RMA/IND - EMCAT - LPD - F1

Energy Management Consultation and Training Project (EMCAT): Loan Portfolio Development Project (LPD)

Pre-Investment Survey
Fertilizer Industry

June 1995

Prepared by: **J. W. Foster, consultant to**
Resource Management Associates of Madison, Inc.

Prepared for: United States Agency for International Development (USAID)
New Delhi, India
Contract Number: 386-05127-C-00-4100-00

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Preface

This report covers the pre-investment survey activities of the Indian fertilizer industry as conducted by Mr. J. W. Foster for Resource Management Associates of Madison, Inc. (RMA) under the Energy Management Consultation and Training Project (EMCAT). EMCAT is funded by the U.S. Agency for International Development (USAID) for which RMA serves as the prime contractor in implementing the project. Under this contract, RMA will provide consulting services until April 1997.

In the course of his work, Mr. Foster surveyed four plants representative of the Indian fertilizer sector. All results are being forwarded to Project partners and funding agencies, but proprietary information is not being shared among the surveyed plants.

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ATTACHMENTS
SCHEMATIC DIAGRAMS

1. Executive Summary

Four Indian Fertilizer Plants were visited and a survey of each was made to identify energy conservation projects for lowering unit energy consumption in the manufacture of fertilizer. The four plants visited are as follows:

C Zuari Agro Chemicals Limited (ZACL)
Goa, India

C Gujarat Narmada Valley Fertilizers Company Limited (GNFCL)
Bharuch, Gujarat, India

C Nagarjuna Fertilizers & Chemicals Limited (NFCL)
Kakinada, Andra Pradesh, India

C Indo Gulf Fertilizers & Chemicals Corporation Limited (IGFCCL)
Jagdishpur, Uttar Pradesh, India

Prior to the site surveys, consultants from the Indian consulting firm of Projects and Development of India Limited (PDIL), visited each plant and prepared a pre-assessment study. This study was thorough and presented the major portion of the information required to do the survey. Since a total of only two weeks in-country was scheduled and significant travel time was required between plants, 1-1/2 to 2 days were spent at each plant. Accordingly, this report is based on information given in the pre-assessment study and obtained from discussion with plant personnel. Although the discussions were brief, the personnel at the plants cooperated fully. Additionally, major credit is extended to the PDIL representative who accompanied Mr. Foster on this trip and helped with data research and clarification of questions in the pre-assessment study.

At all four plants, projects were underway, or were being planned, which not only reflect a reduction in unit energy consumption but, in some cases, will result in an increase in production capacity.

At the present time, India is importing fertilizer to supplement their production to meet the agriculture sector demands. Tender prices of $240 per metric ton for urea and $260 per metric ton for ammonia, CFR/FO, India, are used to indicate savings from additional production achieved. While these tenders are purchased on bid prices, the prices will vary between tenders. Furthermore, savings from increased production, which reduces imports, will not directly benefit the plants. Therefore, economic calculations using capacity increases in this report are used as an indicator only, and the final analysis should be based on a specific import price and benefit to the plant. It would seem appropriate, however, that the Industrial Development Bank of India and USAID give loan consideration to those projects involving increases in production capacity since domestic production is less costly than imported product.

The plant management and technical personnel at all plants have done an excellent job in identifying and completing projects involving energy reduction. Most of the major projects remaining are at the two older plants, ZACL and GNFCL, which started commercial production in 1976 and 1982, respectively. These two plants are in the same category as most of the plants in the U.S., which were built prior to 1977. The two newer plants (completed in 1988 and 1992) employ state-of-the-art low-energy processes and, accordingly, will have lower energy consumption and fewer new projects to consider. In the two latter plants, most of the projects are underway or completed.

Table 1.1 summarizes the energy saving quantities and economics for each plant surveyed. The cumulative benefit of all projects recommended would be a savings of 465,250 metric tons of steam and 26,500 metric tons of oil. The total project investment would be Rs. 1,281 million (US$ 41,000). This investment would be payed back by energy savings in 5.5 years. Additional savings due to production capacity expansion have not been included in this summary. Although believed to be economically attractive, the projects recommended at the Indo Gulf plant are not able to be quantified until further development is completed.

It appears that all four plants can achieve a significant decrease in their unit energy consumption by concentrating on increasing their **A**on-stream@ or on-line factors. Most of the ammonia and urea plants were operating with on-stream factors of 89% **B**90%, or about 330 days of operation per year. It may be more difficult for the naphtha and oil feed stock plants, due their additional machinery and it maintenance, to increase their on-stream factor level to that of the natural gas feed stock plants, but any increase will result in a unit energy reduction. Most of the ammonia and urea plants in the U.S., which use natural gas as a feed stock, will operate in the 94% **B**95% on-stream factor range, or about 350 days per year. The age of the plant has little to no bearing on the on-stream factor, as most of the plants in the U.S. were constructed prior to 1977. The U.S. plants have a good preventative maintenance program and have been well maintained. The situation is the same for the Indian plants. Besides improving on-stream factors, the most common areas of energy savings were in heat recovery and heat exchange equipment. In the newer plants, high-efficiency sieve trays were a commonly recommended improvement.

Discussions indicate that all plants have a sophisticated maintenance work order, planning and scheduling system, and a preventative/predictive maintenance program. All of the plants are well maintained and operated. Therefore, more concentration on equipment preventative maintenance to increase reliability should result in an increased on-stream factor. Plant personnel note that the interval between plant overhauls has been extended to as long as two years. This is due to equipment such as state-of-the-art vibrational monitoring of the large rotating turbine/compressor trains. In the U.S., plant overhauls occur about every two years.

A comparison of energy usage and costs in ammonia plants for India and the U.S. is shown in *Table 1.2*. The plant listed for the U.S is a typical American natural gas plant. It is apparent that the two Indian natural gas plants (ZACL and GNFCL) have a lower energy input per mt of product than the typical U.S. plant. This is because the Indian natural gas plants are very new and state-of-the-art.

All of the plant*s offsite facilities include not only the usual water treating and package boilers but also power generation and nitrogen production. Start up of the ammonia plants is accomplished on nitrogen to conserve natural gas or naphtha. Local power companies are apparently short of a stable electrical supply so the fertilizer companies use their own generated power. In most cases, however, the plants were also tied into the local power company grid. For plant purposes, raw water is processed in treatment plants. This treatment is used to supply potable water and boiler feed water.

In the report that follows, energy programs and projects are described on a plant-by-plant basis. Process descriptions are taken from the pre-assessment study but abbreviated where possible. Schematic diagrams of the various processes at each plant are reproduced from the pre-assessment study and follow at the end of this report. Where data was not available, or could not be obtained at the plants, estimates were made. All energy costs used are those in the pre-assessment study. In all monetary calculations, an exchange rate of 31.25 Rupees per $US was utilized.

This report recommends that all of the proposed projects be given loan consideration and that a detailed economic feasibility study be completed. At IGFCCL, where considerable expenditure has already been made on projects to be completed by mid-1996, projects listed but not planned should be given loan consideration.

Table 1.1 Summary of Anticipated Energy Savings

(assuming implementation of all identified projects)

ZUARI AGRO CHEMICALS LIMITED

ENERGY TYPE	ANNUAL ENERGY SAVED (metric tonnes)	ANNUAL ENERGY COST SAVINGS	PROJECT INVESTMENT	PAYBACK
Steam	170,000	Rs. 52.9 million $US 1.69 million	Rs. 280 million $US 8.95 million	5.3 years
Oil	565			

GUJARAT NARMADA FERTILIZER COMPANY

ENERGY TYPE	ANNUAL ENERGY SAVED (metric tonnes)	ANNUAL ENERGY COST SAVINGS	PROJECT INVESTMENT	PAYBACK
Steam	212,000	Rs. 165 million $US 5.3 million	Rs. 884 million $US 28.3 million	5.4 years
Oil	26,000			

INDO-GULF FERTILIZER AND CHEMICALS CORPORATION

ENERGY TYPE	ANNUAL ENERGY SAVED (metric tones)	ANNUAL ENERGY COST SAVINGS	PROJECT INVESTMENT	PAYBACK
Steam			Rs. 85 million $US 2.7 million	
Oil				

NAGARJUNA FERTILIZER AND CHEMICALS LIMITED

ENERGY TYPE	ANNUAL ENERGY SAVED (metric tonnes)	ANNUAL ENERGY COST SAVINGS	PROJECT INVESTMENT	PAYBACK
Steam	74,250	Rs. 14.3 million $US 0.5 million	Rs. 32 million $US 1.0 million	2.2 years

TOTAL

ENERGY TYPE	ANNUAL ENERGY SAVED (metric tonnes)	ANNUAL ENERGY COST SAVINGS	PROJECT INVESTMENT	PAYBACK
Steam	465,250	Rs. 232 million $US 7.5 million	Rs. 1,281 million $US 41 million	5.5 years
Oil	26,500			

Table 1.2 Comparison of Ammonia Plant Energy Consumption & Costs - U.S. and India

