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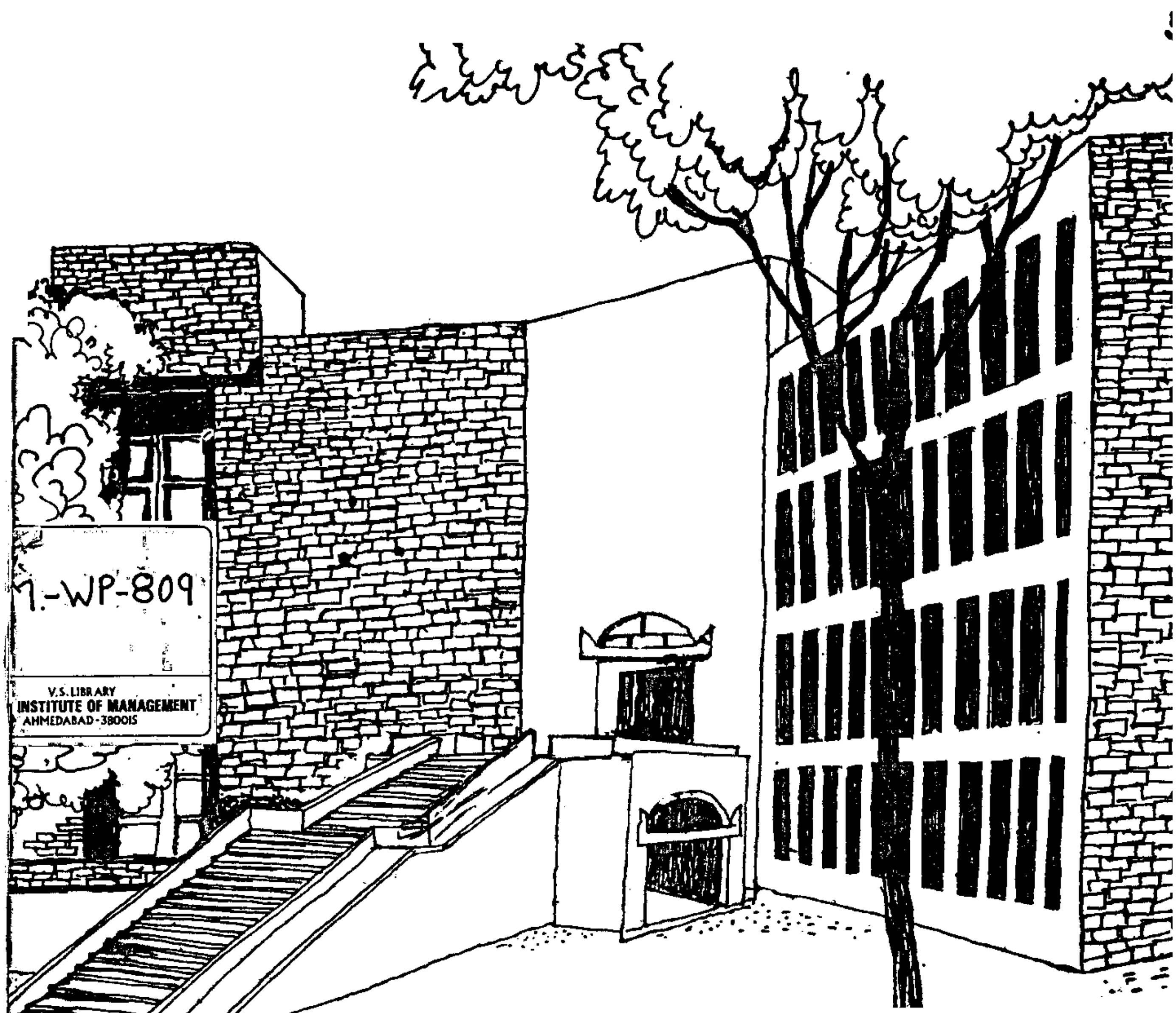

TECHNOLOGY ACQUISITION AND ASSIMILATION IN A FERTILIZER FIRM: A CASE STUDY OF GNFC

By

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Abstract

International technology transfer has for long been an important source of technical know-how for Indian firms. In recent times the importance of this source of know-how has increased substantially because of the increasing trend towards liberalization of the Government's policies. Case histories of firms based on imported technology reveal that the process of technology transfer is quite complex. Successful management of this process in many cases may be extremely important for the overall success of a firm. But little research has been done on understanding this process.

This paper is an attempt at understanding the process of technology transfer and development in the chemical industry through an indepth case study of the Gujarat Narmada Valley Fertilizer Company, Bharuch, Gujarat.

Technology Acquisition and Assimilation in a Fertilizer Firm: A Case Study of GNFC*

Shekhar Chaudhuri**

1. Introduction

The Gujarat Narmada Valley Fertilizers Company (GNFC) is located at Bharuch, in a backward district of Gujarat. The company was set up by the two promoters; the Gujarat State Fertilizer Company (GNFC) and the Government of Gujarat in May 1976, after it was realized that there would be a wide gap between fertilizer demand and supply in the country. Commercial production started on 1st July, 1982 with a capacity of 1350 metric tonnes (m.t) of ammonia and 1800 m.t. urea per day. The company is reported to be the largest single stream ammonia and urea plant in the world with fuel oil as feed stock.

2. Product and Market

As far as chemical related products are concerned, presently the company manufactures ammonia, fertilizer grade urea, methanol and butachlor besides a variety of by-products like liquid nitrogen liquid oxygen, sulphur, etc. GNFC has a separate marketing zone

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** The author is Professor in the Business Policy Area at the Indian Institute of Management, Ahmedabad. He would like to acknowledge the excellent cooperation received from the senior executives of the company. The author also immensely benefited from discussion at a seminar given by him at the International Food Policy Research Institute, Washington D.C. in October, 1988. He is grateful to Dr. Gunvant Desai of IFPRI for his very useful comments and suggestions.

for its "Narmada - Urea". It consists of states of Gujarat; Rajasthan; M.P.; U.P.; Punjab; Haryana and Maharashtra. A major portion of the ammonia produced is used for captive consumption, and the remaining liquid ammonia is sold in the open market. It sells the by-products to a number of industrial units in and outside Gujarat. The company recently started selling butachlor with the brand name "Narmada-Chlor". Besides manufacturing, the company has been involved in trading of imported urea and Di-Ammonium Phosphate (DAP), single super phosphate, muriate of potash and agricultural implements. It is now in the process of diversifying into new product lines like formid acid, nitrophosphate, calcium nitrate, concentrated nitric acid, phosphoric acid, petrochemicals, etc. Gujarat Narmada Auto Limited (GNAL) is a subsidiary company of GNFC.

3. Production Process

A brief outline of the manufacturing process for ammonia, urea and methanol is given in Exhibit 1.

The feedstock in the fertilizer industry is decided by the Government's policy. GNFC uses furnace oil in accordance with this policy. The first phase of ammonia manufacture is to heat up fuel oil and oxygen for genetrating gas, comprising of carbon monoxide, hydrogen, carbon-di-oxide and methane. During this process, a mixture of hydrogen and nitrogen is obtained. This combination is synthesised in high pressure reactors. After cooling it down upto minus 33 ^{o}C, liquid ammonia gets formed.

A combination of two parts of ammonia and one part of carbon-di-oxide gas is required for manufacturing urea. This mixture is fed into high pressure compressors. In the first phase, under high pressure (160 kgf./cm) an exothermic reaction takes place. During this phase 60% of the urea is recovered. The remaining ammonium carbonate is decomposed during the next phase and almost 90% of the urea is recovered. The remaining 10% of the urea may be further collected when the mixture is pumped into reactors and heat exchangers. The fertilizer grade urea is prilled in the prilling unit.

Production of methanol depends entirely on synthesis gas which consists of hydrogen and carbon-di-oxide available from the ammonia plant. In the reactor, sulphur is removed from this gas. The gas is compressed upto 76 kgf. pressure and is further heated to 240 ^{o}C temperature. When it is again fed into the main reactors, formation of crude methanol and gas takes place. During the purification process, methanol is available in liquid state.

4. <u>History of Original Technology</u>

During 1973-74, "The New Fertilizer Project Division" of the Gujarat State Fertilizer Corporation, Vadodara launched a techno-economic feasibility survey for setting up another fertilizer unit in Gujarat. In due course, the Government of India gave the permission for starting a new company on two conditions. It was directed to set up the company in a backward district for the balanced economic development of the region and use fuel oil as feed stock due to the petroleum crisis. Use of fuel oil as feed stock seemed to have increased the initial capital cost of the project. Bharuch was ideally selected as the site not only as a backward district but also by virtue of a number of externalities. A fertilizer firm requires an abundant supply of water. The problem was solved, because of the Narmada river. The town's location adjacent to one of the national highways was an added advantage for transporting raw materials and finished products. Its proximity to Vadodara also ensured an uninterrupted supply of fuel oil and other chemicals.

4.1 Process of Technology Selection

There was no technology available in India for fuel oil based fertilizer manufacture. The promoters floated an enquiry to identify foreign companies having expertise in the field. The promoters had a few criteria for selecting the collaborator. The following ones seem to be significant:

(i) As fuel oil had been recommended by the Government as feed stock for the project, the initial capital expenditure was expected to be very high. The promoters therefore looked for a technology entailing as low an investment as possible.

