OVERVIEW

Year of First UTComp Evaluation 2015
Next UTComp Inspection . 2018
Predicted Year at Critical Percentage of Design Strength (PDS) 2038
Remaining Service Life........ 23
General Corrosion Barrier Condition Some Damage Detected

PDS Values
Critical: 20% Min Section: 66%

![Remaining Service Life Graph]

- Shell above flange (detail A)
- Shell above flange (detail D)
- Nozzle N3
- Shell above ring 1 (detail C)
- Shell above ring 2 (detail C)
- Shell above bottom head joint
- Nozzle N7 Repad
- Bottom Head Joint

Remaining Service Life (RSL) Projection
Critical PDS
Eng Review
CONCLUSIONS

• The FRP vessel is suitable for continued service to the next recommended UTComp inspection.
• Percentage of Design Strength is greater than the Critical PDS.

RECOMMENDATIONS

UTComp System evaluation is recommended after all significant process excursions and environmental events. UTComp recommends that a competent FRP Engineer be engaged for all recommended engineering activities including replacement, review, evaluation, repair design and repair inspection.

<table>
<thead>
<tr>
<th>Action</th>
<th>Basis</th>
<th>Timing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Next UTComp evaluation</td>
<td>UTComp Calculations</td>
<td>2018</td>
</tr>
</tbody>
</table>

SUMMARY

UTComp® data was collected from sections of FRP Caustic Scrubber (Retired) (Equipment Number: 601-40-328) on 07/30/2015 and 08/27/2015. This is the 1st time that UTComp® Evaluation has been completed for this equipment. The vessel was insulated and insulation was removed from the areas to be inspected. Scrubber components were made at different times. The upper, packed bed section was made in 1995 and the lower two (2) sections (Gas Inlet and bottom section) were made in 2002. When determining remaining service life, the actual age of the component was considered. This is reflected in the Remaining Service Life curve, above.

UTComp measurements were taken from 5 sections and 4 reinforcements (or joints). Of these, it was found that readings on 1 reinforcing pad are not useable because a second layer of insulation was present and prevented inspection of the shell and subsequent analysis. This report provides results only from the sections and reinforcements that could be inspected.

No information has been provided regarding visible internal condition of the vessel.

No need for reinforcement updates or repair was detected.
Damage to the corrosion barrier was detected in some sections. The damage is classified as minor and to a depth of about 1.25mm based on analysis of UT readings.

The structural FRP in some sections [Shell Above Ring 2 (Detail C), Shell Above Ring 1 (Detail C), Shell Above Flange (Detail D), Shell Above Bottom Head Joint] shows evidence of a significant mid-wall ply separation 4-5 mm beneath the surface. This may indicate that the outer layer is poorly bonded to the structural FRP for these sections. No significant reduction in Percentage of Design Strength or Remaining Service Life has occurred from this.
VESSEL CONFIGURATION AND INSPECTIONS

The vessel configuration is shown in Figure 1, below. Description of ultrasonic inspections is listed in the Table 1.

Table 1 - Inspections

<table>
<thead>
<tr>
<th>Section or Repad Name</th>
<th>Number of Readings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nozzle 7 Repad</td>
<td>14</td>
</tr>
<tr>
<td>Shell above Ring 2 (detail C)</td>
<td>31</td>
</tr>
<tr>
<td>Shell above Ring 1 (Detail C)</td>
<td>32</td>
</tr>
<tr>
<td>Nozzle 3 Repad</td>
<td>17</td>
</tr>
<tr>
<td>Shell Above Flange (Detail D)</td>
<td>32</td>
</tr>
<tr>
<td>Nozzle 6 Repad</td>
<td>0(^1)</td>
</tr>
<tr>
<td>Shell Above Flange (Detail A)</td>
<td>33</td>
</tr>
<tr>
<td>Shell Above Bottom Head Joint</td>
<td>19</td>
</tr>
<tr>
<td>Skirt Joint on Shell</td>
<td>12</td>
</tr>
</tbody>
</table>

