GILLETTE MADISON PIPELINE PROJECT (GMPP)
TECHNICAL MEMORANDUM #10

TO:	Mike Cole, P.E., City of Gillette
FROM:	Kate Reichstein, P.E., BMcD
DATE:	August 3, 2010
JOB NO.:	MMI #4776.001, BMcD # 54432
RE:	Pipeline Material Evaluation and Recommendation (First Draft)
CC:	Darin Brickman, P.E., BMcD Dan Korinek, P.E., BMcD Carl Anderson, P.E., MMI Casey Hansen, P.E., MMI Bryan Clerkin, P.E., WWDC
ATTACHMENTS:	

☐ **Urgent** ☒ **For Review** ☒ **Please Comment** ☐ **Please Reply** ☐ **For Your Use**

EXECUTIVE SUMMARY

In order to determine what type of piping systems may be acceptable to City of Gillette for the GMPP project a piping manufacturer's work shop and a cathodic protection work shop were held at the Burns & McDonnell offices. The purpose of these workshops was to have an overview of the different types of piping materials that are available for pressurized waterlines and to learn how the different piping materials can be protected from corrosive soils through the use of a cathodic protection system.

The soils in the vicinity of the existing Madison pipeline are very corrosive and there have been numerous issues with the existing cathodic protection system. The City of Gillette is currently upgrading the cathodic protection system on the existing Madison line to eliminate the current cathodic protection issues. In order to determine how to eliminate the same issues on this project, two cathodic protection designers presented at a Cathodic Protection Workshop. The designers are listed in the Table 1:

Table 1
Cathodic Protection Presenters

Cathodic Protection Designer	Presenter
Rust Not	Bill Spickelmire
AC&C and Corrpro	Charles Waits

The following table indicates the pipe manufacturers were invited to speak at the piping manufacturers work shop, the type of pipe material they manufacture, if they presented and the reason why they did not present:

Table 2
Pipe Manufacturer Presenters

Pipe Material	Pipe Manufacturer	Presented	Reason for not presenting
Steel	Northwest Pipe	Yes	
DIP	American Ductile Iron	Yes	
DIP	US Pipe	Yes	
PVC	North American Pipe	Yes	
FRP	Hobas	No	Do not have a restrained joint system approved within the USA
PCCP	Hanson Pipe	No	Was not able to present
HDPE	Performance Pipe a Division of Chevron Phillips	No	Was not able to present

The recommendations from the workshops are that the following pipe material should be allowed into the specifications for the project.

Table 3
Workshop Recommendations

Allowable Material	Material limitations
Steel	
Ductile Iron	
PVC	Only as pressure allows. Will be used with DIP bonded coated fittings.

It was also determined that Mr. Bill Spickelmire will be the cathodic protection designer for the project as he is most familiar with the system as he is performing the design of the modifications to the existing cathodic protection system.

INTRODUCTION

The request for proposal for the GMPP requires an evaluation of different pipeline material and recommendations for materials that will be incorporated into the specifications and therefore allowed to bid for the project. A part of this evaluation is to include cathodic protection requirements. The purpose of this technical memorandum is to provide the procedure and framework for this evaluation through a pipeline material and cathodic protection workshops. This will ultimately lead to the material recommendations and reliable cathodic protection requirements.

BACKGROUND

The final required flows and associated pipeline sizes to be utilized for this project have been determined from the hydraulic analysis performed in Technical Memorandum #7. The preliminary flow requirements and operating pressures for the lines are as follows:

- In-Town Piping: 5.8 MGD at 50 psi
- Transmission Piping: 21MGD at 125 - 250 psi

The preliminary pipe sizes anticipated for the project are as follows:

- In-Town Piping: 16-inches through 24-inch diameter.
- Transmission Piping: 18-inch and 36-inch diameter.

The following pipeline materials were considered for both In-Town Piping and Transmission Piping:

- Ductile Iron
- Steel
- PVC
- HDPE
- PCCP
- FRP

Factors evaluated in this technical memorandum include the history, service life, joints, restraint types, cathodic protection requirements, fittings, pressure class or thickness design, linings, coatings, installation, service connections and production and delivery lead times. This memorandum also compares the piping materials based on internal diameter, velocity and headloss.

PLAN FOR WORKSHOP DEVELOPMENT

In order to recommend which piping materials should be specified and a required cathodic protection system for this project we recommend having a pipe manufacturer and a cathodic protection workshop. The plan for the development of each workshop is provided in the following sessions.

PIPE MANUFACTURER WORKSHOP

In order to recommend which piping materials should be allowed for this project a pipe manufacturer's workshop was held on June 10 and June 11, 2010 at the Burns & McDonnell office in Denver, Colorado. Representatives from the DIP, steel, PVC, HDPE, PCCP and FRP manufacturers were invited to present at the workshop. Appendix A provides a copy of the letter template and attachments that were sent to the piping manufacturers.

Representatives from Northwest pipe (steel), US Pipe (DIP), American Ductile Iron, and North American Pipe Corporation (PVC) presented at the workshop. The meeting minutes from the workshop are included in Appendix B. The Northwest Pipe steel presentation is provided in Appendix C. The American Ductile Iron presentation is provided in Appendix D. The US Pipe

DIP presentation is provided in Appendix E. The North American Pipe Corporation PVC presentation is provided in Appendix F. Each pipe manufacturer was allowed to speak for 45 minutes on the following topics:

- History
- Service Live
- Joints
- Restraint Types
- Cathodic Protection Requirements
- Fittings
- Pressure Class or Thickness Class
- Linings
- Coating
- Installation
- Service Connection
- Production and delivery lead times
- Advantages of allowing this pipe material for this project
- Disadvantages of allowing this pipe material for this project
- Location of Pipe Fabrication and potential means for transport.

A question and answer period followed each pipe manufacturer's presentation.

The intent of the workshop was to provide the GMPP team with an understanding of what piping material is available and what the advantages and disadvantages are for this project. A short recap discussion took place after all of the manufacturer's presentations to discuss pipe material.

CATHODIC PROTECTION WORKSHOP

Cathodic protection is a key component for many of the pipeline materials to be considered for the GMPP project. The City of Gillette had some cathodic issues with the existing Madison Pipeline. The existing line is a steel pipeline with cement mortar lining, coal tar epoxy coating and a magnesium anode cathodic protection system with joint bonding, electrical insulators and test stations. The Gillette Madison Pipeline Internal Pilot Study was performed to determine and correct the cathodic deficiencies of the existing Madison Pipeline. The deficiencies were deterioration of the inner pipe joint cement mortar lining and electrical continuity. All issues may have been caused by poor workmanship during construction. The issued associated with this existing system have put this topic at the forefront for consideration and special requirements to be factored into the design of this project.

Since this is such an important topic to the City of Gillette, our team proposed a dedicated workshop to involve experts in the field of cathodic protection to share theories and ideas regarding the use of various pipeline materials and cathodic protection systems that might be utilized for their use in this project.

A cathodic protection workshop was held on June 11, 2010 at the Burns & McDonnell office in Denver Colorado for this project. The purpose of the workshop was to provide a comprehensive discussion of the technical and economical issues associated with cathodic protection for the GMPP. Two reputable cathodic design firms were invited to speak about cathodic protection for

this project. The firms are Rust Not (Mr. Bill Spickelmire) and AC&C with Corrpro (Mr. Charles Waits). Rust Not performed the cathodic testing and resolved the cathodic issues associated with the existing Madison Pipeline. AC&C has been designing cathodic protection systems throughout the country for the past 30 years. This is their first time teaming with Corrpro.

Each firm discussed the following topics:

- Methodology of cathodic protection system for each pipe material (DIP, steel, PVC (DIP fittings)
- Soil
- Joint bonding
- Consideration for placement of waterline adjacent to high voltage power lines
- Construction inspection and testing
- Rust Not lessons learned from existing Madison Pipeline failures.

The meeting minutes are located in Appendix G. The Rust Not presentation is located in Appendix H and the AC&C presentation is located in Appendix I (The Corrpro portion of the presentation was not provided.)

It is the intent of this workshop to provide the GMPP team with an understanding of the cathodic protection system designs that are available for this project and what will best suit the project based on cost, pipe protection and operation. A short recap discussion took place with the GMPP after the workshop to discuss the best way to proceed with the cathodic protection design.

PIPING MATERIAL

This technical memorandum considers the use of six different types of piping material including ductile iron (DIP), steel, poly vinyl chloride (PVC), high density polyethylene (HDPE), prestressed concrete cylinder pipe (PCCP) and fiberglass reinforced pipe (FRP). The following sections provide information on pipeline history, service life, joints, restraint, cathodic protection, fittings, pressure class, linings, coating, installation and service connections as they apply to this project for each type of piping material.

The following is preliminary information for consideration on the various available pipeline materials:

Ductile Iron Pipe (DIP)

History
Cast Iron Pipe has been in use since the mid 1600's for a variety of water distribution and transmission systems. It was introduced in the United States as early as 1817 for use in the Philadelphia Water System. In 1955 ductile iron pipe was introduced into the water marketplace and replaced the use of cast iron pipe. Ductile iron not only retains all of cast irons qualities, such as machinability and corrosion resistance, but also provides additional strength, toughness and ductility. It is also lighter, stronger and more durable than cast iron.

Service Life
Ductile iron has a service life of at least 50 years. Some cast iron has been in the ground at certain locations for more than 100 years.

Joints
Buried 36-inch and 42-inch ductile iron piping systems can use bell and spigot or push on joints.

Restraint
Ductile iron pipe systems can be restrained through the use of ductile iron restrained joint piping systems or with the use of retainer glands (Megalugs) that are placed at each joint to restrain the pipe. Megalugs can be very effective; however, their use can be labor intensive and time consuming for 36-inch and larger sized pipes. Most manufacturers have developed their own trademark restrained joint mechanism systems which have made installation simpler for the contractor to install and have increased production rates. As such the use of Megalugs has diminished significantly.

Cathodic Protection
Ductile iron pipe is susceptible to corrosion and the Ductile Iron Pipe Research Institute recommends that all ductile iron pipe located in corrosive soils be wrapped with a polyethylene fabric to prevent corrosion of the pipe. The ductile iron pipe can also be protected from corrosive environments with the use of a sacrificial anode system or properly designed rectifier cathodic protection system if soil conditions warrant. Project specific cathodic protection will be discussed at the cathodic protection workshop.

Fittings
Fittings for the ductile iron system are also fabricated of ductile iron in accordance with ANSI/AWWA C110 A21.10 or C153 standards. All fittings manufactured in accordance with the standard have a minimum safety factor of 3 times the rated working pressure. Standard fittings include bends, tees, crosses, base bends, reducers, sleeves etc. The ductile iron used for fittings has a minimum tensile strength of 70,000 psi, minimum yield strength of 50,000 psi and a minimum elongation of 5%. All 36-inch and 42-inch fittings are available in 250 psi pressure class ratings and some ductile iron manufactures can also rate 36-inch and 42-inch fittings for 350 psi.

Pressure Class
The pressure class designation for the pipe will be designed in accordance with AWWA C150, standard for Thickness Design of Ductile Iron Pipe. This takes into consideration the design for internal pressure trench load and deflection. The internal design pressure for the in-town piping is 50 psi and the corresponding test pressure is 62.5 psi. The internal design pressure for the transmission line ranges between 125 and 250 psi and the corresponding test pressure is 160 and 315 psi (1.25 design pressure per Gillette construction specifications we are considering 1.5). These pressures will be utilized in the calculations.

Linings
Ductile iron pipe is lined with cement mortar lining in accordance with ANSI/AWWA C104/A21.4 standards. For a 36-inch and 42-inch lines the cement mortar thickness is generally 0.125-inches. The cement mortar lining helps prevent tuberculation, internal corrosion and provides higher flow coefficients to help maintain the carrying capacity as the pipe ages. This results in energy savings.

Coatings
Ductile iron pipe generally will be coated with the manufacturer's standard bituminous paint coating. In addition it is standard to protect the pipe utilizing polyethylene encasement around the pipe. The ductile iron pipe can also be coated with bonded polyethylene if needed to meet cathodic protection requirements. This will be discussed during the cathodic protection workshop.

Installation
Bedding is important for ductile iron pipe since it is considered a flexible pipe. Although ductile iron is a flexible pipe it is a stiff pipe that does not rely heavily on bedding/backfill envelope for support of external loading. A typical installation does not require select and or highly compacted material in order to provide adequate support. ANSI/AWWA C150/A21.50 outlines five standard laying conditions types with varying soils models and bedding angles. Burns & McDonnell generally designs for the Type 5 laying condition. The geotechnical report for the project will be referred to for specific requirements.

Service Connection
Service connections will be required for this project as discussed in technical memorandum #9. Ductile iron pipe can easily be tapped to provide service connections. Future connections can usually be accomplished by some municipalities through their own crews as special equipment and appurtenances are not required.

Steel Pipe

History
Steel pipe has been in use since the early 1800's, and is used in a variety of industries including water distribution and transmission systems. Steel pipe was originally riveted. Now the pipe seams are welded.

Service Life
Buried steel pipe has a life expectancy of at least 50 years.

Joints
Buried steel pipe systems can use bell and spigot joints with rubber gaskets, welded joints or a combination of the two. There are two different types of rubber gasket joints:
- Fabricated
- Rolled-groove.

There are four different types of welded joints:
- Lap welded
- Single welded butt joint
- Double welded butt joint
- Butt Strap joint

There are two types of combination rubber gasket/welded joints:
- Tied rubber gasket joint
- Carnegie shape rubber gasket /Weldon bell ring

Restraint
Steel pipe systems are restrained by welding the joints.

Cathodic Protection
Steel pipe is susceptible to corrosion in soils exhibiting low resistivity. To prevent corrosion to the steel pipe system where poor soils warrant their use, a sacrificial anode system or other properly designed cathodic protection system such as a rectifier system can be installed. Project specific cathodic protection will be discussed at the cathodic protection workshop.

Fittings
Fittings for a steel pipe system are welded and fabricated from tested steel pipe in accordance with AWWA C208 standards. BMcD requires fittings to be tape wrapped in accordance with AWWA C204. If alternative coatings are required for this specific project the fittings will also require the same coatings.

Thickness Design
Steel pipe is designed in accordance to AWWA C200 and utilizes the techniques described in manual M-11 to determine wall thickness. Wall thickness of steel pipe is affected by many factors including but not limited to, internal pressure, external pressure (deflection and depth of waterline) and handling stiffness. Thickness of the pipe will be the larger thickness from the external load calculation, the transient pressure calculation and handling stiffness. A minimum deflection of 2% is allowed for the design using the Iowa deflection formula. Thickness is determined during the design process after the profile of the line is determined.

Linings
The lining helps prevent internal corrosion and produces and maintains a smooth surface to enhance flow capacity. In steel pipe line lining passivates the steel to prevent iron corrosion. Steel pipe is generally lined with cement mortar lining in accordance with AWWA C205 standards.

Coatings
There are several coatings available for steel pipe systems including coal-tar, cement-mortar, cold-applies tape, liquid epoxy, fusion bonded epoxy, standard tape coating, extruded polyolefin and polyurethane. BMcD generally specifies steel pipe to be tape wrapped in the factory prior to delivery to the site in accordance with AWWA C214. The tape wrapping is a three layer polyethylene backed butyl rubber tape system consisting of a primer (inner layer), corrosion prevention tape (middle layer) and mechanical protective tape (outer layer). Coating is the best means for ensuring a long life for pipe operation by preventing deterioration and corrosion.

Installation
Bedding is an important factor for steel pipe. As wall thickness increases pipe stiffness also increases. A stiff pipe does not relay heavily on sidefill soils (bedding) to help support the external load. A typical installation does not require select or highly compacted material in order to provide adequate support. The pipe is designed so that it does not exceed a deflection of 2%. For steel pipe there are three pipe-zone bedding and backfill classifications including C1, C2, and C3. BMcD to design for a C1 bedding and backfill with a dry density of 95% and that requirement that bedding be placed one foot above the pipe. The geotechnical report for the project will be referred to for specific requirements.

Service Connections
Service connections will be required for this project as discussed in technical memorandum #9. Steel pipe can be easily tapped to provide service connections. Future connections can usually be accomplished by some municipalities through their own crews as special equipment and appurtenances are not required.

Poly Vinyl Chloride (PVC)

History
PVC was discovered in the early 1900's, but became commercially common in the 1950's for use in many industries including water and sewer systems.

Service Life
PVC pipe has a life expectancy of over 50 years.

Joints
Buried PVC systems use bell and spigot push on joints or fused joints. Fused joints were developed for use with horizontal directional drilling but can also be used in conventional open trench excavations for the 16 and 24 inch size.

Restraint
PVC pipe systems are restrained through the use of retainer glands (megalugs), by fusing of the joints, or other mechanical restraints such as bell restraints. Megalugs have been very effective; however, their use can be labor intensive and time consuming especially on 36-inch and 42-inch pipes. Most manufacturers have recently developed their own trademark restrained joint mechanism systems for 24-inch and smaller PVC which have made installation simpler for the contractor to install and have increased production rates. The trademark restrained joint systems are currently not available for 36-inch and 42-inch diameter PVC pipe.

Fittings
Fittings for the PVC pipe system are made from ductile iron in accordance with ANSI/AWWA C110 A21.10 or C153 standards. All fittings manufactured in accordance with the standard have a minimum safety factor of 3 times the rated working pressure. Standard fittings include bends, tees, crosses, base bends, reducers, sleeves etc.

Cathodic Protection
PVC pipe is considered to be strongly resistant to corrosive environments and a cathodic protection system is not required for the piping system. Since the fittings are ductile iron they will require cathodic protection. Cathodic protection can be achieved by the use of polyethylene wrap, the use of a sacrificial anode system or other properly designed cathodic protection system. Project specific cathodic protection will be discussed at the cathodic protection workshop.

Pipe Class and Pressure Rating
The pipe class for PVC pipe is based on a dimension ratio (DR) of the average outside diameter over the average wall thickness of the pipe. The internal design pressure for the in-town piping is 50 psi and the corresponding test pressure is 62.5 psi. The internal design pressure for the transmission line ranges between 125 and 250 psi and the corresponding test pressure is 160

and 315 psi (1.25 design pressure per Gillette construction specifications we are considering 1.5). These pressures will be utilized in the calculations. The DR will also vary depending on the pressure rating. The DR and pressure ratings for C905 PVC pipe are indicated in the following table:

Table 4
DR and Pressure Ratings for PVC Pipe

DR	Pressure Rating	Manufacturing Availability
32.5	125 psi	36” and 42” are available
25	165 psi	36” and 42” are available
21	200 psi	36” is available. 42” is not available
18	235 psi	Not available in 36” or 42”
14	305 psi	Not available in 36” or 42”

The pressure rating does not account for surge so it is recommended that a lower DR be provided. This would further reduce the PVC availability to DR 25 for the 36-inch and 42-inch size and DR 21 for the 36-inch size. The wall thickness for each DR varies so that the outside diameter is the same as ductile iron systems. The inside diameter for the available PVC sizes is indicated in the following table:

Table 5
Wall Thickness and Internal Diameter for 36 and 42-inch PVC Pipe

DR	36-inch		42-inch	
	Wall Thickness	Internal Diameter	Wall Thickness	Internal Diameter
25	1.53	32.25	1.78	40.94
21	1.82	34.65	N/A	N/A

The internal diameter greatly reduces the flow capacity of the line. PVC is not a viable material for the higher operating pressures associated with the transmission pipeline portion of the project.

Linings and Coating
Linings and coatings are not required on the PVC pipe. Linings and coating would be required for the ductile iron fittings. Please refer to the ductile iron section of this report.

Installation
PVC pipe is a very flexible piping system. It relies heavily on the bedding/backfill envelope to offset external loads. The bedding material is required to be select material that is compacted below, around and above the pipe in order to provide the strength required to withstand external loads. The geotechnical report for the project will be referred to for specific requirements.

Service Connections
Service connections will be required for this project as discussed in technical memorandum #9. PVC pipe can be easily tapped to provide service connections. Future connections can usually be accomplished by some municipalities through their own crews as special equipment and appurtenances are not required.

High Density Polyethylene (HDPE)

History
Use of HDPE in the United States began in the 1950's, primarily in the oil and gas field. More recently HDPE has also been used for domestic water distribution systems. High density polyethylene (HDPE) is not considered a common water line material for buried applications and is not widely accepted by many municipalities. HDPE is a great pipe material for above ground bypass piping systems.

Service Life
HDPE pipe has a life expectancy of over 50 years.

Joints
Buried HDPE piping system use fused joints. Special fittings are required to connect the HDPE piping to existing systems of differing material.

Restraint
Restraint is provided through the use of fused joints.

Fittings
Fittings for the HDPE system are either molded or fabricated. Molded fittings are made by injection moldings and are pressure rated. Fabricated fittings, which are fused from pieces of HDPE pipe, have a reduced pressure rating because the miter cuts create a change in the diameter of the fitting. The larger the angle of the miter cut, the greater the stress and the greater the need to decrease the pressure rating to maintain a 2 to 1 safety factor.

Cathodic Protection Pipe
HDPE is considered to be extremely resistant to corrosive environments and therefore a cathodic protection system is not required.

Class and Pressure Rating
The pipe class for HDPE pipe is based on a dimension ratio (DR) of average diameter over the average wall thickness of the diameter of the pipe. The internal design pressure for the in-town piping is 50 psi and the corresponding test pressure is 62.5 psi. The internal design pressure for the transmission line ranges between 125 and 250 psi and the corresponding test pressure is 160 and 315 psi (1.25 design pressure per Gillette construction specifications we are considering 1.5). These pressures will be utilized in the calculations. The DR will also vary depending on the pressure rating. DR and pressure ratings for HDPE pipe are indicated in the following table:

Table 6
DR and Pressure Ratings for HDPE Pipe

DR	Pressure Rating	Manufacturing Availability
11.0	125 psi	36" and 42" are only available from some manufacturers
9.3	151 psi	36" and 42" are only available from some manufacturers
9.0	156 psi	36" and 42" are only available from some manufacturers
7.3	198 psi	36" and 42" are only available from some manufacturers

The pressure rating does not account for surge so it is recommended that a lower DR be provided. The wall thickness for each DR varies so that the outside diameter is the same as ductile iron systems. The inside diameter for the available PVC sizes is indicated in the following table:

Table 7
Wall Thickness and Internal Diameter for 36 and 42-inch HDPE Pipe

DR	36-inch		42-inch	
	Wall Thickness	Internal Diameter	Wall Thickness	Internal Diameter
11.0	3.482	31.34	4.046	36.41
9.3	4.118	30.06	4.785	34.93
9.0	4.256	29.79	4.944	34.62
7.3	5.247	27.81	6.096	32.31

The internal diameter greatly reduces the flow capacity of the line. HDPE is not a viable material for the higher operating pressures associated with the transmission pipeline portion of the project.

Linings and Coatings
Linings and coatings are not required on HDPE pipe.

Installation
HDPE pipe is a very flexible piping system. It relies heavily on the bedding/backfill envelope to offset external loads. The bedding material is required to be select material that is compacted below, around and above the pipe in order to provide the strength required to withstand external loads. The geotechnical report for the project will be referred to for specific requirements.

Service Connections
Service connections will be required for this project as discussed in technical memorandum #9. HDPE pipe can be cut and a fitting with service connection can be installed but the joints will need to be fused together with a fusing machine. Therefore unless the City of Gillette purchases this equipment the fusing will need to be done by a contractor. It is a major undertaking to cut in a fitting on a 36-inch or 42-inch pipe.

Prestressed Concrete Cylinder Pipe (PCCP)

History

Prestressed Concrete Cylinder Pipe (PCCP) was first manufactured in 1942 as lined cylinder pipe. This pipe, constructed by welding steel joint rings to a steel cylinder, was then coated internally with concrete. The outer surface was wrapped with high strength steel wire directly over the steel cylinder and covered with a cement-based mortar coating. Diameters ranged from 16 inch to 48 inch, and it was only after the revision of AWWA C301 Standard in 1979 that lined cylinder pipe standards were increased to include 60 inch diameter pipe. The introduction of the AWWA C301 standard in 1964 accepted thinner sheet steel for cylinders in all Prestressed Concrete Cylinder Pipe (PCCP), which functions more as a form around which the pipe is constructed.

Service Life

Manufacturer information does not indicate the service life of PCCP. The service life will be discussed at the pipe manufacturer workshop.

Joints

The joints consists of a steel bell ring and spigot ring welded to each end of the steel cylinder, this design compresses a rubber O-ring gasket and forms a long lasting watertight joint.

Restraint
Most manufacturers have recently developed their own trademark restrained joint mechanism systems which have made installation simpler for the contractor to install and have increased production rates.

Fittings
Fittings for a PCCP pipe system are fabricated in accordance with AWWA C301 standards.

Cathodic Protection Pipe
In dry conditions PCCP is considered to be strongly resistant to corrosive environments. If placed in areas with wet soils the concrete has the potential to be susceptible to corrosive environments. The concrete can be modified with additives in areas with high sulfide levels.

Design
PCCP pipe is designed in accordance to AWWA C304 and utilizes the techniques described in manual M9 to determine joint restraint.

Linings and Coatings
Linings and coatings are not required on PCCP.

Installation
PCCP is a rigid conduit and does not obtain support through the bedding section. PCCP need no special bedding or backfilling under normal underground conditions. The geotechnical report for the project will be referred to for specific requirements.

Service Connections
Service connections will be required for this project as discussed in technical memorandum #9. PCCP pipe should only be tapped by a reputable contractor for service line connections. It is a major undertaking to cut in a fitting on a 36-inch or 42-inch pipe.

Fiber Reinforced Plastic Pipe (FRP)

History
Centrifugally cast, fiberglass-reinforced plastic (FRP) pipe consists of reinforcement fabric layers saturated with a thermosetting resin, then cured in a casting machine. The glass fabric gives the pipe its structural strength, the resin is highly corrosion resistant and the pipe can be fire resistant. FRP is not commonly used in long, large diameter transmission lines. Common uses include process and industrial applications.

FRP pipe has been used primarily in the oil and gas industry since the 1960's. AWWA standard C950 was first issued in 1981 for use of FRP pipe in the water industry. It has been updated 4 times since its inception to increase the allowable diameter and to add additional pressure classes.

Service Life
Manufacturer information does not indicate the service life of FRP pipe the service life will be discussed at the pipe manufacturer's workshop.

Joints
Several jointing methods are available including bell and spigot, flanged, or butt & wrap.

Restraint
Restraint is provided through the use flanged joints or butt and wrapped joints.

Fittings
Fittings for the FRP are fabricated and are pressure rated.

Cathodic Protection Pipe
FRP is considered to be strongly resistant to corrosive environments and therefore a cathodic protection system is not required.

Pressure Class
The pressure class designation for the pipe will be designed in accordance with AWWA C950. This takes into consideration the design for internal pressure trench load and deflection. Allowable deflection is 5 percent. The internal design pressure for the in–town piping is 50 psi and the corresponding test pressure is 62.5 psi. The internal design pressure for the transmission line ranges between 125 and 250 psi and the corresponding test pressure are 160 and 315 psi (1.25 design pressure per Gillette construction specifications we are considering 1.5). These pressures will be utilized in the calculations. The highest pressure class for FRP is 200 psi. FRP is a viable material for the higher operating pressures associated with the GMPP.

Linings and Coatings
Linings and coatings are not required on FRP pipe.

Installation
FRP is to be installed per the requirements of AWWA M45. FRP is considered a flexible pipeline system. Therefore it relies on support from the bedding/backfill envelope to resist external loads. The bedding material is required to be select material that is compacted below, around and above the pipe in order to provide the strength required to withstand external loads. The geotechnical report for the project will be referred to for specific requirements.

Service Connections
Service connections will be required for this project as discussed in technical memorandum #9. FRP pipe should only be tapped by a reputable contractor for service line connections. It is a major undertaking to cut in a fitting on the 36-inch or 42-inch pipe.

PIPING COMPARISON

The following section provides our initial piping comparison in regards to sizing, headloss and velocity for the City of Gillette 36-inch and 42-inch waterline materials that may be used on this project.

Internal Diameter

Pipe materials are manufactured and marketed using outside diameters as the general classification, however, based on pipe wall thickness, the pipes have varying inside diameters. Pipe wall thickness varies, based on the pressure class selected (for DIP, steel, PVC, HDPE, PCCP and FRP) and design calculations for steel piping. A general example of how the internal diameter of 36-inch and 42-inch water lines compare is shown in the following table.

Table 8
Inside Diameter for 36 and 42-inch Pipe

Material Type	Inside Diameter (36”)	Inside Diameter (42”)
Ductile Iron (Pressure Class 250)	37.36”	43.46”
Steel Pipe	36.00”	42.00”
PVC (DR 21 and DR 25)	34.64”	40.94”
HDPE (DR 9)	29.80”	34.62”
PCCP	36.00”	42.00
FRP (Pressure Class 250)	36.00”	42.00”

DIP – AWWA C150 values, Steel – Manufacturers info, PVC – AWWA C905, HDPE – AWWA C906 w/ DIP equivalent diameters, PCCP – AWWA C304 and FRP – AWWA C950

As indicated in the above table the inside diameters of the PVC and HDEP pipes are smaller than the inside diameter of the other materials. A DR 18 C-905 pipe for PVC material and a DR 9 HDPE pipe would be required for this project to account for surge. These classifications of pipes are currently manufactured through special order since they are not standard sizes.

Velocity and Headloss

Head loss for pipe materials depends on the quantity of water, length, inside diameter, and friction coefficient of the material. As a comparison of different piping materials, the following table indicates the results of transporting 21 million gallons per day of water 1000 feet in a 36” pipe with inside diameters mentioned above. The Hazen-Williams coefficients are the industry accepted values.

Table 9
Velocity and Headloss for Differing Pipe Material

Material	Hazen-Williams	Velocity (fps)	Headloss (ft)
Ductile Iron	140	4.27	1.29
Steel	140	4.60	1.54
PVC	150	4.96	1.63
HDPE	150	6.71	3.40
PCCP	120	4.60	2.05
FRP	150	4.25	1.23

The table indicates that the pipes with smaller diameters (PVC and HDPE) have higher velocity and headloss over the other pipe materials. The greater the headloss per linear foot of pipe the higher the pumping costs required to move water from one location to another.

PIPE MATERIAL BENEFITS AND DISADVANTAGES

This section will describe the pipe material benefits and disadvantage for the City of Gillette project. The proposed line will be required to carry 21 MGD from the proposed well fields to the existing tank on Southern Drive. The overall depth of the proposed 36-inch and 42-inch waterline will be approximately 6.0 feet below grade. The waterline will be placed deeper to avoid existing utilities as required.

The choice of piping materials for a water distribution system is dependent on many factors, including history of use is similar to the specifics of the project considered is key, installation method, performance requirements, location, geological features, corrosive soils, material availability, pumping requirements and system expansion.

Ductile Iron Pipe

Ductile iron pipe has been in some cases left in the ground for over 100 years and still functions as originally designed. As long as the ductile iron piping system is protected from corrosion it can exceed the estimated 50 year life expectancy. Some benefits and disadvantages of DIP for this project are listed below:

Benefits of Ductile Iron

- Established use for waterlines
- Standard availability in pressure class required for this project.
- Varying pressure ratings for a 36-inch or 42-inch water line.
- High Tensile Strength which resists the forces caused by internal hydrostatic pressure and water hammer.
- Low temperature sensitivity
- Direct tapping of DIP is easier, less expensive and faster than PVC, HDPE PCCO and FRP.
- Largest internal diameter results in the lowest pumping costs.
- Corrosion resistance can be provided with a polyethylene sleeve or a cathodic protection system.
- Specialized restraint system
- Available in long lay lengths.

Disadvantages of Ductile Iron

- Susceptible to corrosion – This is corrected by using a polyethylene sleeve or a cathodic protection system when soil conditions warrant its use.
- If a sacrificial anode cathodic protection system is required it will be need to be maintained and tested throughout the life of the pipe.
- Heavy weight of material
- High wave velocity creating potentially high surge pressure

Steel Pipe
Steel pipe systems have been used widely in large diameter waterline systems. As long as the steel piping system is protected from corrosion it can meet or exceed its life expectancy of 50 years. Some benefits and disadvantage of steel piping for this project are listed below:

Benefits of Steel pipe

- Established for larger diameter waterlines.
- Very high strength and ductility
- Can be fabricated in any thickness required.
- High tensile strength which resists the forces caused by internal hydrostatic pressure and water hammer.
- Low temperature sensitivity.
- Pipe can be shaped or sized to any requirements needed. Fittings are fabricated from the same material at the same time as the pipe.
- Fittings are welded
- If a cathodic protection system is required less anodes are required then the same system on a ductile iron pipe.
- Available in long lay lengths

Disadvantages of Steel pipe

- Susceptible to corrosion. This is corrected with a coating system and a cathodic protection system when soil conditions warrant its use.
- If a sacrificial anode cathodic protection system is required it will be need to be maintained and tested throughout the life of the pipe.
- Heavy weight of piping material.
- High wave velocity creating potentially high surge pressure
- Welding for restraining can be time consuming.

PVC Pipe
Small diameter PVC pipe (C-900) is very similar to DIP or steel pipe in regards to strength and internal pressure. On larger diameter PVC pipe (C-905) the required factor or safety for internal pressure is 20% less than what is required for C-900 PVC pipe. This leads to an overall reduction in comparable wall thickness. Some benefits and disadvantages of PVC pipe for this project are listed below:

Benefits of PVC

- Corrosion resistant
- Chemical resistant
- Lighter material weight then HDPE, DIP, PCCP and steel.
- When fused, greater pulling force than HDPE

Disadvantages of PVC

- Not typically used in larger diameter waterlines with higher pressures
- 36-inch DR 18 C-905 PVC pipe is only being manufactured through special order.
- Smaller interior diameter then similar sized steel or DIP which increases velocity, headloss and pumping costs.
- PVC pipe is buoyant. It is possible that the pipe will be installed in some areas which have high groundwater. This could create buoyancy issues.

- Fittings will be DIP requiring them to be poly wrapped and corrosion protection is required if the soils warrant.
- C905 pipe has no allowance for surge pressure in the pressure rating.
- High thermal expansion coefficient. For service temperatures greater than 73.4 degrees F PVC loses tensile strength, pipe stiffness and dimensional stability reducing the pressure capacity of the pipe.
- Impact strength is low in comparison to DIP and steel.
- PVC pipe obtains support from external loads through the bedding section. The bedding material is required to be select material that is compacted below, around and above the pipe in order to provide the strength required to withstand external loads.
- Due to the flexible nature of the pipe it is subject to creep and fatigue which will affect the overall strength of the pipe.
- Pipe can be damaged if tapped improperly under certain temperature conditions.
- PVC pipe cannot be located with a metal detector. Tracer wire can be installed if future locating of the line is required.
- More vulnerable to punctures then DIP or steel.

HDPE Pipe

HDPE is used widely in the oil and gas industry. In comparison to the other products it has only recently been used in water pressure pipe applications and it is still being proven as a viable option for waterlines. It is very useful in temporary above ground applications such as by-pass piping since joints can be cut and fused in the field if equipment is available. Some benefits and disadvantages of HDPE pipe for this project are listed below:

Benefits of HDPE

- Corrosion resistant
- Chemical resistant
- Flexible and able to achieve tighter radii then other materials
- Lighter material weight than steel and DIP

Disadvantages of HDPE

- 36-inch DR 9 HDPE pipe is only being manufactured through special order.
- Subject to expansion/contraction based on temperature which affect the strength of the HDPE.
- Low yield strength
- Smaller interior diameter then other similarly sized PVC, DIP and steel which increases velocity and headloss and overall pumping costs.
- Future fittings or repairs will need to be fused. If the City of Gillette does not have the equipment for fusing joints as well as employees trained in this technology then an outside contractor will need to be hired whenever something needs to be installed or repaired on the line. This could be expensive if an emergency repair is required.
- HDPE experiences tensile creep which can result in pipe deformity.
- Impact strength is low in comparison to DIP or steel.
- HDPE is highly permeable and will easily absorb hydrocarbons if present in the bedding material.
- HDPE pipe obtains support from external loads through the bedding section. The bedding material is required to be select material that is compacted below, around and above the pipe in order to provide the strength required to withstand external loads.

- HDPE cannot be located with a metal detector and tracer wire will be installed if future locating is required.
- Due to the flexible nature of the pipe it is subject to creep and fatigue which will affect the overall strength of the pipe.
- More vulnerable to punctures than DIP or steel
- HDPE pipe is buoyant. It is possible that the pipe will be installed in some areas which have high groundwater. This may cause buoyancy issues.
- Temperature sensitive

PCCP Pipe
Prestressed Concrete Cylinder Pipe (PCCP) is available as prestressed concrete cylinder pipe or bar-wrapped concrete cylinder pipe, and offers good strength, durability, and corrosion resistance. PCCP offers excellent resistance to external loads, because of the concrete core, and steel wire stressed wrap. Some benefits and disadvantages of HDPE pipe for this project are listed below:

Custom fittings, bends, and tees can be produced by the manufacturer.

While this type of pipe has been installed successfully since the 1940's, the performance record in this region is not well established.

Benefits of PCCP
- Corrosion resistant
- Chemical resistant
- Does not obtain support from bedding section.
- Rigid pipe
- Not susceptible to punctures
- Can be located with a metal detector

Disadvantages of PCCP
- PCCP pipe is manufactured specifically for each pipeline project.
- PCCP is heavy (Added trucking and labor charges)
- Fittings are manufactured specifically for each pipeline project
- Field changes are difficult to accomplish
- Taps and future repairs will need to be made by a general contractor.
- Joints have failed in the past
- Documented catastrophic failures
- Not many manufacturers

FRP Pipe
Centrifugally cast, fiberglass-reinforced plastic (FRP) pipe consists of reinforcement fabric layers saturated with a thermosetting resin, then cured in a casting machine. The glass fabric gives the pipe its structural strength, the resin is highly corrosion resistant and the pipe can be fire resistant. Common uses include process and industrial applications. Some benefits and disadvantages of HDPE pipe for this project are listed below:

Benefits of FRP
- Corrosion resistant

- Chemical resistant
- Flexible and able to achieve tighter radii then other materials
- Lighter material weight than steel and DIP

Disadvantages of FRP

- FRP pipe is manufactured through special order.
- Brittle in colder temperatures.
- Future fittings or repairs will need to be performed by a general constructor.
- FRP cannot be located with a metal detector and tracer wire will be installed if future locating is required.
- Due to the flexible nature of the pipe it is subject to creep and fatigue which will affect the overall strength of the pipe.
- More vulnerable to punctures than DIP or steel
- FRP pipe is buoyant. It is possible that the pipe will be installed in some areas which have high groundwater. This may cause buoyancy issues.
- Joint failures

RECOMMENDATIONS

There are many advantages and disadvantages for each pipe material as discussed throughout this technical memorandum, at the piping manufacture presentations and at the cathodic protection presentations. As a result of this information it is recommended that the following piping material be allowed in the specifications:

- Steel
- DIP
- PVC for lower pressure applications and the use of ductile iron fittings.

The three allowable materials will provide a competitive bidding situation to provide the City of Gillette with the most economical material during the time of bidding.

It is also recommended that the cathodic protection system for each pipeline material be designed by Mr. Bill Spickelmire of Rust Not. Mr. Spickelmire is currently working with the City of Gillette on the updating and upgrading of the cathodic protection system on the existing Madison pipeline. His design experience on the existing Madison waterline can be used as a benefit to the City of Gillette in that he be able to design with both projects in mind and provide the most economical design that may connect the cathodic systems of the existing and new pipelines.

APPENDIX A

Pipe Manufacturer Invitation to Present (Template and Attachments)

May 26, 2010

Mr. Michael Hajnos
US Pipe
690 Coyote Trail
Elizabeth, CO 80107

City of Gillette, Wyoming
Gillette Madison Pipeline Project
Burns & McDonnell Project No. 54432

Dear Mr. Hajnos,

The City of Gillette, Wyoming is currently completing a comprehensive expansion to its water supply system and the overall project includes the the design and construction of the Gillette Madison Pipeline Project (GMPP). This project will consist of both in-town and "cross-country" transmission piping. The in-town piping consists of approximately 7.5 miles of pipe ranging in diameter from 16-inchs to 24-inches. The in-town pipeline will run from the "Z1R4" storage reservoir on Southern Drive (just west of State Highway 59) east to State Highway 50, then north along State Highway 50 to Westover Drive, then east along Westover Drive to the "Z1R2" storage reservoir. Exhibit A1 illustrates the proposed alignment of the in-town piping. The "cross-country" transmission piping will consist of approximately 42 miles of pipe ranging in diameter from 36-inches to 42-inches. Pressures are expected to range between 125 and 250 psi. The transmission pipeline will run from the expanded Madison well field located north of Moorcroft, Wyoming, in Crook County to the existing Z1R4 storage reservoir indicated above. Exhibit A2 generally illustrates the proposed alignment of the transmission pipeline.

Representatives of the City of Gillette, Wyoming Water Development Commission, and the Burns & McDonnell/Morrison Maierle design team will be hosting a piping manufacturer's workshop to gather applicable information related to the pipe material that will ultimately be specified on this project. .Representatives from two corrosion control design firms will also be present. The entire team would like to invite your company to participate in the information-gathering workshop. This invitation has been sent to manufactures of DIP, FRP, HDPE, PCCP, PVC and steel pipe.

Please note that the focus of the workshop will be on the pipe material and in no way should it be construed that an invitation to a specific manufacturer represents an endorsement for either the material or the specific manufacturer. Further, attendance does not guarantee that a specific pipe material will ultimately be specified on this project.

The workshop will be held at the offices of Burns & McDonnell in Centennial, Colorado on the afternoon of June 10, 2010 and the morning of June 11, 2010.

9785 Maroon Circle, Suite 400
Centennial, CO 80112
(303) 721-9292

Each manufacturer will have 40 minutes to present information related to their piping material. The project team would like to request that your presentation address the following topics:

- History and Service Life
- Joints
- Restraint
- Fittings
- Design
- Linings
- Coatings
- Installation
- Service Connection
- Location of Pipe Fabrication
- Product delivery and lead times
- Advantages of specifying this pipe material for this project
- Potential disadvantages of specifying this pipe material for this project
- Considerations when installed in close proximity to high voltage electrical power lines.
- Issues related to interconnections with an existing steel water transmission line.

Following the 40 minute presentation, the project team will conduct a question/answer period for up to 20 minutes.

We would like to request that you attend the workshop from 5:30 pm to 6:30 pm on June 10, 2010

Please contact me at 303-474-2208 to confirm that you will be presenting at the workshop. We look forward to your participation.

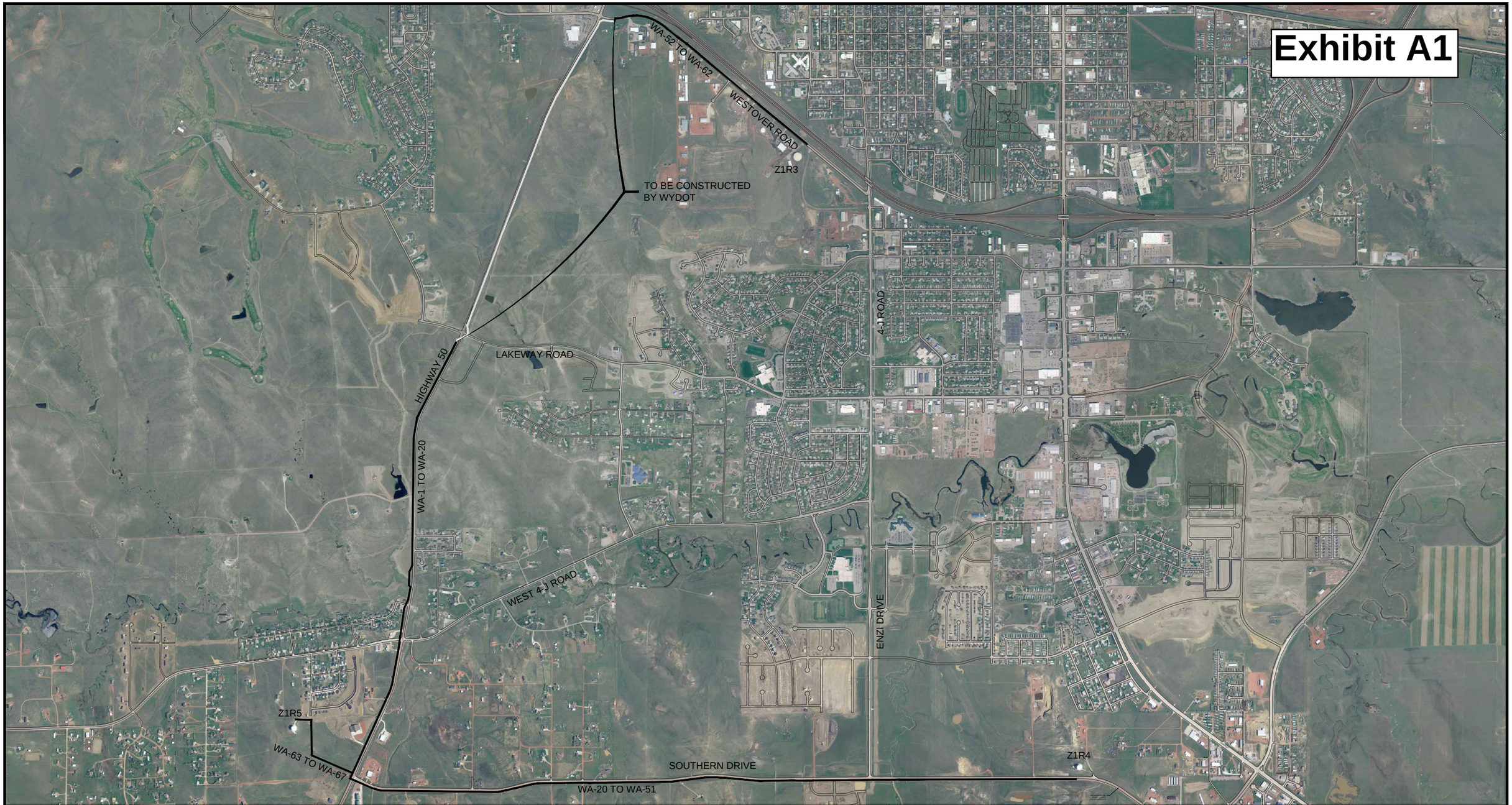
Sincerely,

Kate Reichstein, P.E.
Associate

cc: Mike Cole, P.E. – City of Gillette
Darin Brickman, P.E. – Burns & McDonnell
Dan Korinek, P.E. - Burns & McDonnell
Carl Anderson, P.E. – MMI
Casey Hanson, P.E. – MMI
Jamie Tarver, Tarver Consulting

Attachments: Exhibit A1 and A2

Exhibit A1



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VERIFY SCALE!

