# *Ammonia Production Using HEDCO Technology*

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***Shiraz-Iran***

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## Table of Contents:

## 1) Introduction

Ammonia is the intermediate product in Urea production. Efficient production of Ammonia has greatest impact on Specific Energy consumption of this product as 80% energy for Urea production is consumed for Ammonia production. Currently, technologies have undergone great developments resulting in reduction in capital cost and energy consumption thereby leading to lower cost of production.

After 50 years operation of ammonia plants in Iran, for the first time, "HEDCO" as an Iranian company, with its highly specialized workforce of more than 270 expert employees, in conjunction with "Petrochemical Research & Technology" Company, introduces an optimized and Energy saver process for Ammonia production.

In this regard, all available knowledge and experiences in term of Design, Procurement, Supply, installation, Operation and Maintenance of other Ammonia Plants (which are still running in Iran) is used for doing the best in current job. Minor improvements are continuously also introduced in to the process regarding any new pertinent finding.

This new optimized technology is including new process concepts, improved or new equipment designs and new knowledge gained with respect to the limits acceptable in operation of various units.

## 2) General Conditions of Ammonia Plants

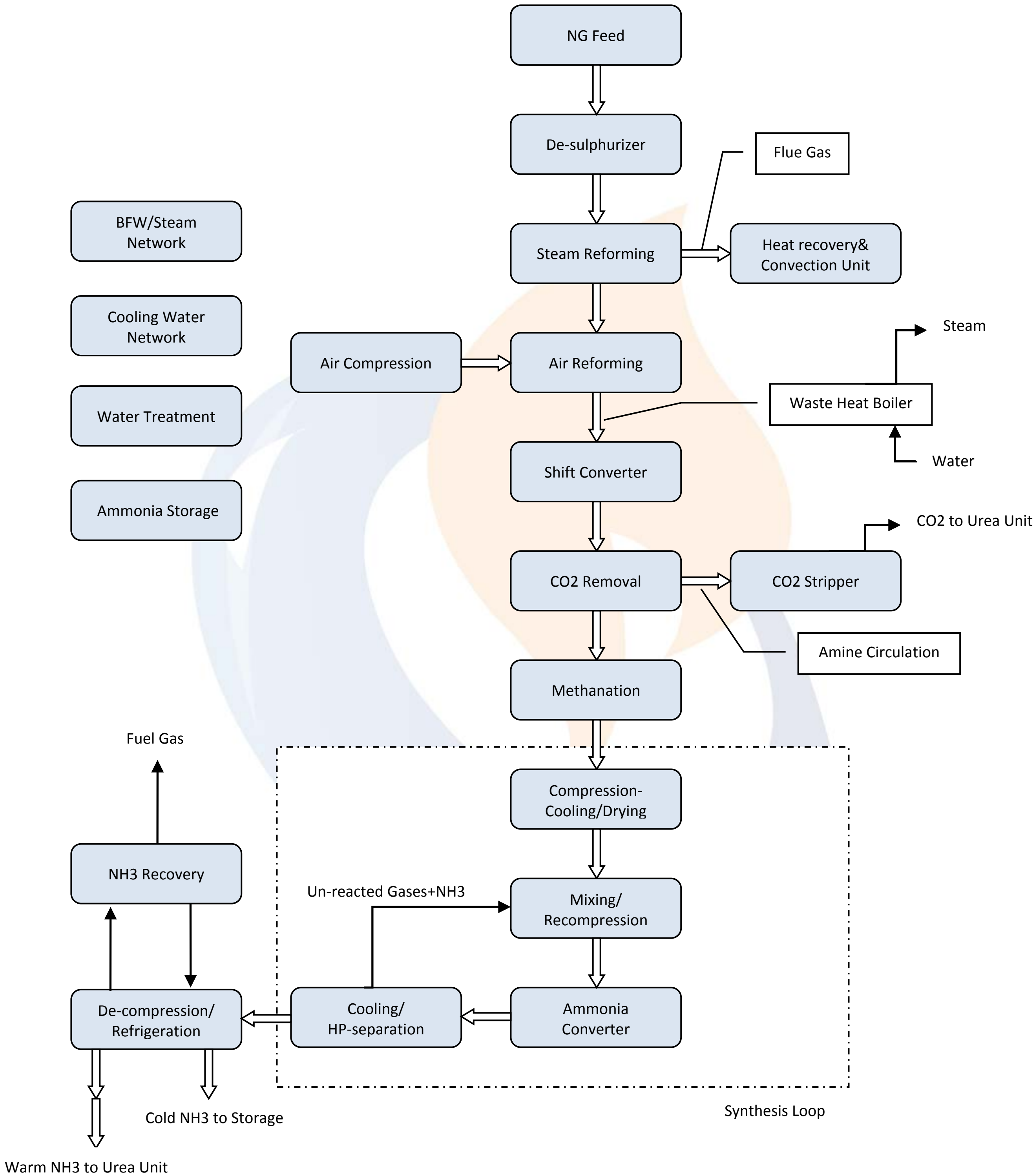
Fertilizers (i.e., Urea) play the key role to meet the ongoing demand of food grain production for the fast growing human population.

