Corrosion Under Insulation (CUI) inspection of cold insulated lines

Savio REBELLO, Paresh GOSWAMI

Reliance Industries Limited, Reliance Corporate Park, Ghansoli, Navi Mumbai-400701.

Savio.Rebello@ril.com; Paresh. Goswami@ril.com

Abstract

Corrosion under Insulation (CUI) is a major integrity concern facing refineries and petrochemicals today. The issue is more serious in older units, which were designed and constructed before the CUI damage mechanism was fully known and appreciated. A major hurdle for in-service CUI inspection is that complete stripping of the insulation is, most often, the most effective inspection method.

Stripping of hot insulated equipment and piping for CUI inspection can be done on-stream with some impact on process temperature and heat loss. However, cold insulated assets operating within the CUI temperature range can be stripped and inspected only during a major turnaround. This significantly increases the shutdown job scope and the overall schedule.

This paper details how a combination of non-destructive inspection methods were used to prioritize the CUI inspection scope for cold insulated piping during the major turn-around. The number of lines requiring complete stripping of cold insulation during the shutdown was greatly reduced. Repair and replacement of suspect sections was also planned beforehand.

Keywords

Corrosion under insulation, thermography, pulsed eddy current, radiation scanning.

Introduction

Corrosion under insulation (CUI) is one of the simplest damage mechanisms to understand, but one of the most cumbersome to detect and tackle. Simply put, CUI is the external corrosion of piping and equipment due to water trapped in the insulation. However it is much more aggressive than external corrosion of bare uninsulated components, as the insulation maintains water and contaminants in continuous contact with the metal surface.

In older units which were designed and installed before this damage mechanism was fully appreciated, insulation was often carried out on equipment and piping without any painting or with only a primer coat. Insulation was installed with inadequate quality assurance - generally as the last activity and sometimes even after commissioning. In-service inspection and maintenance of insulation was a neglected area.

As per best practice documents such as API, CUI of carbon steel occurs in the temperature range of -12°C to 175°C [1]. All equipment and piping operating in this temperature range, especially for older units, needs to be identified and planned for CUI inspection. Complete insulation stripping is generally the most effective inspection method. This becomes a major constraint for cold insulated assets, as such inspection can only be carried out when the assets are at ambient temperature during major turnarounds. Stripping
and re-instatement of insulation in cold insulated assets significant increases the shutdown resource requirement and becomes a critical path activity impacting the shutdown schedule.

A combination of non-destructive techniques were used for pre-shutdown CUI assessment on cold insulated, cryogenic piping to significantly reduce the scope for complete insulation removal during the turnaround.

1.0 Scope of inspection
The total scope of cold insulated piping requiring CUI inspection was identified based on two criteria:

(a) Piping operating within the CUI susceptible range as per the line designation table (LDT);
(b) Cryogenic piping with operating temperatures outside the CUI susceptible range as per LDT, but operated intermittently and / or having stagnant areas where temperatures could reach ambient.

Identification of stagnant and intermittent service piping required the involvement of the unit Operations and Process Technology personnel. A total of approximately 700 cold insulated lines of varying diameters and lengths were identified based on the above criteria, with about 50% each falling under criteria (a) and (b).

If complete insulation stripping was done, the estimated volume of insulation removal / re-instatement required was more than 12000 m$^3$. Apart from the cost and resource requirement, carrying out such a large volume of insulation jobs in the major turnaround would impact other activities in the vicinity.

2.0 Inspection strategy
A multi-pronged inspection strategy was worked out to reduce the scope of CUI inspection in the major turnaround without impacting the mechanical integrity of the unit. The following inspection and NDE methodologies were selected:

(i) Walk-through visual inspection of all the CUI-susceptible piping to identify missing / damaged insulation, missing cladding, improperly sealed branches / protrusions and deterioration at piping supports. These locations would anyway require rectification during the major turnaround.

(ii) Stagnant and intermittent service cold piping, which could be stripped of insulation in-service without affecting the process, were identified by Operations personnel. These locations were visually inspected after removal of insulation, while the unit was in operation.

(iii) Thermography scanning of the cold insulated piping to identify internally damaged / degraded insulation locations based on local temperature differences.

(iv) Damaged insulation locations identified by thermography and walk-through visual inspection to be non-destructively examined by radiation scanning (Lixi Profiler$^{\text{TM}}$) or Pulsed Eddy Current (PEC) to check for underlying corrosion / metal loss without insulation removal.
(v) Complete cold insulation stripping in shutdown of only the suspected corroded locations identified by NDE, as in (iii) and (iv) above, and of CUI-susceptible piping, including stagnant / intermittent service piping that could not be inspected / non-destructively scanned during operation due to location-specific constraints.

See figure 1 for the flow chart indicating this inspection strategy. Table 1 below gives a brief comparison of the inspection and NDE methods selected for CUI assessment.