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MODIFY SCALE ACCORDINGLY!

REVISIONS

NO.	DESCRIPTION	DATE	BY

V:\4776\001\ACAD\Exhibits\In Town Piping Overall Map.dwg Plotted by Kurtis Deshaw on 7/21/10

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Engineers
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Scientists
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DSGN. BY:
APPR. BY:
DATE:

Q.C. REVIEW BY:
DATE:

GILLETTE MADISON PIPELINE PROJECT

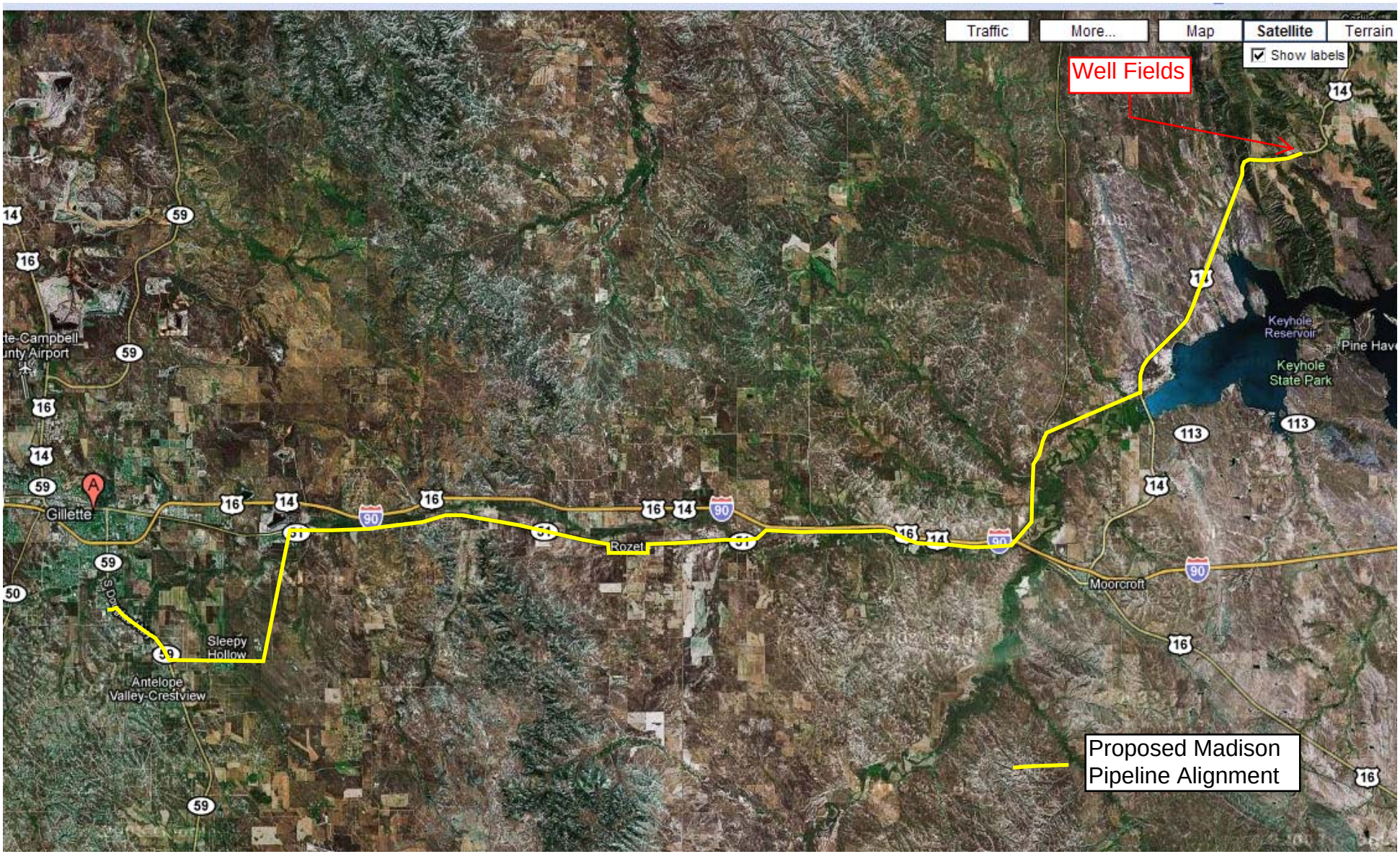
IN TOWN PIPING LAYOUT

PROJECT NUMBER 4776.001

SHEET NUMBER

DRAWING NUMBER

Exhibit A2 - Proposed Madison Pipeline Transmission Alignment



APPENDIX B

Pipe Manufacturer Workshop Meeting Minutes

City of Gillette
Gillette Madison Pipeline Project (GMPP)

Pipe Manufacturer Workshop

June 10, 2010 3:00 pm to 6:30 pm
June 11, 2010 8:00 am to 2:00 pm

Location: Burns & McDonnell Office Summit Conference Room

Meeting Minutes

Attendees:

Name	Representing
Mike Cole	COG
Steve Peterson	COG
Diane Monahan	COG
Dave Galles	COG
Greg Bowman	COG
Bryan Hendershot	COG
Bryan Clerkin	WWDC
Dave Zelenka	WWDC
Carl Anderson	MMI
Darin Brickman	BMcD
Dan Korinek	BMcD
Casey Hanson	MMI
Kate Reichstein	BMcD
Mike Lehrburger	BMcD
Bill Spickelmire	Rust Not
Charlie Waits	AC&C Companies

Owner: City of Gillette
201 East Fifth Street
Gillette, Wyoming 82717
Primary Contact: Mr. Mike Cole, P.E.

Engineers: Burns & McDonnell Engineering Company, Inc.

9785 Maroon Circle, Suite 400
Centennial, CO 80112

Morrison Maierle, Inc.
2200 Foothills Boulevard, Unit A
Gillette, WY 82716

Funding Agency: Wyoming Water Development Commission
6920 Yellowtail Rd.
Cheyenne, WY 82009-6112
Primary Contact: Mr. Bryan Clerkin, P.E.

June 10, 2010

Steel Pipe Presentation (3:00 p.m. – 4:00 p.m.)
Northwest Pipe – Neal Kelemen and Richard Mielke (presenters)

Steel Pipe Presentation (40 min)

- History and Service Life
  - Used in the 1860's during the gold rush
  - 200 installations with 80+ years in the ground
  - 1925 the steel was riveted and dipped in asphalt.
  - Now the pipe is spiral welded
- Joints
  - Gasketed
  - Welded
  - Flexible joints are bell and spigot with O rings. They are not restrained. A joint bond is required to provide electrical continuity
  - Restrained joints are welded bell and spigot joints with out gaskets. Welds can be made inside or outside the pipe.
- Restraint
  - Provided with welded joints
- Fittings
  - Prefabricated
  - Made from straight pieces of pipe per AWWA c208
- Design
  - Meet AWWA Standards
  - Performance based design using project criteria.
  - Calculate the internal pressure and external loading as well as other stresses
- Linings
  - Factory applied cement mortar lined
  - Cement mortar is applied in the field at joints to complete the system
- Coatings
  - Factory applied tape, polyurethane
  - Heat shirk sleeves are applied at joints in the field to complete the system
- Installation
- Service Connection
  - Outlets are welded to the pipe

  - Steel pipe can also be tapped.
- Location of Pipe Fabrication
  - Pipe to be fabricated in Denver
- Product delivery and lead times
  - Lead time is currently 2 months
  - Entire pipeline could be fabricated in 10 months
- Advantages of specifying this pipe material for this project
  - Sticks of pipes are 40 feet long.
- Potential disadvantages of specifying this pipe material for this project
- Considerations when installed in close proximity to high voltage electrical power lines.
  - Polyurethane coating is dielectric and makes it difficult for current to connect. Mag ribbons or other cathodic protection will also prevent current from damaging the line.
- Issues related to interconnections with an existing steel water transmission line.
  - It is easy to connect steel to steel.
- Other topics
  - E' is a measure of the soil pushing back on the pipe. It is an empirical number based on AASHTO trench classifications.
  - Bedding is required 0.7D from the bottom of the pipe.

Questions and Answers (20 min)

1. Is polyurethane as cost effective as tape wrap?
   -Yes especially when contractor handling and repairs are taken into account. Polyurethane is tougher and handles better as there are less tears and dings.

2. Where are the o-ring gaskets supplied from?
   -There are 2-3 vendors which supply the gaskets. They can be supplied from a single manufacturer.

3. What is the approximate cost of 30-inch and 42-inch at 150 psi?
   -The 36-inch is approximately $100 per foot and the 42-inch is approximately $120 per foot. The costs also include fittings and delivery.

4. Who are your competitors at these sizes?
   -Very competitive with ductile iron for the 36-inch size range. For 42-inch steel has the advantage.

5. Questions on E'.
   -Need to determine if E' can be related to blow counts so that E' can be specified for the project. An analysis would need to be performed if soils information is provided. Other pipe materials do not use the same E' values.

6. What type of bedding material is required?
   -Bedding should be ¾-inch or less in size. The angularity does not matter

Break and set up for next session (4:00 p.m. – 4:15 p.m.)

Ductile Iron Presentation (4:15 p.m. – 5:15 p.m.)
American Ductile Iron – Andy Sneed

Ductile Iron Presentation (40 min)

- History and Service Life
  - American is the single largest DIP manufacturer
  - 1804 Cast iron pipe was installed
  - 1922 Cement mortar lining became a standard
  - 1948 Ductile Iron Pipe was developed
  - 1975 Cast iron pipe manufacturing ended
  - 1958 Polywrap became a standard
- Joints
  - Buried joints are push on joints, mechanical joints or restrained joints
  - The push on joint is a successor to the mechanical joint.
  - Exposed joints are flanged or grooved.
- Restraint
  - Restrained joint (Flex Ring)
  - Mechanical joints are restrained with Megalugs
- Fittings
  - Bends come in different configurations with push on joints, mechanical joints or flanges
  - 5 5/8 degree bends are now available
- Design
  - Flexile conduit approach
  - Use worst case of internal or external loads.
- Linings
  - Cement mortar per AWWA C140 C=140
  - High Speed Cement Mortar Lining AWWA C150 C = 150 - 155
- Coatings
  - Asphaltic Coating
  - Primer on the pipe for indoors area that will be painted.
  - Polyethylene Wrap comes in 8 mils or 4 mils. The 4 mils is cross laminated and more resistant to damage in the field.
- Installation
  - Easy, forgiving and high deflection ability.
- Service Connection
  - Tee
  - Weld on outlet. A weld on outlet is more economical that a tee.
- Location of Pipe Fabrication
  - Pipe will be manufactured in Alabama then railed to a depot in Littleton Colorado the trucked to Gillette.
- Product delivery and lead times
  - Lead time is 60 to 100 days. It is shorter in the winter.
  - Transit takes 2 to 3 weeks to get to a depot
- Advantages of specifying this pipe material for this project
- Potential disadvantages of specifying this pipe material for this project
  - There is a higher sales price due to more robust gaskets, thicker the steel with the same yield and large thick bells.

  - There is corrosion potential depending on the corrosiveness of the soil.
- Considerations when installed in close proximity to high voltage electrical power lines.
  - It is usually not a concern. Current is approximately 1% of DC source of corrosion from crossing and parallel areas. Voltage can be induced on a pipeline via magnetic induction.
  - It is best to have electrical discontinuity on the line. Continuity is the worst case because current can built up and exit and damage the pipe
  - One suggestion is not to bond the joints at the crossings.
  - Another option is to place anodes on each piece of pipe.
- Issues related to interconnections with an existing steel water transmission line.
  - DIP can be connected to steel with flanges or couplings and insulating kits.

Questions and Answers (20 min)

1. The soils for this project are very corrosive. Is a polyethylene bag still a good practice?
   -A minimum would be the polyethylene bag with a cathodic protection system. The cathodic protection system is needed to cover the flaws of the polyethylene bag and coating. You may also choose to double polyethylene bag the pipe.

2. All the projects that were presented in the presentation were Bureau of Rec (BOR) projects from the 90's.
   -Andy mentioned that the BOR has changed corrosion requirements and this is a point of contention within the industry. Andy feel the BOR is not the best source.
   -Since there is not BOR or federal money associated with this project their guidelines do not need to be followed.

3. With the given soil conditions and proper polyethylene bag and cathodic protection will ductile iron provide a 100 year design life?
   -Yes

4. What is the AWWA standard for field welding DIP?
   -There are standards for welding DIP. There are also manufacturing guidelines for field welding of the pipe. The field welding is the responsibility of the contractor.
   -Andy recommends against field welding since there are other ways to make connections.
   -The average welder does not know how to weld DIP.

5. What are the allowable pipe defections for pipe and fittings?
   -3 to 4 degrees of deflection is allowable for 36-inch DIP with push on joints.
   -The allowable deflection can be increased one degree with high deflection joints.
   -The allowable defection with restrained joints is 0.5 to 2 degrees.

6. What is the general cost per foot of pipe delivered to Gillette?
   -30-inch pipe runs approximately $60 per foot.
   -36-inch pipe runs approximately $75 to $80 per foot.
   -Add an additional $20 to $30 for restrained joint pipe.
   -Costs are dependent on the cost of scrap which is currently at $450 per ton.

7. Questions on E'
   -Andy indicated that E' is a function of the soil and not the pipe.

-Andy agreed that E' should be the same throughout the industry but since there is only a guide different conservative levels are applied depending on the guide line group.

8. Bedding is a challenge in Gillette, what is the recommendation for bedding?
   -Andy indicated that the bedding should not have sharp edges since it could affect the polyethylene bag.
   DIP is stiffer than other materials so it is less dependent on trench and bedding.

9. What are the available lengths that DIP?
   -DIP comes in 18 to 20 foot lengths.

10. Can polyethylene be put on the pipe in the factory?
    -The polyethylene bag can be placed in the pipe in the factory but it will be more expensive since it is usually put on the pipe by the contractor.

11. Are there any advantages of double bagging the pipe?
    -It is difficult to have a flaw on top of a flaw.

June 11, 2010

Ductile Iron Presentation (8:00 a.m. – 9:00 a.m.)
US Pipe – Mike Hajnos (presenter)

Ductile Iron Presentation (40 min)

- History and Service Life
  - US pipe was incorporated in 1899
- Joints
  - Push on joints are fabricated from 4-inch to 64-inch
  - Restrained joints (TR Flex) are fabricated from 4-inch to 36-inch. They are easy to assemble and disassemble.
  - Restrained joints (HP Lok) are fabricated from 30-inch to 60-inch.
- Restraint
  - Restraint system
  - Mechanical restraints
- Fittings
  - TR Flex (4 inch to 24 inch)
  - HP Lok (30 inch to 64 inch)
  - Flanged
  - Mechanical Joint
  - Tyton Joint
- Design
  - Follow requirements of AWWA
- Linings
  - Cement mortar lining
- Coatings
  - After the pipe is cast it is super heated. This is the annealing process where an oxide layer is developed to provide corrosion protection.
  - The annealing oxide is just as good as a bonded coating on steel.

  - Bonded coatings are not offered due to the incompatibility with the DIP peened surface. There are too many holidays that are created. The same thing applies to tape wrap.
- Installation
- Service Connection
  - Welded outlets are custom made to a specified size.
  - Tapping saddles
  - Tees
  - Direct tap
- Location of Pipe Fabrication
  - The pipe for this project would be provided from the Alabama plant where they make pipe from 14-inch to 64-inch.
- Product delivery and lead times
- Advantages of specifying this pipe material for this project
  - DIP is a proven product
  - There are design standards that should be followed.
  - DIP is a 95% recycled product
  - The installation is easy.
- Potential disadvantages of specifying this pipe material for this project
  - Since DIP is made of metal there will be some corrosion associated with the pipe. The corrosion should be identified and evaluated.
- Considerations when installed in close proximity to high voltage electrical power lines.
  - Use robber gaskets to electrically disconnect the joints.
  - If the joints are bonded together use polywrap. Polywrap is resistant to current.
- Issues related to interconnections with an existing steel water transmission line.
  - Transistion coupling
  - Flanged connection with an insulating gasket

Questions and Answers (20 min)

1. With very corrosive soils what is US Pipe's experience with cathodic protection?
   -If the soil resistivity is low a cathodic protection system can be designed and is usually used. US Pipe recommends working with Corpro on a cathodic protection design. One design may be joint bonding with polywrap.

2. Gillette uses a lot of DIP fittings that have a tight bond coating. Why is the DIP not available with tight bonded coating?
   -For a tight bonded coating to be applied to DIP the peened surface and the asphaltic coating would need to be removed from the surface. This process is not longer performed in the USA.

3. The City of Gillette is looking for a 100 year design on the pipe. Is polyethylene wrap capable of proving this life span?
   -Polywrap has already been in the ground for over 50 years. It should be able to provide the expected design expectancy.

4. The Bureau of Reclamation report indicated that when the soil corrosive level is under 2000 ohm that the pipe should have a tight bonded coating and polywrap should not be used.
   -Polywrap surrounds the pipe with plastic and prevents the electrolyte from hitting the pipe. It has been proven to work from over 20 years of test data.

-The main key is to prevent damage from the polywrap.
Mike will provide some information from DIPRA regarding polywrap.

5. What is a ballpark figure for the cost of the DIP?
   -Mike will provide this information.

6. What are the delivery lead times?
   -Approximately 1600 linear feet of pipe can be made per day. The clients requirements can be met.

7. Field welding of DIP
   -Field welding of DIP can be performed by a certified welder.
   -Outlets are usualyed welded in the factory.
   -Due to the types of restraints available field welding is not usually required.

Break and Set Up for next Session (9:00 a.m. – 9:15 a.m.)

PVC Pipe Presentation (9:15 a.m. – 10:15 a.m.)
North American Pipe– Michael Glasgow

PVC Pipe Presentation (40 min)

- History and Service Life
  - Mike has been a PE for over 36 years
  - North American Pipe is the second largest PVC pipe manufacturer.
  - North American Pipe fabricates pipe up to 36 inches in diameter.
  - JM Eagle makes pipe up to 42 inches in diameter.
  - The Unibell information is considered the industry standard
  - PVC pressure pipe has been installed since 1936
  - The pipe has been in the ground for over 60 years. Tests predict that the pipe will last up to 100 years.
  - Testing is through the Plastic Pipe Institute
- Joints
  - All joints have a rubber gasket.
  - There are reinforcement to make the gasket rigid to lock into the bell of the pipe.
- Restraint
  - Thrust Blocking
  - Mechanical Restraint. EBBA Iron products are epoxy coated.
- Fittings
  - Fittings are DIP
  - There are some fabricated PVC fittings that can be supplied out of California or Alabama
- Design
  - Per AWWA M23
  - Handbook of PVC Pipe is a good reference. The appendix has a design example
  - The pipe is derated depending on the temperature of the water. There is a straight line decrease from 23 degreees C.
  - The standards for C900 and C905 are currently being updated so that they use safety factory and allowances. The standards will be merged in the next 2 to 3 years.
- Linings
  - None needed

- Coatings
  - None needed
- Installation
  - Performed by a contractor
- Service Connection
  - Direct Tap or Saddle tap – Tapping machine needs to have a manual feet so that the process is slow and does not punch through the pipe.
- Location of Pipe Fabrication
  - The pipe is made in California and Alabama
- Product delivery and lead times
- Advantages of specifying this pipe material for this project
  - Corrosion resistant
  - Chemical resistant
  - Flexible
  - Light weight
  - Long term tensile strength
  - Waterthigth joints.
  - Abrasion wear resistance
  - Impact strength
  - Long lengths (20 feet)
  - No lead content
- Potential disadvantages of specifying this pipe material for this project
  - Pressure limitations. 250+ psi cannot be accomadated.
- Considerations when installed in close proximity to high voltage electrical power lines.
  - PVC is used to coat electrical wires
  - No problem with PVC material
- Issues related to interconnections with an existing steel water transmission line.

Questions and Answers (20 min)

1. What is the linear foot price of a 36-inch line?
   The pricing has been very volitable since Katrina. Mike will get back to us.

2. What is the issue with JM Eagle Pipe?
   -It appears that the issue may have been quality control. It also appears that the whole thing may blow over.

3. Restrained joints.
   -Restrained joints are the conventional mechanical joints.
   -Smaller sizes have a bulldog restraint system
   -For larger diameter pipe the restrains are external
   -For bell and spigot the restraint needs to bite into the pipe

4. What is the availability and track record of PVC fittings?
   -36-inch fittings have been made for 6 years.
   -JM Eagle and Diamond have been making fitting for 6 to 8 years.

5. There have been cases of large diameter PVC pipe failing pressure tests and low pressure and not at full pressure. Any information?

-It is possible that all of the air was not removed from the line causing the tests to fail.

6. Where do you see PVC being competitive?
   -More activity on the distribution size due to the size.
   -Smaller diameters
   -Diamond has a maximum operating pressure of 125 psi
   -North American and JM can obtain higher operating pressures

7. What are the installations costs? How much less is PVC?
   -Mike will need to get back to the team on the installation tests.

Information regarding the absence of FRP, HDPE and PCCP manufacturer's

Hobas pipe was contacted to be the FRP presenter. Hobas decided to refrain from the presentations since they do not have a restraint joint in the United States. They have a restraint joint that is being used in Europe. They would prefer to have a restraint joint in the United States that is tested against the existing standards.

- The team decided that FRP could be removed from consideration

Performance Pipe a Division of Chevron Phillips was contracted to be the HDPE presenter. They were not able to make the required dates of the presentations.

- There was one a HDPE supplier in Gillette but they are no longer there. They only made up to 18-inches in diameter.
- Kate will speak with Performance Pipe to gather information regarding bedding and available pressure

Hanson Pipe was contacted to be the PCCP presenter. They were very interested in presenting but were not able to make the required dates. They would like to meet with the team some time in the future.

Lunch

Wrap Up

Cathodic Protection Design

- The advantage for using Bill is that he is currently working on the existing Madison line and he realizes the importance of the cathodic protection system on the new line.
- We want to use whoever is best suited for Gillette
- Cathodic Protection design is pennies of the overall project.
- We could use a combination of cathodic protection consultants. Having one consultant design the system and the other review the design. We could have an issue here if the two consultants do not agree on how the cathodic protection method.

Discussion on allowable piping materials

- A preliminary matrix has been developed. Please review and comment
- More products more competition
- Gillette would prefer not to use ductile iron unless it has a tight bonded coating.
- The goal is to obtain a 100 year life at the best price.

- The cathodic protection design should provide 100 year life for all materials.
- Should keep DIP in the mix with bonded coating. This will provide for additional competition even if they don't submit prices.
- If the price comes in for DIP with a baggie the City of Gillette has to make sure that they would award with that material otherwise it could create a lawsuit
- Since legal rights begin with a bid there is the potential to stop the bidding process.
- The team is not obligated to choose the lowest bidder.
- The team should review the Bureau of Reclamation report
- The City of Gillette is qualified to weld on steel but not DIP

APPENDIX C

Northwest Pipe Presentation (Steel Pipe)

Steel Water Pipe

Design, Manufacture & Installation Overview

Gillette Madison Pipeline Project

City of Gillette, Wyoming
Wyoming Water Development Commission
Burns & McDonnell

Presented by:
Neal Kelemen, Northwest Pipe Company
Richard Mielke, PE, Northwest Pipe Company

Steel Water Pipe

Background

History

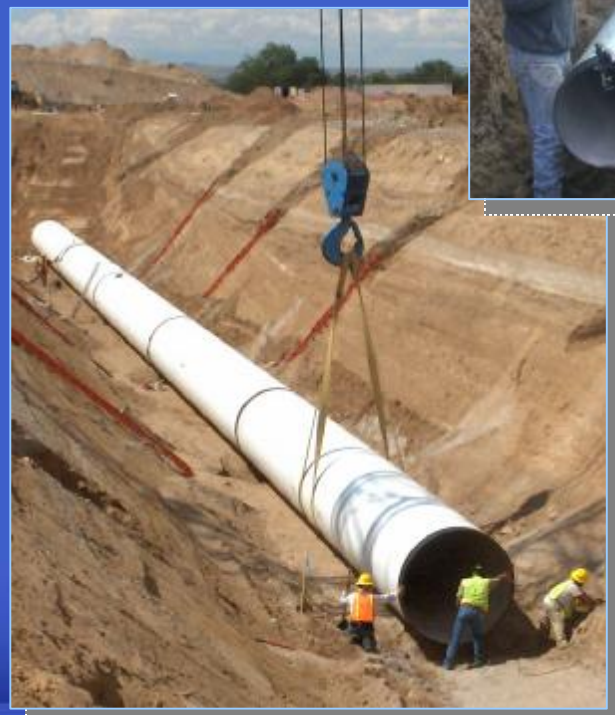
- Earliest uses date to 1860s
- Documented service life over 80+ years in installations across US
- Northwest Pipe traces history to 1878

Steel Water Pipe

Background

Steel Pipe for Water Conveyance

- Engineered for specific application
- Larger diameters, 20” >
- 45 – 50 ft. lengths
- Factory lined and coated
- Pre-fabricated fittings
- Gasketed and welded joints



Steel Water Pipe

Background

Northwest Pipe Company

- Publicly traded: NWPX
- Municipalities represent 88% of WT revenue
- 6 strategically-located plants across US
- Sole nationwide steel water pipe manufacturer
- ISO certified quality management system

Steel Water Pipe

Common AWWA Standards

Design
- AWWA Manual M-11

Pipe Cylinder
- AWWA C200 - Manufacture

Flanges
- AWWA C207

Welding
- AWWA C206

Fittings
- AWWA C208

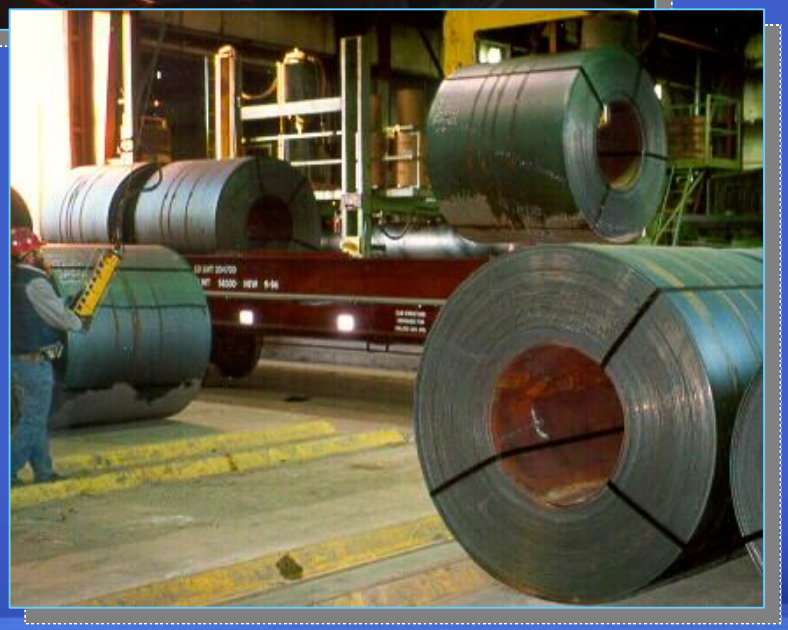
Couplings
- AWWA C219 - Sleeve Type
- AWWA C221 - Expansion

Linings
- AWWA C205 - Cement Mortar
- AWWA C210 - Epoxy
- AWWA C602 - Field Applied Mortar
- AWWA C222 - Polyurethane

Coatings
- AWWA C203 - Coal Tar Enamel
- AWWA C205 - Cement Mortar
- AWWA C209 - Joint Tape
- AWWA C210 - Epoxy
- AWWA C214 - Polyethylene Tape
- AWWA C216 - Heat Shrink Sleeves
- AWWA C218 - Exposed Paint Systems
- AWWA C222 - Polyurethane

Steel Water Pipe

Cylinder Manufacture

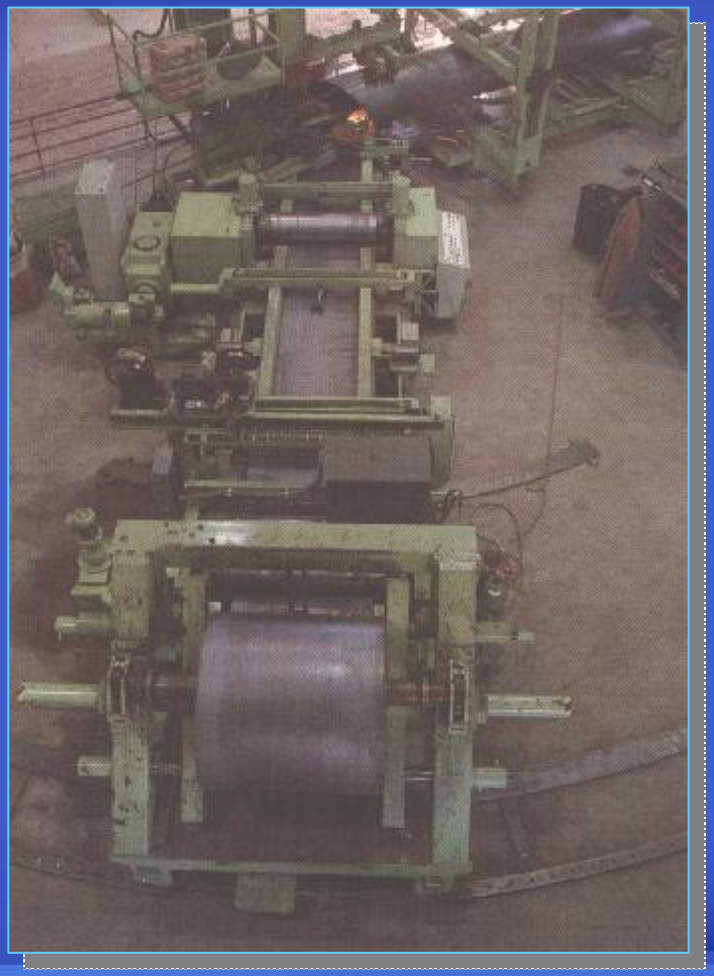


Advantages of Steel

- Ductility with high strength, low weight
- Precise thickness, chemical and physical attributes
- Ability to form, weld and fabricate
- Mechanical properties stable over time

Steel Water Pipe

Cylinder Manufacture



Spiral weld pipe

- Automated process
- Superior weld quality
- 18” - 120” diameters
- .125” to .750” wall thickness
- Close dimensional tolerances

Steel Water Pipe

Cylinder Manufacture

ABS Quality Evalutions, Inc.
Management System Certification
ISO 9001
Certificate No. 33609

Quality assurance

- Hydrostatic pipe test
- Production weld tests
- CWI Inspection
- Radiograph and ultrasonic testing

Performance-based Design

Project specific criteria:

- Design for Internal Pressure
- Design for External Loads
- Design for Other Stresses

Internal Pressure Design

Barlow hoop tension formula:

$$S = \frac{PD}{2t}$$

Where:

S = Allowable Stress
t = Wall Thickness
P = Pressure
D = Diameter

Steel Water Pipe

Internal Pressure Design

Working pressure condition

$$t = \frac{P_w D}{2(.5*Yield)}$$

Transient pressure condition

$$t = \frac{(P_w + P_t)\, D}{2(.75*Yield)}$$

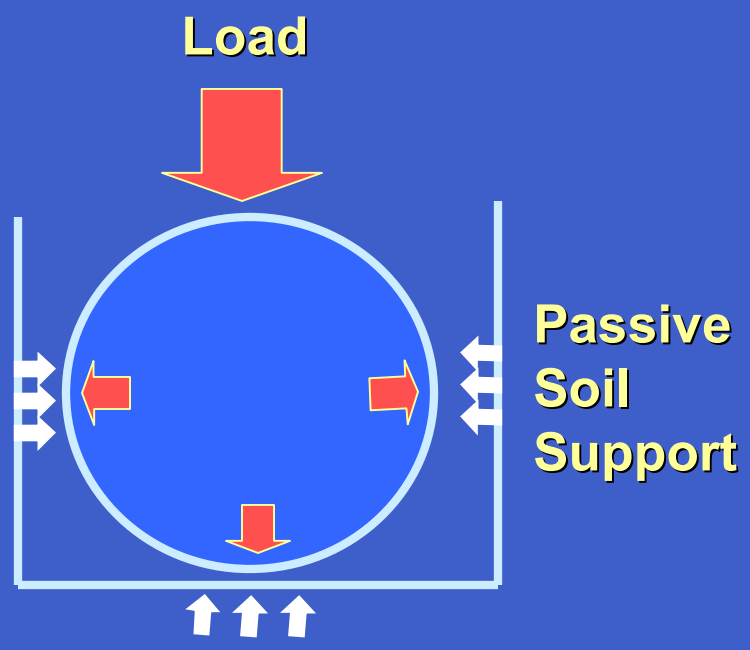
- Allowable stress based on percentage of steel yield strength and internal pressure condition
- Steel options for yield strength range from 36,000 – 46,000 psi (cml pipe)
- Tensile strength provides additional factor of safety

Steel Water Pipe

External Load Design

Control of pipe deflection

Flexible conduits rely on both pipe stiffness and soil reaction to limit effects of vertical dead and live loads



External Load Design

Pipe deflection is predicted by the ratio of load to pipe-soil stiffness:

$$\text{Deflection} = \frac{\text{Load}}{\text{Pipe Stiffness} + \text{Soil Stiffness}}$$

Modified Iowa Deflection Formula (Spangler):

$$D_x = D_l \frac{KWr^3}{EI + 0.061E'r^3}$$

Steel Water Pipe

External Load Design

$$D_x = D_I \frac{KWr^3}{EI + 0.061E'r^3}$$

D_x depends on the linings and coatings used:

	Flexible Lining/ Flexible Coating	CML/ Flexible Coating	CML/ CMC
Allowable Deflection	5%	3%	2%

Steel Water Pipe

External Load Design

$$D_x = D_l \frac{KWr^3}{EI + 0.061E'r^3}$$

E' = modulus of soil reaction

- Measure of soil's resistance to pipe side wall deflection
- Varies based on type of soil, depth of cover, compaction

Steel Water Pipe

External Load Design

AWWA Manual M-11 Duncan - Hartley Table 6-1

E’ = 1,000 psi

- Coarse-grained soil with little or no fines, 5 – 10 ft cover, 85% compaction
- Coarse-grained soil with fines, 10 - 15 ft cover, 85% compaction
- Fine-grained soil with less than 25% coarse-grained particles, 95% compaction

Steel Water Pipe

External Load Design

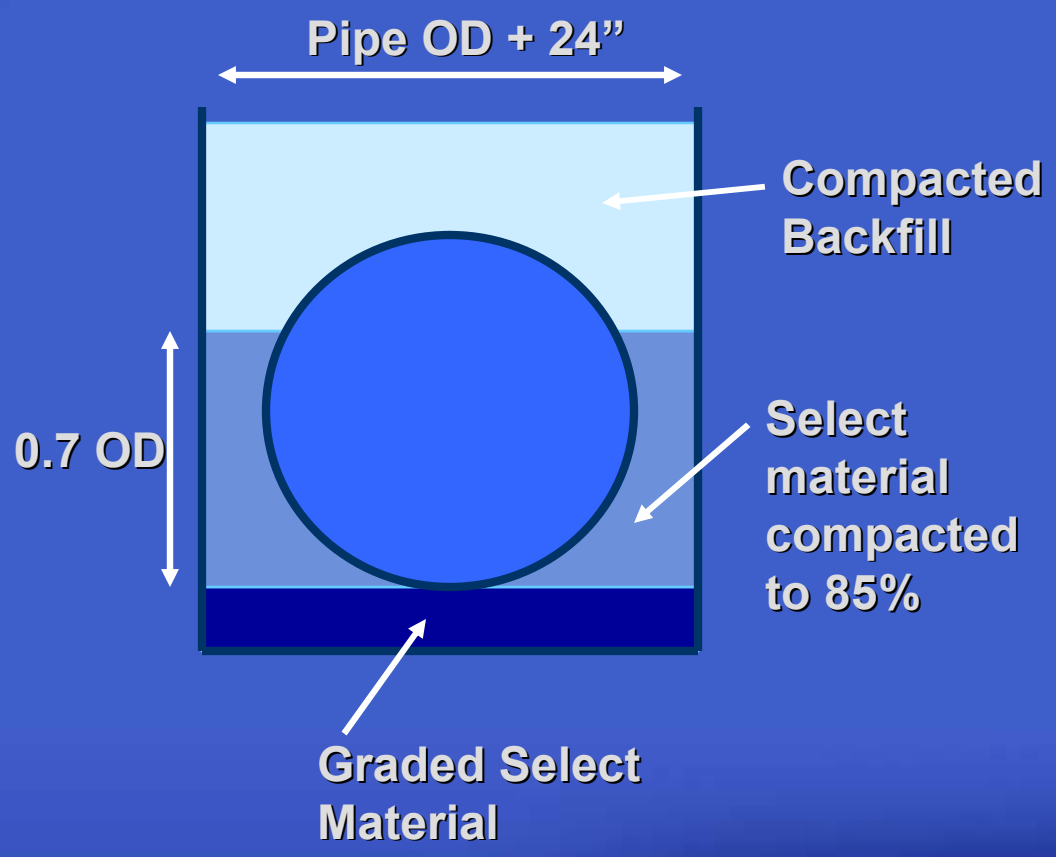
Allowable Fill Height (ft.) - 48” Diameter

E’ vs. Wall thickness

	E’ (psi)		
wall (in)	700	1000	1200
.250	15.6	21.5	25.5
.375	17.6	23.4	27.4
.500	21.4	27.2	31.1

Steel Water Pipe

External Load Design



Trench design

- Select native material often acceptable
- Utilize higher E’ for deeper cover
- Use imported embedment when native soils are poor

Other Design Considerations

D/t ratio limits for handling

- Shop-applied cement mortar lining, *D/t = 240*
- Flexible lining, *D/t = 288*

Vacuum, seismic loads, beam deflection

Joint and fitting stresses

- Hoop stress (internal pressure) generally governs design

Steel Water Pipe

Performance Based Design

Gillette Madison Project

	Pipe Wall (in)	
Pressure class	36 (in)	42 (in)
150	0.156	0.181
200	0.179	0.207
250	0.223	0.259

Depth of cover: Maximum 10 ft

E' = 1,000 psi, D_x = 3%, D_l = 1.0

Steel Water Pipe

Joint Systems

Flexible

- Bell and spigot o-ring rubber gasket
  - Rolled Groove
  - Carnegie

Restrained

- Bell and spigot lap welded
- Butt welded
- Mechanical
  - Split Sleeve
  - Harnessed
  - Flanged
  - Victaulic

Steel Water Pipe

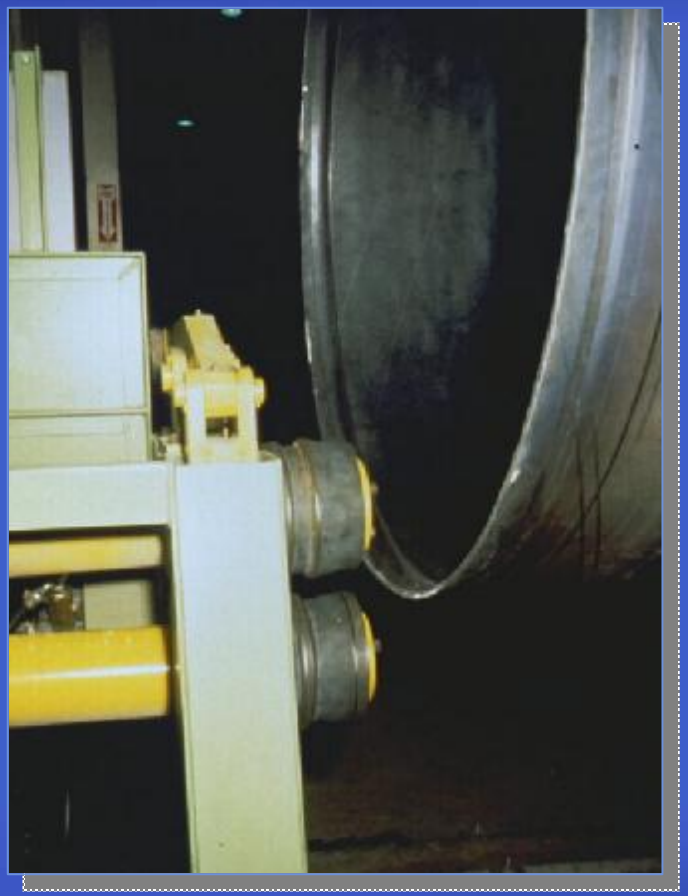
Joint Systems

O-ring rubber gasket

- Rated to 300 psi WP
- Watertight without hydrostatic pressure
- Formed integrally into pipe cylinder
- Economical installation
- Non restrained

Steel Water Pipe

Joint Systems



Bell and Spigot O-ring Joint Formation

Steel Water Pipe

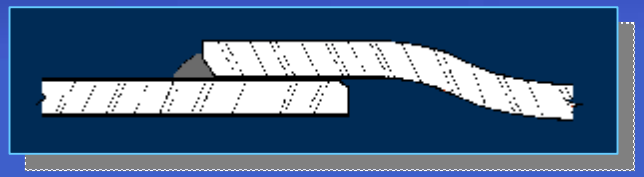
Joint Systems

Bell and Spigot O-ring Gasket Joint Completion

Bonding required for pipeline electrical continuity

Steel Water Pipe

Joint Systems



Bell & Spigot Lap Weld

- Non-mechanically restrained
- Does not require gasket
- Use for higher pressures or other critical locations
- Bell can be mitered for greater angular deflection
- Can be welded either ID, OD or both

Steel Water Pipe

Joint Systems

Split Sleeve

"Depend-o-loc"

Flanged

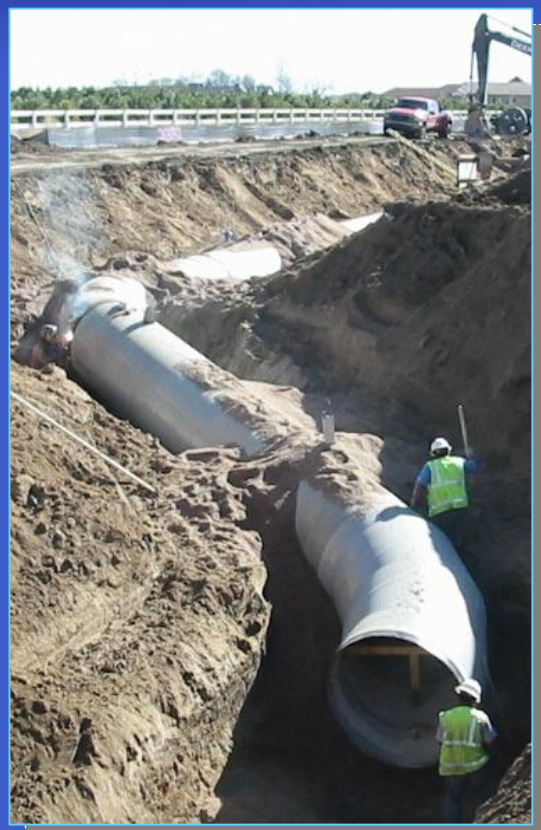
AWWA C207

Harnessed Mechanical

AWWA C219

Steel Water Pipe

Fittings & Specials

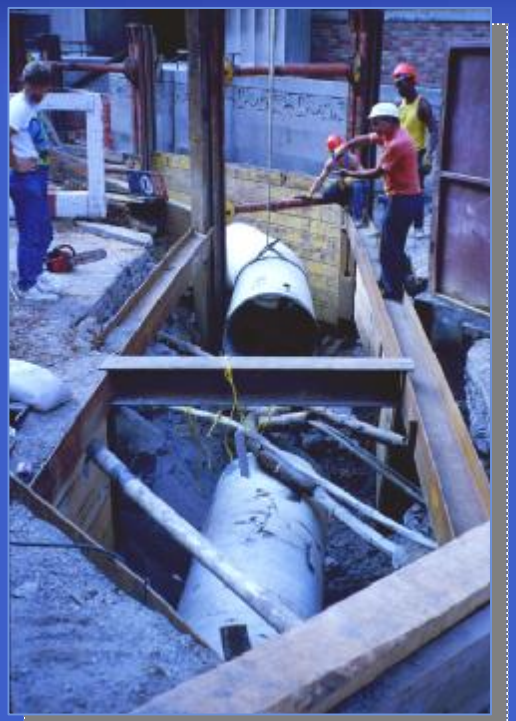


Non-standard sections

- Usually fabricated from lined and coated straight pipe
- AWWA C208 provides dimensional versatility
- Welded construction provides high strength, integral section

Steel Water Pipe

Fittings & Specials



Advantages

- Customized for specific project plan and profile
- Longer section lengths
- Easily modified in field

Steel Water Pipe

Fittings & Specials

Service outlets

Reinforcement per AWWA M-11

Steel Water Pipe

Interior Linings

Cement mortar lining

- Centrifugal-applied, providing smooth, dense durable finish
- Pipe stiffness enhanced for greater trench loads
- Ease of repair and modification
- NSF 61 listed
- C = 140

Steel Water Pipe

Exterior Coatings

Common Steel Water Pipe Coatings

Dielectrics

- Coal Tar Enamel
- Tape
- Spray-applied Systems
  - Epoxies
  - Polyurethane

Cement Mortar

Steel Water Pipe

Exterior Coatings

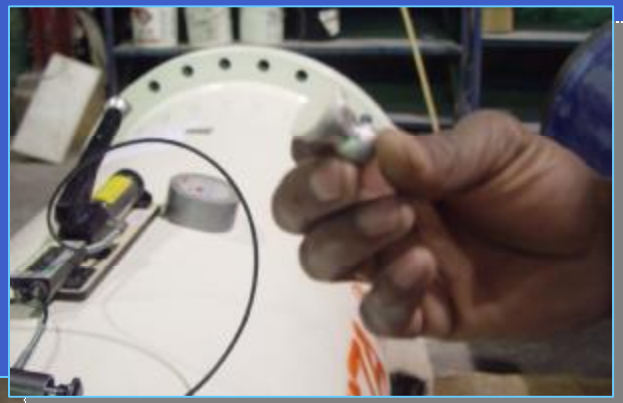
AWWA C222 Polyurethane

- 100% solids, plural component
- High adhesion to steel substrate
- Excellent dielectric properties
- Superior handling durability

Steel Water Pipe

Exterior Coatings

Polyurethane Adhesion Testing



Steel Water Pipe

Exterior Coatings

Heat Shrink Sleeves

- Joint coating system
- Molds to surface geometry
- High adhesion to joint configuration
- Application tolerant
- Dielectric properties equal factory applied coating

Steel Water Pipe

Exterior Coatings

Corrosion protection by coating type:

Dielectric (polyurethane, tape, CT enamel, epoxy)

- Eliminates contact with electrolyte (soil) by impermeable, electrically-resistive barrier

Cementitious (cement mortar)

- Chemically reduces or eliminates potential between anode-cathode (increases ph)

Environmental enhancement

- Polyethylene encasement

Steel Water Pipe

Design Life

Basic Considerations

- Risk of failure
- Consequence of failure
- Time frame: 50 – 100 years is reasonable expectation
- Future conditions
- Upfront vs. long-term cost of preserving buried pipeline asset

Steel Water Pipe

Design Life

Basic Considerations

- Coating should accommodate widest range of site conditions, present and future
- Field coating as important as factory applied
- Provide ability to monitor in-ground condition
- Apply cathodic protection as appropriate
- Maintain the asset

Steel Water Pipe

Design Life

USBR Recommendations

Table 2

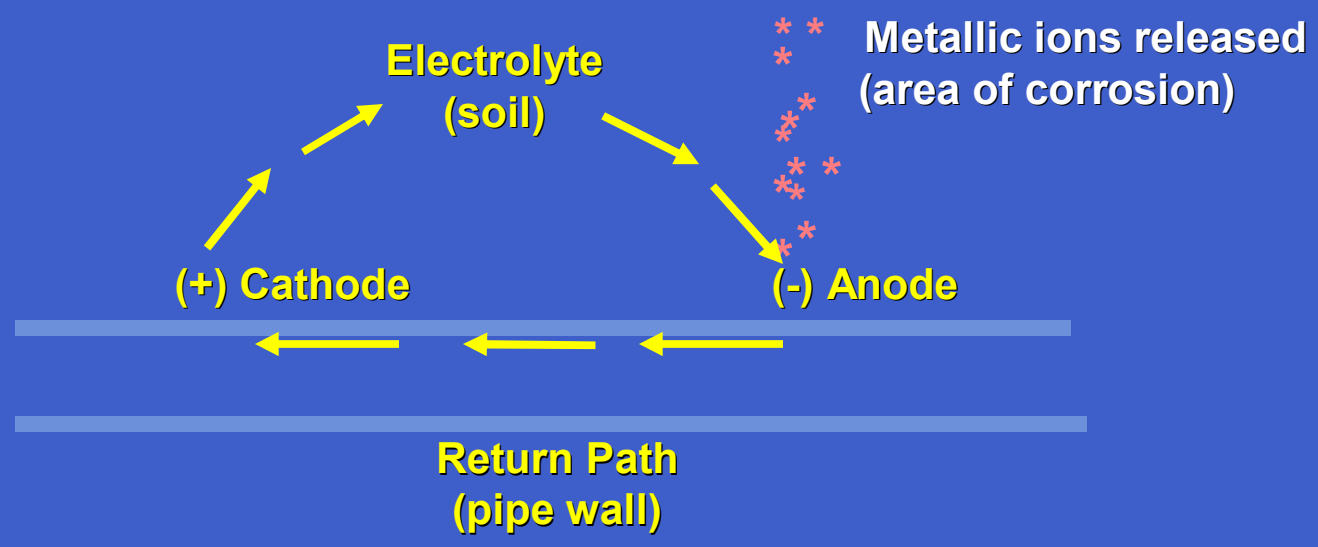
Corrosion Prevention Criteria and Minimum Requirements[1] — **July 2004**

Pipe Alternative	Soil Resistivity – 10% Probability Value (ohm-cm)	Minimum External Protection (Primary/Supplemental)	Corrosion Monitoring	Cathodic Protection[2]
Ductile Iron	≤2,000 ohm-cm	Bonded dielectric[3]	YES	YES
	>2,000 ohm-cm <3,000 ohm-cm	Polyethylene encasement	YES	YES
	≥3,000 ohm-cm	Polyethylene encasement	YES	NO
Pretensioned Concrete	<3,000 ohm-cm	Mortar / coal-tar epoxy	YES	YES
	≥3,000 ohm-cm	Mortar	YES	NO
Reinforced Concrete	<3,000 ohm-cm	Concrete / coal-tar epoxy	YES	YES
	≥3,000 ohm-cm	Concrete	YES[4]	NO
Steel	≤2,000 ohm-cm	Bonded dielectric[3]	YES	YES
	>2,000 ohm-cm <3,000 ohm-cm	Mortar / coal-tar epoxy	YES	YES
	≥3,000 ohm-cm	Mortar	YES	NO

[1] This table should be considered to be the minimum corrosion prevention requirements for a pipeline corrosion design. Additional soil conditions and risk assessment factors should be considered on a case-by-case basis for each specific project.
[2] OMR&E costs for cathodic protection for each pipe type should be evaluated.
[3] Bonded directly to metal to be protected.
[4] Corrosion monitoring is required for concrete pipe with steel joint rings, but not for concrete pipe with concrete joints.