Raw Material Consumption Item	**Plant Name/Feed stock**				
Design: MMkcal/mt*	ZACL/ Naphtha	GNFCL/ Oil	IGFCCL/ Natural Gas	NFCL/ Natural Gas	U.S./ Natural Gas
Feed stock and Fuel	11.07	7.66	8.08	8.04	
Steam	.34	3.62	.41	.46	
Electricity	.15	.78	.18	.08	
Total MMkcal (MMBtu*)	11.56 (45.87)	12.06 (47.85)	8.67 (34.40)	8.58 (34.05)	
1993 - 94 Actual MMkcal/mt					
Feed stock & Fuel	10.42	7.56	8.04	7.88	9.58
Steam	.72	3.57	.91	.60	.40
Electricity	.16	.60	.19	.24	.05
Total MMkcal (MMBtu)	11.30 (44.83)	11.73 (46.54)	9.14 36.26	8.72 34.60	10.03 (39.79)
Energy Costs					
Naphtha Rs/MMkcal ($US/MMBtu)	425		472 (3.81)		
Oil Rs/MMkcal ($US/MMBtu)	379 (3.06)	343 (2.77)	596 (4.81)		
Natural Gas Rs/MMkcal ($US/MMBtu)			353 (2.84)	278 (2.24)	(1.75 - 2.25)
Electricity Rs/kWh ($US/kWh)	2.5 (.05)	1.2 (.038)	.763 (.024)	.732 (.023)	1.1 - 1.9 (.035 - .060)

* NOTE: MMkcal/mt = Million kcal per metric ton
MMBtu = Million Btu

2. Zuari Agro Chemicals Limited, Goa

2.1 Plant Executive Summary

The ZACL Fertilizer Plant is located near the city of Goa. The plant produces urea, diammonium phosphate (DAP), and nitrogen-phosphate-potash (NPK).

Energy sources used in the plant include oil and electricity. The oil is used to generate high and low pressure steam, and the electricity is used to operate electric motors for fans and pumps. The steam is used as a heat source as well as a for turbines which drive compressors.

According to information provided by the plant, the process consumes 44.8 MMBtu/mt as compared with 39.79 MMBtu/mt in similar U.S. plants. This is primarily caused from a larger amount of downtime as compared with similar plants in the U.S. The plant has a very good preventative maintenance program and has been well maintained. Concentration on equipment preventative maintenance focused on increasing reliability will reduce downtime. This reduced downtime will also reduce the amount of energy per unit of plant output.

Process modifications to improve plant energy efficiency include:

1. Replacement of high-pressure steam turbine drive in synthesis compressor of Ammonia Plant
2. Replacement of carbon steel heat exchanger with stainless steel heat exchanger
3. Control system for urea process
4. Replace combustion air preheater
5. Change pall rings in two sections of CO_2 stripper tower
6. Naphtha hydro treater plant stack heat recovery

If all of the above projects were implemented, an estimated 170,000 mt of steam, and 565 mt of oil would be saved each year. The estimated annual cost savings of Rs. 52,900,000 ($US 1,692,000) would pay back the Rs. 280,000,000 ($US 8,950,000) investment in 5.3 years. Additional annual production profit resulting from these measures would be Rs, 7,406,000 ($US 237,000). With the additional profit made, the plant projects have a cumulative payback of 4.6 years.

2.2 Plant Background

The ZACL fertilizer complex consists of 660 metric tons per day (mt/d) ammonia, 1200 mt/d urea, 500 mt/d DAP and 500 mt/d NPK plants. The feed stock for the ammonia plant is naphtha, and steam is generated with oil firing. The complex produces its own power, steam, and nitrogen and has raw water as well as demineralized water treatment. Electrical power produced is provided for ammonia and urea but purchased power from the local utility is used in DAP/NPK. This power is not as stable and has voltage fluctuations which makes it unsuitable for ammonia and urea.

Company vital information is as follows:

Number of employees		996
Corporate Capital available (1993-94)		Rs. 20,815 Lakhs*
Annual Sales:	Urea	Rs. 10,884 Lakhs
	DAP/NPK	Rs. 14,795 Lakhs

*(1 lakh = 100,000)

A meeting was held with ZACL*s General Manager (Projects and Technical Services) and Manager of Process Engineering to review energy projects. To make energy efficiency investments, the plant requires a three-year maximum payback period. It was evident that management and the technical staff had done an excellent job of identifying and, in many cases, completing energy projects. Little discussion was held on the DAP & NPK plant as it had not operated on a regular basis.

The most significant energy savings in these plants are gained from attaining and operating at a high (about 85%) on-stream factor. In most cases, the 85% factor is not attained, and 80% **B** 82% is the norm.

Production Data is as follows:

		Annual Production mt/year (yr)	
	Design Capacity (Mt/yr)	1992-93	1993-94
Ammonia	220,000	286,460	264,735
Urea	400,000	429,808	417,500
DAP/NPK	300,000	298,898	210,113

Energy Costs Are As Follows:

Naphtha	Rs. 4500/mt $US 144/mt
Oil	Rs. 3700/mt $US 118.40/mt

Electricity	Rs. 2.5/kWh $US .05/kWh
Steam cost High Pressure (HP)	Rs. 322/mt $US 10.30/mt
Steam cost Low Pressure (LP)	Rs. 225/mt $US 7.21/mt

Raw material costs and energy values, given in Indian and U.S. equivalents, are as follows:

PRODUCT	**HEATING VALUE**		**COST**		
	MMkcal/mt	**MMBtu/mt**	**Rupees/MMkcal**	**$US/MMBtu**	**$US/ mt of finished product**
Naphtha	10.58	41.98	425.33	3.43	13.60
Oil	9.75	38.68	379.48	3.06	12.12
Steam (HP)			405.00	3.27	12.96
Steam (LP) @70% of HP costs			283.00	2.28	9.05

Product variable/incremental cost is as follows:

Ammonia	Rs. 4,310/mt
Urea	Rs. 3,798/mt

Energy Projects Previously Completed

C Improved pretreatment facilities for boiler feed water to reduce fowling of steam turbines

C Replacement of fan blades in cooling tower by more efficient fan blades to improve air flow rate

C Installation of oxygen analyzer for flue gases in boilers for better monitoring and control of excess air

C Installation of microprocessor based instrument for better combustion control in boiler which reduces fuel consumption and provides savings in steam production.

- Segregation of cold boiler feed water from hot condensate return which provides for steam production savings

- Introduction of better anti-scalants, biocides, bio-dispersants and corrosion inhibitors in the cooling water system for reduction in corrosion rate and fouling, for better heat transfer and for improved life of the heat exchangers

- Recycling of backwash water from various filters for reduction in effluent quantity and water treating

- Treatment of domestic water and reuse for reduction in effluent quantity and water treating

- Heat recovery from blow downs in the ammonia unit

- Improvement and replacement of steam traps and condensate recovery

- CO_2 regenerator overhead boiler feed water heater

2.3 Characteristics of the Existing Processes

Ammonia Plant Process

Raw naphtha used for feed to the ammonia plant contains oxygen and sulfur. For removal of these two contaminants to the reformer catalyst, the raw naphtha is sent to the oxygen stripper for removal of oxygen. The stream comes in contact with a counter-current flow of synthesis gas which strips out the oxygen. This hydrogen-rich stream is then sent to the combustion chamber as purge gas. The oxygen-free naphtha is then pumped to the hydro treater for removal of the sulfur. (The gaseous mixture leaving the Hydro treater will have a sulfur content of less than .05 ppm.)

The gaseous mixture then goes to the steam-methane reforming furnace where it is mixed with steam and then flows over a nickel catalyst in 240 tubes, arranged in six rows of 40 tubes each. This process is endothermic, and the heat is supplied by burning raw naphtha in top-fire burners spaced in seven rows of 12 burners.

The reformer gas then goes to the secondary reformer where it is mixed with heated process air from the process air compressor. The temperature increases to over 1,000 °C (1,830 °F). The process gas outlet of the secondary reformer exits at 940 °C and is cooled to about 500 °C after passing through two waste heat boilers where HP steam is generated.

Next, the raw synthesis gas goes through high- and low-temperature shift conversion which shifts the CO to CO_2. Medium pressure (MP) steam is generated in the process of cooling the gas as it leaves the shift section. The H_2, N_2, CO_2, along with minor amounts of CH_4, argon, and CO, go to the purification section

In the purification section, (CO_2 removal) the CO_2 is stripped, since it is caustic to the converter catalyst, and it is required as a feed stock for the manufacture of urea. The CO_2 is removed using a lean Benfield solution (K_2CO_3), which absorbs the CO_2 in the absorber. The CO_2 is then stripped from the solution in the stripping tower.

Next, the synthesis gas, containing primarily N_2, H_2, Ar, CO, and CO_2, goes to the methanator, where the CO and CO_2 are shifted to CH_4. This process is the reverse of the primary reformer process.

After methanation, the synthesis gas, containing primarily H_2 and N_2, goes through coolers and to the knock-out drum, where it is joined by product hydrogen from the purge gas recovery unit. The H_2-to-N_2 ratio is close to 3.0 at this point. From the knock-out drum, the gas goes to the synthesis gas compressor, where it is compressed to about 130 Kg/cm5g (1,850 psig), joins recycle gas from the converter outlet, and goes to the Synthesis Converter. There the gas is synthesized to ammonia in the presence of a nickel catalyst. Product ammonia gas from the convert is cooled to about -25 1C so the liquid ammonia can be removed in the separator, which operates at about 120 kg/cm5g. The liquid ammonia is then let down to about 20 kg/cm5g in the let-down tank. Dissolved gases, released at the lower pressure, are sent to the fuel gas heater, while the liquid product ammonia goes to storage.

