Guidelines for Integrity Assessment of Cased Pipe for Gas Transmission Pipelines in HCAs

REVISION 0 – March 1, 2010

1. Background

Under the 2002 Pipeline Safety and Improvement Act, all gas transmission pipelines located in High Consequence Areas (HCAs) must have an integrity management program (IMP). One aspect of an integrity management program specifically mandated by Congress is that each gas transmission pipeline located in an HCA must have an integrity assessment by an approved method no later than December 17, 2012 and must be periodically reassessed at least every seven years thereafter[1]. In response to congressional mandates, the Pipeline and Hazardous Materials Safety Administration (PHMSA) promulgated integrity management regulations to implement this and other IMP requirements now contained in 49 CFR 192, Subpart O. These guidelines for integrity assessment of cased pipe are intended to assist operators in complying with 49 CFR 192, Subpart O for cased pipe in HCAs.

Approved assessment methods that PHMSA put into the regulations, as specified in the congressional mandate are:

1. Pressure testing per Subpart J of Part 192
2. In line inspection (ILI)
3. Direct Assessment (DA)
4. Other Technology, provided:
    a. It can provide an understanding of the condition of the line pipe that is equivalent to the other methods, and
    b. The operator notifies PHMSA, or the state agency exercising jurisdiction in advance of its intent to use the technology.

A subset of all pipelines located in HCAs includes pipelines installed inside casing pipe (casing) beneath roadways, railroads and other locations. Complying with the integrity assessment requirement for gas transmission pipe inside a casing has proven challenging for operators, especially distribution system operators, that operate lines that meet the definition of transmission pipelines. In many cases, the pipeline was not designed to be "piggable". Pressure testing is problematic because it disrupts service and introduces water into the system. Direct assessment is problematic because the casing shields many of the indirect inspection instruments used to identify direct examination locations and because it is difficult to expose the carrier pipe for direct examination without removing the casing or the in-service carrier pipe. Other technology (other than Guided Wave Ultrasonic Testing (GWUT) using the PHMSA GWUT "18-point Checklist Go-No Go Criteria") has not yet been demonstrated that satisfactorily and reliably assesses in-service cased pipe.

[Note: *Cased pipelines may be subject to a number of threats including but not limited to external corrosion*[2]*, internal corrosion, stress corrosion cracking, external damage, manufacturing defects, construction defects, etc. These guidelines apply only to assessing for external corrosion and do not apply to other threats, including but not*

[1] During CASQAT discussions, several LDCs and gas associations cited a 1986 interpretation that could be useful in providing clarification on what is required of operators in clearing shorted casings, and the significance of the threat that exists when a short cannot be cleared. To clarify, the 1986 interpretation has no bearing on assessing the integrity of cased piping. It discusses the need to do yearly casing electrical isolation testing separate from the normal annual testing of the cathodic protection on the carrier pipe. The interpretation letter states that if the normal annual testing of the carrier pipe shows adequate cathodic protection at the casing, it may be concluded that the electrical isolation must also be adequate and thus the annual electrical isolation testing on the casing is not necessary. By Act of Congress, the Pipeline Safety Improvement Act of 2002 (as implemented by 49 CFR 192, Subpart O) mandates that all gas transmission pipe in high consequence areas have a baseline integrity assessment and a reassessment using specified methods at least once every 7 years, unless a waiver Is granted. None of the tests discussed in the 1986 interpretation are an integrity assessment method as specified by Congress. Pre-existing interpretation letters regarding rule sections not applicable to IMP requirements may not be used to avoid compliance with subsequent congressional IMP mandates. However, electrical isolation testing data may be considered during the pre-assessment (step 1) and when categorizing and prioritizing locations for direct examinations (step 3).

[2] As used in this document, "external corrosion" means any corrosion metal loss occurring on the exterior (i.e., outside diameter) of the pipe from any cause or corrosion mechanism including, but not limited to atmospheric corrosion, electrochemical corrosion, galvanic corrosion, or microbiologically influenced corrosion.

limited to internal corrosion, stress corrosion cracking, external damage, etc. If other threats (besides external corrosion) apply to cased pipe, other appropriate methods must be used to conduct integrity assessments in accordance with 49 CFR 192, Subpart O.]

