Large Diameter Transmission Pipeline Corrosion Control State-of-the-Art: Advances in the Steel Water Pipe Industry

Northwest Pipe Company

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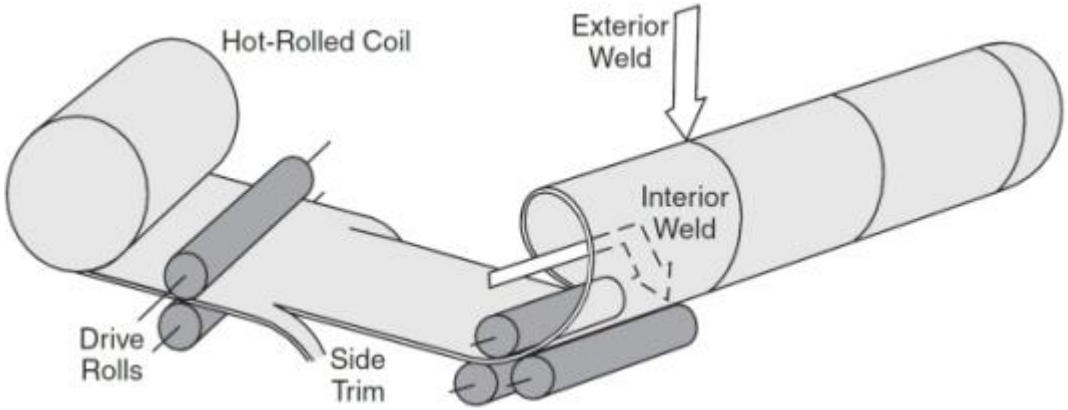
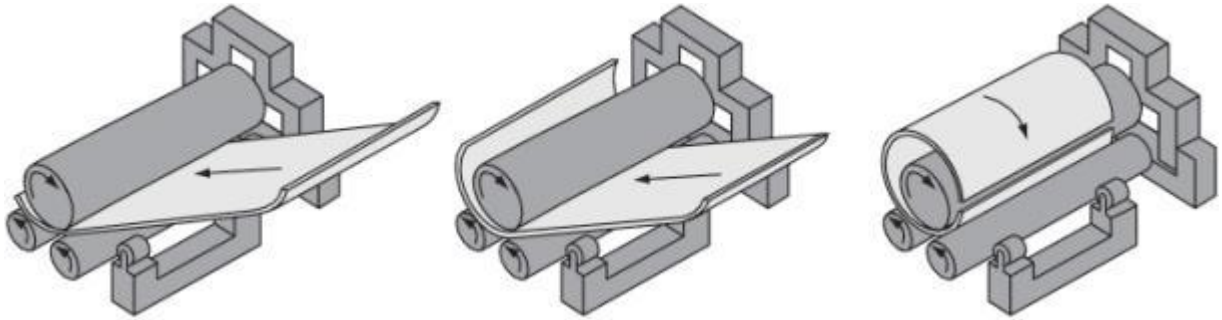
Steel Pipe Manufacture



