Shutdown and Unproductive Energy Analysis of Ammonia Plants at IFFCO-Phulpur

IFFCO is continually striving to be the lowest energy consumer in the fertilizer industry. Continuous efforts in this direction have helped in maintaining the same. An analysis of Shutdowns in last 5 years of 2 Ammonia Plants at Phulpur has been made. The shutdown analysis helps in knowing the weaker areas of the plants. This paper elaborates in detail on the cause of failures, remedial actions taken for its rectification and measures taken on a long term basis to avoid its re-occurrence. The second part of paper deals with the unproductive Energy (GJ) spent on all shutdowns of last 4 years for both Ammonia Plants, tabulated for easy analysis. The paper elaborates the methodology, which has been developed to know the impact of any shutdown in an on-going year on Overall Energy Consumption.

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Introduction

The Indian Fertilizer Industry has come a long way since the establishment of first Super-Phosphate factory in 1906 at Ranipet (Tamil Nadu). The turning point in Indian Agriculture Sector was the introduction of HYV (High Yielding Varieties) seeds of wheat and rice in mid-sixties. The expansion in area of land under cultivation and switchover to HYVs seeds led to a remarkable growth in fertilizer use and crop production.

Subsequently with the aid of government policies for fertilizer production India became self-sufficient in food grain production. Today, fertilizers have become an essential input to Indian Agriculture for meeting the food grain requirements of the growing population of the country. Fertilizer Industries have a mammoth task of providing essential nutrients to Indian farmers so that the growth in the agricultural sector is sufficient for meeting the domestic food front.

Implications of Feedstock and Energy

Main feedstocks used for manufacture of Urea in India are Natural Gas (65%), Naphtha (25%) and Fuel Oil (10%). Because of shortage of gas supplies to gas based Urea plants, many units are operating on mixed feed options wherein naphtha is used along with gas through Pre-Reformer System, which results in higher cost of production.

Improving Reliability of Ammonia-Urea Plants

A significant factor, which is most important in improving productivity, is plant reliability. Plant reliability is measured in terms of improvement in on-stream days. All other parameters in operation of plant meet, finally at reliability. Plant reliability determines directly profitiability, safety and environmental performance.

An Ammonia-Urea Complex is a high energy and capital-intensive industry. Therefore, higher reliability and better energy efficiency is the key to its competitiveness.
Use of cheaper and better feedstock

The type of feedstock has a major influence on energy consumption in an Ammonia-Urea Plant. Hydrogen to carbon ratio increases as we move from liquid hydrocarbons (naphtha, fuel oil) to gaseous hydrocarbons (Natural Gas). Besides, associated impurities namely sulphur, etc. are present only in traces in case of gas.

With the steep rise in the cost of liquid hydrocarbons in the last five-to-six years, Ammonia-Urea production from liquid hydrocarbons plants has become very costly. Keeping this in view, one of the main guidelines provided under the New Policy was that all such plants should switchover to NG/RLNG (Regasified Liquid Natural Gas) so that they can also become viable and compete in the business of Urea manufacturing.

Efforts made at IFFCO-Phulpur in Meeting the Challenges

Indian Farmers Fertilizer Cooperative Limited (IFFCO), globally acclaimed cooperative in fertilizer production and marketing has been striving for socio-economic upliftment of the rural population of India since inception. To ensure timely availability of quality fertilizers to the farmers, IFFCO came into being on 3rd November 1967. Initially, IFFCO commissioned Kalol and Kandla plants in Gujarat in early 1975. Subsequently, the society expanded its base by building two more plants at Phulpur and Aonla in Uttar Pradesh in the years 1981 and 1988 respectively. Subsequently the capacity of all these four units has been increased, either by installing new plants at the existing site or by revamping the existing plants. Last year, it acquired the DAP/NPK unit at Paradeep in Orissa having an annual capacity to produce 1.9 million tonne of NPK/DAP. The marketing of IFFCO’s products – NPK/DAP/UREA – are channeled through 37,500 member cooperative societies and 158 Farmers Service Centers in over 28 States / Union Territories in the country. IFFCO along with a joint venture partner, Oman Oil India Company (OOC) has set up Oman India Fertilizer Company (OMIFCO) at Sur in Oman with annual capacity of producing 1.65 million tonne, of Urea. IFFCO launched another company Indo-Egyptian Fertilizer Company (IEFC), a joint venture with El Nasr Mining Company (ENMC), for setting up a Phosphoric Acid Plant in Egypt. Also IFFCO has signed a MoU with Jordan Phosphates Mines Company (JPMC) for setting up a Phosphoric Acid Plant in Jordan with investment of US $ 570 million.

