
Pipe Coating Failures

Gregory C Hardig,
Senior Certified Coatings Inspector Cert N-3494
CPR Corrosion Protection Resources LLC



Appalachian Underground Corrosion Short Course

Pipeline Coating Failures



Appalachian Underground Corrosion Short Course

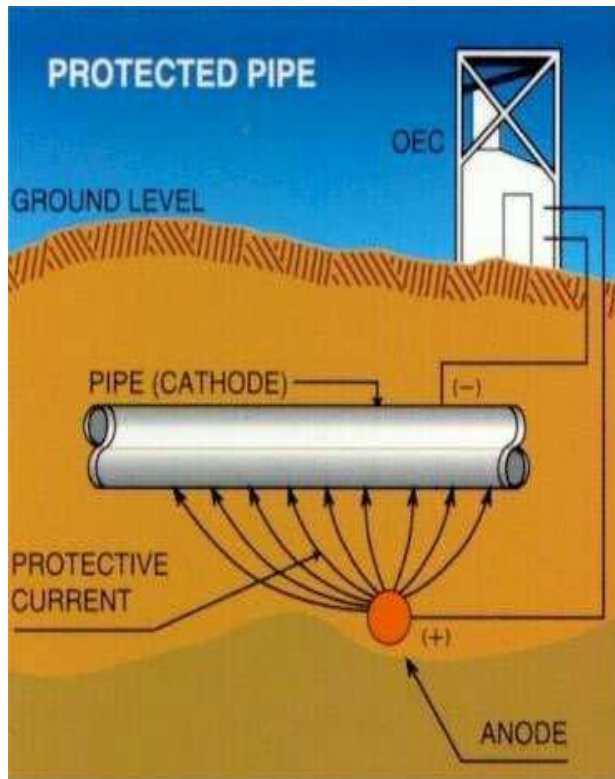
Corrosion Protection

Subsoil Exposure

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

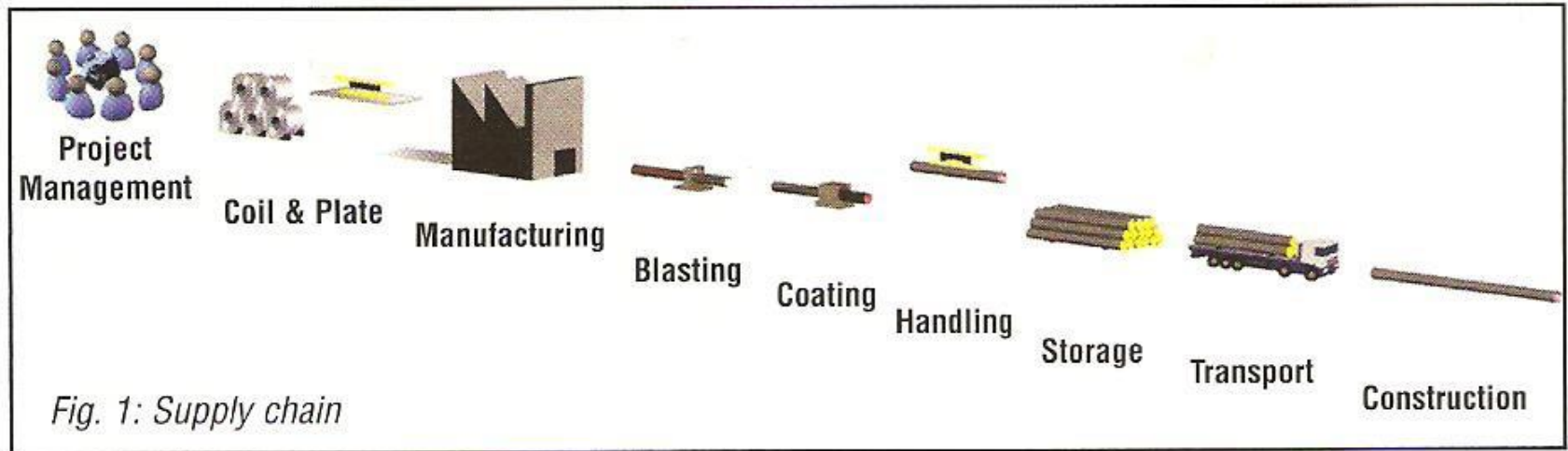


Corrosion Protection



- 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



- 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

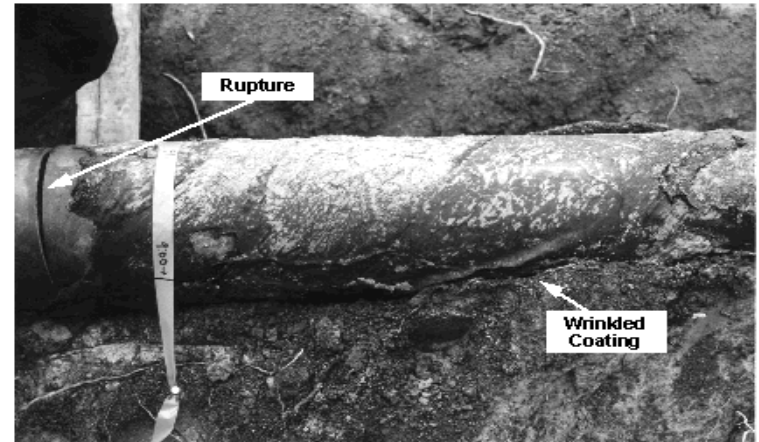


- Atmospheric Exposure
 - UV Degradation
 - Abrasion
 - Environmental
 - Airborne Contaminants
 - Structural Supports
 - Operating Temperatures