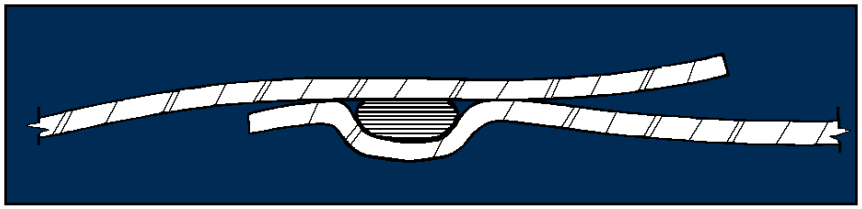
Spiral Welded Pipe



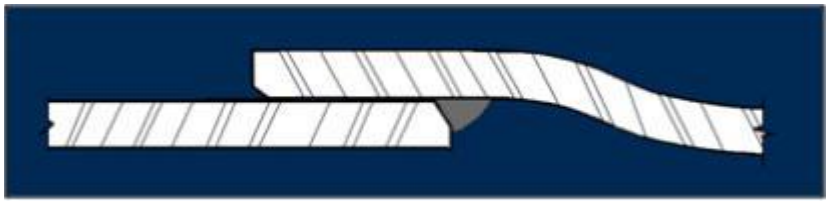
Rolled & Welded Pipe

Types of Materials

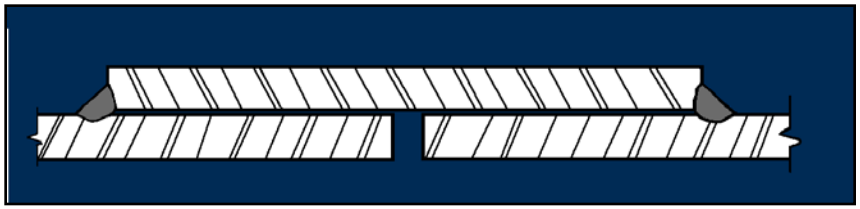
Joint Selection



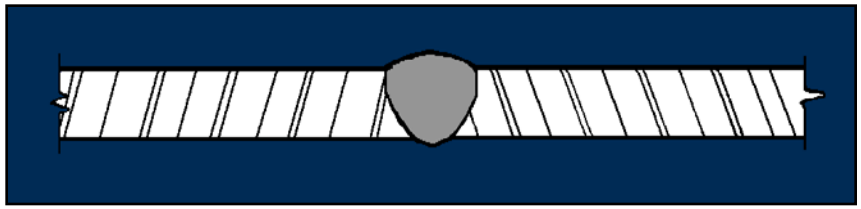
O-ring Joint



Lap Joint



Butt Strap Joint



Butt Weld Joint

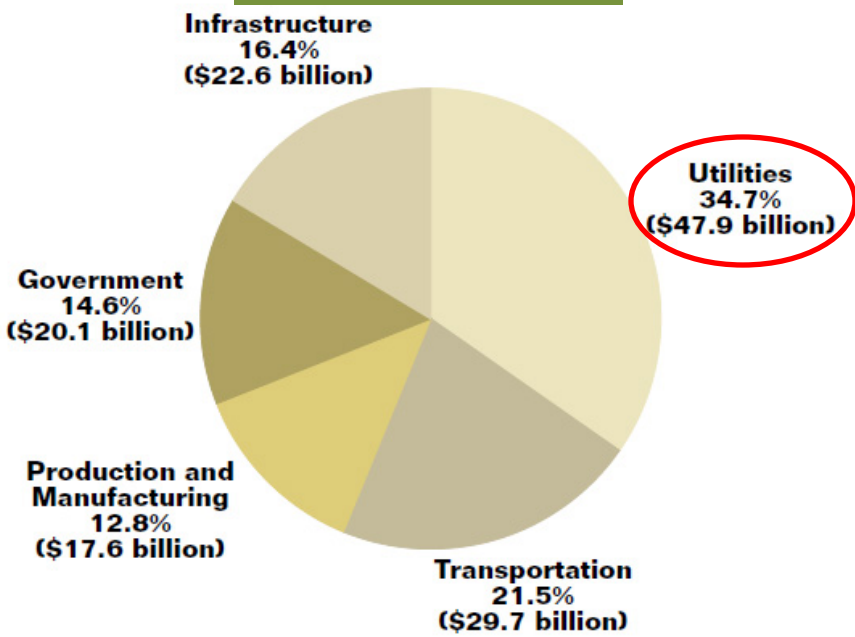
Current Condition of the Infrastructure

2013 REPORT CARD for America's INFRASTRUCTURE

AVIATION	D	PORTS	C
BRIDGES	C+	PUBLIC PARKS AND REC	C-
DAMS	D	RAIL	C+
DRINKING WATER	D	ROADS	D
ENERGY	D+	SCHOOLS	D
HAZARDOUS WASTE	D	SOLID WASTE	B-
INLAND WATERWAYS	D-	TRANSIT	D
LEVEES	D-	WASTEWATER	D

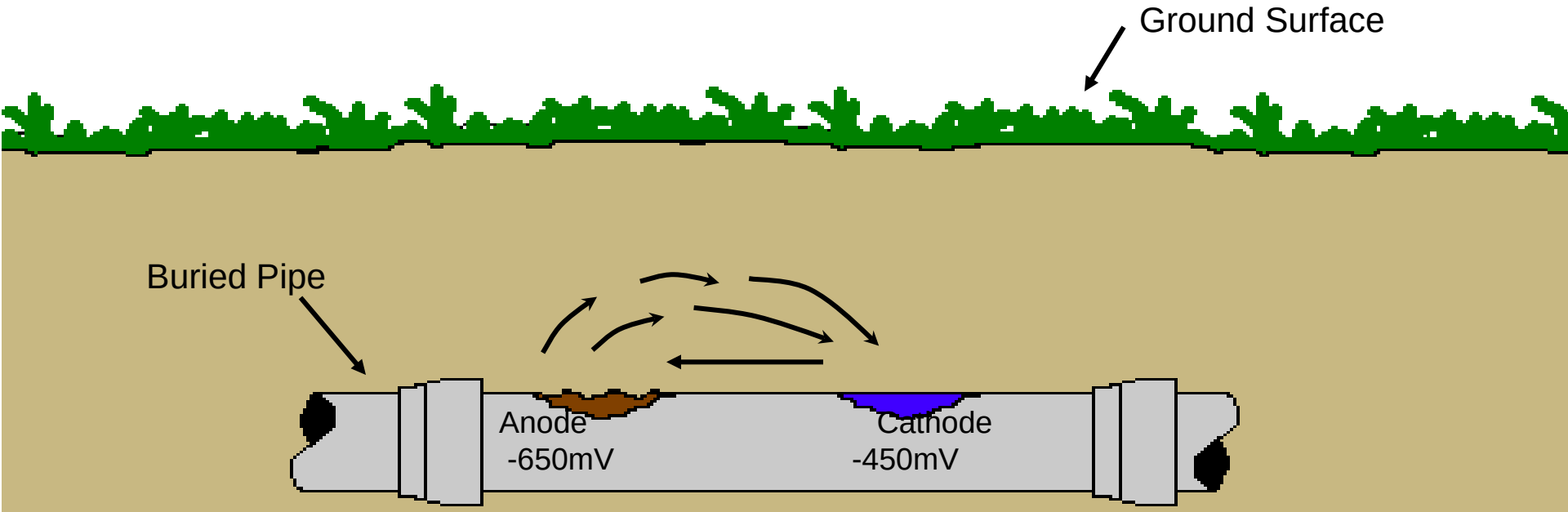
COST OF CORROSION IN INDUSTRY CATEGORIES ($137.9 BILLION)

