

Start-Up of the World Largest Ammonia Plant

by

Mr. Naoya Okuzumi, Engineering Manager (Speaker)
Mitsubishi Heavy Industries, Ltd.
3-3-1 Minatomirai, Nishi-ku Yokohama, Japan

Mr. Brian D. Jones, Director
P.T. Kaltim Pasifik Amoniak
Jl. Paku Aji Kav.79, Bontang, East Kalimantan, Indonesia

Mr. Svend Erik Nielsen, Ammonia Technology Supervisor
Haldor Topsøe A/S
Nymøllevej 55, DK-2800 Lyngby, Denmark

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ABSTRACT

This paper describes the process lay-out and the start-up experiences of the ammonia plant that has recorded the world largest production in May 2000.

The paper includes a list of milestones achieved during the pre-commissioning /commissioning of the plant.

INTRODUCTION

P.T. Kaltim Pasifik Amoniak is a joint venture company established among Mitsui & Co., Tomen Corp. of Japan and P.T. Talang Gumbaru Andhika of Indonesia. The company was set up to build, operate and own the world largest Ammonia plant in Bontang, East Kalimantan Timur, Indonesia and export refrigerated ammonia to the consumers in Asian countries.

The plant, hereinafter called KPA plant, uses natural gas as feedstock. The nameplate capacity of the plant is 2,000 MTPD of refrigerated ammonia with 99.8wt% purity.

Haldor Topsøe A/S is the process licensor for ammonia technology and BASF is the licensor for the CO₂ removal section.

The main contractor is Mitsubishi Heavy Industries, Ltd. for the lump sum, turnkey EPCC Contract (Engineering, Procurement, Construction and Commissioning) based on a 34 months completion period.

PROJECT SCHEDULE

Upon the signing of the EPC Contract between the concerned parties, the project has been implemented following the milestones as described below.

04 Aug.1997	Effective Date of the Contract
30 Apr. 1998	Start of Civil Works (Start of Piling)
01 Oct. 1998	Erection Work Start
18 Jan. 1999	Power Receiving
03 Jan. 2000	Mechanical Completion
24 Jan. 2000	First Ignition of Reformer Burners
11 Feb. 2000	Start of Commissioning
29 Mar. 2000	First ammonia product to storage
21 May 2000	Completion of Sustained Load Test
30 May 2000	Completion of Performance Test

CONTRACTOR MHI

Since 1997, MHI has been awarded four contracts for large scale fertilizer plants based on Haldor Topsøe's ammonia technology and Snamprogetti's urea technology as shown in Table I. Among these four contracts, three projects have been implemented in Bontang, East Kalimantan, Indonesia and the total production capacity will be 4,500 MTPD ammonia.

The world largest ammonia plant for KPA was the first to start-up and remaining two plants are scheduled to start-up in the year of 2002 and 2003 respectively.

Table I
MHI Recent Contracts

Client	Location	Licensor	Capacity	Services	Completion
P.T. Pupuk Kaltimantan Timur	Bontang, Indonesia	NH ₃ : Haldor Topsøe Urea : Snamprogetti Granulation : HFT	1,000 T/ D 1,725 T/ D	BDPC	E 2003
P.T. Kaltim Parna Industri	Bontang, Indonesia	NH ₃ : Haldor Topsøe	1,500 T/ D	BDPC	U 2002
P.T. Kaltim Pasifik Amoniak	Bontang, Indonesia	NH ₃ : Haldor Topsøe	2,000 T/ D	BDPC	2000
Petronas Fertilizer (Kedah) Sdn. Bhd.	Malaysia	NH ₃ : Haldor Topsøe Urea : Snamprogetti Granulation : HFT	1,350 T/ D 2,000 T/ D	BDPC	1999

Abbreviation; B: Basic Design, D: Detail Design, P: Procurement, C: Construction
U: Under Construction, E: Engineering

PLANT CONFIGURATION

As illustrated in Figure 1, the plant configuration consists of ammonia process unit and supporting facilities. The basic principles considered during the design stage were to utilize existing utility supply to the maximum extent.

At the start up of the plant, 80 Kg/cm²g steam and hydrogen (syngas) are imported.

Optimization of the use of sea water and close loop cooling water circulation was made, and sea water cooling were applied wherever possible like for example in steam turbine condenser.

Steam is generated by the recovery of waste heat from the process streams and the excess steam is exported to outside battery limit during normal operation.

