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# "ENERGY CONSERVATION MEASURES : ENERGY AUDIT, PROCESS OPTIMIZATION"

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Ruwais Fertilizer Industries (FERTIL) a été constitué par Décret Amiri le 15 octobre 1980 en tant que projet commun entre Abu Dhabi National Oil Company (ADNOC) et Total Fina Elf. Son objectif est d'utiliser le gaz résiduaire fourni par ADNOC pour produire des engrais et les commercialiser sur les marchés locaux et internationaux. La répartition des actions de la société est ADNOC 66 $^{2/3}$ % et Total Fina Elf 33 $^{1/3}$ %.

Implanté sur la zone industrielle de Ruwais, sur la côte du golf d'Abu Dhabi City, le complexe FERTIL d'unité d'ammoniac et d'urée a une capacité théorique de 1 050 t/j et 1 500 t/j respectivement. Le complexe comprend aussi des installations d'utilités, pleinement intégrées, de stockage, chargement et expédition. La construction de l'usine a commencé en novembre 1980 et le complexe a été réceptionné fin 1983.

Le complexe a été conçu et construit par Chiyoda Corporation, Japon, sur la base de la technologie, des licences et du savoir-faire de :

- Haldor Topsoe, Danemark (Ammoniac)
- Benfield Corporation, USA (Séparation de $CO_2$)
- Stamicarbon b.v., Pays-Bas (Urée)
- Costain Engineering, United Kingdom (Récupération de l'hydrogène)

A l'origine, l'unité d'ammoniac avait une capacité évaluée de 1 000 t/j accrue plus tard jusqu'à 1 050 t/j en incorporant une unité de récupération de l'hydrogène. Le complexe d'engrais est un jalon important dans le programme d'industrialisation d'Abu Dhabi.

Les matières premières sont les gaz associés, envoyés des champs pétrolifères sur terre situés à 150 km de l'unité. Les eaux désalinisées, l'électricité et l'eau de mer sont fournis par l'unité d'utilités de Ruwais adjacente complétée par les propres générateurs d'énergie de FERTIL et les réservoirs d'eau.

## INTRODUCTION:

Ruwais Fertilizer Industries (FERTIL) was established by Amiri Decree on October 15, 1980, as a joint venture between Abu Dhabi National Oil Company (ADNOC) and Total Fina Elf. Its objective is to utilize the lean gas supplied by ADNOC to produce fertilizers and market them in local and international markets. The shareholding split of the Company is ADNOC 66 $^{2}/_{3}$ percent and Total Fina Elf 33 $^{1}/_{3}$ percent.

Based in the Ruwais Industrial Zone, on the Gulf coast of Abu Dhabi City, the FERTIL complex of ammonia and urea plants has design capacity of 1,050 metric tons and 1,500 metric tons per day, respectively. The complex also includes fully integrated utility plants, storages, loading and shipping facilities. Construction of the plant began in November 1980 and the complex was commissioned by the end of 1983.

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- The complex was designed and constructed by Chiyoda Corporation of Japan, based on the technology, license and know-how of :
  - Haldor Topsoe A/s, Denmark [Ammonia]
  - Benfield Corporation, USA [CO2 Removal]
  - Stamicarbon b.v., Netherlands [Urea]
  - Costain Engineering, UK [Hydrogen Recovery]

The ammonia plant initially had a rated capacity of 1,000 metric tons per day, which was later increased, to 1,050 metric tons per day by incorporating a Hydrogen Recovery Unit. The fertilizer complex is an important milestone in Abu Dhabi's industrialization program.

The raw material is associated dry gas, piped from onshore crude oil fields 150 Km from the plant. Desalinated water, electricity and seawater are supplied by the adjacent Ruwais Utility plant, supplemented by FERTIL's own emergency power generators and water tanks.

**BRIEF HISTORY OF OPERATION:**

Both ammonia and urea plants were commissioned at the end of 1983. Ammonia plant achieved a capacity of more than 100% consistently every year from 1985 till date.

Similarly urea plant has consistently operated at more than the design capacity from 1986 till date.