Steel Water Pipe

Design Life



Typical Corrosion Cell- Metallic Pipeline

Steel Water Pipe

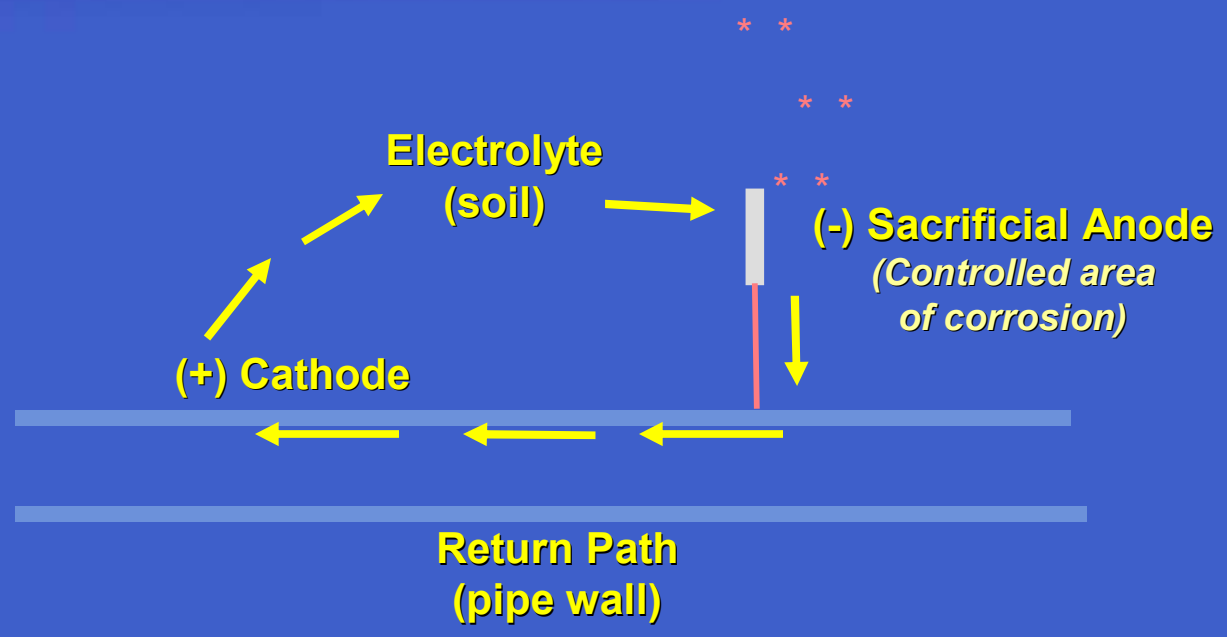
Design Life

Basics of cathodic projection

- A system of induced current that protects the exterior of the pipeline from corroding
- Pipe surface collects current and discharges at localized, controlled anodes
- Current can be induced by system of rectifiers or sacrificial galvanic anodes

Steel Water Pipe

Design Life



Typical Cathodically Protected Pipeline

Steel Water Pipe

Project Logistics

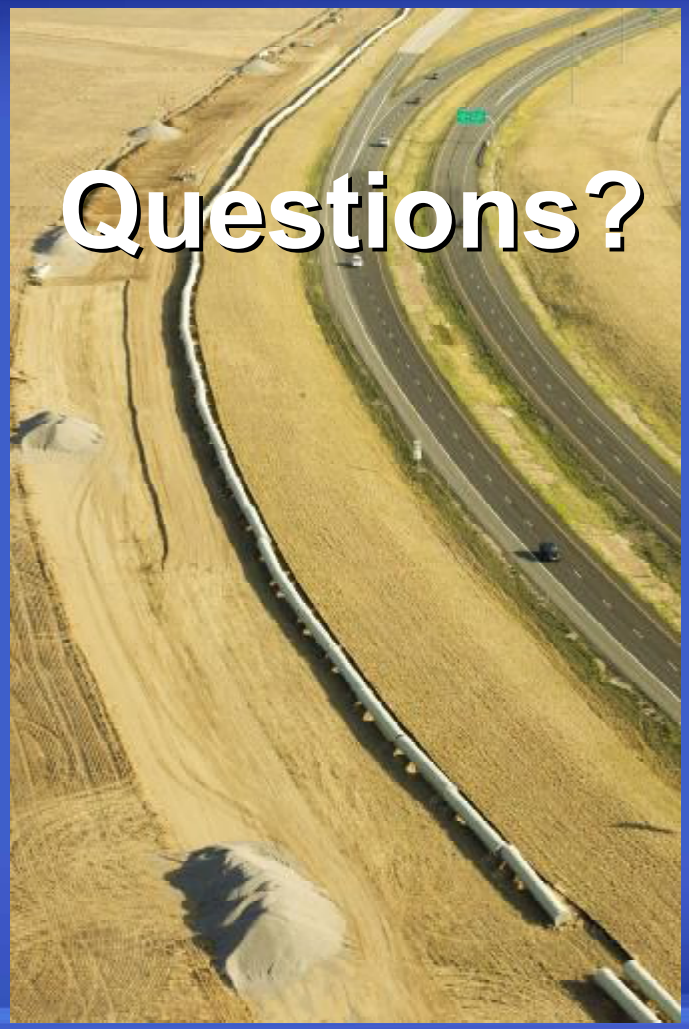
Gillette Madison 40 mile 36”/42” Pipeline

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Initial Steel Procurement	2 months													
Submittals	4 months													
Pipe Manufacture			10 months											
Shipping and Stringing					9 months									
Pipe Installation						9 months								

- 10,000 tons steel
- Approximately 30% of Denver plant annual capacity
- 2005 ECCV project comparable
- 1,160 truck loads freight
- 2 installation crews
- 4,000 lf installed per crew per week

Steel Water Pipe

Gillette Madison Pipeline Project



Neal Kelemen
Sales Representative

Richard Mielke, PE
Director of Engineering

Visit Our Website
nwpipe.com

APPENDIX D

American Ductile Iron Presentation

Application of Ductile Iron Pipe

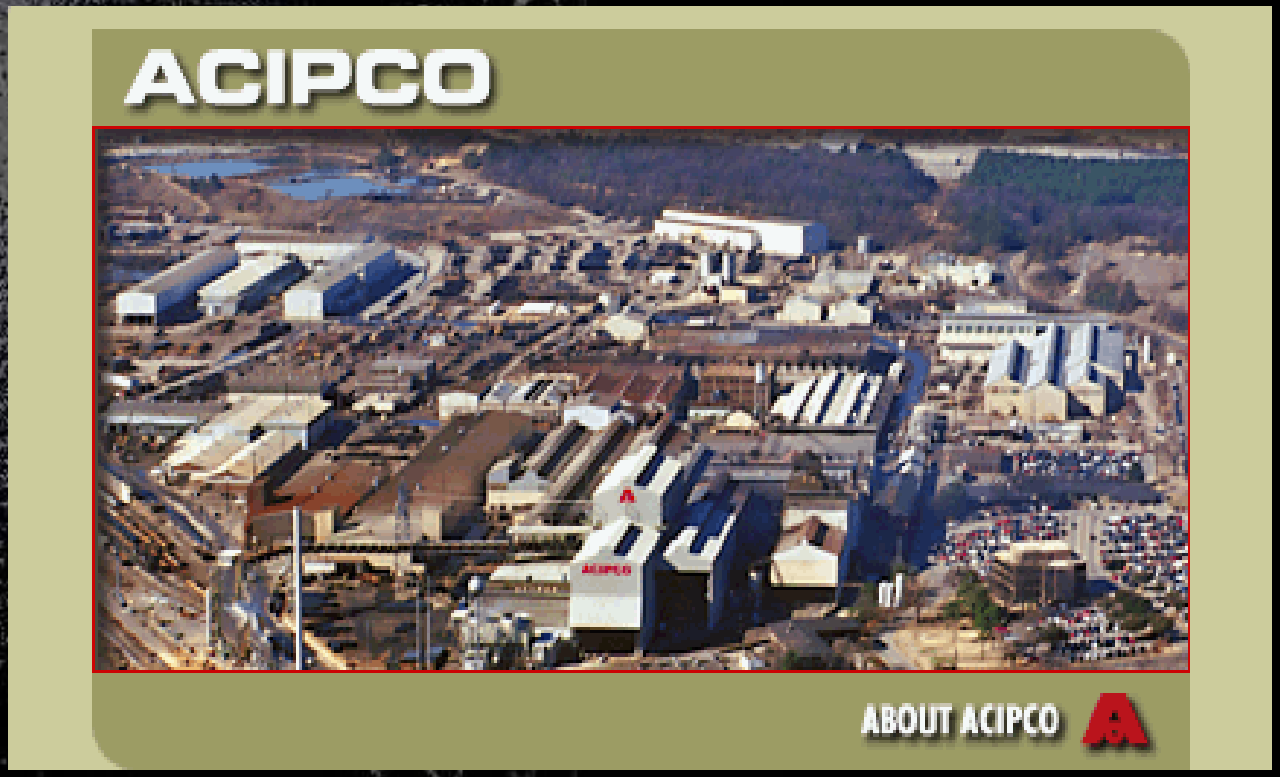
Gillette Madison Pipeline Replacement

By: Andrew G. Sneed, P.E. – 6/10/2010

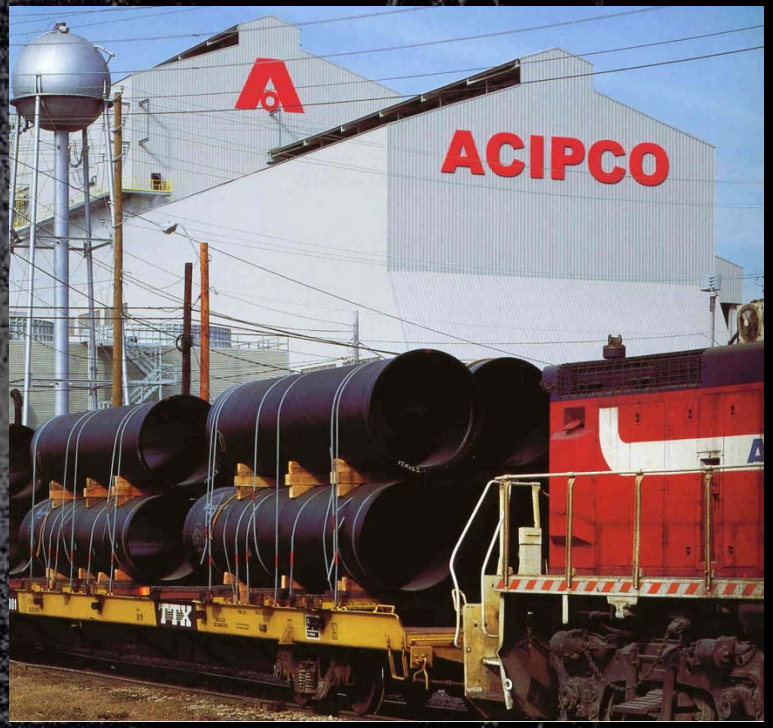
American Cast Iron Pipe Co.

Established in 1905

- American Ductile Iron Pipe –Birmingham, AL
  - Ductile Iron Pipe & Fittings (4”-64”)



American's Denver Area Depot
(Hwy 85 and Titan Pkwy)



- Stock 4"-16" Pipe
- Staging for Big Projects
- Handle Ability 4"-64"

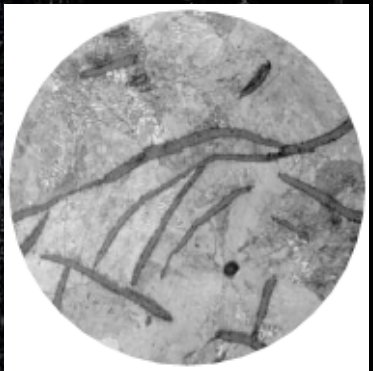
Lead time: 36"- 42" Pipe Ranges from 60-100 Calendar Days

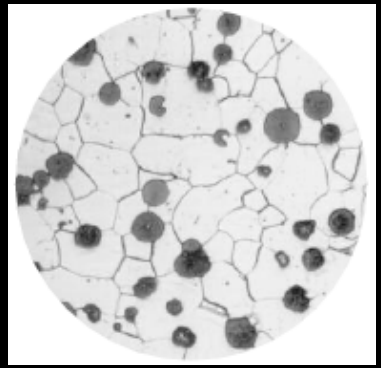
History of Ductile Iron Pipe

- Cast “Grey” Iron Pipe first installed in USA - 1804
- Cement Mortar Lining - 1922
- Ductile Iron Pipe is developed - 1948
- Polyethylene Encasement – 1958
  - Standard (1972)
- Ductile Iron Pipe Only – 1975
- CI Iron Pipe – Still Operating
  - Over 628 utility owners – 100+ yrs
  - Over 28 utility owners – 150+ yrs

Ductile Iron Pipe - Service Life

- Based on long term success of grey iron pipe





- Based on lessons learned from past mistakes
  - Quality Installation
  - Smart Design Specifications
  - Corrosion Control gets properly addressed

Ductile Iron Pipe - Service Life

- Examples of DI Pipe in Corrosive soils…..
- Mid Dakota RWS – SD (15 Years)
  - 100 miles of 24”-30” DI Pipe
- Southwest Pipeline – ND (22 Years)
  - 76 miles of 16”-30” DI Pipe
- Web RWS – SD (24 Years)
  - 145 Miles of 14”-30” DI Pipe

Ductile Iron Pipe - Service Life

DIPRA testing results in Corrosive Soils

The Effectiveness of Polyethylene Encasement

As shown in Table 2, another analysis of the database considered pipe specimens and investigations that were taken from corrosive soils as evaluated by the 10-Point System in Appendix A of ANSI/AWWA C105/A21.5[1].

Table 2: Investigations of Gray and Ductile Iron Pipes in Corrosive Soils

Pipe Condition	Number of Specimens	Mean Deepest Pitting Rate (in./yr.)	Years to Penetration*
Sand Blasted (annealing oxide layer removed)	102	0.025	10
Bare (uncoated)	22	0.0151	17
As-manufactured (Standard Shop Coating)	103	0.0105	24
Polyethylene Encased	151	0.00045	556

DI Pipe & Fittings – Design Guidelines

- AWWA C151 – Manufacturing of Pipe
- AWWA C150 – Pipe Design
- AWWA C600 – Installation
- AWWA C153 – Manufacturing of Fittings
- AWWA C110 – Manufacturing of Fittings
- AWWA C111 – Rubber Gasketed Joints
- AWWA C115 – Flanged Pipe
- AWWA C104 – Cement Mortar Lining
- AWWA C105 – Polyethylene Encasement

AWWA C150
Thickness Design of Ductile Iron Pipe
(Flexible Conduit Approach)

External Loads

are calculated

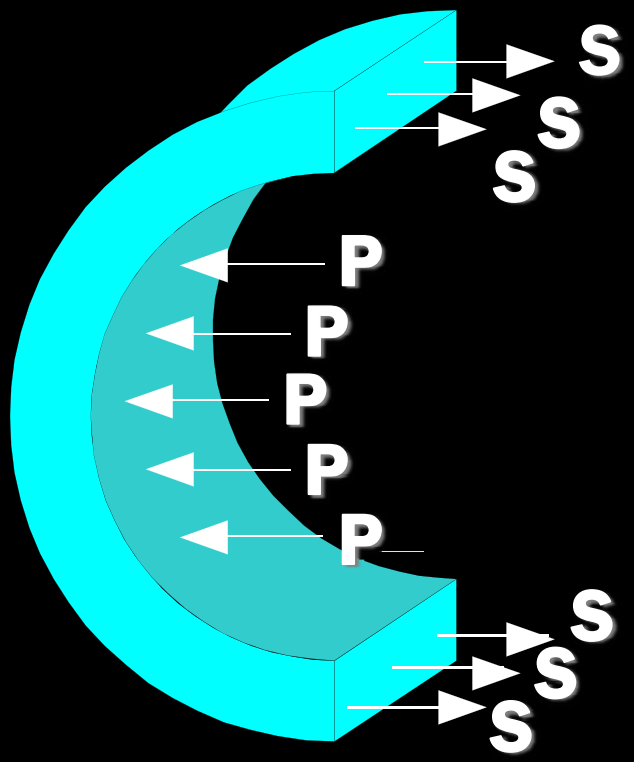
independent of

Internal Loads

Internal Pressure Design, t_1

- Barlow's Hoop Stress Formula

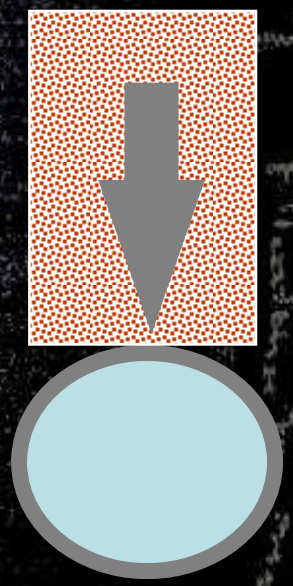
$$t = \frac{P_i D}{2S_y}$$



- t = Wall thickness
- P_i = Design Pressure
  - $P = SF\ (P_w + P_S)$
  - SF = Safety Factor = 2.0
- D = Pipe O.D.
- S_y = Minimum Yield Strength in tension

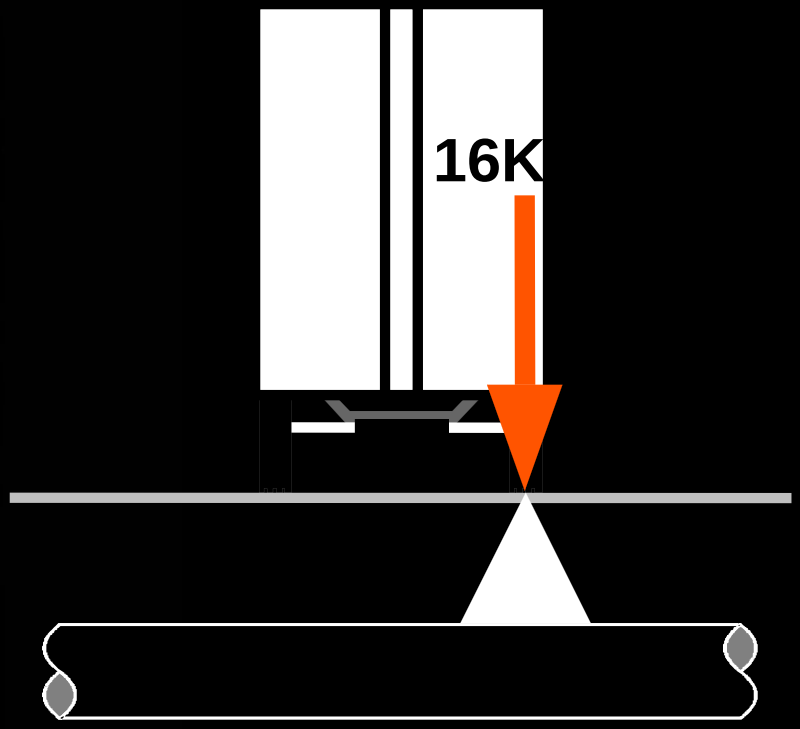
External Loading Design

Earth Load



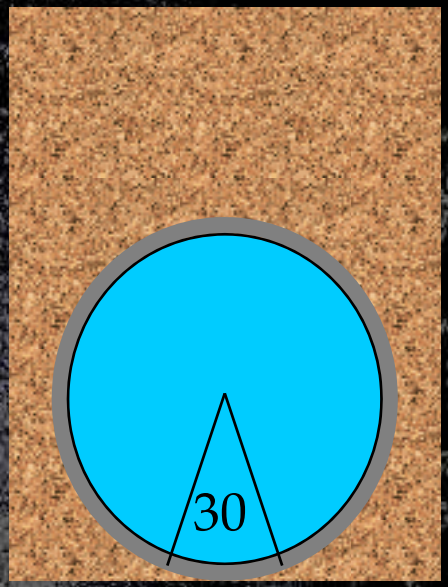
$$P_e = wH$$

Live Load

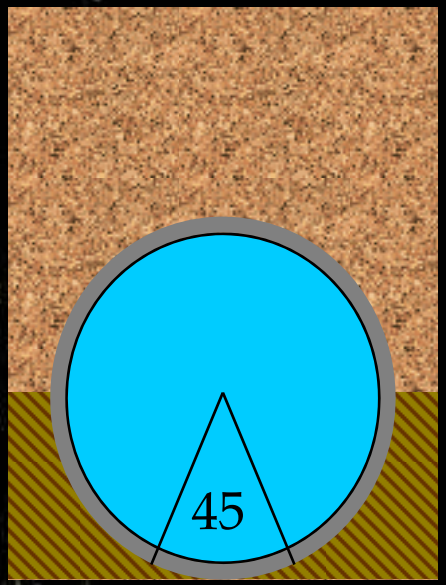


$$P_t = \frac{RFCP}{bD}$$

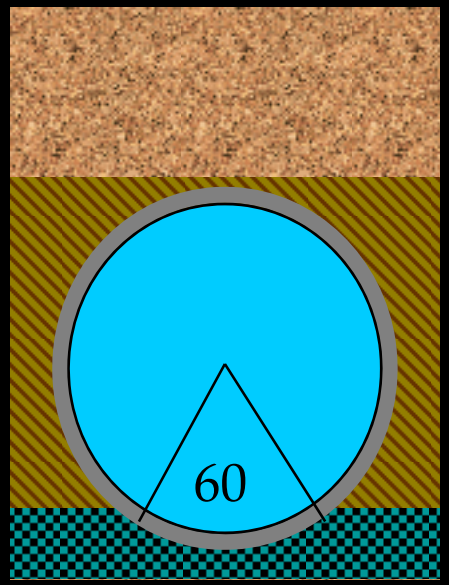
AASHTO H-20



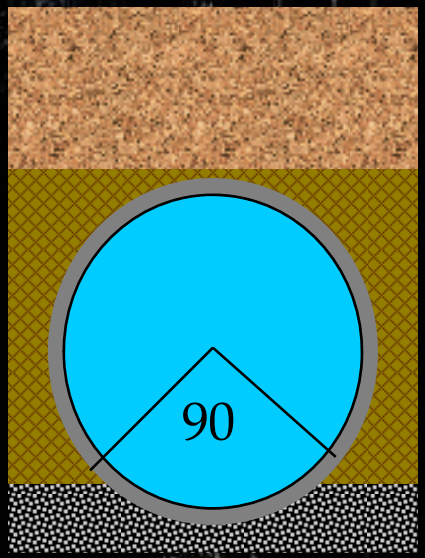
Type 1
E’ 150 psi



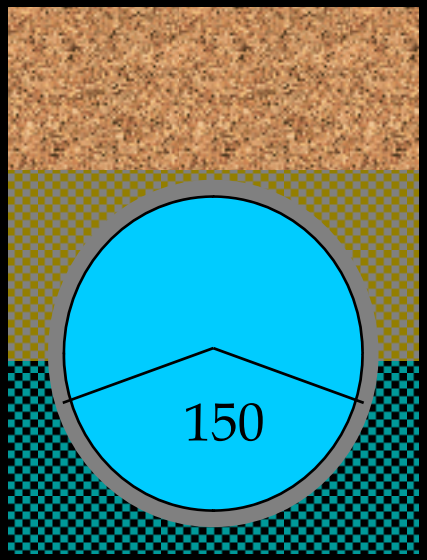
Type 2
E′ 300 psi



Type 3
E′ 400 psi



Type 4
E′ 500 psi



Type 5
E′ 700 psi

Deflection Design, t_2

- Cement Mortar Lining can only handle 6% deflection.
- Limiting it to 3% provides minimum Safety Factor of 2.0.

$$P_v = \frac{\Delta x/D}{12K_x}\left[\frac{8E}{\left(\frac{D}{t_1}-1\right)^3} + 0.732E'\right]$$

E = Young's Modulus = 24,000,000 psi
E' = Modulus of Soil Reaction (Trench Type)
K_x = Deflection Coefficient (Trench Type)
P_v = Trench Load = Earth + Live

3%
(SF=2.0

Spangler
(Deflection)

Bending Stress Design, t_3

- Design Based Upon the Proven Ultimate Bending Strength = 96,000 psi

- Minimum Safety Factor = 2.0.

$$P_v = \frac{f}{3\left(\frac{D}{t}\right)\left(\frac{D}{t}-1\right)\left[K_b - \frac{K_x}{\frac{8E}{E'\left(\frac{D}{t}-1\right)^3}+0.732}\right]}$$

K_b = Bending moment coefficient (Trench Type)
K_x = Deflection coefficient (Trench Type)
f = Design Bending Stress = 48,000 psi

48,000 PSI (SF=2.0)

Marston (Earth Load)

Wall Thickness Selection

- Take the largest thickness of t_1, t_2, t_3
  - Controlling aspect of design
  - Called “Net Thickness”
- Add Service Allowance of 0.08”
  - Called “Minimum Manufacturing Thickness”
- Add Casting Tolerance
- “Total Calculated Thickness”

Allowances for Casting Tolerance

Size in.	Casting Tolerance in.
3-8	0.05
10-12	0.06
14-42	0.07
48	0.08
54-64	0.09

Select Class of Pipe

(Round up….)

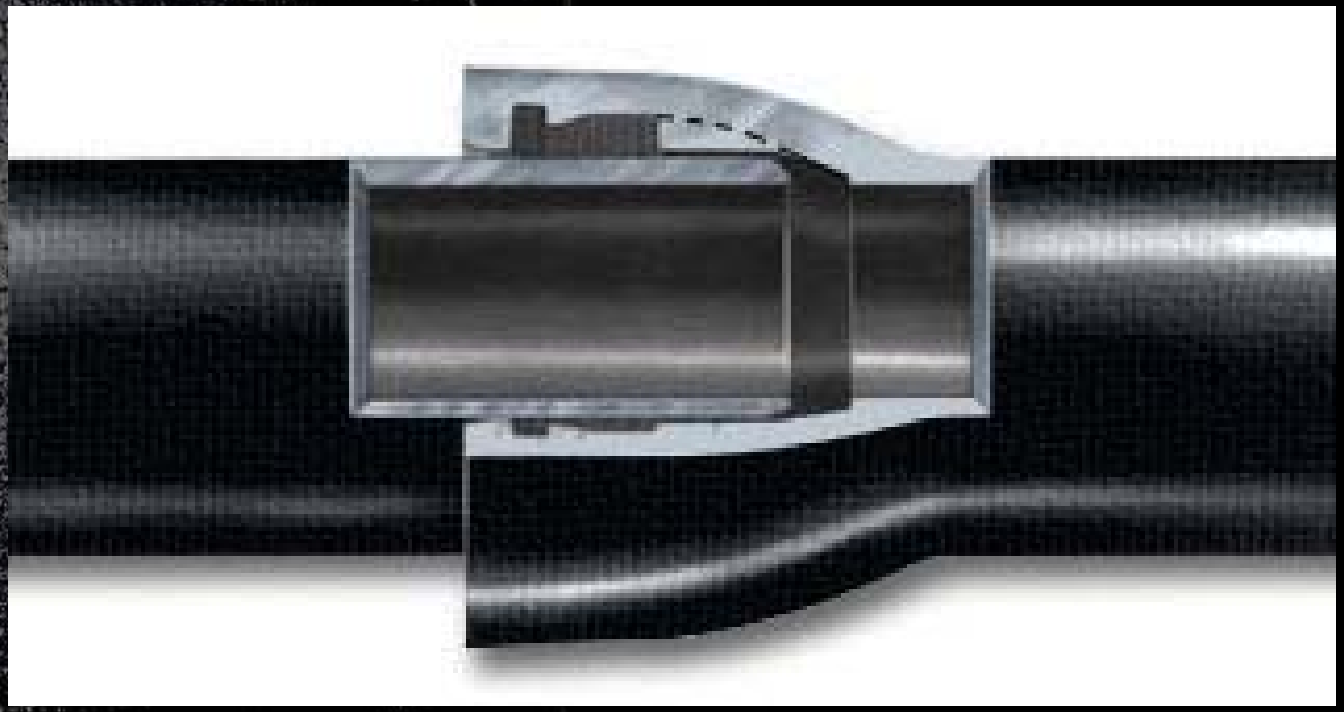
6” Class							50	350
Thick.							.25	.25
24” Class			200	250	50	300	51	350
Thick.			.33	.37	.38	.40	.41	.43
48” Class	150	50	200	250	51	300	52	350
Thick.	.46	.51	.52	.58	.58	.64	.65	.70

DIPRA Computer Program is available…….

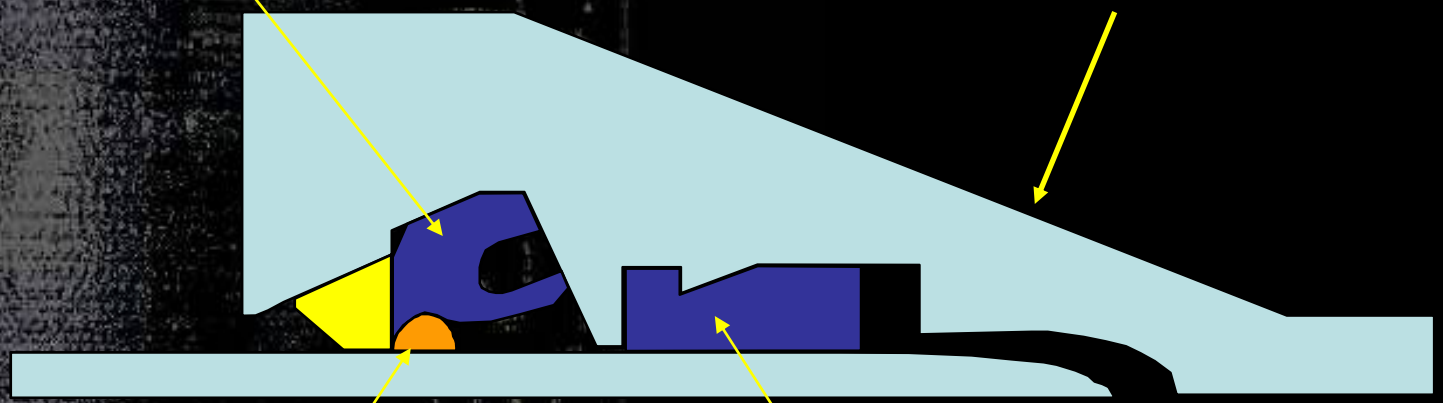
Ductile Iron Pipe & Fitting Joints

- Buried Service
  - Push-on Joint (Fastite®, Tyton®)
  - Push-on, Proprietary Restrained Joint (Flex-Ring®, etc)
  - Mechanical Joint (MJ)
    - Proprietary Restraint Products Available for the MJ Joint
- Exposed Service
  - Flanged (FLG)
  - Grooved (Victaulic)

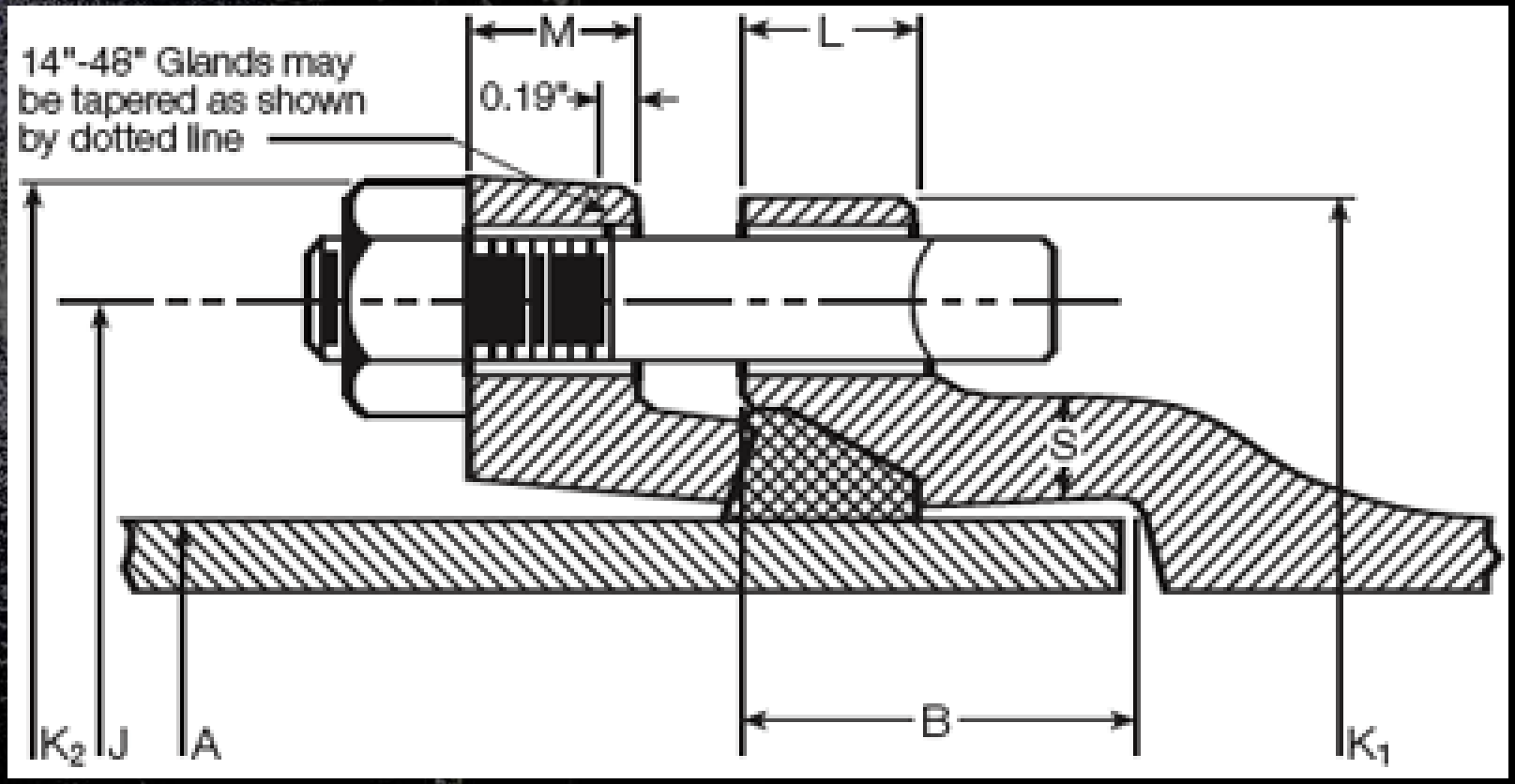
Push-on Joint – AWWA C111



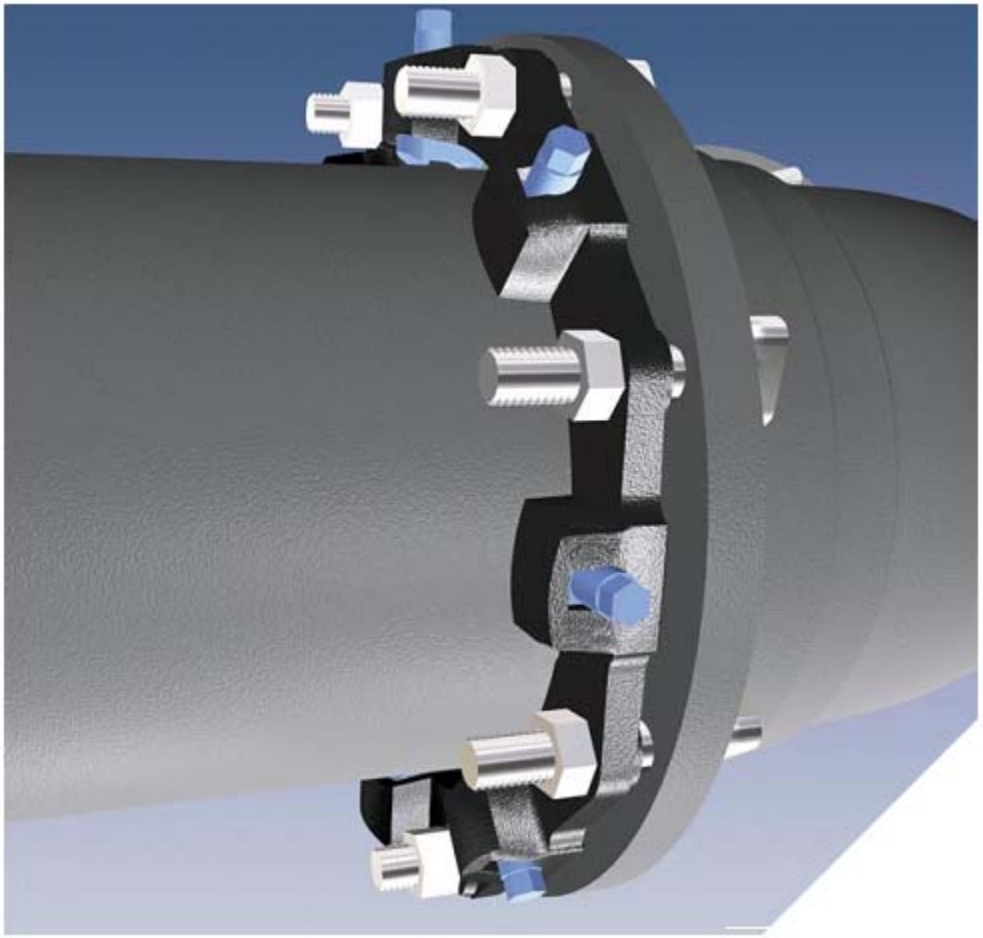
AMERICAN Flex-Ring® Restrained Joint (14”-48”)



Mechanical Joint (MJ) – AWWA C111

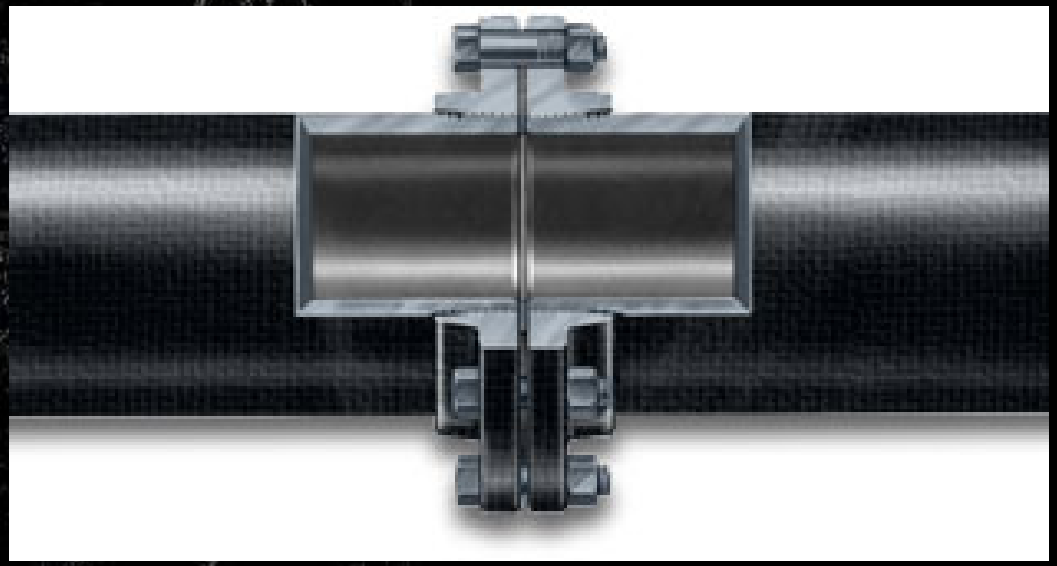


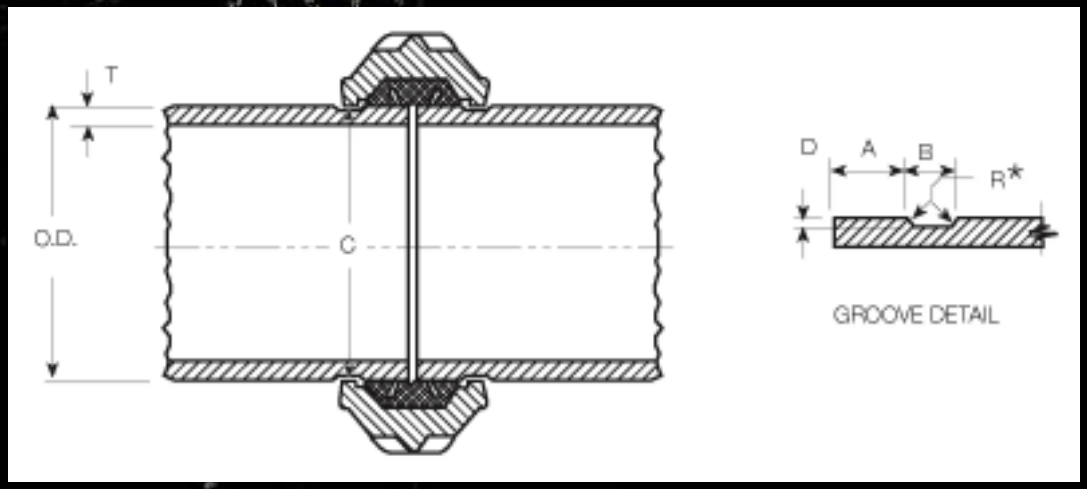
MJ Restraint Devices….



