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Standard Practice

Steel-Cased Pipeline Practices

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Foreword

This standard practice details acceptable practices for the design, fabrication, installation, and maintenance of steel-cased metallic pipelines. It is intended for use by personnel in the pipeline industry.

The use of cased carrier pipe for pipelines crossing under highways and railroads has been common practice in the industry. The first cased crossings were made using large-diameter pipe. The carrier pipe was mechanically coupled and pushed through the casing, and the coupling or collars were in direct contact with it. When coatings came into general use, isolating spacers were made of hemp rope saturated with pipe-coating enamel. End seals consisting of either concrete or pipe-coating enamel were poured into each end of the casing. The current practice of installing cased carrier pipe has changed only slightly since the beginning of its use. External loading of the carrier pipe has now been eliminated by the installation of heavy-wall casing pipe, and isolating spacers are used to prevent electrical contact between the casing and the carrier pipe. End seals are used to keep electrolyte (e.g., mud, water) out of the annular space between the carrier pipe and casing.

This standard was originally prepared in 2000 by NACE Task Group T-10A-18, a component of Unit Committee T-10A, “Cathodic Protection.” It is based on NACE Publication 10A192, “State of the Art Report on Cased Pipeline Practices,” written by the same task group in 1992. This standard was reaffirmed in 2008 by Specific Technology Group (STG) 35, “Pipelines, Tanks, and Well Casings,” and revised in 2014 by Task Group (TG) 012, “Pipelines, Steel-Cased.” It is also sponsored by STG 05, “Cathodic/Anodic Protection.” It is issued by NACE International under the auspices of STG 35.

In NACE standards, the terms *shall, must, should*, and *may* are used in accordance with the definitions of these terms in the NACE Publications Style Manual. The terms *shall* and *must* are used to state a requirement, and are considered mandatory. The term *should* is used to state something good and is recommended, but is not considered mandatory. The term *may* is used to state something considered optional.

Standard Practice

Steel-Cased Pipeline Practices

Contents

Section 1: General

1.1 Steel casings are used to install and maintain pipeline crossings such as those at road and railroad right-of-ways. This standard details acceptable practices for the design, fabrication, installation, maintenance, and monitoring of steel-cased pipelines.

1.2 The use of cased crossings should take into account load considerations, unstable soil conditions, protection from third-party damage, sound engineering practices, and regulatory requirements.

1.3 This standard does not imply that utilization of casings is mandatory or necessary.

1.4 This standard does not imply that cased crossings, whether electrically isolated or electrically shorted, contribute to corrosion of a carrier pipe within a cased crossing. However, cased crossings may adversely affect the integrity of the carrier pipe by shielding cathodic protection (CP) current to the pipe or reducing the CP effectiveness on the pipe in the vicinity of the casing, including if the casing is coated and electrolytic contact exists between the casing and carrier pipe (see Paragraph 3.2.3 in Casing Design).

1.5 The practices contained in this standard may or may not be applicable to casings installed prior to its issuance. It is presumed that all practices described in this standard are performed in a safe manner.

Section 2: Definitions

Carrier Pipe: A pipe inside a casing, which carries a product such as a gas and/or a liquid.

Casing: A metallic pipe used to protect the carrier pipe. Also referred to as *Encasement Pipe*.

Dogleg: A term used to describe a vent pipe that is offset, which may cause the below-ground portion to appear to be shaped like the rear leg of a dog. The vent is offset as necessary to place the above-ground portion in a more acceptable location (e.g., to locate it off a right-of-way or to locate it where it is less susceptible to potential damage).

End Seal: A dielectric material to seal the end of a casing to assist in preventing water and soil ingress.

Electrolytic Couple: Ionic contact between two metallic structures via an electrolyte. Electrolyte inside the casing that is in contact with the carrier pipe is an example of electrolytic couple.

Filler: A product placed in the annular space between the carrier pipe and the casing pipe to inhibit corrosion and assist in preventing the ingress of electroyte.

Isolator or Spacer: A dielectric device specifically designed to electrically isolate a carrier pipe from a casing and provide support for the carrier pipe.

Metallic Short: Direct metallic contact between two metallic structures.

Split Sleeve: A method of in situ casing installation by welding two halves of the casing (split sleeve) together around the carrier pipe.

Test Leads: Electrical wiring attached to the casing and or carrier pipe for conducting electrical tests.

Section 3: Design

3.1 Carrier Design

3.1.1 Unless prohibited by regulation or right-of-way agreement, consideration should be given to adding supplementary carrier pipe wall thickness or pipe burial depth, in lieu of casing (refer to API(1) RP 1102[1] or other applicable standards).

3.1.2 The carrier pipe shall be effectively coated, with consideration being given to the application of supplementary coating. See NACE SP0169[1] for details.

3.1.3 The carrier pipe shall be properly supported inside and outside the casing to prevent metallic contact between the casing and the carrier pipe. See NACE SP0286[2] for details.

3.2 Casing Design

3.2.1 The casing should be kept as short in length as possible.

3.2.2 For pipelines 200 mm (8.0 in) in diameter and larger, the diameter of the casing should be a minimum of 100 mm (4.0 in) larger than that of the carrier pipe. For pipelines smaller than 200 mm (8.0 in) in diameter, the diameter of the casing is normally a minimum of 50 mm (2.0 in) larger than that of the carrier pipe.

3.2.2.1 Selection of casing diameter should also take into consideration the dimensions of isolators and thickness of coatings to be installed on the carrier pipe. This is particularly important if there are additional coatings, such as concrete or epoxy-polymer concrete.

3.2.2.2 Casing diameter selection must also consider adequate clearance for pipe with bell and spigot joints, flange joints, etc.

3.2.3 Casings can be coated or uncoated. However, the use of coated or nonmetallic casings may result in shielding problems.

3.2.4 Vent pipes should be installed on both ends of a casing, one on top of the casing at the high elevation end and one on the bottom of the casing at the low elevation end. The vents should be positioned so that they are not directly over or under any isolating spacer or end seal. Care should be taken that the casing vents are not blocked during installation of the carrier pipe.

3.2.5 The casing vent hole should be at least one-half the diameter of the vent pipe (25 mm [1.0 in] minimum). The casing vent pipe should be a minimum of 50 mm (2.0 in) in diameter.

3.2.6 The casing and carrier pipe shall be properly supported for the entire length of the pipe, especially near the ends, to prevent sagging, metallic contact, and carrier pipe stress. Refer to Paragraphs 4.3 and 4.4.

3.2.7 Casing end seals shall be designed to prevent ingress of water and debris.

3.2.8 Vent pipes shall be designed, using standard industry methods, to prevent intrusion of water and debris.

3.3 Metallic Isolation Design

3.3.1 Sufficient electrically nonconductive spacing material shall be specified to prevent metallic contact between the carrier pipe and the casing, provide adequate support, and minimize coating damage during installation. Refer to Paragraph 4.4.

3.3.2 Casing isolators shall be carefully selected to ensure they have the mechanical strength required to withstand the actual installation, considering all conditions including pipe weight, length of casing, weight of the product the carrier pipe will be conveying, conditions of weld beads, deflections in the casing, and other field conditions. Selection should include an evaluation of the ability of the casing isolators to provide electrical isolation after enduring the rigors of installation, and to position the carrier pipe for proper end seal application. (See NACE SP0286 for additional information.)

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(1) American Petroleum Institute (API), 1220 L St. NW, Washington, DC 20005-4070.

3.3.3 The selection of the appropriate end seal depends on the position of the carrier pipe at the end of the casing. Most watertight seals, such as modular mechnical seals, require that the carrier pipe be positioned in the center of the casing, whereas most rubber boots allow for some amount of off-centered positioning. Other considerations (such as temperature, materials, and pressure capabilities) should be considered (See Appendix A).

3.3.4 Electrical testing facilities shall be designed to permit verification of metallic isolation after installation. Refer to Paragraph 4.5 and Section 6.

3.4 Other Design Considerations for Mitigation of Carrier Pipe Corrosion in the Casing Annulus

3.4.1 CP may be considered in some situations and designed for the casing as required by conditions or regulations. See NACE SP0169 for details.

3.4.2 Consideration may be given to placing inhibited dielectric filler in the annular space. Refer to Appendix A (nonmandatory), *Filling the Casing Annulus with Petrolatum Wax or Petroleum-Based Compounds*, Paragraph A2.

3.4.3 Consideration may be given to using multiphase vapor or gel corrosion inhibitor systems. Refer to Appendix A (nonmandatory), *Treating the Casing Annulus with Corrosion Inhibiting Products*, Paragraph A3.

3.4.4 Sound engineering practices shall be used in the selection of casing materials.

3.4.5 When there are HVAC power lines over the pipeline, electrical system grounding, and/or counterpoise in close proximity to the pipeline, these conditions may create possible electrical safety hazards and an increased risk for AC corrosion. When present, additional precautions should be evaluated. Bonding of the carrier pipe to the casing using a DC decoupling device should be evaluated as a means to reduce the risk.

Section 4: Installation

4.1 This section pertains to the installation of new cased pipeline crossings, casing extensions, and new casing installation on existing lines by the split-sleeve method. Installation of a casing at a highway, railway, or other crossing may be required by the permitting agency or owner company.

4.2 The carrier pipe and casing shall be handled and stored in a manner that minimizes pipe, coating, and end damage. Lifting shall be accomplished utilizing approved slings, wide belts, or appropriate end hooks. If skids are utilized to support the pipe or casing, padding material shall be used to prevent coating damage of the carrier pipe. In addition, the skids shall be removed upon completion of the installation.

4.3 New Casing Installation

4.3.1 Cased crossings are installed using various techniques including jacking, boring, directional drilling, tunneling, and open cutting. If boring or tunneling methods are used, filling of the annular space between the casing and excavation is sometimes required by the permitting agency. Safety is a major factor during all casing installation work, and all applicable government requirements must be followed. If rock or other unexpected obstructions are encountered during boring operations, the use of specialized cutting heads or tunneling with oversized casing and blasting is sometimes necessary.

4.3.2 While casings are being fabricated, proper butt-weld alignment should be maintained to prevent casing, isolator, or spacer damage during push/pull operations. In addition, slag, bows, etc., should be removed to prevent damage to the carrier pipe, coating, isolator, or spacer. Welding of casings should be performed in accordance with the appropriate welding specification. Radiographic inspection of casing welds is normally not specified.

4.3.3 If possible, the casing vent pipe should be installed before inserting the carrier pipe to avoid the possibility of coating damage. If the carrier pipe is already in place when the vent hole is cut, extreme care shall be exercised while cutting the vent hole. The use of nonflammable insulating material to protect the pipe coating is often required by the pipeline owner company. The vent pipe at the lower elevation should be installed on the bottom of the casing to facilitate possible filling of the casing at a later date. If the vent pipe is doglegged, adequate separation and nonmetallic support shall be used between the vent pipe and carrier pipe.

4.3.4 Any internal weld beads should be ground down to allow proper pulling or sliding of the carrier pipe to prevent damage to the isolators and carrier pipe coating.

4.4 Installation of Carrier Pipe

4.4.1 Before the installation of isolating spacers, the carrier pipe coating shall be electrically inspected for holidays using an approved electrical holiday detector and in accordance with NACE Standard RP0274[3] or SP0490.[4] The casing isolators shall be installed according to the manufacturer's instructions and in the quantity recommended by the manufacturer or design engineer. The inspector shall ensure that the installation is conducted in a manner that does not damage the carrier pipe coating. Isolator runners (skids) shall be oriented properly. Bolts, if present, should not remain at the bottom (6 o'clock) position. If possible, end caps should be installed on the carrier pipe to aid in smooth push/pull operations.

4.4.2 The casing shall be visually inspected and, if necessary, cleaned (swabbed) immediately prior to installation of the carrier pipe to remove any debris/foreign material.