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

- Cathodic Disbondment

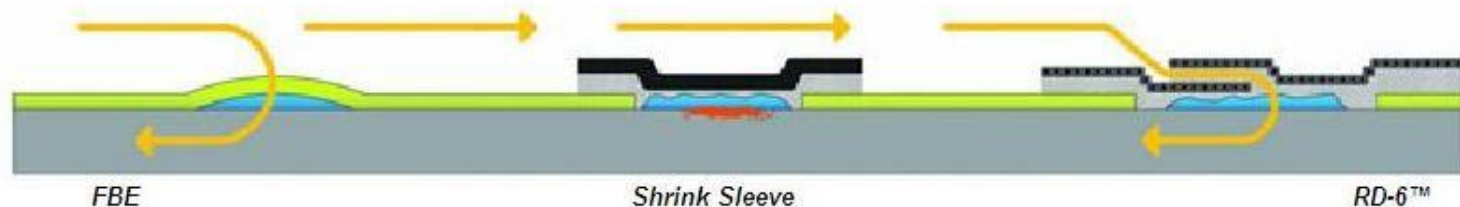


Construction

➤ Cathodic Protection

• CP Sheilding

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

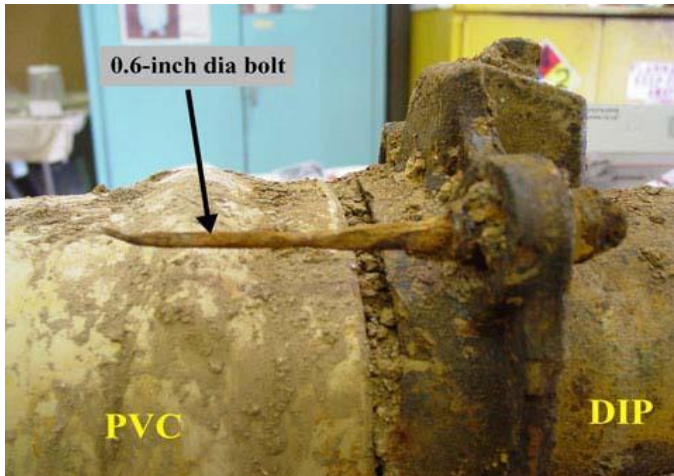


- Current reaches water
- pH raised >9
- No significant corrosion
- **Non-shielding**

- Current shielded from water
- pH remains <9
- Corrosion
- **Shielding**

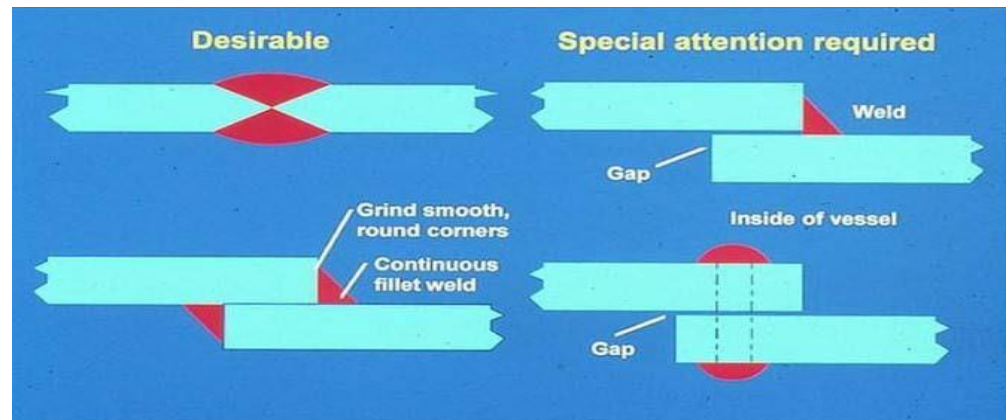
- Current reaches water
- pH raised >9
- No significant corrosion
- **Non-shielding**

