

Ductile Iron Pipe Research Association

**Achieving a Century of Service**

**Pacific Northwest  
Section AWWA**

May 7, 2014



**DIPRA Member Companies**

A collection of seven logos for member companies, arranged in three rows. The top row includes American Cast Iron Pipe Company and Canada Pipe Company Ltd. The middle row includes Atlantic States and CLOW. The bottom row includes M WANE, PSCIPCO, and U.S. PIPE.

**Regional Engineer Program**

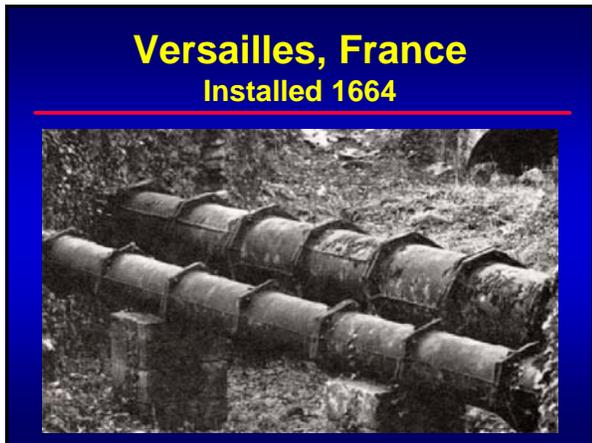
Paul H. Hanson, P.E.  
Regional Director  
NACE Certified Corrosion Specialist

**DIPRA Website**  
(www.dipra.org)

The screenshot shows the homepage of the DIPRA website. The header includes the text 'DUCTILE IRON PIPE RESEARCH ASSOCIATION' and a search bar. A navigation menu lists: Publications, FAQs, Benefits of DIP, Dangers of PVC, Inertial Facts, Take Action, News, Who We Are, and Contact Us. The main content area features a green background with water droplets and the heading 'ENVIRONMENTAL BENEFITS'. A sidebar on the right contains a list of links: Publications, Century Club, Write your State Rep, FAQs, and Iron for America. At the bottom right, there is a contact form with fields for 'Send Title', 'Email Address', and 'Zip Code', along with a 'Submit' button.

**AWWA Standards**

- ANSI/AWWA C104/A21.4 Cement-Mortar Linings
- ANSI/AWWA C105/A21.5 Polyethylene Encasement
- ANSI/AWWA C110/A21.10 Ductile-Iron and Gray-Iron Fittings
- ANSI/AWWA C111/A21.11 Rubber-Gasket Joints
- ANSI/AWWA C115/A21.15 Flanged Ductile-Iron Pipe
- ANSI/AWWA C116/A21.16 Fusion-Bonded Epoxy Coatings for Fittings
- ANSI/AWWA C150/A21.50 Thickness Design
- ANSI/AWWA C151/A21.51 Ductile-Iron Pipe, Centrifugally Cast
- ANSI/AWWA C153/A21.53 Ductile-Iron Compact Fittings
- ANSI/AWWA C600 Installation of Ductile-Iron Water Mains



### BURIED NO LONGER: Confronting America's Water Infrastructure Challenge

www.awwa.org/infrastructure

American Water Works Association

## Buried No Longer

“this report...constitutes the most thorough and comprehensive analysis ever undertaken of the nation's drinking water infrastructure renewal needs.”

p. 5

**Figure 5: Average Estimated Service Lives by Pipe Materials (average years of service)**

Derived Current Service Lives (Years)	CI	CI/CL (LSL)	CI/CL (SSL)	DI (LSL)	DI (SSL)	AC (LSL)	AC (SSL)	PVC	Steel	Conc & PCCP
Northeast Large	130	120	100	110	50	80	80	100	100	100
Midwest Large	125	120	85	110	50	100	85	55	80	105
South Large	110	100	100	105	55	100	80	55	70	105
West Large	115	100	75	110	60	105	75	70	95	75
Northeast Medium & Small	115	120	100	110	55	100	85	100	100	100
Midwest Medium & Small	125	120	85	110	50	70	70	55	80	105
South Medium & Small	105	100	100	105	55	100	80	55	70	105
West Medium & Small	105	100	75	110	60	105	75	70	95	75
Northeast Very Small	115	120	100	120	60	100	85	100	100	100
Midwest Very Small	135	120	85	110	60	80	75	55	80	105
South Very Small	130	110	100	105	55	100	80	55	70	105
West Very Small	130	100	75	110	60	105	65	70	95	75

*LSL indicates a relatively long service life for the material resulting from some combination of benign ground conditions and evolved laying practices, etc.  
SSL indicates a relatively short service life for the material resulting from some combination of harsh ground conditions and early laying practices, etc.*