IFFCO-Phulpur Unit is located at Phulpur, Allahabad in the state of Uttar Pradesh. It has been the world’s largest naphtha based Urea complex; consuming one full naphtha rail wagons train (A rake of 2200 t) daily. Both of its units have been performing well since beginning. Unit–I started its commercial production in March, 1981 and has a 977 metric tonne per day (MTPD) ammonia plant, 1670 MTPD Urea plant, three coal fired boilers having 125 MT/hr capacities each and 12.5 MW Turbo-Generator.

The Second Unit started commercial production in December, 1997 and consists of a 1520 MTPD ammonia plant, two streams of 1310 MTPD Urea plants, a FO fired boiler of 200 MT/hr and 18 MW Turbo-Generator along with other offsite facilities

The Ammonia-Urea complex at Phulpur has been based on naphtha since inception when cost of naphtha was quite low. The Phulpur Unit has been performing well with the help of effective and efficient operation and maintenance practices. Specific energy consumption per MT of ammonia produced in Unit-I was initially at 10.2 GCal/MT (36.7 MMBtu/short ton on LHV basis) and is now being operated at 8.6 (31.0 MMBtu/ton) later. Specific energy consumption per MT of ammonia in Unit-II was 7.8 GCal/MT (28.1
MMBtu/ton). The energy difference was due to the technological difference between the vintages 1976 plant compared to the more modern 1994 plant.

Realizing the importance of improving the productivity of the complex, IFFCO had initiated the following main projects in the year 2004 to 2006 in a phased manner:

A. Energy saving Projects (ESP) in all 5 Ammonia Plants
B. RLNG (Re-gasified Liquid Natural Gas) Conversion at Phulpur
C. Installation of CDR (Carbon Dioxide Recovery plant) at Phulpur & Aonla

All activities pertaining to Energy Savings Project (ESP) RLNG Conversion and Installation of CDR have already been successfully completed.

All the above steps were in line with new policy of Government of India on fertilizer to improve the productivity of plants by way of reduced energy consumption, change over to cheaper feed stock NG to reduce the cost of production and thereby reduction in subsidy.

A) Ammonia 1 Plant Shutdown Problems:

1) Damage in CO₂ Section Semilean Solution Take Off Tray:

The plant was started after taking up the jobs of ESP and LNG conversion. CO₂ removal system revamp was also carried out from UOP LO heat Benfield system to Gianmarco Vertrocoke (GV) system. Modifications were carried out in all the three towers (1 Absorber & 2 Strippers). The plant was running normal and CO₂ slip from absorber was around 300 ppm and Fraction conversion (F_C) for all the three rich, lean & semi lean solutions was within the range. After 9 months of operation CO₂ slip from absorber started going high also F_C of semilean solution was high. Level of semilean solution in LP stripper was going low and it was not possible to control it even after increasing the rich solution and lean solution flow. On 20.04.07 the plant was running at a load of around 1045 MT ammonia per day, CO₂ slip from absorber started increasing and went up to 500 ppm and F_c of lean solution reached 0.35 as against normal value of 0.40. The plant was shutdown and the LP stripper & HP strippers were opened.

In LP Stripper modifications were carried out during ESP and semi lean solution take off tray was modified. Also a new nozzle was connected above the tray with a Y type distributor from HP to LP regeneration for semilean solution flow.
DETAILS OF CHIMNEY

The riser opposite to inlet nozzle was found broken. This was causing semi lean solution flow to enter in the bottom section, which was creating a problem in controlling the levels, and fractional conversion (Fc) of semilean was high. Also cracks were found in the down comer areas of the HP stripper.

In both the Strippers re-inforced pad welding was carried out. Also to give extra support to risers, all the four risers were joined together with steel angle braces. After the repair job both the strippers were closed and the plant was placed in operation. Since then after 11 months of operation there has been no problem.

2) Vibration in Gear Box of Air Compressor (101-J)

On 17.02.06, the plant was operating at a load of around 965 MTPD. At around 16:30 hrs the plant was tripped due to high vibration of the gearbox housing of the air compressor (101-J). The plant was shutdown and 101-J was handed over to mechanical maintenance for inspection. The gear box was opened and the following damage was found: a damage in the gear teeth, a dent in the pinion, damage of one radial bearing of the gear (LP side) and a dent observed at thrust bearing parts of the gear working HP side (Refer figure). Therefore, the gear pinion, all four bearings (radial & composite) and one thrust bearing of the gear (working side) were replaced. Plant was again started and since then there is no such occurrence.
3) Leakage in Primary Shift Effluent Heat Exchanger (103-C)