Notes on Inspections:
1. An additional layer of insulation was present and required removal.
Reference for Photo Location:

- Nozzle 7 Repad Figure 2a
- Shell above Ring 2 (detail C) Figure 2b
- Shell above Ring 1 (Detail C) Figure 2c
- Nozzle 3 Repad Figure 2d
- Shell Above Flange (Detail D) Figure 2e
- Nozzle 6 Repad (No readings taken) Figure 2f
- Shell Above Flange (Detail A) Figure 2g
- Shell Above Bottom Head Joint Figure 2h
- Skirt Joint on Shell Figure 2i
- Nameplate for Bottom and Middle Section Figure 2j

Figure 1
PHOTOS

Photos taken during the inspection are shown in Figure 2 below.

Figure 2a
Nozzle 7 Repad
Figure 2b
Shell above Ring 2 (Detail C)
Figure 2c
Shell above Ring 1 (Detail C)
Figure 2d
Nozzle 3 Repad
Figure 2e
Shell Above Flange (Detail D)
At lowest elevation of the scrubbing section. FRP surface appears to be darker than above.
Figure 2f
Nozzle 6 Repad - incomplete removal of the insulation

Figure 2g
Shell Above Flange (Detail A)
Figure 2h

Shell Above Bottom Head Joint - incomplete removal of the insulation (was subsequently removed for section analysis on 27/08/2015)
Figure 2i
Skirt Joint on Shell - incomplete removal of the insulation (was subsequently removed for section analysis on 27/08/2015)

Figure 2j
Nameplate for Bottom and Middle Section
UTCOMP® SYSTEM ANALYSIS DETAILS

PERCENTAGE of DESIGN STRENGTH

The Percentage of Design Strength (PDS) is a value that is best described by Equation 1. Because of the measurement process used, the values returned directly by the UTComp System can be applied directly to the Flexural Modulus.

\[
PDS = \frac{Current\ Modulus}{Design\ Modulus} \quad (1)
\]

To determine the current flexural modulus, simply apply the PDS to the theoretical modulus obtained from lamination analysis.

The Critical PDS is the value of Percentage of Design Strength which is the minimum allowable value for equipment operation as recommended by UTComp.

Calculation of Critical PDS is given in equation 2. For conservative results, the minimum design factor used for new design is taken to be 10, relative to the UTComp Strength Basis.

\[
Critical\ PDS = \frac{2}{\text{Max}(Design\ Factor, 10)} \times 100\% \quad (2)
\]

The Critical PDS value will change if operating conditions for the equipment change – just as an operating pressure change will change the minimum thickness. These changes are made to ensure that conservative values are used to protect assets and personnel.

UTComp has experience with several incidents where FRP equipment replacement or structural repairs have been required when the PDS was near 40%. From this experience, UTComp recommends further engineering evaluation as soon as there is probability of more than 10% that the PDS value is 40%. This is to ensure the integrity and functionality of FRP equipment. UTComp Engineering Review should be conducted by an engineer who is competent in design, repair and evaluation of FRP.

REMAINING SERVICE LIFE CALCULATIONS

The principal output of UTComp System data readings is PDS. From the PDS, the following calculations are made: The PDS Rate of Change (\(\Delta PDS\)) is the average linear rate at which PDS is changing for the equipment:
The Remaining Service Life (RSL) is the number of years until the PDS of the section is predicted to be at Critical PDS. The calculation to be made is:

\[
\text{Remaining Service Life} = \frac{\text{Critical PDS} - \text{Current PDS}}{\Delta PDS}
\]  

(3)

This calculation is consistent with calculations required by API 653 when PDS is substituted for thickness.

### VESSEL SECTIONS

Table 2 shows the results obtained for the sections evaluated in this inspection.

