Pipe Coating Failures

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Appalachian Underground Corrosion Short Course

Pipeline Coating Failures

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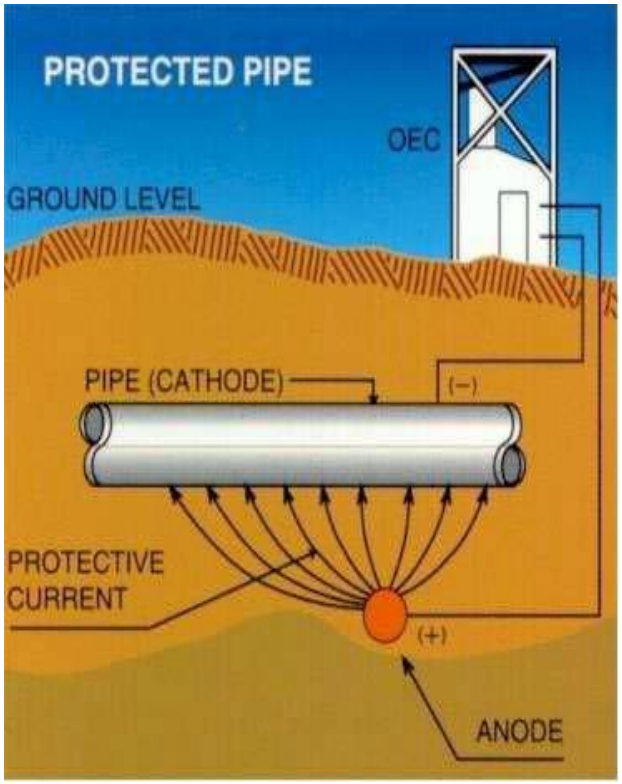
Corrosion Protection

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

Supply Chain

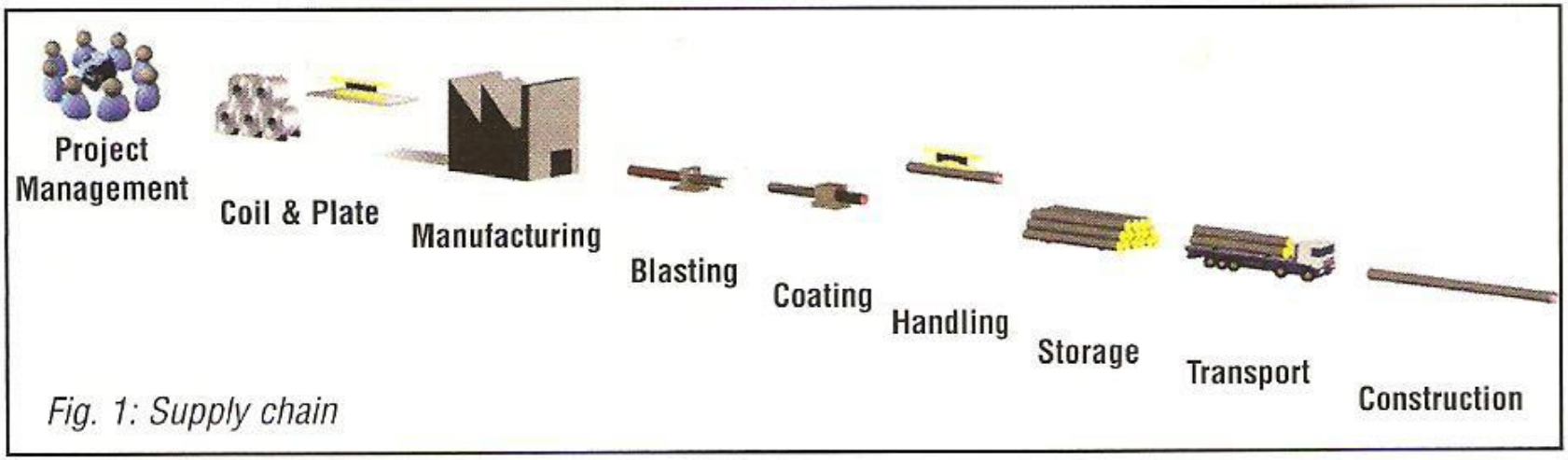


Fig. 1: Supply chain

- 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

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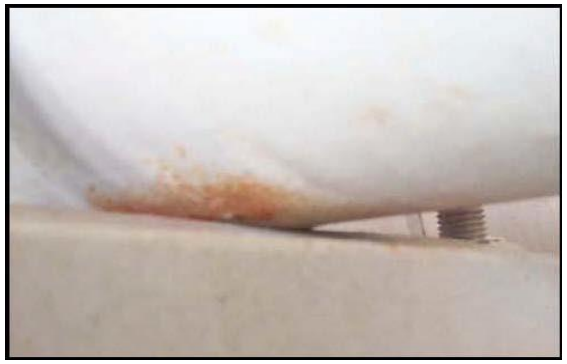
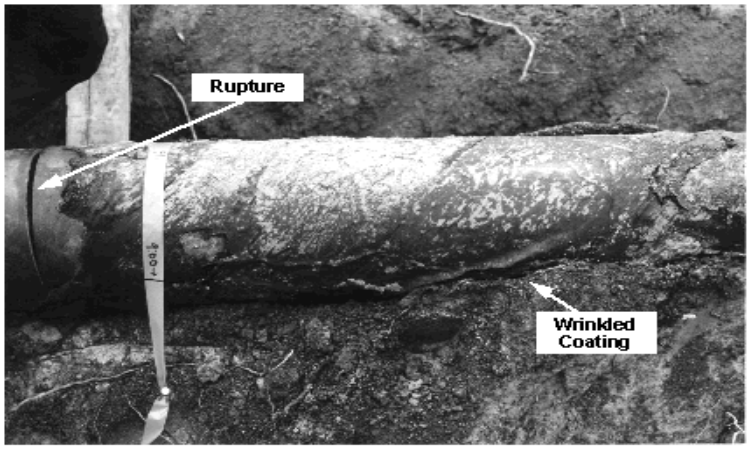
Design



