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Petroleum and natural gas industries — Pipeline transportation systems — Design, construction and maintenance of steel cased pipelines

Industries du pétrole et du gaz naturel — Systèmes de transport par conduites — Conception, construction et maintenance de conduites en fourreau en acier

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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The committee responsible for this document is ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*, Subcommittee SC 2, *Pipeline transportation systems*.

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Introduction

Users of this document are advised that further or differing requirements might be needed for individual applications. This document is not intended to inhibit a vendor from offering, or the purchaser from accepting, alternative equipment, or engineering solutions for the individual application. This might be particularly applicable where there is innovative or developing technology. Where an alternative is offered, it is advisable that the vendor identify any variations from this document and provide details.

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Petroleum and natural gas industries — Pipeline transportation systems — Design, construction and maintenance of steel cased pipelines

1 Scope

This document specifies requirements, including corrosion protection, for the design, fabrication, installation and maintenance of steel-cased pipelines for pipeline transportation systems in the petroleum and natural gas industries in accordance with ISO 13623.

NOTE 1 Steel casings can be used for mechanical protection of pipelines at crossings, such as at roads and railways and the installation of a casing at a highway, railway, or other crossing can be required by the permitting agency or pipeline operator.

NOTE 2 This document does not imply that utilization of casings is mandatory or necessary.

NOTE 3 This document 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 can adversely affect the integrity of the carrier pipe by shielding cathodic protection (CP) current to the carrier pipe or reducing the CP effectiveness on the carrier pipe in the vicinity of the casing. Their use is not recommended unless required by load considerations, unstable soil conditions, or when their use is dictated by sound engineering practices.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 15589-1, *Petroleum, petrochemical and natural gas industries — Cathodic protection of pipeline systems — Part 1: On-land pipelines*

EN 12954, *Cathodic protection of buried or immersed metallic structures — General principles and application for pipelines*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
carrier pipe
pipe that conveys the fluid

Note 1 to entry: Note to entry: This applies to both transmission and distribution piping.

3.2
casing
steel pipe installed around a carrier pipe for mechanical protection

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3.3
electrolyte
medium in which electric current is transported by ions

3.4
electrolytic contact
ionic contact between the carrier pipe and the casing pipe through an electrolyte

3.5
end seal
device installed over or within the end of a casing to keep water, deleterious materials and debris out of the casing or provide a water tight seal between the casing and the carrier pipe

3.6
holiday
unintentional discontinuity in a protective coating that exposes the bare steel surface to the environment

3.7
isolator
spacer
dielectric device designed to electrically isolate a carrier pipe from a casing and provide support for the carrier pipe

3.8
metallic short
unintentional contact between two metallic structures

3.9
P/S potential
pipe-to-electrolyte potential
structure-to-electrolyte potential
potential difference between the surface of a buried or submerged metallic structure (pipe or casing) and the electrolyte that is measured with respect to a reference electrode in contact with the electrolyte

3.10
split sleeve
casing installed in situ by welding two halves of the casing together around the carrier pipe

3.11
tunnel liner plate
steel plate used when micro tunnelling, used to shore horizontal excavations in soft ground

3.12
C/S potential
casing–to–electrolyte potential
potential difference between the surface of a buried or submerged metallic casing and the electrolyte that is measured with respect to a reference electrode in contact with the electrolyte

4 Design

4.1 General

The purpose of a casing is to provide additional mechanical protection to the carrier pipe. A casing can also be required by a permitting authority to allow replacement of a carrier pipe without excavations at the location of a crossing.

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A carrier pipe within a casing is not designed to be cathodically protected. It is designed to be electrically isolated from the casing with non-conducting spacers, or isolated if the annulus of the casing is filled with a dielectric filler material. The carrier pipe is designed to be protected with a protective coating.

Steel casings shall not be cathodically protected by the pipeline's dedicated CP system.

4.2 Carrier pipe design

The carrier pipe shall be coated for corrosion protection. The application of an abrasion resistant coating over the corrosion coating should be considered.

NOTE 1 See NACE/SP 0169 for details of abrasion resistant coatings.

The carrier pipe shall be supported inside the casing with isolating spacers and outside the casing to prevent sagging. Sagging can lead to metallic contact between the casing and the carrier pipe and to carrier pipe stresses.

NOTE 2 See NACE/SP 0286 for details of isolation techniques.

4.3 Casing design

Casing design shall be in accordance with the local, national, or industry requirements/standards.

The casing should be kept as short in length as possible to minimize the risk of electrical shorting over time due to soil stress and pipe movement.

The casing internal diameter shall be selected based on the nominal diameter of the carrier pipe, the thickness of any abrasion resistant coating, such as concrete, duroplastic material, or epoxy polymer and the design of the isolators between carrier pipe and casing.

For individual carrier pipes with a nominal diameter of 200 mm (8.0 in) or greater, the outer diameter of the casing should be a minimum of 100 mm (4.0 in) larger than that of the carrier pipe or if installing parallel cable or conduits the casing should be a minimum of 300 mm larger than that of the carrier pipe.

For individual carrier pipes with a nominal diameter less than 200 mm (8.0 in), the diameter of the casing should be a minimum of 50 mm (2.0 in) larger than that of the carrier pipe.

Uncoated casing should be used. Coated or non-conductive casing may be used if the casing can be harmonized with the carrier pipe cathodic protection.

NOTE 1 The use of coated or nonconductive casing pipe is not recommended due to potential shielding problems when cathodic protection is applied. If coated casings (either internally coated or externally coated or both) are used, external cathodic protection will not provide protection to the carrier pipe in the event that the annulus is filled with a conductive electrolyte.

If vent pipes are required, then they should be installed on both ends of the casing. Vent pipes should be positioned so that they are not directly over any isolation spacer or end seal. If concrete coated pipe is used and no isolating spacers are used, then the vent pipes should only be installed on the top of the casing.

The casing vent hole should be at least one-half the diameter of the vent pipe, with a minimum of 25 mm (1,0 in). The vent pipe should be a minimum of 50 mm (2.0 in) in diameter.

Vent pipes shall be designed to prevent intrusion of water and debris.

Casing end seals shall be installed to prevent ingress of water, deleterious material and debris.

Vent pipes are used for venting, monitoring the casing for carrier pipe leaks, filling the casing and as line markers.

NOTE 2 NACE/SP 0200 gives guidance for design of end seals.

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4.4 Electrical isolation

Sufficient isolators shall be designed to prevent metallic contact between the carrier pipe and the casing, and to provide adequate support. Isolators shall be designed to minimize coating damage. The use of metallic components in isolation spacers should be avoided.

Isolators shall be selected to ensure they have the mechanical strength required to withstand the installation loads, considering all conditions including pipe weight, length of casing, conditions of weld beads, deflections in the casing and other field conditions. Selection should confirm the ability of the isolators to provide electrical isolation after installation and to position the carrier pipe properly for end seal application/installation.

Test leads should be located (connected to the carrier pipe) on the carrier pipe at each end of the casing to permit verification of metallic isolation. One test lead shall be required as a minimum. Test leads to be installed in accordance with 5.3.4. Test leads to be installed after the carrier pipe is inserted in the casing.

Metallic shorts between the vent pipe, test leads and carrier pipe shall be prevented.

4.5 Corrosion protection

Consideration may be given to applying cathodic protection to the casing as required by conditions or regulations. Cathodic protection design shall be in accordance with approved industry standards, such as ISO 15589-1.

Consideration may be given to placing a high dielectric filler or conductive grout in the annular space or injecting a vapour phase inhibitor. Annex A gives guidance on filling and the filling procedure.

Cathodically protected casings using the pipelines dedicated CP system may have a detrimental effect on the carrier pipe.

AC corrosion should be considered as a possible problem when the pipeline is located in an area of AC influence.

5 Installation

5.1 General

This Clause provides requirements for the installation of new cased pipeline crossings, casing extensions and new casing installation on existing pipelines.

5.2 Handling and storage

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

5.3 New casing

5.3.1 General

Cased crossings are installed using various techniques including boring, directional drilling, tunnelling and open cutting.

NOTE 1 Filling of the annular space between the casing and excavation is sometimes required by the permitting agency when the borehole is unstable or fracked out.

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Welding of steel casings should be performed in accordance with the pipeline operator’s line pipe welding specifications.

NOTE 2 ISO 13847 provides guidance on welding.

NOTE 3 Radiographic inspection of casing welds is normally not required.

