Overview

This work procedure identifies the testing procedure to determine if casings are in electrical contact with gas-carrying pipes.

Governing Document

Utility Standard S4133, "Gas T&D Corrosion Control Requirements" *[not yet issued – expected publication 2009]*

Safety

Perform all physical and atmospheric corrosion inspection work safely and in accordance with applicable safety rules, the *Code of Safe Practices*, and Utility Standard Practice (USP) 22, Safety and Health Program.

Testing Procedures for Pipe Casing

1. General Information

Pipeline casings have been required at highway and railroad crossings in the past. Since 1994, Caltrans has allowed non-cased crossings if the conditions in Caltrans memorandum, "Exception to Policy – Uncased High-pressure Natural Gas Pipeline Crossings," are met. Since that time, technology has improved to allow casingless bores in the most difficult ground conditions. However, situations may still exist that require casings when there is no feasible alternative.

Pipe casing tests are only performed under the direction and request of corrosion engineering personnel.

2. Contact Types

There are two types of contacts – metallic contacts and electrolytic contacts, described as follows:

A. Metallic Contacts (Also Known As "Hard" Contacts)

- Metallic contacts often occur at the end of casings where differential settlement is most likely. Differential settlement may be caused by high stress on the pipeline related to tie-ins, fill for overpasses, or ground movement. Corrugated nestable casing (no longer used) often partially collapses, thereby causing the contact.

  Other causes of a "hard" contact include improperly adjusted link seals with the bolts/washers contacting the pipe and casing, poor compaction, insulation spacers which contain metal parts that have been damaged and contact both the pipe and casing, and zinc ribbon that has contacted the casing (installed before 1978 in-casings).

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- As described above, casings can develop a metal-to-metal ("hard") contact with the gas pipeline. With hard contacts, the casing and pipe potentials are approximately the same. If the pipe potential is increased outside the casing, the casing usually reflects a similar shift. Due to the fact that the casing is bare and in contact with the pipeline, it acts as one very large "holiday," requiring excessive amounts of current. Consequently, the pipeline outside and adjacent to the casing may not receive adequate cathodic protection (CP).

B. Electrolytic Contact (i.e., Water or Soil in the Casing Annulus)

- Electrolytic contact can also be of concern. In most cases, the pipe within the casing can be cathodically protected. However, the level of CP cannot be determined.
- Electrolytic contacts between the casing and pipe often develop when end seals fail or corrugated nestable casing allows infiltration at seams and holes in the casing. As the annular space is filled with electrolyte, the protective current passes through the ground, casing pipe wall, and electrolyte to the pipe.

3. Monitoring Program

Supervisors responsible for patrolling pipelines must monitor all casings for gas indications according to Utility Standard S4111, "Patrolling Pipelines and Mains," and must take soil-to-pipe and soil-to-casing potentials annually.

4. Testing Procedures

A. This work procedure outlines several of the more commonly used test methods that do not require excavation or exotic equipment. These test methods are sufficient for the majority of circumstances. However, this document is not intended to describe every possible test for every possible situation.

B. Gas corrosion mechanics must perform testing, as required by this work procedure. If a significant contact is confirmed, follow the remediation procedures in Work Procedure WP4133-04, "Remediating Casing Contacts."

C. Conduct tests or reviews when the difference between the casing and the carrier pipe pipe-to-soil (P/S) potentials are less than 100 millivolts (mV) and/or when casing P/S potentials are greater than 800 mV.

D. A detailed investigation of suspected contact between a pipe and casing is usually conducted in response to information collected during regular monitoring of the pipeline. The primary indication of a possible casing contact is when the P/S and casing-to-soil potentials differ by less than 100 mV. Verification of this data, by repeating these potential measurements, is the first step in the investigation.

E. Observe the following precautions in the interpretation of the potentials:

1) Placement of the reference electrode ($CuCuSO_4$ half-cell) must be the same for the P/S and casing-to-soil potential measurements. The ideal location of the reference electrode is over the pipe and between 2 and 5 feet (ft) from the end of the casing.

