

# In-Line Inspection – Current Industry Initiatives

---

Robert Owen, National Grid  
UKOPA Technical Seminar  
20 June 2007, Eakring Training Centre

# This talk

---

- ◆ Tool capability – assessment of and selection for use
- ◆ Reporting and relevance of contract reporting specification
- ◆ Advice in relation to acting on inspection results
- ◆ National Grid's damage assessment procedure (T/PM/P/11)
- ◆ Updates to the industry procedure for in-line inspection
- ◆ Industry initiatives (e.g. ILI performance JIP, PRCI)

# Reasons for pigging

---

- ◆ Cleaning (dewatering, removal of debris etc)
- ◆ Condition monitoring for fitness for purpose assessment
- ◆ Pipeline mapping
- ◆ Temperature/pressure measurement

# Condition monitoring

---

- ◆ Inspection should be carried out for new pipelines, immediately following commissioning (fingerprinting)
- ◆ Inspection of the pipeline should be carried out periodically to ensure that the pipeline is not deteriorating
  - ◆ Relevant legislation
  - ◆ IGE/TD/1 allows risk-based approach to determine inspection intervals, otherwise recommends 10 year max interval
  - ◆ Dry natural gas - inspection is predominantly to monitor for external corrosion, although provides other information
  - ◆ Assess Fitness for Purpose
- ◆ Alternatives to ILI – above ground surveys, re-hydrotesting

# Condition monitoring - selection of intelligent pigs

---

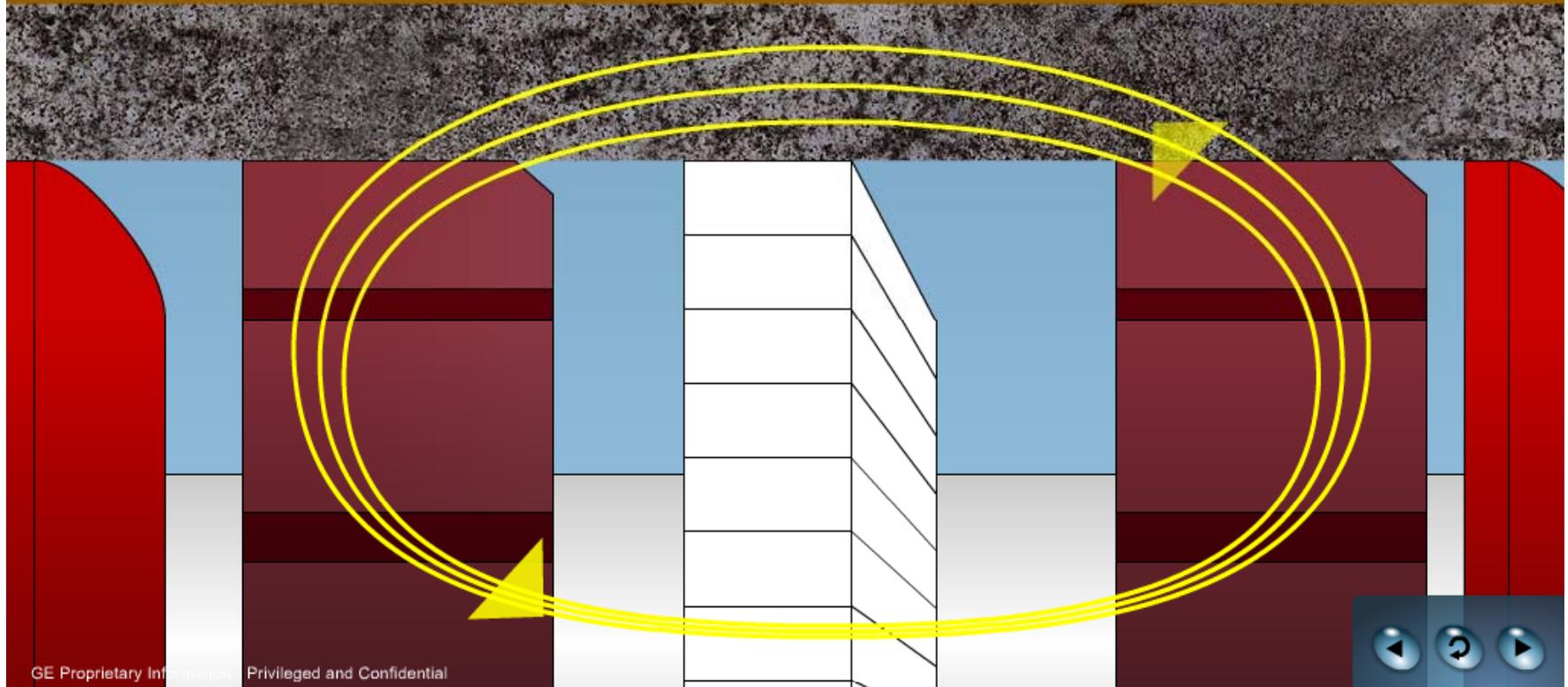
- ◆ Feature detection and sizing capability
- ◆ Feature location accuracy to minimise subsequent excavation
- ◆ Purpose
  - ◆ Geometry/deformation measurement – dents, wrinkles
  - ◆ Metal loss detection – corrosion, gouges
  - ◆ Crack detection – SCC, fatigue

# Intelligent pigs for metal loss detection

---

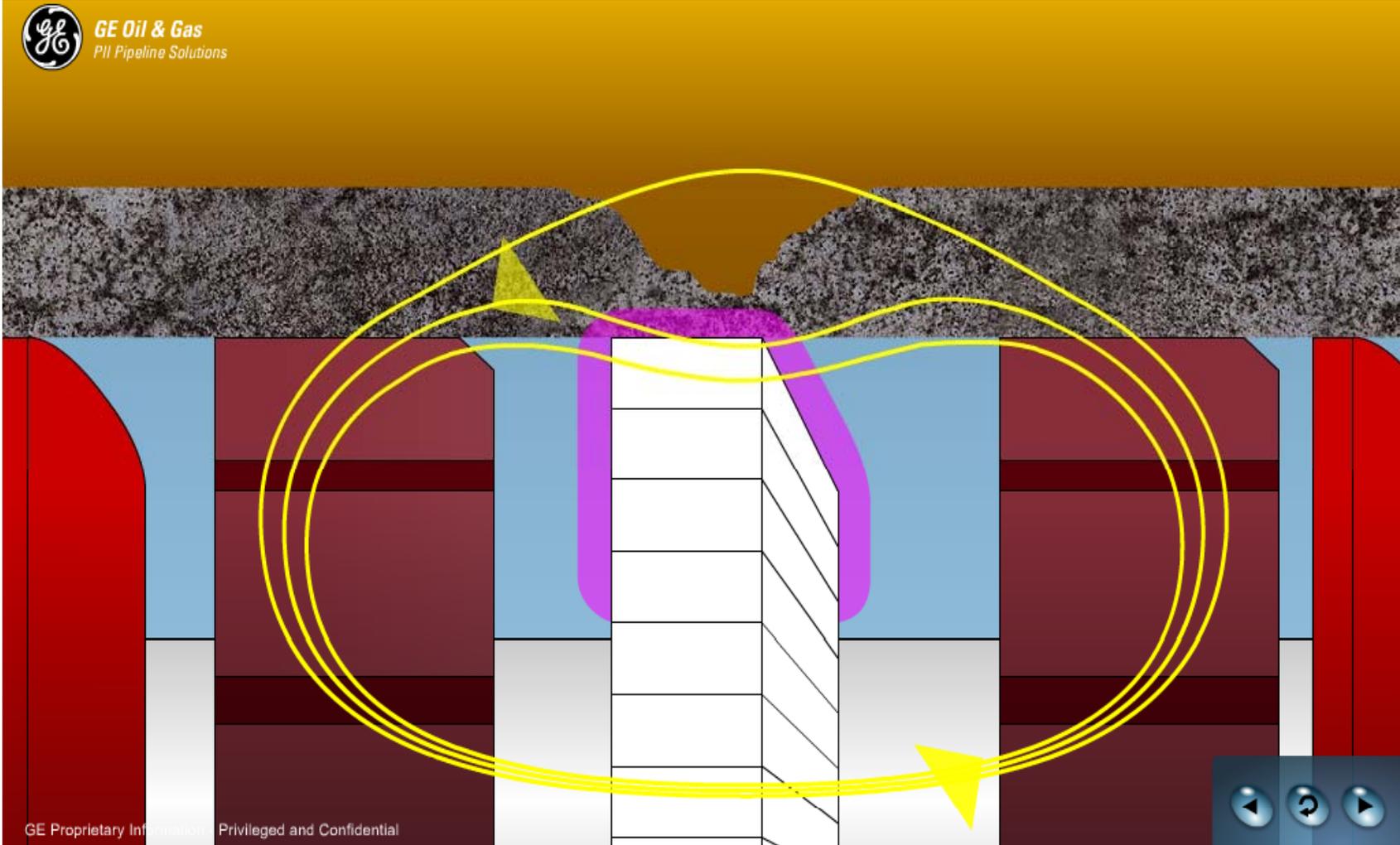
- ◆ Magnetic Flux Leakage (MFL)
  - ◆ Axial field MFL – most common type
  - ◆ Transverse field MFL - for long, axial, narrow metal loss
  - ◆ The selection of MFL tool should consider the type of corrosion expected in a particular pipeline.
- ◆ Ultrasonics
  - ◆ Generally only run in liquid lines
  - ◆ Gives an absolute measure of defect depth