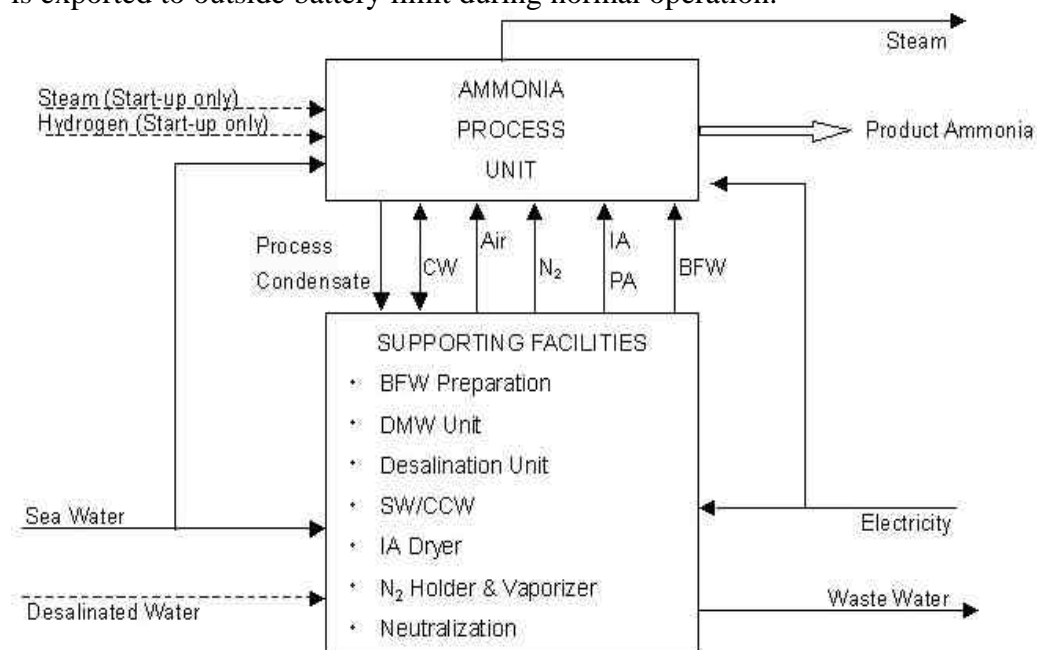


FIG. 1: PLANT CONFIGURATION

PROCESS LAY-OUT

At the design stage of the KPA plant, in close collaboration with the plant owner, a process lay-out was developed comprising desulphurization on ZnO, primary and secondary reforming, two-step shift conversion, MDEA CO₂-removal, methanation, compression, S-250 ammonia synthesis loop, cryogenic hydrogen recovery and product recovery. The process lay-out of KPA plant is illustrated in Figure 2.

The primary reformer in the front-end section is based on the well-known side fired concept supplied by Topsøe for a large number of plants, and to achieve a compact lay-out the convection section is located on top of the reforming furnace. The secondary reformer including the nozzle burner follows to the primary reformer.

Also in the CO₂-removal section a compact lay-out with the stripper as well as the HP/LP flash section in one tower has been selected to minimize the plot area.

The shift section comprises high and low temperature shift converters.

Energy efficiency has been an important factor and the steam to carbon ratio at the reformer inlet is 2.8, thereby matching the heat input requirements of the reboiler in the low-energy CO₂-removal section.

A high conversion per pass is achieved in the ammonia synthesis loop by selecting the S-250 converter system operating at 140 kg/cm²g. Waste heat after the synthesis converter is used for high-pressure steam production, and all boilers in the entire ammonia plant have a common steam drum without sacrificing any operability.

A cryogenic purge gas recovery unit recovering hydrogen at a pressure of 85 kg/cm²g improved the efficiency of ammonia synthesis loop. Ammonia recovery unit was provided prior to the hydrogen recovery unit to minimize ammonia loss and finally leading to NO_x reduction in the primary reformer.

Integration between the process and the steam system is optimized, and all waste heat down to below 160°C is utilized for high-pressure steam production as the off-gas is used as fuel in the primary reformer.