(ii) The promoters preferred a pollution-free technology

(iii) A technology that could be easily implemented and assimilated

(iv) Efficiency, expertise and long term experience of the collaborator in executing such projects.

Ammonia and urea project bids were won by Linde Aktiengesellschaft, West Germany and Snam Progetti, Italy respectively. According to GSFC's New Fertilizer Project Division's report tenders were invited for the establishment of various plants and facilities for the new fertilizer plant. In response to this invitation several tenders were received including one from the contractor. After a lot of correspondence, meetings, discussions and negotiations, the company selected the contractor inter alia for the award of contract for the establishment of a 1350 tonnes per day capacity Ammonia plant. In the same manner,an 1800 tonnes per day urea plant was also negotiated with Snam Progetti, Italy*.

4.2 Collaboration Agreement for Ammonia Plant

Linde's collaboration agreement was purely technical and hence there was no financial participation. Linde happened to be the consortium leader for both the ammonia and urea projects. At the time of execution of the project no Indian contractor was available who had experience and expertise to render services for setting up fuel oil based ammonia plants and no Indian equipment manufacturer was capable of supplying critical components and equipments. Fuel oil gasification could be done either by using the shell gassification or Texaco gasification process. Linde opted for the Texaco process for GNFC. Besides supplying some critical equipments like Air Separator, Rectisol and Nitrogen Washers, Linde approached a number of leading equipment manufacturers and obtained their non-transferable licences. Among them, some of the significant

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* GNFC, New Fertilizer Project Division; Fuel Oil based 1350 Tonnes Per Day Ammonia Plant - Supply and Engineering Contract with Linde Aktiengesellschaft, West Germany; March, 1976.

licences were, for Carbon Monoxide conversion from BASF, West Germany; and Ammonia Synthesis from Haldor Topsoe, Denmark etc. The total price paid for all the imported equipments was $850,000 or DM 62,872.

For the ammonia plant detailed engineering services were rendered by Linde and Engineers India Limited. A variety of Indian equipments not as critical as the imported ones were installed at the ammonia plant. For instance, Bharat Heavy Plates & Vessels (BHPV); Larsen & Toubro supplied high pressure equipments and Bharat Heavy Electricals Limited (BHEL) supplied compressors and boilers. Linde provided assistance in the commissioning of the plant for which they had given full guarantee. GNFC's engineers, many of whom already had a rich experience in other fertilizer plants quickly learnt to operate the plant.Technical training for junior engineers technicians and operators was provided by Linde; equipment suppliers like TEXACO and Haldor Topsoe and other operating plants like VEBA and BASF of West Germany.

The company paid DM 18.88 million as engineering fee to Linde alone. The cost of the total plant and equipment was estimated at DM 110 million apart from the cost of bulk materials like tubes which came to about DM 60 million.@

4.2.1 Advantages Accruing from the Collaboration

1. The company obtained a number of advantages through the collaboration agreement with Linde. Timely execution of the project; and Linde's long term experience were the

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@ Discussion with officials

two most important ones, according to the executives.

2. So far as cryogenic or low temperature technology was concerned, Linde's technology was regarded as superior.
3. Prior to Linde's collaboration agreement with GNFC, no company in India had used the Texaco gasification process. GNFC therefore become the pioneer in using this process.
4. Linde's technology was proven, entailing low energy consumption and low effluent. It was fairly automated and had a reasonably high degree of realiability.

4.3 Collaboration Agreement for Urea Plant

M/s. Snam Progetti of Italy was chosen as the collaborator for the 1800 tonnes per day (TPD) urea project. According to the technical collaboration agreement GNFC could produce prilled fertilizer grade urea for 24 hours stream day considering 330 stream days in a year using liquid ammonia and carbon-di-oxide gas as input materials. Under the agreement M/s. Snam Progetti could import all the necessary critical equipments which were not available in India. Snam Progetti provided all detailed drawings, designs and blue prints for the construction of the urea plant.

GNFC was required to pay U.S. $6.1 million for purchasing imported equipments like the urea reactor, carbonate separator, stripper, condensor, melt urea pump, etc. Some of the critical equipments like stripper, carbonate recycle ejecter were supplied by FBM, Italy, Tuttle, U.S.A. and Weigand, Italy respectively.

The following are some of the equipment suppliers in India:

a. BHEL, Hyderabad	:	Carbon-dioxide (CO_2) Compressors
b. BHEL, Trichy	:	Steam generation plant boiler
c. TRF	:	Coal handling plant
d. Bharat Compressors	:	Pumps
e. PDIL	:	Bagging plant

PDIL, an Indian consultancy firm in the field of fertilizers and chemicals was appointed by the company for undertaking most of the civil and electrical works. PDIL also participated in detailed engineering, erection and commissioning of the plant.

4.3.1 Advantage Accruing from the Collaboration

1. The company obtained one of the leading technologies for its urea plant. According to the officials of GNFC Snam Progetti had satisfied all the production quality criteria. For example, 46% Nitrogen content in urea was achieved.

2. Snam Progetti's technology could be considered as pollution-free; almost corrosion-free and was very reliable.

3. The technology entailed low power consumption and resulted in low cost of production.

4. Both the ammonia and urea projects were commissioned at a cost of Rs. 427 crores against the estimated cost of Rs. 445 crores.

4.4 Collaboration Agreement for Methanol Plant

During 1982-83, GNFC decided to set up a methanol plant. Earlier the Gujarat Industrial Investment Corporation, Ahmedabad had planned to implement a methanol project through Gujarat Amino

Chem. Ltd. However not much progress had been made when GNFC showed interest in this and a result it was able to get a licence for this project. Once again GNFC entered into a collaboration agreement with M/s. Linde, West Germany.

For the methanol project, Linde undertook the feasibility study and detailed project report preparation. M/s. Linde selected a process patented by Imperial Chemical Industries (ICI) of U.K. which seemed to be the latest at the time. The basic engineering services were rendered by Linde. Detailed engineering services related to the synthesis and purification sections were provided by Linde and Tata Consulting Engineers respectively. Apart from the local fabricators a number of equipment manufacturers from abroad also supplied critical equipments like compressors (e.g. GHH Ltd., West Germany). Linde provided technical training to a variety of technical personnel and also helped in commissioning and starting up the plant. Nevertheless, GNFC's engineers had the overall responsibility for commissioning the plant. The actual project cost was Rs.11.5 crores against the estimated cost of Rs.13.65 crores. Commercial production started on 7th August, 1985.

4.4.1 <u>Advantage Accruing from the Collaboration</u>

1. According to the company, the ICI process was of a high level of sophistication, and relatively pollution free.
2. The technology also assured better quality methanol than the product imported into the country by users.

4.5 Collaboration Agreement for Butachlor Project

The implementation of the butachlor project, marked a new epoch in the history of GNFC because the entire project was based on indigenous technology. The company signed a collaboration agreement with M/s. Gharda Chemicals, Bombay a well-known company in the field pesticides in India in January 1986. The agreement was signed for a period of two years on the condition that Gharda Chemicals would not supply the same technology elsewhere in India. The raw material was available from the ammonia plant and the idea for processing the same into butachlor was generated through discussions with officials of the Regional Research Laboratory, Hyderabad.

The feasibility and detailed studies was undertaken by GNFC's Marketing Division. Besides basic engineering and laboratory services for which Gharda Chemicals was involved, GNFC's Design and Construction Department was incharge of over all detailed engineering, construction, erection and commissioning of the plant. The Project Group of GNFC was involved in the initial phase of the project and follow-up. Gujarat Insecticides Limited provided training to 22 operators and shift in-charges for 15 days. A number of equipment suppliers like Steel & Alloy Fabricators, Ankleshwar; Mahishah Engineers, Baroda; Glassline Reactors, Vidyanagar; Graffite Materials, Pune; etc., supplied necessary equipments and critical components.

The total project cost including utilities, and other facilities was Rs. 6.28 crores. Table 1 gives the important elements of project cost.

Table 1

Important Elements of Butachlor Project Cost

Items	Rs. in crores
1. Plant and machinery	2.00
2. Civil work	1.00
3. Effluent treatment plant	0.60
4. Erection and construction work	0.30
5. Technical fees to Gharda	0.43
6. Electrical work	0.58
7. Fire fighting	0.58
Total	5.49

4.5.1 Advantages Accruing from the Collaboration

The company started commercial production of butachlor with the brand name of " NARMADA-CHLOR" on 28th September, 1987. The company's officials were appreciative of their collaboration agreement with Gharda, reported to be well-known in the field of pesticides. The company officials interviewed said that Gharda Chemicals had its own sophisticated in-house R & D Division. GNFC's R & D Division received considerable help in its development through the collaboration agreement. The company's executives gained confidence through this collaboration and felt that the company could diversify easily into other products and by-products pertaining to the field of pesticides.

