Project profile for High Pressure CPU at L&T Krishnapattanam

The project profile is for Wabag’s first of its kind High pressure spherical condensate polishing unit and External regeneration system. Challenges faced during engineering and development.

This project profile illustrates the process for CPU and external regeneration system. It also illustrates some of the challenges faced in designing various sub system & components of this plant. In the following write up we have described the innovative solution arrived at, in the design of critical components for hydraulic and mechanical design.

Summary:

High pressure condensate polishing units are required in super critical power plants. There are very few companies capable of doing this. High pressure design requirement, coupled with requirement of resin transfer for external regeneration poses very significant hydraulic and mechanical design challenges, in addition to requiring special emphasis on manufacturability of the vessel.

This profile demonstrates Wabag’s engineering capability to execute such challenging jobs which ultimately led WABAG to bag many more orders thereafter.
Overview of Condensate Polishing Process

Introduction:
Project is for 2 X 800 MW SRI DAMODARAM SANJEEVAIH THERMAL POWER STATION, KRISHNAPATNAM, ANDRA PRADESH, INDIA and Order placed was by LARSEN & TOUBRO LIMITED.

Currently one phase of this plant is commissioned which is WABAG’s first ever Spherical High pressure CPU Plant commissioned.

Functions of Condensate Polisher:

The condensate polisher has to perform two simultaneous duties:

1. It has to remove the "crud", which is suspended solids (mostly metal oxides) resulting from corrosion and erosion.
2. It has to remove dissolved solids originating from the make-up water, possible leaks of the condenser tubes or from regeneration of the ion exchange resins.

Condensate influent and effluent quality for CPU design during normal continuous operation are shown in Table 1 below:

<table>
<thead>
<tr>
<th>Sr.No</th>
<th>Parameters</th>
<th>Unit</th>
<th>Value In Influent</th>
<th>Value In Effluent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Crud</td>
<td>ppb</td>
<td>50</td>
<td>5 (max.)</td>
</tr>
<tr>
<td>2</td>
<td>Reactive silica</td>
<td>ppb</td>
<td>30</td>
<td>5 (max.)</td>
</tr>
<tr>
<td>3</td>
<td>Copper</td>
<td>ppb</td>
<td>10</td>
<td>Less than 2</td>
</tr>
<tr>
<td>4</td>
<td>Iron</td>
<td>ppb</td>
<td>50</td>
<td>5 (Max.)</td>
</tr>
<tr>
<td>5</td>
<td>Sodium</td>
<td>ppb</td>
<td>10</td>
<td>2 (Max.)</td>
</tr>
<tr>
<td>6</td>
<td>Chloride</td>
<td>ppb</td>
<td>10</td>
<td>2 (Max.)</td>
</tr>
<tr>
<td>7</td>
<td>pH</td>
<td>-</td>
<td>6-7</td>
<td>6.8-7.2</td>
</tr>
<tr>
<td>8</td>
<td>Total dissolved solid</td>
<td>ppb</td>
<td>All influents including Ammonia</td>
<td>25 (Max.)</td>
</tr>
<tr>
<td>9</td>
<td>Conductivity (Max.) at 25 deg C</td>
<td>Micro-mho/cm</td>
<td>-</td>
<td>Less than 0.1 after removal of all amines</td>
</tr>
<tr>
<td>10</td>
<td>TOC</td>
<td>ppb</td>
<td>300</td>
<td>300</td>
</tr>
</tbody>
</table>

Table 1
Design options:

In view of the low salinity of the water to be treated, mixed bed polishers are used in over 90% of the cases. When the operating pressure is not too high, cylindrical vessels are used. But in case of super critical boiler the operating pressure is high, so at 4 MPa (40 bar) or above, use of spherical vessels can keep the shell thickness much lower than in case of cylindrical vessel, thus optimizing the capital cost.

In case of L&T CPU plant, the design pressure was 42 barg. For same pressure in Alkhalij, Libya CPU plant, we had used cylindrical vessel design (as per client requirement). But in L&T CPU plant we got an opportunity to explore the spherical vessel design. After thorough working and comparisons drawn between cylindrical and spherical vessel design, it was concluded that spherical vessel design is more cost effective than cylindrical hence we decided to opt for spherical vessel design. A typical schematic comparison of cylindrical and spherical CPU is given in Figure A below.
**Design Parameters:**
General Design Data for L&T CPU is as below:

- Total No. of polisher vessel—06 No’s (3 X 33 % for each 800 MW Unit).
- CEP Discharge Pressure (operating) -- 29 barg.
- Design Pressure Condensate polishing Unit--42 barg.
- Process-- Cation exchange in Hydrogen, Anion exchange in Hydroxide.
- Regeneration—External.
- Condensate Flow—1956m3/hr per 800MW unit.
- Operating/Mechanical Design Temperature—45/70 degree C.
- Service run cycle—30 days for normal operation.

**Process Description:**

*High Pressure Condensate Polishing Vessel:*

The soluble impurities entering the feed CPU are treated by the condensate polishing system. The condensate-polishing unit is fully automatic type, with semi-automatic operation a manual initiation is provided and is based on ion exchange technology. The CPU can also be operated in manual mode, step by step. CPU vessel consists of Macro porous Cation and Macro porous Anion resins, both the resins are used in completely mixed form to get the required treated water quality. The top distribution consists of inlet flow distributors, a convex deflector shower for uniform flow distribution and the under drain system consist of pipe based wedge wire lateral known as Hub and lateral arrangement.

