Construction and Commissioning of Kaltim-5 2700 mtpd, World’s Largest Ammonia Purifier Plant
Introduction

- The Pupuk Kaltim site that is located in Bontang, East Kalimantan, Indonesia, comprises of six ammonia and six urea plants. Three of the ammonia plants utilize technology supplied by Haldor Topsoe, 2 utilize technology supplied by KBR, and 1 utilizes technology supplied by Lurgi.

- Has three ammonia storage tanks with capacity 2 x 26,000 mt and 1 x 50,000 mt.

- The newly constructed Kaltim-5 using KBR Purifier commenced commercial production in October 2015.
  - Kaltim-5 having a nominal capacity of 2500 MTPD and a nameplate capacity of 2700 MTPD.
  - A 3500 MTPD urea plant, utilizing Toyo ACES 21 process technology with granulated product was also constructed inline with ammonia plant.
Purifier™ Ammonia Process
Ammonia Process Design Features

- Utilizes the BASF licensed OASE White (activated MDEA) solvent for the CO₂ removal process.
- Mild conditions for primary reforming via excess air to the secondary reformer.
- Primary reformer having 2 steam turbine driven forced draft fans and 2 steam turbine driven induced draft fans (all 4 fan operating at full plant load).
- KBR’s non-metallic mixing chamber (no metallic mixer or burner) in the Secondary Reformer.
- Fire tube horizontal waste heat boiler design, supplied by Borsig.
- Two bed of Low temperature shift guard.
- High pressure flash gas compression and re-injection upstream of the CO₂ absorber.
Ammonia Process Design Features

- Synthesis Gas Drying Unit: Two Molecular Sieve Adsorber vessels in parallel.
- KBR Purifier for adjustment of synthesis gas hydrogen and nitrogen ratio and removal of all methane and the majority of the argon present.
- KBR horizontal ammonia synthesis converter with 3 catalyst beds and 2 interchangers.
- KBR Unitized Chiller
- Front end hot vent and a back end flare
- Use of KBR’s operator training simulator
- The feed gas compressor is utilized for front end nitrogen recirculation (From Feed Gas Compressor → Desulfurizer → 1st Reformer → 2nd Reformer → HTS → Raw Gas Separator → Feed Gas Compressor)
### Plant Performance

<table>
<thead>
<tr>
<th>Guarantee Item</th>
<th>Guarantee value</th>
<th>Measured value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia production, mt/day</td>
<td>2500 min</td>
<td>2545</td>
</tr>
<tr>
<td>Product quality ; NH₃, %</td>
<td>99.9 min</td>
<td>99.99</td>
</tr>
<tr>
<td></td>
<td>0.1 max</td>
<td>0.028</td>
</tr>
<tr>
<td></td>
<td>5 max</td>
<td>0.0476</td>
</tr>
<tr>
<td>H₂O, %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oil, ppm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net energy consumption, Gcal/mt</td>
<td>7.15 max</td>
<td>7.05</td>
</tr>
<tr>
<td>Carbondioxide production, mt/day</td>
<td>2633 min</td>
<td>3885</td>
</tr>
<tr>
<td>Carbondioxide purity, %</td>
<td>99.0 min</td>
<td>99.46</td>
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<tr>
<td>MP steam credit, mt/mt</td>
<td>0.518 min</td>
<td>0.418</td>
</tr>
<tr>
<td>Power, Kwh/mt</td>
<td>23.3 max</td>
<td>18.9</td>
</tr>
<tr>
<td>Demin water, mt/mt</td>
<td>0.844 max</td>
<td>0.729</td>
</tr>
</tbody>
</table>
Project Execution

- The project kick-off was in September 2011 with an Engineering Procurement Construction scheme (EPC Contract) as a lump sum project.
- The EPC contract being awarded to Inti Karya Persada Tehnik (IKPT) as consortium leader and Toyo Engineering Corporation (TEC) as partner.
- The project also included a new utility unit.
- Ground breaking for construction took place in mid of November 2011 with plant mechanical acceptance being achieved in December 2014, and commercial operation declared in October 2015.
The main project milestones

<table>
<thead>
<tr>
<th>Major Events</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective Date of Contract</td>
<td>14-Sept-2011</td>
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<tr>
<td>Basic Engineering completion</td>
<td>June 2012</td>
</tr>
<tr>
<td>Detail Engineering completion</td>
<td>Sept. 2013</td>
</tr>
<tr>
<td>Construction Start</td>
<td>Nov. 2011</td>
</tr>
<tr>
<td>Mechanical Acceptance</td>
<td>29-Dec-2014</td>
</tr>
<tr>
<td>Precommissioning phase</td>
<td>March-Nov. 2014</td>
</tr>
<tr>
<td>Natural Gas Receiving</td>
<td>26-Nov-2014</td>
</tr>
<tr>
<td>Commissioning start (Reformer 1st firing)</td>
<td>28-Nov-2014</td>
</tr>
<tr>
<td>Feed-in to Primary Reformer</td>
<td>5-Dec-2014</td>
</tr>
<tr>
<td>Syngas Compressor start</td>
<td>7-Jan-2015</td>
</tr>
<tr>
<td>Catalyst Reduction of Converter Start</td>
<td>9-Jan-2015</td>
</tr>
<tr>
<td>Ammonia 1st drop</td>
<td>12-Jan-2015</td>
</tr>
<tr>
<td>Performance Test completion</td>
<td>19-Oct-2015</td>
</tr>
<tr>
<td>Plant Acceptance</td>
<td>9-Nov-2015</td>
</tr>
</tbody>
</table>
Problems Faced During Plant Initial Start Up and Operation

