# Heavy Water Plant RCF Ltd Thal

Heavy Water Plant (Thal) comprises of two units based on mono-thermal ammonia exchange process. The plant is owned by Department of Atomic Energy and is operated and maintained by Rashtriya Chemicals & Fertilizers Ltd. It produces Heavy Water, which is used in Nuclear Power Stations. It is a highly power intensive process and 80% of the cost of production was due to energy. Subsequently various modifications were undertaken and cost of energy has been brought down to 70 % (approx.)

**(i) Energy Consumption**

With the implementation of various energy conservation measures, the specific energy consumption has steadily declined as shown below:

| DESCRIPTION | UNIT | 2002-2003 | 2003-2004 | 2004-2005 |
|---|---|---|---|---|
| Electrical energy | KWH/kg | **1435** | **1388** | **1185** |
| Thermal energy | M kcal/kg | **2.5211** | **2.4759** | **2.438** |
| Total manufacturing cost | Lakhs/year | **6223.01** | **6659.03** | **6887.06** |
| Total energy bill | Lakhs/year | **4475.7** | **4829.78** | **4348.07** |
| Energy cost as % of total cost of production | % | **71.90** | **72.50** | **63.13** |
| Capacity utilization | % | **67.5** | **77.37** | **86.43** |

The % cost of energy is lowered due to higher capacity utilization, and costs saving measures that have been taken up along with energy conservation drive. The on-stream hours of the plant have increased gradually

## (ii) Energy Conservation Commitment, Policy and Set up

Rashtriya Chemicals & Fertilizers Ltd. Thal

( A Government of India Undertaking )

# ***ENERGY MANAGEMENT POLICY***

We at Rashtriya Chemicals & Fertilizers Ltd. Thal Unit commit ourselves to continually improve our energy performance in all our activities, products & services through:

Continual up gradation of eco friendly technology for production of Fertilizers & Chemicals.

Conservation and optimal utilization of natural resources by adopting reduce, reuse & recycle methods.

Continuous training programme for increasing energy conservation awareness throughout the organization.

Regular management reviews to ensure continual improvement & to achieve our goal of reducing specific energy consumption by 1 % every year till 2010.

**( S.K.BORWANKAR )**

**Date: 22nd December 2003** **EXECUTIVE DIRECTOR (THAL)**

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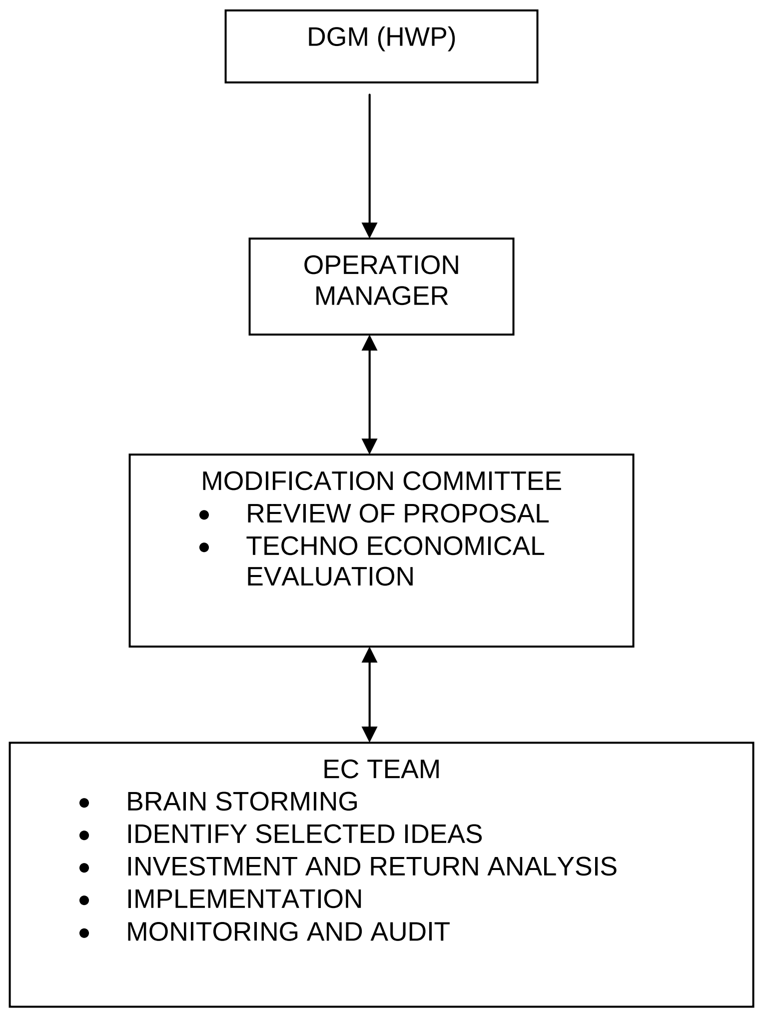
## ENERGY CONSERVATION ORGANISATION STRUCTURE AND WORKING