From commissioning of the plants up to 1990, annual turndowns of 30 days were practised. However, policy was revised and a turn around after every 2 years was started from 1990 to 1996. Thereafter, the period was increased to 2½ years and a plant turn around was taken in October 1998. The next turn around is now planned after 3 years i.e. in October 2001.

From 1986 to 1994, the ammonia plant onstream factor averaged around 88%. The major contributing factor for the downtime was the frequent failures of the waste heat boiler (down stream of secondary reformer) and the main seawater supply line. This line was of special reinforced concrete design known as Bonna Pipe and was failing because of corrosion attack, which penetrated to the steel structure from outside. This line (2.1 M dia. and 500-meter length) was replaced in 1$^{st}$ quarter of 1994 with GRP pipe (Glass Reinforced Plastic) of the same diameter. Waste heat boiler was also replaced in March 1996.

Sustained efforts were started in 1995 to increase the plant loads steadily which reflects on the capacity utilization and the on-stream factor in the subsequent years.

Table 1 presents the results achieved from 1995 to 1999. It may be mentioned here that no formal debottlenecking of the plant has been carried out and the improvements are the results of in-house studies/projects implemented from time to time.

This paper describes the various projects undertaken for improvements as explained above. These projects can be broadly divided into 3 categories namely:

I. Improving reliability / productivity
II. Cost economy
III. Process improvements / Energy optimization

## I. **Improving Reliability / Productivity**:

Waste heat boiler: This boiler was in operation since commissioning of the plant in 1983 and the first failure occurred in April 1989, due to tube to tube-sheet weld failure. Subsequently, the plant suffered three shutdowns due to waste heat boiler tube leakage. It was re-tubed in 1992. As stress relieving of the re-tubed boiler could not be done due to practical constraints, failure again occurred in October 1993. In 1994, PWHT was done but results were not successful. Hence, it was decided to replace this boiler.
The causes of frequent boiler failure were identified as:

1.1 Suspected lapses in maintaining the quality of BFW within specified limits.

1.2 High heat flux near the hot end of the boiler and suspected lower than required circulation ratio, resulting in steam blanketing.

In the design of the new waste heat boiler the above factors were given due consideration. Also the boiler feed water quality was improved and monitoring was enhanced by providing on line oxygen analyses, conductivity and Na-meters. BFW conductivity is now maintained at less than 0.2 us/cm2, as compared to 1.0 us/cm2 before. The boiler was finally replaced in turnaround 1996 and is performing satisfactorily till date.

2.0 Additional Suction Cooling Project for CO2 compressor to increase urea plant capacity:

Urea plant capacity was generally limited by the CO2 throughput available from the CO2 compressor.

FERTIL CO2 compressor is 4-stage centrifugal machine driven by extraction / condensing type of steam turbine. Steam condenser is cooled by seawater whereas inter-coolers of compressor are cooled by close loop circulating cooling water system, which in turn is cooled by seawater (in utilities plant). CO2 compressor performance is based on various factors like:

1.1 Seawater / circulating cooling water temperatures fluctuation (seasonal).
1.2 Limitation of power availability from steam turbine, driving the compressor.

These problems were limiting the CO2 compressor throughput to maximum 110 - 112 % of the design.

In order to overcome the problems of the CO2 machine, additional cooling project for CO2 was conceived.

It is a proven and accepted fact that suction cooling of the gas helps in reducing gas volume and results in reduction of required compression power. This was the fundamental logic behind this project.

Suction cooler and intercoolers are already provided for the CO2 machine, but since they are CW cooled, and in turn is cooled by seawater, CO2 gas temperature exit the coolers varies with the seasonal fluctuation of seawater temperature, which varies widely over the year. Hence, to maintain constant $CO_2$ supply temperature to the machine, a chilling system and two numbers additional coolers, cooled by chilled water were contemplated.

One chilled water cooled additional cooler was provided in the suction of the $CO_2$ machine down-stream of existing cooler and another was provided in the 3rd stage suction. From experience, it was observed that many times and particularly during peak summer conditions, 2nd stage discharge pressure was limiting the compressor speed. To debottleneck this limitation, 2nd additional cooler at 3rd stage suction was provided.