# No corrosion present – flux unaffected



GE Proprietary Information, Privileged and Confidential

# Corrosion present – flux affected

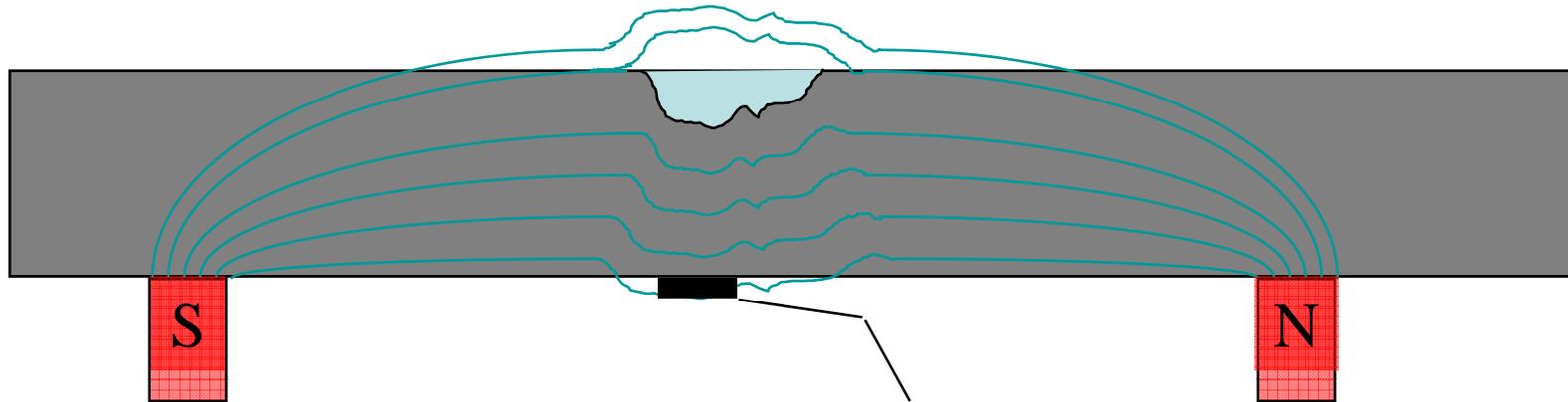


GE Proprietary Information, Privileged and Confidential

**nationalgrid**

# The Primary Sensor System – (Axial Field)

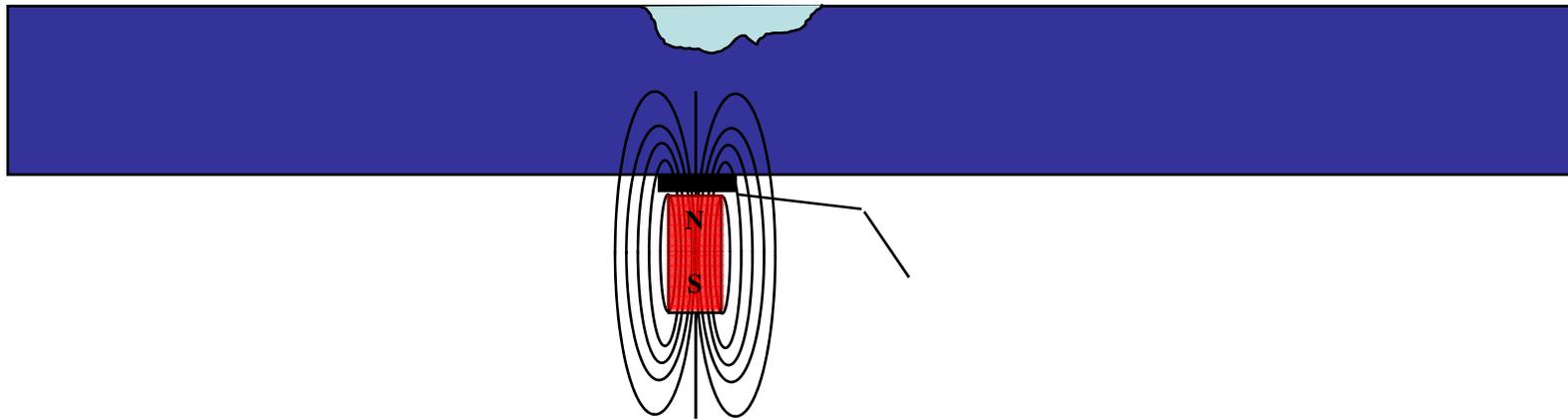
---



- High magnetic flux field imposed parallel to the pipe wall.
- Magnetic flux lines will be deflected:
  - if there is metal loss within the pipe wall.
  - if there is ferrous material near the pipe wall.
  - if the properties of the steel pipe wall change.
- The primary sensor detects any leakage of the magnetic flux.

# The Secondary Sensor System

---



- Low magnetic flux field imposed perpendicular to the pipe wall.
- Magnetic flux lines will be deflected if there is metal loss on the internal surface of the pipe.
- The secondary sensor detects internal magnetic deflection.

# MFL tools – axial field

---

- ◆ The most widespread types of MFL ILI tool use magnets arranged so that the magnetic field direction is parallel to the pipe's axis. They are therefore termed *axial field* tools.
- ◆ The MFL method will only produce a detectable response when a metal loss feature has some variation of depth perpendicular to the field's orientation. Thus, for an axial field device, detectable features must have some extent around the pipe's circumference.
- ◆ A feature such as a flat-bottomed axial groove — even if it is wide enough to be detected — will only cause a signal to be generated from the depth variations at each end.

## MFL tools – transverse field

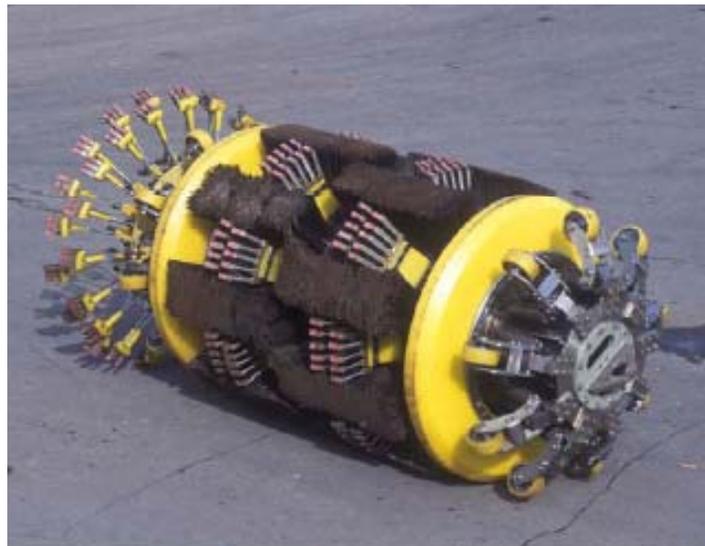
---

- ◆ *Transverse field* MFL tools are constructed so that the direction of magnetization in the pipe wall is around the circumference — that is, transverse to the axis.
- ◆ Narrow axial features therefore have their largest extent at right angles to this transverse field and can be clearly detected.
- ◆ General and pitting corrosion will also be detected, although the sensitivity to pits will not necessarily be as good as for an axial field device.

# MFL tools



Axial Field



Transverse Field

# MFL tutorial

---

- ◆ A web-based tutorial on magnetic flux technologies can be found on Battelle's web site:
- ◆ <http://www.battelle.org/pipetechnology/MFL/Links/tutorial1.html>?

# MFL Inspection Vehicle

---

- ◆ Detects metal loss resulting from corrosion
- ◆ Determines between internal or external corrosion
- ◆ Accurately sizes area and location
- ◆ Identifies pipeline features such as welds, bends, valves, off takes, sleeves, shell repairs
- ◆ Optimum velocity window (typically 1-4 m/s)
- ◆ Minimum pressure required range for successful data collection (typically in excess of 10 bar)

