Improving POI of Crack Detection ILI Calls - an Operator Case Study Using a Predictive Data Driven Process

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Abstract

The main goal of any pipeline operator managing an active cracking threat is to find the real cracks and minimize costly verifications of false positives. Crack detection In-Line Inspection (ILI) is commonly deployed by operators as the primary integrity assessment technique to manage axial Stress Corrosion Cracking (SCC) due to its coverage and relative convenience. Whilst these tools can be excellent at detecting planar crack-like reflectors, the performance specification typically states that there is no guarantee that a reported crack-like reflector will be an actual crack with time-
dependency, which could pose a threat to a pipeline's integrity.

This paper presents how a natural gas transmission operator in Argentina has leveraged their extensive ILI and field database to benchmark a predictive, data driven process to support the management of stress corrosion cracking in-line with API 1176 along their network and minimize the number of future verifications of false positives, allowing focus on real integrity threats.

Introduction

Transportadora Gas del Norte S.A. (TGN) operate and maintain the largest gas pipeline network in Argentina with over 40% of the country's gas being transported through their 11,000 km multi diameter network (see Figure 1). Axial Stress Corrosion Cracking (SCC) is a confirmed integrity threat which is primarily managed by a combination of in-line inspection (ILI) and direct assessment.

Figure 1: Schematic of TGN Pipeline Network

To date, TGN have performed 32 axial crack detection inspections using Electro Magnetic Acoustic Transducer (EMAT) technology. For the purpose of this study a sample of 17 of these EMAT inspections were analysed. These 17 inspections were carried out across 15 individual pipe sections

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to detect and size axial SCC. In total, 859 crack-like anomalies have been reported across the 17 inspections and at the time of writing this paper, 426 have been verified. These sites were selected for verification based failure pressure calculations using the EMAT report dimensions as well as operating parameters and pipe material properties. Of the 426 calls verified, 100 were confirmed to be the target threat of SCC (an SCC hit rate of 23%).

Considering the severity of the SCC threat and relatively low SCC hit rate, TGN initiated a project to try and utilise their extensive field database to develop a data driven process to minimize the number of future false positives.

The results are presented in this paper.

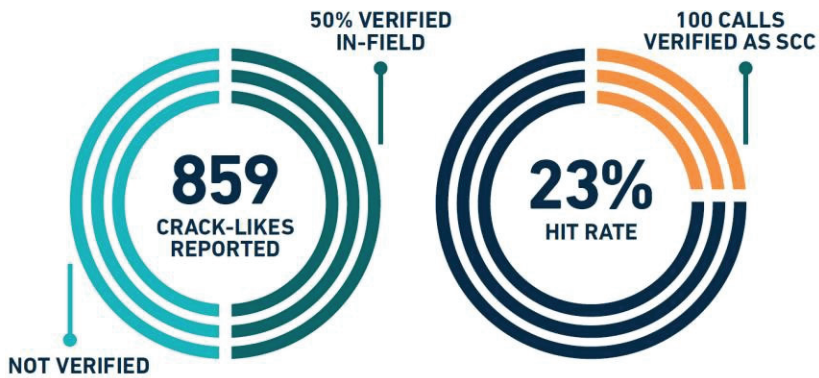

Figure 2: EMAT ILI Anomalies and Field Verification Overview across TGN Network

Crack Detection ILI

Crack detection in-line inspection (ILI) technologies are a key component in the integrity management response to a cracking theat. However, it must be understood that the current generation of market leading ILI technologies (as with almost all forms of NDT crack inspection) have a primary challenge associated with discrimination between feature types. That is, the technologies detect 2D planar 'reflectors' that may or may not represent a time-dependent cracking integrity threat. As recommended by API RP 1176, the current industry standard crack-management best practice, overlaying additional threat information is critical to form a balanced integrity management response on the anomalies that action require attention.

This project focused on the development of a database which combined ILI signal characteristics and confirmed SCC threat drivers. The SCC hit rate was then extracted for each combination or 'bucket'.

A simplistic example of this is shown below in Figure 3.

