Information Provided by PII on April 13, 2012            Number of document: 3

Subject: POD POI and other requested information on ILI tools capabilities

Item -1:  Probability of detection and identification

Item -2:  An explanation of probability of detection and identification

Item -3:  New MagneScan High Res Spec – 25 Jan 09 v 02

# PoD, PoI

# API 1163
# What must ILI vendors supply?

- Can we detect it? – PoD
- Can we classify it correctly? – PoI
- Can we size it accurately? – Sizing Performance
  - > Is the other information accurate?
- Can you prove it? – Client Feedback
  – Dig Verification

# Probability of Detection - PoD

API 1163 defines PoD as:

***"the probability of a feature being detected by an in-line inspection tool"***

What does ***detected*** really mean?

In practice, a defect is detected if:

***The inspection tool records a resolvable signal (wrt to the signal noise level) at the defect location***

One could go further and say that:

***A defect is only detected if that signal has been boxed (or recorded in some way) by either an automatic algorithm or by the analyst***

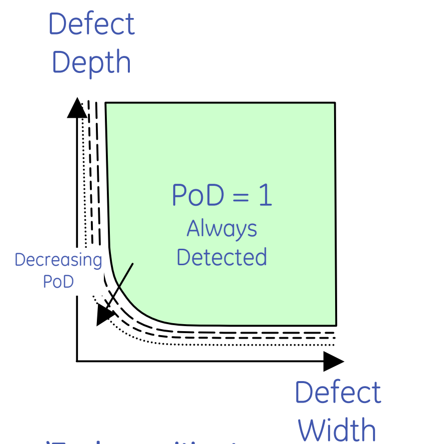
# Probability of Detection – PoD

The signal amplitude,
and consequently the PoD,
is dependent on defect size

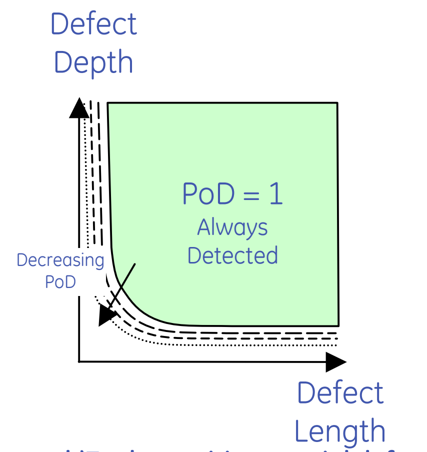
**The PoD of an inspection system can only be determined from a set of defects whose dimensions have been measured and are known**

The PoD is usually derived from pull throughs in spools containing a range of known defects of different sizes

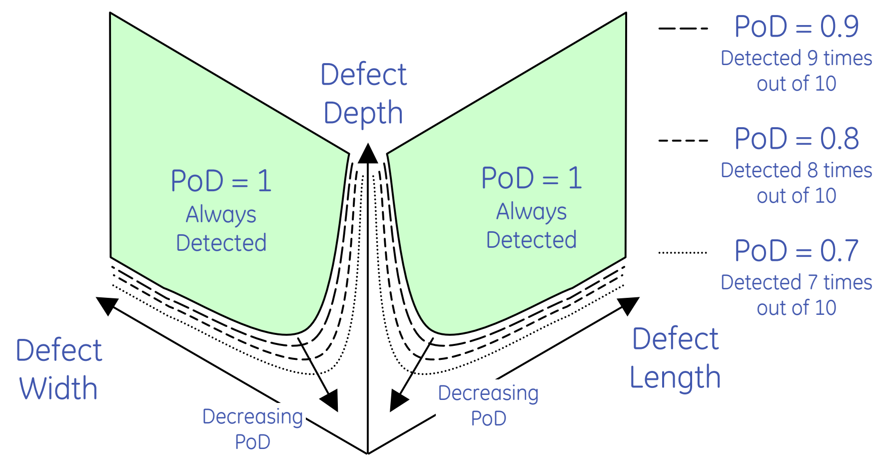
**It is expected that the PoD performance achieved by the tool in a pull through will be replicated during each inspection run**