2. Purpose

Because of the difficulties being encountered while conducting ECDA on cased pipe for completion of baseline assessments, industry identified the need for more detailed guidance.[3] In its response[4], PHMSA committed to hold a workshop to address the issues and to follow up with stakeholders to "identify and craft a consensus path forward to resolve challenges cased crossing pose." That workshop was held in July 2008.[5]

Subsequent to the workshop, PHMSA worked with a group of state regulators, representatives from industry, trade associations, and other stakeholders to develop guidelines for performing ECDA of gas transmission pipe inside casings. This document is largely based on the work of this group and provides guidelines for operators to consider when implementing integrity management requirements for cased pipe.

[Important: *PHMSA provides written clarification of the pipeline safety regulations (49 CFR Parts 190-199) in the form of interpretations, frequently asked questions (FAQs), and other guidance materials. These guidelines for integrity assessment of cased pipe reflect PHMSA's current application of the regulations to the specific implementation scenarios presented. These guidance materials do not create legally enforceable rights or obligations and are provided to help the public understand how to comply with the regulations. Therefore, to the extent the terms "shall" and "must" and other mandatory language are used, they signify actions that are necessary for an operator to conform with this guidance, but do not constitute regulations. However, an operator that is able to demonstrate compliance with this guidance is likely to be able to demonstrate compliance with the relevant regulations. The term "should" is used to recommend good practices, which operators must consider but are not mandatory for purposes of conforming with this guidance. If the operator chooses to address a consideration differently than recommended, the operator needs to develop and document a technical justification for its course of action. The term "may" is used to state something considered entirely optional*.]

3. Guidelines for the External Corrosion Direct Assessment of Cased Pipe

This document describes PHMSA's guidelines for the integrity assessment of cased pipe using External Corrosion Direct Assessment (ECDA) in HCAs. The cased pipe ECDA process and confirmatory direct assessment (CDA) process must conform to 49 CFR 192 Subpart O, which incorporates by reference the 4-step ECDA process in the NACE International Recommended Practice 0502-2002, Pipeline External Corrosion Direct Assessment Methodology (NACE RP 0502-2002). However, cased pipe presents significant challenges to conducting a successful integrity assessment using ECDA/CDA, especially with regard to step 1 (region identification and indirect inspection tool selection), step 2 (indirect assessment) and step 3 (direct examination) of the 4-step process. The 4th step in the ECDA process is post assessment. These guidelines identify important considerations an operator must address in its integrity management plan and procedures for conducting ECDA/CDA on cased pipe. *This document does not describe all tasks, activities or considerations required to successfully and effectively implement the 4-step ECDA process. These guidelines supplement NACE RP 0502-2002 with considerations applicable to cased pipe that have not been addressed by NACE. Nothing in these guidelines (or considerations not addressed in these guidelines) should be construed as creating new requirements not already outlined in NACE RP 0502-2002 or the requirements in 49 CFR 192, Subpart O.*

Under the regulations, operators must maintain documentation and records that demonstrate how the operator has implemented its ECDA/CDA procedures, including documentation to demonstrate compliance with these

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[3] March 6, 2008; Letter from C. Sames, American Gas Association, to J. Wiese and D. Kunz, Pipeline and Hazardous Materials Safety Administration

[4] April 10, 2008; Letter from J. Wiese, Pipeline and Hazardous Materials Safety Administration, to C. Sames, American Gas Association

[5] Information about the workshop is available online at: http://primis.phmsa.dot.gov/meetings/MtgHome.mtg?mtg=54 .

guidelines and the technical justification for its decisions. Such documentation and records must be available for review during an inspection in accordance with 49 CFR § 192.947 and NACE RP 0502-2002, §7. NACE RP 0502-2002 is referenced in 49 CFR 192, Subpart O (incorporated by reference, see § 192.7)

3.1 Pre-Assessment

The initial pre-assessment encompasses historic and current data collection, feasibility, indirect tool selection, region determination, etc. Operators need to address the following important considerations when conducting ECDA/CDA on cased pipe.