Process Licensors for the Ammonia plant are:

Hydrosulfurization	IFP of France
Reformation	ICI of UK
CO_2 Removal	Benfield of USA
Ammonia Synthesis	TEC of Japan

Urea Process

ZACL*s Urea plant is a 1140 MT/D Mitsue Toatsu Total Recycle AC@ process designed by TEC of Japan.

The CO_2 gas compressor and HP ammonia pump feed CO_2 gas and ammonia liquid, along with recycled carbamate solution, at 250 Kg/cm5 (3550 psig), to the urea synthesis reactor. There the ammonia and CO_2 react rapidly to form ammonium carbamate. The ammonia-to-CO_2 ratio is 3.8:1, and 65%-70% of the carbamate coverts to urea.

From the synthesis reactor, the carbamate water solution and urea are let down in the HP decomposer to 16.5 kg/cm5 (235 psig). At this level, the carbamate decomposes, and the urea is separated. The decomposed carbamate-to-ammonia and CO_2 gases are recovered in the high-pressure carbamate absorber for return to the process.

The bottoms from the HP decomposer then flow to the LP decomposer, operating at 2.0 kg/cm5 (30 psig), where the remaining carbamate is decomposed and recovered. The bottoms, a urea solution of 70% B75% urea is sent to the crystallizer.

In the crystallizer, urea goes first to a vacuum evaporator which has a vacuum generator consisting of first and second barometric condensers. In the lower part of the crystallizer, urea crystals are formed and grow in contact with a super-saturated urea solution. The slurry of crystals is then pumped to centrifuges where crystals are separated from the mother liquor, dried, conveyed to the top of the prill tower, and remelted to solution, 139 1C (280 1F). The solution then flows through shower heads to form urea prills which are cooled by concurrent air flow in the tower. The prills are collected at the bottom of the tower and are conveyed to storage for curing and shipment.

DAP/NPK Process

The DAP/NPK plants are a 500 mt/d process designed by TEC of Japan using the Mitsue Toatsu AC@ process, using 52% B54% phosphoric acid and ammonia as feed stock.

Fresh acid, along with effluent scrubber liquor, are metered to the preneutralizer which is an agitated stainless steel vessel equipped with a sparger for the introduction of metered liquid ammonia. Heat released in the reaction raises the temperature of the solution to the boiling point, and a large volume of water is evaporated along with vented fumes from the process.

The vented fumes go to the overhead scrubber system which handle the effluents from the preneutralizer, granulator, dryer, and product cooler. The scrubber medium of water is then recirculated to the preneutralizer for reuse.

Reaction slurry is pumped from the preneutralizer to the granulator via a recorder controller. Metered solid raw material such as urea, potash, and filler mixed with recycled fines are injected into the granulator as needed, depending on the final product requirement. These then are mixed with the slurry. Granulation is promoted by the injection of liquid ammonia into the bed of material, mono-ammonium phosphate, to produce a di-ammonium phosphate or, when potash is added, an NPK grade.
The moist granules agitate to a rotary horizontal dryer where they are dried by a counter-current stream of air quenched with combustion gases. Oil is the firing medium. The dried product is discharged through a grizzly (screening process) to the primary elevator and screening system. Oversized lumps are crushed and returned to the process for reprocessing.

From the screening system, the product goes to the product cooler where it is cooled by a counter-current of ambient air. The product then goes to a coating drum and on to storage. In the case of high urea grades, a coating oil is sprayed on the granules for better storage qualities.

Process licensor:

TEC of Japan using Mitsue Toatsu AC@ process

<u>Offsites</u>

C	DM Water	3
C	Steam Boilers	3
C	Power Generation 7.5 MW	1
C	Cooling Towers	4

2.4 Proposed Process Changes

1. *Replace all cooling tower fan blades with fiber-reinforced plastic (FRP) for increased air flow and reduced power consumption.* This project has not been scoped but should be investigated due to energy saving potential. Power savings of approximately 30% in cooling tower operation have been indicated.

2. *Replacement of insulation material on steam lines with improved material to reduce heat loss.* This project has not been scoped but should be investigated to energy saving potential.

3. *Replacement of HP steam turbine driver in the synthesis compressor of the ammonia plant.* This steam turbine is using considerably more steam than design. After reviewing cost estimates from Delaval, it appears more economical to revamp rather than replace the present turbine. The economics are considered accordingly.

   Estimated cost of turbine revamp: Rs. 62,500,000
   $US 2,000,000

   Annual savings in reduction of steam consumption: 5.5 mt/hr

Assume 330 days or 7920 hrs per year and steam costs of Rs. 322/mt:

Savings 7920 X 5.5 X 322	Rs. 14,026,320 $US 448,842
Payout in years.	4.5
Internal rate of return (IRR), Ten-year project life	18.2%

3. *Replacement of carbon-steel heat-exchanger tube bundles with 304 stainless steal bundles to reduce fouling and improve heat transfer*. One of the gas final coolers has already been modified, leaving one gas final cooler and the reactor effluent condenser in the hydrodesulfurizing section. Each bundle has an area of about 204 m^2 or about 2,200 ft^2. Leak frequency is a problem with the reactor effluent cooler. The conversion to stainless steel would eliminate this problem and reduce the number of shut downs of the unit.

Estimated cost installed:	Rs. 2,400,000 $US 76,800
Estimated annual savings:	Savings have not been calculated but would be estimated to be in the area of Rs. 312,500 or $10,000 annually.
Payout in years.	7.6
IRR, Ten-year project life	5.1%

4. *Distributed Control System (DCS) for Urea*. DCS is now being installed in the ammonia plant. Currently, the conversion to electronic controls is underway, and when this is completed, the DCS will be installed. A total of seven loops are contemplated for the ammonia unit to include steam-to-carbon ratio and hydrogen-to-nitrogen ratio. This system will provide real-time information to the operators and will permit operating the ammonia unit at peak performance on a more continuous basis. This should result in increased production of ammonia with a reduction in energy consumption per ton of product.

   It is estimated that distributed control for the urea unit will result in an increase in urea production of approximately 1.0% and a 1.0% savings in steam energy consumption annually. For economic consideration, a production increase of only .05% will be used.

   The DCS being installed in the ammonia plant is designed by YOKOGAWA, a Japanese Company. Unless the system proves to be unsuccessful in the ammonia plant, it is recommended that this system be installed in the urea plant for compatibility of operator training, spare parts, and maintenance.

Estimated cost of DCS installed: Rs. 31,250,000
$US 1,000,000

Estimated annual savings:
Assume
Steam @2.029 MMkcal/mt,
Production at 400,000 mt/y,
Current steam consumption = 2.029 X 400000 = 811,600 MMkcal

811,600 x 283 = Rs. 229,682,800
$US 7,349,849

Total Steam Savings @1.0% $73,498 annually

Production Increase @.05%: 2000 mt/y

Cash cost of urea Mfg: Rs. 3,798/mt
$US 121.53

Import Urea cost: $US 240/mt
Rs. 7,500

Net Savings (Annually):
(Rs. 7,500 - Rs. 3,798) x 2000 = Rs. 7,404,000
$US 236,928

Total Savings (Annually) Rs. 9,700,812
$US 310,426

Payout in years (with added production capability) 3.2

Payout in years (energy savings only) 13.1

IRR, Ten-year project life (with production savings) 28.5%

Note: A cost for urea of Rs. 3,798/mt was used in this calculation. The proper use would be a variable cost (which was not available). The project is still viable, but would be improved with the variable cost.

5. *Replacement of Lungstrom Combustion Air Preheater in the reformer furnace convection section with a new heater of similar design but with improved sealing.* In the heater's present condition, and by the nature of its construction, there is a continuous leakage of hot gases through the seals. The design leakage is 8%, but the actual leakage is closer the to 20%, leading to excess steam consumption of combustion air in the forced draft fan, excess steam consumption of flue gas in the induced draft fan of flue gas and loss of heat to atmosphere.

Estimated installed cost of new heater:	Rs. 12,000,000 $US 384,000
Estimated savings:	Rs. 5,000,000 $US 160,000
Payout in years	2.4 yrs
IRR, Ten-year project life	40.2%

6. *The CO_2 removal system in the ammonia unit is a Giamarco Vetrocoke, modified and converted to Benfield solution.* The system was designed for 660 mt/d of ammonia production, but the plant is operating at approximately 900 mt/d or about 50% over design. Energy consumption per normal cubic meter (Nm^3) of CO_2 regenerated is over 1,150 kcals. This compares to 800 kcals for the modern low-heat ammonia processes.

This project may require the services of a process engineering design firm specializing in CO_2 removal systems, but it is possible to lower the heat requirement from 1,150 to 1,000 kcal/Nm^3 of CO_2 by changing two sections of pall rings in the CO_2 stripper tower and replacing them with cascaded pall rings.

<u>ALTERNATE 1</u> Install New Cascaded Pall Rings

Assume:

Estimated installed costs of pall rings	Rs. 11,000,000 $US 352,000

Flow rate 26,000 Nm^3 of CO_2/hr
330 days/y or 7,920 hrs/y operation
10.580 MMkcal per tonne of Naphtha
150 kcal heat savings/Nm^3 of CO_2

Naphtha cost is 4,500 Rs. per mt or $144 per mt
Heat Savings = 26,000 x 150 x 7,920 = 3.088 X 10^4 MMkcal
Steam Costs MP @ Rs. 283/MMkcal

Savings:	
Rs/y = 3.088 x 10^4 x 283 =	Rs. 8,739,040 $US 279,649
Payout in years	1.2 years
IRR, Ten-year project life	79.2%

ALTERNATE 2 Install Additional Stripping Tower

This option would involve some additional stripping column capacity as well as inclusion of a new hydraulic recovery turbine in the CO_2 removal section. This estimate of installation costs is rough and should be studied by a Process Design Engineering firm specializing in this work.

