INTERNSHIP

REPORT

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Abstract

This report presents the summary of my six-week internship at MOL Pakistan Oil and Gas Company, where I was assigned to the Condition Monitoring and Inspection Department. During this period, I was actively involved in practical exposure to various non-destructive testing (NDT) techniques and condition monitoring practices used to ensure asset integrity and reliability in oil and gas operations.

My internship primarily focused on the application and understanding of advanced NDT methods such as Ultrasonic Testing (UT), Magnetic Particle Testing (MPT), Dye Penetrant Testing (DPT), Time of Flight Diffraction (TOFD), Phased Array Ultrasonic Testing (PAUT), and Long/Short Range Ultrasonic Testing (LRUT/SRUT). In addition, I contributed to and observed condition monitoring techniques including vibration analysis and infrared thermography, used for early detection of mechanical faults in rotating equipment such as pumps, motors, couplings, and fans.

This hands-on experience provided me with a deeper understanding of industry-standard practices, relevant API and ASME codes, equipment calibration, data acquisition, and the interpretation of inspection results. Overall, the internship enhanced my technical knowledge and skills in predictive maintenance and structural integrity assessment within a real-world oil and gas environment.

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Introduction

MOL Pakistan Oil and Gas Company B.V. is a subsidiary of the MOL Group, a leading international oil and gas company headquartered in Hungary. In Pakistan, MOL operates primarily in the **Tal Block**, located in the **Karak District of Khyber Pakhtunkhwa** province.

MOL entered the Pakistani market in 1999 and has since become a significant contributor to the country's energy sector. The company discovered its first oil and gas field in the Tal Block in 2002 and has since made multiple successful discoveries, including **Manzalai, Makori, Maramzai, Mamikhel**, and **Tolanj** fields.

The Karak region is especially important due to its **rich hydrocarbon reserves**, and MOL's operations here play a key role in **producing crude oil, natural gas, and LPG**. The company works in partnership with local and international firms, including **OGDCL, PPL, GHPL, and POL**, under a joint venture arrangement.

MOL is committed to **safe, efficient, and environmentally responsible** exploration and production, and it also contributes to the **socio-economic development** of local communities in Karak through education, health, and infrastructure project

Health, Safety and Environment (HSE) in Oil & Gas Industry

The HSE system in the oil and gas industry aims to protect **human life**, **assets**, and the **environment**. It ensures safe operations by controlling hazards such as flammable materials, high pressures, confined spaces, and hazardous chemicals.

Key Objectives:

- Prevent accidents and occupational diseases
- Ensure compliance with API, ASME, OSHA, ISO 45001, and local regulations
- Promote safety culture through training, hazard identification, and risk management
- Conduct regular audits and emergency response drills

Life-Saving Rules (LSR)

Life-Saving Rules are a set of critical safety rules developed by organizations like **IOGP (International Association of Oil & Gas Producers)**. Violating these can lead to serious injuries or fatalities.

Common Life-Saving Rules:

1. Work with a valid Permit to Work when required
2. Conduct gas testing when entering confined spaces
3. Verify isolation before work begins and before re-energizing
4. Use fall protection when working at height
5. Wear seat belts
6. Do not walk under suspended loads
7. No alcohol or drugs while working
8. Follow safe lifting procedures

Personal Protective Equipment (PPE)

PPE is the last line of defense against physical, chemical, biological, and thermal hazards.

Common PPE in Oil & Gas:

- Hard Hat (Helmet) – head protection
- Safety Goggles / Face Shield – eye protection
- Flame-Resistant Coveralls – fire/chemical protection
- Gloves – hand protection (mechanical/chemical)
- Safety Boots – foot protection

- Ear Plugs / Muffs – hearing protection
- SCBA (Self-Contained Breathing Apparatus) – for toxic atmospheres

Compliance Standards:

- ANSI/ISEA, EN, OSHA, API RP 15B, and company-specific standards

Permit to Work (PTW) System

PTW is a formal written system used to control certain types of work that are hazardous. It ensures proper risk assessment, authorization, and control before starting the job.

Types of PTW

1. **Hot Work Permit** – for welding, cutting, grinding (ignition sources)
2. **Cold Work Permit** – for non-sparking work like bolting, painting, mechanical jobs

Certificates

Confined Space Entry Permit – for work inside tanks, vessels, pits

Electrical Work Permit – for maintenance on electrical systems

Work at Height Permit – for any job above 1.8 meters (as per OSHA/API)

Excavation Permit – for trenching or digging

Lifting Operation Permit – for crane, hoist, or heavy load handling

Radiography Permit – for NDT using radioactive sources

Vehicle Entry Permit – for vehicles entering hazardous zones

Fire Tracking System

The Fire Tracking System in oil and gas facilities includes **real-time monitoring** and **incident response** through:

- **Heat and Smoke Detectors**
- **Flame Detectors** (UV/IR-based)
- **Gas Leak Detectors** (LPG, H_2S, CH_4, etc.)
- **Control Panels** linked to alarms and shutdown systems
- **SCADA and DCS** integration for live monitoring and historical trends
- Automatic alerts to fire control room and safety officers

Fire Fighting System

Designed to protect personnel and equipment in case of fire. It includes:

1. **Fire Extinguishers** (ABC type, CO_2, Foam)
2. **Fire Water Hydrant Network** – with hose reels and monitors
3. **Deluge System** – automatic flooding system for high-risk areas
4. **Foam Suppression System** – for flammable liquid fires (API 2030)
5. **Gas Suppression System** – like FM-200 for electrical panels
6. **Sprinkler System** – automatic ceiling-mounted fire suppression
7. **Fire Pumps** – electric and diesel backup, with Jockey pumps
8. **Emergency Response Team (ERT)** – trained firefighters and safety staff

Regulations & Guidelines:

- NFPA Standards (e.g., NFPA 10, 20, 25)
- API 2218, API RP 2001
- OSHA 1910 Subpart L
- ASME Section II and VIII (for pressure components of fire systems)

Corrosion Under Insulation (CUI) Inspection of Mild Steel Using DMS-2

Corrosion Under Insulation (CUI) is a serious and widespread form of corrosion that occurs on the external surfaces of insulated piping, tanks, and vessels. CUI affects **carbon steel and low-alloy steels**, particularly **mild steel**, which are common in process industries due to cost and mechanical properties.

CUI can lead to:

- Loss of structural integrity
- Leaks or ruptures in pressure systems
- Unplanned shutdowns and safety hazards

CUI typically occurs due to **moisture ingress** through damaged or degraded insulation. Conditions that promote CUI include:

- **Temperature range:** he typical temperature range for corrosion under insulation (CUI) on carbon steel is -4°C to 175°C (25°F to 347°F)
- **.Damaged insulation** or cladding
- **Improper sealing** around support structures or nozzles
- **Thermal cycling** that leads to condensation
- Use of **chloride-containing insulation materials**

- **Mild steel (carbon steel):** Highly vulnerable to general corrosion under insulation when exposed to moisture and oxygen.
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- **Austenitic stainless steels:** Can suffer stress corrosion cracking due to chlorides under insulation.

API 570 – Piping Inspection Code

- Requires inspection for CUI on **insulated piping systems** in the temperature range where CUI is most likely.
- Emphasizes **external inspection**, **thickness checks**, and **removal of insulation** where signs of CUI are suspected.
- Outlines frequency of CUI inspection based on **corrosivity, temperature, insulation condition**, and prior findings.

ASME Section V – Nondestructive Examination

- Provides requirements for **ultrasonic thickness testing (UTT)** under Article 5.
- Accepts ultrasonic thickness gauges like **DMS-2** for thickness monitoring when calibrated correctly and used with appropriate technique.

Equipment: DMS-2 Digital Thickness Gauge

- Single-element transducer
- Measures thickness from one side without removing large sections of insulation
- High precision suitable for measuring wall loss in carbon steel and mild steel

5.2 Inspection Procedure for CUI

a. Surface Access

- Cut a small inspection window in insulation, or use **"insulation plug inspection ports"** if available
- Clean the exposed surface for probe contact (remove rust/paint locally)

b. Couplant Application

- Apply ultrasonic gel or liquid couplant to improve transmission

c. Device Calibration

- Calibrate DMS-2 using a reference block or known thickness standard of mild steel
- Set correct **sound velocity** for carbon steel (typically ~5900 m/s)

d. Thickness Measurement

- Place probe on the cleaned metal surface
- Take multiple readings to detect **localized thinning or pitting**
- Record minimum values and compare with **design thickness** and **minimum allowable thickness (tmin)** from API 570

Parameter	**Guidance**
Minimum thickness	Refer to original design data / API 579 or API 570 tmin
Corrosion rate	Calculate if previous data exists
Remaining life	Estimate using corrosion rate and future inspection interval
Re-inspection interval	Based on damage rate and criticality

- No need to remove large sections of insulation
- Quick and accurate thickness readings
- Suitable for one-sided access
- Lightweight and portable for field use
- Compliant with ASME and API requirements for UTT

- Only checks localized areas; does not give full area coverage
- Surface cleaning is required at the probe point
- Cannot detect cracks or under-deposit corrosion unless severe wall loss occurs

A-Scan Ultrasonic Testing in Tank Bottom-to-Shell Joints

Introduction to A-Scan Ultrasonic Testing

A-Scan (Amplitude Scan) is a fundamental presentation mode in **Ultrasonic Testing (UT)**. It displays the **reflected ultrasonic waves** as a function of time on a screen, allowing the operator to **determine the location, size, and orientation** of discontinuities inside a material.