- 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



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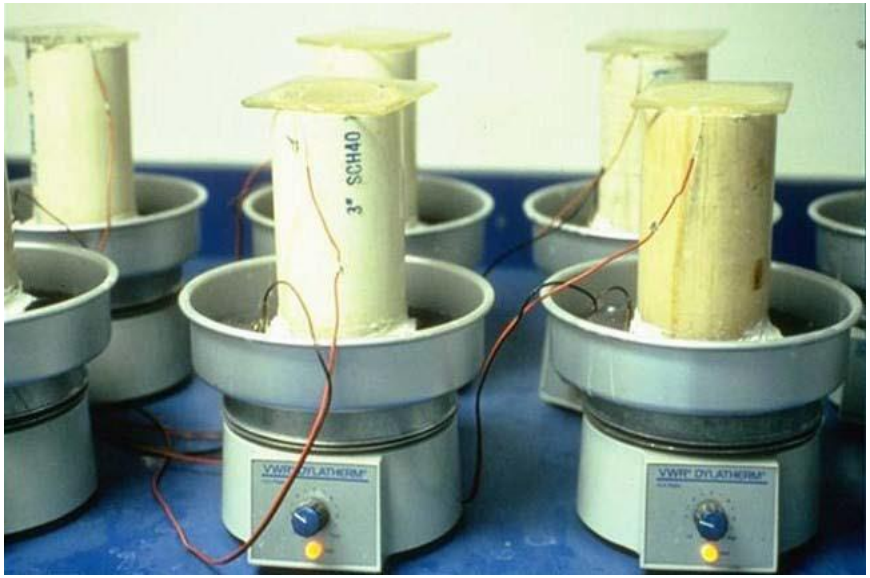
Design