4.6 Collaboration Agreements for Expansion and Diversification Projects

GNFC has shown an increasing interest in vertical and horizontal expansion. It has been constantly endeavouring to look for new avenues and ventures and has attempted to exploit all possible opportunities as is evidenced by the following:

4.6.1 Second Methanol Plant

Owing to increasing demand for methanol, the company thought of expanding the installed capacity for methanol from 20,000 TPA to 1,00,000 TPA. A collaboration agreement was signed with M/s. Toyo Engineering Corporation, Japan for this project. The company did not collaborate with Linde because its technology was reportedly more costly compared to Toyo's. The approval was obtained from the Government of India. According to the 1986-87 annual report of the company "the total estimated cost of the project will be around Rs. 75 crores of which foreign exchange component will be around Rs. 16.27 crores. The project is expected to be completed by the end of 1989".

4.6.2 Formic Acid Plant

The collaboration agreement for a plant for manufacturing 5000 M.T. per annum Formic Acid was signed with Kemira Oy, of Finland and M/s. Leonard Company of the U.S.A. during 1983-84. The final project cost was estimated at Rs. 13.5 crores including Rs. 3.6 crores in foreign currency. The project was expected to have been commenced by the end of 1987, but due to the sinking of an Indian ship in which there were critical items for the project, exported from Finland, the project was delayed and is now expected to commence by the end of June 1988.

4.6.3 Nitrophosphate/Calcium Ammonium Nitrate and Concentrated Nitric Acid

During 1984-85, the company signed a collaboration agreement with

M/s. UDHE, West Germany for setting up a Calcium Ammonium Nitrate plant and a Nitrophosphate plant each of of 475 TPD capacity and a 630 TPD concentrated Nitric Acid plant. Initially the project cost was estimated at Rs. 217 crores. There has been an increase of Rs. 20 crores because of increase in the tariff on imported equipments. The required foreign exchange loan of DM 112.6 million was to be given by International Finance Corporation and a consortium of banks including State Bank of India, Nassau etc. The civil construction work is in progress.

4.6.4 Phosphoric Acid Plant

GNFC entered into an agreement with M/s. Mozak International Incorporated of U.A.E.. sometime during 1985-86 for the establishment of a joint venture project for manufacturing phosphoric acid in U.A.E. The total project cost was estimated at US $71.5 million. GNFC has an equity share of US $4 million in the company, which is the value of the machinery and equipment exported from India.

4.6.5 Petro-chemicals

The company has submitted a proposal to the Government of India for launching a major petrochemical project. The estimated capital cost is of the order of Rs.1200 crores.

5. Performance Trends in GNFC

5.1 Plant Capacity

The company commenced commercial production of both Ammonia and Urea during 1982-83 with an installed capacity of 44500 MTs and 594000 MTs per annum respectively. The commercial production of methanol started during 1985-86 with an installed production capacity of 20,000 MTs per year.

The licensed and installed capacity of ammonia and urea plants remain unaltered. However the licensed capacity of methanol was increased to 100,000 MTs per annum as a result of the company's decision to set up a new methanol plant having a capacity of 80,000 MTs per annum during 1986-87.

a. For ammonia and urea plants the annual production level is determined by 24 stream hours having 3 shifts per day on the basis of 330 days per annum.

b. Uninterrupted supply of fuel oil, other utilities, chemicals and power.

c. Condition of main machines and other critical components without any break-down or failure.

d. Demand for urea; methanol and other by-products despite intermittant seasonal problems.

5.2 Production Rates

Table 2 provides information on the production and sales of ammonia, urea and methanol. It is evident from the figures that the production of ammonia has increased consistently from 356967 MTs. during 1982-83 (18 months) to 412624 MTs. during 1986-87. Figures for capacity utilization also show an increasing trend during the period 1982-83 to 1986-87. The general inference that may be drawn from the figures is that in an overall sense both ammonia and urea production have increased, thereby resulting in increasing capacity utilization.

Table 2

Volume of Production and Sales by Product

Type of products	1982-83 (for 18 months)	1983-84	1984-85	1985-86	1986-87
1. Ammonia					
Production (MTs)	336967	278308	300896	400468	412624
% of installed capacity	53.4	62.5	67.5	89.9	92.6
Captive consumption (MTs)	301121	273922	274705	362986	358155
%of production	79.9	98.4	91.3	90.6	86.8
Sales (MTs)	55846	7284	27492	28763	61033
2. Urea					
Production (MTs)	495638	473382	474303	624773	610176
%of installed capacity	55.6	79.7	79.8	105.2	102.7
Sales (MTs)	423939	491573	448547	594730	653181
3. Methanol					
Production (MTs)	-	-	-	19068*	21806
%of installed capacity	-	-	-	95.3	109
Sales (MTs)	-	-	-	17959	21383

Source: Annual Reports 1982-83 to 1986-87

* Commercial production started on 10th August, 1985.

During 1983-84 the production of ammonia declined. It increased at a slow rate over the next year. Production as a percentage of installed capacity reduced from 69.4% to 62.5% during 1983-84, with a fall in average annual production to 4 tonnes per hour (Table 3). Due to this fall, 98.4% of ammonia was alloted for captive consumption in the urea plant and only 7284 MT ammonia was sold out in the open market. The decline in production was mainly due to technical problems and intermittent power failures.

Table 3

Average Annual Production Per Hour in Various Plants (M.Ts)

Type of plants/ products	1982-83 (18 months)	1983-84	1984-85	1985-86	1986-87
1. Ammonia*	30	35.1	38.0	50.6	52.1
2. Urea*	41.7	59.8	59.9	78.9	77.0
3. Methanol*	-	-	-	2.4	2.7

Source: Calculated on the basis of figure from Annual Reports 1982-83 to 1986-87.

$$* \text{ Ammonia and urea} = \frac{\text{Total production}}{24 \text{ steam hours} \times 330 \text{ days}}$$

$$** \text{ Methanol} = \frac{\text{Total production}}{24 \text{ stream days} \times 333 \text{ days}}$$

During 1984-85, owing to a defect in the Waste Heat Boiler, the plants had to be shut down for 52 days. However, inspite of this, according to the 1984-85 annual report, "the significant achievement during the year was operating the urea plant over 100% capacity for 188 stream days and ammonia plant for 124 stream days". However, if the production of ammonia and urea were to be calculated for the anticipated 330 stream days, then capacity utilization would work out to 67.5% and 79.8% and an average annual production of 38 MT and 59.9 MT per hour respectively.

During 1985-86, the company achieved new heights in ammonia and urea production. According to the 1985-86 annual report, "the company had sent its team of technocrats to study the operations of various fertilizer plants in India and abroad and as a result of constant endeavour on the part of men working at the company's plants both ammonia and urea plants had produced over 100% capacity for 170 and 257 stream days during the year under review". If the production were to be calculated for the required 330 stream days, the capacity utilization in ammonia and urea plants would have been 89.9% and 105.2% respectively. The average annual production per hour increased to 50.6 MT and 78.9 MT respectively.

Another, remarkable achievement was that the company commenced production of methanol. The commercial production started on 10th August, 1986 and according to the data provided by the company it achieved 107% capacity utilization.

During 1986-87 ammonia plant capacity utilization increased from 89.9% to 92.6% and in the urea plant it decreased from 105.2% to 102.7%. According to company officials they achieved the highest capacity utilization for any fuel oil based ammonia plant in the country. The methanol plant also achieved a high capacity utilization (109%) and sales of methanol increased to 21,383 tonnes.

5.3 Power Problem

The company faced 6 major power interruptions which resulted in decrease in production during 1983-84. As a result, the management felt the need to make an alternative arrangement to solve this problem. Process industries like GNFC require continuous and constant power supply. GNFC s base load for zero production had been estimated at 16 MW and with full load it required 21.5 MW. Accordingly, a 25 MW captive power plant was purchased from BHEL, Hyderabad and installed. A second captive power plant of 25 MW capacitywas commissioned towards the end of 1988. This was necessitated by the expansion and diversificati projects.

5.4 Financial Performance

5.4.1 Turnover and Profitability

There has been a gradual increase in the company's turnover from Rs. 1817.3 million during 1982-83 to Rs. 3442.1 million during 1986-87 (Table 4). With the commissioning of the ammonia and urea plants, the company also started producing a number of by-products like sulphur liquid nitrogen and liquid oxygen.

The profitability of fertilizer companies is inter alia determined by the retention price formula fixed by the Government of India. The sale price level is kept uniform irrespective of the brand of a particular product. The government fixes a maximum ex-factory price and fair ex-factory retention price. The factory retention price is based on 12% return on net worth or paid-up capital. One of the conditions was that the company had to achieve a targetterate of capacity utilization. The rationale behind this uniform price formula was (i) to make available to farmers at a stable and reasonable price; (ii) to increase the utilization of plant nutrients on a larger scale and (iii) to reduce unscrupulous competition. According to the 1982-83 annual report of GNFC, the retention price was Rs. 3,351 per MT for urea and Rs. 3,999 per MT for ammonia. During 1983-84 there was a little increase in the company's turnover and more than 3 times increase in net profit, despite a fall in ammonia-urea production. The company undertook trading in Super Phosphate; Muriate of Potash and imported Urea and Diammonium Phosphate. During the year the ratio of net profit to sales increased from 4.3% to 14.6%. Though, there was a mechanical breakdown during 1984-85, there was a nominal increase in turnover but a dip in profitability.