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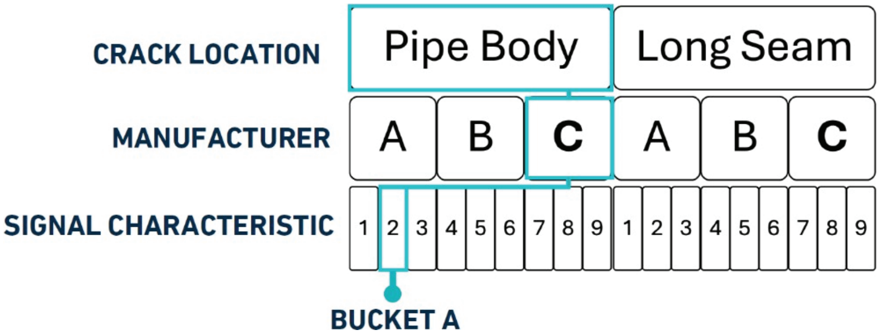

Characteristic	No. Reported	No. Verified	No. SCC Found	% SCC Hit Rate
Pipe Body	134	70	32	46%
Pipe Body + Manufacturer C	107	62	30	48%
Pipe Body + Manufacturer C + Signal Char 2	6	6	2	33%

Figure 3: Example of generating 'Buckets' based on Common Anomaly Signal Characteristics and Threat Parameters

For operators, the cost of repeat verifications of 'False Positive' calls can be expensive and frustrating especially when there is a known validated cracking threat on their pipelines. Through the use of guidance within API 1176 (API, July 2016), operators can begin to generate a robust understanding of which signals are a 'likely' and 'unlikely' time dependent cracks from historical field verification information and therefore apply this knowledge to future ILIs to generate 'intelligent' knowledge led targeted verification campaigns which focus on the real cracking threat.

API 1163 (API, September 2021) is typically used within the industry to assess the performance of a single ILI run, considering probability of detection (POD), probability of identification (POI) probability of Miss-identification (POMI) and probability of sizing (POS).

For operators running crack detection ILI for the first time POI is generally expected to be low given the limited knowledge of the cracking threat and signal characteristics from the ILI. Although this is not always a bad situation as it allows operators to verify and understand multiple variations of crack-like signals and begin to develop their knowledge database and overtime gradually improve POI for further crack detection ILIs across their entire network of pipelines

Operator Challenge

After performing multiple crack detection ILI's and performing extensive field verifications, the operator found that the SCC hit rate overtime did not appear to be significantly improving over time, see Figure 4.

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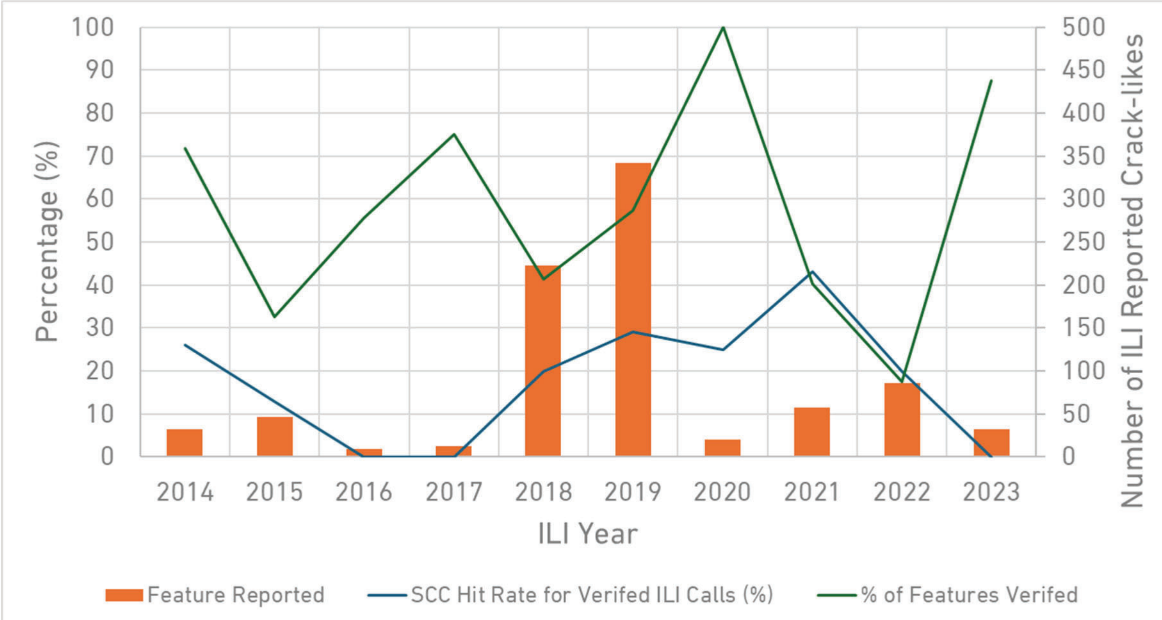

Figure 4: SCC Hit Rate Trend per Year

There are 433 of the reported 859 ILI calls that remain unverified and considering the fairly low average hit rate for SCC (18%) and the vast resources that would be required to excavate all ILI calls, TGN decided to review their extensive database of cracking knowledge for their network and develop an analytically led process supported by API 1176 (API, July 2016) to enhance their future field verification and crack management plan.