<table>
<thead>
<tr>
<th>Inspection / NDE method</th>
<th>Advantages</th>
<th>Disadvantages</th>
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<tbody>
<tr>
<td>Visual inspection</td>
<td>Direct assessment of asset condition</td>
<td>Access to area of interest and insulation removal</td>
</tr>
<tr>
<td>Thermography</td>
<td>Detects damaged insulation; close access not required.</td>
<td>Further inspection / NDE required to confirm CUI</td>
</tr>
<tr>
<td>Pulsed Eddy Current</td>
<td>Detects underlying CUI without insulation removal</td>
<td>Spot measurement; requires access to area of interest</td>
</tr>
<tr>
<td>Radiation Scanning</td>
<td>Detects underlying CUI without insulation removal. Quicker than PEC</td>
<td>Approvals for source; Access along the line required.</td>
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**Figure 1**: Flow chart indicating the inspection strategy

**Table 1**: Brief comparison of selected inspection and NDE methods for CUI assessment
3.0 Inspection Results

3.1 Walk-through visual inspection

More than 200 locations with damaged / missing insulation were identified during walk-through visual inspection while the unit was in operation. The damage was mainly observed at pipe hangers / supports and other protrusions through the insulation, insulation terminations / air-to-insulation interface and high foot traffic areas. These areas were taken up for insulation rectification after inspection of the underlying metal surface during the plant shutdown. See Figure 2 for one of the typical photographs of physical damages observed.

![Figure 2: Photograph showing few of the damaged insulation locations observed in field rounds.](image)

3.2 Inspection of stagnant lines after insulation stripping

A total of 111 stagnant lines, where cold insulation could be stripped in service, were identified by Plant Operations. A total of 59 lines were recommended for replacement based on the CUI damage observed after insulation stripping. See table 2 below for the inspection findings and rectification carried out. Photograph in Figure 3 below shows the typical CUI damage observed after insulation stripping in stagnant cold piping.

<table>
<thead>
<tr>
<th>Total scope of stagnant loops for insulation removal</th>
<th>111</th>
</tr>
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<tbody>
<tr>
<td>Insulation removal of stagnant loops done during plant operation</td>
<td>91</td>
</tr>
<tr>
<td>Insulation removal pending – to be taken up in turnaround</td>
<td>20</td>
</tr>
<tr>
<td>Replacement recommended on inspection after insulation removal</td>
<td>59</td>
</tr>
<tr>
<td>Replacement carried out during plant operation</td>
<td>34</td>
</tr>
<tr>
<td>Replacement pending – to be taken up in turnaround</td>
<td>25</td>
</tr>
</tbody>
</table>

Table 2: Summary of inspection scope, inspection recommendations and rectification required
3.3 Thermography survey

Thermography survey of all the identified CUI-susceptible cold insulated piping (approx. 700 nos.) was carried out using Flir T620 camera through an external specialized vendor. Survey was done across one week during the night hours to avoid the effect of solar radiation on the thermography image. Abnormalities were identified at 55 locations in 35 lines. These locations were marked up on isometrics for further NDE examination and rectification in shutdown. One of the typical thermography images from this survey is included in Figure 4 below.

![Thermography Image](image)

**Figure 4**: Thermography image at one of the abnormalities (cold spot) detected in a cold insulated line

3.4 Pulsed Eddy Current (PEC) examination

PEC examination was carried out through an external specialized vendor over a period of two weeks. Total of 114 lines were scanned at identified locations, based on visual inspection and thermography. Physical access for scanning was provided by erecting scaffolds. Total area scanned was approximately 300 metres. Wall loss more than 15% was identified at around 30 different locations.
These locations were marked up for insulation stripping in shutdown. Photograph in Figure 5 below shows PEC in progress at one of the identified locations.

![Figure 5: Actual site photograph during PEC examination](image)

3.5 Radiation scanning

Radiation scanning by Lixi Profiler™ for line sizes < 8” was planned. However selected vendor could not mobilize and import the equipment in time due to the approvals required for the radioactive source. Fortunately only about 20 lines were balance which could not be fully assessed by other NDE methods. These lines were included in the list for insulation stripping in shutdown. Radiation scanning inspection was subsequently carried out for similar CUI identification in another unit.

4.0 Summary of inspection and NDE done

After successful implementation of the proposed inspection strategy, the number of cold insulated piping requiring inspection by insulation stripping in turnaround was reduced from around 700 nos. to less than 100. This included the lines previously listed for radiation scanning, which could not be mobilized in time. Further insulation stripping was required to be done only at the most vulnerable locations, as identified by visual inspection and non-destructive examination.

The major turnaround frequency for this unit is every 5-6 years. We plan to repeat this inspection strategy about a year and half in advance of the next planned turnaround, so that any insulation damage or CUI corrosion in the intervening period can be detected and planned for rectification.

5.0 Conclusion

Corrosion under Insulation (CUI) is a major mechanical integrity challenge facing refineries and petrochemical plants today, especially in the older units. The sheer volume / number of CUI-susceptible assets to be inspected makes the task appear insurmountable. However as demonstrated in this paper, it is possible to make the insulation removal and CUI inspection scope more manageable by following a proper inspection and NDE strategy to identify and prioritize the most vulnerable areas.

6.0 Acknowledgement

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7.0 References