- The **horizontal axis** represents time or distance (depth),
- The **vertical axis** represents signal amplitude (echo strength),
- Each **spike** (or echo) on the A-scan indicates a reflection from a boundary or defect.

Why A-Scan is Used in Bottom-to-Shell Joints

In **aboveground storage tanks (ASTs)**, especially at the **bottom-to-shell (annular plate) joints**, certain limitations apply:

- **MFL (Magnetic Flux Leakage)** is widely used for tank bottom inspection but is ineffective:
    - Near **welded joints**,
    - In the **critical zone** (typically within 12–18 inches from the shell),
    - When inspection is required from **only one side**,
    - For **non-ferromagnetic coatings** or **non-metallic liners**.

Hence, **A-scan UT** becomes essential for **detection and sizing of corrosion**, **pitting**, and **laminar defects** in this area.

Advantages of A-Scan in This Application

- Detects **loss of wall thickness** due to corrosion.
- Evaluates **remaining plate thickness** in the critical bottom-to-shell transition.
- Accurate for **localized and general thinning**.
- Can be used with **angle probes** for weld root examination.
- Effective for both **in-service** and **out-of-service** inspections.

Procedure for Tank Bottom-to-Shell Joint

1. **Surface Preparation**: Cleaning of the weld area and annular ring.
2. **Couplant Application**: Ensures transmission of sound waves.
3. **Transducer Selection**:
    - **Straight beam** for thickness measurement.
    - **Angle beam** (typically 45°, 60°) for weld discontinuities.
4. **Scanning**:
    - Scanning performed in a grid pattern or full-length sweep,
    - Measurements taken near and along the weld toe, heat-affected zone (HAZ), and annular ring.
5. **Data Recording**:
    - A-scan signals saved and analyzed for flaw sizing and location.

Relevant Standards and Codes

API Standards

1. **API 653 – Tank Inspection, Repair, Alteration, and Reconstruction**
    - **Section 4.3.3 & 4.4.1**: Discusses UT for critical zone inspection near bottom-to-shell.
    - Requires UT in areas where **MFL is not applicable**, especially:
        - Within 3 ft of the tank shell,
        - Near annular plates,
        - In regions with suspected corrosion.
    - **Annular plate inspection** is critical for tanks storing hazardous substances or built per **API 650**.
2. **API RP 575 – Inspection of Atmospheric and Low-Pressure Storage Tanks**
    - Offers guidance on **UT methods** for different tank areas, including inaccessible regions.

ASME Standards

1. **ASME Section V – Nondestructive Examination**
   - **Article 4 (UT – Straight Beam) and Article 5 (Angle Beam)**:
     - Defines UT techniques, calibration, and evaluation criteria.
     - Covers **A-scan presentation requirements**.
   - Mandates proper calibration blocks and technique qualificatio

Limitations of A-Scan UT

- Requires **skilled technicians** for interpretation.
- May miss **laminar inclusions** if scanning angle or direction is incorrect.
- Can be affected by **surface roughness** and **geometry**.

Magnetic Particle Inspection (MPI)

1. Introduction

Magnetic Particle Inspection (MPI) is a **non-destructive testing (NDT)** method used to detect **surface and near-surface discontinuities** in **ferromagnetic materials** such as carbon steel. It is highly effective for identifying:

- Cracks
- Lack of fusion
- Undercut
- Fatigue defects

2. Working Principle of MPI

MPI works based on the principle of **magnetism and magnetic flux leakage**.

Steps:

1. **Magnetization**:
   - The part is magnetized using a **direct or alternating current** (DC/AC).
   - Magnetic lines of force (flux) pass through the material.
2. **Defect Creation**:
   - When a **discontinuity** (e.g., a crack) is present, it interrupts the magnetic field.
   - This causes **leakage fields** to form at the defect.
3. **Application of Magnetic Particles**:

- **Dry or wet magnetic particles** (usually iron filings coated with a fluorescent or visible dye) are applied.
- These particles are attracted to the leakage fields, forming a **visible indication** over the discontinuity.

4. **Inspection**:
    - The surface is observed under **white light or UV light** depending on the type of particles used.

MPI can only be performed on **ferromagnetic materials** such as **carbon steel** and **low-alloy steels**.

3. Use of MPI in Tank Joint Inspection

MPI is widely used in **welded joints** of aboveground storage tanks (ASTs), particularly:

Applicable Areas:

- **Tank shell-to-bottom (annular) joints**
- **Tank roof-to-shell welds**
- **Nozzle welds**
- **Repairs or alterations**

Why MPI is Important Here:

- Detects **surface cracks** in welds which may not be visible visually.
- Effective for **toe cracks**, **cold laps**, or **undercuts** after welding or in-service.
- Used during **fabrication**, **in-service inspection**, or **post-repair verification**.

MPI Limitations:

- Only detects **surface or near-surface flaws**.
- Cannot be used on **non-magnetic** materials (e.g., austenitic stainless steel or aluminum).
- Surface must be **clean and accessible**

3.Relevant API and ASME Code References

API Standards

API 653 – Tank Inspection, Repair, Alteration, and Reconstruction

- **Section 4.3.4 & 4.4**:
    - MPI is permitted for **weld surface crack detection**,
    - Required after certain repairs and alterations.
- **Section 9.5 & 9.6**:
    - Specifies acceptance criteria for weld surface defects detected via MPI.

API 650 – Welded Tanks for Oil Storage

- **Section 8.1 & 8.5**:
  - Requires MPI or other surface NDT methods for weld examination,
  - Especially for **nozzles**, **manways**, and **critical structural welds**.

ASME Standards

ASME Section V – Nondestructive Examination

- **Article 7 – Magnetic Particle Examination**:
  - Details MPI **equipment**, **techniques**, **calibration**, **procedures**, and **reporting**.
  - Specifies requirements for **yoke technique**, **field strength**, and **particle types**.

Holiday Testing

1.Introduction

Holiday Testing, also known as **spark testing** or **pinhole testing**, is a **non-destructive testing (NDT)** method used to **detect discontinuities (holidays)** such as **pinholes**, **voids**, **cracks**, or **thin spots** in **non-conductive coatings** applied over **conductive substrates** (e.g., steel tanks).

It ensures that the **protective coating** is continuous and free of flaws that could lead to **corrosion or underfilm attack**.

2. Working Principle of Holiday Testing

Holiday testing operates on the principle of **electrical conductivity**:

Steps:

1. The coated metal surface is grounded (connected to the negative terminal of the tester).
2. A **high-voltage probe** or **wet sponge electrode** is connected to the positive terminal.
3. As the probe passes over the coated surface:
   - If the coating is **intact**, no current passes.
   - If there is a **pinhole or void**, the voltage arcs through the discontinuity to the metal, triggering an **alarm or spark**.
4. This identifies areas where the substrate is exposed and vulnerable to **corrosion**.

3. Types of Holiday Testers

Type	Application
Low Voltage (Wet Sponge)	For **thin coatings** (typically < 500 µm / 20 mils)
High Voltage (DC Pulse)	For **thicker coatings** (> 500 µm / 20 mils), such as epoxy or coal tar

Why It's Critical:

- Ensures the **integrity of corrosion protection** coatings (e.g., epoxy, polyurethane, coal tar).
- Detects **application defects** before tanks are put into service.
- Prevents **premature coating failure** and **underfilm corrosion**.

Standards

API Standards

API 653 – Tank Inspection, Repair, Alteration, and Reconstruction

- **Section 4.4.4 & 10.5**:
  - Recommends holiday testing for **tank bottom coatings**.
  - Must be performed **after coating** and **before putting tank into service**.

API RP 652 – Lining of Aboveground Storage Tank Bottoms

- **Section 7**:
  - Specifies procedures for **holiday testing** of linings.
  - Recommends voltages and types of testers based on coating thickness.
  - Calls for **holiday detection before hydrotesting** or liquid exposure.

ASME Standards

ASME Section V – Nondestructive Examination

- While ASME Section V does not directly address holiday testing, it **recognizes electrical NDT methods**.
- For pressure vessels or tanks built per **ASME Section VIII**, holiday testing may be required based on **design specification** and **user requirement**.