Ammonia is presently one of the most produced petrochemical products. In 2012, total production of Ammonia was approximately 165 million tons. Most of which was used to produce Urea.

Ammonia plants generally use natural gas as main feedstock (particularly in Iran). Steam and air are other feed stocks. Carbon dioxide is the by-product of Ammonia plant, which is sent to Urea plant at low pressure. Liquid Ammonia is typically produced in cold or warm state. Cold product is sent to refrigerated storage tanks, at the temperature of approximately -35 °C, while the warm product, at 20 °C is directly sent to Urea plant. Ammonia plant shall be designed to be capable of producing Ammonia at 100% capacity, in both warm and cold states. In addition to production of Ammonia for Urea production, Ammonia plant shall be capable of:

- ✓ Production of 10~15 t/h liquid Ammonia to be sent to Granulation section of urea plant, and receive the respective Ammonia vapor returns.
- ✓ Production of around 2000 kg/h compressed air to be sent to urea plant
- ✓ Receiving Ammonia vapor return from Ammonia storage tanks and subsequent refrigeration (liquefaction) of these vapors.

**Figure 1: Schematic representation of the "Ammonia Synthesis Process"**



### 3) Ammonia Plants energy consumption

Steam reforming of hydrocarbons for Ammonia production was introduced in 1930. Since then, the technology has experienced revolutionary changes in its energy consumption patterns [Ranging from an early level of 10 Gcal/MT (39.7 MBtu/ MT) to about 7 Gcal/ MT (27.8 MBtu/ MT) in the last decade of the 20th century].

**Table 1: Reduction in "Specific Energy Consumption" in Ammonia Plants**


First commercial production of Ammonia returns back to 1913 in Germany. Production capacity of plant was 25~30 tons per day while cost of production was very high. Around 1960s, use of developed centrifugal compressors led to large single train Ammonia plants of 1000 or even 1500 tons per day capacity. During last decade of past century, successive improvements in ammonia production lowered the cost of production resulting in liberal use of fertilizer in crop production. At the same time, development of special alloys, reduced the size and weight of equipment and enhanced the capacity of plants. Present level of Specific Energy consumption, is around 7 Gcal/tone of ammonia and economical plants capacity increased to 2300 tons per day or even higher. Further improvements are possible as the theoretical energy requirement is about 4.5 Gcal/ MT (18.8 MBtu/ MT) of Ammonia.

The focus points for future process technologies are:

- ✓ Low specific energy consumption

- ✓ Innovative, yet proven technology
- ✓ Superior economic performance
- ✓ Reducing the emission of Green House Gases (GHG)
- ✓ Looking for various cost effective feed stocks

The energy intensive nature of the process is the key driving force for improving the technology and reducing the overall cost of manufacturing.

## 4) Ammonia Production in Iran

It is over fifty years since the first ammonia and Urea plant was established in Iran. Ever since, although by means of advances in technology, a lot has been changed with respect to the production process, it is still expected that no overseas aid in terms of technology would be required for subsequent plants.

Unfortunately, despite the fact that various plants have been constructed so far, till date there is still need for overseas technological help. After construction of Shiraz and RAZI (formerly known as SHAHPOUR) Ammonia and Urea plants in the early 40's, several plants have come into operation, one after another:

- ✓ Shiraz 2nd Ammonia and Urea plant
- ✓ Khorasan Ammonia and Urea plant
- ✓ Kermanshah Ammonia and Urea plant
- ✓ Pardis 1st & 2nd Ammonia and Urea plant

In addition to the above, following plants are presently in different stages of execution:

- ✓ Shiraz 3rd Ammonia and Urea plant
- ✓ Pardis 3rd Ammonia and Urea plant
- ✓ Three provincial Ammonia and Urea plants in Golestan, Lordegan and Zanjan

These plants have all used overseas technology.

Presently, drastic collaboration of Hampa Energy Engineering and Design Company and Petrochemical Research and Technology Company, has led to generation of domestically independent Ammonia production technology. These companies are honored to play their historical role in taking the first steps in generation of comprehensive technology for Ammonia production, and proudly raise the flag of self-sufficiency. Continuing in this way will evidently create the opportunity for domestic manufacturing of materials and equipment for this particular plant and other plants consequently.