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Note: The location of the end of the casing may not be immediately apparent, and extended casing vents may be deceiving.

Where this location is not available or identifiable, use other reference placements. Adequately document the location of the reference electrode for every potential measurement to permit reproducible data.

2) If a casing has its own CP system, disconnect this system and allow the casing sufficient time to depolarize before comparing the pipe and casing potentials.

5. Acquiring Additional Information

Obtain and record as much information as possible from a review of the available documents before going to the test location. Some information may require verification in the field.

Record the following information on Form F4133-03-2, "Casing Investigation Report Form" (Attachment 2):

A. Pipe material, type, age, diameter (if possible, specify nominal, inside, or outside), wall thickness, and resistance per ft (calculate from weight per ft, if necessary).

B. Casing material, type, length, age, diameter (if possible, specify nominal, inside, or outside), wall thickness, and resistance per ft (calculate from weight per ft, if necessary).

C. Casing vent(s) material, type, length, age, diameter (if possible, specify nominal, inside, or outside), wall thickness, and resistance per ft (calculate from weight per ft, if necessary).

D. Test wire number, size, length, and resistance per ft.

6. Field Testing Methods

The selection of test methods for investigation may depend upon accessibility and the test facilities available. Where several test methods are possible, the order of selection is usually based on simplicity and convenience. Typically, it is not necessary to conduct every possible test at every site. However, it is desirable to confirm the results of one test with at least one other approach (either from the opposite end of the casing or with another test method). For each test method, note the operating status of any permanent or temporary current sources.

Each of the listed test procedures can provide an indication regarding the presence or absence of a metallic contact between the pipe and casing. However, only the Electronic Signal Trace and the Internal Resistance Test provide indications of the contact location.

The electrical continuity of a corrugated nestable casing is questionable. Consequently, it may not be possible to obtain reliable data from the listed techniques when this type of casing is present.

A. Verification of Original Conditions

Reproduce the original P/S and casing-to-soil potentials (at one or both ends) that prompted the investigation. As nearly as possible, duplicate the system operating conditions that existed at the time of the previous testing.

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Follow the precautions in Section 4, "Testing Procedures, Item E," on Page 2 of this work procedure. Record the results on Form F4133-03-1, "Casing Investigation Report Form – Field Data" (Attachment 1).

B. Temporary Intentional Short

While the previous potential test arrangements are in place, temporarily short the pipe and casing together. If both the pipe and casing have two test wires, this may be accomplished by connecting one wire of each pair. If the only access to the casing is through the vent, attach one of the pipe leads to the vent.

Repeat the P/S potential and record this value for comparison with the previous data. If the temporary contact does not produce a significant change in the P/S potential, a metallic contact is strongly indicated.

This test may be repeated with the temporary intentional short at the end of the casing opposite where the potentials are measured or with the locations of the potential tests and intentional short reversed. Remove any temporary connections before conducting any other test.

C. Electronic Signal Trace

A simple method to verify the presence and often the location of a metallic contact between the pipe and casing is to trace a radio signal transmitted between the pipe and casing. Use a transmitter and receiver system such as the Model "PD," manufactured by Tinker and Rasor. Set up the transmitter at minimum power with the output terminals connected to the pipe and casing (ground terminal). Position the receiver to detect the maximum signal (at a right angle to the position for tracing a "null signal"). If a metallic contact is present, the signal may be traced along the pipe to the contact where the signal "doubles back" along the casing. If no contact is present, the signal should disperse endwise along the pipe to points of earth contact at coating flaws.

Note: For the safety of the test personnel, exercise extreme care to avoid traffic while tracing a signal along the pipe/casing where roadways or railroad tracks may be crossed.

D. Interrupted Current Source

For this technique, it is typical to interrupt the nearest permanent CP rectifier that provides current for the subject pipeline. When the distance between the rectifier and the test site makes this inconvenient, or when the potential shift from the rectifier is small, it may be more effective to set up a temporary current source (portable rectifier, battery, etc.) and ground bed at a convenient location.