ASME B31.3 – Process Piping

- **Para 341.4.3**: Coatings applied to piping systems should be checked using **appropriate NDE methods**, including **holiday detection**.

Working Principle

Magnetic Flux Leakage (MFL) is a **non-destructive testing** method used to detect **corrosion**, **pitting**, and **material loss** in **ferromagnetic materials**, especially **tank floors**.

Principle:

- A strong **magnetic field** is applied to the steel tank floor using permanent magnets or electromagnets.
- In areas with **no metal loss**, the magnetic field flows **uniformly**.
- At areas with **corrosion or thinning**, the magnetic field **leaks out** of the metal surface.
- **MFL sensors** detect this leakage field and convert it into **electrical signals**, identifying the location and severity of flaws.

API 653 – Tank Inspection, Repair, Alteration, and Reconstruction

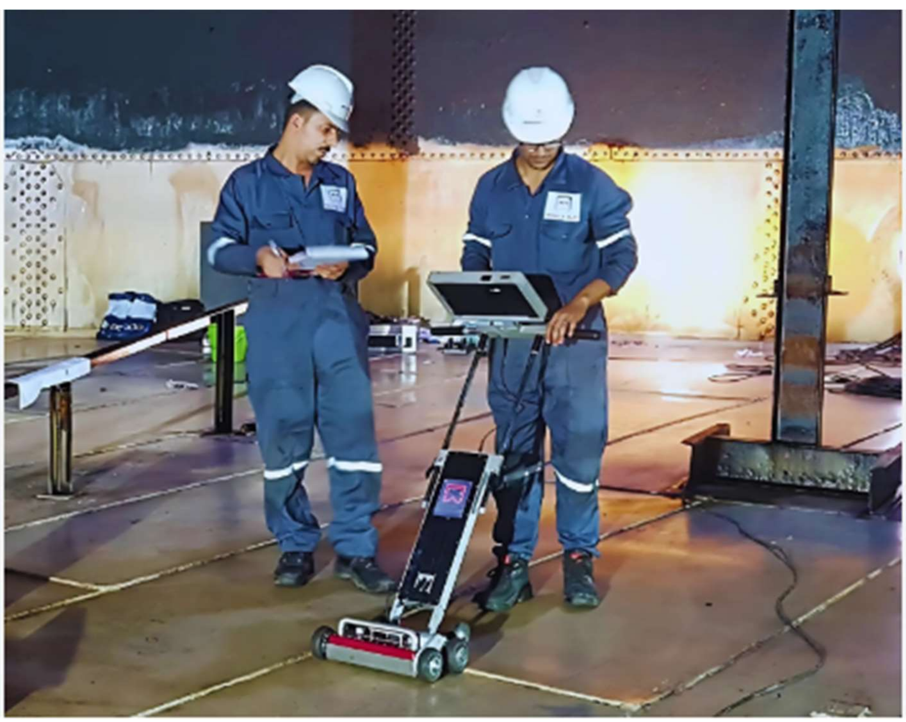
- **Section 4.4.1.1 & 4.4.3**:
  - MFL is an acceptable method for **tank bottom inspection**.
  - Used for screening to identify areas requiring further **ultrasonic testing** (UT).
- **Section 6.4.4.1**:
  - Requires MFL scanners to be **calibrated** using reference plates with known defects.
- **Section 4.4.3.3**:
  - Notes that **MFL cannot detect all types of flaws** and should be followed by UT for confirmation.

API RP 575 – Inspection of Atmospheric and Low-Pressure Storage Tanks

- Provides detailed **guidance on the use of MFL** for in-service tank bottom inspection.
- Recommends MFL for **screening large surface areas efficiently**.

ASME Standards

- **ASME Section V** does **not explicitly cover MFL** as a standard method.
- However, it allows use of **non-listed NDE methods** when:
  - Approved by the **authorized inspector**,
  - Supported by a **written procedure** and **demonstrated effectiveness**.



TOOL Station

Introduction

A **Tool Station** is a **fixed reference point** established on the **tank bottom** or **foundation** for the purpose of **monitoring elevation changes** over time. Tool stations are laid out in a **radial grid pattern** from the tank **center to shell**, usually at regular angular intervals (e.g., every 30° or 45°).

These points serve as **measurement locations** to assess **differential settlement**, **floor deformation**, or **shell distortion** in aboveground storage tanks (ASTs).

Working Principle

The **Tool Station Test** is a **dimensional survey technique** used to identify **bottom and shell settlement** by measuring the **vertical elevations** of tool stations over time.

Steps:

1. Tool stations are marked on the **tank bottom** (typically on weld seams or floor plates).
2. Using **precision leveling instruments** (e.g., digital level or total station), elevation readings are recorded from:
    - **Center of tank** to the **shell** (radial lines),
    - All around the **tank circumference**.
3. The measured data is compared against:
    - The **original construction profile**,
    - A **prior baseline survey**, or
    - A mathematically **ideal flat plane**.
4. **Deviations** indicate **settlement** or **uplift**.
5. The results are plotted to visualize **floor distortion patterns**.

Evaluation Focus

- **Edge settlement** (near the shell),
- **Center uplift** or depression,
- **Localized plate buckling**,
- **Shell-to-bottom weld stress due to tilt**.

API 653 – Tank Inspection, Repair, Alteration, and Reconstruction

- **Section 5.5**:
    - Requires inspection of **settlement** using elevation readings from **tool stations**.

- **Figures 5.5 & 5.6**:
  - Show recommended **tool station layout** and **evaluation zones**.
- **Section 7.4.6**:
  - Provides criteria for acceptable **bottom deformation**; exceeding limits may require repair or engineering evaluation.

API 650 – Welded Tanks for Oil Storage

- **Annex B – Foundations**:
  - Discusses design to prevent **excessive settlement**,
  - States the importance of monitoring and maintaining **foundation levelness**.

Phased Array Ultrasonic Testing (PAUT) – Report Content

1. Introduction to PAUT

Phased Array Ultrasonic Testing (PAUT) is an advanced **Non-Destructive Testing (NDT)** technique used to detect internal flaws, measure material thickness, and inspect weld quality. Unlike conventional ultrasonic testing

(UT), PAUT uses multiple ultrasonic elements and electronic time delays to steer, focus, and scan the beam. This allows for more comprehensive and faster inspections, with enhanced imaging of complex geometries.

2. Working Principle of PAUT

PAUT works on the principles of ultrasonics but uses an array of small piezoelectric transducers. These transducers are individually controlled by a computer, enabling:

- **Beam steering**: Changing the angle of the ultrasonic beam without moving the probe.
- **Beam focusing**: Concentrating sound energy at specific depths for clearer detection.
- **Electronic scanning**: Rapid scanning of the target area without mechanical movement.

The phased array probe sends high-frequency sound waves into the test material. Reflected signals (echoes) from flaws, geometrical boundaries, or material interfaces are received and interpreted into visual data (S-scan, A-scan, and C-scan).

3. Applications of PAUT in Oil & Gas

- Inspection of welds in pipelines, pressure vessels, storage tanks.
- Detection of cracks, lack of fusion, porosity, and corrosion.
- In-service inspection of equipment under **API 570** and **API 653**.
- Evaluation of high-temperature components during shutdowns or turnarounds.

4. Key Features

Feature	Description
High sensitivity	Capable of detecting small defects
Real-time imaging	Visual representation of flaws
Precise flaw sizing	Useful in fitness-for-service analysis
Coverage of complex shapes	Good for nozzles, elbows, T-joints
Repeatability	Allows consistent data for trending

5. Advantages over Conventional UT

- Faster inspection and data collection.
- More detailed defect characterization.
- Scans can be recorded and reviewed.

- Reduced need for multiple probes.

6. PAUT Scanning Types

- **Linear Scan** – Steered beam across the test surface.
- **Sectorial Scan (S-Scan)** – Sweeps beam over a range of angles.
- **Compound Scan** – Combines linear and angular steering**.**

7. Standards and Codes

API Standards:

- **API 650**: Weld inspection in welded tanks; PAUT may be used as an alternative to RT.
- **API 653**: PAUT is approved for in-service inspection of welds in storage tanks.
- **API 570**: Applicable for in-service inspection of piping systems using advanced UT.

ASME Standards:

- **ASME Section V – Nondestructive Examination**:
  Article 4 (UT) and Article 4 Appendix III specifically address advanced ultrasonic methods like PAUT.
- **ASME Section VIII, Div. 1 & 2 – Pressure Vessels**:
  Allows PAUT as an alternative to RT under certain conditions with proper qualification.
- **ASME B31.3 – Process Piping**:
  PAUT accepted for weld examination where radiography is not feasible.

