Leveraging Validation Data to Improve ILI Performance for SSWC

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Abstract

Managing the assorted threats associated with pipelines is an evolving process. Selective seam weld corrosion (SSWC), while not a new threat, is now receiving increased scrutiny amid existing and new regulatory requirements.

SSWC tends to have a complex morphology, with a relatively high length-to-width ratio compared to general corrosion and a localized area of maximum depth described as a V-shape. SSWC creates a significant risk for operators because it is more difficult to detect, classify, and size using established in-line inspection (ILI) technology. Furthermore, well-established methods to assess the severity of the corrosion may not be appropriate. Operators often manage the threat through a combination of low specificity ILI assessments and in-ditch validation. However, when many ILI metal loss indications coincident with the longitudinal seam weld are identified, establishing an effective and efficient response can be challenging.

Over the past two years, a significant body of data from ILI, field excavations and metallurgical verification has been captured to evaluate and help improve technologies for detecting and characterizing SSWC. In combination with updated regulatory requirements and inspection specification improvements, this has brought renewed attention to the question of how the threat of SSWC can be managed.

This paper highlights the results of recent pull tests used to help develop an improved performance specification for the circumferential magnetic flux leakage Ultra tool (MFL-C Ultra) currently offered to more effectively manage the threat of SSWC. Examples illustrate how collaborative efforts performed by operators have been used to refine probability of detection (POD) and probability of identification (POI), with a focus on differentiating SSWC from coincident corrosion crossing the long seam.

Leveraging existing guidance regarding the management of the threat of corrosion on the long seam, this paper also presents the results of extensive nondestructive and destructive testing of validated SSWC anomalies. The goal is to share learnings and discuss the considerations for assessing these anomalies in order to identify an appropriate response based on all the information available to the operator.

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What is Selective Seam Weld Corrosion (SSWC)?

Selective Seam Weld Corrosion (SSWC) is an environmentally assisted time dependent threat, described as an axially orientated pattern of linear corrosion that is centered on the longitudinal weld. It has a localized area of maximum depth, which appears in a “V”-Shape (see **Figure 1**). SSWC is most commonly observed in the bond line of autogenously welded pipe, namely electric resistance welded (ERW) or electric flash welded (EFW) pipe. Literature suggests that a number of factors can be responsible for promoting SSWC. Many of the factors are commensurate with ‘vintage’ pipe manufacturing and steels i.e pre 1970, which as a result tend to be more susceptible to SSWC than ‘modern’ pipe.

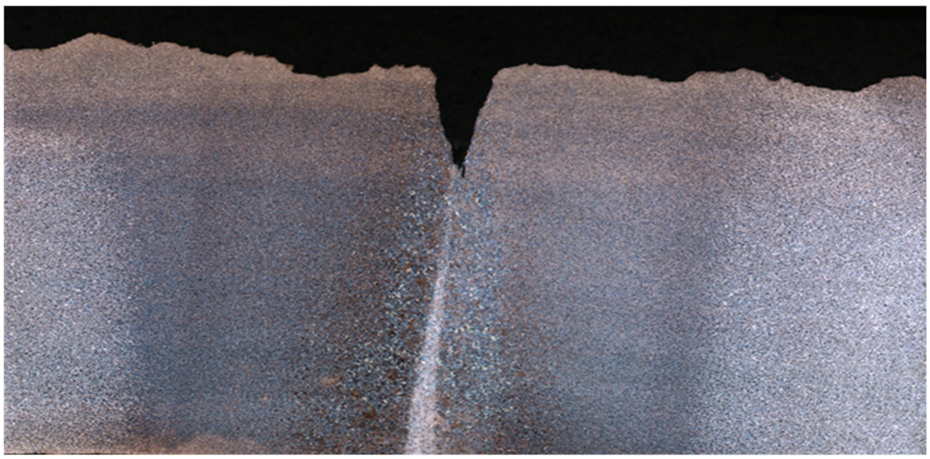

Figure 1: Characteristic “V”-shape of SSWC

Compared to general corrosion, SSWC has a high length / width ratio. Due to this it can be best described as axial slotting or axial grooving according to the POF (Pipeline Operators Forum) anomaly dimension classes for corrosion (see **Figure 2Figure 2**) [1].

