

Ammonia-Urea Industry in Bangladesh

Bangladesh has seven ammonia-urea complexes (six, in the public sector and one in the private sector as a joint venture between the Government of Bangladesh (GOB) and foreign companies) with a total installed capacity of 2,895,700 tons of urea and 1,886,700 tons of ammonia per year.

Bangladesh Chemical Industries Corporation (BCIC) operates six ammonia-urea complexes (built during the period 1961-1994)

Table 1: Relevant Information on Seven Ammonia – Urea Complexes

COMPLEX	NGFF	UFFL	ZFCL	PUFF	CUFL	JFCL	KAFCO
Location	Fenchugonj	Ghorasal	Ashugonj	Polash	Rangadia	Tarakandi	Rangadia
Year of commissioning	1961	1970	1981	1986	1987	1991	1995
Plant capacity							
Urea (TPY)	106,000	469,260**	528,000	95,000	561,000	561,000	575,425
Ammonia (TPY)	66,000	272,250**	307,000	56,160	330,000	355,740	499,500
Type of urea	Prill	Prill	Prill	Prill	Prill	Granular	Granular
Electric power	captive	captive	captive	captive	captive	captive	captive
Ammonia Process Licensor	CCC (USA)	Toyo	Uhde	China	Kellogg	Haldor Topsoe	Haldor Topsoe
Urea Process Licensor	CCC (USA)	(TEC-MTC C-process) + ACES	Stami carbon	China	TEC-MTC D-Process	Snam pro-getti	Stami carbon
CO ₂ -removal system for the reformed gases	CCC (USA)	(Vetro coke) + Benfield	Benfield	China	Benfield	Benfield	UOP
Type of compression	Reciprocating	Centrifugal	Centrifugal	Reciprocating	Centrifugal	Centrifugal	Centrifugal
i) ammonia synthesis	Reciprocating	Centrifugal	Centrifugal	Reciprocating	Centrifugal	Centrifugal	Centrifugal
ii) urea synthesis	Reciprocating	Centrifugal	Centrifugal	Reciprocating	Centrifugal	Centrifugal	Centrifugal

*When commissioned; **capacity after revamping (originally urea: 340,000t, ammonia; 200,000t); +Original Process.

NGFF (Natural Gas Fertilizer Factory)

UFFL (Urea Fertilizer Factory Ltd.)

ZFCL (Zia Fertilizer Co. Ltd.)

PUFF (Polash Urea Fertilizer Factory)

CUFL (Chittagong Urea Fertilizer Ltd.)

JFCL (Jamuna Fertilizer Co. Ltd.)

KAFCO (Karnaphuli Fertilizer Company Limited)

Table 2: Natural Gas Consumption per Ton of Urea by Different Complexes under BCIC

Plant(capacity in t/y urea), year of commissioning	Consumption of NG per ton urea as per design, MSCF
NGFF (106,000), 1961	59.0
UFFL (340,000) 469,260*, 1970	35.2
ZFCL (528,000), 1981	28.0
PUFF (95,000), 1986	49.9
CUFL (561,000) 1987	27.5
JFCL (561,000), 1991	24.4
KAFCO(575,425), 1994	23.2

*after 1991 revamping

Urea Manufacturing Process can be divided as three distinct plants and they are

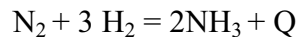
- 1.0: Utility Plant
- 2.0: Ammonia Plant
- 3.0: Urea Plant

Ammonia Plant

Ammonia is predominantly used in producing urea, which in turn is used for making fertilizers. It is also essential in manufacturing plastics and explosives and is the active product of “smelling salts”. More than a sniff of this toxic, reactive and corrosive gas can make one ill and can even be fatal. Ammonia is a chemical with a variety of uses, its largest application being as the primary feed stock for the nitrogenous fertilizer industry. Under normal conditions of temperature and pressure it exists as a gas, which is lighter than air, has a sharp irritating odor and burns the eyes and skin. It dissolves readily in water.

Fundamentals of Ammonia Production

Ammonia synthesis is a reversible process accompanied by the release of heat and a considerable reduction in volume:



1. Without a catalyst, ammonia synthesis proceeds at an extremely slow rate even at very high temperatures.
2. An increase in temperature reduces the equilibrium content of ammonia.
3. With a rise in pressure and drop in temperature the equilibrium shifts towards the formation of ammonia.

4. A catalyst, which increases the rate of synthesis at low temperature, must be used.
5. Catalyst used is iron obtained by reducing its oxides (Fe_2O_3 , Fe_3O_4)
6. To maintain high and stable activity of the catalyst, promoters such as Al_2O_3 , K_2O , CaO and SiO_2 are added to the Iron catalyst in their manufacture.
7. When oxygen-containing compounds (H_2O , CO_2 , CO) are present in the synthesis gas the activity of the catalyst drops sharply. But with pure Hydrogen- Nitrogen gas its activity can be restored to its former level. This is known as reversible poisoning of catalyst.
8. H_2S and other sulfur containing compounds poison the catalyst irreversibly.

Raw Materials:

1. Natural Gas
2. Air
3. Steam

Product: Ammonia

Byproduct: Carbon dioxide.

Table 3: Shows Hydrogen Generation Raw Materials and Processing

Raw Material	Process Description	Feedstock Conversion Reaction
Natural Gas	Steam Reforming	$\text{C}_n\text{H}_{(2n+2)} + n\text{H}_2\text{O} = n \text{CO} + (2n+1)\text{H}_2$
Naptha	Steam Reforming	$\text{C}_n\text{H}_{(2n+2)} + n\text{H}_2\text{O} = n \text{CO} + (2n+1)\text{H}_2$
Fuel Oil	Partial Oxidation	$\text{C}_n\text{H}_{(2n+2)} + n/2\text{O}_2 = n \text{CO} + (n+1)\text{H}_2$
Coal	Coal Gasification	$\text{C} + 1/2\text{O}_2 = \text{CO}$ $\text{CO} + \text{H}_2\text{O} = \text{CO}_2 + \text{H}_2$
Water	Electrolysis	$\text{H}_2\text{O} = 1/2\text{O}_2 + \text{H}_2$

Reactions

Table 4: Shows Hydrogen Generation Raw Materials and Processing

Hydrogenator	: Unsaturated Organic S + $\text{H}_2 \rightarrow \text{H}_2\text{S}$ + Saturated Organic Compound
DSV	: $\text{ZnO} + \text{H}_2\text{S} \rightarrow \text{ZnS} + \text{H}_2$
PRF	: $\text{CH}_4 + \text{H}_2\text{O} \rightarrow \text{CO} + 3\text{H}_2$ $\text{CH}_4 + 2\text{H}_2\text{O} \rightarrow \text{CO}_2 + 4\text{H}_2$
SRF	: $\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$ $\text{CH}_4 + \text{H}_2\text{O} \rightarrow \text{CO} + 3\text{H}_2$ $\text{CH}_4 + 2\text{H}_2\text{O} \rightarrow \text{CO}_2 + 4\text{H}_2$
HTS & LTS	: $\text{CO} + \text{H}_2\text{O} \rightarrow \text{H}_2 + \text{CO}_2$
BFD	: $\text{K}_2\text{CO}_3 + \text{H}_2\text{O} + \text{CO}_2 = 2\text{KHCO}_3$ (For Absorption) $2\text{KHCO}_3 = \text{K}_2\text{CO}_3 + \text{H}_2\text{O} + \text{CO}_2$ (For Regeneration)
MTN	: $\text{CO}_2 + 4\text{H}_2 \rightarrow \text{CH}_4 + 2\text{H}_2\text{O}$ $\text{CO} + 3\text{H}_2 \rightarrow \text{CH}_4 + \text{H}_2\text{O}$

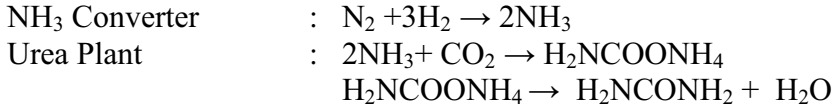


Table 5: Shows Unit name, Catalysts and Operating Conditions

Name	Catalyst/ Packing Type	Operating Conditions		
		Temperature, °C		Pressure, kg/cm ²
		in	out	
Hydrogenator	Co-Mo	390	390	40
DSV	ZnO	390	385	40
PRF	Ni	520	750	38
SRF	Ni	Air:550 PRF:750	950	36
HTS	Fe ₂ O ₃ +Cr ₂ O ₃	350	420	34
LTS	CuO+ZnO	220	300	31
Absorber (gas)	Packing (Rasching ring)	70	75	28
Regenerator	Packing (Rasching ring)	113	126	1
Methanator	Ni	363	392	26
Converter	Fe	250	430	140-150