Butt-weld alignment during casing fabrication shall be maintained to prevent casing, isolator, or spacer damage during push/pull operations.

Slag and any welding debris shall be removed from inside the casing to prevent damage to the carrier pipe, coating, isolator, or spacer.

Internal weld beads should be removed by grinding (when practical and allowed) to allow pulling or sliding of the carrier pipe without damage to the isolators and coating.

The casing vent pipe should be installed before the carrier pipe to avoid coating damage. If the carrier pipe is already in place when the vent hole is cut, measures shall be taken to prevent coating damage.

NOTE 4 The use of non-flammable insulating material to protect the carrier pipe coating is often required by the pipeline operator during installation of the vent pipes to prevent coating damage to the carrier pipe.

If two vent pipes are used, the one 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 non-metallic support between the vent pipe and carrier pipe shall be provided to keep the vent pipe from resting on the carrier pipe and possibly shorting between the casing and carrier pipe.

5.3.2 Carrier pipe installation

Before the installation of isolators, the carrier pipe coating shall be inspected for coating holidays using an electrical holiday detector.

NOTE 1 NACE/SP 0274 or NACE/SP 0490 provides guidance for holiday testing of the carrier pipe coating.

Isolators shall be installed according to the manufacturer’s instructions and in a manner that does not damage the carrier pipe coating. Isolator runners (skids) shall be oriented to avoid a shorted condition. Bolts, if present, should not remain at the bottom (6 o’clock) position. Clearance between isolator extremities and casing should be a minimum of 25 mm (1.0 in) to allow adequate clearance during installation. The use of metallic components in isolation spacers should be avoided.

NOTE 2 Additional information is given in NACE/SP 0286.

End caps should be installed on the carrier pipe to keep debris and deleterious material from entering the carrier pipe and to aid in smooth push/pull operations.

The casing shall be visually inspected where possible and practical and, if necessary, cleaned immediately prior to installation of the carrier pipe to remove any debris or foreign material.

All coating damage on the carrier pipe shall be repaired prior to insertion into the casing in accordance with the applicable specifications and manufacturer’s recommendations.

NOTE 3 The requirements on handling pipe are also applicable to the installation of uncoated carrier pipe.

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. The push/pull operation shall continue in a smooth motion until the carrier pipe is properly positioned.

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The alignment of the carrier pipe and casing shall be ensured both prior to and during insertion of the carrier pipe into the casing. During the installation operation, it shall be ensured that there is no isolator or spacer displacement or damage to the carrier pipe coating.

NOTE 4 Isolators can slide along the carrier pipe during installation if not installed properly, if the casing is bent, or if the installation is out of line. Inadequate support of the carrier pipe allows the carrier pipe to sag and make metallic contact with the casing.

The cased crossing shall be inspected in accordance with Clause 6 to confirm that the casing and carrier pipe are electrically isolated.

The carrier pipe and casing or tunnel liner plate shall be cleaned as necessary for the installation of the end seals in accordance with design specifications and the manufacturer's recommendations.

NOTE 5 One procedure is to fill the annulus with water after carrier pipe has been pulled in temporarily for test purposes.

A CP drainage test is executed to verify the condition of the carrier pipe coating. Acceptance procedure is described in ISO 15589-1.

5.3.3 Casing end seals

Isolating end seals shall be installed on both ends of casing.

Particular attention should be paid to the selection process, application method and applicator skills when installing casing end seals.

Failure of end seals is a major cause of unwanted water and soil ingress into the annulus between the carrier pipe and the casing. This material ingress can give rise to accelerated corrosion of the carrier pipe if the ingress is coincidental with a coating breakdown. The end seal may be a pressure and water tight seal or a simple seal to prevent debris, deleterious material and water from entering the annular space between the casing and carrier pipe. The selection of the seal should consider:

— the position of the carrier pipe at the end of the casing;

— operating temperature;

— end seal materials;

— pressure rating of the seal.

NOTE 1 Annex A gives additional guidance on casing end seal selection.

NOTE 2 Most water tight seals, such as modular mechanical seals require that the carrier pipe be positioned in the centre of the casing (centralized), whereas most simple end seals allow for some amount of off-centred position.

5.3.4 Test leads

Test leads for cathodic protection testing shall be installed on the carrier pipe and should be installed at both ends of the casing. The leads shall be attached using pin brazing or thermite welding or other approved process.

Two test lead wires should be installed at each location in order to confirm the integrity of the leads and as a contingency in case of test lead damage.

The test lead connection to the carrier pipe shall be coated. The coating shall be compatible with the carrier pipe coating, the test lead insulation and conform to the shape of the test lead/carrier pipe connection. Damage to the carrier pipe or coating shall be repaired. The coating shall be made in such a way as to eliminate any voids that may permit the ingress of moisture. There shall be no strain on the test lead that might dislodge the protective coating. Any coating damage shall be repaired with a compatible repair coating to return the coating to a holiday free condition.

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To prevent electrical shorting, test leads shall not be wrapped around the vent pipe or the casing.

Test leads shall be installed on the casing when

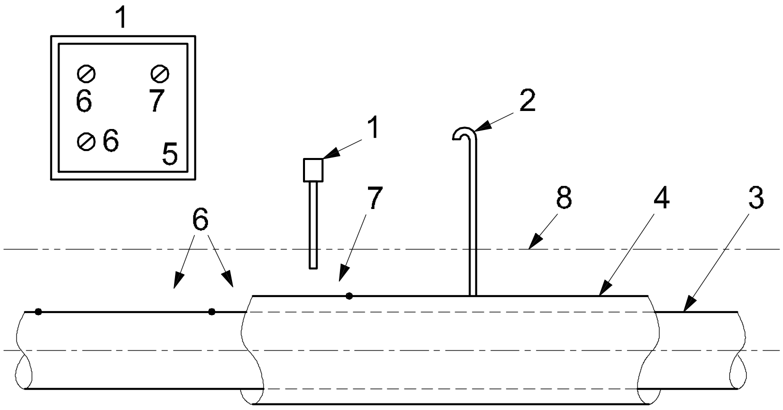
— required by the documents or specifications,

— no vent pipes are installed,

— non-metallic vent pipes are installed, or

— metallic vent pipes are installed using mechanical couplings/fittings.

Test leads shall be labelled or colour coded in accordance with the design and pipeline operator requirements.



Key

1	test station	5	insulated test panel inside test station
2	vent pipe	6	pipe test lead
3	carrier pipe	7	casing test lead
4	casing	8	ground level

Figure 1 — Typical Test Station at cased Crossing

5.3.5 Backfilling

The carrier pipe and casing shall be supported to prevent settlement during the backfilling operation. The method of support, for example, earth filled bags or compacted earth, shall be approved by the pipeline operator.

The backfill material shall be free of debris and deleterious material.

Caution shall be exercised to prevent test lead damage, which is a common cause of shorting.

Inspection as described in Clause 6 shall be performed upon completion of the backfilling operation.

5.4 Split-sleeve type casing extensions and installations

Extension of existing casings or construction of new casings on existing pipelines often involves installation by the split-sleeve method.

NOTE This method is used if the pipeline cannot be taken out of service and the subsequent blow down (gas), or drain-up (liquid), and cutting out of the crossing to allow a casing to be slipped over the pipeline is not feasible or cost-effective.

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Split-sleeve casing extensions should be specified to match the size of the existing casing. If required by the configuration of the existing pipeline, an oversized casing extension may be installed. In this case, an eccentric or concentric reducer should be used to achieve the size transition.

The carrier pipe section to be cased shall be excavated and supported to prevent sagging.

The carrier pipe shall be cleaned and the coating shall be inspected and repaired as needed.

Existing end seals and vents shall be removed and the vent pipe hole shall be capped with a steel plate. To prevent coating damage, the carrier pipe shall be protected during cutting and welding operations with an insulating shield of non-flammable material.

The existing casing ends shall be prepared for welding in accordance with the owner company/operator specifications.

Isolators shall be installed in accordance with the pipeline operator’s specifications.

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

If a manufactured split casing is not used, splitting of the casing shall be performed in a manner that minimizes warping or disfigurement. Hinges may be welded to the casing to maintain proper alignment of the two halves during installation. Carbon steel backing strip of 2 mm to 3 mm may be used for the long seam welding of the casing pipe over the existing carrier pipe.

The split casing shall be 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 may be tack welded at intervals prior to the continuous welding operation to prevent warping. During the welding operation, non-flammable, insulating backing material shall be used, where needed to protect the carrier pipe.

