ILI-Reported Longitudinal Seam Weld Versus Pipe Body Metal Loss Anomalies – A Case Study

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Abstract

Results from magnetic flux leakage (MFL) in-line inspection (ILI) surveys provide valuable information that help pipeline operators make informed and defensible integrity management decisions. When subsequent ILI survey data are available, meaningful and data-driven corrosion growth rates can be derived along the length of a pipeline by performing a comprehensive ILI-run-to-run comparison (i.e., ILI run-to-run comparison that includes statistical and engineering analyses that are complemented by detailed ILI signal review comparisons).

ILI vendors typically identify metal loss anomalies that are on (i.e., within or crossing) or near (i.e., adjacent to, or in the heat affected zone) the longitudinal seam weld versus those that are in the pipe body (i.e., away from the longitudinal seam weld). During a comprehensive ILI run-to-run comparison analysis, the authors of this paper observed a trend in which 'spreadsheet-based' corrosion growth rates for metal loss anomalies reported on or near the longitudinal seam weld were consistently higher than those reported in the pipe body. Following this observation, the authors performed an in-depth analysis to better understand this trend. The following tasks were completed as a part of the analysis:

- Literature and industry review to establish whether the studied pipeline is susceptible to preferential longitudinal seam weld corrosion, including selective seam weld corrosion.
- Detailed statistical analysis to identify whether differences between the corrosion growth rates among metal loss anomalies reported on or near the longitudinal seam weld versus those that are in the pipe body are statistically significant.
- Comprehensive signal review comparisons between the subsequent ILI surveys at select and targeted locations that demonstrated the largest differences in corrosion growth rates between metal loss anomalies reported on or near the longitudinal seam weld versus those reported in the pipe body.
- Determine whether 'true' corrosion growth rates at metal loss anomalies on or near the longitudinal seam weld are higher than those in the pipe body.

This paper details the methodology and results of the authors' analysis. Key findings and practical applications are presented. The paper will provide valuable insights into managing pipeline integrity with respect to ILI-reported metal loss anomalies on or near the longitudinal seam weld.

Introduction and Background

A North American pipeline operator operates a pipeline system that utilizes in-line inspection (ILI) tools to perform integrity assessments within their pipeline system. The primary pipeline system is comprised of three separate ILI pipeline routes (i.e., there are three sets of ILI tool launchers and receivers in the pipeline system), which are herein referred to as Route 1, Route 2, and Route 3.

All three pipeline routes share the same essential variables, including, 1) outside diameter, 2) nominal wall thickness (NWT), 3) pipe grade, 4) longitudinal seam weld type (double submerged arc welded

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[DSAW] line pipe), 5) coating type, 6) maximum allowable operating pressures [MAOPs][1], 7) environmental conditions, and 8) inspection systems (as detailed in the following paragraph). Therefore, it is a valid approach to combine ILI results from the three pipeline routes when analyzing results of the ILI surveys [1].

The routes were inspected in 2021 utilizing axial magnetic flux leakage (MFL) high resolution ILI tool technology. The routes were previously inspected in 2018 also utilizing MFL high resolution ILI tool technology. The 2021 and 2018 ILI surveys on the three pipeline routes utilized the same ILI vendor. The authors conducted a comprehensive ILI run-to-run comparison utilizing results from the 2021 and 2018 ILI surveys. The ILI run-to-run comparison utilized engineering and statistical analyses that were complemented by detailed ILI signal review comparisons between the subsequent ILI surveys. At the conclusion of the ILI run-to-run comparison, corrosion growth rates (CGRs) were established along the length of the pipeline routes on a per-joint basis.

During and after the ILI run-to-run comparison analysis, it was observed that 2021 ILI-reported metal loss anomalies on or near the longitudinal seam weld (LSW) were consistently reported as deeper than metal loss anomalies that were reported away from the LSW (i.e., within the pipe body). The authors of this paper sought to further investigate this observation to evaluate and confirm whether the pipeline routes are susceptible to corrosion that is preferential to the LSW (indicative of the threat of selective seam weld corrosion [SSWC]).

The authors have conducted several studies to date on the pipeline routes to evaluate anomalies reported on or near the LSW. This paper summarizes combined efforts from the various studies to provide a comprehensive review of methodologies and results from the authors' analyses. Key findings and practical applications are presented which provide valuable insights into managing pipeline integrity with respect to ILI-reported metal loss anomalies on or near the LSW.