Series 1112, for 12" Mechanical Joint Pipe or Fittings

Flanged and Grooved Joints



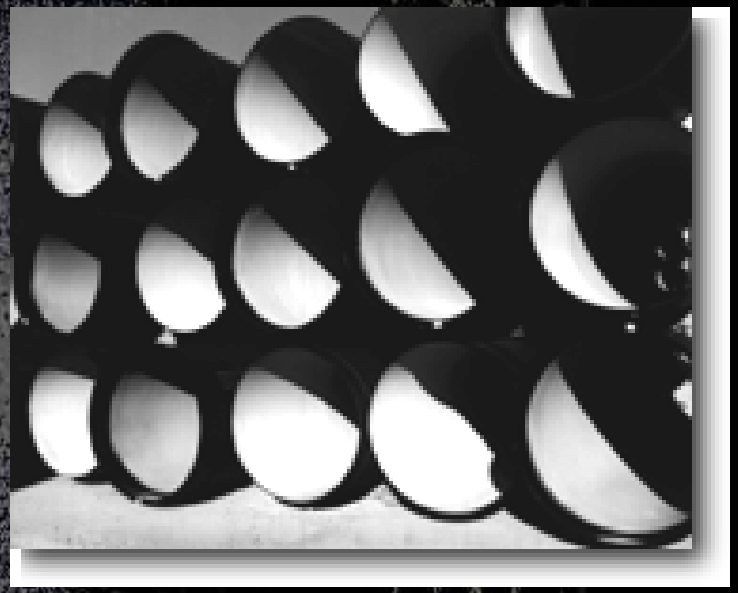


Statically Cast Fittings

Push-on Joints are Superior…..

Linings for Ductile Iron Pipe…

Cement Mortar



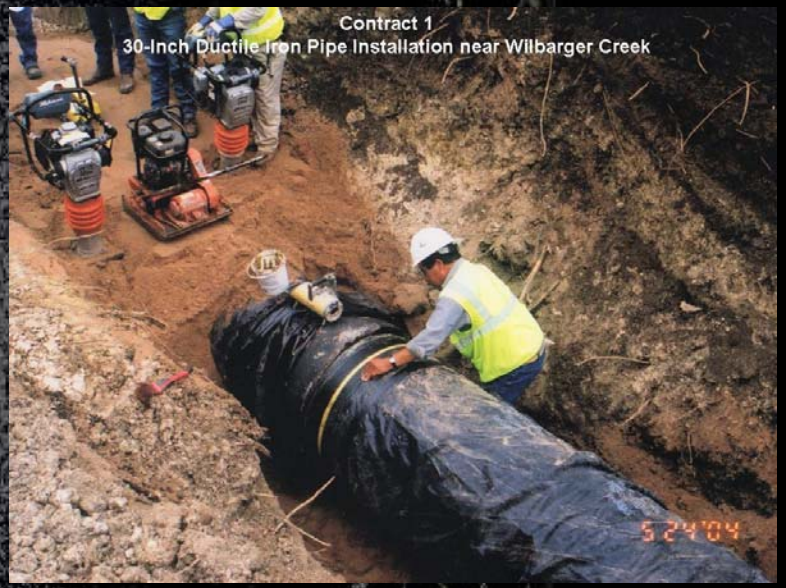
- Best Available lining for Potable/Raw Water
  - AWWA C104
  - Long Term Hazen Williams - C Factor = 140
  - Special high speed CM Lining Available
    - Utah State Flow tests suggest C=150 to C155

Ductile Iron Coatings.....

Wasser FerroClad
Urethane Primer

Standard, Black
Asphaltic Coating

Polyethylene Encasement – AWWA C105



ANSI/AWWA C105/A21.5
Installation Methods

Method A

In this method, which is preferred by most utilities and contractors, one length of polyethylene tube, overlapped at the joints, is used for each length of pipe.

Method B

A length of polyethylene tube is used for the barrel of the pipe and separate lengths of polyethylene tube or sheets are used for the joints. Note: Method B is not recommended for bolted-type joints unless an additional layer of polyethylene is provided over the joint area as in Methods A and C.

Method C

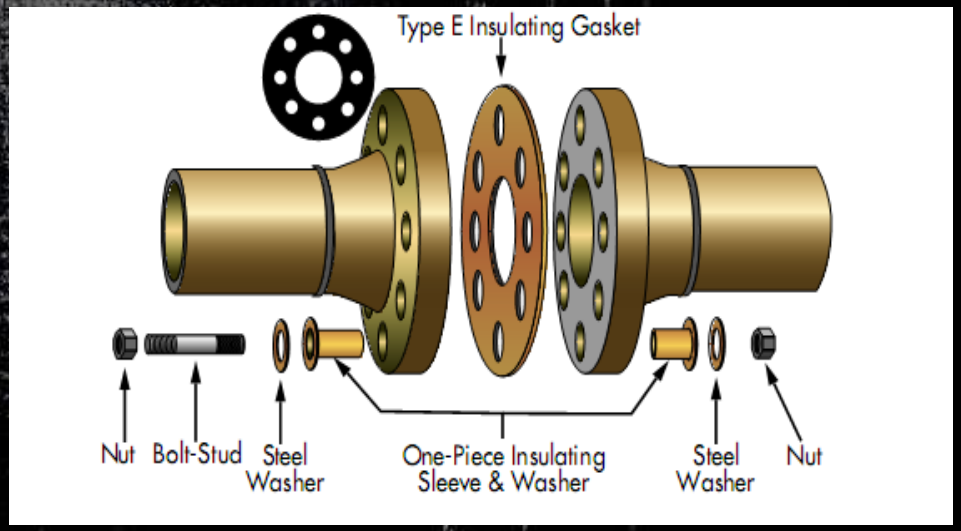
Each section of pipe is completely wrapped with a flat polyethylene sheet.

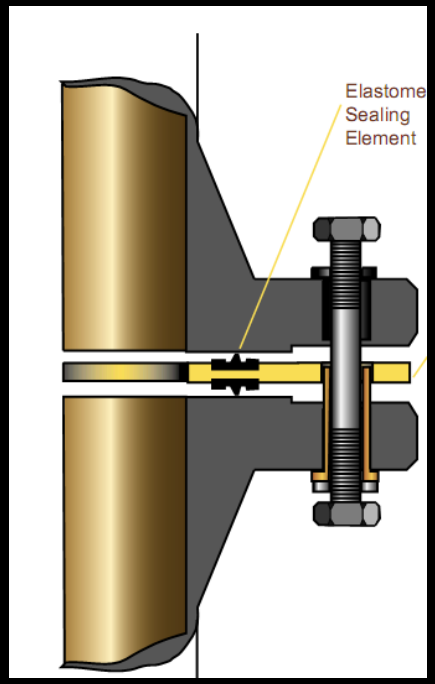
Welded Outlets on Ductile Iron

ARV, Blow-offs, Small Connections

Connection to Existing Steel Pipe

- Assuming existing steel pipe has a CP System
- Need to Insulate the joint
  - Dissimilar metals
  - Isolation from a separate CP System



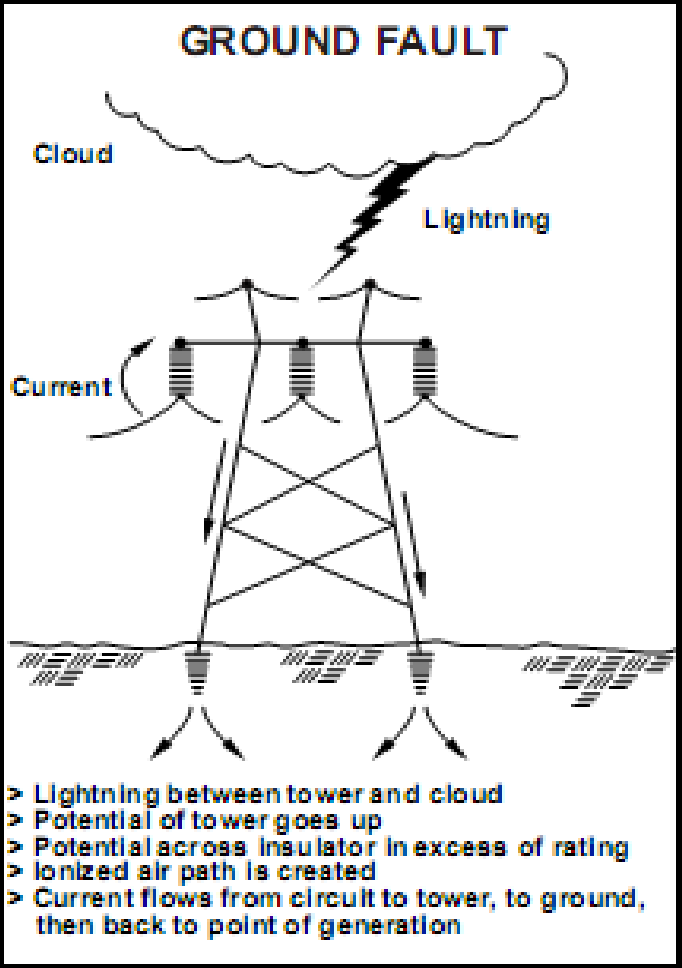


Installation of Ductile Iron Pipe AWWA C600

- User Friendly
- Very Forgiving Joints
- High Deflection Ability
- Less Bedding Required

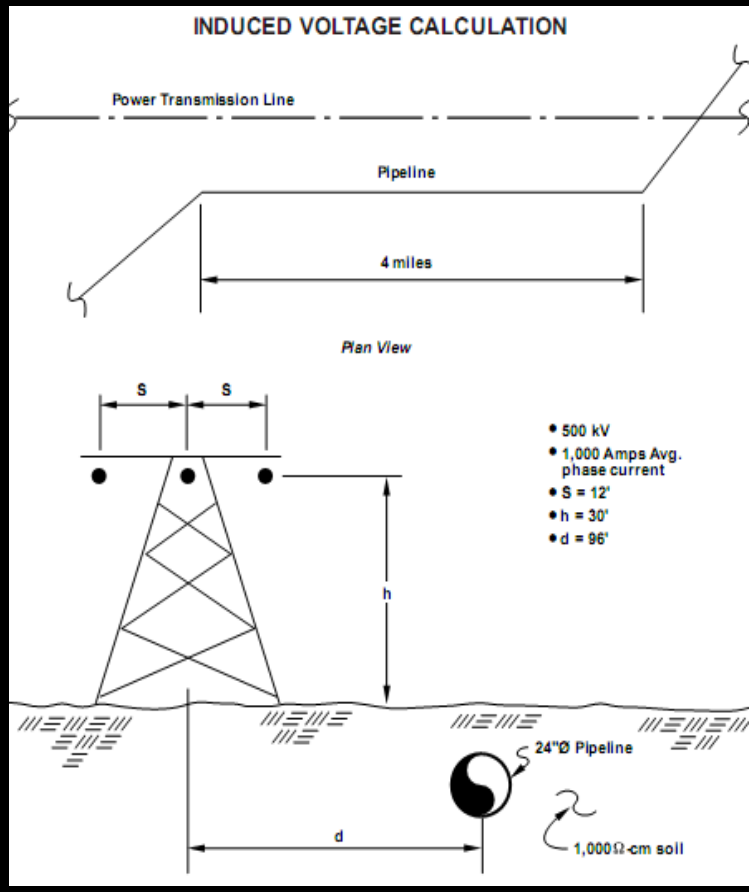
High Voltage AC Power Lines

- Generally, AC Voltage is generally not a corrosion concern.
  - Studies indicate only 1% corrosion rate of similar DC source with same current density
- Voltage can be induced on a pipeline via magnetic induction
- AC Voltage poses a danger for electrical shock to people.
  - Installation Guidelines
  - Grounded Equipment
  - Grounded Metallic Pipe
  - Grounded Appurtenances



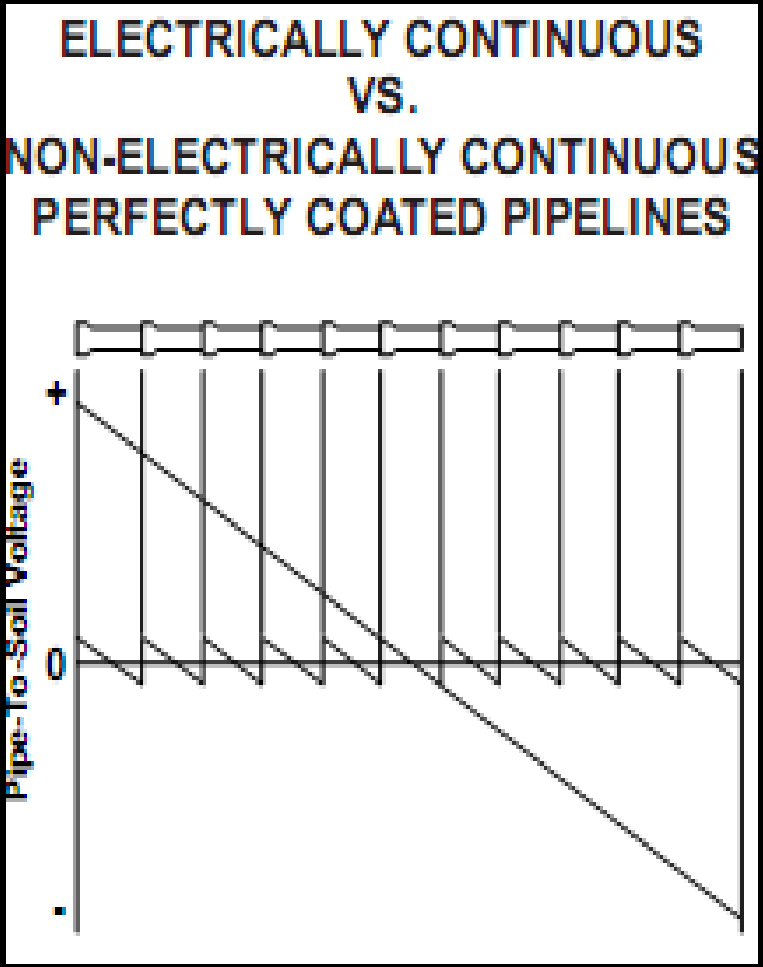
High Voltage AC Power Lines…

- Pipeline Considerations
  - Electrical Discontinuity is best
  - Continuity with a bonded coating is worst case scenario
  - DI Pipe is also effectively "Bare" and grounded to adjacent earth.



High Voltage AC Power Lines…

- Possible Options…
  - Crossings
    - Unbonded Joints
    - Anodes on each pipe $$
    - Isolation at some point
  - Parallel Areas
    - Same as Crossings if length not substantial
    - Otherwise, Bonded Joints with Isolation at end points to limit length of pipe



Disadvantages of DI Pipe

- Higher material cost
  - Much Thicker than steel pipe w/same yield strength
  - More Robust Rubber Gasket
  - Large, Thick Bells
- Corrosion Potential
  - Must be addressed in corrosive soil conditions

Advantages of Ductile Iron Pipe

- Conservative Design – Higher Inherent S.F.

Material	SF Pw	Surge, psi	E' Range, psi	Live Load	Testing, psi	Stiffness, psi
DI Pipe	2.00	100	100 to 700	H-20 (1.50)	500 (Each)	86-108
Steel	1.33	50% of Pw	200 to 3000	H-20 (1.50)	75% Yield (Each)	15-22
PVC	2.00	0	50 to 2000	H-20 (1.0-1.1)	2 x Wp (Each)*	20-28
HDPE	2.00	0	Not Addressed	0	1 pc per run	37-57
FRP	1.80	0	1000-3000	H-20 (1.0-1.1)	2 x Wp (Each)	50-63
PCCP	1.33	50% of Pw	200-1000	H-20(1.50)	Steel Cyl only	Semi-Rigid

Advantages of Ductile Iron Pipe

- Most Robust and Flexible Joint Systems

Material	Joint Deflection (Std)	Joint Deflection (RJ)
DI Pipe	3.00 to 4.00	0.50 to 2.00
Steel	1.35 to 1.57	N/A (Welded)
PVC	1.00	< 1.00*
HDPE	N/A (Fused)	N/A (Fused)
FRP	1.00 to 1.50	<1.00
PCCP	1.29 to 1.49	0.00 to 0.50*

Advantages of Ductile Iron Pipe

- Lower Head Loss based on larger I.D.

V= 3 ft/sec, Pipe Size =36", $.07/kw-hr, 24 hrs/day, Eff. = 75%, P=200 psi

Material	ID	C Factor	Annual Pump Cost	Increase	50 yr Increase
DI Pipe	37.21	140	$227,332	$0	$0
Steel	36.00	140	$267,049	$39,717	$1,985,850
PCCP	36.00	140	$267,049	$39,717	$1,985,850
FRP	35.55	155	$270,203	$42,871	$2,143,550
PVC	34.43	150	$291,903	$64,571	$3,228,550
HDPE*	34.02*	150	$309,574	$82,242	$4,112,100

Advantages of Ductile Iron Pipe

- Proven Longevity and Track Record in 36”-42”
  - Challenge Manufacturers to provide references
  - DI and Steel have distinguished track records
  - PVC, HDPE, FRP, and PCCP do not.

- Easiest to Repair or Tie-into Existing Pipe
  - DI Pipe – Sleeves, Joint Clamps, Tapping Saddles
  - PVC Pipe – Same as DI except limited strength
  - Steel Pipe – Requires HQ welder
  - HDPE – Requires Fusing Machine
  - PCCP – Special Pieces of Pipe/Adapters

Thank You For Your Time !!!

APPENDIX E

US Pipe Presentation (DIP Pipe)

Gillette
Madison Pipeline Project (GMPP)

Mike Hajnos

US Pipe

Topics

- History and Service Life
- Joints
- Restraint
- Fittings
- Design
- Linings
- Coatings
- Installation
- Service Connection
- Location of Pipe Fabrication
- Product delivery and lead times
- Advantages of specifying this pipe material for this project
- Potential disadvantages of specifying this pipe material for this project
- Considerations when installed in close proximity to high voltage electrical power lines.
- Issues related to interconnections with an existing steel water transmission line.

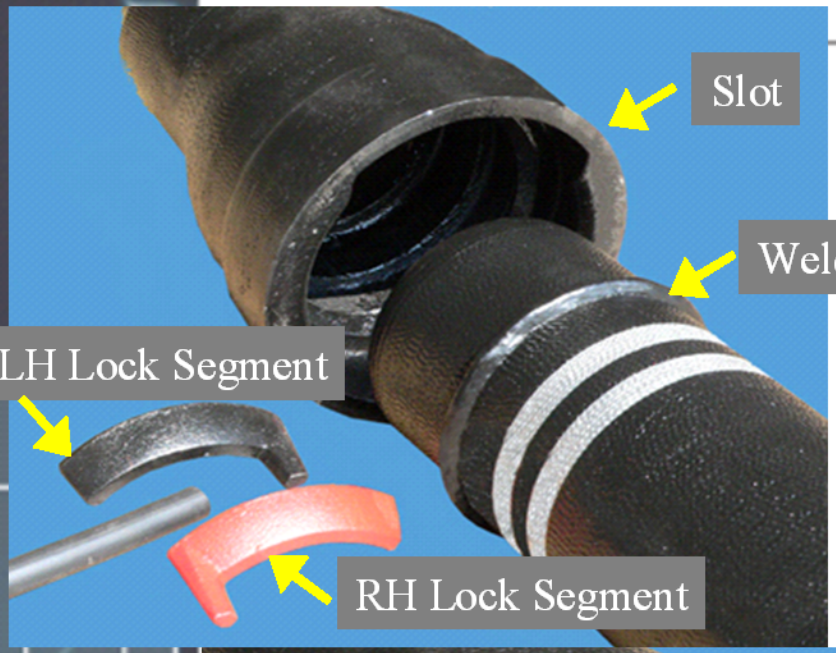
US Pipe

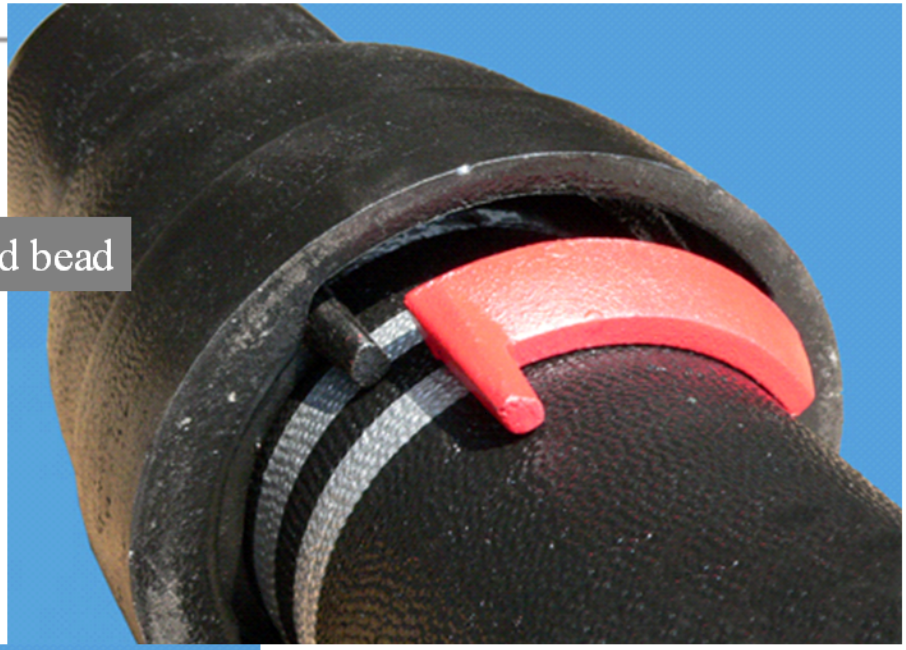
- 1899 – Incorporated
- Plants
  - Foundry, Bessemer, AL (14” – 64”)
  - Mini Mill, Bessemer, AL (6” - 12”)
  - Union City, CA (4” – 24”)
- 100+ years expected life (346 years and running current record)

Pipe Joints

- Tyton® Joint
  - Developed by U. S. Pipe in 1955
  - Available 4" – 64"
  - Pressure Rating from 150-350 psi
  - 95% of pipe sold by U. S. Pipe has a Tyton® Joint

TR FLEX®- Components



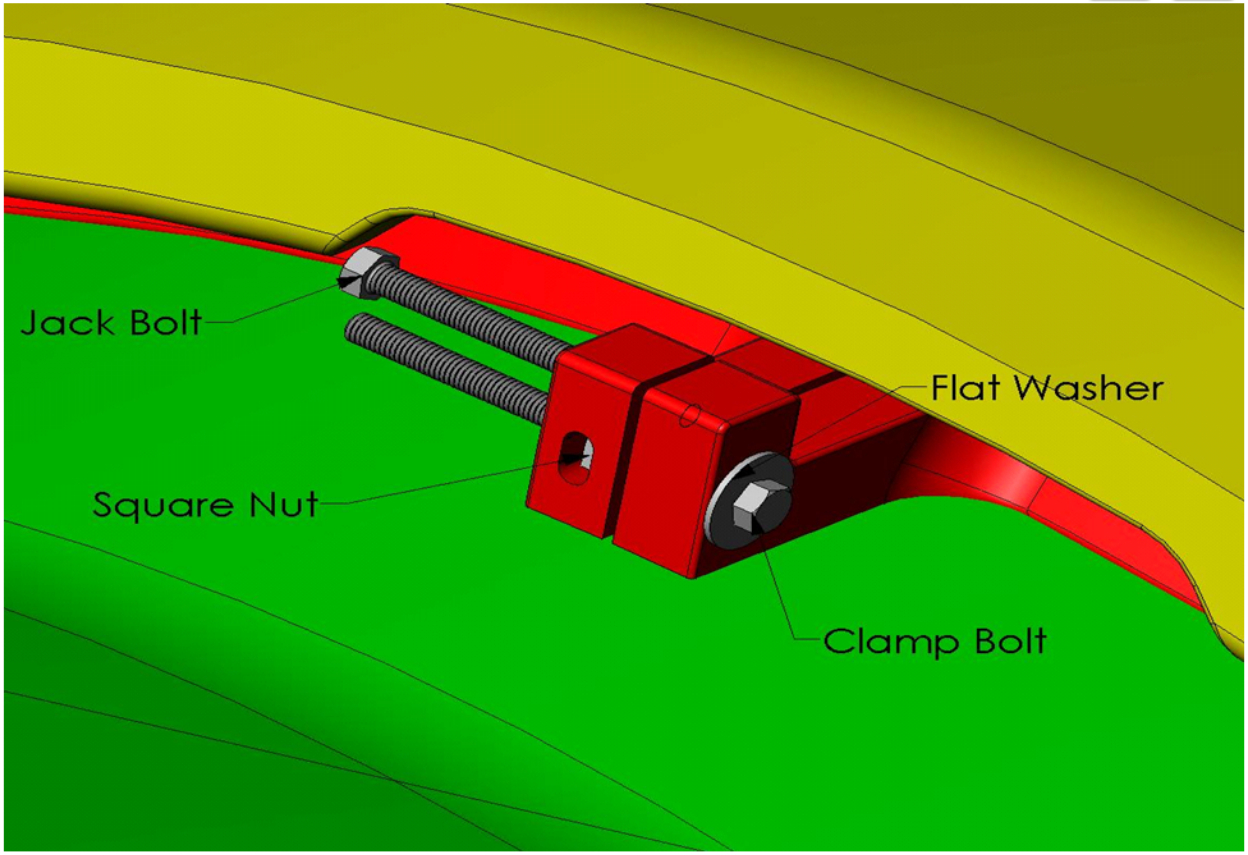


MORE THAN JUST PIPE. US PIPE

HP Lok Restrained Joint

HP Lok Restrained Joint

HP LOK Pipe and Fitting Joint



HP Lok

Pipe is shipped with rings installed. Ring is DI

Cross-section of ring

MORE THAN JUST PIPE.

US PIPE

Service Connections

- Tapping Saddles
- Welded Outlets (widest range of diameters and joints available)
- Tee’s
- Direct Tap available ¾” to 2”

Cement Mortar Lining

- Prevent tuberculation
- Centrifugally lined at the factory

US Pipe DIP Fittings

- TR Flex Restrained Joint (4”-24”)
- HP Lok Restrained Joint (30”-64”)
- Flange
- Mechanical Joint (C153, C110)
- Tyton Joint (C153, C110)

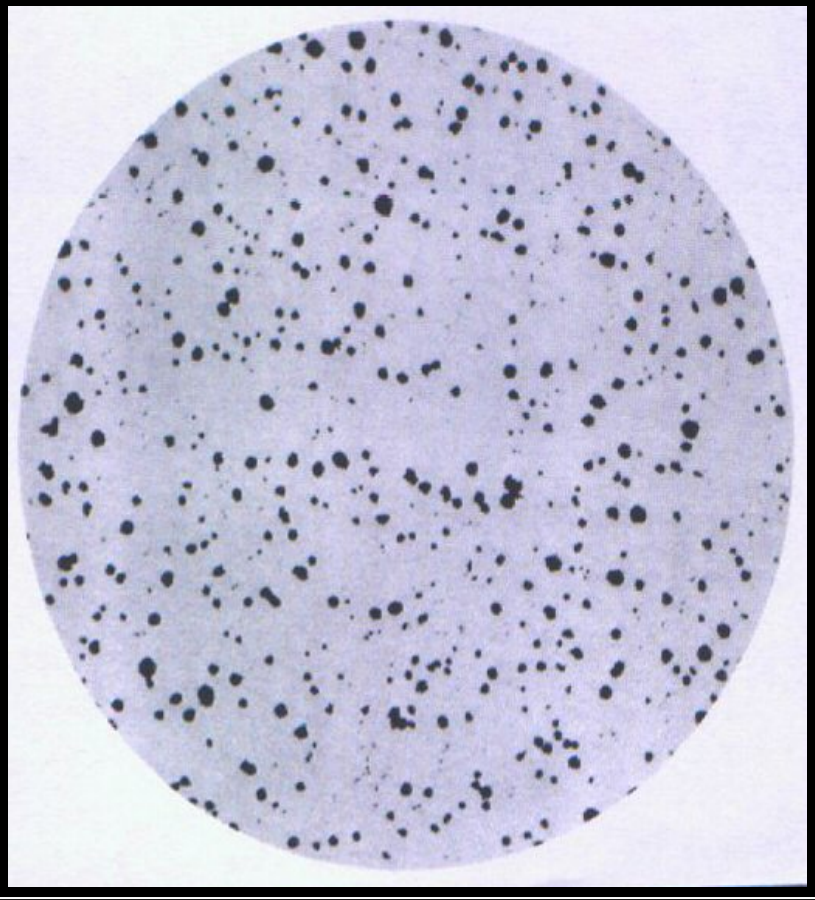
Installation

- AWWA
  - **C600 Standard for Installation of Ductile Iron Water Mains**
- DIPRA
  - **Installation Guide for Ductile Iron Pipe**

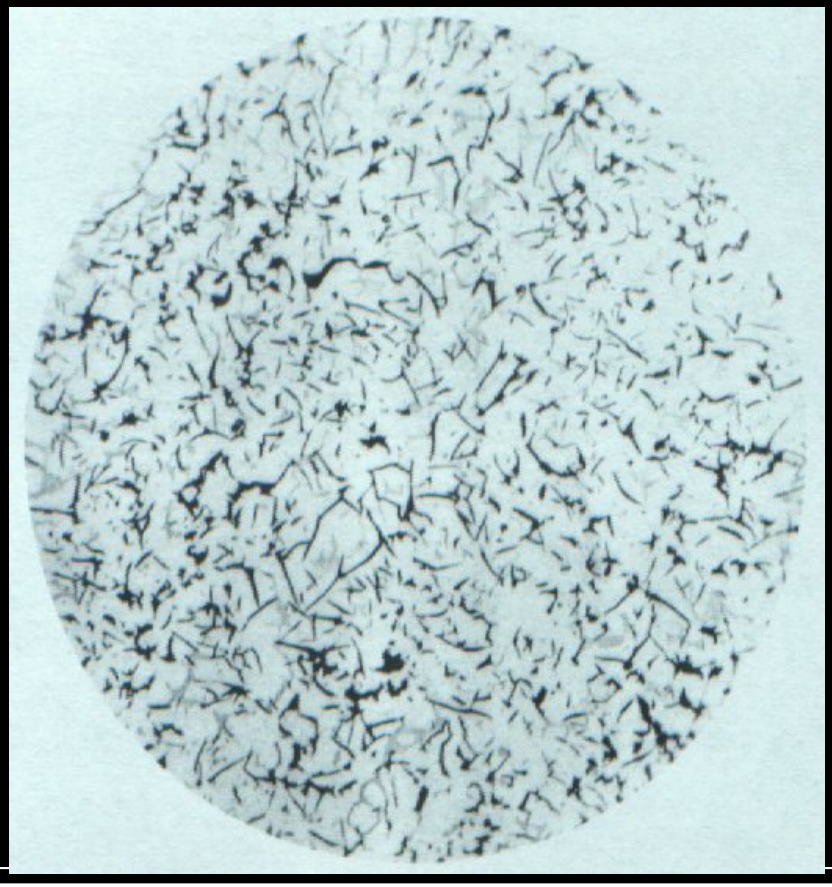
Transition to Existing Steel Line

- Transition Coupling
- Flange Connection (insulating kit)

PHOTOMICROGRAPHS



Ductile Iron



Cast Iron

Design

- Cast Iron Pipe required iron strength of 18-40

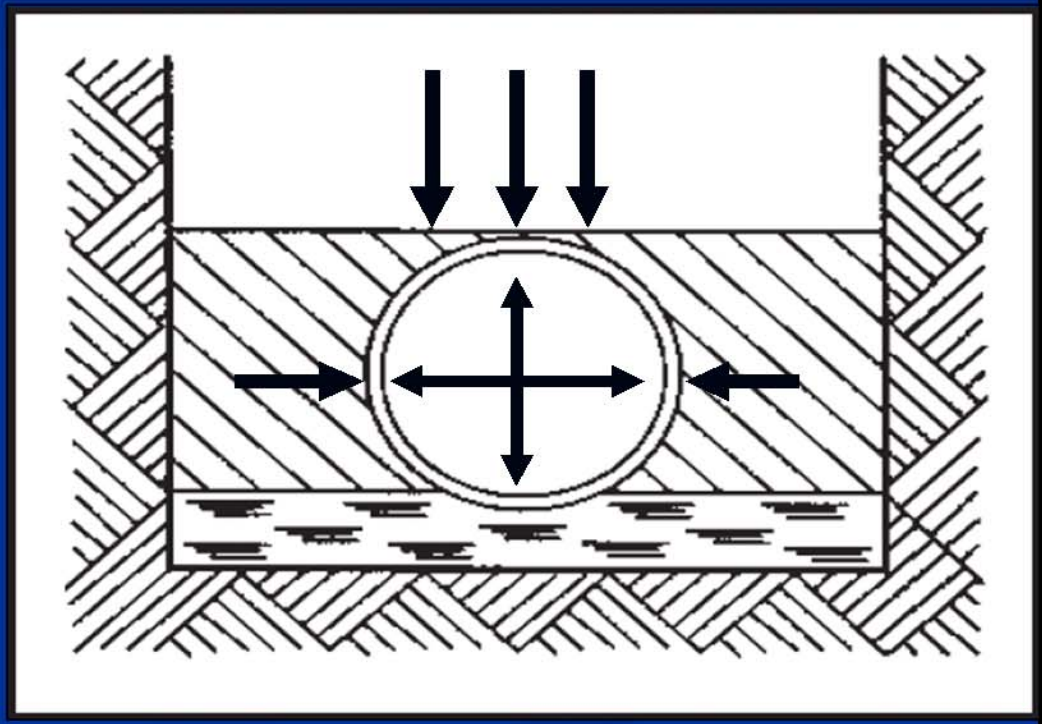
  (18,000 psi Bursting Tensile Resistance and 40,000 psi Ring Modulus of Rupture, 20,000 psi Ultimate Tensile Strength, with no measurable Yield Strength or Elongation.

- Ductile Iron Pipe 60-42-10

  (60,000 psi Ultimate Tensile Strength, 42,000 psi Yield Strength, and 10% Elongation.)

Major Factors in Pipeline Design

- External Loading
  - Dead Load
  - Live Load
  - Trench Dynamics
- Internal Pressure
  - Test Pressure
  - Working Pressure
  - Surge Pressure
- Corrosion Control
  - Passive
  - Active
- Economics
  - Energy Usage
  - Flow Characteristics



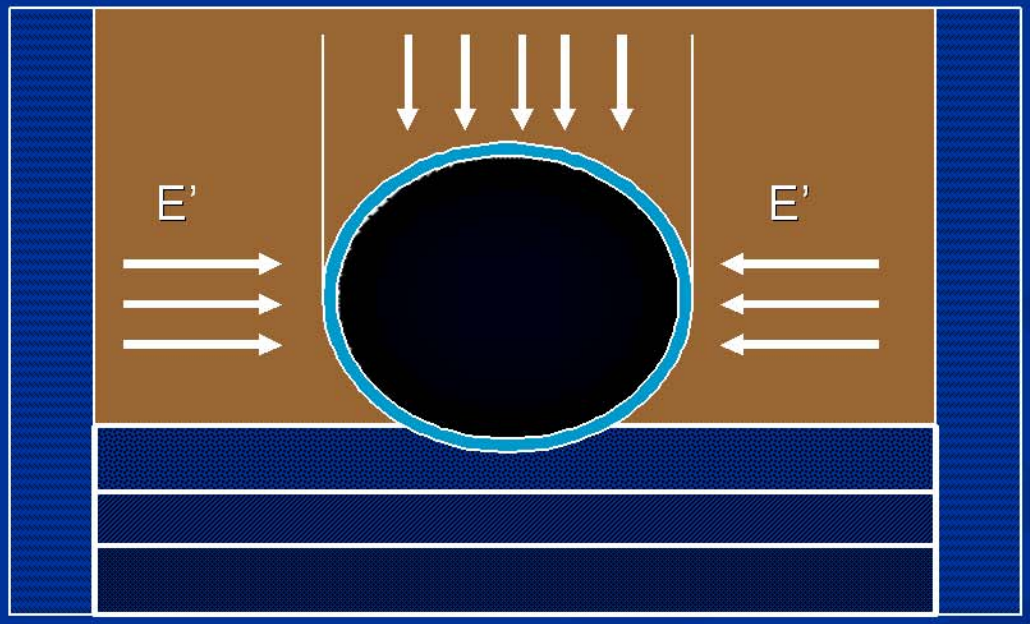
External Design

E' The Modulus of Passive Sidefill Soil Reaction

The ability of the sidefill soil to resist deflection or egging of the pipe due to earth load above the pipe. Measured in psi

The Higher the psi

The More Resistance



The Higher the psi

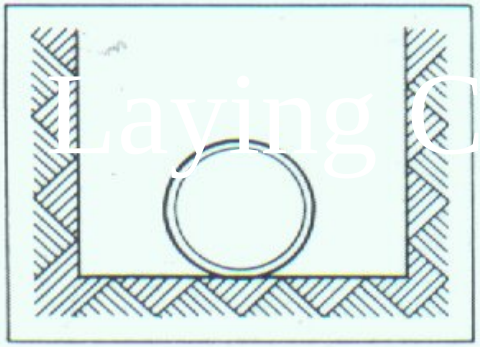
The More Resistance

E’

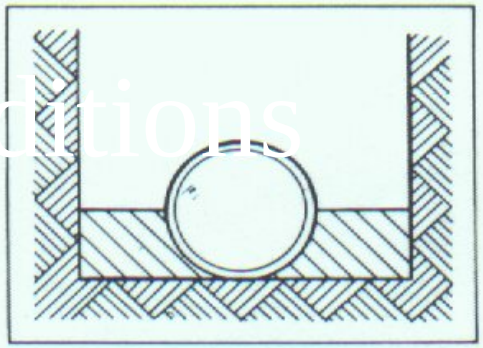
- E’ is dependent on the soil, trench type, and bedding. It is independent of pipe material.
- E’ must be the same for all flexible conduits!
- Recommend an E’ for a type 3 trench of 400psi.

Standard Laying Conditions for Ductile Iron Pipe

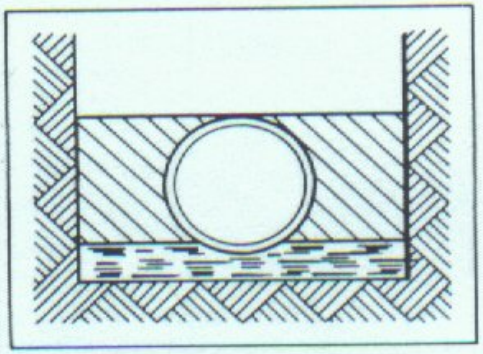
Laying Conditions



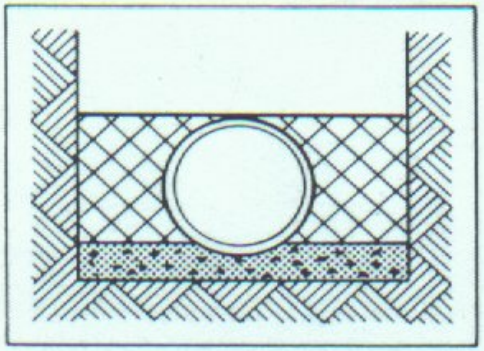
Type 1*
Flat-bottom trench.†
Loose backfill.



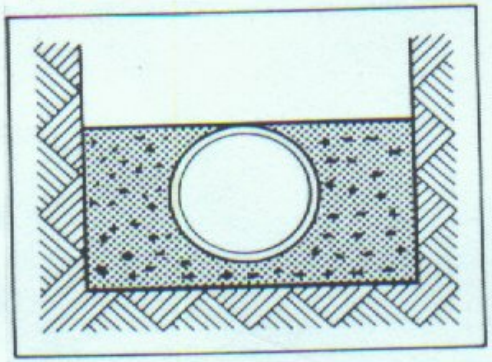
Type 2
Flat-bottom trench.†
Backfill lightly consolidated to centerline of pipe.



Type 3
Pipe bedded in 4-in. minimum loose soil.‡ Backfill lightly consolidated to top of pipe.



Type 4
Pipe bedded in sand, gravel, or crushed stone to depth of 1/8 pipe diameter, 4-in. minimum. Backfill compacted to top of pipe. (Approximately 80% Standard Proctor, AASHTO T-99.)



Type 5
Pipe bedded to its centerline in compacted granular material, 4-in. minimum under pipe. Compacted granular or select‡ material to top of pipe. (Approximately 90% Standard Proctor, AASHTO T-99.)

Ductile Iron Standard E' Values

Table 2 Design values for standard laying conditions

Laying Condition*	Description	E' *psi*	Bedding Angle *deg*	K_b	K_x
Type 1†	Flat-bottom trench.‡ Loose backfill.	150	30	0.235	0.108
Type 2	Flat-bottom trench. Backfill lightly consolidated to centerline of pipe.	300	45	0.210	0.105
Type 3	Pipe-bedded in 4-in.-minimum loose soil.§ Backfill lightly consolidated to top of pipe.	400	60	0.189	0.103
Type 4	Pipe bedded in sand, gravel, or crushed stone to depth of ⅛ pipe diameter. 4-in. minimum. Backfill compacted to top of pipe. (Approximately 80 percent Standard Proctor, AASHTO T-99)**	500	90	0.157	0.096
Type 5	Pipe bedded to its centerline in compacted granular material, 4-in. minimum under pipe. Compacted granular or select material§ to top of pipe. (Approximately 90 percent Standard Proctor, AASHTO T-99)**	700	150	0.128	0.085

External Loading

- C150 American National Standard for the Thickness Design of Ductile-Iron Pipe
  - Checks 2:1 FS for Ring Bending Stress (48k psi) and Deflection (3% CL)

$$P_v = \frac{f}{3\left(\frac{D}{t}\right)\left(\frac{D}{t}-1\right)\left[K_b - \frac{K_x}{\frac{8E}{E'\left(\frac{D}{t}-1\right)^3}+0.732}\right]}$$

$$P_v = \frac{\frac{\Delta x}{D}}{12\,K_x}\left[\frac{8E}{\left(\frac{D}{t}-1\right)^3}+0.732E'\right]$$

EXTERNAL DESIGN SUMMARY

	DIP	Steel	PVC
E’ Soil Modulus	700 max	Up to 3000	Up to 3000
Deflection	3% for Cem. 5% for 401	2% for Cem. 3% for Tape	None Stated
Deflection Safety Fact.	2 to 1	None Stated	None Stated
Ring Def. Safety Fact.	2 to 1	None Stated	None Stated
Impact Strength	17.5	None Stated	.65
Time/Temp. Affected	No	No	Yes

Ductile Iron Pipe - Review

4.1.2 *Step 2—Design for internal pressure.* Calculate the net thickness required for internal pressure using the equation for hoop stress:

$$t = \frac{P_i D}{2S}$$

Where:

t = net thickness, in. (mm)
P_i = design internal pressure, psi (kPa) = $2\,(P_w + P_s)$
P_w = working pressure, psi (kPa)
P_s = surge allowance, 100* psi (689 kPa)
D = outside diameter of pipe, in. (mm)
S = minimum yield strength in tension = 42,000 psi (289,590 kPa)

*(If anticipated surge pressures are other than 100 psi (689 kPa), the actual anticipated pressure should be used.)

4.1.3 *Step 3—Selection of net thickness and addition of allowances.*

a. Select the net thickness t from step 1 or step 2, whichever thickness is larger.

b. Add the service allowance of 0.08 in. (2.0 mm) to the net thickness t. The resulting thickness is the minimum manufacturing thickness t_1.

c. Add the casting allowance from Table 3 to the minimum manufacturing thickness t_1. The resulting thickness is the total calculated thickness.

FOR COMPLETE INFO...

