Corrosion Prevention for AST’s and Piping Systems
2004 OSC Readiness Training Program

Presented by:
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NACE International – The Corrosion Society

1. NACE International Overview
2. Cost of Corrosion
3. Aboveground, Underground Storage Tanks, and Associated Piping Systems
4. NACE Resources
NACE International – Overview

Our Vision

NACE International will be recognized as a world-class corrosion society by contributing significantly to the enhancement of global corrosion efforts.

Our Mission

To reduce the impact of corrosion.
NACE International – Overview

• Global Forum for Corrosion Technology
• Global Source for Corrosion Education & Training
• Internationally Recognized Standards
NACE International – Overview

• 60th Anniversary
• Not-for-Profit Organization
• 15,000 Individual Members in 91 Countries
• 275 Corporate Members
• Organized in 82 Sections
NACE International – Overview

- Education Programs
- Professional Recognition
- Coating Inspector Training
- Cathodic Protection Certification
NACE International – Overview

• NACE Standards
• Conferences/Expos
  • CORROSION/2004 – Houston, TX. March 2005
  • Corrosion Technology Week 2004 – Phoenix, AZ, Sept. 2004
• Periodicals
• Publications & Software
NACE International – Education & Certification

NACE Education Classes Designed To:

• Introduce fundamentals of corrosion control
• Expand existing knowledge
• Provide professional recognition & certification
NACE International – Education & Certification

10 Certification Categories

• Coating Inspector Program
  • Three Courses
  • 5,500 recognized individuals – worldwide

• Cathodic Protection Certification
NACE International – Education & Certification

- NACE Certification Specified Worldwide
- Qualified Personnel
- Ensure Safe Operations
- Extend Asset Life
- Reduce Downtime
- Improved Quality Assurance
NACE International – Standard & Reports

Standards Recognized Worldwide

• 118 NACE Standards
  • 19 Material Requirements
  • 69 Recommended Practices
  • 30 Test Methods
• 60 Technical Committee Reports
What is the Cost of Corrosion?
$276 Billion

The United States Cost of Corrosion Study
Cost of Corrosion

• All costs are direct corrosion costs
  • Cost of labor attributed to corrosion management activities
  • Cost of the equipment required because of corrosion related activities
  • Loss of revenue due to disruption in supply of product
  • Cost of loss of reliability
  • Cost of lost capital due to corrosion deterioration
Methods & Services

• All costs are direct corrosion costs
• Disadvantage: many costs are missed
  ➢ Cost of labor attributed to corrosion management activities.
  ➢ Cost of the equipment required because of corrosion-related activities.
  ➢ Loss of revenue due to disruption in supply of product.
  ➢ Cost of loss of reliability.
Cost of Corrosion – Industry Sector Analysis
Extrapolated Corrosion Costs: $276 Billion, 3.1% of GDP

- Manufacturing, 31.5% $86.8 Billion
- Transportation and Utilities, 34.9% $96.2 Billion
- Construction, 18.1% $50.0 Billion
- Services, 5.2% $14.3 Billion
- Federal Government, 7.3% $20.1 Billion
- State and Local Government, 3.0% $8.3 Billion
Non-Technical Preventive Strategies

- Increase awareness of the widespread effects of corrosion
- Build awareness of the huge cost associated with corrosion
- Build awareness of potential savings
- Change the misconception that nothing can be done about corrosion
- Change policies, regulations, standards, and management practices to increase corrosion savings
- Improve education and training of staff
Technical Preventive Strategies

• Advance design practices for better corrosion management
• Advance life prediction and performance assessment methods
• Advance corrosion technology through:
  • Research
  • Development
  • Implementation

Recognize the commonality of the problem regardless of the structure; but also that corrosion may manifest itself differently in each application.
Aboveground and Underground Storage Tanks and Associated Piping Systems
Impact of Corrosion

8.5 million tanks in the U.S. (regulated and non-regulated)
$4.5 Billion Cost to AST
$2.5 Billion Cost to UST
Total Cost of $7 Billion annual cost

Corrosion is one of the leading causes of storage tank and piping failures
Corrosion Control Regulations

• By the Oil Pollution Act of 1990:
  ➢ The owner *must* have a Spill Response Plan
  ➢ The owner *must put in place measures, practices, etc. to limit the possibility of releases* based upon industry accepted sound engineering practice in *design, operation, and maintenance of the facility*
  ➢ The reg. does not regulate corrosion control, but does say prevent release.