4.4.3 The carrier pipe shall be installed by the boring sled, a crane, or side-boom tractor using slings or belts that do not interfere with the isolators or damage the coating. If attached to the end caps, the pull cable shall be fed through the casing in a manner that does not damage the casing. The alignment of the pipe and casing should be ensured both prior to and during insertion of the carrier pipe into the casing. During the installation operation, it should be ensured that there is no isolator or spacer displacement or damage to the carrier pipe coating. The push/pull operation should continue in a smooth motion until the carrier pipe is properly positioned.

NOTE: Casing isolating spacers may slide along the carrier pipe during installation, causing damage to the coating, if not installed properly, if the casing is bent, or if the installation is out of line. Inadequate support of the pipe may allow the carrier pipe to sag and make metallic contact with the casing. The inspector should be aware of this potential problem during the installation.

4.4.4 The cased crossing shall be tested in accordance with Section 6 to confirm that the casing and carrier pipe are not electrically shorted. The carrier pipe and casing shall be cleaned as necessary for the installation of the end seals in accordance with design specifications and the manufacturer's recommendations. All coating damage shall be repaired in accordance with the coating vendor's or applicable specifications.

4.4.5 Isolating casing end seals shall be installed on both ends of casing. A pressure-tight seal may be required to prevent backfill from intruding into annular space within the casing A pressure-tight seal requires the casing materials to be designed to hold the pressure.

4.5 Test Leads: Test lead wires shall be installed on the carrier pipe using a thermite weld or other approved process. Test lead wires should be installed on the carrier pipe at both ends of the casing. In the event that the original cable is lost or damaged, a spare lead wire may be installed to perform the tests recommended in Appendix B (nonmandatory) and to confirm the integrity of the other lead. The test lead-to-pipe connection shall be properly coated, and any damage to the pipe or pipe coating shall be repaired in accordance with applicable specifications. Wrapping the test leads around the vent pipe shall be avoided to prevent the possibility of electrical shorting. Test lead wires shall be installed on the casing if nonmetallic vent pipes are installed or if the metallic vent pipes use mechanical couplings/fittings. The use of color-coded test lead wires is desirable.

4.6 Backfilling: The casing and carrier pipe shall be backfilled with a material to prevent voids and minimize damage to the carrier pipe and coating. The carrier pipe and casing shall be supported using earth-filled bags, compacted earth, or other methods to prevent settlement during the backfilling operation. Caution should be exercised to prevent test lead damage, which is a common cause of shorting. Testing as described in Section 6 shall be performed upon completion of the backfilling operation.

4.7 Split-Casing Extensions and Installations

4.7.1 Extension of existing casings or construction of new casings on existing pipelines often involves installation by the split-casing/split-sleeve method. This method is necessary if it is not feasible or cost effective to take the pipeline out of service to allow a casing to be slipped over the pipeline.

4.7.2 Split-casing extensions are normally specified to match the size of the existing casing. Occasionally, the configuration of the existing pipeline requires the installation of an oversized casing extension. In this case, a standard welded or conical reducer may be used to achieve the size transition.

4.7.3 The carrier pipe section to be cased shall be carefully excavated. The carrier pipe shall be cleaned, properly coated where necessary, and properly supported to prevent possible damage resulting from sagging. After existing casing seals and vents are removed, the vent pipe hole shall be capped with a steel plate. To prevent coating damage, the carrier pipe shall be protected during burning and welding operations with an insulating shield of nonflammable material or other approved method.

4.7.4 The existing casing ends shall be prepared for welding in accordance with applicable specifications. The carrier pipe coating shall be inspected and repaired. The electrical isolating and spacing materials shall be installed in accordance with applicable specifications.

4.7.5 The pipe to be used in the casing extension shall be specified to provide metallurgical and physical compatibility with the existing casing.

4.7.6 If a manufactured split casing is not used, splitting of the casing shall be performed in a manner that minimizes warping or disfigurement of the pipe. Hinges are sometimes welded to the casing to maintain proper alignment of the casing halves during installation. The new casing vent hole shall be cut using the procedure described in Paragraph 4.3.3.

4.7.7 The split casing shall be carefully positioned over the existing carrier pipe in a manner that avoids any damage to the pipe, coating, or spacing materials. Seam welding shall be performed in accordance with applicable specifications. The casing seams are often tack welded at specified intervals prior to the continuous welding operation to prevent warping. During this welding operation, nonflammable, insulating backing material shall be used to protect the carrier pipe while the split casing halves are being properly supported. The installation of new vent piping, test leads, and backfilling shall be performed in accordance with Paragraphs 4.3.3, 4.5, and 4.6, respectively.

Section 5: Maintenance And Repair

5.1 Maintenance of cased crossings is sometimes necessary. Typical situations include:

- Corrosion or other damage to the carrier pipe or casing pipe is indicated by inspection.
- Casing extension or removal is necessary.
- The casing is in electrical metallic contact with (shorted to) the carrier pipe.
- The casing becomes filled or partially filled with electrolyte and an internal electrolytic couple develops.

5.2 Actions that may be necessary in the course of pipeline and casing maintenance may include:

- Monitoring the condition of the casing.
- Providing supplemental CP to the casing.
- Removing electrolyte from inside the casing.
- Eliminating metallic contact.
- Removing the casing.
- Replacing the carrier pipe.
- Implementing options for annular space metal corrosion mitigation (see details in Appendix A (nonmandatory).
- Coating or recoating the carrier pipe.
- Replacing end seals.
- Installing a new cased crossing.

To monitor the risk of corrosion in the annulus, see Paragraph 6.5.

5.3 Metallic shorts may result in the need for remediation.

- Corrosion or other damage to the carrier pipe or casing pipe as indicated by inspection.
- Casing extension or removal is necessary.

Causes of metallic shorts between the casing and carrier pipe include the following examples:

- The carrier pipe moved in the casing, causing it to come into metallic contact with the casing at some point; such contact often occurs at the ends of the casing.
- Spacing materials failed during or after the original installation of the carrier pipe.
- The pipe was inadequately supported inside the casing, allowing it to sag and come into metallic contact with the inner wall of the casing.
- The carrier pipe was intentionally shorted or installed without isolators, inadequate isolators, installed with an inadequate number of isolators, or installed with too great a distance between isolators.
- A foreign metallic material present at the construction site was accidentally left in the casing.
- A short developed between the test lead and the vent pipe, the casing, or the casing test leads.

5.4 Maintenance of Vents and Test Leads: Maintenance of casing vents includes coating at the soil/atmosphere interface and painting, repair, or replacement of vents and vent caps. Test leads should be checked annually to determine their integrity, and in some cases, is mandated by regulations.

5.5 Clearing of Shorted Casings: The point of metallic contact between the carrier pipe and the casing (such as contact with the metallic portions of end seals, isolating spacers, bond wires or straps, test leads, debris, or the casing itself) can often be removed. Established construction techniques shall be used to realign the pipe or casing to eliminate pipe metallic contact. Equipment used in this situation includes hydraulic jacks, tripods, air bags, side-boom slings, and belts. The pipe and casing shall be maintained in this realigned position by the use of supports such as compacted earth or sandbags placed under the pipe. In certain situations, the elimination of a metallic contact may be accomplished by removing a portion of the casing. Further details are provided in Appendix C (nonmandatory). Once metallic contact is eliminated, spacing materials, end seals, vents, and test leads shall be reinstalled.

CAUTION: Engineering, metallurgical, operational concerns, and regulatory requirements shall be considered before moving the carrier pipe. Consideration shall be given as to whether a pressure reduction is necessary prior to moving the pipe.

5.7 Mitigation of Carrier Pipe Corrosion in the Casing Annulus: In certain situations, casings may be filled with dielectric material or corrosion inhibitor for the purpose of mitigating carrier pipe corrosion in the casing annulus. Options are presented in Appendix A (nonmandatory).

5.8 Removal of Casings: In some instances, it may be appropriate to remove the casing whether it is shorted or not. Guidelines for this process are in Appendix D (nonmandatory).

Section 6: Monitoring

6.1 The following methods may be used to determine whether the casing is shorted to the carrier pipe:

6.1.2 A recommended initial test for a shorted casing is to compare the casing-to-electrolyte potential with the pipe-to-electrolyte potential. A shorted casing may exist if there is a small difference or if there is no difference between the pipe-to-electrolyte potential and casing-to-electrolyte potential. If a test suggests that the casing may be shorted, subsequent testing should be performed.

NOTE: If CP is applied to the casing, the CP system must be disconnected from the casing and the casing allowed to depolarize before any tests are conducted. The presence of direct-connected galvanic anodes on the casing during the test may negate the test results.

6.2 Monitoring: One or more of the following basic electrical test methods should be used to monitor pipelines and casings on a periodic basis. A description of the various methods and their applicability is provided in Appendix E (nonmandatory). Further details on the methodologies listed below are provided in Appendix B.

6.2.1 Potential Survey: This method is the initial test conducted to identify a shorted casing. A voltmeter and a reference electrode are used to conduct the test.

6.2.1.1 Close Interval Survey (CIS), No Interruption: Comparison of Pipe to Electrolyte Casing Electrolyte Readings

6.2.1.2 CIS, Interruption: Compare pipe to electrolyte and casing to electrolyte shift magnitude. Same direction and similar magnitude suggest metallic contact. Same direction but reduced casing to electrolyte shift suggests electrolytic path. Casing to electrolyte shift small or opposite indicates clear.

6.2.2 Internal Resistance: This method indicates whether direct metal-to-metal contact exists between a carrier pipe and the casing pipe by measuring electrical resistance. The resistance value is obtained using standard corrosion field instrumentation. A battery and a multimeter or four-pin soil resistance meter along with four test leads (two on casing, two on carrier pipe) are used to conduct the test. This is an especially useful test immediately after construction and before the carrier pipe is tied in. If this test is performed after the carrier pipe is tied in, the resistance of the parallel path through the soil should be considered. A low resistance value indicates a need to take remedial action. A high resistance value indicates an isolated casing; however, the resistance of the test lead wire and vent pipe must be considered for valid interpretation. (Long vent lines and test lead wire may introduce more resistance.)

6.2.3 Four-Wire IR Drop: This method may indicate the existence and location of a short. A battery, suitable test leads or probe bars, and a multimeter are used to conduct the test. A four-pin resistance meter to determine the as-found resistance between the carrier and casing may also be used as part of this test.

6.2.4 Cycling Rectifier: Cycling the CP rectifier is a method used to evaluate the electrical isolation between pipe and casing. For this test, the nearest influencing rectifier(s) is interrupted. An interrupter, voltmeter, and reference electrode are used to conduct the test. If the pipe-to-electrolyte potentials taken on the pipe and the casing are identical during both the rectifier on and off cycles (with the reference electrode at the same position), a shorted casing is indicated.

6.2.5 Casing Depolarization: This technique verifies isolation status by discharging a direct current (DC) from the casing. A significant potential difference occurs between the casing and carrier pipe if the two structures are not in metallic contact. A temporary cathode or ground electrode, variable DC power source, and combination multimeter are used to conduct the test.

6.2.6 Direct Resistance Measurement: This technique uses a four-pin resistance meter or megger to determine the as-found resistance between the carrier and casing. This method works best with the four-wire method. Using fewer than four wires introduces a lead resistance problem into the circuit.

6.2.7 Pipe/Cable Locator: The presence and location of a pipe-to-casing metallic contact may also be approximated by following a low-power audio or radio signal (pipe locator trace) set between the pipe and the casing. The signal returns at the point of metallic contact, which should be verified from the opposite end.

6.2.8 Direct Current Voltage Gradient (DCVG): Coating holiday indication near the end of the casings denotes a possible metallic or electrolytic path between the casing and the pipe.