Reference ANSI/AWWA C150/A21.50 and ANSI/AWWA C151/A21.51

DIP – Internal Design

$t=PD/2S$

Where:

t = thickness

P = 2(Pw + Ps)

D = Outside Diameter

S = Yield Strength

INTERNAL DESIGN SUMMARY

	DIP	Steel	PVC
Yield (psi)	42,000	36,000	7,000 (Ult.)
Pipe Modulus	24×10^6	30×10^6	400,000
Surge Allow.	100 psi	None (must specify)	None (must specify)
Safety Factor	2 to Yield (WP + SP)	2 to Yield (WP only)	2 to Failure (4,000 HDB)
Cast./Mfr. Tol.	Added .05" to .09"	*Minus* .01" Allowed	None
Service Allow.	Added (.08")	12.5% Defect Allowed	None

DIP – 42” Internal Design

t=PD/2S

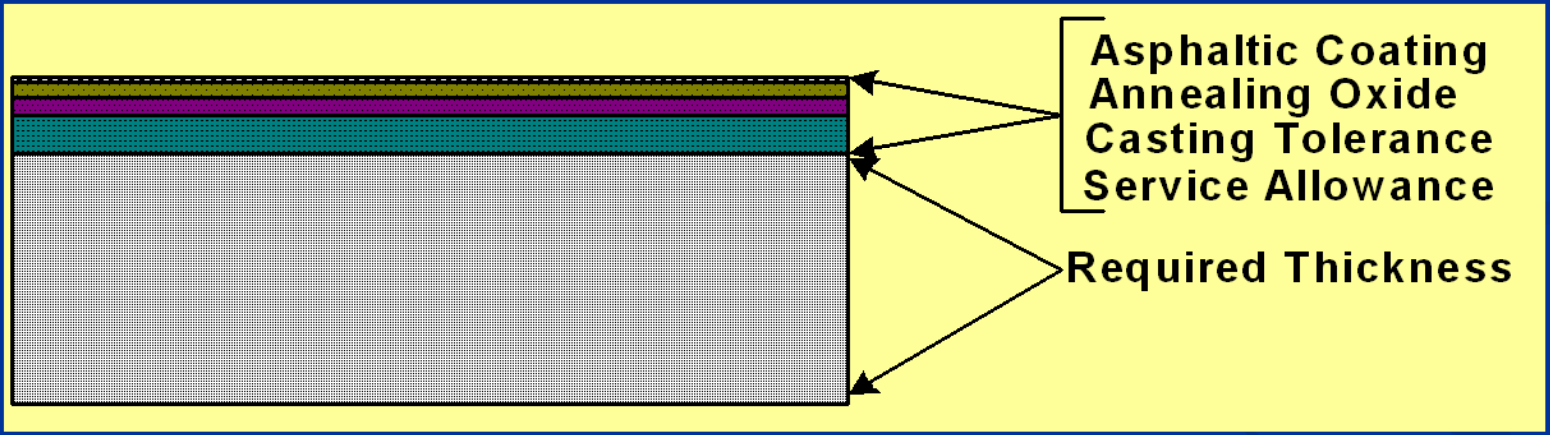
t= 2(150psi+100psi)(44.5”) / 2(42,000psi)

t=.26”

Add .08” casting tolerance and .08” service tolerance

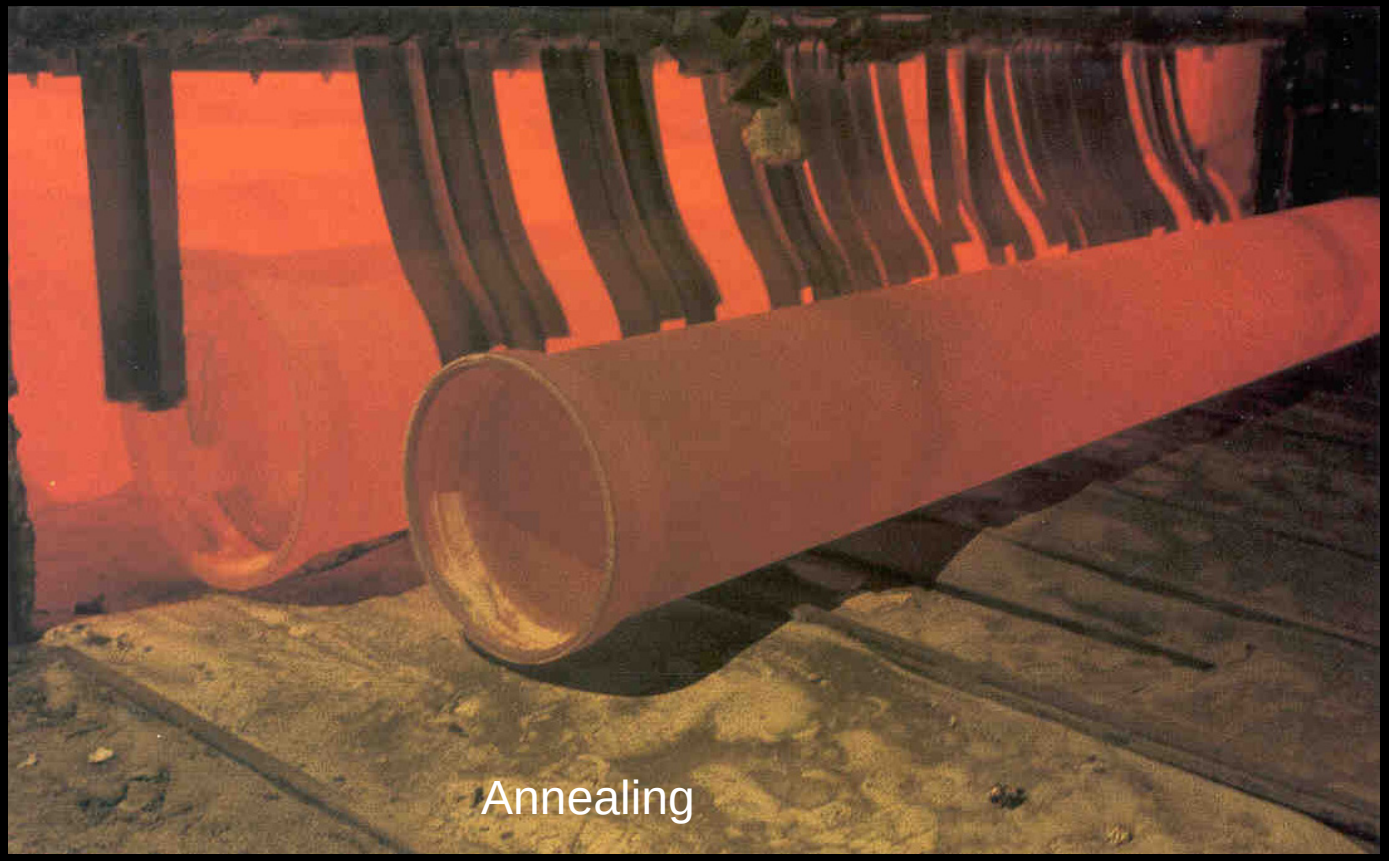
t=.42” total thickness

Ductile Iron Pipe wall Thickness

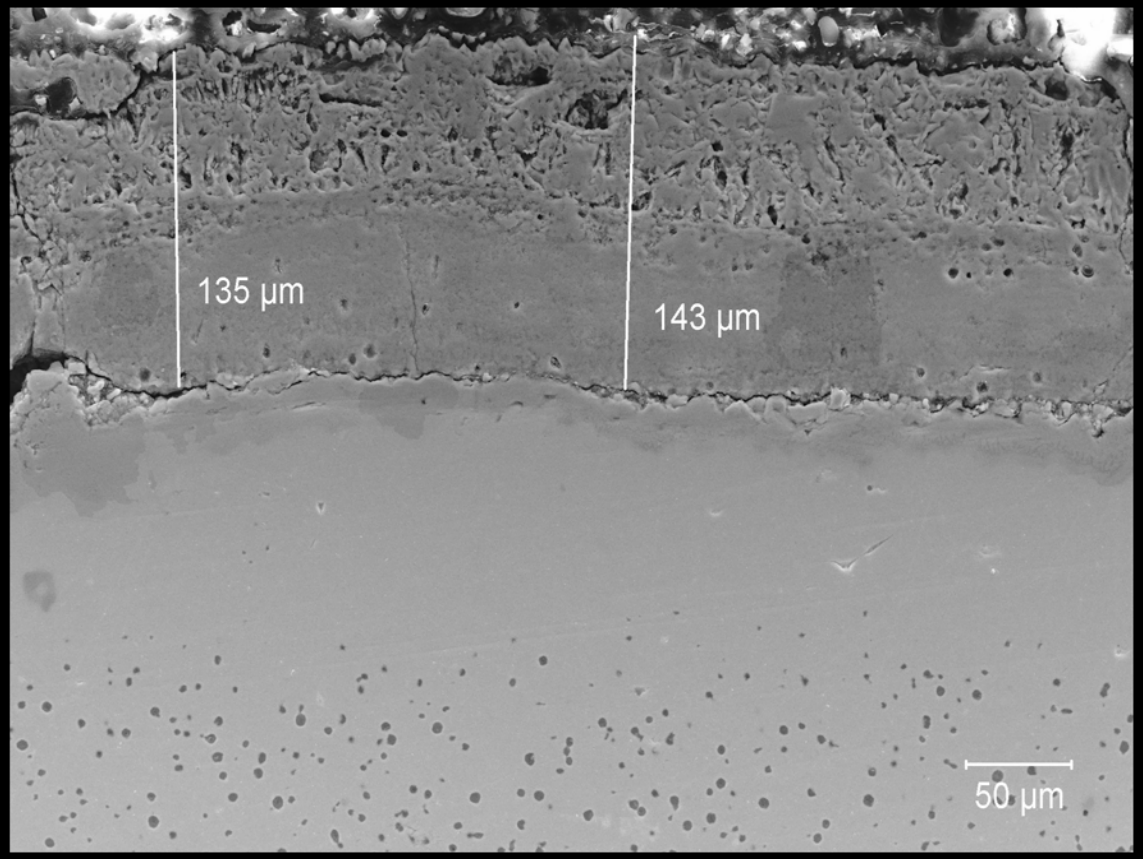


Manufacturing Tolerances
Positive Impact

Manufacturing



Annealing Oxide Layer



Design Decision Model (DDM™)

Practical Corrosion Control for Ductile Iron Pipe

- The DDM™ is a risk based design engineering tool for Ductile Iron Pipe developed jointly by DIPRA, CORRPRO, and DIP manufacturers.

DUCTILE IRON PIPE
RESEARCH ASSOCIATION

CORRPRO
COMPANIES INC
For Every Corner of Your World

Dr. Graham Bell

SCHIFF ASSOCIATES

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Principal

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Dr. Graham E.C. Bell, P.E., is the President and Principal Engineer of Schiff Associates. Dr. Bell has more than 20 years of experience in designing and testing corrosion control facilities and forensic evaluation of corrosion damage on buried and submerged structures. Dr. Bell is a registered Corrosion Engineer in the State of California and a registered Mechanical Engineer in the States of Arizona, Tennessee and Nevada. Dr. Bell is certified by NACE International as both a Corrosion and Cathodic Protection Specialist. In 2002, the Western Area of NACE International named Dr. Bell Engineer of the Year, making him the youngest recipient of this honor. Dr. Bell has authored and coauthored more than 50 technical papers and given more than 100 technical conference presentations.

Dr. Bell is the current chairman for the AWWA Committee on Corrosion (519) and was the Chairman of the NACE International Task Group T-10A-21 on Corrosion Control for Cast and Ductile Iron Pipe. These committees are preparing a new version of their state-of-the-art reports for corrosion control and condition assessment of pipe materials used in the water industry.

Graham E.C. Bell, Ph.D., P.E.

Measurement of Performance of Corrosion Control Mechanisms on DIP

NACE Conference, July 29, 2008

So what did we learn from the Lab?

- Corrosion rate of DIP with Oxide removedis very close to that of bare steel.
  - Composition and not microstructure dominates with out the annealing oxide.
- Oxide alone increases R_p by a factor of 4.
  - Oxide is important
- DIP + Oxide with Asphaltic Material behaves similarly to coated steel.

Visual Representation of Findings

Annealing Oxide vs Unprocessed Pipe

Uncoated Steel Pipe

Annealed-Uncoated DIP

DIP resistant to current from overhead power lines

- **DIP News Fall/Winter 2001 Publication**
- **DIP – rubber gasketed, electrically discontinuous joints prevent magnetic induction from being a problem.**
- **Polywrap is recommended if bonded joints are used due to its dielectric strength per AWWA C105.**
- **ASTM D4976 10^{15} Ohm-cm**
- **ASTM D149 800V/mil**

External Corrosion Protection DIP

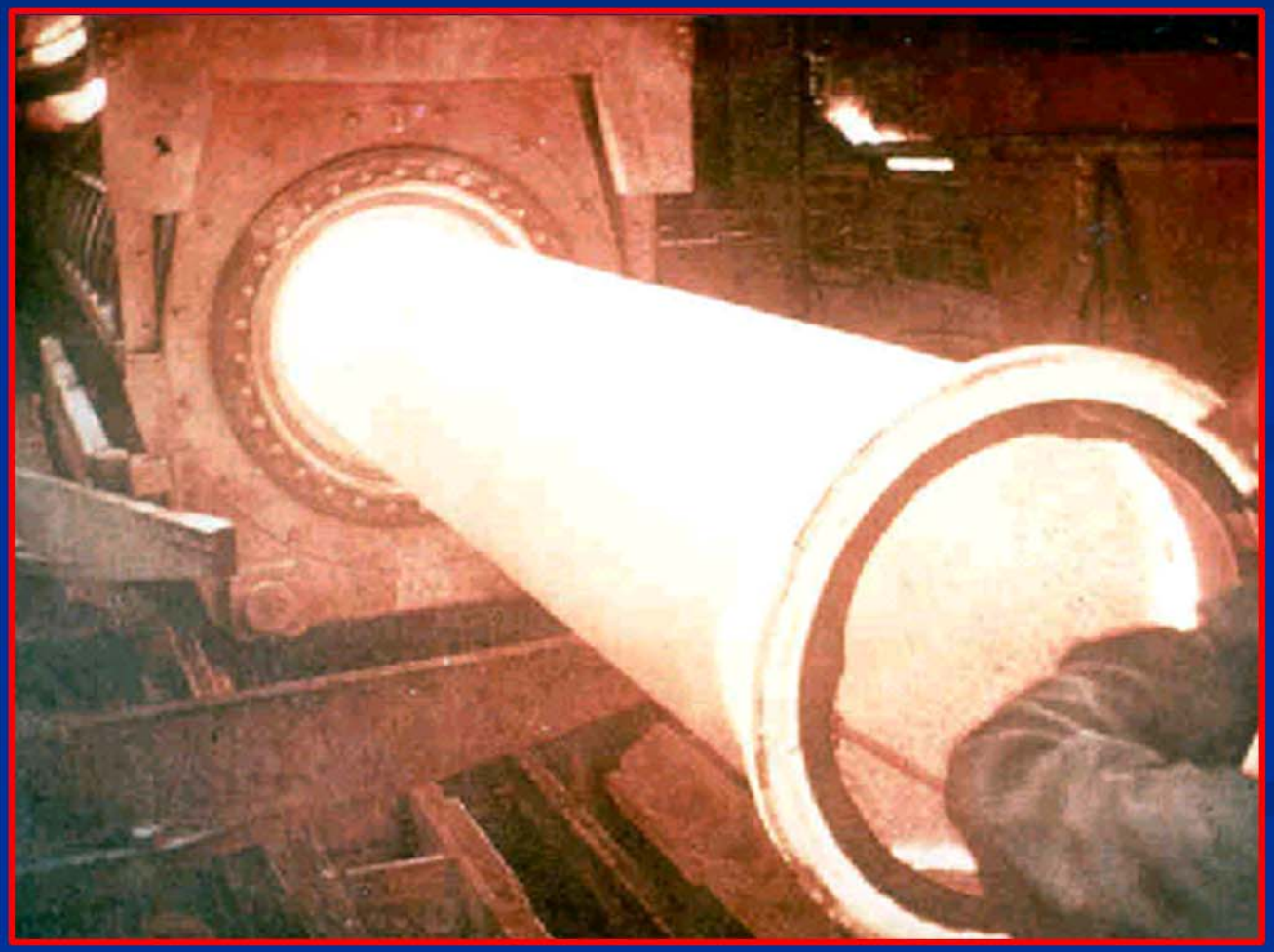
- Annealing Oxide Layer
- Asphaltic Coating
- Polyethylene Encasement

- Bonded coatings are no longer offered due to incompatibility with DIP

Polywrap

- Manufactured and Installed in conformance with AWWA C105

Ductile Iron pipe is a Cast Product



Peen Pattern

- The peen pattern on Ductile Iron pipe averages approximately 10 mils (0.010”) but may be as high as 30 mils (0.030”).

Peen Pattern & Surface Layer

- With spray applied coatings like polyurethane and epoxy, the peen pattern and the thin porous surface layer on Ductile Iron Pipe many times results in "holidays" (i.e. pinhole type voids).

Peen Pattern

- This inherent peen pattern is over the maximum specified by some coatings. (i.e. AWWA standard for tape wrap coating of steel requires a 3 mil (0.003”) maximum profile) As cast DIP may have as high as a 30 mil (0.030”) profile.
- Poor adhesion of tape wrap coatings can result.

- **Advantages of Polyethylene Encasement**

- • It is inexpensive, and easy to install
- • It requires no monitoring or maintenance.
- • It has no operating costs.
- • It will NOT deteriorate while underground.
- • It is easy to repair damaged areas.
- • It requires no special handling or packaging during shipment of the pipe.

Potential Disadvantages DIP

- Corrosion Potential, if it exists, must be identified and evaluated.

Advantages of specifying this pipe material for this project

- Proven Product History
- Strongest product due to Design Standards
- US Pipe is made of 95% recycled material
- Easy Installation
- Maintenance Free Corrosion Protection

Good for the Environment

U.S. Pipe qualifies for Federal Procurement under Public Law No. 94-580, Section 6002, known as the Resource Recovery Act of 1976, since, due to modern technology, recycled iron and steel scrap is used to a large degree in our Ductile Iron pipe production.

APPENDIX E

American Ductile Iron Presentation

APPENDIX F

North American Pipe Corporation Presentation (PVC Pipe)

North American Pipe Corporation

Right, On Time, All the Time

Affiliations

Memberships

American Water Works Association - resource on safe water, providing knowledge, information and advocacy to improve the quality and supply of water in North America and beyond

Uni-Bell PVC Pipe Association – helps people gain access to safe, sustainable water and wastewater sanitation through the responsible and resource-efficient use of PVC pipes and fittings

Industry Associations

NSF International - standards development, product certification, education, and risk-management for public health and safety

Underwriters Laboratories – product compliance

Factory Mutual – third party certification

ASTM International – standards development (ANSI Standards)

IAMPO – plumbing and mechanical product certification agency

North American Pipe Corporation

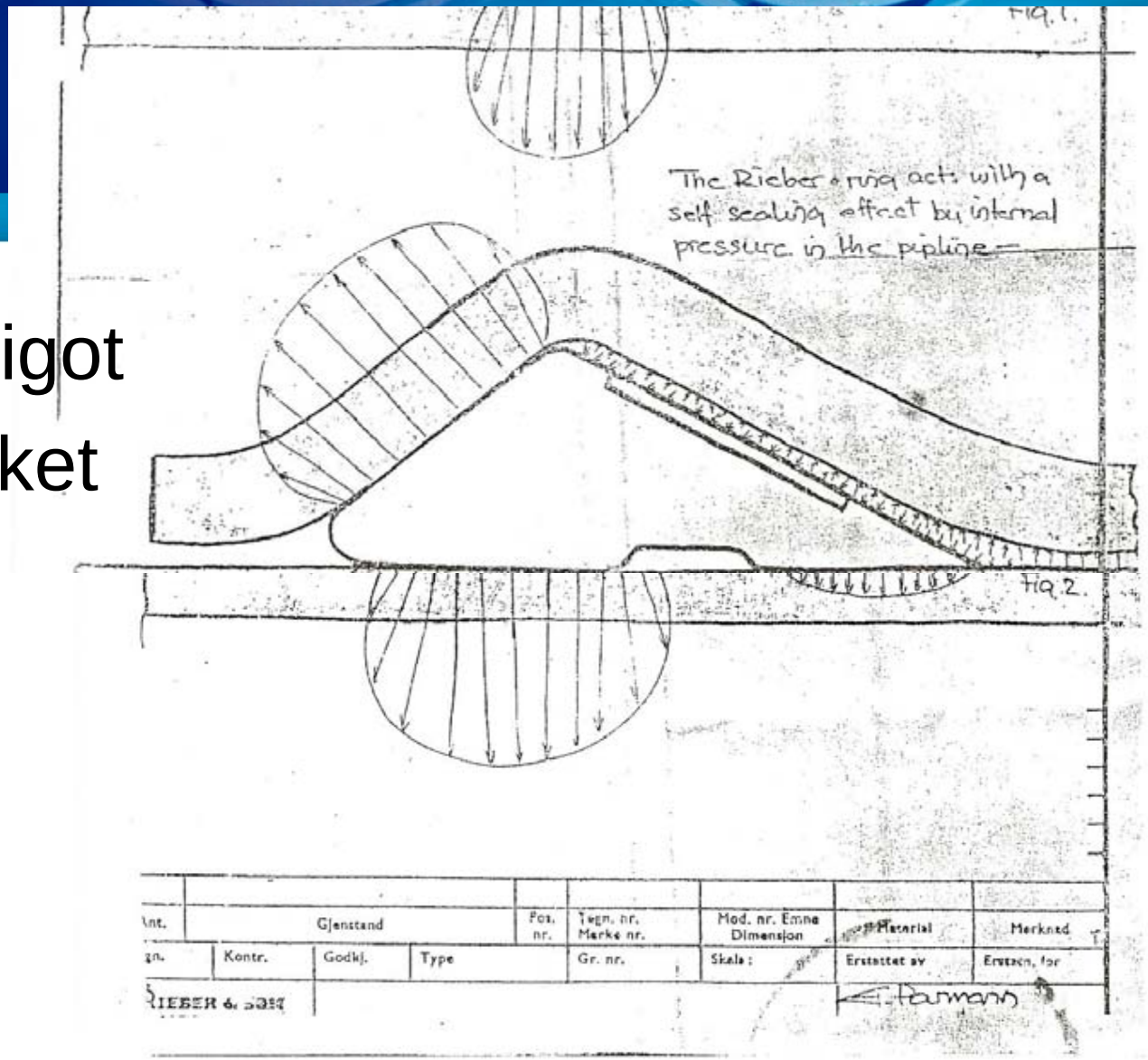
History and Service Life

- Original Installation
- Service Life

North American Pipe Corporation

Joints

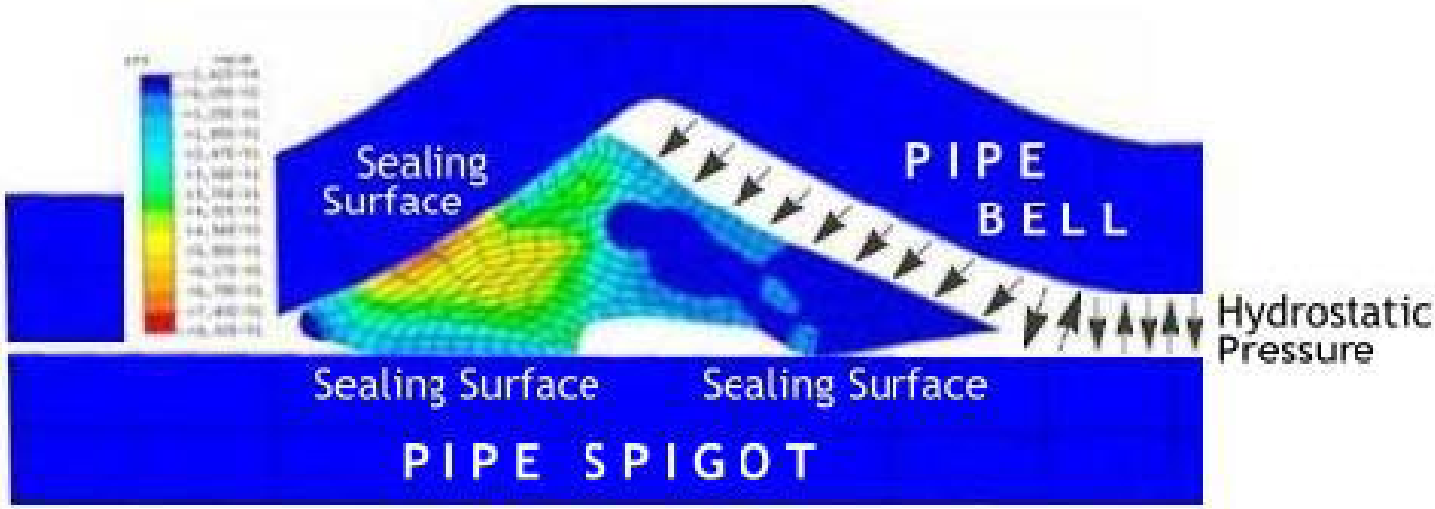
- Bell and Spigot
- Reiber Gasket



North American Pipe Corporation

Joints

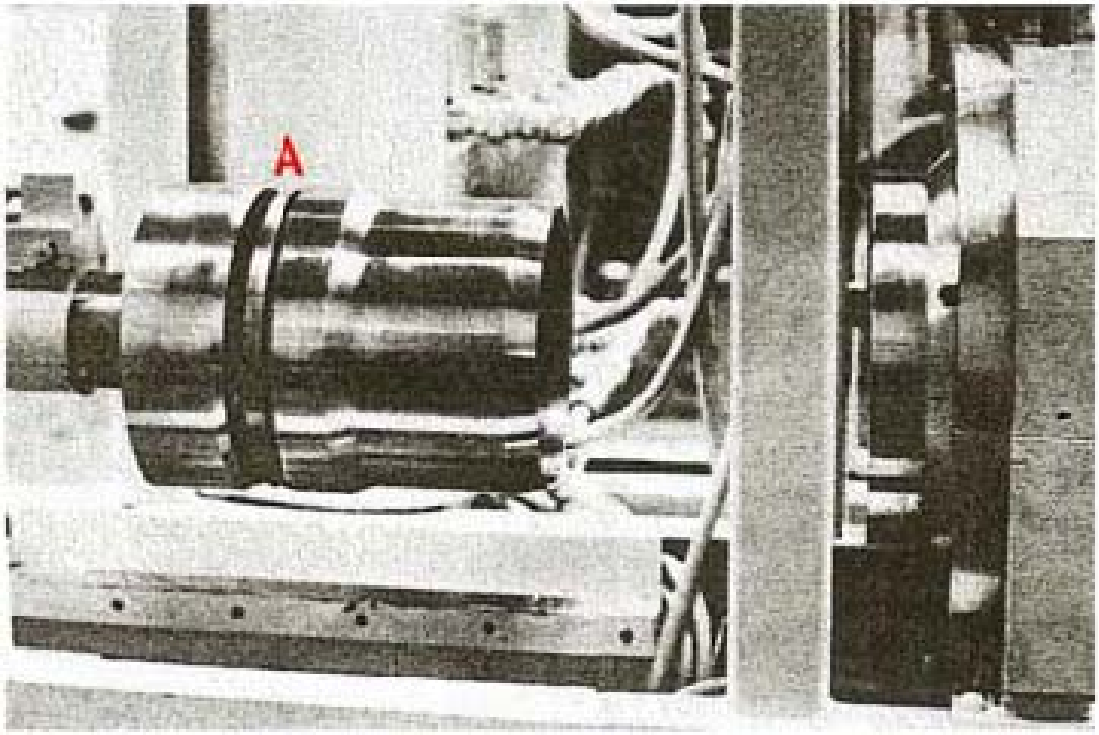
- Bell and Spigot
- Reiber Gasket



North American Pipe Corporation

Joints

- Bell and Spigot
- Reiber Gasket



North American Pipe Corporation

Joints

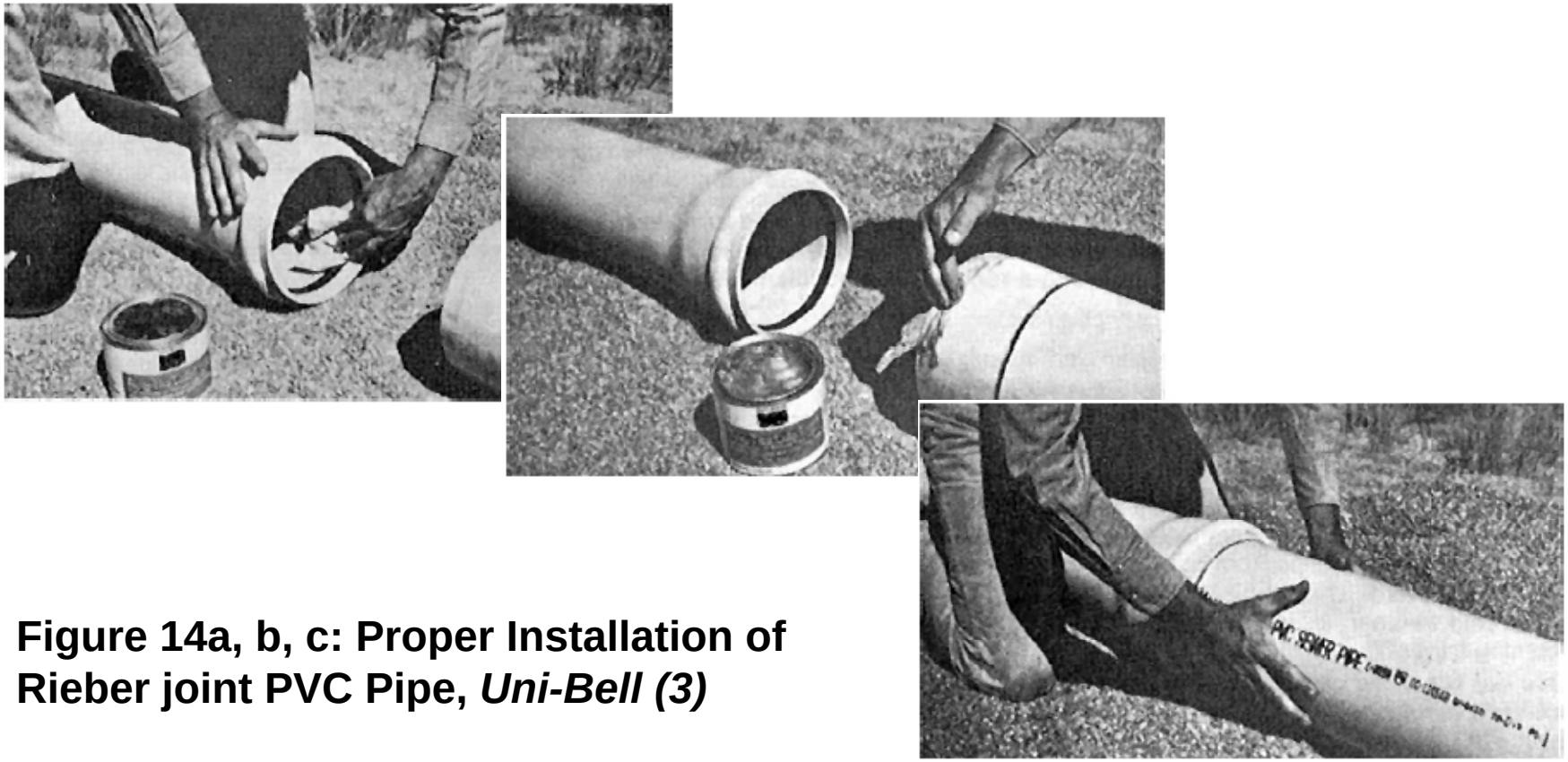
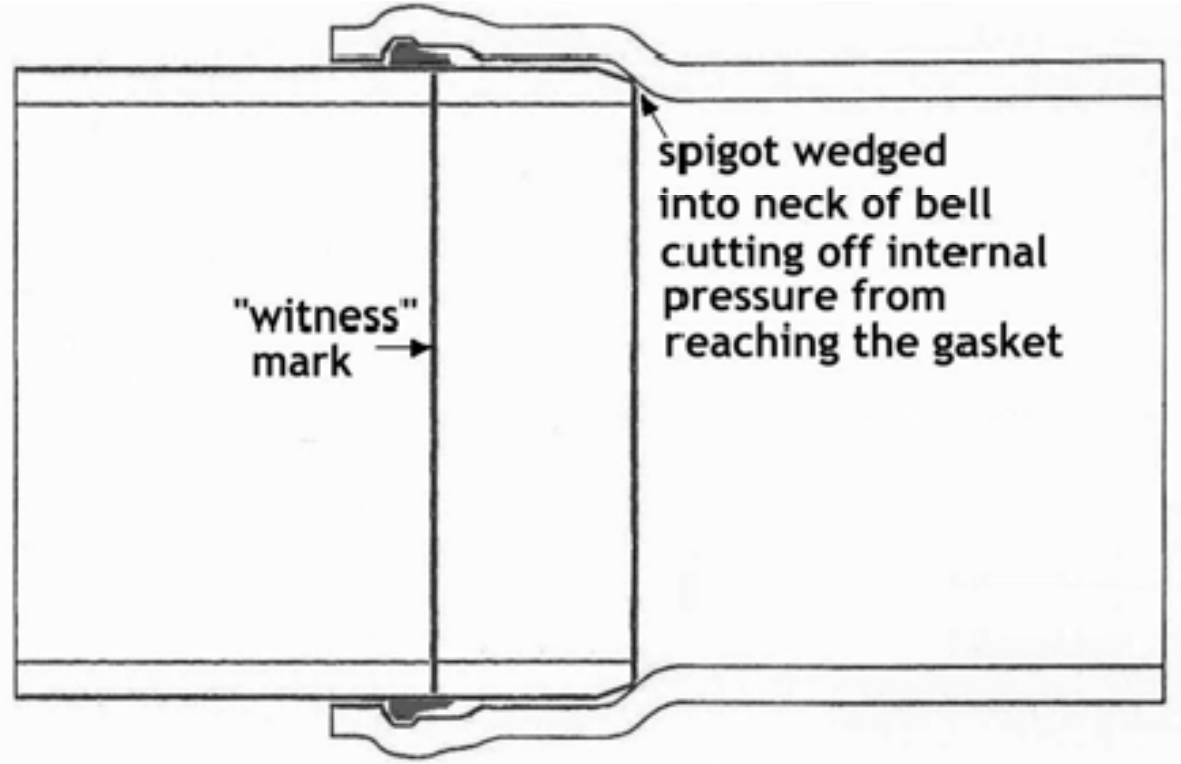


Figure 14a, b, c: Proper Installation of Rieber joint PVC Pipe, *Uni-Bell (3)*

North American Pipe Corporation

Joints

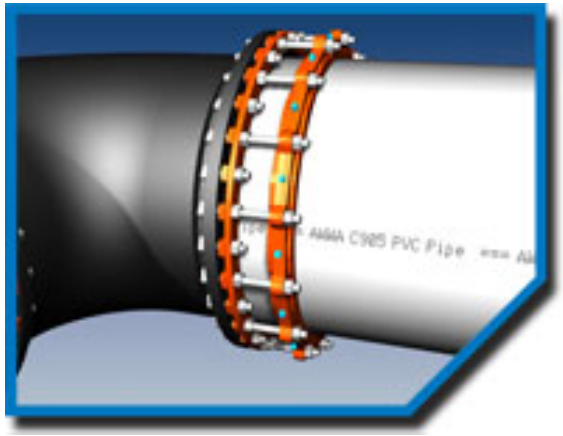
- Improper Installation

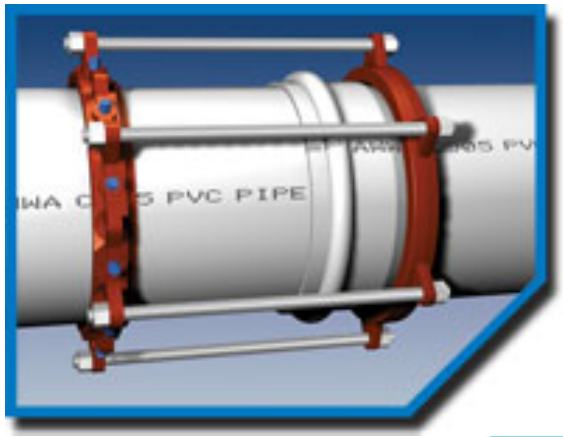


North American
Pipe Corporation

Restraints

- Thrust Blocking
- Mechanical Restraints





North American Pipe Corporation

Fittings

- Ductile Iron
- PVC Fabricated Fittings

North American Pipe Corporation

Design

- AWWA M23 PVC Pipe Design and Installation
- The Handbook of PVC Pipe
- ASTM / ANSI Standards
- AWWA products – EVERY Joint is tested to a minimum of 2 x Operating Pressure

North American Pipe Corporation

Design

- ISO Formula

$$P = \frac{2S}{DR - 1} xDF$$

PVC: Hydrostatic Design Basis, S = 4,000 psi

DR = OD/t

Design Factor = 2:1 or 0.5 multiplier

North American Pipe Corporation

Linings

- None Needed

North American Pipe Corporation

Coatings

- None Needed

North American Pipe Corporation

Installation

- AWWA M23 PVC Pipe Design and Installation
- The Handbook of PVC Pipe
- ASTM / ANSI Standards

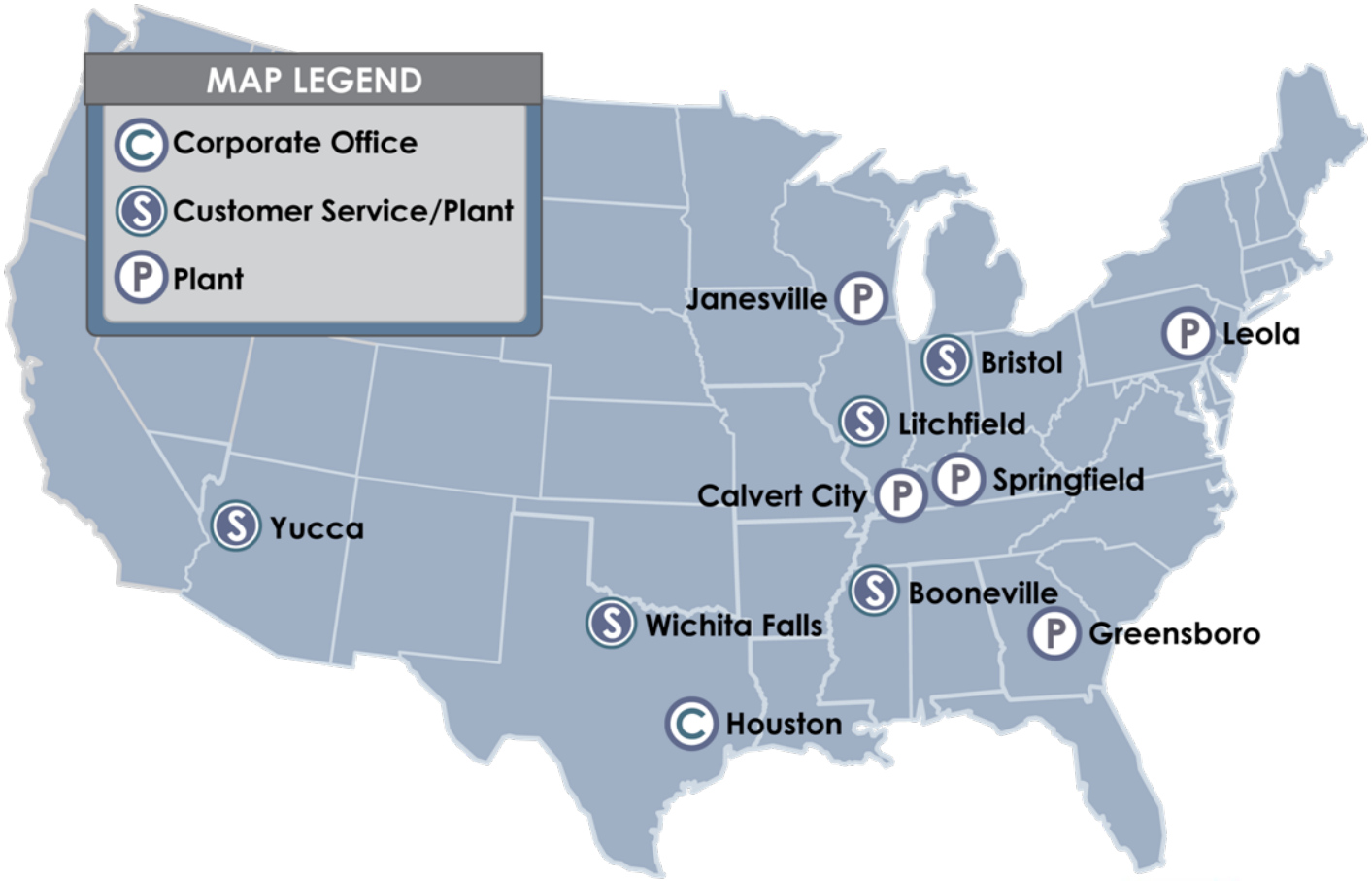
North American Pipe Corporation

Service Connections

- Direct Taps
- Saddle Taps

North American Pipe Corporation

Locations



North American Pipe Corporation

Delivery and Lead Times

- 36” – Two Plants
- Distribution Sizes – Nine Plants

North American Pipe Corporation

North American Pipe Corporation

- Corrosion Resistance
- Chemical Resistance
- Strength to Weight Ratio, Light Weight
- Flexibility
- Long-Term Tensile Strength
- Watertight Joints
- Abrasion/Wear Resistance

- Impact Strength
- Coefficient of Friction
- Longer Lengths
- Water Quality – NSF 61
- Permeation Resistance – AwwaRF Study
- NSF Appendix G Listed (No Lead Content)
- Favorable Cost

North American Pipe Corporation

Right, On Time, All the Time

- **Pressure Limitations**

e

North American Pipe Corporation

- 36” – Two Plants
- Distribution Sizes – Nine Plants

North American Pipe Corporation

- Proximity to High Voltage Lines
- No Issues

APPENDIX G

Cathodic Protection Workshop Meeting Minutes

APPENDIX H

Rust Not Cathodic Presentation

City of Gillette
Gillette Madison Pipeline Project (GMPP)

Cathodic Protection Workshop
June 10, 2010

Bill Spickelmire
RUSTNOT Corrosion Control Services, Inc.
325 Chester Drive, Boise, Idaho 83706
208-384-9752 bspickelmire@rustnotconsulting.com

Considered How to Approach This Talk

- One of Most Controversial Subjects in Pipe Design Field Today, Corrosion Control May Be Market Differential Between Pipe Types
- Discuss From **M** Viewpoint What I See In the Pipe Industry & Where It's Going
- Like to Review a Risk Assessment Method (25 Point) and Life Cycle Analysis Approach That I Use
- Give Examples and Reasons Why My Approach is More Conservative Than 10 Point System and Pipe Manufacturers Sometimes and in Agreement Other Times
- Presentation Only a Quick Review, More Detail in Paper
- Thought I would Start With A Joke

BUT Reactive Corrosion Control is NO Joke and the COST is Not Either, 2001 FHWA/NACE Study Identified Water and Wastewater Annual Corrosion Cost at 36 Billion Dollars (Largest Component)

Corrosion Happens All Types Of Pipe Even For Wood

Corrosion Control Approach

- A Successful Corrosion Control Approach Requires Understanding of the Engineering Principals, But Also the Political and Economical Pressures Involved Too
- Show Some Examples Why Our Approach May Be Different Than The Pipe Manufacturers
- Will Discuss Some of these Political Pressures
- Provide Additional Information (NRC Report, Department of Interior Letter to DIPRA, My Ductile Iron Corrosion Considerations Paper, Tables 1 through 5 Handouts, Etc.)

Recommended Corrosion Control Approach and Design

- Phase I - Determine Route Corrosivity
- Phase II – Review Risk Assessment with Client
- Phase III – Identify Corrosion Control Measures required For Different Pipe Materials Based on Risk
- Phase IV – Complete Corrosion Control Life Cycle Cost Analysis with Operation and Maintenance and Leak Repair Costs to Evaluate Actual Pipe Material Costs
- Phase V – Develop Specifications and Designs that Provide Equal Life for All Pipe Materials
- Phase VI – Train Contractor/Engineer, Inspect and Test

Water System Corrosion Control

- Not Required by Regulations
- Base on Economical Factors Not ONLY Initial But Life-Cycle
- Evaluate Risk Based On:
  - Corrosivity of Environment
  - Reliability Required, Cost of Leak Repairs
  - Type of and Size of Structure (Single Source Transmission Line Versus Distribution Piping for example)
  - Design Life

Level of Corrosion Control Based Mainly on Route Corrosivity

Ohms Law $I = \frac{E}{R}$

Where:
I = Current
E = Voltage
R = Resistance

Small Driving Voltage and High Resistance = Less Corrosive
If High Driving Voltage and/or Low Resistance = More Corrosive

1 amp of current flowing for 1 year will consume 20 pounds of iron

Pipe Manufacturers

- May Overstate Material Resistance To Corrosion
- Understate Need for Corrosion Control
- Recommend Methods That Keep Their Product Cost Competitive
- Corrosion Costs May Be Market Differential
- Not As Concerned With Leaks or Failures As You Will Be

Corrosion Consultants More Conservative

- Our approach influenced by number of failures that we have seen
- Not just influenced by “new car look”
- Goal is to provide greatest reliability to Owner at lowest cost and to minimize liability for design team
- Typically we work more for Clients that have failures and are knowledgeable about corrosion problems
- Have Done a POOR Job of communicating to Owners Actual Risk and Life Cycle Cost Savings

Where Are We?