## 5) Presentation of HEDCO Technology

Different processes for production of Ammonia in large industrial scale, using natural gas as main feed stock (existing technologies), have all the same principals. Generally, the following are distinguishable as main sections in an Ammonia plant:

- ✓ Reforming
- ✓ Shift reaction
- ✓ Carbon dioxide absorption/desorption
- ✓ Synthesis
- ✓ Refrigeration

Various existing technologies for production of Ammonia in this scale, share similar sections; hence effort is always made to optimize the process and decrease the amount of consumed energy, by applying proprietary equipment design and different arrangements.

HEDCO, with partnership of “Petrochemical Research and Technology” Company, is honored to, after years of effort and providing the required infrastructures, and for the first time in history of the country, present the technology for production of Ammonia.

In this regard, aforesaid companies have made efforts towards energy efficiency of the plant, using proprietary equipment design and special arrangements.

In order to achieve that, following (patented) equipment and systems are introduced, being exclusive to this particular technology:

I. Patented Ammonia Converter; making use of different unique process streams (The Reactor internals is designed and delivered by Euroslot Pars Company).

II. Carbon dioxide absorption/desorption section; making use of a proprietary solution called H-MDEA® as absorbent solution.

III. Ammonia Fog Distributor-Mixer (AFDM®); used to eliminate water from synthesis gas (by means of liquid Ammonia).

IV. Integrated “Start-up Heater”; specially designed Coil inside the Primary Reformer in dual function, being partly used as Start-Up Heater, which eliminates the requirement of having such equipment (separately).

V. $NH_3$ Hydraulic Turbine; used to recover energy in the junction of Ammonia plant “Synthesis loop” and “Refrigeration section”.

VI. Optimized Steam Generation network; resulting in an increase in HP steam production (exported to outside of Ammonia plant).

Above mentioned improvements, provide a specific and Low energy (Utility cost) process which is comparable with all available/famous worldwide technologies. The extent, to which the proposed changes can be applied to a specific project, varies depending upon the specific situation and location of new production plant.

HEDCO particular process, for production of Ammonia, contain all above mentioned improvements, now is legally and officially patented in Iran.

What follows hereinafter, presents introduction to the aforesaid items in the proposed technology.

### 5.1 Patented Ammonia Converter

The “Ammonia Converter” comprises a vertical cylindrical pressure shell and an internal cylindrical basket that contains catalyst beds (Radial Pattern) and heat exchangers.

Feed gas to the Ammonia Converter is divided into two streams:

I. “Main Feed”: about 58% of the feed gas flows through the annular space.

II. “Petty Feed”: approximately 42% of the feed gas is preheated in the lower inter-changer (E2) that cools the hot gas leaving the second bed. “Petty Feed” is mixed with “Main Feed” at tubes side inlet channel of upper inter-changers (E1) that cools the hot gas leaving the first bed. Pre-heated feed gas is passed to the first catalyst bed.

The reaction takes place at about 160 barg and 350~ 500°C. The reaction is exothermic, but is limited by the chemical equilibrium. Therefore a run-away reaction cannot occur.