# High resolution MFL tools

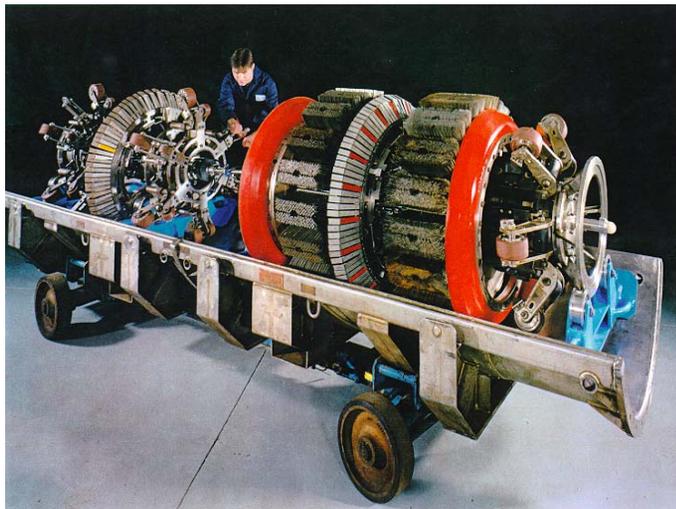
Baker Hughes CPIG



ROSEN CDP



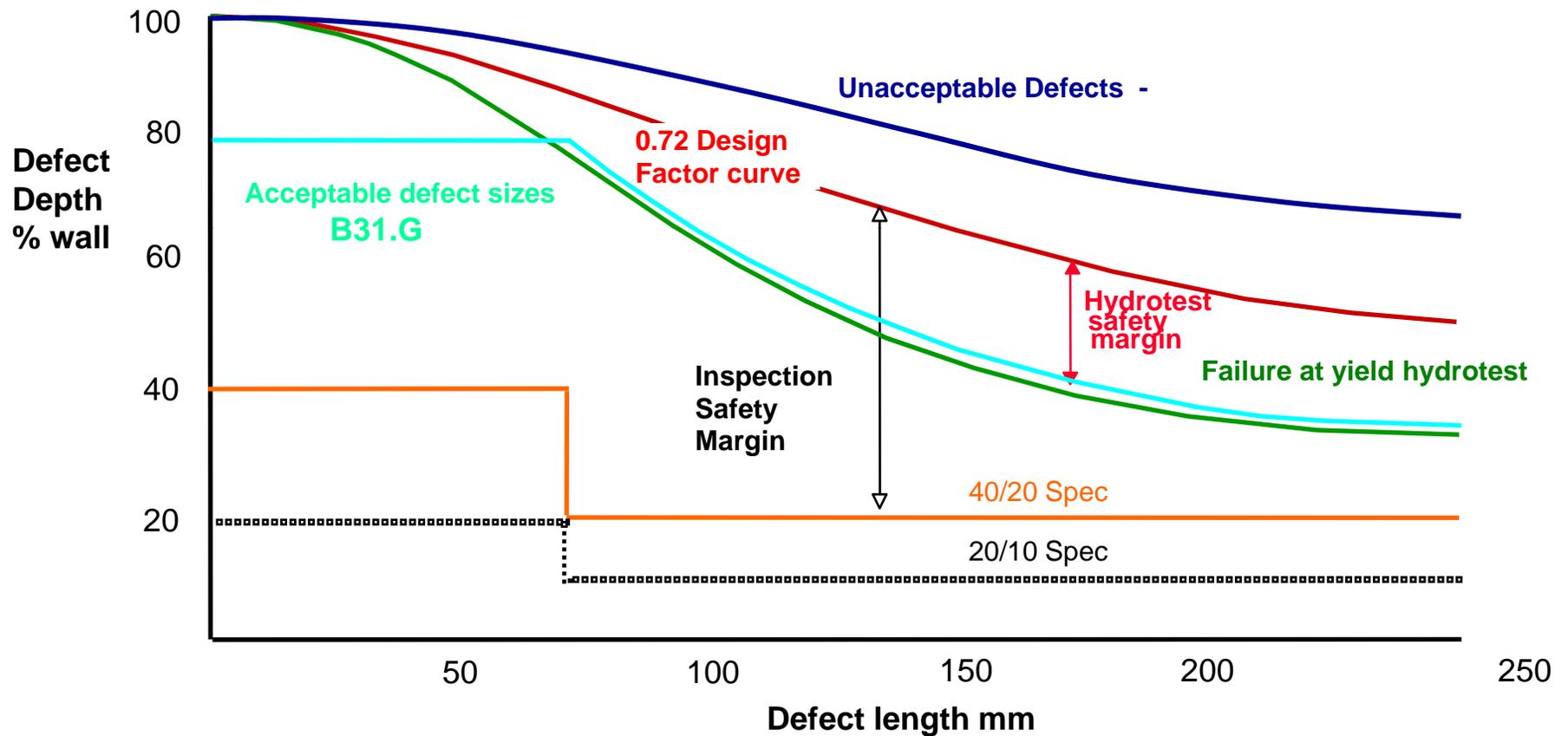
GE- PII



BJ VECTRA

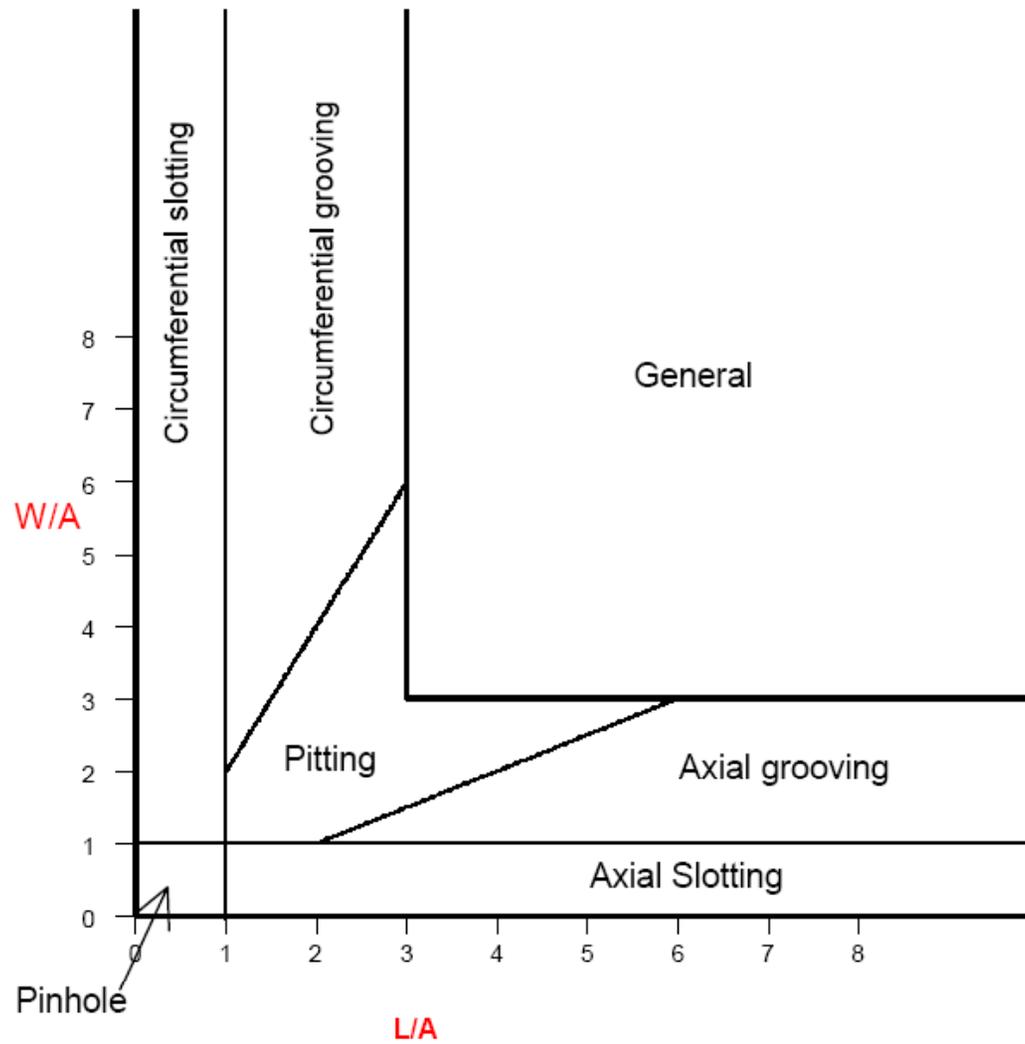
**nationalgrid**

# Safety margins for pipeline operation



Ref: GE-P11

# Metal loss anomalies (POF)



# GE-P11 Reporting Specifications

---

- ◆ **For all 8" & 10" pipelines, 30/50 specification applies**
  - ◆ >30% wall thickness metal loss is required for General Corrosion
  - ◆ >50% wall thickness metal loss is required for Pitting Corrosion
- ◆ **For all pipelines 12" and above, 20/40 specification applies**
  - ◆ >20% wall thickness metal loss is required for General Corrosion
  - ◆ >40% wall thickness metal loss is required for Pitting Corrosion
- ◆ **The only exception to this rule is for pipelines updated above 72% SMYS, 15/40 specification applies**
  - ◆ >15% wall thickness metal loss is required for General Corrosion
  - ◆ >40% wall thickness metal loss is required for Pitting Corrosion

# GE-P11 Feature Report Summary

---

- ◆ Inspection sheet produced for a feature classed as 'Reportable.
- ◆ Up to a maximum of 15 Feature Reports. More are available but at an additional cost.
- ◆ Selection based on percentage of the wall thickness loss and its categorisation in order of significance to damage assessment procedure T/PM/P/11
- ◆ All features are reported on 'Peak Depth', but inspection sheets also show a calculated average depth.
- ◆ Irrespective of whether the metal loss feature is reportable or not '*If the vehicle can detect it, it will be included in the Pipeline Listing / Tally, with the exception of Mill / Manufacturing Faults*'.
- ◆ An asterisk against the feature depth, indicates that the feature has been manually sized by the Analysis Engineer.

