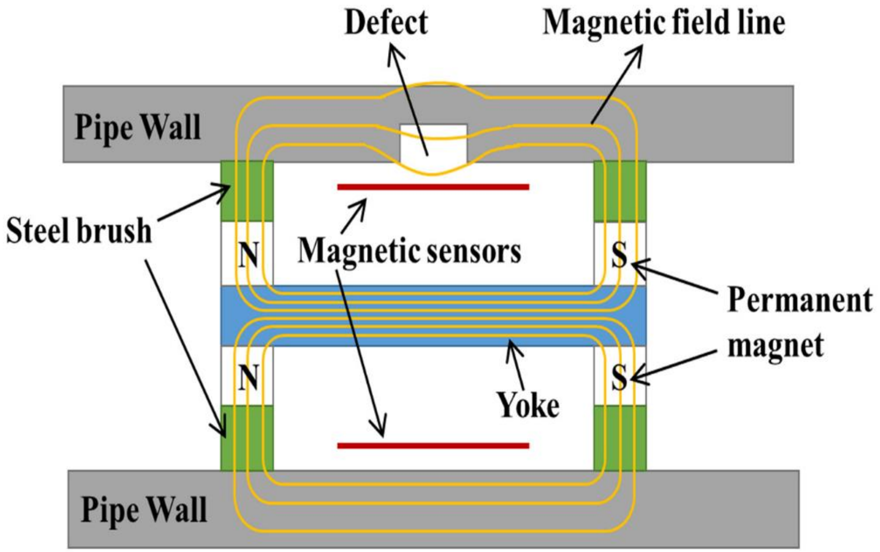
Indraprastha Gas Ltd

- New Technologies for Health Assessment of Piggable & Non-Piggable Pipeline

Assessing the health of pipelines, whether piggable (able to be inspected internally using pipeline inspection gauges, or "pigs") or non-piggable, is crucial for maintaining infrastructure integrity and preventing failures.

Here are some of the latest technologies and methods for both types of pipelines:

For Piggable Pipelines



1.Magnetic Flux Leakage (MFL):

MFL pigs use strong magnets to magnetize the pipeline and sensors to detect leakage fields caused by metal loss (like corrosion or pitting).It's widely used for detecting corrosion and wall thickness variations.

How MFL Works

1. Magnetization:
   - The material under inspection is magnetized using a strong magnetic field, typically generated by permanent magnets or electromagnets.

2. Flux Leakage:
   - In the presence of a defect such as a crack or corrosion, the magnetic field "leaks" out of the material. This leakage occurs because the defect alters the path of the magnetic flux, causing it to exit and re-enter the material at different points.

3. Detection:

- Sensors (such as Hall effect sensors, magnetoresistive sensors, or induction coils) are used to detect the magnetic flux leakage at the surface of the material. These sensors convert the magnetic flux leakage into electrical signals.

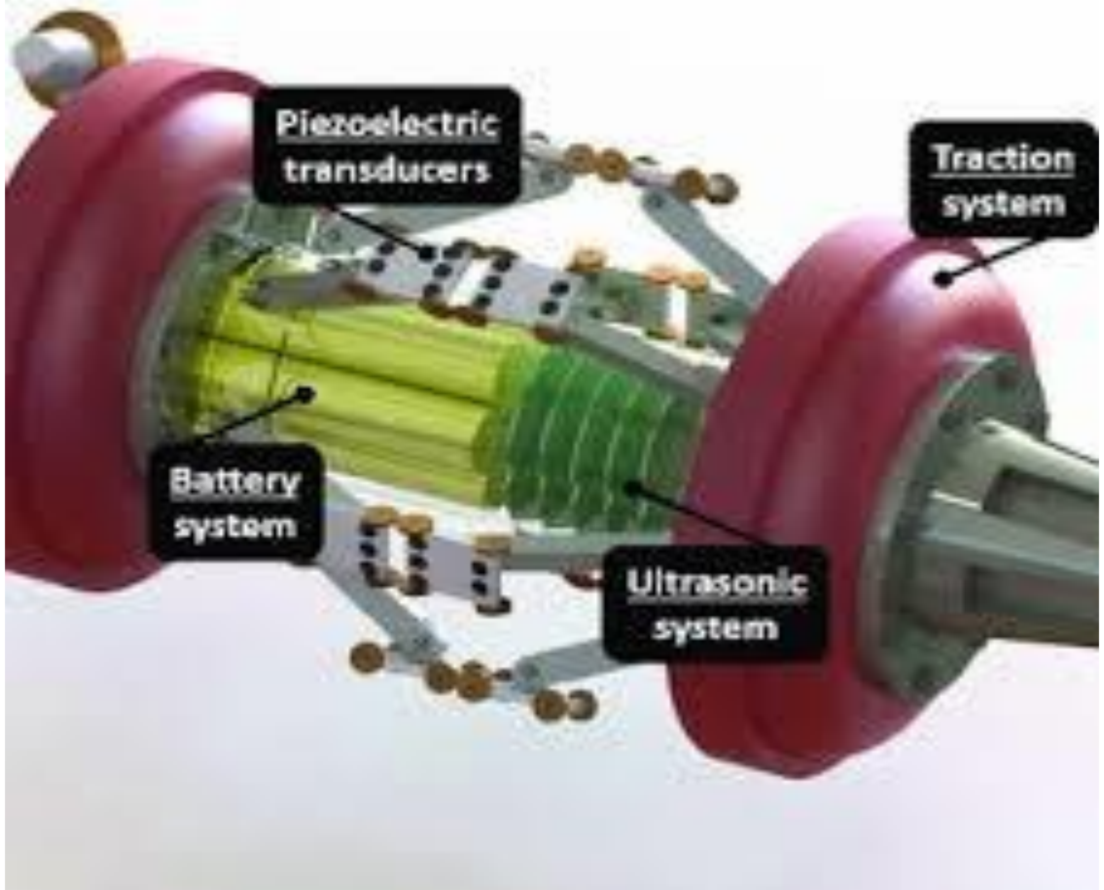
4. Data Analysis:

- The collected data is then analyzed to determine the location, size, and nature of the defect. This analysis can be performed using software that generates a visual representation of the detected anomalies

2.Ultrasonic Testing (UT):

UT pigs send ultrasonic waves through the pipeline walls to measure wall thickness and detect cracks.

Advanced UT tools can provide detailed 3D images of the pipeline's interior.



How UT works

1. Design: A smart pig equipped with UT sensors is designed to travel through the pipeline. These pigs can be propelled by the product flow or by a separate driving mechanism.

2. UT Sensors:
These sensors emit ultrasonic waves and receive the echoes reflected back from defects.
- Data Storage: The pig has onboard data storage to record inspection data.
- Battery: It is powered by batteries to operate the sensors and data recording systems

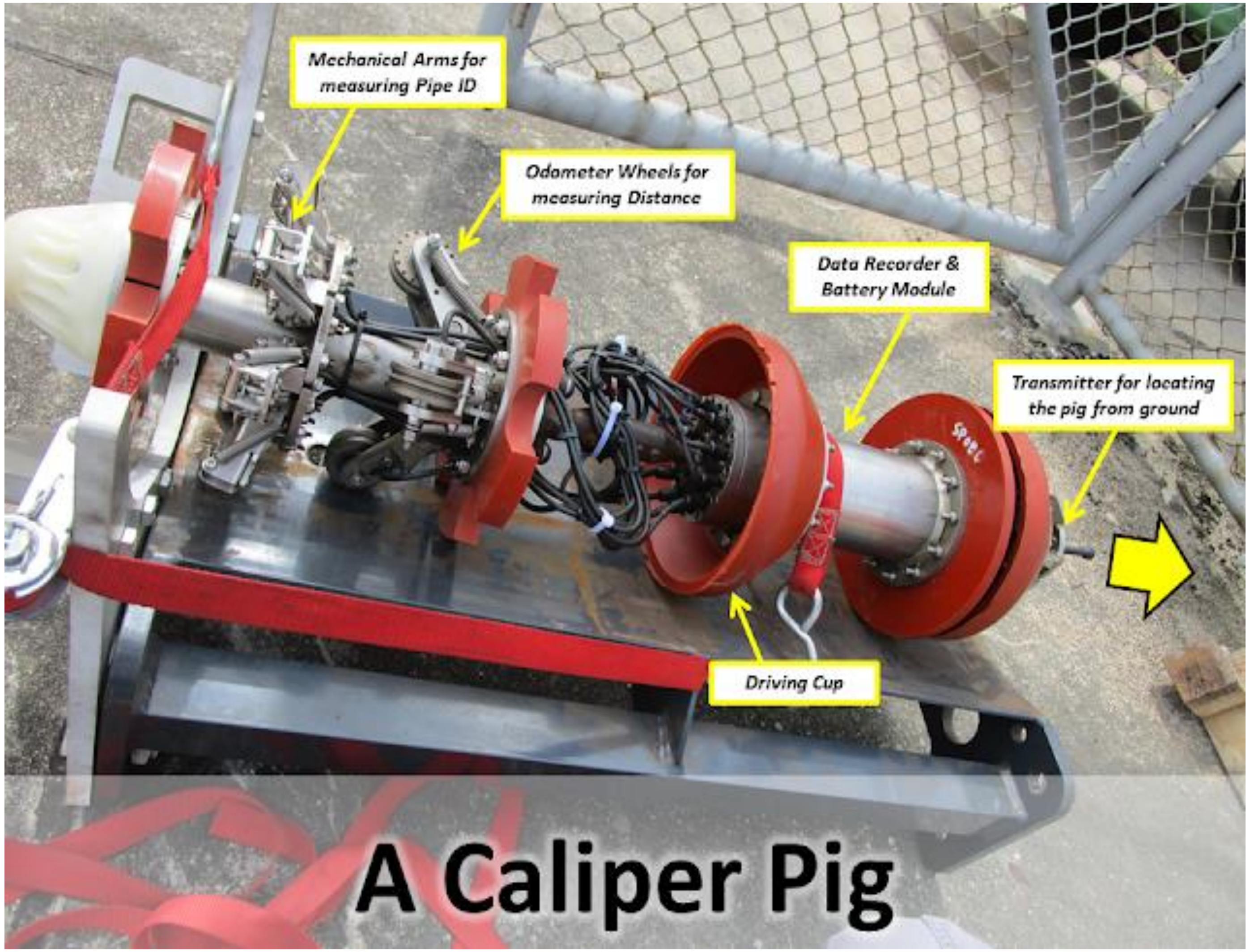
3. Traveling and Data Collection:
As the pig travels, the UT sensors continuously emit ultrasonic waves into the pipeline wall and receive the reflected echoes. The data collected includes the time-of-flight of the echoes, which is used to determine the location and size of defects..