3.1.1 Data Collection

NACE RP 0502-2002, §3.2.1.1 states[6]:

> *The pipeline operator shall define minimum data requirements based on the history and condition of the pipeline segment. In addition, the pipeline operator shall identify data elements that are critical to the success of the ECDA process.*

For cased pipe, PHMSA considers the following data critical to the success of the ECDA process. This data is important for proper selection and use of indirect inspection tools, ECDA region identification, feasibility determination, use and interpretation of indirect inspection tool results, and selection of casings for direct examination.

- Data needed for indirect tool selection (see Exhibit A *Indirect Inspection Tools for Cased Pipe*),
- Data needed for region identification (see Exhibit B *Guidelines for Establishing ECDA Regions for Cased Pipe*),
- Data on casing construction (see Exhibit D *Casing Quality and Monitoring Guidelines* for complete details),
- For filled casings, type of fill material (see Exhibit D for complete details),
- Casing monitoring data (for example, if the casing is shorted, or wax fill is in poor condition; see Exhibit D for complete details),
- Operating conditions (operating pressures above 60% SMYS and operating temperatures above 120° F should be considered higher risk),
- Coating type and condition (note: these guidelines may not be used if the carrier pipe is bare, i.e., uncoated),
- History of metallic shorts and/or electrolytic contact.

In particular, the selection of casings for direct examination should be prioritized to reflect the above information.

3.1.2 Feasibility

NACE RP 0502-2002, §3.3.2, states, in part:

> *If there are locations along a pipeline segment at which indirect inspections are not practical, for example, at certain cased road crossings, the ECDA process may be applied if the pipeline operator uses other methods of assessing the integrity of the location. The other methods of assessing integrity must be tailored to the specific conditions at the location and shall be selected to provide an appropriate level of confidence in integrity.*

[6] Since all of NACE RP 0502-2002 is incorporated by reference in § 192.925, all subsections of NACE RP0502-2002 are requirements of 49 CFR 192 Subpart O.

The guidelines in this document address considerations for tailoring the ECDA methodology to conditions specific to cased pipe. Whenever these guidelines cannot be effectively implemented for a casing/region, PHMSA considers the ECDA process not feasible for that casing/region.

3.1.3 Selection of Indirect Inspection Tools
NACE RP 0502-2002, §3.4.1.1, states:

> *The pipeline operator shall select indirect inspection tools based on their ability to detect corrosion activity and/or coating holidays reliably under the specific pipeline conditions to be encountered.*

Indirect inspection tools have limited ability to detect corrosion activity and/or coating holidays reliably for pipe inside casings. This is reflected in NACE RP 0502-2002, Table 2, footnote 3, ECDA Tool Selection Matrix, which states the following for each type of tool for application to cased pipe:

> *Not applicable to this tool or not applicable to this tool without additional considerations.*

This is also reflected in NACE RP 0502-2002, Table 1, ECDA Data Elements, which states that *locations of, and construction methods used at, casings may preclude use of some indirect inspection tools.*

In order to select appropriate indirect inspection tools for use on cased pipe, additional considerations need to be evaluated and applied to the tool selection process, as specified by NACE RP 0502-2002. Such additional considerations should reflect the level of performance of each tool, and the nature of the data or information that can reasonably be expected from the tools, when used on cased crossings. The practical limitation[7] of most indirect inspection tools is that they can only reliably identify if there is a pipe-to-casing electrical continuity of some kind (either metallic short or electrolytic contact). Guidelines on these additional considerations for the selection of indirect inspection tools, when conducting ECDA on cased pipe, are provided in Exhibit A.