# National Grid damage assessment procedure

---

- ◆ T/PM/P/11 - Inspection, Assessment And Repair Of Damaged (Non-Leaking) Steel Pipelines Above 150 mm Nominal Diameter And Designed To Operate At Pressures Greater Than 2 bar
- ◆ Screening level assessment

# T/PM/P/11

---

- ◆ Inspection
- ◆ Damage categories (superficial, moderate, severe, extreme) depending on severity of damage for different stress levels
- ◆ Safe working practices – pressure reductions
- ◆ Repair methods – dressing, epoxy shell repair, snug fitting shells, stand-off shells, cut out and replace

# Damage types

- ◆ Gouge
- ◆ General corrosion
- ◆ Pitting corrosion
- ◆ Smooth dent
- ◆ Kinked dents
- ◆ Dent and gouge
- ◆ Spalling or cracks
- ◆ Arc strikes
- ◆ Stress corrosion cracking
- ◆ Also includes damage near/on welds



# Damage categories - 1

---

- ◆ Superficial Damage
  - ◆ Damage does not significantly affect the integrity of the pipeline. Generally no action is required although if already excavated the defect should be inspected and if necessary repaired. Gouges classified as Superficial do require action.
- ◆ Moderate Damage
  - ◆ Again the integrity of the pipeline is not significantly affected. However, cracking may be present and so must be excavated, inspected and if necessary repaired.

## Damage categories - 2

---

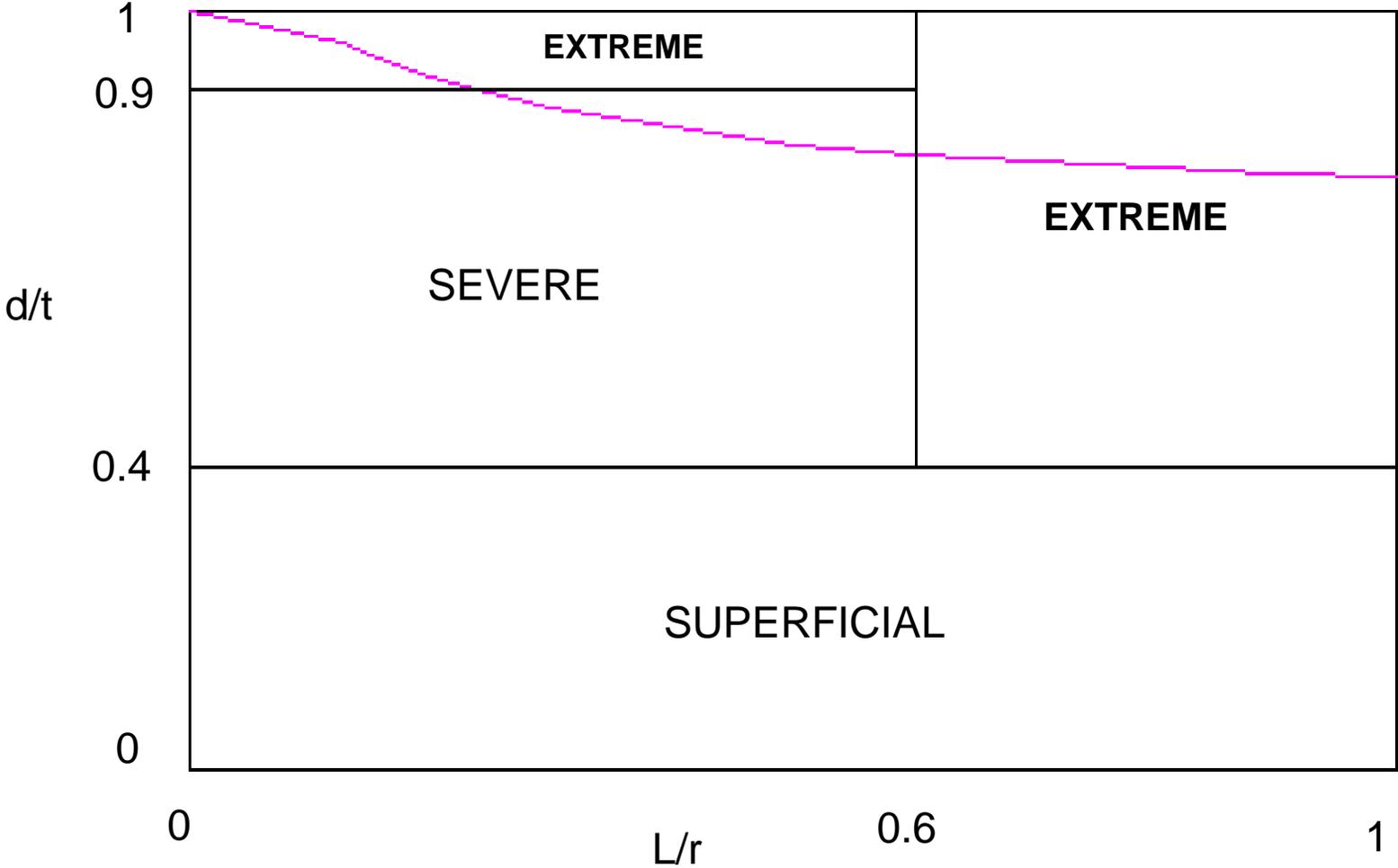
- ◆ Severe Damage
  - ◆ Defect constitutes significant damage which could fail as a leak
- ◆ Extreme Damage
  - ◆ Defect constitutes significant damage which could fail as a rupture
- ◆ Severe and Extreme damage must be repaired by a shell type repair or a cut-out and replace

# T/PM/P/11 – superficial corrosion limits

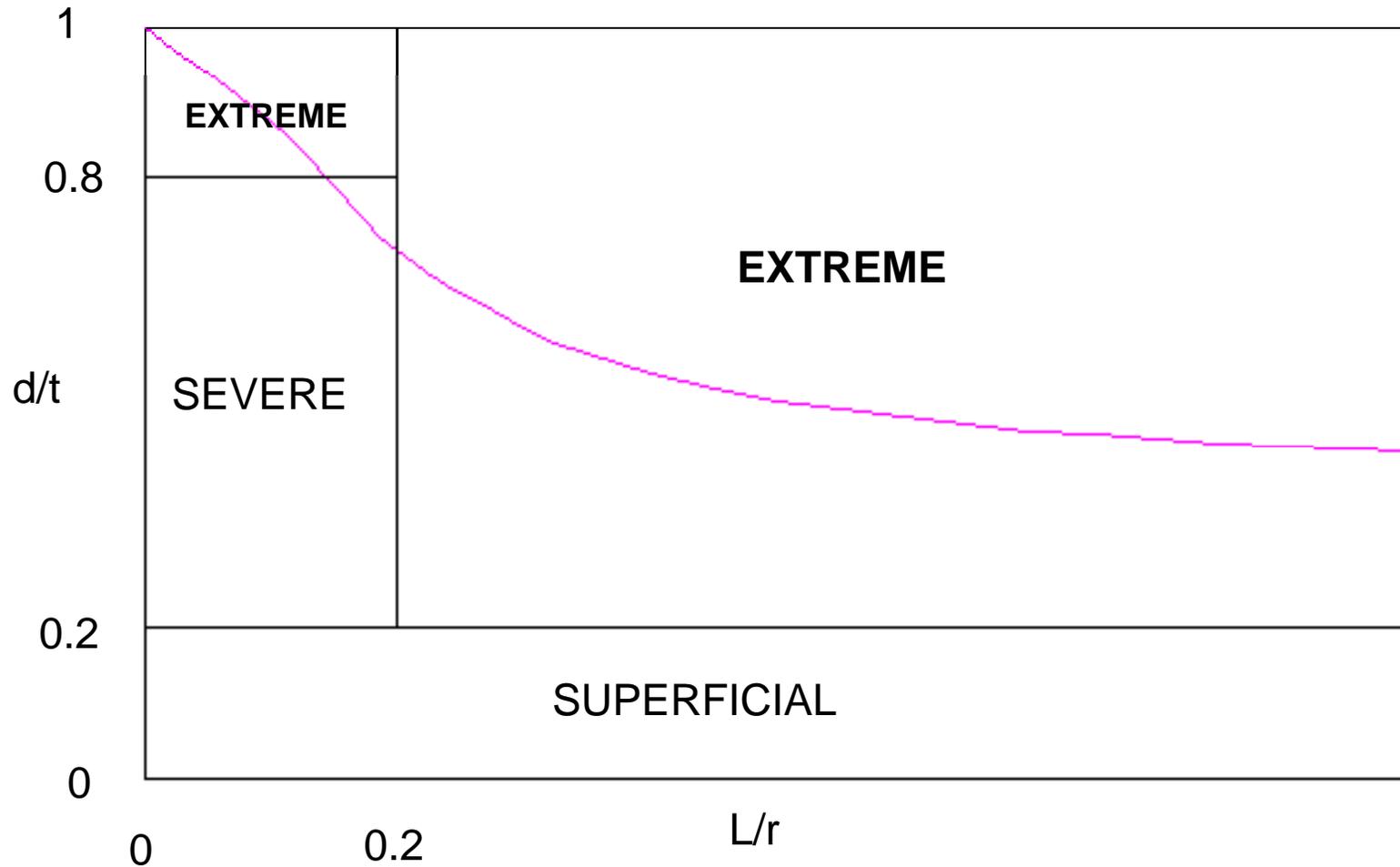
---

- ◆ Up to 30% SMYS
  - ◆ General corrosion: depth less than or equal to 40% wall thickness
  - ◆ Pitting corrosion: depth less than or equal to 60% wall thickness
- ◆ Up to 72% SMYS
  - ◆ General corrosion: depth less than or equal to 20% wall thickness
  - ◆ Pitting corrosion: depth less than or equal to 50% wall thickness