- Both Corrosion and Pipe Industry is in a State Of Change and Flux
- Steel Merging, Concrete with Steel Plants, and DIP with Steel Plants
- Very Interesting and Challenging Times
- Controversy Between Some Pipe Manufacturers and Consultants
- Wide Variety of Approaches and Beliefs

Steel - ACCEPTENCE OF CORROSION CONTROL

- Little Controversy Over Corrosion Control Methods (Converted)
- Acceptance by Pipe Manufacturer to Provide Tight Bonded Coatings and CP As Standard Approach
- Actively Promotes Corrosion Control As Part of Marketing
- Investigating and Trying New Coatings

Steel Leaks Usually Pin Holes

Concrete - AWKNOWLEDGEMENT

- Reluctantly Acknowledges That Additional Corrosion Control May Be Needed (Recent Conversion)
- Some Controversy and Reluctance To Accept Corrosion Consultants
- Corrosion Control Viewed as Cost Not A Benefit
- Starting to Think About Cathodic Protection and Coatings
- Prestressed Concrete Failures Have Required Change

Concrete Coated Structures

- May allow formation of aggressive galvanic corrosion cells at bare or dielectric coated locations
- Pipe stub electrically connected into building rebar
- Concrete coated portion is cathode and bare or coated portion is anode -- POOR ANODE/CATHODE RATIO
- Make Sure Entire Pipe Coated and/or Galvanic Anode

Galvanic Corrosion At Bolts on Concrete Coated Pipe

Corrosion At Partially Diapered Joint

Prestressed Concrete Cylinder More Disruptive Type of Leak

Concrete Cylinder Pipe Warning

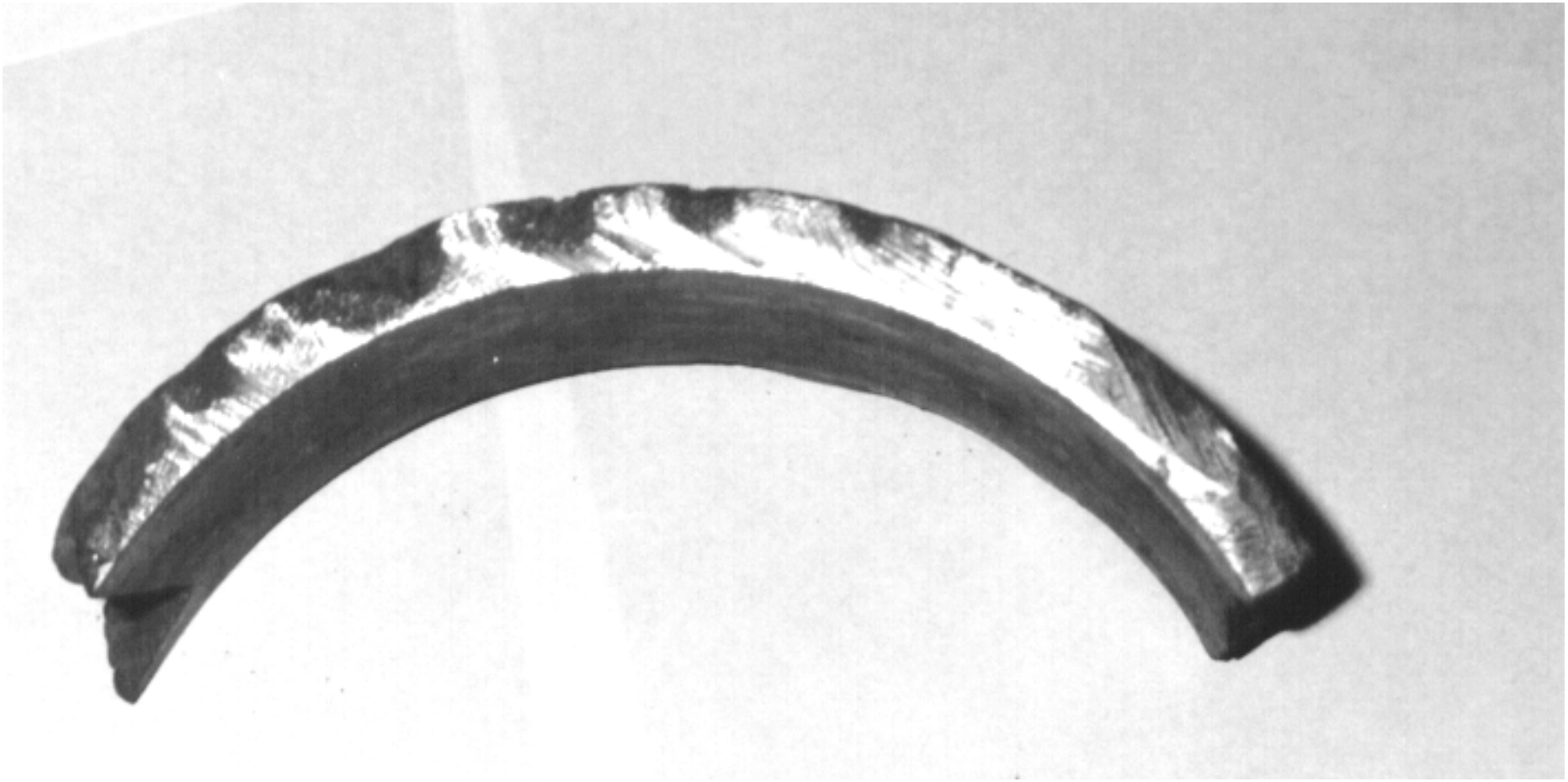
Ductile Iron - STILL IN DENIAL

- Does Not Think Corrosion A Problem (Not Converted Yet)
- Only Corrosion Control Method Recognized is Polyethylene Encasement
- Effectively Utilizes DIPRA Lobby To Promote View Point
- Actively Argues Against Tight Bonded Coatings and Cathodic Protection
- Major Disagreements With Corrosion Consultants

Cast and Ductile Iron Graphitic Corrosion (Graphitization)

- Corrosion May Not Be A Problem In Some Soils
- Corrosion Results in Selective Leaching of Iron
- Leaves Graphitization Layer of Silicon and Graphite (Carbon)
- Graphitization and Mortar Lining Demonstrated Ability to Hold Pressure Therefore No Perceived Corrosion Because No Leaks
- Only Problem if Soil Movement or Physical Stress
- Breaks May Be More Catastrophic for CIP Than DIP
- Sometimes Graphitization Not Visually Recognized

But Black Graphitization Pockets Visible On Pipe Edge That Are Soft and Can Be Cut With Knife Like Pencil Lead



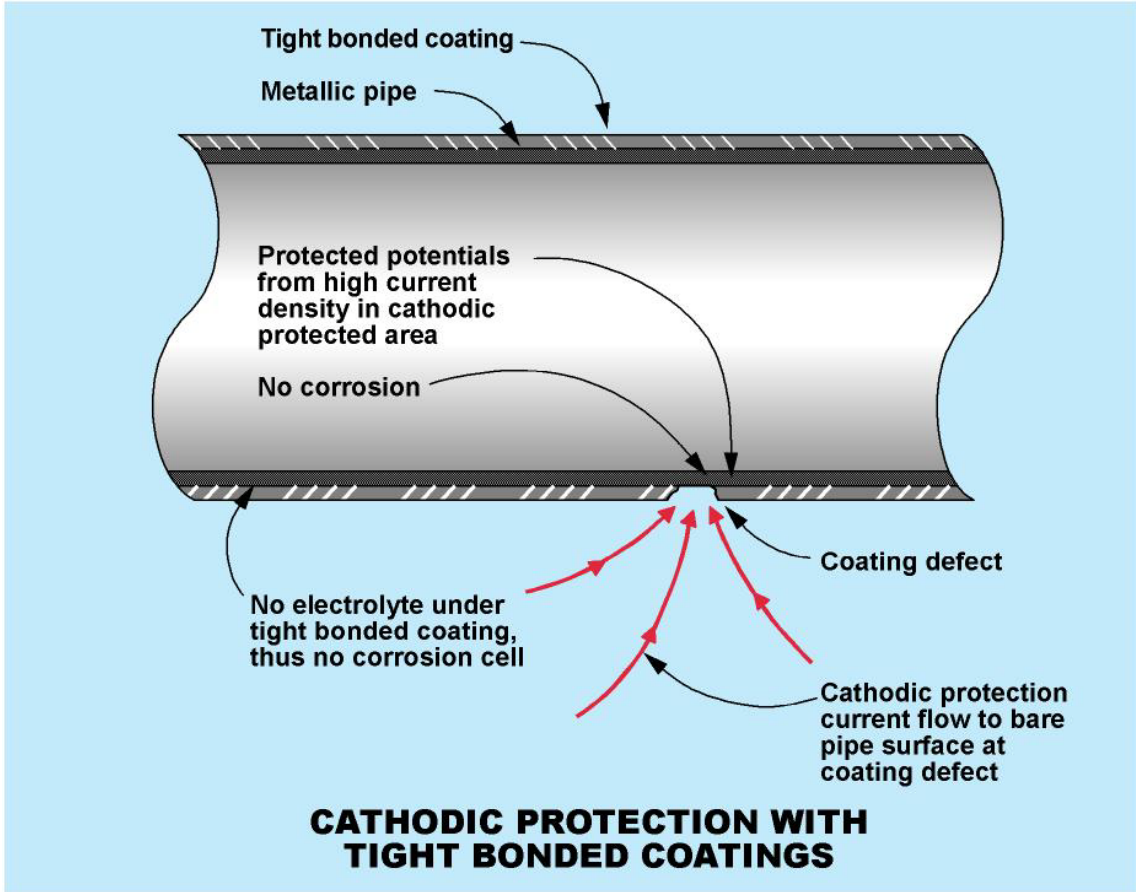
Wide Range Corrosion Control Methods Available Depending on Pipe Type, Route Corrosivity and Risk Assessment

- Bare Pipe and Fittings
- Polyethylene Encasement
- Tight Bonded Coatings
- Electrical Isolation
- Electrical Continuity (Joint Bonds)
- Test Stations (Monitoring Stations)
- Cathodic Protection (Impressed Current or Galvanic)
- Or A Combination Of These Items
- NO STANDARD APPROACH ACCEPTED

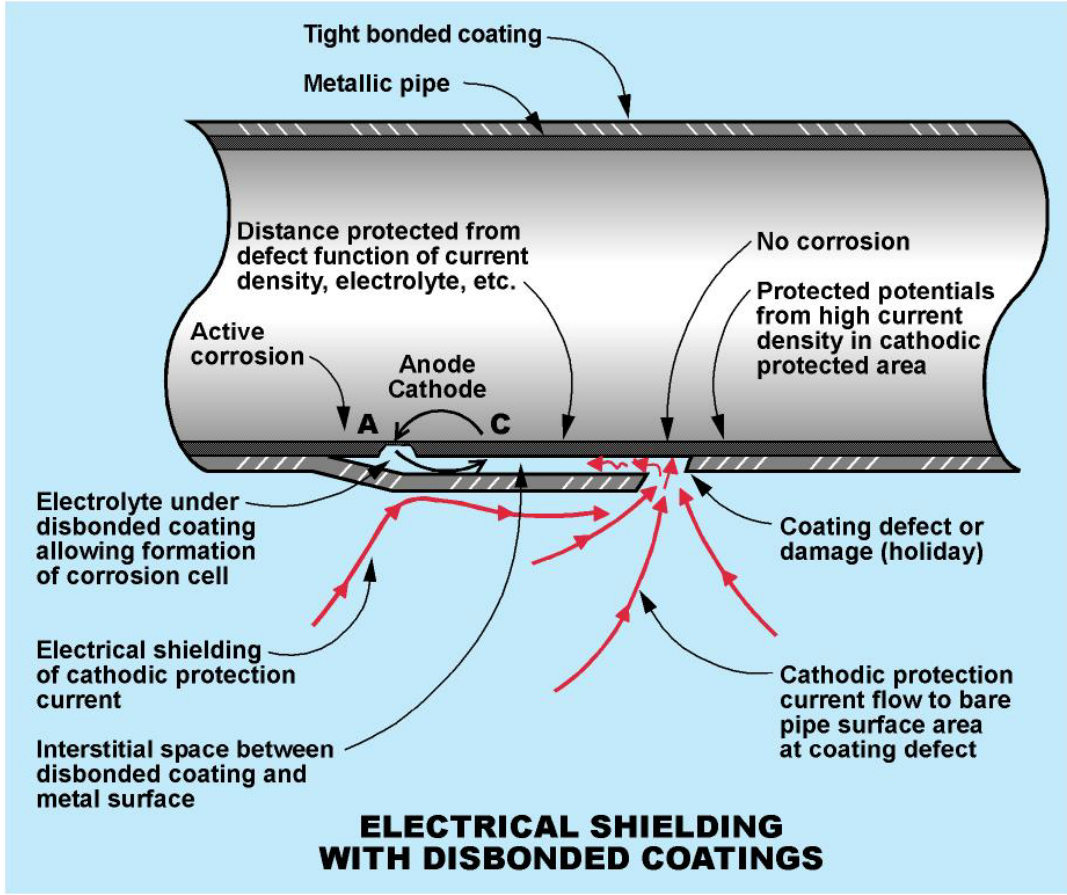
Coatings and Linings

- Provide Protection By Physical Barrier
- Electrical Isolation (dielectric type coatings)
- Cement Coatings and Linings Maintain Alkalinity to Passivate the Steel or Iron Surface
- Coating First Line of Defense Backed up by Cathodic Protection

Cathodic Protection Backs Up Coatings At Defects



Electrical Shielding Concerns



Electrical Continuity and Isolation Critical

- Electrical Continuity required for cathodic protection and to allow interference testing
- Rule of thumb joint resistance equal to one length of pipe
- Redundant joint bonds, tested individually, and collectively to minimize future dig-ups to repair or failure of cathodic protection system
- Electrical isolation required to minimize current requirements, galvanic corrosion cells, and electrical shielding in shorted casings

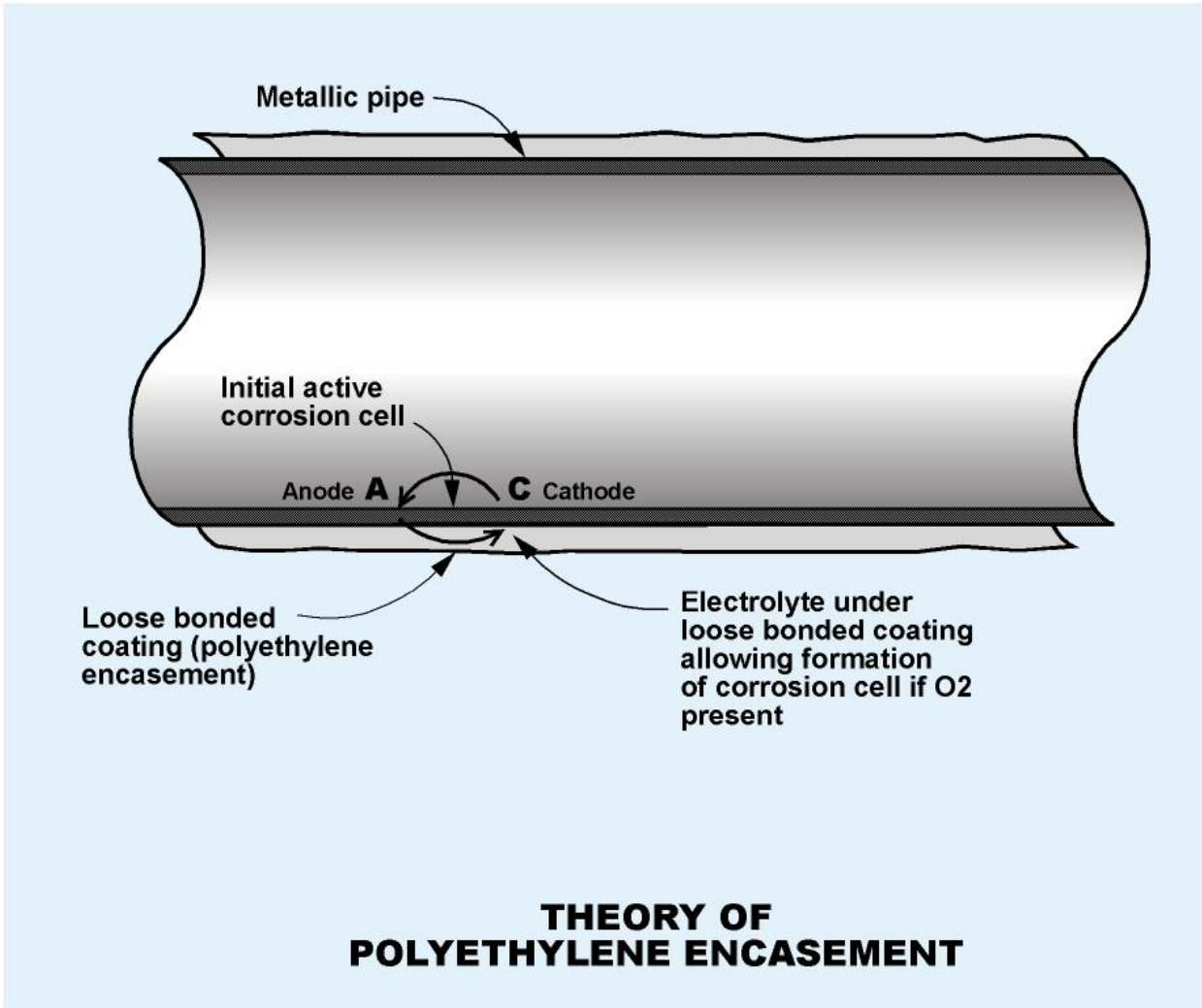
High Resistant Joint Bonds

Loose Bond Wires at Terminal

Ductile Iron

- Polyethylene Encasement Promoted by Manufacturers As All That Is Needed
- Major Controversy In Corrosion Industry
- Same corrosion control methods as required for steel can be provided
- Presently Moratorium By DIP Manufacturers on Pipe Coatings

Polyethylene Encasement



Polyethylene Encasement

- Passive Type System (Corrosion Rate Similar to Bare at Damaged Locations)
- Barrier Between Soil and Pipeline
- Needs to Be Installed In An Intact Condition
- Not Intended to Be Water Tight
- Initial High Rate of Corrosion Slows and Halts
  - If Oxygen is Consumed and Not Replaced
  - Creates an Anaerobic Condition

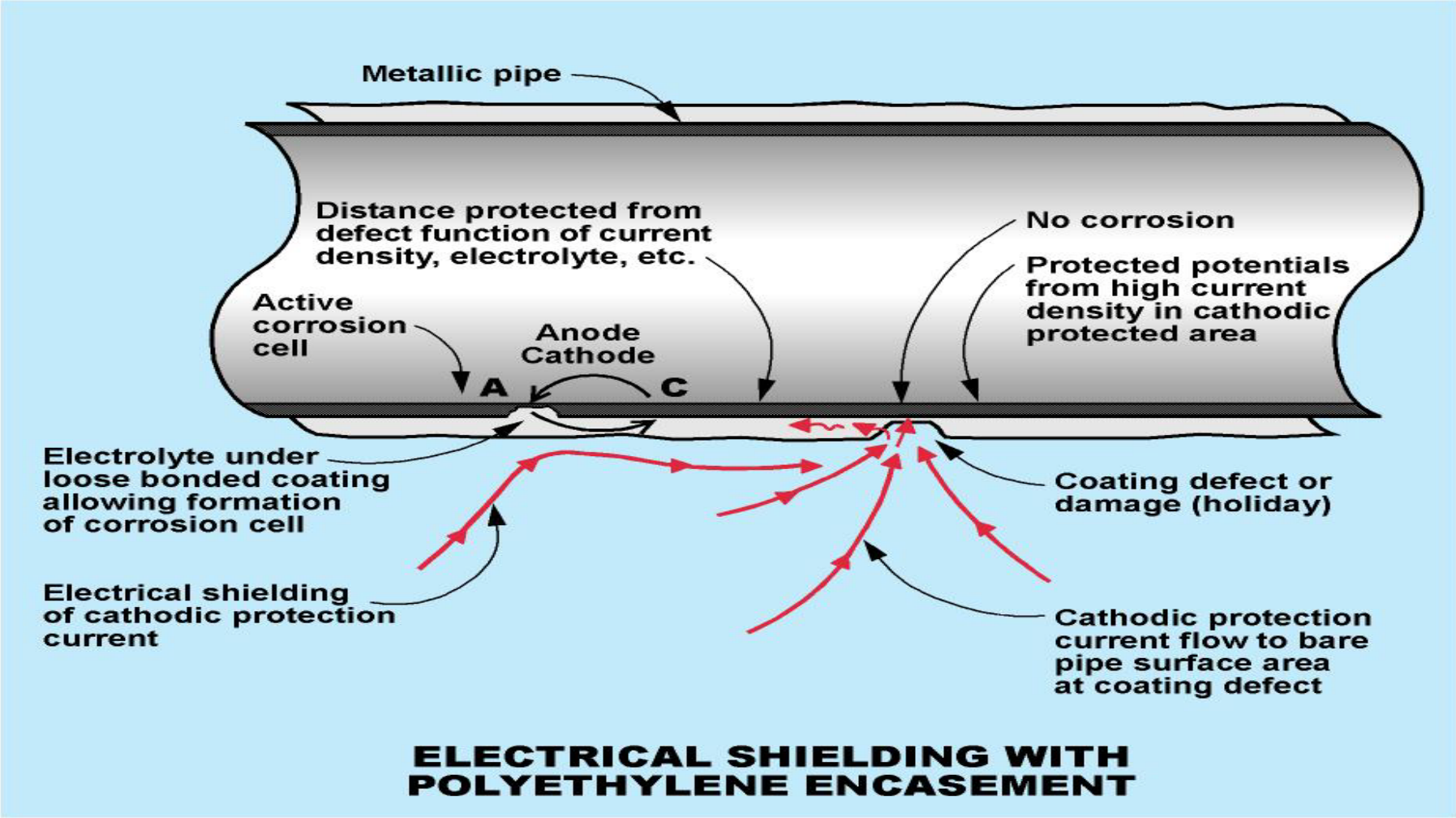
Polyethylene Encasement Concerns

- What is Actual Long Term Protection Provided By This Passive Protection Type System?
- Initial High Corrosion Rate Under Film May Continue If Oxygen Supply Replenished
- Areas of Problems Reported
  - High Salts (Chlorides, Sulfates)
  - Microbiological Influenced Corrosion (MIC)
    - Sulfate Reducing Bacteria
    - Sewer Lines and Force Mains (Possible Food Source)
- Can It be Installed In An Intact Condition, If Not Then What?

Cathodic Protection Electrical Shielding Concerns with Polyethylene

- Controversial With Two Schools of Thought
- Higher Current Requirements Than Bonded Coating
- Accurate Monitoring Protection Under PE More Difficult
- Experience Indicates that CP With Loose Coatings Can Not Be Completely Cathodic Protected In All Cases
- Against NACE SPO169 & Federal DOT OPS Standards
- Long Term Current PE Electrical Effectiveness Unknown
- NO Long Term Non Biased Study That Proves or Disproves

Concerns Over Polyethylene Encasement Shielding of CP Current



22 Years CP PE-DIP Sewer Line Replaced, 6 Corrosion Leaks, Exterior Thick Black Layer and Graphitization of Pipe Observed Even With Measured -1.1 Volt Potential

California City 14” DIP With PE and CP, 1st Leak 8 years, Replaced 12 years

We Treat Polyethylene Encasement Like a Coating to Improve Performance

- Treat as Coated Pipe, do NOT damage PE, asphaltic shop coating or epidermal layer, No metallic chains, tongs, or forks
- Repair shop coating damage with asphaltic repair coatings (Royston Roybond 747, etc.) to minimize anodic locations
- Get Certified PE Material Only, require certifications from both polyethylene manufacturer and pipe manufacturer to assure quality
- Utilize 4-mil high density cross laminated polyethylene for improved tear and puncture resistance
- Use 8-mil linear low density with anti-MIC additive in sewer and high sulfate environments with 4-mil outerwrap

Use of Anti-MIC Polyethylene Encasement on Sewer Pipes or In High MIC Soils

Our Experience with Polyethylene Encasement

- Used Anti-MIC Polyethylene Encasement for Sewer or High Salt Contaminated Areas (as the first and only installation in U.S. for Minneapolis/St Paul Force Mains)
- Specified Micro-perforated Polyethylene Encasement to minimize electrical shielding concerns (first project possible in Cheyenne, 30-inch now being bid)
- Allowed polyethylene encasement with CP (Utilized distributed type cathodic protection systems to minimize shield concerns).

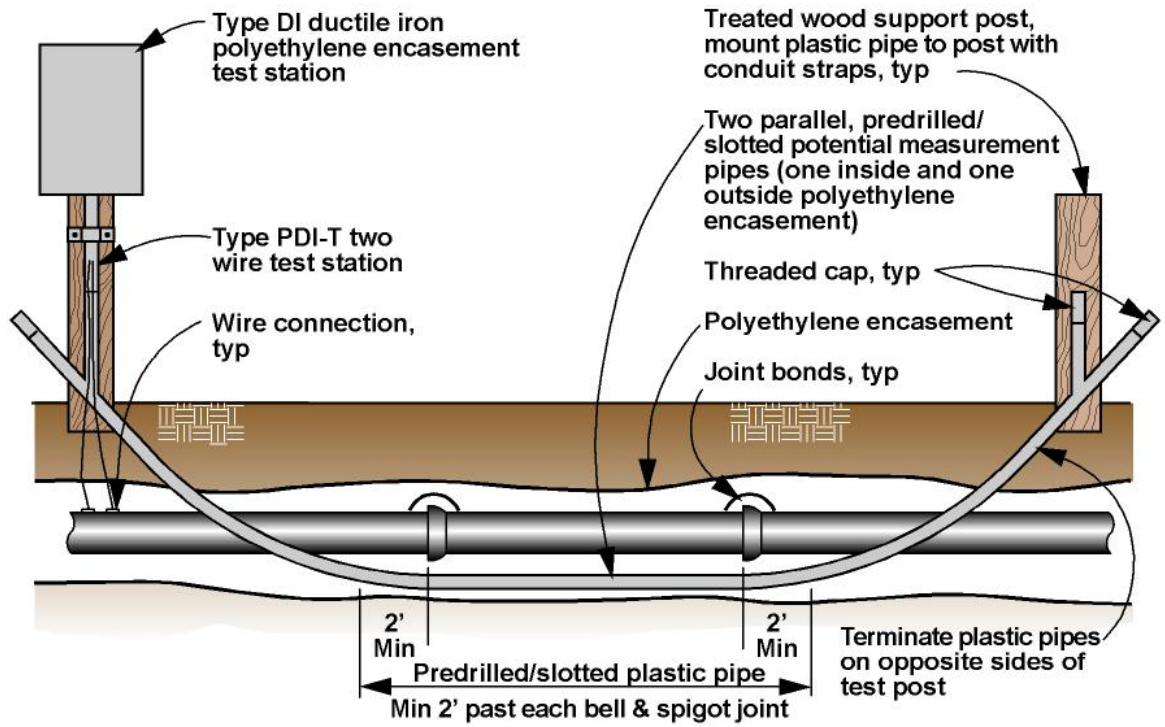
Magnesium Galvanic Ribbon Anode and Monitoring System

Riverdale Distributed Groundbed (103 to 137 Micro-Amps Current Requirements)

Higher CP Current Requirements With PE or Concrete Than Coated

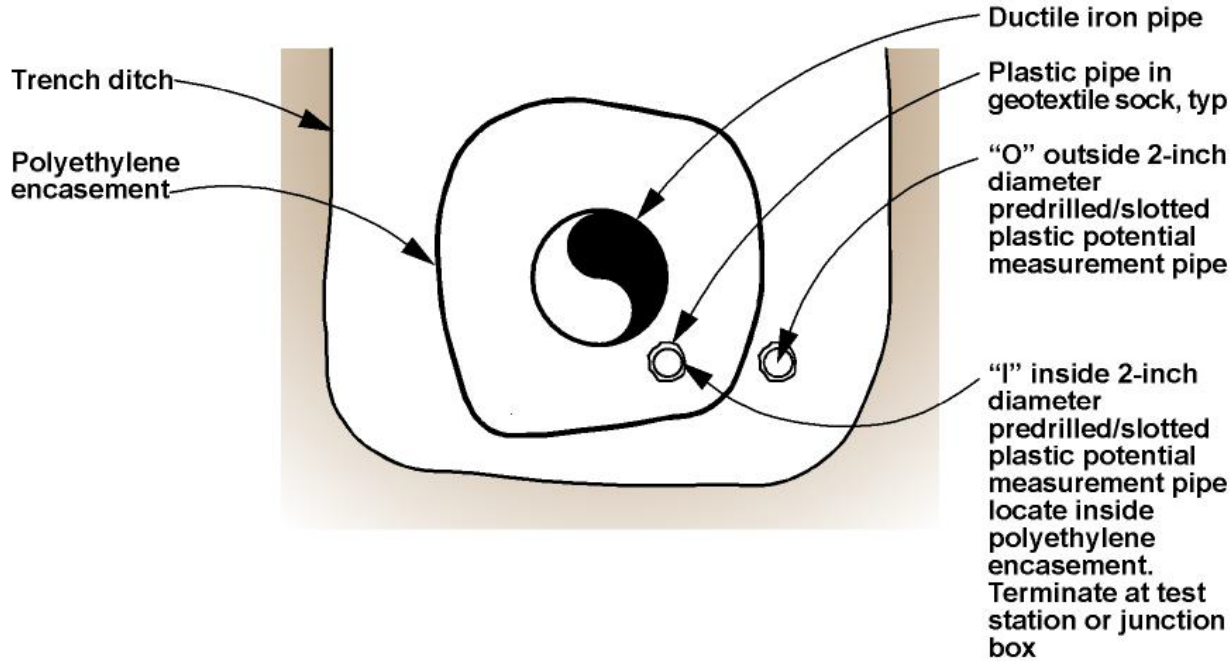
- 28 times that of tape per Project in North Dakota MP Article 1993 (Recent reported values are higher 62X in some areas)
- Denver Riverdale (10yrs) 103 to 137 micro-Amps in Corrosive Dry Soils
- Cape May and Trinidad/Tobago 700 to 800 micro-Amps/square foot in Salt Contaminated Soils
- PE Current Requirements May Be Up To 25 to 50 Times in Dry Soils and 75 to 100 Times in Contaminated Soils Times That Of Tight Bonded Coatings
- NEEDS to be factored into both Design and Life Cycle Cost Comparisons

Type PDI-T with Plastic Pipes



TYPE PDI-T DUCTILE IRON POLYETHYLENE TEST STATIONS

Type PDI-T Test Station Plastic Monitoring System Reveals Difference in Potentials



DUCTILE IRON TYPE PDI
PLASTIC PIPE MONITORING SYSTEM

Present Moratorium On Coating DIP Pipe by U.S. DIP Pipe Manufacturers

- DIP has minor problems with surface preparation like other pipe
  - Overblasting and surface delamination
  - Different pipe manufacturer, different appearance
- Historically able to do from a technical standpoint
- Likely moratorium more to do with economical and political pressures in U.S. market than technical
- Seems Owners Should Be Able to Get What They Want, If Willing to Pay For Increased Cost

City and County of Honolulu Board of Water Supply Requires Tight Bonded Coated and CP For Ductile Iron Pipe

Extruded Polyethylene Coated DIP with Bell Coating and Spigot Hold Back

Seattle Thermoplastic Pipe Coating Allows Engagement of Spigot Directly into Bell

1992/1993 Cairo, Egypt Tape Coated DIP Direct to Asphaltic Shop Coating With Strap Bonds And Heat Shrink Sleeves Similar to Tape Manufacturers Present Proposed Approach

Polyurethane Coated and Lined DIP For San Diego, California

2006 Direct Hand Taping of Small Pipe with FBE Fittings

In Europe, Polyurethane Lined and Coated DIP Still Being Done, Also Zinc/Aluminum Oxide with PE or Epoxy Coating (PAM) Available, Extruded Polyethylene, Asia > 3,000 miles Polyurethane Alone

Bureau of Reclamation Corrosion Prevention Criteria July 2004 Table 2

- Table 2 Handout (Similar to Our Approach In That Corrosion Control Measures are Determined by Corrosivity Rating)
- More Conservative Requirements More Corrosive Soils
- Table Notes That Additional Soil Conditions and Risk Assessment Factors Should Be Considered
- Recommends that OMR&E costs for cathodic protection for each pipe type should be evaluated
- Moratorium Still on Prestressed Concrete Cylinder Pipe

Bureau TM No. 8140-CC-2004, Corrosion Considerations For Buried Metallic Water Pipe, July 2004, Page 5 Table 2 (Our Table 2 Handout)

Table 2
Bureau of Reclamation's Corrosion Prevention Criteria and Minimum Requirements[1] July 2004

Pipe Alternative	Soil Resistivity – 10 % Probability Value (ohm-cm)	Minimum External Protection (Primary / Supplemental)	Corrosion Monitoring	Cathodic Protection[2]
Ductile Iron	≤2,000 ohm-cm	Bonded dielectric[3]	YES	YES
	>2,000 ohm-cm <3,000 ohm-cm	Polyethylene encasement	YES	YES
	≥3,000 ohm-cm	Polyethylene encasement	YES	NO
Pretensioned Concrete	<3,000 ohm-cm	Mortar / coal-tar epoxy	YES	YES
	≥3,000 ohm-cm	Mortar	YES	NO
Reinforced Concrete	<3,000 ohm-cm	Concrete / coal-tar epoxy	YES	YES
	≥3,000 ohm-cm	Concrete	YES[4]	NO
Steel	≤2,000 ohm-cm	Bonded dielectric[3]	YES	YES
	>2,000 ohm-cm <3,000 ohm-cm	Mortar / coal-tar epoxy	YES	YES
	≥3,000 ohm-cm	Mortar	YES	NO

[1] This table should be considered the minimum corrosion prevention requirements for a pipeline corrosion design. Additional soil conditions and risk assessment factors should be considered on a case-by-case basis for each specific project.
[2] OMR&E costs for cathodic protection for each pipe type should be evaluated.
[3] Bonded directly to the metal to be protected.
[4] Corrosion monitoring is required for concrete pipe with steel joint rings, but not for concrete pipe with concrete joints.

From the Bureau of Reclamation Technical Memorandum No. 8140-CC-2004-1, Corrosion Considerations for Buried Metallic Water Pipe, July 2004, Page 5, Table 2, "Corrosion Prevention Criteria and Minimum Requirements."

Pipe Alternative	Soil Resistivity 10% Probability Value (Ohm-cm)	Minimum External Protection (Primary /Secondary)	Corrosion Monitoring	Cathodic Protection
Ductile Iron	≤ 2,000 ohm-cm	Bonded dielectric	YES	YES
Pretensioned Concrete	< 3,000 ohm-cm	Mortar/coal-tar epoxy	YES	YES
Reinforced Concrete	< 3,000 ohm-cm	Concrete/coat-tar epoxy	YES	YES
Steel	≤ 2,000 ohm-cm	Bonded dielectric	YES	YES

Bureau Enlisted NRC To Evaluate DIP Corrosion Requirement Controversy

- In 2008, Bureau Hired National Research Council to evaluate Bureau Technical Memorandum 8140-CC-2001-1 (DIP <2,000ohm-cm Tight Bonded Coating)
- 2009 Final Report "Review of the Bureau of Reclamation's Corrosion Prevention Standards for Ductile Iron Pipe"
  - National Materials Advisory Board (www.nationalacademies.nmab)
  - National Academies Press (www.nap.edu)

NRC Committee Evaluation

- Bureau Provided Risk Tolerance 0.000044 (1 in 450 mi)
- In North America More Tight Bonded DIP with CP (877 miles, no leaks) than PE DIP with CP (369 miles, 9 leaks)
- Critical of DIPRA Testing Approach and Reporting Methods, NRC Calculated Different Corrosion Rates Than DIPRA Averages of Averages
- Random digs, not adequate to find fastest corrosion rate
- A number of failures (9 total) evaluated, (only agreed on 3 for analysis) resulted in 0.00038 or 1 failure in 53 miles

NRC Committee Responses to Bureau's Question No. 1

- Question - Does polyethylene encasement with cathodic protection work on ductile iron pipe installed in highly corrosive soil?

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NRC Committee Response to Bureau's Question No. 2

- Question – Will polyethylene encasement and cathodic protection reliably provide a minimum service life of 50 years?

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So Now That You Understand Political Controversy, Our Approach Is:

- Phase I - Determine Route Corrosivity
- Phase II – Review Risk Assessment with Client
- Phase III – Identify Corrosion Control Measures Required For Different Pipe Materials Based on Risk
- Phase IV – Complete Corrosion Control Life Cycle Cost Analysis with Operation and Maintenance and Leak Repair Costs to Evaluate Actual Pipe Material Costs
- Phase V – Develop Specifications and Designs that Provide Equal Life for All Pipe Materials
- Phase VI – Train Contractor/Engineer, Inspect and Test

Phase I – Determine Corrosivity

- Determine Route Corrosivity (Minimum Field Testing Required for This Project, Utilize Existing Data Table 1)
  - Assess Soil Conditions (Part of Geotec Investigation)
  - Soil Resistivity (Lower Resistivity More Corrosive)
  - Moisture Content
  - Chemical Analysis (pH, Chlorides, Sulfates)
- Interference (CP)
- HVAC Interference
- Internal Pipe - Water Corrosivity

Corrosivity Rating Vs Soil Resistivity

Risk Assessment or Soil Corrosivity one	Soil Resistivity Range (ohm-cm)	Corrosivity Rating
1	<2,000	Extremely Corrosive
2	> 2,001 – 3,000	Very Corrosive
3	> 3,001 – 5,000	Corrosive
4	> 5,001 – 10,000	Moderately Corrosive
5	> 10,001	Mildly Corrosive

Gillette Madison Pipeline Original Soil Resistivity Information Summary

Based on 130 Total Test Measurements and 226,225 feet long	one 1 (2,000 ohm-cm)	one 2 (2,001 – 3,000 ohm-cm)	one 3 (3,001 – 5,000 ohm-cm)	one 2 (5,001 – 10,000 ohm-cm)	one 2 (> 10,001 ohm-cm)
Number of Measurements In Each Zone	60	22	20	18	8
Percentage of 130 Tests	46%	17%	15%	14%	6%
Approximate Distance Ft. in Each Zone	102 ,890’	39,025’	43,198’	28,762’	10,000’
Percentage of Route	45%	17%	19%	13%	4%

Sulfate Attack on Concrete

Relative Degree of Sulfate Attack	Percent	Converted to PPM	PPM Sulfate (as SO4) in Water Samples (mg/L)
Negligible	0.00 – 0.10	0 – 1,000	0 - 150
Positive (a)	0.10 – 0.20	1,000 – 2,000	150 – 1,500
Severe (b)	0.20 – 2.00	2,000 – 20,000	1,500 – 10,000
Very Severe (c)	2.00 or more	20,000 or more	10,000 or more
(a) Use Type II cement			
(b) Use Type V cement			
(c) Use Type V cement plus approved pozzolan			
Per Concrete Manual (eighth edition) published by the U.S. Bureau of Reclamation			

High Chloride and Sulfate Salt Levels

- Sulfate Range 0.03% (300 ppm) to 1.08% (18,000 ppm)
- Chloride 30 ppm to 572 ppm
- High Sulfate and Chlorides will accelerate corrosion activity
- Concern Microbiological Influenced Corrosion (MIC) Corrosion from High Sulfates and Sulfate Reducing Bacteria
- CP not able to halt MIC if electrically shielded

Original 1980 Corrosion Consulting Service Corporation Comments

- February 28, 1980 Letter Stated:
  - "The soil along the transmission main right-of-way is one of the most corrosive that we have encountered. It is clear that without corrosion control this pipeline will have limited life. Coating and cathodic protection are the prime anti-corrosion measures."

- We concur with that evaluation based on the original corrosion measurements.

Possible Cathodic Protection Interference Sources

- Better Coated Pipeline Minimizes Possible CP Interference on Other Pipelines and Structures
- Better Coating Also Minimizes Amount of Interference From Other Cathodic Protection Systems
- Presently There Are A Number of Cathodic Protection Systems in Proposed Route (Well Field and Foreign Pipeline Crossings)

HVAC Evaluation and Mitigation

- Evaluate Parallel and Separation Distances
- Examine Pipeline and Powerline Characteristics
- Mitigation if Required May Include:
  - Zinc Ribbon Ground In Pipe Ditch
  - Ground Mats Around Appurtenances
  - Ground to Casings or Other Structures with Polarization Cell Replacement (PCR) Electronic Decoupler Devices

Existing Parallel Pipeline Considerations

- Existing Tight Bonded Coated Steel Pipeline with Galvanic and Impressed Current Cathodic Protection
- Existing CP System Will Compliment Tight Bonded Lines
- Control Potentials on New Pipeline by Cross bonding and Location and Size of Rectifiers
- If Polyethylene Ductile Iron Pipe or Concrete Coated Pipe May Require Electrical Isolation and Separate Cathodic Protection Systems (More Expensive and Possible Mutual Interference)

Internal Corrosion Control Considerations

- Madison Water Hard With Tendency to Plate Out on Pipe Wall Relatively Non-Corrosive
- Cement Mortar Lining Should Work Well IF Installed Correctly, No Attack Noticed on Existing Pipeline
- Cement Mortar Has Longest Historical Performance of Metallic Pipe Linings and Most Economical
- For Flexible Metallic Pipe Requires Attention to Maintaining Pipe Roundness (Minimize Deformation)

Phase II – Develop Corrosion Control Risk Assessment

- Several Risk Assessment Methods (Bureau of Reclamation, 25 Point, DIPRA/Corrpro DMM Model, Etc.)
- 25 Point Procedure modification of 10-Point, Dillon, Washington Suburban Procedure Can Be Used For All Types of Pipe (Table 3 Handout)
- Review Risk Assessment Factors with Client Based On:
  - Corrosivity of Route
  - Life Desired
  - Function/Importance of Line
  - Hydraulic and System Considerations
  - Risk Tolerance of Owner

So How Do I Assess Risk to Select Corrosion Control Methods Needed?

- Use the 25 Point Risk Assessment Method As Check List to Determine Possible Risk and Level of Corrosion Control Needed (Summarized in more detail attached paper, Table I handout, and NACE July 2002 Materials Performance Article)
- Discuss Approach With Client Go Through What Factors I Think Are Important And Why
- Let Numbers and Experience Dictate Control Methods
- Treat Transmission Different Than Distribution, 60” vs. 6”

25 Point Risk Assessment Procedure Evaluates and Assigns Values For:

- Table 2 Example or in 2010 Paper (Handout)
- Soil Corrosivity
  - pH, Chlorides, Sulfates, Redox Potential, Soil Type, Soil Resistivity, Sulfides (sulfate reducing bacteria), and Moisture
- Pipeline Function
  - Pipe Size, Max. Pressure, Design Life, Transmission or Distribution, Copper Services, Sewer Force Mains
- Other Factors
  - Location and Leak Repair Difficulty, Interference Sources, Future Contamination, Previous Corrosion Leaks, Etc.

25 Point Risk Assessment Procedure

- Check List of Items to Consider For 15 Different Factors
  - Factors 1- 8 are corrosivity rating related
  - Factors 9 – 15 are design and pipeline related
- Numerical Values are Somewhat Arbitrary, Can Modify
- Total Point Value Determines Risk Assessment Zone
  - Zone 1 and 2 > 25 total points - Severe Rating
  - Zone 3 - 20.0 to 24.5 total points – Appreciable Rating
  - Zone 4 – 15.0 to 19.5 total points - Moderate
  - Zone 5 – 0 to 14.5 total points - Mild

Phase III Determine Corrosion Control Requirements

- Recommend Corrosion Control Requirements for Different Pipe Material Alternatives Being Considered Based on Route Corrosivity and Risk Factors
- Develop Corrosion Control Requirements For Each Pipe Type and Review with Owner and Pipe Design Engineer
- Similar Approach as Earlier Example Bureau of Reclamation (Table 2 Handout)
- RUSTNOT Approach (Transmission and Distribution (Tables 4 and 5 Handouts)

Steel Pipe Corrosion Control Methods (All Corrosive Zones)

- Tight Bonded Coatings
- Cathodic Protection (Impressed Current or Galvanic)
- Electrical Isolation
- Electrical Continuity (Joint Bonds)
- Test Stations (Closer Than Oil and Gas Lines to Allow Electrical Continuity Testing of Joint Bonds)
- Our Approach Actually Penaltilizes Steel Economically in Higher Corrosivity Zones

Steel Pipe Corrosion Control Requirements Per Zone

Corrosion Control Methods	one 1 (2,000 ohm-cm)	one 2 (2,001 – 3,000 ohm-cm)	one 3 (3,001 – 5,000 ohm-cm)	one 2 (5,001 – 10,000 ohm-cm)	one 2 (> 10,001 ohm-cm)
Tight Bonded Coatings	X	X	X	X	X
Joint Bonding	X	X	X	X	X
Cathodic Protection	X	X	X	X	X
Test Stations	X	X	X	X	X
Insulators	X	X	X	X	X

Ductile Iron

- Corrosion Procedures all way from bare pipe and fittings
- To loose bonded coating (polyethylene encasement)
- To coated fittings
- To coated pipe
- To coatings, joint bonds, and cathodic protection
- Most varied approach and most controversial pipe material concerning the need for and corrosion control
- More detail in attached paper and NRC report and Department of Interior Letter

Ductile Iron Pipe Corrosion Control Requirements Per Zone

Corrosion Control Methods	one 1 (2,000 ohm-cm)	one 2 (2,001 – 3,000 ohm-cm)	one 3 (3,001 – 5,000 ohm-cm)	one 2 (5,001 – 10,000 ohm-cm)	one 2 (> 10,001 ohm-cm)
Tight Bonded Coatings	X	X			
Polyethylene Encasement			X	X	
Joint Bonding	X	X	X	X	X
Cathodic Protection	X	X	X		
Test Stations	X	X	X	X	X
Insulators	X	X	X	X	X

Concrete Cylinder Pipe

- Specify Thicker Concrete Coating
- Concrete Coated Joints (Diaper)
- Electrical Isolation of Appurtenances (Dielectric Coated)
- Joint Bonding and Continuity Plates
- Epoxy Top-Coat In Some Cases
- Cathodic Protection In Some Cases
  - Carefully Applied To Minimize Hydrogen Embrittlement
  - Consider Zinc Anodes or Automatic Potential Rectifiers To Minimize Too High of Potentials

Concrete Pipe Corrosion Control Requirements Per Zone

Corrosion Control Methods	one 1 (2,000 ohm-cm)	one 2 (2,001 – 3,000 ohm-cm)	one 3 (3,001 – 5,000 ohm-cm)	one 2 (5,001 – 10,000 ohm-cm)	one 2 (> 10,001 ohm-cm)
Thicker Concrete	X	X	X	X	X
Epoxy Top Coat	X	X			
Joint Bonding	X	X	X	X	X
CP	X	X	X		
Test Stations	X	X	X	X	X
Insulators	X	X	X	X	X

Metallic Fittings On Plastic Lines

- Remember metallic fittings, appurtenances, tapping saddles, etc. exposed to same corrosive environment
- Consider Coating of Fittings and Anodes
- Joint Bonding of Fittings Required if CP provided
- Thinner Wall Fittings Now Being Used, No Longer Previous Corrosion Allowance
- Bolting (Fasteners) Selection Most Critical Item Stainless steel and FBE Coated
- Test Stations (Representative Sample 10% of Time)

Metallic Fittings Corrosion Control Requirements Per Zone

Corrosion Control Methods	one 1 (2,000 ohm-cm)	one 2 (2,001 – 3,000 ohm-cm)	one 3 (3,001 – 5,000 ohm-cm)	one 2 (5,001 – 10,000 ohm-cm)	one 2 (> 10,001 ohm-cm)
Coatings	X	X	X	X	X or PE
Joint Bonding	X	X	X	X	X
Cathodic Protection	X Zinc Anode	X Zinc Anode	X Mag. Anode	X Mag. Anode	
Fasteners	Stainless Steel or FBE	Stainless Steel or FBE	Stainless Steel or FBE	Stainless Steel or FBE	Stainless Steel or FBE
Test Stations (10%)	X	X	X		

Recommended Zone 1 and 2 Corrosion Control Requirements for This Project

Corrosion Control Methods	Steel Pipe	Ductile Iron Pipe	Concrete Pipe	Plastic Pipe Metallic Fittings
Tight Bonded Coatings	X	X		X
Thicker Concrete Coating			X	
Epoxy Top Coat of Concrete			X	
Insulate Appurtenances			X	
Joint Bonding	X	X	X	X
Cathodic Protection	X	X	X	X
Test Stations	X	X	X	X (10%)
Insulators	X	X	X	

Phase IV - Life Cycle Costs

- Will Utilize Data From Risk Assessment, Pipe Manufacturers, and Corrosion Supply Houses to Complete Life Cycle Cost Analysis and Predesign TM
- Calculate for Corrosion Costs Only
- Calculate Leak Costs Per Rossum (AWWA June 1969)
- Life Cycle Costs Similar For CP Tight Bonded & Loose Bonded Coated IF Only O & M Considered & Not Leaks
- Similar Results as in Oil and Gas Industry (Invest in Better Coatings, First Line of Defense)

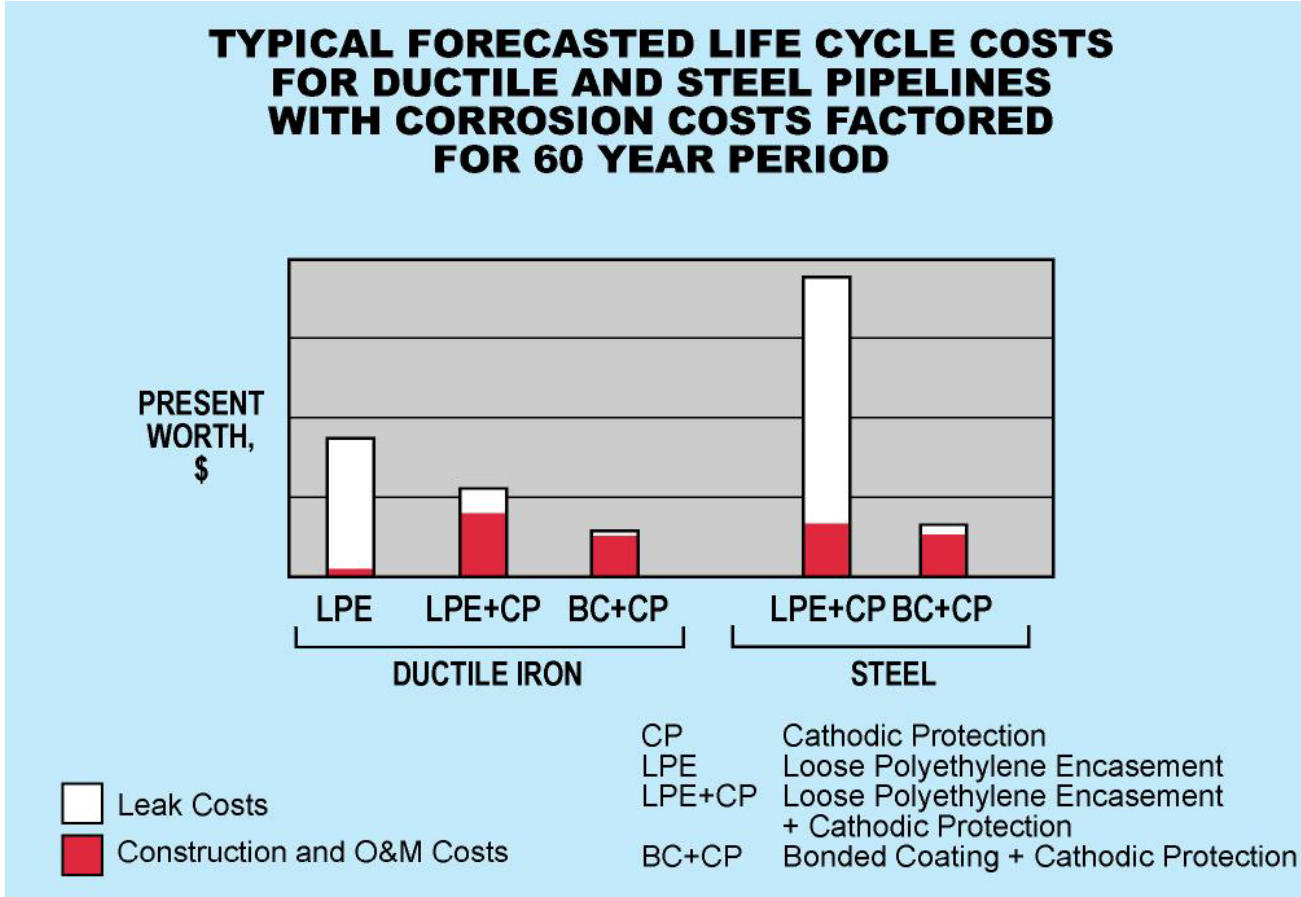
Use Risk Assessment and Life Cycle Analysis to Select Corrosion Control

- Corrosion Control Levels Can Vary From Bare to Tight-Bonded Coated With CP Depending on Risk Assessment and Economics
- CP Factors to Consider for PE versus Tight-bonded Coating:
  - CP Current Requirement (Actual Reported 28 to 62 X Coated) Larger Or More Groundbeds Required
  - Shorter Groundbed Life & Higher Replacement Costs
  - Greater Chance of Interference & Cost of Mitigation
  - Greater Cost to Accurately Monitor (Plastic pipe, resistance probes)
  - Ability to Obtain Tight Bonded Coatings if Desired
- Life Cycle (Not Only Initial Cost But Operational with Leak Costs)

Example of Steel and DIP Life Cycle Comparison

- Example Shown For 60-year Life on 24-inch Diameter Pipe
- Example for Both Loose Bonded (PE) and Tight Bonded Coatings on Both Ductile Iron and Steel
- Now Will Use 50, 80, and/or 100 Year Time Periods
- PE Lower Coating Cost But Higher CP and Monitoring Costs
- Higher Leak Costs For PE with CP Because of Less Effective Coating and Percentage Assigned as Bare

Life Cycle Cost Comparison



Life Cycle Corrosion Control Cost For Ductile Iron vs. Steel

- Coated and CP Ductile Iron Approximately $1 per lineal foot More Than Steel for Construction and O and M.
- Difference In Cost Mainly From Higher Joint Bonding Cost Because of Shorter Pipe Lengths
- CP and Tight Bonded Coating Costs Almost The Same Per Square Foot for Steel and Ductile Iron
- Coated and CP Ductile Iron Lowest Life Cycle Cost If Leaks Considered
- Result of Thicker Wall DIP in Leak Calculations

Concrete and Plastic Pipe Life Cycle

- Will Utilize Similar Approach For Concrete and Plastic Pipe
- Concrete Pipe Will Have A Thinner Steel Cylinder that Either Ductile Iron or Steel Pipe Alternatives, So Leak Rates Will Be Higher
- Plastic Pipe Will Have Lower Leak Rates As Corrosion Minor Issue, But Will Assign a Factor for Dig-Ins

Benefit to Cost Ratio for Corrosion Control

- Based on Study by East Bay MUD (Oakland)
  - Review 45 year of their corrosion control program of coatings and cathodic protection
  - Water Distribution Piping was 24 to 1
  - Water Transmission was 42 to 1
- They are convinced that they can not afford not to apply coatings and cathodic protection to all metallic pipe and fittings

Department of Interior Letter Cost Analysis Table 1

- In response to claims by DIP, Reclamation conducted a cost analysis on Reclamation projects and concluded:
- Using the cost/inch diameter/foot metric indicates steel pipe bids were about 10% higher when DIP did not bid and ductile iron bids were about 8% higher when steel did not bid.
- Using the more commonly acceptable cost per pound metric, steel prices when DIP did not bid were slightly lower (about 4%) than when DIP did bid.