• 1998 EPA Regulation for UST – Requires that all tanks to have corrosion control, as well as overflow and spill protection
Spill Prevention Control and Countermeasure (SPCC) Regulation

- Provide buried piping that is installed or replaced after August 16th, 2002 with a protective coating and cathodic protection.

- Should a section of line be exposed for any reason it must be inspected for deterioration. If corrosion damage is found you must take additional examination and corrective action.
NACE has either developed or is in the process of developing standards to address Tank and Pipeline integrity:

- **RP0169-2002, Control of External Corrosion on Underground or Submerged Metallic Piping Systems**
- **TM0101-2001, Measurement Techniques Related to Criteria for Cathodic Protection**
- **RP0193-2001, External Cathodic Protection of On-Grade Carbon Steel Storage Tank Bottoms**
NACE Standards (con.)

• RP0285-2002, Corrosion Control of Underground Storage Tank Systems by Cathodic Protection

• TM0497-2002, Measurement Techniques Related to Criteria for Cathodic Protection on Underground or Submerged Metallic Piping Systems
API Standards

• API 570 Piping Inspection Code
• API 651 Cathodic Protection of Aboveground Petroleum Storage Tanks
• API 652 Lining of Aboveground Petroleum Storage Tanks Bottoms
• API 653 Tank Inspection, Repair, Alteration, and Reconstruction
• API 1632 Cathodic Protection of Underground Petroleum Storage Tanks and Piping Systems
Thank You!
Corrosion Control
& Cathodic Protection for Storage Tanks and Piping Systems

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What we will cover:

- Causes of Corrosion
- Regulatory Issues (State/Federal)
- Cathodic Protection for Tanks and Piping
- Operation & Maintenance
1.2.1 An aboveground storage tank is a stationary container of greater than 500 barrel capacity, usually cylindrical in shape, consisting of a metallic roof, shell, bottom, and support structure where more than 90% of the tank surface is above grade.
AST Storing

- Gasoline
- Diesel
- Kerosene
- Aviation Fuel
- Fuel Oil
- Hazardous Material/Chemicals
Spill Prevention Control and Countermeasure (SPCC) Regulation (Implementation Required by 8/16/06)

- Provide buried piping that is installed or replaced after August 16th, 2002 with a protective coating and cathodic protection.

- Should a section of line be exposed for any reason it must be inspected for deterioration. If corrosion damage is found you must take additional examination and corrective action.
Spill Prevention Control and Countermeasure (SPCC) Regulation (Implementation Required by 2/18/05)

- Provide buried piping that is installed or replaced after August 16th, 2002 with a protective coating and cathodic protection.

- Should a section of line be exposed for any reason it must be inspected for deterioration. If corrosion damage is found you must take additional examination and corrective action.
Federal Level (Breakout Tanks)

a) Relieves surges in a hazardous liquid pipeline system or b) receive and store hazardous liquid transported by a pipeline for reinjection and continued transportation by pipeline
Breakout Tank

Main Line

Product Tank (Breakout)

OPS Inspection
Valve
Meter

M
State Level

- Approximately 25% of States now require cathodic protection be installed and maintained on new, refurbished, or repaired tanks in contact with soil or sand foundations.

- A number of other states are in the process of implementing regulations governing AST’s.
Why is Cathodic Protection Important?

