Improving Cooling Tower Performance with Innovative Horizontal Outflow Design

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ABSTRACT

Cooling tower design has not advanced significantly in the last decade. Recognising this, Outotec has developed an innovative horizontal outflow cooling tower with increased performance compared to conventional design cooling towers.

Outotec® Cooling Towers operate today in applications such as spent electrolyte cooling in zinc plants and for gypsum removal before copper solvent extraction. In such applications the use of this latest design has enabled increased production and lower maintenance costs in the downstream operations.

In actual operations, the cooling performance has been confirmed at start-up, and has demonstrated that the towers operate in accordance with the CFD modelling. In the last three years these towers have proven themselves in commercial operation to operate with high efficiency and availability.

This case study will outline comparative data, collected over two years at a site where both Outotec and conventional cooling towers are operating. The data shows that Outotec cooling towers require less than half the maintenance time of conventional cooling towers, when adjusted to a total solution flow basis. A close partnership approach with the site has allowed continual development, ensuring high availability and high performance.

Experience with previous cooling tower installations guided the development of maintenance philosophies and procedures; this resulted in a design where maintenance intensive components were accessible from the top of the cooling tower. This allows safe access to components and maintenance with little or no downtime.

INTRODUCTION

Following years of in-house research, and close collaboration with customers operating traditional cooling towers, a new horizontal outflow cooling tower has been developed. The new Outotec® Cooling Tower has been globally patented and is now operational at various sites. This tower is targeted at applications such as cooling spent electrolyte in zinc plants and for gypsum removal circuits in zinc plants and copper solvent extraction (SX) plants. Evidence from present installations has shown that the new towers have good process efficiency and are easy to maintain. In electrolyte cooling applications, an increase in electrolyte flow to the electrolysis cells has been possible, together with an increase of the electrolysis current (Hirsi et al, 2013a).

With one particular supplier, IMMSA in Mexico, the performance of this new design has lead to the subsequent purchase of an additional tower in 2014. In a gypsum removal process in Zambia, considerable savings in solvent extraction equipment maintenance were achieved. (Hirsi et al, 2013a; Hirsi et al, 2013b). Other tower deliveries have been made in Russia and Mexico, and recent sales have been made to Australia and Turkey, with start-ups scheduled for 2015 to 2017.
Figure 1 – Outotec® cooling tower installation in San Lui Potosi, Mexico.

Operational data has also confirmed the accuracy of product design methods and enabled further development work. This includes Computational Fluid Dynamics (CFD) to first estimate cooling tower efficiency and then 3D-Cad design of the tower (Hirsi et al, 2013a).

**SOLUTION COOLING TOWERS**

The maintenance needs of solution cooling towers are somewhat different to those of water cooling towers, which are the most common cooling tower type. The harsh process operating conditions inside solution cooling towers can cause serious problems of corrosion and/or scaling of tower components. However the harsh operating conditions of solution cooling towers do prevent diseases such as the legionnaire’s disease; common water cooling towers foster the ideal operating environment to develop such disease. (Bhopal and Barr, 1990).

Given the challenge of scaling and corrosion caused by harsh process conditions in solution cooling towers, the new horizontal outflow design has durable materials of construction and the tower is equipped with an internal curtain to minimize scaling formation. In addition the tower is designed with maintenance front of mind, with easier access to components that require maintenance.

**Cooling tower description**

The Outotec solution cooling tower differs from conventional cooling towers primarily in that the direction of the air outflow is horizontal. Conventional solution cooling towers typically have vertical outflow demister units, with the airflow upwards from the top of the tower. The airflow is normally developed by a fan blowing air horizontally into the lower part of the tower. In the Outotec designed cooling tower the air is blown into the lower part of the tower tangentially using a specially developed axial flow fan.

The hot solution is introduced through pressure nozzles to generate droplets that are of suitable size to aid the evaporation and heat transfer between the droplet and the cooling air. This droplet size is a necessary compromise between cooling efficiency and droplet carryover to the demisters. The solution is removed from the bottom of the tower either from the side via a water lock to prevent air escape from this location, or through an outlet in a bottom cone that is used when solids content in the solution is high.
The air swirls around inside the tower, markedly increasing the maximum specific airflow rate that is possible and exits the tower at the top in a horizontal direction through one of eight outlet demister panels. The demisters are vane type, designed so that the droplets collide with the vanes and drain out perpendicular to the airflow. The increased airflow rate increases cooling efficiency and the use of horizontal demister outlets allows the capture of smaller droplets, resulting in lower emissions.

The horizontal outlet design allows for a flat roof that can be fitted with handrails, and used for maintenance. The demisters and nozzles are designed and located such that with suitable access hatches, maintenance can be performed while the tower is operating.

**Process benefits**

Improving the performance of the cooling tower provides additional benefits to other parts of the plant, further increasing the overall process efficiency and reducing maintenance costs.

