REPLACEMENT OF ELECTROLYSIS PLANT WITH STEAM NAPHTHA REFORMATION PLANT, ITS INTEGRATION WITH OLD HEAVY WATER PLANT

HEAVY WATER PLANT BASED ON CRYOGENIC DISTILLATION OF HYDROGEN TO PROCESS HD ENRICHED HYDROGEN GAS GENERATED BY POWER INTENSIVE ELECTROLYSIS PROCESS, WHICH WAS COMMISSIONED IN AUGUST, 1962 HAS NOW BEEN RETROFITTED TO PROCESS HYDROGEN GENERATED BY ENERGY EFFICIENT STEAM NAPHTHA REFORMATION FOLLOWED BY MODERN COMPUTER CONTROLLED PRESSURE SWING ADSORPTION PURIFICATION PROCESS, RESULTING IN NET SAVING OF ELECTRICAL ENERGY TO THE TUNE OF 75 MW.

Nangal Unit of National Fertilizers Limited enjoys proud privilege of continuing operation of India's first heavy water plant based upon cryogenic distillation of HD enriched hydrogen since Aug. 1962. HD enriched hydrogen was generated by power intensive water electrolysis plant arranged in Cascade. This plant which was commissioned along with commissioning of country's first multi-purpose hydro electrical project after attaining independence came into operation in February, 1961, to manufacture hydrogen for production of fertilizer. Power consumption for a plant to produce 1000 Tn CAN/Day and 42 kg/day heavy water was 164 MW. Schematic arrangement is given in Fig-I. At the time of commissioning of this project, power requirement in the northern sector of country was insignificant. With the passage of time and development in the agricultural sector as well as industrial sector power requirement in this region increased by leaps and bounds. Due to this reason, need was felt to reduce power consumption in the fertilizer factory and release power for the other industrial and agricultural sectors for development of the region. To meet the increased requirement of fertilizer as well as to bring down power consumption.
expansion of fertilizer factory based upon partial oxidation of fuel oil/LSHS for additional production of 1000 Te./day of Urea was commissioned in November, 1978. With commissioning of this facility, hydrogen generation through power intensive electrolysis route was to be stopped which would have resulted in stoppage of Heavy Water production also. However, in order to continue heavy water production, electrolysis plant was continued to run on reduced load. With this production of Heavy Water got reduced from 14 Te./Yr. to 7 Te/year. With this arrangement power consumption came to 98 MW. Utilising of such a huge amount of power to produce only 7 tonnes per year of heavy water was considered to be a national wastage. However, power tariff also increased substantially resulting in uneconomical increase in cost of production of heavy water as well as Ammonia produced in this way.

Through a study conducted by an expert agency, it was confirmed that old Ammonia synthesis, air liquefaction plant, Heavy Water Plant and Nitric Acid Plant are capable of further continuous run for 10-15 years. So it was thought prudent to replace power intensive Electrolysis plant with energy efficient Naphtha Reformation Plant, followed by modern computer controlled pressure swing adsorption purification process so as to produce ultra pure hydrogen to meet the requirement of heavy water plant. Block flow diagram of the modified system is given in Fig-II. Modified arrangement came into commercial production with effect from March, 1990. Total power consumption of the system as shown in Fig-II has got reduced to approximately 40MW. Efforts are on to further reduce power consumption by adopting energy efficient modifications. Keeping in view, the age of Ammonia Plant and other down-stream plants, the capacity of Naphtha reformation unit has been fixed as 18000Nm³/hr. of H₂ so as to operate ammonia plant on 200 Te./day capacity instead of 300 Te/day capacity. Heavy Water production will be 7-8 tonnes per annum.
Right from the design stage of Steam Naphtha Reformation unit, requirements of Heavy Water plant were kept in consideration, the main factor considered was purity of hydrogen as well as achieving of maximum possible HD concentration with the existing set up of plants in Nangal. Following are the main features of this scheme:

1. Selection of pressure swing adsorption unit in place of other purification units such as Benfield process and Rectisol process so as to generate hydrogen of ultra pure nature for processing with the available systems of heavy water plant. For this purpose, provision of secondary reformation stage has not been made.

2. Total system of steam naphtha reformation plant has been designed in such a way that not even a drop of steam and process condensate is discharged outside so as to conserve HD concentration in the system.

3. In this system, arrangement has also been made to utilise 10M³/hr. effluent of shift conversion section of 900 Te/day ammonia plant based upon partial oxidation of fuel oil to further enrich hydrogen with HD.

Steam naphtha reformation system consist of following main sections:

i) hydro-desulphurisation
ii) primary reformer and waste heat recovery
iii) recovery of power by utilising waste steam for captive power consumption of the plant.
iv) shift conversion
v) Pressure swing adsorption and offsite facilities such as:
   a) Naphtha unloading storage and handling system
   b) D.M. water unit.
   c) Polishing unit or condensate of shift conversion section of 900 Te/day of Ammonia plant.
   d) Instrument air unit.
   e) Cooling tower
   f) Fire protection system
To utilise surplus steam and to conserve condensate for recycling in the process so as to maximise HD content in hydrogen, a turbo-generator unit has also been installed. Power generated is sufficient to meet the power requirements of the naphtha reforming system. Block diagram of the system is given in Fig-III and schematic flow diagram of the steam naphtha reforming system along with pressure swing adsorption unit is given in Fig-IV.

With implementation of the project, the overall energy consumption as feedstock, fuel and electric power for hydrogen production equivalent to 1 MT of Ammonia has got reduced to 8.1 MM K Cal as against 12-13 MM K Cal with electrolysis plant.