Estimated installed costs for tower, piping, and power recovery turbine	Rs. 156,250,000 $US 5,000,000
Savings (annually): 350 Kcals per Nm^3 of CO_2	
350/150 = 2.33 X 279,694 =	Rs. 20,391,063 $US 652,514
Payout in years	7.66
IRR, Ten-year project life	5.1%

Note: This project will need a process engineering review to determine the feasibility. It appears economically attractive and should be studied.

7. Two naptha-fired heaters in the naphtha hydro treater plant have flu gases exiting @ 500°C. *It is proposed to install a heat exchanger to capture the heat in the flue gas, lowering the exit temperature from 500°C to 250°C and then reduce the firing on the heaters.*

Estimated Cost of Installing Exchanger:	Rs. 4,062,500 $US 130,000

Estimated Savings	Rs. 2,100,000 $US 67,200
Payout in years	1.9
IRR, Ten-year project life	50.8%

3. Gujarat Narmada Valley Fertilizers Company Ltd., Bharuch, Gujarat

3.1 Plant Executive Summary

GNFCL is located in Bharuch, Gujarat in India. Their facility produces fertilizers, including ammonia, urea, nitric acid, ammonium nitrophosphate, and calcium ammonium nitrate.

The energy sources used on the plant sites include fuel oil and electricity. The oil is used to generate steam. The steam is used as a process heat source as well as to drive compressor turbines. Electricity is used to operate motors and lighting. Areas to conserve energy are based on recovering waste heat, reducing heat consumption by increasing efficiency in sieve trays, and reducing down time losses. Measures which are recommended for implementation are:

1. Heat recovery from ammonia compressor discharge.
2. Heat recovery in Urea Plant MP condenser.
3. Heat recovery capacity improvement in acid unit boiler.
4. Installation of molecular sieves in air separation unit and gasification train.
5. Installation of high-efficiency sieve trays in urea reactor.

If all of these projects were implemented, 212,000 mt of steam and 314,500 MMkcal of oil would be saved each year. This annual energy cost savings of Rs. 165,000,00 ($US 5,300,000) would pay for the Rs. 883,560,000 ($US 28,270,000) investment in 5.4 years. A 3.3 year plant payback would be seen if additional production profits are included in the savings.

3.2 Plant Background

The Gujarat Narmada Fertilizer Company, is one of the largest chemical producers visited. In addition to the fertilizer plants, GNFCL has several organic chemical plants. An acetic acid plant was under construction.

Company vital information is as follows:

Number of employees	2490
Corporate Capital Available	Rs. 1,049.5 Crore*
Annual Sales	Rs. 653.0 Crore
How energy efficiency investment decisions are made:	Economic evaluation and based on payback period of about three years

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* 1 Crore = 10,000,000

A meeting was held with GNFCL*s Chief Manager of Technical Services, the Senior Manager of Technical Services, and the Manager of Technical Services. Complementary meetings were held with the General Manager of Production and the Plant Executive Director.

The fertilizer complex consists of a 1,350 mt/d partial oxidation process ammonia plant, which operates on oil as a feed stock, and an 1,800 mt/d Snam-Progetti prilled urea plant. In addition, there is a 630 mt/d nitric acid plant, 475 mt/d ammonium nitrophosphate plant and a 475 mt/d calcium ammonium nitrate plant. Again, minimal time was spent on the nitric acid and phosphate plants as their energy intensity, compared to ammonia and urea, is less. Although difficult to maintain over the long-term, cleaning procedures which keep down corrosion and allow a high on-stream factor (about 85%), offer the best energy-reduction plan.

Of the four ammonia plants visited, this plant is possibly the most energy-intensive and the most difficult to operate. This is because thee ammonia plant is supported by an Air Separation Unit for its supply of liquid oxygen and nitrogen. This unit has experienced a significant amount of donwtime, start-up of the ammonia plant can take as long as six days, and any process interruption can cause outages of two to three days. To operate this plant efficiently requires constant attention and planning.

GNFCL*s staff of operating and technical personnel have done an excellent job in energy reduction projects and process improvements to improve on-stream factors and reduce energy consumption. The ammonia plant, while rated at 1,350 mt/d, is operating at 1,550 mt/d.

Production Data is as follows

		Annual Production (mt/yr)	
	Design Capacity (mt/yr).	1992-93	1993-94
Ammonia	445,500	505,429	473,207

	Design Capacity (mt/yr).	Annual Production mt/yr 1992-93	1993-94
Urea	594,000	660,818	653,731
Nitric Acid	207,900	160,339	186,099
Nitrogen Phosphate (NP)	142,500	141,492	132,974
Calcium Ammonium Nitrate (CAN)	142,500	93,807	160,547

Energy Costs are as follows:

LSHS Oil Feed	Rs. 3,550 $US 113.60
Fuel Oil	Rs. 3,650 $US 116.80
Electricity	Rs. 1.2/kWh $US .038/kWh
Steam HP (Estimated)	Rs. 310/mt $US 9.92/mt
Steam LP (Estimated)	Rs. 217/mt $US 6.94/mt

Raw material costs and energy values, given in Indian and U.S. equivalents are as follows:

PRODUCT	**HEATING VALUE**		**COST**		
	MMkcal/mt	**MMBtu/mt**	**Rupees/MMkcal**	**$US/MMBtu**	**$US/ MMkcal/mt**
LSHS Oil	10.34	41.03	343	2.77	10.98
Fuel Oil	10.27	40.76	355	2.86	11.36
Steam (HP)			386	3.11	12.35
Steam (LP)			270	2.17	8.64

Product variable/incremental costs are as follows:

Ammonia	Rs. 4,000
Urea	Rs. 2,800

Energy Projects Previously Completed

We reviewed energy reduction projects with the technical personnel and outlined below is a compilation of the projects already completed and those that are contemplated:

- Oxygen/ratio controller for controlling the ratio of liquid oxygen feed to feed oil going to the gasifier.
- Modification of soot cooler from a two-pass to a single-pass exchanger to prevent seal strip leakage. Soot water temperature dropped from 220°C to 180°C resulting in a savings of approximately 4 MMkcal/hr of energy.
- Higher conversion in CO shift reactor by water injection saved approximately .08 MMkcal/mt of ammonia.
- Synthesis loop pressure reduced by increasing diameter of circulation turbine impeller giving an increase in circulation through the converter by about 10%. Allowed for an increase in production, at the same loop pressure, and a decrease in the energy consumed per ton of ammonia produced.
- Redesign of converter third-stage strainer resulted in lowering loop pressure and savings in compression steam requirements.
- Installed Series-200 Topsoe radial converter basket which increased conversion per pass and allows a significant drop in energy consumption in compression.

There are numerous other projects completed which have had a favorable affect on energy reduction in the fertilizer plants. The projects shown above are representative of the projects which have been completed.

3.3 Characteristics of the Existing Process

<u>Ammonia Plant Process</u>

Unlike steam-methane reforming of natural gas, this 1,350 mt/d ammonia process utilizes oil as the feed stock and a Texaco gasification process for the cracking of the oil to hydrogen and other components. The gasifiers (2) operate at a temperature of about 1,400°C (2,550°F) and 85 atm (1,250 psia) pressure. Oil, fed by high-pressure pumps, is heated to 280°C and mixed with HP steam then fed to the gasifiers along with preheated oxygen from the air separation unit. The hot gases are cooled by quenching in the quench section of the gasifier. The products of the gasification process are primarily H_2, CO and carbon.

The raw synthesis gas leaving the gasifiers goes through a process for soot removal and then to shift conversion in order to shift CO to CO_2. The gas is cooled in exchangers and waste heater boilers where HP saturated steam is generated.

The raw synthesis gas then goes to the Rectisol wash unit for removal of CO_2 and H_2S. The shifted gas is cooled to -22°C, and a slight amount of methanol is added to prevent icing of the

moisture before going to the wash tower. Cold lean methanol is added to the top of the tower and CO_2 is removed to below 20 ppm. Rich methanol solution is used for H_2S removal in the bottom of the tower and H_2S is further removed in the stripping column. The stripped H_2S is directed to a Claus unit, and the regenerated methanol is recycled to the process.
From the Rectisol wash unit, the purified synthesis gas is passed through molecular sieve absorbers to remove traces of CO_2 and methanol. The gas is cooled and sent to the nitrogen scrubber. Pure nitrogen is cooled and is directed to the top of the tower, while one stream is mixed with the pure hydrogen in a synthesis ratio. The bottoms of the wash column, containing CO_2, argon, methane, nitrogen, and a small amount of hydrogen, are warmed and used as a fuel gas.

The gas stream then goes to the ammonia synthesis section where the purified hydrogen and nitrogen, in a 3:1, ratio is compressed to 232 atm (about 3,400 psia) by a multistage, turbine-driven synthesis compressor and synthesized to ammonia in the ammonia converter. The converter is a Haldor-Topsoe radial-flow 200 converter, which is of recent technology. HP saturated steam is generated in the synthesis section in the heat removal of the synthesized gas streams.

