Corrosion Monitoring of Non-Common Carrier North Slope Pipelines

Technical Analysis

Of

Phillips Alaska Inc. – 2001 Commitment to Corrosion Monitoring for Greater Kuparuk Area & Alpine

Submitted by

COFFMAN ENGINEERS
800 F Street
Anchorage, Alaska 99501
907/276-6664
907/276-5042 Fax
www.coffman.com

ADEC Contract Number – 18-6000-02

Table of Contents

EXECUTIVE SUMMARY

Coffman Engineers, Inc. has been charged with reviewing the 2001 corrosion program report submitted by Phillips Alaska Incorporated (PAI) to the Alaska Department of Environmental Conservation (ADEC). The report outlines the measures undertaken to mitigate corrosion in PAI's non-common carrier North Slope pipelines. In addition, Coffman reviewed the presentation materials from the October 2001 and April 2002 Meet & Confer sessions. PAI and ADEC mutually agreed to a performance metric guide prior to drafting the 2001 report. The results are a much improved report that better defines the service categories and basic summary statistics.

Internal corrosion in cross-country lines indicates a clear degree of corrosion inhibition: no leaks and no saves were reported in 2001. Corrosion control, primarily inhibitor injection, has maintained the low leak/save frequency; corrosion damage increases have been almost eliminated in the cross-country gathering lines through corrosion control. However, coupon pitting rates for three phase and water injection pipelines have seen relatively steady increases since 1998. While the rates are still below the target limits, PAI changed inhibitors late in 2001 in an effort to reverse this trend. In addition, the number of locations with corrosion damage increases (UT and RT) has increased compared to 2000, 35 versus 13.

Internal corrosion in well lines is an area that requires PAI's continued focus; no leaks and 24 saves (repairs) were reported in 2001. The number of saves has increased over the past three years, albeit at slower rate than the amount of pipe inspected. This suggests PAI could be approaching the "top of the curve" for internal well line corrosion control. The number of locations with corrosion damage increases (UT and RT) has also increased compared to 2000, 163 versus 115.

External corrosion at weld-packs (above and below grade) continues to pose an integrity risk. There has been an average of one leak per year over the past five years (1997-2001) due to external corrosion mechanisms. A baseline inspection of all weld-packs on off-pad, cross country pipelines was completed in 2001. Baseline inspection of on-pad weld-packs (well and cross country lines) is progressing ahead of schedule and average percent of corroded weld-packs has dropped slightly to ~2%. There were four repairs and 800+ weld-packs refurbished on above grade piping. One leak in 2001 (1HBWI) occurred on below grade piping at a weld-pack. PAI has responded by accelerating the screening inspections for below grade piping during 2001 and plans to continue at an accelerated rate in 2002. Nine below grade locations were excavated and two locations required repair; one location was sleeved and the other location was on piping that was, and has remained, out of service.

There was one failure in 2001 attributed to wind induced vibration (WIV) coupled with a potential weld anomaly. An evaluation of the design envelope is underway to ensure it is still valid. Another structural concern is well subsidence. The well subsidence mitigation plan was being implemented to control further subsidence. The corrosion group will need to continue its close coordination with those tasked with maintaining pipeline structural integrity in order to address the confluence of corrosion and structural concerns.

CORROSION PROGRAM STATUS

Internal Corrosion Management

Cross Country Pipelines – Monitoring & Inspection

Internal corrosion in cross-country lines indicates a clear degree of corrosion inhibition: no leaks and no saves were reported in 2001. Corrosion control, primarily inhibitor injection, has maintained the low leak/save frequency; corrosion damage increases have been nearly eliminated in the cross-country gathering lines through corrosion control. However, coupon pitting rates for three phase and water injection pipelines have seen relatively steady increases since 1998. While the rates are still below the target limits, if the trend continues unabated, the average pitting rate will exceed the nominal threshold of 10 mpy. In addition, the total number of locations with corrosion damage increases (UT and RT) has increased compared to 2000, 35 versus 13. PAI responded by changing inhibitors late in 2001 in an effort to reverse this trend.

PAI reports that coupon or probe corrosion rates exceeded threshold targets in 19 lines and they responded by increasing the corrosion inhibitor concentrations for all 19 lines. In addition, inspection showed nine lines with "minor" corrosion where the coupons did not exceed the target corrosion rate. The corrosion inhibitor concentrations for all nine of these lines were also increased. This helps to illustrate and reinforce the importance of both programs.