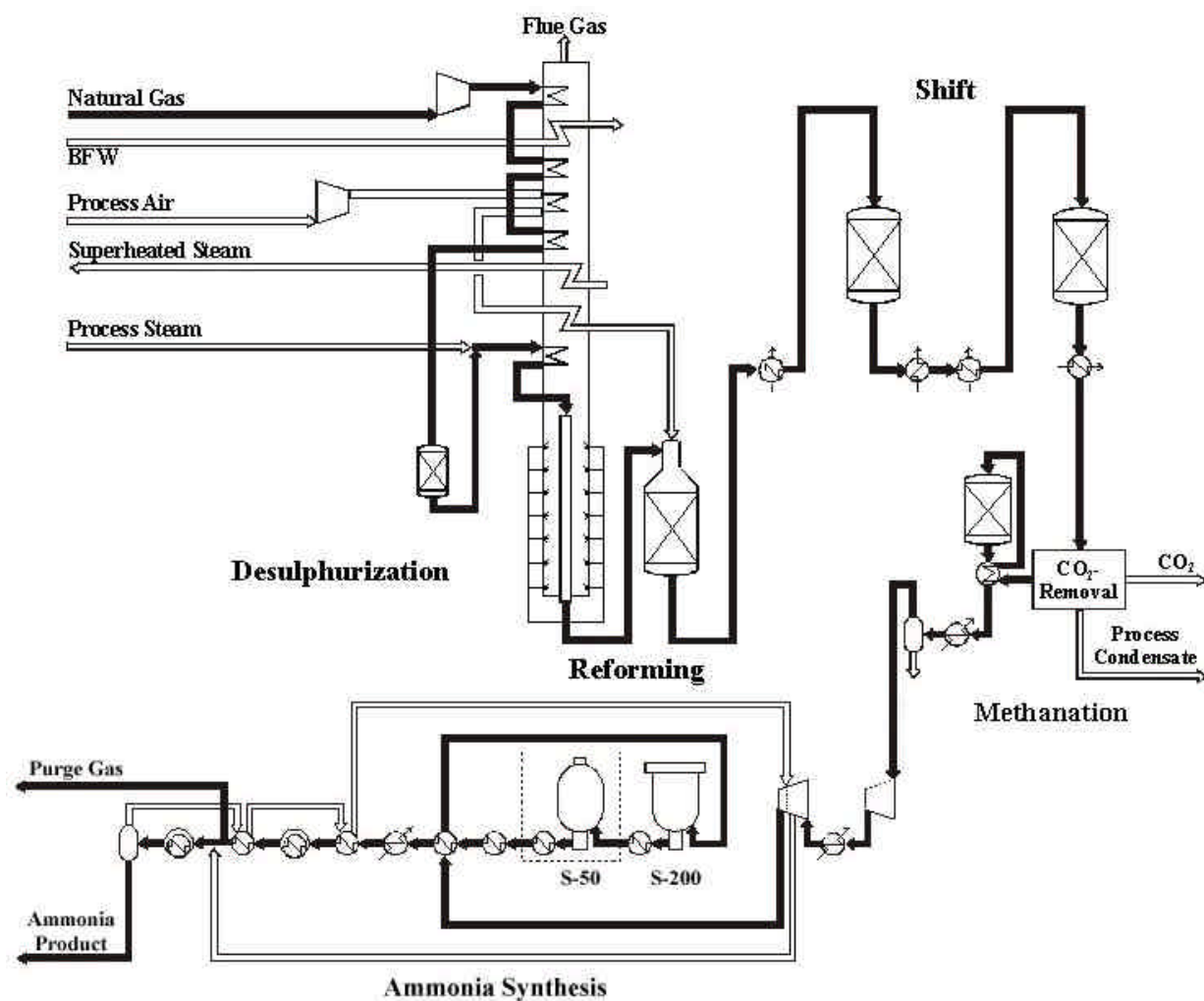


Fig. 2: Basic Flow Diagrams of the KPA Ammonia Plant

SPECIAL FEATURES

The reforming section is very compact and features state-of-the-art design utilizing reformer tube materials allowing operation at more severe conditions such as higher heat flux, higher pressure, etc. The number of tubes as well as the physical size of the reforming box is therefore relatively smaller compared to what has been used in the plants designed in the past.

A very low specific energy consumption figure of 6.89 Gcal/MT NH_3 has been possible with the efficient plant lay-out (credit and debit for steam and power is included). After a small scheduled turn around in October 2000, the specific energy consumption figure has been reduced even further.

S-250 Converter Configuration

The S-250 synthesis loop with two converters, a two-bed (S-200) converter followed by a one-bed (S-50) converter is shown in Figure 3. The S-250 synthesis loop is very energy efficient due to the high conversion per pass and the improved possibility for integration with the steam system.