It was not possible to provide chilling / additional cooling to all the four stages of compressor because of limitation of refrigeration compressor to take extra vapor load generated by chiller.

The entire basic engineering i.e. effect of cooling on the compressor's capacity, process specification data sheets for additional 2 heat exchangers, 2 pumps, and a chiller; as well as associated piping and instruments was done in-house.

Based on this information, inquiries were floated and action for procurement was initiated.

Detailed engineering and equipment installation along with piping and instrumentation job was contracted out.

After commissioning of $CO_2$ additional cooling project in middle of 1997 FERTIL urea plant is able to run at 120-121 % load consistently even in summer conditions. The targeted objective is achieved.

2.0 Upgradation of relay based shutdown system to triple modular redundant programmable logic control system :

On analyzing the plants shutdown from 1984 to 1998, it was found that out of total 34 plant trips related to instruments, 28 trips were due to false actuation of field switches, trip bypass switches, shutdown / let down valves and interlock relays. This amounts to staggering 82% false instrument trips; which caused a total downtime of 1110 hours (~ 46 days) which is equivalent to more than 3 days per year over the last 15 years. The problem was further deteriorating due to the aging of individual components of various instruments and also vendors / suppliers being unable to support the spares of these old instruments / components.

Furthermore, after a trip had occurred, the trouble shooting was difficult, as there were many components involved and no latching circuits available for diagnosing the spurious and momentary trips.

It was therefore; felt necessary to upgrade the existing system and a detailed engineering study was initiated.

Based on the findings of this study, the following was decided to implement:

1.0 A single TMR system with remote I/0 to be connected by fiber optic triplicate input / output buses, for both the plants and the main compressors.

2.0 Software switches instead of field instruments to be used to increase the reliability and reduce the hardware.

3.0 Trip circuits and alarm circuits to be segregated. TMR system for trips and SIL 2 for alarm annunciation.

4.0 The selected system to have interface with existing DCS system (TDC 3000 APM UCN system).

5.0 Segregation of field sensors according to their criticality and going to 3 inputs (3 instruments) instead of single instrument for these critical sensors, i.e. 2 out of 3 voting system was selected for the important plant shutdown system.

The above TMR system by Triconex was implemented in turnaround 1998 at a total cost of about 1 million USD. Along with this, following were also implemented :

1. The critical shutdown and let down valves were identified and dual pneumatic control system components (positioner, booster, lock up valves, etc.) were fixed and position indications were provided to CCR.

2. The steam system controls for boilers functioning in dedicated hardware electronic controllers were shifted to redundant TDC 3000 - APM system for reliability.

3. The bypass switches with 2 contacts, one for lighting and other for bypass were routed through PLC for indications and interlocking.

The implemented system has following benefits :

1.0 MTTF (mean time to failure) off 34 years with testing interval of 36 months.
2.0 High system availability of 99.965 % with mean time to repair of 8 hours.
3.0 Easy maintenance.
4.0 No single point failure can trip the plant.
5.0 Single window operation for the user to access both plant control and ESD system.
6.0 Sequence of event facility for each section separately.
7.0 Bypass switch status in universal station.
8.0 Interlocking between DCS control and ESD system through Safety Manager Module (SMM).

Since the implementation of the above system, in Oct. 1998, not a single plant trip due to spurious instrument fault has occurred till date. The onstream factor of ammonia plant in 1999 is 100% (365 days of operation).

In order to increase the reliability of plant, following critical equipments have been replaced during turnaround 1998.

1. Primary reformer tubes and outlet pigtails along with hot collectors.

Design life of the original primary reformer tubes was 100,000 hours and the material was IN-519 (24% Cr. - 24 Ni). They were replaced in 1998, when they had completed 116,000 operating hours, with improved HP modified material (KHR 35 CT by Kubota of Japan). Taking advantage of the improved material characteristics the ID of the tubes was increased, which accommodated about 24% extra catalyst volume and allowed increased throughput.

