Corrosion Monitoring of Non-Common Carrier North Slope Pipelines

Technical Analysis

Of

BP Exploration (Alaska) Inc. – Commitment to Corrosion Monitoring Year 2003 for Greater Prudhoe Bay, Endicott, Northstar and Milne Point

Submitted by

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EXECUTIVE SUMMARY

Coffman Engineers, Inc. is responsible for the technical review of the 2003 corrosion program report submitted by BP Exploration (Alaska) Inc. (BPXA) to the Alaska Department of Environmental Conservation (ADEC). The report outlines the measures undertaken to mitigate corrosion of BPXA's non-common carrier North Slope pipelines. In addition, Coffman reviewed the presentation materials from the April and August 2004 Meet & Confer sessions.

From a global perspective of oil and gas production, Greater Prudhoe Bay (GPB) and related facilities have an aggressively managed corrosion control program. This suggests an adequate long-term commitment to preserving facilities for future production and sensitivity to environmental consequences.

Monitoring, mitigation, and inspection data support the conclusion that the GPB assets are being preserved, but isolated locations of accelerated corrosion exists and have been found by inspections. The isolated locations of corrosion are where leaks may occur (including Endicott's duplex stainless steel system). BPX has responded to this threat by implementing aggressive and thorough monitoring and mitigation programs; however, it does not appear to be presently possible to predict the onset of all new locations of accelerated corrosion.

Monitoring data, presented by BPX, is in conformance to metrics agreed to by ADEC. However, the significance of isolated areas of aggressive internal corrosion is not intuitively reflected by monitoring data because 1) extreme values cannot be readily determined, and 2) monitoring tools are generally not located where the isolated corrosion occurs. In the future, it would be beneficial for the distribution of coupon corrosion rate data be presented for an improved representation of the extreme corrosion rates.

Inspection data supports the conclusion that the seawater and produced water systems are being adequately managed for internal corrosion and program improvements are continuously being made.

External corrosion of above-ground piping is largely confined to weld packs and BPX has made a notable commitment to removing this threat through inspection and repair (where necessary) of all weld pack locations.

Long range inspection tools are used to detect external corrosion of cased pipe and buried pipe. Although this is a proactive risk based approach, it should be recognized that industry experience with these inspection methods are mixed and there may be technical issues to be resolved as is the case with many state-of-the-art technologies. It is recommended that BPX provide a comparison of inspection results versus direct examination so that the accuracy and reliability of this inspection method can be evaluated by ADEC.

CORROSION PROGRAM STATUS – GREATER PRUDHOE BAY

Internal Corrosion Management

Production System (Well Lines and Flow Lines)

The data provided by BPX supports the conclusion that the internal corrosion control/inspection program is well managed and effectively preserving the facilities for the future. However, the existence of isolated locations of accelerated corrosion could potentially result in leaks. Although isolated locations of corrosion are repairable, they could have an environmental consequence if not detected. BPX has responded to this threat by implementing aggressive and thorough monitoring, inspection and mitigation programs.

From a global perspective of oil and gas production, GPB has one of the most aggressively managed internal corrosion control programs. The level of inspection and corrosion mitigation resources directed by BPX corrosion experts is commendable. This suggests a long-term commitment to preserving facilities for future production and sensitivity to environmental consequences.

Inspection, monitoring, and mitigation data support the conclusion that the GPB assets are being adequately maintained and preserved. Corrosion control efforts exceed standard oilfield industry practice. The average corrosion rates of coupons and probes are as low as can be practically achieved (i.e., <1 mpy). A 1 mpy corrosion rate is put into context by considering that a 0.375 inch wall thickness pipe would have 80% of its wall thickness after 75 years. Inspection data supports the conclusion that most of the asset has insignificant corrosion. However, isolated locations with high corrosion rates remain. It would be beneficial to identify in future reports (in one location, if possible) what fraction of the piping experiences accelerated corrosion rates, what the pipeline services are, what the accelerated corrosion rates are (i.e., >10 mpy) and the remedial action that was taken to reduce the corrosion rates (Note: This information is currently not required by the reporting metrics agreed to by ADEC and some of the information is currently identified in various sections of the report).

The significance of isolated areas of accelerated corrosion within GPB is not intuitively reflected in the monitoring data presented by BPX because many of the coupons and probes are not located where accelerated corrosion occurs. Rather, they are installed at locations that are convenient for installation and retrieval (as is common practice in the industry). Future coupons should be placed at locations that represent the highest susceptibility to corrosion.

The impracticality of prioritizing susceptibility to isolated aggressive corrosion is compensated by an aggressive field-wide inspection program. The effectiveness of this program is demonstrated by the high ratio of ‘saves’ to leaks (with ‘saves’ defined by detecting damage requiring repair or pressure reduction).

Seawater and Produced Water Injection

The seawater and produced water systems have relatively low corrosion rates and appear to be well managed. The presence of only one phase (i.e., water) makes corrosion management less complicated than the multiphase production system. Corrosion of the seawater system is mitigated by removing oxygen and injecting biocides. Corrosion of the produced water injection system is mitigated by oxygen removal, injecting biocides and by carryover inhibition from the production system.

