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.
Design

- 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
Surface Preparation

- Abrading - Abrasive
  - Surface Profile
  - Anchor Pattern
  - Mechanical Tooth
Surface Preparation

- Abrading- Abrasive
  - Surface Profile
  - Anchor Pattern
  - Mechanical Tooth
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
Construction

- 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 of 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
    - Anarobic

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