**a)Tools sensitive to circumferential defects (MFL 2.0, MFL3.0, SmartScan, etc)**

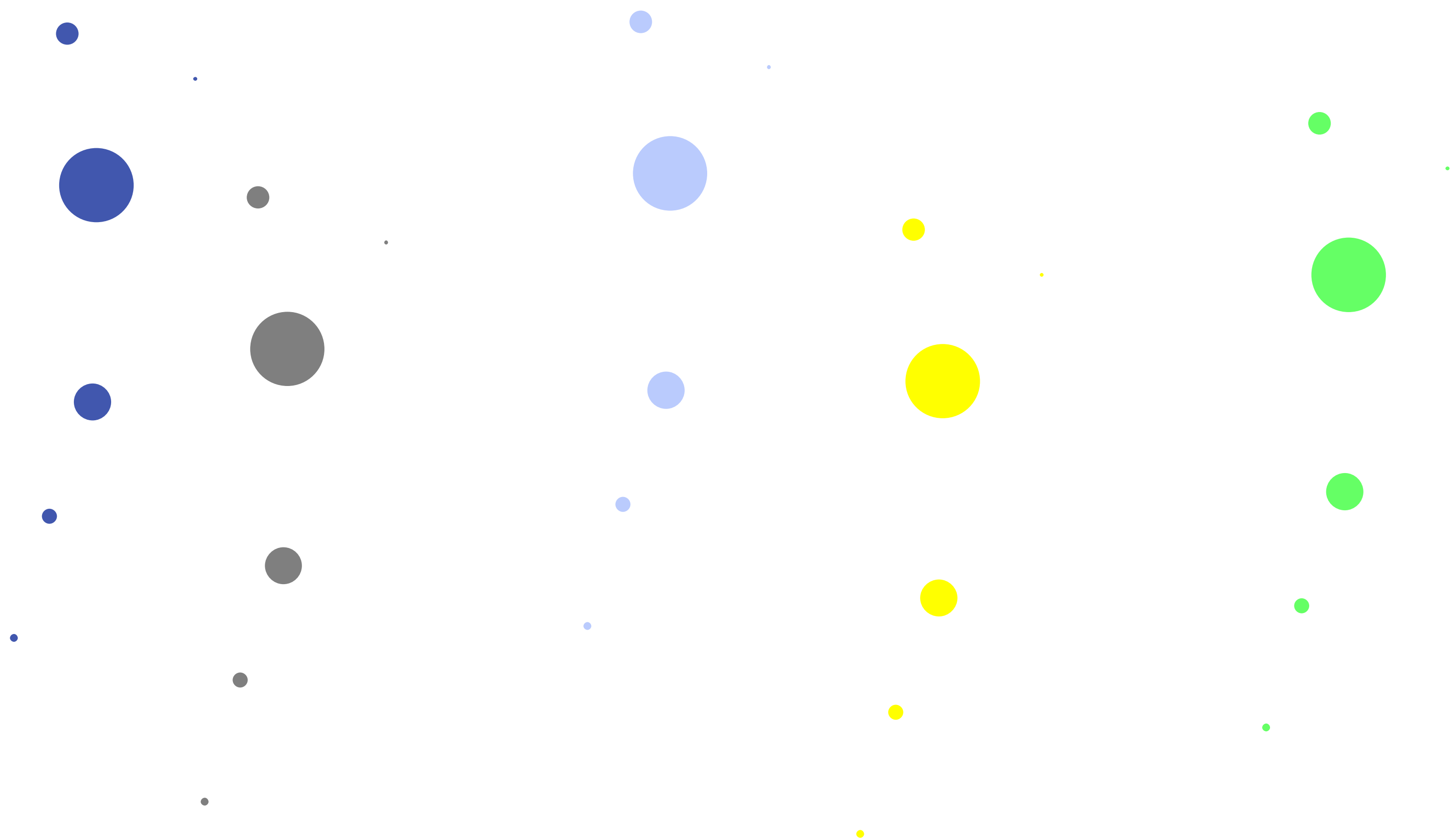



**b)Tools sensitive to axial defects (USCD, EMATScan, Elastic Wave, TransScan, etc)**




**c)Tools sensitive to defect volume (Triax, USWM, USDUO, etc)**

# Probability of Detection – PoD
## 6 dots – 5 colours



The PoD of large dots is 1. The PoD of the smallest dots is <1

PoD depends on size of and shape of defect

# Probability of Detection – PoD

***How should we calculate PoD?***

From the pull through results:

