Internal corrosion monitoring in NSPL

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PHQ, GUWAHATI
Presentation Outline

Brief about Multi-Product Pipeline

NSPL Schematic Layout

Monitoring through Corrosion Coupons

Monitoring Results

Sludge Analysis

Conclusions & Recommendations

Discussion on Test Protocols for Crude Trunk line
Oil India Limited owns and operates a cross country multi-product pipeline from Numaligarh Refinery in Assam to Rangapani (Siliguri) in West Bengal, India.

The Pipeline transports different products of Numaligarh Refinery namely Motor Spirit, High Speed Diesel and Superior Kerosene Oil.

Pipeline design throughput is 1.721 MMTPA.

It is a 16” pipeline, 653.4 km in length and was commissioned in June 2009.
The design throughput for MS is 0.135 MMTPA, for SKO is 0.219 MMTPA and for HSD is 1.367 MMTPA. The other design parameters are:

- Operating Hours: 8000 Hrs/ Annum
- Pipeline operating life: 35 Years
- Design pressure: 84.5 kg/cm²
- Max. Operating Pressure: 76 kg/cm²
- Hydro Testing Pressure: 106 Kg/cm² (min.)
- Design Consideration: ASME B31.4, OISD 141
- Pipe MoC: Carbon Steel
  - Converted & existing (259 Km): API5LX46/X52 - Pipe thickness 7.9/11.9 mm
  - New (394Km): API5LX60/X46 - Pipe thickness 6.4/8.7/11.9 mm
- Pipeline corrosion allowance: 0.5 mm
Numaligarh Dispatch Terminal

Intermediate Pigging Station with provision for corrosion coupons

Sectioning Valve

Receiving Terminal

Bihar

West Bengal

Meghalaya

Manipur

Nagaland

Myanmar

Bhutan

Arunachal Pradesh

Assam

Numaligarh Dispatch Terminal

Intermediate Pigging Station with provision for corrosion coupons

Sectioning Valve

Receiving Terminal

RT

SV1

IPS1

SV2

IPS2

SV3

IPS3

SV4

IPS4

SV5

IPS5

SV6

IPS6

SV7

IPS7

SV8

IPS8

SV9

IPS9

NDT
R&D Department’s association with NSPL corrosion monitoring

- R&D Department was approached in July 2011 for providing assistance in measurement of corrosion rates based on weight loss coupons.
  
  - Coupons that were installed during commissioning stage in 2009 were retrieved in July 2011 by a joint team of R&D and PLM Section.

- The corrosion rates observed was 0.6 mpy considering exposure for 2 years.

- R&D Department adopted the testing procedure, analysis and interpretation of weight loss coupons based on industry best practices and available standards.
Monitoring through Corrosion Coupons

- This presentation is based on experiences of internal corrosion monitoring using flush disc weight loss coupons and the results thereof.

- Provisions for internal corrosion monitoring using corrosion coupons at the six locations at 12 ‘0 clock position were incorporated during the commissioning of the pipeline.

- From July 2011, the coupons are exposed for a period of approximate 1 year, and then retrieved and replaced with fresh set of coupons.
Flush Disc Coupons

- Generally used in applications where the coupon cannot extend into the pipe to interfere with the flow or pigging operations.

- Disc coupons are usually mounted flush with the wall of the pipe (or vessel) so that conditions are as close as possible to those at the process/containment interface.

- NSPL uses a circular coupon with a diameter of 1.25”, a thickness of 0.125” and a mounting hole ID 0.312”.

- The hole is countersunk, and uses a flathead, stainless steel screw, insulating washer and insulating disc for mounting.

- The exposed area is 2.5 sq. in. (16 sq. cm).
Flush Disc Coupon
NACE Standard RP0775-2005 outlines procedures for preparing, installing and analyzing metallic corrosion coupons to monitor mass-loss and pitting corrosion in oilfield operations.

- The average corrosion rate is calculated as uniform rate of thickness loss per unit time in mils per year (mpy).
- 1 mpy = 0.0254 mmpy

\[
\text{Corrosion rate, mpy} = \frac{22300 \times W}{ATD}
\]

Where,
- \( W \) = mass loss, g
- \( A \) = initial exposed surface area of the coupon, 2.5 sq. in.
- \( T \) = exposure time, days
- \( D \) = density of the coupon metal, 7.833 g/cm\(^2\)
The Max. Pitting rate is calculated using the depth of deepest pit and dividing it by the exposure time.