Table 4

Turnover and Profitability (Rupees in million)

Items	1982-83 (for (18 months)	1983-84	1984-85	1985-86	1986-87
1. Turnover	1817.3	1919.4	2304.7	3044.6	3442.1
2. Gross profit	508.1	711.6	752.3	1087.2	687.4
3. Net profit*	78.6	280.9	320.4	640.1	186.7
4. Net profit/ sales (%)	4.3	14.6	13.9	21.0	5.4

Source: Annual reports from 1982-83 to 1986-87

* Net profit = Gross profit --(depreciation + provision for taxation)

The year 1985-86 witnessed a significant increase in sales turnover; gross profit and net profit. This was achieved to a significant extent because of the company's constant endeavour for technical improvement and in the ammonia-urea plants. During 1985-86, the net profit doubled and the net profit to sub ratio increased markedly from 13.9% to 21%. The increase in profitability was to some extent due to the reduction interest burden on repayment of loans. The profit also included the insurance amount of Rs. 107.5 million received on account of mechanical break-down during 1984-85. But the profit declined drastically during the next year. According to the 1986-87 annual report, "in the revised retention price effective from 1-4-85, some of the consumption norms were revised to the disadvantage of the company -----. The company was required to refund the excess amount of subsidy received by it for the year 1985-86".

Profit during 1986-87 reduced inspite of the highest ever turnover achieved by the company. It had to pay a corporate tax of Rs. 35 million during the same year apart from depreciation cost. Market conditions too were not favourable. The urea stock was reported to have accumulated to the extent of 3.5 lakh tonnes in 1987.@ The company has also decided not to import urea and DAP due to the adverse market situation. The fertilizer market turned to a buyers one. Companies began to face stiff competition. Many firms started adopting long term strategies for expansion and diversification into chemical related commercial products instead of relying on fertilizers alone.

5.4.2 Cost of Production

The cost of production for the past five years is given in Table 5. Raw material or fuel oil consumed by the plants contributed the highest proportion of cost over the period of time followed by power; fuel (coal for boiler) and other

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@ Discussion with officials

utilities. The recent two years witnessed a spurt in raw material cost because of rise in price of fuel oil and other raw materials. The expenditure on indigenous spare parts was reported to be higher than that on imported ones. There were wide differences between these two during 1983-84 and 1985-86. The packing expenditure increased over four years from Rs.55.2 million during 1982-83 to Rs. 126.4 million during 1985-86 reduced somewhat to Rs.119.7 million during 1986-87.

Table 5

Cost of Production

(Rupees in million)

Items	1982-83 (for 18 months		1983-84		1984-85		1985-86		1986-87	
	Amt.	%of turn-over	Amt.	%of turn-over	Amt.	%of turn-over	Amt.	%of turn-over	Amt.	%of turn-over
1. Raw materials consumed	411.9	22.7	288.2	15.0	306.3	13.3	487.4	16.0	549.4	16.0
2. Power, fuel and other utilities	342.0	18.8	271.5	14.1	271.1	11.8	359.3	11.8	452.0	13.1
3. Stores and spares	37.5	2.1	19.1	1.0	21.9	1.0	26.6	0.9	42.4	1.2
4. Packing expenses	55.2	3.0	59.6	3.1	98.9	4.3	126.4	4.2	119.7	3.5
5. Repairs & maintenance	39.6	2.2	45.9	2.4	89.1	3.9	77.6	2.5	85.5	2.5
6. Payments & provision for employees	36.3	2.0	38.3	2.0	48.1	2.1	62.4	2.1	98.4	2.9

Source: Annual Reports 1982-83 to 1986-87.

Table 6

Value of Imported and Indigenous Raw Materials and Spare Parts

(Rupees in million)

	1982-83 (for 18 months)	1983-84	1984-85	1985-86	1986-87
1. Raw materials:					
a) Imported	-	-	-	-	1.3
b) Indigenous	411.9	288.2	306.3	487.4	548.1
2. Spare parts:					
a) Imported	11.3	8.9	34.4	12.6	34.2
b) Indigenous	26.2	53.4	41.0	52.6	41.3

Source: Annual Reports 1982-83 to 1986-87

Repair and maintenance cost increased to Rs. 89.1 million during 1984-85 due to major repair expenditure on Waste-Heat Boiler. Payments to and provision for employees increased significantly to Rs. 98.4 million during 1986-87 from a low of 36.3 during 1982-83.

5.4.3 Capital Cost on Plant and Machinery

The capital cost on plant and machinery is given in Table 7. The company's total capital cost increased from Rs. 3,776.3 million at the end of the first financial year to Rs. 4,277.6 million as on 30th June, 1987. In the beginning of 1982, the capital cost was reported to be Rs. 23.9 million. The installation of ammonia - urea plants during the year accounted for the additional investment Rs. 3,752.4 million. During the subsequent two years there was only marginal additional investment. Once again it increased during 1985-86 and 1986-87 due to the commissioning of methanol and butachlor plants. The additional investment during

1986-87 also included the investment in Gujarat Insecticides Limited which was taken over by GNFC.

Table 7

Capital Cost on Plant and Machinery

(Rupees in million)

Year	Capital cost at the beginning of the year	Additional investment	Deduction	Total capital cost at the end of the year	Depreciation	Net block*
Jan 82-June 83	23.9	3752.4	-	3776.3	425.3	3351.1
July 83-June 84	3776.3	11.9	3.5	3784.7	420.6	2939.0
July 84-June 85	3784.7	9.9	2.9	3791.7	421.2	2524.7
July 85-June 86	3791.7	124.2	0.8	3915.1	434.9	2213.2
July 86-June 87	3915.1	365.5	3.0	4277.6	449.8	2125.9

Source: Annual Reports 1982-83 to 1986-87

Net block = Total capital investment of 1982-83 + corresponding years' additional investment - (total deduction + total depreciation)

Obviously, in the recent past the company started investing more on plant and machineryin pursuit of its expansion and diversification strategy. Part of the investment, however, went towards improvement and modification projects carried out in the various plants.

6. Technology Absorption and Assimilation

Physical performance in various plants has improved due to the increased efficiency over time. The company has to its credit a number of technical improvements. The modifications carried out have been classified under the following heads:

(i) Improvement in operating parameters

(ii) Reduction in energy and power consumption

(iii) Modifications in equipments

(iv) Pollution control and safety.

A systematic approach has been adopted for approving any modification either suggested by the Performance Monitoring Group or any production/maintenance group. The suggestion is first discussed in a joint meeting considering all techno-economic details and only then sent to the Technical Services Group for their approval. The Design and Construction Department then carries out detailed engineering and final cost estimates are worked out which have to be approved by the Finance Department.

In the following sub-sections the functions of the various technical departments which have been involved in the technology absorption and assimilation process are described.

6.1 Research & Development Department

Researh and Development had its genesis in the company almost immediately after the performance guarantee run was completed by the collaborator as the management felt the need to develop a substitute material for treating cooling water. The imported material being expensive and the fact that considerable quantities of it were required it was thought useful to develop an import substitute. Initially the research and development activities were carried out by persons from the Quality Control

Department. With the establishment of a separate in-house R & D unit in a small way in March 1986, the company turned towards a new dimension in technology development. R & D personnel have maintained a constant touch with the process control units. The following are the objectives of the R & D Department:

1. Association with the production and process group in existing and new projects.

2. To suggest and develop indigenous substitutes for imported catalysts.
3. To undertake special studies on pollution and suggest better methods of effluent treatment.
4. To conduct studies on water use and recycling of coolant water.
5. To suggest better utilization of waste products and by-products profitably.
6. To develop processes for commercially viable new products.

6.1.2 Sources of Ideas

Persons in the R & D Department keep abreast of the developments in fertilizer technology through scientific journals and magazines. The R & D personnel reported having constant interaction with R & D centres of other fertilizer and chemical companies, like GSFC and IPCL. Their participation in the Fertilizer Association of India annual meetings on research and development also provides an opportunity to get an overview of fertilizer research and development in the country.

GNFC's R & D personnel were actively involved in developing Butachlor, a weedicide for paddy. GNFC engaged the services of Gharda Chemicals, Bombay one of the most well-known chemical companies in the country to help them develop the know-how for producing Butachlor. Gharda Chemical also provided consultancy for scaling-up the process from pilot plant to commercial production and basic engineering services. GNFC paid Gharda Chemicals approximately Rs. 40 lakhs for the services. According to the R & D Department the collaboration helped the company develop expertise to diversify into the field of pesticides. Recently the R & D Department was given reognition by the Department of Scientific Research of the Ministry of Science and Technology.

6.1.3 Organization of R & D

In GNFC, R & D has been placed under Quality Control Department. The QC Department has under it three process control laboratories for (i) ammonia and urea, (ii) methanol and boiler and (iii) effluent treatment related activities. It also has under it the Cooling Water Control Laboratory and Fertilizer Research Laboratory.