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

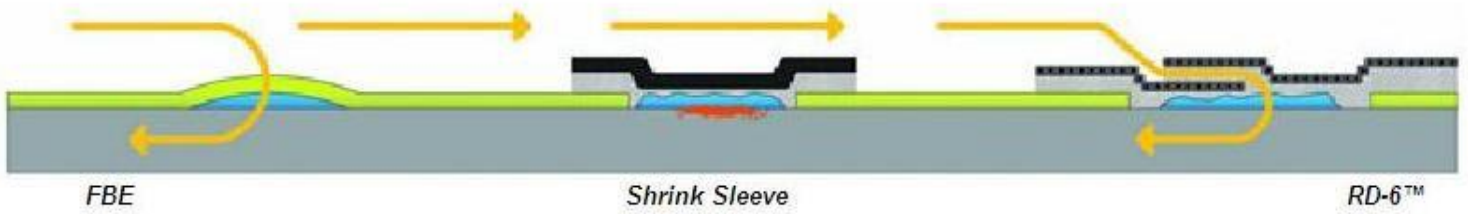
Design

- Cathodic Protection
  - Cathodic Disbondment



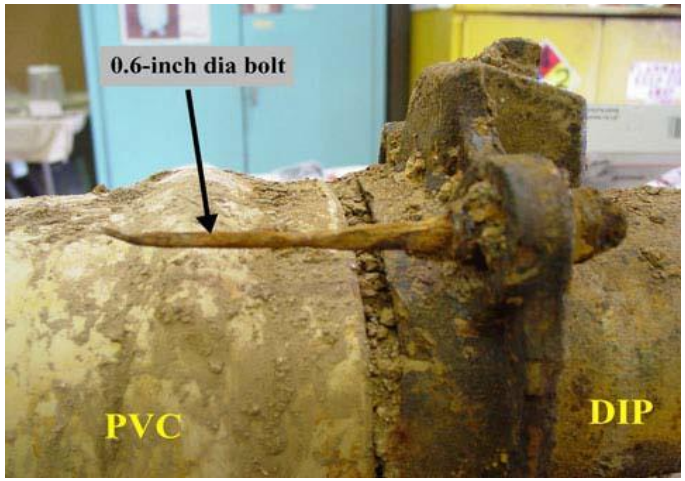
Construction

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

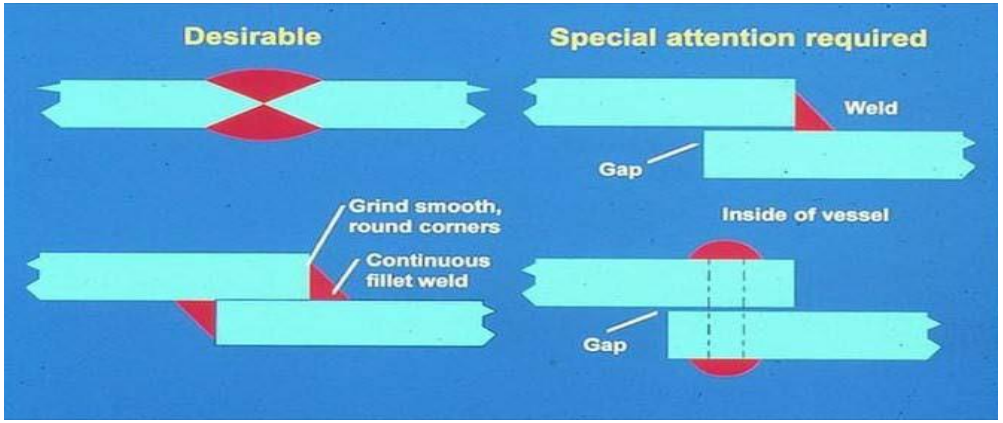


FBE	Shrink Sleeve	RD-6™
• Current reaches water	• Current shielded from water	• Current reaches water
• pH raised >9	• pH remains <9	• pH raised >9
• No significant corrosion	• Corrosion	• No significant corrosion
• **Non-shielding**	• **Shielding**	• **Non-shielding**

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

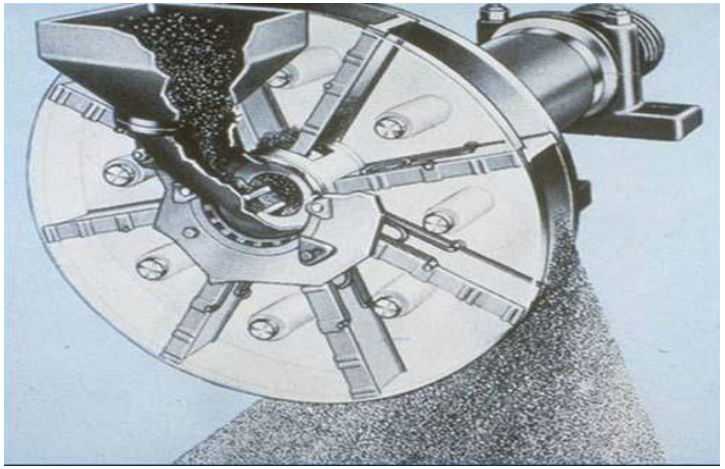
Surface Preparation

- Decontamination

Surface Preparation

Surface Preparation

Surface Cleanliness



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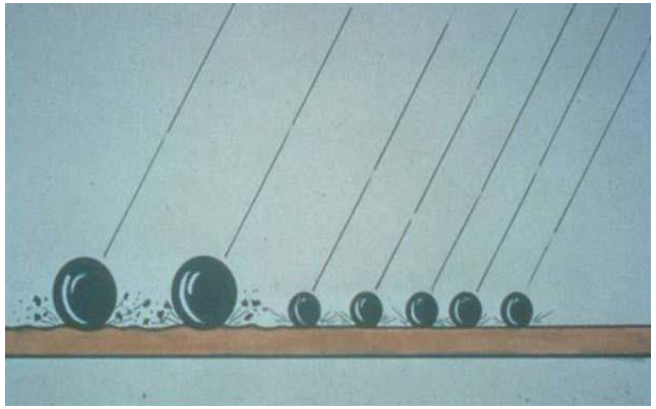
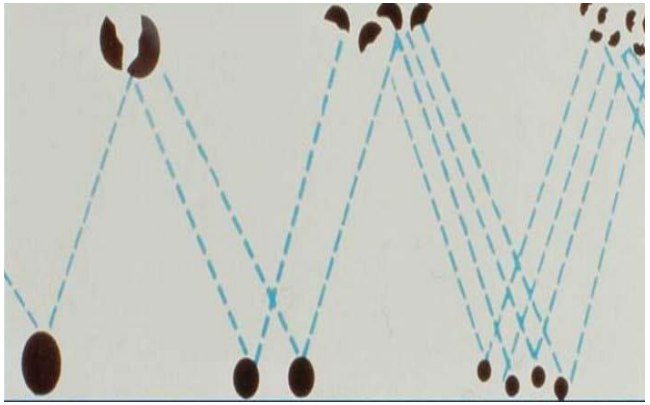
Surface Preparation





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

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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

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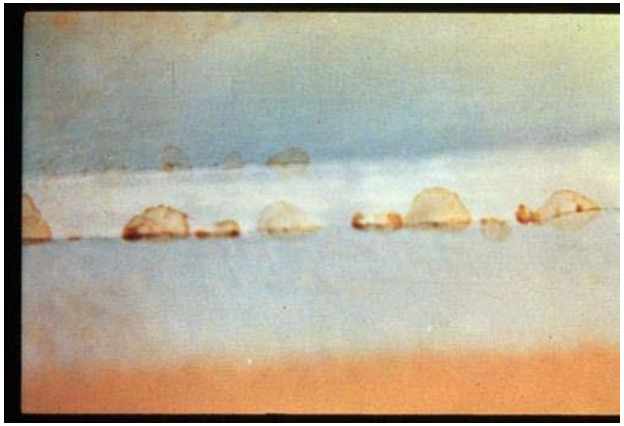
Surface Preparation

Surface Preparation

- Quality Control
  - Surface Conditions
    - Contamination
    - Weld defects
    - Profile
      - Too deep
      - Too shallow



