**Cathodic Protection of Cast Iron Piping**

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**Cathodic Protection of Cast Iron Piping**

**Executive Summary**

One of the biggest blunders in Title 49 CFR Part 192 is the failure to require external corrosion control of cast iron piping. This blunder has existed since 1970. There are overwhelming technical information and requirements that indicate that cast iron corrodes, but most of the external corrosion is through a process called graphitization where the external corrosion process removes the ferrous material or iron in the pipe and leaves behind a carbon or graphite matrix.

Many gas pipelines made of cast iron have gone without external corrosion protection for over 100 years. Because the high leakage through bell and spigot joints and through graphitization areas, gas pipeline companies have reduced gas main pressure to levels approaching the minimum levels required for delivery to customers for their gas usage equipment. This lowering of gas main pressure is reaching a point of diminishing return and all cast iron pipe needs to be removed from gas distribution systems.

Despite efforts to accommodate leakage through cast iron pipe by operating at very low pressure, section 192.621 of Title 49 CFR Part 192 continues to allow cast iron pipe gas pressures up to 25 psig. This 25-psig limit may be appropriate for new cast iron pipe, but not for over 100 years old cast iron pipe that has never been protected from external corrosion.

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**Cathodic Protection of Cast Iron Piping**

**Introduction**

Purpose of this message is to document sources related to external corrosion control of gray cast iron pipe. Sources will include:

1. Title 49 CFR Part 192;
2. Appendix D to Title 49 CFR Part 190;
3. NACE *Basic Corrosion Course*;
4. U.S. Department of Transportation (DOT) Corrosion Enforcement Guide for Title 49 CFR Part 192;
5. Title 49 CFR Part 195;
6. NACE SP 0169;
7. Peabody’s Control of Pipeline Corrosion, Second Edition;
8. *Pipeline Corrosion Final Report* for U.S. Department of Transportation (DOT) Order DTRS 56-02-D-70036;
9. GPTC Z380.1 *Guide Material Appendix G-192-18* on Cast Iron Pipe.
10. ASME B31.4; and
11. ASME B31.8.

**Title 49 CFR Part 192**

Subpart I – Requirements for Corrosion Control contain the following requirements.

1. Section 192.451 on scope indicates:

“This subpart prescribes minimum requirements for the protection of metallic pipelines from external, internal, and atmospheric corrosion.”