6.2.9 Alternating Currrent (AC) Current Attenuation: Compares current flow at each end of casing. Measurement in mA or dBmA/m (dBmA/ft).

6.2.10 A-Frame AC Voltage Gradient (ACVG): Measure dBuA signal strength and direction at each end of the casing.

6.2.11 Temporary Intentional Short: Compare pipe to electrolyte and casing to electrolyte potential or shifts with temporary short between pipe and casing in place and removed. No change indicates contact of similar resistance already existed.

6.3 Instrumented (Smart) Pigs

6.3.1 If feasible and practical, in-line inspection of a pipeline may be used to determine the presence or absence of external corrosion damage on carrier pipe inside a casing. In-line inspection techniques are capable of detecting corrosion damage with a high degree of accuracy. ILI may not detect metal-to-metal contact between the casing and carrier pipe.

6.4 Leakage Survey

6.4.1 Visual Inspection: The casing vent and the area in the vicinity of the casing end may be observed for evidence of product leakage such as product, product odor, or dead and dying vegetation.

6.4.2 Instrumented Surveys for Pipe Carrying Combustible Hydrocarbons: Appropriate leak-detection instruments, such as combustible gas indicators, may be used to analyze the atmosphere within a casing for the presence of combustible hydrocarbons. Pressure tests or other leak-detection devices are used on other systems. These surveys should be done at the frequency required by the applicable code or in accordance with the operating company's practice.

6.5 Evaluating the Corrosiveness of the Annular Spaces in Cased Pipeline Systems

6.5.1 The corrosiveness of the annular space may be evaluated by inserting coupons, electrical resistance probes, or other monitoring devices into the annulus. General descriptions of advantages and limitations of monitoring techniques are provided in NACE standards.

CAUTIONARY NOTE: Care should be taken to ensure that the insertion of a coupon or electrical resistance probe into the casing annulus does not cause a metallic short between the carrier pipe and the casing.

6.5.2 These monitoring tools are used to measure the rate of corrosion within the annulus and estimate the corrosion rates at holidays in the carrier pipe coating and on the inside of the casing pipe wall.

6.5.3 Users must be cautious in the interpretation of data from monitoring devices used within a casing annular space, because:

- Conditions within the casing vary seasonally and over time; thus, the measurements taken over a short period of time may not accurately reflect historical corrosion rates or mechanisms.

- Corrosion monitoring devices may not experience the same potentials or polarization as the carrier pipe.

- Corrosion monitoring devices may not accurately reproduce conditions present beneath damaged or disbonded coating on the carrier pipe.

References

1. API RP 1102 (latest revision), "Steel Pipelines Crossing Railroas and Highways" (Washington, DC: API).

2. NACE SP0169 (latest revision), "Control of External Corrosion on Underground or Submerged Metallic Piping Systems" (Houston, TX: NACE).

3. NACE SP0286 (latest revision), "Electrical Isolation of Cathodically Protected Pipelines" (Houston, TX: NACE).

4. NACE Standard RP0274 (latest revision), "High-Voltage Electrical Inspection of Pipeline Coatings" (Houston, TX: NACE).

5. NACE SP0490 (latest revision), "Holiday Detection of Fusion-Bonded Epoxy External Pipeline Coatings of 250 to 760 μm (10 to 30 mils)" (Houston, TX: NACE).

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Appendix A
Options for Mitigation of Carrier Pipe Corrosion in the Casing Annulus
(Nonmandatory)

This appendix is considered nonmandatory, although it may contain mandatory language. It is intended only to provide supplementary information or guidance. The user of this standard is not required to follow, but may choose to follow, any or all of the provisions herein.

A1 The technology and chemistry are readily available to actively manage corrosion inside cased pipelines through the use of a wax petrolatum system and/or multi-phase vapor corrosion inhibitors.

A2 Filling the Casing Annulus with Petrolatum Wax or Petroleum-Based Compounds

A2.1 Preparation

A2.1.1 Casing Vent Pipes

A vent pipe shall be installed on each end of the casing, and an opening in the casing at the vent pipe connection shall be provided. The casing vent hole should be at least one-half the diameter of the vent pipe (25 mm [1.0 in] minimum). Greater flexibility in the fill operation is provided by installing a bottom vent pipe on the lower elevation of the casing and a top vent pipe at the higher elevation. The vent pipes and the casing annulus should be free of restrictions to allow adequate flow of the casing filler material and to obtain a maximum fill volume.

A2.1.2 Casing End Seals

A2.1.2.1 Casing end seals should be inspected to ensure their integrity and ability to contain the casing filler material during installation. If necessary, new casing end seals shall be installed prior to the filling operation. In evaluating appropriate end seals, consideration should be given to postion of carrier pipe within the casing and end seal material compability with casing fill material (including application temperatures). The design pressure of the end seal should be reviewed with potential casing fill pressures.

A2.1.2.2 Air communication test—An air communication test should be conducted in accordance with manufacture recommendations to ensure positive air flow between the fill and discharge vents prior to filling.

A2.2 Fill Procedure

A2.2.1 Filler Material

A2.2.1.1 Casing filler material is composed mainly of petrolatum wax or petroleum-based compounds and contains corrosion inhibitors, plasticizers, and thermal extenders. The following are recommended characteristics for filler material:

- A minimum congeal point of 41 °C (105 °F), in accordance with ASTM D 938.[5]
- A 50 minimum cone penetration, in accordance with ASTM D 937.[6]
- Is nonhazardous and nonflammable.
- Is not water-soluble.

A2.2.1.2 A heated, insulated tanker with a permanent, variable flow pump should be used to fill the casing. For drum installation, a 10:1 ratio mastic pump with inductor plate should be used.

A2.2.1.3 An environmentally acceptable corrosion inhibitor may be poured down the fill vent pipe just prior to the installation of the casing filler.

A2.2.1.4 Hoses should be connected to the fill vent pipe. The filler material shall be pumped into the casing until it is full. If the casing contains water, the casing filler should be installed through the vent pipe at the high elevation of the casing.

A2.2.2 Verification of Casing Fill Volume

A2.2.2.1 Upon completion of the filling procedure, casing fill percentage should be calculated using Equation (A1).

$$\frac{\text{Actual Volume}}{\text{Theoretical Volume}} \times 100 = \text{Casing Fill Percentage} \tag{A1}$$

A2.2.2.2 The following steps assist in determing whether a casing has been adequately filled:

A2.2.2.2.1 Estimate the volume the casing can accept based on its length, and diameters of the carrier and casing, respectively. In addition, the coating thickness of the carrier pipe should be taken into consideration. The displacement of the isolators should also be taken into account, if known.

A2.2.2.2.2 A reliable procedure should be utilized to fill the casing and consideration for possible settlement should be reviewed with filler manufacturer.

A2.2.2.2.3 Wait at least one hour for settlement of the filler to occur inside the casing and pump additional filler, if needed.

A2.2.2.2.4 Note the volume pumped by the metering system on the truck or pump mechanism to determine the fill ratio of theoretical vs. actual volume pumped.

A2.2.2.3 This calculation gives a rough approximation of the effectiveness of the casing filling. Individual casing fill percentages may vary considerably.

A2.2.2.4 Casing fill percentages may be unusually low because of:

- A casing length that is smaller than that depicted on the as-built drawings;
- Significant variations in the thickness of the coating on the carrier pipe;
- Accumulation of dirt, mud, etc., in the casing;
- Water entrapped in the casing during the fill; and
- Failure to take into account the displacement of the isolators.

A2.2.2.5 Casing fill percentages of individual casings may be unusually high because of:

- Discrepancies on the as-built drawings;
- Holes in the casing; and
- Leaks in the casing end seals.

A2.2.2.6 Taking the average of several individual casing fill percentages provides a useful measure of the overall performance of the casing filling procedure. An average casing fill percentage lower than 85% is considered questionable and should be investigated.

A2.2.3 Monitoring and Maintenance of the Casing Filler

A2.2.3.1 The following steps assist with the monitoring and maintenance of the casing filler:

A2.2.3.1.1 If desired, electrical resistance corrosion rate monitoring probes may be utilized to monitor the effectiveness of the filler.

A2.2.3.1.2 The level of the filler may be intermittantly monitored.

A3 Treating the Casing Annulus with Corrosion-Inhibiting Products

A3.1 There are two fundamental options available to accomplish this method of corrosion mitigation inside casings:

A3.2 Option 1: Fill the Casing with a Corrosion-Inhibiting Gel Filler

A3.2.1 The basic criteria for the corrosion-inhibiting gel filler should include the following.

A3.2.1.1 The filler should contain ample quantities of multiphase vapor corrosion inhibitor products to mitigate corrosion on the external surface of the carrier pipe and the internal surface of the casing.

A3.2.1.2 The filler should be electrically conductive to support distribution of CP system current onto the external surface of the carrier pipe.

A3.2.1.3 The filler should have the viscosity of water and be at ambient temperature when pumped into the casing, then transform into a high viscosity gel after a short time inside the casing.

A3.2.1.4 The multiphase vapor corrosion inhibitors contained in the filler should produce effective mitigation of corrosion on the annular space metals within the area of any voids in the fill.

A3.2.1.5 The viscosity of the filler should be sufficiently high to prevent the infiltration of water into the casing annulus and migration of the filler out of the annulus.

A3.2.1.6 The filler should have a pH greater than 8 and be neutral to elastomers and other nonmetallics.

A3.2.1.7 The filler should not be harmful to the environment.

A3.2.1.8 The presence of small water quantites inside the casing should not reduce the effectiveness of the filler's ability to mitigate corrosion of the annular space metals.

A3.2.2 The process for installation of the corrosion inhibiting gel filler is as follows:

A3.2.2.1 The filler specifications and installation process design should be produced by personnel experienced with the products and their application for cased pipeline systems.

A3.2.2.2 The liquid tightness of the casing system should be assesed as needed.

A3.2.2.3 The majority of existing water should be removed from inside the casing annular space.

A3.2.2.4 The proper mixing ratios should be engineered to ensure that the filler will transform into a gel within the specified time required for each casing system.

A3.2.2.5 A reliable process should be utilized to ensure that the casing is completely filled.

A3.2.3 Guidelines for monitoring and maintenance of the casing filler include:

A3.2.3.1 If desired, electrical resistance corrosion rate monitoring probes may be utilized to monitor the effectiveness of the filler.

A3.2.3.2 The level of the filler may be intermittantly monitored.

A3.2.3.3 The casing vents should be capped with devices that control and significantly limit air exchange.

A3.3 Option 2: Leave the Casing Annulus Unfilled and Apply a Multiphase Vapor Corrosion Inhibitor System

A3.3.1 The basic criteria for this process should include the following:

A3.3.1.1 The corrosion inhibitor system should contain ample quantities of multiphase vapor corrosion inhibitors to mitigate corrosion on the external surface of the carrier pipe and the internal surface of the casing.

A3.3.1.2 The multiphase vapor corrosion inhibitor should be proven to migrate sufficient distances from the injection points so as to produce effective corrosion mitigation along the entire length of the casing system.

A3.3.1.3 The corrosion inhibitor should be neutral to elastomers and other nonmetallics.

A3.3.1.4 The corrosion inhibitor should not be harmful to the environment.

A3.3.1.5 The presence of small water quantites inside the casing should not reduce the effectiveness of the corrosion inhibitor's chemistry to mitigate corrosion of the annular space metals in contact with the water.

A.3.3.2 The process for installation of the multiphase vapor corrosion inhibitor system is as follows:

A3.3.2.1 The specifications and installation process design should be produced by personel experienced with the products and their application for cased pipeline systems.

A3.3.2.2 The liquid tightness of the casing system should be assesed as needed.

A3.3.2.3 The majority of existing water should be removed from inside the casing annular space.