Process Description

Ammonia production process may be divided into three major steps:

1. Preparation of Raw Synthesis Gas:

This section consists of reforming section-

- (a) Primary Reformer (PRF) and
- (b) Secondary Reformer (SRF)

2. Raw Synthesis Gas Purification Section: This section includes-

- (a) High Temperature Shift Converter (HTS)
- (b) Low Temperature Shift Converter (LTS)
- (c) Carbon dioxide Removal Section
- (d) Methanation Section

3. Synthesis and Refrigeration Section: This section includes-

- (a) Ammonia Converter and
- (b) Ammonia Liquefaction and Storage Section

DESCRIPTION OF MAJOR UNITS

Desulphurization

The natural gas feed stock is preheated and passed over a catalyst bed through which sulphur is removed. The sulphur may be present in natural gas as organic or as inorganic form. The inorganic sulphur mainly present as hydrogen sulfide, which reacts with zinc oxide catalyst and removed from natural gas. To remove organic sulfur from natural gas the gas is passed initially through Co-Mo catalyst bed, where hydrogenation reaction takes place, and organic sulfur converted to inorganic sulfur as hydrogen sulfide.

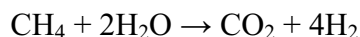
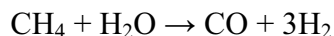
Reaction:



Primary Reformer

Steam is mixed with the natural gas and the combined stream further heated and routed through tubes in a reforming furnace containing nickel catalyst. Here a reforming reaction occurs in which methane in the natural gas is predominantly converted into hydrogen, carbon dioxide and carbon monoxide.

Reaction



Checklist

Pressure: Feed NG, Steam and draught Pressure

Temperature: All coils and Reformer outlet

Steam/C ratio

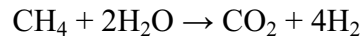
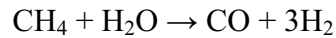
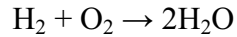
Residual Methane content at outlet of PRF

Excess Air with fuel

Secondary Reformer

The process gas leaving the primary reformer usually contains 5% to 15% methane. The object of secondary reforming step is to complete the conversion of methane into H₂, CO, CO₂, and to supply the required amount of nitrogen for ammonia synthesis reaction.

Reactions

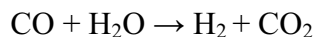


The process gas leaving the primary reformer is routed to the secondary reformer, which is a refractory – lined vessel, filled with nickel catalyst. A controlled proportion of air is also introduced after pre heating into the secondary reformer. In the upper hollow space of the secondary reformer, a highly exothermic reaction between hydrogen and oxygen takes place which raising its temperature high enough to virtually complete the conversion of the residual methane into additional hydrogen, carbon dioxide and carbon monoxide.

Shift Converter

In shift conversion, carbon monoxide formed in the primary and secondary reforming steps is further reacted in a two-stage process. During this stage the carbon monoxide is almost completely converted to hydrogen and carbon dioxide by reacting with steam.

Reaction



The reaction is exothermic; therefore it is carried out with two steps with heat removal between steps. The rate of reaction is more rapid at high temperature, but equilibrium is more favorable at low temperature. The process gas is first passed over an iron – chromium catalyst followed by further cooling and heat recovery, and then over a copper -zinc catalyst

Carbon Dioxide Removal

Carbon dioxide (CO₂) is removed from the process gas by absorption in a solution of Hot Potassium Carbonate known as Benfield solution. The gas is contacted with the Benfield solution in an Absorber and leaves at the top. The solution itself is regenerated by reducing pressure, heating in a

stripper column and flushing in a flush drum. The released CO₂ is either vented to atmosphere or used as a feedstock in the production of methanol, urea etc.

Component	Composition, %(approx.)
K ₂ CO ₃	29.0
DEA	3.0
V ₂ O ₅	0.9
H ₂ O	67.1

Reaction: $K_2CO_3 + H_2O + CO_2 = 2KHCO_3$ (For Absorption)

$2KHCO_3 = K_2CO_3 + H_2O + CO_2$ (For Regeneration)

DEA: Acts as an activator by lowering vapor pressure of CO₂.

V₂O₅: Acts as a corrosion inhibitor.

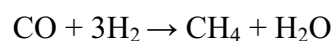
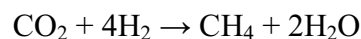
Operating variables

1. Solution Circulation rate
 - Total Solution Circulation rate
 - Solution Split rate
2. Heat input to regenerator
3. HPC solution concentration
4. Temperature
5. Pressure
6. Residual CO₂
7. Foaming

Methanator

The gas stream leaving the Absorber consists primarily of hydrogen and nitrogen in addition to small quantities (ppm) of unabsorbed carbon oxides and unconverted carbon monoxide. Since these will cause poison the ammonia synthesis catalyst the concentration must be reduced to less than 10 ppm. In the Methanator the carbon oxide is converted back to methane over a nickel catalyst in a reaction, which is reversed to that of steam reforming.

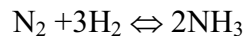
Reaction



Ammonia Converter

The gas leaving the Methanator (27.5 kg/cm²G pressure and 40°C temperature) is compressed to 132.5 kg/cm²G pressure (called make-up gas), mixed with recycled gas, and sent to the ammonia synthesis reactor, which is a vessel containing catalyst. The single pass conversion of ammonia is not more than 25% and the reaction is exothermic. Synthesis gas comes out from converter at 450°C with 17.1% ammonia and passes through waste heat boiler, boiler feed water preheater and hot exchanger (*exchanged heat with recycled stream i.e. feed gas*) etc to recover energy. To separate product ammonia from other components in the product stream, further cooling and chilling is done. Ammonia itself is used as refrigerant in the chiller shell side (product mixture is passed through the chiller tube side). Ammonia form mist in the product gas mixture which is separated in a separator at 118 kg/cm²G pressure. The separated ammonia is flushed, stored or sent to urea plant for producing urea. The gas mixture separated from ammonia in ammonia separator is mixed with make-up gas and recycled to the converter after compressing and attaining to inlet temperature by exchanging heat with converter outlet gas. Some percent of recycled gas is purged to maintain the inert level in the synthesis loop. Normally purging is done before mixing with make-up gas.

Reaction



The rate of ammonia synthesis process depends on

- a. Temperature
- b. Pressure
- c. Space velocity
- d. Concentration of N₂, H₂, and NH₃ in the feed gas
- e. Content of inert impurities
- f. Activity of the Catalyst

The space velocity is the volume of gas in m³ passed through 1 m³ of catalyst in 1 hr (m³ / m³-hr)

Waste Heat Recovery

- Heating BFW
- Generating Steam
- Heating Process Stream
- Superheating Steam

Process Condensate Treatment and Recovery

Since process condensate comes from process steam, it contains metal ions, methanol, formaldehyde, ammonia, etc as it goes through catalyst beds. Thus conductivity of PC is high and need to treatment for further use.

Physical Properties of Ammonia

Ammonia is under pressure, a liquefied gas, which is recognizable at the smell. It is lighter than air, and be explosive and flammable under certain circumstances. Ammonia is soluble in water in an exothermic reaction. Ammonia has the following physical properties

Density (liquid, 20 kg/cm ² , 25 ⁰ C) :	603 kg/m ³
Melting point:	-78 ⁰ C
Boiling point:	-33 ⁰ C
Ignition temperature	630 ⁰ C
Lower explosion limit(in air)	15 vol% ammonia
Upper explosion limit (in air)	29 vol% ammonia
Molecular weight	17.03

Physical Properties of Carbon Dioxide

Carbon Dioxide is a colorless, odorless gas, which is also not inflammable and not explosive. It is heavier than air.