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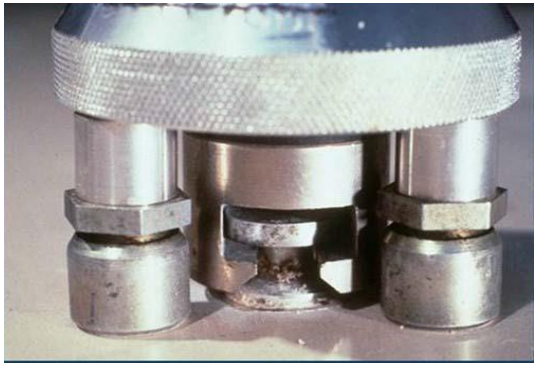
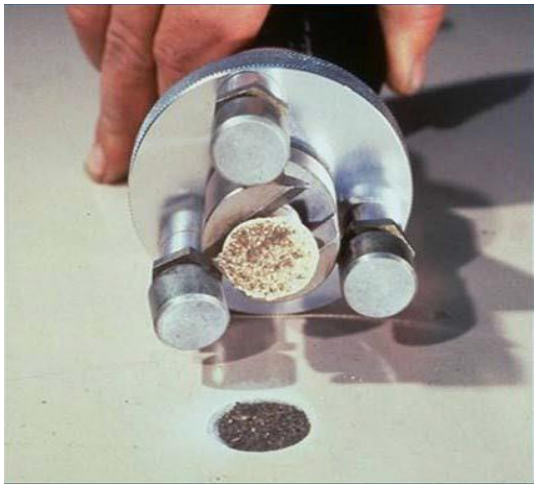
Surface Preparation

- Quality Control
  - Adhesion





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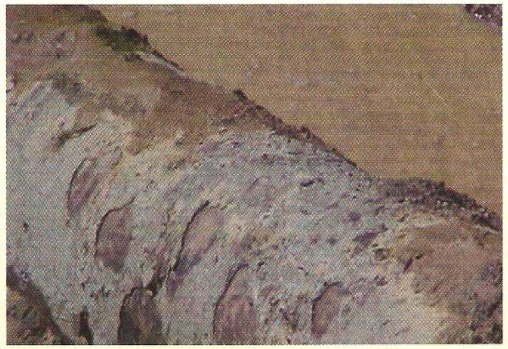
Coating

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

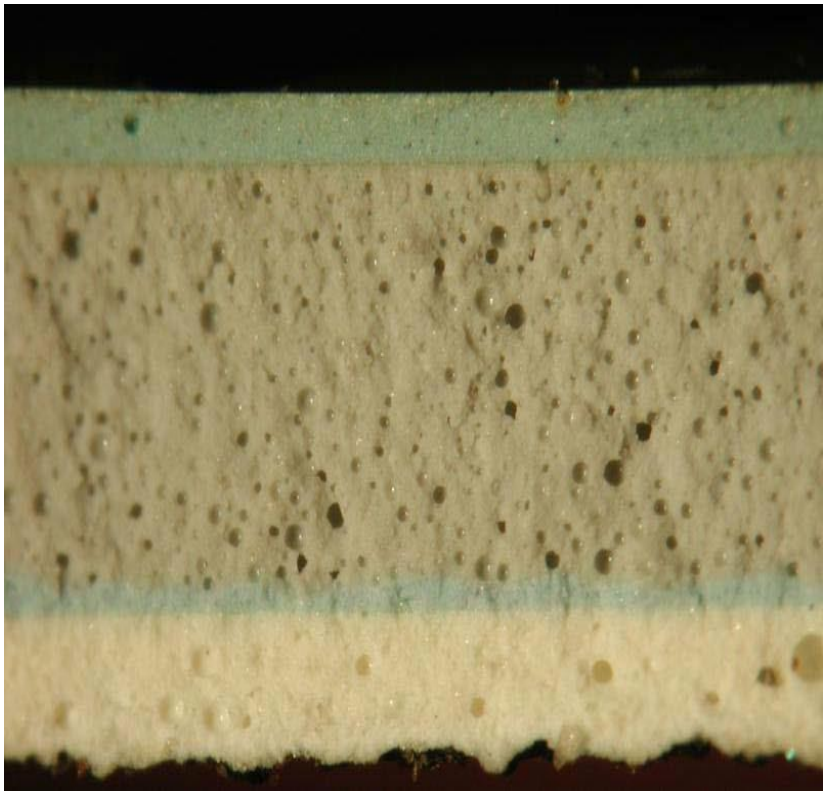


Coating

- 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

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Handling

- Damage
  - Lifting and Loading
    - Trailers
    - Trains
    - Vessels- Maritime