The installation of new vent piping and test leads, if required, shall be performed in accordance with 5.3.1 and 5.3.4.

Backfilling shall be performed in accordance with 5.3.5.

6 Inspection and monitoring

6.1 General

The inspection and monitoring of cased pipelines should include:

— integrity inspection of carrier pipe;

— monitoring of carrier pipe and casing;

— leakage survey.

Inspection and monitoring shall be performed throughout the life of the pipeline. Monitoring shall also be undertaken immediately after the installation of the casing to verify its status.

6.2 Integrity inspection of carrier pipe

If available, integrity inspection data (such as in-line inspection or Guided Wave data) should be used to determine the presence or absence of steel defects (such as pitting corrosion) in the carrier pipe.

NOTE Some in-line inspection techniques are capable of detecting the presence of a casing around a carrier pipe but are unable to accurately detect metal-to-metal contact between the casing and carrier pipe or carrier pipe metal loss.

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6.3 Monitoring of carrier pipe and casing

Carrier pipe and casing shall be monitored on a periodic basis to determine the condition for continuing suitability and electrical status using the following method: potential survey.

The electrical status of carrier pipe and casing shall be assessed using one or more of the following methods:

— internal resistance test;

— four-wire IR drop test for cased crossing;

— cycling the rectifier;

— casing depolarization test (see Note);

— pipe/cable locator;

— Panhandle eastern method.

Details of test methods are given in Annex B and Annex C.

NOTE Results from these measurements allow the verification of the CP effectiveness according to ISO 15589-1:2015, D.4.2.

WARNING — If cathodic protection is applied to the casing, the cathodic protection system shall be disconnected from the casing and allowed to depolarize before any tests are conducted. The presence of direct-connected galvanic anodes on the casing during the test can negate the test results.

6.4 Leakage survey

Leakage surveys should be carried out for the pipeline and the casing at the frequency required by the applicable pipeline code.

The casing vent and the area in the vicinity of the end seals should be observed for evidence of product leakage such as product, product odour, or dead and dying vegetation.

Leak-detection instruments, such as combustible gas indicators, may be used to analyse the atmosphere within a casing for the presence of combustible hydrocarbons.

The results of pressure tests and leak detection systems may be used if available.

6.5 Corrosiveness of the annular space

The corrosiveness of the annular space may be evaluated by inserting corrosion coupons and/or electrical resistance probes into the annulus to estimate the rate of corrosion at holidays in the carrier pipe coating and on the inside of the casing pipe wall.

7 Maintenance and repair

7.1 General

If inspection and monitoring of a steel cased pipeline indicates risk to the integrity of the carrier pipe, the presence of a shorted casing or a product leak, then maintenance shall be undertaken using one or more of the following actions:

— post-lay coating evaluation shall be carried out by competent persons and a determination made as to whether or not the levels of coating damage are acceptable.

— eliminating metallic contact;

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- removing the casing;
- repositioning the carrier pipe in the casing;
- repairing or replacing the carrier pipe;
- providing supplemental cathodic protection to the casing;
- filling the casing with a dielectric or non-dielectric (conductive) material;
- installing a new crossing;
- monitoring the electrical condition of the casing;
- coating or recoating the carrier pipe;
- replacing end seals;
- removing electrolyte from inside the casing.

NOTE Typical examples of maintenance and repair situations include:

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

7.2 Maintenance of vents and test leads

The maintenance of casing vents should include coating at the soil/atmosphere interface and painting, repair, or replacement of vents and, if necessary, vent caps.

Test leads shall be checked periodically in accordance with ISO 15589-1 or EN 12954 to determine their integrity.

7.3 Clearing of shorted casings

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) should be removed.

NOTE 1 The casing could have come into electrical contact with the carrier pipe in several ways:

- 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 pipeline;
- the carrier pipe was inadequately supported within the casing, allowing it to sag and come into metallic contact with the bottom of the casing;
- the carrier pipe was intentionally shorted or installed without isolators;
- a foreign object, such as a shovel or other metallic material present at the construction site was accidentally left in the casing;
- a metallic short developed between the test lead and the vent pipe or the test leads.

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Established construction techniques shall be used to realign the carrier pipe, permanently maintained in the aligned position after realignment to eliminate metallic contact.

NOTE 2 Equipment typically used in this situation includes hydraulic jacks, tripods, air bags, side-boom slings and belts.

The carrier pipe and casing shall be permanently maintained in the realigned position by the use of supports, such as compacted earth, sandbags or isolated concrete piers.

The carrier pipe should be coated with ARO coating when installed on an isolated concrete pier. The concrete should have an FRP shield installed between the pipe and the pier and be bonded to the pier.

If the casing and carrier pipe cannot be realigned, elimination of a metallic contact may be accomplished by removing a portion of the casing.

Once metallic contact is eliminated, spacing materials, end seals, vents and test leads should be reinstalled as necessary.

CAUTION — Engineering, metallurgical and operational concerns and regulatory requirements shall be considered before moving the carrier pipe.

Annex D gives further guidance on clearing of shorted casings.

7.4 Filling of casings

If required, casings may be filled with a dielectric material, inert material, or corrosion inhibitors in an attempt to eliminate a corrosive environment. Alternatively, a non-dielectric (conductive) material (e.g. concrete, sand, flowable fill, etc.) can be used to allow CP current to flow from the casing to the carrier pipe.

NOTE Information on casing filling with a high dielectric material is provided in Annex A.

A vapour phase inhibitor may be injected into the casing annulus through the vent pipes. The inhibitor is allowed to vaporize and coat the carrier pipe. Periodically, the inhibitor should be replenished. A vapour phase inhibitor is not considered a casing filler since they rely upon the continuous emission of corrosion inhibiting vapour for deposition of mono-molecular film on the steel surface rather than filling of the annulus with a dielectric. They can be used to reduce the corrosion rate to acceptable limits provided they are adequately sized and/or periodically replenished or incorporated into a gel.

7.5 Removal of casings

Guidelines for removal of casings are given in Annex E.

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Annex A
(informative)

Casing filling procedures for Dielectric Filler Materials

A.1 General

This Annex provides information on procedures for filling the annulus between carrier pipe and casing.

A.2 Preparation

A.2.1 Vent (fill) pipes

A vent (fill) pipe should be installed on each end of the casing, with an opening adequate in size to allow for the flow of filler into the casing. Several parameters effect the minimum size required for the vent (filler) pipe, such as fill material viscosity, fill material temperature, pump pressure and casing length. The fill material supplier can recommend a minimum vent (filler) pipe size. Normally, a minimum vent pipe opening of 50 mm (2.0 in) is recommended.

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 end. The vent pipes and the annulus should be free of restrictions to allow adequate flow of the filler material.

An air communication test should be conducted to ensure positive air flow between the fill and discharge vents.

A.2.2 End seals

End seals should be inspected to ensure their integrity and ability to contain the filler material during installation. If necessary, new end seals should be installed prior to the filling operation. In evaluating appropriate end seals, consideration should be given to the position of the carrier pipe within the casing and end seal material compatibility with the fill material (including application temperatures). Maximum design pressure of the end seals should be reviewed to confirm that they can withstand the potential casing fill pressures.

A pressure test of the end seals should be conducted prior to filling. Normally, this is an air pressure test.

A.3 Fill procedure

A.3.1 Filler material

Typical fillers are petrolatum, paraffin or microcrystalline wax, or polyisobutylene compounds and may contain corrosion inhibitors, plasticizers and thermal extenders.

The following are recommended characteristics for filler material:

— minimum congeal point of 41 °C (105 °F), in accordance with ASTM D938;

— minimum cone penetration of 50 deci mm, in accordance with ASTM D937;

— resistivity $>1\times10^{8}$ Ω.m;

— dielectric strength >1 kV.mm^{-1};

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— non-carcinogenic according to Regulation (EC) No 1272/2008, Annex VI, 1.1.3, Note N;

— displaces water from the steel substrate;

— non-hazardous and non-flammable;

— not water-soluble.

NOTE When filling casing downstream of compressor stations, a filler material with a higher minimal congeal point can be necessary.

A.3.2 Fill process

Prior to filling, the annular space should be cleaned/flushed if the fill material selected requires a clean/flushed annular area.

A heated, insulated tanker with a permanent, variable flow pump should be used to fill the casing.