In case of L&T CPU unit, all the pressure vessels were in 3 x 33% configuration for each 800 MW plant i.e. all 6 vessels are in operation simultaneously. The system has been designed in such a way that each successive vessel will be taken for regeneration once in 30 days (once it is exhausted) as round robin basis and rest are in service mode. The resins will be regenerated in common regeneration station. One CPU vessel at a time shall be taken for regeneration. At the end of service run (i.e. 30 days), the CPU vessel will be isolated to enable resin transfer. A spare resin quantity required for one 1 CPU operation is stored in RMSV, once the exhausted resin is transferred from CPU to CRV; this spare resin is immediately transferred to the empty CPU. Turnaround time for taking CPU in operation is 2 hours. During the turnaround time the condensate is allowed to bypass and mix with polished condensate.

**Unique Design of Self-Cleaning Candle Filter:**

In order to reduce the crud load and maximize the time between regeneration cycles a candle filter with self-cleaning facility was introduced for cases where crud value of influent is high. The Candle filter is facilitated with auto backwash facility with volume of back wash water stored inside the filter itself. The back washing is initiated based on differential pressure across the filter i.e. dirty condition pressure drop, an air and water mixture passes from inside to outside direction to clean the cartridges and achieve clean condition pressure drop. We use this on case to case basis and is not part of CPU for L&T Krishnapattanam.
**Bypass conditions for condensate:**
- Differential pressure across CPU exceeds 2.5 Kg/cm².
- Conductivity exceeds 0.1 micro Siemens/cm at 25 degree C.
- Sodium > 20 ppb
- Condensate temperature exceeds 55 degree C.

**External Regeneration System:**
Exterior regeneration system consists of: the cation regeneration/resin separation vessel (CRV), anion regeneration vessel (ARV), Intermediate Resin Vessel (IRV), Resin Hopper (to charge initial fill and make up resin) and resin mixing & storage vessel (RMSV). There is a chemical dosing and hot water arrangement as well for regeneration process.

Resin regeneration is initiated by transfer of exhausted resin from the Condensate polisher vessel to the CRV. After the resin is cleaned by air scrubbing, it is backwashed to remove residual corrosion product particulates and resin fines. Next is to separate the anion and cation resin within CRV. This is achieved by air scoring and bumping of resin in tall CRV which is having minimum 100% free board. Separation is attained due to the fact that anion resin has a lower density than the cation resin and is also purchased with a smaller average particle size.

The selective hydraulic resin transfer was a challenge since we were not using any optical instrument which is capable of sensing resin colour and do automatic selective transfer. This optical transmitter is a special instrument but it is very costly and contributes heavily in capital cost. This is where innovation comes into picture, positioning of resin transfer nozzles were such that it will transfer only the anions first and then mixed layer of cation and anion. Transferred anion resin is then caustic regenerated through caustic, mixed layer is transferred to IRV for storage and the cation resin is acid-regenerated in CRV itself.

After the regenerated cation and anion resin fractions are rinsed with demineralized water, they are transferred to the RMSV. After air mixing, the mixed resin bed is rinsed to a low effluent conductivity and stored for replacing the upcoming exhausted resin. A syphon loop is provided in all resin handling vessels to keep the resin in wet condition. At the end of the regeneration sequence the mixed resin, which has been stored in IRV is transferred to the empty CRV and regenerated during the subsequent regeneration process. Further the resin hopper is provided for transferring initial charge of resin as well as topping up the resins which are lost due to attrition. Refer Figure E for block diagram of external regeneration system.

Further to provide smoother surface for resin transfer with minimum head loss and also to optimize the material cost we have given rubber lined piping for transfer of resin. The challenge here was to transfer resin to a stretch of 600m. Resin being sticky it was must to have smoother surface as well as high velocity availability. Bends used were 5D to ensure that resin gets a least resistance path and does not get stuck due to higher resistance. To avoid abrasion of lining because of resin transfer a hard rubber of 90 Shore A was used in this case.
Figure E: Block Diagram for external regeneration System
Conclusion:

Design of Spherical vessel, under drain hub and laterals, distribution shower, special rubber lining, venting system, equalizer for hydro testing, pad flanges, Resin separation and transfer process, 5D bends for reduced frictional losses were critical aspects of this project.

Design of spherical CPU necessitated all the above mentioned critical design conditions to be evaluated and finding solutions thereof for proper performance. The innovation/solutions though appearing very fine in terms of detailing put together have led to a very High performance product.

Similar type of design was implemented in below listed packages:

- For 1X600 MW RAYALSEEMA THERMAL POWER PROJECT, ANDHRA PRADESH
  \( \varnothing \) 3800 mm, 973 m³/hr, 2 No’s
- For 1X600 MW KAKATIYA THERMAL POWER PROJECT, ANDHRA PRADESH
  \( \varnothing \) 3400 mm, 792 m³/hr, 2 No’s
- For 1X500 MW KORBA WASTE THERMAL POWER PROJECT, CHATTISGARH
  \( \varnothing \) 2900 mm, 658 m³/hr, 3 No’s

Unloading of CPU vessel at L&T Krishnapattanam Site

Abbreviations Used:

- HP: High pressure.
- CPU: Condensate Polisher Unit.
- CRV: Cation regeneration vessel.
- ARV: Anion regeneration Vessel.
- IRV: Intermediate resin vessel.
- L&T: Larsen and Tuobro Ltd.
- RMSV: Resin Mixing and storage vessel.