**iv)Energy conservation achievements.**
**Project (Provision of Ejector)**

Extraction of deuterium is favored at low temperature and high pressure in presence of potassium amide catalyst. Low temperature is maintained by vapor compression refrigeration. There are three refrigeration compressors in HWP that were operational for main plant and synthesis unit refrigeration requirements. The refrigeration circuits of main plant are having working temperature levels of $-25^0$C & $-11^0$C and Synthesis unit works at temperatures of $-13^0$C & $+13^0$C. Main plant refrigeration compressors have power rating of 2.2 MW each and Synthesis unit refrigeration compressor has power rating of 4.4 MW. One 2.2 MW machine was stopped after integration of the refrigeration system and the condensers as well.

Modifications in pipelines and plant operating parameters had to be carried out to reduce the refrigeration load further. On analysis it was observed that the plant refrigeration requirements can be met by running only the 4.4 MW machine. The second 2.2 MW machine also could be stopped.
However, the main challenge in stopping second 2.2 MW refrigeration machine boiled down to maintaining the $-25^0$C circuit. The 4.4 MW machine operates at $-13^0$C and $+13^0$C. Lot of discussion was held and lots of possibilities were explored. Following options were discussed.

1. Putting up a small compressor and compressing $-25^0$C circuit vapors up to $-13^0$C circuit.
2. Operating the plant at only two-refrigeration levels of $+13^0$C and $-13^0$C.
3. Installation of an ejector with high pressure vapor ammonia as motive fluid

Putting up an extra compressor would have meant additional equipment and power consumption, and operating at two levels of refrigeration would have meant lower deuterium extraction. Extensive calculations for ejector design were done. Also, discussions were held with suppliers for possibility of designing and fabrication of such ejector, which would suit for the application.
The installation of ejector helped in maintaining $-25^0$C refrigeration circuit and compress these vapors into $-13^0$C circuit and finally resulted in eliminating the operation of second 2.2 MW machine, which otherwise was required to be run for maintaining $-25^0$C circuit.
An ejector was designed, procured and was installed. After commissioning of the ejector, second 2.2 MW machine was stopped. This resulted in net saving of 1100 KW load. The net saving achieved due to this modification is to the tune of **Rs.290 Lakhs per annum.**
**Corrocoating and impeller trimming of cooling water pump:**

Cooling water pump 32P11/12/13/14 discharge valves had to be kept throttled as they were slightly oversized. For minimizing this loss energy due to throttling it was decided to trim the size of impeller. Corrocoating of cooling water pump with hydrophobic material along with trimming of impeller from 712-mm diameter to 706mm diameter has been carried out. This has resulted in saving in electrical energy to the tune of **Rs.17 lakhs per annum**.

**Condensate recycle to improve deuterium concentration in feed gas.**

The process condensate in Ammonia plant is having a normal deuterium concentration of 180 PPM against normal concentration of 150 PPM available naturally. This process condensate is recycled back completely and the feed gas deuterium concentration has been increased from 105PPM to 110 PPM. This has increased the net production by 5 Tons/year. This has resulted in increase of production for same energy input saving **Rs.500 lakhs per annum**.