NOTE For cold fill (drum) installation, a minimum 10:1 ratio mastic pump with inductor plate is required.

An environmentally acceptable corrosion inhibitor (specified and supplied by the filler material supplier) may be poured or pumped into the casing through the fill vent pipe just prior to the installation of the filler.

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

A.4 Verification of filler volume

Upon completion of the filling procedure, casing fill percentage should be calculated using Formula (A1):

$$\frac{ActualVolume}{TheoreticalVolume} \times 100 = Casing\ fill\ percentage \qquad (A.1)$$

The following steps assist in determining if a casing has been adequately filled.

1) Estimate the theoretical volume the casing can accept based on its length and diameters of the carrier pipe and the casing.

2) Fill the casing to its capacity allowing the filler to discharge from the opposite end vent pipe.

3) Wait at least one hour for any possible settlement of the filler material to occur and then pump additional filler material, as/if needed.

4) Note the volume pumped by the metering system on the filler truck or pump and arrive at a fill ratio of theoretical volume vs. actual volume pumped.

This calculation gives an approximation of the effectiveness of the casing filling.

NOTE 1 Individual casing fill percentages can vary considerably.

NOTE 2 Casing fill percentages can be unusually low because of

— a casing length that is smaller than that depicted on the as-built drawings,

— 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.

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NOTE 3 Fill percentages of individual casings can be unusually high because of

— discrepancies on the as-built drawings,

— holes in the casing, and

— leaks in the end seals.

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Annex B
(informative)

Examples of cathodic protection testing and monitoring techniques for carrier pipes and casings

B.1 Potential survey

B.1.1 Purpose

Cathodic protection potential surveys are made to determine the effectiveness of any applied cathodic protection to the carrier pipe and are the initial tests to identify shorted casings. A metallic contact between the carrier pipe and the casing can be identified by measuring both the pipe-to-electrolyte and casing-to-electrolyte potentials with respect to a reference electrode placed in the soil and/or a close interval potential survey of the carrier pipe.

Unless the carrier pipe is uncoated and the casing annulus is entirely filled with a conducting medium, the carrier pipe cannot be cathodically protected from an external source.

B.1.2 Procedure

B.1.2.1 General description

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

More definitive results are obtained if the cathodic protection current source is cycled on/off while the carrier pipe and casing potentials are recorded.

Potential measurements should be made with a recording voltmeter that is synchronized to the cyclical switching of the cathodic protection power source. In this way, accurate ON and OFF potential measurements can be recorded. The recording voltmeter should have at least two channels so that simultaneous measurements of the carrier pipe and the casing potential can be made. Analysis of the relationship between the ON and OFF potentials of the carrier and the casing can assist in locating any metallic connection.

B.1.2.2 Measuring carrier pipe potential

The positive lead of the voltmeter is connected to the carrier pipe by either a test lead or probe bar (if no test lead is available). The negative lead of the voltmeter is connected to the reference electrode, which is placed on the ground directly over the pipeline and near the end of the casing (see Figure B.1).

B.1.2.3 Measuring casing potential

The positive lead of the voltmeter is connected to the casing by either the vent pipe, test lead, or probe bar (if no vent pipe or test lead is available). The negative lead of the voltmeter is connected to the reference electrode, which should be placed at the location where the carrier pipe potential was taken (see Figure B.1).

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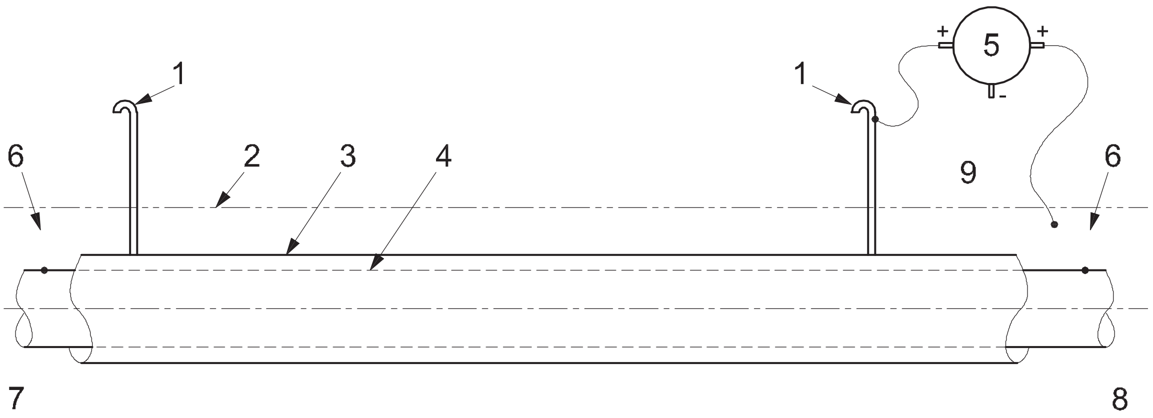

Key

1 vent pipe
2 ground level
3 casing
4 carrier pipe
5 voltmeter
6 test lead
7 upstream or upstation (U/S) end
8 downstream or downstation (D/S) end
9 reference cell

Figure B.1 — Potential survey measurement

The electrode should be placed near the end of the casing directly over the carrier pipe. The reference electrode should not be placed directly over the casing to avoid shielding of the potential. The location of the end of the casing can usually be verified with a pipe locator.

B.1.3 Acceptance criteria

It is unlikely that potential measurements alone will be sufficient to quantify casing/carrier pipe contact. More than one technique should be used to verify any conclusions made using measured potential results. On the basis that the measurements are made synchronously (i.e. the recording voltmeter measurement is made synchronously with the current interruption) then the following guidelines apply.

— If the carrier pipe is 0,95 V more negative than the casing, then this is acceptable.

— If the carrier pipe is less than 0,1 V more negative than the casing pipe, then this indicates a contact between the carrier and casing.

The location of a casing to carrier pipe short can be determined by plotting the difference between the carrier pipe measured before the casing starts and the potential of the casing measured at close intervals over the length of the crossing. Where the difference is close to zero, there will be a direct metallic contact.

A clear or not shorted casing is typically 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.

A shorted casing can 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.

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B.2 Internal resistance test

B.2.1 Purpose

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

Only personnel with cathodic protection qualifications should analyse the results for these tests. Suitable qualifications are described by NACE and EN 15257.

NOTE EN 15257 or NACE Cathodic Protection Training and Certification Program constitute suitable methods of assessing competence of cathodic protection personnel.

B.2.2 Procedure

This procedure requires an appropriate DC power source (e.g. battery), a properly rated ammeter or shunt, a properly rated resistor, sufficient lead wire, clamps, and a multimeter.

The procedure consists of the following four steps.

1) The pipe-to-casing potential should be measured at terminals T1 and T2 (see Figure B.2).

2) One battery lead should 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 should be connected in series with the ammeter to the carrier pipe at T4.

3) A constant current should be applied between terminals T3 and T4.

4) The pipe-to-casing potential should be measured between terminals T1 and T2 with the current applied.

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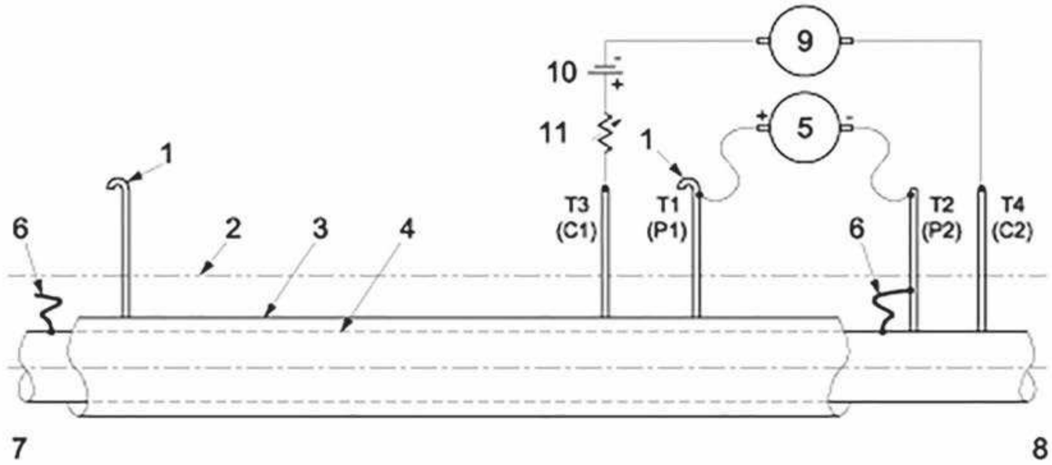

Key

1 vent pipe
2 ground level
3 casing
4 carrier pipe
5 voltmeter
6 test lead
7 upstream or upstation (U/S) end
8 downstream or downstation (D/S) end
9 ammeter
10 battery
11 variable resistor

Figure B.2 — Internal resistance test

CAUTION — It is dangerous to short the leads of a battery. The above procedure can 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 should be used. Maximum battery output should be limited to 10 A. The variable resistor should be adjusted as necessary to maintain the current output less than 10 A.

