Pipe Coating Failures

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Pipeline Coating Failures
Corrosion Protection

Subsoil Exposure

➢ Coatings - Designed to protect the pipe surface from its external environment.
  - Adhesion
  - Thickness
  - Hardness
  - Dielectric Strength
Corrosion Protection

➢ Cathodic Protection-
  Designed to protect the pipe from corrosion should the coating be damaged or become disbonded from the pipe.

➢ Electrical current
  • -850 to 800 mv potential range (Coatings / CP)
  • Temperature
  • Soil resistivity
The “Supply Chain” is the sequential efforts of Engineers, Suppliers, Services and Installers. Each party has a well defined role to accomplish specific tasks that will result in a completed pipeline project.
Supply Chain

Project Sequence
- Design
- Manufacture
- Surface Preparation
- Coating
- Handling
- Storage
- Transportation
- Construction
Design

➢ Atmospheric Exposure
  - UV Degradation
  - Abrasion
  - Environmental
  - Airborne Contaminants
  - Structural Supports
  - Operating Temperatures
Design

➢ Subsoil Exposure
  - Operating Temperature
  - Cathodic Protection
  - Pipeline Insulation
  - pH / Moisture
  - Abrasion / Impact Resistance
  - Backfill Composition
  - Chemical Resistance
Design

- Immersion / Marine
  - Operating Temperature
  - Cathodic Protection
  - Water Resistance
  - Weight Coating
  - Resistance to Water
    - Fresh
    - Salt
    - Brackish
Design

➢ Cathodic Protection
  • Cathodic Disbondment
Cathodic Protection

- CP Shielding
  - Occurs after coating failure
  - Prevents CP current access to the steel
  - Limited to buried pipelines onshore.

- FBE
  - Current reaches water
  - pH raised >9
  - No significant corrosion
  - Non-shielding

- Shrink Sleeve
  - Current shielded from water
  - pH remains <9
  - Corrosion
  - Shielding

- RD-6™
  - Current reaches water
  - pH raised >9
  - No significant corrosion
  - Non-shielding
Fasteners Field Joints
- Nuts & Bolts
- Crevices
- Welds
Manufacture

➢ Fabrication
  • Rolling defects
  • Weld Spatter
  • Sharp edges
  • Surface defects
Manufacture

➢ Material Type
- Carbon Steel
- Galvanized Steel
- Aluminum
- Copper
- Ductile iron
- Concrete
Surface Preparation

➢ Decontamination
Surface Preparation

Surface Cleanliness

AUCSC
Appalachian Underground Corrosion Short Course
Surface Preparation

➢ Abrading - Abrasive
  • Surface Profile
  • Anchor Pattern
  • Mechanical Tooth

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Surface Preparation

➢ Quality Control
  - Environmental Conditions
    - Air temperature
    - Relative humidity
    - Dew point
Surface Preparation

Quality Control

- Surface Conditions
  - Contamination
  - Weld defects
  - Profile
    - Too deep
    - Too shallow
Surface Preparation

➢ Quality Control
  ● Adhesion
Coating

➢ Coal Tar Enamel
  - Water resistant
  - Moisture resistant
  - Chemical resistant
    - Acid
    - Alkali
  - Petroleum products
  - Surface tolerant
  - Bacteria resistant
  - Dielectric strength
Coating

➢ Coal Tar Enamel
  ● Coating System
    • Coal Tar Enamel
    • Glass Reinforced
      ● Inner Wrap
      ● Outer Wrap- Saturated
    • Kraft Paper Protection
      ● UV Rays
Coating

➢ Curing
  - Function of time and temperature
  - Uncured coatings will absorb moisture
    • Amines- Epoxies
    • Isocyanates- PUR
  - FBE- Passivation
    • Chromate wash
    • Phosphate wash
    • Acid wash
Coating

➢ Quality Control
  • Pipe Temperature
    • Temple sticks
    • Infrared sensors (mixed results)
  • Dry Film Thickness (DFT)
    • Surface Temperature
  • Holiday detection
  • Traceability of pipe
    • Barcodes
      • Standardization
Handling

➢ Damage
  ● Lifting and Loading
    • Trailers
    • Trains
    • Vessels- Maritime
Handling

Equipment

- Fork Lifts
- Grippers
- Pipe Hooks
- Minimize Damage
  - Hydraulic Spreaders
  - Vacuum Lifters
Storage

➢ Stacking
  • Causes stresses on the piping.
  • Deforming the diameter of the pipe.
  • Stress is increased at every level
Storage

Stacking

- Causes stresses on the coating.
- Stacking- Abrasion and Impact damage where the pipes touch. (3 & 9 o’clock positions)
  - Pipe stacks should be blocked to prevent rolling.
Storage

➢ Environment
  - Soluble Salts
    - Chlorides
    - Nitrates
    - Sulfates
  - Dirt, Dust & Mud
  - Oil, Grease & Lubricants
  - Chemicals
    - Acids
    - Alkalines
Storage

➢ Exposure
  • UV Degradation
  • Chalking: Deterioration of the resin / binder because of UV exposure.
  