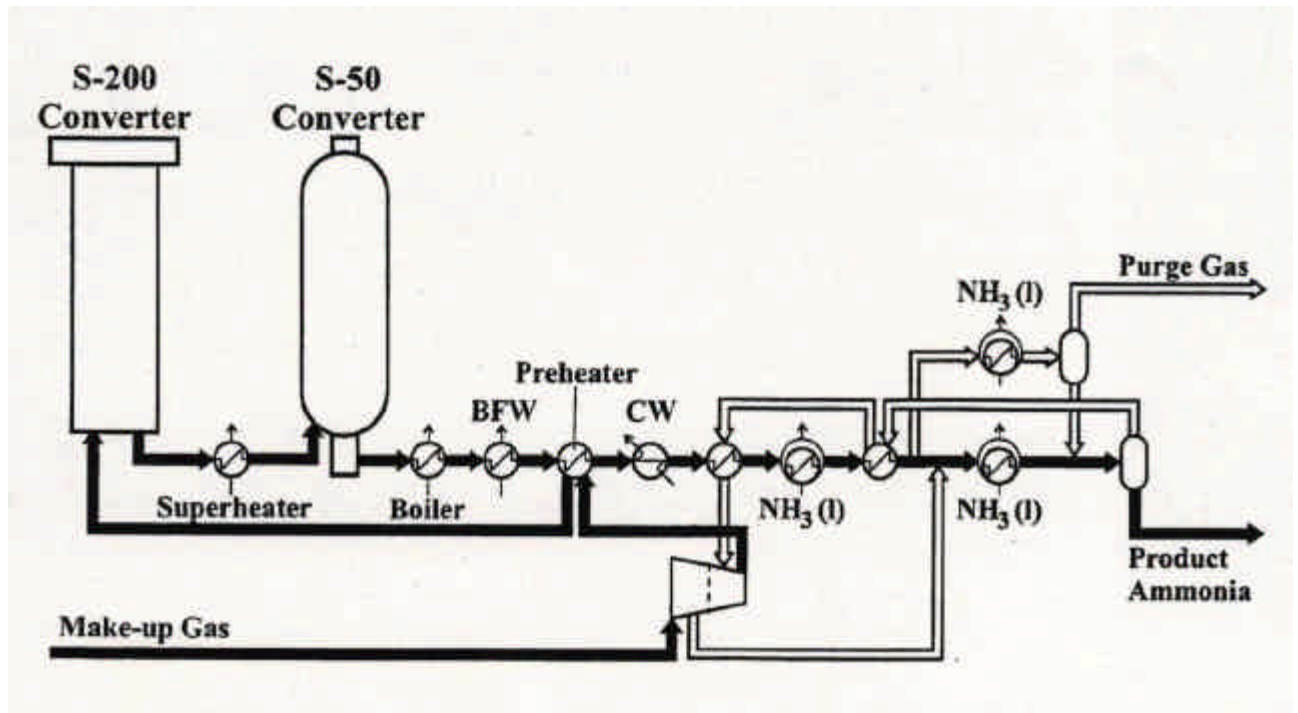


FIG. 3: S-250 CONVERTER CONFIGURATION - LAY-OUT OF SYNTHESIS LOOP

In addition to the converter system, the loop comprises:

- Start-up heater
- Waste heat recovery by generation and superheating of high-pressure steam and preheat of boiler feed water
- Feed effluent heat exchanger (hot exchanger) for preheat of the converter feed gas
- Water cooler in which part of the product ammonia is condensed
- Chillers at two temperature levels for further condensation of the product ammonia
- Gas-gas heat exchangers (cold exchangers) at the inlet to each chiller for recovery of the refrigeration energy
- Product ammonia separator

The waste heat recovery and the control of the temperature in the converter are integrated in a manner that ensures maximum plant efficiency under all operating conditions.

The make-up gas is added to the loop upstream of the last chiller, where most of the ammonia has already been condensed. Traces of carbon dioxide and water vapour are removed by co-condensation in the last chiller so that the risk of poisoning of the synthesis catalyst with these compounds is eliminated.

Purge gas is drawn from the loop after the second cold exchanger just before addition of the make-up gas. At this point the gas has the maximum content of inerts. The purge gas is transferred to a purge gas recovery unit for recovery of hydrogen. Recovered hydrogen is recycled to the process and introduced between first and second casing of the synthesis gas compressor.