Density (gas, 1 kg/cm ² , 25 ⁰ C) :	1.8 kg/m ³
Triple point	-57 ⁰ C and 5.1 atm
Critical point	31 ⁰ C and 72.8 atm
Molecular weight	44.01

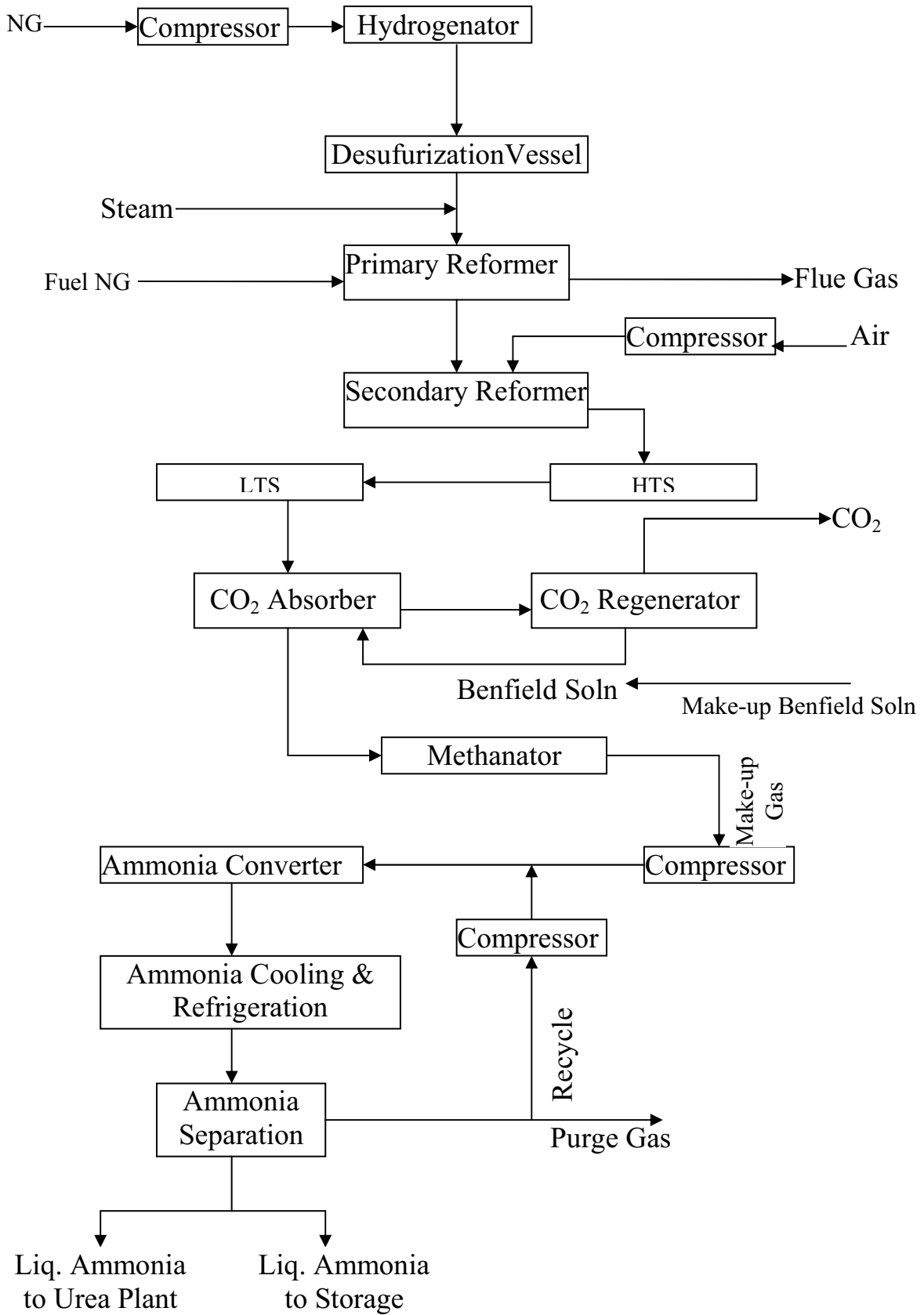


Figure 1: Block Diagram of Ammonia Plant

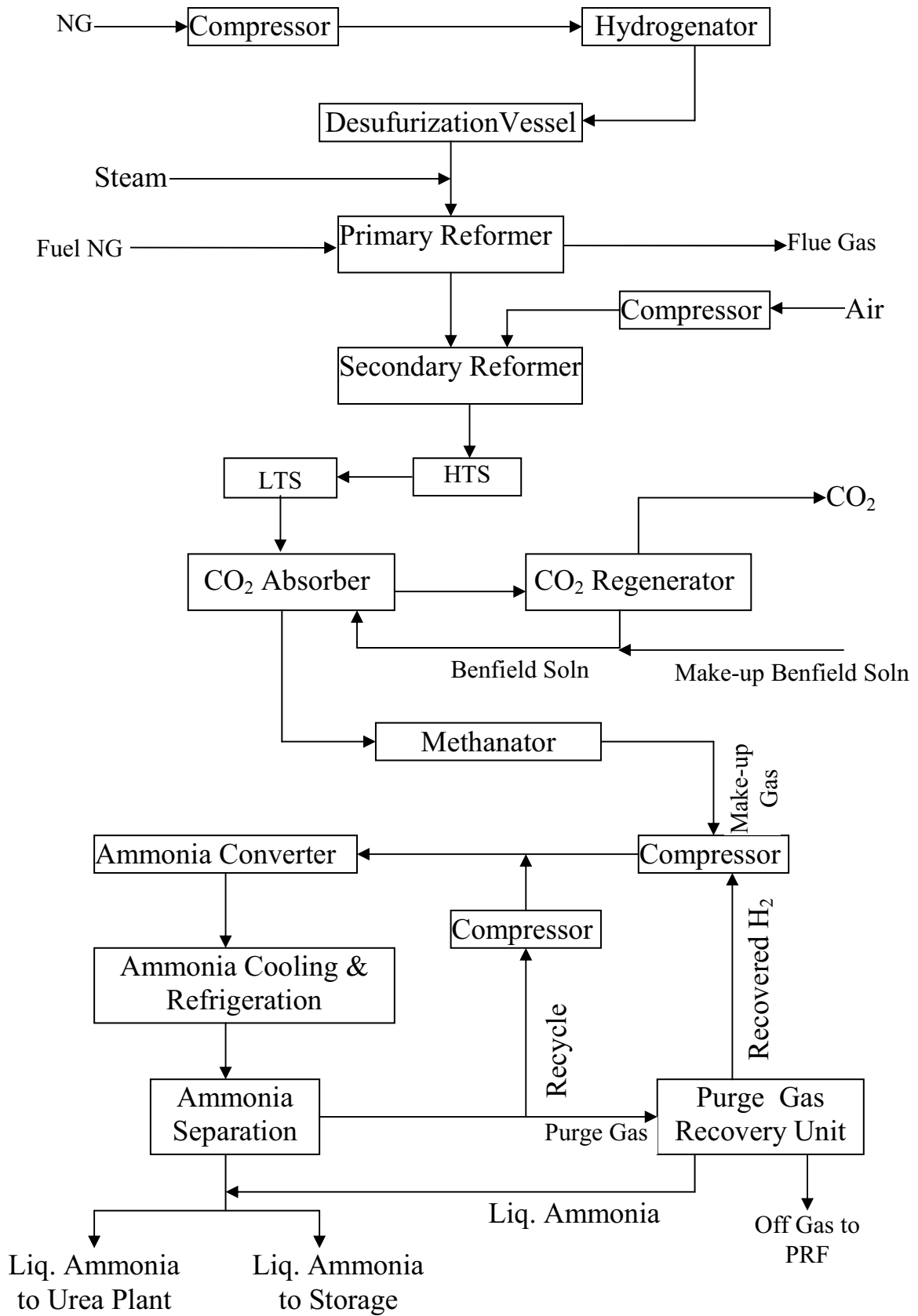