- Known defects that have been detected are ***true positives***
- Known defects that have not been detected are ***false negatives***

| | Defect Detected | |
|---|---|---|
| | Yes | No |
| Known and measured defect of a specific type and size | True Positive (TP) | False Negative (FN) |

$$PoD_{\text{specific defect type and size}} = \frac{\text{No. of times a defect of that type and size has been detected}}{\text{No. of opportunities to detect a defect of that type and size}}$$

$$= \frac{TPs}{(TPs + FNs)}$$

imagination at work

# Probability of Detection – PoD

***How should we calculate PoD?***

Example:

- Pull Through Data recorded from
  - > 5 identical defects
  - > Over 10 pull through runs
  - > Signal detected = 48 times - ***TP***
  - > Signal not detected = 2 times - ***FN***

| | Defect Detected | |
|---|---|---|
| | Yes | No |
| Known and measured defect of a specific type and size | True Positive (TP) | False Negative (FN) |

$$PoD_{\text{specific defect type and size}} = \frac{TPs}{(TPs + FNs)}$$

$$= \frac{48}{48 + 2} = 0.96$$

If there is only one defect of each size in the pull through then from a single run the PoD for each defect can only be calculated to be either 1 or 0

So a number of repeat runs and/or duplicate defects are needed to enable a more meaningful PoD value to be calculated

# Probability of Identification - PoI

API 1163 defines PoI as:

***"the probability that the type of anomaly or other feature, once detected, will be correctly identified (e.g. as metal loss, dent, etc.)"***

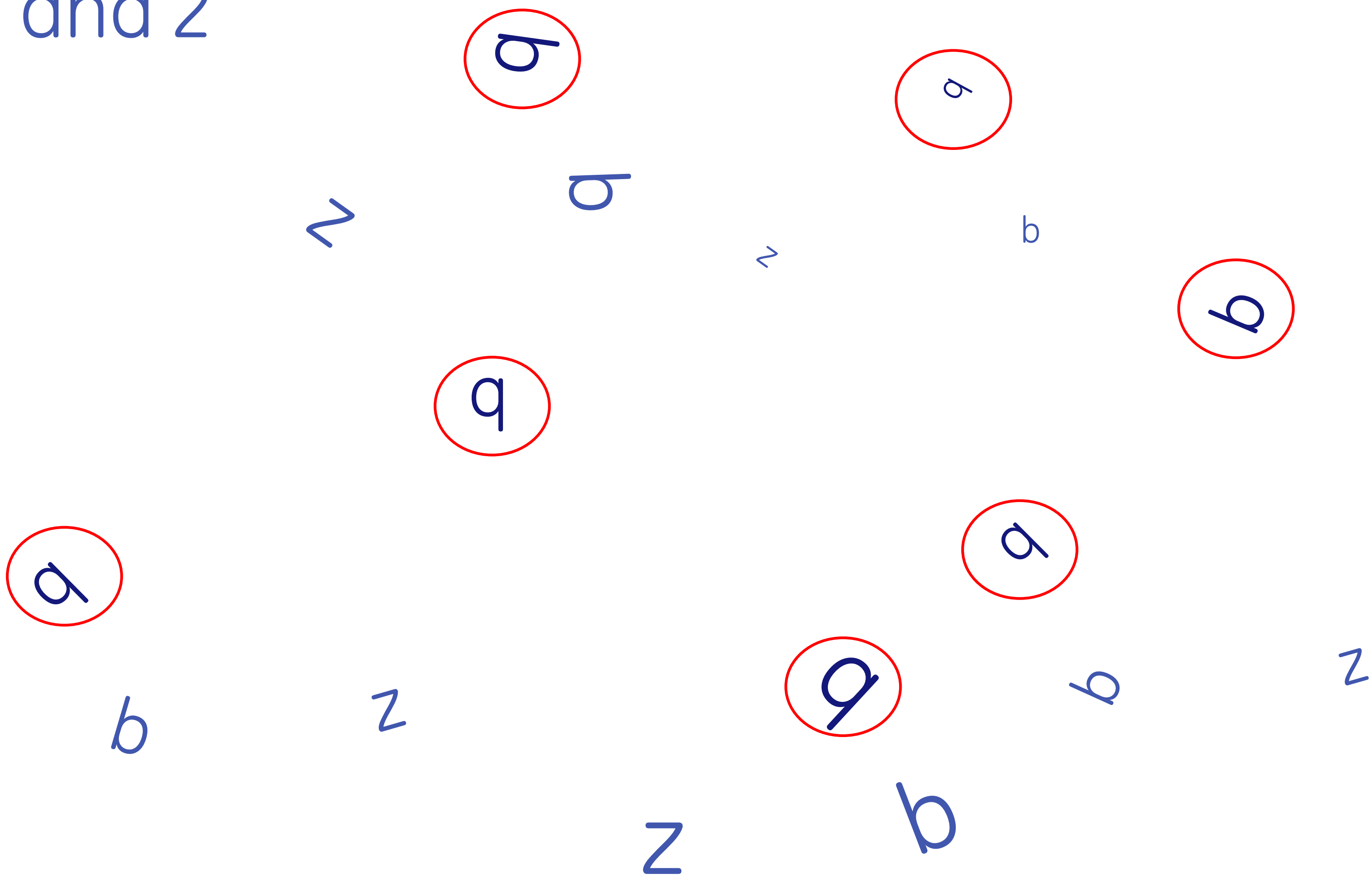
The PoI of an inspection system can only be determined from a set of defects where we have **both**