FHWA Study (2002)



Percentage and dollar contribution to the total cost of corrosion for the five sector categories analyzed.

How Does Corrosion Occur in Metallic Pipe?



Corrosion in Metallic Pipe (Steel, DIP, Concrete Pipe) Requires 4 Components to Occur:

- **Anode**
- **Cathode**
- **Electrolyte**
- **Electrical Connection**

Two Methods of Corrosion Protection

- ***Passivating*** the Steel surface by inducing a high pH using a cementitious mix which reduces the electrical potential between the anode and cathode. Cement Mortar Coatings
- ***Dielectric*** System which isolates the electrolyte from the metallic surface. Tapes, Paint Systems

- Both systems have a long history of effectively reducing or stopping corrosion on steel pipelines

AWWA Standards for Coatings

AWWA Standard Designation	Standard Title
C205	Cement-Mortar Protective Lining and Coating for Steel Water Pipe-Shop Applied
C602	Standard for Cement-Mortar Lining of Water Pipelines In Place
C203	Coal-Tar Protective Linings and Coatings for Steel Water Pipelines—Enamel and Tape--- Hot Applied
C209	Cold Applied Tape Coatings for the Exterior of Special Sections, Connections, and Fittings for Steel Water Pipelines
C210	Liquid-Epoxy Coating Systems for the Interior and Exterior of Steel Pipelines
C213	Fusion-Bonded Epoxy Coating for the Interior and Exterior of Steel Water Pipelines
C214	Tape Coating Systems for the Exterior of Steel Water Pipelines
C215	Extruded Polyolefin Coatings for the Exterior of Steel Water Pipelines
C216	Heat-Shrinkable Cross-Linked Polyolefin Coatings for the Exterior of Special Sections, Connections, and Fittings for Steel Water Pipelines
C217	Cold-Applied Petrolatum Tape and Petroleum Wax Tape Coatings for the exterior of Special Sections, Connections, and Fittings for Buried or Submerged Steel Water Pipelines
C218	Coating the Exterior of Aboveground Steel Water Pipelines and Fittings
C222	Polyurethane Coatings for the Interior and Exterior of Steel Water Pipelines
C224	Two-Layer Nylon-11-Based Polyamide Coating System for the Interior and Exterior of Steel Water pipe, Connections, Fittings, and Special Sections
C225	Fused Polyolefin Coatings for the Exterior of Steel Water Pipelines
C229	Fusion-Bonded Polyethylene Coatings for Steel Exterior Water Pipelines

Passivating Systems

Typical Linings and Coatings for Steel Pipe

Linings

AWWA C205 – Cement Mortar, Shop Applied
AWWA C602 – Cement Mortar Lining, In-Place
AWWA C222 – Polyurethane
AWWA C210 – Liquid Epoxy

Coatings

AWWA C222 – Polyurethane
AWWA C205 – Cement Mortar, Shop Applied
AWWA C214 – Tape Coating
AWWA C203 – Coal Tar
AWWA C210 – Liquid Epoxy

Coating System Properties

- **Dielectric Coatings**

  Water absorption, permeability, dielectric strength, cathodic disbondment, adhesion, handling, lack of holiday

- **Cement Mortar Coatings**

  Compressive strength, water absorption, water soluble chlorides ions, cement mixture and moisture content.

Dielectric Application and QA/QC

AWWA Standard	Thickness	Adhesion	Adsorption	Holiday Testing	Original Publication	Current Edition
C203	50 mil	Pull Test	N/A	Required	1940	2009
C209	30 mil	20 ozf/in. width	Water Vapor Transmission	Required	1976	2007
C210	16 mil	800 psi	Water Vapor Transmission	NACE RP0188	1978	2008
C213	12 mil	Knife Test	N/A	NACE RP0490	1979	2008
C214	50-80 mil	200 oz/in. width	0.2% max.	NACE RP0274	1983	2007
C215	30-68 mil	20-30 psi	0.2% max.	NACE RP0274	1988	2010
C216	45-60 mil	15 lb/in. width	Water Vapor Transmission	Required	1989	2007
C217	43 mil	N/A	Water Vapor Transmission	N/A	1991	2009
C218	7-14 mil	V-Cut	N/A	NACE RP0188, if specified	1991	2008
C222	20-25 mil min.	1500 psi	2% max.	NACE RP1088	1999	2008
C224	12 mil min.	Rating of 8 per ASTM D6677	1.9% max.	NACE SP0188	2001	2011
C225	50-75 mil	32 lbf/in.	Water Vapor Transmission	NACE RP0188	2003	2008
C229	63-90 mil	17 lbf/in. width	0.1% max.	NACE RP0274	2008	2008

