YRD EXPERIENCE ON RTR UNDERGROUND PIPING FAILURE

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ABSTRACT: In Yanbu refinery both cement lined and RTR piping systems are used for the underground fire water piping network. Frequent leaks and failure were experience from the newly installed RTR piping system. There was deferent root causes for these failures, one and main cause was the workmanship during initial installation. In addition to that system design and section were another main root cause. This report will highlight on the experience of YRD with RTR piping system and type of failures that been experience and the root causes of these failures.
1. **INTRODUCTION:**

The first major use of Reinforced Thermosetting Resin (RTR) non-metallic piping in Yanbu refinery was in 2006 as part of new expansion project. It is used for underground fire water network system. The fire water underground piping network for the old plant is still as it is cement lined piping system. There are tie-in points between the RTR and cement lined underground network piping.

Frequent leaks were experienced in the first three years. Most of the leaks were experienced in small RTR pipe system and especially in 3”, 4” and 8”.

Failure analysis was conducted and root causes had been identified and correction actions were implemented. As a result number and frequency of RTR leak failure were reduced significantly.

2. **DESIGN AND SPECIFICATIONS:**

   - **Services:** Fire Water
   - **Design Temperature:** 93°C
   - **Design Pressure:** 15.0 Bars
   - **Tube Material:** RTR
   - **Standard:** ASTM D-2310

3. **RTR PIPING FAILURE:**

   First underground RTR fire water pipe failure occurred just after the commission of new expansion and occurred in 2006 on 8” pipe. The main root cause was missing thrust block on the pipe bend and direction change which lead to joint disbanding and through hole at the joint. Table 1 shows summary of failures location and the cause.

   **TABLE 1:** Summary of RTR piping failure during 2006 & 2007

<table>
<thead>
<tr>
<th>#</th>
<th>Date</th>
<th>Location</th>
<th>Description</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>April 2006</td>
<td>8” elbow to straight pipe disbanding</td>
<td>8” joint to 16” main line</td>
<td>Crane activities and missing of thrust block</td>
</tr>
<tr>
<td>2</td>
<td>November 2006</td>
<td>ISOM plant</td>
<td>Excavations were conducted on five locations with 8” RTR pipe bends to check for the availability of thrust blocks.</td>
<td>Three out of the five were found without required thrust block. Correction actions were taken.</td>
</tr>
<tr>
<td>3</td>
<td>December 2006</td>
<td>ISOM</td>
<td>4” line leak</td>
<td>No crane movement</td>
</tr>
<tr>
<td>4</td>
<td>April 2007</td>
<td>DHT near Amine unit</td>
<td>4” pipe hole noted with previously repaired failure</td>
<td>Crane movement and poor workmanship</td>
</tr>
<tr>
<td>5</td>
<td>April 2007</td>
<td>SFU</td>
<td>4” RTR pipe leak at elbow</td>
<td>Truck movement near the in addition to weight of fire hydrant foundation.</td>
</tr>
<tr>
<td>6</td>
<td>Jan 2007</td>
<td>ISOM</td>
<td>3” RTR pipe leak</td>
<td>Corroded flange bolts for 26” &amp; 3” flanges</td>
</tr>
</tbody>
</table>
4. PHOTOS OF RTR FAILURE:

**FIGURE 1:** 4” pipe in DHT plant with through hole at elbow to straight pipe joint

**FIGURE 2:** Close view for the 4” hole. Notice pipe wall thickness
5. FAILURE ANALYSIS AND ROOT CAUSE:

Two defective samples were sent to CSD for failure analysis and to identify the root causes of these failures. The main root causes were as follow:

- **Poor Workmanship**: Figure 4 & 5 show that the pipe tapering was extended beyond the joining area. This cause the pipe to be thin at failure area. In addition to that excessive adhesive material was used.

- **Surge Water Hammer**: during the test of fire water pump, the surge water hammer is produce and causing failure of RTR piping especially with narrow deference between pipe design pressure and test pressure. Hydraulic analysis was conducted on the system and recommendations for controlling the operating parameters were implemented. This was one of the major factors of RTR piping failure.