2. Secondary Reformer:

The old secondary reformer had developed hot spots due to refractory cracks, which were repaired from time to time during various turnarounds. However, the condition of the refractory continued to worsen and warranted its total replacement. This, however, was not possible during limited time available in a plant turnaround. It was, therefore, decided to replace the secondary reformer. The new vessel is of upgraded material (previous one was Cr, ½ Mo and new one is 1¼ Cr, ½ Mo) and was refractory lined and dried in the vendor shop before transporting to the site. It was installed in turnaround 1998 and is performing satisfactorily.

3. Ammonia Converter Basket / Catalyst Replacement.

The ammonia synthesis catalyst installed during 1983 was approaching the end of its useful life, which necessitated its replacement. However, keeping in view the criticality of service and the unknown converter basket conditions (nitriding effect, etc.), it was decided to install a new converter basket along with catalyst, which was successfully executed during the turnaround in 1998.

## II. <u>COST ECONOMY</u>:

Following projects / operational changes have been implemented to economize the cost of utilities. It is worth mentioning here that the cost of imported desalinated water is 2.27 USD/$M^3$, which is quite significant. Since both ammonia and urea plants are operated at higher than design loads the steam balance is such that surplus low pressure (3.5 kg/ $CM^2$) is generated, which had to be vented. This problem was studied in-house and following projects were implemented:

2.1 Using $N_2$ cooler in ammonia plant for surplus steam condensation. This $N_2$ cooler is utilized during LTS catalyst reduction (once every six years) for $N_2$ cooling. Its suitability for steam condensing service was studied and found feasible. Necessary piping modifications were carried out. Although, we anticipated to condense 6~8 MT/Hr. of LP steam, when it was commissioned, it was found that this cooler was condensing about 14 MT of steam/Hr. Thus the cost saving by this project was about 0.28 million USD/year.

2.2 Using removed desorber heat exchanger (PHE) for condensing surplus LP steam in urea plant.

As explained above, there is a surplus of 8~10 T/Hr. of LP steam (3.5 bar) in urea plant.

There was an old plate heat exchanger, which was lying redundant. Its suitability for steam condensing service was studied and found feasible. Necessary modifications were carried out and was successfully used for condensing about 5 to 8 T/Hr. of surplus steam which was earlier being vented. This resulted in the savings of about 0.1 million USD per year.

## INCREASING IN-HOUSE POWER GENERATION

FERTIL has in-house steam turbine generator (STG) of 3750 KVA, 3000KW, 3.3 KV capacity. It is normally synchronized with import power to supply our fertilizer complex, which consumes nearly 6.5 MW power. This unit had been running at 2.3 MW since 1983 and increasing the power generation more than 2.3 MW was leading to desynchronization of STG with import power and tripping of STG by over speed due to inability of STG governor to react to ejected load at the time of desynchronization. There were number of reasons attributed by the manufacturer and construction contractor during the period of commissioning in 1983 for the tripping of STG when running more than 2.3 MW like (a) governor droop was high (b) moment of inertia of rotor was too small (c) friction in the steam control valve stems, servo motor piston, pilot valve or floating lever.

A detailed in-house study was carried out to increase power generation from 2.3 MW to 3 MW on continuous basis from the excess steam available while maintaining the highest availability of the generator during upsets.

Following actions were taken as a result of this study:

- The base load (STG stand-alone load) was increased from 0.6 MW to 1 MW. By this, the ejected load will be less when STG goes for desynchronization and consequently speed variation also will be less.

- Addition of a load anticipator to back up regular speed governor. The speed regulator can keep the maximum speed rise at low value. This is a solenoid valve connected to the control oil line of speed governor and is actuated when synchronizing breaker opens up and dumps control oil to oil reservoir and makes the regulated oil pressure to go down. Consequently power piston goes down and governor output lever which is attached to governor output shaft turns the governing valve towards close direction and decreases the load. Through this action, only oil under the power piston is released and no influence on the main stop valve or other oil supplied equipment takes place.

- The setting of the reverse power relay was increased to 110%.
  (That is 2.64 MW at 0.8 P.F), so that nuisance trip during motor (connected load) start/stop can be avoided.

  The above actions were implemented in Feb. 1999 and the performance of STG at its design load of 3 MW was tested by tripping the synchronizing breaker of the imported power and found satisfactory. Since then the machine is steadily running at its design load and has resulted in an annual saving of 0.27 million USD per year.