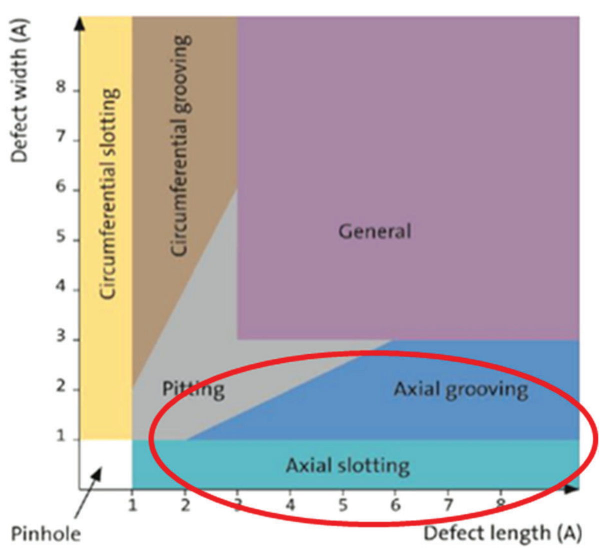

Figure 2: SSWC in POF anomaly dimension classes for corrosion

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Detecting and sizing of SSWC presents significant challenges. Various in-line-inspection (ILI) systems are just now available to detect, identify, and size critical flaws in longitudinal seam welds, including SSWC. As a result, operators are exploring how existing services can help manage the threat associated with SSWC. The ILI service needs to distinguish between SSWC and general corrosion that may occur close to or on the longitudinal weld.

Why did SSWC become such an important topic in the industry in recent years?

Selective seam weld corrosion (SSWC) is not a new threat and has been observed in both liquid and gas pipelines for many years. SSWC poses a significant risk to operators as defining an appropriate integrity assessment and response plan is challenging:

- SSWC is more difficult to detect, classify and size (including in the field).
- Well established methods to assess the severity of features may not be appropriate.
- SSWC growth rates are less well defined than general corrosion.

Until the recent changes were implemented, SSWC was not named as a specific threat in the gas regulations, 49 CFR Part 192 [2]. However, updates to 49 CFR Part 192 now indentify SSWC as a specifc integrity threat that must be managed and explicitly discounted (confirmed as not present) or assessed (defects identified, mitigated and managed safely) on a pipe segment.

The gas regulations acknowledge that longitudinal seams formed by DC, LF-ERW, HF-ERW, and EFW, or that have a longitudinal joint factor of less than 1.0, are more prone to failure. As such, more stringent repair criteria is necessary for SSWC that affects these longitudinal seams. The response criteria is defined based on predicted failure pressures (PFP) and failure pressure ratios (FPR) determined in accordance with §192.712.

For the purposes of assessment the gas regulations considers SSWC as a crack-like defect. A crack-like defect could adversely affect the integrity of the pipeline and therefore the inference is that SSWC must be evaluated using fracture mechanics modeling. Failure pressures of cracks and crack-like defects must be determined using a technically proven fracture mechanics model appropriate to the failure mode i.e. ductile, brittle or both. Understanding the material properties of your asset becomes that much more important in determining regulatory compliance as it affects the applicable feature assessment model and ultimately the response condition.

In accordance with §192.712, if seam weld toughness values are unknown for your pipe population i.e. wall thickness, grade, manufacturer and vintage, lower bound toughness values are to be assumed. Where SSWC is found to exist in association with poor or unknown material properties (namely toughness and tensile properties in the weld zone), it will be very difficult to develop a response other than remediation. If SSWC is identified and affecting a detected longitudinal seam, that was formed by DC, LF-ERW, HF-ERW, EFW, or a weld that has a longitudinal joint factor less than 1.0, it is considered an immediate condition if the predicted failure pressure is less than 1.25 times the MAOP, triggering a five (5) day repair condition. This is applicable for both HCA (high-consequence area) and Non-HCA. 1 year and 2 year conditions are also set based on the estimated FPRs of set class locations. **Figure 3**Figure 3 presents an overview of the applicable repair conditions.

