal and with natural gas, it is recommended that a study be authorized to work out the most economical and, for Pakistan, most promising method of enlarging the factory.

(8) Pending the outcome of this study and a decision regarding the enlargement of the factory, no money should be spent for the processing and refining of the liquid products made in the Lurgi-gasifiers.

(9) A very much improved first aid room, adequately equipped and staffed, should be provided.

(10) An immediate study should be made to assess the economic justification of the purchase of a compressor for the gas to be discharged from the sulphation plant. The expense of this compressor should be justified on the basis that the plant capacity may be doubled in, say, 3 years with natural gas instead of coal as the source of hydrogen.

(11) Consideration should be given to the purchase of another factory truck, to be used both for general factory hauling and as a standby for gypsum transportation.

(12) A foreign currency credit in favor of the Daud Khel factory should be opened in a European country or the United States so that the factory management can order necessary spare parts and replacement equipment directly, rather than having to go through the firm's headquarters in Karachi. This will save a great deal of time and may well constitute the difference between keeping the factory going or having to stop it from time to time on account of lack of parts.

(13) More storage for ammonia should be provided. This should be either in the form of a Horton sphere, which will require refrigeration, or in the form of pressure vessels.

(14) At least three more Pakistani chemical engineers should be assigned for the operation of the plant.

(15) PIDC should engage a number of additional engineers, chemical, mechanical and electrical, for training in the factory. Some of these engineers should be ready for employment in other chemical factories, in say, three or four years' time. The most promising ones of these young engineers may be given a training in Europe or the United States for a certain period after they have gained sufficient knowledge and experience, including operating experience, to warrant the expectation that their stay abroad will be profitable.

B. Living and Recreational Facilities

(1) All B and C type bungalows and all bachelor quarters should be equipped with running hot water.

(2) A decent, 50-bed hospital should be built immediately. This hospital should be furnished with modern equipment; hot water and steam supply should be provided.

(3) The mess hall should be improved.

(4) The kitchens of all B and C type bungalows and of the mess hall should be improved and modernized. Each kitchen should have an electric range.

(5) The mess hall and all occupied bedrooms of the B and C type bungalows and the bachelor quarters should be provided with air conditioning units.

(6) Each of the F type houses should get its own water tap.

(7) All A and F type houses should be equipped with electricity.

(8) For the sake of hygiene, all houses, including the F type houses, should be provided with flush toilets.

(9) New bungalows should be built as follows:

(a) At least one and possibly two A type bungalows. These bungalows should be as good as the best bungalows built by the Canadians at Narsak.

(b) [illegible] 10 to 15 [illegible] type bungalows of better quality than the ones now existing in the housing colony, with mortar between the bricks, containing decent kitchens with electric range and running cold and hot water.

(c) A number of C type bungalows also with mortar between the bricks and containing decent kitchens with electric range and hot and cold running water

Serious consideration should be given to the question whether these new bungalows should be erected in the same housing colony or whether it might be better to start a new housing colony for A, B and C type bungalows only. This colony should, if at all possible, be located nearer to the factory.

(10) At least one and possibly two more tennis courts should be built.

(11) A well-equipped swimming pool should be built.

(12) The housing colony should be equipped with a cinema. Movies are shown in the workmen's cafeteria at the factory. However, this is too far away from the housing colony to be of any real use.

C. Coal Supply

(1) Electrical equipment necessary for initial increase of production at the Mallakh 1 and Cullakhal mines and already proposed to PLUC for purchase should immediately be ordered.

(2) Additional equipment necessary to further increase production of the Mallakhel and Cullakhel mines and already proposed to PLUC for purchase should be ordered now.

(3) Equipment necessary to develop the Lamshiwal and Simpson mines which will be accessible once the tunnel has been completed should be ordered well in advance. The expected completion date of the tunnel is two years from now.

(4) Mechanical equipment to provide the Makarwal station workshop with adequate tools and machinery should be ordered immediately.

(5) Serious consideration should be given to the replacement of the two old diesel generators, still located in the enlarged and modernized Makarwal power station, by a new generator of much larger capacity, say, 400 to 500 kw at least.

(6) More coal cars or heavier locomotives should be ordered to remove the bottleneck in the coal transportation from Makarwal station to Mari Indus.

D. Water Supply

The broken casing of well No. 4 left in the ground by the Pakistan Boring Company should be removed. It is understood that Swissboring Co. will attempt this job. If they should be unsuccessful, UCIL should try to do this job with factory and hired equipment or should engage a reliable company to finish this work. The well is potentially too good to be abandoned.

E. Gypsum Supply

(1) A crusher with a 20" x 36" jaw should immediately be purchased.

(2) Additional equipment necessary to develop the quarry in a systematic way from the top down should be ordered as soon as possible.

(3) A foreign mining engineer, fully acquainted with explosive mining and, if possible, with gypsum mining as well, should be engaged forthwith.

F. General

(1) PIDC should employ a European or American doctor, a registered nurse, a mess steward and a welfare officer and assign them permanently to the factory.

(2) Adequate transportation should be provided for the foreign and Pakistan staff of the factory both to and from the factory and for recreational purposes.

(3) Daudkhel is practically isolated. PIDC should therefore organize cultural entertainment and cultural education. This could, for instance, be done by inviting for a few days at a time prominent people who can lecture on chemical, scientific, political and cultural subjects.

(4) The road between the housing colony and the factory should be improved.

(5) The road between the factory and the gypsum quarry needs widening and an improved surface