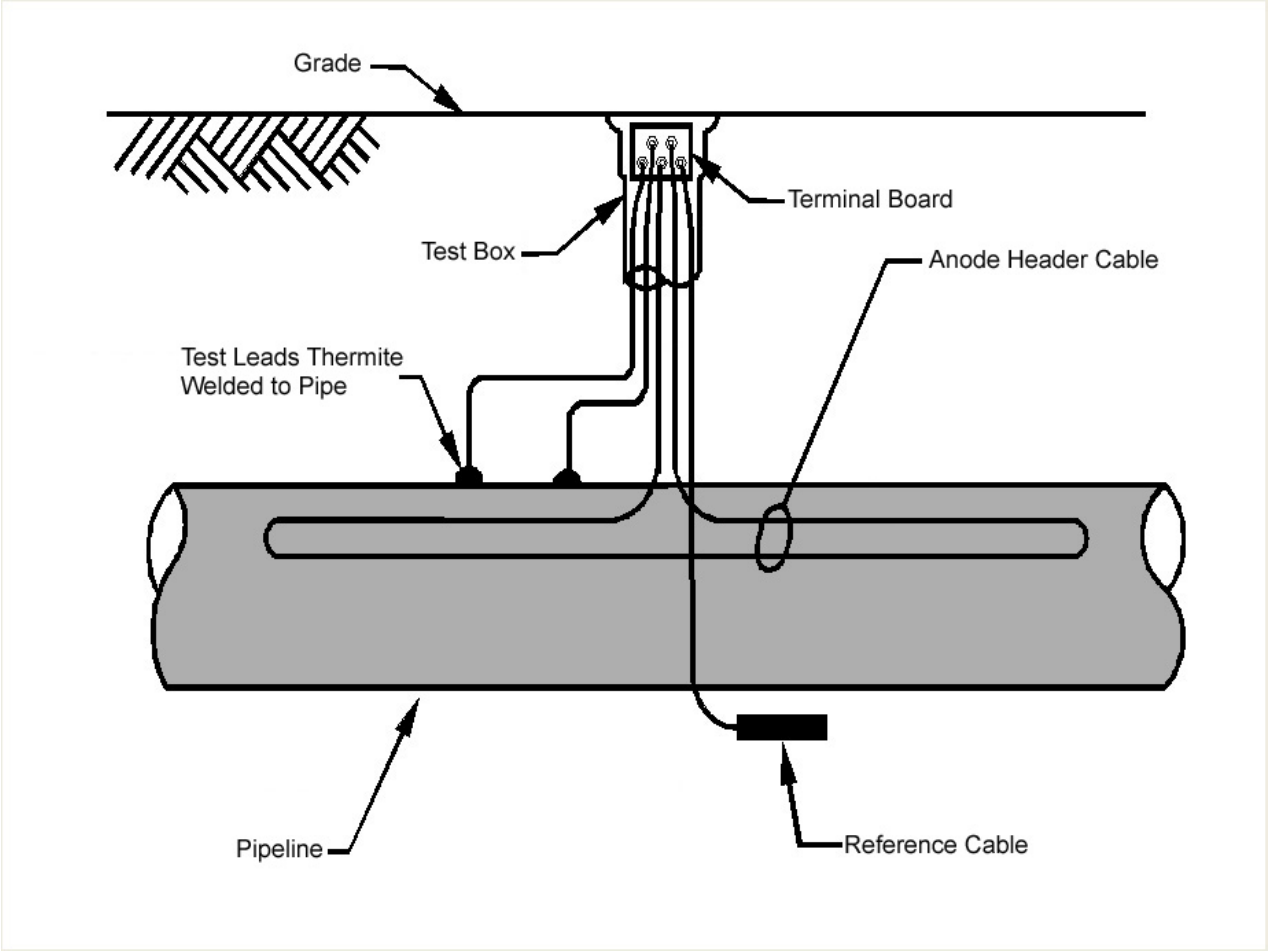
Cement Mortar Coatings

- First standard in 1941
- Provide a high pH, reduces or shifts potential
- Low Manufacturing Costs
- Increased weight
- Deflection Limitations
- Limitations of Allowable internal design stress