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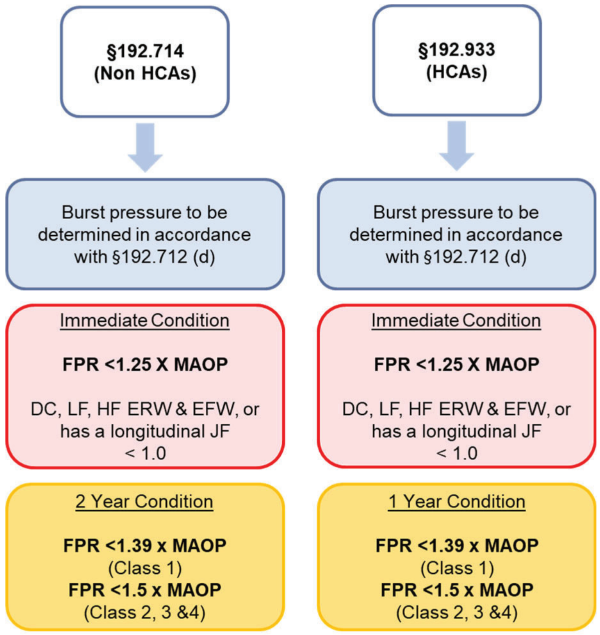

Figure 3: Repair condition of SSWC in gas regulation (49 CFR Part 192)

Understanding the susceptibility to SSWC and the material properties of your asset becomes that much more important in determining regulatory compliance as it affects the applicable feature assessment model and ultimately the response condition for both oil and gas pipelines.

Conversely, SSWC is not named as a specific threat in the liquid regulations, 49 CFR part 195 [3]. It is inferred in §195.452 (h) (4) (iii) (H), as "corrosion of or along a longitudinal seam weld" and is identified as a 180 day condition in High Consequence Areas (HCA). The language does not acknowledge that the threat of SSWC is different from that of general corrosion commensurate with the longitudinal seam location. This is a critical distinction, as SSWC compared to 'general' corrosion that is in close proximity or crossing the longitudinal seam requires a very different approach from an integrity management perspective.

Outside of the formal regulations it is recognized that the response to SSWC must be different from the response to 'general' corrosion. Classification is therefore critical as it pertains to integrity management and defining appropriate response criteria.

How can SSWC be managed?

Gas and liquid regulations both recognize the use of in-line inspection (ILI) tools or tool combinations as an acceptable and effective method for assessing the integrity of longitudinal seam welds [2,3].

Understanding the morphology of threats like SSWC is critical for selecting the appropriate ILI configuration. SSWC typically appears as narrow, 'V'-shaped slots along the weld bond line, which may be short with minimal metal loss. Even when longer, the volume change is often small. Properly understanding SSWC's morphology is essential for optimizing the ILI system to ensure high probability of detection (POD), probability of identification (POI), and accurate sizing of anomalies.

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The discovery of an anomaly is when an operator has gathered sufficient data about a defect, anomaly, or other pipeline feature, allowing operators to assess its potential threat to pipeline integrity. In cases where ILI detects metal loss in the longitudinal seam weld, determining the correct response can be challenging. In pipelines experiencing active external corrosion, where SSWC is a credible threat, both SSWC and general corrosion near or on the longitudinal seam may occur. Differentiating between these scenarios is crucial for selecting the appropriate response. If a clear distinction between SSWC and general corrosion cannot be made, operators may need to conservatively treat all detected corrosion anomalies associated with the longitudinal seam weld as potential SSWC.

To extract greater value from the available ILI and material properties data, one approach is to classify SSWC as “Likely,” “Possible,” or “Unlikely.” This aligns with the guidance in API RP 1176, "Assessment and Management of Cracking in Pipelines" [4], for defining appropriate responses to ILI findings. The aim is to establish a process-driven distinction between SSWC and general corrosion in the seam weld area. This is hihglighted belwo in **Figure 4**.