4. Data Analysis:
- Advanced software is used to visualize the pipeline's interior, highlighting areas with anomalies or defects.
- Based on data it is characterize the type and severity of defects, such as cracks, corrosion, or wall thinning.

3. **Caliper Pigs**

These tools measure the internal geometry of the pipeline, identifying dents, deformations, and other anomalies that could affect pipeline integrity.

What is Caliper Pigging? Caliper Pipeline Integrity Gauges (PIGs) use mechanical arms to accurately record the geometric conditions of a pipeline as well as pipeline features by measuring changes in a pipeline's internal diameter (I.D.).

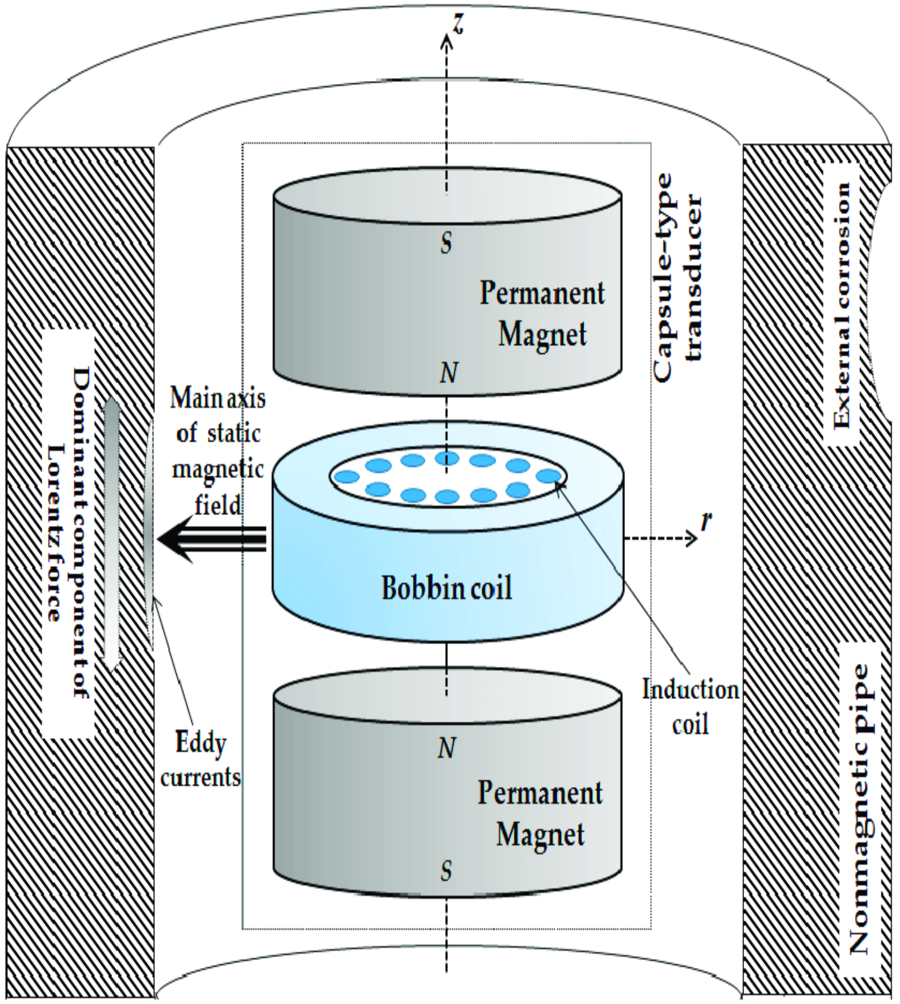


4.Electromagnetic Acoustic Transducer (EMAT):