1. Section 192.455 on external corrosion control of buried or submerged pipelines installed after July 31, 1971 indicates:
	1. Each buried or submerged pipeline must be protected against external corrosion, including:
		1. It must have an external protective coating meeting section 192.461.
		2. It must have a cathodic protection system designed to protect the pipeline within one year.
	2. An operator need not comply with the external coating and cathodic protection requirements if the operator can demonstrate by tests, investigation, and experience that a corrosive environment does not exist.
	3. An operator need not comply with the external coating and cathodic protection requirements for a pipeline with an operating service life of less than five (5) years if the operator can prove that corrosion within the five (5) years will not be detrimental to public safety.
2. Section 192.457 on external corrosion control of buried or submerged transmission lines installed before August 1, 1971 indicates:
	1. Except for piping at compressor, regulator, and measuring (metering) stations, each buried or submerged pipeline that has an effective external coating must be cathodically protected along the entire area that is effectively coated.
	2. Except for cast iron or ductile iron, each of the following buried or submerged pipelines must be cathodically protected:
		1. Bare or ineffectively coated transmission lines;
		2. Bare or coated pipelines at compressor, regulator, and measuring stations; and
		3. Bare or coated distribution lines.
3. Section 192.459 on examination of buried pipeline when exposed requires:
	1. Whenever an operator has knowledge than any part of a buried lines is exposed, the exposed part must be inspected for evidence of:
		1. External corrosion if the pipe is bare or
		2. Coating deterioration.
	2. If external corrosion is found requiring remedial action (repair or derating), the operator shall investigate other areas around and along the pipeline beyond the exposed portion to determine if additional remedial action is required.
4. Section 192.461 on external protective coating requires:
	1. Each external protective coating must:
		1. Be applied on a properly prepared surface;
		2. Have sufficient adhesion to the metal surface to resist underfilm moisture migration;
		3. Be sufficiently ductile to resist cracking;
		4. Have sufficient strength to resist damage due to handling, soil stress, and ditch conditions;
		5. Be compatible with supplemental cathodic protection;
		6. Low moisture adsorption; and
		7. High electrical resistance.
	2. Each external coating must be protected from damage.
5. Section 192.463 on cathodic protection requires the level of protection comply with one or more of the criteria in Appendix D.
6. Appendix D gives criteria for pipelines made of:
	1. Steel, cast iron, and ductile iron;
	2. Aluminum;
	3. Copper; and
	4. Other metals of different anodic potentials.
7. Section 192.7 on documents incorporated by reference lists:
	1. ANSI/ASME B31.8, *Gas Transmission and Distribution Systems*;
	2. ANSI/ASME B16.1, *Gray Iron Pipe Flanges and Flanged Fittings*; and
	3. NACE SP 0502, *Pipeline External Corrosion Direct Assessment Methodology*.
8. Section 192.489 on remedial measures for cast iron and ductile iron pipelines requires:
	1. Each segment of cast iron or ductile iron pipe where general graphitization is found to a degree where a fracture or any leakage might result, must be replaced.
	2. Each segment of cast iron or ductile iron pipe where localized graphitization is found to a degree where any leakage might result, must be replaced, repaired, or sealed by internal sealing methods to prevent or arrest any leakage.
9. Section 192.755 on protecting cast iron pipelines requires an operator with knowledge that the support for a segment of a buried cast iron pipe has been disturbed to:
	1. Protect as necessary against damage during any disturbance caused by:
		1. Vibrations from heavy construction equipment, trains, trucks, buses, or blasting;
		2. Impact forces by vehicles;
		3. Earth movement;
		4. Future excavations near the pipeline; and
		5. Other foreseeable outside forces which may subject that segment of pipeline to bending stress.
	2. As soon as feasible, provide permanent protection for the disturbed segment from damage.

**Appendix D to Title 49 CFR Part 192**

Appendix D to Title 49 CFR Part 192 is titled *Criteria for Cathodic Protection and Determination of Measurements*. Stated requirements include:

1. Section I: For steel, cast iron, and ductile iron (ferrous metals) piping structures:
	1. A negative (cathodic) voltage of at least 0.85 volt, with reference to a saturated copper-copper sulfate half cell. Determination of this voltage shall be made with the protective current applied and in accordance with Sections II and IV of this appendix.
	2. A negative (cathodic) voltage shift of at least 0.300 millivolts. Determination of this voltage shift must be made with the protective current applied and in accordance with Sections II and IV of this appendix.
	3. A minimum negative (cathodic) polarization voltage shift of 100 millivolts determined in accordance with Sections III and IV.
2. Section II: Voltage drop other than those across the metal structure electrolyte boundary must be considered for valid interpretation of the voltage measurements in Section II.
3. Section III. The polarization voltage shift must be determined by interrupting the protective current and measuring the polarization decay. When the current is initially interrupted, an immediate shift occurs. The voltage reading after the immediate shift must be used as the base reading from which to measure polarization voltage decay.
4. Section IV: Negative (cathodic) voltage must be measured between the piping structure surface and a saturated copper-copper sulfate half cell contacting the electrolyte (backfill or water)

**Cathodic Protection (CP) Current Requirements to Protect Buried Pipelines**

Chapter 5 of the textbook for the National Association of Corrosion Engineers (NACE) *Basic Corrosion Course* was written by A.W. Peabody and contained the following information on estimating the amount of CP current required to protect buried steel pipelines and how to estimate the condition of external coatings on buried pipelines. These CP current estimates and criteria for determining the condition of underground pipeline coating are as follow.

|  |  |
| --- | --- |
| Condition of Coating | CP CurrentMilliamps per Sq. Ft. |
| Bare ferrous metal in earth | 1 to 3 |
| Poorly coated ferrous metal in earth |  0.1 |
| Well coated in earth |  0.003 |
| Very well coated in earth |  0.0003 |

Since cast iron pipelines in earth is seldom coated, the cathodic protection current for ferrous metals such as steel and cast iron should be at least 1 milliamp per square foot.