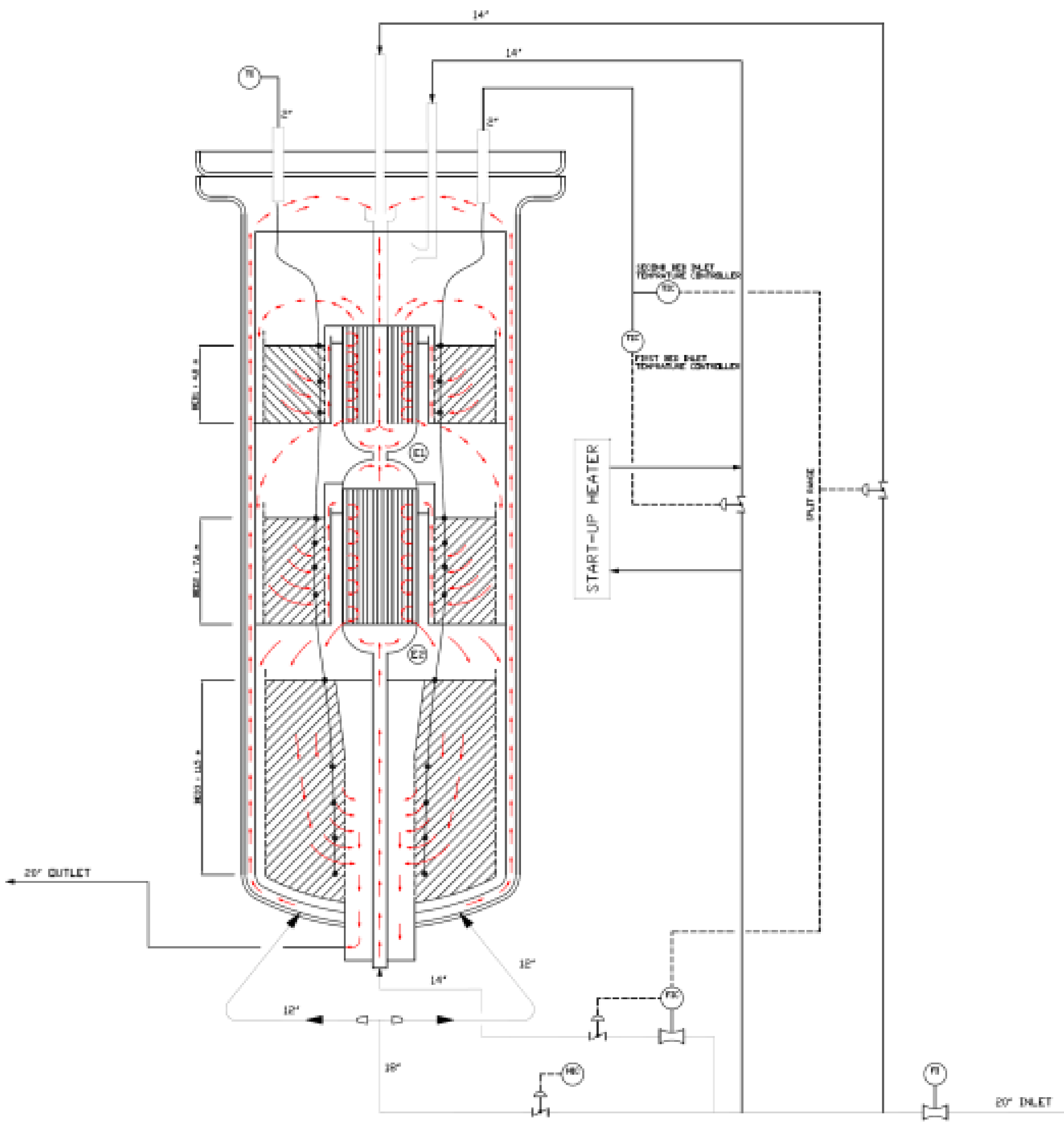
The design ammonia content in the reactor effluent is around 19.7 volume percent.

Submitted converter contains a unique arrangement which specially and specifically designed for HEDCO Ammonia technology as patented equipment.

Reactor internals is designed so that all baskets and pertinent accessories are fully dismountable to low weight portions. Consequently, internals can be easily taken out from reactor shell using only Winch and Davit.

Reactor internal’s, are now patented in Iran. Activities for overseas registration of the HEDCO Ammonia Converter, is under progress.

**Figure 2: Particular Ammonia Converter Schematic**



## 5.2 Carbon dioxide absorption/desorption section using H-MDEA®

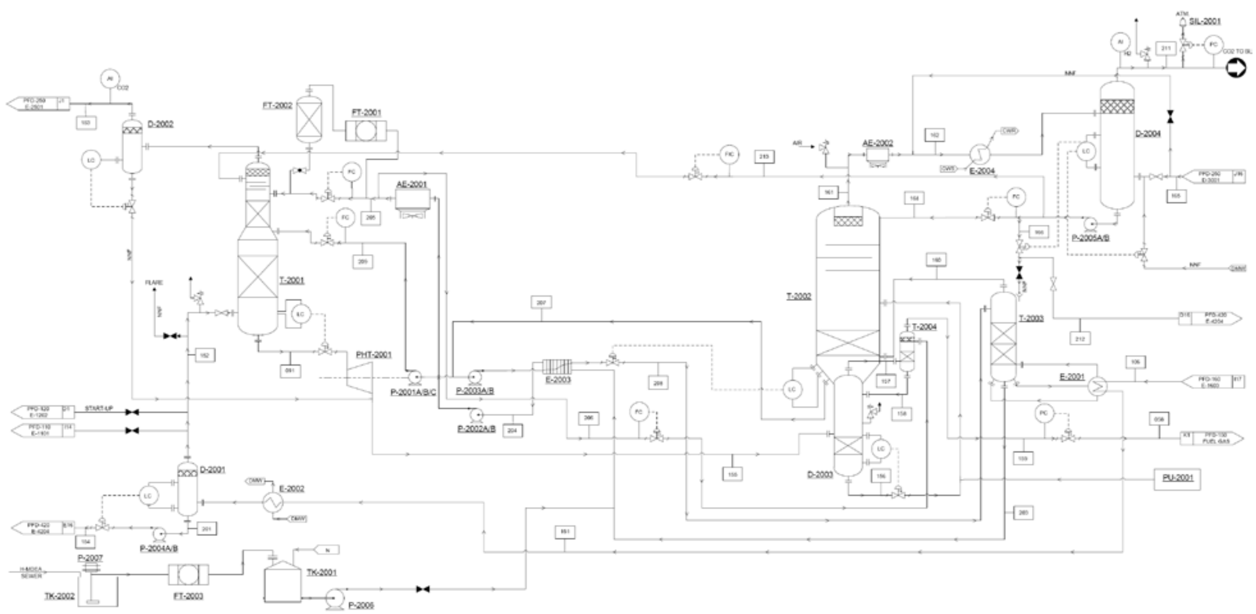
The Unit is designed to reduce the carbon dioxide content in the synthesis Gas to less than 500 ppmV. The CO2 is removed from the process gas stream by the two-stage CO2 Absorber.