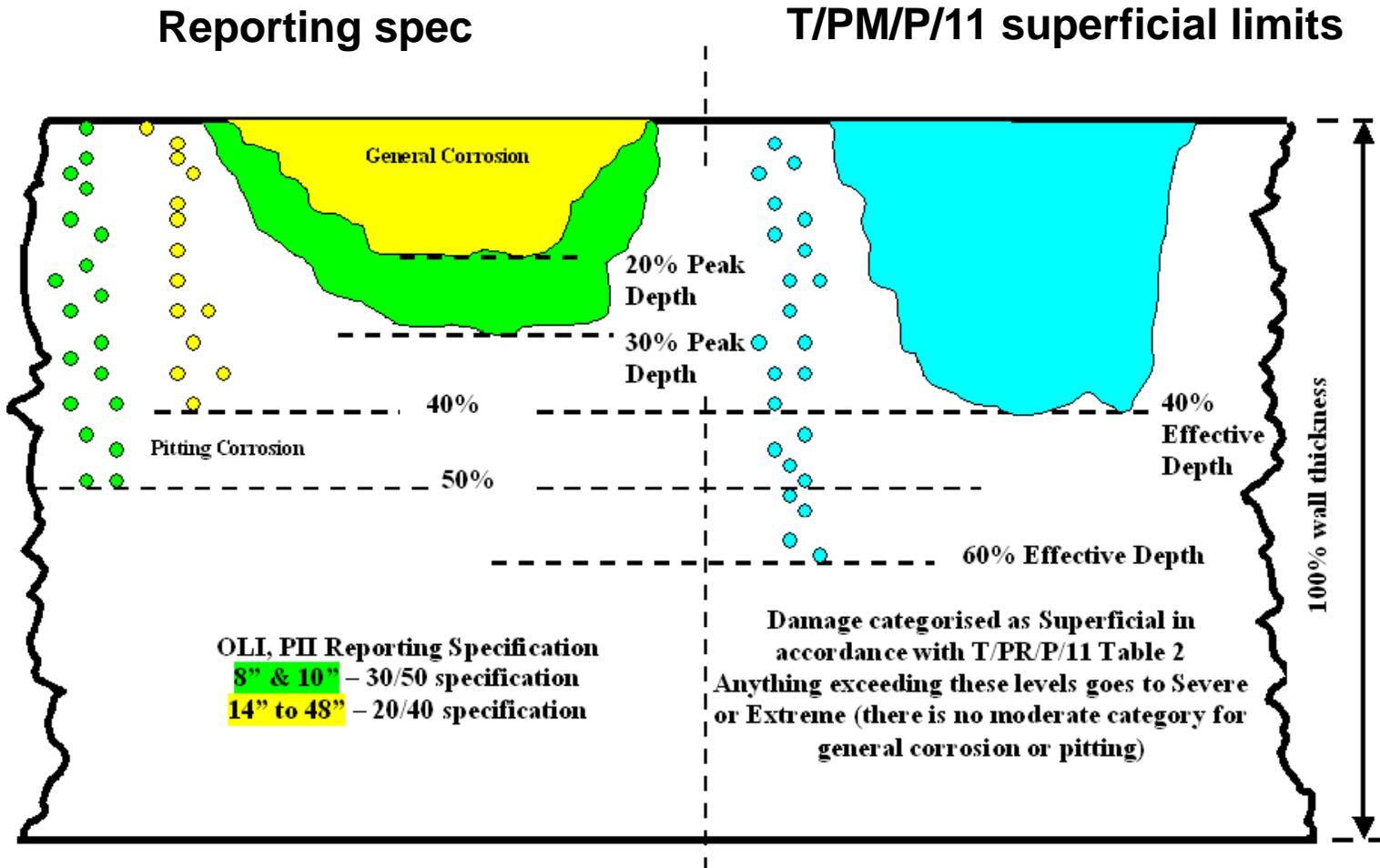
# General corrosion limits at 30% SMYS



# General corrosion limits at 72% SMYS

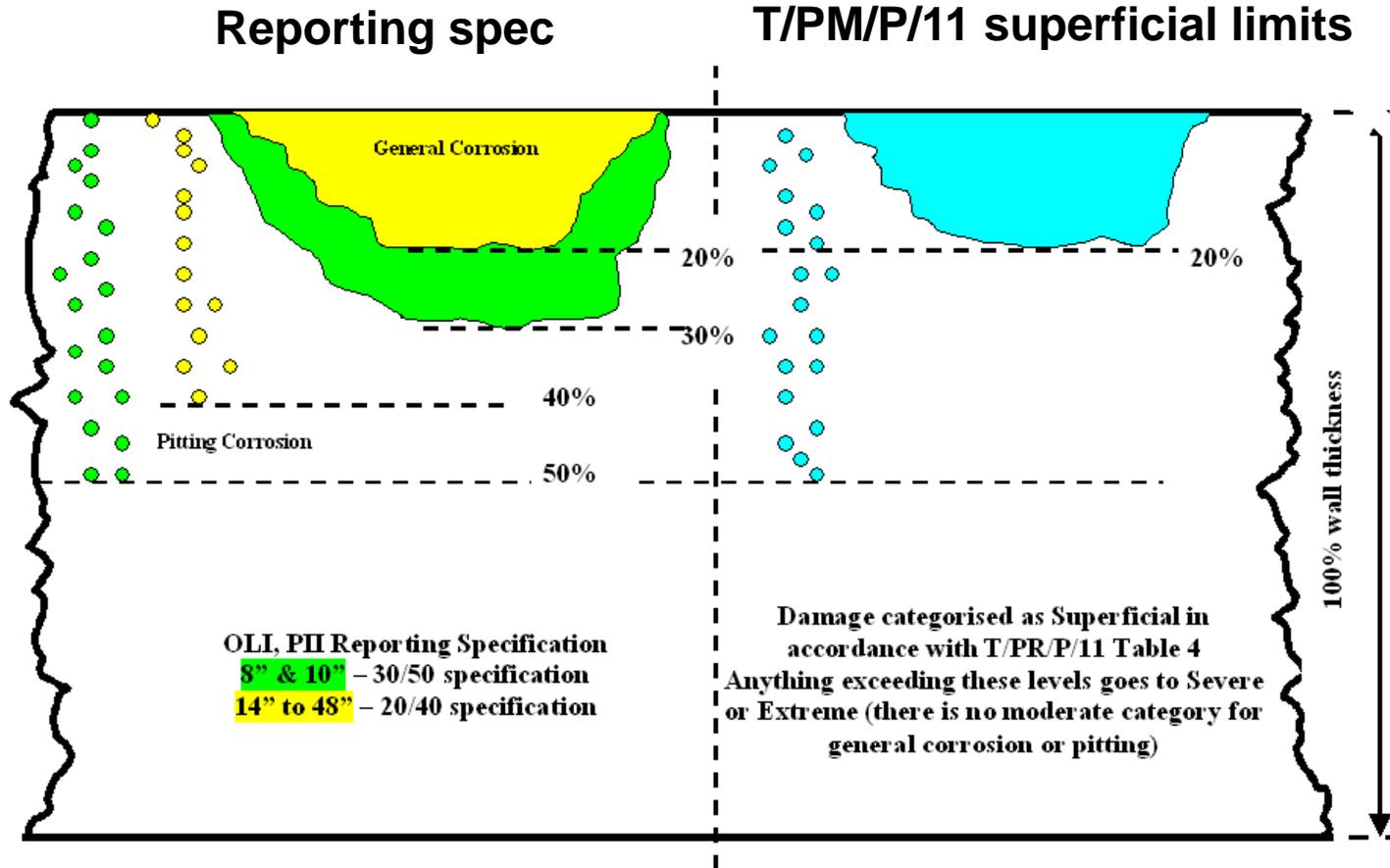


# Pipelines designed to operate up to 30% SMYS



Section through pipe wall

# Pipelines designed to operate up to 72% SMYS



Section through pipe wall

# T/PM/P/11

---

- ◆ Simple to apply
- ◆ Conservative
- ◆ Acceptable limits are unambiguous and uncomplicated
- ◆ Safe

# Expert level assessment

---

- ◆ If simplified approach is not acceptable, an expert level assessment is possible
- ◆ Uses more accurate, less conservative, defect assessment
- ◆ Advanced assessment methods, finite element methods, detailed defect assessment, testing
- ◆ Specialist skills required

# General tool specifications

---

- ◆ Wall thickness range
- ◆ Speed range
- ◆ Temperature range
- ◆ Maximum pressure
- ◆ Minimum pressure for operation
- ◆ Minimum bend radius
- ◆ Minimum internal diameter
- ◆ Tool length, weight and number of bodies
- ◆ Differential pressure required to run and launch the tool
- ◆ Minimum and maximum length of pipeline that can be inspected in one run (may be coupled to run times and state of the pipeline)
- ◆ Minimum length for launcher
- ◆ Minimum distance between trap isolation valve and reducer in the receiver
- ◆ Type of batteries
- ◆ Indication of by pass flow in case of tool stuck

