ILI Axial Strain Measurement – sharing of over 10 years of operational experience and technology advances for the future

Phil English

Introduction

- Why was AXISS™ developed?
- Axial versus bending strain
- 10 years of operational success – how was the tool used successfully?
- Managing the pipelines total stress landscape
- New AXISS Generation - Advancements

Why was AXISS developed?

- Joint Industry Program (JIP)

- Geotechnical hazards, e.g.:
  - Landslides
  - Subsidence
  - Excavations
  - Erosion

- Operational conditions/loading

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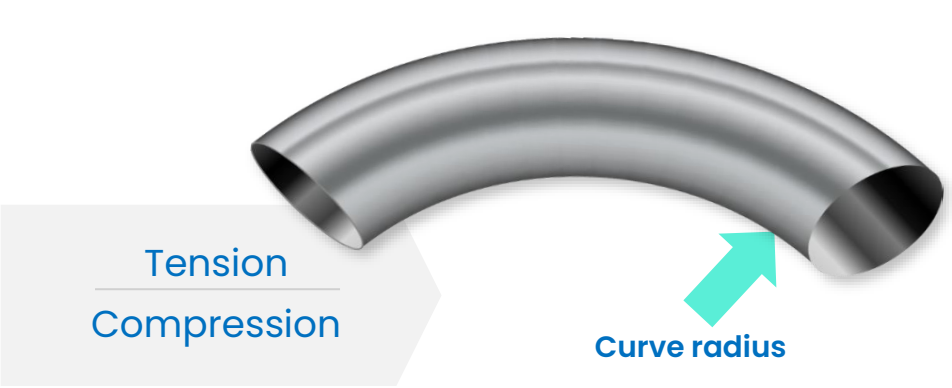
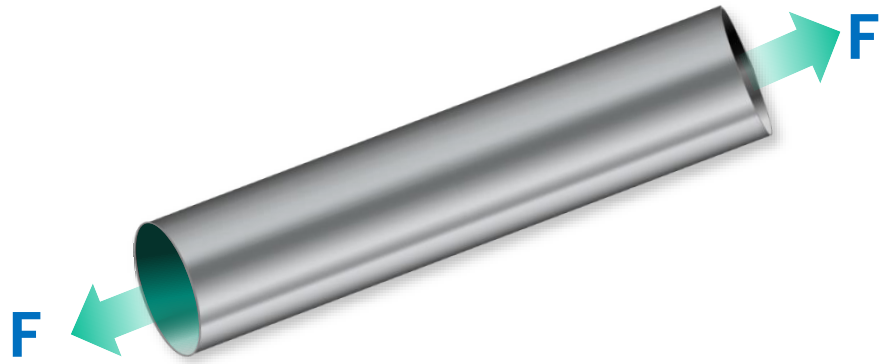
Axial versus bending strain

Bending strain



- Strain is defined as the increase in length divided by the original length
- Any pipe with forced curvature over any distance will result in a bending strain
- The pipe wall may experience a resulting tensile and compressive stress

Axial strain



- Strain is defined as the increase in length divided by the original length
- Any pipe with expansion or shrinking in the direction of flow of product will cause axial strain
- The pipe wall may experience a resulting tensile or compressive stress