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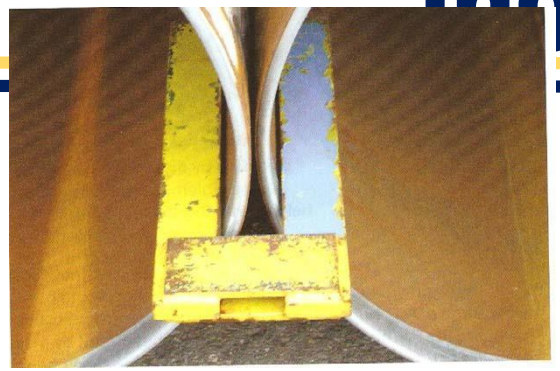
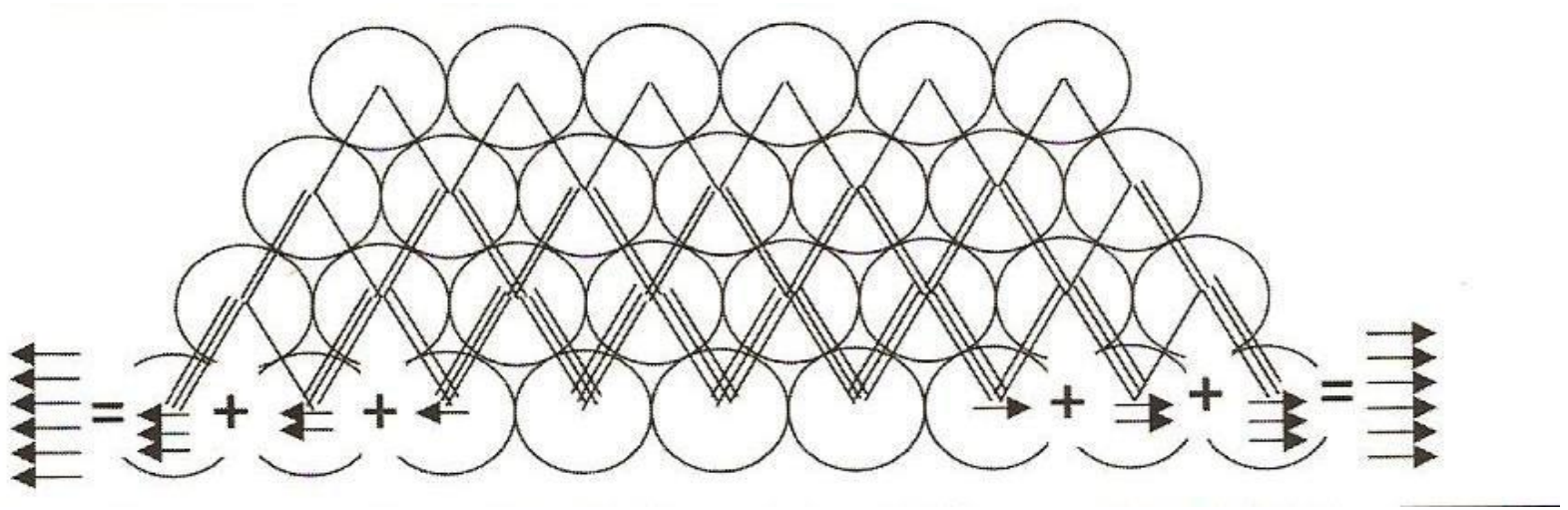
Handling



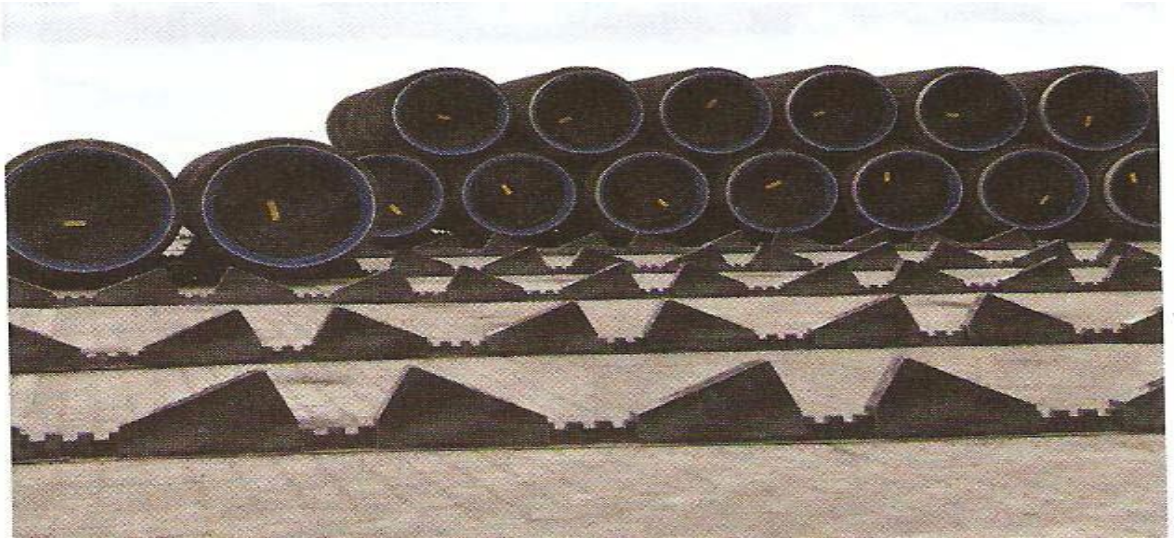
- Equipment
  - Fork Lifts
  - Grippers
  - Pipe Hooks
  - Minimize Damage
    - Hydraulic Spreaders
    - Vacuum Lifters

Storage



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

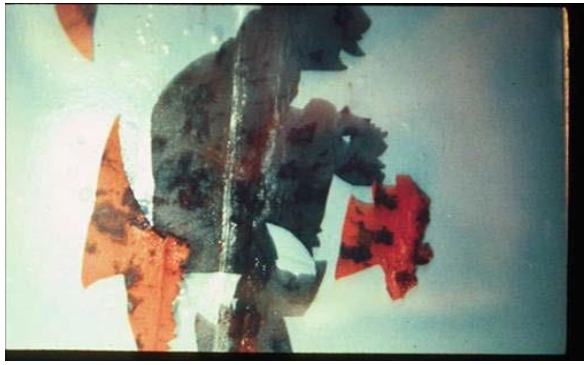
Storage

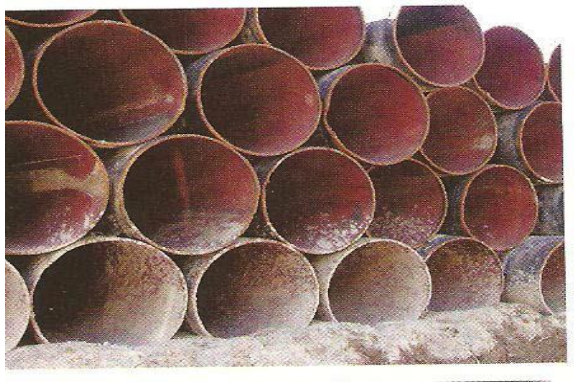


- Stacking
  - Causes stresses on the coating.
  - Stacking- Abrasion and Impact damage where the pipes touch. (3 & 9 o'clock positions)
    - Pipe stacks should be blocked to prevent rolling.