Figure 2: Block Diagram of Ammonia Plant with

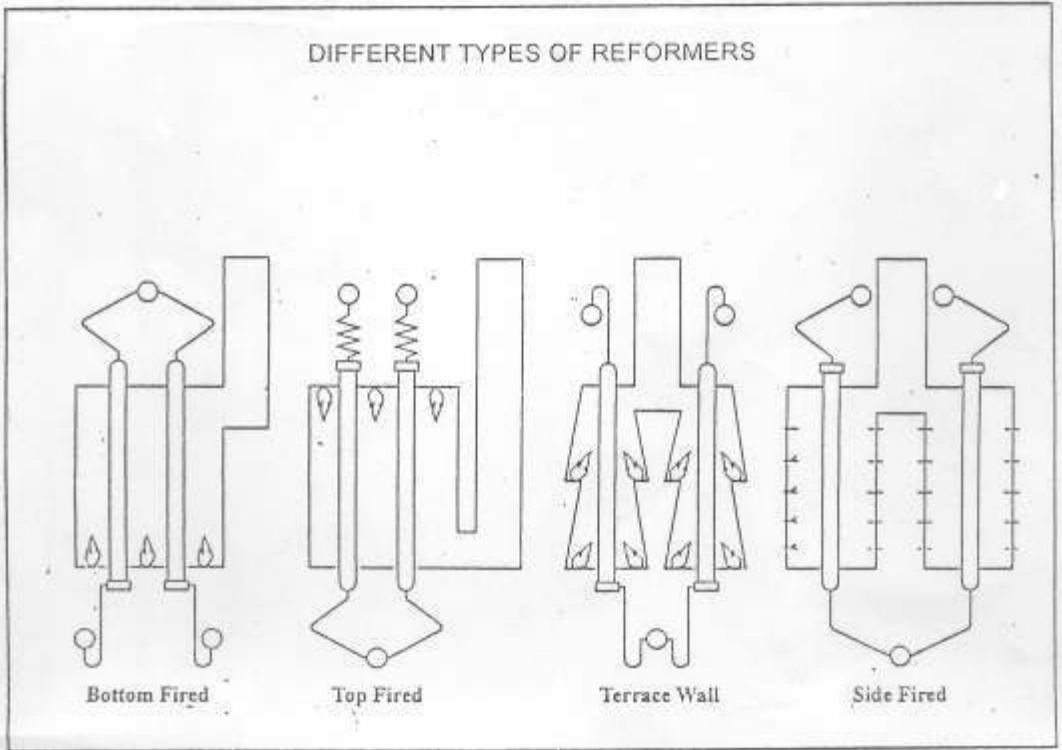


Figure 3: Different types of firing system

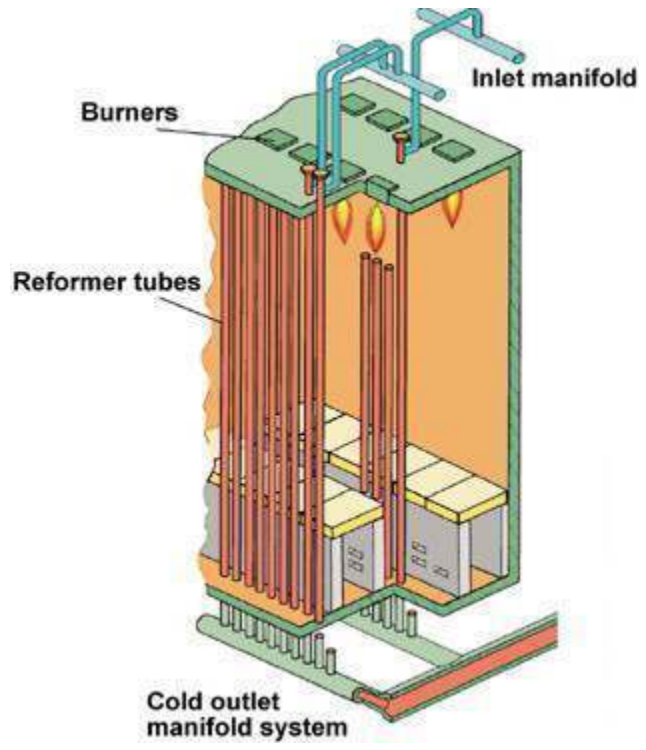


Figure 4: Cross Sectional view of Primary Reformer (Uhde-Top Firing)