The Chief Manager, Quality Control coordinates all R & D projects. The R & D Department, however, has a person at the level of Manager as its head. The Executive Director (Projects) is incharge of all R & D activities undertaken in the company at the top management level.

6.1.4 R & D Manpoweer and Budget

The manpower chart of the R & D unit is given in Table 8 below:

Table 8

R & D Manpower

Qualification	Personnel
Ph.D.	2
M.Sc.	1
B.E. (Chemical)*	1

Source: Discussion with R & D offiials
* Part time

The R & D Department is at present in a nascent stage. In spite of its relatively short existence the R & D unit has carried a number of innovations and modifications carriedat various plants. The R & D unit has its own budget. It is given in Table 9.

Table 9

R & D Budget (1984-1987)

(Rs. in million)

Year	R & D excenditure (capital + recurring)
1984-85	5.03
1985-86	0.63
1986-87	3.70

Source: Discussion with officials

6.2 Mechanical Maintenance Department

In GNFC, Mechanical Maintenance Department is responsible for looking into all mechanical problems at various plants. The department has facilities for fabrication, welding, machining and replacement of all machinery and equipments except maintenance of compressors. This department has also been involved in a number of technical improvement programmes in collaboration with the other technical departments.

6.3 Inspection Department

It is absolutely essential for process industries to keep machinery and equipment in good condition so as to achieve high reliability in operations. This department was set up sometime during 1982-83 for developing proper welding and fabrication procedures. It has provided services related to plant condition monitoring, non-destructive testing, investigation of plant failures, vibration measurement to check condition of all machines and submitting recommendations to top management.

The basic difference betweenthe Quality Control Department and Inspection Department is that the former has been concerned with quality control of raw materials, inputs and finished products, while the latter is involved with inspection of machinery and equipment only.

6.4 Performance Monitoring Group

In September 1983 the Reliability Group was formed with the objective of the improving the reliability of plant operations. This group was renamed in 1985 as the Performance Monitoring Group. This group performs the following functions; with the ultimate aim of improving the reliability of the plant and reducing energy consumption:

1) Monitoring of critical process parameters
2) Trouble Shooting and related modification jobs
3) Energy Conservation

4) Safety Audit and Lubrication Audit

The group identifies various problems in the plant for reliability, improvement and to bring down energy consumption, thereby, improving the productivity. This group has developed all the systems and sub-systems for process monitoring on a micro computer without the help of any external agency. The group prepares a fortnightly report on production performance which is a modest beginning towards a computerised MIS at GNFC.

6.5 Design and Construction Department

The Design and Construction Department was set up during 1985-86. It has rendered a variety of services: procurement, detailed engineering, inspection and supervision services for the butachlor plant. It has also helped in design modifications in the past to improve performance. Work of this nature is done in conjunction with the Performance Monitoring Group which provides the process design parameters in relation to any modifications. Apart from serving the company's needs, this department has also provided its services to neighbouring industrial units. It also provided engineering and procurement services for the designing and commissioning of Moisture Separator Plant of TISCO, Jamshedpur during 1985-86. It undertook a project related to environmental control for the Oil and Natural Gas Commission.

6.6 Start-up and Commissioning Unit

The company formed a Start-up and Commissioning Unit sometime during 1984-85. During 1985-86 this department offered technical services for commissioning the Krishak Bharati Cooperative's Hazira plant. It also imparted services for starting-up an LPG plant owned by ONGC and a hydrogen gas plant located in the U.S.A.

6.7 Pollution Control Department

GNFC's Pollution Control Department has played an important role in the technology development process. The company claims to have attained a very low level of pollution inspite of a rise in the production level. The company's stated policy is to achieve zero pollution level. The effluents discharged by the company are reported to be well within the maximum prescribed limits. The company has adopted an innovative policy of utilising some of the effluents to produce by-products which are of commercial value. A number of waste gases and effluents have been converted into lucrative by-products. This policy has to some extent helped to reduce the pollution level. The major pollutants in the company are in three forms viz; gaseous, liquid and solid wastes. A list of major pollutants is provided in Appendix 1.

In order to reduce pollution, the collaborators installed full-fledged treatment plants for removing obnoxious gases like ammoniacal nitrogen, vanadium cyanide, oil, ash slurry, carbon, etc. They also set up the Demineralized Water Plant and Raw Water Filtration Plant for better water treatment.

The Pollution Control Department's work involves (i) collection of wastes, (ii) treatment and (iii) disposal. From various plants the effluents are collected in pits and then pumped to treatment plants. For instance, grey water generated from the ammonia plant is pumped into the effluent plant and is mixed with

10% lime solution, for the formation of lime sludge. Similarly, oil effluent collected from various pits adjacent to the plants is passed through beds of hot coke. Oil content is totally removed by absorption and the treated water is sent to the effluent pond to cater to irrigation needs of demonstration farms. It is also used by farmers living nearby areas for agriculture. Its chemical content is within the permissible limits prescribed by the Government of India. The company has spent about Rs.180 million on pollution control equipments.

6.8 Process of Improving Performance

6.8.1 Period Before Commissioning

Even prior to establishing a separate R & D unit, the company paid attention to cooling water treatment. The required chemicals were obtained from some companies in the U.S.A. The Quality Control Department was given the task of developing indigenous chemicals for cooling water treatment. Subsequently with the setting up of a pilot plant, it started monitoring the behaviour of cooling water and observing heat exchangers performance sometime in 1981. The quality of cooling water was improved during the year resulting in reduction of blow-down by 3000 cu.m. per day.

Apart from this, a number of equipments were modified. In 1981, the Mechanical Maintenance Department successfully made a number of changes like increasing the length of burner, angle of baffle plates, and geometrical change in the shape of quench bore, etc., for improving plant performance.

6.5.2 1982-83

With the commissioning of ammonia and urea plants in 1982, the modification process was accelerated. The company was very particular in reducing power consumption which was achieved to some extent by modifying pump impellers. Further, it introduced capacitors in main power supply system in July 1982. Sometimes during the period, leakage in heat exchangers created operational problems. The performance was poor because they had been made of carbon steel.

The Performance Monitoring Group (PMG) studied in detail problems related to heat-exchanger design, vibration analysis and material of construction. A number of exchangers were modified by this group and some critical exchanger tube bundles were replaced by stainless steel material. Now the group monitors, with the help of computer programme, almost all critical exchangers for their performance.

The company also undertook detailed analysis of filter back wash water from raw water reservoir. The Pollution Control Department made efforts to recycle the water successfully and as part of this effort started alkaline effluent analysis. Another significant measure undertaken by the department was to use the treated effluent water for preparing ash slurry in the steam generation plant thus saving about 9000 cu.m. of fresh water. The installation of a sulphur recovery unit had mainly two objectives, (i) to reduce the pollution created by hydrogen sulphide gas and (ii) to recover the 99.9% pure sulphur as a by-product.

As a part of the efforts towards improving operating parameters, the company took the first step to increase the pressure of carbon-di-oxide in the section between the Ammonia plant and the Urea plant. The Carbon Monoxide compressor had certain limitations which resulted in restrictions in the urea plant load. In order to avoid this, the company could raise the pressure upto 2.1 kg/cm under certain operating conditions of the ammonia plant without affecting ammonia production. This increase in the pressure allowed an increase in the urea plant load.

6.8.3 <u>1983-84</u>

During the year the company took effective measures to use the condenser of the urea plant for reducing the temperature of ammonia gas in the ammonia plant. The temperature of ammonia gas recorded in the Ammonia Synthesis Unit used to be 430 ^{o}c. The gas used to be cooled by passing it through heat exchangers and a water cooler. The performance of water cooler and ammonia condensors in the refrigeration unit was reported to be poor which might have contributed to decline in production during the year. In April 1984, effective measures were undertaken to use the condensor of the urea plant for condensing ammonia which increased production by 50 MT ammonia per day in the next two months.

The Mechanical Maintenance Department was also involved in changing construction material of refractories. Equipment manufacturers also helped in the process.

6.8.4 1984-85 Period:

In the Carbon Monoxide shift section, three catelytic reactors are used for converting carbon monoxide into carbon dioxide. The third catalyst was originally designed to have a maximum of 1.5% carbon monoxide slippage. In September 1983, with the consultation of equipment supplier BASF, West Germany, the temperature at the third bed was reduced from 322 ^{o}C to 280 ^{o}C and hence it resulted in a fall in carbon monoxide slippage to 0.6%. A large reduction of fuel oil and energy consumption was recorded in the ammonia plant in July 1984, as a result of these measures.

The company undertook the second phase of increasing pressure of carbon-di-oxide from ammonia to urea plant in February 1985 which in turn increased urea production further. On 5th June, 1985, the company faced a serious break-down. This happened due to the failure of Waste-Heat Boiler (E-703) and resulted in a shut down of plants for 52 days. The top management approached the collaborator in West Germany and were unable to get equipment in time. The Mechanical Maintenance Department undertook a challenging repair task with its own welders. A 110 mm thick metal having 1.4 metre length was repaired successfully in a record time.

The company's recycled effluent water was reported to be within the permissible limits and is widely used for irrigation purposes now, which bears testimony to better effluent treatment in the plant.