## III. PROCESS IMPROVEMENTS / ENERGY OPTIMIZATIONS:

3.1 Use of new activator (ACT-1) in Benfield CO2 removal suction of ammonia plant:

FERTIL's ammonia plant utilizes the conventional UOP (Benfield) process for the removal of CO2 from the process gas. The hot K2CO3 solution contains diethanolamine (DEA) as conventional promoter for the absorption reactor. The energy requirement for this process is about 1300 ~ 1400 Kcal/nm3 of CO2 removed. However, DEA decomposes chemically and thermally and forms complex degradation products, which effects the system performance (e.g. foaming, etc.).
A new activator was introduced by the Licensor - UOP called ACT-1, which was claimed to be chemically and thermally more stable and enhances the rate of CO2 absorption, while requiring less energy.

FERTIL switched over to the new promoter in May 1999, which has resulted in lower energy requirement of the system by about 15%. (The live steam of about 15 MT/Hr, which was used earlier in the CO2 regenerator has been completely stopped).

Along with the energy reduction, other benefits like system stability, less chemicals consumption, etc. have also been achieved.

3.2 Installation of 4 bar absorber downstream of HP scrubber in urea plant :
As per the design, the off-gases from HP scrubber after scrubbing are vented to atmosphere. However, it contains significant quantity of ammonia (approx. 500 kg/Hr.), which has two impacts on the operation of the plant, namely (1) Economic Loss; (2) Environmental Problem.

In view of the above, FERTIL decided to recover this ammonia by installation of 4 bar absorption system downstream of HP scrubber. This is a proprietary design of Urea Process Licensor M/s. Stamicarbon. The project is expected to be completed at a cost of USD 0.75 million and shall be commissioned in Oct. 2001. The project has a payback period of less than 2 years.

**CONCLUSION:**

Although FERTIL plants are now 18 years old, they are being maintained and operated in a thoroughly professional manner, at much above the rated capacities, with high onstream factor and are comparable to the best operated plants in the world. Presently Ammonia and Urea Plants are running at 130% and 122% capacities respectively without undergoing any major debottlenecking.

Even though being located in an energy rich Gulf region, Fertil is conscious of the importance of energy and is committed to its optimum usage. The energy consumption of its ammonia plant is consistently lower than the design of 9.4 Gcal/MT and the average value of 9.0 Gcal/MT for the 1995-1999 period is better than the world average of 9.2 Gcal/MT of similar design plants as pointed out through a benchmarking survey.

## TABLE 1 : AMMONIA PLANT

| Year | Design Capacity (MT) | Actual Production MT | Capacity utilization (%) | Onstream factor (%) | No. of S/Ds | S/D days. |
|---|---|---|---|---|---|---|
| 1995 | 346,500 | 441,219 | 127.3 | 99.02 | 3 | 3.58 |
| 1996 | | 402,943 | 116.3 | 88.45 | 6 | 42.16 |
| 1997 | | 453,121 | 130.8 | 99.36 | 2 | 2.35 |
| 1998 | | 403,639 | 116.5 | 91.13 | 6 | 32.27 |
| 1999 | | 463,076 | 133.6 | 100 | 0 | 0 |

## UREA PLANT

| Year | Design Capacity (MT) | Actual Production MT | Capacity utilization (%) | Onstream factor (%) | No. of S/Ds | S/D days. |
|---|---|---|---|---|---|---|
| 1995 | 495,000 | 638,327 | 129 | 99.1 | 4 | 3.34 |
| 1996 | | 561,823 | 113.5 | 86.1 | 8 | 50.73 |
| 1997 | | 651,331 | 131.6 | 97.7 | 5 | 8.38 |
| 1998 | | 564,219 | 114 | 87.8 | 14 | 44.54 |
| 1999 | | 590,536 | 119.3 | 93.1 | 5 | 25.21* |

Note. Onsteam factor and S/D days include T/A days (1996 & 1998)
Design capacity & capacity utilization based on 330 days.
* 13 days out of this were for Marketing reasons (to sell more ammonia)