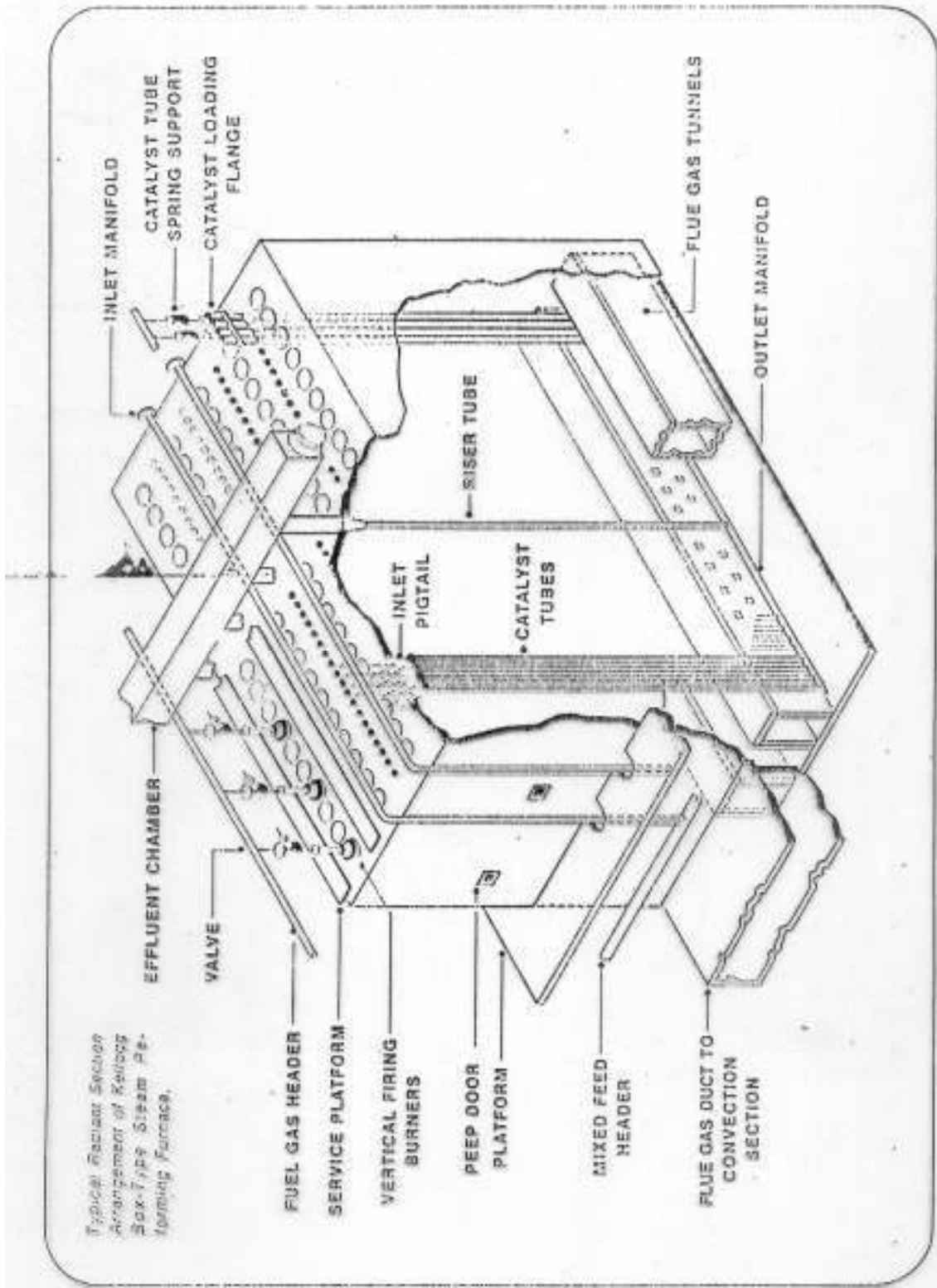


Figure 5: Cross Sectional view of Primary Reformer

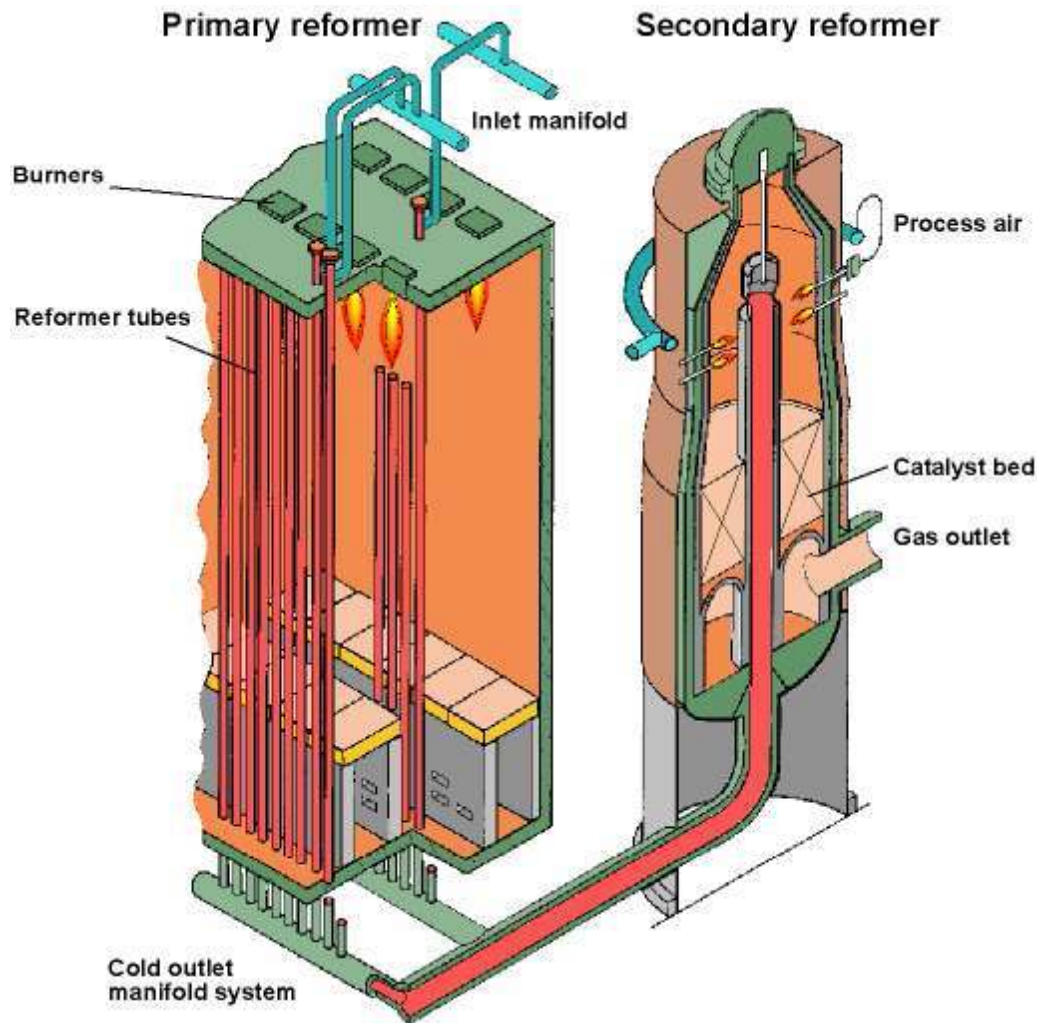


Figure 6: Cross Sectional view of Secondary Reformer along with Primary Reformer (Uhde Process)

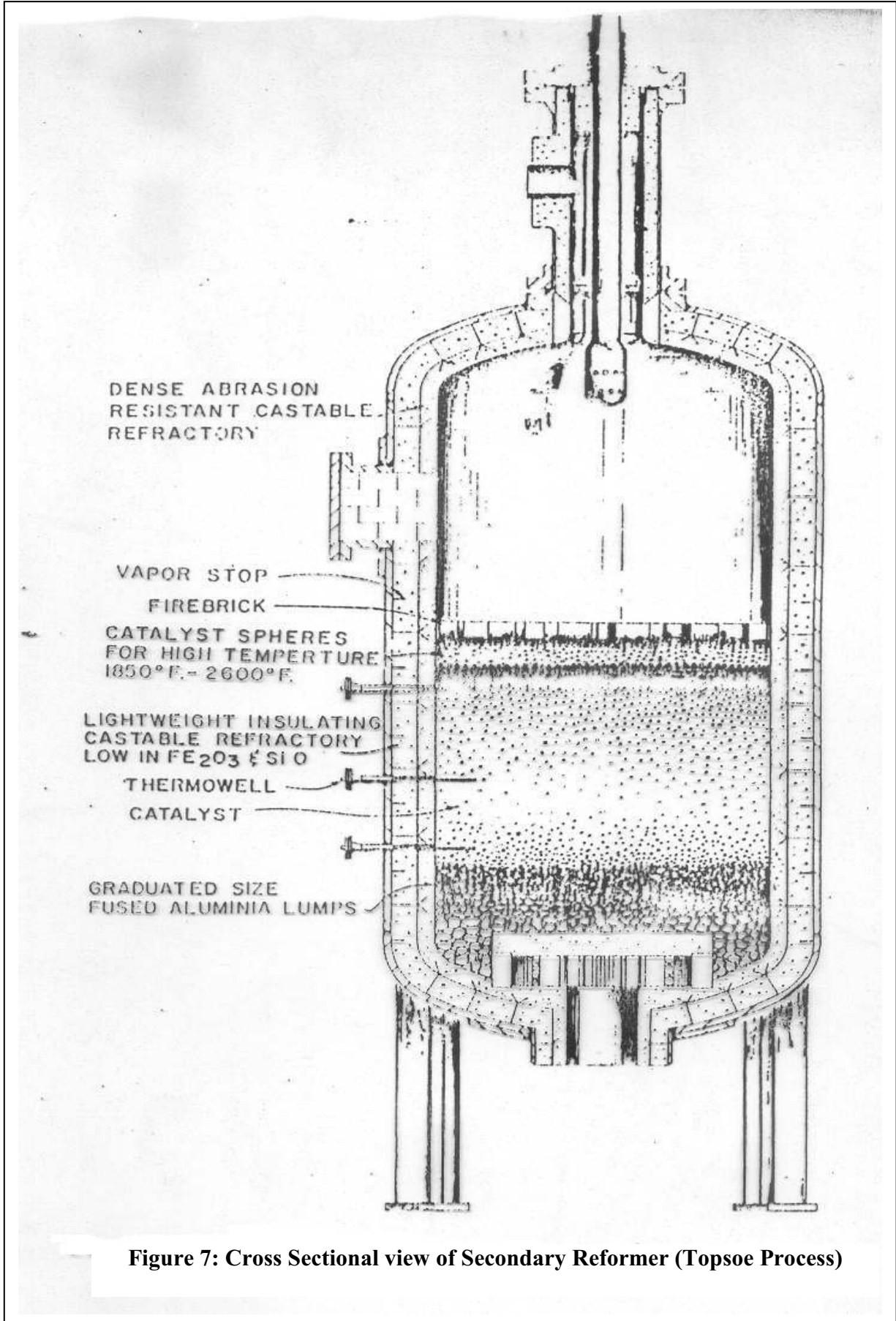


Figure 7: Cross Sectional view of Secondary Reformer (Topsoe Process)

