Rehabilitation of 32" Gas Pipeline in the most Cost Effective way - A Case study

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Abstract

Kuwait Oil Company (KOC) is one of the leading crude oil producing countries in the Middle East. It was established in the year 1934 and is estimated to hold 9.5% of the world's oil reserve.

As a part of Pipelines Integrity Assessment Programs, the intelligent ultrasonic inspection pigging of the 32" HP gas transmission pipeline (built in the year 1979) was conducted in the year 2002. This was first of its kind in KOC and it revealed significant external corrosion especially at the bottom portion of the pipeline making the operation of the pipeline at its maximum operating pressure unsafe. In order to ensure the integrity of the pipeline and its safe operation, it became necessary for the Company to either replace the pipeline or rehabilitate the pipeline.

The subject case study highlights the following aspects:

- Analysis of the options: Replacement vs. Rehabilitation.
- Adoption of the most economical methods for prolonging the life of the pipeline.
- Minimizing the down time of pipeline.
- Rehabilitation of the pipeline in a safe way under extreme and adverse weather conditions prevailing in the Middle East.
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REHABILITATION OF 32” GAS PIPELINE IN A MOST COST EFFECTIVE WAY- A Case Study

1.0 BACKGROUND:

Kuwait Oil Company (KOC) is one of the leading crude oil producing companies in the Middle East. It was established in the year 1934 and is estimated to hold 9.5% of world’s oil reserve. Currently, the crude oil production is approx. 2.4MBPD and expected to be 4.0MBPSD by 2030. Associated gas production is approx.1.1 BSCFD and total gas production (inclusive of non-associated gas) expected to go up to 4.0BSCFD by 2030. KOC’s current pipelines network constitutes approximately 5,000 Km of Crude oil and Gas pipelines distributed in an area of 18,000 Km sq.

In order to sustain the increasing demand of production levels, the implementation of Pipeline Integrity Management Program assumed a great significance keeping in view the age of the existing pipeline network in particular.

The present case study is the outcome of the Company’s commitments towards implementation of Pipeline Integrity Management Program. The case study deals with how the problems associated with the health of the 32”dia HP gas pipelines were identified, and the methodology/strategies adopted to prolong the life of the pipeline in the most cost effective way.

2.0 HISTORY OF 32” GAS PIPELINE:

The above Gas Transmission Pipeline was originally constructed in the year 1979 as part of the KGUP (Kuwait Gas Utilization Project) by M/s Bechtel without providing any corrosion allowance assuming that upstream gas dehydration plant would have high efficiency and that dew point would be controlled in order to avoid hydrate formation.

This gas transmission pipeline is used basically to transport produced gas (714 MMSCFD) from Booster Station (BS-150) to GCMB Manifold. Due to the pressing demand of increased exports of produced gas at BS-150, functioning of this pipeline
was mandatory and as a result it could not be released for necessary maintenance. However, to keep the operations on, necessary maintenance were carried out in critical sections of the pipeline as and when required depending upon it's availability and the pipeline continued to operate until 2008. Construction data of the pipeline are tabled in Annexure-A.

3.0 INSPECTION FINDINGS

Intelligent Ultrasonic Inspection Pigging was carried out in the year 2002. While inspection results did not show signs of any significant internal corrosion but external corrosions were observed.

- Wide spread external corrosion mostly at bottom sides with high density at the Launcher/Receiver areas.

- Extensive external corrosion suggested that the existing coating had deteriorated and dislodged. At various locations, disbanding of coating was noted at the excavated portions of the line.

A total of 594 locations were found to have external corrosion and metal loss. The distribution of location and metal loss percentage is illustrated in the Table-1 below.