Scope of Work and Results

The goal of this study was to 1) perform a threat assessment to evaluate whether the pipeline routes are susceptible to SSWC, and 2) confirm the results of the threat assessment by analyzing the ILI spreadsheet listings and accompanying ILI signal data. The following tasks were implemented in order to achieve these goals:

- Task 1: Threat assessment
    - Task 1a: Review relevant literature
    - Task 1b: Review pipeline historic field investigations
    - Task 1c: Review regulations
- Task 2: Analysis and prioritization
    - Task 2a: LSW versus pipe body CGR analysis
    - Task 2b: Signal review prioritization
    - Task 2c: ILI signal review analysis and final prioritization

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[1] MAOP values vary along the lengths of each of the three pipeline routes based on design pressures associated with outside diameters, pipe grades, and NWT values. However, the range of MAOP values is consistent within each of the routes.

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The following subsections describe the methodologies and associated results.

Task 1: Threat assessment

To assess the threat of metal loss anomalies that are preferential to the LSW (including SSWC), the authors reviewed the following:

- Pipeline safety regulations,
- PHMSA frequently asked questions (FAQs) and interpretations,
- Industry documents (standard practices, recommended practices, etc.),
- Technical publications,
- Pipe characteristics and attributes, and
- Historic field inspection results on the pipeline routes (with a particular focus on inspections that targeted anomalies on or near the LSW).

As is supported by the information in the following sub-sections, it is reasonable to conclude that DSAW longitudinal seams are not considered by the pipeline industry to be susceptible to SSWC. This position is further substantiated from review of historical excavation records for each pipeline route within which no preferential attack of the DSAW LSWs was observed. It is also reasonable to conclude that the intent and spirit of the original rulemaking was to specifically call out and identify selective corrosion of LSWs. Incidental corrosion of the LSW would be evaluated and treated like pipe body corrosion as specified in industry standards (e.g., ASME B31G).

The following sub-sections detail the results of the threat assessment task.

Task 1a: Threat assessment; Review relevant literature

LSW weld failure mechanisms have been the subject of many industry initiatives and research. Specific to SSWC, a recent publication was presented by Michael J. Rosenfeld, RSI Pipeline Solutions, LLC, at the 2022 Pipeline Pigging and Integrity Management conference, “Accepting Metal Loss Corrosion on Longitudinal Seams” [2]. Mr. Rosenfeld summarizes much of the previous work done on corrosion interaction with longitudinal seams and provides a comprehensive bibliography of sources. Rosenfeld’s review of the available literature indicates that SSWC is limited to low frequency ERW welds that were not heat treated. He specifically excludes DSAW pipe seams from being susceptible.

Rosenfeld further concludes “that blunt corrosion defects associated with DSAW seam welds, HF ERW seam welds, LF ERW seam welds confirmed to have been subjected to post-weld heat treatment, and the heat affected zones of ERW and EFW welds can be safely evaluated using methods described in ASME B31G or similar.” [2]

The Pipeline & Hazardous Materials Safety Administration (PHMSA) has published a fact sheet specific to SSWC. The fact sheet defines SSWC as “a form of corrosion that tends to affect pipe manufactured prior to 1970 using low-frequency electric resistance welding (LF-ERW) or electric flash welding (EFW) processes.” It further states that SSWC is “a localized corrosion attack along the weld bondline of ERW and EFW pipe, that leads to the development of a wedge-shaped groove that is often filled with corrosion products.” PHMSA’s fact sheet does not mention the threat of SSWC being applicable to line pipe with DSAW longitudinal seams. [3]

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SSWC is defined in API RP 1160 as a "form of external or internal corrosion attack that occurs preferentially along the weld bond line of ERW or FW line pipe that often has the appearance of a wedge-shaped groove when conditions exist that cause the bond line region or the ERW or FW seam to corrode at a faster rate than the surrounding base metal."[2] The recommended practice does not include DSAW longitudinal seams in its definition of the threat of SSWC.