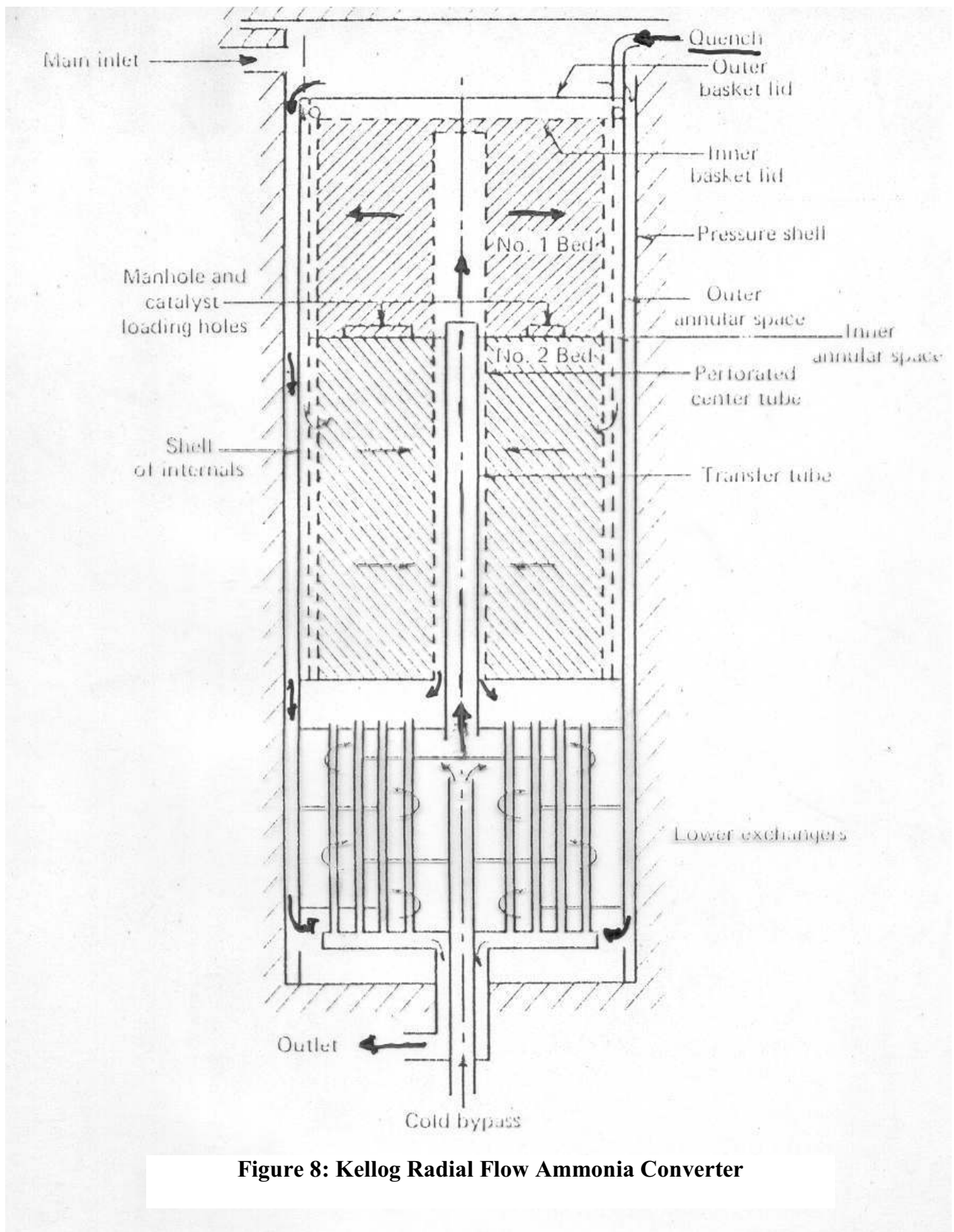


Figure 8: Kellogg Radial Flow Ammonia Converter

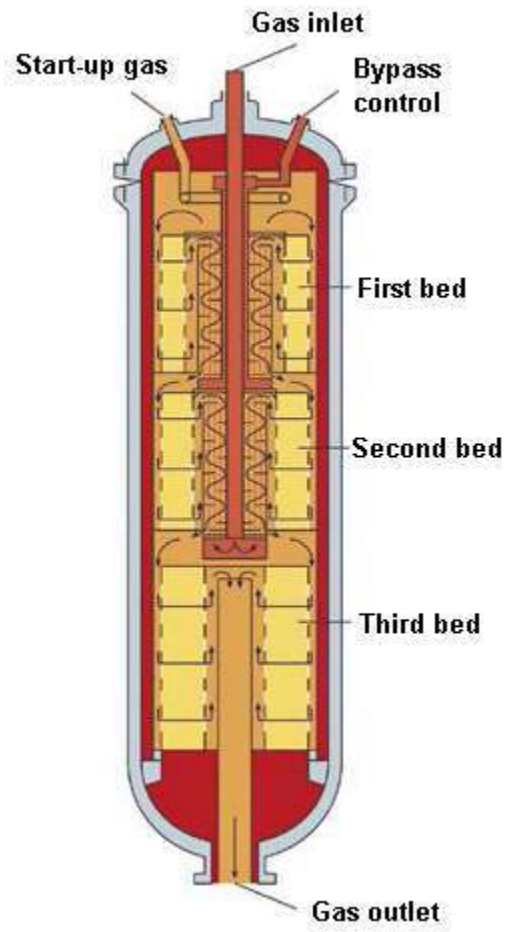
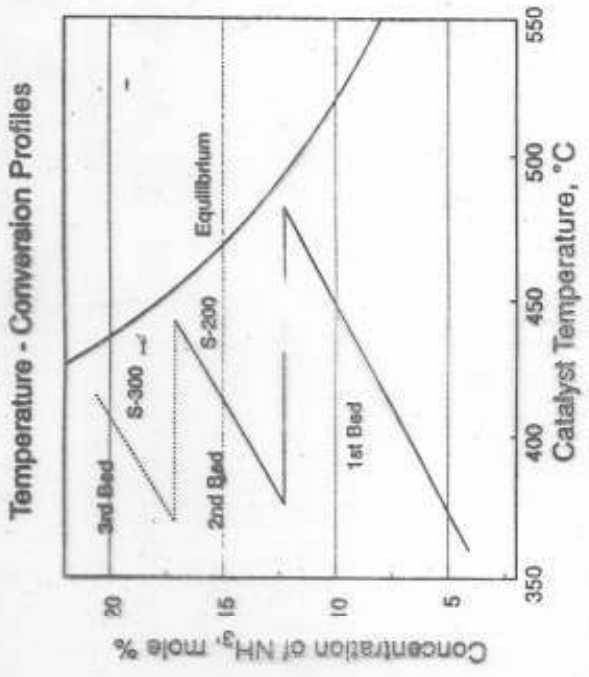


Figure 9: Radial Flow Ammonia Converter(Uhde Process)



Temperature-Conversion Profiles in Topsoe Converters.

Figure

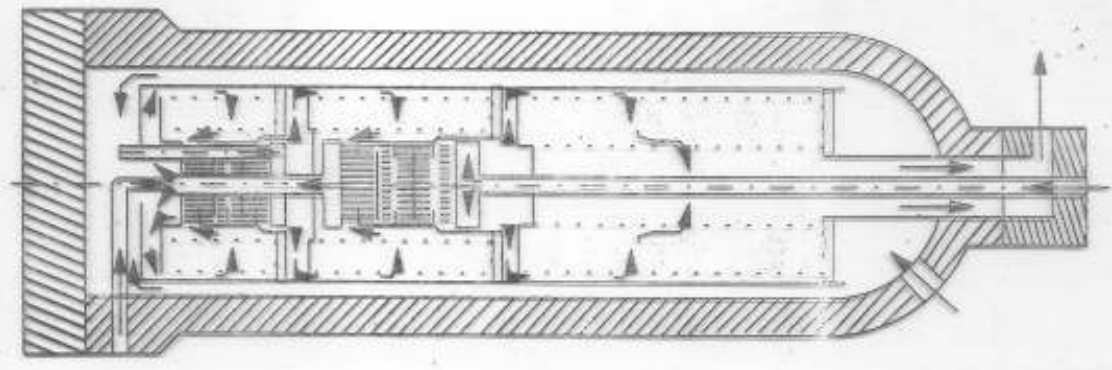


Figure 10: Topsoe Radial Flow Ammonia Converter

UREA PLANT

Raw Materials:

1. Ammonia
2. Carbon dioxide

Product: Urea

Physical Properties of Urea

Urea is a white crystal, which is not inflammable, not conductive and has the following properties

Density (solid, 20 ⁰ C) :	1335 kg/m ³
Melting point:	132.6 ⁰ C
Melting heat (melt point):	13.6kJ/mol
Specific heat (melt):	126 J/mol ⁰ C
Molecular weight	60.056
Formula	H ₂ N-CO-NH ₂

PROCESS DESCRIPTION

Urea is synthesized from ammonia and Carbon dioxide, which is first organic compound, prepared by inorganic synthesis reaction. It is most popular nitrogen fertilizer in Asia and in many other countries on other continents. Solid urea fertilizer is easier to use in the field. More than 50 million tons of urea is now produced annually.

The urea plant has 5 sections excluding utility system.

1. Synthesis sections
2. Purification section
3. Concentration and prilling section
4. Recovery section
5. Process condensate treatment section

PROCESS REACTIONS

Two principal reactions take place in the formation of urea from ammonia and carbon dioxide. The first reaction is exothermic and the second reaction is endothermic. Both reactions combined are exothermic.