• Preserve Assets
• Reduce Maintenance Costs
• Reduce Inspection Cost
• Company/Government Requirement
• Preserve The Environment
Corrosion Can be Defined as Either:

- **Practical**
  Tendency of a Metal to Revert to its Native State

- **Scientific**
  Electrochemical Degradation of Metal as a Result of a Reaction with its Environment
IRON OXIDE REFINING + MILLING =

IRON OXIDE

STEEL + CORROSION =

IRON OXIDE

THE PROBLEM.....
1) ANODE
2) CATHODE
3) ELECTROLYTE
4) ELECTRICAL CONNECTION
Corrosion of Metallic Structure
External Corrosion of Tank Bottom

Anodic Area -600mV

Cathodic Area -550mV

SAND

CURRENT FLOW
## PRACTICAL GALVANIC SERIES

<table>
<thead>
<tr>
<th>Material</th>
<th>Potential*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pure Magnesium</td>
<td>-1.75</td>
</tr>
<tr>
<td>Magnesium Alloy</td>
<td>-1.60</td>
</tr>
<tr>
<td>Zinc</td>
<td>-1.10</td>
</tr>
<tr>
<td>Aluminum Alloy</td>
<td>-1.00</td>
</tr>
<tr>
<td>Cadmium</td>
<td>-0.80</td>
</tr>
<tr>
<td>Mild Steel (New)</td>
<td>-0.70</td>
</tr>
<tr>
<td>Mild Steel (Old)</td>
<td>-0.50</td>
</tr>
<tr>
<td>Cast Iron</td>
<td>-0.50</td>
</tr>
<tr>
<td>Stainless Steel</td>
<td>-0.50 to + 0.10</td>
</tr>
<tr>
<td>Copper, Brass, Bronze</td>
<td>-0.20</td>
</tr>
<tr>
<td>Titanium</td>
<td>-0.20</td>
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<tr>
<td>Gold</td>
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<tr>
<td>Carbon, Graphite, Coke</td>
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* Potentials With Respect to Saturated Cu-CuSO₄ Electrode
1) ANODE
2) CATHODE
3) ELECTROLYTE
4) ELECTRICAL CONNECTION
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2) CATHODE
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1) **ANODE**

2) **CATHODE**

3) **ELECTROLYTE**

4) **ELECTRICAL CONNECTION**

Diagram: Copper -300mV, Steel -600mV, Magnesium -1.7V.
1) ANODE
2) CATHODE
3) ELECTROLYTE
4) ELECTRICAL CONNECTION

Copper -300mV
Steel -600mV
Magnesium -1.7V

Electrical Connection Diagram
WIRE (CONDUCTOR)

CARBON ROD (CATHODE) +0.30mV

ZINC CASE (ANODE) -1.10mV

MOIST PASTE (ELECTROLYTE)
Piping Installation
Corrosion Cell Caused by Foreign Material in Sand Cushion

Steel Tank Floor

SAND

CLAY

CURRENT FLOW
Corrosion Caused by Poor Water Drainage
Bimetallic Corrosion

Corrosion occurs on tank bottom

Steel Tank Floor

CURRENT FLOW

SAND

Copper Ground Rod
New Steel Coupled to Old Steel

New Bottom (Anode)

CURRENT FLOW

SAND

Old Bottom (Cathode)

SAND
Types of Cathodic Protection

**Galvanic**: Current obtained from a metal with a higher energy level.

**Impressed Current**: Requires external power source (transformer rectifier).
Galvanic Anode Cathodic Protection

- Current is obtained from a metal of a higher energy level
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* Potentials With Respect to Saturated Cu-CuSO$_4$ Electrode
Galvanic Cathodic Protection

- Magnesium
- Anode
- Current Flow
- Structure
Cathodic Protection Test Station

Magnesium Anode

Structure
Kenmore Gas Water Heaters

It's their performance and dependability that keep you in hot water...
check their features, check the facts:

- Warranty...our 5 to 10-year limited warranties...KENMORE quality and longevity.
- Polyurethane foam or fiber glass insulation resists heat loss and helps save energy.
- Polyurethane insulation provides 75% greater heating insulation than fiber glass.
- Anode rodes help protect water tank from internal corrosion and premature tank failure.
- Energy cut-off automatically shuts off power supply if thermostat fails, prevents overheating.
- Adjustable thermostat keeps your hot water at pre-selected levels. "Low" setting lets you save energy while you're away.
- Porcelain glass lining in our steel tanks helps prevent rust to extend tank life and helps maintain hot water supply.