On 7th November 2005, the plant was shutdown because of a leakage in Primary Shift Effluent Heat Exchanger (103-C) inlet channel cover dome. The gas from the high temperature shift converter enters the tube side inlet of this waste heat boiler and gives heat to the boiler feed water coming from a steam drum. On observation it was found that there were circumferential cracks (refer diagram) in the weld seam of the dome of 22 mm thick of material SA 204 Gr. B connected to the neck flange (material SA 182 Grade Gr. F1.). The cracks were found because of ageing over a period of more than 25 years. The following sequence was followed for the repairs:

i) NDT was carried out for determining the extent of damage.

ii) De-hydrogenation of the affected area was done by electrical heating up to a temperature of 375 deg C (707 Deg F) and held for 8 hours.

iii) Removal of cracked material and weld joint preparation was done. A double V joint was a preferred weld joint as it can be welded from inside also after back grinding).

iv) Preheating and its maintenance: A preheat of 150 deg C (302 deg F) was maintained during welding by electrical heating coils wrapped round the affected area and covering min 8 inches (203_mm) on both sides of the weld.

v) Welding: SMAW process was used for a double V joint while GTAW and SMAW process was used for single V joint. Electrode for SMAW used was 4 mm E7018-A-1 and filler wire for GTAW was ER 70S-1B.

Post heating to 300 deg C (572 deg F) was carried out after final welding but before cooling to room temperature.

vi) NDT after Welding and PWHT: Dye Penetrant test of the completed weld joint and adjacent areas was done. Radiography of the new weld joint was done (in a subsequent inspection after one year it was found normal). The repair was carried out successfully and the plant was restarted after a shutdown of about 8 days. As a long term measure the inlet channel dome as well as outlet channel dome of improved metallurgy 1 ¼ Cr. ½ Mo P11 material has been procured and was replaced in April 2008 Annual shutdown.

4) Leakage in LT Shift Converter Exchanger (112-C)

The gas from LT Shift converter at 256 °C (493 deg F) is cooled in this exchanger and the temperature of LT shift converter inlet is maintained with a hot by-pass around this exchanger. The shutdown because of the failure of this exchanger resulted in a loss of about 12 days. On observation it was found that failure was due to leakage of the tubes. The boiler feed
water, which is on shell side, gets heated so as to generate low-pressure steam. The shift effluent gas is on the tube side with 560 tubes of 1” size. The failure was suffered due to corrosive stagnant boiler feed water, which had resulted in pitting and cracks in the tubes. All tubes of material CS A178 were replaced with new tubes and thereafter there have been no cracks or failure.

B) Ammonia 2 Plant Shutdown Problems:

1) Reformer Tubes Failure

Plant was started on 26.04.06 after attending a cooling tower failure. After starting the plant there were frequent interruptions due to tripping of the gas turbine (GT) on loss of flame and the plant was to be started frequently. The LNG conversion job was also carried out very recently. On 16.5.06 too, there was tripping of GT on loss of flame and trip interlock (IS-2) got activated i.e. air to secondary reformer was cut. Venting of process feed gas was done at the CO2 Section (GV - Gianmarco Vertrocoke) inlet. Since the LNG conversion was carried out very recently by mistake, the control valve PV-8 was opened, which is provided for transferring the gases to the flare in case feed is to be cut to the reformer. PV-8 is situated after R-3202 (Secondary Desulphuriser), though the feed was cut to the reformer, fuel firing to the reformer was not stopped since the trips (Low feed to reformer, low steam flow to reformer) were bypassed. Since the plant was getting frequently tripped most of the interlocks were bypassed which is a usual practice during start-up. Therefore since the interlocks were bypassed plant continued running and fuel firing continued though the feed was cut. This resulted in excessive rise of temp in primary reformer and the flue gas temperature at the outlet of radiant section i.e. before mixed feed coil went up to 1200 °C (2192 deg F). This resulted in failure of few tubes due to excessive heating. The plant was stopped immediately. After inspection 22 tubes were found damaged and were replaced. Few tubes were also found weak but could not be replaced because of non-availability. The plant was again started on 29.5.06; the process gas outlet temp from the reformer was kept at 745 °C (1373 deg F) instead of the designed temp of 769 °C (1416 deg F) to avoid chances of tube failures, since thorough inspection of all the tubes could not be carried out. During April 2007 S/D all reformer tubes gauging and scanning was carried out. A total of 35 of tubes (14 in AB chamber and 21 in CD chamber) were found weak and were replaced. It is planned to replace the balance of all tubes during the May 2008 shutdown.