8 BURIED NO LONGER: CONFRONTING AMERICA'S WATER INFRASTRUCTURE CHALLENGE

## Buried No Longer - Average DI Life

**SSL – 56 years**  
**LSL – 110 years**

SSL = Relatively Short Service Life  
LSL = Relatively Long Service Life

Figure 5, p. 8

## Buried No Longer - Average Pipe Life

SSL = Relatively Short Service Life based upon some combination of harsh ground conditions and early laying practices

LSL = Relatively Long Service Life based upon some combination of benign ground conditions and evolved laying practices

Figure 5, p. 8

## To Achieve a Century of Service from your DI Pipe...

- Design
- Installation
- Corrosion Control
- O & M

## Thickness Design of Ductile Iron Pipe

From ANSI/AWWA C150/A21.50

## Internal Pressure - DIP



$$t = \frac{P (D)}{2 S}$$

D = Outside Diameter

$$P = 2(P_w + P_s)$$

$P_w$  = Max. Working Pressure

$P_s$  = Surge Pressure

S = Min. Allowable Yield  
= 42,000 psi

t = Required Thickness

## Total Calculated Thickness



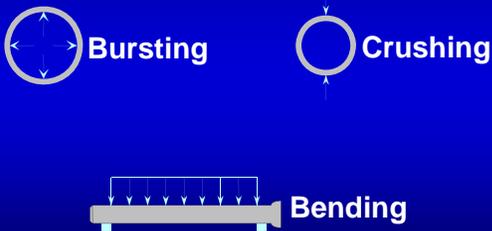
Net Thickness plus  
Service Allowance plus  
Casting Tolerance

## Nominal Thicknesses for Standard Pressure Classes of DIP From Table 5 of ANSI/AWWA C150/A21.50

Pipe Size (in.)	Outside Diameter (in.)	Pressure Class				
		150	200	250	300	350
Nominal Thickness (in.)						
3	3.96	--	--	--	--	0.25*
4	4.80	--	--	--	--	0.25*
6	6.90	--	--	--	--	0.25*
8	9.05	--	--	--	--	0.25*
10	11.10	--	--	--	--	0.26
12	13.20	--	--	--	--	0.28
14	15.30	--	--	0.28	0.30	0.31
16	17.40	--	--	0.30	0.32	0.34
18	19.50	--	--	0.31	0.34	0.36
20	21.60	--	--	0.33	0.36	0.38
24	25.80	--	0.33	0.37	0.40	0.43
30	32.00	0.34	0.38	0.42	0.45	0.49
36	38.30	0.38	0.42	0.47	0.51	0.56
42	44.50	0.41	0.47	0.52	0.57	0.63
48	50.80	0.46	0.52	0.58	0.64	0.70
54	57.56	0.51	0.58	0.65	0.72	0.79
60	61.61	0.54	0.61	0.68	0.76	0.83
64	65.67	0.56	0.64	0.72	0.80	0.87

\* Calculated thickness for these sizes & pressure classes are less than those shown above. Presently, these are the lowest nominal thickness available in these sizes.

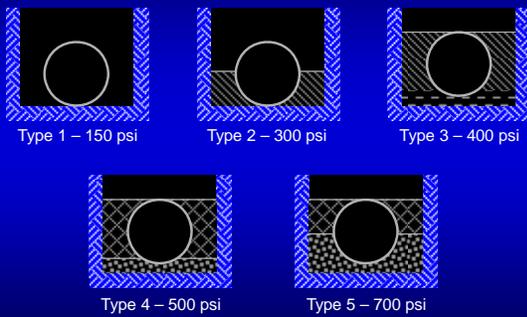
## Forces Acting on Pipe



## Ductile Iron Beam Strength

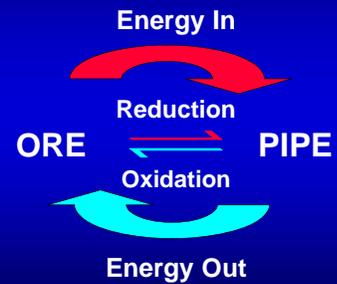


## Laying Conditions

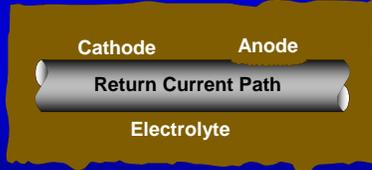


## Corrosion Control For Ductile Iron Pipe

Corrosion is a naturally occurring phenomenon



## The underground pipe corrosion cell . . .



## DIPRA Research Examples

- 1928 – Strength of Corrosion Products
- 1940 – Coatings
- 1949 – Bolt Corrosion
- 1952 – Coatings and Loose Polyethylene
- 1971 – Stray Current
- 1989 – Copper Service