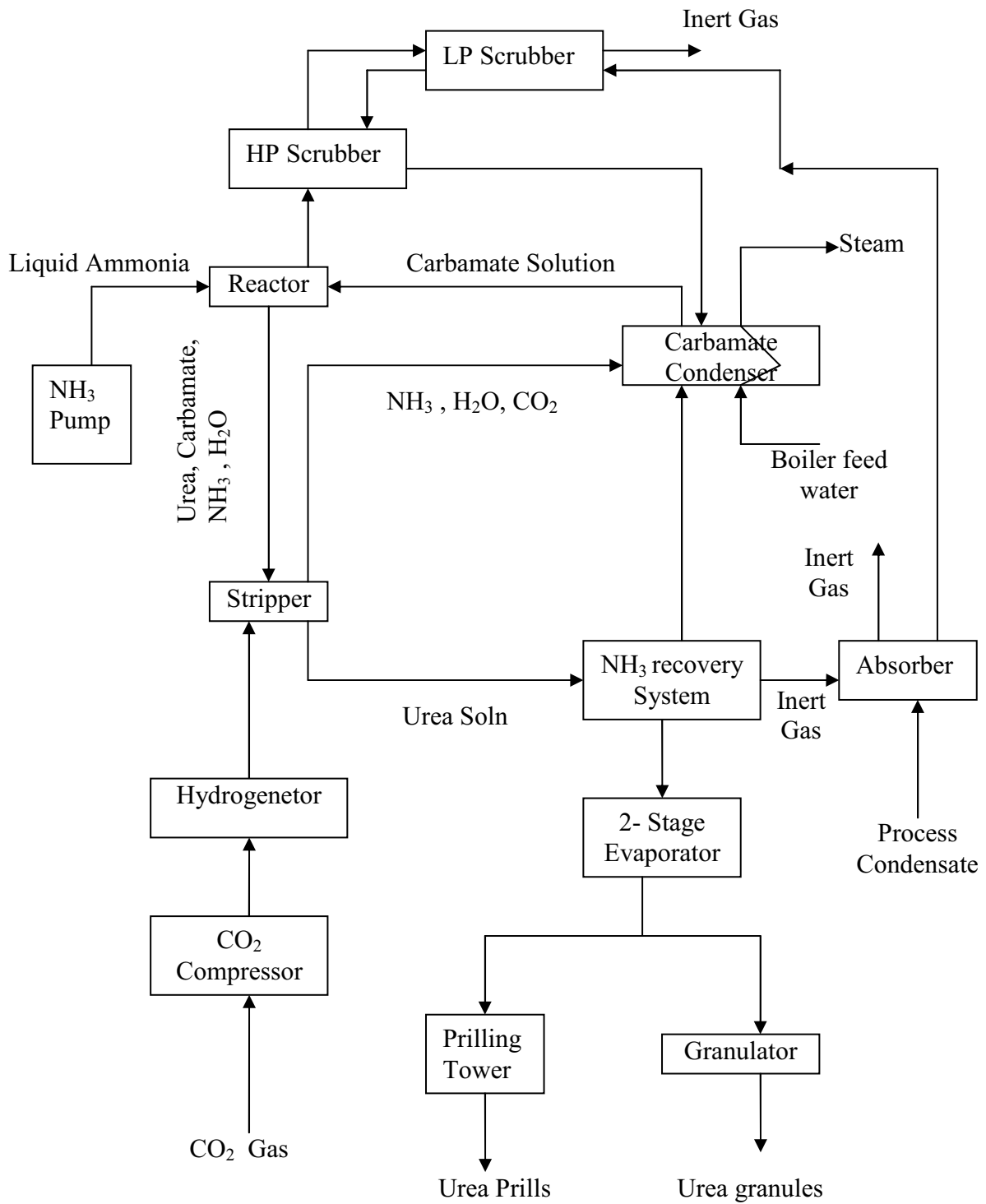


Figure 11: Block Diagram of Stamicarbon Stripping Process

STAMICARBON PROCESS

In the Stamicarbon stripping process, Carbamate is decomposed at the reaction pressure by reducing its partial pressure with an atmosphere of carbon dioxide. Recombination of ammonia and carbon dioxide to form Carbamate also takes place at this pressure and at high temperature, thereby aiding heat recovery in the form of steam production. The vessels the reactor, stripper and condenser are so positioned that the recycled carbamate solutions flows into the reactor from the condenser by gravity. The reactor is a vessel lined with stainless steel and containing a series of trays to assist mixing of the reactants. Traces of air are injected to the reactor along with CO₂ to inhibit corrosion. The optimum NH₃ /CO₂ mole ratio of 2.8 is maintained in the reactor by feeding NH₃ into it. This gives the minimum equilibrium pressure allowing savings in equipment and compression costs. The reactor temperature and pressure are kept in the range of 180⁰ – 190⁰C and 120-150 bars. The conversion based on the product leaving the reactor is 50-60 while based on the product leaving the stripper is about 85%.

Stripping takes place at the reaction pressure in a vertical steam-heated tubular exchanger having fixed tube sheets and a special distributor for the CO₂ feed. Uniform liquid distribution is also essential. The steam used for heating the solutions at a pressure of about 25 bars.

The stripped Ammonia and Carbon dioxide recombined to form Carbamate in a condenser operating at the same pressure as the reactor. The heat of reaction and the sensible heat of solution are used to raise low-pressure steam in the shell of the condenser. The reaction is allowed to proceed to 80% completion by manipulation of the steam pressure. The optimum NH₃/CO₂ ration in the condenser feed is 2.4. This value gives the maximum equilibrium temperature and is more favorable for steam generation. Ammonia is added at the condenser inlet to maintain the ratio. The reactant temperature at the condenser outlet is 170⁰C.

On leaving the stripper, urea solution is letdown to a pressure of 3-6 bar and heated with steam to release small amount of ammonia, carbon dioxide and water vapor it contains. These are then condensed in a water cooled condenser and the resulting weak carbamate solution is pumped back to the high pressure condenser. Inert gases are purged from the reactor and any ammonia or carbon dioxide present in it is absorbed in water and reused.

The urea solution is then pumped to a storage tank from which it is drawn for further processing – prilling and granulation.

Because of the corrosive nature of the process fluids, special stainless steels are used in the construction of all process equipment

UTILITY PLANT

Raw Materials:

1. Natural Gas
2. Air
3. Water

Product:

1. Steam (HP, MP, LP)
2. Power
3. Natural Gas (Process, Fuel, Flare Stack, Kitchen)
4. Boiler Feed Water
5. Cooling Water (Utility, Main)
6. Drinking Water
7. Service Water
8. Plant Air
9. Instrument Air
10. Nitrogen

Major Units

1. Clarifier
2. Sand filter
3. Cooling Tower
4. Demineralization Unit
 - Carbon Filter
 - Cation Exchanger
 - Degasifier
 - Anion Exchanger

- Mixed Bed Polisher
- 5. Boiler
- 6. Instrument Air and Plant Air Supply
- 7. Nitrogen Production Plant
- 8. Waste Water Treatment Section

Description

1. Clarifier

In clarifier different chemicals are added into water in the mixing zone. During this stage microflocs are formed. Water from the mixing section of the clarifier is routed to the coagulation and flocculation section of the clarifier through distribution pipes. Water is spread out evenly through the bottom of the clarifier water flows upwards uniformly by the effect of the bottom shape. The microflocs become larger and adhere in the slurry blanket layer. The clarified water passed through the slurry blanket layer, which is collected by the collecting trough installed at the upper part of the clarifier and send to sand filter. The excess slurry is drained from the bottom by logic control valve.

Chemicals:

- **Caustic Soda:** To control P^H at 7.0, because at this P^H coagulation and flocculation is favorable.
- **Alum**
 - To grow fine flocs into large size
 - To settle out mud in the clarifier
- **Chlorine**
 - To sterilize Raw Water
 - To oxidize the dissolved iron as ferric hydroxide as precipitate
- **Coagulant Aid:** one type of polymer, which helps to coagulate quickly.

2. Sand Filter

Sand filter is used to remove Mn, As and other fine particles, microflocs remaining in the clarified water. Fine particles are caught by sieving, adhesion, sedimentation etc and are retained in the void space of sand. Diatomaceous earth is used as sand filter.

3. Cooling Tower

Cooling water becomes hot when it exchanges heat with process gas or (other fluid) through different exchanger. In closed re-circulation cooling water system, this water is cooled in a secondary cooler using seawater, air etc. it is then re-circulated and reused. Cooling Tower is such type of secondary cooler where air and water flows counter current way. Air is induced into cooling tower by using fan. Cooling water may be cooled 10 to 15⁰C by using cooling Tower. The cooling mechanism of cooling tower is the vaporization of some water. The atom, which is vaporized, takes latent heat from its neighbor, vaporized itself and cooled the neighbors.

Chemicals:

- **Sulphuric Acid:** To control P^H
- **Chlorine:** To kill bacteria and other such types of microorganism
- **Dispersant:** Zn based Phosphate polymer, which is used to prevent scale formation.
- **Corrosion Inhibitor:** Zn based Phosphate polymer, which is used to prevent corrosion.

4. Demineralization unit

- **Carbon Filter:**
- **Cation Exchanger:** To remove Ca⁺⁺, Mg⁺⁺, Na⁺, etc
 - $R-H + Na^+ = R-Na + H^+$
- **Degasifier:** To remove dissolved carbon dioxide in water.
 - $H_2CO_3 \rightarrow CO_2 + H_2O$
- **Anion Exchanger:** To remove SO₄⁼, CO₃⁼ etc
 - $R-OH + SO_4^= \rightarrow R_2-SO_4 + OH^-$
- **Mixed Bed Polisher:** It is used to obtain highest purities in the treatment of feed water and condensate for high-pressure steam boiler. Upper bed is cation exchanger.

5. Boiler

Boiler is used to generate High Pressure steam.