<table>
<thead>
<tr>
<th>Section</th>
<th>Average Thickness (mm)</th>
<th>Section Average PDS</th>
<th>Corrosion Barrier Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shell Above Flange (Detail A)</td>
<td>19.8</td>
<td>87%</td>
<td>No damage detected</td>
</tr>
<tr>
<td>Shell Above Flange (Detail D)</td>
<td>27.8</td>
<td>66%</td>
<td>No damage detected</td>
</tr>
<tr>
<td>Shell Above Ring 1 (Detail C)</td>
<td>19.8</td>
<td>69%</td>
<td>Minor damage detected in 23% of readings</td>
</tr>
<tr>
<td>Shell Above Ring 2 (Detail C)</td>
<td>19.8</td>
<td>72%</td>
<td>Some damage detected in 16% of readings</td>
</tr>
<tr>
<td>Nozzle 3 Repad</td>
<td>41.5</td>
<td>93%</td>
<td>No damage detected</td>
</tr>
<tr>
<td>Nozzle 7 Repad</td>
<td>43.6</td>
<td>66%</td>
<td>Some damage detected in 50% of readings</td>
</tr>
<tr>
<td>Shell above bottom head joint</td>
<td>16.0</td>
<td>72%</td>
<td>No damage detected</td>
</tr>
<tr>
<td>Bottom head joint</td>
<td>33.8</td>
<td>100%</td>
<td>No damage detected</td>
</tr>
</tbody>
</table>

### REINFORCING PAD CONDITION AND BONDING

Reinforcements and repairs are applied that add to vessel thickness in locations where stresses are concentrated or additional strength is required. This UTComp inspection includes data acquired from at least one reinforcement pad (repad).

Reinforcing pads are generally designed to increase the thickness of FRP in a zone that must support additional loads or stress concentrations. If reinforcement is less than 6mm thick, immediate Engineering Review and repair will be recommended since inadequate reinforcement is frequently the root cause of failures. If the PDS of the total reinforced thickness is less than the surrounding section, this will be used to determine Suitability for Service.
Bonding between repairs and reinforcements applied and vessel sections was determined as Percentage of Theoretical Bonding. Many design specifications consider the possibility that secondary bonds, such as those used to attach reinforcing pads, may have as little as 50% of their theoretical shear strength. For this reason, UTComp uses the criterion that a bond exists when the percentage shown in the UTComp data is greater than 50%. If 2 or more consecutive points or more than 25% of the points are not bonded, immediate repair is recommended.

For the nozzle repads tested for this vessel, the condition of the bonding around the repads is shown in Figures 2 and 4. In these figures, the red line shows the Bonding Threshold at 50%. Any points within that circle are considered to be unbonded. The tables below Figures 3 and 5 contain the statistics for this evaluation. Figures 4 and 6 show the history available for PDS, Percentage of Bonding and percentage of unbonded readings for these repads.
Nozzle 3 Repad Bonding

Note: No readings are available for the zone where no data appears.

<table>
<thead>
<tr>
<th>Item</th>
<th>Data</th>
<th>Repairs Recommended?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness +6mm?</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Number of Readings Not Bonded</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Percentage of Readings Not Bonded</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Maximum Consecutive Number of Readings Not Bonded</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Figure 3 – Nozzle 3

Nozzle 3 Repad Bond History

Figure 4
### Nozzle 7 Repad Bonding

Note: No readings are available for the zone where no data appears.