**Cold recovery from synthesis gas returning to Ammonia plant**

A cold recovery exchanger E-4109 has been installed in synthesis unit as a part of energy conservation in heavy water plant. This exchanger recovers cold from the gas going to Ammonia plant. The return gas exchanges cold with the synthesis gas going from HP chiller to LP chiller (There is two level refrigeration system in synthesis unit Viz. HP & LP). This has resulted in net power saving of **250 kWh**. The total savings is **Rs.83.40 lakhs.**

**Parallel running of purification towers to increase gas processing.**

Purifier parallel running modification carried out for running both purifiers in parallel thereby increase in gas throughput by reduction in differential pressure across purification towers from 2.5 $Kg/cm^2$ to 0.7 $Kg/cm^2$. Gas processing has increased by **1 ton/hr**. per plant. This has resulted in net increase of production by **2 Tons/year**.

**Provision of Variable Frequency Drive for boiler feed water pumps (31P41/42)**

Variable Frequency Drive is provided for The Boiler Feed Water pumps to reduce its capacity. The capacity of these pumps is very high and good amount of energy was getting lost in discharge control valve. This has resulted in net saving of power by **27 KWh**, equivalent to **Rs. 8.10 Lakhs per annum.**

**Removal of impeller from 12P62/61(Main cracker liquid feed pump)**

The Main cracker feed pumps have 10 impellers, five on each side of motor. The capacity of these pumps is very high and some amount of energy was getting lost in discharge control valve. One impeller on each side has been removed as a part of energy saving scheme. Actual energy saving achieved is **4 kW** per pump, equivalent to **Rs. 2.8 Lakhs per annum**.

**Main cracker burner head insulation**

Main cracker furnace is having 72 burners for required cracking capacity. All these burners head-having area of 0.24 $M^2$ was not covered by hot insulation. Total burner head is insulated which has resulted in saving of **19, 20,536 kcal** per day equivalent to **242 $sm^3$ of natural gas per day**.

**Ammonia synthesis converter catalyst and loop Boiler replacement**

Ammonia synthesis catalyst had lost its activity over a long service and was replaced; this has resulted in increase in Ammonia production from 13% by volume earlier, to 17 % by volume now. Also loop boiler was replaced due to aging and higher capacity boiler is installed which has resulted in decrease in steam import by aprox 50%.

**Energy Conservation Plans and Targets**

Heavy Water Plant is committed to further improve its energy performance by finding out new avenues on continuous basis. The plant is working on the following major proposals as a part of its future plans for energy conservation.

1. Bifurcation of cooling water system into two pressure system
2. Heat recovery from main crackers flue gas. (Additional tube bundle for air pre-heater)
3. Heat & cold recovery by installing a suitable heat Exchanger between the liquids going to 14S3 & 14R7.
4. Installation of steam turbine to recover 2.2 MW power
5. Installation of condensate storage tank to maintain deuterium concentration in feed gas.

## (iii) Environment and Safety

The Heavy Water Plant is committed to preserve its environment and safety of its employees.

a) Liquid effluent: The liquid effluent generated in the plant is well below the limits specified by Maharashtra pollution control board. Continuous efforts are being made to reduce liquid effluent generation to zero.
b) Gaseous emissions: Gaseous emissions generated in the plant are well below the limits specified by Maharashtra pollution control board.
c) Solid waste: No solid waste is generated in the plant.

**Super Heater of Main Cracker Unit**

<u>**Loop Boiler**</u>

**Ammonia Synthesis Converter Basket**

## Ammonia Synthesis Converter Basket

**Cold Recovery Exchanger (E4109C)**

**MAN GHH EJECTOR**

**COOLING WATER PUMP CORROCOATING**

Heavy water plant owned by Heavy Water Board is a constituent of Rashtriya Chemicals and Fertilizers Ltd. Thal unit. The plant is owned by Heavy Water Board and is Operated and Maintained by M/s RCF ltd.

In the year 1931, Harold Clayton Urey and his associates discovered presence of a heavier Isotope of Hydrogen. This Isotope was called Deuterium and later a third isotope "Tritium" was also discovered. In the nucleus of Hydrogen, there is only a proton whereas in the nucleus of Deuterium there is a proton and a neutron as well.

The name hydrogen and symbol H is used both for lighter isotope. Symbol D is used for deuterium. Similarly, the oxides of the two are differentiated as light water ($H_2O$) and heavy water ($D_2O$) respectively.