The circulating solution is H-MDEA®, a unique admixture which is specially provides for CO2 adsorbing Process in HEDCO technology.

Advantages of H-MDEA® are:

I. Availability of H-MDEA® ingredients in Asian market
II. CO2 slip is decreased to less than 500 ppmV
III. Lower solution circulating rate (results in more efficient and economical process)
IV. A lower amount of CO2 loss from HP flash section (meanwhile, a new/economical absorption column is foreseen at off-gas stream which enables approximately 1% more CO2 recovery)
V. The recovered CO2 purity is 99.2 % vol. min. (on dry base), inert gas in this stream is less than 1.0 % vol. H2 content is less than 0.5% vol.

**Figure 3: CO2 Removal section Process Flow Diagram**

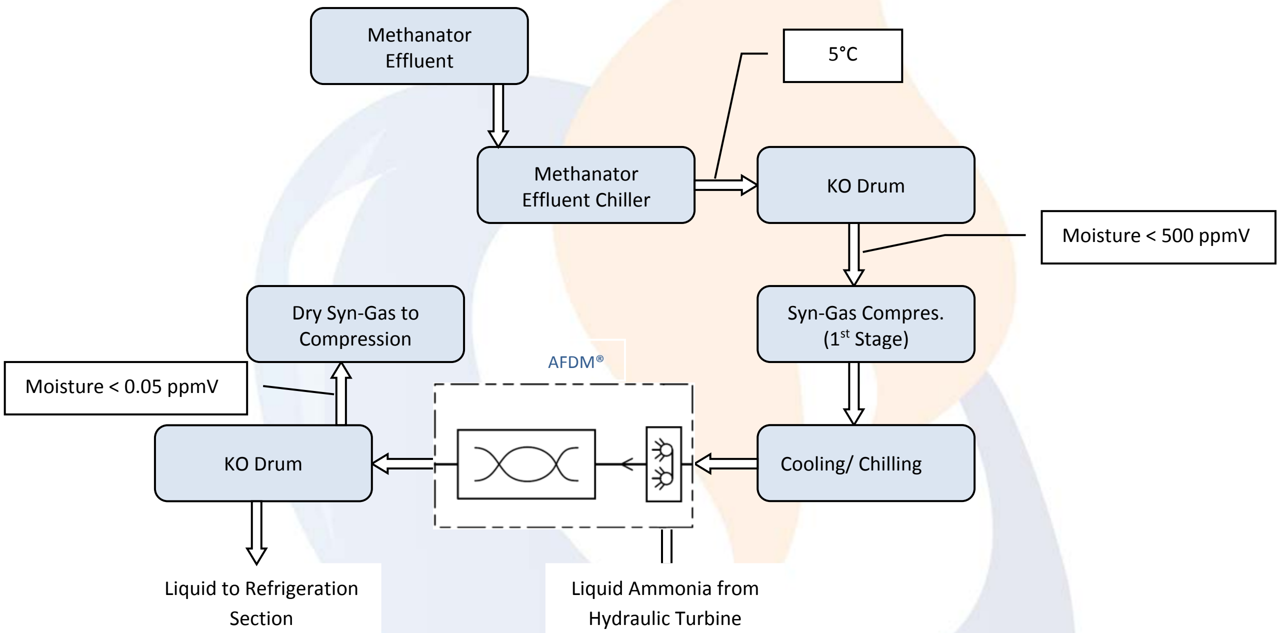



## 5.3 Ammonia Fog Distributor-Mixer (AFDM®)

In HEDCO technology, Compression and Drying of make-up Synthesis Gas takes place using an efficient and particular loop. The makeup gas from Methanator is first cooled down to 5°C in “Methanator Effluent Chiller”. Water content is knocked down in “Syn-Gas Compressor Suction KO Drum”. By this means, the water content in process gas (going to the 1st stage of compressor) is decreased to less than 500 ppmV. Less temperature in make-up gas also increases Syn-Gas compressor efficiency.