The liquid ammonia from the synthesis section is then cooled in the refrigeration section and sent to storage consisting of two 10,000 mt atmospheric storage tanks.

The ammonia process is energy intensive and generally, the major energy savings are generated in this facility.

Ammonia Process Licensors are as follows:

Air Separation Unit	Linde of Germany
Fuel Oil Gasification & Carbon Recovery	Texaco of USA
H_2S/CO_2 Removal	Linde of Germany
Ammonia Synthesis	Haldor Topsoe of Denmark
Detail Engineering	Linde of Germany EIL of India

Urea Process

GNFCL*s urea plant is an 1,800 mt/d, Snam-Progetti stripping process with prilling tower to produce solid prilled urea. This process, although conventional, is state-of-the-art and similar to another European process that uses CO_2 for stripping, whereas the Snam-Progetti process uses ammonia. In both processes, stripping of carbamate is carried out near reactor pressure, thereby saving compression energy **B**an advantage over the older processes. One of the major energy saving sources in urea process is to assure that the process is operating close to design assuring that ammonia unit consumption is maintained at the lowest level possible.

Liquid ammonia from the receiver is fed by two HP ammonia pumps through the carbamate ejector as a driving fluid. It then goes, along with gaseous CO_2 from the compressor in the urea plant, to the reactor which operates at a pressure of approximately 150 kg/cm5 (2150 psig) and 190 1C (370 1F). This mixture of ammonia, water, carbamate, and CO_2 reacts rapidly with the formation of ammonium carbamate and is highly exothermic. With a residence time of 45 minutes to one hour, the carbamate dehydrates to form urea and water with 65% B70% of the carbamate being converted to urea. The ratio of ammonia to carbon dioxide for the process is 3.6:1.

A small amount of air is injected into the CO_2 compressor*s first stage suction to passivate the 316L stainless steel liner surface in the reactor.

The reaction products flow from the reactor to the HP steam-heated falling film stripper where the carbamate is decomposed and the urea exiting the bottom of the stripper goes to the MP decomposer. The overhead gases are recovered.

The MP decomposer operates at 18 atm (265 psia). Additional carbamate at the lower pressure is decomposed and the overhead gases are recovered. Inert gases from the top of the carbamate separator are sent to the bottom of this MP decomposer for passivating purposes.

The bottoms from the MP decomposer flow to the LP decomposer where the operating pressure is 4.5 atm (65 psia), all remaining carbamate is decomposed, and the overhead is recovered. A 70% B71% solution of urea from the LP decomposer is fed to vacuum separators where the urea solution is concentrated to 99.7%.

The 99.7% urea melt is pumped to the top of the prill tower where it is formed into spherical droplets by a prilling bucket which are cooled by concurrent air flowing up the prill tower as the prill fall. The prills are collected at the bottom of the tower and sent to storage for curing and shipment.

Urea Waste Water

Excess water can be a problem in the urea process; getting rid of waste water can also be difficult. The scheme used by GNFCL Ba distillation tower to get rid of ammonia and CO_2 and the hydrolyzing of carbamate to ammonia and CO_2 for further removal Bis about the best one can accomplish. The water can be stripped of ammonia and CO_2 to the extent that it can be reused.

Nitric Acid Process

A 630 mt/d nitric acid plant utilizing the UHDE7 process is installed at GNFCL. This plant is a dual pressure unit producing a 60% nitric acid product.

Liquid ammonia is vaporized, heated to 60 1C, and fed through an ammonia filter to the mixer. There the ammonia is mixed with filtered air from the main air compressor in a mixer. Part of the air stream is diverted for use in the bleaching tower. This mixture is filtered again and enters the converter at about 200 1C and 4.4 bars (about 65 psig). Here the ammonia passing over the platinum/rhodium catalyst is oxidized at a temperature of about 890 1C. The hot gases pass to the

La-Mont waste heat boiler, tail gas heaters, ammonia stripper, platinum filter, and cooler condenser, and then move on to the bottom of the absorber tower.

The absorber tower has sieve trays with water-cooled coils above the tray. As demineralized water is pumped to the top of the tower, nitric acid forms as the nitrous gas is absorbed into the tower water. The acid formed collects in the bottom of the tower and, after being pumped to the bleach tower, is sent to nitric acid storage. The acid strength is about 60%.

The tail gas from the top of the absorber tower flows through four tail gas heaters where the gas is heated to 420°C (790°F) before entering the tail gas turbine. The NO_x level of the gas is less than 200 ppm.

This process is highly exothermic, allowing more than 70% of the energy requirements to be met by process-generated heat.

Nitrophosphate (NP) Process

In the nitrophosphate process, phosphate rock is acidulated with weak nitric acid in a series of three digestors to form a solution of calcium nitrate (CN) in NP acid. It is necessary to remove the bulk of the CN from the NP acid before neutralizing with ammonia to produce a compound fertilizer.

The solution is cooled, and the calcium nitrate is crystallized. The crystallized dissolving solution is sent to a vacuum belt filter where the crystals are separated, washed, and dissolved in ammonium nitrate solution. They are then sent to the CN conversion unit for conversion to lime and ammonium nitrate.

The NP acid which has a CaO/P_2O_5 wet ratio of 0.24 is sent to the neutralizer for ammoniation with ammonia gas. The neutralization is accomplished in two steps. First, under close control of temperature and pH, about 90% of the neutralization is completed. Second, again under close control of temperature and pH, the final 10% of neutralization is accomplished in a stirred tank reactor. The final product has a 94% concentration and moisture of 6%. This product is sent to the granulation unit.

The product is granulated in a rotary drum granulator and is then cooled to 40°C in a fluidized bed cooler using air with controlled humidity.

This product has a N:P2O5 ratio greater than one, and DAP must be added to the product to make 23-23-0 fertilizer.

In the CN conversion unit, the calcium nitrate tetra hydrate (CNTH) crystals separated from NP acid are dissolved in ammonium nitrate to form CN melt solution. This process is carried out under controlled conditions in two stirred tank reactors, arranged in parallel, to form ammonium nitrate and calcium carbonate (lime).

The process licensor for the NP acid plant is BASF of Germany

Calcium Aluminum Nitrate Process

In the CAN plant, dried and process lime are mixed with a 94% ammonium nitrate solution from the NP acid plant to achieve a homogeneous mixture. Mixing takes place at about 155 1B160 1C. The mixing tank is steam jacketed and has heating coils installed to hold the temperature constant.

The mixture flows by gravity to the granulation unit and from there to the dryer. The product is screened and on-size granules are sent to a two-stage fluidized bed cooler. They are then coated with oil/amine in the coating drum. The final CAN product contains 25% nitrogen.

The Process Licensor is UHDE of Germany.

Offsites

C	Instrument Air	7
C	Raw Water	2
C	DM Water	4
C	Steam Boilers	4
C	Power Generation 25 MW	2
C	Cooling Towers	5

3.4 Proposed Process Changes

1. *Heat Recovery from Ammonia Refrigeration Compressor Discharge Gas in Ammonia Plant* The final refrigeration compressor discharge gas is 140EC and is presently cooled in cooling water exchangers. By installing a new exchanger in which plant process air compressor turbine condensate is heated before going to the de-aerator, 7.27 mt/hr of LP steam or 5.88 mt/hr of HP steam equivalent can saved.

Steam costs:	Rs. 310/mt
Annual Savings:	
5.88 x 330 x 24 =	46,569 mt of steam/yr
310 x 46,569 =	Rs. 14,436,576/yr
	$US 461,970/yr
Estimated installed Cost of Exchanger:	Rs. 8,500,000
	$US 270,000
Payout in years	0.6

2. *Waste Heat Utilization of Waste MP Condenser in Urea Plant*. In the urea plant, overhead MP decomposer gases are absorbed in the MP condenser and cooled to about 85EC by a tempered water system using cooling tower water for cooling. The heat duty at design conditions is about 11.8 MMkcal/hr for the exchange in the tempered water system.

   It is proposed to recover this heat load by heating about 250 m^3/hr of condensate. Provisions will be made to control the inlet temperature on the tube side of the MP condenser as well as process outlet temperature. This will take care of any upsets in the urea plant. Heat savings are estimated to be 11.3 mt/hr of LP or 9.15 mt/hr of HP steam.

Total Annual Savings:	
330 x 24 x 9.15 x 310 =	Rs. 22,465,080/yr $US 718,882/yr
Estimated Installed Costs	Rs. 39,000,000 $US 1,250,000
Payout in years	1.7
IRR, Ten-year project life	56.8%

3. *Installation of Additional Tail Gas Exchange to Preheat Acid Unit Waste Heat Boiler Make-Up Water*. Presently, the temperature of the tail gas going to the tail gas turbine is higher than design limits for the turbine blading and contains excess O_2. Adding an exchange and extracting some of the heat by heating DM makeup water, will allow more air to be diverted to the ammonia/air mixer. This will not only allow heat savings, but will lower the power loading on the air compressor turbine. This modification will also result in an estimated increase in acid production of about 43 mt/d of 60% tower acid for approximately three months each year during the cooler weather.