The product ammonia is depressurized and taken to the let-down vessel where the main part of the dissolved gases are flashed off. The ammonia content of the flash gas is recovered either by absorption and distillation or by refrigeration.

From the let-down vessel the product ammonia is transferred to the flash vessel and from here the product can be sent either to a urea plant or to storage.

Integrated Steam System

Figure 4 shows schematically the steam generation in the 2000 MTPD ammonia plant. Boiler feed water preheat is provided downstream the low temperature and the high temperature shift converters in the reformer waste heat section, and in the synthesis loop.

Steam boiling is downstream the secondary reformer (there is no steam superheater at this location) downstream the S-50 synthesis converter in a S-250 converter configuration, and steam superheaters are installed in parallel between the S-200 and the S-50 converter downstream the high temperature shift and further for final superheat in the reformer waste heat section.

With only a boiler after the secondary reformer the tube metal temperature is rather low, and in spite of the low steam to carbon ratio, the risk of metal dusting is minimized. The total steam production is around 4.0 tons of high-pressure steam per ton of ammonia at 510°C and 110 kg/cm²g.

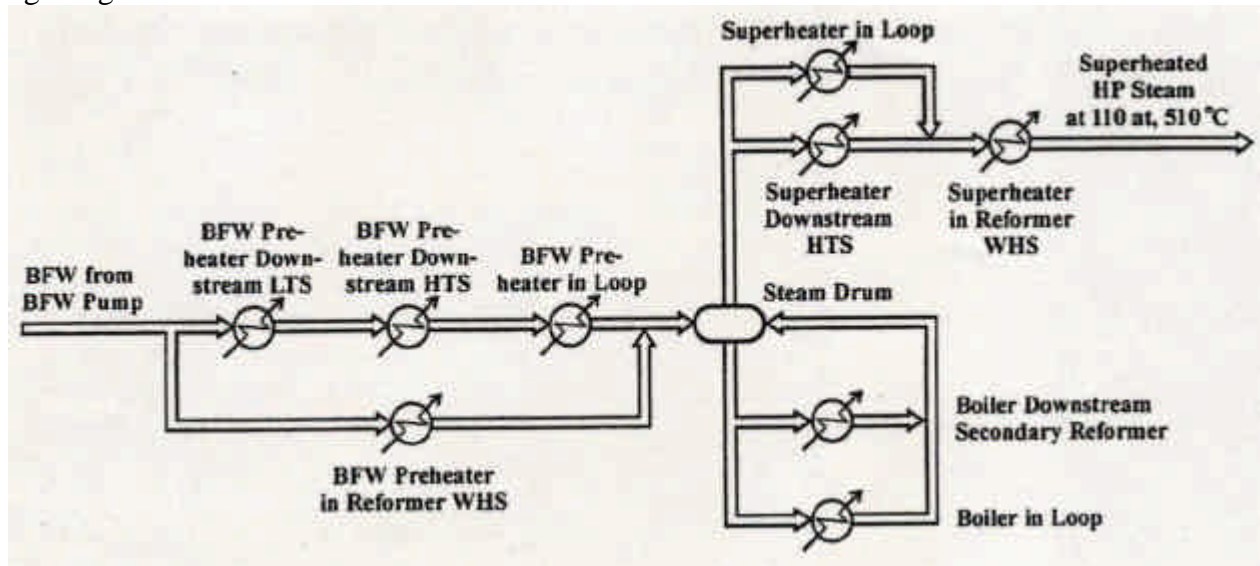


FIG. 4: INTEGRATED STEAM SYSTEM IN 2000 MTPD AMMONIA PLANT

Reforming Section

The primary reformer is based on the well-proven side fired reformer design. Despite the large capacity of the plant, the number of reformer tubes is 240 only.

By designing the reforming section for operation at a steam to carbon ratio of 2.8, and for a relatively high methane leakage of 0.6% methane outlet the secondary reformer, the size of the primary reformer is relatively modest. It has been possible to select these operating conditions in view of the high conversion per pass in the S-250 synthesis loop, and also due to the inclusion of a cryogenic purge gas recovery unit. The reformer inlet pressure is 38 kg/cm²g, a slightly higher operating pressure than used in the past.

By using Ti-containing microalloy for the reformer tubes it is possible to design for and operate at high heat flux, thereby the size of the primary reformer has been minimized.

Preheating of all the process steams as well as final superheating of the high-pressure steam takes place in the reformer waste heat section located on the top of the radiant box of the reformer. This lay-out is very compact, and a separate reformer stack is avoided with this lay-out,

and quite common construction in Kaltim area due to the need for a compact design as the soil conditions are very special.