# Measurement specifications

---

- ◆ Identification of features
- ◆ Detection and sizing accuracy of anomalies in body of pipe
- ◆ Detection and sizing accuracy of anomalies in girth weld and heat affected zone
- ◆ Detection and sizing accuracy of cracks or crack-like defects
- ◆ Detection and sizing accuracy of dents and ovalities

# Typical feature sizing for general corrosion

---

- ◆ Confident of sizing 90% of features 5% and above of wall thickness.
- ◆ Depth sizing accuracy is typically +/- 10% of wall thickness in parent pipe
- ◆ Example
  - ◆ Feature depth is claimed to be 30% deep,
  - ◆ Wall thickness is 15.88mm
  - ◆ Feature depth is 4.77 +/- 1.59mm

# Factors affecting MFL performance

---

- ◆ Cleaning
- ◆ Sensor damage
- ◆ Magnetic properties of line pipe
- ◆ Remnant magnetization
- ◆ Wear to mechanical components such as drive cups and suspension arms due to length of run or aggressive in-pipe conditions.
- ◆ Speed excursions
- ◆ Wall thickness

# MFL reporting

---

- ◆ Tool operational data
- ◆ Details of metal-loss features, size and orientation
- ◆ Pipeline features - bends, valves, off-takes, girth welds
- ◆ List of anomalies - girth weld anomalies, eccentric casings etc
- ◆ Summary and statistical data
- ◆ Fully assessed feature sheets
- ◆ Defect assessment method

# MFL developments - 1

---

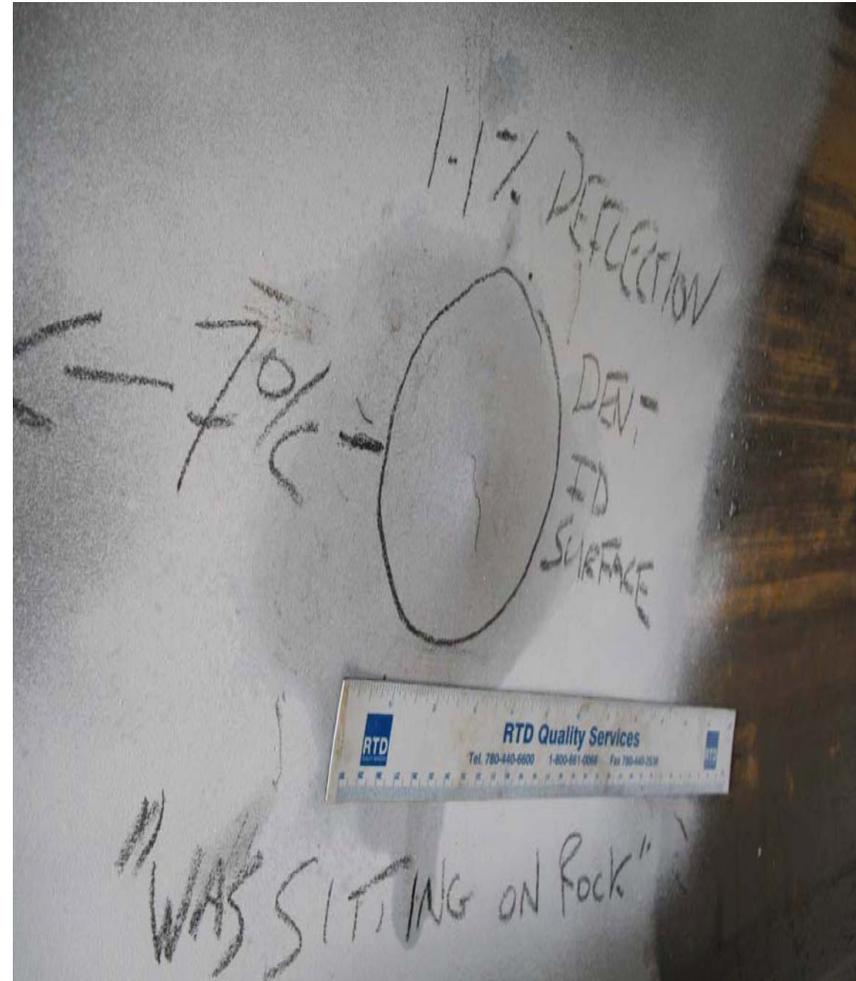
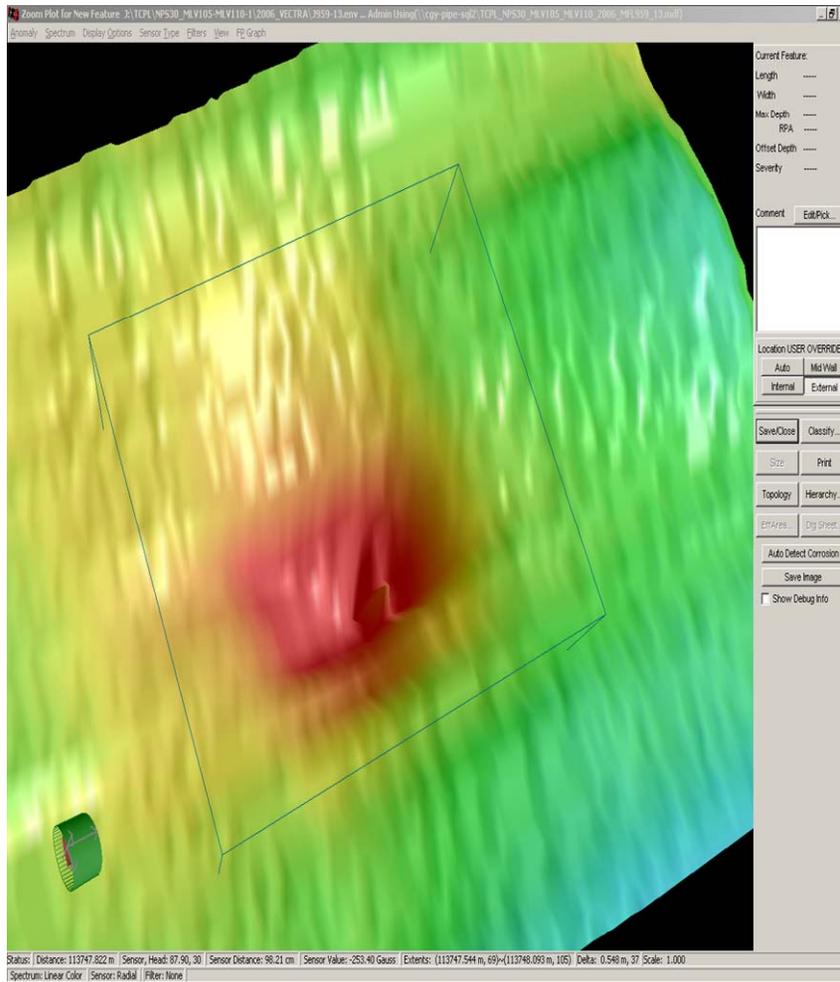
- ◆ Increased number of sensors, data storage, battery capacity
- ◆ Improved data quality with solid state memory
- ◆ Bend passing capability down to 1.5D in most diameters
- ◆ Matched with the developments in analysis tools
- ◆ Hall sensors – accurate inspection at low inspection speeds

## MFL developments - 2

---

- ◆ Inertial mapping – inertial navigation system integrated into ILLI tools
- ◆ Three-axis Hall effect sensors (measuring axial, circumferential and radial components of flux) – improved feature detection and characterisation
- ◆ Gas bypass with active speed control – uninterrupted gas throughput
- ◆ Combination tools - e.g. combined MFL/geometry/mapping

# MFL developments – mechanical damage



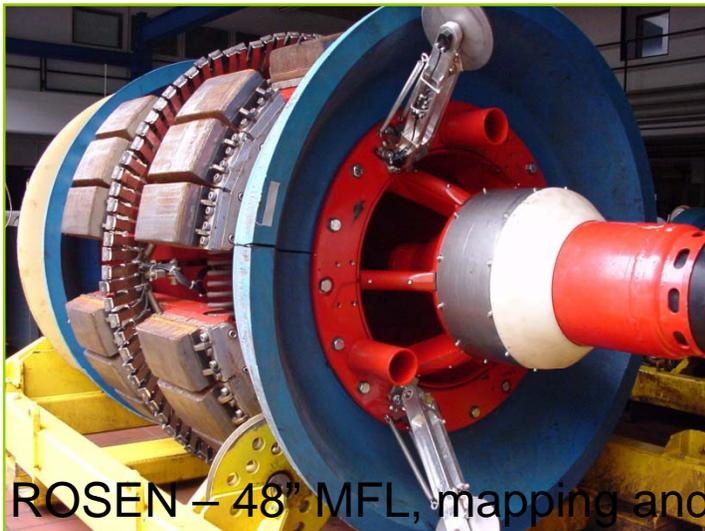
BJ, use of MFL triaxial sensors, 75% deep crack in 1% dent - gas **nationalgrid**