Storage

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





Storage

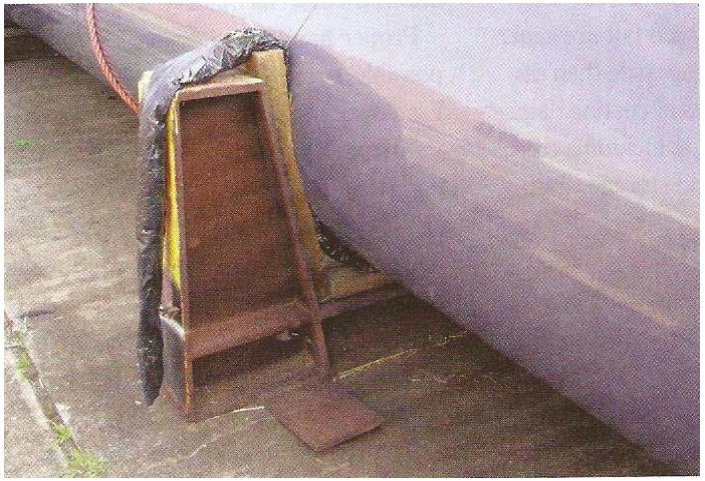
- Exposure
  - UV Degradation
  - Chalking: Deterioration of the resin / binder because of UV exposure.
  - Loss of plasticizers will make the coating brittle and eventually checking in the coating.

Transportation

- Damage
  - Abrasion from travel movement
  - Loading & Unloading
    - Handling

Transportation

- Damage
  - Supports and Stops
    - Abrasion and Impact



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Transportation

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

Transportation

- Climate / Environment

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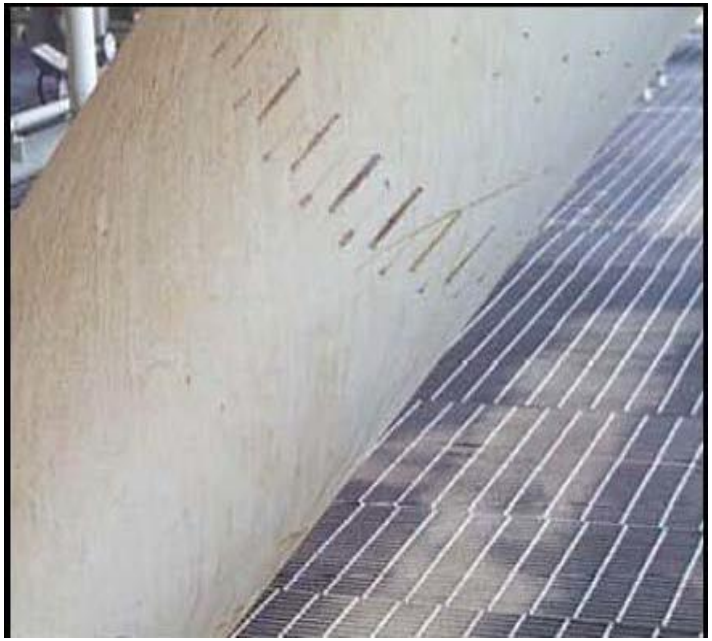
Construction

- Handling



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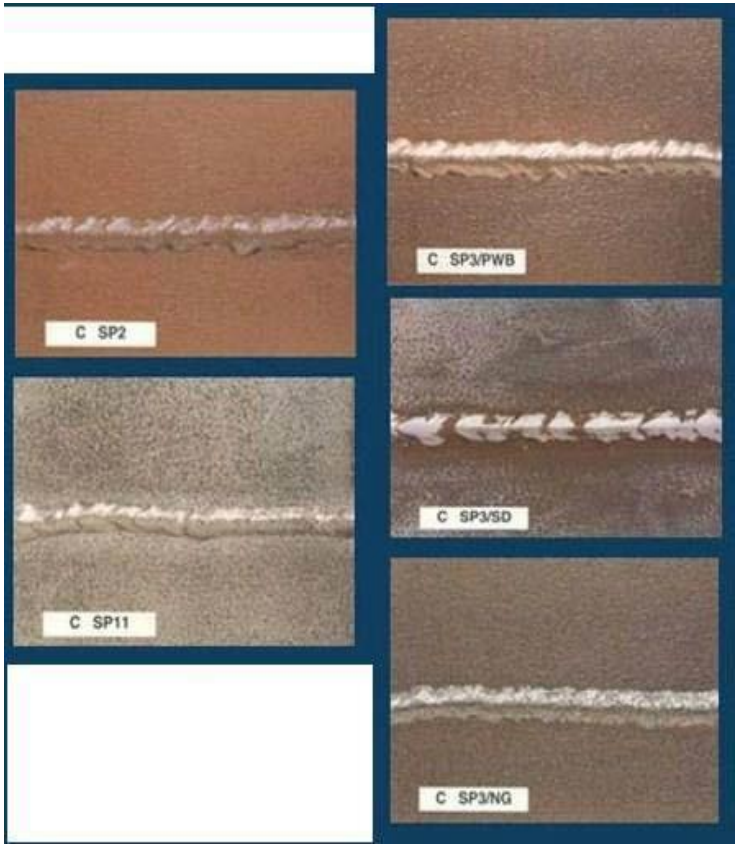
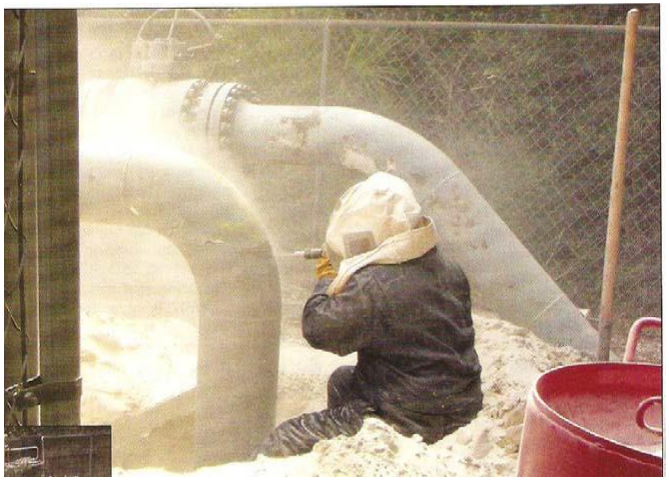
Construction