In summary, pipeline industry literature does not include or reference DSAW longitudinal seams when defining or describing the susceptibility of seams to SSWC which is indicative of the industry consensus that the threat of SSWC is highly unlikely to occur in line pipe that contain DSAW longitudinal seams. [4]

Task 1b: Threat assessment; Review pipeline historic field investigations

The authors reviewed historic field investigation results on Route 1, with a particular focus on investigations targeting potential seam weld threats. Based on the available data, the authors identified 37 previous investigations (conducted between 2004 and 2019) where corrosion was identified on or along the DSAW LSW. Of the 37 investigations, six reports noted "preferential" corrosion of the long seam. These reports and associated investigation photos were reviewed in detail. In summary, the authors observed the following:

- Corrosion observed on or along the LSW was no more severe (in depth) than corrosion in the pipe body.
- The traditional wedge-shaped groove typically associated with SSWC was not observed in any of the excavation report photo documentation or described as such by on-site personnel.
- Corrosion observed on or along the LSW did not appear to be preferential to the weld metal or bond line.
- Corrosion observed on or along the LSW did not appear to be preferential to the weld heat affected zone (HAZ) or appreciably deeper within the HAZ.
- Corrosion of or along the LSW appeared to coincide with areas that display attributes consistent with tape wrap "tenting" or localized disbondment.

It was also noted that areas of generalized corrosion[3] crossed the long seam weld with no preferential grooving or appreciable depth change (**Error! Reference source not found.**). This indicates the pipe weld at this location is not susceptible to SSWC. Similar results could be expected at other locations along each pipeline route given the commonalities in essential variables described in **Introduction and Background** section of this paper.

Task 1c: Threat assessment; review regulations

The authors reviewed pipeline safety regulations contained in 49 CFR Part 195 as well as frequently asked questions (FAQs), correspondences, and interpretations thereof to assess the spirit of the 180-day repair condition regarding "Corrosion of or along a longitudinal weld". Specifically, 49 C.F.R.

[2] ERW refers to electric resistance welded LSWs while FW refers to flash welded LSWS.
[3] Generalized corrosion is defined for the purpose of this report as widespread pitting corrosion of the general pipe surface.

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§ 195.452(h)(4)(iii)(H) 180-day conditions, which states "Except for conditions listed in paragraph (h)(4)(i) or (ii) of this section, an operator must schedule evaluation and remediation of the following within 180 days of discovery of the condition: (H) Corrosion of or along a longitudinal seam weld."[4] This language has remained essentially unchanged since the promulgation of the integrity management rule in 2000. Also included in the original 2000 rule was a condition (F) Weld Anomalies with a predicted metal loss >50% of nominal wall. [5] [6]

The preamble to the integrity management rule was published in the Federal Register/Vol. 65, No. 232/ Friday, December 1, 2000/ Rules and Regulations and reads "OPS is basing the provisions in section 195.452(h) on initial indications of what will be in the final consensus standard (API 1160). We believe that the criteria being considered by the standard's workgroup adequately address pipeline integrity concerns because the criteria are based on a structured methodology for evaluation of internal inspection devices data." (FR Page 75384, [7]). Other language in the preamble addresses the evaluation of corrosion and seam anomalies, but not specifically SSWC as follows: "We have revised the rule to delete the footnote about not using a magnetic flux leakage or ultrasonic internal inspection tool on ERW pipe. We recognize that technology in the internal inspection industry has been changing rapidly. Now, there are readily available tools, for example, ultrasonic (shear wave) and circumferential magnetic flux leakage tools, that can detect longitudinal seam failures.

Therefore, the rule now allows an operator to use integrity assessment methods on ERW pipe and on lapwelded pipe susceptible to longitudinal seam failures that can assess seam integrity and can detect corrosion and deformation anomalies. An operator's integrity management program would also have to address the special risks of these types of pipe." (FR Page 75388). "We expect an operator to consider at least two types of internal inspection tools for the integrity assessment of the line pipe: geometry pigs for detecting changes in circumference and metal loss tools (magnetic flux leakage (MFL) pigs or ultra sonic pigs) for determining wall anomalies, or wall loss due to corrosion. Both high resolution and low resolution tools can be beneficial in integrity assessment. For example—Corrosion/metal loss: With respect to corrosion, high-resolution tools can identify anomalies and, with the use of engineering critical assessments, use a conservative evaluation of the potential for the anomaly to have affected remaining pipe strength (or affected the pressure capacity of the pipeline route). This assessment uses analytical techniques that estimate average depth of metal loss. Based on the evaluation of internal inspection results, a prioritized listing of potential defects is developed to guide the initiation of the field digging, inspection, confirmation and the necessary repair program. Once in the field, additional calculations based on actual profile of metal loss are used to confirm the need and type of appropriate repair." (FR Page 75396). Due to the extensive changes between the previously proposed and the final rules, additional comments related to repair criteria were accepted in the docket until March 31, 2001, Docket number RSPA-99-6355; Amendment 195-70.