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

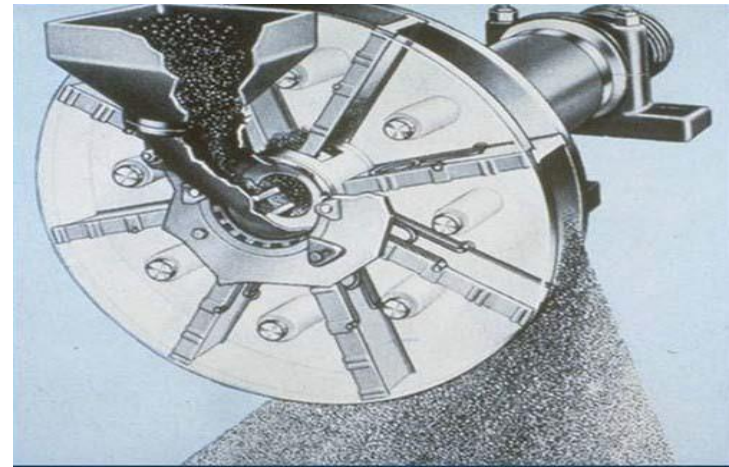
Surface Preparation

➤ Decontamination



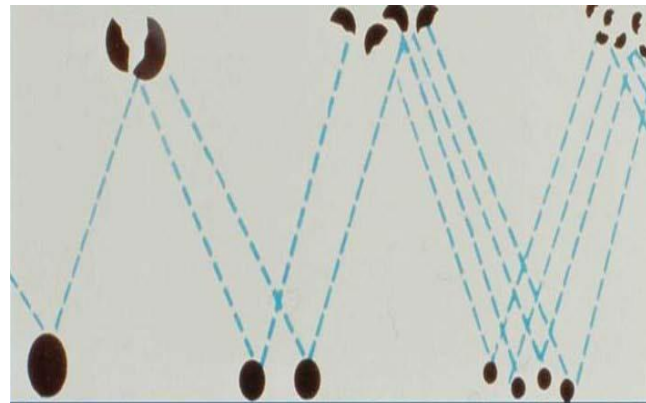
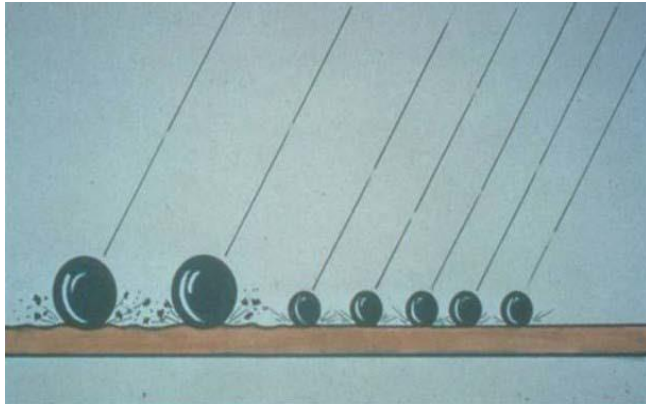
Surface Preparation