2) Partition Plate problem in Steam Super heater (E-3208)

The HP Steam Superheater (E-3208) is a vertical tube bundle heat exchanger with 2 shell & 2 tube pass configuration with reformed gases in the shell side and HP steam in the tube side. The service of this superheater is to superheat the steam generated inside the plant from the Syn. loop boiler and RG Boiler. The steam is superheated from the reformed gases (RG) coming out of RG boiler. Thereafter reformed gases are sent to High Temp. Shift inlet and partially superheated steam goes to the LT coil and HT coils located in convection zone of primary reformer for further superheat.

The design inlet temp. of reformed gases to E-3208 is 594 °C (1101 deg F) while the outlet temp. is 350 °C (662 deg F). The HP Steam
inlet temperature is 324 °C (615 deg F) and the outlet temperature is 438 °C (820 deg F).

In the year 2004-05 it was observed that the HP steam temperature outlet of E-3208 was low i.e. in the range of 420-425 °C (788-797 deg F) while the outlet temperature of reformed gases was high i.e. in the range of 360 °C – 365 °C (680-689 deg F). This problem continued even after making some major operational changes. On 16.05.04 the plant was shutdown to open E-3208 and rectify the steam superheat problem. After opening the equipment it was found that the partition plate separating the tube side inlet into two shells was in broken (loose) condition, resulting in bypassing of steam which was creating low temperature of superheated steam and high temperature of reformed gases.

The partition plate was repaired and the plant was again started on 29.12.2005. Since then the plant has operated without recurrence of this problem.

3) Problem of corrosion in LNG LT coil in Ammonia-II

LNG Coil (E-3233B) was installed in the primary reformer convection section just before the ID fan. During inspection corrosion was observed.

Possible reason for corrosion may be:

Sulphur corrosion since the stack temperature was as low as 110-112 °C (230-233.6 deg F). Though the LNG is being used as fuel for reforming in which sulphur content is nil but sulphur ingress may happen from the hydrotreater off gases because some quantity of naphtha was used in the feed along with LNG. The following table shows the acid dew point vs. SO₃ in flue gas.

<table>
<thead>
<tr>
<th>SO₃ (ppm)</th>
<th>Dew point °C (deg F)</th>
</tr>
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<tbody>
<tr>
<td>0.5</td>
<td>108 (226.4)</td>
</tr>
<tr>
<td>1</td>
<td>114 (237.2)</td>
</tr>
<tr>
<td>2</td>
<td>118 (244.4)</td>
</tr>
<tr>
<td>5</td>
<td>122 (251.6)</td>
</tr>
<tr>
<td>10</td>
<td>125 (257.0)</td>
</tr>
</tbody>
</table>

The primary reformer stack analysis shows a SO₂ content in flue gases less than 1 ppm. Therefore there are chances of acid corrosion. The stack temperature should be kept at more than 114 °C (237 deg F).

Another reason may be due to water condensation on the surface. The LNG supply temperature during summer is between 35-40 °C. (95-104 deg F). In winter when ambient temp. is low the LNG supply temp. to E-3232 B was observed as 17 °C (62.6 deg F). This may lead to low metal temperature of the tube skin. The dew point of water is 56 °C (132.8 deg F) at this flue gas composition and pressure. There may be condensation of water at the surface.
near the inlet since at that point tube skin
temperature, may be lower than 56 °C (132.8
deg F).

To avoid such problems the stack temp. is
maintained above 115 °C (239 deg F) and also a
LNG preheating system has been installed.

4) Leakage in RG Boiler (E-3206) in
Ammonia-II

After shutdown of the Ammonia-II plant, the
manholes on the gas inlet and outlet side of the
reformed gas waste heat exchanger (E-3206)
were opened and the boiler was ventilated.

The observations are listed below:

Gas Inlet Channel:

The refractory lining was found damaged in
some places. The tubesheet protection shield
and refractory was found damaged severely at
the bottom of the tubesheet, due to water/steam
jets from the tube to tubesheet weld leaks.
Leaks from 2 tubes were observed after removal
of the castable refractory.

Gas Outlet Channel:

No damage and/or irregularies were found on
the chamber walls.
No obvious damage and/or tube-to-tube sheet
weld leaks were noted.
No damage and/or irregularies were found on
the bypass valve internals. One plug was found
leaking.

Testing carried out:

NDT (PT) of the inlet tube sheet revealed severe
tube sheet ligament cracking at the 7'o' Clock
area.
All tubes were RFT (Remote Field Eddy
Current Test) tested, two tubes were found to
have obstruction of their inner diameter.

Metallographic examination was performed on
the gas inlet tube sheet and the tubesheet
material was found usable.