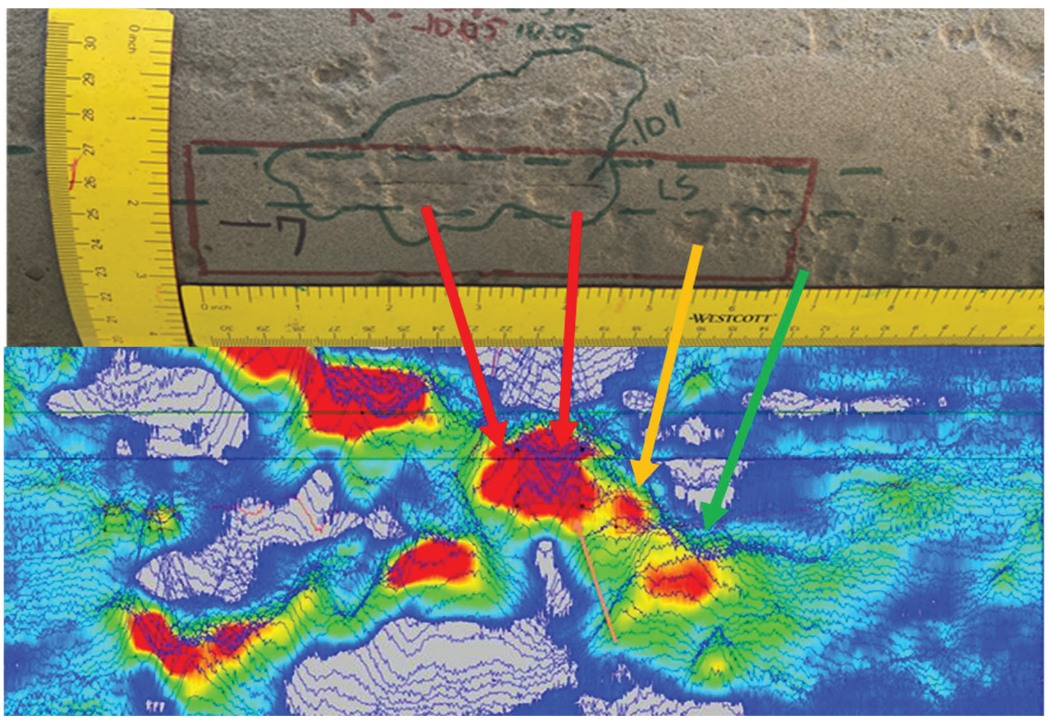

Figure 4: Differentiation of SSWC and general crossing close to /crossing the long seam

This approach relies on an advanced evaluation of the ILI signal data to gain a comprehensive understanding of the different signal characteristics and feature classifications reported by the MFL-C Ultra ILI system.

Approaching the management of SSWC in this way allows operators to define a structured response for excavation activities to verify the process and remediate features as required. By using likelihood classification the risk to pipeline integrity can be reduced by acting on the most likely SSWC features as a priority, whilst collecting the data needed to make informed decisions on where to focus

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resources and efforts on what is a very complicated and difficult to manage threat. This classification is crucial to:

- Define an appropriate and prioritized response based on the threat.
- Ensure regulatory requirements can be addressed relating to the specifically named threat of SSWC.
- Ensure the correct models are used in anomaly assessments.

Development of a SSWC Performance Specification

The above described approach to manage SSWC was successfully implemented in many projects in the past 3-4 years. However, a final important piece was missing: a performance specification. In order to judge a service on its quality and success, a sound foundation of data is required that can be utilized to derive the performance of the service. When it comes to SSWC the focus was on the identification of SSWC and discriminating it from corrosion near the long seam, corrosion touching the long seam and corrosion crossing the long seam.

The SSWC performance specification was derived out of field verifications from 13 ultra-high resolution MFL-C inline inspections for different pipeline operators in varying wall thicknesses, media, and diameters from 8" to 36". A data set of 816 verified anomalies associated with the long seam was gathered with a depth range between 4% and 73% wall loss.

Following the SSWC process during data analysis, all 816 anomalies have been classified as either 'Likely' SSWC, 'Possible' SSWC or 'Unlikely' SSWC prior to the field verifications. According to the existing performance specification for the MFL-C service using ultra-high resolution sensors, the POD, POI and POS for axial slotting anomalies on the long seam is:

Table 1: Excerpt of RoCorr MFL-C Performance Specifications

	Axial Slotting on Long Seam
Depth at POD = 90%	0.25t
Depth sizing accuracy at 80% certainty	±0.25t
Width sizing accuracy at 80% certainty	±0.79" (20mm)
Length sizing accuracy at 80% certainty	±0.98" (25mm)

with *t* = wall thickness or 5mm, whichever is greater

Applying the limits of **Table 1**to the data set, a total of 93 applicable verified anomalies remain with a depth of ≥ 25%. The results of the comparison between the reported SSWC classification and the verified identification can be found in Table 2 below.

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Table 2: Comparison of ILI Results to Field Results

		ILI reported classification			Grand Total
		Likely	Unlikely	Possible	
Verified as SSWC	Yes	**36**	3	7	46
	No	8	**29**	10	47
	Grand Total	**44**	**32**	17	93

This means that 44 anomalies with a depth ≥25% wall loss were classified as 'Likely' SSWC by the ILI data analysis team. Out of these 44 anomalies, 36 have been confirmed in the field to be SSWC, 8 anomalies were found as not being SSWC. The same logic applies for the 'Unlikely' and 'Possible' calls.