Surface Cleanliness



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Surface Preparation

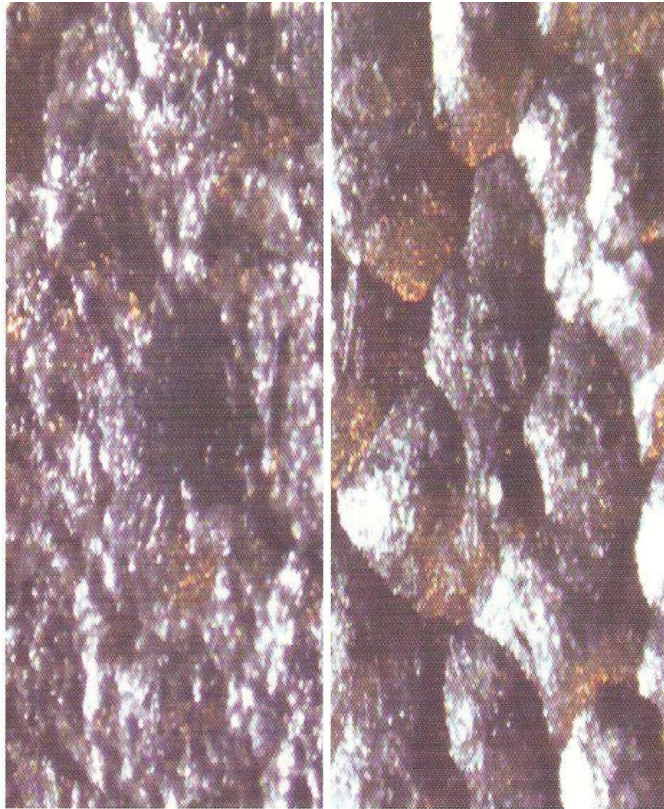


➤ Abrading- Abrasive

- 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

Surface Preparation



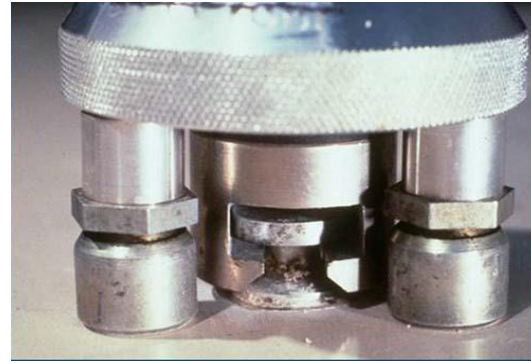
➤ Quality Control

- 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

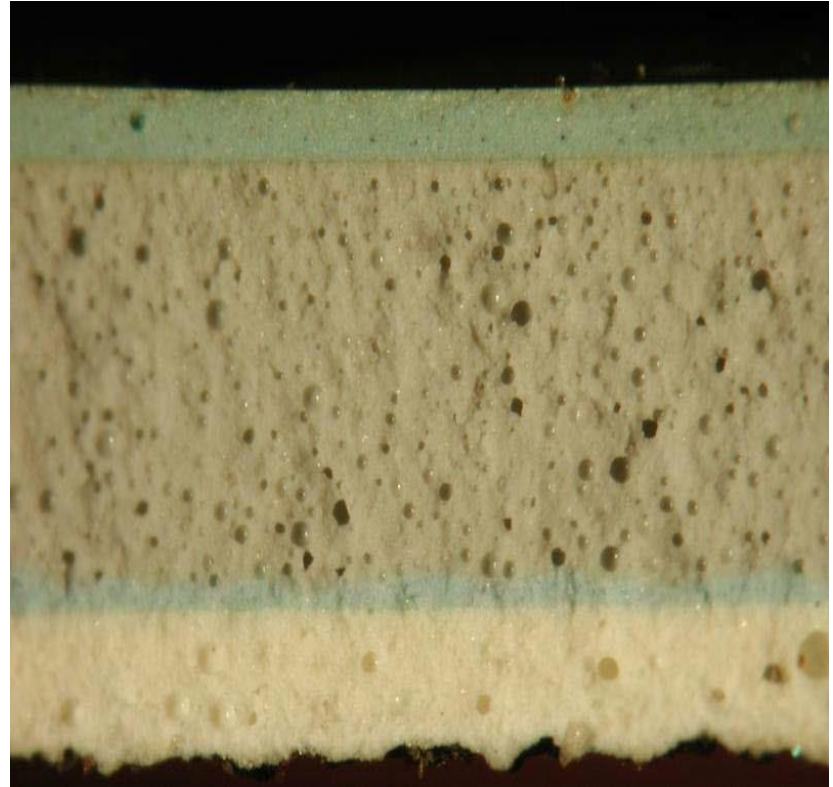
- Coating System
 - Coal Tar Enamel
 - Glass Reinforced
 - Inner Wrap
 - Outer Wrap-Saturated
 - Kraft Paper Protection
 - UV Rays



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

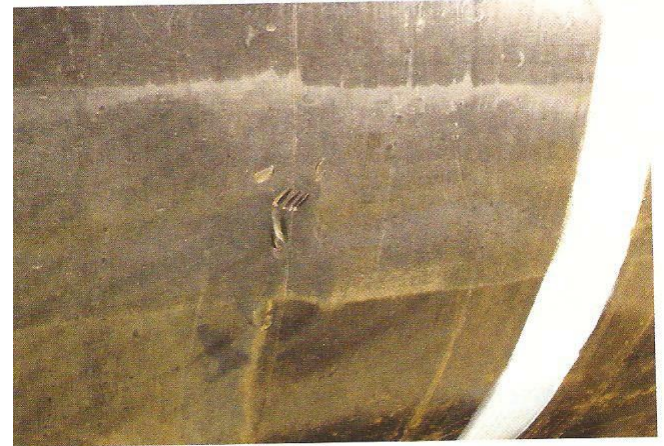


➤ Quality Control

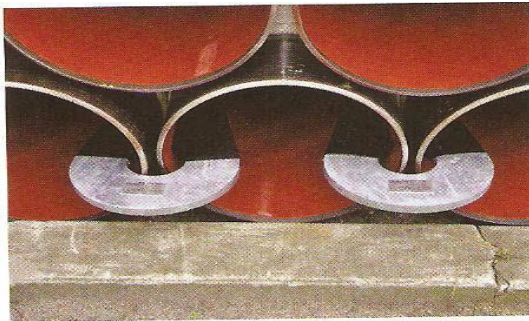
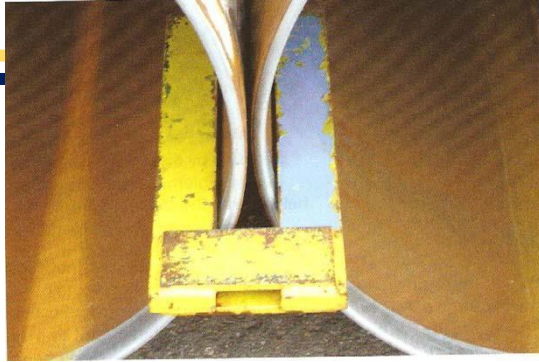
- Pipe Temperature
 - Temple sticks
 - Infrared sensors (mixed results)
- Dry Film Thickness (DFT)
 - Surface Temperature
- Holiday detection
- Traceability of pipe
 - Barcodes
 - Standardization