The pipe connection for the current circuit may be made using a pipe lead at one end of the casing if the temporary ground bed structure is sufficiently remote (preferably at least 50 ft from the pipe). Record the location and magnitude of the cycled current.

1) While the current is cycled, P/S and casing-to-soil potentials are measured "on" and "off" for comparison. Maintain the same reference electrode placement(s) for each test location. If possible, compare the pipe and casing potentials at both ends of the casing. A metallic contact is indicated if the potential shifts for the pipe and casing are in the same direction and

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approximately the same magnitude. If the casing potential shift is much smaller or in the opposite direction, a metallic contact is unlikely.

2) Repeat any set of "on" and "off" potentials at least twice to confirm that the values are not experiencing excessive variations. If the potential values cannot be repeated within a few mV, record additional data until an accurate and consistent shift is identified with confidence.

3) While the current source is cycled, it may be useful to obtain a limited close interval potential profile over the pipe and a portion of the casing. Typically, as a shorted casing is approached, the P/S potential profile is progressively less negative (less protected). If the casing is electrically isolated from the pipe, the P/S potential tends to remain relatively flat until the casing is reached.

E. Pipe-to-Casing Resistance

This technique measures the resistance of the suspected metallic path along the pipe, through the contact, and back along the casing. This value is then compared to the theoretical resistance of a path with a particular length to approximate the location of the contact.

1) Set up a test current circuit with a current source between the pipe and casing. Also set up a voltage circuit between the pipe and casing. As the test current is applied and interrupted, measure the "on" and "off" voltage between the pipe and casing.

   As with other techniques involving interrupted current sources, repeat these measurements a number of times to confirm the accuracy of the data. Calculate and divide the voltage shift by the test current to determine the pipe-to-casing resistance. If a metallic contact is present, this value is often quite small (0.001 ohm or less). Then, divide the pipe-to-casing resistance by the sum of the per-ft resistances of the pipe and casing to obtain the approximate distance from the end of the casing to the contact (if possible, verify this with the same test procedure from the opposite end of the casing).

2) The above example assumes that a pair of wires is available for test access to the pipe, and a pair of wires is available for test access to the casing. In this case, the current circuit is independent of the voltage circuit, and none of the voltage test wires carry current to introduce an IR drop error.

   If the test facilities are less complete, it is still possible to conduct this test and calculate corrections for any elements of the voltage circuit which must carry current. The most common situation arises when the only access to the casing is a single vent pipe. In this case, both the current circuit and voltage circuit must use a portion of the vent pipe. The portion of the vent pipe, which is in the voltage test circuit, contributes to the measured value of the resistance. However, if the per-ft resistance and length of the vent pipe are known, this resistance may be calculated and subtracted from the measurement. The same may be done with the resistance of any voltage test wire which carries current as part of the current circuit.

3) The resistance values involved in these calculations are small and must be known with considerable accuracy to produce meaningful results. However, in practice the principal determination is whether a pipe-to-casing metallic contact exists at either end of the casing (in

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which case it may be practical to attempt to clear the short) or elsewhere (in which case it is unlikely to matter exactly where the contact is).

F. Current Loss or Pipeline Current Mapper (PCM) Test

A bare, shorted casing allows transmitted current to travel back to ground. Make and compare measurements of CP currents or pipeline current mapper (PCM) currents upstream and downstream of the casing. Locate the PCM transmitter at least 300 ft from the casing and set it so that the current measurement upstream of the casing measures between 100 and 300 milliampere (mA). If 20% or more of the PCM current dissipates across the casing, a casing contact is likely. Alternatively, similar testing can be conducted with a measurement of CP current before and after the casing.

Make current span (IR drop) measurements to allow calculation of the currents. No acceptance criterion has been established because of the variety of field conditions. Sources of error include distance of the current spans to the end of the casing, round-off error due to short span length, incorrect span length, and incorrect K value for the pipe. Review the results from this method with a gas corrosion specialist.