***the analyst's classification***

AND

***the in-the-ditch classification made by a competent NDE/NDT operator***

# Probability of Identification – PoI
## b, q and z



Our ability to classify z prevents p & q being misclassified as z

PoI on a particular pipeline depends on mix of defect types

# Probability of Identification – PoI

## *How should we calculate PoI?*

From the analysis results and
the excavation data:

- Defects reported as Defect Type X (such as crack) and assessed in-the-ditch as of Defect Type X are ***true positives***
- Defects reported as Defect Type X but assessed in-the-ditch as **not** of Defect Type X are ***false positives - (False Digs)***
- Defects reported as **not** Defect Type X but assessed in-the-ditch as of Defect Type X are ***false negatives - (Missed Threats)***
- Defects reported as **not** Defect Type X and assessed in-the-ditch as **not** of Defect Type X are ***true negatives***

| | | Excavated: Crack | Excavated: Not a Crack |
|---|---|---|---|
| Reported | Crack | TP | FP |
| | Not a Crack | FN | TN |

$$PoI_{\text{specific defect type}} = \frac{\text{No. of correct identifications}}{\text{No. of opportunities to classify a defect}}$$

$$= \frac{TPs + TNs}{(TPs + FNs + FPs + TNs)}$$

# Probability of Identification – PoI

***How should we calculate PoI?***

Example:

- 50 features were reported and excavated
- 15 of these were reported as Cracks
  - > 10 were found to be cracks – ***TP for Cracks***
  - > 5 were classified in-the–ditch as metal loss - ***FP***
- 35 of these were reported as Notch-like
  - > 33 were classified in-the–ditch as notch-like - ***TN***
  - > 2 were found to be cracks – ***FN***

| Reported \ Excavated | Crack | Not a Crack |
|---|---|---|
| Crack | TP | FP |
| Not a Crack | FN | TN |

$$PoI_{\text{Cracks}} = \frac{TPs + TNs}{(TPs + FNs + FPs + TNs)}$$

$$= \frac{10+33}{10+2+5+33} = 43/50 = 0.86$$

$$PoI_{\text{Notch-like}} = \frac{33+15}{33+0+2+15} = \frac{48}{50} = 0.96$$

## An explanation of POD, POI and 80% confidence intervals in sizing of ILI Tools.

### POD Probability of detection

The probability of a feature being detected by an in-line inspection tool. This is based upon the minimum detection level defect dimensions and type detailed in the tool reporting specification. The probability of detecting larger defects increases in relation to the dimensions of the defect. As this then an infinite number of larger features, the specification is determined on the smallest detectable feature dimension, which is based upon the physics of the tool technology and pipeline parameters.