<table>
<thead>
<tr>
<th>Depth of External Corrosion</th>
<th>% Metal Loss</th>
<th>No. of Locations</th>
<th>% Locations</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 1.2 mm</td>
<td>≤ 15%</td>
<td>6</td>
<td>1.0</td>
</tr>
<tr>
<td>1.4-1.8 mm</td>
<td>17.7-22.8%</td>
<td>229</td>
<td>38.6</td>
</tr>
<tr>
<td>1.8-2.2 mm</td>
<td>22.8-27.8%</td>
<td>130</td>
<td>21.9</td>
</tr>
<tr>
<td>2.2-2.6 mm</td>
<td>27.8-32.9%</td>
<td>95</td>
<td>16</td>
</tr>
<tr>
<td>2.6-3.0 mm</td>
<td>32.9-37.9%</td>
<td>45</td>
<td>7.6</td>
</tr>
<tr>
<td>3.0-3.4 mm</td>
<td>37.9-43%</td>
<td>42</td>
<td>7</td>
</tr>
<tr>
<td>3.4-3.8 mm</td>
<td>43-48%</td>
<td>41</td>
<td>6.9</td>
</tr>
<tr>
<td>3.8-4.2 mm</td>
<td>48-53%</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>≥ 4.2 mm</td>
<td>-</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td><strong>594</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

The external corrosion was a result of the deterioration of the existing coal tar enamel coating. On examination of excavated areas at 17 locations (out of 19 locations classified by UT as ‘lamination’), it was concluded that the coating had detached from
the metal surface, disbanded and resulted in Cathodic shielding that hampered the CP protection.

The photos fig (1), (2), (3) & 4 provided herein show the deteriorations at the 32” Gas Pipeline coating.

Since, the pipeline was constructed by M/s Bechtel without any corrosion allowance, the strength calculations of corroded pipe line was made according to ASME B31G (Strength of corroded pipelines) which revealed reducing the MAOP of this corroded pipeline.

3.0 REPLACEMENT vs. REHABILITATION

To ensure the integrity of the pipeline and to restore its safe operation, the options available with the company were:

Option No. 1: Replacement & construction of a new 32” pipeline
Option No. 2: Rehabilitation of the existing 32” pipeline

Evaluations of options are illustrated in the decision tree diagram shown below:

- Replace or Rehabilitate
  - Replace
    - Investment (US$ 12.0M)
    - Expected Life (30 years)
    - Down time (16 months)
  - Rehabilitation
    - Investment (US$ 4.0M)
    - Expected Life (20 years)
    - Down time (12 Months)

After analysis of above options, following conclusions emerged:

- Replacement/Construction of a new pipeline will be more costly and time consuming since it involves removal of the existing pipeline followed by the construction of a new pipeline.
- The operational activity would be badly affected due to longer downtime of the pipeline owing to the construction of a new pipeline.

Further interpretation of the Intelligent Pigging report indicated that the corrosion is of isolated nature and generally of pitting type. This situation suggested a longer life of the pipeline provided the corrosion is appropriately mitigated and/or prevented.

To stop further deterioration, the external coating must be replaced with a high performance & proven coating material allowing the pipeline to be rehabilitated and remain functional for at least 20 more years. Although, the 32” gas pipeline did not have any corrosion allowance, it still can be safely used after repairs to the corroded areas of the pipeline.

Thus, rehabilitation of the existing 32” pipeline was found to be the most economical way to ensure the integrity of the pipeline.
International trends also recommend repairs to pipelines as long as the costs of repairs are economically viable and the integrity of the pipeline is ensured.

3.0 REHABILITATION STRATEGIES

Coating is the primary protection method and must remain in a healthy condition. Hence, removal of existing disbanded coating, necessary repairs of the pipeline, and recoating with a reliable and high performance new coating material was adopted as the most cost effective method for rehabilitation of the pipeline. The entire work was accomplished using conventional manual methods rather than mechanized line travel methods used for coating removal, surface preparation, and coating applications and the desired quality of coating was achieved despite adverse conditions prevailing in the Middle East.

The entire rehabilitation work of the pipeline was completed within the estimated cost and ahead of the schedule.

Following were the prime considerations for adopting manual methods over the mechanized one:

- Economic considerations – To hire automatic travel machine for a pipeline of small length (8.7 Km) not economical.