Process Gas at discharge side of 1st stage (around 62 barg), is further cooled down to 5°C (using two exchangers in series) and then mixed with an Ammonia Rich stream in AFDM® (Ammonia Fog Distributor-Mixer) to absorb the remaining water (Rich Ammonia comes from Hydraulic Turbine located at HP-Separation section). The water content (at feed stream of second stage of Syn-Gas compressor) will fall down to less than 50 ppb.

**Figure 4: Schematic arrangement of Syn-Gas Drying loop using AFDM®**




### 5.4 Integrated "Start-up Heater"

In HEDCO design, Process Air Coil Heater (located at Convection section of Primary Reformer) comprises of two dedicated coils in series. The first coil has a dual function duty and is also used as "Start-up Heater" for synthesis section warm-up. In case of requirement (initial or regular start-up of Synthesis section), by a fully safe and automated sequence, coil will be isolated from process air stream and is further put in second function mode.

For proper functionality of this coil, some considerations will be taking into account:

- ✓ Coil is designed for No-flow condition.
- ✓ A fully automated logic, equipped with TSO Valves is considered.
- ✓ Intermediate purging, using Pressurizing/De-pressurizing operation will be provided.

Sequential purging& start-up, will lead to a safe and reliable operation. The best location for coil is chosen based on reformer/convection coils duty.

In case the coil is in “Start-up Heater” operation mode, Secondary Reformer Air inlet temperature will fall down to almost 300°C and methane slip will be increased up to 0.8 mol%. It is expected that no irregular effect occurs in Front-end section of Ammonia plant.

**Figure 5: Primary Reformer equipped to integrated “Start-up Heater”**

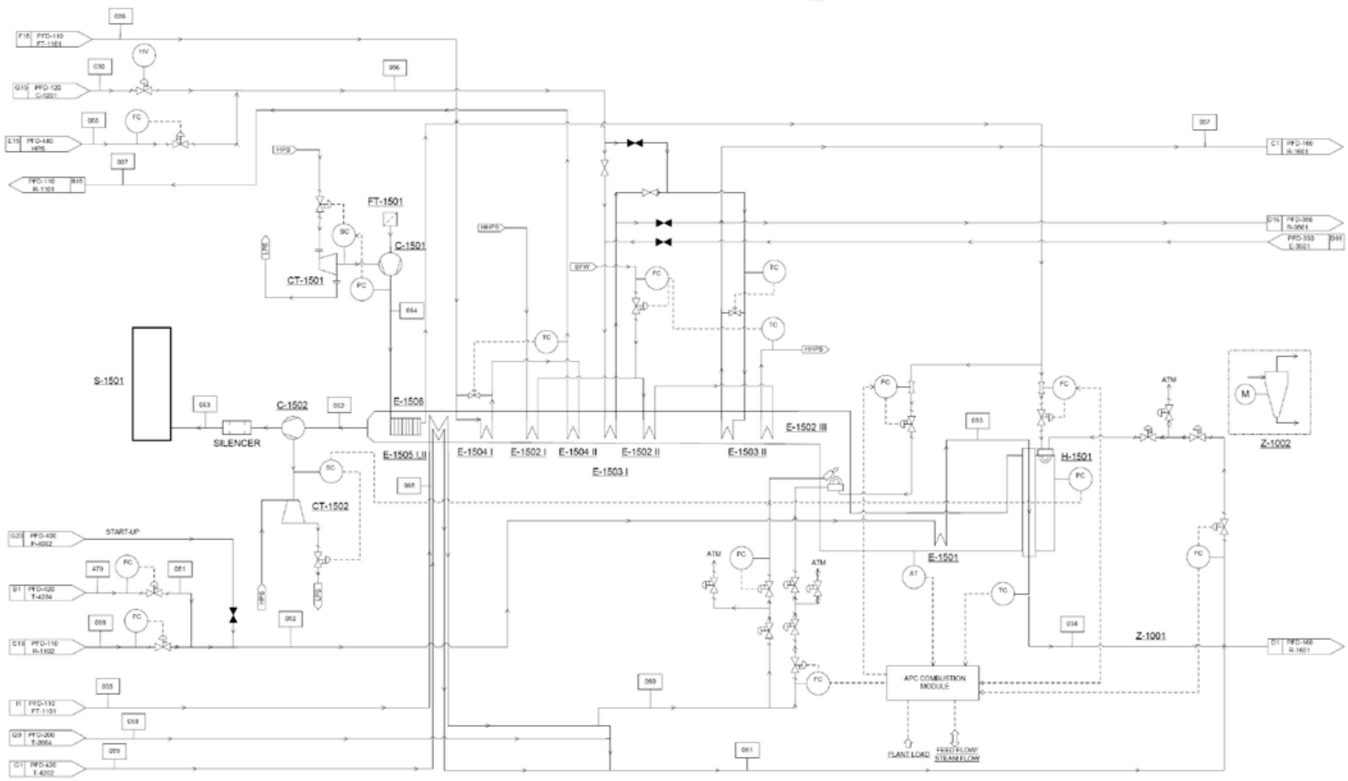
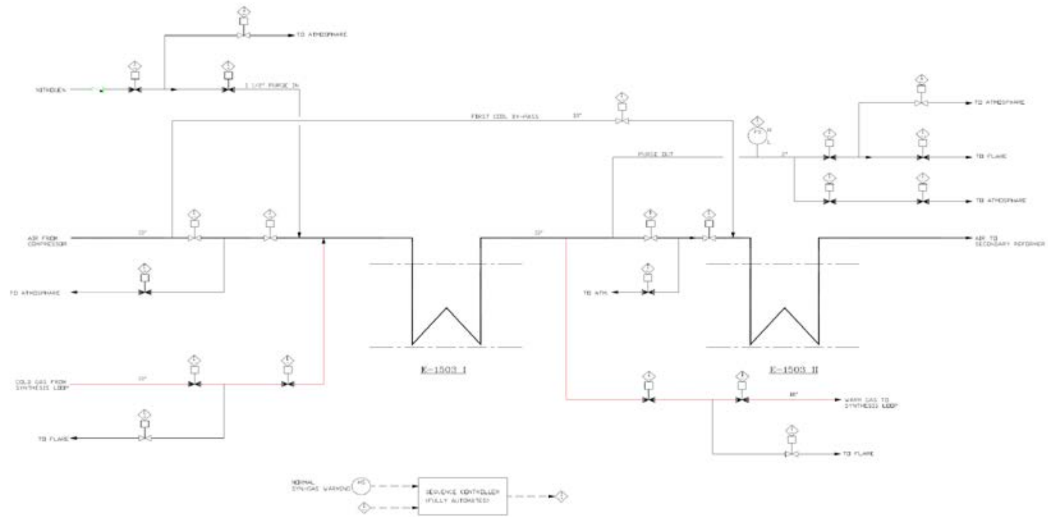


