External Corrosion Comparisons: Steel & Ductile-iron Pipe

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Introduction

Steel and ductile-iron are the two primary water transmission pipeline materials presently in use throughout the United States for pipe diameters 24" and larger. The steel pipe and ductile-iron pipe industries have differing opinions on what levels of protection their products should receive in corrosive environments, even though both products are ferrous materials. Both materials' chemical composition is approximately *95%* iron (Fe). Therefore, it is expected that both materials will react similarly to corrosive environments. *See Fig. 1.*

Figure 1 *[References 7 & 24]*

Chemical Composition		
Material	Steel	Ductile-Iron
Carbon (%)	0.15 - 0.25	2.00 - 3.80
Manganese (%)	1.5	0.02 - 1.25
Silicon (%)	0.01 - 0.40	1.10 - 2.80
Phosphorus (%)	0.04	0.15
Sulfur (%)	0.04	0.2
Iron (%)	97.77 - 98.26	91.80 - 96.35

This paper is intended to clarify the two industries' corrosion protection differences by 1) reviewing some ductile-iron pipe claims and facts, supported by published technical information, 2) presenting side-by-side comparisons of the industries' corrosion protection recommendations, 3) reviewing the six levels of corrosion protection for installed pipelines, and 4) providing recommendations for the proper use of both materials in potentially corrosive environments.

How Important is Corrosion Protection?

The United States annual estimated cost of corrosion for water and sewer systems is $36 billion. The country experiences over 240,000 pipe breaks per year, over 90% corrosion related. The costs in dollars, customer inconvenience, and potential health hazards are unacceptable. Pipeline system owners and operators should develop sound asset management programs including the principle that pipeline corrosion is unacceptable and controllable. Present day corrosion protection technology offers a variety of methods to support this belief. Allowing corrosion permits the loss of assets while controlling corrosion retains assets. With operating budgets continuing to shrink, there is even more reason to invest capital project dollars into long-term asset protection strategies.

When evaluating pipeline designs, two basic considerations should be included. First, consider corrosion protection from an engineering perspective. A pipeline's design team should determine the protection necessary for a system to function through its design life. Since several corrosion protection solutions exist, the second consideration is to determine what level is best for the taxpayer and/or owner's investment. Full life cycle cost modeling can be utilized to weigh the benefits of each option. Only then can it be determined how to properly manage the asset and provide the best value for the system owner.

<u>Sound Engineering and the Use of Ductile-iron Pipe: Claims and/or Misunderstandings</u>

Throughout the United States, most independent corrosion engineers do not agree with the ductile-iron pipe industry's recommendations for evaluating potential corrosive conditions and corrosion protection for ductile-iron pipe. These engineers' positions are supported by the ongoing publication of independent scientific research and resource materials as well as experience reports. *See attached reference list, page 9.*

Ductile-iron pipe has only been in service for approximately 50 years. The ductile-iron industry infers the reliable longevity of their product based on the use experience of gray cast-iron. If the products were the same wall thickness, this may be a valid assumption. However, since they are different in wall thickness for equivalent pressure classes, comparing ductile iron's design life to that of cast iron is irrational. Ductile-iron's manufacturing process produces significantly higher minimum yield and ultimate strengths than gray cast-iron. This innovation allows the ductile-iron industry to offer a more competitive product with thinner walls to create a comparable pressure class. With the same level of corrosion protection used for the thicker gray cast-iron pipe, thinner wall pipe cannot provide an equivalent service life in a corrosive environment.

The ductile-iron industry approach to corrosion protection appears to do the minimum possible when initially installing a pipeline. A "bury the pipe and forget about it" strategy hangs its hope on the pipe not failing until after the assumed design life. Accepting corrosion and ultimate failure of infrastructure can no longer be considered economically prudent.

There are many claims and/or misunderstandings regarding ductile iron pipe in the design community. The following claims and facts are provided with supporting references to reassess the validity of the ductile-iron industry's recommendations.

CLAIM 1:

Ductile-iron naturally provides greater corrosion protection than mild steel and other ferrous materials.

FACT:

Buried unprotected mild steel and ductile-iron, exposed to the same corrosive environment, will corrode at approximately the same rate. Since the corrosion rates are essentially the same, corrosion protection considerations should also be the same.