Annual Heat or Energy Savings	$US 27,500/yr
Sales of increased acid production	
92 days @ 43 mt/d =	3,956 mt
60% acid selling price =	Rs. 3,600/mt

Less ammonia used in manufacture

.28 mt/mt of ammonia @ variable cost of Rs. 4000/mt

Acid selling price = Rs. 3,600

Ammonia cost .28 x 4,000 =	Rs. (1,120)
Profit Margin	Rs. 2,480
2,480 x 3,956 =	Rs. 9,810,880
	$US 313,948

Total Annual Savings

$313,948 + $27,500 =	$US 341,448/yr

Estimated installed cost of heat exchanger = $130,000

Payout in years	0.38 years
Payout in years (heat savings only)	4.72 years
IRR, Ten-year project life	16.5%

4. *Converting Three-Step CO Shift Conversion to Two-Step Conversion in the Ammonia Plant.* The low-sulfur high-density (LSHD) feed oil used in the ammonia process has impurities, including nickel, which are not removed in the refining process. This metals sludge is causing problems in the partial oxidation ammonia process, as it accumulates in the bottoms of the gasifiers. This results buildup on top of the CO shift converter's top catalyst beds and in the naphtha separator. As previously noted, this ammonia plant is very energy intensive for startup and shutdowns. It takes as long as six days for a cold startup. Consequently, any operational problem that causes regular shutdowns must be eliminated or minimized if this ammonia process is to be viable and competitive.

   In order to maintain pressure drop through the shift converters within operating limits, the plant has to be shut down and the slag and scale removed from the top of the top beds about once every four months. The plant is normally down for four days for the cleaning. After discussions with BASF (the technology supplier) and Linde (the contractor), it was decided to modify the process and go to a two-shift design (instead of a three-shift) by manifolding the first two converters into a parallel pass through two beds instead of a series pass. This spreads the flow of raw synthesis gas over two beds instead of one. It is projected that this will allow a year's operation between shutdowns thus saving four days of production, or about 5,400 tonnes at a rated production of 1,350 mt/d. In reality, the plant is operating at about 1,550 mt/d so the savings would be more like 6,200 tonnes annually.

   Estimated savings:

Imported ammonia @$260/mt or	Rs. 8,125/mt
Variable cost of ammonia production	Rs. 4,000/mt

Total Savings (annually) = 6200 x (8125-4000) =	Rs. 25,575,000/yr $US 818,400/yr

Note: This does not include any energy loss caused by shutdown

Estimated cost of modifications	Rs. 100,000,000 $US 3,200,000
Payout in years	3.9
IRR, Ten-year project life	22.1%

5. *Increasing On-Stream Factor from 330 days (90%) to 344 days (94%) by Installing Molecular Sieves in Air Separation Unit and Third Gasification Train.* The major energy savings in an ammonia plant, in general, will be achieved by increasing the on-stream factor to the 94% **B**95% range. When this is accomplished, energy consumption per ton of product will be reduced. While this report does not address maintenance, except in instances where it has a direct bearing on energy, this improvement will lower maintenance costs per unit of production.

   In addition to Improvement #4, (converting the CO shifts from a three-train to two-train configuration to extend the period between shutdowns to clean out slag and scale caused by metals in the feed oil), there are two other projects that should be investigated. These are in the air separation unit and a third gasifier train.

   The air separation unit is ten years old and near the design life of this fin-and-plate type exchanger (which reverses on a scheduled time period while removing CO_2 and water). Molecular sieves can perform this function and by installing them, the fin-and-plate exchangers can then perform a function of heat transfer only and not need to be reversed on a timed cycle. It is believed that this installation would extend the life of the fin-and-plate exchangers and replacement could be delayed. In addition, the capacity of the auto sequencing reversal (ASR) can be increased by replacing the existing expansion turbine with a booster and turbine combination. This installation and modification should increase the reliability and on-stream time of this unit.

   The last area for increasing reliability and the ability to extend on-stream time is at the gasifier train. Due to the problem of metals in the oil, GNFCL technical personnel designed a knock-out pot which was installed on the bottom of each gasifier. When the hot synthesis gas is water-quenched in the bottom of the gasifier, the movement of the gas results in the collection of metal, nickel, and slag in the knock-out pot. While this has aided in minimizing downstream problems, it is necessary to shut the gasifiers down on a regular basis and clean out the pots. By installing a third gasifier train, the shut down periods can be extended, thus increasing the on-stream factor and reducing energy consumption. It is estimated that by increasing the on-stream factor from 330 days to 344 days, the unit energy consumption can be lowered by 5% or about .59 MMkcal/mt of product. Production can also be increased by about 21,700 tonnes of product.

Combining these two projects with Improvement #4, the savings and payout would be as follows:

Annual Savings from unit energy reduction	
1550 x 0.59 x 344 =	314,588 MMkcal/yr
314,588 x 343 =	Rs. 107,903,680/yr
	$US 3,452,917/yr
Annual Savings on Imports	
21,700 x (8125 - 4000) =	Rs. 8,951,250/yr
	$US 2,864,400/yr
Total Annual Savings	$US 6,317,317/yr
Total Estimated Installed Cost	Rs. 800,000,000
	$US 25,600,000
Payout in years	4.0
IRR, Ten-year project life	21%

6. *Install new high-efficiency sieve trays in the urea unit reactor to increase conversion and lower recycle of carbamate solution.* Lowering the carbamate recycle reduces heat requirements in the decomposition process.

Based on proposal information, the following benefits should be achieved:

Increase in CO_2 conversion by 4%
Reduction in carbamate recycle by 15%
Decrease in steam consumption by 150 kg/mt of urea

Annual Savings:	
594000 x 150/1000 =	89,100 mt of steam/yr
217 x 89,100 =	Rs. 19,334,700/yr
	$US 618,710/yr
Estimated Cost of trays installed	Rs. 32,000,000
	$US 1,020,000

Pay out in years	1.6
IRR, Ten-year project life	60.1%

4. Indo-Gulf Fertilizer & Chemicals Corporation Limited, Jagdishpur, Uttar Pradesh

4.1 Plant Executive Summary

The Indo-Gulf Plant is located Jagdishpur, Uttar Pradesh. Fertilizers produced by the plant include ammonia and urea.

Energy sources used within the plant are oil and electricity. Oil is used to produce steam, and the steam is used to generate electricity and for process heating. The electricity is used for motors, and lighting. Good process management and maintenance tools prevail in this facility. The facility was started in November 1988 and was designed with energy efficiency in mind. Some proposed energy improvement projects are already being implemented while others do not offer sufficient payback, due to the already high efficiency at the plant. The projects achieve energy savings by elimination of down time or by recovering waste heat. The potential energy projects include:

1. Dual fuel firing of the primary reformer located in the ammonia plant
2. Installation of self cleaning type filter for gas turbines
3. Heat recovery by using gas turbine exhaust air for combustion air in service boiler

Implementation of these projects would require an investment of Rs. 85,000,000 ($US 2,720,000). An estimate of savings was not able to be reached with confidence. It is believed that these project are economically viable, and should be investigated further.

4.2 Plant Background

IGFCCL started production of ammonia and urea in November 1988. The complex consists of a 1,350 mt/d ammonia plant and two 1,125 mt/d urea plants. The ammonia plant is a Haldor-Topsoe process, while the two urea plants employ the Snam-Progetti process. Natural gas is used as a feed stock for ammonia manufacture. The urea prill tower, one of the largest in the world, is 22 meters in diameter and 75 meters in height.

Company vital information is as follows:

Number of employees	758
Corporate capital available	Rs. 973.26 Crore
Annual Sales	Rs. 408.44 Crore

To make energy efficiency investments, the plant requires a maximum three-year payback.

Meetings were held with the Manager of Process Engineering and the Senior Process Engineer. A complementary meeting was held with the General Manager of Technical Operations.

The ammonia and urea plants have good capacity utilization with the ammonia plant operating at about 1490 mt/d and the urea plants operating at about 2,500 mt/d combined. The on-stream factor is still in the range of 89% **B**90%. From the pre-assessment study, it appears that there has been an abnormal number of equipment failures which have adversely affected the plant*s ability to increase the on stream factor. The synthesis converter waste heat boiler has been replaced once, and from conversation with the technical personnel, another replacement is contemplated. There have been several other failures, small in nature, which have had an unfavorable impact on downtime and energy consumption.

Good process management and tool maintenance prevail. The ammonia plant will be equipped with Taylor Mod 300 Distributed Control System with a process computer for process control. The equipment was being installed at the time of this visit. Maintenance has a planning and scheduling function installed and a preventative/predictive maintenance program. From the pre-assessment study, it does not appear that all machinery and equipment is on preventative maintenance yet.

At the time of the visit, it was noted that the scope of IGFCCL*s energy conservation program as stated in the pre-assessment study had been revised. IGFCCL had planned to increase ammonia and urea capacity but decided against this plan instead opting to concentrate on equipment reliability, improvement of current operations, and increasing the on-stream factor. This is a good decision, since the plant has only operated a little over three years and is still experiencing start-up problems with equipment.

Although the scope has changed, IGFCCL scheduled several energy conservation projects which have either been completed or are in progress, and are expected to be completed by mid-1996.

New projects for energy reduction have been identified but not planned, because the company is concentrating on completing present projects which will achieve the greatest energy savings. Future projects will have a diminishing return as these plants house low-energy, efficient processes so that much of the energy reduction was built into the plants.