Possible reason of tube sheet damage:

In the RG Boiler in both the hot and cold
channel side tube sheet material used is F-12
(1Cr \( \frac{1}{2} \) Mo). The tube-to-tube sheet welding is
done on the inner side. Ferrules have been
inserted at the inlet of tubes. The tube sheet has
a refractory coating. When tube started leaking,
BFW from shell side where the pressure is
12749 kPa (130 kg/cm\(^2\)) started entering into
tubes where the pressure in only 3040 kPa (31
kg/cm\(^2\)). This high-pressure water damaged the
ferrules and refractory & the tube sheet were
exposed to hot gases of 975 °C. The material of
tube sheet is P-2, which is not suitable for such
a high temperature. The material for this high
temperature should be P-11 (1.25 Cr, \( \frac{1}{2} \) Mo),
Therefore cracks developed on the hot channel
side.

WELDED TUBESHEET

Observations to find the leakage:

1. When BFW has leaked into the process
gas side, the temperature at the outlet of
RG Boiler reduced. (from 496 °C to 475
°C) The steam generation was same 157
MT/h.
2. To maintain the same steam generation
from the RG Boiler, BFW flow should
increase.
3. Extra Condensate from process gas separates in Separator (B-3302) before entering into GV section.

4. Condensate finally goes to the PC (Process Condensate) stripper. Therefore the condensate to CPU (condensate polishing unit) should also increase.

The possible reason for the tube leak was due to phosphate deposition on tubes as per Babcock Borsig, supplier of the boiler. The tube sheet was repaired and leaking tubes were plugged. After that the plant was started and since then there has been no recurrence of problem.

5) Leakage in downstream of control valve (35-TV-49) in by pass line of Syn. Loop Boiler (E-3531) in Ammonia-II

A new Topsoe single bed S – 50 converter (R-3502) was installed under the energy saving project of Ammonia-II. A new HP horizontal boiler was also installed to utilize the reaction heat

Recycle gas and make-up gas after compression in 4th stage of synthesis compressor enters into old converter (R-3501). Here the ammonia reaction takes place. Ammonia concentration outlet of R-3501 is around 19% and the temperature rises up to 440 °C. These gases are sent to the new HP boiler E-3531, for generating HP steam. Thereafter gases are sent to the new S-50 converter for further conversion. The outlet ammonia concentration from the S-50 is around 24%. The temperature is around 410 °C (770 deg F). These gases are sent to the old vertical Syn. Loop boiler (E-3501) for HP steam generation. Thereafter the gases are sent to series of chillers and finally to ammonia condenser E-3501 and separator to separate ammonia. Vapors are recycled back to Syn. gas compressor.

To control the inlet temperature of the S-50 converter a hot by-pass is provided. This is done by the help of control valve TV-49. If the temperature is high it opens and bypasses the gases to E-3531 and if too low it closes and more gases are sent to S-50 converter.

After a few months of operation a leak was found in the elbow weldolet near the weld joint of the drain point. The reason for the leak was investigated.
It was found that the material downstream of the control valve was P-22 as recommended by HTAS, however the material up stream of control valve was SS-347-H. The material was kept P-22 since this line is coming out of E-3531 after exchanging heat and the temperature will be lower, however the bypass of this boiler is also provided therefore there is the possibility of higher temperature downstream of the control valve for which material P-22 is not suitable.

6) Cooling Tower Failure in Ammonia-II Event:

On April 11, 2006, the East side of the seven (7) cell Induced Draft Cooling Tower serving IFFCO-Phulpur Ammonia-II plant collapsed; forcing the 1520 MTPD Ammonia Plant and the 2620 MTPD Urea Plant, out of service.

Cooling Tower Collapse

The Cooling Tower consisting of seven (7) cells supplies the complete requirement of cooling water to the Ammonia-II plant and was constructed by M/s Paharpur Cooling Towers Ltd. in 1997. On April 11, 2006 at around 11:20 hrs. the entire East side fill sections of the tower including the nozzle deck of the cooling tower covering the seven cells collapsed along with hot water distribution header. West side nozzle deck, distribution header & all fans, along with its structure of the cooling tower remained intact. The circulating water flow & header pressure to ammonia plant before collapse was steady at 19700-m³/hr (86736 GPM) (nearly 80 % of the tower’s rated capacity) and 3.2 kg/cm².
(45.5 psig) respectively. All seven fans were in service on the tower. The ammonia plant production had been lined up after the annual turnaround only a few hours prior to this incident. The plant load was around 60 % at the point of time. The weather was sunny, mild with normal winds. No storms were present. The cooling tower operator heard a loud sound and observed the collapse and “flood” situation in the area of the ammonia tower when the east side riser pipe separated at the ground level welding joint. Immediate shutdown of the tower was taken by stopping both the pumps & all fans.

