Subject Matter Study Report

**Inaccuracy of Metal Loss In-Line Inspections in**

**Older Pipelines**

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By

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**Executive Summary**

Some in-line inspection companies determine their stated accuracy specifications by performing pull tests in new, uncorroded pipe with individually machined, metal loss areas that are isolated. In pipelines, real corrosion does not have the shape and isolation of artificial metal loss areas. The in-line inspection signals generated by real corrosion is different than machined artificial metal loss areas and have a significant effect on the accuracy of in-line inspections.

Areas of pipeline corrosion also generate “noise” that interferes with and makes interpretation of in-line inspection signals difficult. Each pipeline is different and inspection performance must be determined individually for each pipeline with comprehensive dig sites, metal inspections, and proper statistical analysis. Each pattern of corrosion should be identified and an adequate number of inspection digs need to be performed for each pattern of corrosion in each pipeline. Some of the individual corrosion patterns that should be investigated include:

1. Location of corrosion:
   1. In pipe seams,
   2. In girth weld areas,
   3. In pipe body, and
   4. Combinations of locations.
2. Corrosion patterns:
   1. Isolated,
   2. General pitting, and
   3. General corrosion.

Uncertainties should be determined in the width, length, and depth at each dig site. These uncertainties should be added to each metal loss area detected by in-line inspection before the integrity of each metal loss area is evaluated.

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**Background**

In 2010, a natural gas pipeline operator conducted an in-line metal loss survey of their Dumas and Amarillo Stations. Previous in-line inspection (ILI) surveys had indicated this pipeline had thousands of metal loss areas and mechanical damage areas. After the survey of about 47 miles of 24-inch pipeline, the pipeline operator decided to excavate and inspect 18 sites identified with metal loss and other anomalies by the in-line inspection survey crew.

**Vendor Accuracy Specifications**

The vendor’s specification claims for detection, sizing, and location accuracy of this high resolution in-line survey for metal loss (corrosion and gouges) were:

1. Corrosion pitting (less than 3*t* x 3*t*)\*
   1. If surface dimension is greater than 0.275 inch x 0.275 inch or 4*t* x 4*t*, whichever is greater, minimum detectable depth for sizing = 0.2*t*.
   2. If surface dimension is equal to or less than 0.275 inch x 0.275 inch or 4*t* x 4*t*, whichever is greater, the minimum detectable depth for sizing is unknown.
   3. Depth accuracy = + 0.1*t*.
   4. Length accuracy = + 0.4 inches.
   5. Width accuracy = + 0.8 inches.

\* *t* = pipe thickness

1. General corrosion (larger than 3*t* x 3*t*)
   1. Minimum detectable surface depth = 0.1*t.*
   2. Depth accuracy = + 0.1*t*.
   3. Length accuracy = + 0.8 inches.
   4. Width accuracy = + 0.8 inches
2. Gouges
   1. If gouge width greater than 0.5*t* or 0.275 inches, whichever is greater, minimum detectable surface depth = 0.2*t.*
   2. If gouge width greater than 3*t*, minimum detectable surface depth = 0.1*t*.
   3. Depth accuracy = + 0.1*t*.
   4. Length accuracy = + 0.8 inches.
   5. Width accuracy = + 0.8 inches.

The methods to develop the above inspection specification and statistical confidence levels for the accuracy statements were not stated in the specification.

**Comparisons of Metal Loss Areas**

The pipe dig inspection reports only reported the depth of anomalies. Metal loss width and length should have also been reported, but were not. Areas of isolated pitting found and reported at excavation and inspection sites are summarized below.

Metal Loss Depth, %*t*

|  |  |  |  |
| --- | --- | --- | --- |
| Number | Predicted | Found | Difference |
| 1 | 56 | 36.84 | +19.16 |
| 2 | 16 | 13.16 | +2.84 |
| 3 | 48 | 40.17 | +7.29 |
| 4 | 6 | 8.78 | -2.78 |
| 5 | 44 | 29.01 | +14.99 |
| 6 | 65 | 64.75 | +0.25 |
| 7 | 62 | 58.61 | +3.39 |
| 8 | 54 | 44.80 | +9.20 |
| 9 | 50 | 35.02 | +14.98 |
| 10 | 73 | 88.17 | -15.17 |
| 11 | 66 | 91.46 | -25.46 |
| 12 | 67 | 35.48 | +31.52 |
| 13 | 12 | 23.21 | -11.21 |
| 14 | 58 | 58.96 | -0.96 |
| 15 | 57 | 53.31 | +3.69 |
| 16 | 57 | 43.78 | +13.22 |
| 17 | 35 | 44.18 | -9.18 |
| 18 | 63 | 48.99 | +14.01 |
| Average |  |  | +3.9 |

The range of the above differences is 0.507*t* and the estimated standard deviation for 18 measurements is 0.14*t*. The uncertainties at several confidence levels of individual isolated corrosion depth predictions were:

1. At 95% confidence level = + 0.294*t*.
2. At 90% confidence level = + 0.242 *t.*
3. At 80% confidence level = + 0.186*t*.