Energy Costs

Natural Gas	Rs 2.95/sm^3 Rs 2950/Msm^3 $2.67/Mcf
Naphtha	Rs. 5,012/mt @10.600 MMkcal/mt Rs. 472/MMkcal $15.13/MMkcal $3.81/MMBtu
Oil	Rs 5800/mt @9.717 MMkcal/mt Rs 596/MMkcal $19.10/MMkcal $4.81/MMBtu
Generated Electricity	Rs.763/kWh $.024/kWh
Steam Costs (Estimated)	Rs. 530/mt Rs. 608/MMkcal

Energy Projects Previously Completed or Underway

C Changing of reformer furnace tubes from existing IN 519 to Mamurite 36 XM

C Replacement of tubes in ammonia condenser from carbon steel to stainless steel for less fouling and improved heat transfer

C Replacement of tube bundles in synthesis gas compressor intercoolers for improved heat transfer

C Replacement of water coolers in ammonia synthesis loop with water on tube side for better heat transfer

C Installation of new higher efficiency sieve trays in urea reactor to increase conversion of carbamate to urea

C Heat recovery from stripped process condensate for pre-heating natural gas input to ammonia plant

C Heat recovery from stack of waste heat boiler for gas turbine in power generating plant. Plan to use this gas as combustion air to the oil-fired steam boilers.

C Installation of an on-line advance control system to control critical process parameters at optimal level as an energy saving measure

C Modification of firing system in steam superheater to enable dual firing, i.e. naphtha and natural gas, to reduce downtime.

4.3 Characteristics of the Existing Process

Ammonia Process

Natural gas is fed to the zinc oxide desulfurizers and then mixed with superheated steam, giving a steam to carbon ratio of 3.3:1, before going to the reformer furnace. In the reformer, which is a side-fired furnace with radiant burners, the gas flows over a catalyst contained in the furnace tube and is cracked to H_2, CO, argon, and a small amount of CH_4. The raw synthesis then goes to the secondary reformer, containing a nickel catalyst, where air is injected in quantity to give an H_2-to-N_2 ratio of about 3:1. The heat of reaction raises the temperature to about 1,300 1C (2,375 1F). HP steam is generated in a waste heat boiler with the exit temperature of the gas at about 380 1C (710 1F).

The raw synthesis gas, containing about 0.6% CH_4, then goes to a high-temperature (HT) and low-temperature (LT) shift converter, containing catalyst, where essentially all CO is converted to CO_2. Much heat is generated and MP steam is produced in heat recovery.

The raw synthesis gas then goes to the CO_2 removal section of the plant where CO_2 is removed in the absorber and then stripped out in the stripper tower. It is then directed to the urea unit as a feed stock. The raw synthesis gas, now containing mostly H_2, N_2 and traces of CO, $CO_{2,}$ CH_4, and argon goes to the methanator, which contains a nickel catalyst, for removal of the CO and CO_2.

The gas exiting the methanator is cooled and the moisture removed. This is completed in a knock-out suction drum of the synthesis gas compressor. The gas is essentially pure H_2 and N_2 with some CH_4 and argon. The gas pressure is raised from 24 kg/cm5 to 212 kg/cm5 (,3000 psig) in the synthesis gas compressor and, after preheating, goes to the ammonia converter containing promoted iron catalyst where the nitrogen and hydrogen are combined to form ammonia. The uncombined gas from the converter is recycled through the recycle stage of the compressor and is returned to the loop.

Heat is removed from the gas in a waste heat boiler that produces HP steam, and the gas is further cooled by heat exchangers and refrigeration to a temperature of -33 **1**C (-27 **1**F) before going to storage.

Vented purge gas from the loop, which controls the amount of inerts in the loop, contains hydrogen and, in older plants, is sent back to the reformer furnace as a fuel gas. This plant, like a lot of newer plants, has a cryogenic hydrogen recovery unit which recovers the H_2 and puts it back into the process for ammonia production. For a 900 mt/d plant, this recovery amounts to about 35 to 40 mt/d of additional ammonia production.

Urea Process

The urea plant process is a Snam-Progetti 1,125 mt/d stripping process. The Snam-Progetti urea process has been in existence since the 1960s, and while there are variations to the process, it is essentially the same between plants with only minor process changes to improve energy consumption.

CO_2 gas, along with some air for passivation, is fed directly to the synthesis reactor along with liquid ammonia and recycle carbamate solution. The pressure of the CO_2 and ammonia is increased to 156 kg/cm**5** (2200 psig) by the CO_2 compressor and HP ammonia pumps. The carbamate solution is injected into the reactor supplied by the HP ammonia pumps. The reaction of CO_2 and ammonia is exothermic and takes place rapidly, producing ammonium carbamate. With a residence time of about an hour in the reactor, about 65% **B**70% of the carbamate converts to urea.

The overhead stream goes to the stripper where carbamate is stripped and recovered, and from here the urea goes to the MP decomposer where the pressure is reduced. The decomposed carbamate and the gases go overhead to recovery while the urea from the bottom of the decomposer is sent to the LP decomposer. There the pressure is further reduced and essentially all of the carbamate is decomposed and the gases recovered. The final product of urea, a 70% **B** 75% urea product, goes to evaporation.

In evaporation, the urea is concentrated to 99.8% urea and is pumped to the top of the prill tower to the prilling basket. Prilled droplets of urea free fall through a flow of natural draft air and are cooled before reaching the bottom of the tower. The prill tower is a 22 m-(72 feet-)diameter-by-75 m (246 feet) free fall tower utilizing natural draft. This is a low-energy consuming prilling operation.

Carbon-Dioxide Recovery from Flue Gas

To supplement CO_2 requirements for urea manufacture, IGFCCL constructed a CO_2 removal system for removing CO_2 from the ammonia plant reformer flue gases. This system operates much like the CO_2 removal system in the ammonia plant but utilizes a DOW FS-1 solvent in the absorber tower.

Offsite Facilities

Raw Water Treatment Plant		1
Demineralized Water Plant		3
Instrument Air Plant		2
Inert Gas Generation Plant		1
Cooling Tower		2
Power Generation Plant	18 MW	2
Steam Generation Plant, gas/oil-fired		2
Ammonia Storage	15,000mt	1
Urea Storage	30,000mt	1
Naptha Storage	10,000 m;	1
Effluent Treatment Plant		1
LSHS Oil Storage	10,000 m;	1

4.4 Proposed Process Changes

It should be pointed out that IGFCCL has already financed major energy-savings projects which are scheduled to be completed by mid-1996. Feasibility studies have not been completed for the projects listed below, so the economics will have to be reviewed at a later date. While some of the projects appear to be backup projects to allow for continued operation of the ammonia unit in case of natural gas curtailment, internally produced ammonia is less expensive than imported ammonia. Therefore, financial assistance should be considered for these projects at a later date.

1. *Provision of Dual Fuel firing in the primary reformer of the ammonia plant so that the ammonia production level could be maintained to the design conditions during the days when natural gas supply is restricted from GAIL, the gas supplier.*

Estimated Cost	Rs. 67,812,500 $US 2,170,000

2. *Installation of self-cleaning type filter for our gas turbines*. This will reduce energy consumption caused by the down time for cleaning the turbines.

Estimated Cost	Rs. 8,750,000 $US 280,000

3. *Installation of flue gas blower for diverting the flue gases of gas turbine waste heat boiler as a part requirement of combustion air to service boiler.*

Estimated Cost	Rs. 8,437,500 $US 237,000

5. Nagarjuna Fertilizer & Chemicals Limited, Kakinada, Andra Pradesh

5.1 Plant Executive Summary

Nagarjuna Fertilizer is located in Kakinada, Andra Pradesh. The plant produces ammonia and urea fertilizers. The plant was built in 1992 and was well-designed for energy efficiency.

The primary energy source used on plant site is natural gas. Steam is generated from natural gas for process heating and electricity generation. Electricity is used for motors and lighting. The plant:s greatest potential for increasing energy efficiency is to reduce down time. Since they are still basically in a start-up mode, maintenance records which are being kept will improve predictive maintenance measures. Energy projects that the plant has planned include:

1. High-efficiency sieve trays for the urea reactor
2. Install additional ammonia converter in synthesis section

Of these two projects, #1 is developed to a greater degree. It would save 74,250 mt of steam per year. This Rs. 14,256,000 ($US 456,000) annual savings would payback the Rs. 32,000,000 ($US 1,020,000) investment in 2.2 years.

Project #2 has an estimated investment of Rs. 500,000,000 ($US 16,000,000). A projected energy cost savings is not possible until the project is developed further.

5.2 Plant Background

Nagarjuna Fertilizer & Chemicals Limited complex consists of a 900 mt/d ammonia plant and a 1,500 mt/day urea plant. The plant went into commercial production of fertilizer in August 1992. Another ammonia and urea plant of identical capacities is now under construction, along with specific offsite facilities. The plant was originally conceived to use fuel oil as feed stock but was changed to use natural gas when, in 1988, it was learned that sufficient natural gas would be available. The natural gas is delivered to the plant from the Tatipaka Gas Collection Station in the K-G basin via a 94 km pipeline.

Company vital information is as follows:

Number of employees	802
Corporate Capital Available (28.2.95)	Rs. 3285.3 Million
Annual Sales, Manufactured urea (1994-95)	Rs. 5325.5 Million
Annual sales, Total (1994-95)	Rs. 7895.4 Million

Note: Total sales include sales of traded products like pool urea, pesticides, etc.