7. Recordkeeping

Record the actions taken on CP records, and file the test results in the appropriate cathodic protection area (CPA) folder.

Document all conditions, test data, and calculations on Form F4133-03-1, "Casing Investigation Report Form – Field Data" (Attachment 1). Sketches can clarify locations of test circuits and other critical information. The tabular framework of the Form 4133-03-02 "Casing Investigation Report Form" (Attachment 2) provides a guideline to record the data and perform typical calculations and other information, as appropriate.

Definition of Terms

Annular: Describes the space between the outside wall of the gas-carrying pipe and inside wall of the casing pipe.

Annulus: The space between the outside wall of the gas-carrying pipe and inside wall of the casing pipe.

Casing: A pipe that does not carry gas in normal operations, but is used to facilitate the installation or repair of a gas-carrying pipe normally used under a railroad or highway crossing.

Casingless bores: A construction technique to install a gas-carrying pipe underground by drilling a hole through the earth and pushing and/or pulling the pipe through it without using an open trench or a casing, typically used under a freeway or water crossing.

Cathode: The electrode of a corrosion cell where a net reduction reaction occurs. In the corrosion process, the cathode is usually the area which does not corrode.

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Cathodic protection (CP): Reduction or prevention of corrosion of a metal surface by making it cathodic; for example, by the use of sacrificial anodes or impressed current rectifier protection systems.

ETS (electrolysis test station): A structure to house the test wires that are bonded to buried metallic piping or structures. These wires are run up to the ETS, in a location normally at or above ground level to test the adequacy of the cathodic protection system.

Holiday: A break or imperfection in a coating exposing the metal (typically a gas-carrying pipe) directly to the electrolyte (typically soil).

Interrupt rectifiers: A process where a rectifier is turned on and off at preset time intervals, typically used to troubleshoot a cathodic protection area.

IR drop: Voltage change that results from current flow through a resistance.

K: pipe constant (amperes per mV per foot).

mV (millivolts): The typical unit of electrical measure for pipe-to-soils.

Sacrificial anodes: The electrode of a corrosion cell designed to corrode to protect the cathode (typically a gas-carrying pipe). Usually, it is made of zinc, magnesium, or other metals which are buried and expended over time by the application of DC current flows into the soil.

Shielding: A condition in which the cathodic protection current cannot reach the carrier pipe to achieve minimum cathodic protection levels.

SMYS (specified minimum yield strength): The minimum yield strength prescribed by the specification under which the pipe is manufactured and qualified.

Recision

This work procedure cancels and supersedes Utility Standard D-S0354/ S4126, "Cathodic Protection Standards for Cased Pipeline Crossings."

Reference Documents

Caltrans memorandum, "Exception to Policy – Uncased High-pressure Natural Gas Pipeline Crossings," November 9, 1994

Code of Federal Regulations (CFR), Title 49, "Transportation," Section 192.467 (c), "External corrosion control: Electrical Isolation"

Code of Safe Practices

UO Policy 3-7, "Gas and Electric Operation, Maintenance, and Construction"

Letter from DOT RSPA to California Public Utilities Commission, August 19, 1993 (WIN.DOT Letter #9 Section 192.467)

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Letter from DOT RSPA to Public Service Commission, Kentucky, July 24, 1986 (WIN.DOT Letter #8 Section 192.467)

Numbered Document O-16, "Corrosion Control of Gas Facilities"

Utility Standard Practice (USP) 22, Safety and Health Program

Utility Standard S4111, "Patrolling Pipelines and Mains"

Work Procedure WP4133-04, "Remediating Casing Contacts"

Attachments

Attachment 1, "Casing Investigation Report Form – Field Data" (Form F4133-03-1)

Attachment 2, "Casing Investigation Report Form" (Form F4133-03-2)

Contact for More Information

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Approved by

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Revision History

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00	November 2008	Issued new work procedure.	[redacted]

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