Section 192.459 of 49 CFR Part 192 requires examination of each buried pipeline when exposed. The buried portion must be examined for evidence of external corrosion if the pipe is bare or if the coating has deteriorated. If external corrosion requiring remedial action under Sections 192.483 through 192.489 is found, the pipeline operator shall investigate circumferentially and longitudinally beyond the exposed area to determine if additional remedial actions are required.

Section 192.491 covers corrosion control records and subsection 192.491(c) requires:

Each pipeline operator shall maintain a record of each test, survey, or inspection required by the subpart (Subpart I on Corrosion Control) in sufficient detail to demonstrate the adequacy of corrosion control measures or that a corrosive condition does not exist. These records must be retained for at least five years except those/that records related to 192.405(a) and (e) (external corrosion monitoring).

Section 192.489 covers inspection and remedial measures for cast iron pipe including:

1. Each segment of cast iron pipe on which general graphitization is found to a degree where a fracture or any leakage might result, must be replaced.
2. Each segment of cast iron on which localized graphitization is found to a degree where any leakage might result, must be replaced or repaired or sealed by internal sealing methods adequate to prevent or arrest any leakage.

Section 192.491 on corrosion control records does not exclude corrosion control activities on buried cast iron pipe.

**U.S. DOT Enforcement Guide for Title 49 CFR Part 192**

The *U.S. Department of Transportation Enforcement Guide* for Title 49 CFR Part 192 does not address corrosion control of gray cast iron or ductile iron.

**Title 49 CFR Part 195**

Regulations for hazardous liquids pipelines which contain little gray cast iron or ductile iron piping do address external corrosion control of these piping materials as follow.

1. Section 195.3 on documents incorporated by reference includes:
	1. ASME B31.4, *Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids;*
	2. NACE SP 0169, *Control of External Corrosion on Underground or Submerged Metallic Piping Systems*; and
	3. NACE SP 0502, *Pipeline External Corrosion Direct Assessment Methodology*.
2. Subpart H – Corrosion Control in Section 195.551 states “This subpart prescribes minimum requirement for protecting steel pipelines against corrosion.”
3. Section 195.571 on criteria to determine the adequacy of cathodic protection references paragraphs 6.2 and 6.3 of NACE SP 0169.

**NACE SP 0169**

National Association of Corrosion Engineers (NACE) since 1969 has been titled *Control of External Corrosion on Underground Submerged Metallic Piping Systems* and contains the following requirements.