The depth of the deepest pit is measured using stereo microscope calibrated for depth measurement.

\[
Pitting \ rate, \ mpy = \frac{Depth \ of \ deepest \ pit \ (mil) \times 365}{Exposure \ time \ (days)}
\]
Qualitative Categorization of Carbon Steel Corrosion Rates for Oil Production Systems as per NACE RP0775-2005

<table>
<thead>
<tr>
<th></th>
<th>Average Corrosion Rate</th>
<th>Maximum Pitting Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mm/y</td>
<td>mpy</td>
</tr>
<tr>
<td>Low</td>
<td>&lt;0.025</td>
<td>&lt;1.0</td>
</tr>
<tr>
<td>Moderate</td>
<td>0.025-0.12</td>
<td>1.0-4.9</td>
</tr>
<tr>
<td>High</td>
<td>0.13-0.25</td>
<td>5.0-10</td>
</tr>
<tr>
<td>Severe</td>
<td>&gt;0.25</td>
<td>&gt;10</td>
</tr>
</tbody>
</table>
Results
Results

NSPL Elevation Profile and Corrosion rates for 2011-12

- Elevation
- mpy

Chainage, km

Chainage, km

NDT

SV1 IPS1

SV2

SV3

IPS2

SV4

SV5

IPS3

SV5

SV6

IPS4

SV7

SV8

RT

0.029

0.413

0.374

0.248

0.114

0.078
Results

Fig a: General corrosion rates vs. Pitting corrosion rates at different locations
b: Max. pit depth (mils) at different locations for 2012-13
Results

General corrosion rates last three years
Results

Comparison of Pitting Corrosion Rates

2013-14
- RT (Rangapani)
- IPS-4 (Madarihat)
- IPS-3 (Bongaigaon)
- IPS-2 (PHQ Ghy)
- IPS-1 (Sekoni)
- NDT (NRL)

2012-13
- RT (Rangapani)
- IPS-4 (Madarihat)
- IPS-3 (Bongaigaon)
- IPS-2 (PHQ Ghy)
- IPS-1 (Sekoni)
- NDT (NRL)

Legend:
- ▢ Max. PR (Non-Flush Side)
- □ Max. PR (Flush Side)
No. of Pits per sq. cm for Loc. IPS-4 (Madarihat) 2013-14
Results
Table 1: Results of analysis of flush side of XT-491 sample.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Identification</th>
<th>Reading (Microns)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Maximum pit depth</td>
<td>41.0</td>
</tr>
<tr>
<td>2</td>
<td>Maximum pit diameter</td>
<td>89.7</td>
</tr>
</tbody>
</table>
## Results

**SAMPLE ID: XT-491- NON-FLUSH SIDE**

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Identification</th>
<th>Reading (Microns)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Maximum pit depth</td>
<td>343.6</td>
</tr>
<tr>
<td>2</td>
<td>Maximum pit diameter</td>
<td>1274.4</td>
</tr>
</tbody>
</table>
## Results

![Sample ID: XT-491](image)

<table>
<thead>
<tr>
<th>Plate: 1 Non-Flush Side</th>
<th>Plate: 2 Flush Side</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pit Density on Non-Flush Side</strong></td>
<td><strong>Pit Density on Flush Side</strong></td>
</tr>
<tr>
<td>Frame No.</td>
<td>Number of pits per frame</td>
</tr>
<tr>
<td>-----------</td>
<td>--------------------------</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
</tr>
</tbody>
</table>

*Note: Testing is done considering worst five fields.*
Sludge Analysis from NSPL
In the absence of any standard test method for analysis of pipeline sludge sample, an in-house test protocol was developed and adopted based on literature survey for carrying out analysis of the received samples in order to establish presence of corroded products.

- The samples received were a mixture of oily sludge associated with water and free oil. Free oil was separated and the samples were air dried to maintain consistency.

- A portion of the air dried sample was soxhlet extracted using dichloromethane to remove organics. The left over insoluble sample was analysed under X-ray powder diffraction instrument to identify presence of corrosion products.

- Remaining portion of the air dried sludge sample was ashed in a muffle furnace at 700 °C to quantify ratio of organics/inorganics.
# Sludge Analysis

## Table 1: Pigging sample as-received condition

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Sample ID</th>
<th>Physical State</th>
<th>Free Oil &amp; Associated water</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>IPS-1</td>
<td>Oily Sludge</td>
<td>150 ml</td>
</tr>
<tr>
<td>2</td>
<td>IPS-2</td>
<td>Oily Sludge</td>
<td>25 ml</td>
</tr>
<tr>
<td>3</td>
<td>IPS-3</td>
<td>Oily Sludge</td>
<td>220 ml</td>
</tr>
<tr>
<td>4</td>
<td>IPS-4</td>
<td>Oily Sludge</td>
<td>40 ml</td>
</tr>
</tbody>
</table>