Handling

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



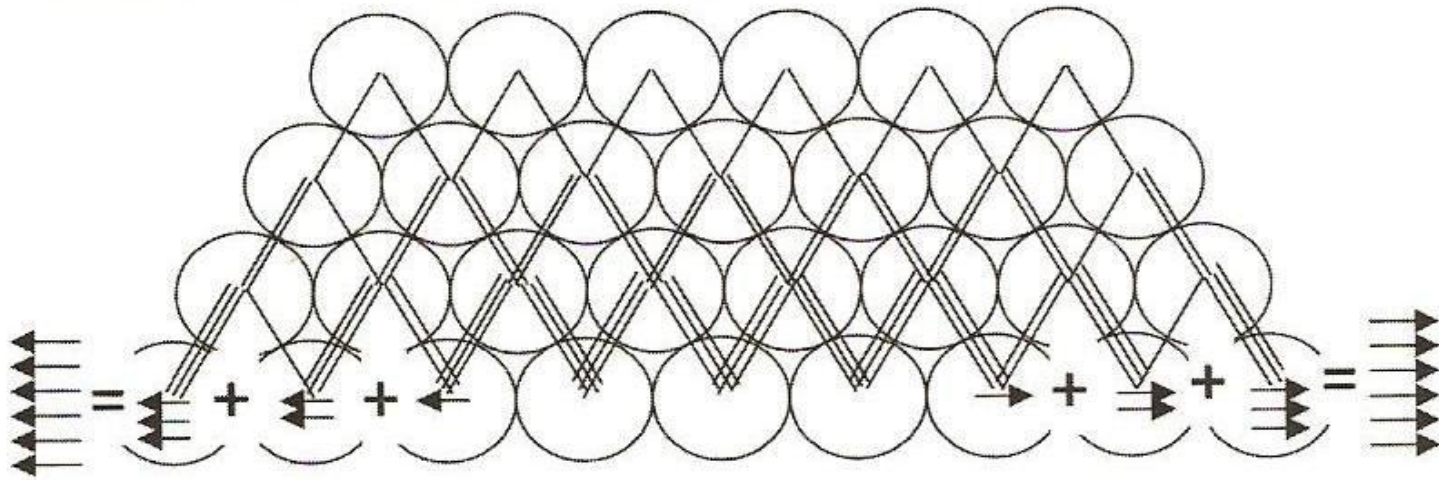
Handling



➤ Equipment

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

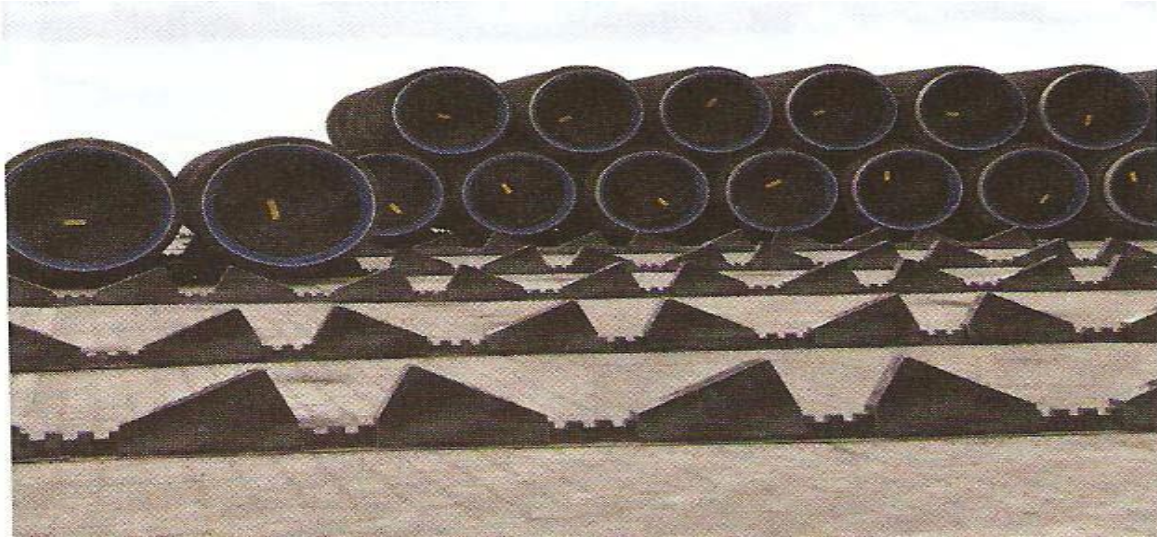
Storage



➤ Stacking

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

Storage



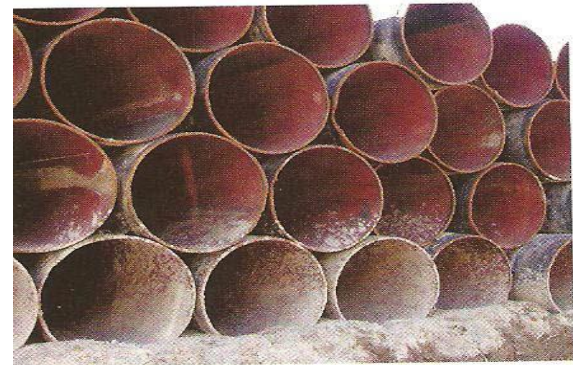
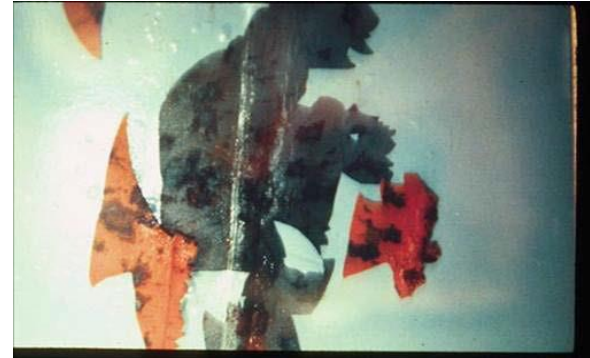
➤ Stacking

- 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.

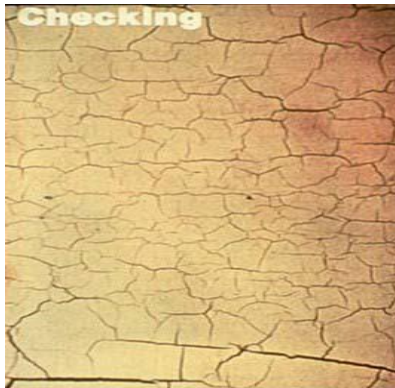
Storage

➤ 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

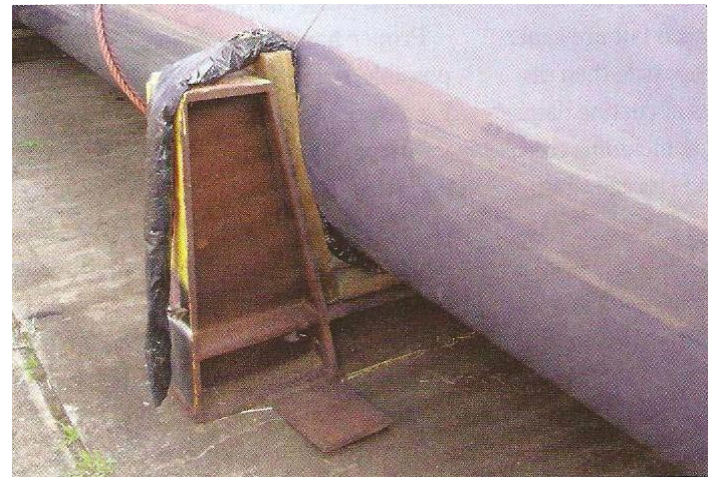
- Abrasion from travel movement
- Loading & Unloading
 - Handling