1. Section 1.1. This recommended practice (RP) presents acknowledged practices for the control of external corrosion on buried or submerged steel, cast iron, ductile iron, copper, and aluminum piping.
2. Section 1.2. This RP is intended to serve as a guide for establishing minimum requirements for control of corrosion in:
	1. New piping systems,
	2. Existing coated systems, and
	3. Existing bare systems.
3. Section 1.2 also requires:
	1. For new piping systems, corrosion control by a coating supplemented with cathodic protection (CP) or by some other proven method should be provided in the initial design and maintained during the service life of the piping.
	2. For existing coated piping systems, CP should be provided and maintained, unless investigations indicate that CP is not required.
	3. For existing bare piping systems, studies should be made to determine the extent and rate of corrosion. If these studies indicate that corrosion will affect the safe or economic operation of the piping system, adequate corrosion control measure shall be taken.
4. Section 1.3 requires the provision of this RP should be applied under the direction of a competent corrosion engineer (as stated herein).
5. Section 2 contains definitions including:
	1. **Cathodic protection**: A technique to prevent corrosion of a metal surface by making that surface the cathode of an electrochemical cell.
	2. **Corrosion**: The deterioration of a material, usually a metal, because of a reaction with its environment.
	3. **Polarized**: The change in open potential (voltage) as result of CP current across the reference electrode and electrolyte interface (boundary).
	4. **Polarized Potential**: The electrical potential or voltage across the structure (pipe)/electrolyte (ground) interface that is the sum of the corrosion potential and the cathodic polarization.
6. Section 3 on determination of need for external corrosion control contains the following information and requirements:
	1. Metallic structures, buried in soil or submerged in water, are subject to corrosion. Adequate procedures for corrosion control should be adopted to meet safe and economical practices.
	2. The need for external corrosion control should be based on data obtained from one or more of the following sources:
		1. Corrosion surveys;
		2. Operating records;
		3. Visual observations;
		4. Test results from similar systems in similar environments;
		5. In-line inspections;
		6. Engineering and design specifications; and
		7. Operating, safety, and economic requirements.
7. Section 4 on piping system design contains the following information and requirements:
	1. This section provides accepted corrosion control practices in the design of an underground or submerged metallic piping system.
	2. A person qualified to engage in the practice of corrosion control should be consulted during all phases of pipeline design and construction.
	3. External corrosion control must be a primary consideration during design of a piping system.
	4. Electrical isolation devices should be installed within piping systems to facilitate the application of external corrosion control activities.
	5. Non-welded pipe joints may not be electrically continuous. Electrical continuity can be ensured by the use of pipe joint fittings manufactured for this purpose or by bonding across and to the mechanical joints.
	6. Underground piping systems should be installed so that they are physically separated from all foreign underground metallic structures in a way to ensure electrical isolation is maintained.
	7. Consideration should always be given to lightning and fault current protection of pipelines and personnel safety.
	8. Test stations for electrical potential (voltage), current, and/or resistance measurements should be provided at sufficient locations to facilitate cathodic protection testing.
8. Section 5 on external coatings contain the following information and requirements:
	1. The function of external coatings is to control corrosion by:
		1. Isolating the external surface of the underground or submerged piping from the environment,
		2. To reduce cathodic protection (CP) current requirements, and
		3. To improve CP current distributions to the piping system.
	2. Pipeline external coatings shall be property selected and applied to ensure that adequate bonding is obtained. Unbonded coatings can create electrical shielding of piping to prevent CP from reaching the pipe bare surface.
9. Section 6.2.2 on cathodic protection contains the following information and requirements for steel and cast iron piping:
	1. External corrosion control can be achieved at various levels of cathodic polarization depending on the underground environmental conditions.
	2. In the absence of specific environmental data that demonstrate that adequate CP has been achieved, one or more of the following criteria shall apply:
		1. A negative cathodic potential of at least -850 mV with the CP applied using a copper/copper sulfate reference electrode in contact with the electrolyte environment around the pipe. Voltage drops other than those across the structure to electrolyte boundary must be considered in these criteria. (An instant off CP voltage reading will meet this requirement.)
		2. A negative polarized potential of at least -850 mV relative to a copper/copper sulfate reference electrode. (An instant off CP voltage reading will meet these criteria.)
		3. A minimum of 100 mV of cathodic polarization voltage shift between the structure surface and a stable reference electrode contacting the electrolyte.
	3. In some situations, such as the presence of sulfides, bacteria, elevated temperature, acid environments, and dissimilar metals, the above criteria in Section 6.2.2 may not be adequate. (Higher CP polarized voltage readings are needed.)
	4. Polarized potentials less negative than -0.850 mV with CP when conditions are conducive to stress corrosion cracking.
	5. Excessive polarized potentials can cause disbonding of external coatings and formation of hydrogen-induced cracking.