Department of Interior Letter Life Cycle Cost Analysis

- Reclamation life cycle cost analysis for DIP with PE and CP were nearly 5% higher than comparable steel with coating and CP, if pipe prices and leak costs were not considered.

- Reclamation analysis for total life cycle costs for DIP with PE and CP were nearly 19% higher than comparable steel with coating and CP, if pipe prices and cost of leaks were included.

Department of Interior Letter Cost Analysis, Reclamation Concluded:

- "Therefore, while the decision by DIP manufacturers not to supply their pipe with a bonded dielectric coating may lead to fewer bidders on Reclamation pipeline projects installed in severely corrosive soils, this analysis indicates the initial and long-term economic effects of this reduced competition is relatively modest. We consider this modest additional incremental cost acceptable given the increased likelihood that the pipeline will provide performance for the long-term (50 year minimum) service life of the project."

Phase V Specifications and Designs

- Develop Specifications and Designs That Are Commensurate With the Corrosivity and Risk Assessment
- Provide Anticipated Equal Life to All Pipe Products Being Considered
- This May Require Different Corrosion Control Measures Depending on the Pipe Types

Phase VI SDC Training, Inspection, Final Testing and O and M Training

- Conduct Pipe Plant Inspections to Verify Coating and Welding Procedures
- Provide Pipe School at Start of Construction to Train Contractor, Engineer, and Owner on Corrosion Control
- Conduct Inspection at Critical Times and Provide Technical Assistance to Engineer During Construction
- Require Contractor to Test Joint Bonds (DLRO), Field Coatings, Test Stations, and Tracer Wires
- Conduct Final Testing, Train Owner and Provide O & M

We Need To Be Smart and ACT Accordingly To Minimize Long Term $

- Correctly Considering and Implementing Corrosion Control in Initial Design and Construction Stage Will Have More of A Major Influence on Pipe Life and Actual Long Term Costs than structural, water pressure, or soil stresses.
- So Accurately Identify Risk and Act Accordingly
- Use Corrosion Knowledge NOT Sales Pitches or Political Pressure
- Look at Life Cycle Costs Not Just Initial Cost
- Thank You, Glad To Try and Answer Any Questions?

APPENDIX I

AC&C Cathodic Presentation

AC&C Companies, Inc.

Corrosion Protection

Who we are. . .

- Woman Owned Self Certified Small Business Firm Incorporated in Colorado in in 1995
- Based in Aurora, Colorado But Serving Across USA from California to Florida
- Offering NACE Certified & Professional Engineering Services with Over 30 years of Industry Experience

What we do. . .

AC&C is a Technical Service Company providing corrosion engineering services including:

- Corrosion Control Evaluations
- Corrosion Control Design Plans and Specifications
- Project Management for Construction Activities
- Cathodic Protection Surveys/Audits
- EPA, DOT Compliance Inspections
- Corrosion Control Training

Markets Served

Regulated and Unregulated Client Base

Markets Served . . .

Regulated

- Airlines Aviation Fueling Systems
- Oil / Gas Production / Processing Industry
- Natural Gas Transmission & Distribution Industry
- Fuel / Oil Storage Systems

Regulated Clients

DENVER INTERNATIONAL AIRPORT

ASIG

Continental Airlines

TESORO

Hertz

Sinclair

Chevron

UNITED

bp

MOLSON Coors

Roche

Markets Served

UnRegulated

- Electric Power Production & Transmission
- Transit Industry - Light Rail Systems
- Water Works Industry
- Concrete Structures

UnRegulated Clients

RTD

MTS

HYATT

CDM

UTA

CH2M HILL

Qwest

DENVER WATER

SOUNDTRANSIT

City of St. George

TETRA TECH

Brown AND Caldwell

Waterworks . .

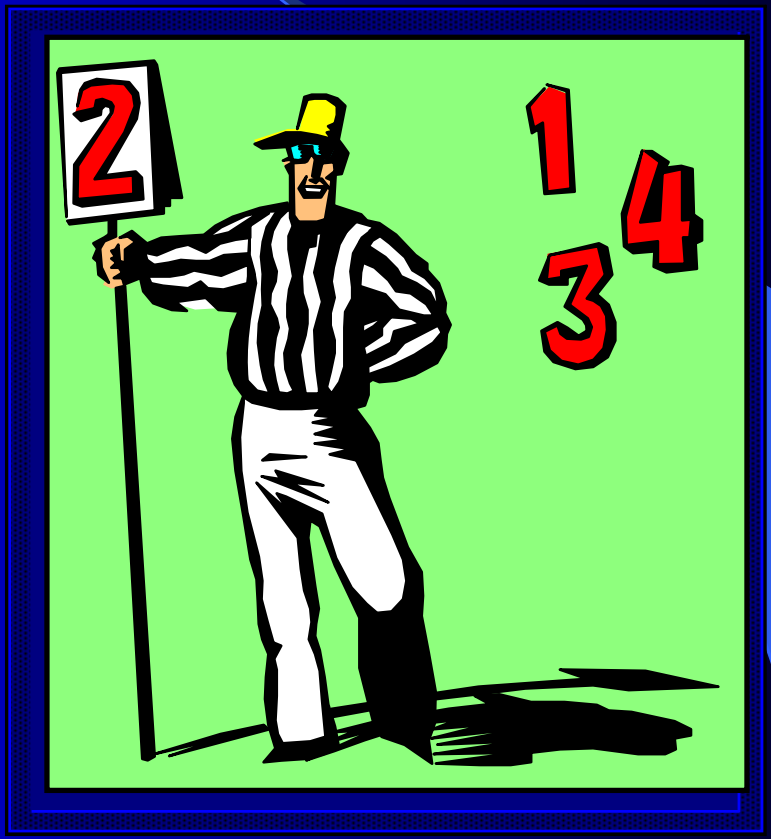
- **Water & Waste Water Systems**
  - Water Wells
  - Water Reservoirs / Tanks
  - Water Transmission / Distribution Pipelines
  - Water & Wastewater Plant Equipment
    - Treatment Vessels (filter beds, clarifiers, flocculators)
    - Lift Stations
    - Process Piping

Corrosion Facts

- Corrosion is defined as the degradation of a material or its properties due to a reaction with the environment.
- While corrosion exists in virtually all materials, it is most often associated with metals.
- Latest NACE Study Indicates Current Cost Estimate of USA Corrosion = ~$227 Billion/year
- On July 31, 2009, Congressman Kevin Brady, 8th District Texas, introduced H.R. 3462, the "Corrosion Prevention Act of 2009," which will provide the energy industry with a tax credit for costs associated with preventing or mitigating corroding metals

THERE ARE ONLY TWO (2) BASIC FORMS OF CORROSION

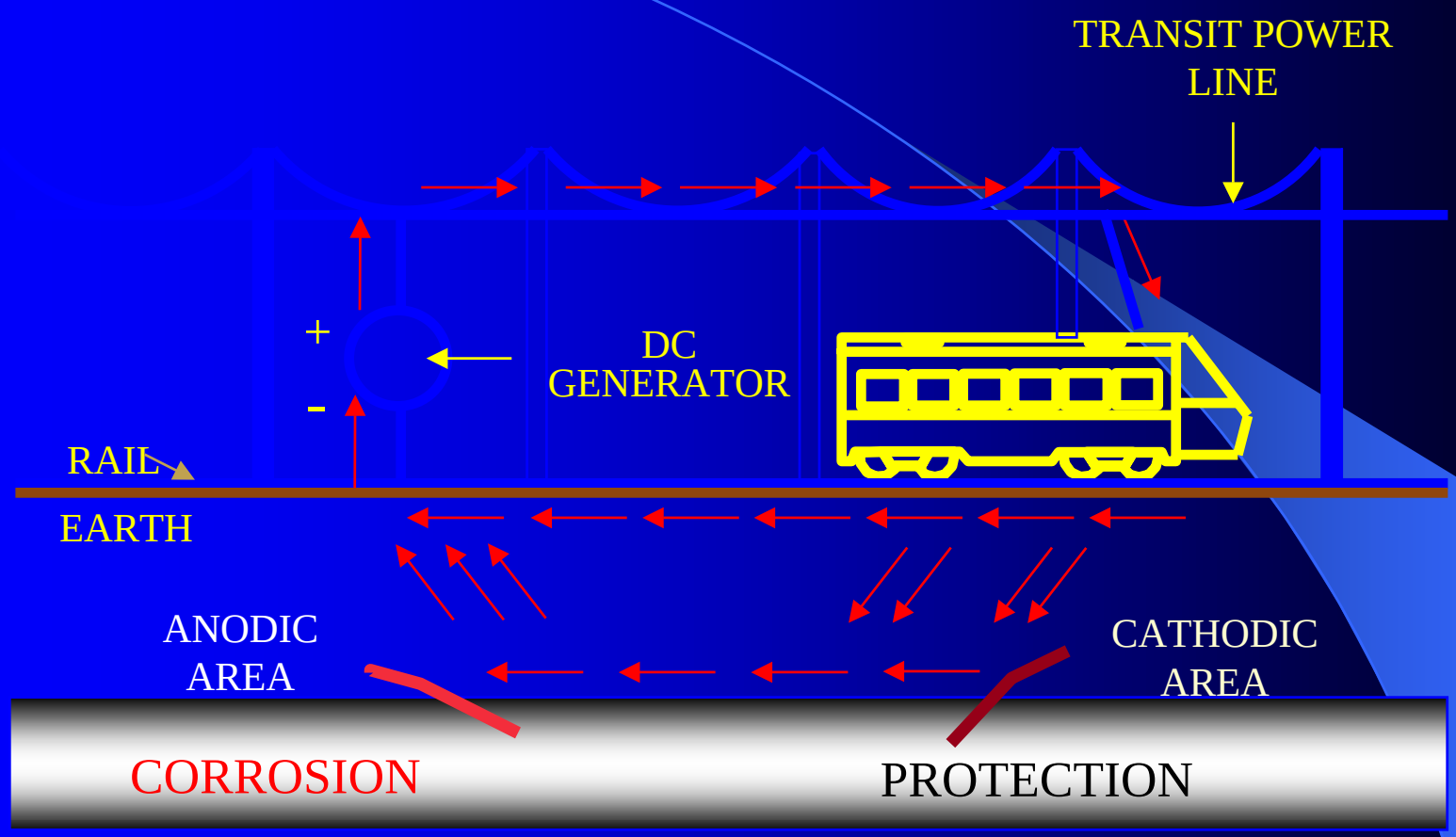
- Stray Current
- Naturally Occurring Galvanic



STRAY CURRENT CORROSION

- MOST COMMONLY A MAN MADE CORROSION
- AN EXTERNAL SOURCE OF DIRECT CURRENT (DC) TRAVERSING THROUGH THE SOIL (ELECTROLYTE) STRAYS ONTO THE STRUCTURE
- CATHODIC REACTIONS OCCUR (protection) WHERE THE CURRENT IS PICKED UP BY THE STRUCTURE
- ANODIC REACTIONS OCCUR (corrosion) WHERE THE CURRENT LEAVES THE STRUCTURE

STRAY CURRENT CORROSION



Steel Pipe

GALVANIC CORROSION

- Natural, Predictable, Controllable Process
- Metals Corrode in an attempt to achieve a Balance of Energy

FOUR ITEMS REQUIRED FOR CORROSION

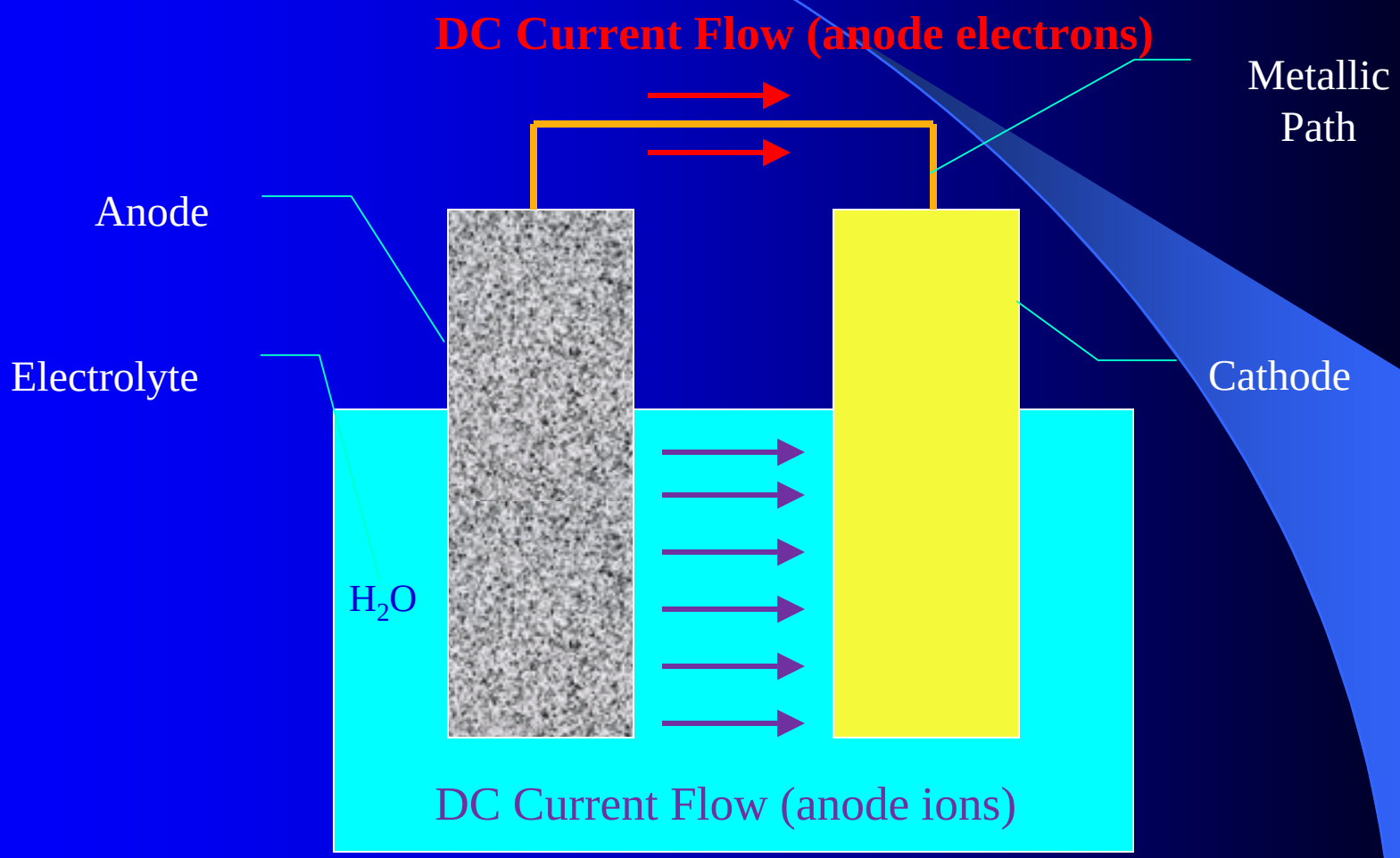
ANODE

CATHODE

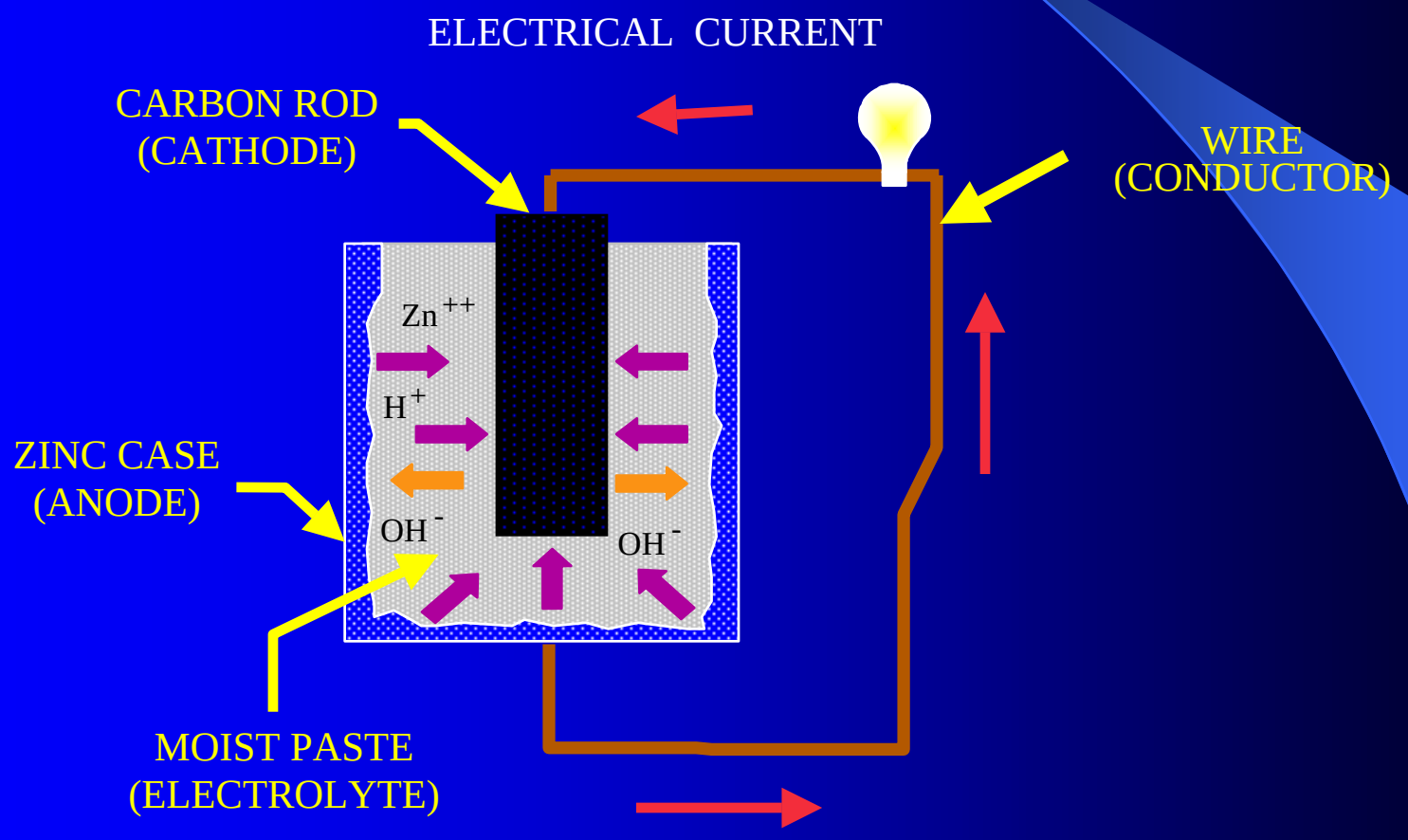
IONIC CONDUCTOR (Electrolyte)

ELECTRON CONDUCTOR (Metal Structure)

Corrosion Cell

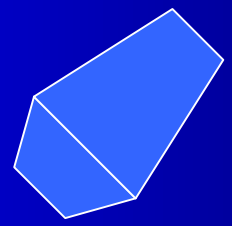


A COMMON DRY CELL BATTERY IS A GALVANIC CORROSION CELL

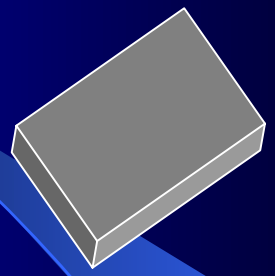


The making of a metal structure...

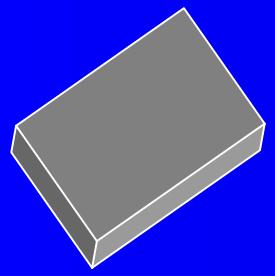
Iron Ore



Furnace



Steel

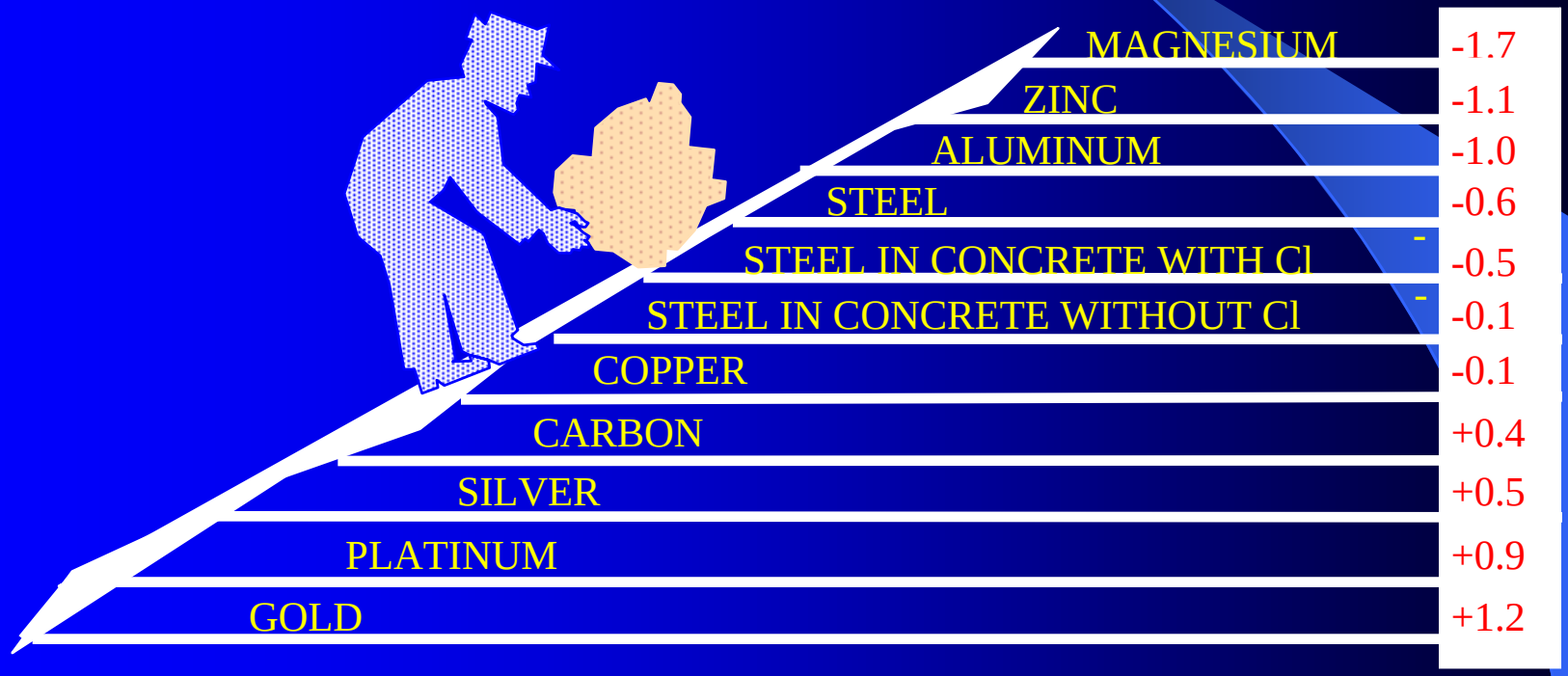


Steel

Tank or Pipe

Relative Energy Levels of Various Refined Metals

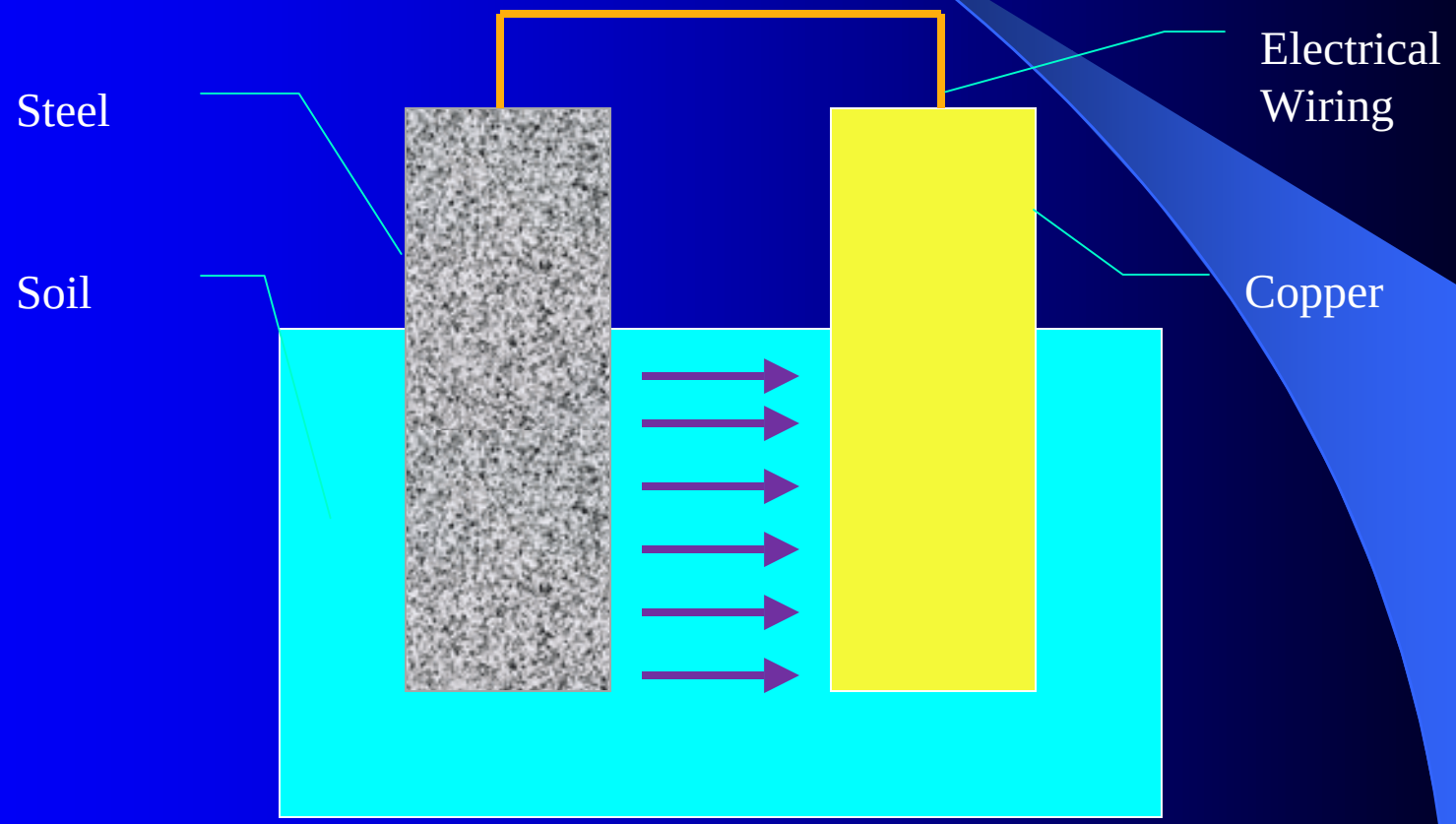
Energy Level in Volts vs. $Cu/CuSO_4$ Reference



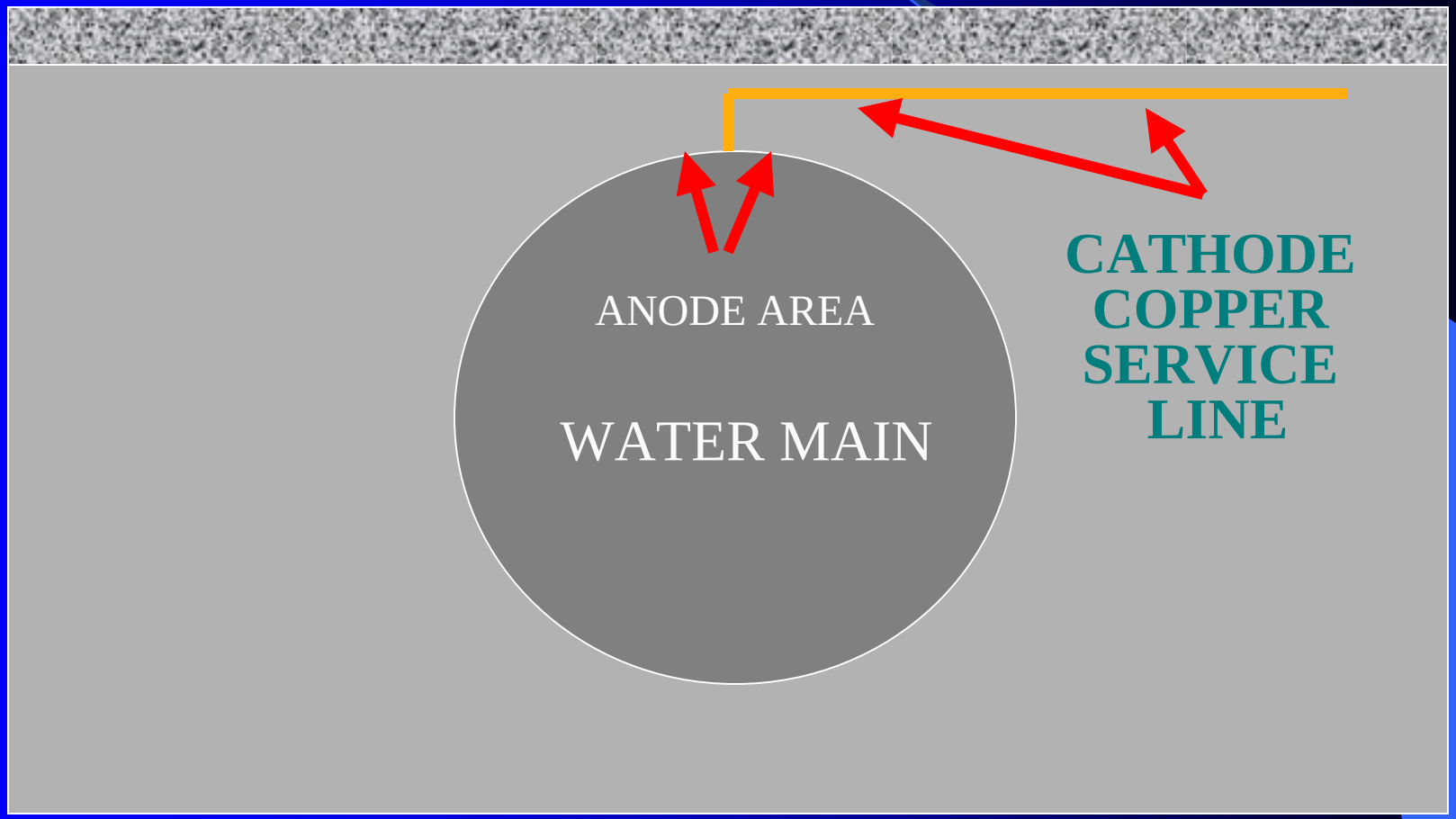
NATURALLY OCCURRING CORROSION

- 3 BASIC MECHANISMS
  - –DISSIMILAR METAL
  - –DISSIMILAR ELECTROLYTE
  - –OXYGEN CONCENTRATION

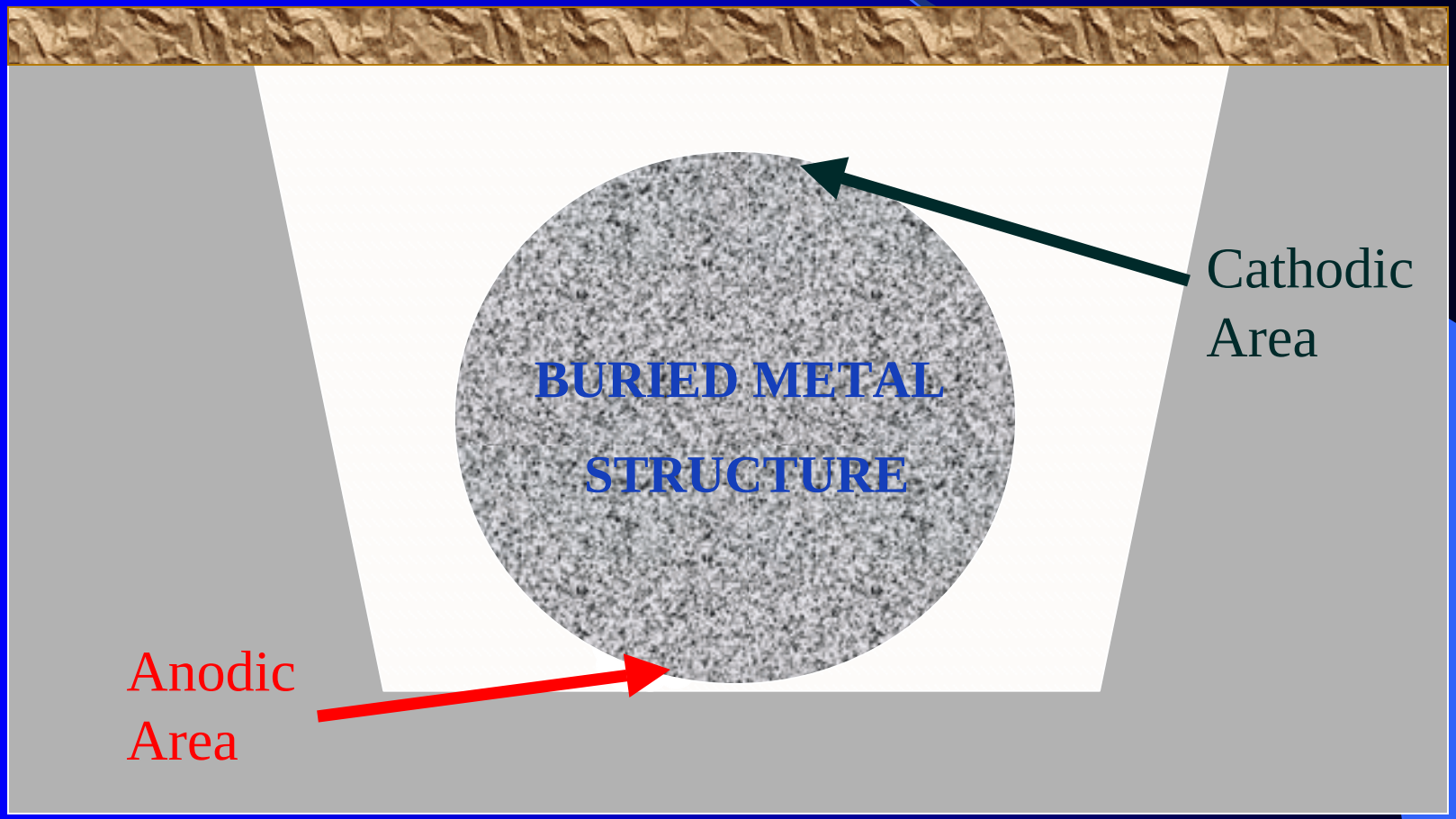
Bi-metallic Corrosion
(DISSIMILAR METALS)



DISSIMILAR METALS

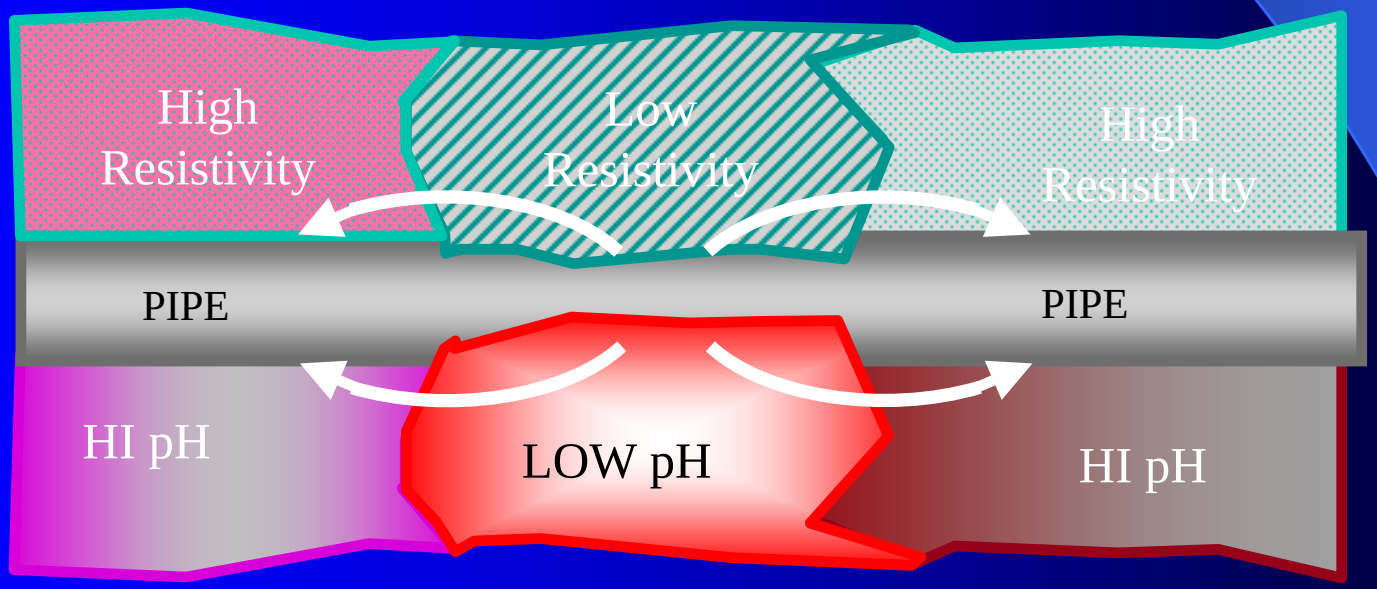


Non-Homogenous Backfill Oxygen Concentration Cell



DISSIMILAR ELECTROLYTE CORROSION

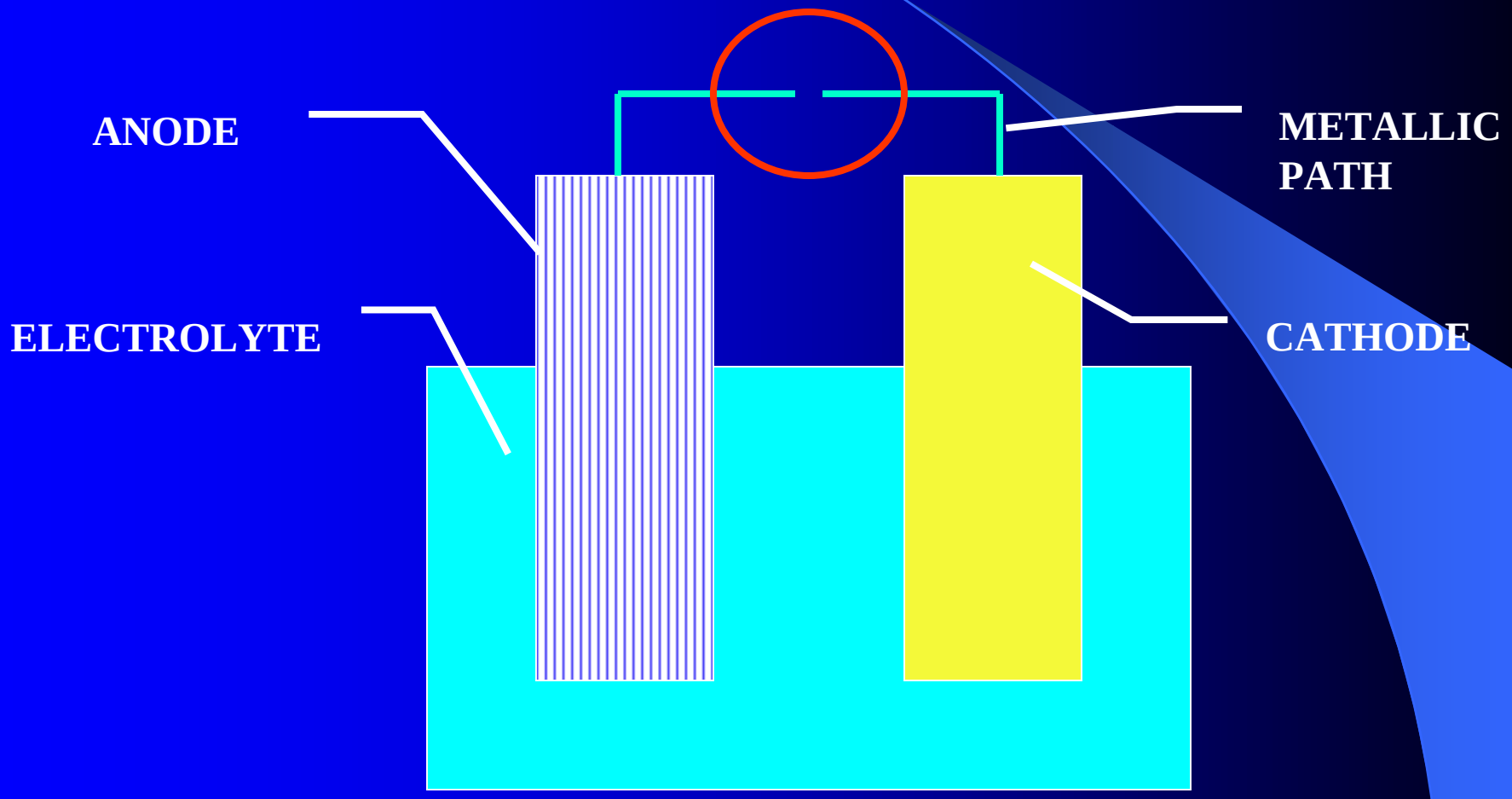
- CAUSED BY VARIATIONS IN SOIL CHEMISTRY AND PHYSIOLOGY



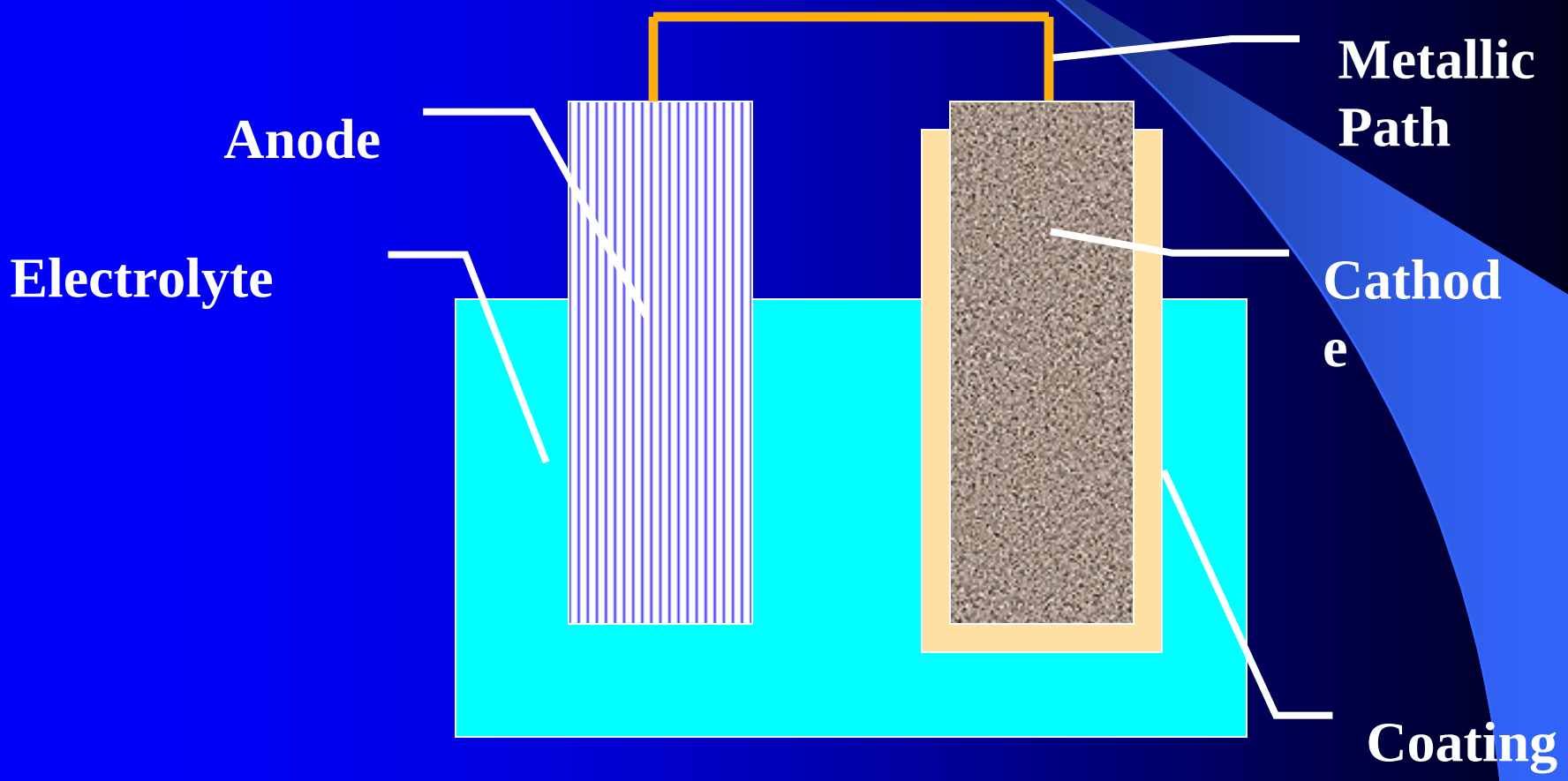
Corrosion Control

- Isolation
  - Breaks the connection between different metals
- Coatings
  - Isolates the structure from the electrolyte.
- Cathodic Protection
  - Creates a corrosion cell where the structure is the cathode instead of the anode.