A3.3.2.4 Utilize a reliable process to ensure that the multiphase vapor corrosion inhibitor is uniformly dispersed the entire length of the casing system.

A.3.3.3 Guidelines for monitoring and maintenance of the casing filler include:

A3.3.3.1 Electrical resistance corrosion rate monitoring probes or corrosion coupons should be utilized to monitor the effectiveness of the corrosion inhibitor and identify any need for replenishment of the inhibitor.

A3.3.3.2 The casing vents should be capped with devices that control and significantly limit the exchange of air inside the casing system.

Appendix B
Monitoring Techniques
(Nonmandatory)

This appendix is considered nonmandatory, although it may contain mandatory language. It is intended only to provide supplementary information or guidance. The user of this standard is not required to follow, but may choose to follow, any or all of the provisions herein.

B1 Potential Survey

B1.1 Purpose

Potential surveys of pipelines and casings are made to monitor CP and are the initial tests conducted to identify shorted casings. The presence of a metallic contact may also be evaluated by measuring both the pipe-to-electrolyte and casing-to-electrolyte potentials with respect to a reference electrode placed in the soil.

B1.2 Procedure

B1.2.1 Potential measurements (surveys) of pipelines and casings are made using a voltmeter and a reference electrode (usually a copper-copper sulfate electrode [CSE]).

B1.2.2 More definitive results are obtained if the CP current source is cycled on/off while the pipe and casing potentials are recorded.

B1.2.2.1 Measuring pipeline potential: One lead of the voltmeter shall be connected to the pipeline by way of the test lead or probe bar. The other lead of the voltmeter shall be connected to the reference electrode, which is placed on the ground directly over the pipeline and near the end of the casing (see Figure B1).

B1.2.2.2 Measuring casing potential: One lead of the voltmeter shall be connected to the casing by way of the vent, test lead, or probe bar. The other lead of the voltmeter shall be connected to the reference electrode, which shall be placed at the same location as where the pipeline potential was taken (see Figure B1).

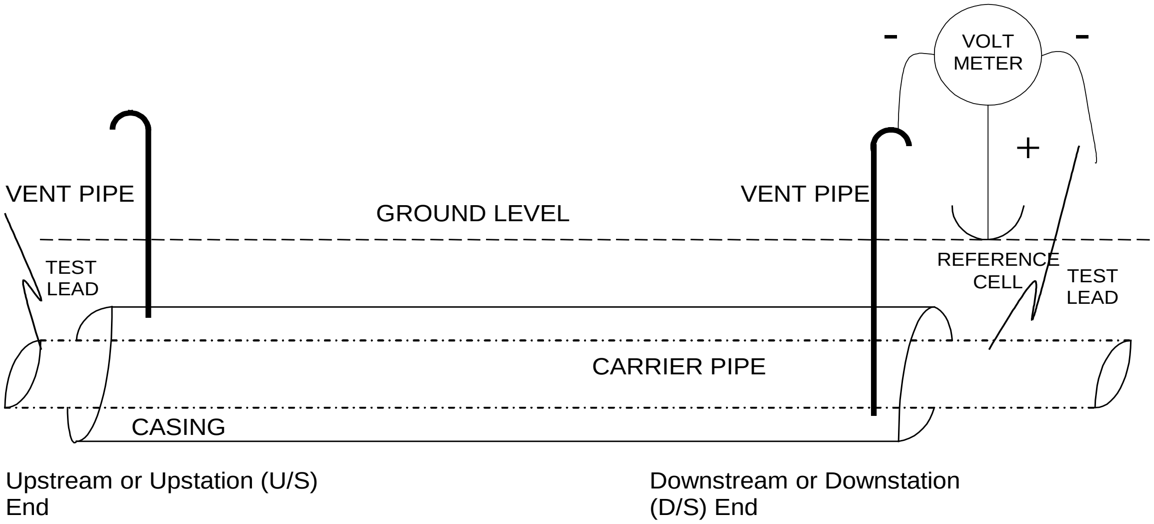

Figure B1: Potential Survey Measurement

Note: The electrode should be placed near the end of the casing directly over the carrier pipe. The reference electrode shall not be placed directly over the casing.

B1.3 Analysis

B1.3.1 A clear or not shorted casing is indicated by a potential difference between the casing and the carrier pipe. For example, a pipe-to-soil potential of 1.6 V CSE and a casing potential of 0.65 V CSE has a potential difference of 0.95 V and would indicate the casing is clear.

B1.3.2 A shorted casing may exist if a small potential difference exists between the pipeline potential and the casing potential. This is typically less than 100 mV. Additional testing should be conducted if the difference in potential is 100 mV or less.

B1.3.3 If operator data and experience indicate that it is appropriate, a difference in potential as small as 20 mV, or as large as 200 mV, may be considered a criterion indicating that the casing under test requires further examination.

B2 Internal Resistance Test

B.2.1 Purpose

B2.1.1 This technique may indicate whether direct metal-to-metal contact exists between a carrier pipe and a casing pipe by measuring electrical resistance.

B2.2.2 Only qualified CP personnel should analyze the results when this test is performed.

B2.2 Procedure

B2.2.1 This procedure requires an appropriate wet cell battery (e.g., car battery), a properly rated ammeter or shunt, a properly rated resistor, sufficient lead wire, clamps, and a multimeter. Other acceptable current sources could include generator and rectifier, or a four-terminal soil resistance meter. See cautionary note following Figure B2.

B2.2.1.1 Step 1: The pipe-to-casing potential shall be measured at terminals T1 and T2. See Figure B2.

B2.2.1.2 Step 2: One battery lead shall be attached to a casing test lead at T3 (if no test lead is available, then the casing vent [T1] may be used). The other lead shall be connected in series with the ammeter to the carrier pipe at T4.

B2.2.1.3 Step 3: A constant current shall be applied between terminals T3 and T4. The current (I) shall be measured in amperes.

B2.2.1.4 Step 4: The pipe-to-casing potential shall be measured between terminals T1 and T2 with the current applied.

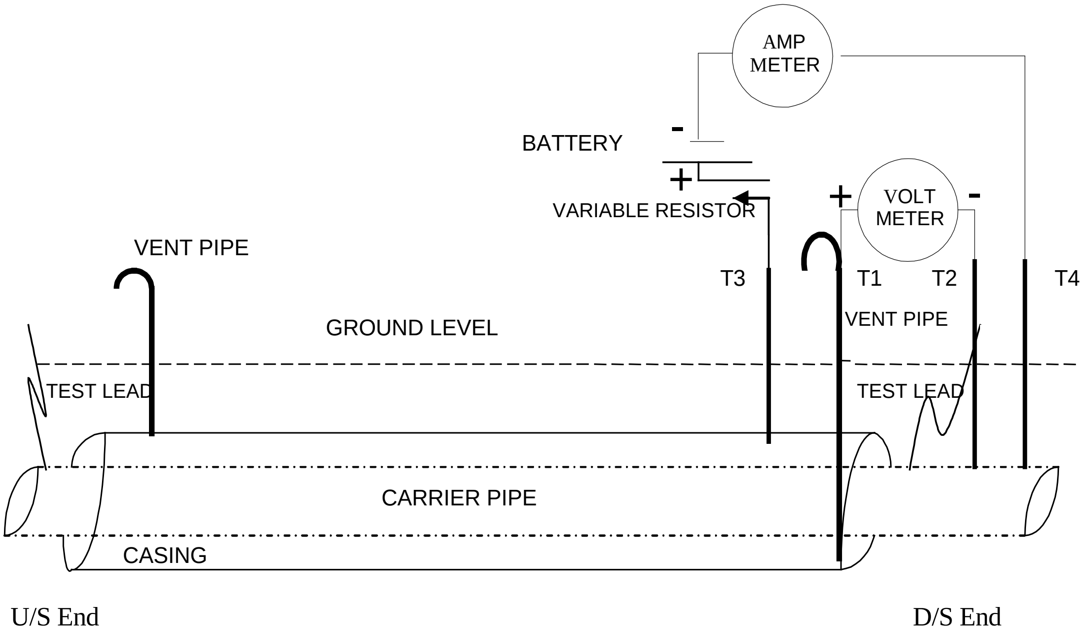

Figure B2: Internal Resistance Test

CAUTION: It is very dangerous to short the leads of a wet cell battery together. The above procedure may produce a direct short if a metal-to-metal contact exists between the carrier pipe and the casing. Therefore, only dry cell batteries or a wet cell battery with a properly rated resistor installed in series shallbe used. Maximum battery output should be limited to 10 A.

Note: A four-pin soil resistivity meter may replace the battery, voltmeter, and ammeter shown in Figure B2 so that the resistance may be read directly. If a four-pin soil resistivity meter is used, the locations of the test leads are the same as those shown in Figure B2. C1 is connected to T3, P1 to T1, P2 to T2, and C2 to T4.

B2.3 Analysis—Resistance Calculation using Ohm's Law

The pipe-to-casing potential difference (ΔV) is calculated by subtracting the result of Step 4 from the result of Step 1. Because Ohm's Law states that the direct current flowing in an electric circuit is directly proportional to the voltage applied to the circuit, ΔV shall be divided by the current (I). A casing-to-pipe (metal-to-metal) contact may exist if the resultant value is less than 0.01 ohm.

B2.3.1 Example 1

B2.3.1.1 A potential survey indicates that the difference between the casing potential and the pipeline potential is less than 100 mV. Using the above procedure to perform an internal resistance test, a potential of +0.090 V is measured between terminals T1 and T2 prior to the application of current. After a current of 1.70 A is applied on terminals T3 and T4, a pipe-to-casing potential of +0.106 V is measured.

Pipe-to-Casing Potential Before Current is Applied:	+0.090 V
Pipe-to-Casing Potential with the Current Applied:	+0.106 V
Change in Potential (ΔV):	+0.016 V

B2.3.1.2 By dividing the absolute value of the potential change (ΔV) by current (I), as in Equation (B1), the value of the resistance (R) is obtained:

$$0.016\ V \div 1.7\ A = 0.0094\ \Omega \tag{B1}$$

B2.3.1.3 The resistance is 0.0094 Ω. Because the pipe-to-casing resistance is less than 0.01 Ω, the presence of a short is indicated.

B2.3.2 Example 2

B2.3.2.1 A pipe-to-casing potential of +0.100 V is measured between terminals T1 and T2 (prior to the application of current). After 1.70 A of current is applied between terminals T3 and T4, a pipe-to-casing potential of +0.302 V is measured between terminals T1 and T2.

Pipe-to-Casing Potential Before Current is Applied:	+0.100 V
Pipe-to-Casing Potential After Current is Applied:	+0.302 V
Change in Potential (ΔV):	+0.202 V

B2.3.2.2 By dividing the absolute value of the potential change (ΔV) by current (I), as in Equation (B2), the value of the resistance (R) is obtained:

$$0.202\ V \div 1.7\ A = 0.12\ \Omega \tag{B2}$$

B2.3.2.3 The resistance is 0.12 Ω. Because the pipe-to-casing resistance is greater than 0.01 Ω, pipe-to-casing (metal-to-metal) contact is not indicated.

Note: While a pipe to casing resistance of less than 0.01 ohms is indicative of an electrical short, a resistance of greater than 0.01 ohms does not necessarily indicate that a short does not exist. Depending on the nature of the pipe to casing contact, an electrical short could have a contact resistance of much more than 0.01 ohms, although the likelihood of a short decreases as the measured resistance increases. In this particular example, the relatively low pipe to casing resistance of 0.12 ohms would suggest that further testing may be necessary to determine the status of the casing.

B3 Four-Wire IR Drop Test for Cased Crossings

B3.1 Purpose

This method may indicate the presence and location of a metallic short to the casing.