- Requirement of wide excavations and maintaining it intact for movement of mechanized system was not feasible due to condensate line running parallel to the pipeline.

- Free movement of mechanized machine not feasible due to flow lines crossing the gas pipeline at many locations.

- Carrying out wide excavation and ensuring a dry excavated trench for a pipeline passing through marshy areas with a very high water table were uphill tasks.

- Supporting pipeline during in-situ application of coating material.

Steps followed for rehabilitation of the pipeline:
a) **EXCAVATION & REMOVAL OF EXISTING COATING:**
   To avoid damage to the pipeline, manual excavation methods were adopted. Removal of the existing coal tar coating was carried out through mechanical scraping followed by sweep blasting.

b) **SURFACE PREPARATION:**
   Adequate and correct surface preparation is the most important factor in controlling the success or failure of a protective coating. Even the best quality coating materials may fail when applied over a poorly prepared surface.

   Although, Oscillating Abrasive Blast System provides a much better surface preparation than the manual method but due to the space constraints and economic reasons, the company opted for Manual Abrasive Blasting to achieve near-white surface Sa 2.5, anchor profile of 75-125μ.

c) **REPAIRS OF Pitted SURFACE:**
   At 600 locations compatible cold weld compound (*Devcon* Titanium Putty) was applied to fill the pitted surface followed by application of Cold Tape (Clock springs) where required.

d) **RECOAT WITH NEW PROVEN COATING MATERIAL:**
   The choice of the new coating material to be applied to the pipeline was an important consideration for KOC, particularly in light of the failure of the existing coating material (Coal tar enamel).

   Major factors that were considered by KOC are:
   - Cause of the failure of previous coating material;
   - Operating temperature of the line and the maximum temperature;
   - Soil conditions and amount of soil stress the line would be subjected to;
   - Field application conditions;
   - Desired additional life of the pipeline;
   - Cost of coating material/cost of application.

   Considering the above factors and after evaluation of various options, the Corrosion & Inspection Team yielded to application of coating material - two components solvent-free Polyurethane meeting the ASTM D4541 requirements. Recoat of the complete length of the pipeline with Polyurethane
coating material (FUTURA, PROTEC-II) was manually completed using an airless hot spray system with utmost care to achieve the required quality.

e) REPLACEMENT OF CORRODED SECTION:

About 165 meters length (8 locations) of leaky & corroded sections of the pipeline was replaced.

f) REPLACEMENT OF DAMAGED COUNTER BLOCKS IN MARSHY AREA:

40Nos. rubber embedded concrete counter blocks replaced to neutralize buoyancy effect. To prevent new polyurethane coating, 5mm thick rubber sheet provided in between pipeline and the existing (340 Nos.) concrete counter blocks.

In addition, to prevent internal corrosion, pigging operations to expel the free water from the pipeline at the current frequency or closer intervals have been made mandatory.

5.0 CHALLENGES FACED

Shifting sands, salt marshes, extreme heat (55 °C) and sand storms are some of the challenges that pipeline projects face in the Middle East. Rehabilitation of the above Gas Transmission Pipeline was not an exception to the above and the project team was faced with numerous challenges.

Some of challenges / adverse conditions that were successfully overcome are narrated below:

- Pipeline passing through marshy areas with a very high water table makes the excavation of trenches difficult. Maintaining the trenches free of water and ensuring the pipeline surface dry for application of polyurethane coating under such situation was the real challenge. Continuous injection type dewatering system was deployed to keep the excavated trenches dry during
the entire duration of works.

- Proper supporting of the pipeline especially for the portions passing through marshy areas was very critical in order to maintain the stresses within the limit and to avoid any mechanical failure of the pipeline. To overcome this problem, the entire work had to be carried out in a pre-defined sequence i.e. excavate 100m followed by 50m unexcavated stretch, then complete the coating work for 100 meter stretch in all respects and backfill. Repeat the same sequence for the entire line. Temporary supports were provided for the 100 m stretch as required.