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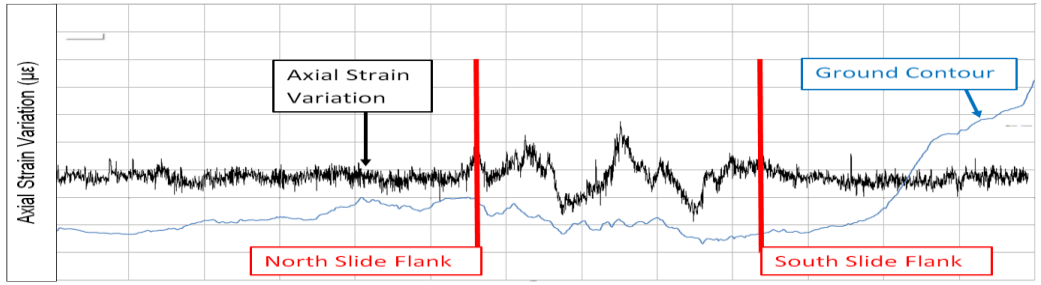
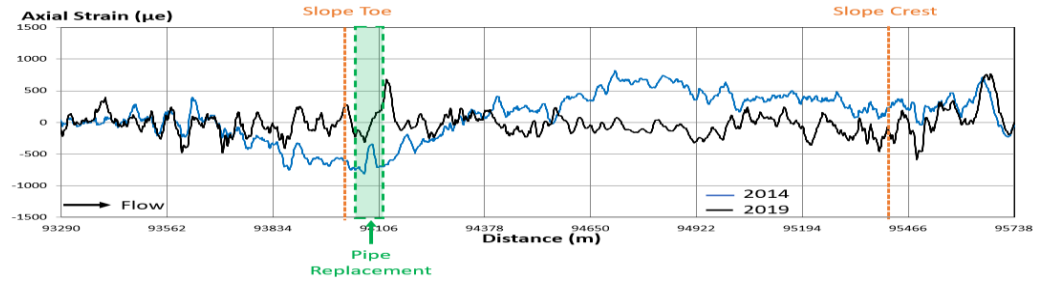
How has AXISS been used successfully?

10 Years of Operational Success

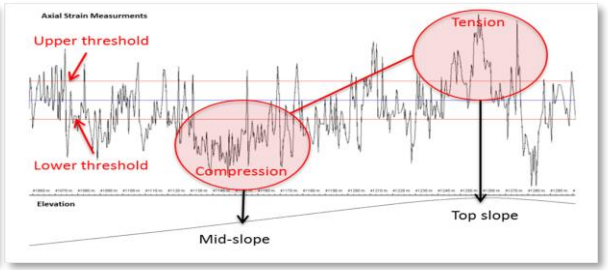
200+	Total AXISS Projects
Over 25,000 kms	Total kms inspected
1150	Strain Features Detected