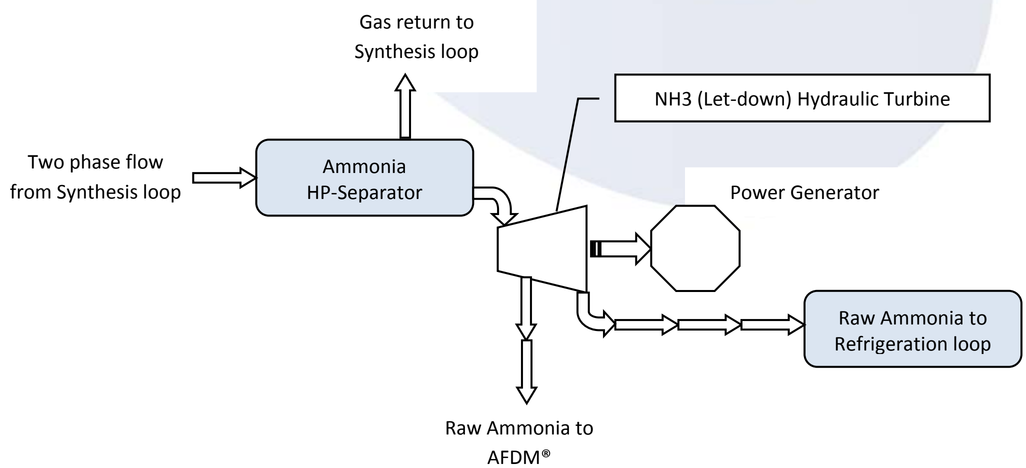
**Figure 6: Integrated "Start-up Heater" Coil arrangement**



## 5.5 $NH_3$ (Let-down) Hydraulic Turbine

To have more efficient process, raw liquid Ammonia, coming from bottom side of "Ammonia HP Separator", passes through a "Let-down Hydraulic Turbine" before being sent to Refrigeration section. In other words, hydraulic turbine is situated at conjunction point of Synthesis loop and Refrigeration loop. The mentioned turbine; provides almost 300 KW power, which can then be used directly as pump driver or even be coupled with a power generator to generate electricity.

**Figure 7: Schematic for location of NH3 (Let-down) Hydraulic Turbine**



### 5.6 Optimized Steam Generation network

In HEDCO particular design, in order to have an efficient production, a fully optimized heat recovery and steam generation system is considered to achieve maximum rate of steam production. By this means, during normal operation, the Ammonia Plant (with capacity of almost 2000 MT per day), exports more than 60 ton per hour of HP Steam.