API 1176 Analytically Led Solution

To support the project, the operator utilised a cloud-based digital solution to perform the following tasks:

- Identify, trend and analyse key location specific material, construction and ILI anomaly parameters associated with historically verified sites.
- Extract SCC hit rates for all 'buckets' considering the above.
- Apply these trends to newly reported (unverified) ILI calls to predict whether these are 'likely', 'possible' or 'unlikely' to be SCC in line with API 1176 (API, July 2016).
- Calibration of the predictions.
- Development of an optimised remediation plan.

The developed process contained the following steps (Figure 5) with details of each step provided in Table 1

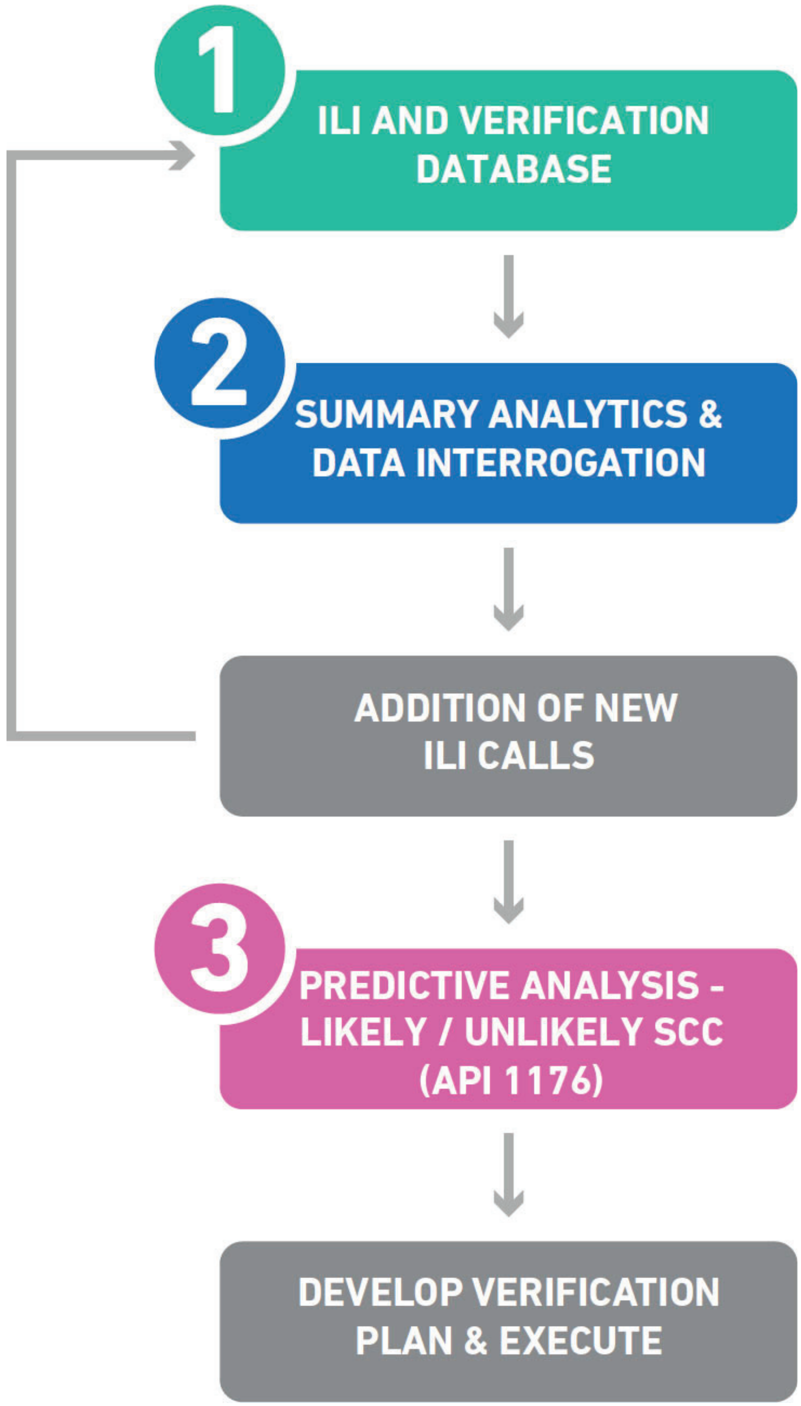

Figure 5: Process developed to support management of SCC following repat EMAT ILI Campaigns