6.8.5 1985-86

During the year the modification programme was enhanced to a considerable extent. The company once again modified the design of the pump impellers to reduce power consumption. There are six cooling water pumps. It was found that five of these pumps having lower head, could increase the required flow and could also give considerable power. A booster pump was provided for exchangers located at the top elevation of the plant. By making these and other modifications the company was able to reduce the power requirements by about 500 KW.

A number of modifications were made in the cooling water plant. The R & D Department has developed cooling water treatment chemicals indigenously and has developed expertise to render cooling water treatment services to chemical and fertilizer units. The collaboration with M/s. Gharda Chemicals, Bombay helped GNFC develop a number of industrial chemicals and as a result reduced the purchase of chemicals from other manufacturers.

The R & D Department has started developing slow release fertilizers by coating urea with other chemicals. Having 40 to 50% nitrogen content, these fertilizers seem to be more efficient than ordinary urea. The following are some of the fertilizers developed by the R & D Department; Gypsum coated urea with micro nutrients, Formaldehyde coated Urea, Fly Ash coated urea and

Ureaform. A successful attempt was made to recover vent gases from waste water which had high ammonia content. A new Ammonia Absorber having a diameter of 450 mm and 1500 mm height was installed in September 1985. This enabled the company to recover 50 to 100 kilograms/litre of ammonia.

6.8.6 1986-87

Bearing in mind increased water requirements in the near future the company was in search of a possible alternative to solve the problem. It was estimated that 20 to 25 tonnes of boiler feed water was being utilized daily. Various methods have been developed to use water produced as a result of the chemical process. Water produced as a result of the chemical reactions in the urea plant was collected and diverted for utilization in the boiler. A number of additional benefits like reduction of demineralized water consumption and energy saving were also achieved.

In the Urea plant, 5 MT of steam was flashed out (per hour) to atmospheric pressure. It was decided to use it for heating polished condensate/demineralized water. This scheme has now been implemented. Similarly, a number of other innovative methods to make use of heat energy were planned to be adopted. For instance, the company was planning to utilise energy from turbine condensate for heating to mineralized water. It has also decided to use impure carbon-di-oxide generated from the ammonia plant in the nitrophosphate plant which is under implementation.

The R & D Department set up a pilot plant for production of fumed silica. A number of industrial chemicals were also developed on laboratory scale.

7. Factors Facilitating Technical Change and Effectiveness

Given that the price of fertilizer and its distribution is regulated and also the fact that a fixed rate of return on investment of 12% is allowed by the Government on attainment of 80% capacity utilization and meeting stipulated consumption norms it could be assumed that fertilizer manufacturing firms would be strongly motivated to increase capacity utilization as much beyond 80% as possible and improve the efficiencies. However, the history of the Indian fertilizer industry does not seem to bear this out. There are numerous examples of fertilizer firms which were not able to meet the Government's not too difficult targets. For the purpose of illustration Fertilizer Corporation of India's plants at Gorakhpur, Sindri, Talcher and Ramagundam could be quoted. On the other hand there are quite a few firms which could be commended for their success in technology management. The case of GNFC stands out. The company has been quite successful in making technical adaptations to improve capacity utilization and increase efficiency. It has also successfully developed substitutes for imported materials to reduce operating costs. Its endeavour to utilize and further strengthen its technological base has enabled it to convert otherwise waste effluents into commercially useable products. What were the reasons for the success of GNFC? A number of factors may be identified as having contributed positively to the process of technical change in GNFC. These are discussed in the following paragraphs:

7.1 Emphasis on Learning, Innovation and Results Orientation

Senior executives emphasized the fact that a culture of innovation and results orientation had been developed in the company. The top management had assiduously built this environment over a period of time. Freedom and encouragement was given to employees to do things in a different way. As expressed by Mr. N. Vittal, one of the managing directors of GNFC: ... the creative aspects of the assimilation technologies arises once the Guarantee Test Runs are over and the plants start operating. It is possible to tackle the technological problems only if an environment is created whereby every person who is connected with the operations of the plant is encouraged to think creatively and contribute his ideas. Therefore, the first step in the creative management strategy adopted in GNFC was to introduce a very effective 'Suggestion Scheme'.

A circular was issued in July 1982 inviting suggestions in the following areas:

1. Improvement of productivity
2. Improvement of cost effectiveness
3. Improvement of safety
4. Improvement of morale

Suggestion boxes were kept in different parts of the plants and suggestions were collected regularly every week. A Committee consisting of the executive directors/general managers was set up to screen all suggestions and it was decided to give rewards to those whose suggestions were accepted. The Managing Director personally monitored the implementation of the suggestions. The success of the scheme may be guaged from the following data:

Table 10

Operation of Suggestion Scheme (till April, 1986)

No. of suggestions received	3922
No. of suggestions accepted	305
Total savings achieved	Rs. 64.08 lakhs per year
Amount given by way of cash awards	Rs. 0.70 lakhs

Source: N. Vittal, "Creative Management in Fertilizer Industry", talk given at a meeting.

Two important suggestions implemented on the technological side are given below:

1. Bypassing of Synthesis Gas/Process Condensate Exchanger (E-403) and Grey Water Exchanger (E-404) to reduce process condensate and grey water temperature to approximately 180 ^{o}C as against the design temperature of 255 ^{o}C to reduce pressure drop in the first Carbon Monoxide Shift Reactor (R-401). By adopting the suggested scheme Ammonia production increased by 4400 MT per annum.

2. Heat recovery from turbine condensate by using idle exchanger (E-414) of Carbon Monoxide Shift Conversion Unit. By implementing this scheme the company achieved a saving of Rs. 3,60,000 per year.

The suggestion scheme enabled the company to tap the latent ideas of the employees and also helped in creating a sense of participation amongst the people. Another management technique was used to supplement the Suggestion Scheme in the process of creating an atmosphere conducive to learning and innovation and this was termed as "Management by Survey". This was evolved by the management to draw from the experience of other companies.

"Management by Survey" could be introduced in GNFC because of one unique characteristic of the Indian fertilizer industry. The fertilizer industry in India essentially had its origin in the Sindri Unit of the Fertilizer Corporation of India and most of the top technocrats in the different companies had their initial training there. This fact as well as the lack of much competition in the industry had helped in the development of a camaraderie amongst fertilizer technologists. GNFC being one of the 7 companies using fuel oil as feedstock was in a position to learn from the experiences of others inspite of the fact that its problems were somewhat different, its plant being the largest single stream Ammonia-Urea plant based on fuel oil as feedstock.

However, GNFC's management felt that learning from sharing of experiences in seminars, meetings organized by the Fertilizer Association of India was not adequate and hence the concept of Management by Survey was evolved. Teams having a mix of both senior and junior level engineers from various disciplines; Chemical Engineering, Mechanical Engineering, and Electrical Instrumentation were sent to various plants in the country. A team also visited Chinese fertilizer plants. At the end of the visit each team submitted a report highlighting significant features of the plant and its management like; culture of the organization, process control, material handling, maintenance practices, manpower/facilities, management information system, medical facilities, technical problems faced and the manner in which they were resolved, pollution control, etc.

According to one member of the top management team the benefits achieved by implementing the concept of Management by Survey were the following; a) broadening of perspective, b) strengthening of relationships between mechanical, chemical and instrumentation engineers, c) development of a culture of accepting problems and d) development of a strong team spirit. Besides the above many suggestions that emerged from the reports submitted by the teams have been implemented.

According to Mr. N. Vittal, one of the erstwhile managing directors, "...there is nothing new in what GNFC has done because for all the time, there is continuous interaction among the technical people within the Fertilizer Industry and modifications are made. I would, however, like to emphasize that what is new, is the institutionalization and systematic approach by GNFC to send teams of people including youngsters so that they are exposed to a wider horizon of technology and a systematic attempt at internalising the ideas that have been picked up as a result of the survey."

The management had also attempted to develop a culture of "results orientation". The employees were encouraged to face challenges and solve problems instead of being overwhelmed by them. A few examples of actions taken by the company would help to illustrate this point. During the construction phase the supply of an ammonia storage tank was being delayed by the contractor. On investigation GNFC's managers found that the contractor had taken too many orders simultaneously and hence did not have the funds to take delivery of the imported steel plates from the customs authorities. Negotiating with the other companies who had placed orders would have taken a long time, so GNFC decided to help the contractor with funds to clear the plates from the customs authorities and save time.

Another example helps illustrate the point. In the initial days after the Performance Guarantee run was over 2 heat exchangers in the Rectisol Wash Unit started performing poorly. Their efficiency went down to 10%. There did not seem to be any solution in sight. Delivery period for a new head exchanger was 1 year. Only M/s. Linde, the collaborator had the know-how for this special type of heat exchanger. GNFC contacted more than 10 suppliers who said they could supply alternate designs but not the type which had to be replaced. GNFC's engineers were not deterred by this situation. They used a stand-by heat exchanger from another section to improve the efficiency and thus achieve a much higher capacity utilization. M/s. Linde's engineers were very surprised to know of the improvisations made by GNFC. This is evident from the telegram sent by them to GNFC in 1986; "... with astonishment we learned... of the excellent production and financial results... although we had carried out our final appraisal on the project in May 1985 we are interested to learn which measures have been carried out in the meantime in order to increase the production... and the costs of these measures..."