## Table 2: Soxhlet extraction results using dichloromethane

<table>
<thead>
<tr>
<th>Lot No.</th>
<th>Sample ID</th>
<th>Sample Wt., g</th>
<th>Extracted wt., mg</th>
<th>Insolubles, wt., g</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>IPS-1</td>
<td>2.2048</td>
<td>849.5</td>
<td>1.3553</td>
</tr>
<tr>
<td></td>
<td>IPS-2</td>
<td>2.3437</td>
<td>297.7</td>
<td>2.046</td>
</tr>
<tr>
<td></td>
<td>IPS-3</td>
<td>2.022</td>
<td>276.7</td>
<td>1.7453</td>
</tr>
<tr>
<td></td>
<td>IPS-4</td>
<td>2.2787</td>
<td>233.1</td>
<td>2.0457</td>
</tr>
<tr>
<td>2</td>
<td>IPS-1</td>
<td>3.1249</td>
<td>1201.6</td>
<td>1.9233</td>
</tr>
<tr>
<td></td>
<td>IPS-2</td>
<td>3.385</td>
<td>443.7</td>
<td>2.9413</td>
</tr>
<tr>
<td></td>
<td>IPS-3</td>
<td>3.254</td>
<td>473.3</td>
<td>2.7803</td>
</tr>
<tr>
<td></td>
<td>IPS-4</td>
<td>3.157</td>
<td>338.8</td>
<td>2.8182</td>
</tr>
</tbody>
</table>
Sludge Analysis - Results

![Bar chart showing Avg solubles for IPS-1, IPS-2, IPS-3, and IPS-4. IPS-1 has the highest Wt. %, followed by IPS-2, IPS-3, and IPS-4.]

- IPS-1: Highest Wt. %
- IPS-2: Moderate Wt. %
- IPS-3: Moderate Wt. %
- IPS-4: Lower Wt. %
Sludge Analysis – Powder XRD
Sludge Analysis – Powder XRD
Sludge Analysis – XRD Results

- The diffraction data of all these samples show the presence of several iron corrosion products with varying oxidation states, including magnetite, goethite and iron sulphide along with silica and quartz.

- The presence of magnetite was significant as it is a common corrosion deposit.

- Other detected minor elements included silicon and sulphur.

- Presence of silicon suggests some siliceous material such as sand, silt or clay minerals.
Scraper Barrel Corrosion
MIC Tests

Samples from IPS-3 (Bongaigoan)
MIC Tests
Current Location of Coupons
Current Location of Coupons
Summary

- The general corrosion rates for all the six coupons from the six different locations can be categorized as low.

- Pitting corrosion has been observed in all the six coupons on both flush and non-flush sides.

- Pitting corrosion on the non-flush sides of the coupons, indicates scaling and under deposit corrosion on the non-flush sides.

- The Pit density per unit area ranges from 20 – 90 pits.
Summary

- While the maximum pitting rates on the flush sides of all the coupons is low; the same is found to be on the higher side on the non-flush sides of coupons ranging from 9 – 14 mpy at three locations IPS-2, IPS-3 and IPS-4.

- From the elevation profile, it may be inferred that corrosion rates are likely to be more in uphill/downhill segments such as between the region IPS-4 and SV7/SV8.

- Sludge analysis shows presence of corrosion products.
Conclusions

- The important conclusions of internal corrosion monitoring experience using flush disc coupons in the multi-product pipeline carrying refined products are:

  - Weight loss monitoring technique has limitations in many respects;

  - Nevertheless, continuous monitoring and a history of accumulated coupon test results does offer an excellent inexpensive source of information.

  - The weight loss data can easily be integrated in a corrosion appraisal to aid a robust pipeline integrity program.
Recommendations/Suggestions

- Locations that have highest susceptibility to accumulation of corrosion causing substance such as water or solids have highest likelihood of experiencing internal corrosion.

- Those locations where probability of water and / or solid accumulation is more are to be identified or flagged for selecting these sites for installation of coupons at 6’o clock position.

- The uninterrupted dosing of Cl should be ensured to mitigate internal corrosion. The Cl dosing vessels may also be cleaned periodically.

- Provision of Cl dosing may also be incorporated at Madarihat IPS-3 as this would provide internal protection further downstream till the Receipt Terminal in Siliguri.
Recommendations/Suggestions

- Microbiologically influenced corrosion is also another important mechanism that is widely active in oil transmission pipelines.

- It is advisable to carry out proper sampling in sterile sampling pots during next field visits to monitor biological activities.

- The scraper barrels should be periodically cleaned to ensure that no water is accumulated inside the barrels. Accumulation of water leads to corrosion and biofouling.
Recommendations/Suggestions

- It is advisable to carry out random sampling of products from 6’o clock position to determine the water percentage.

- Rectification of ER Probes and online corrosion monitoring, as stipulated in statutory guidelines.

- ILI and or Corrosion audit of NSPL may be carried out in detail through domain experts to develop a robust long term corrosion management plan or pipeline integrity program.
Thank You!