The first cooling tower installation to go live was the tower at IMMSA Zinc Electrolysis Refinery, at San Luis Potosi, Mexico. The new design provided 149% more cooling potential, when compared to the tower against tower (fan rated at 100%), the operational performance of new towers is shown in more detail in table 1 below. The increased cooling enabled a process performance increase of ~28% to the electrolyte flow to each electrolysis cell due the better cooling of the solution (Hirsi et al, 2013a).

<table>
<thead>
<tr>
<th>Item</th>
<th>Outotec</th>
<th>Traditional towers, IMMSA</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Towers</td>
<td>1</td>
<td>3</td>
<td>pcs</td>
</tr>
<tr>
<td>Cross sectional area²</td>
<td>28.3</td>
<td>58.8</td>
<td>m²</td>
</tr>
<tr>
<td>Solution feed</td>
<td>750</td>
<td>1370</td>
<td>m³/h</td>
</tr>
<tr>
<td>Fan speed</td>
<td>62%</td>
<td>67%¹</td>
<td></td>
</tr>
<tr>
<td>ΔT</td>
<td>4.2</td>
<td>3</td>
<td>C</td>
</tr>
<tr>
<td>Cooling Power</td>
<td>4.55</td>
<td>5.93</td>
<td>MW</td>
</tr>
<tr>
<td>Cross sectional cooling efficiency</td>
<td>0.16</td>
<td>0.10</td>
<td>MW/m²</td>
</tr>
<tr>
<td>Relative cooling potential 1 vs 1 (fan 100%)</td>
<td>249%</td>
<td>100%</td>
<td></td>
</tr>
</tbody>
</table>

**Notes**

1. One fan of the conventional towers was not operational, other 2 at 100%

2. Cross sectional area is the free flow area inside tower horizontally
High performing cooling towers can also provide maintenance savings downstream. The Outotec cooling tower installed at the Chambishi metals plant, Zambia is for gypsum removal duty at the solvent extraction plant. Since being installed, the cooling tower is estimated to have removed over 6000 kg/day of gypsum from the process, see table 2 below. This is gypsum which would otherwise have settled inside the solvent extraction equipment. Gypsum causes scaling and blockages inside piping and the SX mixers and settlers requiring frequent shutdowns to clean out. This would have lead to higher maintenance costs and production loss. In addition, the removal of gypsum from the circuit results in higher end product quality, thereby increasing revenue to the producer (Hirsi et al, 2013a; Hirsi et al, 2013b).

Table 2 – Removal of the calcium from the PLS flow.

<table>
<thead>
<tr>
<th>Component</th>
<th>Amount</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change of Calcium concentration in flow, i.e. amount removed in gypsum</td>
<td>72</td>
<td>mg/l</td>
</tr>
<tr>
<td>PLS flow</td>
<td>170</td>
<td>m³/h</td>
</tr>
<tr>
<td>Mass of Calcium removed</td>
<td>12</td>
<td>kg/h</td>
</tr>
<tr>
<td>Mass of gypsum removed (CaSO₄*2H₂O)</td>
<td>52</td>
<td>kg/h</td>
</tr>
<tr>
<td>Mass of crud prevented (assumed 20% solid material and 80 SX solutions)(Gypsum converted to Crud)</td>
<td>6300</td>
<td>kg/d</td>
</tr>
</tbody>
</table>

Another important consideration with solution cooling towers is the performance related to emissions. Acid mist emissions are costly not only for the cost of the acid that is lost, but also for the surrounding area, both in terms of environmental degradation and corrosion of nearby equipment. Conventional solution cooling towers have vertical outflow demisters, i.e. the air out of the tower flows upwards from the top of the cooling tower. When air flows vertically through the demister out of the tower, the drainage of droplets out of the demisters is countercurrent to the gas flow. With vertical demisters as used in traditional cooling towers, the limiting gas velocity, i.e. the breakout point out of the cooling tower, is approximately 5-6 m/s. The breakout point of the demister is a function of the gas and liquid flow rates into the demister.

There are two layers of demisters in the tower to ensure optimal droplet separation; this is also a common approach in traditional models. The first demister is a coarse layer for removing larger droplets and eliminates most of the droplets coming from the tower. The second demister is a fine layer for removing residual smaller droplets. The coarse and fine refer to the size of the spaces between the vanes of the demister. The larger gaps in the first layer also allow the demister to be cleaned more easily.

With horizontal outflow design and demisters, the velocity out of the cooling tower can be increased to as much as 8 m/s before the breakout point is reached, with some horizontal demister types reaching 10 m/s. In the horizontal demisters the droplet drainage is not countercurrent but perpendicular to the gas flow.