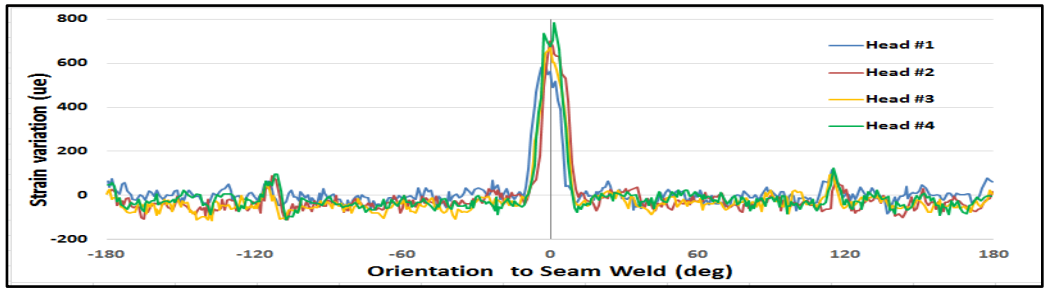
Strain Feature Identification



Monitoring



Geohazards



Residual Strain from manufacturing and construction

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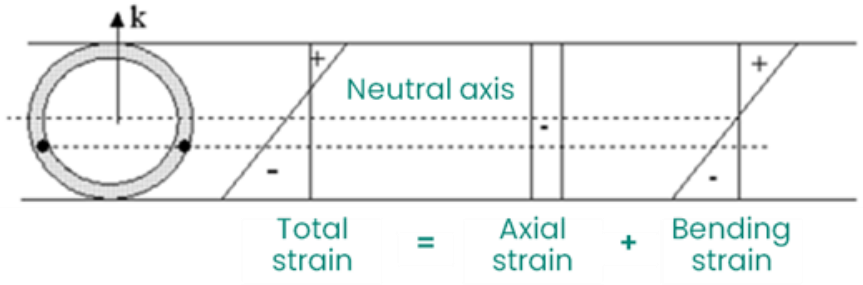
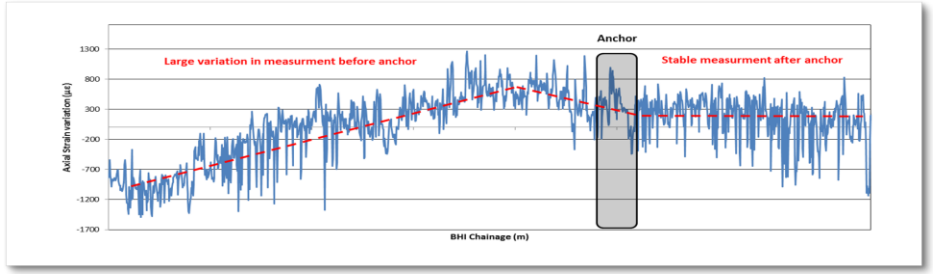
How has AXISS been used successfully?

General Benefits

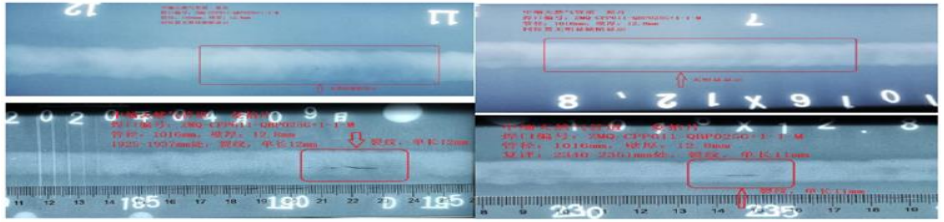
- Reduction in the number of digs needed
- Elimination of the need for destructive tests and associated cut-outs
- Reduction in costly surface and geotechnical surveys
- Measurement of current total axial strain accumulated through pipeline history
- Improved confidence in pipeline integrity assessments
- Improved safety by assessment for potential injurious geohazards before they become critical
- Reduced repair costs by minimizing unnecessary mitigation



Total longitudinal strain demand



Effectiveness of strain mitigation methods



Augmenting susceptibility models for select local features

Threats amplified by introducing H_2 into pipelines

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Case Study:
Outside force – N. Europe - Lowland

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18” Natural Gas Pipeline

Pipeline Length	: [redacted]
Diameter	: 18 inch (863.6 mm)
Commissioned	: c. 1967
Constructed	: 1967
Pipe Specification	: API 5L Grade B
Nominal Wall Thickness	: 9.52 mm (12.7 mm)
Specified Minimum Yield Strength	: 245 MPa
Ultimate Tensile Stress	: 415 Mpa
MAOP	: 34 bar
Design Pressure	: Unknown
Hydrotest Pressure	: Unknown
Product	: Natural Gas

Feature of interest

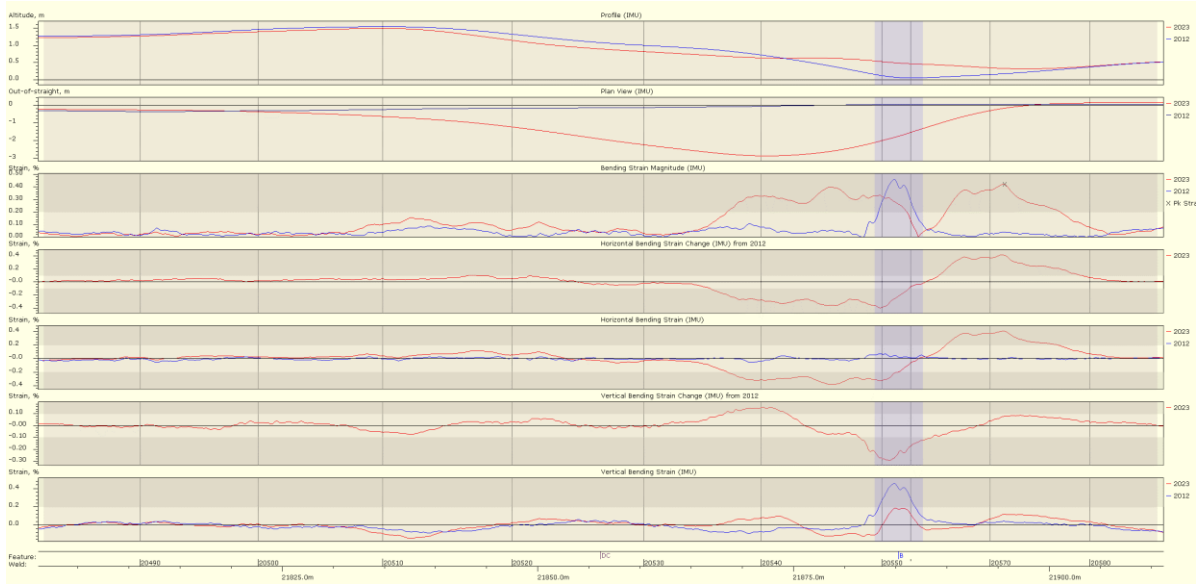
BH performed a strain assessment in 2012 showing no indication of issues.