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

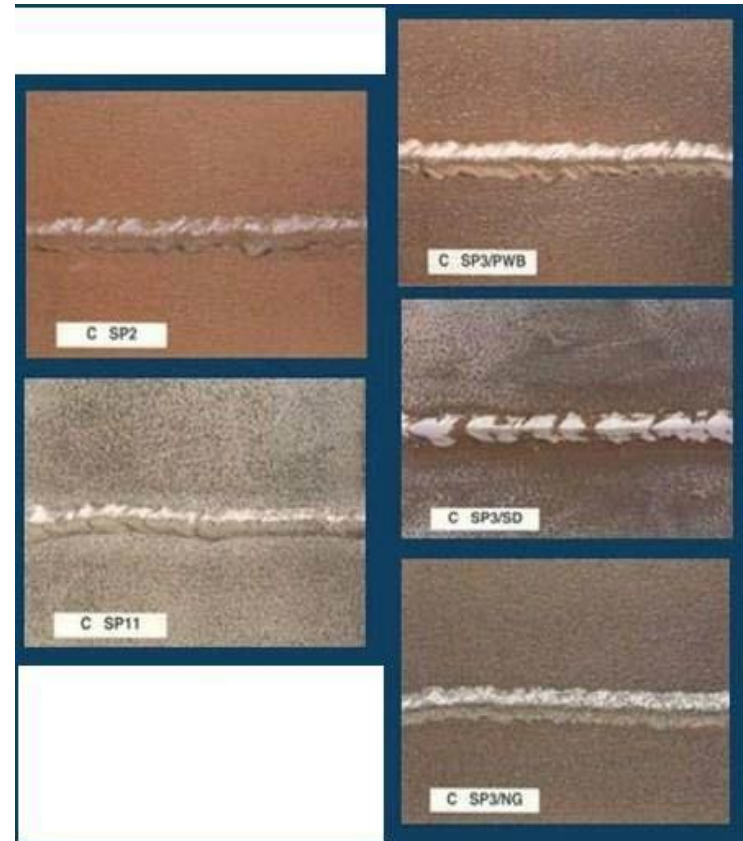


Construction



➤ 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

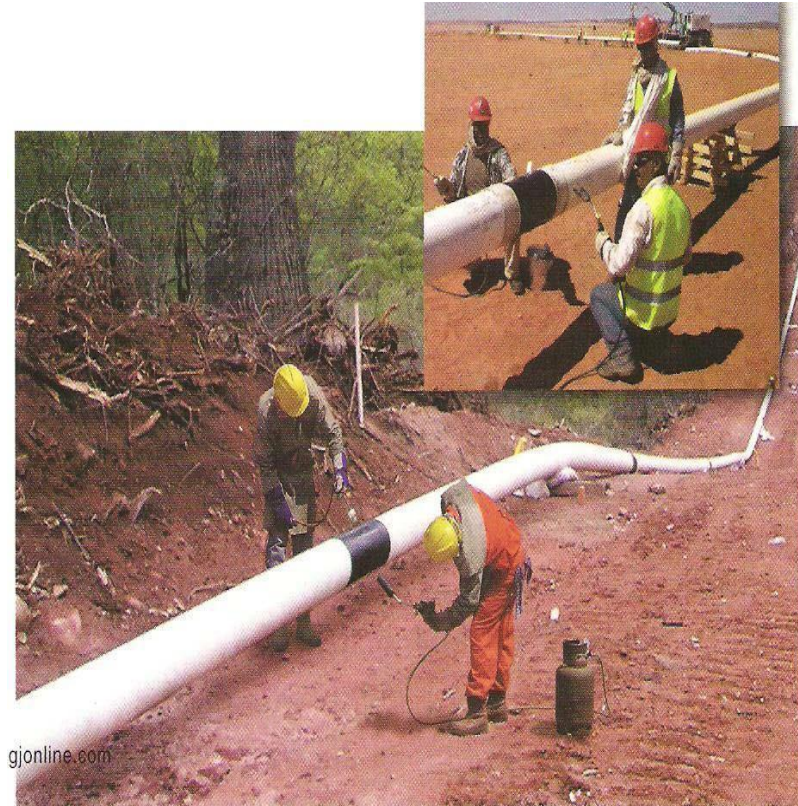
- Field Welds- Surface Preparation
 - Surface Profile
 - 2.0- 4.0 mils
 - Measurement method
 - Testex tape



Construction

➤ Field Welds (HSS)