In parallel with the integrity management rule, industry was working on a consensus standard for hazardous liquid pipeline integrity management. API RP 1160, Managing System Integrity for Hazardous Liquid Pipelines, First Edition, November 2001 was published subsequent to the 2000 rule. API RP 1160 addresses SSWC as follows; "The following areas should be evaluated, repaired or otherwise mitigated, if necessary, within six months of receipt of the final in-line inspection report. Mitigative actions, if necessary, for these defects can be taken after the defect is evaluated by excavation:

[4] Regulatory requirements in 49 CFR § 195.452 applies only to pipeline routes that "Could Affect" a "High Consequence Area" (HCA) with a plausible spill.

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- Selective seam corrosion of or along detected seam welds."

Following the additional comment period, the integrity management rule was amended and published in Federal Register / Vol. 67, No. 9 / Monday, January 14, 2002 / Rules and Regulations. The preamble of the amendment addresses comments received relative to 195.452(h) and finalizes repair criteria. The preamble states "The 180- day conditions category is consistent with the most recent draft of API–1160, ''Managing System Integrity for Hazardous Liquid Pipelines,'' except for minor differences. We included gouges and grooves greater than 12.5 percent of wall thickness, which are not in the API–1160 draft." (FR Page 1656). "We also clarified an apparent inconsistency in which we listed weld anomalies with predicted metal loss greater than 50 percent of wall thickness and corrosion of or along seam welds as 6-month conditions. We deleted from the list weld anomalies with a predicted metal loss greater than 50% of nominal wall. The rule now lists as 180-day conditions corrosion of and along a longitudinal seam weld, and metal loss greater than 50% that can affect a girth weld." (FR Page 1657). Although PHMSA's intent was to be consistent with API 1160, the language "corrosion of or along a longitudinal seam" remained unclear. In an effort to clarify the rule and provide guidance, PHMSA published a series of FAQs in 2002.

Prior PHMSA IMP FAQ guidance from 2002-2012 (FAQ 7.16) clarified that the rule does not require all corrosion coincident with a longitudinal seam to be mitigated; rather "a pipeline operator must consider the type of corrosion anomaly indicated as well as the age of their pipe and type of seam and be able to demonstrate that detected corrosion does not affect the seam to any greater extent than the pipe body if corrosion near a longitudinal seam is not to be repaired under this criterion." This FAQ aligns with the intent of API 1160 and further demonstrates PHMSAs objective that the rule be consistent with repair guidelines in API 1160 which addresses the specific threat of SSWC.

However, in 2018 PHMSA issued an interpretation, PI-17-0014 (Apr. 26, 2018) which strictly applies the language in 49 C.F.R. § 195.452(h)(4)(iii)(H) regardless of the type of weld or corrosion along the weld. About this time, the original FAQ addressing seam weld corrosion was removed from PHMSA's website. This interpretation would indicate that any corrosion coincident to a longitudinal seam would be a 180-day condition and conflicts with the original rule preambles and FAQ guidance. In an apparent reversal, the California State Fire Marshall granted a waiver of 49 C.F.R. § 195.452(h)(4)(iii)(H) for the use of an alternative assessment method to address corrosion anomalies identified on longitudinal seam welds. Plains West Coast Terminal State Waiver (Aug. 31, 2020). PHMSA concurred with issuance of the waiver (Sep. 4, 2020).

In its final rule "Safety of Gas Transmission Pipelines: Repair Criteria, Integrity Management Improvements, Cathodic Protection, Management of Change, and Other Related Amendments" PHMSA defined new criteria for corrosion of seam welds as "Metal loss preferentially affecting a detected longitudinal seam, if that seam was formed by direct current, low frequency or high frequency electric resistance welding, electric flash welding, or has a longitudinal joint factor less than 1.0". This criteria was applied to immediate repair, two-year, and monitored conditions based on the severity of the corrosion and Class location. Although the final rule is not applicable to hazardous liquid pipelines, it is further validation of the original intent of the integrity management rule and provides further support that DSAW pipe seams are not considered susceptible to SSWC. Incidental corrosion of a DSAW LSW would therefore be evaluated and treated like pipe body corrosion as specified in industry standards.

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Task 2: Analysis and prioritization

The authors reviewed ILI spreadsheet listings, ILI final reports, ILI signal data, and corrosion growth analyses (i.e., ILI run-to-run comparisons) to create a prioritization and assign qualitative scores for joints that contain ILI-reported external metal loss anomalies on or near the LSW. This review was completed in three subtasks: 1) identify target locations to be included in signal review based on spreadsheet information/analyses, 2) perform signal review analyses, and 3) create a prioritization.