1. Front End Vent Silencer Internal Damage

   - The front end vent Silencer located at an elevation of 55 meters above grade.
   - The wire flame arrestor mesh contained was emitted from the silencer housing while steaming the primary reformer with 65 tph of steam during start up.
   - The root cause of this event was the vent silencer flame arrestor mesh becoming partially blocked with construction debris which was transported from the front end vent header into the vent silencer.
   - The accumulated debris created an increased pressure drop across the flame arrestor mesh leading to a rupture of the mesh.
   - Configuration of 36” vent header and vent point elevation during pre-commissioning was not effectively cleaned or visually inspected.
Problems Faced During Plant Initial Start Up and Operation

2. Primary Reformer Catalyst Tube “Hot” spots/Zones

- The primary reformer was operating at a gas load of 30%, a steam to carbon ratio of 4.5, and a catalyst tube outlet temperature of 700°C.

- It was noted that 77 of the primary reformer catalyst tubes exhibited “hot” spots/zones.

- The principle cause of the hot catalyst tubes was identified as poor catalyst loading practices. A secondary cause was identified that the smaller (lower heat liberation) wall burners were found to be installed either side of the riser along the walls of the radiant box.
Problems Faced During Plant Initial Start Up and Operation

2. Primary Reformer Catalyst Tube “Hot” spots/Zone

- On the 17th February 2015 the plant was shut down for 17 days to identify the cause and to replace the catalyst in the “hot” tubes. A review of the tube pressure drop measurements made during initial catalyst loading and a tube pressure drop survey made at the time of the plant shutdown revealed numerous tubes had a pressure drop greater than +/- 10% of the tube average pressure.

- After reloading of 77 tubes with a new catalyst, pressure drop within range +/- 5%
Problems Faced During Plant Initial Start Up and Operation

3. Synthesis Gas Dryer Desiccant Milling

- Each synthesis gas dryer bed comprised of 2 layers of type 4A molecular sieve and a top layer of silica gel.

- After a 2 ½ months of plant operation it was noted that the synthesis dryer bed pressure drops were trending upwards and the frequency of waste gas filter cleaning was also increasing.

- From the investigation was concluded that desiccant passed through clearance between wire mesh screen and shell of hemispherical head.
Problems Faced During Plant Initial Start Up and Operation

3. Synthesis Gas Dryer Desiccant Milling
   - Modification was carried out to reduce such clearance and more reinforce was added on grating to avoid from mounding.
   - At a plant shutdown, the silica gel was removed and substituted with 4A molecular sieve.
Problems Faced During Plant Initial Start Up and Operation

4. Expander Seal Pack Replacement

- While performing expander pre-start-up checks on the 16th January 2015, it was noted that the expander casing had filled with water.

- Investigation revealed that the expander casing vent line had been incorrectly piped to the front end vent header. While steaming the primary reformer at a plant start-up or shut down the front end vent header contains steam a portion of which was able to flow in a reverse direction into the expander casing where it cooled and condensed.

- The expander supplier recommended that the expander be removed to the main workshop for remediation and seal pack replacement.

- To avoid such accident in the future the drain line has been disconnected from vent header and routed to atmospheric safe location.
Problems Faced During Plant Initial Start Up and Operation

5. OASE White Carryover From LP Flash Drum

- On January 23rd, 2015 severe foaming of the OASE White solution occurred in the LP flash drum resulting in a carryover of OASE White solution into the carbon dioxide product header. Approximately 25mt of OASE White concentrate was lost into the plant drainage system.

- It was initiated by compressor 103-J surging which was also caused from Purifier fluctuation.

- It caused 6 segments tray removed, 9 segments tray bending, and 50% demister fall down in LP Flash 122-D1, many cap trays were removed and loosen.

- To reinforce the cap trays, bottom side of cap tray was tag-welded to the plate.
5. OASE White Carryover From LP Flash Drum

- During water circulating operation (low flow), the water entered from nozzles H1 and H2 directly falls onto the flash gallery with high downward flow velocity. Hence, it can be concluded that the liquid distributor damage was caused by the localized high liquid velocity through the flash gallery.
Problems Faced During Plant Initial Start Up and Operation

6. Purifier Rectifying Column Level Transmitter Calibration

- During the Purifier initial start-up and operation a higher than expected rectifying column differential pressure, waste gas flow, and unstable synthesis gas compressor suction pressure were observed.
- The actual level in the Rectifier was actually high more than 100% instead of 50% as indicated on DCS.
- The liquid level transmitters were re-calibrated from range 0 – 1141 mmH$_2$O becoming 0 – 730 mmH$_2$O.
Problems Faced During Plant Initial Start Up and Operation