In addition, NACE RP 0502-2002, Table 1, states that locations of, and construction methods used at, casings “may require operator to extrapolate nearby results to inaccessible regions”, and *“**additional tools*** and other assessment activities may be required” (***emphasis added***). One additional tool not listed in NACE RP 0502-2002 is Guided Wave Ultrasonic Testing (GWUT). This tool has been used successfully in conjunction with other tools in the ECDA process to screen cased pipe and select pipe for direct examination. The use of GWUT on casings when other indirect assessment options are not feasible is important, since it is one of the few indirect inspection tools that can actually give an indication of potential corrosion activity on pipe inside a casing.[8]

3.1.4 ECDA Region Identification
NACE RP 0502-2002, §3.5.1.1.1, states:

[7] This limitation must be addressed when establishing criteria for classifying the severity of indications and prioritizing indications for direct examination. See §§ 3.2.3 and 3.3 for guidance.

[8] ECDA, under the provisions of Subpart O and the NACE standard, requires the use of two indirect inspection tools. GWUT used alone therefore does not constitute ECDA under the rule. GWUT may be used, without use of another tool, as “other technology” provided the operator notifies PHMSA (and states exercising jurisdiction) in advance. CDA, as defined in 49 CFR § 192.931 allows use of only one indirect inspection tool. Use of GWUT as part of the CDA process can thus be considered an acceptable method for conducting CDA without prior notification. In all cases, when a GWUT tool is used, the PHMSA GWUT 18 Point Checklist guidance must be followed.

An ECDA region is a portion of a pipeline segment that has similar physical characteristics, corrosion histories, expected future corrosion conditions, and that uses the same indirect inspection tools.

Further, NACE RP 0502-2002, Table 1, requires that casings be treated as separate ECDA regions.

For cased pipe, region identification can be particularly problematic. PHMSA and State inspectors have observed a wide disparity among approaches to ECDA region identification for cased pipe. Some operators have placed every cased pipe in a single region. This extreme example is unlikely to comply with NACE RP 0502-2002 unless the system is very small with few casings, because other factors including corrosion histories and expected future corrosion are unlikely to be the same. On the other extreme, operators have placed a single casing in each region. The effect of this is that many casings could require excavation during every subsequent reassessment. Depending on the specific situation, this approach may be too conservative and divert integrity management resources from activities that would provide more risk reduction benefit.

PHMSA has developed guidelines (see Exhibit B) for assuring that all casings in a single region are sufficiently similar, as specified in NACE RP 0502-2002, §3.5.1.1.1, while still maintaining enough flexibility to allow the grouping of casings (where warranted) into a single region.

3.2 Indirect Inspection

3.2.1 Supplementary Guidance on Using Indirect Assessment Tools to Assess Cased Pipe

NACE RP 0502, Appendix A, Indirect Inspection Methods, provides guidance on the use of a number of indirect assessment tools and on the interpretation of the resulting data. However, the NACE RP 0502 document focuses exclusively on using the tools for buried pipe, not cased pipe. Exhibit C of these guidelines provide supplementary guidance on special considerations, cautions, engineering considerations, and limitations that should be taken into account when using, interpreting, and analyzing the results of indirect inspection tools used to assess cased pipe.

PHMSA has previously released guidelines for using, interpreting, and analyzing the results of GWUT used to assess cased pipe.[9]

3.2.2 Other Assessment Activities

In addition, NACE RP 0502-2002, §3.3.2 and Table 1, states that locations of, and construction methods used at, casings may require usage of *"other assessment activities."* Because indirect assessment tools have limited effectiveness when used for cased pipe, other assessment activities are necessary to effectively conduct an integrity assessment for cased pipe. The other assessment activities (such as monitoring casing integrity) supplement the indirect inspection tool data with additional data which is indicative of the effectiveness of engineered systems (such as casings, end seals, and wax fill) in preventing corrosion and protecting carrier pipe integrity.

PHMSA has identified guidelines for these other assessment activities in order to:

1. Compensate for the limited effectiveness of indirect inspection tools when conducting indirect inspections of cased pipe and,
2. Assist the analysis of indirect assessment results and allow the selection the highest risk casings for direct examination.