Task 2a: Analysis and prioritization; LSW versus pipe body CGR analysis

A statistical analysis was performed for each pipeline route comparing CGRs on pipe joints that had both LSW and pipe body ILI-reported metal loss anomalies. CGRs were established as follows:

- Mean joint CGR: Change in average metal loss depth divided by time between the 2018 and 2021 ILI surveys for a given joint.
    - The calculations were performed separately for the subset of 1) anomalies on or near the LSW and 2) anomalies in the pipe body.
- Max joint CGR: Change in maximum metal loss depth divided by time between the 2018 and 2021 ILI surveys for a given joint.
    - The calculations were performed separately for the subset of 1) anomalies on or near the LSW and 2) anomalies in the pipe body.

The results of this work were used to guide signal review in assessing if there was sufficient evidence to find a difference between the pipe body and LSW CGRs. Anomaly interaction with the LSW was established based on the ILI vendor comments within the spreadsheet listings.[5] The ILI vendor utilized a proximity threshold of 1-inch to establish whether a given metal loss anomaly was 'near' the LSW (i.e., within the HAZ). For example, an anomaly within 1-inch of the LSW (but not crossing the LSW) would be designated as 'near' the LSW. Anomalies crossing the LSW would be designated as 'on' the LSW. The authors spot checked the proximity threshold utilizing ILI-reported anomaly circumferential positioning (considering the reported anomaly widths and boxing location definitions) and confirmed that the ILI vendor comments sufficiently characterized anomaly location with respect to the LSW. This was an important confirmation, as it allowed the authors to sufficiently parse out ILI-reported anomalies on or near the LSW from those in the pipe body.

For each of route, the ILI data was partitioned into two separate files based on the location of the ILI-reported metal loss anomaly (pipe body or LSW). A statistical program was run individually for the pipe body and LSW ILI reported metal loss anomalies. Joints that had both pipe body and LSW ILI-reported metal loss anomalies were used in the statistical comparison of CGRs in each of the three routes.

- Route 1 had 1,449 joints with both pipe body and LSW ILI-reported metal loss anomalies,
- Route 2 had 6,549 joints with both pipe body and LSW ILI-reported metal loss anomalies, and
- Route 3 had 7,460 joints with both pipe body and LSW ILI-reported metal loss anomalies.

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[5] The ILI vendor comments denote whether an anomaly is 'near' or 'on' the LSW. Anomalies without a comment of 'on' or 'near' the LSW are located in the pipe body (away from the LSW).

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For each joint with both pipe body and LSW ILI-reported metal loss, the change over time from the 2018 ILI to the 2021 ILI was computed separately for pipe body and LSW. If the change was negative, the estimate was changed to zero as the pipe cannot heal itself over time. Next the pipe body and LSW growth estimates were compared using hypothesis testing done at the 95% confidence level. This resulted in one of three outcomes: 1) no statistically significant difference for a joint between pipe body and LSW growth; 2) LSW growth was significantly higher than pipe body growth on that joint; 3) Pipe body growth was significantly higher than LSW growth on that joint. The results are summarized below for each route.

The CGRs for pipe body and LSW were compared joint by joint for a statistically significant difference at the 95% confidence level. Most joints showed no significant difference. For those joints with statistically significant differences, it was more common for these to have higher LSW CGRs than pipe body CGRs. For each pipeline route, the mean joint CGR and max joint CGR (defined above) were analyzed separately. These results are summarized in Table 1 (mean CGR) and Table 2 (max CGR). As an example, there are 1,449 joints within Route 1, as detailed above, that contain both pipe body and LSW ILI-reported metal loss anomalies. Of those 1,449 joints, 253 have a statistically significant difference (at the 95% confidence level) between the LSW and pipe body mean CGRs. Of those 253 joints, 216 are instances in which the LSW CGR is significantly higher than the pipe body CGR, and 37 are instances in which the pipe body CGR is significantly higher than the LSW CGR.

Table 1 and Table 2 summarize all joints, from each of the pipeline routes, that had both LSW and pipe body ILI-reported metal loss anomalies. As seen in both tables, there was no significant difference at the 95% confidence level in most of the joints. However, among the joints with significant differences in CGRs (i.e., a joint with significantly higher LSW CGR as compared to pipe body CGR, and vice versa), it was more common for these joints to have higher LSW CGRs.