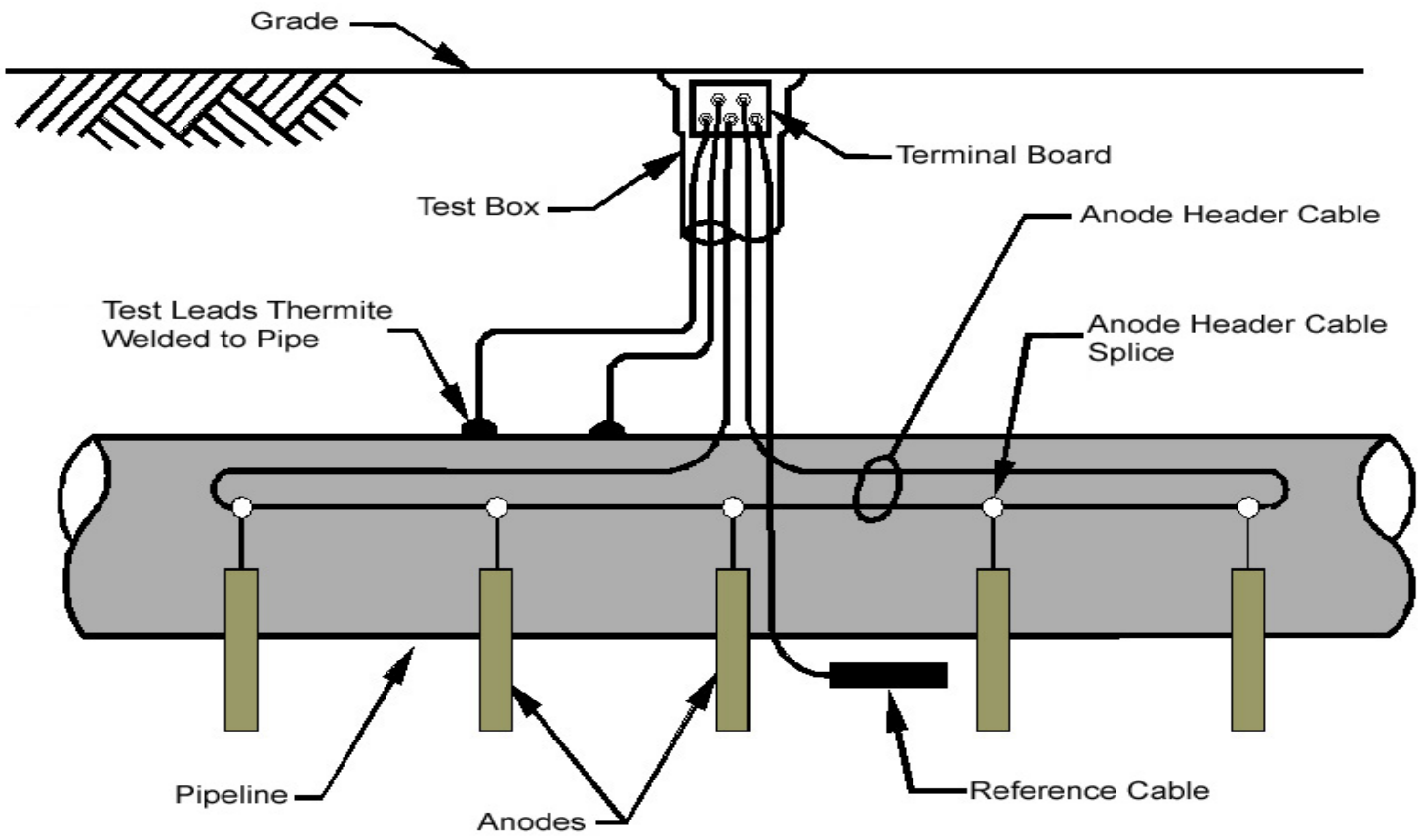
How Cement Mortar Works

- Applied directly on bare steel
- High alkaline environment (pH=12.5) at the metal surface
- Steel becomes cathodic and is protected by iron oxide film
- Passivation film needs to remain intack to provide protection – use monitoring system to verify and CP if needed.
- Chloride and sulfate ions are a practical concern as are soils with pH < 5

Monitoring System



Cathodic Protection



Dielectric Coatings, Tapes and Paints

- First used in the early 1900's
- Higher allowable design stresses and deflection limits
- High Durability and Flexibility
- 100% solids increased application efficiencies
- Holiday check at factory
- Compatible with corrosion monitoring and CP

How Dielectrics Work

- Isolates the electrolytes from the metallic surface
- Must be tightly bonded to the metal surface
- Coating may be damaged during installation, therefore electric continuity is recommended along with test stations to monitor pipe to soil potentials
- CP can be applied as needed or when necessary

Polyurethanes

- Extremely durable and tough
- Economical to apply due to fast cure and handling times
- Excellent physical properties
- Great adhesion