In Figure 2 the generic droplet separation graphs for vertical and horizontal flow demisters is shown. This shows the largest particle that can pass through each type of demister. In both cases the spacing between the demister vanes is the same. The graph illustrates that the horizontal demister performance is superior since it can capture smaller droplets for the same face velocity. (Hirsi et al, 2013a).
MAINTENANCE BENEFITS OF THE NEW COOLING TOWER DESIGN

When the new horizontal cooling tower was installed at IMMSA zinc plant, Mexico, the maintenance requirements were studied to provide a comparison between the traditional towers and the new cooling tower. The resulting study shows that in recent years the cooling tower maintenance work has reduced and that the Outotec cooling tower has required less maintenance time compared to the traditional cooling tower design. It should be noted however that overall, maintenance times are dependent on factors such as solution composition and local climate conditions. At other sites the times may vary considerably.

Table 3 – Maintenance time required for the cleaning of the towers demisters at IMMSA.

<table>
<thead>
<tr>
<th></th>
<th>Old towers</th>
<th>New towers</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow</td>
<td>457</td>
<td>750</td>
<td>m³/h</td>
</tr>
<tr>
<td>Interval of demister washing</td>
<td>20</td>
<td>30</td>
<td>days</td>
</tr>
<tr>
<td>Duration of demister washing</td>
<td>12</td>
<td>8</td>
<td>hours</td>
</tr>
<tr>
<td>Average downtime/month</td>
<td>18</td>
<td>8</td>
<td>hours</td>
</tr>
<tr>
<td>Av downtime/month/flow</td>
<td>0.039</td>
<td>0.011</td>
<td>hours/m³/h</td>
</tr>
</tbody>
</table>

The reduced maintenance time is achieved due to the innovative design and easy maintenance procedures. The new cooling tower is equipped with an internal curtain that reduces scaling of the tower walls and also minimises tower wall wear caused by cleaning of the towers. The curtain can be changed from the top platform without the need to build any scaffolding inside the tower. At the IMMSA, Mexico site the internal scale curtain design of the Outotec cooling tower has enabled the client to reduce traditional tower internal washing time from 14 days to five days per 100 day period. The reason for the reduced cleaning time when comparing old towers and new Outotec design was largely due to the fact that most of the maintenance work can be done from the top platform of
the cooling tower and inside the demister compartments. This arrangement has meant that special height protection measures are not required, thus increasing worker safety and ease of access.

The inlet piping for the new cooling tower can be easily dismantled for cleaning and the nozzle holders can be removed via quick connectors enabling efficient nozzle maintenance or replacement. The tower internals can also be cleaned from the top of the tower.

Demister washing can be performed from the top of the cooling tower while the tower is operating. The horizontal flow out of the cooling tower via demister channels enables the isolation of one to three channels, depending on the flow situation. This isolation requires a very short stoppage of the cooling tower. An isolation plate is inserted in front of the coarse demister, blocking the airflow. The demister can then be cleaned on both sides with spray washers from the top of the tower platform, or removed from the compartment to be cleaned more thoroughly (See Figure 3). The panels can also be easily replaced if required.

![Figure 3 - A demister panel being washed after having been lifted out of the cooling tower.](image)

Each of the demisters is a one piece construction that requires a lifting device to lift from the tower compartment. This is due to it being heavier than those constructed from multiple pieces. The one piece construction allows the demisters to be removed with one lift. Additionally, performance is better than piecemeal construction, because there are no leaking gaps between the demisters sections. In various traditional towers, especially after a long time in operation, this has been found to be a problem.

**Safety benefits of the new cooling tower design**

In addition to maintenance benefits, the design of the new cooling tower provides significant safety benefits and is a major step forward in cooling tower development. Fewer required maintenance hours reduces exposure to risks, and the capacity to undertake maintenance duties from the top platform of the tower, where there is space to do so, makes tasks easier and safer to perform. The inside of a demister compartment provides a safe place from which the inside of the tower (roof and walls) can be cleaned. This improves safety since there is no need to go inside the tower before it has been cleaned. The fact that there is no need to erect scaffolding to change the anti-scale curtain also improves safety.
Cooling towers as part of plant solutions

The new cooling tower design has illustrated the need to further develop other equipment units of the cooling process. Outotec is presently studying these aspects of the gypsum removal process with a view to further increasing the availability of cooling tower plant unit. This reflects the importance of recognising the cooling tower as part of a larger process.

![Illustration of Outotec Gypsum removal plant.](image)

**SUMMARY**

The new horizontal design solution type cooling tower has considerably reduced maintenance requirements, increased cooling efficiency and reduced emissions.

The horizontal outflow design has enabled the use of the tower roof for maintenance purposes, giving easy access to critical parts of the tower that require maintenance. It is now possible to wash demisters while the tower is operating, maintain nozzles and clean the inside of the tower without special scaffolding construction. In addition to maintenance benefits, the design of the new cooling tower provides significant safety benefits.

Outotec Cooling Towers are now operating in multiple locations around the world and results show that they have provided considerable benefit for users in the form of increased production and product quality.

**REFERENCES**