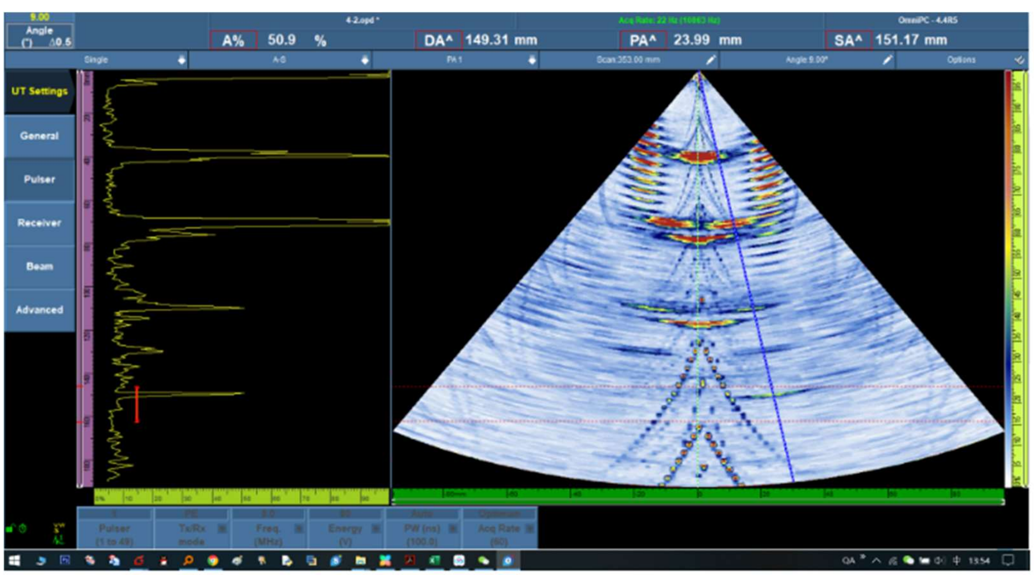
8. Equipment Used

- **Phased Array Flaw Detectors**: Olympus OmniScan, Sonatest Veo3, GE Mentor UT.
- **Probes**: Linear arrays with 16–128 elements.
- **Wedges**: Designed for specific angles and materials.
- **Encoded Scanners**: For accurate sizing and mapping of defects.

9. Units and Parameters

Parameter	**Unit**	**Description**
Frequency	MHz (Megahertz)	Typically 2–10 MHz
Angle Range	Degrees (°)	30°–70° commonly used for welds
Amplitude	% Full Screen	Strength of return signal

Parameter	Unit	Description
Depth	mm or inches	Distance to the flaw or feature
Sound Velocity	m/s or in/µs	Depends on material type



Time of Flight Diffraction (TOFD) – Report Content

Introduction:

Time of Flight Diffraction (TOFD) is an advanced ultrasonic testing technique used for detecting and sizing defects in welds and structural components. It is widely applied in oil & gas, power generation, and fabrication industries due to its high accuracy in defect sizing.

Principle:

TOFD works by transmitting a short ultrasonic pulse from one probe and receiving diffracted signals at another probe on the opposite side of a weld. The probes are typically placed at an angle, and sound waves travel through the material, diffracting from the tips of any flaws. The time it takes for the diffracted signals to reach the receiver is measured and used to calculate the flaw's location and size.

Applications:

- Weld inspection (especially thick-section welds)
- Corrosion mapping
- In-service and fabrication inspection

Advantages:

- High accuracy in defect sizing
- Rapid scanning and data acquisition
- Permanent record of inspection (D-scan)

Relevant Codes and Standards:

- **API 1104 (Welding of Pipelines and Related Facilities):**
  Recognizes TOFD as an alternative or supplementary method to radiography for weld inspection under qualified procedures.
- **ASME Section V (Nondestructive Examination), Article 4 and Article 23 (Mandatory Appendix II):**
  Provides detailed procedures for ultrasonic testing including TOFD. Article 23 specifically addresses TOFD for flaw detection and sizing.
- **ASME B31.3 (Process Piping):**
  Permits TOFD as an accepted method for volumetric examination under certain conditions, typically when qualified and approved by the owner or inspector.

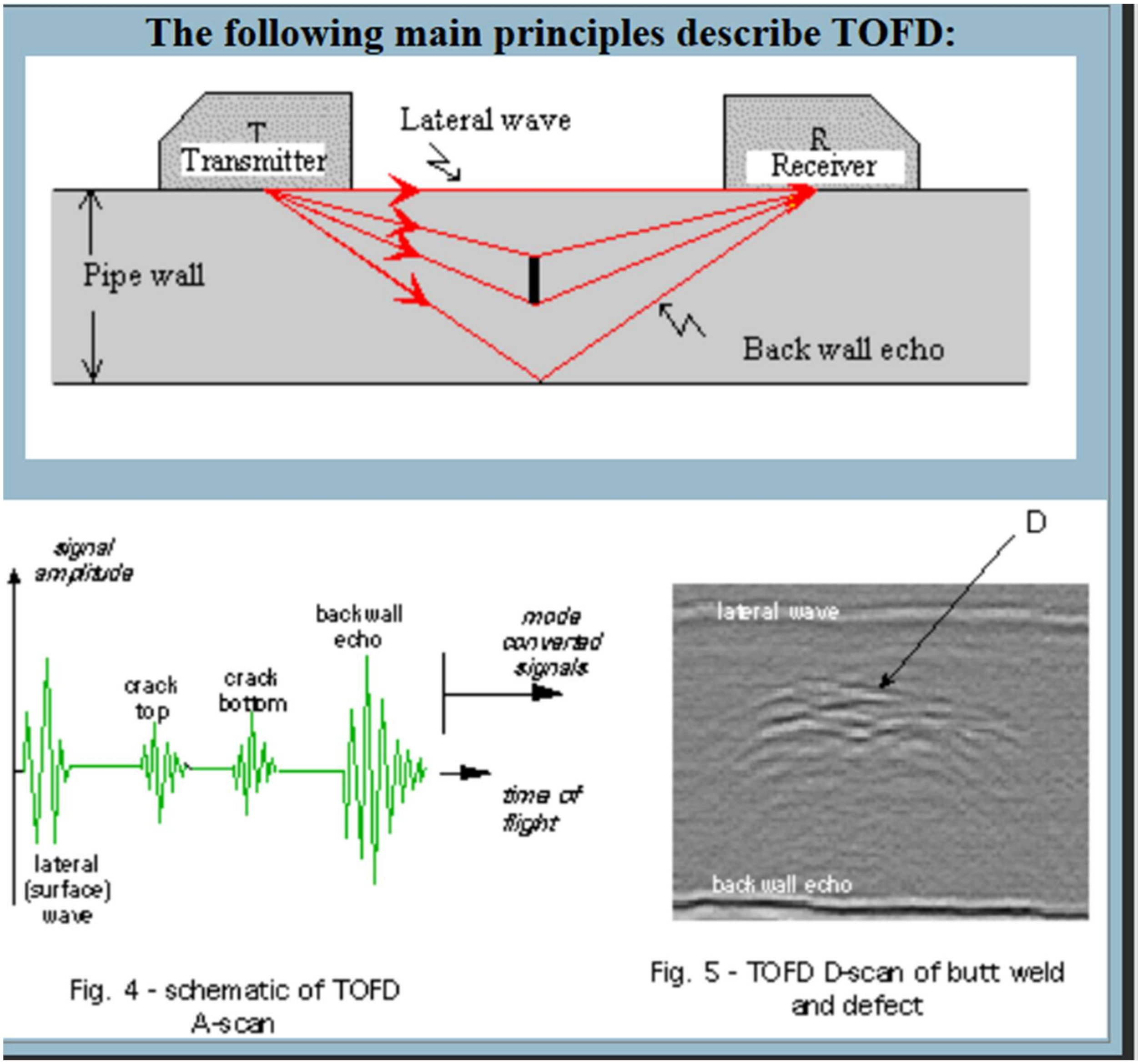


Fig. 4 - schematic of TOFD A-scan

Fig. 5 - TOFD D-scan of butt weld and defect

Long Range Ultrasonic Testing (LRUT) – Report Content

Introduction:

Long Range Ultrasonic Testing (LRUT) is a screening technique used to inspect long lengths of piping and pipelines from a single inspection point. It is primarily used for detecting corrosion and wall loss in insulated or buried pipes without requiring full surface access.

Principle:

LRUT uses low-frequency guided ultrasonic waves that propagate along the length of a pipe. A transducer ring induces these waves, which travel both directions along the pipe and reflect from changes in cross-section, such as corrosion or welds. Reflected signals are analyzed to identify the presence and approximate location of defects.

Applications:

- Inspection of aboveground, insulated, or buried pipes
- Detection of corrosion under insulation (CUI)
- Screening inaccessible or hazardous areas

Relevant Codes and Standards:

- **API RP 583 (Corrosion Under Insulation and Fireproofing):**
  Recommends LRUT as a screening tool for identifying potential CUI locations on piping and pipelines.
- **ASME B31.3 (Process Piping):**
  Accepts alternative examination techniques like LRUT if they are qualified and approved by the owner or inspection authority.
- **ASME Section V (Nondestructive Examination):**
  While LRUT is not explicitly detailed, general ultrasonic testing requirements apply, and LRUT may be accepted under documented procedures.