## DIPRA Test Sites



## DIPRA Research



## 10 Point Soil Evaluation

Resistivity - ohm-cm (based on water-saturated soil box):	
< 1,500	10
≥ 1,500 - 1,800	8
> 1,800 - 2,100	5
> 2,100 - 2,500	2
> 2,500 - 3,000	1
> 3,000	0
pH:	
0 - 2	5
2 - 4	3
4 - 6.5	0
6.5 - 7.5	0
7.5 - 8.5	0
> 8.5	3
Redox potential:	
> +100 mV	0
+50 to +100 mV	3.5
0 to +50 mV	4
Negative	5
Sulfides:	
Positive	3.5
Trace	2
Negative	0
Moisture:	
Poor drainage, continuously wet	2
Fair drainage, generally moist	1
Good drainage, generally dry	0

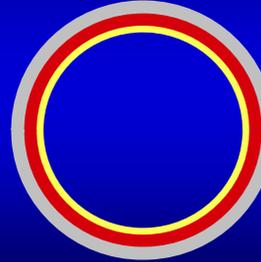
## Corrosive Environments

- Coal
- Cinders
- Swamps
- Expansive Clays
- Peat Bogs
- Mine Wastes
- Landfill Areas
- Alkali Soils

## Corrosion Control Methods

- Additional Wall Thickness
- Trench Improvements
- As-manufactured
- Polyethylene Encasement
- Cathodic Protection

## Total Calculated Thickness



Net Thickness plus  
Service Allowance plus  
Casting Tolerance

## Everglades Test Site



Everglades, FL – 6-inch D.I.P  
Exposure 4.25 years

**Sacrificial  
Metal**

## Trench Material Improvements



## 75 Years of Research

### Corrosion and corrosion control of iron pipe:

75 years of research

It was known to farmers in prehistoric ages, and there is ample evidence of its use in early history. However, ability to cast pipe produced developed from or coincided with the manufacture of cast iron, which occurred as early as 1513. There is an official record of cast iron pipe manufactured at Augsburg, Germany, in 1813 for installation at the Dillingberg Castle. In 1846, Louis NEP de France initiated the construction of a cast iron main to supply water for the town and its environs. This cast iron pipe provided continuous service for more than 100 years. Cast iron pipe was first used in the United States around 1816 (AWWA, 2001).

Ductile iron pipe was cast experimentally for the first time in 1948 and was introduced to the marketplace in 1953. Since 1963 ductile iron pipe has been manufactured in accordance with the Standard for Ductile Iron Pipe, Compactly Cast, for Water and Other Fluids (AWWA/CAN, 2002), using centrifugal casting methods that have been continuously developed and refined since 1923.

#### POLYETHYLENE ENCASEMENT FOR CORROSION CONTROL

Continuous protection of these early iron pipes was typically nonexistent until the mid-1990s. Still, this early pipe fared well in most soil environments, and its integrity is well documented. More than 600 utilities in the United States and Canada have had cast iron pipe that provided more than 100 years of continuous

### Polyethylene Encasement Inspections, Asphaltic Coated Inspections and DIPRA Test Sites



### Non-corrosive Soils Mean Deepest Pitting Rate

Pipe Condition	Number of Pipe	Mean Deepest Pitting Rate (in/yr)	Years to Penetration*
As-manufactured	43	0.0007	375
Polyethylene Encased	12	0.0000	Infinity

\* Based on single deepest pit in each specimen, linear pitting rate and minimum pipe wall thickness of 0.25 inches

Princeton, Kentucky – 16 inch Ductile Iron Pipe  
Installed: 1963-1964 – Inspected: 1998



### Polyethylene Encasement





### Corrosive Soils Mean Deepest Pitting Rate

Pipe Condition	Number of Pipe	Mean Deepest Pitting Rate (in/yr)	Years to Penetration*
Sandblasted	102	0.025	10
Bare	22	0.015	17
As-manufactured	103	0.010	24
Polyethylene Encased	151	0.00045	552

\* Based on single deepest pit in each specimen, linear pitting rate and minimum pipe wall thickness of 0.25 inches





### Damaged Polyethylene Encased DIP versus As-manufactured DIP

Pipe Condition	Number of Specimens	Mean Deepest Pitting Rate
Damaged Polyethylene Encasement	62	0.0125 in/yr
As-manufactured	89	0.0247 in/yr

Damaged polyethylene encasement does not result in the concentrated corrosion cells that occur with damaged bonded coatings