References: 14,15,12,7

CLAIM 2:

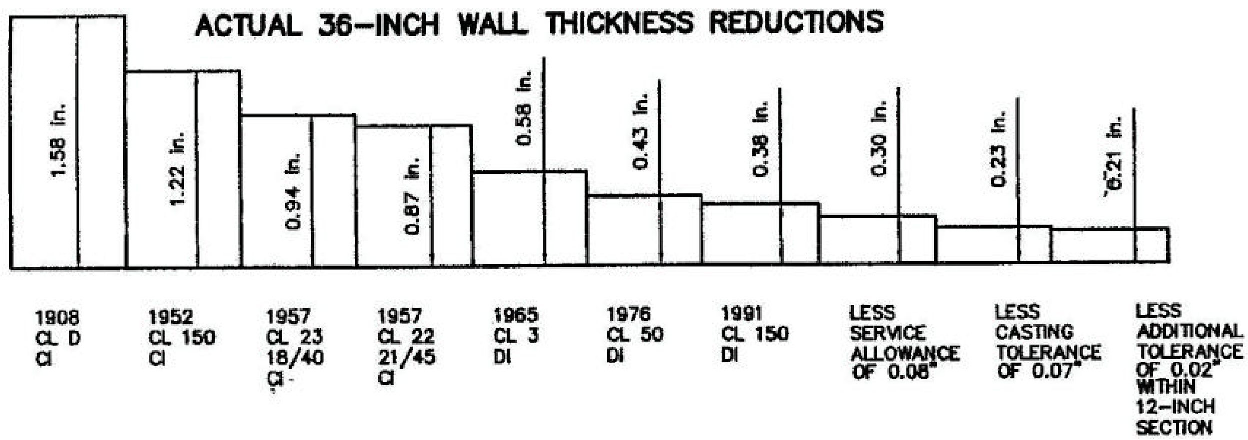
Ductile-iron pipelines will last 100 years because many cast-iron pipelines have survived that long.

FACT:

Ductile-iron pipe, designed for the same installation conditions, will not provide the equivalent life of cast-iron pipe in the same corrosive environment. 36" AWWA Class 150 ductile-iron pipe wall thickness has been reduced more than 75% of the old cast-iron pipe. Present day 36" ductile-iron wall thickness is less than *25%* of the 1908 cast-iron wall (1.58" in 1908 versus 0.38" in 1991). *See Fig. 2*

References: 12,16,8,2

Figure 2



CLAIM 3:
Loose polyethylene encasement provides adequate protection in corrosive environments.

FACT:
There have been numerous failures of ductile-iron pipelines installed with loose polyethylene encasement. For transmission pipelines, bonded coatings should be specified as part of the corrosion protection design when exterior protection is deemed necessary. *See Fig. 3*
References: 16, 17, 3, 6

Figure 3

A section of failed polywrapped pipe being removed. Failure occurred from external corrosion at breaks in the wrap.

Raw sewage from an adjacent failure was trapped between intact polywrap and the pipe at this location. Trapped sewage resulted in accelerated corrosion and penetration on the DI Pipe under the intact polywrap.

Less than 25-year old ductile-iron pipe in Northern California.

CLAIM 4
Cathodic protection and bonded coatings are poor investments.

FACT
Each year approximately 240,000 pipeline failures will cost North America more than one billion dollars. Based on site conditions, cathodic protection costs have a life cycle current rate of return of between 5 and 24 times investment.
References: 4, 11, 3, 18

CLAIM 5:
The ductile-iron pipe "Ten Point" system adequately evaluates corrosive environments.

FACT:
After following the recommendations of the "Ten Point" system, ductile-iron pipelines experienced corrosion failures, some in less than twenty years. *See Fig. 4*
References: 16, 17, 6

Figure 4

DI fitting after 15 year of service, showing widespread corrosion penetrations typical of the entire pipeline. No corrosion protection was provided for this line. The soil sample from this location scored zero on the 10-point scale, indicating essentially noncorrosive conditions.

5-year old ductile-iron pipe in polyethylene encasement

CLAIM 6:
Ductile-iron pipe is not available, or cannot be coated, with bonded coatings.

FACT:
Many ductile-iron pipelines with bonded coatings are in service. Ductile-iron bonded coating specifications exist and new standards are in development. *See Fig. 5*
References: 13, 10, 5, 9

Figure 5

Tape-coated ductile iron pipe.

Polyurethane-coated ductile iron pipe.

Comparison of Corrosion Protection Recommendations

Corrosion protection references herein pertain primarily to external corrosion only.

One very important agreement between steel pipe and ductile-iron pipe engineers is their recommendations regarding "Corrosion Allowance" and/or "Sacrificial Metal." Both agree that this practice is obsolete, unscientific, and should not be used. AWWA Manuals M11 Steel Pipe and M41 Ductile-Iron Pipe both state this position. AWWA M41, Section 10.6.5, Sacrificial Metal, states:

> "Increasing pipe wall thickness to allow sacrificial metal loss is totally unscientific because there is no assurance that corrosion will attack the pipe wall uniformly. Instead, corrosion attack may occur in the form of localized pitting, which can result in premature failure of the pipe by perforation, regardless of wall thickness. In addition to being unreliable, the practice of increasing pipe wall thickness as a safeguard against corrosion is also not cost-effective. The availability of more reliable and economical methods of corrosion prevention has generally rendered this practice obsolete." (Underlining added)