**Peabody’s Control of Pipeline Corrosion, Second Edition**

Chapter 1 on introduction to corrosion lists the galvanic series for metals in a neutral soil and water solution when measured with a copper/copper sulfate reference electrode. These measured potentials or voltage reading include the following.

|  |  |
| --- | --- |
| Metal | Volts |
| High silicon cast iron | -0.2 |
| Cast iron (not graphitized) | -0.5 |
| Steel (rusted) | -0.2 to -0.5 |
| Steel (clean and shiny) | -0.5 to -0.8 |
| Pure aluminum | -0.8 |
| Zinc | -1.1 |
| Magnesium | -1.75 |

**U.S. DOT Corrosion Final Report**

The report was prepared for the U.S. DOT to provide a “non-technical, high-level common understanding of issues related to pipeline corrosion”. The report recommended that readers who desire a more technical depth to rely on:

1. Peabody’s Control of Pipeline Corrosion, Second Edition;
2. Technical papers published by the National Association of Corrosion Engineers (NACE);
3. Technical papers published by the American Society of Mechanical Engineers (ASME), and
4. Other technical societies.

The report is stated to provide concise information on the state of pipeline corrosion control, the gaps in current knowledge, and direction of current research and development.

The report treats pipeline corrosion in general terms for all metals without a distinction between steel, cast iron, ductile iron, and other metallic materials in pipelines.

**GPTC Z380.1, *Guide Material Appendix G-192-18 on Cast Iron Pipe***

This document in GPTC Z380.1 states that much of the guide material in Subpart I of 49 CFR Part 192 on corrosion control has general applicability to cast ion pipelines.

**ASME B31.4, *Pipeline Transportation Systems for Liquids and Slurries***

Requirements for materials in pipelines are grandfathered. Only the operating, maintenance, and corrosion control provisions apply to grandfathered pipelines. Chapters VII and VIII cover corrosion control and contain the following information.

1. Section 453 in Chapter VII states: “Protection of ferrous pipe and components from external and internal corrosion, including tests, inspections, and appropriate corrective measures shall be as prescribed in Chapter VIII.”
2. Section 460 in Chapter VIII contains the following information.
	1. This Chapter contains the minimum requirements and procedures for controlling external and internal corrosion and erosion of exposed, buried, or submerged metallic pipe and components.
	2. Provisions of this Chapter should be applied under the direction of competent personnel.
	3. Deviations from the provisions of this Chapter are permissible in specific situations, providing the operating company can demonstrate that the objectives expressed herein have been achieved.
	4. Corrosion control requirements and procedures may in many instances require measures in addition to those in this Chapter.
3. Section 461.1.1 requires all new buried or submerged pipelines and associated terminal and pump station piping, except thermally insulated piping and where it can be demonstrated by tests or experience that cathodic protection is not needed, shall be:
	1. Externally coated and
	2. Cathodically protected.
4. Section 461.1.1.3 requires all buried or submerged pipelines with barrier type coatings shall be cathodically protected, except facilities installed with a limited service life.
5. Section 461.2 covers buried or submerged steel pipelines and requires:
	1. Procedures shall be established for evaluating the need for a corrosion control process or the effectiveness of existing corrosion control programs, or both.
	2. If continuing corrosion, that, unless controlled, could result in a condition that is detrimental to public or employee safety is found, appropriate corrective measures shall be taken including:
		1. Application of protective coatings,
		2. Installation of cathodic protection facilities,
		3. Electrical isolation,
		4. Stray current control,
		5. Other effective measures determined by sound engineering practices, and
		6. Combination of the above.
6. Section 461.2.4 on cathodic protection criteria requires:
	1. A pipeline is considered to be cathodically protected when it meets one or more of the criteria listed in Section 6 of NACE SP 0169-2007.
	2. It is not intended that cathodic protection be limited to the criteria in NACE SP 0169 if it can be demonstrated by other sound engineering practice that adequate control of corrosion has been achieved.
7. Appendix I on mandatory referenced standards includes 18 NACE documents including:
	1. NACE SP 0169,
	2. NACE SP 0177, and
	3. NACE SP 0188.