Short Range Ultrasonic Testing (SRUT) – Report Content

Introduction:

Short Range Ultrasonic Testing (SRUT) is a guided wave technique used for detecting corrosion or wall loss over a limited area range. It is commonly applied for corrosion under insulation (CUI), soil-to-air interfaces, and inaccessible areas such as tank annular rings and pipe supports.

Principle:

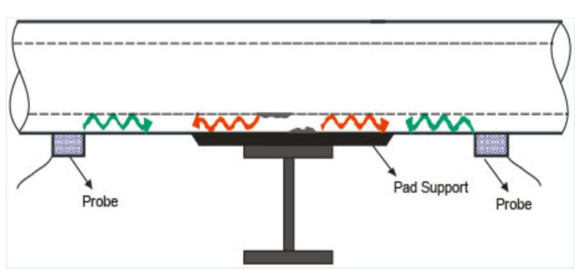
SRUT operates by transmitting low-frequency guided ultrasonic waves into the component. These waves propagate over short distances and reflect from areas with cross-sectional changes such as corrosion. The reflections are analyzed to determine flaw presence and location.

Applications:

- Inspection of tank annular plates
- Corrosion under pipe supports
- Soil-to-air interface corrosion
- Corrosion under insulation (CUI)

Relevant Codes and Standards:

- **API 653 (Tank Inspection, Repair, Alteration, and Reconstruction):**
  Supports the use of SRUT for annular plate inspection in aboveground storage tanks.
- **API RP 583 (Corrosion Under Insulation and Fireproofing):**
  Recommends SRUT as a technique for detecting localized CUI damage.
- **ASME Section V (Nondestructive Examination):**
  Permits advanced ultrasonic methods like SRUT under qualified procedures.
- **ASME B31.3 (Process Piping):**
  Allows use of SRUT as an alternative NDE method when approved by the owner or designated inspector.



Penetrant Testing (DPT)

Dye Penetrant Testing (DPT), also called **Liquid Penetrant Testing (LPT)**, is a **non-destructive testing (NDT)** method used to detect **surface-breaking defects** such as cracks, porosity, laps, seams, and lack of fusion in **non-porous materials** (both ferrous and non-ferrous).

Working Principle

DPT works on the principle of **capillary action**:

1. **Cleaning**: The test surface is thoroughly cleaned to remove grease, dirt, and debris.
2. **Penetrant Application**: A visible red or fluorescent dye is applied to the surface and allowed to dwell so it enters surface discontinuities by **capillary action**.
3. **Excess Removal**: The surface is wiped to remove excess dye, leaving dye only in the defects.
4. **Developer Application**: A white powder developer is applied, which draws the dye out of flaws, creating visible **indications**.
5. **Inspection**: The surface is visually examined under **white light (for visible dye)** or **UV light (for fluorescent dye)**.

Applicable Standards

API 650 – Welded Tanks for Oil Storage

- **Section 8.1 & 8.5**:
    - Permits use of DPT to inspect welds in **nozzles**, **roof components**, and **shell-to-bottom joints**.
- Used when **magnetic particle testing (MPI)** is not suitable (e.g., for austenitic stainless steels).

API 653 – Tank Inspection, Repair, Alteration, and Reconstruction

- **Section 9.5**:
    - Allows **DPT for weld inspection** after repairs or alterations, especially when surface-breaking flaws are suspected.
- **Section 12**:
    - Requires DPT for certain **nozzle welds** or **patch repairs**.

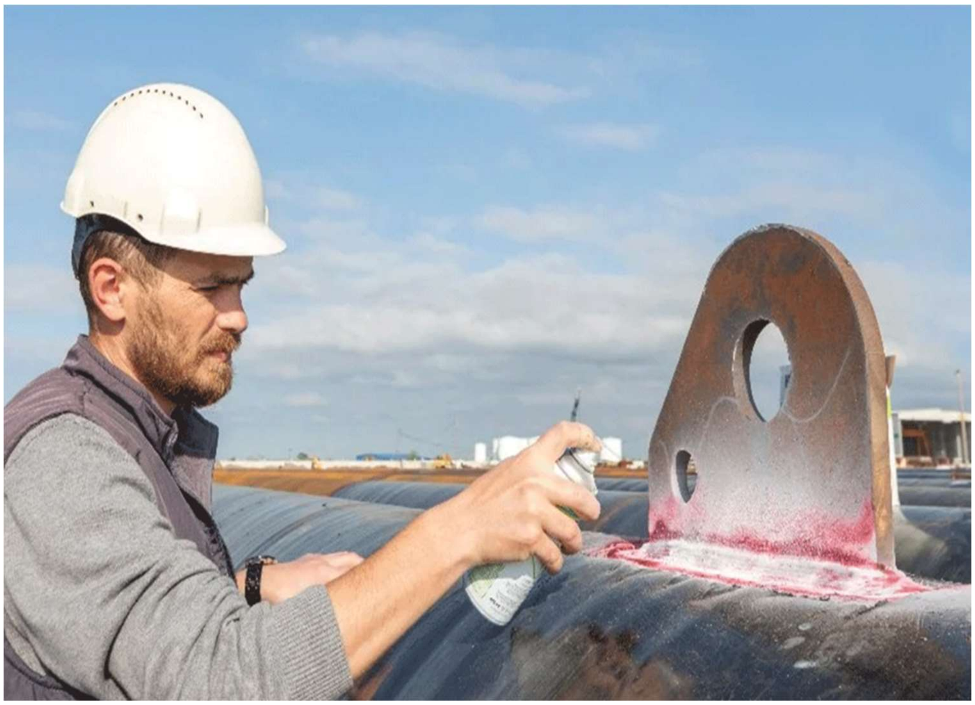
ASME Section V – Nondestructive Examination

- **Article 6 – Liquid Penetrant Examination**:
    - Specifies requirements for:
        - Types of penetrants (visible or fluorescent),
        - Surface preparation,
        - Dwell times,

    - Developer types,
    - Evaluation criteria.
- Includes **mandatory procedure requirements** for qualification and execution.

ASME Section VIII – Pressure Vessels

- Requires **DPT for surface flaw detection** in welds, especially for **non-magnetic materials**.
- Acceptable per **UW-50 and Appendix 8** for weld examination.



Thermography

Thermography, also known as **Infrared (IR) Thermographic Testing**, is a **non-contact, non-destructive testing (NDT)** method that detects and visualizes **temperature differences** on the surface of materials using **infrared radiation**.

It is used to identify:

- **Corrosion under insulation (CUI)**
- **Delamination or disbonding**
- **Thermal insulation defects**
- **Hot spots or leaks** in storage tanks and piping

Working Principle

Thermography is based on detecting infrared energy **(heat) emitted from a surface and converting it into a** thermal image **(thermogram).**

Steps:

1. All objects emit **infrared radiation** proportional to their temperature.
2. An **infrared camera** captures this emitted energy from the object's surface.
3. **Temperature variations** appear as color contrasts on the thermogram.
4. Areas with **insulation damage**, **moisture**, or **corrosion** show **abnormal heat patterns**.

There are two types:

- **Passive Thermography**: Relies on natural temperature differences (e.g., during operation).
- **Active Thermography**: Uses external heat or cooling sources to induce detectable differences.

API Standards

API 583 – Corrosion Under Insulation and Fireproofing

- Recommends **infrared thermography** for detecting **CUI** in insulated piping and vessels.
- Identifies it as a **screening tool** to locate areas for further inspection.

API RP 575 – Inspection of Atmospheric and Low-Pressure Storage Tanks

- Lists **thermography** as a valid NDT technique for identifying:
    - **Thermal anomalies**
    - **Leaks**

- **Loss of insulation**

ASME Standards

ASME Section V – Nondestructive Examination

- **Article 13 – Infrared Testing (IR)**:
  - Defines requirements for:
    - Equipment calibration,
    - Test procedures,
    - Image interpretation,
    - Thermal sensitivity of instruments.

ASME B31.3 – Process Piping

- Permits **infrared thermography** as a **supplementary inspection** method for detecting temperature-related defects.

Vibration Analysis

1. Introduction

Vibration analysis is a **non-destructive testing (NDT)** method used to assess the mechanical condition of rotating equipment by measuring vibration levels. It helps prevent catastrophic failures by detecting faults such as imbalance, misalignment, bearing wear, and resonance. It's commonly applied to **pumps**, **fans**, **motors**, and **couplings** in oil and gas facilities.