The reformer flue gas fan is located on top of the furnace, and the required shaft power during normal operation of the fan is thus minimized.

Catalytic Reactor, MDEA CO₂-removal

More active catalysts for the shift converter and the methanation reactor in the synthesis gas preparation section assure that smaller catalyst volumes can be used. The dimensions of the catalytic reactors in the front-end are therefore modest and hence larger plant capacities than envisaged for the actual 2000 MTPD ammonia plant is possible.

In designing the CO₂-removal section, especially the compactness of the unit has been considered during the design stage.

The stripper and the HP/LP flash vessels have been located on top of each other. Thereby the plot area is minimized and the extent of piping is also at a minimum. The overall dimensions of the tower in the MDEA section are relatively large, but still it is low-pressure equipment, and not critical.

S-200 “Cold Wall” Radial Flow Converter

The S-200 converter is shown in Figure 5. The main part of the converter feed is introduced at the bottom of the converter (A) and passes upward through the outer annulus between the basket and the pressure shell, keeping the latter cooled. It then passes to the bottom tube sheet of the interbed heat exchanger through transfer pipes in the interbed heat exchanger and passes the tubes in upward direction, thereby cooling the exit gas from the first bed to the inlet temperature to the second bed.

The remaining part of the feed gas, the “cold shot” gas, is introduced at the bottom of the converter (B) and flows through the transfer pipe to the top of the converter where it mixes with the gas leaving the interbed heat exchanger tubes below the basket cover. The mixed gas flows to the gas distributor panels around the first catalyst bed, in inward direction through the catalyst bed to the annulus between the bed and the interbed heat exchanger, and through the shell side of the interbed heat exchanger to the panels around the second catalyst bed. The second catalyst bed is passed in inward direction, and the gas leaves via the annulus between the catalyst bed and cold shot pipe to the converter outlet (C).

S-50 “Hot Wall” Converter

With the “hot wall” design, the pressure shell will be exposed to only bed inlet temperatures, whereas the higher bed outlet temperatures are confined to the central part of the converter and the bottom piece. Maximum advantage of the “hot wall” design without shell cooling gas is obtained in a single-bed converter with a very simple design.

The actual size of the S-200 converter corresponds to a production of approx. 1600 MTPD of ammonia, and the remaining quantity of approx. 400 MTPD of ammonia is produced in the S-50 converter. No special design features have been required to cope with the large plant capacity. Inner diameter of the pressure shell is 3300 mm, and converters with even larger dimensions can be manufactured in the workshops. The limitation for a given project will be a compromise between the actual transport restrictions at the specific site and the equipment weight, and thereby the requirement for heavy lift cranes, etc. at site.

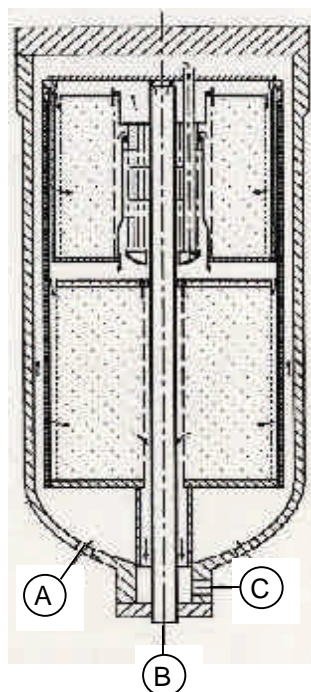


FIG. 5 : TOPSØE S-200 CONVERTER WITHOUT LOWER HEAT EXCHANGER

Compressors and Turbines

Around 360 t/h of high-pressure steam ($110 \text{ kg/cm}^2\text{g}$, 510°C) is produced in the ammonia plant.

All the major compressors as well as the large pumps are steam turbine driven as shown in Figure 6. The synthesis gas compressor and the refrigeration compressor are driven by high-pressure steam with extraction of medium pressure steam. The synthesis gas compressor turbine comprises an additional condensing turbine to balance the load on the medium temperature steam header.