Power Miser II
- Tank has limited 8-year warranty against leaks.
- 1-inch polyurethane foam insulation (R-value 8.33).
- Roto-Swirl™ cold water inlet tube swivels water to help prevent mineral build-up at bottom of tank...extends tank life.
- Porcelain glass lining and 2 anode rods help fight rust and corrosion.
- Fastest hot water recovery rate of any gas unit we sell.
- Natural gas only.

$239.99 and up
$11.99/monthly

Estimated annual energy costs based on:

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Recovery (°F)</th>
<th>Capacity (gals)</th>
<th>Heating (BTU/hr)</th>
<th>Manufacturing (BTU/hr)</th>
<th>Actual Efficiency (BTU/hr)</th>
<th>Annual Energy Cost (kwh)</th>
<th>Annual Fuel Cost (dollars)</th>
<th>10-Year Warranty</th>
<th>10-Year Warranty</th>
</tr>
</thead>
</table>
FLANGE INSULATION KIT

INSULATING UNIONS
Kenmore Gas Water Heaters

It's their performance and dependability that keep you in hot water...

- Warranty...our 5 to 10 year limited warranties convey our confidence in Kenmore quality and longevity.
- Polyurethane foam or fiber glass insulation resists heat loss and helps save energy. Polyurethane insulation provides 75% greater heating insulation than fiber glass.
- Anode rods help protect water tanks from internal corrosion and premature tank failure.
- Energy cut-off automatically shuts off power supply if thermostat fails, prevents overheating.
- Adjustable Thermostat keeps your water at pre-selected levels. "Low" setting lets you save energy while you're away.
- Porcelain glass lining in our steel tank helps prevent rust to extend tank life and helps maintain hot water supply.

Power Miser II
High Performance
- Tank has limited life warranty against leaks.
- Loctite™ coated water inlet & outlet swivets water in and help prevent mineral build up at bottom of tank...extends tank life.
- Porcelain plate lining and 2 anode rods help guard against hard water and corrosion.
- Rarest hot water recovery rate of any gas unit we sell.
- Natural gas only.

$349.99 and up

[Table with energy costs and specifications]
Anodic Area: -600mV  
Cathodic Area: -550mV  
CURRENT FLOW: SAND
CURRENT FLOW

SAND

ELECTRICAL CONNECTION

CATHODE

CURRENT FLOW

Anode
-1.7V
Recommended Practices

**API-651** - Cathodic Protection of Aboveground Petroleum Storage Tanks:

“Galvanic anodes method is not practical for protection of large bare structures.”

**NACE RP0193-2001** - External Cathodic Protection of On-Grade Carbon Steel Storage Tank Bottoms:

“Galvanic protection systems can be applied to tank bottoms where the metallic surface area exposed to the electrolyte can be minimized through the application of a dielectric coating or the area is small due to the tank size or configuration.”
Impressed Current System

- Rectifier
- Anode
- Groundbed
- Pipeline (Structure)
- Current Flow
Impressed Current Cathodic Protection System

- Anodes
- Rectifier
- Wiring
Impressed Current Cathodic Protection

Current Flow

Rectifier

Anode

Return

(-)

(+)
Shallow Anodes
Above Ground Storage Tank Vertical Impressed Current Anodes - Existing Tanks

- Rectifier
- Negative Connection
- Anodes
- Concrete Ringwall
- Sand
- Anodes
Deep Anode System

“One or more anodes installed vertically at a depth of 50 feet or more below grade, in a drilled hole, for the purpose of supplying cathodic protection…”

NACE International Definition
Anodes

Junction Box

Rectifier

Anodes
Deep Anode
Deep Anode System

Advantages

- Better distribution of protective current
- Smaller right-of-way requirements
- Easily installed in congested areas
Conventional Deep Anode System Disadvantages

- Premature system failure
- Costly re-drilling at failure
- Potential for cross mixing of subsurface aquifers
- Creates conduit for surface spills
1999 REQUIREMENTS FOR ASTs