### POI Probability of Identification

Once a feature has been detected as per the POD description above. The probability that the type of an anomaly or other feature, once detected, will be correctly identified (e.g. as metal loss, dent, crack field etc.).

### Sizing accuracy % confidence level

The accuracy with which an anomaly dimension or characteristic is reported. Typically, accuracy is expressed by a tolerance and a certainty. Each technology tool will have specific tolerances related to the type of feature described in the report. As an example, depth sizing accuracy for MFL metal loss is commonly expressed as +/- 10% of the wall thickness (the tolerance), 80% of the time (the certainty or confidence level).

API 1163 and POF (pipeline operators forum) give detailed explanations and examples of POD, POI and % confidence levels. Whereas API is more general POF is more metal loss orientated and detailed in the various types of metal loss defects and how they are described and seen differently by the various technologies. In Europe POF require vendors to publish yje % confidence their tools have in seeing 7 different categories of metal loss (See attached example of a typical MFL POF spec)

### ILI tool limitations:-

There is a variety of ILI tools designed for specific missions. The specifications detail the minimum size and determination of a feature, for which a specific tool can detect (POD, POI) and the accuracy in which it can estimate the size at the given confidence level. Each ILI tool will have physical limitations relating to the minimum diameter, bend configurations, internal fittings dimensions, pressure, product being transported and its speed.

Geometry tools :- Are designed to detect and size, internal diameters and changes, dents, ovalities, expansions and gouges in a pipeline. They cannot detect cracking or external metal loss and cannot size accurately, if detected, internal metal loss or wall thinning.

Metal loss :- Magnetic Flux Leakage (MFL) These tools are designed to detect and measure volumetric metal loss, both situated on the internal and external surface of the pipeline. The minimum dimensions of specific defects are available from the vendors specification sheet. Each ILI tool will have physical limitations relating to the minimum diameter, bend configurations, internal fittings dimensions, pressure, product being transported and its speed. Wall thickness, along with tool speed dictates the level of magnetism in the pipe wall and therefore is a limitation on the detection and sizing ability of magnetic tools. Each tool will have a max/min wall thickness value in its published specifications.

These tools are good at detecting and sizing metal loss that crosses the lines of magnetic field produced by the permanent magnets (i.e. MFL is good for circumferentially orientated features and Transverse Field magnetic tools are good for axially aligned features). They cannot detect SCC cracking, mid wall laminations or general wall thinning (erosion).

Ultrasonic Wall Measurement USWM) tool:- These tools are designed to measure the remaining wall thickness, mid wall laminations and wall thinning of pipelines transporting liquids (as the technology requires a liquid medium to transfer the sound waves into the pipe wall and back to the tool sensors. Each ILI tool will have physical limitations relating to the minimum diameter, bend configurations, internal fittings dimensions, pressure, product being transported and its speed. With Ultrasound it is also important to have a clean environment, therefore loose debris and adhered wax or salt deposits can prevent a good ultrasound coupling and result in degraded or failed runs.

Ultrasonic Crack Detection (USCD) tools;- These tools are designed to detect various types of axially aligned cracks. Each ILI tool will have physical limitations relating to the minimum diameter, bend configurations, internal fittings dimensions, pressure, product being transported and its speed. The minimum dimensions of axial (within +/- 5 degrees perpendicular to the central axis of the pipe) features and with minimum length and depth, depending upon speed and wall thickness of the pipeline, will be supplied by the tool vendor.

Metal loss, sharp dents and general wall thinning cannot be detected and sized by this technology.