# MFL developments – 4

GE-PII MagneScan Triax



BJ – speed control with gas bypass



ROSEN – 48" MFL, mapping and speed control

# MFL developments – combo tools



ROSEN MFL, geometry and mapping

GE-P11 MFL and geometry



Baker Hughes 10" combo tool



**nationalgrid**

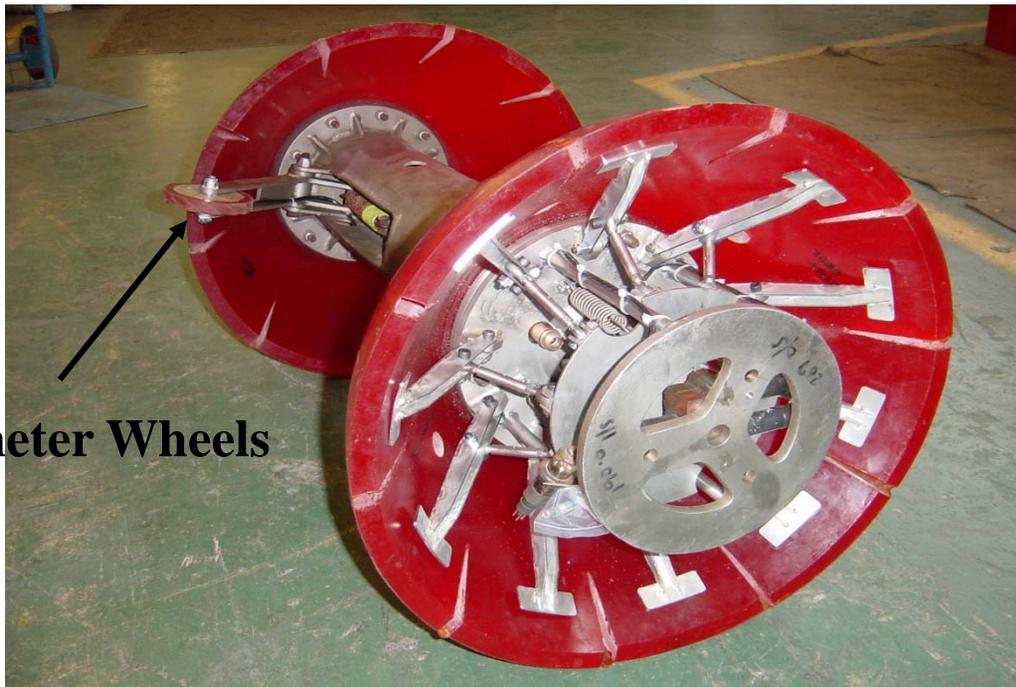
# Geometry/deformation tools

---

- ◆ Single channel geometry caliper
- ◆ Multi-channel high resolution caliper/geometry tools

# Single channel geometric (caliper) pig

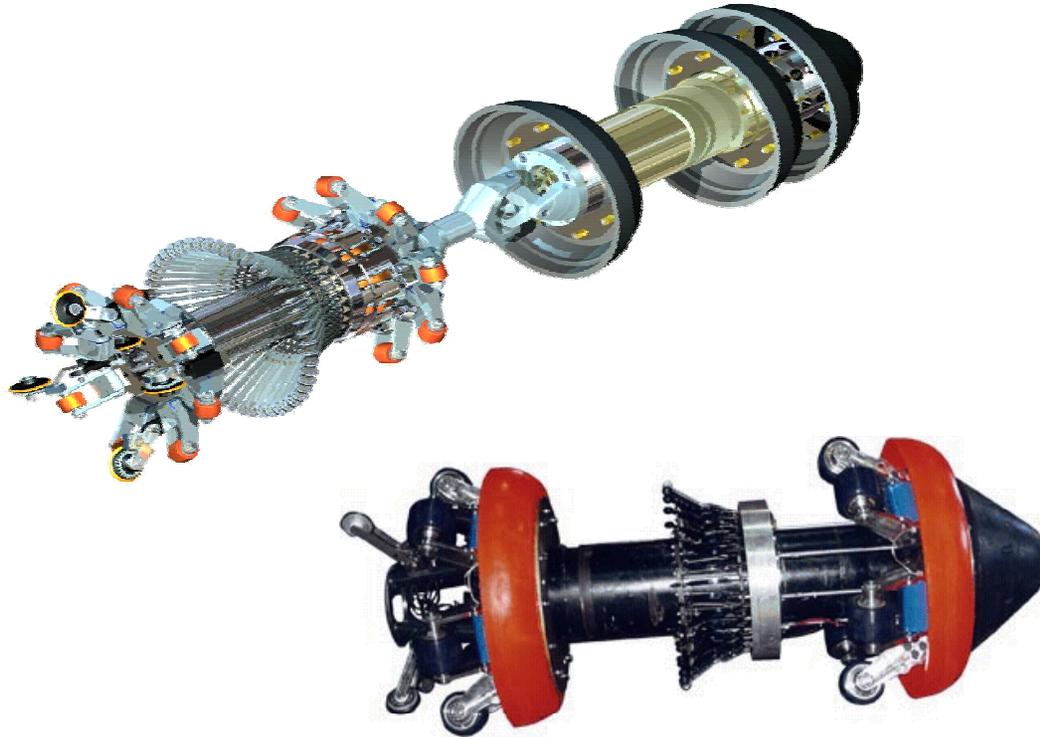
- ◆ Records any bore reductions in the pipeline
- ◆ Can identify pipeline features, such as bends, valves, thick wall
- ◆ Normally two runs to discount spurious debris readings
- ◆ Any long hold up or damage must be investigated
- ◆ Ideal velocity range 1.5 to 2.5m/s
- ◆ Only records peak depth (not shape or orientation)



Odometer Wheels

# High resolution geometry/deformation tools

- ◆ Geometry tool: Configuration pig designed to record conditions, such as dents, wrinkles, ovalities, bend radius and angle



ROSEN

# High resolution geometry results

---

- ◆ Data quality
- ◆ Main pipeline features, such as valves, tees, bends etc
- ◆ All bore reductions and geometric deformations, such as dents, wrinkles, buckles, partially closed valves, debris in pipeline etc
- ◆ Profile of all dents, wrinkles, buckles and other bore changes

# Assessment of results

---

- ◆ Results to be reported in a suitable form to enable location and significance to be readily determined and to provide comparison with previous inspection results.
- ◆ Results of inspection should be examined as soon as possible and appropriate remedial work initiated to ensure the continued fitness for purpose of the pipeline.

# Initiative to improve inspection reporting and assessment of results

---

- ◆ National Grid initiative a couple of years ago to:
  - ◆ Improve the information provided in the Executive Summary of our GE-PII inspection reports
  - ◆ Improve how this information is assessed and acted upon
  - ◆ Improve skills and competencies
- ◆ Workshop held:
  - ◆ PMC - preparatory pigging and reporting specification
  - ◆ GE-PII - MFL tools, capability and reporting
  - ◆ Guidance and best practice for assessing results and application of damage assessment procedure

# GE-PII MFL inspection report - executive summary template

---

- ◆ Metal loss features due to corrosion
- ◆ Metal loss features with appearance of a gouge (note tool limitations)
- ◆ Smooth dents (note tool limitations)
- ◆ Smooth dents with metal loss (note tool limitations)
- ◆ Kinked dents (note tool limitations)
- ◆ Girth weld anomalies
- ◆ Mill and construction defects
- ◆ Ferrous metal objects near to the pipeline
- ◆ Eccentric casings
- ◆ Pipeline repairs
- ◆ Pipeline anomalies
- ◆ Speed restrictions and degraded data



# Guidance on assessing the inspection results

---

- ◆ General guidance
  - ◆ Types of features or damage that are reported by the inspection tool and the types of damage in P/11 (damage assessment proc),
  - ◆ Range of technical skills required to review inspection report,
  - ◆ Review previous reports and other available data,
  - ◆ Tracking, audit and close out of actions from the inspection.
- ◆ Specific guidance on each of the topics in the GE-PII report
  - ◆ Metal loss features due to corrosion,
  - ◆ Metal loss features with appearance of a gouge,
  - ◆ etc.

# Industry initiatives

---

- ◆ ILI performance JIP
- ◆ PRCI - ILI projects: mechanical damage and corrosion
- ◆ National Grid update to Intervals

# ILI performance JIP - 1

---

- ◆ Members of phase 1 - BP, Gasunie, Gaz de France, National Grid.
- ◆ Review of methods and technology.
- ◆ Factors affecting ILI performance (reliability and accuracy).
- ◆ Review of modelling.
- ◆ Review use of post-run assessment.
- ◆ Next phase being conducted through PRCI.



## ILI performance JIP - 2

---

- ◆ Strong emphasis to be placed on field data validation rather than pull through or flow loop tests.
- ◆ The focus will be on data gathering and analysis.
- ◆ A high priority objective is to determine whether significant differences exist between the performances of tools.
- ◆ The quality of available field comparison data is a key factor.
- ◆ The initial focus will be on axial field MFL technology.