**ASME B31.8 *Gas Transmission and Distribution Piping Systems***

Requirements for corrosion control of cast iron piping include:

1. Section 852.6.1 requires whenever any part of an existing distribution piping system is uncovered for operating and maintenance purposes or installation of new facilities, the following information shall be recorded:
	1. Condition of the surface of bare pipe if pitted or generally corroded,
	2. Condition of any pipe coating, and
	3. Any repairs made.
2. Section 852.6.2 on cause of cast iron breakage requires the cause of breakage shall be recorded.
3. Section 852.6.3 on analysis of pipeline condition records states:
	1. Distribution piping condition records shall be analyzed periodically.
	2. Any needed remedial action on the piping system shall be taken and recorded.
4. Section 852.7.3 on inspection for graphitization requires when a section of cast iron pipe is exposed for any reason, an inspection shall be made to determine if graphitization exists in the pipe section that is detrimental to public safety. If detrimental graphitization is found, the affected segment must be replaced.
5. Section 803 on definitions includes the following information:
	1. **Pipeline**: all parts of physical facilities through which gas moves in transportation.
	2. **Transportation of gas**: gathering, transmission, or distribution of gas by pipeline or storage of gas.
	3. **Pipeline section**: a continuous run of pipe.
	4. **Segment**: a length of pipeline or part of a system that has unique characteristics in a specific geographic location.
6. Section 860.1(a) on scope of corrosion control indicates Chapter VI, Corrosion Control, contains minimum requirements and procedures for corrosion control of exposed, buried, and submerged metallic piping and components.
7. Section 860.1(b) requires the provisions of this Chapter should be applied under the direction of competent corrosion personnel.
8. Section 860.1(d) indicates that corrosion control requirements and procedures may, in many instances, require measures in addition to those shown in this Chapter.
9. Section 860.1 requires records of tests, surveys, inspection results, leaks, etc., necessary for evaluating the effectiveness of a corrosion control program measures shall be maintained and retained for as long as the piping remains in service.
10. Section 860.2(a) requires procedures shall be established for evaluating the need for and effectiveness of a corrosion control program.
11. Section 860.2(b) requires records of a result of leakage surveys and normal maintenance work shall be continually reviewed for evidence of continuing corrosion.
12. Section 860.2(d) requires the continued effectiveness of a cathodic protection system shall be monitored in accordance with Section 863 on operation and maintenance of cathodic protection (CP) systems, as follows:
	1. Inspections shall be made as required to maintain continuous and effective cathodic protection.
	2. Electrical tests shall be made periodically to determine that the piping system is protected in accordance with the applicable CP criteria.
	3. The type, frequency, and location of inspections and test shall be adequate to establish with reasonable accuracy the degree of CP protection provided on the piping system. The frequency of inspections and test should be determined by:
		1. Condition of the pipe;
		2. Method of cathodic protection;
		3. Corrosiveness of the environment;
		4. Probability of loss or interruption of CP;
		5. Operating experience, including prior inspections and leak investigations;
		6. Design life of the CP installation; and
		7. Public and/or employee safety.
	4. Where tests, surveys, and inspections indicate that adequate CP does not exist, appropriate corrective measures shall be taken.
13. Section 862.1 indicates a facility is considered to be cathodically protected when it meets one or more of the criteria in Mandatory Appendix K.
14. Mandatory Appendix K is titled “Criteria for Cathodic Protection” (CP). Requirements in Appendix K include:
	1. Section 6.1.1 indicates the scope of Appendix K is to list criteria for cathodic protection which will indicate that adequate CP of a metallic system in its electrolyte has been achieved.
	2. Section 6.2.1 indicates the objective of using cathodic protection is to control the corrosion of metallic surfaces in contact with an electrolyte.
	3. Section 6.2.4 requires voltage measurements on pipelines are to be made with reference electrode located on the electrolyte surface as close as feasible to the metallic structure being investigated.
	4. Section 6.2.5 indicates a combination of CP criteria is needed for a single surface.
15. Section 6.3 in Appendix K covers criteria for CP of metallic surfaces as follows:
	1. Section 6.3.1 is titled “Steel and Cast Iron Structures” indicating that the same CP applies to all ferrous materials.
	2. Section 6.3.2 is titled “Aluminum Structures” and covers CP criteria for aluminum surfaces.
	3. Section 6.3.3 is titled “Copper Structures” and covers CP criteria for copper surfaces.
	4. Section 6.3.4 is titled “Dissimilar Metal Structures” and covers CP criteria for dissimilar materials.
	5. Section 6.3.5 is titled “Special Considerations” and covers “special cases” and “abnormal conditions”.