Owner Agencies Using Polyurethane

Alaska Electric Light & Power | Alaska Power & Telephone | City of Amarillo, TX | American Electric Power | City of Anacortes, WA | Arlington County, VA | **City of Atlanta, GA** | Aurora Brule Rural Water System | Aurora Water, CO | City of Aurora | **City of Austin, TX** | **City of Baltimore, MD** | Baltimore DOT | City of Baton Rouge, LA | British Columbia Hydro | Bear River Canal Company | Belize Water Authority | Benton Irrigation District | Big Horn Regional Joint Powers Board | Big Wood Canal Co | Birch Power Company | Bitter Root Irrigation District | Boise Project Board of Control | **Boston Water & Sewer, MA** | City of Boulder, CO | Brazos River Water Authority | City of Broken Arrow, OK | Brookfield Renewable Power | City of Broomfield, CO | Brushy Creek Regional Utility Authority | CAASD | City of Calgary | Canadian Hydro Developers/Canadian Projects Limited | Canadian River Municipal Water Authority | CANTARELL | Cascade Water Alliance | CEA Campeche (ST Water Commission) | CEA Edo Mexico (ST Water Commission) | Central Arkansas Water Authority | Central Oregon Irrigation District | **Central Utah Water Conservancy District, UT** | Central Vermont Public Service |

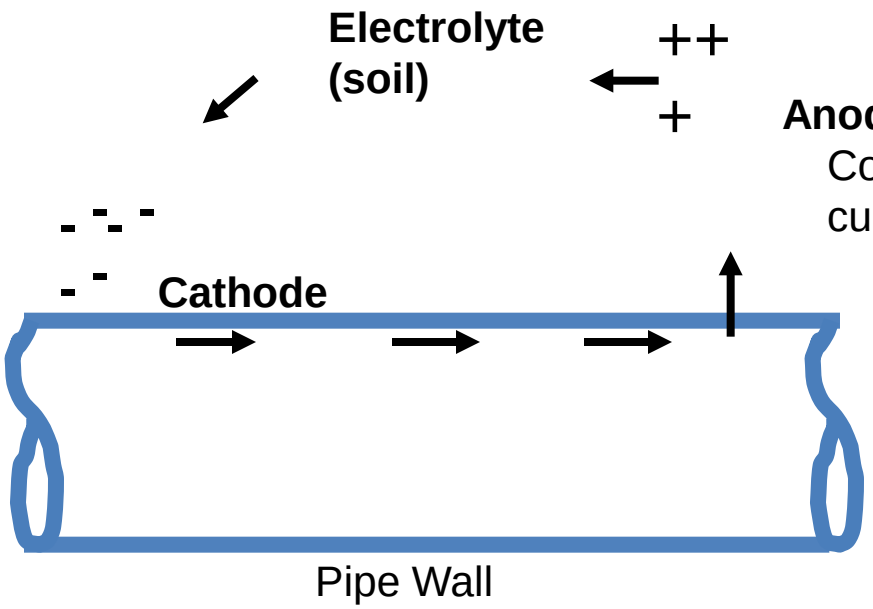
We estimate that since 2000, approximately **8,700,000 Feet (~ 1,650 Miles)** of Polyurethane Lined and/or Coated Steel Pipe has been used in Municipal Water Transmission and Distribution, Wastewater and Penstock Applications in the US and Canada

Regional Wastewater Reclamation Department | Pima-Maricopa Irrigation Project | Plutonic Power Corporation | PNM Resources | Polarconsult Alaska | City of Port Huron, MI | Port of Walla Walla | Portland Bureau of Environmental Services | **Portland Water Bureau, OR** | Prince William County Service Authority | Progress Energy | Provo River Water Users Association | Public Service of New Hampshire | Public Utilities Board | Puget Sound Energy | City of Rapid City, SD | Region of Peel | Regional Municipality of Wood Buffalo | Regional Power Inc. | **San Diego County Water Authority, CA** | Regional Transportation District of Denver | City of Rochester, MN | City of Round Rock, TX | S. Nevada Water Authority | San Antonio Water System | Santa Clara Valley Water District | **Seattle Public Utilities, WA** | **San Francisco Public Utility Commission, CA** | Saskatoon Water | City of Sheridan | Sheridan Area Water Supply | Silt Water Conservancy District | Skagit County PUC | City of Southlake, TX | City of St. Joseph, MI | City of Statesville, NC | Swalley Irrigation District | Swift Power | Symbiotics LLC | Tacoma Public Utilities | Tarrant Regional Water District | Tennessee Valley Authority | City of Thornton, CO | Trinity River Authority | City of Tucson, AZ | **US Bureau of Reclamation** | Utah DOT | Velasco Drainage District | City of Virginia Beach, VA | Washington County Water Conservancy District | **DC-WASA** | City of Waxahachie, TX | Weeminuche Construction Authority | Westar Energy | Western Wake Water | Authority | City Wichita, KS