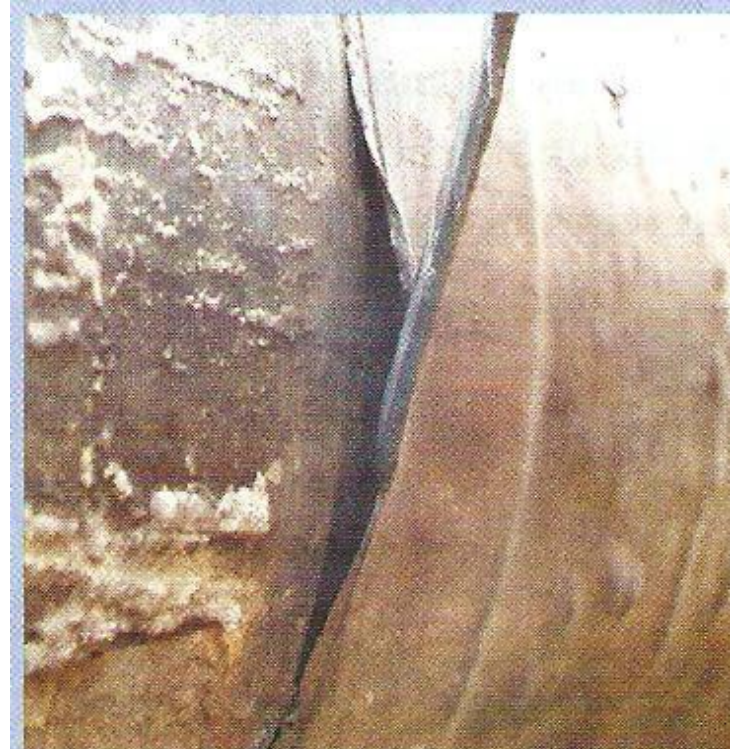
- Heat- Shrinkable Sleeves
 - 30 year history
 - Cross linking polyolefin.
 - Cured by “Electron irradiation”
- Polyethylene and Polypropylene coatings
- Epoxy primer is used for 3-layer systems
- Peel test- Adhesion and cure.



Construction (HSS)

18 in Oil Pipeline

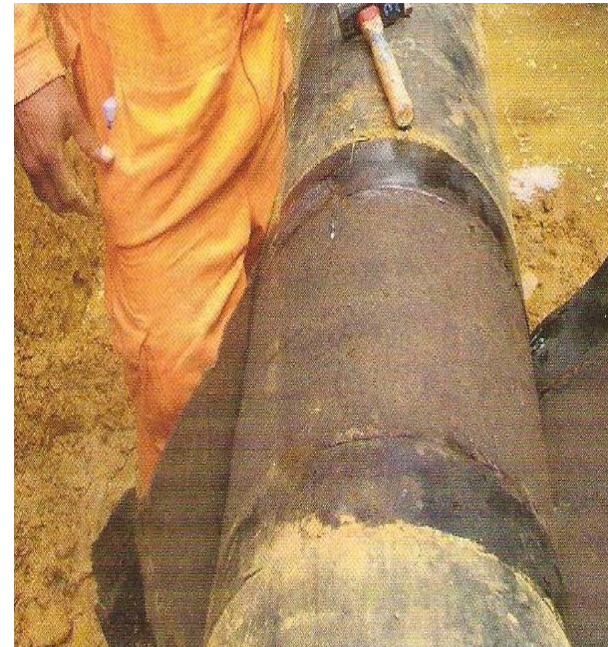
- 3 layer Polyethylene
- In Line Inspection (ILI)
 - Corrosion 1st 15 km
- 131F Operating Temp
- Service- 15 yrs
- Wet, compacted sand pH 5.4
- HSS
 - Hot melt type / Epoxy Primer
 - Surface Prep Power tool



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

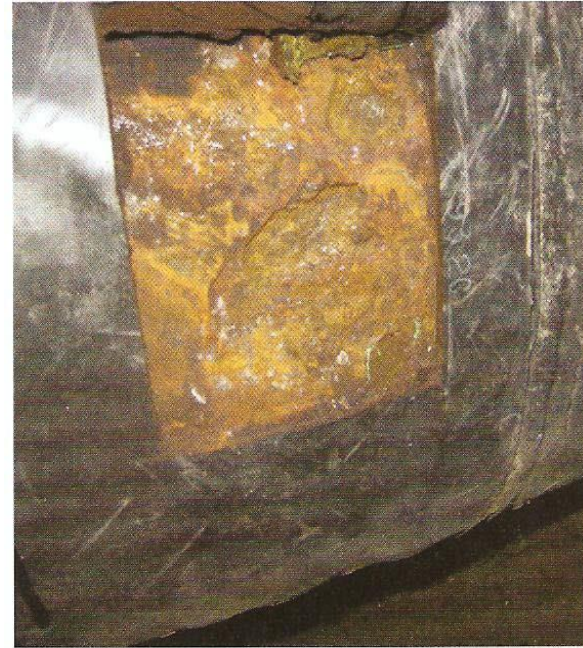
- Longitudinal cracking at the 3 and 9 o'clock positions.
- Showed signs of thermal aging
 - Brittleness
 - Lack of flexibility
- Issues:
 - Storage conditions
 - Soil exposures
 - Service conditions



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)



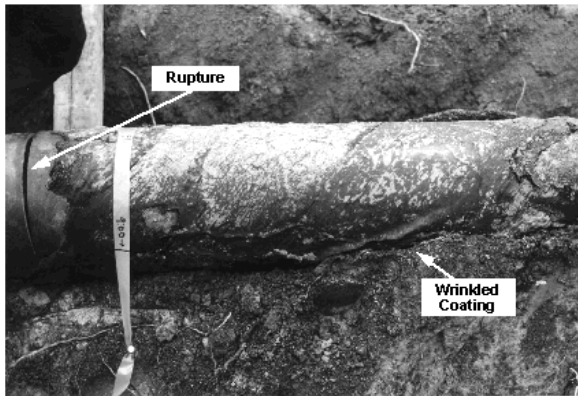
Construction (HSS)

16 in Oil Pipeline

- Disbonding of HSS
 - Steel surface
 - 3LPE coating system
- Significant corrosion
 - Field joint
 - Steel surface
 - Salt crystals under HSS
- Disbondment 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.