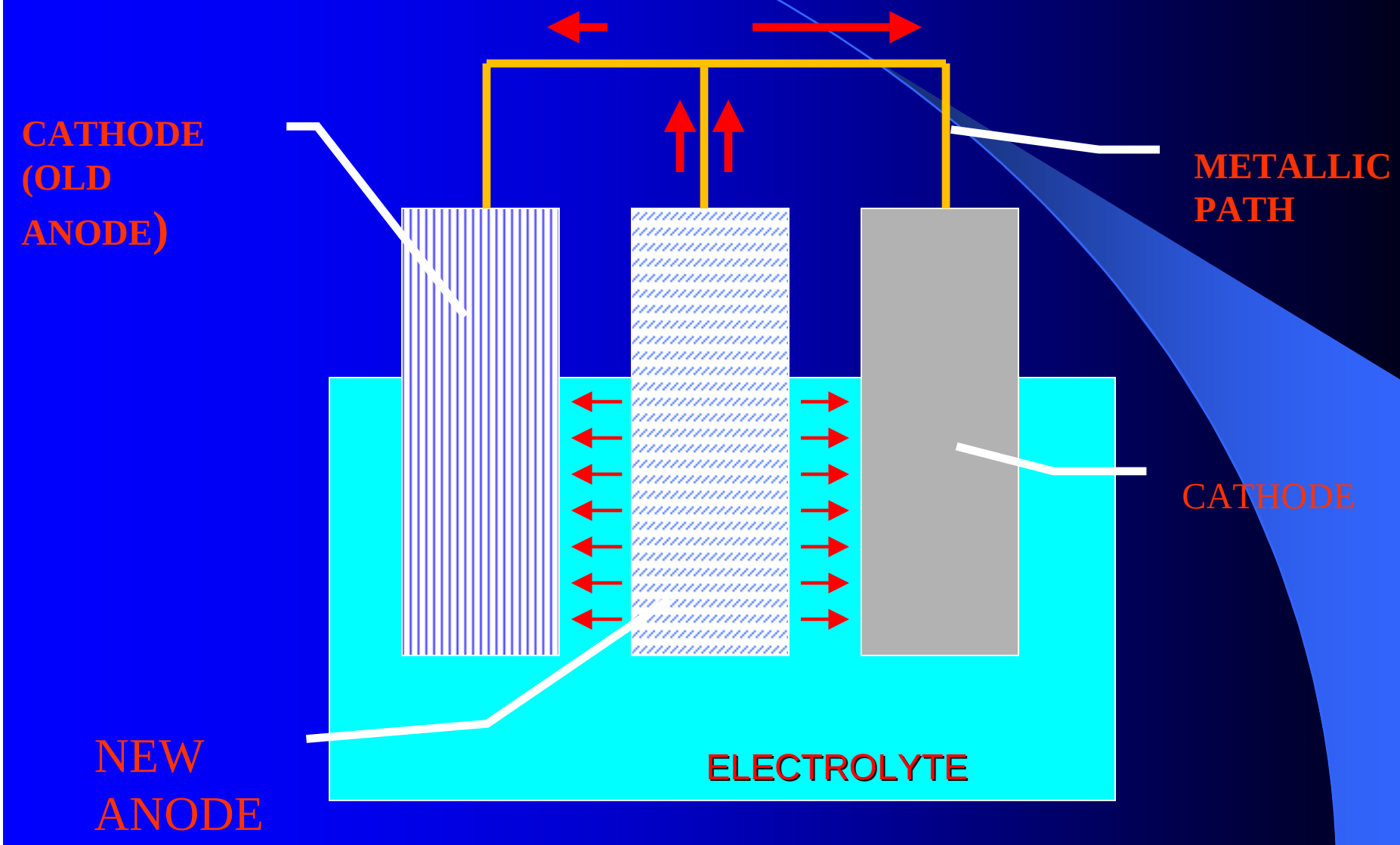
Electrical Isolation



Coatings



Cathodic Protection



Cathodic Protection

- Galvanic
  - Uses the energy inherent in different materials to create current flow. For example high energy magnesium as anode for buried or submerged steel.

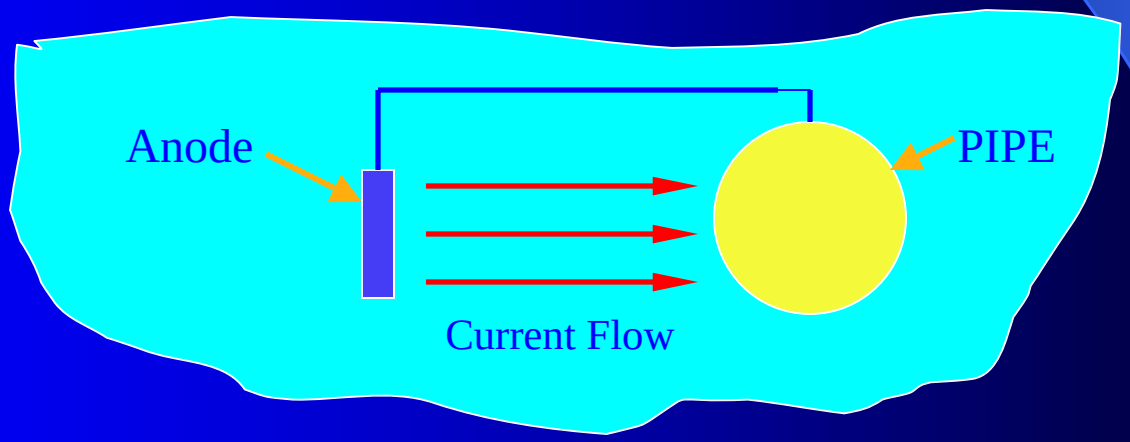
- Impressed Current
  - Uses an outside power source to create current flow.

Galvanic Cathodic Protection

- Low Cost
- Limited current output
- Often used in new construction applications
- Typically used with coatings for corrosion control
- Typically used with dielectric fittings to contain current

Galvanic Cathodic Protection

DIRECT ANODE CONNECTION

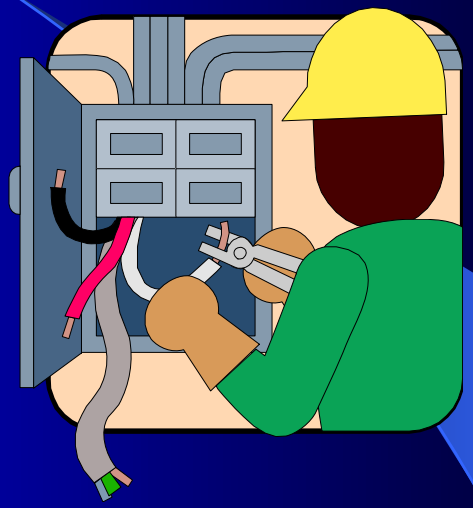


GALVANIC ANODE

Impressed Current Cathodic Protection

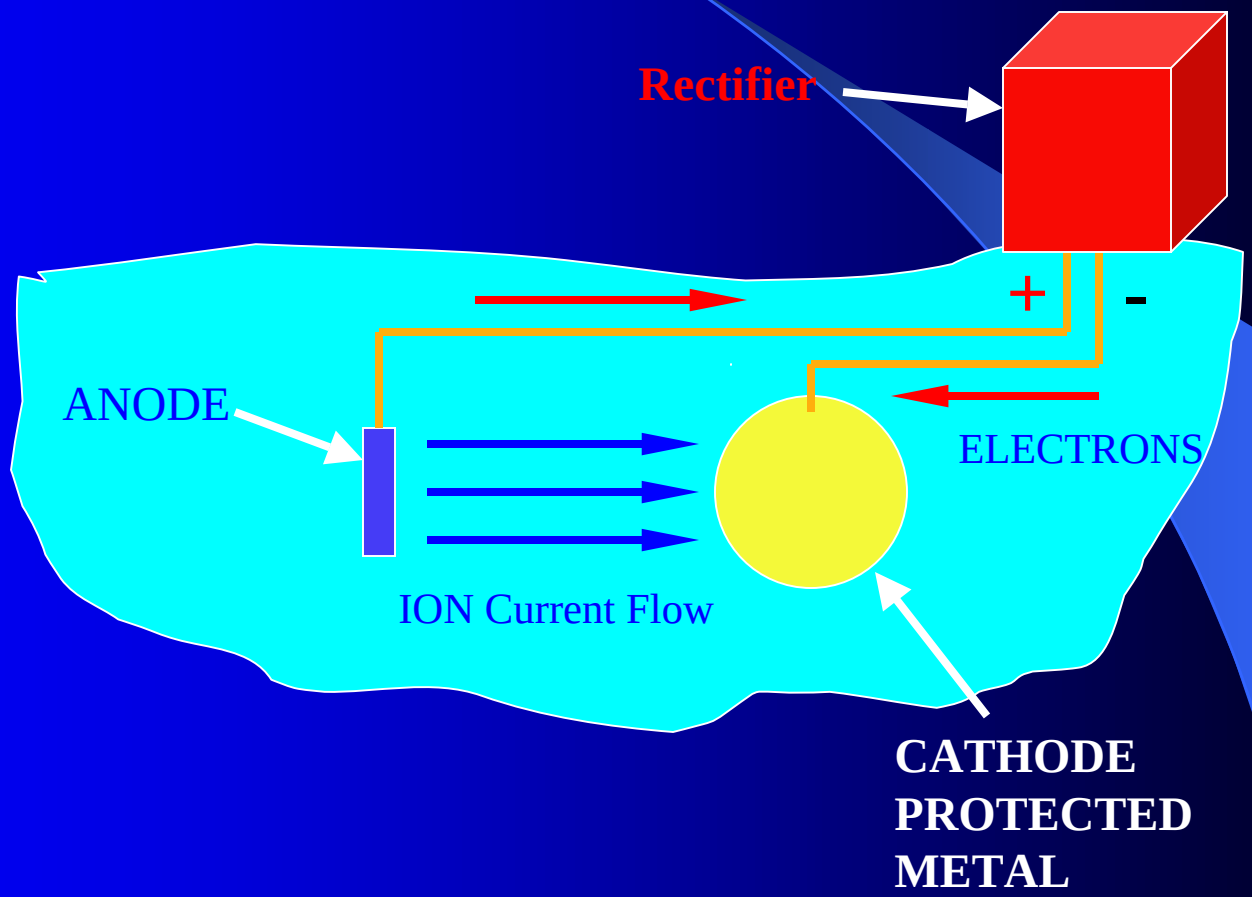
- Unlimited power available
- Typically used where large surface areas must be protected
- Often the only choice for upgrade of existing piping systems
- Requires bi-monthly rectifier monitoring
- Allows maximum flexibility in design
- Can create electrolytic corrosion

Impressed Current System



- Typically includes:
  - Rectifier
  - Anodes
  - Junction Box
- The negative connection from the rectifier ALWAYS goes to the structure being protected!

Impressed Current Cathodic Protection



RECTIFIER

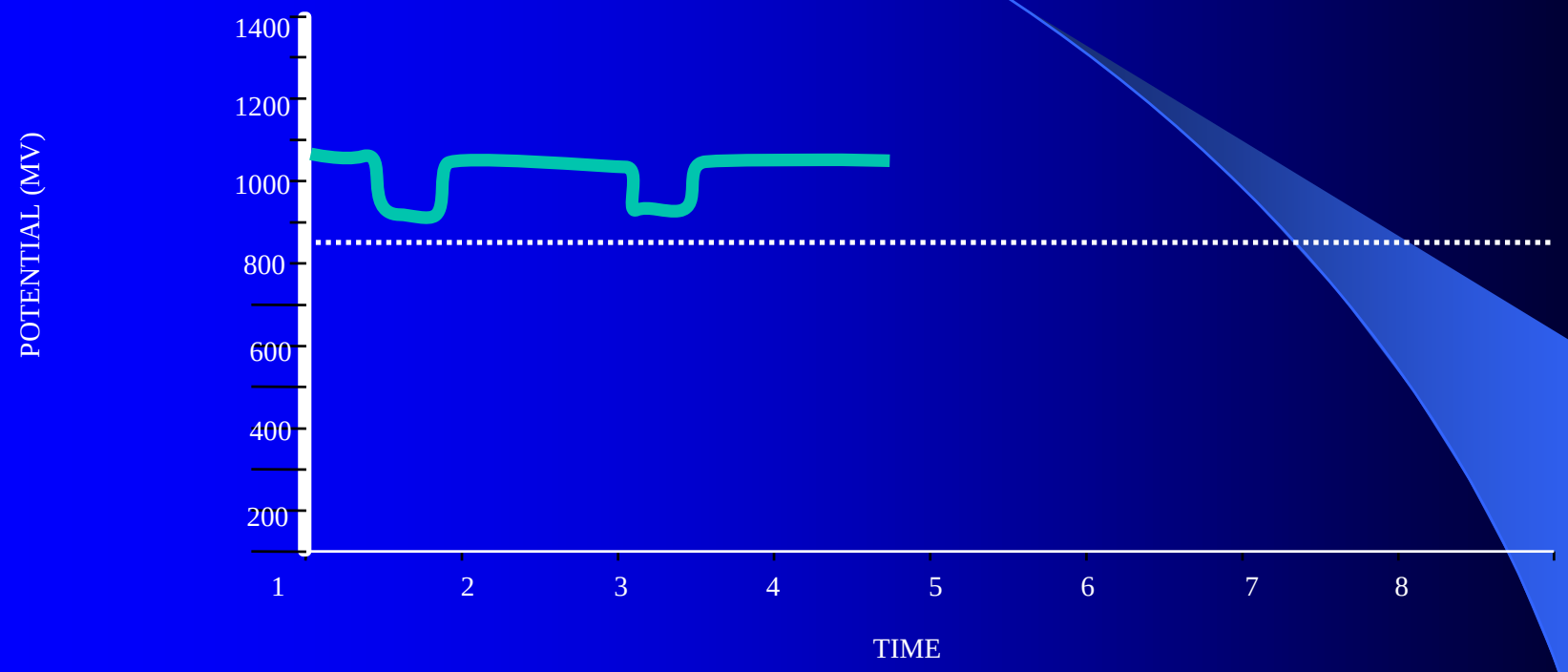
USED FOR IMPRESSED CURRENT CATHODIC PROTECTION

RECTIFIER MODELS DIFFER BY MANUFACTURER AND PROJECT SPECIFCATIONS

Cathodic Protection Criteria

- 850 mV Structure to Soil Potential
  - Potential measured with a copper/copper sulfate reference cell and voltmeter. Measurement must allow for IR Drop.
- 100 mV Polarization
  - Requires record of potential of structure prior to application of cathodic protection

IR drop must be removed from the measurement to obtain the actual potential of the structure.



Eliminate the current flow for a short time period, I = 0 AND I x R = 0

Regulations

THE LAW

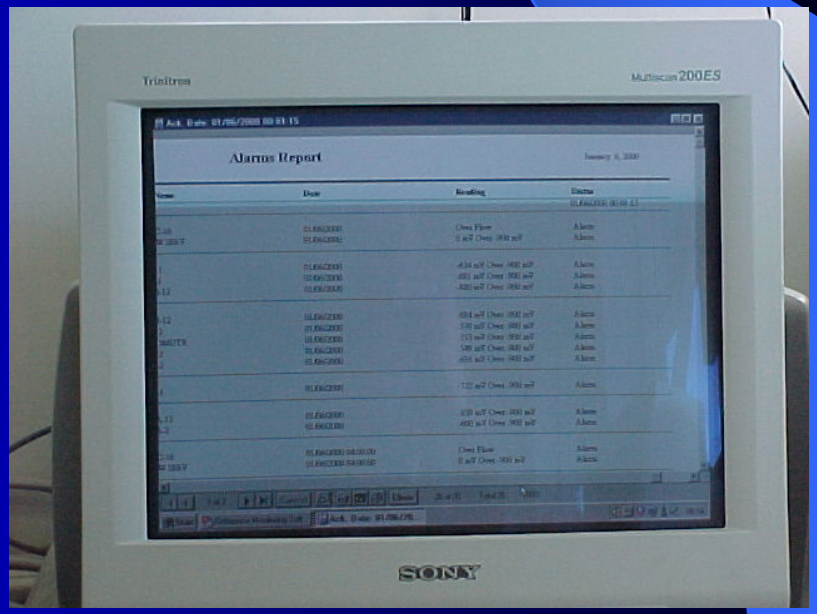
- DOT
- EPA

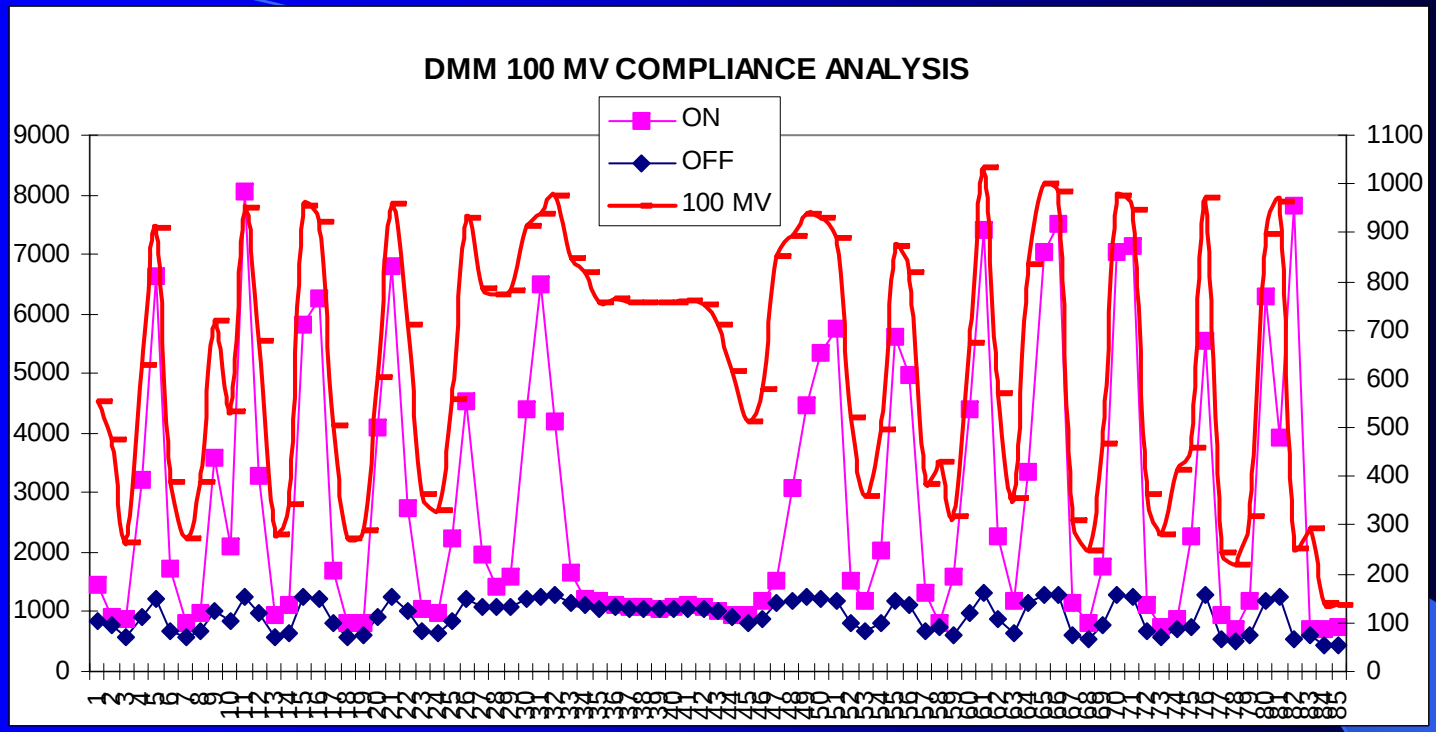
Design & Performance Standards

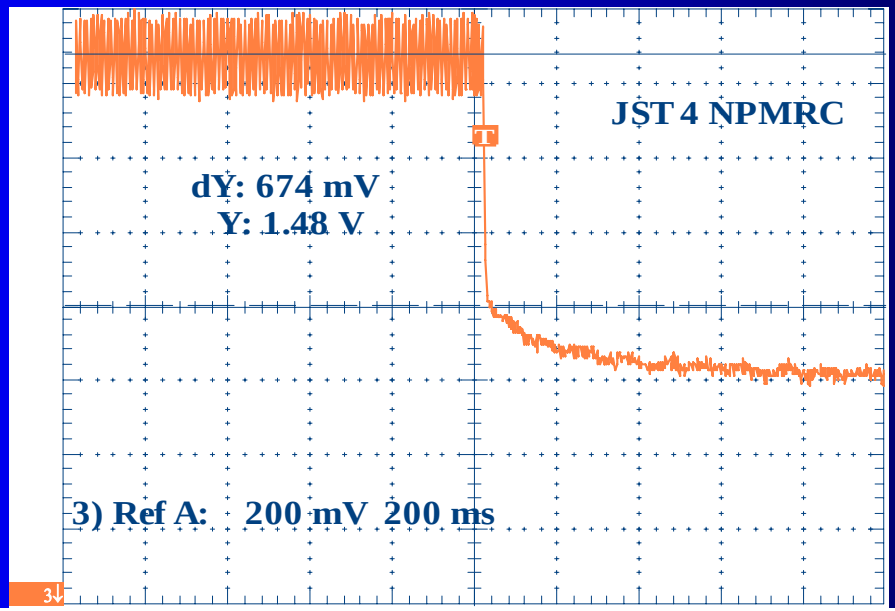
STANDARDS

- NACE
- AWWA

Paris
13 5:46PM


Trinitron
Multiscan 200ES
Alarms Report
SONY


DMM 100 MV COMPLIANCE ANALYSIS
ON
OFF
100 MV
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
1100
1000
900
800
700
600
500
400
300
200
100
0

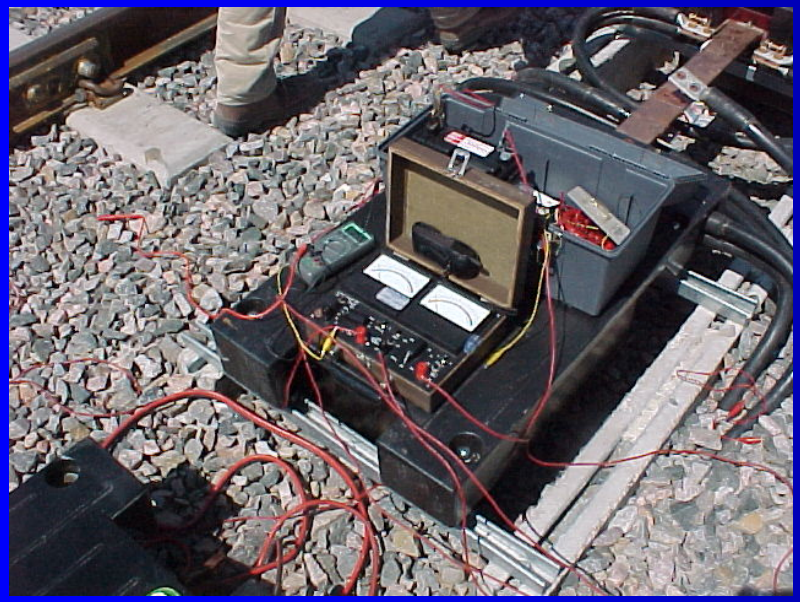

JST 4 NPMRC
dY: 674 mV
Y: 1.48 V
3) Ref A: 200 mV 200 ms

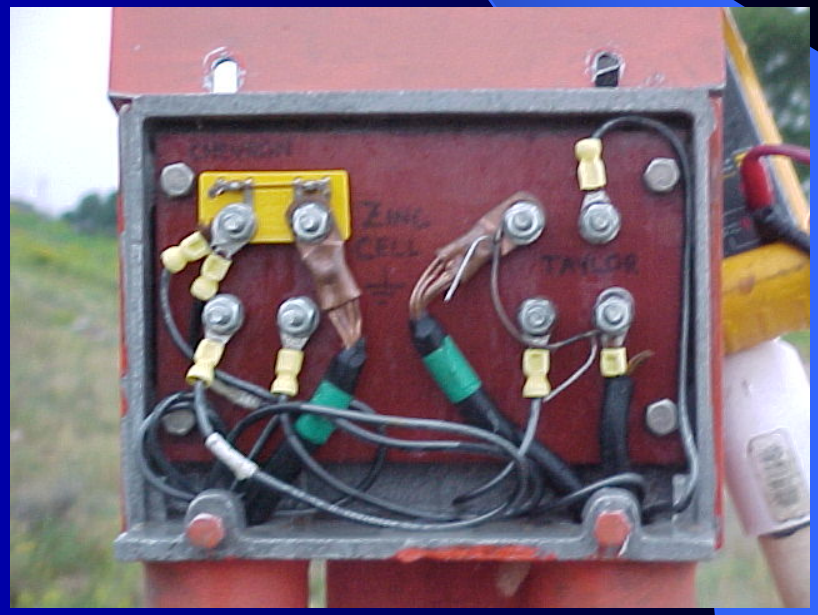
7

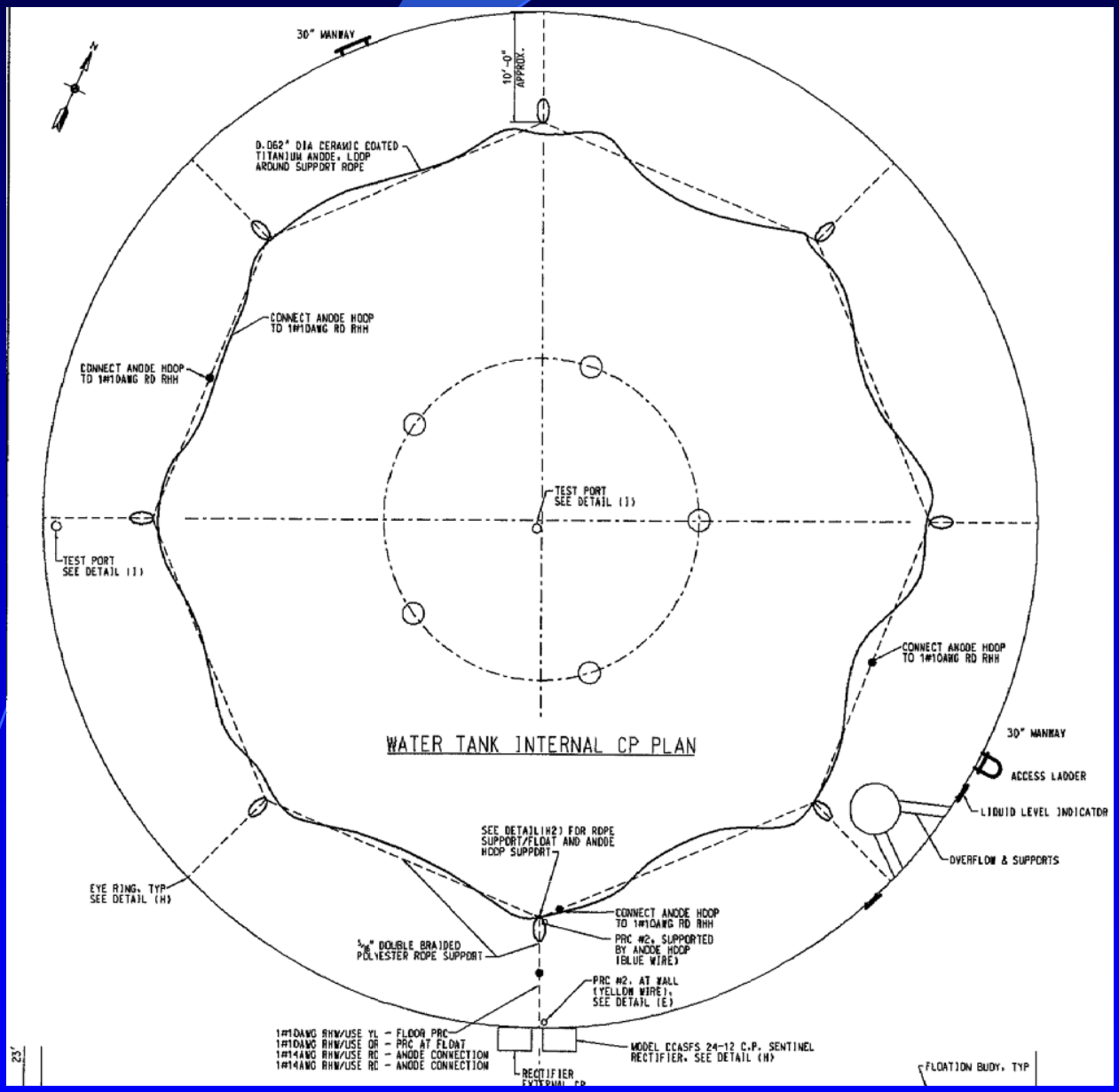
Universal
RECTIFIERS

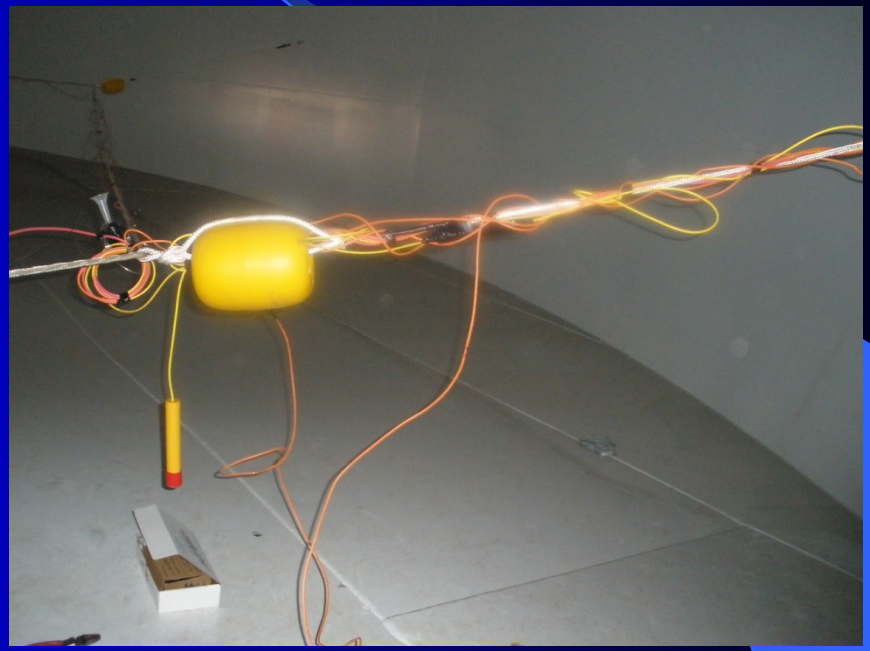
2008. 9. 18

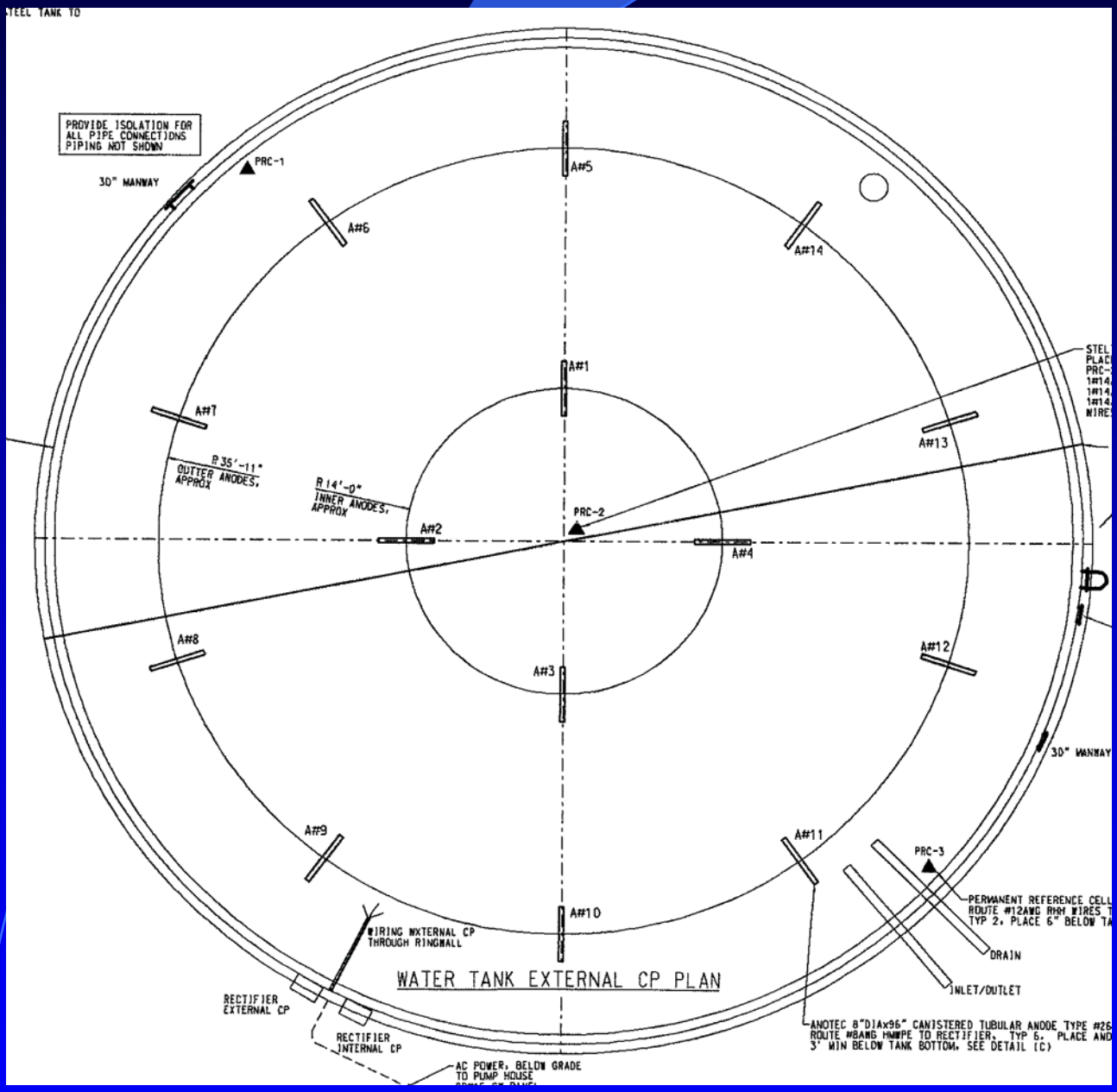
OUT OF SERVICE
RTD

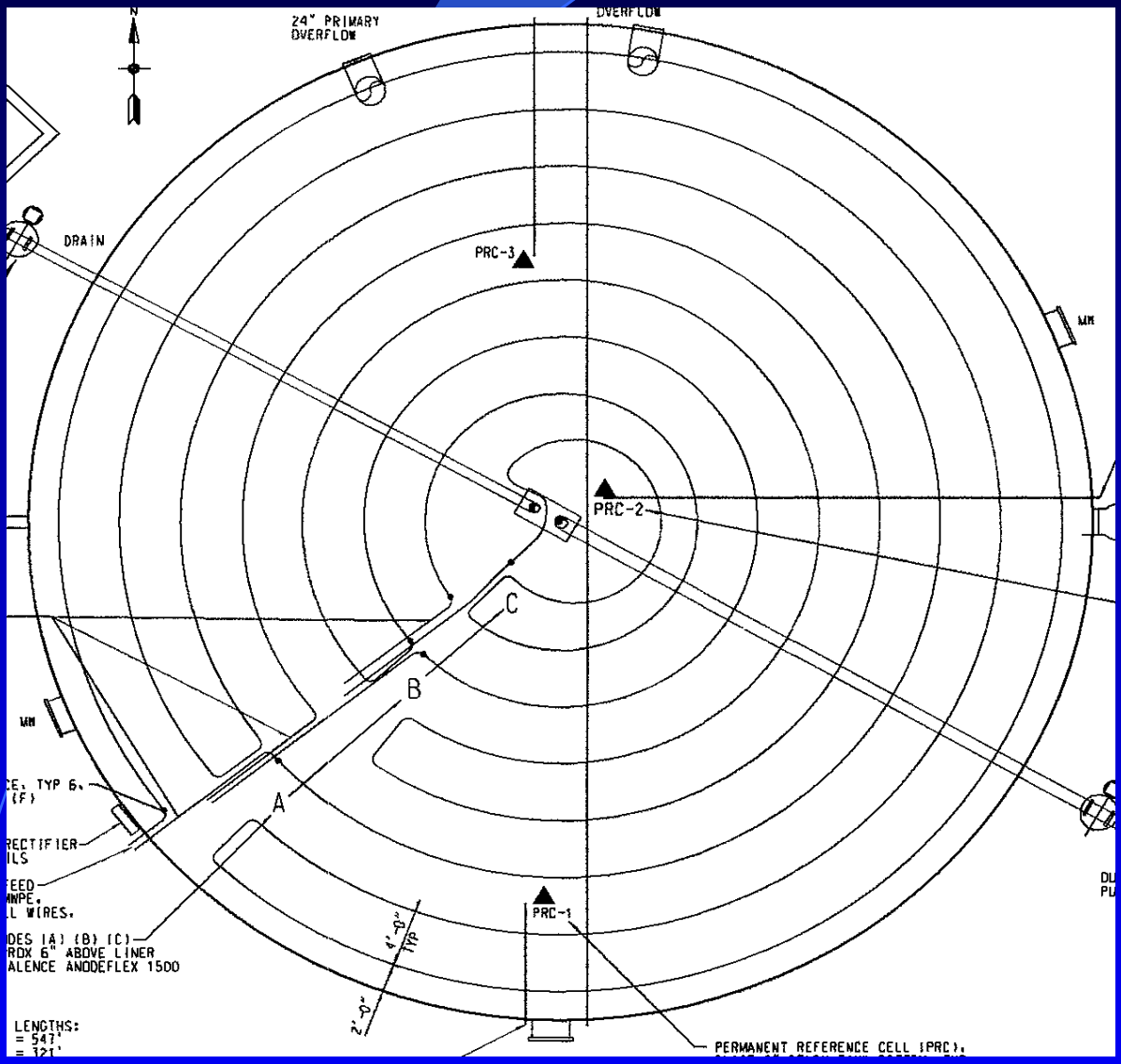



ZINC
CELL
TAYLOR


30" MANWAY
10'-0" APPROX.
0.062" DIA CERAMIC COATED TITANIUM ANODE, LOOP AROUND SUPPORT ROPE
CONNECT ANODE HOOP TO 1#10AWG RD RHH
CONNECT ANODE HOOP TO 1#10AWG RD RHH
TEST PORT SEE DETAIL (I)
TEST PORT SEE DETAIL (I)
CONNECT ANODE HOOP TO 1#10AWG RD RHH
WATER TANK INTERNAL CP PLAN
30" MANWAY
ACCESS LADDER
LIQUID LEVEL INDICATOR
OVERFLOW & SUPPORTS
SEE DETAIL (H2) FOR ROPE SUPPORT/FLOAT AND ANODE HOOP SUPPORT
EYE RING, TYP SEE DETAIL (H)
CONNECT ANODE HOOP TO 1#10AWG RD RHH
PRC #2, SUPPORTED BY ANODE HOOP (BLUE WIRE)
5/16" DOUBLE BRAIDED POLYESTER ROPE SUPPORT
PRC #2, AT WALL (YELLOW WIRE), SEE DETAIL (E)
1#10AWG RHW/USE YL - FLOOR PRC
1#10AWG RHW/USE OR - PRC AT FLOAT
1#14AWG RHW/USE RD - ANODE CONNECTION
1#14AWG RHW/USE RD - ANODE CONNECTION
MODEL CCASFS 24-12 C.P. SENTINEL RECTIFIER. SEE DETAIL (H)
RECTIFIER
23'
FLOATION BUOY, TYP




PROVIDE ISOLATION FOR ALL PIPE CONNECTIONS PIPING NOT SHOWN
30" MANWAY
PRC-1
A#5
A#6
A#14
A#1
A#7
A#13
R 35'-11" OUTTER ANODES, APPROX
R 14'-0" INNER ANODES, APPROX
PRC-2
A#2
A#4
A#8
A#12
A#3
30" MANWAY
A#9
A#11
PRC-3
A#10
WIRING NXTERNAL CP THROUGH RINGWALL
WATER TANK EXTERNAL CP PLAN
DRAIN
INLET/OUTLET
RECTIFIER EXTERNAL CP
RECTIFIER INTERNAL CP
AC POWER, BELOW GRADE TO PUMP HOUSE


N
24" PRIMARY
OVERFLOW
OVERFLOW
DRAIN
PRC-3
MH
PRC-2
C
B
A
MH
RECTIFIER
ILS
FEED
WIRES.
DES (A) (B) (C)
RDX 6" ABOVE LINER
ALENCE ANODEFLEX 1500
PRC-1
4'-9"
TYP
2'-9"
LENGTHS:
= 547'
= 321'
PERMANENT REFERENCE CELL (PRC).

POOR WORKMANSHIP?

Corrosion Prevention Act of 2009

HR 3462

Energy Industry Tax Credit for Corrosion Control

- 50% tax credit for energy industry that employ corrosion control technologies
- Activities must exceed federal, state, or local requirements.

Tax Credit Applies to All Major Energy Sources

50% tax credit applies to:

Biofuels	Nuclear
Coal	Solar
Oil	Wind
Natural Gas	Alternative Sources

Tax Credit Applies to All Major Phases of Energy Production

50% tax credit applies to all energy industry:

- Exploration
- Production
- Refining
- Transportation

Tax Credit Applies to All Major Corrosion Control Expenditures

50% tax credit applies to corrosion control expenditures for:

- Engineering design
- Materials
- Application
- Installation

Promotes Leading Corrosion Control Technologies

50% tax credit applies to leading corrosion control technologies:

- Protective coatings
- Chemical treatment
- Corrosion resistant metals
- Cathodic protection

- **NACE Legislative Day 2010**
- **May 5-6, 2010**
  Holiday Inn Capitol Hill
- **Take a Stand Against Corrosion! Pull up a chair with your legislator May 5-6, 2010, at the NACE Legislative Day in Washington, D.C., and help raise awareness of corrosion and corrosion prevention**