Following are figures showing sample of the defective pieces that been sent for failure analysis.
FIGURE 4: Close view for the hole on 4” defective part. Reference CSD report.

FIGURE 5: Excessive pipe chamfering at pipe joint causing thinning of the pipe.
FIGURE 6: Rupture on 10” RTR pipe due to pump surge pressure.

FIGURE 7: Close view for the rupture of 10” RTR pipe.
FIGURE 2: flow of decoking water to potable tank.

6. GENERAL FACTORS CAUSING RTR PIPING FAILURE:
Base on inspection experience and type and number of failures that were reported, following are some to the main factors that causes frequent RTR failures:
• Poor workmanship:
• Poor soil back filling with no good compaction
• Missing thrust blocks
• Narrow difference between RTR pipe design pressure and the surge pressure of fire water pump.
• Heavy truck movements on or near to the buried RTR piping network.

Table 2 below shows the type of failure, location and expected causes based on YRD field experience.

**TABLE 2: Types of RTR pipe defects & failures and the causes**

<table>
<thead>
<tr>
<th>Failure type</th>
<th>Failure Location</th>
<th>Causes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hole/punching</td>
<td>• Near elbow&lt;br&gt;• Straight pipe&lt;br&gt;• Short nipple</td>
<td>• Stones &amp; no good soil backfilling&lt;br&gt;• Heavy track movement&lt;br&gt;• Thin pipe wall thickness&lt;br&gt;• Workmanship</td>
</tr>
<tr>
<td>Cracks</td>
<td>• Straight pipe&lt;br&gt;• Short nipple</td>
<td>• Heavy equipment movement&lt;br&gt;• no good back filling, no sweet sand&lt;br&gt;• Heavy weight at one end.</td>
</tr>
<tr>
<td>Rupture</td>
<td>• Straight pipe</td>
<td>• Excessive pressure due to pump surge&lt;br&gt;• Narrow deference between design and operating pressure.</td>
</tr>
<tr>
<td>Dis-bonding</td>
<td>• Elbow to straight pipe joint</td>
<td>• Lack of thrust blocks&lt;br&gt;• Excessive pipe end chamfering cause by poor workmanship.</td>
</tr>
<tr>
<td>Surface defect</td>
<td>• Construction</td>
<td>• Original defect during construction.</td>
</tr>
</tbody>
</table>
FIGURE 8: Thickness of RTR piping based on design pressure. Reference is vendor product data.

7. AREAS OF INSPECTION CONCERN:
Inspector shall pay great attention to following points during repair or erecting new RTR piping system:

- External visual inspection of all RTR piping components for any manufacturing or handling defects.
- Inspection during repair or installation:
  - Joint preparation: square or tapered.
  - Sanding or tapering of the joint.
  - Size of the sanding area
  - Thickness of the wrapping tape after repair. See figure 9 below.
  - Curing time
  - Lamination shall be applied within 2 hours after sanding. Re-Sanding will be required after passing the two hours.
  - Use correct resin mix ratio.
  - Providing thrust blocks as required by standard for more than 4” bends.
  - Sweet sand to be used for backfilling.
  - Good compaction of the soil.

8. CONCLUSION:
- Initial proper installation of RTR piping system play major roll for the future integrity of none-metallic piping system.
- Initial and wright selection of design parameter also play major roll for future health condition of RTR piping system.
- Surge pressure shall be part of selection and specification criteria.
- Nominal RTR pipe wall thickness shall be enough to carry on load of soil and the impact of external loads and effect on the system.

**Figure 1. Straight-Ends Jointing (12-Bar Pressure Rating)**

**Lamination Procedure (Figure 1...)**

**STEP 1: PIPE CUTTING**

**STEP 2: SANDING/GRINDING**

**STEP 3: FIT LAYER**

**STEP 4: LAMINATION**

**STEP 5: LAMINATION**