These other assessment activities are provided in Exhibit D, *Casing Quality and Monitoring Guidelines*, and address activities necessary to assure that casing construction and on-going maintenance after the baseline assessment of the carrier pipe is sufficient to prevent the development or growth of corrosion cells on the carrier pipe. Guidelines addressing these other assessment activities are provided in Exhibit D. The

[9] Guided Wave UT Target Items for Go-No Go Procedures, PHMSA "18 Point Checklist", dated 11/07/07.

guidelines have been tailored to the specific considerations applicable to both wax filled casings and unfilled casings, and are summarized in Sections 3.2.2.1 and 3.2.2.2, below.

3.2.2.1 Other Assessment Activities Associated with Wax Filled Casings

For a wax filled casing, successful application of the ECDA 4-step process is predicated upon demonstrating a quality wax fill and the subsequent on-going maintenance and monitoring of casing integrity, fill level, and fill condition. Operators must have documentation that verifies that a quality casing fill was initially installed, effectively maintained, and periodically monitored. PHMSA guidelines for assuring a quality casing fill and for implementing a quality casing fill monitoring program, are provided in Exhibit D.1. These guidelines address fill quality issues that have been observed by PHMSA and state inspectors. The verification of quality casing construction/fill and the monitoring of continued casing integrity, fill level, and fill quality are “other assessment activities” that supplement the indirect inspection tool results for wax filled casings as described in NACE RP 0502-2002, Table 1.

3.2.2.2 Other Assessment Activities Associated with Unfilled Casings

For an unfilled casing, successful application of the 4-step ECDA process is predicated upon demonstrating it has achieved a successful casing installation to assure that the carrier pipe is electrically isolated from the casing. Operators need to periodically monitor the casing to assure that conditions do not change. PHMSA guidelines for assuring the quality construction of an unfilled casing, and implementing an unfilled casing monitoring program, are provided in Exhibit D.2 below. These guidelines address unfilled casing issues that have been observed by PHMSA and State inspectors. The verification of quality casing construction and the monitoring of continued casing integrity are “other assessment activities” that supplement the indirect inspection tool results for wax filled casings, as described in NACE RP 0502-2002, Table 1.

3.2.3 Classifying Severity of Indirect Inspection Tool Indications for Cased Pipe

NACE RP 0502-2002, §4.3.2.1 requires that criteria be established for classifying indications. Example severity classification criteria are provided in Table 3 of the NACE standard. However, as shown in Exhibits A and C, many indirect inspection tools, when used for cased pipe, provide indications which can only distinguish between a shorted or non-shorted casing. Indications of a shorted casing appear similar to indications of large coating holidays or bare pipe. NACE RP 0502-2002, §4.3.2.2 further states:

> *The criteria for classifying the severity of each indication should take into account the capabilities of the indirect inspection tool used and the unique conditions within an ECDA region.*

Because of the limitations of indirect inspection tools when used under the unique conditions associated with cased pipe, classification criteria for cased pipe regions must reflect these capabilities and conditions in accordance with NACE RP 0502-2002, §4.3.2.2. *PHMSA considers that an indication of a metallic short or electrolytic contact should be treated like a large coating holiday or bare pipe. PHMSA considers any indication of a shorted casing to represent a “severe” indication, and should be classified as such for usage of this guideline.*

3.3 Direct Examination

Because of the complexity of pipe in casings, options for direct examination are limited. In some situations, the anomaly may be located at or near the ends of the casings. In these situations, cutting back the casing and doing a visual inspection in that area and as far into the casing as possible with boroscopes or cameras may assist in finding anomalies that can be evaluated *in situ* and repaired. In any circumstance, excavation of a cased pipe is expensive and often involves taking the pipeline out of service in areas where the pipeline is a single feed to public services. As a result, it is important to select the riskiest casings to be excavated and directly examined.