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Table 1: Description of key components of each stage of developed process

Stage	Description
1	Ability to integrate the following information: • Historic crack detection ILI calls, per pipeline • Verification findings to date (at reported crack detection ILI calls and cracks not reported by ILI), per pipeline, per campaign • Crack detection data quality information, per joint, per pipeline (velocity) • SCC susceptibility ranking, per joint, per pipeline • SCC risk assessment ranking, per joint, per pipeline • Joint-wise Material information (dia., WT, grade, pipe type, manufacturer, bend) • Any new crack detection ILI calls, per pipeline
2	Ability to analyse the following: • Number and type of ILI call reported, per pipeline or per system • Number and type of ILI calls verified, per pipeline or per system • Field findings per ILI call and joint characteristics • Ability to filter and interrogate the date on a system wide basis or a combination of defined filters e.g. o Filter on System A (Pipelines 1-5) o Filter crack call type: Pipe body crack 'with metal loss' o Filter for manufacturer A o View dig findings e.g. 8 digs, 0 SCC, 8 Corrosion
3	Ability to analyse the following: • Add new crack detection ILI calls • Overlay complimentary datasets such as SCC susceptibility ranking, per feature • Review the number of 'similar' calls across the system and any verifications • Per crack call, perform statistical analysis to determine is a call likely or unlikely to be a crack as per API 1176 • Support verification prioritisation planning

Calibration Phase

In order to validate the API 1176 predictions generated by the cloud-based platform the following 4 phases were adopted:

1. Phase 1 – Data upload (five EMAT ILI data, four corresponding field verification data sets)
2. Phase 2 - Data Analysis identifying common feature characteristics and SCC hit rates
3. Phase 3 – Review of prediction for fifth EMAT data sets and comparison to field results
4. Phase 4 – Repeat of Phases 1 to 3 with upload of 11 further EMAT data sets and 10 field verification data sets followed by prediction for the 11th EMAT data set

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Phase 1

TGN initially uploaded five EMAT data sets along with corresponding field verification information associated with four of these EMAT inspections. This is Stage 1 of the developed cloud-based process

Phase 2

During Stage 2, TGN used the cloud-based platform to review common characteristics and the threat drivers for historical EMAT reported anomalies which were verified to be SCC and verified to not be SCC. This resulted in a number of 'buckets' of features to be generated as shown below:

Table 2: Feature Grouping

Variable	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8
'Possible Manufacturing'	Yes	Yes	Yes	Yes	No	No	No	No
Coating Type	Asphalt	Asphalt	Liquid Epoxy	Liquid Epoxy	Asphalt	Asphalt	Liquid Epoxy	Liquid Epoxy
Dis. to U/S Compressor (KM)	0-30	50-300	0-30	50-300	0-30	50-300	0-30	50-300
Report ILI calls	3	4	5	3	2	11	9	20
Reported Field Inspection Calls	4	15	4	17	6	72	41	88

Phase 3

Taking the learnings from Stage 2, these were overlayed in Stage 3 to predict which EMAT crack-like anomalies in the fifth EMAT inspection for which field verification findings had not been uploaded. Were 'likely', 'possible' and 'unlikely' to be SCC. The cloud based platform predicted the following based on historical hit rates for each 'bucket' alongside using joint-wise susceptibility information.