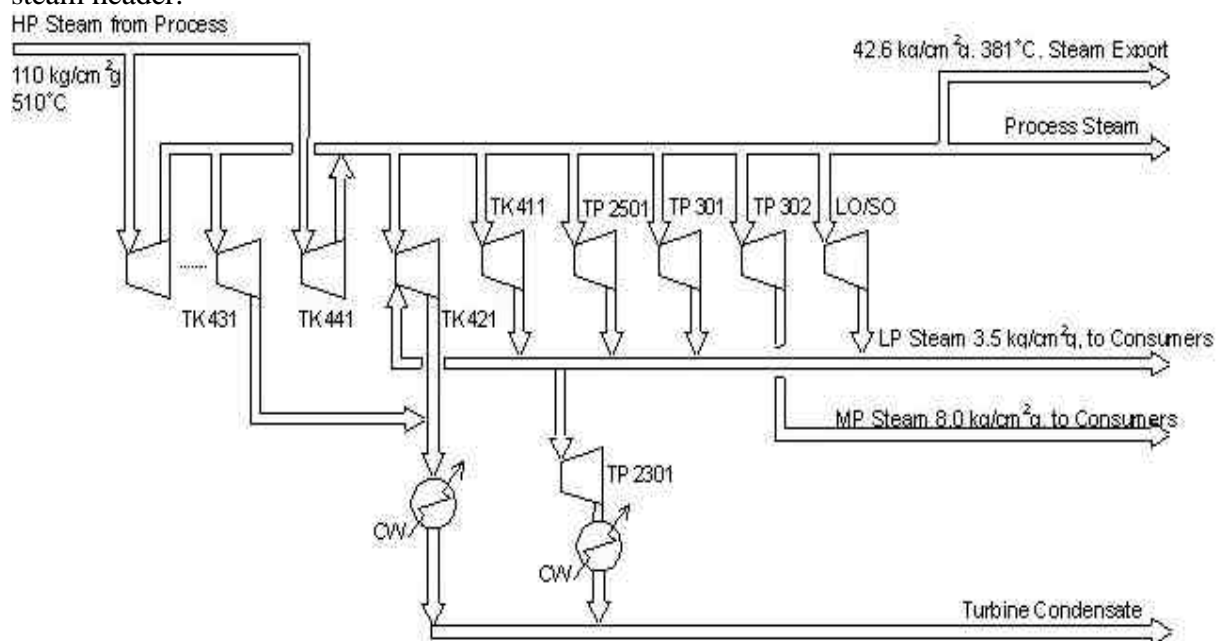


FIG. 6: STEAM CONSUMER CONFIGURATION

The low-pressure steam header is balanced by injection of low-pressure steam in the turbine running the process air compressor.

With the relatively low-pressure in the ammonia synthesis loop the shaft power requirements on the synthesis gas compressor are not very high. By operating both the synthesis gas compressor as well as the refrigeration compressor turbine on high-pressure steam, a reasonable flow can be assured to both turbines. At the present time there is no restrictions in the selection of steam turbines. Steam turbines corresponding to a higher plant capacity are available on the market.

The design of the 2000 MTPD ammonia plant for P.T. Kaltim Pasifik Amoniak is based purely on proven process technology.

It has been possible to optimize the lay-out of the plant to ensure a compact unit, and the excellent energy efficiency has been confirmed. The final lay-out and process scheme have been developed jointly between Topsøe and the plant owner from Mitsui and Tomen.

MANUFACTURER MHI

MHI is well known as a manufacturer of heavy duty rotating machinery and critical equipment. In KPA plant, major compressors and their drivers, steam turbines, are all supplied by MHI's Hiroshima Machinery Works. Mitsubishi Advanced Compressors (MAC) and their steam turbines ensures the reliability and the highest efficiency as well as the plant whole efficiency.

Semi-lean solution pumps with large flow circulation rate are also one of the product of MHI.

S-50 "Hot Wall" Converter were fabricated at MHI's Kobe Shipbuilding and Machinery Works who has a strong background in manufacturing critical equipment like steam generators for nuclear power plants.

Combining all these engineering and manufacturing capabilities as well as the project management as described hereinafter, the project quality was demonstrated at the highest level in the world.



PRE-COMMISSIONING / COMMISSIONING / INITIAL START-UP

The following are the major start-up milestones achieved during the pre-commissioning and commissioning of the plant.