GE

Oil & Gas

PII Pipeline Solutions

Detection Capabilites

# Metal Loss

# POF New MagneScan 6”, 8”, 10”

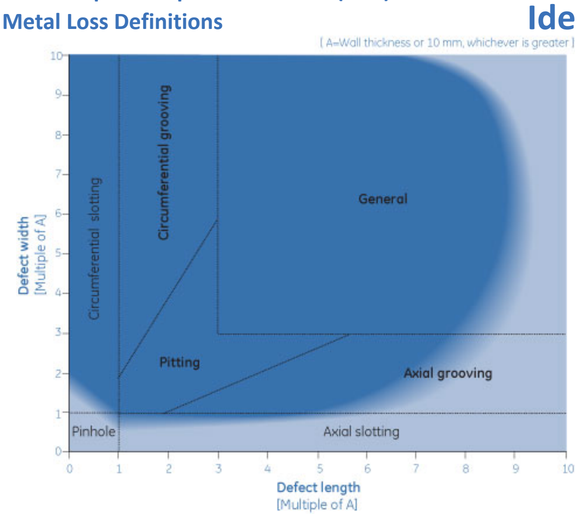
## Inspection of Seamwelded Pipes – Manual Sizing – High Resolution

| Property | Full detection and sizing accuracy or metal loss in body of pipe | | | | | Full detection and sizing accuracy for metal loss in the vicinity of a weld* | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Certainty (Probability) | General Metal loss | Pitting | Axial Grooving | Circumferential Grooving | General Metal Loss | Pitting | Axial Grooving | Circumferential Grooving |
| Min. Depth At 90% POD | | 8% | 10% | 10% | 8% | 12% | 14% | 14% | 12% |
| Depth Sizing Accuracy | 80%<br>90% | ±10%<br>±15% | ±10%<br>±15% | -15%/+10%<br>-20%/+15% | -10%/+15%<br>-15%/+20% | ±15%<br>±20% | ±15%<br>±20% | -20%/+15%<br>-25%/+20% | -15%/+20%<br>-20%/+25% |
| Width Sizing Accuracy | 80%<br>90% | ±20 mm<br>±25 mm | ±20 mm<br>±25 mm | ±20 mm<br>±25 mm | ±20 mm<br>±25 mm | ±25 mm<br>±30 mm | ±25mm<br>±30 mm | ±25 mm<br>±30 mm | ±25 mm<br>±30 mm |
| Length Sizing Accuracy | 80%<br>90% | ±15 mm<br>±20 mm | ±10 mm<br>±15 mm | ±20 mm<br>±25 mm | ±20 mm<br>±25 mm | ±20 mm<br>±25 mm | ±15 mm<br>±20 mm | ±25 mm<br>±30 mm | ±25 mm<br>±30 mm |

* The vicinity of the weld refers to the heat affected zone – not in the weld material.
POD = Probability of Detection (reference diameters of the defect areas: 4t for General Metal Loss and 2t for Pitting)
POI =Probability of identification.

### Pipeline Operators Forum (POF)

### Metal Loss Definitions





Axial External Corrosion


General Corrosion


Shallow Pitting

## Identification of Features

| | |
|---|---|
| POI > 90% | - internal/external discrimination<br>- corrosion/metal loss; corrosion/metal loss cluster; artificial metal loss; pipe mill anomaly (metal loss)<br>- wall thickness change (between two pipe joints and within a pipe joint)<br>- dent<br>- presence of debris; presence of touching metal to metal<br>- eccentric pipeline casing; welded sleeve repair, composite sleeve repair (if metal content)<br>- external support; ground anchor; pipeline fixture<br>- off-take; tee; valve<br>- bend<br>- reference magnet |
| POI < 50% | - arc strike<br>- crack in base material or longitudinal weld; anomaly in longitudinal weld<br>- HIC; SCC; spalling<br>- ovality<br>- presence of weld deposit; presence of coating |
| POI ≤ 90%<br>POI ≥ 50% | - anode/CP connection (depending on wall thickness & type)<br>- buckle; wrinkle; dent with metal loss<br>- gouging; grinding<br>- girth weld or spiral weld crack; girth weld or spiral weld anomaly; lamination<br>- diameter change; adjacent tapering<br>- crack arrestor |