EMAT generates ultrasonic waves without direct contact with the pipeline, useful for detecting cracks, corrosion, and other defects in challenging conditions.

5. Inertial Mapping Unit (IMU):

Combined with MFL or UT tools, IMUs help in mapping the pipeline's route and identifying areas of deformation, bending, or other mechanical damages.



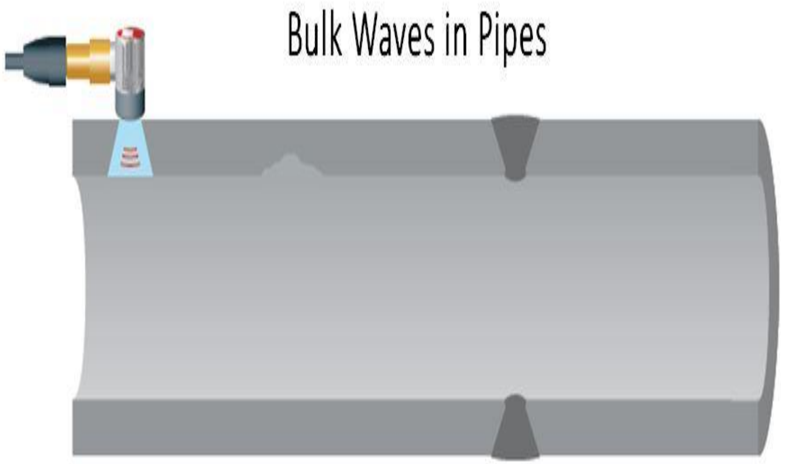
For Non-Piggable Pipelines

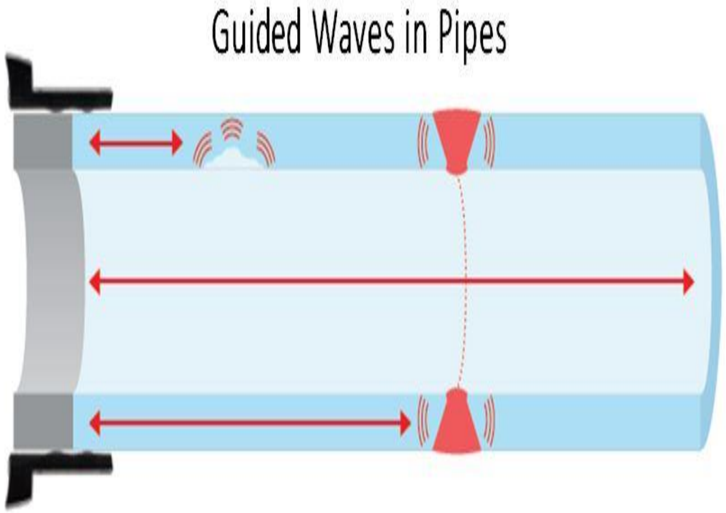
1. External Corrosion Direct Assessment (ECDA):
   ECDA involves external surveys such as close-interval surveys (CIS) and Direct current voltage gradient (DCVG) to detect corrosion.

2. Direct Assessment Techniques
   These techniques involve excavating and inspecting specific sections of the pipeline based on risk assessments and indirect inspection results.