NACE RP 0502-2002, §5.2.1.1 states:

> *Prioritization, as used in this standard, is the process of estimating the need for direct examination of each indication based on the likelihood of current corrosion activity plus the extent and severity of prior corrosion.*

In accordance with NACE RP 0502-2002, §5.2, all casings in each region must be prioritized for excavation and direct examination (based on which casings are most likely to have corrosion metal loss defects) using the data gathered and analyzed in step 1 (pre-assessment) and step 2 (indirect inspection, including other assessment activities). In addition, NACE RP 0502-2002, §5.2.2.1.5 states:

> *Indications for which the operator cannot determine the likelihood of ongoing corrosion activity should be placed in [the immediate] priority category.*

For casings, it is often difficult or impossible to determine the likelihood of ongoing corrosion, based on indirect inspection tool results. In this circumstance, NACE RP 0502-2002 §5.2.2.1.5 requires that indications be placed in the "immediate" prioritization category. Therefore, PHMSA considers the following indications to be "immediate" priority when using this guideline for carrier pipe Integrity Management (IM) in accordance with 49 CFR 192, Subpart O.

- Any indication of a metallic short between the casing and carrier pipe.
- GWUT indication of corrosion metal loss in excess of 5% of the cross sectional area, in accordance with GWUT, Guided Wave UT Target Items for Go-No Go Procedures (i.e., "18-point checklist), Guideline 17 - Direct examination of all indications above the testing threshold is required.
- Any indication of a change in casing integrity, or (for a filled casing) fill level or fill quality based on an evaluation of the casing monitoring program data using the guidelines in Exhibit D.

PHMSA considers the following indication to be "scheduled" priority when using this guideline for carrier pipe Integrity Management (IM) in accordance with 49 CFR 192, Subpart O. Scheduled indications must not be downgraded to "monitored."

- Any indication of an electrolytic contact between the casing and carrier pipe.[10]

Direct examination results for selected casings within a region may not be used to justify not performing a direct examination for other casings in the same region with immediate indications. As required in NACE RP 0502-2002, §5.10.2.1:

> *All indications that are prioritized as immediate require direct examination.*

For reassessments using ECDA or CDA, a previous direct examination is a key factor in determining if an individual casing must undergo a direct examination (provided immediate-action indications do not exist). For reassessments, a cased pipe that has been previously directly examined may not need to be directly examined during the reassessment (unless other data or indications suggest there is a likelihood of ongoing corrosion) if all of the following are true:

- The casing has had an integrity assessment in accordance with the required reassessment interval (refer to §192.939(b)(6)), and

[10] Operators must still comply with § 192.467, External corrosion control: Electrical isolation.

- All corrosion metal loss and other defects identified during the original direct examination were repaired, as needed, to restore the carrier pipe's original design safety factor for the class location in which it is located, and
- The carrier pipe and casing were re-installed in accordance with the guidelines in Exhibit D,
- The casing was effectively monitored in accordance with Exhibit D, and
- Indirect inspection tools and other assessment activities did not identify any "immediate" indications, and
- There is no evidence of a gas leak since the last assessment, and
- Excavation of the casing is not otherwise required or needed in order to comply with NACE RP 0502-2002 (e.g., to comply with the additional direct examinations to assess ECDA effectiveness).

For purposes of identifying the minimum number of direct examinations, regions can be combined under the following circumstance. If all casings in multiple regions do not contain any immediate or scheduled indications, a direct examination is not required in each region. Instead, one excavation is required in one of the ECDA regions identified as most likely to have external corrosion during the pre-assessment, as specified in NACE RP 0502 §5.10.2.3, which states:

> *If multiple ECDA regions contain monitored indications but did not contain any immediate or scheduled indications, one excavation is required in the ECDA region indentified as most likely for external corrosion in the Pre-Assessment Step. For initial ECDA application, a minimum of two direct examinations shall be performed.*

For example, if all casings in multiple ECDA regions contain no scheduled or immediate indications, then the direct examination step is allowed to be applied to a single region, selected as the most likely to have external corrosion. Direct examinations may not be required in the other regions.

3.4 Post Assessment

These guidelines do not provide supplemental information for step 4, post-assessment. However, PHMSA strongly encourages operators to carefully consider, and rigorously implement the post assessment process. Because the use of the 4-step ECDA process for cased pipe is so challenging, PHMSA expects operators to have a very strong program to assess ECDA effectiveness (NACE RP 0502-2002, §6.4) and to continually seek to improve the ECDA process for cased pipe (NACE RP 0502-2002, §6.5).