Boiler feed Water Treatment

Includes:

- Removal of Air (oxygen).
- Keeping P^H at a certain range

Removal of Air (oxygen)

Air is removed from boiler feed water due to its corrosion effects in boiler.

Deaeration process combined of two steps: First mechanical and then chemical treatment.

1. Mechanical: Dissolved air is removed from the water by a countercurrent flow with steam.
2. Chemical: Hydrazine is added to remove dissolve Oxygen.

Keeping P^H at a certain range

- Ammonia is used to raise pH above 9.0 so as to prevent corrosion.
- Phosphate Solution is added to inlet of the steam line control pH (buffer solution).

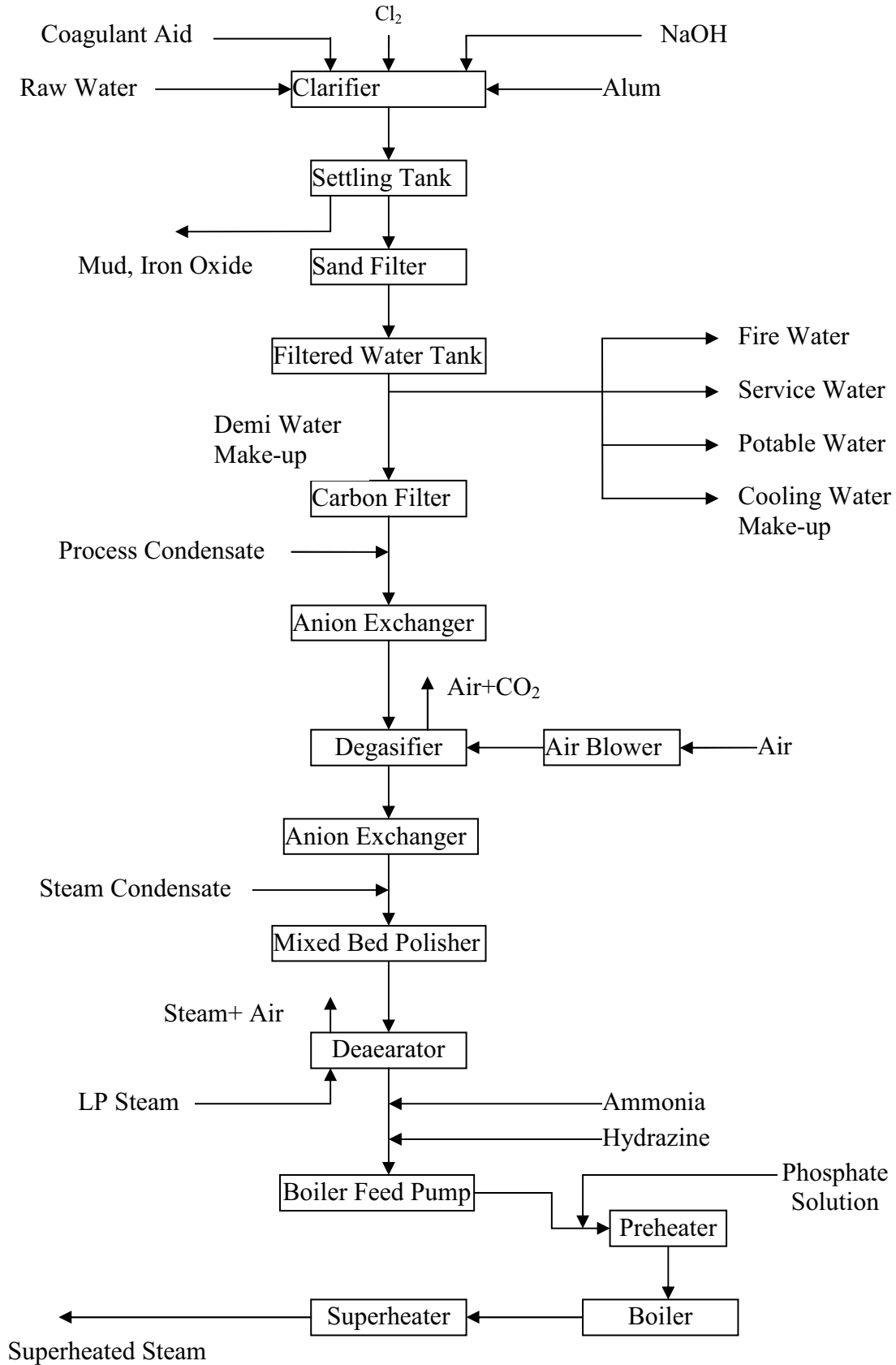


Figure 12: Block Diagram of Superheated Steam Production

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WATER TREATMENT FLOW DIAGRAM

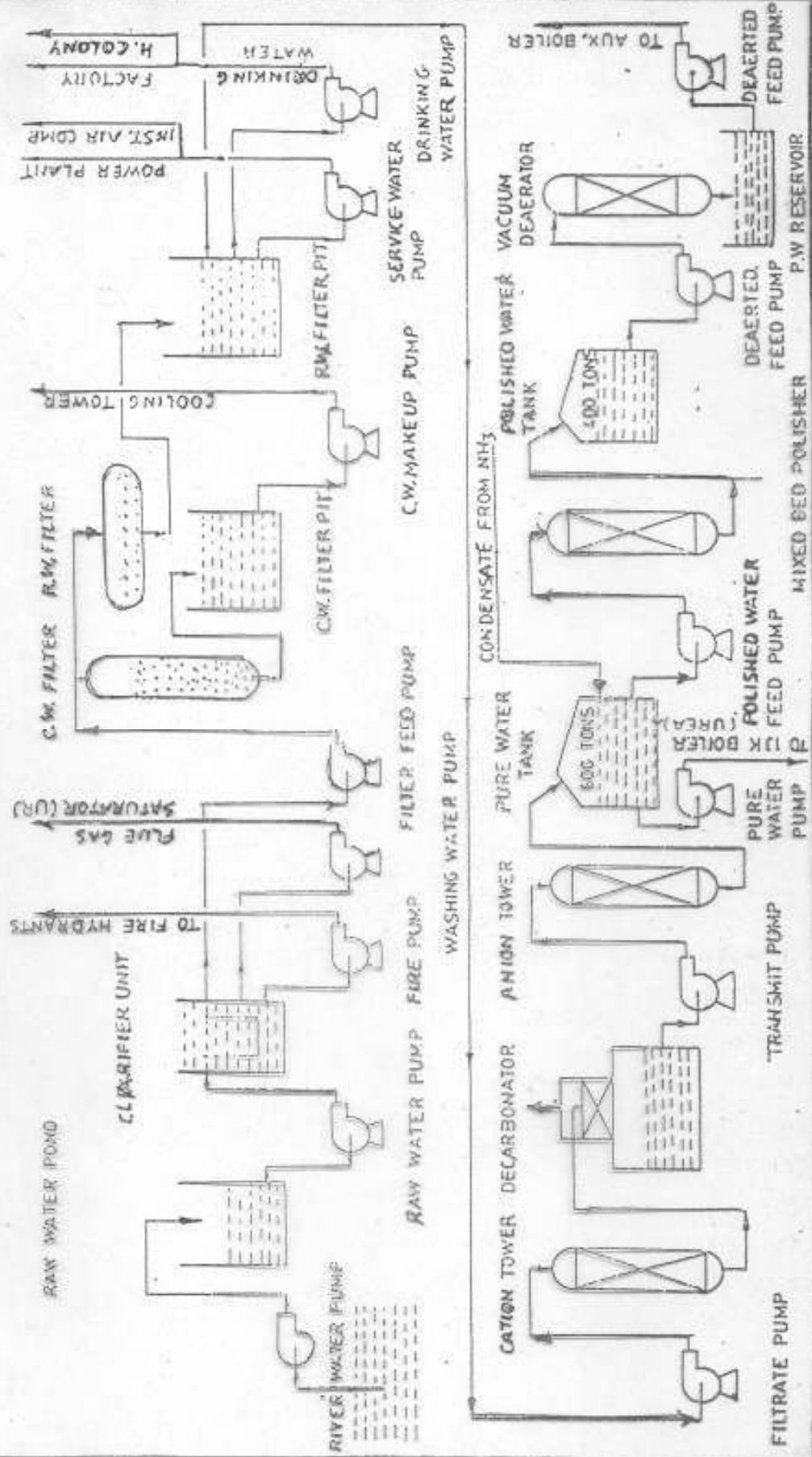


Figure 13: Block Diagram of Boiler Feed Water Preparation



Figure 14: Cooling Tower