Heavy Water Plant at Thal is the first indigenously built plant based on Mono-thermal Ammonia Hydrogen isotopic exchange process. Heavy water plant is highly energy intensive plant of its kind. Nuclear Grade Heavy water is produced by extraction of deuterium present in the Hydrogen of Ammonia Synthesis Gas. The synthesis gas contains very low deuterium (around 110 PPM only). In this process deuterium is enriched from this low deuterium concentration level to the Nuclear Grade Heavy Water of concentration >99.84%. This requires processing of a large amount of gas to enrich through mass cascading and therefore becomes highly energy intensive. However, with in-house energy conservation measures the energy consumption is gradually decreasing every year. The impact of the energy conservation schemes implemented every year is in accordance with the planning

We wish to participate in the National Energy Conservation Award. However due to the strategic nature of the product the production figures of the plant are not given in the report. The absolute energy consumption and specific energy consumption figures are given in the prescribed format. The data given is self explanatory.

**Process Description**

Heavy water or Deuterium oxide is used as moderator and coolant in nuclear power plants. Also, its uses in Medical field are being established. It can be used as stabilizer in Polio Vaccine.

Thal Ammonia Extension Plant has two streams of isotopic exchange sections with production capacity of 78 Tons / year, with a common $NH_3$ synthesis section. The process is based on the 'Mono Thermal' $NH_3$ – $H_2$ exchange technology. The Synthesis gas of ammonia plant contains Deuterium, which is extracted by Ammonia in presence of Potassium Amide as a catalyst at a pressure of 220 kg/cm2 and temperature of – $25^0$C. The Ammonia reflux needed for the exchange process is produced by conversion of $N_2 + 3H_2$. The deuterium-depleted synthesis gas is sent back to Ammonia Plant.

Synthesis Gas required for the process is taken from both Ammonia Plants. Utilities like D.M.Water, Raw water and start up steam are also drawn from the Ammonia Plant/water treatment plant. The other raw materials used are Potassium metal and Natural gas as fuel for ammonia crackers.

It is necessary that oxygenated impurities in the feed Synthesis gas are minimum and the Deuterium concentration is maximum.

The pressure drop across the plant is compensated by a centrifugal booster compressor. The gas is then purified, removing all the traces of moisture and oxygenated impurities. It is also cooled down to – $25^0$C. After purification and cooling, the gas is passed through an extraction tower where it transfers Deuterium to a counter flowing stream of liquid Ammonia containing Potassium Amide as a catalyst. There is a net downward transport of Deuterium to a concentration 5 times of the inlet gas concentration. The depleted gas from the top of tower is passed through an Ammonia converter to obtain the Ammonia needed for the process. The Ammonia obtained in one pass of the gas in the converter is sufficient for the process and no circulation of synthesis gas is required.

The liquid Ammonia from the bottom of the Extraction Tower is taken to the preliminary enrichment tower where its flow is counter current to a stream of enriched synthesis gas obtained by cracking of enriched Ammonia. Again there is a net downward transport of Deuterium and liquid at the bottom is enriched to 200 times that of plant inlet gas concentration. A small portion of this liquid and gas is taken to the final enrichment section, which is similar to the earlier sections but smaller in size.

The gas flow handled in the first tower of this section is approximately 1/25th of the preliminary enrichment unit and in the second tower is 1/100th of the preliminary enrichment unit.

The rich liquid from the tower is converted to synthesis gas in a small cracker unit and portion of this is burnt with dry air to get the product Heavy water ($D_2O$). The low concentration product is further upgraded to nuclear grade in an upgrading plant by vacuum distillation.

Main chemical reactions that take place during the above mentioned process can be listed as follows:

$$NH_3 \text{ (L)} + HD \text{ (G)} \longleftrightarrow NH_2D \text{ (L)} + H_2 \text{ (G)}$$

$$NH_2D \text{ (L)} + HD \text{ (G)} \longleftrightarrow NHD_2 \text{ (L)} + H_2 \text{ (G)}$$

$$NHD_2 \text{ (L)} + HD \text{ (G)} \longleftrightarrow ND_3 \text{ (L)} + H_2 \text{ (G)}$$

$$2ND_3 \longleftrightarrow N_2 + 3D_2$$

$$2D_2 + O_2 \longleftrightarrow 2D_2O \text{ (Heavy Water)}$$

The main and only product is Heavy Water, which is used as Moderator in Nuclear Power Plants. Generation of power through Nuclear power plants is considered as very clean source of power (Second to Hydel power generation).