Exhibit A Indirect Inspection Tools for Cased Pipe

The following table provides guidance on indirect inspection tool selection for conducting ECDA on cased pipe. Information in this table is not valid if the carrier pipe is weight coated with concrete.

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

Table A.1 Guidelines for Selection of Indirect Inspection Tools for Cased Pipe

Item	Name Type Reference	Electrical Contact Required		Applicability						Identifies	Description	Comments	Limitations
				Bare Casing			Coated Casing						
		Pipe	Case	Clear	Short	Electrolytic	Clear	Short	Electrolytic				
1	DCVG Direct Current Voltage Gradient NACE RP 0502	No[1]	No	A	A	A	A	3	3	Holidays, which may be a metallic path, in the coating of the pipe near the edge of the casing	Coating holiday indications near the end of the casing denote a possible metallic or electrolytic path between the casing and the pipe. Metallic=Very Large Indication	There is a gradient. Possible to have holiday detected and there is no short.	Stray DC currents must be considered. For bare casings, a survey must be done over the casing to determine if it has an electrolytic contact or metallic short.
2	PCM AC Current Attenuation NACE RP 0502	No[1]	No	A	A	A	3	3	3	Metallic or electrolytic path between pipe & casing	Compares current flow at each end of casing. Measurement in mA or dBmA/ft	Signal attenuates at a contact	HVAC power lines or changes in alignment

Table A.1 Guidelines for Selection of Indirect Inspection Tools for Cased Pipe

Item	Name Type Reference	Electrical Contact Required		Applicability						Identifies	Description	Comments	Limitations
				Bare Casing			Coated Casing						
		Pipe	Case	Clear	Short	Electrolytic	Clear	Short	Electrolytic				
3	PCM/A-frame AC Voltage Gradient NACE RP 0502	No[1]	No	A	A	A	A	A	A	Metallic or electrolytic path between pipe & casing	Measure dBμV signal. Strength & direction at each end of the Casing	Coating anomaly tool. Reliable detection of electrolytic contact	HVAC power lines
4	CIS (no interruption) Electrical Potential NACE RP 0200	Yes[2]	Yes	A	A	A	4	4	4	Metallic or electrolytic path between pipe & casing. A preliminary screening tool	Comparison of "on" P/S and C/S readings	On Survey. Utilize a criterion. Preliminary check. With coated casing, there can be a problem with electrolyte in the casing or near a rectifier	Telluric Currents, AC and DC Strays, HVAC considerations. Complementary tool
5	CIS (interrupted) Electrical Potential. Comparing P/S and C/S shifts NACE RP 0200	Yes[2]	Yes	A	A	A	4	4	4	Metallic or Electrolytic Path between the Pipe and Casing	Compare P/S and C/S shift magnitude. Same direction and similar magnitudes 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 Strays, HVAC – considerations

Table A.1 Guidelines for Selection of Indirect Inspection Tools for Cased Pipe

Item	Name Type Reference	Electrical Contact Required		Applicability						Identifies	Description	Comments	Limitations
				Bare Casing			Coated Casing						
		Pipe	Case	Clear	Short	Electrolytic	Clear	Short	Electrolytic				
6	Pipe/Cable Locator Radio Signal NACE RP 0200	Yes	Yes	A	A	A	4	4	4	Metallic or electrolytic path between the pipe and casing	Signal between pipe and casing is traced to point of metallic contact and returns (no appreciable signal outside casing) or signal reduction within casing may indicate electrolytic path. Clear casing results in strong endwise signal outside casing along pipe.		HVAC power lines. Cannot determine if it is electrolytic contact or metallic short for bare casings. Can determine if it is clear for bare casings.
7	Panhandle Eastern "B" Reverse Current Applied to Casing for P/S & C/S Comparison AGA Research Project	Yes	Yes	U	A	U	U	4	U	Confirmation of suspected pipe-to-casing metallic contact	Reverse current applied to casing to produce anodic polarization. C/S & P/S shifts from 3 levels to applied current are used to calculate approximate pipe-to-casing resistance with values < 0.08 ohms confirming a metallic contact.	0.080 ohm may need to be adjusted for coated casings where the casing contains an electrolyte.	Stray DC Currents & Telluric Currents- consideration. Only detects if metallic short. Cannot determine the difference between clear and electrolytic.