- Maintaining the required quality of surface preparation to near white SA 2.5 (EN ISO 8501-1/SSPC-SP10) due to frequent sand storms on a regular basis was always a challenge, which often resulted in the loss of valuable man-hours. To minimize this, following strategies were adopted:
  
  o Rescheduling of work to early morning and late afternoon.
  o High pressure water washing for pipe surfaces followed by air drying to remove dust and achieve the chloride level $<5 \, \mu g/cm^2$ (BRISLE Kit EN ISO 8502-9).
  o Protection of prepared surfaces to achieve the desired quality of coating.

- Maintaining the Polyurethane coating quality in a highly humid, dusty atmosphere with high temperatures during summer was always a difficult task. As per the coating manufacturer’s recommendations, RH of $< 80\%$ and substrate temperature of at least 3 °C above the dew point to avoid condensation had to be maintained. Introduction of two shifts working coupled with dynamic planning & rescheduling of the critical works viz coating application work to early morning or late afternoon when the desired climatic conditions could be achieved, were adopted as the project management strategies. Despite presence of adverse conditions, the team came across with bare minimum “holiday” repairs of the coating, which can be attributed to the adoption of the best project management practices and commitments towards quality.

- In all, the work had to be suspended for around 100 days on account of dust storms or other unfavorable factors. As a recovery plan, to control the schedule additional resources had to be deployed to crash the schedule. An additional coating machine with a complete set of crew members was deployed and the schedule recovered successfully.
Since the pipeline was passing through a number of road crossings, replacement of corroded pipe sleeves was a difficult proposition. To tackle this issue, shop coated split type pipe sleeves were introduced from accredited workshop.

6.0 GAINS FOR KOC

Major gains achieved by KOC

- Extended service life of existing pipeline by **more than 20 years** without any significant cost.
- Cost saving of approximately 8 Million US dollars due to adoption of correct strategy i.e. Rehabilitation over Replacement.
- Minimal loss of production - Rehabilitation took only 12 months as compared to 16 months estimated for Removal & Replacement of pipeline.

7.0 CONCLUSIONS

Effective implementation of Pipeline Integrity Management Program is imperative to the success of any Oil & Gas Company.

**REPAIRING THE PIPELINE AT AN ECONOMICALLY VIABLE COST, WHILE PRESERVING THE INTEGRITY OF THE PIPELINE IS THE BEST STRATEGY.**
## ANNEXURER-A

<table>
<thead>
<tr>
<th>ITEM</th>
<th>DETAILS OF 32” PIPE LINE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Construction Data</strong></td>
<td></td>
</tr>
<tr>
<td>Year Constructed/Operation</td>
<td>1979</td>
</tr>
<tr>
<td>Length</td>
<td>8.7 km</td>
</tr>
<tr>
<td>Material and Thickness</td>
<td>API-5L-X52 Spiral, 0.312” W.T</td>
</tr>
<tr>
<td>Design Code</td>
<td>ANSI-B31.8 (1979)</td>
</tr>
<tr>
<td>Design Factor</td>
<td>0.72</td>
</tr>
<tr>
<td>Construction Factor</td>
<td>Not Considered originally</td>
</tr>
<tr>
<td>Design Pressure/MAOP</td>
<td>- /700 psig</td>
</tr>
<tr>
<td>Flange Rating</td>
<td>300</td>
</tr>
<tr>
<td>Corrosion Allowance</td>
<td>None</td>
</tr>
<tr>
<td>External Coating</td>
<td>Coal Tar Enamel (AWWA-C203)</td>
</tr>
<tr>
<td>Internal Lining</td>
<td>None</td>
</tr>
<tr>
<td>Block Isolation Valves</td>
<td>One at Launcher and one at Receiver. (Valves are of the welded type)</td>
</tr>
<tr>
<td>NACE MR0175 applied</td>
<td>Yes, Tested to NACE TM0177, 1979</td>
</tr>
<tr>
<td>HIC Testing</td>
<td>No, NACE TM0284 did not exist that</td>
</tr>
</tbody>
</table>
CONSTRUCTION STAGE PHOTO’S