- 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

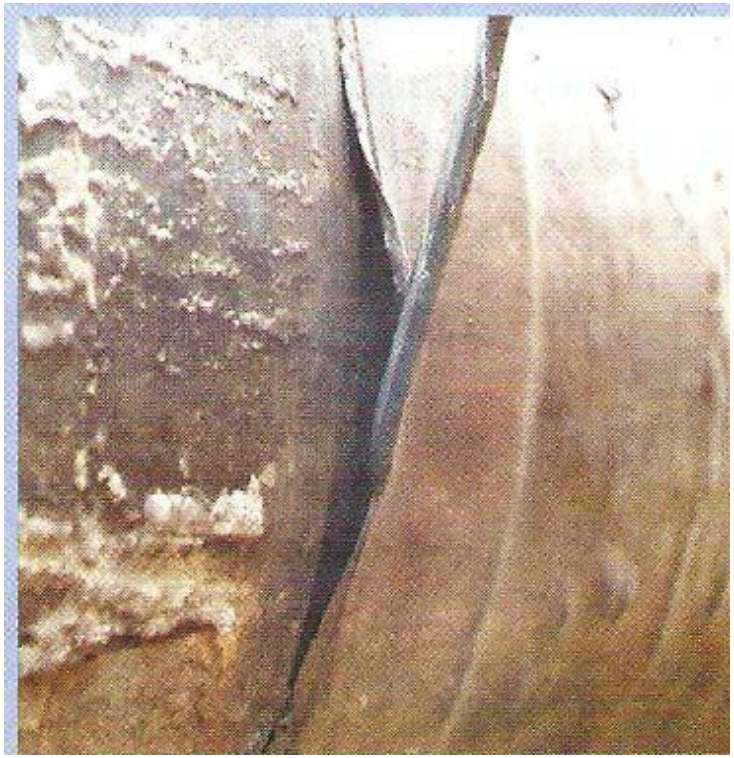
Construction

- 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

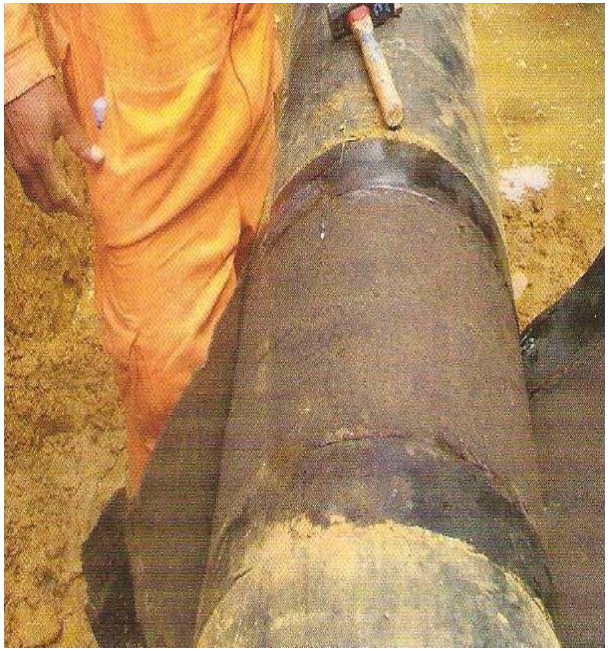
- 3 layer Polyethylene
- In Line Inspection (ILI)
  - Corrosion 1st 15 km
- 131F Operating Temp
- Service- 15 yrs
- Wet, compacted sand pH 5.4
- HSS
  - Hot melt type / Epoxy Primer
  - Surface Prep Power tool



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)