For isolated corrosion pitting, the uncertainty in measurement of the depth of isolated metal loss areas was a bias or systematic error of +0.039*t* and a random uncertainty of + 0.294*t* at the 95% confidence level. The range of uncertainty in predicted metal depth at the 95% confidence level was -0.255*t* to +0.333*t*. The depth of isolated corrosion pitting at locations not excavated and inspected should have been increased by at least 0.255*t* for integrity analysis.

The only way to approach the accuracy specified by the vendor is to determine the uncertainty of the average depth by dividing the above uncertainty values by the square root of 18 isolated corrosion pits. At a 95% confidence level, the uncertainty of the average isolate corrosion pit depth becomes + 0.07*t*. However, anomalies found during in-line surveys are evaluated individually, not as averages, and an uncertainty based on the average pit depth is totally inappropriate.

Areas of interconnected pitting are summarized below.

Metal Loss Depth, %*t*

|  |  |  |  |
| --- | --- | --- | --- |
| Number | Predicted | Found | Difference |
| 1 | 45 | 32.1 | +12.90 |
| 2 | 51 | 51.35 | -0.35 |
| 3 | 29 | 41.47 | -12.57 |
| 4 | 26 | 36.08 | -10.08 |
| 5 | 29 | 48.63 | -19.63 |
| 6 | 63 | 58.04 | +4.96 |
| 7 | 59 | 51.63 | -0.63 |
| 8 | 55 | 40.87 | +14.13 |
| 9 | 8 | 21.91 | -13.91 |
| 10 | 38 | 35.22 | +2.78 |
| 11 | 73 | 69.17 | +3.83 |
| 12 | 54 | 52.38 | +1.62 |
| Average |  |  | -1.4 |

The range of the above differences is 0.338*t* and the estimated standard deviation for 12 measurements is 0.104*t*. The average systematic error was -0.014*t*. At a 95% confidence level, the estimated uncertainty in individual depth predictions is + 0.23*t*. The depth of interconnected pitting at locations not excavated and inspected should have been increased by 0.244*t* for integrity analysis.

For areas of interconnected pitting, the uncertainty in the depth of measurements was a bias or systematic error of 0.014*t* and a random uncertainty of + 0.23*t* at the 95% confidence level.

Areas of pitting with general attack are summarized below.

Metal Loss Depth, %*t*

|  |  |  |  |
| --- | --- | --- | --- |
| Number | Predicted | Found | Difference |
| 1 | 52 | 52.63 | -0.63 |
| 2 | 74 | 67.18 | +6.82 |
| 3 | 50 | 49.79 | +0.21 |
| 4 | 0 | 4.35 | -4.35 |
| 5 | 51 | 74.8 | -23.8 |
| 6 | 41 | 43.5 | -2.5 |
| 7 | 51 | 60.91 | -9.91 |
| 8 | 56 | 37.04 | +18.96 |
| Average |  |  | -1.9 |

The range for the above differences is 0.428*t* and the estimated standard deviation is 0.15*t.*  At a 95% confidence level, the estimated uncertainty in individual depth measurements is + 0.35 *t.*

For areas of pitting of general corrosion, the uncertainty in the depth of measurements was a bias or systematic error of 0.019 *t* with a random uncertainty of + 0.35*t* at the 95% confidence level. Areas not excavated and inspected should increase the predicted depth by 0.369*t* for integrity analysis.

**Industry Standards**

American Petroleum Institute Standard 1160, *Managing System Integrity for Hazardous Liquid Pipelines* in section 9 contains the following information and recommendations:

1. Accuracy and reliability of in-line inspection tools varies with each tool, pipeline conditions, and other factors.
2. In conducting an in-line inspection program, the operator should evaluate the capabilities of the available inspection tools for the intended application and formulate a plan to validate the results.
3. Sufficient verification excavations should be made to show that the tool is accurate and reliable. Then and only then, can the operator have adequate confidence that the critical injurious anomalies will be found so they can be removed or repaired.
4. An operator should take into consideration the in-line inspection vendor’s stated statistical accuracies, analysis techniques, and the operator’s experience in determining an effective anomaly investigation program.
5. Table 9-1 contains information on the capabilities and limitations of in-line inspection survey to detect and size various pipeline integrity conditions.
6. Table 9-1 also shows that a co combination of in-line inspection surveys can detect dents containing a gouge, one of the highest risk integrity conditions to be found in a pipeline.
7. Table 9-1 also shows a combination at least in-line inspection tools are required for the vast majority of loss of integrity conditions in a pipeline other than dents with gouges.

**Bibliography**

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