**Background:**

The ammonia cooling tower is an induced draft cross flow type system having seven (7) cells with 2 hot return water distribution decks, one on each side. The cooling tower was in operation since 1997. The design capacity of CT is 24500 M3/Hr (107870 GPM). The tower is designed to cool 24500 m³/hr of cooling water flow from 43.5 ºC to 33.5 ºC (110.3 deg F to 92.3 deg F) at a wet bulb temperature of 29 ºC (84.2 deg F) i.e. 10 ºC (50 deg F) range and 4.5 ºC (40.1 deg F) approach. The structural material of the tower is treated Pine timber. PVC ‘V’ bar fill is supported by glass reinforced polyester (GRP) grids and is oriented perpendicular to the airflow. The cross section of the main supporting structural columns is 4” X 6” and 4” X 4“. Columns of size 4” X 6” are used under the hot water distribution pipe > 36 “ size. The louvers and tower end wall casings are constructed of corrugated asbestos cement board material.

Supply of cooling water to the Ammonia Plant is through 2. C.W. Pumps each has a capacity of 10500 M³/hr (46230 GPM) each driven by a 1570 kW motor. All original solid GRP blade fans were replaced with efficient hollow FRP (Fibre Reinforced Plastic) blades, which reduced fan power consumption by 20 % at design airflow. The normal operating load on each fan was 62 kW connected on 82 kW motors.

Total Length of C.T. = 85.55 Meters.
Width of C.T. = 22.08 Meters.
Total Tower Height = 16.79 Meters.
Louvers Height = 10.97 Meters.

**Cause of failure**

Possible causes of collapse are:

- Sudden release of huge quantity of Process gas.
- Water hammering.
- Shearing of pipe due to thinning.
- Sudden failure of Main Supporting Wooden Columns.

None of the exchangers in the ammonia plant were found leaking. Hence, the possibility of a sudden release of process gas was ruled out. As the plant was running consistently without any change in the cooling water flow and pressure the possibility of water hammering was also ruled out. As the hot water return riser & distribution pipe have sufficient thickness, sudden shearing of pipe cannot take place. Hence, the possibility of a sudden shearing of pipe was also ruled out.

The root cause of failure was the sudden failure of main supporting wooden columns of the tower. This might have resulted in breaking of hot water distribution header leading to collapse of fill sections of the tower due to hydraulic load and mechanical impact. The failure of supporting wooden columns is due to decreased strength and durability of timber. This fact is evident from many subsequent collapses taken place in the fertilizer industry.
Tower Reconstruction

As the procurement of tower material for fallen tower structure, fills, connectors, jointing material & its erection take longer time; our immediate plan of action was quick resumption of plant production. The total job of rebuilding of the fallen tower was divided into three phases.

- Checking healthiness of west side of cooling tower & modification of hot water distribution header to place them at ground level to reduce the operating load on tower deck. Wooden load members on west side were in better shape as compared to east side.
- Providing interconnections with the adjacent urea-cooling tower so that part of the hot water from ammonia plant can be cooled in urea cooling tower.
- Reconstruction of the fallen east side seven cells, keeping the healthy west side-cooling tower in operation.

Tower Reconstruction Program:

The tower manufacturer was called immediately to assess the damage & material required for reconstruction of the fallen east side 7 cells. The bills of quantities were finalized & orders placed for reconstruction material within 2 days after collapse. The fallen hot water distribution header in the basin had been cut at three places taking precautions to prevent fire in the fallen debris. With the help of a crane, the distribution header was removed from the basin debris. Fallen wood, fill sections, asbestos louvers and other debris were removed in four days time. The first lot of wooden structural material was received from Paharpur, Kandla works on April 20, 2006. By working round the clock, with 100 workmen from Paharpur & 50 workmen from IFFCO, reconstruction work of all the east side 7 cells was completed on May 29, 2006. Ammonia-II cooling tower was successfully and safely restored to its full operational capacity within 48 days occurred.

C) Unproductive Energy Analysis of Ammonia Plants

There are two ammonia plants at IFFCO Phulpur. The on-stream days and capacity utilization of both ammonia plants of the last 5 years have been tabulated.