This was repeated in 2023.

A feature of interest was identified due to the magnitude of the absolute bending strain measured in the 2023 inspection but also the change since 2012.

Max out-of-straightness: c.3m

The bending strain feature extended from approximately 21,825m to 21,920m, c.95m



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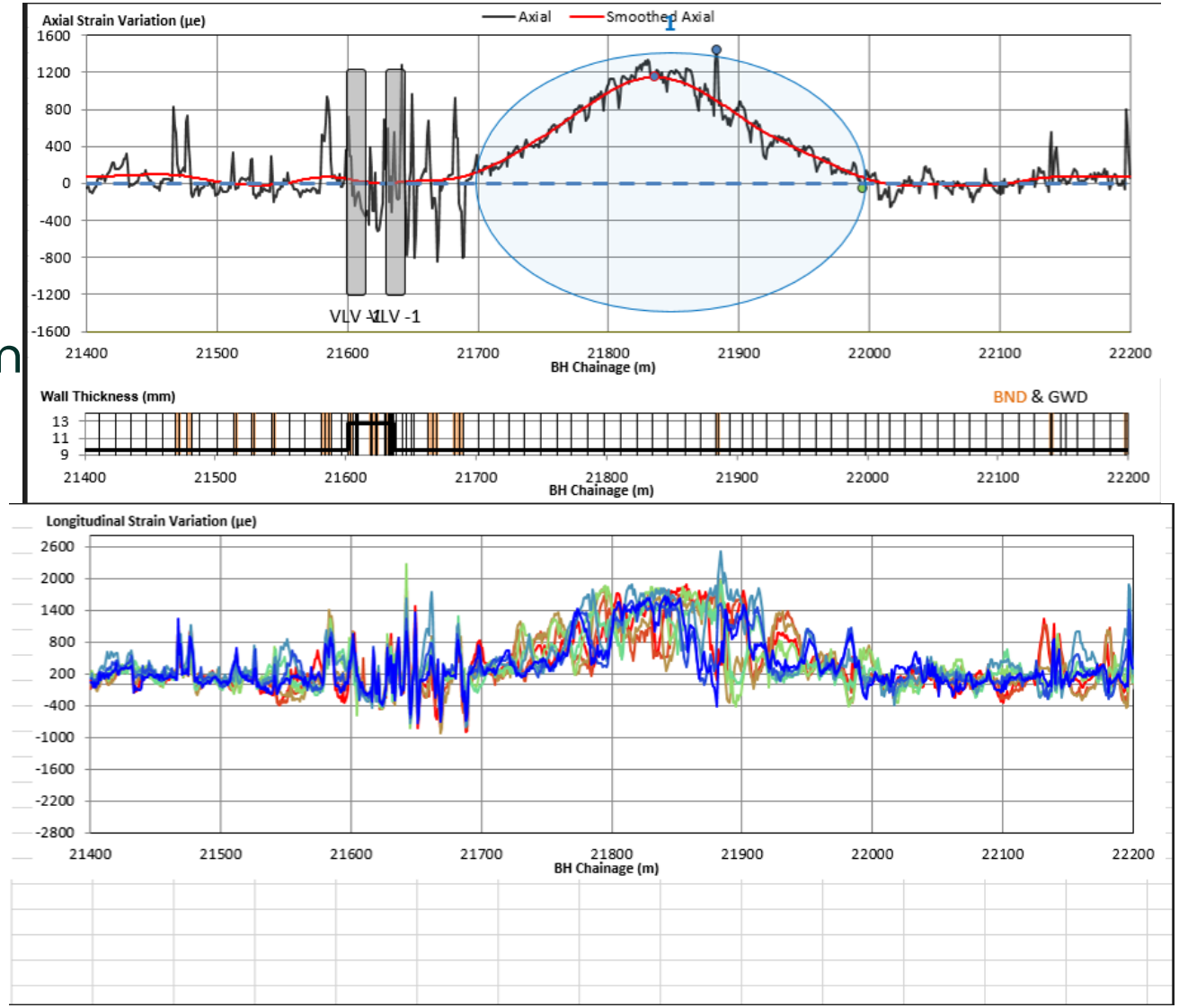
Further investigation