7. Under Performance Of HTS Effluent Steam Generator (103C1/C2)

- The HTS effluent steam generator (103C1/C2) were designed to cool the HTS effluent stream to the target inlet temperature necessary for the LTS.
- Boiler feed water flow to the 103C1/C2 is higher than design of 196 mt/hr.
- A short fall in the overall medium pressure steam production and export of 41 mt/hour (instead of 54 mt/hr as design basis).
- A redistribution of heat load between the 2nd reformer WHB and the HP steam super heater – this heat load redistribution being necessary in order to partial compensate for the short fall in steam generation by 103C1/C2.
Problems Faced During Plant Initial Start Up and Operation

Numerous actions were undertaken in an effort to resolve this issue:

- The tube side (boiler feed side) channel covers were removed. The gap existed between the partition plate for each tube side pass which allowed some bypassing of boiler feed water. The gaps were sealed by welding.

- Channel covers were again removed. Inspection revealed that the twisted tape inserts from 5th & 6th tube side passes of 103C1 had become dislodged. The twisted tapes were removed. Removal of the tapes had no effect upon the exchanger performance.
Pre-commissioning Activities

a. Cooling and sea water system cleaning, which combined manual cleaning of the large diameter sections of pipe work and water flushing using strategically placed temporary supply to return header jumper pipe work.

b. Process Air Compressor inter-stage pipe cleaning

Process air compressor inter-stage pipe work was cleaned by rapid decompression air blowing utilizing the CO₂ absorber as an air volume tank. Temporary pipe work was provided to route air from the CO₂ absorber to the process air compressor inter-stage pipe work.

c. Process Gas line air blowing

The Process gas pipe work was cleaned by continuous air blowing utilizing the process air compressor to provide up to 115000 Nm³/hr of air at a pressure of 12 kg/cm². Some temporary pipe work was required to route air to all locations to be blown.
Pre-commissioning Activities

d. Steam System Blowing,

The plant steam network was blown utilizing medium pressure steam supplied by a coal fired boiler located outside the plant battery limit. A maximum steam flow of 80 mt/h was made available for blowing. Steam blows were made at a total of 80 points excluding utility stations.

e. Steam Generation System Chemical Cleaning,

The tube side of the secondary reformer waste heat boiler, the high pressure steam drum, the inter-connecting riser and downcomer pipe work between the boiler and the steam drum, and the high pressure steam header (bypassing the high pressure steam superheater tube side) were chemically cleaned.

f. Catalyst loading

Catalyst and desiccant was loaded into a total 12 vessels including 2 synthesis gas dryers. Total quantity 616 m$^3$ of catalyst and 103 m$^3$ of desiccant were loaded.
Pre-commissioning Activities

g. Dry out of Primary Reformer, Secondary Reformer and Start up heater.

Two portable burners were used for dry out of Secondary Reformer and it took 5 days to complete it.

Primary Reformer dry out used 3 burners and took 3 days. During dry out, all burner was flame on one by one for confirmation its function.

Start up heater dry out was done along with Synthesis Loop commissioning.

h. Alkali cleaning for aMDEA system

All the OASE White containing sections of the CO$_2$ removal system were cleaned by once through water flushing.

Followed by water recirculation using the installed pumps and capturing particles on the pump suction strainers.

Oil and grease was removed from the column random dumped packed beds by using the installed pumps to recirculate 2%\textsubscript{w/w} sodium hydroxide solution followed by water rinsing.

Final rinsing was completed until foaming and turbidity achieving allowable number.
Problems Faced During Pre-commissioning

Air Compressor Suction Duct Deformation

The 88” diameter air intake duct to the compressor 1st stage was deformed during plant pre-commissioning activity.

The lower than normal pressure in the air intake duct was created by a greater than design pressure drop occurring across the air intake filter housing/elements.
Problems Faced During Pre-commissioning

Air Compressor Suction Duct Deformation

The pulse cleaning nozzles were removed from the filter elements to lower the pressure drop across the air intake filter housing/elements.
Problems Faced During Pre-commissioning

CO₂ Removal Low Pressure Flash Drum Distributor Tray Damage

At the end of the CO₂ removal system cleaning activities, all vessels in the system were opened and inspected for cleanliness. During this inspection it was noted that 19 gas riser chimneys had become dislodged from a liquid distributor tray within the low pressure flash column.
Problems Faced During Pre-commissioning

OASE WhitePump Suction Strainer Damage

Cleaning of the CO₂ removal system involves frequent cleaning of the OASE White solvent recirculation pump suction strainers. During this activity it was noted that the pump suction strainers (107-JAHT, 107-JC, 107-JB) required reinforcing with an additional reinforcing ring. Additional support reinforcement was given not only to the pump suction strainers but also to major compressor suction strainers.
Conclusion

- Plant currently operates successfully at capacity above 2700 MTPD

- Presentation emphasizes on the need to have a focused and cautious approach during pre-commissioning of the plant

- This has significant impact on the duration within which plant can be commissioned successfully

- Focus on pre-commissioning activities is equally important for both commissioning of grass-root plants as well as revamps either big or small.