1. Leak Detection
2. Cathodic Protection
3. Internal Lining

- Liquid Level
- Cathodic Protection Rectifier (2)
- Internal Lining (3)
- Slotted PVC Conduit
- HydroCarbon/Leak Detection Probe (1)
- Cathodic Protection Anode (2)
- Cathodic Protection Reference Cell (2)
Directional Boring Under Existing AST
ABOVEGROUND STORAGE TANK

CATHODIC PROTECTION

3”Ø PVC 20% Exposure

Anode Material

Anode Tube

Test/Access Station

Aboveground Storage Tank

Grade

10’ Typical

ABOVEGROUND STORAGE TANK
CATHODIC PROTECTION
TYPICAL ANODE INSTALLATION

- Tank Bottom
- Slotted Pipe
- Native Earth
- Coke Breeze
- Anode Material Centered in Coke Breeze
Cathodic Protection Monitoring
Computer Guided Horizontally Bored Anode System

- Rectifier
- Anode Splice Box
- Anode Pipe
- Monitoring Pipe
- Tank

(+), (-)
Leak Detection Monitoring Station
CP Applications for Re-bottomed or New Tanks
New Floor Installation on Existing AST
CP Installation on Rebottomed Tank
Titanium Anode Ribbon and Reference Cells
Above Ground
Storage Tank Bottoms
with Secondary Containment
Secondary Containment

- Environmental Protection
- Minimize Liability
- State and Local Regulations
CP Installation on Double Bottom Tank
Anode & Reference Cell Placement in High Resistance Sand
Ringwall Conduit for CP Wiring
Floor Plate Installation
Air Bag Lift
Install Containment Liner
Installation of CP System on Lifted AST
Cathodic Protection Monitoring

- Read rectifiers every 60 days.
- Conduct annual inspection (obtain potentials) by NACE certified individuals.
Inspection of CP System
- Record Volts/Amps
- Compare values to target settings
Qualifications of the corrosion engineer

- Certified by N.A.C.E. (National Association of Corrosion Engineers)
- Experienced in Cathodic Protection
- Experienced in Cathodic Protection of Fuel Storage Systems
Remote Monitoring of CP
Computerized Potential Logging Survey

Test Station

Backpack Computer Unit

Chainer/Wire Dispenser & Counter

Reference Cells

Pipeline
MFL Floor Inspection
Portable Reference Cell

Soil

Tank

Rim Potential Measurements

(+)

-850mV

???
Tank to Soil Potential Measurements
Annual Cathodic Protection Survey
<table>
<thead>
<tr>
<th></th>
<th>Rim</th>
<th>25'</th>
<th>Center</th>
<th>55'</th>
<th>Rim</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>On</strong></td>
<td>-1411</td>
<td>-698</td>
<td>-404</td>
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<td>-902</td>
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<td>-402</td>
<td>-578</td>
<td>-911</td>
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[Typical Potentials (mV)](image-url)
Internal Corrosion

Fuel Product

Water / Sediment

Anode

Cathode
Internal Corrosion
<table>
<thead>
<tr>
<th>Galvanic</th>
<th>Impressed</th>
</tr>
</thead>
<tbody>
<tr>
<td>No external power</td>
<td>External power required</td>
</tr>
<tr>
<td>Fixed driving voltage</td>
<td>Voltage can be varied</td>
</tr>
<tr>
<td>Limited current</td>
<td>Current can be varied</td>
</tr>
<tr>
<td>Small current requirements</td>
<td>High current requirements</td>
</tr>
<tr>
<td>Used in lower resistivity</td>
<td>Used in almost any resistivity</td>
</tr>
<tr>
<td>environment</td>
<td>environment</td>
</tr>
<tr>
<td>Usually negligible interference</td>
<td>Must consider interference</td>
</tr>
<tr>
<td></td>
<td>with other structures</td>
</tr>
</tbody>
</table>
Cathodic Protection Design Considerations