An ongoing item of concern is the difficulty of inspecting produced water injection piping with diameters larger than eight to ten inches, which is considered radio-opaque and limits the use of radiographic techniques. PAI states they are going to "evaluate the possibility of smart pigging cross-country water injection lines larger than 8" O.D." during 2002. However the report states the corrosion tends to manifest in the un-piggable, stagnant portions of the systems. It is not clear if there are segments that met both criteria (>8" and stagnant flow) and how they will be inspected.

Well Lines - Monitoring & Inspection

Internal corrosion in well lines is an area that requires PAI's continued focus; no leaks and 24 saves (17 injection and 7 production) were reported in 2001. The number of saves has increased over the past three years, albeit at slower rate than the amount of pipe inspected. This suggests PAI could be approaching the "top of the curve" for internal well line corrosion control. PAI will need to reassess its corrosion management situation when new production horizons are brought on line and fed into the existing production gathering system. Corrosion control may be lost due to the addition of new production.

Production well line coupon data indicate very low general and pitting corrosion rates. Injection well line coupon data indicates very low general corrosion rates. Pitting rates for this service are below the action limit; however they are above the historic average and have an increasing trend over the past 5 years.

The number of locations with corrosion damage increases (UT and RT) has also increased compared to 2000, 163 versus 115. 124 increases were in production service and 39 increases were in the injection service. The 2000 data is presented as an aggregate so comparisons

between service types are not possible. It is unclear if there are specific targets for repeat inspections using manual RT and UT techniques but the percent repeated for each inspection type and service type vary widely. It is also unclear if there is a target or action limit for the percent increase value.

Internal Corrosion Mitigation

PAI switched to a different corrosion inhibitor (Cortron 2000-25) during 2001, but has plans to return to the previous incumbent (Cortron RU-276) in 2002. Figure 6 depicts the field wide corrosion inhibitor usage, recommended volume, and the % difference between the recommended volume and the actual volume. PAI's compliance with its own corrosion inhibition targets has improved over time; reporting an average deviation of +0.7% for 2001; a slight over-treatment, showing an excellent level of control. Figure 6 also shows a step-like increase in inhibitor volume occurring in the third quarter of 2001.

PAI is continuing to move forward with the wellhead inhibitor injection program, but the program appears to be slipping in schedule. The 2000 Report and April 2001 slides indicated 3-5 drill sites were scheduled for startup in 2001. The November 2001 slides indicated one drill site (1G) would be constructed late 2001 to early 2002. April 2002 slides indicate construction is still planned for 1G and other sites are funded and in the design/procurement stages. As discussed previously, the well lines should benefit greatly from this program.

External Corrosion Management

Above Grade Piping

PAI exceeded their stated external inspection goals in 2001. During 2001, the baseline inspection for all off-pad weld-packs was completed and all weld-packs found with corrosion have been refurbished. Also during 2001, the baseline inspection for on-pad weld-packs was 48% complete overall and is progressing ahead of PAI's stated 2005 completion schedule.

There were three repairs on off-pad piping, two repairs on on-pad piping and more than 800 weld-packs refurbished. The percent corroded and percent repaired results for 2001 are consistent with the overall average percentages, and likely means there are 5-10 repairs to be made on the remaining ~18,000 weld-packs. Refer to Table 1 for the overall weld-pack program status of the PAI weld-pack inspection program.

In April 2001, PAI stated they were going to test "inhibitor spikes" on 25-50 weld-packs, however little information was provided as to the status of this test program.

In 2003, PAI will begin a prioritized program to re-inspect weld-packs that have not been previously refurbished (five years after the baseline inspection). This activity will likely remain necessary through the end-of-field life.

Table 1 - Above grade weld-pack inspection status

Service	Total Number (approx.)	Number Inspected During 2001	Number Inspected thru YE2001	% Inspected thru YE2001	Number Remaining	2002 Forecast
X-Country-Off-pad	67,291	292	67,291	100%	0	0
X-Country-On-pad	10,400	3,919	6,344	61%	4,056	1,780
Well LinesOn-pad	24,000	5,489	10,320	43%	13,680	4,000
Totals	**101,691**	**9,700**	**83,955**	**83%**	**17,736**	**5,780**

Note: This table represents an effort to reconcile numbers presented in the 2000 and 2001 PAI reports. There is the possibility for minor discrepancies.

Below Grade Piping

PAI exceeded their stated below grade inspection goals in 2001, inspecting 228 new locations using a combination of electromagnetic pulse and guided wave technologies. One additional screening technology, guided-ultrasonic, was evaluated and deemed "not superior" to the incumbent and will not be used at this time. Additionally all cased crossings are visually inspected to ensure they are clear of debris and if found, they are cleaned out.

One leak in 2001 (1HBWI) occurred on below grade piping at a weld-pack. PAI has responded by accelerating the screening inspections for below grade piping during 2001 and plans to continue at an accelerated rate in 2002. Nine below grade locations were excavated and two locations required repair; one location was sleeved and the other location is on piping that was, and has remained, out of service.