Another example of the results orientation of GNFC was the opening up of an old port at Dahej. GNFC was instrumental in reopening the unused port at Dahej, approximately 65 kms. from Bharuch. Nearly 1000 people of the area were employed in the port operations. Similarly another port at Mandvi, Kutch District was also reopened for handling fertilizer.

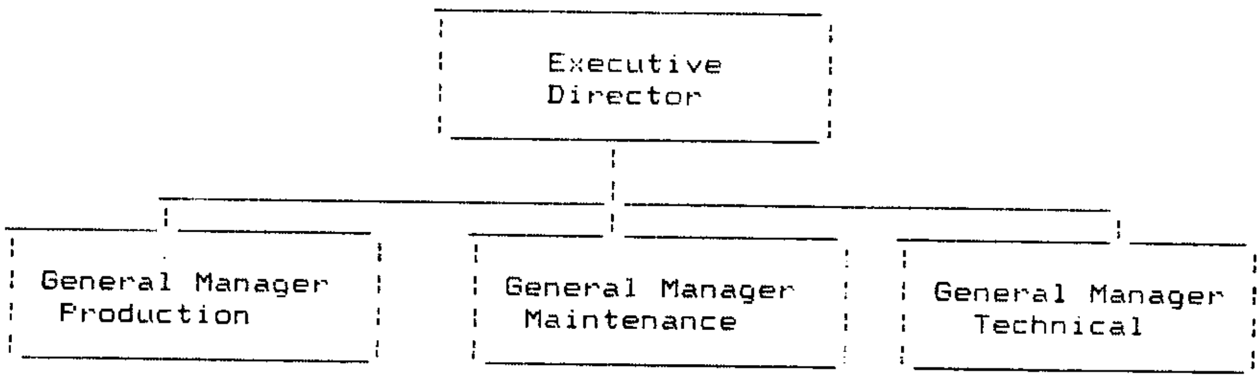
7.2 Adapting Organization Structure to Technical Task Requirements

Another important factor which seems to have facilitated the process of technical change towards greater effectiveness was the evolution of organization design to meet the requirements of the technical tasks at different phases of the project. During the first two years the organization structure on the technical side was as shown below:

It is evident from Figure 1 that the coordination of production, maintenance and technical matters could take place only at the top. Over a period of time the management felt that there were many issues which could be resolved at lower management levels but were being pushed up for resolution. Also due to the nature of the organization structure which apparently viewed Production, and Maintenance as separate functions some rift had developed between the two. After the performance Guarantee run was

Figure 1

Structure of Technical Organization (1981-83)



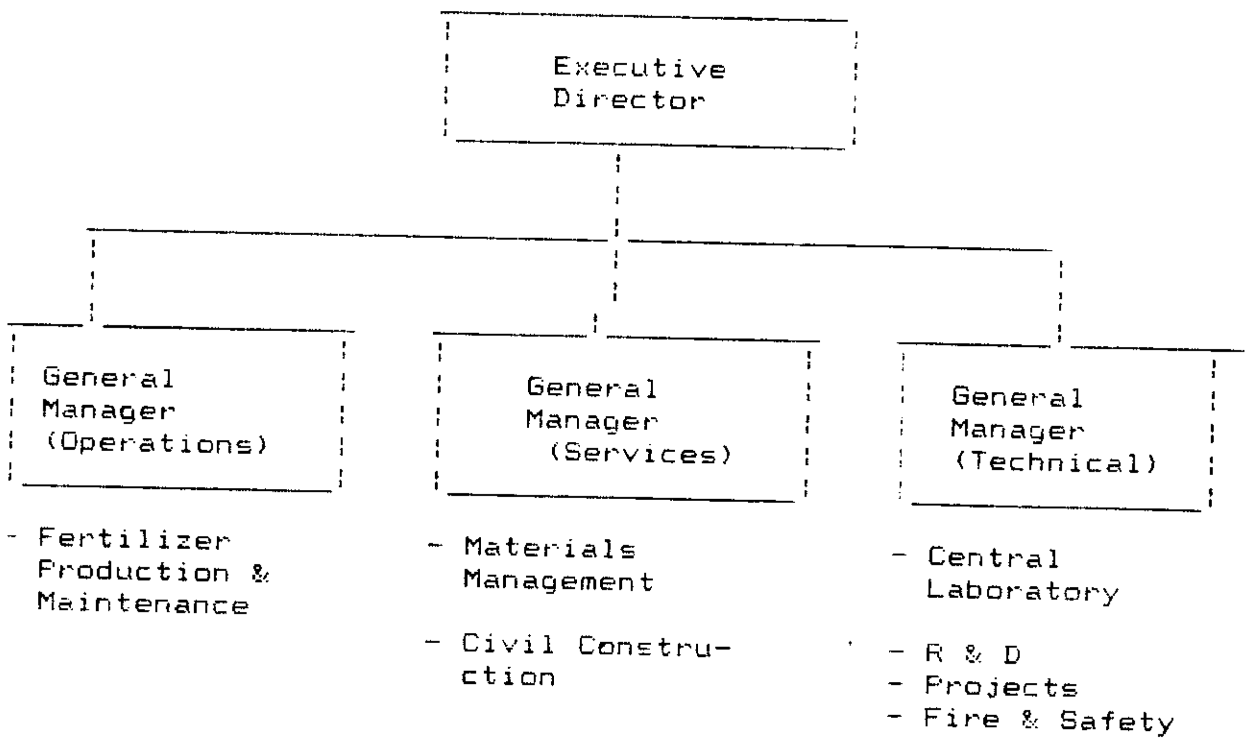
completed by the collaborator many technical problems cropped up and it was felt by the top management that the existing structure would not be appropriate for meeting the new challenges.

To respond appropriately to the emerging technical tasks the top management structure was modified. In August-Sepetmber 1983 Production and Maintenance were clubbed together under General Manager (Operations). Some restructuring of the other department was done and a new top management structure emerged, which is depicted below in Figure 2.

In 1986 the three general managers were promoted to the rank of Executive Director. This change again triggered off a few more changes which had an important bearing on technical task performance. On January 1, 1986 Executive Director (Operations) (ED (O)) had immediately under him 2 officers at the level of Deputy General Manager, one looking after Production and the other Maintenance. Immediately afterwards the new Methanol Project got commissioned and came under the charge of E.D. (O).

Figure 2

Structure of Technical Organization (1983-86)



One of the deputy general managers was transferred to the new Methanol Project. No additional senior managers were brought in. So both the production and maintenance functions related to fertilizer operations were brought under the Deputy General Manager (Dy. G.M). Most operational decisions were now pushed down to the level of Dy. G.M. Shortly afterwards this position was upgraded to Assistant General Manager (Operations). The close interaction between Production and Maintenance that resulted was found very useful in resolving many technical problems swiftly. Inspite of the significant increase in production since the commissioning of the plant no additional senior level officers were added to the Operations group.

However, a structural innovation was made using the existing people. It has been previously mentioned that a task force called Reliability Group was created to look into problem areas and come up with solutions with the ultimate objective of improving the reliability of operations. When most of the technical problems had been resolved the role of the Reliability Group was redesigned to focus on monitoring of operations. With the modification of its goals the group was renamed Performance Monitoring Group. Details regarding the functions of this group have been discussed earlier in the paper. Other departments of GNFC which played significant roles in the process of technology absorption and management were the following:

a) Inspection Department

b) Quality Control Department

c) Maintenance Planning Group and Design and Construction Department

d) Start-Up and Commissioning Unit

e) Research and Development Department

The contribution of these departments to GNFC has been discussed earlier in this paper. It is evident from the previous discussion that technology acquisition and assimilation is a process that cuts across the organization involving persons from a number of departments and is not the exclusive preserve of the production and maintenance departments only. Each of the departments in GNFC focused on a narrow set of tasks. These narrow sets of tasks had to be harmonised to achieve superior results. The top management of GNFC was successful in creating special groups to look after specialized tasks as well as in integrating them to achieve the corporate goals.

To sum up, the organization design that was adopted by GNFC's top management enabled the following:

a) lateral flow of technical information between technical departments within GNFC

b) flow of information from other plants enabling "learning by sharing"

c) focusing on critical tasks through the use of task forces

d) a relatively "fluid" organization which allowed continuous redefinition of the roles of different technical groups in accordance with technical task requirements

e) participation by a large number of people through mechanisms like the suggestion scheme and a number of committees.

.3 Transfer of Experienced Engineers from GNFC

t has been mentioned previously that the GNFC project was conceived by the Gujarat State Fertilizer Company, Vadodara. At the time of formation of GNFC only those executives who had had prior experience in various areas like plant operations, maintenance, start-up and commissioning were given the option of joining the newly formed company. Many of those executives had previously worked in the other fertilizer units in the country. By transferring them to GNFC the new company's management ensured a technically strong management team which was essential to its success.

7.4 Training and Development

Training and development has been given considerable importance by the company's management.