- Safety
- Codes
- Economics
- Performance
- System Life
- Interference
- Monitoring & maintenance
- Governmental Regulations
Hot Asphalt Tank Bottoms
• **Linings**
  - Must be compatible with product stored
  - Must maintain properties at operating temperatures
  - Must be applied to properly prepared surface
  - Must be applied with strict inspection
Ductile Iron Water Piping

Pitting (concentrated) corrosion attack on ductile iron pipe.
Suspended Horizontal Anode System

Top View Diagram

- Steel anchors welded to side wall
- Polyester rope supports
- Platinized niobium wire anode or titanium rod with mixed precious metal oxide
- Permanent reference electrodes

Submerged Anode Support System

Automatic Potential Control Rectifier

Pressure Entrance Fitting
Cathodic Protection
Design Considerations

- Safety
- Codes
- Economics
- Performance
- System Life
- Monitoring & Maintenance
- Governmental Regulations
Recommended Practices

**API-651** - Cathodic Protection of Aboveground Petroleum Storage Tanks:

**NACE RP0193-2001** - External Cathodic Protection of On-Grade Carbon Steel Tank Bottoms:
Application Makes the Difference

Good Job

Poor Job
Proper Application

Application is the most expensive and most important part of the job...give it the attention it deserves!
Cost Breakdown

Typical Coating Project

- Surface Preparation: 65%
- Material: 10%
- Application: 25%
Approximate Percentage of Coating Failure Occurrences, Grouped by Root Cause

- Poor Surface Preparation / Application: 80%
- Poor Specification / Mat'l Selection: 20%
- Poor Coating Mat'l from Manufacturer: 0%
Coating Inspection
Pipeline Integrity Inspections
Pipeline Inspection Tool
Galvanic Cathodic Protection System
Steel H-Piles or Pipe Piles

Galvanic Anodes Welded to Structure

Mudline
Corrosion Induced Cracking of the Concrete

- Carbonation
- Chloride Contamination
Summary

- Be aware of all regulations that may pertain to your tanks and piping. When in doubt talk to the governing agencies.

- Engage NACE qualified & experienced personnel to engineer/maintain your cathodic protection system.

- Refer to NACE/API Standards for guidance.
Questions...
Thank You

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Arc-Sprayed Al-Zn-In (Galvanic)

- Thermally sprayed onto concrete
- Al-20Zn-0.2In
- Applicable in marine & northern deicing salt environments
- Indium (In) used as activating agent
Computerized Potential Logging Survey

- Test Station
- Backpack Computer Unit
- Chainer/Wire Dispenser & Counter
- Reference Cells
- Bonded Joints
- Pipeline
Rim 25' Center 55' Rim
On -1411 -698 -404 -601 -1455
Off -902 -664 -402 -578 -911

Reference Cell
Bullseye® Monitoring Tube
Test / Access Station

aboveground storage Tank
grade

3'
Typical

Potentials (mV)

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Impressed Current Cathodic Protection

Return

Rectifier

(-)

(+)

Anode

CURRENT FLOW
Annual Cathodic Protection Survey
Shallow Anodes

Diagram showing a rectifier, an anode with a typical depth of 20', and a splice connecting the rectifier and anode.
Double Bottom Seal

New Floor

Sand

Liner

Old Floor

Seal

Weld
Pennsylvania DEP Summary of Technical Requirements for Aboveground Storage Tanks, Chapter 245, Subchapter F, Effective October 11, 1997...

Cathodic Protection Systems (§245.532)

“When corrosion prevention is required on new, reconstructed or relocated tanks, or on tank bottom replacement, the cathodic protection system must be either: sacrificial anodes and dielectrical coating, or impressed current. (Another method is acceptable if it is recognized in a code of practice, such as API 651, or by a nationally-recognized association, such as NACE.)”
Conventional Deep Anode System Disadvantages

- Premature system failure
- Costly re-drilling at failure
- Potential for cross mixing of subsurface aquifers
- Creates conduit for surface spills
API 653 Floor Scan
Our Business

Engineering Design, Application & Installation of:

- Cathodic Protection
- Corrosion Monitoring
- Material Selection
- Chemical Treatment Systems
- Protective Coatings
- Pipeline Integrity Assurance Programs