Coating and Lining Type by Usage

Coating or Lining System	NWP Analysis of projects bid since 2000		*CoatingsPro* Article May 2012	
	% Pipe with Exterior Coating	% Pipe with Interior Lining	% Pipe with Exterior Coating	% Pipe with Interior Lining
Portland Cement Mortar	**18%**	**81%**	**45-55%**	**>95%**
Coal Tar Enamel (CTEC)	4%	<1%	5-10%	<1%
Liquid Epoxy	2%	5%	<1%	<3%
Fusion Bonded Epoxy	<1%	<1%	<1%	<1%
Tape and Cement Mortar Overcoat*	**10%**	**NA**	**35-45%**	**NA**
Extruded Polyolefin (Pritec)	1%	NA	5-10%	NA
Polyurethane	**31%**	**11%**	**<5%**	**<2%**
Polyamide	<1%	<1%	<1%	<1%
Fused Polyolefin	<1%	NA	<1%	NA
Fusion-Bonded Polyethylene	<1%	NA	<1%	NA
Paint	2%	2%	-	-
Tape Only	**28%**	**NA**	**	**NA**
CTEC or Paint and Cement Mortar Overcoat*	2%	NA	-	-
Other	1%	0%	-	-

Cathodic Protection

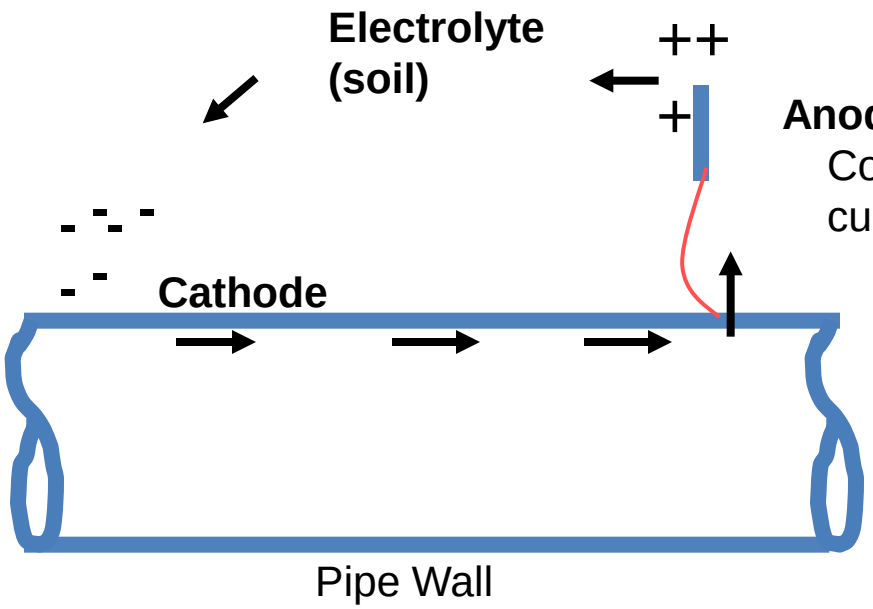


Cathodic Protection of Metallic Pipeline

- NACE Standard **SP0169** provides guidance on the use of Cathodic Protection for Dielectric Coated Pipes
- NACE Standard **SP0100** provides guidance on the use of Cathodic Protection for Cement Mortar Coated Pipes

Placement of **TEST STATIONS** at typical intervals of 1000-ft or greater enables an owner to continuously monitor for corrosion and to effectively determine whether a cathodic protection system is required at a later time