Energy efficiency investment decisions are made through discussions by the departments concerned and consider safety, reliability, and flexibility of operation. Economics are calculated and the final go ahead decision is made depending on merits of the project.

Cost of Energy

Natural Gas	Rs. 2,450/MSM^3	@8,794 kcal/Nm^3
	\$2.22/Mcf	@988 Btu/cf
	\$2.24/MMBtu	
Steam Manufacture (HP)	Rs. 275/mt @812 kcal/kg	
	Rs. 339/MMkcal	
	\$10.83/MMkcal	
	\$2.73/MMBtu	
Electricity Generation	Rs, .732/kWh	
	\$ .023/kWh	

We met with the Manager of Process and the Senior Process Engineer. Complementary meetings were held with the General Manager of Operations, the Maintenance Manager and the General Manager of Retrofit Projects.

This complex was correctly planned and constructed from the ground up. Both the ammonia and urea units have Distributed Control Systems installed, and electronic instrumentation was designed into the system from the outset.

The ammonia plant was operating at 1260 mt/d, and the urea unit was operating at over 2,000 mt/d. Offsites include power generation, water treatment, a nitrogen plant, and steam generation boilers. NFCL is tied to the local power company grid. but the power voltage is so unstable that it cannot be utilized in the plant.

Maintenance personnel indicated that sophisticated maintenance programs are in place and include a planning and scheduling system, preventative/predictive maintenance program, and a computerized stores inventory system. Although the plant is still in a startup mode, equipment history is being generated which will allow the preventative/predictive maintenance system to positively affect the equipment reliability which, in turn, should allow for an increase in on-stream factor.

Management is aware of the need to increase the on-stream factor upwards from the current 89%–90%. There is no reason that this complex should not be operating at less than a 94% on-stream factor assuming no problems with gas supply.

5.3 Characteristics of the Existing Process

Ammonia Plant Process

The process is based on Haldor-Topsoe steam reforming, Giammarco-Vetrocoke CO_2 removal process, and Haldor-Topsoe synthesis technology with the S-200 radial flow converter.

Natural gas from the K-G basin is used for feed stock to the ammonia plant. This is a very lean gas, low in sulfur and rich in methane (CH_4). The plant requirements are about 1.3 MM Sm³/day (45.9 MMcf) which are supplied through a 94-km-long pipeline from the basin.

Natural gas feed is fed to the zinc oxide desulfurizers and then mixed with superheated steam, giving a steam-to-carbon ratio of 3.3:1, before going to the reformer furnace. In the reformer, which is a side-fired furnace with radiant burners, the gas flows over catalyst contained in furnace tubes and is cracked to H_2, CO, argon, and a small amount of CH_4. The raw synthesis then goes to the secondary reformer, containing a nickel catalyst, where air is injected in quantity producing a ratio of H2-to-N_2 of about 3:1. The heat of reaction raises the temperature to about 1,300 °C (2,375 °F). HP steam is generated in a waste heat boiler with the exit temperature of the gas at about 380 °C (710 °F).

The raw synthesis gas containing about .6% CH_4 then goes to HT and LT shift converters containing catalyst where essentially all CO is converted to CO_2. Much heat is generated, and MP steam is produced in heat recovery.

The raw synthesis gas then goes to the CO_2 removal section of the plant where CO_2 is removed in the absorber and then stripped out in the stripper tower to be directed to the urea unit as a feed stock. The raw synthesis gas, now containing mostly H_2, N_2, with traces of CO, CO_2, CH_4, and argon goes to the methanator which contains a nickel catalyst for removal of the CO and CO_2.

The gas exiting the methanator is cooled, and the moisture removed in a knock-out suction drum for the synthesis gas compressor. The gas is essentially pure H_2 and N_2 with some CH_4 and argon. The gas pressure is raised from 24 kg/cm**5** to 142 kg/cm**5** (2,000 psig) in the synthesis gas compressor . After preheating, it goes to the ammonia converter, containing promoted iron catalyst, where the nitrogen and hydrogen are combined to form ammonia. The uncombined gas from the converter is recycled through the recycle stage of the compressor and is returned to the loop.

Heat is removed from the gas in a waste heat boiler that produces HP steam and is further cooled by heat exchangers and refrigeration before going to storage.

Vented purge gas from the loop, which maintains controls the amount of inerts in the loop, contains hydrogen and, in older plants, is sent back to the reformer furnace as a fuel gas. This plant, like a lot of newer plants, has a Cryogenic Hydrogen Recovery Unit which recovers the H_2 and puts it back into the process for ammonia production. For a 900 mt/d plant, this recovery amounts to about 25-30 mt/d of additional ammonia production.

Urea Process

The Urea plant process at NFCL is a Snam-Progetti 1500 mt/d stripping process. The Snam-Progetti urea process has been in existence since the 1960s, and while there are variations to the process, it is essentially the same between plants, with only minor process changes to improve energy consumption.

CO_2 gas, along with some air for passivation, is fed directly to the synthesis reactor along liquid ammonia and recycle carbamate solution. The pressure of the CO_2 and ammonia is increased to 156 kg/cm**5** (2,200 psig) by the CO_2 compressor and HP ammonia pumps. The carbamate solution is injected by use of an ejector receiving energy from the liquid ammonia stream to the reactor supplied by the HP ammonia pumps. The reaction of CO_2 and ammonia is exothermic and takes place rapidly, producing ammonium carbamate. With a residence time of about an hour in the reactor, about 65% **B**70% of the carbamate converts to urea.

The overhead goes to the stripper where carbamate is stripped and recovered. From there the urea goes to the MP decomposer where the pressure is reduced. The carbamate that decomposes and the gases go overhead to recovery, while the urea from the bottom of the decomposer is sent to the LP decomposer. There the pressure is further reduced, and essentially all of the carbamate is decomposed and the gases recovered. The final product of urea, a 70% **B**75% urea product goes to the evaporation section.

In the evaporation section, the urea is concentrated to 99.8% urea and is pumped to the top of the prill tower to the prilling basket. Prilled droplets of urea free fall through a flow of natural draft air and are cooled before reaching the bottom of the tower. The prill tower is a 22 m diameter (72 feet) by 75 m (246 feet) free fall tower utilizing natural draft. This is a low-energy consuming prilling operation.

Offsite Facilities

100 mt/hr HP steam Boilers	2
7.5 MW Gas Turbine Generators with HRSG Boilers	2
1175 M;/hr Raw Water Pre-Treatment Plant	2
60 M;/hr DM water plant	4
Cooling Towers	2
Nitrogen inert gas plant	1
Instrument Air Compressors	2
5000 mt Atmospheric Ammonia Storage Tanks	2
25 mt/hr Bagging Lines	6
30000 mt Urea Silo	1

5.4 Proposed Changes to Process Changes

1. *High-Efficiency Sieve trays for the urea reactor to increase conversion and reduce energy consumption.* The urea unit is operating with a 58% **B**60% conversion of carbamate to urea in the reactor. New high-efficiency sieve trays can be installed in the reactor in place of the old sieve trays to improve the conversion. These new trays should allow the plant to achieve the following results:

Increase in CO_2 conversion by 4%
Reduction in carbamate recycle by about 15%
Decrease in steam consumption by 150 kg/mt of urea

Savings:
Assume: LP steam cost @ 70% of HP costs
or Rs. 192/mt of steam

495,000 x 150/1,000 =	74,250 mt of steam
192 x 74,250 =	Rs. 14,256,000 (annually) $US 456,192

Estimated installed cost of trays	Rs. 32,000,000 $US 1,020,000
Payout in years	2.2
IRR, Ten-year project life	43.5%

2. *Install additional ammonia converter in synthesis section to reduce loop operating pressure and circulation.* The original design of the ammonia unit called for an operating pressure, in the loop of the synthesis section, of 134 kg/cm5. With the increase in production rate and some aging of the converter catalyst, the loop pressure has slowly increased to about 149 kg/cm5. This increased synthesis compressor power requirement has increased energy consumption.

   It is proposed to install an additional ammonia converter in the loop which will increase conversion per pass, reduce loop pressure, and power requirements on the synthesis gas compressor. This installation should permit reducing loop pressure to about 138 kg/cm5 which will have a significant affect on power reduction in the compressor train.

   Final planning is not complete on this project, but ,at a gross estimate of Rs. 400-500 million ($US 12-16,000,000) for completion of the project, it is expected to be an economically viable project.

Glossary

atm	atmosphere = 14.7 psia
CAN	calcium aluminum nitrate
cf	cubic feet
CN	calcium nitrate
Crore	10 million
d	day
DAP	diammonimum phosphate
DM	demineralized
HP	high-pressure
hr.	hour
HT	high-temperature
IRR	internal rate of return. The intereste rate that would yield identical profits if all money were invested at that rate for the specified period of time.
kcal	kilocalories
kg	kilogram = 2.2 pounds
lakhs, lacs	100,000
LP	low-pressure
LSHD	low-sulfur, high-density
LT	low-temperature
m	meter
M	1,000
MM	million
MP	medium-pressure
mt	metric tonne
Nm^3	normal cubic meter (at 1 atm and 20 EC)
NP	nitrogen phosphate
NPK	nitrogen-phosphate-potash
ppm	parts per million
Rs.	Rupee(s)
sm^3	standard cubic meter
yr	year

Attachment A
Schematic Diagrams