A four pin soil resistivity meter or megger may replace the battery, voltmeter and ammeter shown in Figure B.2 so that the resistance can 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 B.2. C1 is connected to T3, P1 to T1, P2 to T2, and C2 to T4.

B.2.3 *Analysis* — Resistance calculation using Ohm's Law

The change in pipe-to-casing potential (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 is divided by the current (I) to determine the resistance (R). A casing-to-pipe (metal-to-metal) contact might exist if the resultant value is less than 0, 01 Ω.

EXAMPLE 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.

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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

By dividing the absolute value of the potential change ΔV by current (I), as in Formula (B.1), the value of the resistance (R) is obtained:

$$R = \frac{0,016}{1,7} = 0,009\ 4 \qquad \text{(B.1)}$$

The resistance is 0,009 4 Ω. Because the pipe-to-casing resistance is less than 0,01 Ω, the presence of a metallic short is indicated.

EXAMPLE 2 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

By dividing the absolute value of the potential change ΔV by current (I), as in Formula (B.2), the value of the resistance (R) is obtained:

$$R = \frac{0,202}{1,7} = 0,12 \qquad \text{(B.2)}$$

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.

B.3 Four-wire IR drop test for cased crossings

B.3.1 Purpose

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

B.3.2 Procedure

B.3.2.1 Step 1: Measuring the lineal resistance of the casing

a) The potential difference should be measured between terminals T3 and T4 while a measured battery current is simultaneously passed between terminals T1 and T2 (see Figure B.3). This can be done with suitable test points (vents or test leads), or the use of probe bars if no vent pipe, test lead/test point is available.

b) The battery current in amperes is divided by the change in potential difference from T3 to T4 (ΔV) in mV to express the calibration factor in A/mV, as shown in Formula (B.3):

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$$C_{F1} = \frac{B_C}{\Delta V_{T3\ to\ T4}} \qquad (B.3)$$

where

C_{F1} is the calibration factor 1 in ampere per millivolt;

B_C is the battery current in ampere;

$\Delta V_{T3\ to\ T4}$ is the potential difference from T3 and T4 in millivolt.

c) Calibration Factor 2 is determined by dividing the factor obtained from using the formula in Note. The corresponding value is the factor used in Formula (B.4):

$$C_{F2} = \frac{F}{l_{T3\ to\ T4}} \qquad (B.4)$$

where

F is the factor determined from formula in Note;

$l_{T3\ to\ T4}$ is the length of the pipe form T3 to T4 in metre;

NOTE The formula for calculating the longitudinal resistance of a unit length of pipe is:

$$r = \rho / \left(\pi \cdot (\varphi + s) \cdot s\right) \text{ ohms}$$

where

ρ is the 10×10^{-8} steel resistivity in ohm metre;

φ is the external diameter in metre;

s is the wall thickness in metre.

EXAMPLE If you take a value of 18×10^{-8} ohm.m for the resistivity, 0,254 m for the diameter and 8 mm for the wall thickness that is equal to $2{,}734 \times 10^{-5}$ ohms m^{-1}.

This is based on the resistivity value at 25 °C.

d) 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 %.

Formula (B.5) can be used to convert ohms to ampere/mV, resistance to conductance

$$\text{A/mV/m} = \frac{1}{\mu\ \Omega \cdot m^{-1}} \times 1\ 000 \qquad (B.5)$$

B.3.2.2 Step 2: Establishing the circuit [upstream (U/S) end]

a) The circuit should be established by connecting the negative terminal of the battery to T5 (pipe lead), and connecting T2 (upstream vent) to the positive terminal of the battery (see Figure B.4).

b) The inside terminals T3 and T4 are the same as those used for the measurement of potential difference in Figure B.3. The voltage drop is measured across the current measuring span (between T3 and T4), while a known amount of battery current passes between T5 and T2.

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c) The percent of the distance "a" to the contact from the upstream end (T4) is calculated using Formula (B.6):

$$D_{T4} = \frac{\Delta V_{T4} \times C_{F1}}{I} \times 100\ \% \quad \text{(B.6)}$$

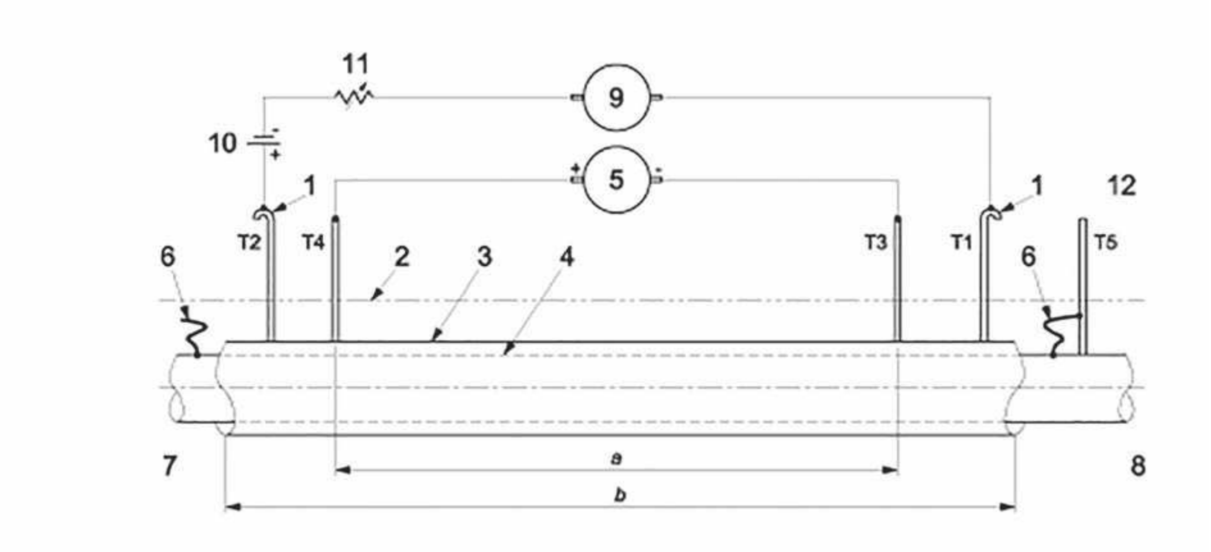
where

D_{T4} is the distance (in percent) from T4 in metre;

ΔV_{T4} is the potential from T4 in millivolt;

C_{F1} is the calibration factor 1 in ampere per millivolt;

I is the current in ampere.



Key

1	vent pipe	7	upstream or upstation (U/S) end
2	ground level	8	downstream or downstation (D/S) end
3	casing	9	ammeter
4	carrier pipe	10	battery
5	voltmeter	11	variable resistor
6	test lead	12	pipe lead

Figure B.3 — Four wire IR drop test (calibrating the inside terminals)

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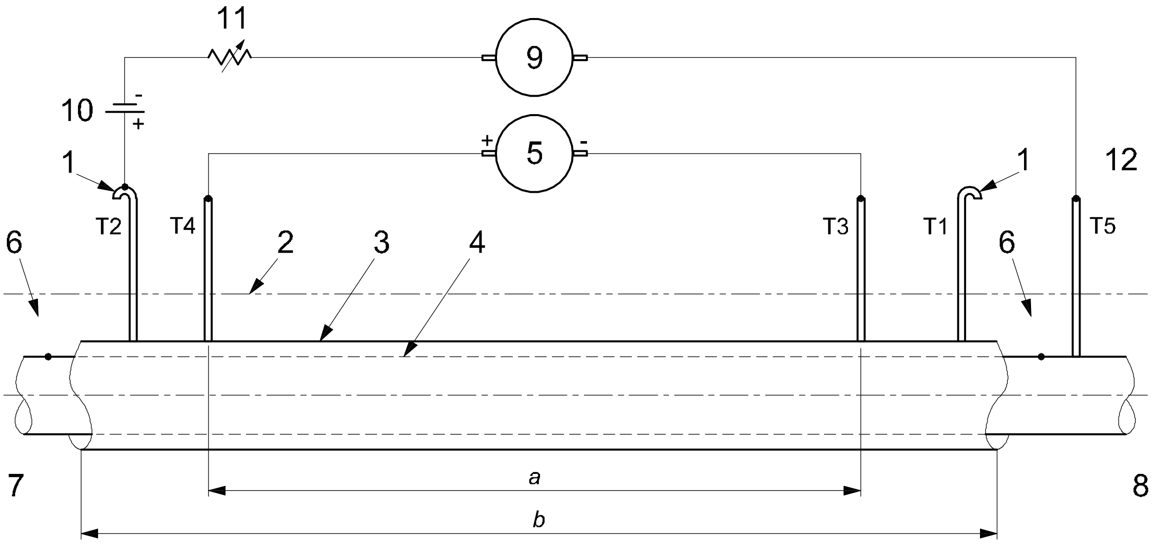