Table 1. Summary of mean joint CGR counts

SAC Mean CGR Counts				
Route	Number of joints with both pipe body and LSW ILI-reported anomalies	LSW CGR significantly greater than pipe body CGR (counts)	Pipe body CGR significantly greater than LSW CGR (counts)	No significant difference between LSW and pipe body CGRs (counts)
Route 1	1,449	216	37	1,196
Route 2	6,549	1,971	27	4,551
Route 3	7,460	1,890	52	5,518

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Table 2. Summary of max joint CGR counts

SAC Max CGR Counts				
Route	Number of joints with both pipe body and LSW ILI-reported anomalies	LSW CGR significantly greater than pipe body CGR (counts)	Pipe body CGR significantly greater than LSW CGR (counts)	No significant difference between LSW and pipe body CGRs (counts)
Route 1	1,449	199	165	1,085
Route 2	6,549	1,661	268	4,620
Route 3	7,460	1,717	524	5,219

The results of this statistical comparison were used to identify a subset of the joints to be included in signal review analyses and prioritization, as described in Task 2b and Task 2c.

Task 2b: Analysis and prioritization; Signal review prioritization

The authors utilized the ILI-reported information among these locations of interest (i.e., joints that had both LSW and pipe body ILI-reported metal loss anomalies) to identify joints that potentially have characteristics of metal loss anomalies that are preferential to the LSW, as well as to further confirm that the pipeline routes are not susceptible to SSWC (as established in Task 1). The authors created a scoring system and assessed for the following when identifying target locations:

- Corrosion growth rates: SSWC anomalies are expected to have higher CGRs than "general" pipe corrosion anomalies. Therefore, joints in which the LSW CGR is significantly higher than the pipe body CGR (as presented in Task 2a) were more heavily weighted.
- External metal loss anomaly aspect ratios (length divided by width) amongst anomalies reported on or near the LSW: SSWC anomalies are expected to have a relatively higher length to width ratio than non-SSWC anomalies. Therefore, the authors assigned higher qualitative scores for:
  - Joints that contain external metal loss anomalies with relatively higher aspect ratios (the highest aspect ratio value identified was 15.0),
  - Joints that contain one or more external metal loss anomalies with an aspect ratio greater than five (151 total joints), and
  - Joints that contain a relatively higher count of metal loss anomalies that have an aspect ratio greater than five (the most a joint contains is four anomalies).
- External metal loss anomaly depths amongst anomalies reported on or near the LSW: The authors calculated the average and maximum metal loss depths on a per joint basis amongst external metal loss anomalies on or near the LSW. Joints with relatively deeper average and maximum metal loss depths were assigned a higher qualitative score.
- Extent of external metal loss anomalies on or near the LSW: The authors computed the percentage of the joint length that contained external metal loss anomalies on or near the LSW (considering cumulative ILI-reported anomaly lengths divided by the joint length among the unclustered external metal loss anomalies that were commented as on or near the LSW). Joints with a higher percentage were assigned a higher qualitative score.

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Cumulative scores were derived on a per joint basis utilizing the parameters described above. The cumulative scores (and associated relative rankings) were utilized to identify candidate joints to include in the signal review analysis, which is described in Task 2c.

Task 2c: Analysis and prioritization; ILI signal review analysis and final prioritization

The authors utilized the results of the signal review prioritization described in Task 2b to identify joints to be included in the signal review analysis. Axial oriented MFL tools have limited capabilities for detecting and characterizing narrow and axially oriented anomalies (including SSWC anomalies). However, the specific ILI technology utilized in these inspections employed circumferential flux leakage fields. The tool specification document states that the circumferential flux leakage fields, when combined with the axial and radial fields, increase accuracy and provide the ability to identify long, narrow, and axially oriented anomalies.

In total, 456 joints were included in the signal review analysis, prioritizing based on the results from Task 2b. The authors developed an ILI signal analysis qualitative scoring system based on several parameters reviewed during its signal review analyses. The parameters considered in the review included, but were not necessarily limited to, the following:

- Signal amplitude: The authors reviewed the signal amplitude of the metal loss anomaly (or anomalies) to determine if the metal loss anomaly is at, near or away from the LSW. In addition to this, the authors reviewed the signal amplitude for interaction with the LSW, orientation, and classification of the metal loss anomaly.
- Incidence to the LSW: The authors reviewed the targeted and prioritized joints to determine if the external metal loss anomaly (or anomalies) reported as on or near the LSW were coincidental or preferential to the LSW. In order to perform this assessment, the following criteria were evaluated:
    - Whether the deepest portion of the anomaly was present at the LSW or outside of the LSW area,
    - Whether the anomaly crosses/interacts with the LSW or if the anomaly footprint is outside of the LSW area,
    - The axial length of the anomaly at the LSW and the propensity for the anomaly to traverse along the LSW,
    - Evaluation of the linearity of the anomaly at the LSW, and
    - Comparison of signal amplitudes for external metal loss anomalies reported on or near the LSW versus signal amplitudes for external metal loss anomalies reported in the pipe body.
- Volumetric (as is typically associated with metal loss) versus signal spike (as is typically associated with sensor movement, noise or mill-like seam anomalies): The authors reviewed the ILI signals of the metal loss anomaly detected at the LSW to determine if they were more indicative of being a corrosion feature or more consistent with a seam weld signal.
- Proximity to other features that may present increased likelihood/risk (i.e., extrados of bends): The authors reviewed if the metal loss anomaly was more at risk due to the interference of a bend or the presence of any other pipeline feature (i.e., locations in which the MFL ILI tool(s) may have had difficulty accurately characterizing the anomaly).

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- Low level corrosion connecting: The authors reviewed if the low-level metal loss being detected interacted with other metal loss at the LSW.
- Corrosion growth: The authors compared the signal data from the subsequent ILI surveys to establish whether corrosion growth was present. Corrosion growth was determined based on changes in the anomaly footprint (length, width, and shape) and/or signal amplitudes between the subsequent ILI surveys.

The authors observed the following as a result of the signal review analysis:

- Of the 456 joints included in the signal review analysis, no evidence of SSWC characteristics based upon the ILI signal data was observed by the authors. Additionally, no metal loss preferential to the LSW was observed with exception to manufactured anomalies located on a test spool. Rather the metal loss observed was either coincidental to the LSW or likely the result of 1) a helical pattern associated with the tape wrap coating seams, and/or 2) potential tenting of the tape wrap around the DSAW LSW.
- The authors did not observe any evidence of significant corrosion growth based on comparisons to the subsequent ILI signal data.
- As stated above, the authors did not observe characteristics of SSWC, nor evidence of metal loss anomalies that are preferential to the LSW. Additionally, as the authors' signal review analysis progressed through the relatively ranked list of joints (based on the targeting analyses), the authors observed diminishing evidence of metal loss anomalies on or near the LSW (i.e., coincidental to the LSW).
- Based on the results of the Threat Assessment (Task 1), these pipeline routes are not susceptible to SSWC, and this assertion is supported from the ILI signal review analysis. However, the results of the prioritization task can be leveraged to opportunistically identify locations to be included in future field investigations.

An example ILI signal review screenshot comparison is provided in Figure 1. Within this joint, the spreadsheet based LSW CGR was calculated as 27.47 mpy, while the spreadsheet based pipe body CGR was calculated as 0.00 mpy (negative CGRs were adjusted to 0.00 mpy). However, comparisons between the subsequent ILI signal data indicate there is minimal (if any) corrosion growth, and that the evidence of SSWC is not present.