<u>Date</u>	<u>Activity</u>
Beg of Aug. 1999	Steam flushing started
09 Jan. 1999	Air flushing started
13 Dec. 1999	Primary reformer catalyst loading started (completed 17 Dec. 1999)
15 Nov. 1999	Ammonia converter catalyst loading started (completed 02 Dec. 1999)
24 Jan. 2000	First ignition of burners in primary reformer (drying purpose)
19 Feb. 2000	First process steam and natural gas feed to primary reformer
23 Feb. 2000	Secondary reformer ignited
26 Feb. 2000	Low temperature shift reactor put into operation
27 Feb. 2000	Process gas feed to MDEA section
15 Mar. 2000	Methanator put into operation
26 Mar. 2000	Synthesis gas compressor started
29 Mar. 2000	Ammonia refrigeration compressor started
29 Mar. 2000	First ammonia product sent to storage

As the steam supply from outside battery limit was not stable in respect of continuity and quantity, the steam flushing was suspended many times and resulted in long time lag between the start of steam flushing and air flushing. However, as can be seen from the above list of milestones, the contractor, Mitsubishi Heavy Industries, by means of an extremely tight planning recovered the loss caused by the steam flushing and managed to put the entire unit on stream within a period of approximately 40 days after the first process steam and natural gas had been fed into the primary reformer in spite of the time loss caused by the replacement of one complete dry gas seal unit for synthesis gas compressor.

START-UP DELAYS

The overall project schedule has been successfully met and that the first product was obtained 34 months from the effective date of the contract even though some delays did occur during the initial start-up.

During the start-up of the Process Air Compressor, which was scheduled to be put in service for air flushing of the process gas pipings, a heavy vibration problem in the Compressor was encountered. Due to insufficient flushing in the oil system, small foreign particle remaining in the lubrication piping system was the principal cause of the vibration.

Initially the MDEA Semi-lean solution pumps were suffering due to a damage in the shaft bearing. With the newly installed shaft bearing relieving fully the radial thrust, the trouble have been corrected.

One of the intercoolers had an acoustic resonance problem and full load was not achieved during the pre-commissioning stage. After the addition of a longitudinal baffle during the short period shutdown prior to the process start-up, the noise and vibration caused by the acoustic resonance disappeared entirely at full load operation.

Minor things have also been experienced, however, they never reached to serious constraints and the cooperative effort by the contractor, MHI and the owner, KPA, resolved each problem diligently and patiently.

PERFORMANCE - PROCESS

40 days after feed gas and steam were introduced to the primary reformer, the first drop of ammonia have been delivered to the storage. On-spec 99.8 wt% product was achieved two days after while the reduction of the S-50 synthesis catalyst was conducted simultaneously.

An average of 104% production rate has been achieved since then. The largest production capacity demonstrated was 2,100 MTPD which is the largest ever commercially recorded.

The product quality for ammonia was quite acceptable and exceeded the specification of 99.8 wt% even for the reduction period of S-50 ammonia converter. Oil content was around 2-3 ppm wt. For the byproduct CO₂, nothing wrong was observed with regard to the quality and always exceeded the specification of 99.0 vol% dry.

The energy consumptions inside the battery limit of the plant were all within the guaranteed value. As fluctuation in the natural gas composition was observed, a higher setpoint on the process steam was settled. However, the natural gas consumption of 6.6 Gcal (LHV)/m-ton with credit for steam export and utilities has been achieved.

Steam export from the Plant was around 0.45 m-tons/m-ton which exceeded the expected value.

Electric power consumption of 22 kWh/m-ton was achieved with motor driven machineries such as two IDFs, one semi-lean pumps (partially covered by power recovery turbine), recycle gas compressor and utility pumps.

PERFORMANCE - HSE

Some parameters regarding the environmental control have been measured as an additional program of the KPA plant evaluation.

The plant component are all plotted and accommodated in a very confined area and close to the adjacent plant, noise level at the process plant battery limit was around 80 dB(A).

Neither SO₂ nor NO_x emission measured at the battery limit exceeded 5 ppm.

Safety records have reached 5,765,978 Work Hours total without Lost Time Accident.

CONCLUSION

The challenging job of establishing the large scale ammonia plant was successfully proved by the design, construction and operation of the KPA plant. This successful result may force other plant owners to eager towards the larger production capacity in single-line unit based on tubular reforming.

ACNOWLEDGE

The plant commissioning was carried out by well trained operators supplied by KPA who have rich experience in PT. Pupuk Kaltim existing plants. Thanks to them, the world largest production capacity have been demonstrated successfully.

LITERATURES

1. S.E. Nielsen & H.Kato, "The Largest Ammonia Plant in Asia, The 2000-t/d Topsøe-Designed Ammonia Plant for PT Kaltim Pasifik Amoniak", Asia Nitrogen '98.