Cathodic Protection



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Handling, Joints & Repairs

Rigid and Flexible Linings

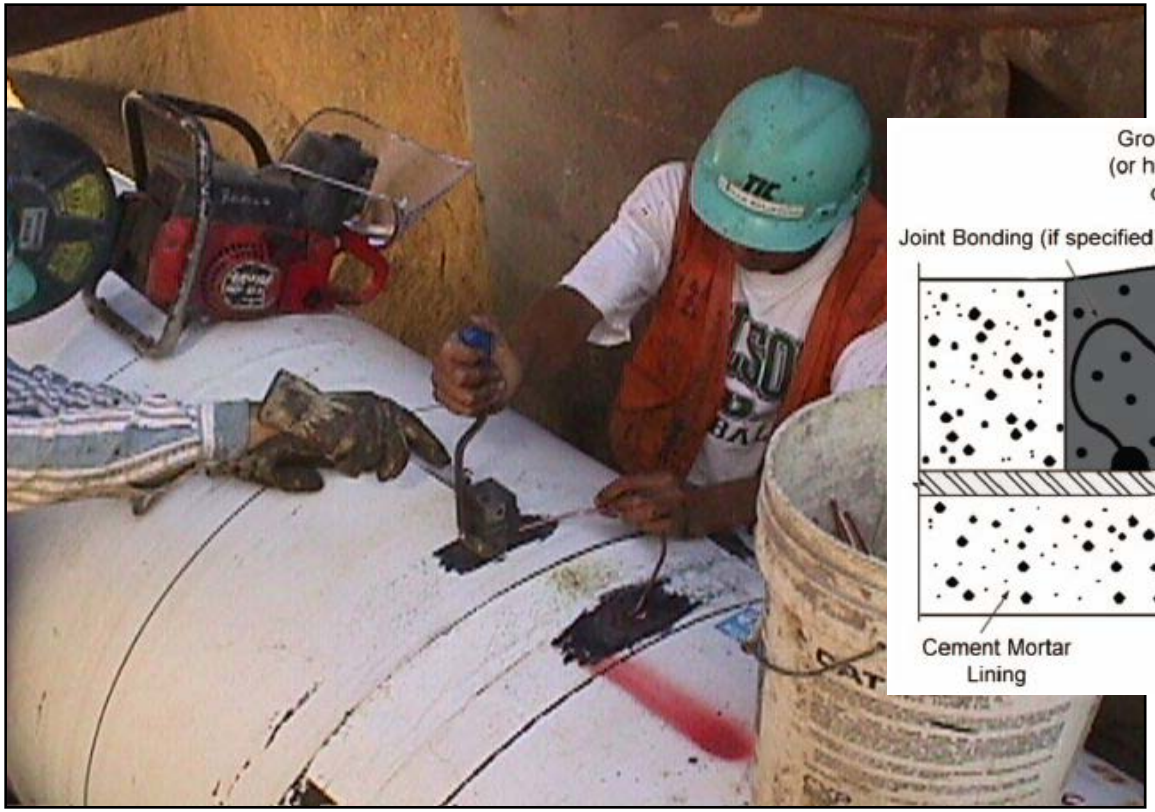
Rigid and Flexible Coatings

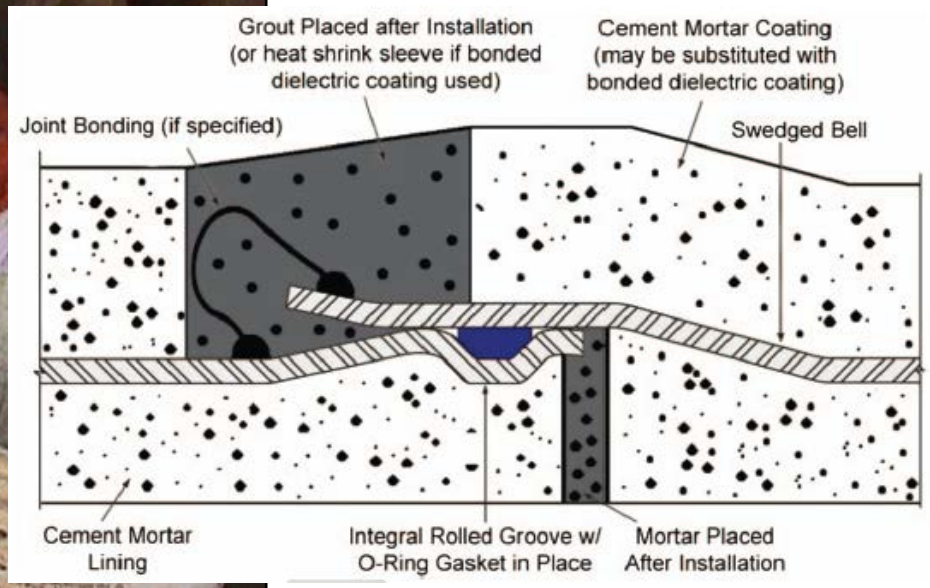
Rigid Cement Mortar Linings should be visually inspected, Flexible Linings such as Polyurethanes should be Holiday Tested

Based on whether the Lining and Coating is RIGID and/or FLEXIBLE, allowable vertical deflection of the pipe is limited after underground installation. This protects against damage of the Lining and Coating

Rigid Cement Mortar Coatings should be visually inspected, Flexible Coatings should be Holiday Tested

Joint Completion: O-ring Joints





Attach Bonding Wires

Joint Completion: Cement Mortar Coated Pipe

- External Cement Mortar Coating is completed using *GROUT DIAPERS* or *GROUT BANDS*
- Mortar placement is done from one side of the diaper, to allow the mortar to flow around the bottom and up the opposite side of the pipe, to preclude possibility of any voids inside the diaper.
- Discussed in **AWWA C604**, and **AWWA C205**

Joint Completion: Cement Mortar Lined Pipe

- Unlike other Cement Mortar Lined Pipes such as DIP, CML-Steel Pipe joints are completed by manual application of Cement Mortar following Joint Assembly
- Result is a truly protected lining system

Joint Completion: Welded Joints w/ Flexible Coatings

JOINT COMPLETION OF BONDED FLEXIBLE COATINGS

- Pipe Coated with Flexible Products such as Polyurethanes (AWWA C222), Tape Coating (AWWA C214) and Liquid Epoxy (AWWA C210), are Completed using **Heat Shrink Sleeves per AWWA C216**

Conclusions

- High cost of corrosion can be reduced with proper design, installation, monitoring and maintenance
- Corrosion is mitigated by coating systems which isolate or passivate the metal surface
- Installation damage possible
- Pipelines must be installed with electrical continuity and monitored regularly to ensure a long service life

Conclusions

- Coatings are the best investment for life cycle costs. CP where needed
- Polyurethanes have shown from history and advances in chemistry to be the current state-of-the-art best practice of protection of steel water transmission projects

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