Key

1	vent pipe	7	upstream or upstation (U/S) end
2	ground level	8	downstream or downstation (D/S) end
3	casing	9	ammeter
4	carrier pipe	10	battery
5	voltmeter	11	variable resistor
6	test lead	12	pipe lead

Figure B.4 — Establishing a circuit for a four wire IR drop test (U/S end)

B.3.2.3 Step 3: Establishing the circuit (downstream [D/S] end)

a) The circuit should be established by connecting the battery negative to T5 (pipe lead).

b) T1 (downstream vent) should be connected to the positive side of the battery as shown in Figure B.5.

c) T3 and T4 should remain the same for measurement of potential difference as shown in Figure B.3.

d) The percentage of distance “a” from T3 should be calculated as in Formula (B.7):

$$D_{\mathrm{T3}} = \frac{\Delta V_{\mathrm{T3}} \times C_{\mathrm{F1}}}{I} \times 100\ \% \qquad \text{(B.7)}$$

where

D_{T3} is the distance (in percent) from T3 in metre;

ΔV_{T3} is the potential from T3 in millivolt;

C_{F1} is the calibration factor 1 in ampere per millivolt;

I is the current in ampere.

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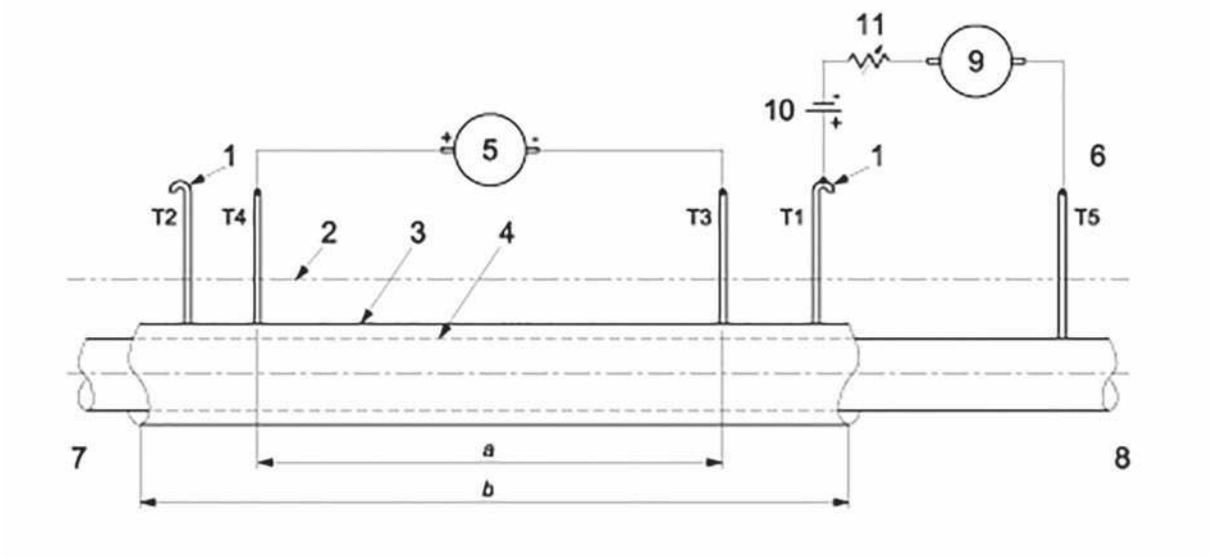

Key

1	vent pipe	7	upstream or upstation (U/S) end
2	ground level	8	downstream or downstation (D/S) end
3	casing	9	ammeter
4	carrier pipe	10	battery
5	voltmeter	11	variable resistor
6	pipe lead		

Figure B.5 — Four wire IR drop test (establishing the circuit) (D/S end)

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 can result. If more than one metal-to-metal contact exists, this test may not accurately identify the location of the shorts. Safety precautions should be implemented when lead acid batteries are used. The variable resistor should be adjusted as necessary to maintain the current output less than 10 A.

EXAMPLE 1 A casing is 760 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 (49.0 ft.)

Diameter = 760 mm (30.0 in)

Wall thickness = 7,92 mm (0.312 in)

NOTE 1 Gives us the resistance for 1 m:

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Pipeline steel resistivity $\rho = 18 \times 10^{-8}\ \Omega{\cdot}\mathrm{m}$

Pipeline internal diameter $\phi_\mathrm{i} = 760$ mm

Pipeline wall thickness $s = 7{,}92$ mm

Pipeline external diameter $\phi = \phi_\mathrm{i} + (2{\cdot}s) = 0{,}776$ m

Unit length $L = 1$ m

$$r' = \frac{\rho}{\left(\pi \cdot \left(\phi_\mathrm{i} + s\right) \cdot s\right)} = 9{,}421 \cdot 10^{-6}\,\Omega \cdot \mathrm{m}^{-1}$$

Step 1 Find the calibration factor

Factor 1 calculates as:

Battery current $I = 9$ A

Potential difference between T3 and T4 $\Delta V = 1\,035$ mV

$$C_{\mathrm{F1}} = \frac{I}{\Delta V} \cdot \frac{1}{L} = 8{,}696\ \mathrm{S} \cdot \mathrm{m}^{-1}$$

NOTE 2 This calibration method is similar to that used to calibrate a typical shunt used in a rectifier.

Factor 2 is determined by using the calculated resistance (see Note 1), expressed in Siemens [see Formula (B.5)]

Factor form Note 1 is Calibration Factor 1 = $9{,}421{\cdot}10^{-6}\ \Omega{\cdot}\mathrm{m}^{-1}$

Length between T3 and T4 Length = 12,2 m

Convert Calibration Factor 1 to compatible units of A/mV/m:

$$C_{\mathrm{F2}} = \frac{\left(\dfrac{1}{r' \cdot L \cdot 10^{3}}\right)}{L} = 8{,}701\ \ \mathrm{S} \cdot \mathrm{m}^{-1}$$

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

Step 2 Measure the voltage with current applied at the upstream end

Calculate the distance (in percent) from contact to T4 using Formula (B.6):

$$D_{\mathrm{T4}} = \frac{1\,035\,\mathrm{mV} \times 8{,}70\,\mathrm{A} / \mathrm{mV}}{9{,}00\,\mathrm{A}} \times 100\,\% = 100\,\%$$

Check Step 2 using the formula from Note 1 in B.3.2.1:

— Find the resistance for a carrier pipe with a 760 mm diameter and 7,92 mm wall thickness.

— Determine the length from the positive, inside terminal to the metallic short, using Formula (B.5).

$$L = \frac{1\,035\ \mathrm{mV} \times 10^{-3}}{9{,}00\mathrm{A} \times 9{,}48 \times 10^{-6}\,\Omega / \mathrm{m}} = 12{,}1\ \mathrm{m}$$

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

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

Calculate the distance (in percent) to contact from T3 using Formula (B.7):

$$D_{T3} = \frac{\Delta V_{T3} \times C_{F1}}{I} \times 100\%$$

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.

If a metallic 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 metallic short can be determined by finding the percentage of current at either end of the carrier pipe and then calculating the distance in A/m (A/ft.) (as shown in Step 2).