The results shown in **Table 3** lead to a POI of:

Table 3: POI for SSWC for Anomalies with a Depth ≥25%

Identification Class for Axial Slotting (SSWC)	POI @ Anomaly Depth of ≥25%
Likely SSWC	82%
Unlikely SSWC	91%

A review of the entire data base including all anomalies down to a depth of 4% completes the picture for the POI of SSWC when using the ultra-high resolution MFL-C ILI tool with the SSWC evaluation approach. It can be seen that with increasing depth the POI for 'Likely' increases as well (**Figure 5**).

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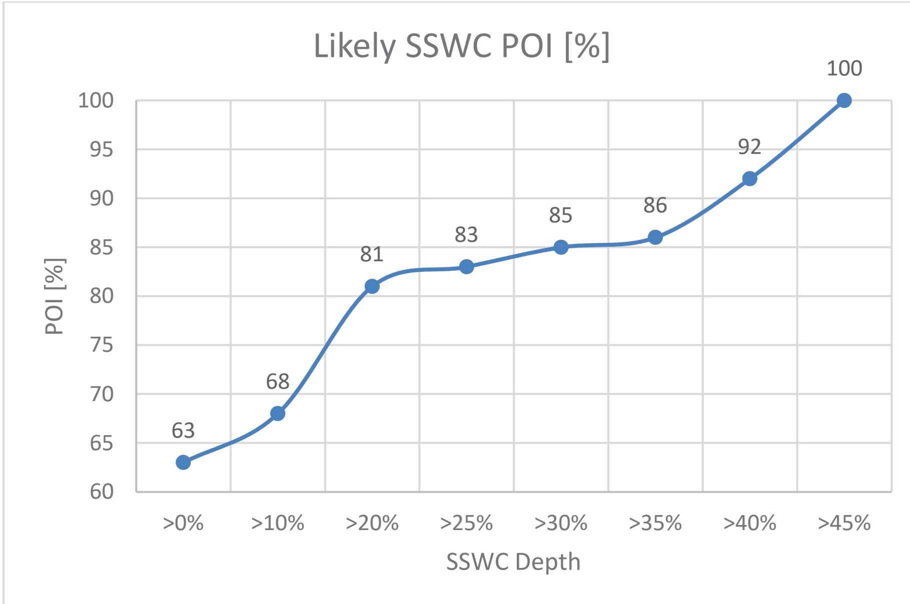

Figure 5: Dependency between anomaly depth and POI for "likely" SSWC

With this information and data in hand after years of gaining experience, a performance specification for SSWC could consequently be stated **(Table 4)**.

Table 4: Performance Specification for SSWC

Identification Class for Axial Slotting (SSWC)	**POI @ Anomaly Depth of >25%**	**POI @ Anomaly Depth of >40%**	**POS**
Likely SSWC	> 80%	> 90%	For sizing of SSWC, **Table 1** applies.
Unlikely SSWC	> 90%	> 90%	

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Conclusion

SSWC is not a new threat in pipelines, but it gained much attention in recent years due to changes in regulations. The continuous developments of ILI technologies makes it possible today to identify SSWC despite its complex morphology with a high-degree of certainty. However, it can still be seen that a classification of long seam anomalies into 'Likely'', 'Possible' and 'Unlikely' SSWC presents benefits in managing the SSWC threat as the ILI signals cannot always be unambiguously interpreted. Of great importance is the POI for SSWC as it will determine how many "unnecessary" digs a pipeline operator most likely has to perform when trying to verify anomalies that are classified as SSWC. These are digs that cannot confirm the presence of SSWC and could have been avoided by a more accurate assessment.

It is still required to constantly verify ILI calls in the field, especially those that are classified as 'Possible'. By steadily reviewing and comparing field verifications to ILI data, the confidence in interpreting SSWC calls will further increase and subsequently lead to a more precise sizing.

The experience gathered in the past 3-4 years in collaborating with pipeline operators across the country on identifying SSWC led inevitably to the development of a performance specification for the assessment of SSWC when using ultra-high resolution MFL-C ILI data. This will help operators to gain confidence in SSWC services and to manage the threat of SSWC going forward.

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References

[1] Specifications and requirements for in-line inspection of pipelines, Pipeline Operators Forum, version 2016.

[2] CFR 49 Part 192 Transportation of Natural and Other Gas by Pipeline: Minimum Federal Safety Standards.

[3] CFR 49 Part 195 Transportation of Hazardous Liquids by Pipeline.

[4 API Recommended Practice 1176, 'Recommended Practice for Assessment and Management of Cracking in Pipelines', First Edition, July 2016.

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