Axial strain

Identified increased pipeline loading from 21,700m to 22,000m, c.300m.

Line shutdown and client excavating/remediating.



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AXISS Bi-axial Stress Measurement Applications

Geohazard/Movement Monitoring Assessment

- Identify areas of the pipeline affected by external loading.
- Quantify effect of external loading and determine threat to integrity.
- Monitor the ongoing effect of active and changing external loads over time.
- Prioritise and optimize repairs.
- Assess success of mitigation activity.
- Remove unnecessary safety factors to offset "unknowns."

Construction & Manufacturing Defect Assessment

- Understanding the as-built condition and integrity of the pipe.
- Understanding of areas of poor quality and strength and the significance of them.
- Understand the influence of the stress history of the pipeline through manufacturing and construction.
- Quantify residual stresses and understand their influence on operational active loading and stress concentrations.
- Remove unnecessary safety factors to offset "unknowns."

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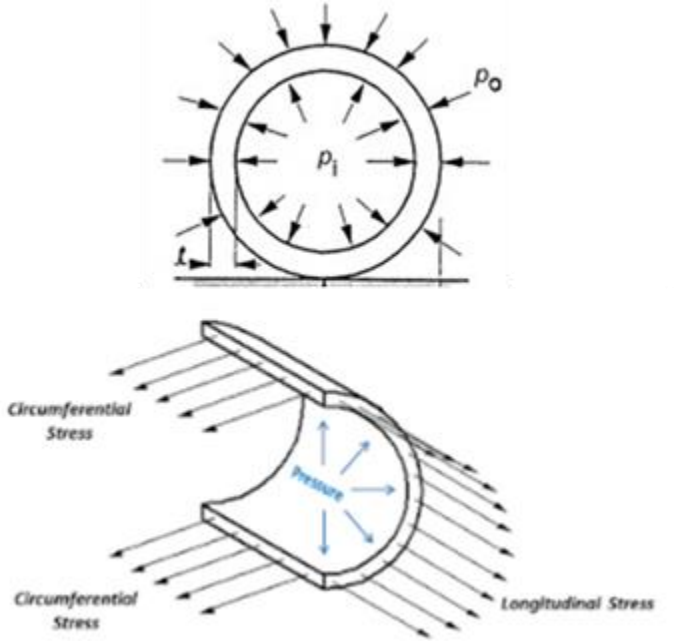
AXISS Advancements

- Next generation AXISS system targeting advancements needed based on years of operators' feedback and clear knowledge of industry requirements.
  - Addition of proprietary sensors to directly measure bi-axial stress.

- Reporting stress/strain in both plastic (patent pending) which enables:
  - Identification of plastically deformed regions.
  - Threat quantification and prioritization of high-risk zones within plastically deformed pipe sections.
  - Quantification of residual stresses and their influence on operational active loading and stress concentrations .
  - Assessment of high stress concentration zones upstream and downstream of GWD.
  - Prioritisation and optimisation of repairs.