<table>
<thead>
<tr>
<th>Item</th>
<th>Data</th>
<th>Repairs Recommended?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness +6mm?</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Number of Readings Not Bonded</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Percentage of Readings Not Bonded</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Maximum Consecutive Number of Readings Not Bonded</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Figure 5 – Nozzle 7

### Nozzle 7 Repad Bond History

Year: 2015

- PDS
- Average Bonding
- % Not Bonded

Figure 6
### Bottom Head Joint Bonding

![Graph showing bond results and threshold](image)

<table>
<thead>
<tr>
<th>Item</th>
<th>Data</th>
<th>Repairs Recommended?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness +6mm?</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Number of Readings Not Bonded</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Percentage of Readings Not Bonded</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Maximum Consecutive Number of Readings Not Bonded</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 7 – Bottom Head Joint**

### Bottom Head Joint Bond History

![Bar chart showing bond history](image)

- **PDS**
- **Average Bonding**
- **% Not Bonded**

**Figure 8**
SUITABILITY FOR SERVICE

The Inspector has provided information that is requested to determine Suitability for Service\(^1\). The information provided is shown in Table 3.

<table>
<thead>
<tr>
<th>Information Requested</th>
<th>Yes</th>
<th>No</th>
<th>Unknown</th>
<th>Details and Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vessel Service has not changed since last inspection</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standards used for Vessel Design</td>
<td>X</td>
<td></td>
<td></td>
<td>DuPont Specs</td>
</tr>
<tr>
<td>Vessel Contents provided</td>
<td>X</td>
<td></td>
<td></td>
<td>Empty, not in service</td>
</tr>
<tr>
<td>Operating Internal Pressure Known and Provided</td>
<td></td>
<td>X</td>
<td></td>
<td>Internal Pressure is taken as dominant</td>
</tr>
<tr>
<td>Installation Year or Age Known</td>
<td>X</td>
<td></td>
<td></td>
<td>Constructed in 2002</td>
</tr>
</tbody>
</table>

The Asset design follows known Standards.
For the vessel contents provided, maximum time interval between inspections is set to 3 years.

DISCUSSION

Sections of the scrubber have been replaced since its original construction in 1985. Date of Manufacture on the Bottom Section nameplate (April 2002) differs significantly from the date shown on the drawing under Nameplate Information (August 1985). The analysis provided uses the latest date (2002) so that conservative results are presented.

Damage to the corrosion barrier to a depth of about 1.25mm was detected in some of the readings from the upper packed section. This is about 25% of the original corrosion barrier thickness and has small effect on the structural capacity of the scrubber. No actions are recommended at this time.

The thickness calculated for the Shell Above Bottom Head Joint is less than 90% of the thickness value listed on the drawing. This difference may serve to reduce the service life. No recommendations are made.

For Shell above flange (detail A), readings were taken 1’ above flange (approx. 14’ above base) in 4 areas of cut out insulation. Insulation was not completely removed for 2 of the 4 areas. Readings taken where insulation remained have not been used.

For Shell above flange (detail D), readings were taken 1’ above flange (detail D) (approx. 19’ above base), clockwise from 0 to 180 degrees. These readings are taken over a joint with additional thickness (refer to detail D on drawing).
For Shell above ring 1 (detail C), readings were taken 6’ above flange (approx. 24’ above base), clockwise from 315 to 180 degrees.

For Shell above ring 2 (detail C), readings were taken 135° above flange (approx. 29’ above base), clockwise from 315 to 180 degrees.

For the Nozzle 3 Repad on Shell above flange (detail D), readings were taken on the repad close to the knuckle, clockwise from 8 o’clock to 12 o’clock.

For the Nozzle 7 Repad on Shell above ring 2 (detail C), readings were taken on the repad close to the knuckle, clockwise from 7 o’clock to 11 o’clock.

CERTIFICATION

The person who collected the data has certified that the data was obtained and provided in accordance with UTComp procedures, training and licensing.

Data analysis and reporting has been completed by UTComp Inc in accordance with UTComp procedures and training. Analysis and reporting are valid only for data received. Warrantee or representation is limited to areas or sections of an asset from which data or inspection information has been provided.

For further information about the UTComp System or the results reported above contact the licensee. UTComp may be contacted directly at:

Telephone: +1 519.620.0772
Email: inquiries@utcomp.ca
Web: www.utcomp.ca

DATA ANALYST: REVIEWED BY:

Mark Putt Geoff Clarkson

REFERENCES