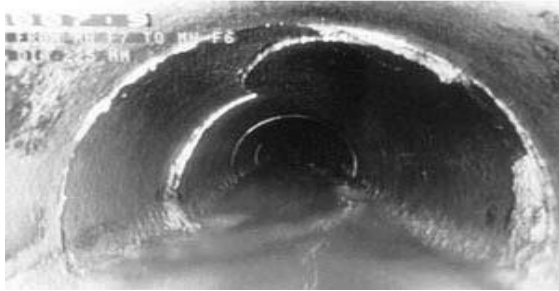
Internal Coatings

➤ Immersion Exposure

- Abrasion Resistance
 - Impact
 - Sludge
- Chemical Resistance
- Inhibitors
 - Scavengers
 - Oxygen
 - Sulfide
- Biocides- MIC Fighters

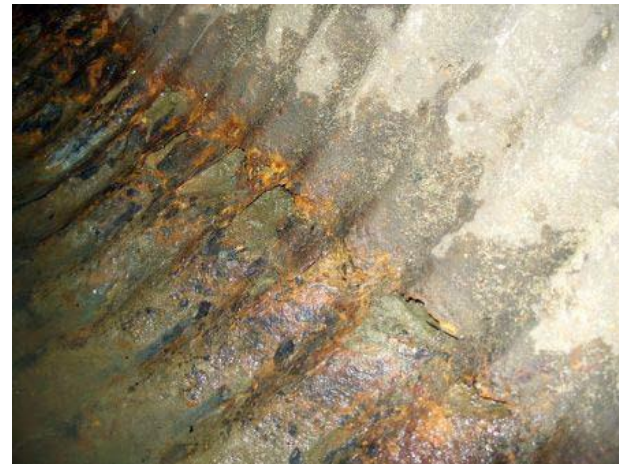


Internal Coatings



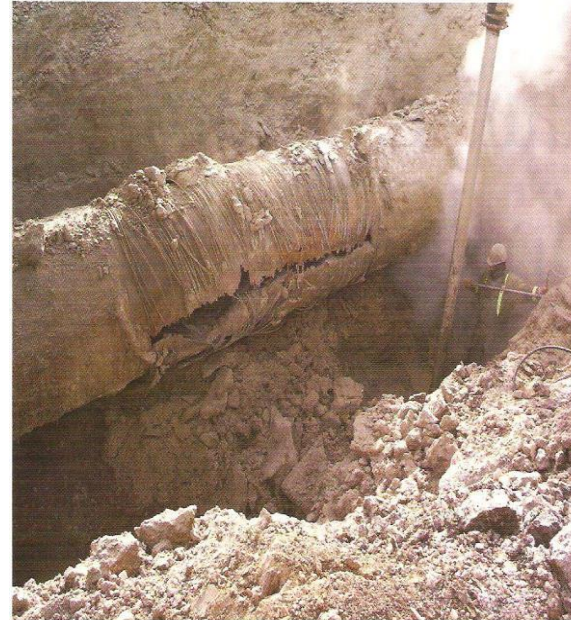
➤ Vapor Exposure

- Hydrogen Sulfide H_2S
 - Concrete and steel deterioration



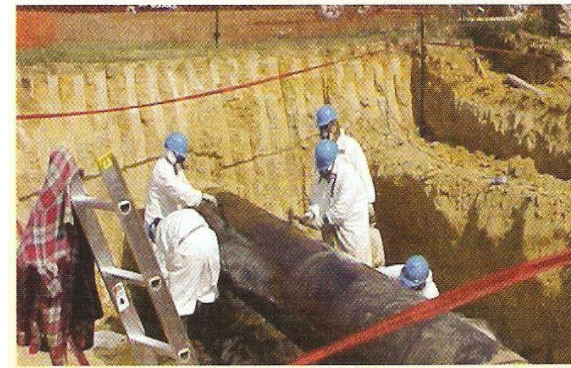
Case History

- 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



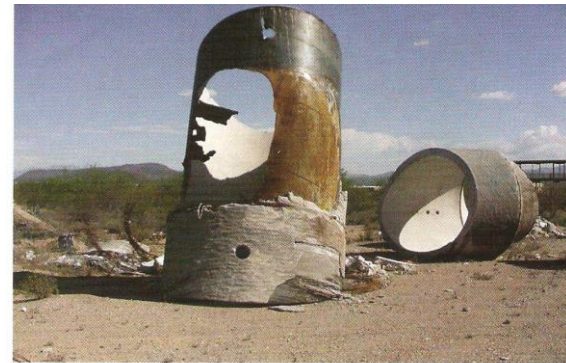
Case History

- 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



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