2. Equipment Monitored

a. Pumps

- **Function:** Transfer fluids in pipelines and process systems.
- **Common Issues:** Unbalance, misalignment, cavitation, bearing failure.
- **Typical Vibration Levels:**
    - Overall Velocity: ≤ **4.5 mm/s RMS** (per API 610)
    - Acceleration (bearing fault): **g** or **mm/s²**
- **Spectrum Peaks:**
    - 1× RPM → unbalance
    - 2× RPM → misalignment
    - High-frequency broadband noise → cavitation

b. Fans

- **Function:** Used in ventilation, cooling, combustion air supply.
- **Common Issues:** Blade pass frequency, structural looseness, imbalance.
- **Typical Limits:**
    - Velocity: **2.8 – 4.5 mm/s RMS**
    - Displacement: **µm peak-to-peak**
- **Peaks:**
    - Blade Pass Frequency = (No. of Blades × RPM)/60
    - Looseness shows harmonics beyond 3× RPM

c. Motors

- **Function:** Drive compressors, pumps, and fans.
- **Issues Detected:** Electrical faults, rotor bar problems, unbalance.
- **Typical Readings:**
    - Acceleration: **g RMS**
    - Displacement (low-speed): **µm or mils (1 mil = 25.4 µm)**
- **Spectrum Peaks:**

- 1× RPM → unbalance
- 2× RPM → mechanical misalignment
- Electrical sidebands around 50/60 Hz (line frequency)

d Couplings

- **Function:** Transfer torque between shafts.
- **Common Faults:** Angular/parallel misalignment, coupling wear.
- **Limits:**
  - Displacement: **< 75 µm p-p (peak-to-peak)**
  - Axial vibration: should be minimal
- **Peak Signature:**
  - Strong 2× RPM in spectrum → angular misalignment
  - Multiple harmonics → coupling looseness

3. Vibration Spectrum and Interpretation

a. Common Parameters & Units

Parameter	Description	Unit
Displacement	Low-frequency motion	µm (micron) or mil (1 mil = 25.4 µm)
Velocity	General condition monitoring	mm/s RMS or in/s RMS
Acceleration	High-frequency fault detection	g RMS or m/s^2 RMS

b. Peak Frequency Causes

Frequency Peak	**Fault Type**	**Signal Type**
1× RPM	Rotor unbalance	Velocity
2× RPM	Misalignment	Axial velocity
3× RPM+	Looseness, structural issues	Velocity or acceleration
High-Frequency (≥10 kHz)	Bearing defects	Acceleration (g)
Sidebands around Line Frequency (50/60 Hz)	Electrical faults	FFT Spectrum

4. Maintenance Strategies

Type	Description	Based On	Tools/Units
Reactive	Run until failure	None	No monitoring used
Preventive	Scheduled checks	Time/usage hours	Velocity: mm/s; Time
Predictive (PdM)	Condition-based maintenance	Real-time data (e.g., vibration)	Vibration: mm/s, µm, g
Proactive	Root cause elimination	Failure analysis	FFT spectrum analysis

5. Guidelines

Machine Type	Velocity (mm/s RMS)
Good	≤ 2.8
Satisfactory	≤ 4.5
Unsatisfactory	> 4.5
Unacceptable	> 7.1

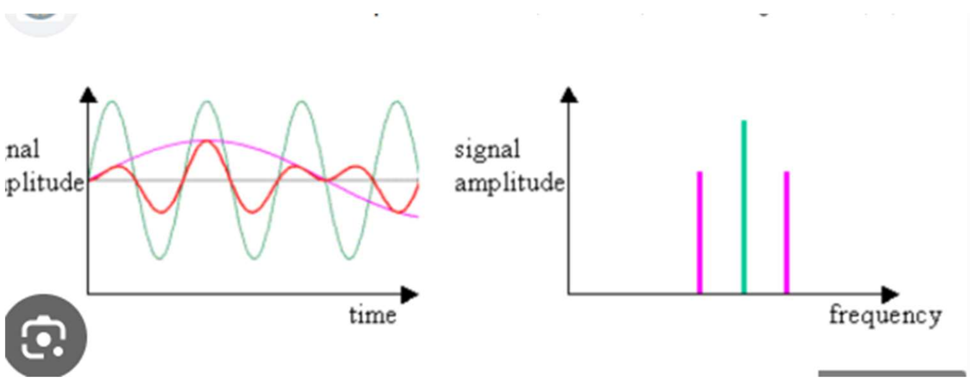
6. Measurement Tools and Units

Tool	Measured Unit	Application
Accelerometer	**g RMS**, **m/s²**	High-frequency faults, bearings
Velocity Sensor	**mm/s RMS**, **in/s**	General machine condition
Proximity Probe	**µm**, **mil (peak-to-peak)**	Shaft displacement
Vibration Analyzer	Digital Spectrum (FFT)	Trend monitoring and diagnostics

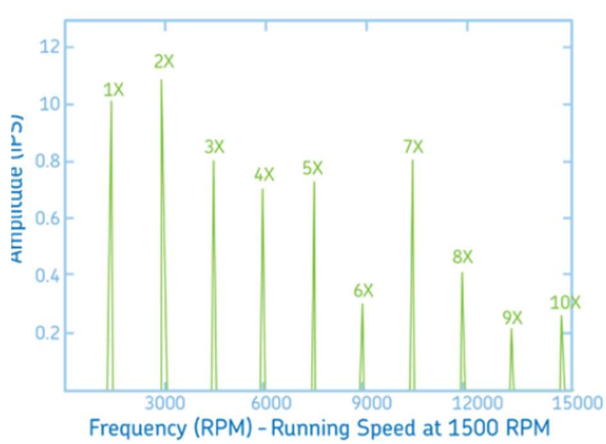
7. Case Examples (Real or Simulated)

- **Centrifugal Pump**:
  - Issue: Bearing wear
  - Vibration: 1× and high-frequency spikes
  - Units: 5.2 mm/s RMS velocity (exceeds API 610)
- **Induced Draft Fan**:
  - Issue: Imbalance
  - Vibration: High 1× RPM at 3.8 mm/s
  - Action: Field balancing reduced to 1.2 mm/s
- **Motor Misalignment**:
  - Issue: Shaft misalignment after installation
  - Vibration: High 2× RPM at axial point, 80 µm p-p
  - Correction: Laser alignment brought within API 686 limits

Complex Waveform Into Spectrum



Signal Peaks



Basic Corrosion Mechanism in Oil and Gas Industry

Corrosion is the natural degradation of metals due to chemical or electrochemical reactions with their environment. In the oil and gas industry, corrosion is a major threat to the integrity of **pipelines, pressure vessels, tanks, offshore structures**, and **buried components**, potentially leading to leaks, failures, or catastrophic accidents.

1. Electrochemical Corrosion Process

Corrosion typically occurs as an **electrochemical reaction** that involves:

- **Anode** – Metal loses electrons (oxidation)
- **Cathode** – Accepts electrons (reduction)
- **Electrolyte** – Conductive medium (e.g., water with dissolved ions)
- **Metallic Path** – Allows electron flow

Anodic Reaction:

$Fe \rightarrow Fe2+ + 2e-$

Cathodic Reaction (in neutral aerated water):

$O2+2H2O+4e- \rightarrow 4OH-$

The metal (iron or steel) oxidizes at the anode, releasing electrons and forming **iron ions**. These electrons travel to the cathode, where a reduction reaction occurs. The metal corrodes at the anodic site.

2. Types of Corrosion

- **Uniform Corrosion** – Even metal loss across surface
- **Pitting Corrosion** – Localized attack forming deep pits
- **Crevice Corrosion** – Occurs in shielded areas like joints
- **Galvanic Corrosion** – Between dissimilar metals in contact
- **Stress Corrosion Cracking (SCC)** – Caused by tensile stress and corrosive environment
- **Microbiologically Influenced Corrosion (MIC)** – Caused by bacteria like *SRB* (Sulfate-Reducing Bacteria)
- **Under-Deposit and CUI (Corrosion Under Insulation)** – Hidden corrosion zones, especially in insulated or coated systems

3. Factors Influencing Corrosion

- **Environmental**: Moisture, temperature, pH, salinity
- **Material Properties**: Metallurgy, surface finish, coatings
- **Electrolyte Presence**: Water, dissolved salts (e.g., chlorides, CO_2, H_2S)
- **Mechanical Stress**: Promotes cracking and fatigue-corrosion
- **Flow Conditions**: High velocity may cause erosion-corrosion