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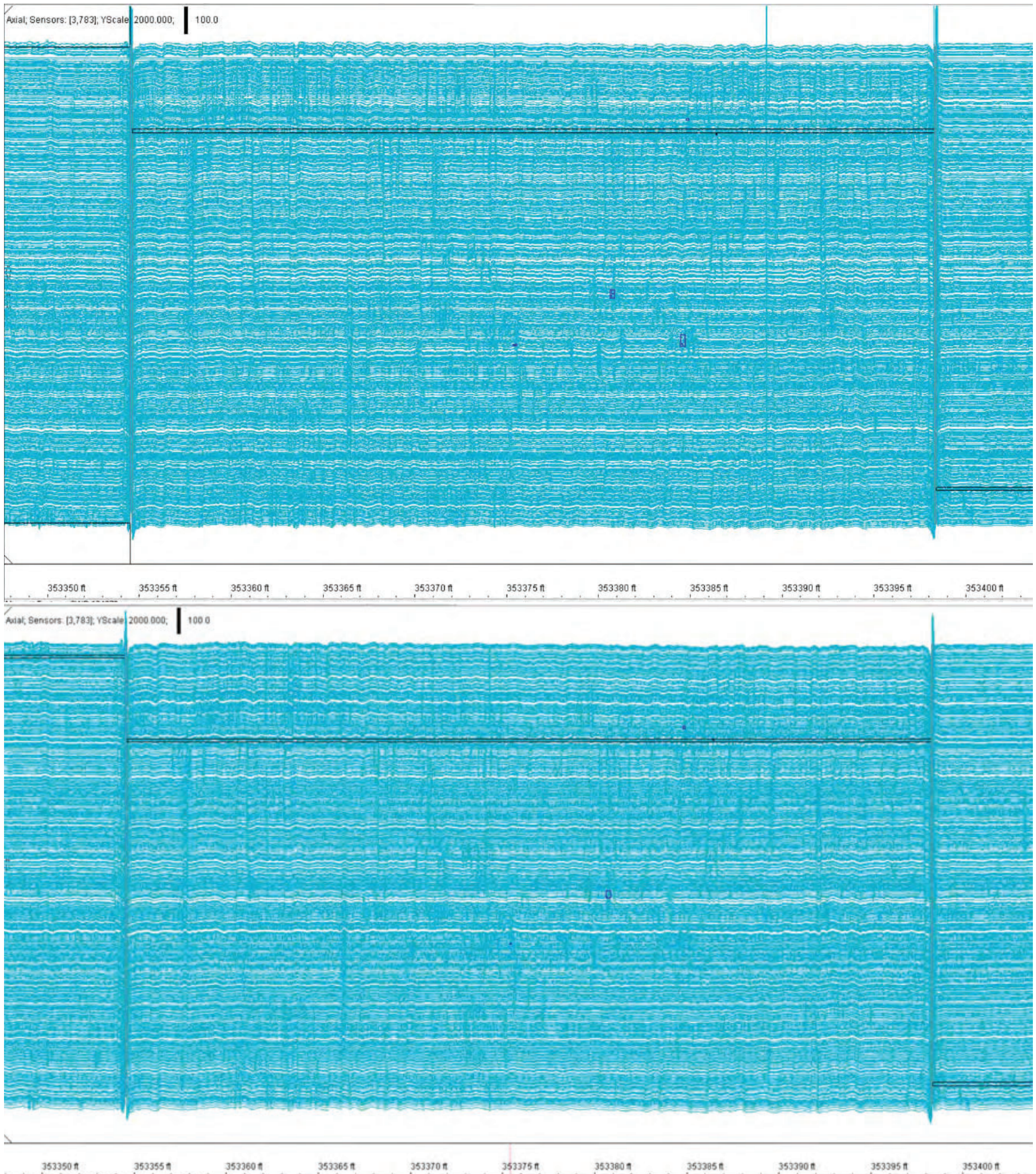

Figure 1. 2018 (top) vs. 2021 (bottom) ILI signal data screenshot comparison

Upon completion of the ILI signal review analysis, the authors established a combined qualitative score considering the sum of the spreadsheet and signal review analyses. These are the 'final' scores, and when sorted, present a prioritization of joints containing metal loss anomalies that may be preferential to the longitudinal seam weld versus those that are coincidental with the seam weld, if the threat were unexpectedly applicable to the DSAW line pipe within the pipeline routes.

Conclusions and Discussion

Based on the threat assessment (Task 1) and analysis and prioritization (Task 2) of ILI-reported metal loss anomalies on or near the LSW, the authors have concluded and/or observed the following:

- Threat Assessment:
  - DSAW LSWs are not considered by the pipeline industry to be susceptible to SSWC.
  - Based on historical field inspection results reviewed by the authors, no evidence of SSWC (i.e., preferential attack) of the DSAW LSWs was observed.
  - The preamble to the integrity management rule [7] indicates the intent and spirit of the original rulemaking was to specifically call out and identify selective corrosion of the LSWs and not coincidental corrosion.
  - Corrosion that is incidental to the LSW should be evaluated and treated similar to pipe body corrosion in accordance with industry recommended practices (e.g., ASME B31G).
- Analysis and Prioritization:
  - As a part of the signal review analyses:
    - The authors did not observe any typical characteristics that are associated with SSWC. The corrosion observed was considered to be coincidental and not preferential to the LSW, and should be evaluated similar to pipe body corrosion as described in the "Threat Assessment" portion of this paper.
    - Significant corrosion growth would be expected in the presence of SSWC. However, the authors did not observe any evidence of significant corrosion growth based on comparisons between the subsequent ILI signal data.
    - The corrosion the authors did observe was either coincidental to the LSW or likely the result of a helical pattern associated with the tape wrap coating seams and/or potential tenting of the tape wrap around the DSAW LSW.
- Based on the results of the Threat Assessment (Task 1), these pipeline routes are not susceptible to SSWC, and this assertion is supported from the ILI signal review analysis (Task 2). However, the results of the prioritization task can be leveraged to opportunistically identify locations to be included in future field investigations.

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