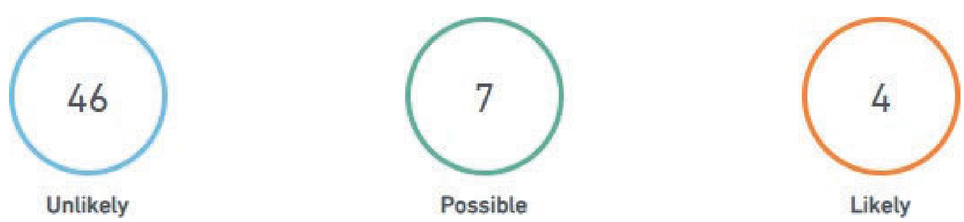

Figure 6: Cloud Based Platform API 1176 Predictions

Once the cloud-based platform had made the predictions these were compared to the actual field findings for 23 of the EMAT crack-like anomalies, the results are shown below:

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Table 3: Cloud Based Platform API 1176 Predictions Vs. Verification Findings – Test 1

		Cloud Based Platform API 1176 Prediction		
		Likely	Possible	Unlikely
Verified Feature Type	SCC	4	6	0
	Non-Scc Planar Defect	0	0	2
	Metal Loss	0	0	6
	Nothing Found	0	0	5

As shown above of the 11 EMAT crack-like anomalies which were predicted to be 'Likely' or 'possible' SCC, 10 have been verified infield and all found to be SCC. In addition to this, 13 EMAT crack-like anomalies which were predicted 'unlikely' to be SCC were all verified not to be SCC. This showed excellent accuracy of the cloud-based platform predictions.

<u>Phase 4</u>

To extend the validation TGN took the decision to perform a larger scale test whereby all 859 EMAT crack-like anomalies were uploaded to the cloud-based platform and field verification findings for 16 of the 17 EMAT inspections (in total 50% of the total reported EMAT calls have corresponding field data uploaded to the platform). The same process as detailed above was then performed.

The field inspection results related to the 17th EMAT inspection were used as a 'blind test' where the actual field findings were compared to the cloud-based platform API 1176 predictions. The results for the sites where SCC was confirmed in field showed a strong correlation, see Figure 7. The full results are shown Table 4. It should be noted that 'nothing found' is attributed to ILI error.

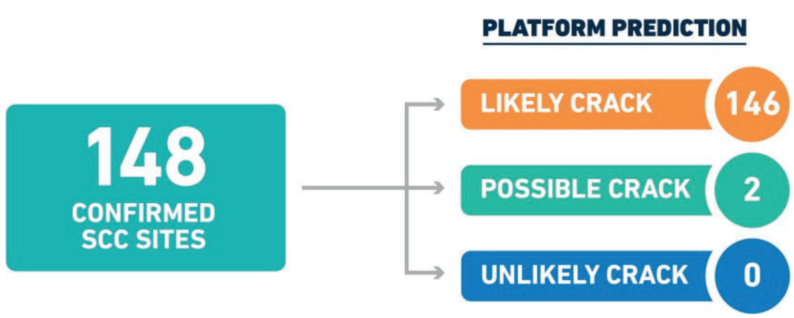

Figure 7: Platform predictions at SCC Confirmed Sites

Table 4: Cloud Based Platform API 1176 Predictions Vs. Verification Findings – Test2

		Cloud Based Platform API 1176 Prediction			Comment
		Likely	Possible	Unlikely	
Verified Feature Type	SCC	148	2	0	-
	Non-Scc Planar Defect	0	0	3	-
	Metal Loss	9	2	94	All likely located in same joint as where SCC was verified.
	Nothing Found	125	2	161	

Although a significant number of EMAT anomalies which were predicted to be 'likely' SCC by the cloud-based platform was found to be 'nothing' infield, upon further review all of these anomalies were located in the same pipe joints to where SCC was verified. This has led TGN to understand that further understanding around signal characteristics should be investigated for future predictions as location specific threat drivers do not allow differentiation for these features.

Had the platform been available prior to excavating the reported anomalies along this pipe section (blind test), it is likely that over 30 digs would have been saved when considering the model prediction alongside feature severity.

Conclusions

Operators managing a confirmed time-dependent integrity threat will inevitably collate a vast amount of data overtime from field investigations as well as from in-line inspections. It can be highly beneficial both from a financial and also safety perspective to spend the time now to collate and understand this data for the long-term management of the cracking threat.

The process outlined in this paper shows how TGN have adopted a cloud-based solution and integrated it into their crack management strategy to not only further develop their knowledge of their cracking threat but also to assist in the targeted management of EMAT ILI calls. This process aims to prioritise the real cracking integrity threats to TGNs assists and help focus valuable resource where it really matters.

Whilst the cloud-based platform is not designed to give a black or white answer on which sites to excavate. It has been developed to support operators to concisely analyse the data and arms them with key information to use alongside other data to make integrity related decisions, which should reduce unnecessary costly verifications which focus efforts on the primary integrity theat.

References

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