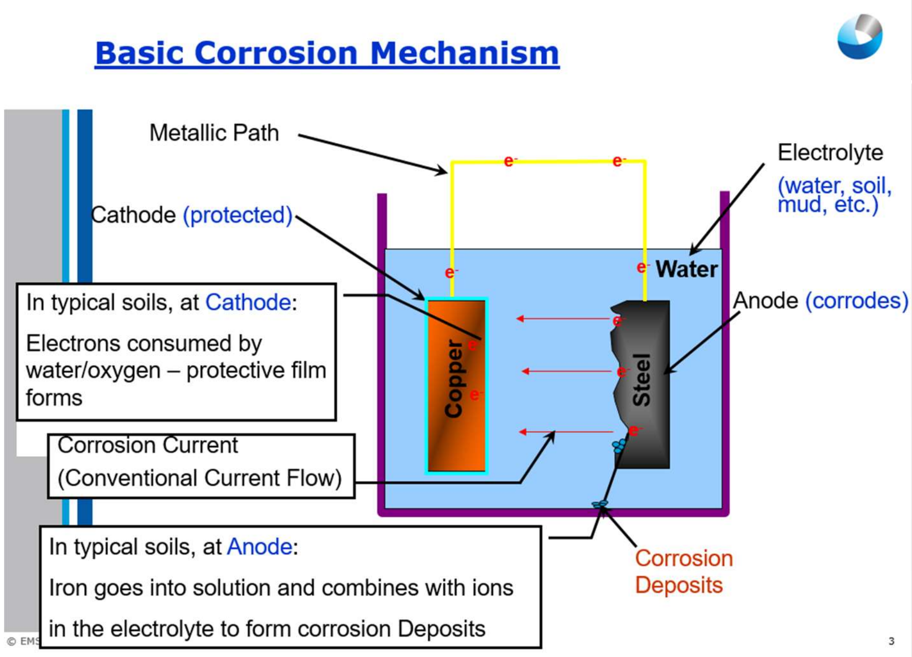
4. Corrosion Prevention Methods

- **Cathodic Protection** (Sacrificial and ICCP)
- **Protective Coatings and Paints**
- **Corrosion Inhibitors** (chemical dosing in pipelines or vessels)
- **Material Selection** (stainless steel, corrosion-resistant alloys)
- **Design Modifications** (avoiding crevices, drainage improvement)
- **Monitoring Techniques** (UT, corrosion coupons, ER probes)

Relevant API and ASME Standards

Standard	Title	Application
API 571	Damage Mechanisms Affecting Equipment in Refining	Covers corrosion types and their effects
API 510	Pressure Vessel Inspection Code	Guides inspection of corrosion in vessels
API 570	Piping Inspection Code	Evaluates corrosion in process piping
API RP 574	Inspection Practices for Piping System Components	Focus on corrosion monitoring techniques
API RP 651	Cathodic Protection of Aboveground Storage Tanks	Guidelines for CP design
ASME B31.3	Process Piping	Includes corrosion allowance and material selection
ASME VIII Div 1	Pressure Vessels	Considers corrosion in design thickness
NACE SP0169	External Corrosion Control of Buried Pipelines	Widely used for pipeline corrosion control

Standard	Title	Application



Cathodic Protection (CP) in Oil and Gas Industry

Cathodic Protection (CP) is a corrosion prevention technique widely used in the oil and gas sector to protect **buried pipelines**, **underground tanks**, **offshore platforms**, and **storage tanks** from corrosion. It works by converting the protected structure (typically steel) into the **cathode** of an electrochemical cell.

There are two primary types of cathodic protection systems:

1. Sacrificial Anode Cathodic Protection (SACP)

Sacrificial anodes are made of **more active metals** such as **zinc**, **magnesium**, or **aluminum**, which corrode **preferentially** to protect the steel structure.

How it Works:

- Anode has lower electrode potential than steel
- Connected electrically to the steel pipeline or tank
- Current flows from the anode to the steel, stopping steel corrosion
- Anode corrodes (sacrifices itself)

Common Uses:

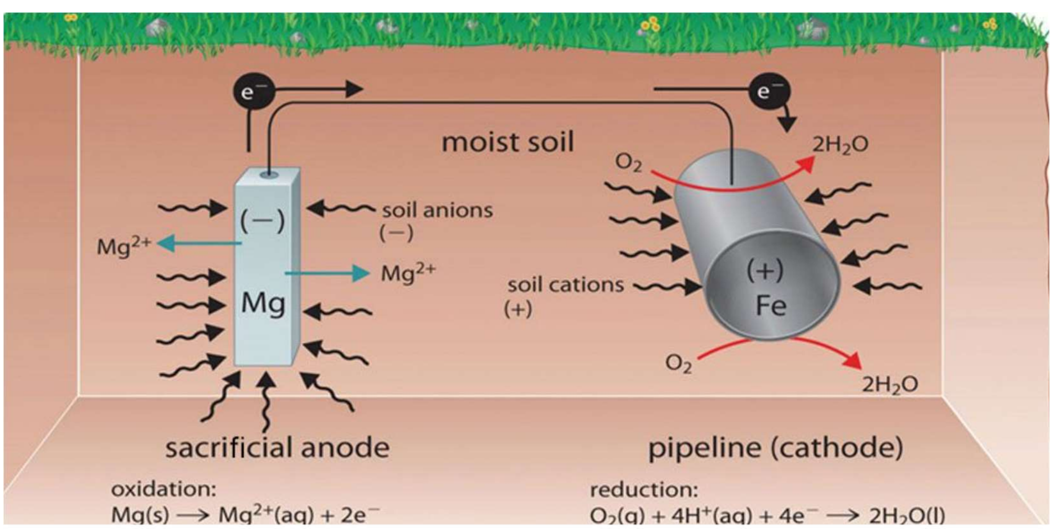
- Short pipelines
- Underground storage tanks
- Internal protection of water tanks
- Marine structures

Advantages:

- No external power source required
- Simple to install and maintain
- Low initial cost

Disadvantages:

- Limited current output
- Anodes need periodic replacement
- Not suitable for long pipelines or high-resistance soils



2. Impressed Current Cathodic Protection (ICCP)

ICCP systems use an external **DC power source** (rectifier) to force current through **inert anodes** such as **graphite**, **mixed metal oxide (MMO)**, **silicon cast iron**, or **titanium** into the pipeline.

How it Works:

- Rectifier supplies controlled DC current
- Current flows from the inert anode to the protected steel
- Steel becomes cathodic and corrosion is minimized
- Anodes are long-lasting and do not dissolve

Common Uses:

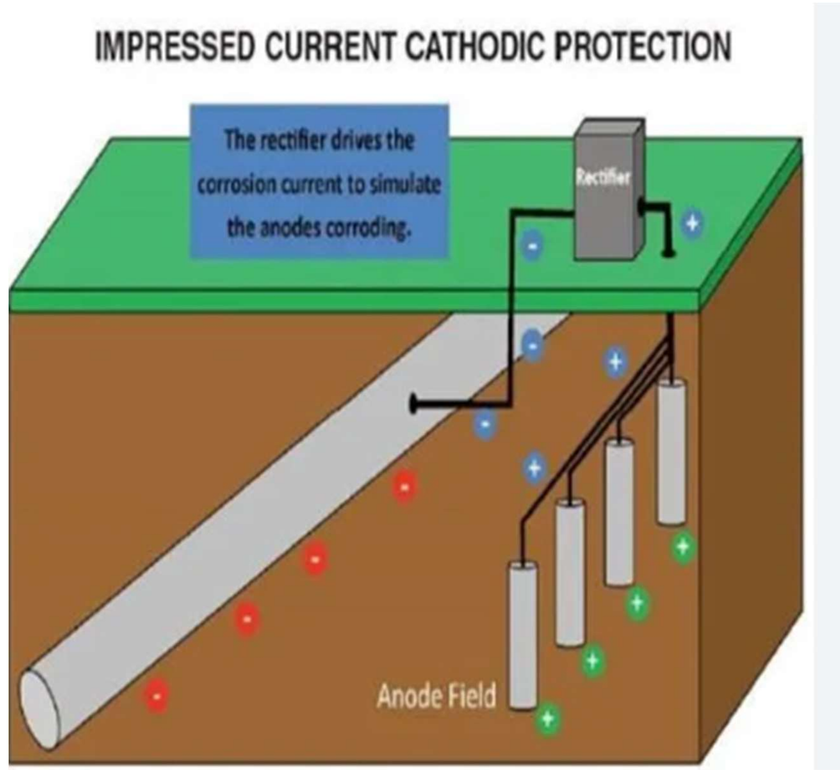
- Long-distance pipelines
- Large tank farms
- Offshore platforms
- High-resistivity soils