B3.2 Procedure

B3.2.1 Measuring the Linear Resistance of the Casing

B3.2.1.1 Step 1: The potential difference shall be measured between terminals T3 and T4 while a measured battery current is simultaneously passed between terminals T1 and T2 (see Figure B3). This may be done with suitable test points (vents or test leads), or the use of probe bars.

B3.2.1.2 Step 2: The battery current in amperes is divided by the change in potential difference from T3 to T4 (ΔV) in mV to express Calibration Factor 1 in A/mV, as shown in Equation (B3).

$$\text{Calibration Factor 1} = \frac{\text{Battery Current (A)}}{\text{Potential Difference from T3 to T4 (mV)}} \tag{B3}$$

B3.2.1.3 Step 3: Calibration Factor 2 is determined by dividing the factor obtained from Table B4 by the length of the pipe, as in Equation (B4). The corresponding value in the factor column is found for the given wall thickness and diameter of the pipe.

$$\text{Calibration Factor 2} = \frac{\text{Factor (from Table B4)}}{\text{Length T3 to T4}} \tag{B4}$$

B3.2.1.4 Step 4: If the value for Calibration Factor 1 is within ±5% of Calibration Factor 2, the tester should proceed to Step 2. If Calibration Factor 1 is not within ±5% of Calibration Factor 2, the test should be repeated until factors are within 5%.

Note: Equation (B5) can be used to convert ohms to amperes/mV (resistance to conductance):

$$\text{A/mV/m} = \frac{1}{\mu\,\Omega/\text{m}} \times 1{,}000 \tag{B5}$$

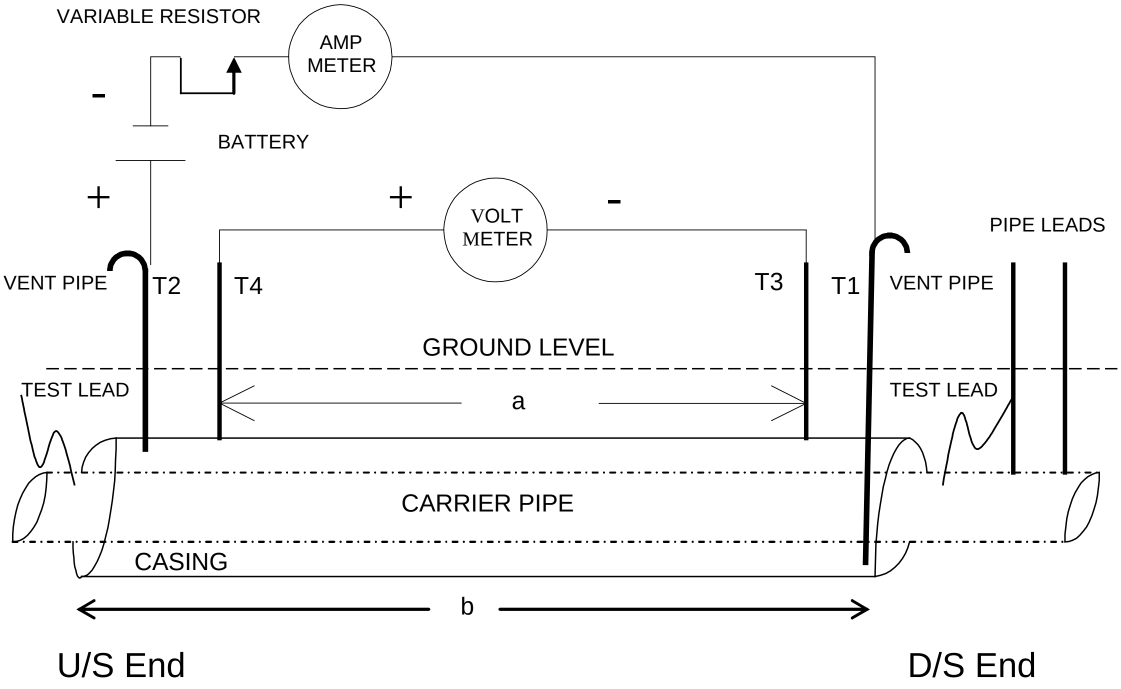

Figure B3: Four-Wire IR Drop Test (Calibrating the Inside Terminals)

B3.2.2 Establishing the Circuit (Upstream [U/S] End)

B3.2.2.1 The circuit shall be established by connecting the negative terminal of the battery to T2 (pipe lead), and connecting T1 (upstream vent) to the positive terminal of the battery. (See Figure B4.)

B3.2.2.2 The inside terminals T3 and T4 are the same as those used for the measurement of potential difference in Figure B3. The voltage drop is measured across the current measuring span (between T3 and T4), while a known amount of battery current passes between T1 and T2.

B3.2.2.3 The percent of the distance “a” to the contact from the upstream end (T4) is calculated using Equation (B6).

$$\text{Distance (in percent) from T4} = \frac{\Delta V\ (\text{T4}) \times \text{Calibration Factor 1}}{\text{Current}} \times 100\% \tag{B6}$$

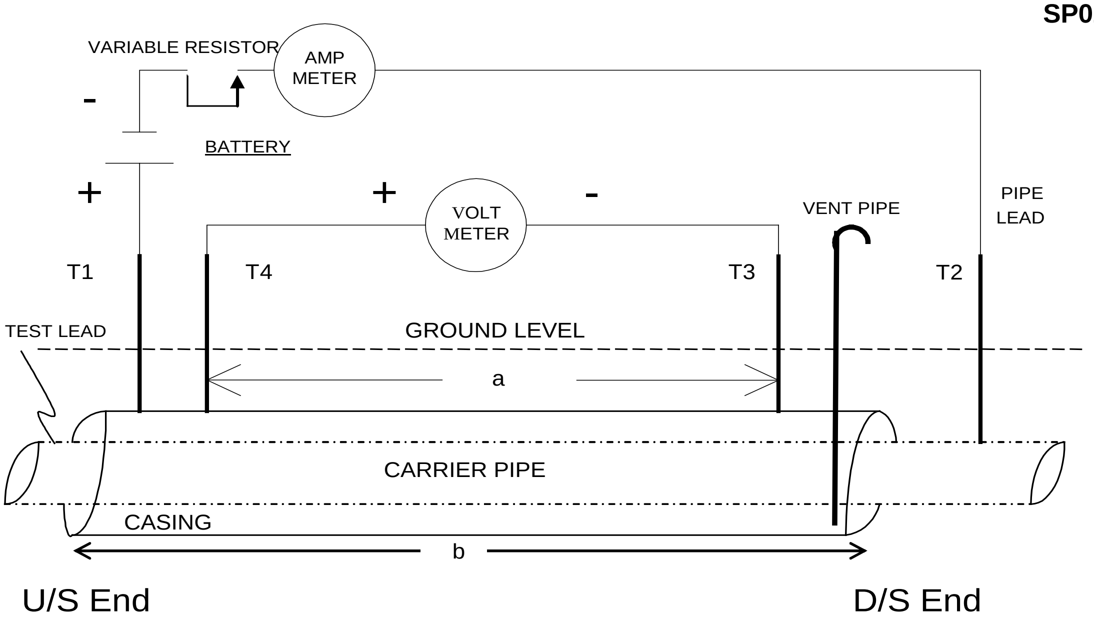

Figure B4: Establishing a Circuit for a Four Wire IR Drop Test (U/S End)

B3.2.3 Establishing the Circuit (Downstream [D/S] End)

B3.2.3.1 The circuit shall be established by connecting the battery negative to T2 (pipe lead).

B3.2.3.2 T1 (downstream vent) shall be connected to the positive side of the battery as shown in Figure B5.

B3.2.3.3 T3 and T4 shall remain the same for measurement of potential difference as shown in Figure B3.

B3.2.3.4 The percentage of distance "a" from T3 shall be calculated as in Equation (B7).

$$\text{Distance (in percent) from T3} = \frac{\Delta V\ (T3) \times \text{Calibration Factor 1}}{\text{Current}} \times 100\% \tag{B7}$$

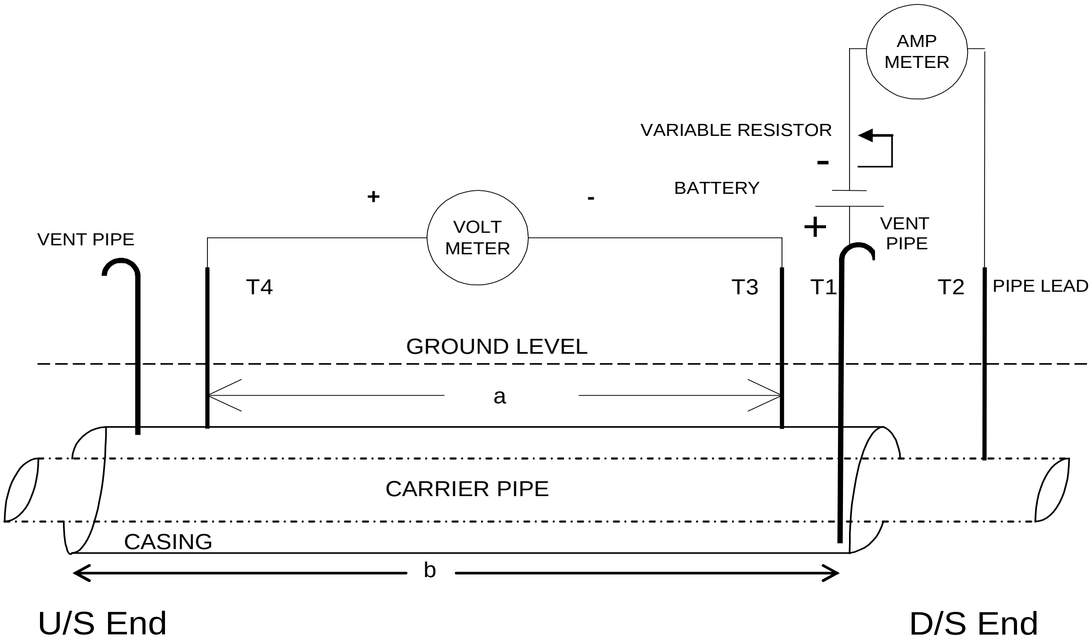

Figure B5: Four-Wire IR Drop Test (Establishing the Circuit) (D/S End)

B3.2.3.5 CAUTION:

- Proper placement of the insulated probe bar and test leads is required to obtain contact for measurement of the IR drop on T3 and T4, or erroneous readings may result.

- If more than one metal-to-metal contact exists, this test may not accurately identify the location of the shorts.

- Appropriate safety precautions shall be implemented when lead acid batteries are used.

B3.3 Example 1

B3.3.1 A pipe casing is 762 mm (30.0 in) in diameter, 12.2 m (40.0 ft) long, and has a wall thickness of 7.92 mm (0.312 in).

Casing Data:
Length a = 12.2 m (40.0 ft)
Length b = 15 m (49 ft)
Diameter = 762 mm (30.0 in)
Wall Thickness = 7.92 mm (0.312 in)

B3.3.2 Step 1: Find the calibration factor.

B3.3.2.1 A potential difference of 0.465 mV is measured between T3 and T4 before the application of current at T1 and T2. A potential difference of 1.50 mV is measured after the application of current (9.00 A).

Potential Difference Before Current is Applied:	+0.465 mV
Potential Difference After Current is Applied:	+1.500 mV
Change in Potential (ΔV):	+1.035 mV

B3.3.2.2 The calibration factor is calculated using Equation (B8):

$$\text{Calibration Factor} = \frac{9.00\ \text{A}}{1.035\ \text{mV}} = 8.70\ \text{A/mV} \qquad \text{(B8)}$$

Note: This calibration method is similar to that used to calibrate a typical shunt used in a rectifier.

B3.3.2.3 Check Step 1 using Table B4:

B3.3.2.3.1 Find the factor for a pipe with a 762 mm (30 in) diameter and 7.92 mm (0.312 in) wall thickness in the table.