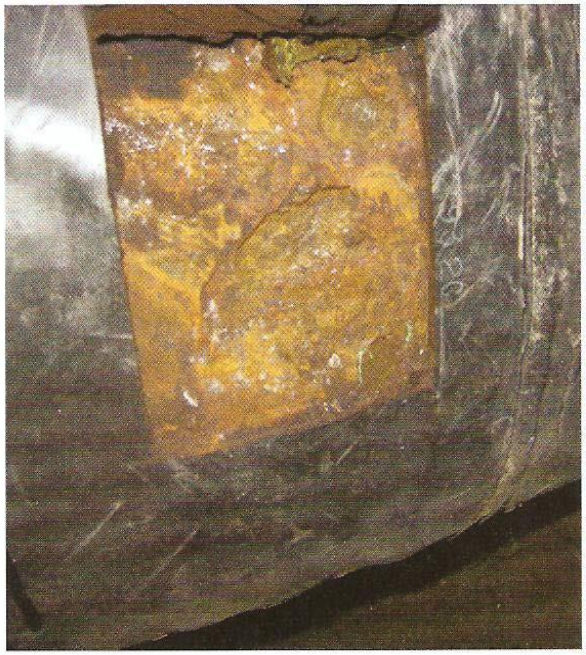
18 in Oil Pipeline

- 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)

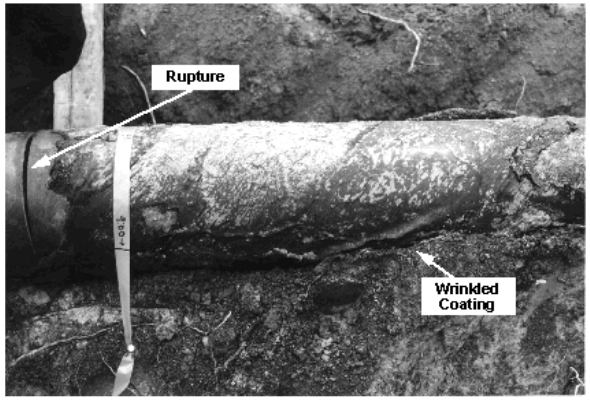


Construction (HSS)

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.

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Construction

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

Construction

- Backfill Materials
  - Select according to coating type
  - Pipeline Research Council Interantional 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

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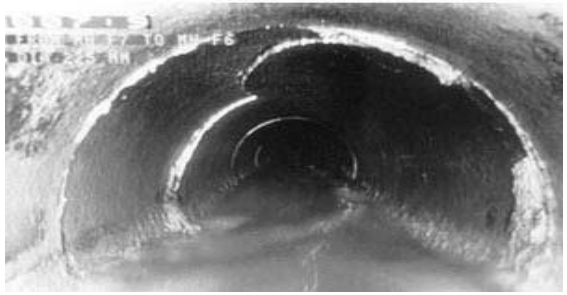
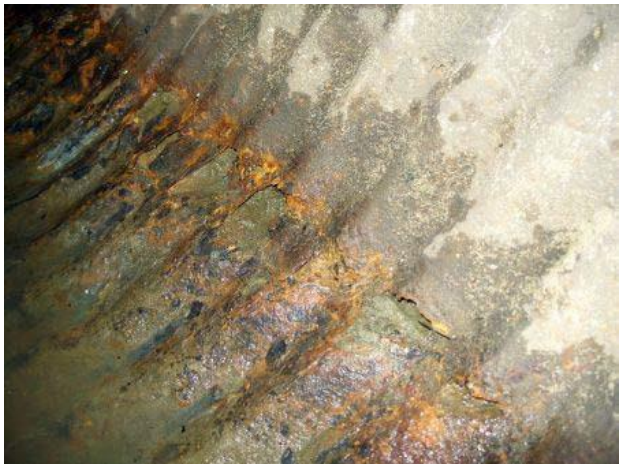
Internal Coatings



- Vapor Exposure
  - Hydrogen Sulfide H2S
    - Concrete and steel deterioration



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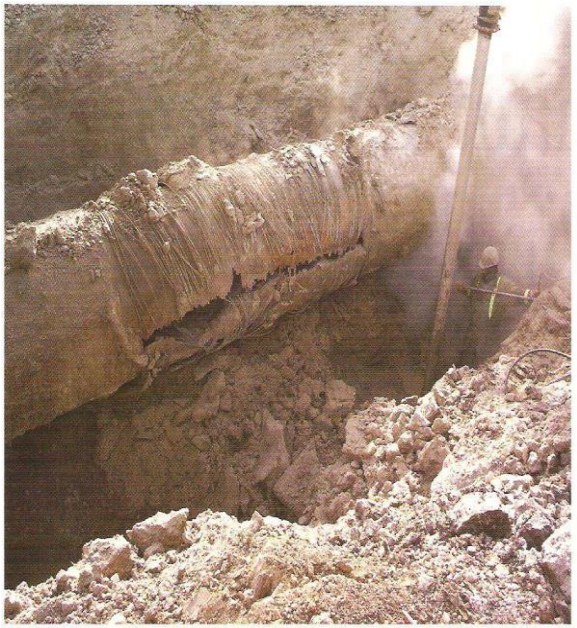
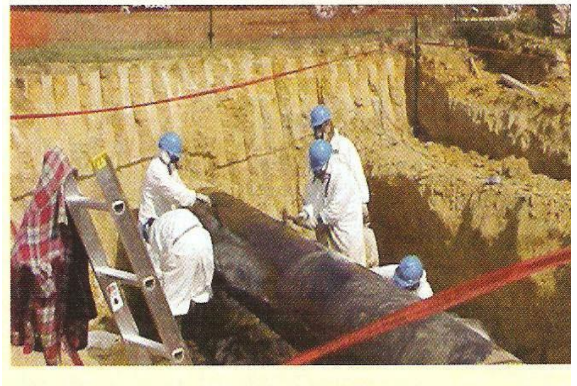
Case History

- 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



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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!!

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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

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