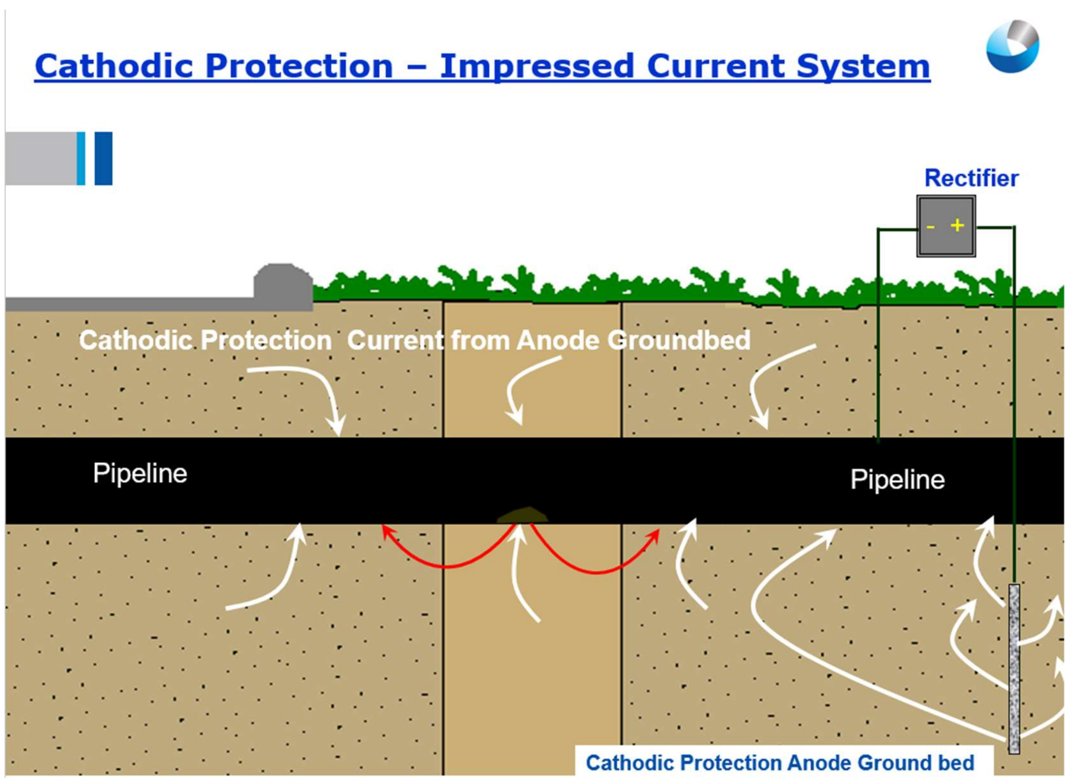
Advantages:

- High current capacity
- Controlled output
- Effective for large-scale applications

Disadvantages:

- Requires continuous power
- Needs monitoring and maintenance
- Higher installation and operating costs


IMPRESSED CURRENT CATHODIC PROTECTION
The rectifier drives the corrosion current to simulate the anodes corroding.
Rectifier
Anode Field


Cathodic Protection – Impressed Current System
Rectifier
Cathodic Protection Current from Anode Groundbed
Pipeline
Pipeline
Cathodic Protection Anode Ground bed

3. Pipe-to-Soil Potential (PSP) Measurement

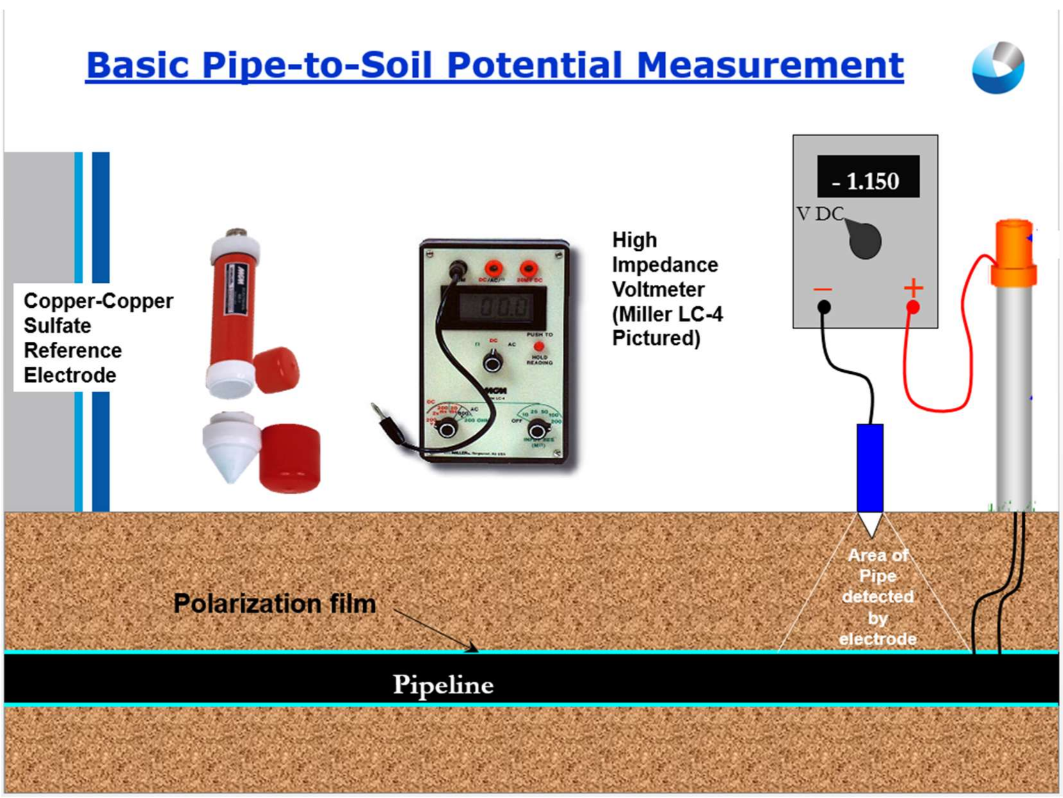
Pipe-to-Soil Potential is a key method to assess the effectiveness of cathodic protection. It measures the voltage difference between the buried pipeline and a **reference electrode** placed on the soil surface (typically **$Cu/CuSO_4$** electrode).

Acceptable Criteria (per NACE SP0169 & API RP 651):

- **−850 mV or more negative** (with respect to $Cu/CuSO_4$ electrode)
- c
- Instant-off potential more accurate than on-potential

Interpretation:

- If PSP ≥ −850 mV: Protection is adequate
- If PSP < −850 mV: Protection is insufficient; risk of corrosion
- If PSP is excessively negative (e.g., −1.5V), risk of overprotection (coating damage or hydrogen embrittlement)



Relevant Standards and Codes

Standard	Title / Focus
API RP 651	Cathodic Protection of Aboveground Petroleum Storage Tanks
API RP 1632	Cathodic Protection for Underground Storage Tanks and Piping
API 571	Damage Mechanisms Affecting Fixed Equipment (Corrosion)
API 570	Piping Inspection Code – In-service Inspection
ASME B31.3	Process Piping – Includes design for corrosion allowance
ASME B31.4 / B31.8	Design and Maintenance of Liquid & Gas Pipelines
NACE SP0169	Control of External Corrosion on Underground or Submerged Metallic Piping
NACE SP0575	Internal CP of Steel Water Tanks

Leakage Incident Report: Firewater Pipeline near Pond – GPF Plant

*Location: Fi*rewater Line – Near Water Pond, GPF (Gas Processing Facility)
System: Firewater Supply Network
Issue Type: Pipeline Leakage
Date of Observation: [Insert Date]

Background

During routine inspection near the water pond area of the GPF plant, a **leakage** was identified in the **firewater pipeline system**. The firewater system is a critical safety infrastructure responsible for delivering water to emergency hydrants and sprinkler systems across the facility.

Observation and Findings

Upon close examination, it was observed that the leak was occurring at an **elbow joint** in the pipeline. A **small pinhole leak** was detected at the joint, which was releasing pressurized water. Further inspection revealed that the root cause of the leak was **inadequate or substandard welding** during the installation of the elbow fitting. This poor-quality weld failed to maintain integrity under operational pressure and environmental conditions.

Additionally, the **external coating** in that area appeared to have degraded, potentially exposing the joint to corrosion, which may have accelerated the development of the leak.

Root Cause Summary

- Presence of a **pinhole leak** at the elbow joint.
- **Improper welding** technique or lack of post-weld inspection.
- Possible degradation of protective **external coating**.
- Environmental exposure (e.g., moisture near pond area) contributing to corrosion.

Corrective Actions Taken

1. The affected section was **isolated** to prevent further water loss and pressure drop in the firewater system.
2. The **external coating** around the leaking joint was **removed** for full access and inspection.
3. A **temporary clamp** was installed to stop the leak and restore functionality.

Permanent Remedial Measures Proposed

To ensure long-term reliability and safety, the following steps are recommended:

1. **Remove the existing coating** from the leaking joint and surrounding area.
2. Perform a **proper weld repair** at the elbow joint, ensuring it meets applicable welding standards and codes (e.g., ASME B31.3).
3. Conduct **non-destructive testing (NDT)** on the weld to verify its integrity.
4. **Apply a new protective coating** after the welding work is completed.
5. Install a **permanent clamp or sleeve**, if needed, to reinforce the joint.
6. Monitor the area during routine inspections to detect any signs of future deterioration.