B3.3.2.3.2 Divide the factor by the length to find the calibration factor using Equation (B9).

$$\text{Calibration Factor} = \frac{105.41\ \text{A/mV/m}}{12.2\ \text{m}} = 8.64\ \text{A/mV} \qquad \text{(B9)}$$

B3.3.2.2.3 Because these two calculations are within ±5%, proceed to Step 2.

B3.3.3 Step 2: Measure the voltage with current applied at the upstream end.

B3.3.3.1 Calculate the distance (in percent) from contact to T4 using a modified version of Equation (B10):

$$\text{Distance (in percent) to contact from T4} = \frac{1.035\ \text{mV} \times 8.70\ \text{A/mV} \times 100\%}{9.00\ \text{A}} = 100 \qquad \text{(B10)}$$

B3.3.3.2 Check Step 2 Using Table B4:

B3.3.3.2.1 Find the resistance for a pipe with a 762 mm (30 in) diameter and 792 mm (31.2 in) wall thickness in Table B4.

B3.3.3.2.2 Determine the length from the positive, inside terminal to the short. The resulting equation is a modified version of Equation (B11):

$$\text{Length} = \frac{1.035 \text{ mV} \times 10^{-3}}{9.00 \text{ A} \times 9.48 \times 10^{-6} \text{ ohms/m}} \qquad \text{(B11)}$$

$$\text{Length} = 12.1 \text{ m}$$

B3.3.3.3 Because the length from the positive, inside terminal to the short is equal to the entire length of the pipe, this test indicates that the short is at the downstream end.

B3.3.4 Step 3: Measure the voltage with current applied at the downstream end.

B3.3.5 Step 4: Calculate the distance (in percent) to contact from T3 using Equation (B12):

$$\text{Distance (in percent) to contact from T3} = \frac{0 \text{ mV} \times 8.70 \text{ A/mV} \times 100\%}{9.00 \text{ A}} = 0\% \qquad \text{(B12)}$$

B3.3.5.1 A potential change of 0 mV when current is applied is observed between T3 and T4, confirming that the metal-to-metal contact is located at the downstream end of the casing.

B3.3.5.2 Notes: If a short is located near the middle of the casing and all of the currents are confirmed by the IR drop method, the location of the short may be determined by finding the percentage of current at either end of the pipe and then calculating the distance in A/m (A/ft) (as shown in Step 2).

B3.3.5.3 If the currents do not sum algebraically, the results of the testing should be considered inconclusive.

B3.4 Alternate Method to Step 4: Longitudinal Resistance Values for the Casing

B3.4.1 The preceding calibration procedure can also be used to provide the actual longitudinal resistance for the casing (voltage drop between casing test leads, divided by applied current). Then using Equation (B13), the distance from the end of the casing to the point of contact can be calculated:

$$L_{C1} = \frac{R_{C1,}}{R_{CT}} L_{CT} \qquad \text{(B13)}$$

Where:

L_{C1} = Distance from end of casing to point of contact
R_{C1} = Longitudinal casing resistance (calculated from end of casing to point of contact = $\Delta V_1/I$)
R_{CT} = Total longitudinal resistance of casing
L_{CT} = Total length of casing

B3.4.2 The actual resistance per unit length (R_{CT}/L_{CT}) for the casing should be compared with the theoretical resistance per unit length for the casing, found in Table B4.

B3.4.3 When the test is repeated at the opposite end of the casing (end No. 2), Equation (B14) can be used to find the distance from that end of the casing to the point of contact.

$$L_{C2} = \frac{R_{C1,}}{R_{C2}} L_{CT} \qquad \text{(B14)}$$

B3.4.4 For the test results to be accurate, $R_{C1} + R_{C2} = R_{CT}$ and $L_{C1} + L_{C2} = L_{CT}$. The ends of the casing are considered to be the locations where the test leads for the potential measurements are located. The potential measured across the casing is the potential change that occurs when current is applied.

B3.4.5 A sample equation is shown as Equation (B15):

$$R_{c1} \text{ (from Paragraph B3.3.2.1)} = 1.035 \text{ mV or } 0.001035 \text{ V}/9.0 \text{ A} = 0.000115 \text{ Ohm} \qquad \text{(B15)}$$

Where:
R_{ct} for 760 mm (30 in) diameter casing from Table B4 = 9.48 micro Ohms/m or 0.00000948 Ohms x 15 m length = 0.000142 Ohms
L_{ct} = 15 m

Using the formula in Paragraph B3.4.1, L_{c1} (distance from end of casing to point of contact) = 12.1 m, which equals the result calculated in Paragraph B3.3.3.2.2.

B4 Cycling the Rectifier

B4.1 Purpose

Measurement of structure-to-earth potentials under steady-state conditions of applied CP may not provide conclusive evidence regarding the state of electrical isolation between casing and pipeline. The same potential measurement, if taken while the CP rectifier is being cycled, may provide additional information for evaluation of casing isolation conditions.

B4.2 Procedure

B4.2.1 This technique may be applied to a pipeline survey using an interrupter in the most influential CP rectifier unit. The location of the cycling rectifier selected shall be sufficiently remote from the casing under test so that anode bed voltage gradients do not influence the measurement.

B4.2.1.1 Pipeline and casing potentials shall be measured with the CP current applied.

B4.2.1.2 Step 1 shall be repeated at the same instant that the CP current is switched off.

B4.3 Analysis

B4.3.1 If the on- and off-potentials from the casing are close in magnitude to the on- and off-potentials of the carrier pipe, the presence of an electrical (metallic) short may be indicated.

Note: If water or soil is present in the casing, this test procedure may not give a conclusive result. In such situations, additional testing techniques should be employed.

B5 Casing Depolarization Test

B5.1 Purpose

Isolation may be verified by discharging DC from the casing. If the two structures are not metallically connected, a significant potential difference occurs between the casing and carrier pipe.

B5.2 Procedure

B5.2.1 Step 1: A temporary metallic structure shall be constructed laterally to, and spaced an appropriate distance from, the carrier and casing (a spacing of 15 m [50 ft] is usually an adequate distance). Steel rods driven into the earth or sheets of aluminum foil in contact with the earth (usually placed in standing water) may provide an adequate temporary structure.

B5.2.2 Step 2: The negative terminal of a variable DC power source shall be connected to the temporary metallic structure.

B5.2.3 Step 3: The positive terminal of the same variable DC power source shall be connected to the casing.

B5.2.4 Step 4: A reference electrode should be positioned over the carrier pipe near the casing end. The reference electrode shall not be placed over the casing.

B5.2.5 Step 5: An appropriate DC voltmeter shall be used to measure and record the carrier and casing potentials.

B5.2.6 Step 6: A small increment of current (0.1 A is a satisfactory first increment of current) shall be discharged from the casing for a short period of time, such as one or two minutes.

B5.2.7 Step 7: The current shall be interrupted; then the carrier and casing instant-off potentials shall be measured and recorded to determine the effect of the applied current; the increment of current shall also be recorded.

B5.2.8 Step 8: Steps 6 and 7 shall be repeated using additional increments of current (e.g., 0.2, 0.3 A). A minimum of three different values of test current and measurement of the effects should be taken. The amount of current necessary for an effective evaluation varies because of the size of the structure and condition of any coating present. A maximum of 10 A of DC should adequately develop significant potential shifts.

B5.3 Analysis

B5.3.1 Casing Shorted

If the casing is shorted, the casing-to-soil potential shifts in a positive direction. The pipe-to-soil potential also shifts in a positive direction, usually by about the same magnitude as the casing. As subsequent steps are taken, the pipe-to-soil potential largely tracks the positively shifting potentials of the casing.

B5.3.2 Casing Clear

B5.3.2.1 If there is no short, the pipe-to-soil potential may shift in a positive direction by only a few millivolts, whereas there will be a dramatic shift in the casing-to-soil potential. In some cases, the pipe-to-soil potential may shift in a negative direction by a few millivolts.

B5.3.2.2 If the casing potential shifts in a positive direction and the carrier (pipeline) potential remains near normal, electrical isolation is indicated. If the casing and pipeline potentials both shift in the positive direction, a shorted condition is indicated.

B5.4 Examples

Examples 1 and 2 shown in Tables B1 and B2 illustrate values that indicate electrical isolation (casing clear), and Example 3 shown in Table B3 illustrates values that indicate an electrically shorted condition (casing short).

Table B1
Example 1: Electrical Isolation

			Pipe Potential	**Casing Potential**	**Potential Difference**
Initial Readings			– 0.975	– 0.850	0.125
Step 1	6.0 Volts	0.25 Amps	– 0.974	– 0.710	0.264
Step 2	18 Volts	0.68 Amps	– 0.975	– 0.505	0.470
Step 3	45 Volts	1.0 Amps	– 0.981	– 0.210	0.771
Step 4	65 Volts	1.8 Amps	– 0.986	+ 0.0100	0.996

Conclusion: Casing is clear (not shorted).

Table B2
Example 2: Electrical Isolation

			Pipe Potential	**Casing Potential**	**Potential Difference**
Initial Readings			– 1.250	– 1.21	0.04000
Step 1	6.0 Volts	0.0860 Amps	– 1.139	– 0.700	0.4390
Step 2	18 Volts	0.258 Amps	– 1.104	– 0.140	0.9640
Step 3	30 Volts	0.413 Amps	– 1.060	+ 0.240	1.300
Step 4	42 Volts	0.566 Amps	– 1.022	+ 0.490	1.512

Conclusion: Casing is clear (not shorted).

Table B3
Example 3: Electrically Shorted Condition

					Pipe Potential	Casing Potential	Potential Difference
Initial Readings					– 1.246	– 1.242	0.0040
Step 1	6.0	Volts	0.234	Amps	– 1.211	– 1.195	0.016
Step 2	18	Volts	0.594	Amps	– 1.050	– 0.9800	0.070
Step 3	30	Volts	1.00	Amps	– 0.7960	– 0.7100	0.086
Step 4	45	Volts	1.20	Amps	– 0.6100	– 0.5400	0.070
Step 5	75	Volts	2.00	Amps	– 0.1350	– 0.1000	0.035

Conclusion: Casing is shorted.

NOTE: During this test, current is being discharged from the casing and this could result in creating a temporary interference condition with other structures.

B6 Use of Pipe/Cable Locator

The presence and location of a pipe-to-casing metallic contact may also be approximated by following a low-power audio or radio signal (pipe locator trace) set between the pipe and the casing. The signal returns at the point of contact, which should be verified from the opposite end.