Industry Recommendations and Conclusions

Ductile-Iron Pipe	Steel Pipe
The 10 Point System is an adequate method for evaluating potentially corrosive environments. *Ref. AWWA M41, 10.4*	The 10 Point System is inadequate. Corrosive evaluation should be by qualified engineers who are not pipe industry representatives.
Coatings are not required for many soil environments. *M41, 10.5*	Bonded coatings are recommended for all buried pipe.
Joint bonding is not recommended except where electrical continuity is needed for corrosion monitoring and cathodic protection. *M41, 10.3*	Bonded rubber gasket joints or welded joints are recommended. A monitoring system of test leads at appropriate intervals is recommended.
Polyethylene encasement is recommended for protection in corrosive soil environments as well as stray current corrosion conditions. *M41, 10.5*	Polyethylene encasement is not recommended.
The single most important polyethylene encasement installation criterion is that the polyethylene completely prevents contact between the pipe and soil. *M41, 10.5*	Polyethylene encasement can't be installed on a continuous basis without some holes or tears. It cannot completely prevent contact between the pipe and soil.
Bonded coatings are not recommended. *M41, 10.6*	Bonded dielectric or cement mortar coatings are recommended.
It is seldom cost effective to install cathodic protection. In most cases it is also unnecessary. *M41, 10.6.2*	Cathodic protection, when needed, is recom-mended and provides an excellent rate of return. Monitoring systems add 2-3% cost to a new pipeline. Impressed current CP systems add 3-4%, for a total additional cost of *5-7%* for full cathodic protection.
Insulated joints should be installed when warranted. *M41, 10.6.3*	Use insulated joints when connecting dissimilar metals and appurtenances or to isolate specific reaches of pipeline.
The practice of wall thickness sacrificial metal is unscientific, obsolete, and should not be used. *M41, 10.6.5*	The practice of wall thickness corrosion allowance is unscientific, obsolete, and should not be used.
Pipelines should fulfill design life requirements.	Properly designed, installed, and maintained pipelines should not fail due to corrosion. Corrosion failures can and should be prevented.
Representatives of the ductile-iron industry have notified some customers that they will no longer supply pipe with bonded coatings for their projects.	Steel pipelines can be supplied with whatever quality level of corrosion protection specifying engineers require.
Corrosion protection recommendations are unique to ductile iron and may not apply to other materials. *M41, 10.1 & 10.4*	Buried steel and ductile-iron pipelines require equivalent corrosion protection for equivalent service life.

Corrosion Protection Levels

There are six basic levels of corrosion protection for installing ferrous-based pipe materials. After evaluating site conditions and pipe materials the design engineer and/or corrosion engineer designs and specifies a protection system that falls within one of the following levels.

Level 1) No protection, pipe installed bare without monitoring system
Level 2) Install pipeline bare with polyethylene encasement, without monitoring system
Level 3) Add monitoring system (bonded joints and test leads) to Level 2
Level 4) Bonded dielectric coatings or cement mortar coating without monitoring system
Level *5)* Add monitoring system (bonded joints and test leads) to Level 4
Level 6) Add cathodic protection to Level 3 or Level 5

Application to Steel & Ductile-iron

Both steel and ductile-iron pipe can be supplied in accordance with the above levels of corrosion protection. If the design engineer decides that polyethylene encasement is adequate for one material, then it should be specified for both. If he decides that bonded coating is needed for one, then it is needed for both since both materials require the same levels of protection. There is no sound engineering basis for specifying one level of protection for one material and another level for the other.

Conclusions

A careful review of steel and ductile-iron pipe corrosion considerations reveals a number of interesting conclusions. They include:

- The corrosion resistance of bare steel and ductile-iron are essentially equal.
- The practice of specifying additional wall thickness or sacrificial metal for corrosion protection is unscientific, not cost-effective, and therefore should not be used.
- Steel and ductile-iron pipelines require the same levels of corrosion protection for equal life expectancy.
- Pipelines produced from ferrous-based materials, installed using current corrosion control procedures, should not fail because of external corrosion.
- Inadequate pipeline corrosion protection can result in catastrophic, costly failures.
- Corrosion protection systems that include coatings, monitoring systems, and cathodic protection (installed incrementally as needed) are very cost effective.
- Steel and ductile-iron pipelines should, at the very least, include a monitoring system of bonded joints and test leads. This provides a window to assess activity and provides the ability to increase protection if and when needed.
- Bonded coatings are recommended. Practically speaking, polyethylene encasement does not provide the same level of protection available from a bonded coating system.
- Steel and ductile-iron pipe can be supplied with whatever quality level of corrosion protection design engineers require.
- Design engineers must determine and specify the required quality level of corrosion protection for transmission pipelines.

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