3. Guided Wave Ultrasonics (GWUT):
   GWUT uses low-frequency ultrasonic waves that can travel long distances along the pipeline,detecting corrosion, cracks, and other defects from a single inspection point

4. Acoustic Emission (AE) Monitoring:
   AE monitoring detects the release of energy from defects such as cracks or corrosion in real- time, providing continuous monitoring of pipeline integrity.





5. Remote Field Eddy Current (RFEC):

RFEC technology uses electromagnetic fields to detect internal and external corrosion,wall loss, and other defects.It can inspect pipelines through coatings and insulation.By inducing eddy currents and measuring their response.

6.Long Range Ultrasonic Testing (LRUT):

Similar to GWUT, LRUT sends ultrasonic waves along the pipeline to detect changes in wall thickness and other defects over long distances.

7. Fiber Optic Sensing:

Fiber optic cables installed along pipelines can detect changes in temperature,strain, and vibration, indicating potential leaks or mechanical damage.

Integrative and Advanced Techniques

1. Machine Learning and AI:
   Advanced algorithms can analyze data from various inspection tools to predict failures and identify patterns that might indicate emerging issues.
   These technologies analyze large datasets from various inspection methods to identify patterns, predict potential issues, and optimize maintenance schedules.

2. Digital Twins Technology:
   Creating digital replicas of pipelines using data from inspections and sensors to simulate and analyze pipeline behavior under different conditions.

3. Drones:
   Equipped with high-resolution cameras and sensors, drones can inspect pipelines from the air, providing visual and thermal imaging to detect leaks and damage.

COMMON TECHNOLOGY IN USE FOR PIGABLE AND NON PIGABLE PIPELINE

Magnetic Tomography Method (MTM) is an advanced non-destructive testing (NDT) technique used for the inspection of non-piggable and piggable pipeline. This method is particularly useful for detecting and evaluating pipeline defects such as corrosion, cracks, and other anomalies without the need for internal inspection tools (pigs).

Principles of Magnetic Tomography Method (MTM)

1. Magnetic Field Measurement:
   MTM relies on measuring the natural magnetic field around a pipeline. When pipelines are subjected to stress (due to pressure, temperature changes, or mechanical forces), they generate a magnetic field due to the magnetoelastic effect.

2. Anomaly Detection:
   Defects or irregularities in the pipeline structure alter the magnetic field distribution. MTM sensors detect these changes in the magnetic field.

3. Data Acquisition and Processing:
   The sensors collect magnetic field data along the pipeline's length. This data is then processed using specialized algorithms to identify and locate areas with abnormal magnetic signatures indicative of potential defects.

4. Non-Contact Inspection:
   MTM is a non-contact method, meaning it does not require direct access to the pipeline's interior. This makes it ideal for pipelines that are buried, underwater, or inaccessible for conventional pigging operations.

Advantages of MTM

- Non-Intrusive: Since it doesn't require insertion of tools into the pipeline, it avoids the need for shutdowns or disruptions in pipeline operations.

- Suitable for Complex Pipelines: It can be used on pipelines with bends, varying diameters, or other features that make them non-piggable.

- Early Detection: MTM can detect early-stage defects, allowing for timely maintenance and repair before severe damage occurs.

- Safety: Reduces the need for potentially hazardous physical inspections, especially in difficult-to-access or hazardous environments

Application Process

1. Pre-Inspection Planning:
   - Evaluate the pipeline's layout, material, and operating conditions to plan the inspection.
   - Determine sensor placement and coverage area.

2. Field Data Collection:
   - Deploy MTM sensors along the pipeline route. These sensors can be handheld or mounted on vehicles for long pipelines.
   - Collect magnetic field data over the pipeline’s length.

3. Data Analysis:
   - Process the collected data using MTM software to identify magnetic anomalies.
   - Analyze the anomalies to determine the type, size, and location of defects.

4. Reporting:
   - Generate detailed inspection reports outlining the condition of the pipeline, identified defects, and recommendations for maintenance or further investigation.

Case Studies

For 12” dia DESU-Maruti Pipeline - 16 years at operating pressure 22Kg/cm2 .

The carried out complex health assessment of the gas pipelines included:

- Analysis of provided documentation deals with the pipeline design and operating parameters
- Computer modeling of gas pipelines deflected modes;
- Pipelines Contactless Magnetometric Diagnostics (CLMD);
- Additional inspection (dig verification) in the zones of class II anomalies identified by the CLMD survey.