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

B.3.3 Alternate method: Linear conductance values for the casing

The preceding calibration procedure can also be used to provide the actual linear resistance for the casing (voltage drop between casing test leads, divided by applied current). Then using Formula (B.8), the distance from the end of the casing to the point of contact can be calculated:

$$L_{C1} = \frac{R_{C1,}}{R_{CT}} L_{CT} \tag{B.8}$$

where

L_{C1} is the distance from end of casing to point of contact;

R_{C1} is the linear casing resistance from end of casing to point of contact = $\Delta V_1/I$;

R_{CT} is the total linear resistance of casing;

L_{CT} is the total length of casing.

The actual linear resistance for the casing should be compared with the theoretical linear resistance for the casing, calculated using the formula from Note 1 in B.3.2.1.

When the test is repeated at the opposite end of the casing (end No. 2), Formula (B.9) can be used to find the distance from that end of the casing to the point of contact.

$$L_{C2} = \frac{R_{C1,}}{R_{C2}} L_{CT} \tag{B.9}$$

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.

B.4 Cycling the rectifier

B.4.1 Purpose

Measurement of structure-to-soil potentials under steady-state conditions of applied cathodic protection does not necessarily provide conclusive evidence regarding the state of electrical isolation between casing and carrier pipe. The same potential measurement, if taken while the cathodic protection rectifier is being cycled, can provide additional information for evaluation of casing isolation conditions.

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B.4.2 Procedure

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

Step 1 Pipeline and casing potentials should be measured with the cathodic protection current applied.

Step 2 Measurements made for step 1 should be repeated at the same instant that the cathodic protection current is switched off.

B.4.3 Analysis

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 a possible metallic short is indicated.

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

B.5 Casing depolarization test

B.5.1 Purpose

Isolation can 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.

B.5.2 Procedure

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

Step 2 The negative terminal of a variable DC power source should be connected to the temporary metallic structure.

Step 3 The positive terminal of the same variable DC power source should be connected to the casing.

Step 4 A reference electrode should be positioned over the carrier pipe near the casing end.

Step 5 An appropriate DC voltmeter should be used to measure and record the carrier pipe and casing potentials.

Step 6 A small increment of current (0,1 A is a satisfactory first increment of current) should be discharged from the casing for a short period of time, such as one or two minutes.

Step 7 The current should be interrupted, then the carrier pipe and casing instant-off potentials should be measured and recorded to determine the effect of the applied current; the increment of current should also be recorded.

Step 8 Steps 6 and 7 should be repeated using additional increments of current (e.g. 0,2 A, 0,3 A). A minimum of three different values of test current and measurement of the effects should be taken. The amount of current required for an effective evaluation varies due to the size of the structure and condition of any coating present. A maximum of 10 A should adequately develop significant potential shifts.

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B.5.3 Analysis

B.5.3.1 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.

B.5.3.2 Casing clear

If there is no metallic 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.

If the casing potential shifts in a positive direction and the carrier pipe 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. Tables B.1 and B.2 illustrate examples of values that indicate electrical isolation (casing clear), and Table B.3 illustrates example of values that indicate an electrically shorted condition (casing short).

Table B.1 — Casing is clear (not shorted; example 1)

	V	A	P/S potential V	C/S potential V	Potential difference V
Initial Readings			−0,975	−0,850	0,125
Step 1	6,0	0,25	−0,974	−0,710	0,264
Step 2	18	0,68	−0,975	−0,505	0,470
Step 3	45	1,0	−0,981	−0,210	0,771
Step 4	65	1,8	−0,986	+0,0100	0,996

Table B.2 — Casing is clear (not shorted; example 2)

	V	A	P/S potential V	C/S potential V	Potential difference V
Initial Readings			−1,250	−1,21	0,040
Step 1	6,0	0,0860	−1,139	−0,700	0,439
Step 2	18	0,258	−1,104	−0,140	0,964
Step 3	30	0,413	−1,060	+0,240	1,300
Step 4	42	0,566	−1,022	+0,490	1,512

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Table B.3 — Casing is shorted

	V	A	P/S potential V	C/S potential V	Potential difference V
Initial Readings			−1,246	−1,242	0,004
Step 1	6,0	0,234	−1,211	−1,195	0,016
Step 2	18	0,594	−1,050	−0,980 0	0,070
Step 3	30	1,00	−0,796 0	−0,710 0	0,086
Step 4	45	1,20	−0,610 0	−0,540 0	0,070
Step 5	75	2,00	−0,135 0	−0,100 0	0,035

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

B.6 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 carrier pipe and the casing. The signal returns at the point of contact, which should be verified from the opposite end.

B.7 Panhandle Eastern method

B.7.1 Purpose

The Panhandle Eastern method (developed in the 1950s by Panhandle Eastern Pipeline Company) involves determining whether the casing is electrically isolated or not by discharging DC current from the casing and comparing the electrolytically coupled response of the carrier pipe. If the two structures are not metallically connected, a significant potential difference occurs between the casing and the carrier pipe. Because the casing is anodically polarized with respect to an independent ground, the casing-to-soil — C/S potential shifts in a positive direction. If the carrier pipe and casing are metallically shorted, pipe-to-soil — P/S potential also shifts in a positive direction, usually by about the same magnitude as the casing. As additional current is applied to the system, the P/S potentials largely track the positive shifting potentials of the casing.

If the casing potential shifts in a positive direction and the carrier pipe potential remains near normal, electrical isolation is indicated. For electrolytic coupling, no conclusion can be determined in many situations, so this test is not recommended for determination of electrolytic connection between a casing and carrier pipe.

B.7.2 Procedure

B.7.2.1 Access requirements

Test access to the pipeline and casing is required, at least on one end of the casing.

Test access to the casing may consist of one or more test leads or a casing vent.

Best results are obtained when available access includes two points of access to the casing so that current and voltage circuits can be established separately.

An isolated ground should be available for use as the cathode of the applied current circuit. The preferred configuration of this structure is perpendicular to the casing and at least 15,24 m (50 ft.) from the carrier pipe and casing at its nearest approach.

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B.7.2.2 Resistance measurement

Using a portable generator and rectifier, battery or other power source, establish a current measurement circuit, including an ammeter or voltmeter and shunt, between the isolated ground (negative/cathode side) and casing (positive/anode side). The source current output should be variable by means of control rheostats or tap settings.

With no current applied, measure and record P/S and C/S “off” potentials, relative to a copper-copper sulfate reference electrode positioned over the pipeline and just outside the casing.

With approximately 0,5 A of applied current, obtain P/S and C/S “on” potential measurements, relative to a copper-copper sulfate reference electrode positioned over the pipeline and just outside the casing. Record all potentials and the magnitude of the test current.

Repeat steps B.7.2.2 and B.7.2.3 at applied currents of approximately 1,0 A and 2,0 A.

B.7.2.3 Interpretation of the pipe-to-casing reference

For each level of applied current, calculate the pipe-to-casing resistance as follows:

R (ohms) = [(P/S “off”) – (P/S “on”) – (C/S “off”) + (C/S “on”)]/ (Applied Current)

NOTE All potentials are measured in millivolts (typically negative) and all currents are measured in milliamps.

The resistance value obtained from each set of measurements should be similar to others.

Resistance values of 0,08 Ω or less typically indicate a metallic contact.

Resistance values greater than 0,08 Ω may indicate the presence of an electrolytic path or effective isolation.

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Annex C
(informative)

Inspection tools for cased carrier pipe

C.1 General

Table C.1 describes inspection techniques applicable to cased pipe.