Corrosion rates in the seawater systems decreased in 2003, reversing a 5-year trend. A number of actions were taken to address dissolved oxygen levels and microbiological corrosion control. Corrosion rates in the produced water systems also decreased in 2003. The upstream 3-phase corrosion inhibitor was changed and the corrosion mitigation programs were expanded specifically to address the produced water system in 2002.

External Corrosion Management

Above Grade Piping

BPXA plans to inspect and repair (as necessary) approximately 35,000 weld packs per year. This is a commendable commitment to address and remove the pipeline integrity problems associated with corrosion under insulation. Additionally, the priority for inspection is based on the consequence of failure (e.g., weld packs over tundra are higher priority than over the pad), ensuring that the highest consequence locations are repaired first. A new weld pack design is in use and is intended to prevent future water ingress and corrosion at these field-applied insulation locations.

Below Grade Piping

BPX plans to inspect cased crossings using long range inspection methods (i.e., electromagnetic pulse and guided wave technologies). Although this is a proactive risk based approach, there may be issues to be resolved with these technologies, as is the case with many state-of-the art technologies. BPX should provide data that quantifies the ability of long range inspection to detect defects that could lead to failure (i.e., compare inspection results with subsequent direct examination of the cased pipe). Where it is not practical to perform a direct exam, determining the ability to characterize defects on a pipe where a defect has been detected by long range inspection would provide added confidence to the method.

SATELLITE FIELDS

Endicott

The majority of the Endicott production system piping is constructed of Duplex Stainless Steel (DSS) that is intended to be corrosion resistant in the produced fluid environment. Minor components within the facility (i.e., C-spools) are carbon steel with corrosion managed by monitoring, inspection and repair/replacement (when necessary). Carbon steel coupons are used to monitor corrosivity, and their average rate in 2002-2003 was approximately 3 mpy. It should be noted that the coupons are not expected to reflect the rate that would be seen on the DSS (if it were to corrode) because its mechanism and rate of corrosion differs. That is, a breakdown in DSS passivity would result in localized corrosion (i.e., pitting) with a corrosion rate much higher than the rate observed by the carbon steel coupons.

The stated BPX primary corrosion concern at Endicott is the inter-island-water-line (IIWL). However, its corrosion management is similar to the produced water injection system at Prudhoe Bay and the monitoring data shows average corrosion rates near zero.

There were seven repair activities at Endicott. Five C-spools were replaced due to corrosion, one C-spool was replaced due to erosion and one stainless steel well line was sleeved due to erosion.

Milne Point

BPX has significantly improved the internal corrosion management of Milne Point production and produced water systems. These improvements include increases in corrosion inhibition, maintenance pigging, and inspection. Monitoring data shows reduction of average corrosion rates to insignificant levels (i.e., <1 mpy).

Milne Point has buried pipe containing produced fluids that require excavation for external inspection. Because of this, BPX is considering the use of long range inspection methods (i.e., guided wave ultrasonics). As previously stated, there may be issues to be resolved regarding these technologies.

There were 7 repair activities at Milne Point. Six of the repairs were on the K-pad production flow line. Additional areas have been identified for sleeve repair.

Northstar

The threat of corrosion at Northstar is considered low. Production began in late 2001 and fluids have low corrosivity. The production lines are inhibited and corrosion coupons indicate adequate effectiveness. Inspection activities have also increased.

Badami

Badami is shut-in, so damage as a result of corrosion should not result in leaks (i.e., there is no environmental consequence). From an asset preservation standpoint, external corrosion can occur on buried and/or insulated piping, and internal corrosion can occur where lines have been insufficiently dried or treated (e.g., for bacteria).

RECOMMENDATIONS

Recommendations for areas that warrant further review or information that should be included in future reports are as follows:

1. Continue the commitment to external corrosion inspection and mitigation on the weld packs. Identify the number of weld packs remaining to be inspected and the forecasted completion date.
2. Future coupons should be placed at locations that represent the highest susceptibility to corrosion.
3. Identify criteria to be used for locating future coupons.
4. Based on the inspection methodology and guidelines in the GPB corrosion inspection program, define matrix or priority indices used for selecting inspection locations that may be prone to accelerated corrosion.
5. Provide data that quantifies the ability of long range inspection to detect defects that could lead to failure (i.e., compare inspection results with subsequent direct examination of the cased pipe).

CONCLUSIONS

BPXA has presented sufficient information to demonstrate that its corrosion control program meets the spirit of the Charter Agreement. This suggests a proactive long-term commitment to preserving facilities for future production and sensitivity to environmental consequences. Recommendations and observations contained in this document should be viewed as opportunities for incremental improvement.

Although the vast majority of internal pipeline corrosion is being mitigated, isolated areas of accelerated corrosion have been detected through comprehensive inspections and by way of leaks that have occurred on isolated occasions. Priority should be given to those locations that represent the highest susceptibility to corrosion for future inspections.

Two significant external corrosion threats are below-ground cased crossings and weld packs on above-ground pipe. BPXA has made a notable commitment to inspect and repair (when necessary) weld-packs. BPXA also intends to inspect cased crossings with long-range inspection tools; however, it should be recognized that long-range inspection tools may have technical issues that need to be resolved.