Table B4
Pipe Data

OD		Wall Thickness		Weight		Resistance		Factor		External Area			
mm	**in**	**mm**	**in**	**kg/m**	**lb/ft**	**µohm/m**	**µohm/ft**	**A/mV/m**	**A/mV/ft**	**m^2/m**	**ft^2/ft**	**100 m^2/km**	**100 ft^2/mi**
64	2.5	5.23	0.206	8.62	5.79	122.3	37.27	8.178	26.83	0.199	0.654	1.995	34.56
73.03	2.875	7.01	0.276	11.4	7.66	92.42	28.17	10.8	35.5	0.230	0.753	2.294	39.74
89	3.5	5.49	0.216	11.3	7.58	93.41	28.47	10.71	35.13	0.279	0.916	2.793	48.38
110	4.5	6.02	0.237	16.06	10.79	66	20	15	50	0.3591	1.178	3.59	62.2
110	4.5	8.56	0.337	22.29	14.98	47.28	14.41	21.16	69.42	0.3591	1.178	3.59	62.2
168.3	6.625	5.56	0.219	22.28	14.97	47.31	14.42	21.14	69.37	0.5285	1.734	5.287	91.58
168.3	6.625	7.1	0.28	28.23	18.97	37.34	11.38	26.79	87.91	0.5285	1.734	5.287	91.58
168.3	6.625	7.92	0.312	31.36	21.07	33.60	10.24	29.76	97.64	0.5285	1.734	5.287	91.58
168.3	6.625	9.53	0.375	37.25	25.03	28.3	8.62	35.354	115.99	0.5285	1.734	5.287	91.58
168.3	6.625	11.0	0.432	42.53	28.58	24.8	7.55	40.368	132.44	0.5285	1.734	5.287	91.58
219.1	8.625	6.4	0.25	33.28	22.36	31.7	9.65	31.580	103.61	0.6882	2.258	6.8822	119.22
219.1	8.625	7.95	0.313	33.84	22.74	31.1	9.49	32.120	105.38	0.6882	2.258	6.8822	119.22
219.1	8.625	8.18	0.322	42.49	28.55	24.8	7.56	40.33	132.3	0.6882	2.258	6.8822	119.22
219.1	8.625	9.53	0.375	49.17	33.04	21.4	6.53	46.66	153.1	0.6882	2.258	6.8822	119.22
273.1	10.75	6.4	0.25	41.73	28.04	25	7.7	39.606	129.94	0.8577	2.814	8.578	148.6
273.1	10.75	9.27	0.365	60.24	40.48	17.5	5.33	57.174	187.58	0.8577	2.814	8.578	148.6
273.1	10.75	9.53	0.375	61.83	41.55	17.0	5.19	58.686	192.54	0.8577	2.814	8.578	148.6
273.1	10.75	11.1	0.438	71.72	48.19	14.7	4.48	68.065	223.31	0.8577	2.814	8.578	148.6
273.1	10.75	13	0.50	81.46	54.74	12.9	3.94	77.316	253.66	0.8577	2.814	8.578	148.6
323.9	12.75	6.4	0.25	49.68	33.38	21.2	6.46	47.146	154.68	1.017	3.338	10.174	176.24
323.9	12.75	7.14	0.281	55.73	37.45	18.9	5.76	52.895	173.54	1.017	3.338	10.174	176.24
323.9	12.75	7.95	0.313	61.77	41.51	17	5.2	58.628	192.35	1.017	3.338	10.174	176.24
323.9	12.75	9.53	0.375	73.75	49.56	14.3	4.35	70.000	229.66	1.017	3.338	10.174	176.24
323.9	12.75	13	0.50	97.36	65.42	11	3.3	92.400	303.15	1.017	3.338	10.174	176.24
360	14	6.4	0.25	54.63	36.71	26	7.8	39.054	128.13	1.117	3.665	11.171	193.52
360	14	7.92	0.312	67.98	45.68	20.6	6.27	48.597	159.44	1.117	3.665	11.171	193.52
410	16	6.4	0.25	62.58	42.05	22.3	6.81	44.735	146.77	1.277	4.189	12.767	221.17

Table B4
Pipe Data (Continued)

OD		Wall Thickness		Weight		Resistance		Factor		External Area			
mm	in	mm	in	kg/m	lb/ft	µohm/m	µohm/ft	A/mV/m	A/mV/ft	m^2/m	ft^2/ft	100 m^2/km	100 ft^2/mi
410	16	6.35	0.250	62.58	42.05	22.3	6.81	44.735	146.77	1.277	4.189	12.770	221.17
410	16	7.92	0.312	77.92	52.36	17.9	5.47	55.705	182.76	1.277	4.189	12.770	221.17
410	16	9.53	0.375	93.13	62.58	15.0	4.58	66.577	218.43	1.277	4.189	12.770	221.17
410	16	16.7	0.656	160.0	107.5	8.76	2.67	114.37	375.22	1.277	4.189	12.770	221.17
460	18	6.35	0.250	70.53	47.39	19.8	6.05	50.417	165.41	1.436	4.712	14.360	248.81
510	20	6.35	0.250	78.47	52.73	17.8	5.43	56.098	184.05	1.596	5.236	15.960	276.46
510	20	7.14	0.281	88.15	59.23	15.9	4.84	63.014	206.74	1.596	5.236	15.960	276.46
510	20	7.92	0.312	84.40	56.71	16.6	5.05	60.332	197.94	1.596	5.236	15.960	276.46
510	20	9.53	0.375	117	78.6	12.0	3.65	83.622	274.35	1.596	5.236	15.960	276.46
560	22	6.35	0.250	86.42	58.07	16.2	4.93	61.780	202.69	1.756	5.760	17.560	304.11
593.73	23.375	9.53	0.375	137.2	92.19	10.2	3.11	98.079	321.78	1.865	6.120	18.650	323.11
593.73	23.375	11.9	0.469	170.7	114.7	8.20	2.50	122.07	400.49	1.865	6.120	18.650	323.11
610	24	7.14	0.281	106.0	71.25	13.2	4.02	75.801	248.69	1.915	6.283	19.150	331.75
610	24	7.92	0.312	117.7	79.06	11.9	3.62	84.110	275.95	1.915	6.283	19.150	331.75
610	24	8.74	0.344	129.2	86.85	10.8	3.30	92.397	303.14	1.915	6.283	19.150	331.75
610	24	10.3	0.406	152.3	102.4	9.19	2.80	108.91	357.31	1.915	6.283	19.150	331.75
610	24	11.9	0.469	175.3	117.8	7.97	2.43	125.33	411.20	1.915	6.283	19.150	331.75
610	24	12.7	0.500	186.8	125.5	7.48	2.28	133.51	438.01	1.915	6.283	19.150	331.75
610	24	15.9	0.625	232.2	156.1	6.04	1.84	166.02	544.68	1.915	6.283	19.150	331.75
660	26	7.24	0.285	117	78.3	12.0	3.66	83.302	273.30	2.075	6.807	20.750	359.40
660	26	7.92	0.312	142.5	95.73	9.81	2.99	101.85	334.14	2.075	6.807	20.750	359.40
660	26	8.26	0.325	132.6	89.12	10.5	3.21	94.811	311.06	2.075	6.807	20.750	359.40
660	26	9.53	0.375	152.73	102.63	9.15	2.79	109.19	358.22	2.075	6.807	20.750	359.40
660	26	12.7	0.500	202.65	136.17	6.89	2.10	144.87	475.29	2.075	6.807	20.750	359.40

Table B4
Pipe Data (Continued)

OD		Wall Thickness		Weight		Resistance		Factor		External Area			
mm	in	mm	in	kg/m	lb/ft	µohm/m	µohm/ft	A/mV/m	A/mV/ft	m^2/m	ft^2/ft	100 m^2/km	100 ft^2/mi
760	30	7.92	0.312	147.4	99.08	9.48	2.89	105.41	345.83	2.394	7.854	23.939	414.69
760	30	8.26	0.325	153.12	102.89	9.12	2.78	109.46	359.13	2.394	7.854	23.939	414.69
760	30	8.74	0.344	162.03	108.88	8.63	2.63	115.83	380.03	2.394	7.854	23.939	414.69
760	30	9.1	0.36	169.59	113.96	8.23	2.51	121.24	397.77	2.394	7.854	23.939	414.69
760	30	9.53	0.375	176.57	118.65	7.91	2.41	126.23	414.14	2.394	7.854	23.939	414.69
760	30	10.3	0.406	191.1	128.4	7.32	2.23	136.60	448.17	2.394	7.854	23.939	414.69
760	30	11.1	0.438	205.56	138.13	6.79	2.07	146.95	482.13	2.394	7.854	23.939	414.69
760	30	10	0.50	234.43	157.53	5.97	1.82	167.59	549.84	2.394	7.854	23.939	414.69
910	36	8.74	0.344	194.8	130.9	7.19	2.19	139.26	456.89	2.873	9.425	28.727	497.63
910	36	9.53	0.375	212.33	142.68	6.59	2.01	151.79	498.01	2.873	9.425	28.727	497.63
910	36	10.3	0.406	229.82	154.43	6.10	1.86	164.29	539.02	2.873	9.425	28.727	497.63
910	36	11.9	0.469	264.72	177.88	5.28	1.61	189.24	620.87	2.873	9.425	28.727	497.63
910	36	10	0.50	282.12	189.57	4.95	1.51	201.68	661.68	2.873	9.425	28.727	497.63
910	36	14.3	0.562	316.82	212.89	4.43	1.35	226.49	743.07	2.873	9.425	28.727	497.63
910	36	15.9	0.625	351.41	236.13	3.97	1.21	251.21	824.19	2.873	9.425	28.727	497.63
910	36	17.4	0.687	385.86	259.28	3.61	1.10	275.84	904.99	2.873	9.425	28.727	497.63
1,070	42.0	9.53	0.375	248.13	166.73	5.64	1.72	177.38	581.95	3.3516	10.996	33.516	580.57
1,070	42.0	9.9	0.39	257.92	173.31	5.41	1.65	184.38	604.92	3.3516	10.996	33.516	580.57
1,070	42.0	11.1	0.438	289.3	194.4	4.82	1.47	206.82	678.53	3.3516	10.996	33.516	580.57
1,070	42.0	10	0.50	329.84	221.64	4.23	1.29	235.80	773.61	3.3516	10.996	33.516	580.57
1,070	42.0	14.3	0.562	370.1	248.7	3.77	1.15	264.58	868.06	3.3516	10.996	33.516	580.57
1,070	42.0	15.9	0.625	411.07	276.22	3.41	1.04	293.86	964.12	3.3516	10.996	33.516	580.57
1,220	48.0	10	0.50	377.52	253.68	3.71	1.13	269.89	885.45	3.8301	12.566	38.301	663.50
1,220	48.0	15.9	0.625	470.67	316.27	2.99	0.910	336.472	1,103.91	3.8301	12.566	38.301	663.50
1,220	48.0	19	0.75	563.31	378.52	2.49	0.760	402.699	1,321.19	3.8301	12.566	38.301	663.50

Appendix C
Clearing a Shorted Casing
(Nonmandatory)

This appendix is considered nonmandatory, although it may contain mandatory language. It is intended only to provide supplementary information or guidance. The user of this standard is not required to follow, but may choose to follow, any or all of the provisions herein.

C1 Clearing a shorted casing normally involves excavating one or both ends of the casing, exposing several ft (m) of pipe, examining the ends of the casing, possibly lifting the pipe and replacing the casing vents, spacers/isolators, end seals, and test stations.

C2 All work performed in attempting to clear a shorted casing should include a work plan documenting what is necessary for personal safety, public safety, pipeline excavation, moving and lifting procedures, ditch safety, and any local or national codes and permits that apply.

C3 The first step in clearing a shorted casing is to research the method of construction, materials used for the casing, spacers, end seals, etc., alignment sheets, records, and any history about the cased crossing. Doing this research and determining how it was installed may highlight the area of the casing that is shorted and may verify the location of the short or may determine that the casing was installed shorted because of the materials used and/or the construction methods.

C4 The second step is to analyze the corrosion records, any in-line inspection (ILI) information and any previous attempts to clear the short. The ILI data may locate the short if it is a “hard” metallic contact. Knowing where the short is located simplifies the process. If the ILI data cannot determine the location of the short, then the casing could be resting on collapsed spacers and is shorted at multiple locations.

C5 The third step is to procure casing spacers, end seals, shims, vent pipe material, test station material, and pipe coating and all other materials that might be needed. This assists in preventing delays to the project.

C6 The fourth step is to expose the casing end and carrier pipe by excavating according to the work plan. Enough of the casing should be exposed to permit:

- Access to the vent pipe.
- Adequate work area.
- Cutting off or trimming the casing.

C7 The pipeline (carrier pipe) should be exposed and stripped back several ft (m) to start, and possibly several hundred ft (m) if it is determined the pipe is to be moved.

C8 After the casing and pipeline have been adequately exposed:

C8.1 The existing end seal (if any)should be removed.