A proper accounting of the total population of below grade piping would lend context to the status of this program. Based on information presented in the 2000 and 2001 reports there appears to be a total population of ~740 below grade locations. Refer to Table 2 for an initial attempt to summarize the status of this program.

Table 2 - Below Grade Piping Baseline Inspection Status

	Total Number (approx.)	Number Inspected During 2001	Number Inspected thru YE2001	Number Remaining
Oil - Significant	385			
Non Oil - Significant	210			
Oil - Low Risk	46			
Non Oil – Low Risk	95			
Totals	**739**	**228**	**438**	**301**

Note: This table represents an effort to reconcile numbers presented in the 2000 and 2001 PAI reports. There is the possibility for minor discrepancies.

Structural Concerns

Subsidence

There were no leaks attributed to subsidence in 2001. PAI continues to prioritize and upgrade existing wellhead riser supports and flooring susceptible to subsidence. Thermal siphons are also being installed in near well-bore location to promote re-freezing and stabilization of the soil. PAI has updated its new well construction and water injection conversion requirements to include thermal siphons and riser supports on the well installations.

Wind Induced Vibration

Vibration dampeners are installed on all lines lying within a range of degrees perpendicular to the prevailing wind direction. One failure (DS2X) occurred at a weld on a pipeline orientated 1º outside of the range. Metallurgical analysis is being performed to rule out a weld defect. In response PAI is re-evaluating the design criteria to ensure the envelope is still large enough. Perhaps of greater concern is the identification of one "area" that is within the existing envelope but did not have dampeners installed. While dampeners are planned for installation during 2002, the integrity of pipelines in this "area" should be verified. Information such as age of lines/length of exposure, corrosion history, etc. could be used in a qualitative assessment to ensure there are no anomalies in the susceptible areas of the pipelines.

RECOMMENDATIONS

Recommendations for future reports are as follows:

1. Total number/population of well lines, cross country lines, weld packs, below grade pipe segments would be beneficial. In addition, the number of baseline inspections and related percentages for the weld-pack and below grade piping programs would be beneficial to track overall progress during the multi-year effort. These data could be presented as a cumulative graph or in a tabular format.
2. A histogram depicting the number of pipelines in each service within different %SMYS categories would be beneficial. Suggested %SMYS categories are: <10%, 10-20%, 20-30%, and >30%.
3. Provide an explanation/procedure used for selecting location for re-inspection as well as how the results are used.
4. Provide more details on the inspection of large diameter (>8") cross-country water injection piping and the results of the proposed smart-pigging evaluation.
5. In addition to the existing data presentation, consider combining the leaks and saves from the BGPP with the External Leaks and Saves data. Presently it appears the 2001 leak is included but the two repairs (saves) are not.
6. Additional information on the number and integrity of lines identified in the WIV envelope without dampeners.

CONCLUSIONS

PAI continues their vigorous corrosion control program and has met or exceeded all of the stated inspection goals during 2001. The new report format is much improved and easier to comprehend.

Cross-country pipelines inspection data indicates a clear degree of internal corrosion control however the coupon pitting rates have been increasing in recent years and the number of corrosion damage increases also increased over last year. PAI has responded by returning to a previous inhibitor formulation as well as increasing the overall inhibitor concentrations. Lastly, smart-pigging is being investigated for inspection of large diameter Mixed Water cross-country piping.

Well line internal corrosion control appears to be approaching the "top of the curve," but still requires significant effort. The number of corrosion increases and number of saves were greater than the previous year. The schedule for testing wellhead inhibitor injection has slipped; but there should be preliminary results during 2002.

External corrosion control is progressing and all of the off-pad piping baseline inspections are completed. There are still more than 17,000 on-pad weld-packs remaining, and extrapolating the results to date, means there are several areas that will require repair. After the failure (1HBWI), the below grade screening program was accelerated during 2001 and two additional repairs were required.

Improvements were made to the well construction specifications to include floors with permanent pipe supports and thermo-siphons on new wells and retrofits to existing structures. Wind-Induced-Vibration specifications are being evaluated to determine whether or not a change needs to be made in light of the failure (DS2X) in 2001.

Beyond the Mitigation, Monitoring and Inspection goals outlined for 2002, PAI will be performing testing and/or improvements in the following areas:

- Engineered surfactant treatment aimed at removing solids in hard to treat water injection distribution lines.
- Corrosion Inhibitor development/testing
- Kuparuk corrosion database improvements
- Alpine database development
- WIV and well subsidence prioritization/evaluation.