**Ammonia-I Plant: Annual plant capacity 322400MT (977 MTPD x 330 on-stream days)**

<table>
<thead>
<tr>
<th>Year</th>
<th>Available Days</th>
<th>On-Stream Days</th>
<th>Cap. Util. %</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003-04</td>
<td>366</td>
<td>325.4</td>
<td>102.4</td>
</tr>
<tr>
<td>2004-05</td>
<td>365</td>
<td>337.1</td>
<td>104.3</td>
</tr>
<tr>
<td>2005-06</td>
<td>365</td>
<td>314.5</td>
<td>99.3</td>
</tr>
<tr>
<td>2006-07</td>
<td>365</td>
<td>324.5</td>
<td>105.9</td>
</tr>
<tr>
<td>2007-08</td>
<td>366</td>
<td>340.6</td>
<td>116.6</td>
</tr>
</tbody>
</table>

**Ammonia-II Plant: Annual plant capacity 501600MT (1520 MTPD x 330 on-stream days)**

<table>
<thead>
<tr>
<th>Year</th>
<th>Available Days</th>
<th>On-Stream Days</th>
<th>Cap. Util. %</th>
</tr>
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<td>96.2</td>
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<td>365</td>
<td>328.7</td>
<td>99.0</td>
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<td>365</td>
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<tr>
<td>2006-07</td>
<td>365</td>
<td>316.2</td>
<td>100.9</td>
</tr>
<tr>
<td>2007-08</td>
<td>366</td>
<td>329.5</td>
<td>103.7</td>
</tr>
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</table>

The unproductive energy Gcal (MMBtu) spent each year on all shutdown has been given in Table 1 for easy analysis. Apart from the annual turnaround, the unproductive energy consumed in each interruption/shutdown has been added in that particular year.

As the energy cost is becoming exorbitant, there is more awareness on reducing energy consumption not only on continuous operation but also to reduce unproductive consumption.
during any interruption/shutdown. Now the need is to monitor ammonia plant energy in a break-up of 2 constituents, the productive continuous basis in Gcal/MT and a sum of total unproductive consumption of all shut-down period in Gcal but to be divided by annual capacity of the plant. In this way at any point of time energy of plant will give true reflection of energy and monitoring will be far easier. The continuous operational energy is to be monitored with design/expected energy. The unproductive energy is also to be monitored so as to know the improvement areas where reliability of the plant.

To illustrate the above point, energy of Ammonia I and Ammonia II plant of last 4 years is reported in 2 constituents. The analysis trend of productive energy is carried out separately and the unproductive energy consumption of each year is done separately.

**Analysis of Ammonia-I Plant:**

As it is evident the productive energy 8.429 Gcal/MT (30.34 MMBtu/ton) in last year 2007-08 has been reduced by 17.3% as compared to base energy of the year 2004-05. The reduction in energy has been due to energy savings project and changeover of feed switch from naphtha to LNG. There has also been a reduction of 48% in unproductive energy. The contribution of unproductive energy has been 0.127 Gcal/MT (0.46 MMBtu/ton) in last year 2007-08 as compared to base unproductive energy 0.245 Gcal/MT (0.88 MMBtu/ton in the year 2004-05. The reduction in unproductive energy is due to decrease in no. of interruptions as there has been improvement in reliability in continuous operation of plant. Also consumption of raw materials in each downtime is closely monitored, including the measures taken for reducing the downtime itself.

**Methodology Developed to Analyze Unproductive Energy:**

A term AUE i.e. Annual Unproductive Energy has been evolved in order to analyze unproductive energy. 1 AUE of a plant in GCal is termed to be equal to its annual production capacity divided by 10. Thus at Phulpur-I it is equal to 322400 / 10 = 32240 GCal and for Phulpur-II it is equal to 501600 / 10 = 50160 GCal. A plant normally should aim for consuming in a year unproductive energy less than 1 AUE. All interruptions and annual shutdown and start-up should be calculated in terms of AUE. This will help in monitoring all unproductive consumptions in a year and also help in knowing the impact of all such shutdowns on Yearly Energy.

Detailed analysis of energy for the Year 2007-08 has been done. The yearly operation can be summarized: there was unproductive energy consumption due to initial shutdown in April 2007. Thereafter there was 1 more interruption. And finally the plant was stopped on 15th March 2008 on completion of yearly target. The weekly and yearly energy has been tabulated in the chart. The yearly energy initially after 1st interruption was 9.0 GCal/MT, (32.4 MMBtu/ton) while daily energy was 8.3 GCal/MT. The yearly energy came down before second shutdown to 8.7 GCal/MT (29.9 MMBtu/ton). But after shutdown it increased again to 8.8 GCal/MT (31.7 MMBtu/ton). Finally before final stopping of plant on 15th March 2008 it decreased up to 8.53 GCal/MT (30.7 MMBtu/ton) but due to unproductive consumption during stopping it again increased to finally 8.556 GCal/MT (30.8 MMBtu/ton). The unproductive consumptions during the total year were three: i) In April 2007 it contributed for 16500 GCal which is 0.051 Gcal/MT (0.18 MMBtu/ton) as it has been derived by dividing it by annual capacity (322410 MT) Thus we can call it 0.51 AUE (Annual Unproductive Energy).

ii) Similarly due to second interruption the loss was 24200 GCal which is 0.075 Gcal/MT (0.27 MMBtu/ton). Thus we can call it 0.75 AUE.
iii) Unproductive consumption from 16th Mar. to 31 Mar. '08 has been 7185 GCal which is 0.022 Gcal /MT (0.08 MMBtu/ton) or 0.22 AUE.