This is a considerable value which can be attained in current design only.

### 5.7 Utilities/Feed Consumption and comparison

As mentioned earlier, forasmuch as age of operation of Ammonia plants in Iran, all the efforts of the professionals in this field have been focused on reducing the energy consumption, optimizing the arrangements and more favorable performance of the equipment. In the intervening time, efforts are underway, trying to improve the operation of plant catalysts (especially Ammonia synthesis catalysts). This issue is out of scope of this description. The following table's present expected amount of consumed utilities and energy in HEDCO Ammonia technology and comparison of them with other worldwide available technologies:

**Table 2: Expected Utility Consumption (*)**

| *Utility* | *Unit* | *Value* |
|---|---|---|
| Electrical Power | KW/Ton $NH_3$ | 55.1 |
| Cooling Water<br>(15629 Ton/hr) | Ton / Ton $NH_3$ | 195.4 |
| DM Water (Polisher Unit Make-up)(**)<br>(65.2 Ton/hr) | Ton / Ton $NH_3$ | 0.81 |
| Nitrogen<br>(300 $Nm^3$ /hr) | $Nm^3$ / Ton $NH_3$ | 3.73 |

(*)Values are brought for an Ammonia plant with 1930 ton/day (80.4 ton/hr) production capacity.

(**) Mentioned value is captured by balancing of return condensate from both Ammonia and Urea plants to the "Condensate Polisher Unit".

**Table 3: Expected Energy Consumption (based on Natural Gas feed):**

| # | Unit | Value |
|---|---|---|
| Natural Gas (Feed)<br>LHV 187'159 kcal/kgmol | Kgmol/hr<br>G cal /hr | 2410<br>451.05 |
| Natural Gas (Fuel)<br>LHV 187'159 kcal/kgmol | Kgmol/hr<br>G cal /hr | 822.5<br>153.94 |
| Total Natural Gas<br>LHV 187'159 kcal/kgmol | Kgmol/hr<br>G cal /hr | 3232.5<br>604.99 |
| HP Steam Export<br>Net enthalpy content 712 kcal/kg | Kg/hr<br>G cal /hr | 63000<br>44.86 |
| Total Energy Consumption<br>(Total Natural Gas) – (HP Steam Export) | G cal /hr | 560.13 |
| **Specific Energy Consumption** | **G cal /Ton NH3(*)** | **6.969** |

(*)Values are brought for an Ammonia plant with 1930 ton/day (80.4 ton/hr) production capacity.

**Table 4: Total Energy Cost for HEDCO Technology in comparison with other well-known competitors:**

| *Licensors (*), (**)* | | *HEDCO* | *Licensor 1* | *Licensor 2* |
|---|---|---|---|---|
| *#* | *Unit* | | | |
| Natural Gas Energy (Feed & Fuel) | G cal / Ton NH3 | 6.969 | 7.101 | 6.922 |
| Electrical Power | KW/ Ton NH3 | 55.1 | 59.6 | 56.8 |
| Cooling Water | Ton/ Ton NH3 | 195.4 | 188.7 | 257.1 |
| **Total Energy Cost** | **US $ /Ton NH3(*)** | **102.2** | **103.86** | **103.72** |

(*) HEDCO data is belongs to whatever is issued in bidding stage of an Ammonia/Urea project at south part of Iran. Data for other competitors are directly extracted from their official documents (PDP) which are officially submitted for same projects in Iran.

(**)The price for Feed Natural Gas and Utilities are captured from:

- ✓ Natural Gas global market: 3.40 US$ per each MBtu (means: 11.27 US$ Cent / Nm3)
- ✓ Electrical Power price (Iran official issue for industrial customers): 2.37 US$ Cent / KWh (617 Rials/KW)
- ✓ Cooling water price (Assaluyeh): 3.42 US$ Cent / Ton (889 Rials/Ton)

## 6) Conclusions

The most vital parameter in all of the Ammonia technologies is the "Specific Energy Consumption", and comparison of this value among different technologies.

In other words, effect of any optimization with respect to Ammonia production process will eventually appear in this parameter.

Comparison of this value with other costly imported technologies indicates that the presented technology stands in very good and efficient performance point.

A simple mathematical fact shows that this reduction in energy consumption, would lead to tens of millions of dollars saving during 20 years of lifetime of a plant, which obviously reduces the production costs. Yet, the capital cost of equipment (in HEDCO Ammonia technology, compared to other technologies) has not increased. The reduction in amount of electricity and cooling water consumption is also evident.

Furthermore, as there is vast experience with the problems engaged within existing operating plants (along with respective solutions) various small optimizations will be applied in detailed design stage in order to increase safety and ease of operation.