### Polyethylene Encasement Investigations



### Simulated Polyethylene Encasement Study

The pH of the moisture under the wrap tends to increase

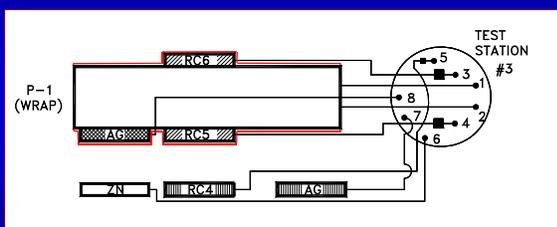
The dissolved oxygen within this moisture decreases very rapidly

Both tend to make the dominant, ultimate corrosion mechanism –

### Surface Oxidation



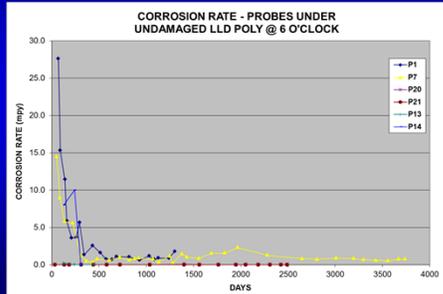
### Florida Everglades Corrosion Testing (above ground monitoring)



### Florida Everglades Corrosion Testing



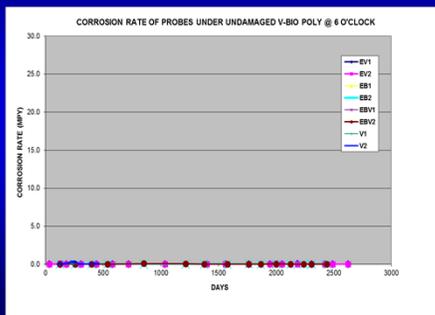
## Corrosion Probes under Polyethylene Encasement



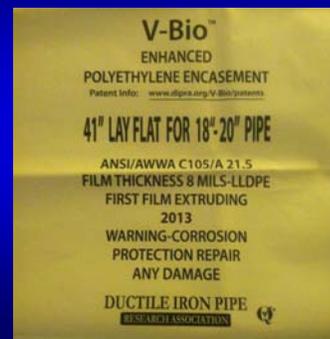
## RECOMMENDED ADDITIONAL RESEARCH (Polyethylene Encasement with Corrosion Inhibitor & Biocide in film - V-BIO )



## Corrosion Probes under V-Bio Polyethylene Encasement



## V-Bio™ Polyethylene



## Advantages of Polyethylene Encasement

- Inexpensive
- Easily installed and repaired
- Eliminates concentration cells
- Yields to soil stresses
- Shields against stray current
- Does not deteriorate underground
- Passive protection system



## Buried No Longer

Average DI life (LSL) – 110 years

LSL = Relatively Long Service Life

Figure 5, p. 8

American Water Works Association  
ANSI/AWWA C150/A21.50



AMERICAN NATIONAL STANDARD  
FOR  
THICKNESS DESIGN OF  
DUCTILE-IRON PIPE



### Nominal Thickness for Standard Pressure Classes of DIP From Table 5 of ANSI/AWWA C150/A21.50

Pipe Size (in.)	Outside Diameter (in.)	Pressure Class				
		150	200	250	300	350
3	3.96	--	--	--	--	0.25*
4	4.80	--	--	--	--	0.25*
6	6.90	--	--	--	--	0.25*
8	9.05	--	--	--	--	0.25*
10	11.10	--	--	--	--	0.26
12	13.20	--	--	--	--	0.28
14	15.30	--	--	0.28	0.30	0.31
16	17.40	--	--	0.30	0.32	0.34
18	19.50	--	--	0.31	0.34	0.36
20	21.60	--	--	0.33	0.36	0.38
24	25.80	--	0.33	0.37	0.40	0.43
30	32.00	0.34	0.38	0.42	0.45	0.49
36	38.30	0.38	0.42	0.47	0.51	0.56
42	44.50	0.41	0.47	0.52	0.57	0.63
48	50.80	0.46	0.52	0.58	0.64	0.70
54	57.56	0.51	0.58	0.65	0.72	0.79
60	61.61	0.54	0.61	0.68	0.76	0.83
64	65.67	0.56	0.64	0.72	0.80	0.87

\* Calculated thickness for these sizes & pressure classes are less than those shown above. Presently, these are the lowest nominal thickness available in these sizes.

Chicago, Illinois – 12 inch Ductile Iron Pipe  
Installed: 1965 – Inspected: 2009



Resistivity = 1,080 ohm-cm  
pH = 9.4  
Redox = - 290 mV  
Sulfides = Positive  
Chlorides = Positive  
Moisture = Saturated



Integrity isn't Expensive  
it's  
**PRICELESS**

Ductile Iron Pipe  
The Right Decision