Sizes 12-48"

Extensive validation and technical development successfully completed.

Overall performance exceeds existing strain probe capabilities.

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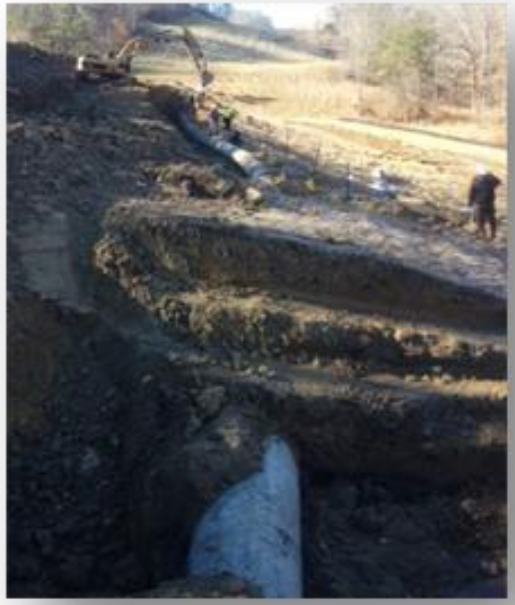
AXISS Advancements

- High resolution sampling
  - Refine GWD strain assessment.
  - Enable more precise integration and alignment with other inspection data for critical flaw integrity assessment – including level 3 assessments.
  - Increase POD and POI of higher risk conditions from operational and residual stress areas interacting with other stress concentrators.
- Run in combination with MagneScan™ and VECTRA™ GEMINI hybrid tools.
- Backward compatibility to support run-to-run analysis between current and new AXISS generations data sets.



Pilot runs Q4 2024 for field validation.

Delivers stress/strain in elastic and plastic regions

Patents pending.

Operational, analysis and reporting process optimized based on 10 years of experience.

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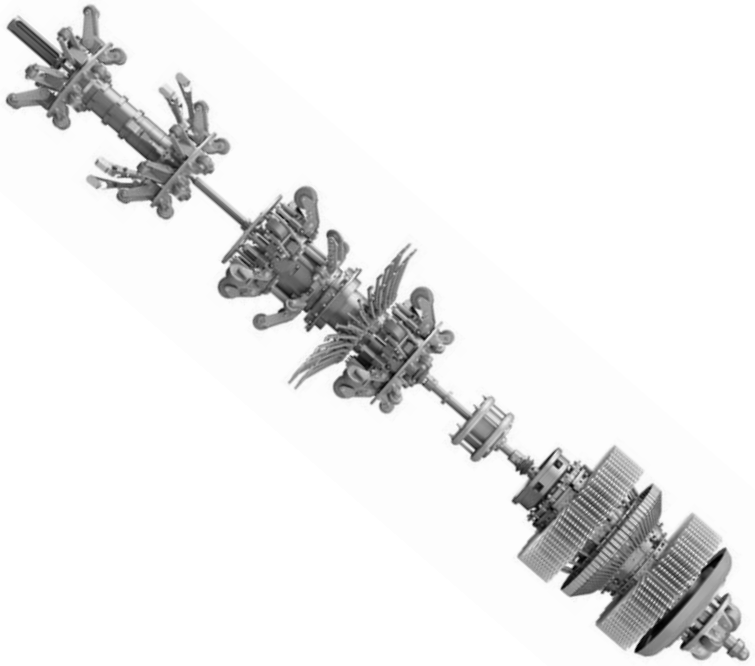
Conclusions



Many critical features continue to be identified and mitigated by today's technology.

New AXISS generation is in advanced phases of development capturing operational experience and valuable insights provided by operators aiming to improve effectiveness of the application.

Next Generation removes remaining gaps of information, that currently need to be estimated to complete comprehensive fitness for service assessments.

With new capabilities, it is anticipated that ILI stress and strain measurement will play an increasing role in regular pipeline monitoring, validation and in the energy transition.

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Questions?

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