Nov 2008

GE

Oil & Gas

PII Pipeline Solutions

Detection Capabilites

# Metal Loss

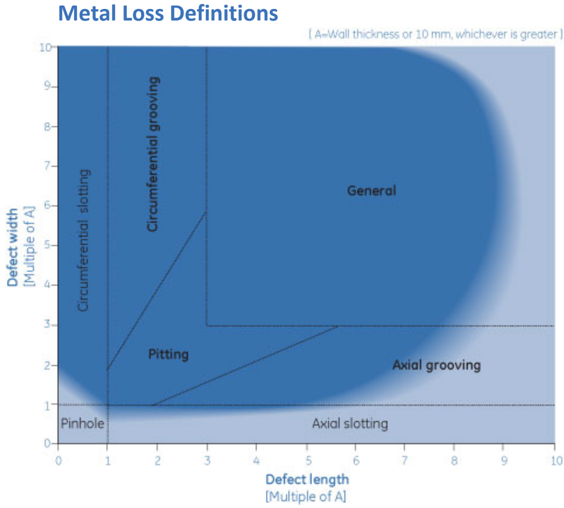
# POF New MagneScan 6”, 8”, 10”

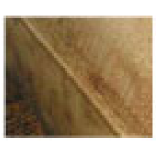
## Inspection of Seamless Pipes – Manual Sizing – High Resolution

| Property | Full detection and sizing accuracy or metal loss in body of pipe | | | | | Full detection and sizing accuracy for metal loss in the vicinity of a weld* | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Certainty (Probability) | General Metal loss | Pitting | Axial Grooving | Circumferential Grooving | General Metal Loss | Pitting | Axial Grooving | Circumferential Grooving |
| Min. Depth At 90% POD | | 12% | 15% | 15% | 12% | 18% | 24% | 24% | 18% |
| Depth Sizing Accuracy | 80%<br>90% | ±10%<br>±15% | ±10%<br>±15% | -15%/+10%<br>-20%/+15% | -10%/+15%<br>-15%/+20% | ±15%<br>±20% | ±15%<br>±20% | -20%/+15%<br>-25%/+20% | -15%/+20%<br>-20%/+25% |
| Width Sizing Accuracy | 80%<br>90% | ±20 mm<br>±25 mm | ±20 mm<br>±25 mm | ±20 mm<br>±25 mm | ±20 mm<br>±25 mm | ±25 mm<br>±30 mm | ±25mm<br>±30 mm | ±25 mm<br>±30 mm | ±25 mm<br>±30 mm |
| Length Sizing Accuracy | 80%<br>90% | ±15 mm<br>±20 mm | ±15 mm<br>±20 mm | ±20 mm<br>±25 mm | ±20 mm<br>±25 mm | ±20mm<br>±25 mm | ±20 mm<br>±25 mm | ±25 mm<br>±30 mm | ±25 mm<br>±30 mm |

* The vicinity of the weld refers to the heat affected zone – not in the weld material.
POD = Probability of Detection (reference diameters of the defect areas: 4t for General Metal Loss and 2t for Pitting)
POI =Probability of identification.

### Pipeline Operators Forum (POF)
### Metal Loss Definitions





Axial External Corrosion


General Corrosion


Shallow Pitting

## Identification of Features

| | |
|---|---|
| POI > 90% | - internal/external discrimination<br>- corrosion/metal loss; corrosion/metal loss cluster; artificial metal loss; pipe mill anomaly (metal loss)<br>- wall thickness change (between two pipe joints and within a pipe joint)<br>- dent<br>- presence of debris; presence of touching metal to metal<br>- eccentric pipeline casing; welded sleeve repair, composite sleeve repair (if metal content)<br>- external support; ground anchor; pipeline fixture<br>- off-take; tee; valve<br>- bend<br>- reference magnet |
| POI < 50% | - arc strike<br>- crack in base material or longitudinal weld; anomaly in longitudinal weld<br>- HIC; SCC; spalling<br>- ovality<br>- presence of weld deposit; presence of coating |
| POI ≤ 90%<br>POI ≥ 50% | - anode/CP connection (depending on wall thickness & type)<br>- buckle; wrinkle; dent with metal loss<br>- gouging; grinding<br>- girth weld or spiral weld crack; girth weld or spiral weld anomaly; lamination<br>- diameter change; adjacent tapering<br>- crack arrestor |


Nov 2008