**Summary of Cathodic Protection (CP) Information and Requirements for Cast Iron Piping**

Information and requirements on CP of cast iron piping presented herein are summarized as follows.

1. Title 49 CFR Part 192
	1. Prescribes minimum requirements for protection of metallic pipelines.
	2. Each buried or submerged cast iron pipeline installed after July 31, 1971 must be protected against external corrosion including
		1. External protective coating and
		2. Cathodic protection.
	3. Each buried or submerged cast iron pipeline installed before August 1, 1971 does not require protection from external corrosion.
	4. Buried cast iron pipelines must be inspected when exposed. If external corrosion requiring remedial action is found, adjacent piping shall be inspected.
	5. Cathodic protection of buried cast iron piping shall comply with Appendix D of 49 CFR Part 192. The criteria for cast iron CP is the same as steel and ductile iron.
	6. ASME B31.8 is a referenced document for compliance purposes in 49 CFR Part 192.
	7. All cast iron piping shall be protected as necessary against damage by any of the following:
		1. Vibrations from heavy construction equipment, trains, buses, trucks, and/or blasting;
		2. Impact forces by vehicles;
		3. Earth movement;
		4. Excavations near the pipeline; and
		5. Other foreseeable outside forces which may subject the cast iron from bending stress.
2. Appendix D to Title 49 CFR Part 192 covers the criteria for cathodic protection and determination of measurements.
3. Chapter 5 of the NACE *Basic Corrosion Course* was written by A.W. Peabody and contains information for estimating the condition of external contains on buried pipelines.
4. U.S. DOT Enforcement Guide does not specifically address external corrosion of cast iron pipe.
5. Title 49 CFR Part 195
	1. References ASME B31.4 and
	2. References NACE SP 0169.
6. NACE SP 0169
	1. Presents acknowledged practices for the control of external corrosion on buried or submerged steel, cast iron, ductile iron, copper, and aluminum piping.
	2. For existing coated piping systems, CP should be provided and maintained, unless investigations indicated the CP is not required.
	3. For existing bare piping systems, studies should be made to determine the extent and rate of corrosion. If these studies indicate that corrosion will affect the safe operation of the piping system, adequate corrosion control measures shall be taken.
	4. Corrosion is defined broadly as “The deterioration of a material, usually a metal, because of a reaction with its environment.”
	5. Metallic structures buried in soil or submerged in water are subject to corrosion.
	6. The provisions of SP 0169 should be applied under the direction of a competent corrosion engineer.
	7. External corrosion control must be a primary consideration during design of a piping system.
	8. Non-welded pipe joints may not be electrically continuous and may need to be bonded across for electrical continuity.
	9. Test stations for electrical voltage, current, and/or resistance measurements should be provided at sufficient locations to facilitate CP testing.
7. Peabody’s Control of Pipeline Corrosion, Second Edition
	1. The definition of corrosion encompasses all materials, including plastics, ceramics, and metals.
	2. This book focuses on the corrosion of metals with emphasis on corrosion of steels used in underground pipelines.
	3. Corrosion of most common engineering materials at near-ambient temperatures occurs in water containing environments and is electrochemical in nature.
	4. An underground corrosion cell requires:
		1. An anode,
		2. A cathode,
		3. Metallic path connecting the anode and cathode, and
		4. Electrically conductive electrolyte (normally moist soil).
	5. Cast iron has galvanic potential similar to steel because both are 98% to 100% iron.
8. U.S. DOT Corrosion Final Report