At the very inception of the company a large number of executives from the various technical departments were sent to the collaborator's plant for intensive exposure to the technology that was to be transferred. At the same time some fresh graduate engineers were recruited and sent to GSFC for on-the-job training for 2 years. They were sent back to GNFC on completion of their training.

Visits to collaborator's works have been a continuing feature of the training programme developed by GNFC. Senior officers have been deputed for training programmes organized by different organizations like International Fertilizer Development Centre, U.S.A., National Training Laboratory, U.S.A.; I.C.I., U.K., British Sulphur, U.K.; Snam Progetti, Italy; Oregon State University, U.S.A.' DuPont, U.S.A.; Siemens, West Germany, etc.

GNFC's management has enunciated a training philosophy and policy for the company. Training needs of all employees are regularly identified and assessed on the basis of task analysis, organizational analysis and analysis of each individual's needs. On-the-job and off-the-job training and development programmes have been designed to meet the training needs.

The company laid emphasis on inhouse programmes as they were less expensive and also helped save valuable time of the employees.

Vacancies in all discipline were filled through recruitment of trainees at different levels. Trainees were selected through campus interviews and were given training for one to three years depending on the category.

Employees were nominated for training programmes by their line managers. The nominations were scrutinised and approved by the Training Co-ordination Committee (TCC), based on previous training record, training need indicated in the performance appraisal reports and guidelines received from various training organizations. The TCC comprised of all heads of departments, Personnel Department and Human Resource Development Department. The Committee oversaw all training and development activities. The TCC met periodically and reviewed progress of training and approves training plans.

In the process of industrialization firms which set up in backward areas quite often have to suffer because they are forced to provide employment to land losing families lacking in technical skills. GNFC however tackled this potential problem imaginatively by providing a well designed training programme for them in the local Industrial Training Institute at Ankleshwar for a period of two years before employing them.

GNFC had also trained in its plants about 300 people sent by other companies.

7.5 Relationships with Workers' Union

An important factor which contributed to the process of technical change for high organizational effectiveness was the fact that the relationship between the management and the workers' union has generally been cordial and relatively free from serious frictions. The union was formed with external support sometime in 1982. Long term agreements were signed with the union in 1983 and then in 1987. Uptil now GNFC has not faced any labour unrest.

7.6 Quality of Leadership

Leadership played a very important role in the process of technology assimilation in GNFC. The role of leadership in the management of technology in this company would become clear from the following description of the problems faced and the manner in which they were overcome. Inspite of the fact that GNFC had collaboration with world renowned companies there were quite a few technical problems which had to be faced during the initial days.

During 1982-83, the first year of operation, the plant had to be shut down for more than 75 days. The major problems were failure of gasifier, defective performance of air separation switching devices, choking up of the revex box, mechanical problems with the centrifugal compressors, etc.

Again during second year (1983-84) several problems were faced in the Ammonia plant as a result of which it had to be shut down for more than 67 days. The major problems were; damage to compressor rotor; failure of gasifier internals; failure of steam control nozzle of turbine; leakage of water cooled condenser in synthesis loop requiring shut down at an interval of 1 $\frac{1}{2}$ to 2 months for plugging the tubes; leakage of gas into cooling water thus affecting the Ammonia Condensers of refrigeration section; problems in the utility plant, etc.

Major modifications were carried out in the plant during the first two years to improve the level of capacity utilisation and efficiency.

GNFC was fortunate to be led by very able men at the helm of affairs at different points in time. The company having been set up as a joint sector unit comes under the jurisdiction of the Government of Gujarat and so the managing director is appointed from amongst the senior officers of the state cadre of the Indian Administrative Service. Inspite of the fact that GNFC has always had bureaucrats at the top who are moved frequently from one position to another it did not face problems. The executives interviewd by the author give the impression that executives enjoyed an appropriate degree of authority and independence to discharge their duties ably. By giving the technocrats an adequate amount of decision-making power the top managers of GNFC were able to inspire a high level of commitment and enthusiasm in the managers.

The top men at GNFC may be credited with having developed a culture of openness, a willingness to experiment, motivation to excel in their endeavours, and a sense of results orientation.

An environment conducive to learning has been built up which has been to a great extent responsible for the success achieved in technology adaptation. The organization seems to have developed a culture of "never-say-die". People in the organization would not be deterred by failures but would be egged on to achieve higher goals. Some examples may help illustrate this. In July 1982 when the plant went into production it was found that if the surplus ammonia was sold for non-fertilizer use there would be a loss of Rs. 500 per tonne. As the plant was an unbalanced one there was a surplus of 270 tonnes per day of ammonia. Systematic efforts were made to pursuade the Government to permit GNFC to sell the surplus ammonia to IFFCO's plant at Kandla and also to GSFC. However, a permanent solution had to be found for disposal of ammonia. GNFC proposed a small area plant of 450 tpd capacity. After about 2 years of efforts for getting the project the Government rejected it because the plant according to them was uneconomical. However, GNFC did not lose hope. The management then came up with the idea of using the ammonia for another set of fertilizers viz; Nitrophosphate and Calcium Ammonium Nitrate. Finally the Government issued a licence to GNFC to manufacture 475 tpd of Nitrophosphate and 475 tpd of Calcium Ammonium Nitrate.

When the proposal for the urea plant was struck down by GOI, GNFC started looking into other areas as well. Another idea that was struck down by the Government was the proposal for setting up a seamless steel tube plant in collaboration with GIIC. Finding themselves in a jam GNFC's top management launched the corporate planning process to generate new business to achieve its ambitious growth objectives.

7.7 Policy Environment

The aim of this study was to develop an understanding of the process of technological development at the level of the firm in the chemical industry. Hence the indepth case study method was adopted. However during the study it became clear that the Government's policies relating to industrial licensing, foreign collaboration, imports, pricing of fertilizer, etc. had a significant impact on the process of technology selection, adaptation and assimilation. In this section some observations have been made regarding the nature of impact of the Government's policies on technology assimilation in GNFC.

The effect of the Retention Price Scheme, which ensured 12% return on networth on achieving 80% capacity utilisation and meeting stipulated consumption norms was not very clear. There were firms in the fertilizer industry which were unable to meet the conditions laid down by the Government. On the other hand there were many firms which were able to meet the norms and thus make a minimum of 12% return on networth. Senior executives of GNFC pointed out that through considerable efforts they had been able to meet and in some cases even better the consumption norms even though there were a lot of technical problems after the Performance Guarantee was over. This achievement was, according to them, not rewarded by the Government as the stipulated norms were gradually made more stiff for GNFC. So to earn the minimum 12% return tasks were becoming more and more challenging.

However, they mentioned that for those companies which had not been able to meet the conditions the norms were less challenging. In a sense the Government's policy of upgrading the norms for those firms which were more efficient created a disincentive for them.

The Government's policy on foreign collaboration in the fertilizer industry in the past allowed only technical collaborations. Though in general this policy forced Indian firms to experiment and learn about the imported technology to run the plants better the ultimate results preclude any definitive conclusions. However, in the case of GNFC the effect of the Government's policy was very positive. There were major technical problems which had not been faced in other Indian fertilizer plants before, GNFC's plant being the largest fuel-oil based single stream ammonia-urea unit.The collaborators could not be faulted as they had successful completed the Performance Guarantee run. The only way out was for GNFC's engineers to face the problems on their own and they realized this. The management and the technical staff took the problems as a challenge and were able to solve them. The crux of the matter was therefore one of how the technical problems were viewed by the company's engineers and management. In the case of GNFC even the collaborators were amazed at the performance achieved in spite of many unfamiliar problems.

Exhibit I

Manufacturing Process Flow Chart

AMMONIA

Heating up fuel oil and oxygen

↓

Gas generation (Carbon monoxide, Hydrogen, Carbon-di-oxide, Methane)

↓

Changing Carbon monoxide to Carbon-di-oxide

↓

Generation of more Hydrogen in the process

↓

Purification of gas when CO_2 and hydrogen sulphide gases are removed

↓

Purification through Liquid Nitrogen wash

↓

Pure Hydrogen & Nitrogen mixture for reaction (Hydrogen 3: Nitrogen 1)

↓

High pressure reactor for synthesis of ammonia

↓

Cooling down through refrigeration to $-33^{o}C$

↓

Ammonia in liquid form

UREA

Ammonia + CO_2 + Utility

↓

160 kg. pressure from compressors

↓

Reactor (exothermatic reaction) and 60% urea recovery

↓

Recovery of Ammonium Carbonate

↓

Heal Exchanger

↓

Ammonium Carbonate decomposes

↓

60% to 70% urea concentration

↓

70 to 99% concentration in evaporators

↓

Prilling of Urea

↓

Conveying urea for packing

Exhibit I (contd.)

METHANOL

$H_2 + CO_2$ (Synthesis gas) from Ammonia plant

↓

Removal of sulphur in reactor

↓

Compressing gas upto 76 barg pressure (compressors)

↓

Heating upto temperature 240^{o} (Heat Exchangers)

↓

Feeding to Main Reactors

↓

Methanol Formation (Conversion ratio 4 to 5%)

↓

Crude Methanol + Gas

↓

Gas circulation back to compressor

↓

Purification

↓

Methanol in liquid form