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Table C.1 — Inspection tools for cased carrier pipe

Name type	Electrical contact required		Applicability						Identifies	Description	Comments	Limitations
			Bare casing			Coated casing						
	Carrier pipe	Casing	Clear	Metallic short	Electrolytic	Clear	Metallic short	Electrolytic				
DCVG Direct Current Voltage Gradient	No	No	A	A	A	A	1	1	Holidays, which may be a metallic path, in the coating of the carrier 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 carrier pipe	There is a gradient. Possible to have holiday detected and there is no metallic short	For uncoated (bare) casings, a survey should be done over the casing to determine if it has an electrolytic contact or metallic short
AC Current Attenuation	No	No	A	A	A	1	1	1	Metallic or electrolytic path between carrier pipe and casing	Compares current flow at each end of casing. Measurement in dB/ft.	Signal attenuates at a contact	HVAC power lines or changes in alignment
AC Voltage Gradient	No	No	A	A	A	A	A	A	Metallic or electrolytic path between carrier pipe and casing	Measure dB signal. Strength and direction at each end of the casing	Coating anomaly tool, Reliable detection of electrolytic contact	HVAC power lines
CIPS (no interruption) Electrical Potential	Yes	Yes	A	A	A	2	2	2	Metallic or electrolytic path between carrier pipe and casings. A preliminary screening tool	Comparison of “on” P/S and C/S readings	On Survey. Utilize 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 stray current. HVAC considerations. Complementary tool

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Table C.1 *(continued)*

Name type	Electrical contact required		Applicability						Identifies	Description	Comments	Limitations
			Bare casing			Coated casing						
	Carrier pipe	Casing	Clear	Metallic short	Electrolytic	Clear	Metallic short	Electrolytic				
CIPS (interrupted) Electrical Potential. Comparing P/S and C/S shifts	Yes	Yes	A	A	A	2	2	2	Metallic or Electrolytic Path between the Carrier pipe and Casing	Compare P/S and C/S shift magnitude. Same direction and similar magnitude suggest metallic contact. Same direction but reduced C/S shift suggest electrolytic path. C/S shift small or opposite indicates clear		Telluric Currents, AC and DC stray current. HVAC considerations.
Carrier pipe/Cable locator Radio Signal	Yes	Yes	A	A	A	2	2	2	Metallic or electrolytic path between the carrier pipe and casing	Signal between carrier 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 path. Clear casing results in strong endwise signal outside casing along carrier pipe		HVAC power lines. Cannot determine if it is electrolytic contact or metallic short for bare casing. Can determine if it is clear for bare casing

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Table C.1 *(continued)*

Name type	Electrical contact required		Applicability						Identifies	Description	Comments	Limitations
			Bare casing			Coated casing						
	Carrier pipe	Casing	Clear	Metallic short	Electrolytic	Clear	Metallic short	Electrolytic				
Panhandle Eastern "B" Reverse Current Applied to Casing for P/S and C/S Comparison	Yes	Yes	U	A	U	U	2	U	Confirmation of suspected pipe-casing metallic contact	Reverse current applied to casing to produce anode polarization. C/S and P/S shifts from 3 levels to applied current are used to calculate approximate pipe-to-casing resistance with values <0,08 Ω confirming a metallic contact	0,08 Ω may need to be adjusted for coated casings where the casings contain an electrolyte	Stray DC Currents and Telluric Current consideration. Only detects if metallic short. Cannot determine the difference between clear and electrolytic.
Internal Resistance Electrical Resistance	Yes	Yes	U	A	U	U	A	U	Pipe-casing metallic or electrolytic contact	Measured resistance equated to path down casing and back along carrier 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
Isolation Checker/Tester Type: Casing-Pipe Capacitance	Yes	Yes	U	A	U	U	A	U	Pipe-to casing metallic contact	Uses isolation checker to indicate clear or shorted condition based on pipe-to-casing capacitance		Electrolytic range not established. Complementary tool. Can determine metallic shorts only

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Table C.1 *(continued)*

Name type	Electrical contact required		Applicability						Identifies	Description	Comments	Limitations
			Bare casing			Coated casing						
	Carrier pipe	Casing	Clear	Metallic short	Electrolytic	Clear	Metallic short	Electrolytic				
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 Metallic short Electrical Potential Comparing P/S and C/S shifts	Yes	Yes	A	A	U	A	A	U	Confirmation of suspected metallic contact	Compare P/S and C.S potential or shifts with temporary metallic short between carrier pipe and casing in place and removed. No change indicates contact of similar resistance already existed	Carrier pipe and casing test wires offer better results	Long casing vents, if used, may distort results. Can only determine metallic shorts

NOTE 1 Contact to pipeline is required at the location of signal transmitter set-up but not in the vicinity of the casing.

NOTE 2 Contact to pipeline is not necessary in the immediate vicinity of the casing.

A – Acceptable. This method should yield reliable results to identify metallic short or electrolytic contact.

U – Unacceptable. This method does not yield reliable results.

1 – Capability exists but protocol and procedures have not been validated.

2 – Indeterminate. Data that is not available to establish effectiveness.

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Annex D
(informative)

Clearing a shorted casing

Clearing a shorted casing normally involves excavating one or both ends of the casing, exposing a length of carrier pipe, examining the ends of the casing, possibly lifting the carrier pipe and restoring the casing spacers and end seals.

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

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 can highlight the area of the casing that is shorted and can verify the location of the metallic short or can determine that the casing was installed shorted due to the materials used and/or the construction methods.

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

The third step is to prepare for the attempt to clear the casing by procuring casing spacers, end seals and shims, vent pipe material, test station material and carrier pipe coating. Having all the materials available is important as most casing clearing projects are time critical with need to avoid delays, and the work should be performed safely and efficiently.

The fourth step is to excavate the casing end(s) to locate or clear the metallic short. Using the work plan to ensure it is a safe project, the casing should be excavated and several meters (feet) exposed. Normally several meters (feet) are exposed to expose the vent pipe and to have sufficient casing length exposed in case it should be cut off and trimmed to provide adequate area for working. The carrier pipe also should be excavated and initially stripped back several meters (feet) to start and possibly several hundred meters (feet) if it is determined that the carrier pipe requires to be moved. Once the carrier pipe is excavated and the casing end exposed, the existing end seal(s) (if any) should be removed, and the annular space between the carrier pipe and casing examined. Any broken/damaged casing spacers should be removed. Spots where casing and carrier pipe are touching should be evaluated to determine whether they are the indicated shorts.

NOTE When the carrier pipe is excavated it can move (rise) on its own depending on the installation methods and sometimes clear the metallic short on its own.

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

If the casing cannot be trimmed back to clear the metallic short, then the carrier pipe should be moved/lifted in accordance with the work plan to attempt to clear the metallic short. This can be accomplished using air bags, Jacks, excavation equipment, cranes or other methods that allow the carrier pipe to move in accordance with the work plan and not have any point loads on the carrier pipe. If this is accomplished and the metallic short clears, than the coating should be repaired and a spacer(s)

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or shim should be installed between the casing and carrier to keep the casing from shorting out again. End seals, test leads and vent pipes should be installed as necessary.

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

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Annex E
(informative)

Removing and cutting a casing

E.1 Removing process

Removing a casing normally involves excavating a section of, or all of, the casing and then removing that section of casing.

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

Step 1:

— Perform any Close Interval Potential Survey (CIS), Direct Current Voltage Gradient Survey (DCVG), Pipeline Current mapping (PCM), Alternating Current Voltage Gradient Survey (ACVG) and intentional metallic short prior to starting the excavation.

— Take a P/S potential reading and a C/S potential reading on each end of the casing before starting the excavation.

Step 2:

— Excavate carrier pipe to 30 cm (12 in) below casing bottom, support as necessary.

— Examine casing ends to see if carrier pipe is centred.

— Remove any end seals.

— Confirm that the casing is not wax filled or filled with any other type of casing filler material.

— Document amount of water in casing, if any.

— Sample water for MIC, microbial influenced corrosion.

— Document the pH of the medium (if any) inside the casing

— Install shims to hold carrier pipe away from casing.

Step 3:

— Cut casing off with 2 longitudinal cuts 180° apart taking care not to damage the carrier pipe.

— Align cuts with largest gap between carrier pipe and casing.

— Make a girth cut every 245 cm (8 ft.) to 305 cm (10 ft.).

— Once the half section is removed, cut the second half section using increasing gaps between the carrier and the casing.

— Remove sections of casing.

— Remove any spacers.

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Step 4:

— Document type of end seal and spacers, as well as dimension between spacers.

— Document any mud or debris in annulus.

— Document soil environment (pH, resistivity).

— Clean off existing coating on carrier pipe.

Step 5:

— Abrasive blast carrier pipe to allow inspection.

— Perform a direct examination of the carrier pipe.

— Take a P/S on both ends of the excavation opening once the casing is removed.

Step 6:

— Clean and recoat carrier pipe.

— Take a P/S potential reading and a C/S potential reading after the carrier pipe is covered.

E.2 Cutting process

Cold cutting is the preferred method of casing removal.

Acetylene torch cutting, grinding with abrasive disc, or saw with a diamond blade may be used, taking precautions as described below.

If torch cut:

a) look for signs of damaging the coating on the carrier pipe;

b) use a hammer to break any slag holding casing sections together.

If grinding:

a) use a side grinder to make the first pass cut, removing 70 % to 90 % of the metal;

b) use a die grinder to finish the cut.

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

NOTE Coated casings make use of a diamond blade difficult as it coats the surface, reducing effectiveness.

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