If the effect on energy due to interruption is separately accounted for in the yearly energy than it becomes very simple to know not only the right energy at any point of time but also the quantum of energy consumed due to that particular interruption.

**Analysis of Ammonia-II Plant:**

As it is evident the Productive Energy 7.753 Gcal/MT (27.9 MMBtu/ton) in last year 2007-08 has been reduced by 1.8 % as compared to base energy of the year 2004-05. The energy last year is not the lowest as in the year 2005-06 it was lowest and thereafter there has been problem in Primary Reformer and for safe operation at reduced firing the methane slip has been high. The shutdowns contributing to higher energy have already been covered in the beginning.

**Conclusion**

The shutdown analysis is very important as it reveals the weak points in the plant where attention is required in order to improve the reliability. Also the tool developed for monitoring unproductive energy of the plant shall help in correctly analyzing all interruptions besides knowing accurately both the constituents Productive and Unproductive Energy separately.

### TABLE-1

**Ammonia-I Plant**

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Ammonia Production (MT)</td>
<td>336168</td>
<td>320248.8</td>
<td>341389.7</td>
<td>375861.4</td>
</tr>
<tr>
<td>Productive Energy Gcal/MT (MMBtu/ton)</td>
<td>10.0989 (36.36)</td>
<td>9.8410 (35.43)</td>
<td>9.1381 (32.90)</td>
<td>8.4290 (30.34)</td>
</tr>
<tr>
<td>Unproductive Gcal</td>
<td>82438.8</td>
<td>72558.7</td>
<td>51655.2</td>
<td>47885</td>
</tr>
<tr>
<td>Unproductive Gcal/MT (MMBtu/ton)</td>
<td>0.2452 (0.88)</td>
<td>0.2266 (0.82)</td>
<td>0.1513 (0.54)</td>
<td>0.1274 (0.46)</td>
</tr>
<tr>
<td>Total Energy Gcal/MT (MMBtu/ton)</td>
<td>10.3441 (37.24)</td>
<td>10.0676 (36.24)</td>
<td>9.2894 (33.44)</td>
<td>8.5564 (30.80)</td>
</tr>
</tbody>
</table>

**Ammonia-II Plant**

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Ammonia Production (MT)</td>
<td>496783.8</td>
<td>516240.2</td>
<td>506171.6</td>
<td>519950.0</td>
</tr>
<tr>
<td>Productive Energy Gcal/MT (MMBtu/ton)</td>
<td>7.7517 (27.91)</td>
<td>7.5457 (27.16)</td>
<td>7.7238 (27.81)</td>
<td>7.6163 (27.42)</td>
</tr>
<tr>
<td>Unproductive Gcal</td>
<td>34179.7</td>
<td>24115.5</td>
<td>89522.44</td>
<td>69673.3</td>
</tr>
<tr>
<td>Unproductive Gcal/MT (MMBtu/ton)</td>
<td>0.1017 (0.37)</td>
<td>0.0753 (0.27)</td>
<td>0.2622 (0.94)</td>
<td>0.1367 (0.49)</td>
</tr>
<tr>
<td>Total Energy Gcal/MT (MMBtu/ton)</td>
<td>7.8533 (28.27)</td>
<td>7.6210 (27.44)</td>
<td>7.9860 (28.75)</td>
<td>7.7530 (27.91)</td>
</tr>
</tbody>
</table>
Ammonia I

GCal / MT of Ammonia

Energy (Total)  Energy (Productive)

CHART-2

Ammonia -I : Unproductive Energy

Unproductive Energy

Baseline AUE : 1.0

Unproductive GCal

AUE

Years


82438.8 72558.7 51655.2 47885

2.58 2.27 1.61 1.49
CHART-3

Ammonia-II

- GCal / MT of Ammonia
- Energy Total
- Energy (Productive)

CHART-4

Ammonia -II : Unproductive Energy

- Unproductive GCal
- AUE

Baseline AUE : 1.0

Unproductive GCal

Years

AMMONIA TECHNICAL MANUAL 2008