	1. Report treats pipeline corrosion in general terms for all metals.
	2. Recommends readers study:
		1. NACE publications,
		2. ASME publications, and
		3. Peabody’s Control of Pipeline Corrosion, Second Edition.
9. GPTC Z380.1 *Guide Material Appendix G-192-18*
	1. Applies to cast iron pipe.
	2. Indicates that Subpart I on corrosion control in 49 CFR Part 192 applies to cast iron.
10. ASME B31.4
	1. Chapter VII indicates that protection of ferrous pipe and components from corrosion is prescribed in Chapter VIII.
	2. All new buried or submerged pipeline facilities, except thermally insulated piping and where it can be demonstrated by tests or experience that cathodic protection is not needed, shall be:
		1. Externally coated and
		2. Cathodically protected.
	3. A pipeline is considered to be cathodically protected when it meets one or more of the criteria in NACE SP 0169-2007.
	4. Appendix I on mandatory references includes 18 NACE documents including NACE SP 0169.
11. ASME B31.8
	1. When any part of an existing distribution piping system is uncovered, the following information shall be recorded:
		1. Condition of the surface of bare pipe and
		2. Any repairs made.
	2. The cause(s) of cast iron breakage shall be recorded.
	3. Distribution piping condition records shall be analyzed periodically.
	4. All remedial action on a piping system shall be recorded.
	5. When a section of cast iron pipe is exposed for any reason, an inspection of the exposed pipe shall be made to determine if graphitization that is detrimental to public safety exists in the pipeline section.
	6. If detrimental graphitization is found, the affected segment must be replaced.
	7. Pipeline section is defined as “a continuous run of pipe”.
	8. Segment is defined as “a length of pipeline or part of a system that has unique characteristics in a specific geographic area”. (This definition also applies to risk management.)
	9. Corrosion control requirements in ASME B31.8 cover minimum requirements for corrosion control of exposed, buried, and submerged metallic piping and components.
	10. Corrosion control requirements, in many instances, require measures in addition to those in B31.8.
	11. Corrosion control records for evaluating the effectiveness of corrosion activities shall be made and maintained for as long as the piping remains in service. Records requirements include:
		1. Tests,
		2. Surveys,
		3. Inspections,
		4. Leaks,
		5. Continuing surveillance,
		6. Repairs, and
		7. Other activities related to corrosion control.
	12. Written procedures shall be established for evaluating the need for and the effectiveness of a corrosion control program.
	13. Records of the results of leakage surveys and normal maintenance activities shall be continually reviewed for evidence of continuing corrosion.
	14. The continued effectiveness of a cathodic protection system shall be monitored as follows:
		1. Inspections shall be made as required to maintain effective cathodic protection.
		2. Electrical tests shall be made periodically to determine the piping system is under CP.
	15. The frequency of inspections and tests should be based on:
		1. Condition of the pipe,
		2. Method of cathodic protection,
		3. Probability of CP loss or interruption,
		4. Prior inspection results,
		5. Prior leak investigations,
		6. Design life of the CP facilities, and
		7. Public and employee safety.
	16. Where tests and inspections indicate that adequate CP does not exist, corrective measures shall be taken.
	17. A pipeline facility is considered to be cathodically protected when it meets one or more criteria in mandatory Appendix K of B31.8.
	18. Section 6.3.1 in Appendix K is titled “Steel and Cast Iron Structures” indicating Appendix K applies to cast iron piping.
	19. The CP criteria in Appendix K is the same as appears in NACE SP 0169-2007.

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