Due to adequate precautions taken at design stage of the system, no difficulty was experienced at the time of integration of the new system with heavy water plant as well as Ammonia Plant. System is operating smoothly without any problem. However, few problems were faced after commissioning of the system as detailed below:-

a) Heavy water plant had to be stopped without any problem in this plant due to problem of steam naphtha reforming plant as well as ammonia plant where depleted hydrogen gas of heavy water plant is utilised to produce ammonia. Due to this limitation, production of heavy water used to get discontinued for a period of 72-96 hours because of even for a small down period in steam naphtha reforming plant as well as ammonia plant. Following modifications have been incorporated to overcome the above problems:-

i) 2 nos. cell lines of the old electrolysis plant are being maintained so as to run the cell lines whenever there is a tripping of steam naphtha reforming plant and ammonia plant, to meet hydrogen requirements of heavy water plant for keeping the plant running on close circulation to avoid loss of cold.
ii) Modification has been carried out to flare depleted gas of Heavy Water plant in the eventuality of stoppage of ammonia plant. After implementation of this modification it has now become possible to sustain heavy water production when steam naphtha reformation plant is running and ammonia plant is under shutdown.

b) To maintain purity of heavy water, regular supply of ultra pure oxygen is required to oxidise deuterium for production of heavy water. To meet this requirement, 2 nos. mini electrolysers have been provided to conserve electrical power and to maintain oxygen requirement of heavy water plant. With this arrangement, difficulty has been experienced at the time when oxygen supply get suspended from mini electrolysers due to any local problem. At one occasion, this resulted in unsafe conditions in D₂ burning section of heavy water plant. To overcome this problem, scheme has been finalised to install oxygen gas holder of the capacity 160M³ so as to maintain uninterrupted supply of oxygen for oxidation of deuterium to safeguard against problems mentioned above.

C) Inadequate supply of HD enriched condensate from shift conversion section of 900 Te/day ammonia plant;-

System provided to remove impurities from this condensate was inter-linked with regeneration facility of BFW Plant. Due to this reason, this plant was getting last priority for regeneration after exhaustion of its resin beds resulting in dis-continuation of supply of this condensate to steam naphtha reformation plant. To overcome this problem, this facility has now been made independent for the purpose of regeneration of resin beds.
d) **Low HD concentration in hydrogen as compared to design expectations:**

Steam Naphtha Reformation plant was designed to produce hydrogen containing at least 300 ppm HD with following inputs:

i) The feed naphtha 276 ppm HD.

ii) D.M. water contains 290 ppm HD.

iii) 10 Te/hr. of shift conversion condensate contains 400 ppm HD.

Presently, we are getting approximately 225-235 ppm HD in hydrogen gas generated from steam naphtha reformation plant instead of 300 ppm HD. One of the reasons attributable for less concentration of HD in product hydrogen gas is less concentration of HD in condensate of CO shift conversion section. On analysis, it has been seen that this condensate contains approximately 350-360 ppm HD as against 400 ppm HD which is expected from such type of system. On investigation, reasons for reduced HD concentration have been found to be dilution taking place in condensate circulating system of shift conversion section due to internal leakages. Action plan has been made to overcome this problem.

**IMPROVEMENT IN PRODUCTIVITY AND REDUCTION IN POWER CONSUMPTION:**

Heavy Water Plant was originally designed to handle 5500 NM³/hr. of feed hydrogen gas. Later on, cyclidal blower was introduced to boost suction pressure of feed hydrogen compressors from 200 mm water column to 0.25 kg/cm². With this modification, feed gas hydrogen processing capacity of plant increased to 7800 NM³/hr.
In steam naphtha reforming plant, hydrogen is generated at a pressure of 22 kg/cm². Arrangement has been provided to let down this pressure to 4.5–5.0 kg/cm² and feed this gas at down-stream of feed compressors of heavy water plant. With this modification, it has now become possible to process at least 9000 NH₃/hr of hydrogen gas. Besides this, it has also been possible to discontinue operation of cyclidal blower and 2 nos. feed compressors in heavy water plant resulting in net saving of 1.0 MW electrical power.

Schematic flow diagram of Heavy Water Plant is given in Fig-V.
PROCESS WATER FROM EXISTING FACILITY

NAPHTHA THROUGH RAIL WAGONS → NAPHTHA STORAGE 9000 M³

674.2 KJ/DAY

HYDRO DESULPHURISATION

PRIMARY REFORMER

COOLING TOWER 1800 M³/hr

INSTRUMENT AIR UNIT

DM WATER PLANT 50 M³/hr

HT CO SHIFT CONVERSION

PSA UNIT

PURGE GASES (FUEL)

18000 NM³/hr HYDROGEN

200 TE/DAY AMMONIA

AMMONIA PLANT (EXISTING)

HEAVY WATER PLANT (EXISTING)

9000 NM³/hr HYDROGEN

HEAVY WATER 8 MT/A.

FIG. III
**Fig. 1. Diagram of heavy water plant**

- **K1**: Feed hydrogen compressor
- **K2**: Hydrogen recycle compressor
- **K3**: Nitrogen recycle compressor
- **K4**: Nitrogen vacuum pump
- **K5**: HD compressor
- **K6**: O₂ recycle blower
- **W1**: 1.2 Amm. Cooler
- **V1**: Nitrogen evaporator
- **V2**: Vacuum nitrogen evaporator
- **V3**: E₂ Liquefier

**Fig. 2. Schematic Flow Diagram of Heavy Water Plant.**

- **A1**: Warm regenerator
- **A2**: Cold regenerator
- **A1,2**: Separation for dry vapour
- **A3**: Adsorber
- **T1,2,3**: Dryer
- **C₁,2,3,4**: Catalysts
- **S1**: Three stage rectification column
- **S2**: HD Column
- **S3**: D₂ column

**AI**: Analysis take off points