# PRCI – ILI projects

---

- ◆ Mechanical damage
  - ◆ Considerable effort on better detecting and characterizing mechanical damage from ILI
  - ◆ Dual field MFL demonstration
  - ◆ Performance of existing ILI tools for mechanical damage
- ◆ Corrosion metal loss
  - ◆ ILI tool performance (follow on from JIP)
  - ◆ Procedures for comparing successive ILI runs to establish corrosion growth
  - ◆ Re-inspection optimisation software

## PRCI: Dual Field MFL to detect mechanical damage - 1

---

- ◆ Establish the capability of dual magnetic field MFL to detect mechanical damage and discriminate between critical and benign anomalies.
- ◆ Aim is to find mechanical damage that has survived the initiation and will potentially grow to give a delayed failure.
- ◆ Development by Battelle, prototype tool being built by Rosen
- ◆ Trial in Enbridge pipeline later this year

## PRCI: Dual Field MFL to detect mechanical damage - 2

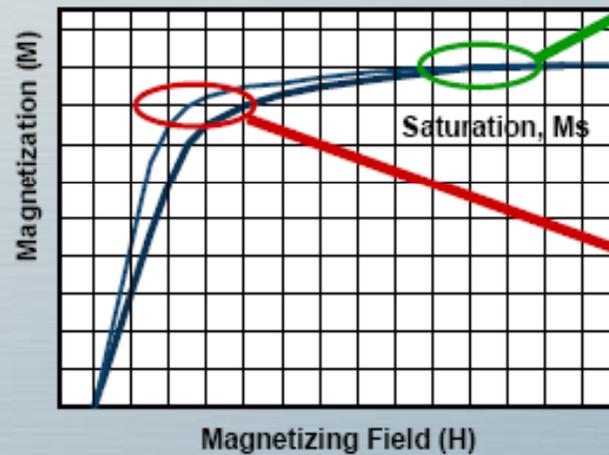
---

- ◆ To attain more accurate corrosion sizing information, MFL tools use high fields to reduce the variation in magnetic properties of pipeline steels
- ◆ MFL signals at high magnetization levels are almost entirely due to geometry changes (moved and removed metal)
- ◆ MFL signals at low levels are due to both geometry and magnetic changes
- ◆ Characterization: processing can show areas of
  - ◆ Cold working
  - ◆ Residual stresses

# PRCI: Dual field MFL concept

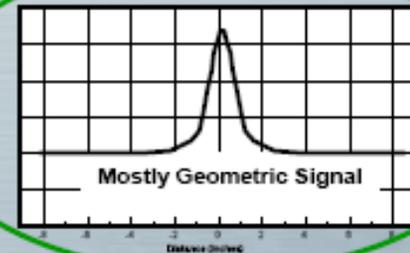
Defect: cold worked area with removed metal

Two magnetization levels



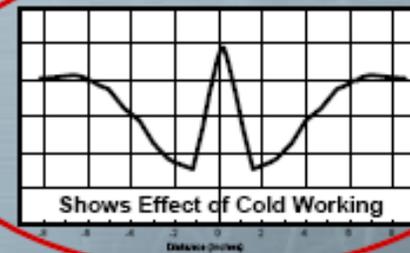
High Magnetization

150 Oersteds



Low Magnetization

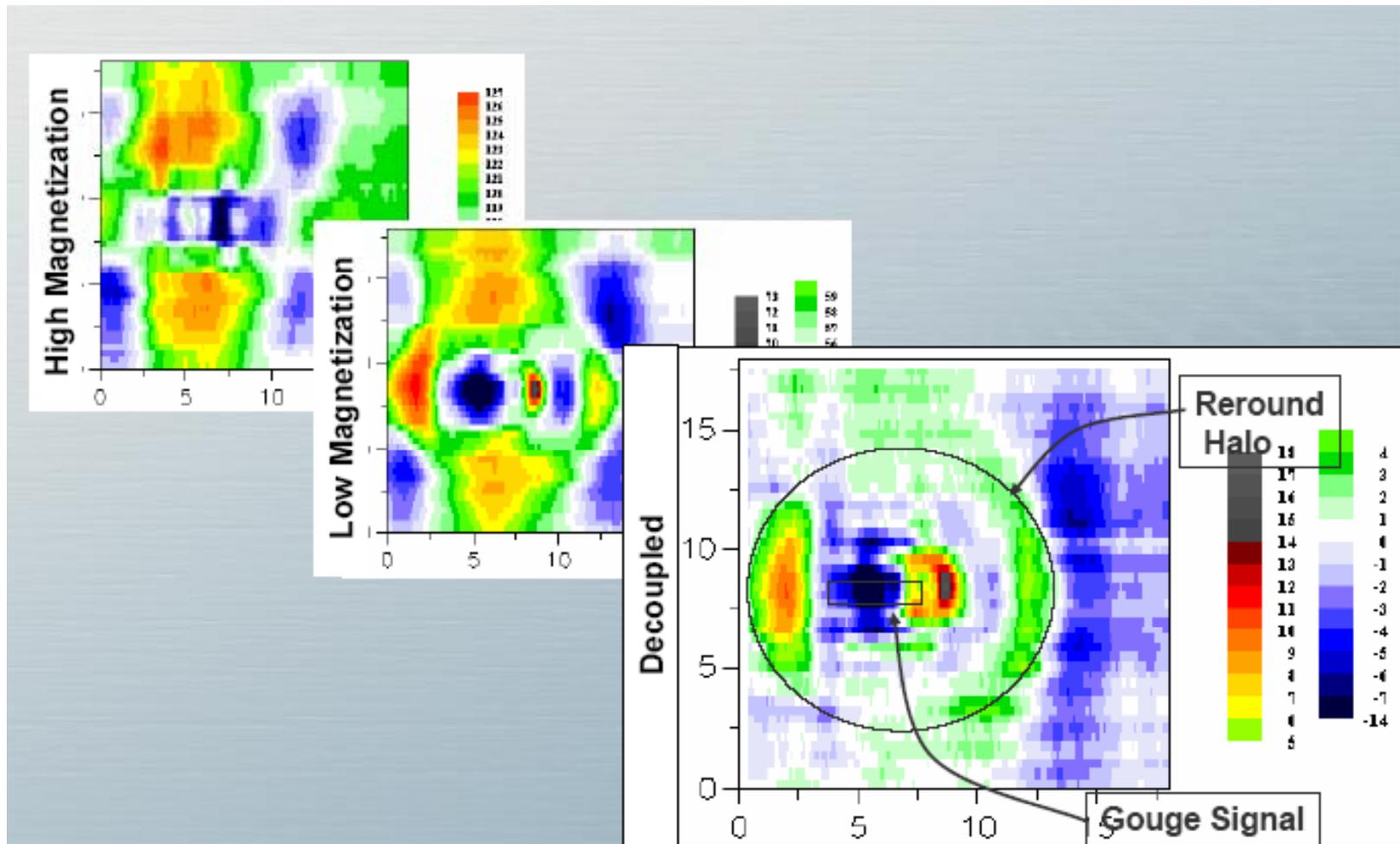
70 Oersteds



**Battelle**  
The Business of Innovation

**nationalgrid**

# PRCI: Dual field MFL - example



## **PRCI: Performance characteristics of current ILI technologies for mechanical damage detection - 1**

---

- ◆ Relative capability of commercial inspection methods (e.g. deformation tools, MFL tools etc).
- ◆ Capabilities, attributes and deficiencies of each method as they pertain to mechanical damage

## PRCI: Performance characteristics of current ILI technologies for mechanical damage detection - 2

---

- ◆ Provide a comprehensive and in-depth review and establish the current status of in-line-inspection technologies
  - ◆ Magnetic (Axial MFL, Circumferential MFL)
  - ◆ Ultrasonic (UT)
  - ◆ Electromagnetic Acoustic (EMATs)
  - ◆ Geometrical (Caliper) methods,
- ◆ Review in terms of their **capabilities**, **limitations** and **potentials** in **detection**, **discrimination** and **characterization** of various forms of pipeline mechanical damage such as dents with corrosion, dents with cracks (and other secondary features), gouges and dents combined with gouges

# National Grid: Intervals pipeline inspection scheduling - 1

---

- ◆ IGE/TD/1 requires pipeline inspection frequencies to be determined using a risk-based approach.
- ◆ Current Intervals – based on structural reliability model for growth of external corrosion, includes costing information on inspections and repairs but doesn't reflect current financial regime, includes user defined inputs (quality of CP etc), does not use full details of features below reporting threshold.
- ◆ New Intervals – based on structural reliability model for growth of external corrosion, greater emphasis on integrity, makes greater use of details of reported features.

# National Grid: Intervals pipeline inspection scheduling - 2

---

- ◆ New Intervals project
  - ◆ Project in progress, with prototype demonstrated, specification developed, pilot demonstration in progress
- ◆ Benefits
  - ◆ Improved emphasis on risk assessment approach, so can better manage the pipeline risks.
  - ◆ More flexible inspection - no plans to change 15 year inspection cap.
  - ◆ Greater confidence

# Safety

---

- ◆ Nitrogen purging to ensure safe atmospheres
- ◆ Loading/unloading of pigs
- ◆ Opening of pig trap doors
- ◆ Ensure either side of pig is fully depressurised
- ◆ Non-routine operations, with detailed written procedures giving valve operating sequences
- ◆ Pig cleaning and disposal of any waste (NORM dust)



# Pig cleaning

---



# Concluding remarks

---

- ◆ High resolution MFL is widely used to detect metal loss
- ◆ Increasing use of high resolution geometry/deformation tools
- ◆ ILI developments to better quantify mechanical damage
- ◆ Initiatives to better understand the actual performance of ILI tools
- ◆ Reminder of the importance of safety