C8.2 The annular space between the carrier pipe and casing should be examined.

C8.3 The amount of water in the annular space should be estimated.

C8.4 Water in the annular space should be drained.

C8.5 Water in the annular space should be tested for microbiologically influenced corrosion (MIC).

C8.6 Any broken casing spacers that are accessible should be removed.

C9 If the casing and carrier pipe are in contact, the point of contact should be evaluated to determine whether it is the short.

Note: When the pipe is unearthed, it may move (rise) on its own, depending on the installation methods, and sometimes clear the short on its own.

C10 The fifth step is to clear the short. If the short is at the end of the casing and adequate space is available, the casing may be cold cut and trimmed back to eliminate the casing to carrier pipe contact. Once this is completed and the short is cleared, the coating shall be repaired. Next, a casing spacer or shim should be installed between the casing and carrier to keep the casing from shorting again. An end seal, as well as test leads, and vent pipes shall be installed as necessary.

C11 If the casing cannot be trimmed back to clear the short, then the pipe should carefully be moved and lifted (in accordance with the work plan) to attempt to clear the short. This may be accomplished by using air bags, jacks, excavation equipment, cranes, or other methods that allow the pipe to move, in accordance with the work plan, while not having any point loads on the pipe. (Note: An engineering analysis should be performed to determine the stress on the pipe, if it must be moved. The analysis should also determine whether a pressure reduction is required.) If this is accomplished and the short clears, then the coating shall be repaired Additionally, casing spacer(s) or shim(s) should be installed between the casing and carrier to prevent future shorts from developing. An end seal, as well as test leads and vent pipes, shall be installed as necessary.

C12 If these attempts fail and the short is determined to not be at the ends, then consideration should be given to removing the carrier pipe and replacing the crossing with a new pipe. If loading requires a casing, the casing shall be removed and replaced with a split sleeve casing.

Appendix D
Removing a Casing
(Nonmandatory)

This appendix is considered nonmandatory, although it may contain mandatory language. It is intended only to provide supplementary information or guidance. The user of this standard is not required to follow, but may choose to follow, any or all of the provisions herein.

D1 Removing a shorted casing normally involves excavating the entire casing, or possibly a short segment of casing, then removing that section of the casing.

D2 All work performed in attempting to remove a shorted casing should include a work plan to document what is necessary for personal safety, public safety, pipeline excavation, moving and lifting procedures, ditch safety, and any local or national codes and permits that apply.

D3 Removal Procedure

D3.1 Step 1

D3.1.1 Perform any CIS, DCVG, PCM, ACVG, and intentional short prior to starting the excavation.

D3.1.2 Take a pipe to electrolyte reading on each end of the casing before starting the excavation.

D3.2 Step 2

D3.2.1 Excavate pipe to at least 300 mm (12 in) below casing bottom; support as necessary.

D3.2.2 Examine casing ends to determine whether the carrier pipe is centered.

D3.2.3 Remove any end seals.

D3.2.4 Document whether the casing is filled, the type of filler material (if known).

D3.2.5 Document amount of water in casing, if any.

D3.2.6 Sample water for microbiological testing (e.g., acid-producing bacteria [APB], sulfate-reducing bacteria [SRB]).

D3.2.7 Install shims to hold carrier pipe off casing.

D3.3 Step 3

D3.3.1 Cut casing off with two cuts 180° apart, typically at 3:00 and 9:00.

D3.3.1.1 Align cuts with largest gap between carrier and casing.

D3.3.1.2 Make a girth cut every 2.45 m (8 ft) to 3.05 m (10 ft).

D3.3.1.3 Once the previous section is removed, realign cuts to largest gaps between carrier and casing.

D3.3.1.4 Remove sections of casing.

D3.3.1.5 Remove any spacers.

D3.3.1.6 Larger diameter/longer lengths of pipe may require three cuts or a girth cut, resulting in shorter lengths.

D3.4 Step 4

D3.4.1 Document the type of end seal and spacers, as well as dimension between spacers.

D3.4.2 Document any mud or debris in the annulus and test for MIC.

D3.4.3 Inspect the condition of the exposed pipe coating in its current condition.

D3.4.4 Clean existing coating on carrier pipe.

D3.5 Step 5

D3.5.1 Abrasive blast carrier pipe (if necessary) to allow inspection.

D3.5.2 Perform a direct examination of the exposed portion of the carrier pipe.

D3.5.3 Document the soil environment (e.g., pH, resistivity).

D3.5.4 Take a pipe to electrolyte on both ends of the excavation opening once the casing is removed.

D3.6 Step 6

D3.6.1 Clean and recoat carrier pipe.

D3.6.2 Take a pipe to electrolyte after the pipe is covered.

D3.7 Cutting Process

D3.7.1 Cold cutting such as grinding with abrasive disc or saw with a diamond blade should be used if possible for the removal of the casing.

Note: Coated casings make use of a diamond blade difficult, as coating deposits onto the blade surface, reducing its effectiveness. This may be allieviated by removing the coating by mechanical methods or abrasive blast prior to cold cutting.

D3.7.2 If a torch, plasma cutter, or air arc is used:

D3.7.2.1 Operator should look for signs of damaging the coating on the carrier pipe.

D3.7.2.2 Use a hammer to break loose any slag holding casing sections together.

D3.7.2.3 The following safety concerns shall be addressed prior to cutting

D3.7.2.3.1 Ensure there is not a combustible atmosphere.

D3.7.2.3.2 Ensure that the cutting process does not cut into the carrier pipe.

D3.7.3 If grinding is used:

D3.7.3.1 Use a side grinder to make the first pass cut, removing 70% to 90% of the metal.

D3.7.3.2 Use a die grinder to finish the cut.

D3.7.3.3 The following safety concerns shall be addressed prior to cutting.

D3.7.3.2.1 Ensure there is not a combustible atmosphere.

D3.7.3.2.2 Ensure that the cutting process does not cut into the carrier pipe.

D3.7.3.3 The operator should pay close attention to the area being cut, looking for signs of complete cut of the casing without cutting into the coating of the carrier pipe.

Appendix E
Guidelines for Selection of Indirect Inspection Tools for Cased Pipe
(Nonmandatory)

This appendix is considered nonmandatory, although it may contain mandatory language. It is intended only to provide supplementary information or guidance. The user of this standard is not required to follow, but may choose to follow, any or all of the provisions herein.

Legend
A—Acceptable. This method should yield reliable results to identify metallic short or electrolytic contact.
U—Unacceptable. This method does not yield reliable results. Additional testing is needed.
1—Contact to pipeline is required at the location of signal transmitter set-up but not in the vicinity of the casing
2—Contact to pipeline is not necessary in the immediate vicinity of the casing
3—Capability exists but protocol and procedures have not been validated.
4—Intedeterminate. Data are not available to establish effectiveness

Table E1
Inspection Tools for Cased Pipe

Name Type	Electrical Contact Required		Applicability						Identifies	Description	Comments	Limitations
			Bare Casing			**Coated Casing**						
	Pipe	Casing	**Clear**	**Short**	**Electrolytic**	**Clear**	**Short**	**Electrolytic**				
Direct Current Voltage Gradient (DCVG)	No[1]	No	A	A	A	A	3	3`	Holidays, which may be a metallic path, in the coating of the pipe near the edge of the casing	Coating holiday indication near the end of the casings denote a possible metallic or electrolytic path between the casing and the pipe	There is a gradient. Possible to have holiday detected and there is no short	Stray DC currents should be considered. For bare casings, a survey should be performed over the casing to determine whether it has an electrolytic couple or metallic short
AC Current Attenuation	No[1]	No	A	A	A	3	3	3	Metallic or electrolytic couple between pipe and casing	Compares current flow at each end of casing. Measurement in mA or	Signal attenuates at a contact	

Name Type	**Electrical Contact Required**		**Applicability**						**Identifies**	**Description**	**Comments**	**Limitations**
			Bare Casing			**Coated Casing**						
	Pipe	Casing	**Clear**	**Short**	**Electrolytic**	**Clear**	**Short**	**Electrolytic**				
										dBmA/ft (dBmA/m)		
A-Frame AC Voltage Gradient (ACVG)	No[1]	No	A	A	A	A	A	A	Metallic or electrolytic couple between pipe and casing	Measure dBµA signal. strength and direction at each end of the casing	Coating anomaly tool. Reliable detection of electrolytic couple	
Pipe to Casing Current Attenuation	Yes	Yes	A	A	A	A	A	A	Metallic in mA or dBmA/m (dBmA/ft)	Compress current flow outside each end of casing.	Measurement in mA or dBmA/m (dBmA/ft)	Current will not travel outside the casing ends if a metallic short exists and is less than 80% of the output of the transmitter when electrolytic conditions exist.
Close-Interval Survey (CIS) (No Interruption) Comparing Pipe to Electrolyte and Casing to Electrolyte Potentials	Yes[2]	Yes	A	A	A	4	4	4	Metallic or electrolytic couple between pipe and casings. A preliminary screening tool	Comparison of on pipe to electrolyte and casing to electrolyte readings	On-survey. Utilizes a criterion. Preliminary check. With coated casings, there can be a problem with electrolyte in the casing or near a rectifier	Telluric currents, AC and DC strays. HVAC considerations. Complementary tool
CIS (Interrupted) Comparing Pipe to Electrolyte and Casing to Electrolytepotential Shifts	Yes[2]	Yes	A	A	A	4	4	4	Metallic or electrolytic couple between the pipe and casing	Compare pipe to electrolyte and casing to electroyte shift magnitude. Same direction and similar		Telluric currents, AC and DC strays. HVAC considerations.

Name Type	**Electrical Contact Required**		**Applicability**						**Identifies**	**Description**	**Comments**	**Limitations**
			Bare Casing			**Coated Casing**						
	Pipe	Casing	**Clear**	**Short**	**Electrolytic**	**Clear**	**Short**	**Electrolytic**				
										magnitude suggest metallic contact. Same direction but reduced casing to electrolyte shift suggest electrolytic path. Casing to electrolyte shift small or opposite indicates clear		
Pipe/Cable Locator Radio Signal	Yes	Yes	A	A	A	4	4	4	Metallic or electrolytic couple between the pipe and casing	Signal between pipe and casing is traced to point of metallic contact and returns (no appreciable signal outside casing) or signal reduction within casing may indicate electrolytic couple. Clear casing results in strong endwise signal outside casing along pipe		HVAC power lines. Cannot determine whether it is electrolytic couple or metallic short for bare casing. Can determine whether it is clear for bare casing

Name Type	Electrical Contact Required		Applicability						Identifies	Description	Comments	Limitations
			Bare Casing			Coated Casing						
	Pipe	Casing	**Clear**	**Short**	**Electrolytic**	**Clear**	**Short**	**Electrolytic**				
Internal Resistance Electrical Resistance	Yes	Yes	U	A	U	U	A	U	Pipe-casing metallic or electrolytic couple	Measured resistance equated to path down casing and back along pipe to calculate distance to contact	Resistance of path external to casing should be considered	Stray DC Current consideration. Complementary tool. Can determine metallic short only
Four-Wire Drop Test Current Flow Direction and Magnitude	Yes	Yes	U	A	U	U	U	U	Pipe-to-casing metallic contact	Using current span testing to indicate the presence and location of contact of the carrier pipe to the casing	Access over top of casing required	Not typically used
Temporary Intentional Short Electrical Potential Comparing Pipe to Electrolyte and Casing to Electrolyte Shifts	Yes	Yes	A	A	U	A	A	U	Confirmation of suspected metallic contact	Compare pipe to electrolyte and casing to electrolyte potential or shifts with temporary short between pipe and casing in place and removed. No change indicates contact of similar resistance already existed	Pipe and casing test wires offer better results	Long casing vents, if used, may distort results. Can only determine metallic shorts

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