Figure 4.1 12” dia DESU-Maruti Pipeline from SV-5 to SV-10

Figure A3.42. Scheme of localized anomalies (Stress Concentration Zones) at the « DESU-Maruti » pipeline

Figure 1. Damaged coating (A1 dent 25x35x6 mm)

Out of 14 class II anomaly, 4 anomalies were dig and verified and no significant metal loss was observed in all 4 of verified anomalies.

Class I – Sections of the pipeline with possible corrosion or mechanical defects. Mandatory test in the pits by conventional NDT methods;

Class II – Sections of the pipeline, with possible defects, the value of which has not reached critical values.

Class III – Pipeline sections that require careful attention during subsequent inspections by CLMD to evaluate the trends in the stress-strain state.

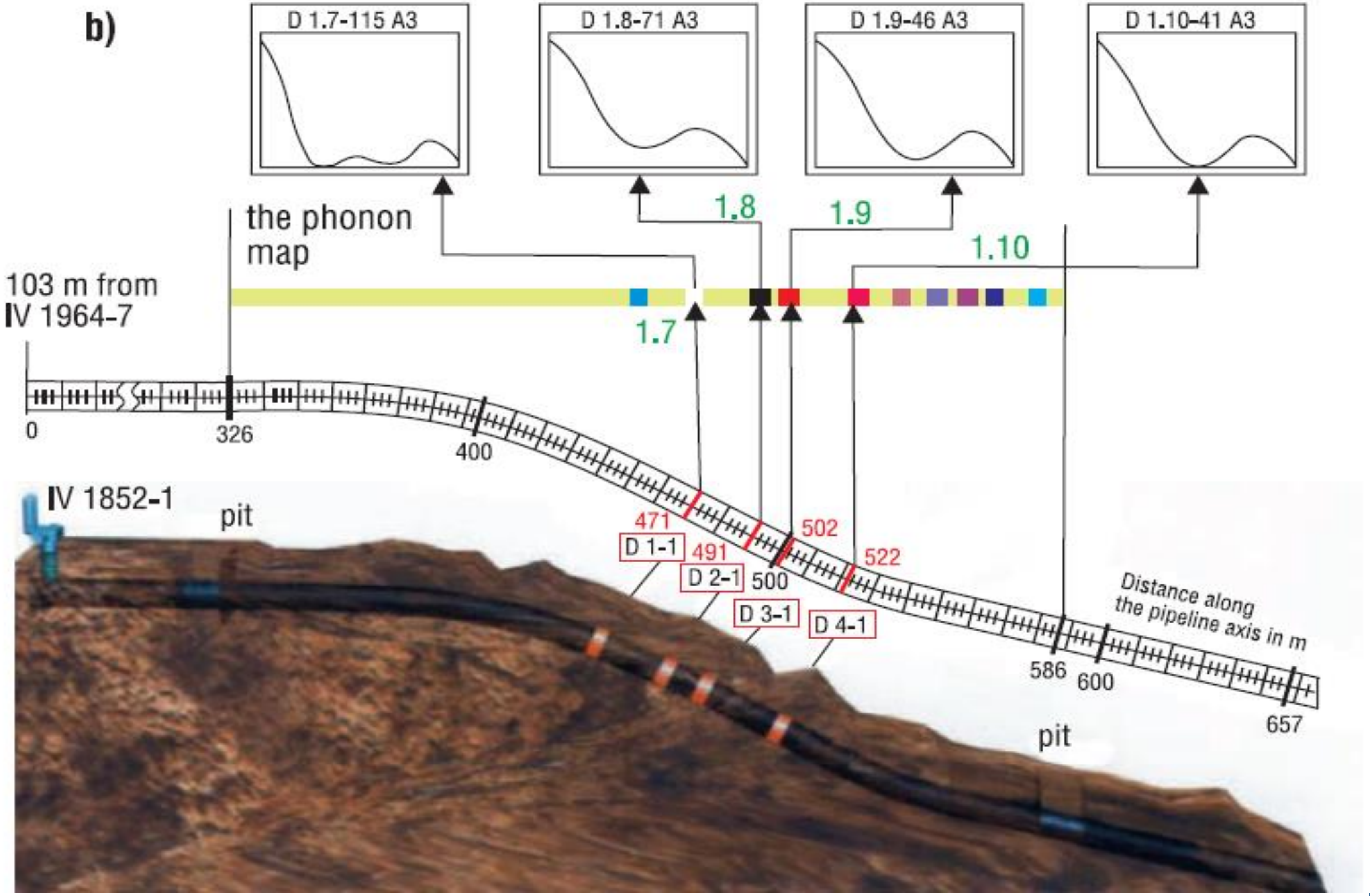
Limitations

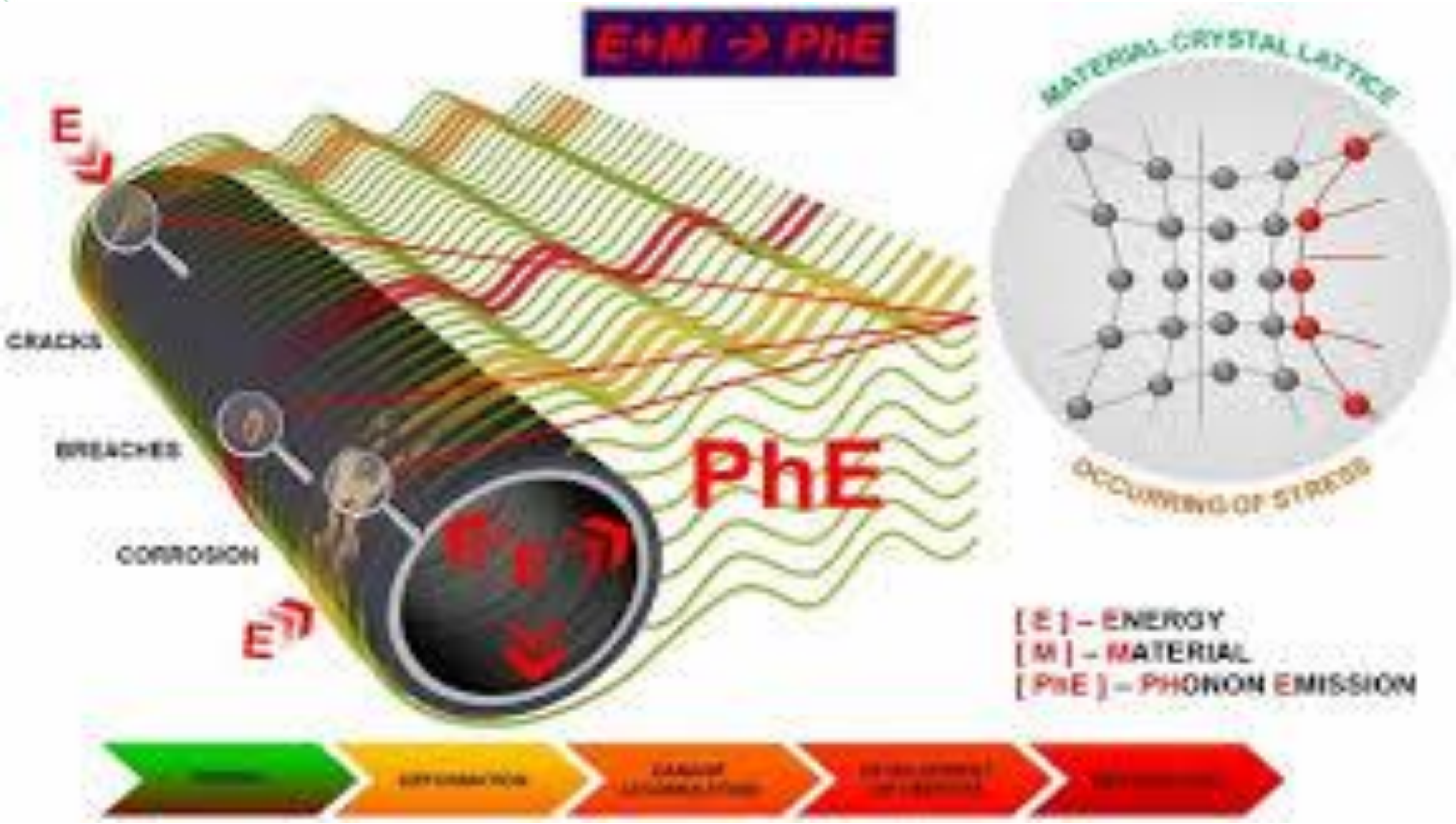
- Sensitivity to Environmental Noise: Magnetic field measurements can be affected by external magnetic sources, requiring careful filtering and calibration.

- Depth Limitations: Effectiveness can diminish with increasing pipeline burial depth or in highly magnetically noisy environments.

Overall, Magnetic Tomography Method (MTM) is a valuable tool for maintaining the integrity and safety of non-piggable pipelines, offering a blend of advanced technology and practical application that can significantly enhance pipeline inspection and maintenance programs.