  Loss of plasticizers will make the coating brittle and eventually checking in the coating.
Transportation

➢ Damage
  • Abrasion from travel movement
  • Loading & Unloading
    • Handling
Transportation

Damage
- Supports and Stops
  - Abrasion and Impact
Transportation

➢ VDI 2700 Association of German Engineers
  • Manual- Securing of loads on road vehicles
Transportation

➢ Climate / Environment
Construction

➢ Handling
Construction

➢ Field Welds
  • Surface Preparation
    • Abrasive blast cleaning
    • Hand / Power tool cleaning
Construction

➢ Field Welds- Surface Preparation
  - Nace No. 2
  - SSPC SP 10
    - Minimum cleaning standard
Field Welds- Surface Preparation

- Surface Profile
  - 2.0- 4.0 mils
- Measurement method
  - Testex tape
Field Welds (HSS)
- Heat-Shrinkable Sleeves
  - 30 year history
  - Cross linking polyolefin.
  - Cured by “Electron irradiation”
- Polyethylene and Polypropylene coatings
- Epoxy primer is used for 3-layer systems
- Peel test - Adhesion and cure.
Construction (HSS)

18 in Oil Pipeline
➢ 3 layer Polyethylene
➢ In Line Inspection (ILI)
   • Corrosion 1st 15 km
➢ 131F Operating Temp
➢ Service- 15 yrs
➢ Wet, compacted sand pH 5.4
➢ HSS
   • Hot melt type / Epoxy Primer
   • Surface Prep Power tool
Construction (HSS)

18 in Oil Pipeline

➢ Massive disbonding of HSS
  ● Steel surface
  ● 3LPE coating system

➢ Significant corrosion
  ● Field joint
  ● Steel surface

➢ No significant corrosion at lower operating temperatures.
Construction (HSS)

18 in Oil Pipeline
➢ Longitudinal cracking at the 3 and 9 o’clock positions.
➢ Showed signs of thermal aging
  • Brittleness
  • Lack of flexibility
➢ Issues:
  • Storage conditions
  • Soil exposures
  • Service conditions
Construction (HSS)

- 16 in Oil Pipeline
- 3 layer Polyethylene
- In Line Inspection (ILI)
  - Severe external corrosion
  - Pitting- “Craters” at field joints
- 122F Operating Temp
- Service- 12 yrs
- Brackish w/ 2g/liter chlorides
- HSS
  - Hot melt type / Epoxy Primer
  - Surface Prep- Wire brush
  - Millscale on surface
  - Overlap 1 cm (~ 1.2 in)
Construction (HSS)

16 in Oil Pipeline

- Disbonding of HSS
  - Steel surface
  - 3LPE coating system
- Significant corrosion
  - Field joint
  - Steel surface
  - Salt crystals under HSS
- Disbondment fo coating system
Construction (HSS)

Causes of Disbondment

➢ Surface preparation
  - Minimum Near white blast

➢ Application
  - Fish mouths
  - Overlaps

➢ Service Conditions
  - Operating temperature
  - Soil conditions

➢ UV Degradation during storage.
Construction

➢ Field Welds- PUR
  - Liquid applied Polyurethane
  - Epoxy modified
  - Operating temperature 176 F
Construction

➢ Backfill Materials
- Select according to coating type
- Pipeline Research Council International Catalogue
  - No. L52208 July 2005
  - Smaller particles do less damage
  - Average 20 mm size produce the least amount of holidays
Internal Coatings

- Coating Selection
  - Chemical Resistance
    - Carbon Dioxide
    - Hydrogen Sulfide
  - Abrasion Resistance
    - Erosion
  - Impact Resistance
  - Temperature Resistance
  - VOC Requirements
  - Corrosion Under Insulation
    - CUI
Internal Coatings

- **Immersion Exposure**
  - Water / Moisture
  - Microbiologically Induced Corrosion (MIC)
    - Planktonic Bacteria
    - Sessile Bacteria
    - Sulfate Reducing
    - Anaerobic

Photo: Extensive tuberculation can discolor and contaminate water as well as result in greatly reduced water flow and pressure.
Internal Coatings

➢ Immersion Exposure
   - Abrasion Resistance
     • Impact
     • Sludge
   - Chemical Resistance
   - Inhibitors
     • Scavengers
       • Oxygen
       • Sulfide
   - Biocides- MIC Fighters
Internal Coatings

➢ Vapor Exposure
  • Hydrogen Sulfide H2S
    • Concrete and steel deterioration
Case History

➢ Water main 48 in.
  • Pre-stressed Concrete Cylinder Pipe PCCP
  • 25 years service
  • Wrapped with High strength reinforcement wire- externally
  • Coated with cement rich mortar
  • No Cathodic Protection
  • Backfill native soil
Case History

Water main 48 in.
- Failure location
  - 10 ft long
  - Along pipe wall
- Concrete coating deteriorated and spalled
- Reinforcement wires broke
- Exposed steel substrate to soil conditions
Case History

- Water main 48 in.
  - High sulfate levels
  - Water in soil
  - Corrosion of concrete, steel wires and steel pipe
  - Water pressure exceeded the strength of the deteriorated pipe
  - BURST!!
Coating Maintenance Program

1. Identify the service conditions
2. Coating selection
3. Coating specification
4. Identify inaccessible areas
5. Contractor capabilities
6. Coating inspection
7. Pre-job meeting
8. Teamwork-communication
9. Document all phases
10. Monitor performance after installation
The End