Phonon technology can be used for pipeline health assessment through techniques that involve monitoring and analyzing the acoustic and vibrational characteristics of the pipeline material.




E+M → PhE
MATERIAL CRYSTAL LATTICE
E
CRACKS
BREACHES
CORROSION
E
PhE
OCCURRING OF STRESS
[E] – ENERGY
[M] – MATERIAL
[PhE] – PHONON EMISSION

Basics of Phonon Technology

Phonon technology involves the detection and analysis of sound waves (phonons) that propagate through materials. For pipelines, these sound waves can provide valuable information about the structural integrity and operational conditions of the pipeline.

Components of Phonon Technology Systems

- Geophones: Ground-based sensors that detect vibrations and sound waves transmitted through the soil surrounding the pipeline.

- Piezoelectric Sensors: Devices that convert mechanical vibrations into electrical signals, used for detecting sound waves on the pipeline surface

- Signal Processors: Devices that collect and process acoustic data from sensors, filtering out noise and identifying relevant signals.

- Data Loggers: Equipment that records acoustic data for analysis, storing large volumes of data over time

Installation and Deployment

a. Sensor Placement

- On-Pipe Sensors: Sensors can be directly attached to the pipeline at intervals to detect sound waves generated by internal leaks or structural defects.

- In-Soil Sensors: Sensors can be buried in the soil near the pipeline to detect acoustic signals propagating through the ground.

b. Network Configuration

- Distributed Sensor Networks:Deploy a network of acoustic sensors along the pipeline length to provide continuous monitoring coverage.

- Wireless Communication:Use wireless technology to transmit data from remote sensors to central monitoring stations, especially in difficult-to-access areas.

Acoustic Data Collection

a. Continuous Monitoring

- Real-Time Detection: Sensors continuously monitor the pipeline, capturing sound waves generated by leaks, cracks, or other anomalies.

- Event Recording: Record acoustic events that exceed predefined thresholds, indicating potential issues.

b. Periodic Inspections

- Scheduled Monitoring: Perform periodic acoustic inspections using portable sensors and equipment to supplement continuous monitoring systems.

- Data Comparison: Compare data from different time periods to identify changes and emerging issues.

Data Analysis and Interpretation

a. Signal Processing

- Noise Filtering: Use advanced algorithms to filter out background noise and enhance the detection of relevant acoustic signals.

- Frequency Analysis: Analyze the frequency spectrum of detected sound waves to identify characteristic signatures of different types of defects (e.g., leaks, corrosion, mechanical stress).

b. Anomaly Detection

- Pattern Recognition: Employ machine learning techniques to recognize patterns In acoustic data that correspond to specific types of pipeline defects or operational issues.

- Localization:** Determine the location of detected anomalies by analyzing the time delay and signal strength from multiple sensors.

Maintenance and Response

a. Preventive Maintenance

- Early Detection: Identify and address potential issues before they become critical, reducing the risk of catastrophic failures.

- Data-Driven Decisions: Use acoustic data to prioritize maintenance activities and allocate resources efficiently.

b. Emergency Response

- Rapid Intervention: Quickly respond to detected leaks or structural failures, minimizing damage and environmental impact.

- Safety Enhancements: Improve overall pipeline safety by providing early warnings and reducing the likelihood of accidents.

Advantages of Phonon Technology

- Non-Invasive: Phonon technology does not require direct access to the pipeline interior, making it suitable for buried pipelines.

- Real-Time Monitoring: Continuous monitoring capabilities provide immediate detection of issues, enhancing pipeline safety and reliability.

- High Sensitivity: Acoustic sensors can detect very small leaks and defects, allowing for early intervention and preventive maintenance.

Challenges and Considerations

- Environmental Noise: Acoustic signals can be affected by environmental noise, requiring advanced filtering and signal processing techniques.

- Sensor Placement: Optimal placement of sensors is critical for effective monitoring and accurate anomaly detection.

- Data Management: Handling large volumes of acoustic data requires robust data management and analysis systems.

Phonon technology, through the use of acoustic sensors and advanced signal processing techniques, provides an effective method for the health assessment of buried pipelines. By continuously monitoring acoustic signals, identifying anomalies, and enabling early detection of leaks and structural defects, phonon technology enhances the safety, reliability, and maintenance efficiency of pipeline infrastructure.

These advanced technologies and integrated approaches enhance the ability to detect, assess, and manage potential risks in both piggable and non-piggable natural gas pipelines, ensuring their safe and efficient operation.

THANK YOU