Table A.1 Guidelines for Selection of Indirect Inspection Tools for Cased Pipe

Item	Name Type Reference	Electrical Contact Required		Applicability						Identifies	Description	Comments	Limitations
				Bare Casing			Coated Casing						
		Pipe	Case	Clear	Short	Electrolytic	Clear	Short	Electrolytic				
8	Internal Resistance Electrical Resistance NACE RP 0200	Yes	Yes	U	A	U	U	A	U	Pipe-to-casing metallic or electrolytic contact	Measured resistance equated to path down casing and back along pipe to calculate distance to contact	Resistance of path external to casing must be considered	Stray DC Currents - consideration. Complementary tool. Can determine metallic shorts only.
9	Tinker & Rasor Isolation Checker Type: Casing-Pipe Capacitance Ref: N/A	Yes	Yes	U	A	U	U	A	U	Pipe-to-casing metallic contact	Uses Tinker & Rasor 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
10	Four Wire Drop Test Current Flow Direction & Magnitude NACE RP 0200	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
11	Temporary Intentional Short Electrical Potential. Comparing P/S and C/S shifts NACE RP 0200	Yes	Yes	A	A	U	A	A	U	Confirmation of suspected metallic contact	Compare P/S & C/S potential or shifts with temporary short between pipe and casing in place and removed. No change indicates contact of similar resistance already existed.	Pipe and casing test wires offer best results.	Long casing vents, if used, may distort results. Can only determine metallic short.

Exhibit B Guidelines for Establishing ECDA Regions for Cased Pipe

The following Table B.1, *Guidelines for Establishing ECDA Regions for Cased Pipe*, lists 17 attributes that must be analyzed and considered when establishing regions for ECDA of cased pipe. Guidance is provided on how these attributes should be applied when establishing ECDA regions for cased pipe. "R" indicates that this attribute alone requires a separate ECDA region. "C" indicates that this attribute must be considered when determining ECDA regions, but alone does not always require a separate ECDA region, depending on case-specific circumstances.

Table B.1 Guidelines for Establishing ECDA Regions for Cased Pipe

Item	Attribute	R	C	Comments	Additional Guidance Material
1	Carrier Pipe Coating	R		Cased pipe with coatings that tend to shield cathodic protection (CP) shall be placed in a separate region. All other coatings that do not tend to shield CP may be placed in the same cased region. Operators may use as many regions as there are types of coatings. Carrier pipe that is bare must also be placed in a separate region.	It is envisioned that there will be two main groups of carrier pipe coatings, shielding type coatings and non-shielding type. Operators can segregate coatings into additional groups if they desire.
2	Casing Materials and Design	R		Cased pipe with problematic casing materials and designs that are known to cause or promote external corrosion require separate regions. These may include such things as wooden spacers, metal band/runner type spacers, corrugated casings, and casings with extremely oversized or undersized annuli. Coated casings require separate regions, since they can significantly impact the resolution and interpretation of the indirect inspection data. Additionally, casings that are too long to be fully inspected by a guided wave inspection as part of ECDA step 3 (indirect assessment) shall be evaluated in the pre-assessment to determine if ECDA is feasible. All data gathered and analyzed as part of the pre-assessment must be utilized in the decision process.	There are several types of casing designs and materials that behave differently from others. Among these are split sleeve type, nested type, coated type and those that are only tack welded. Each requires a separate region. In addition, the centralizer design can be critical to the behavior of the casing. Certain types present more problems than others: wooden, all metal, metal banded, and directly attached can create shorted conditions if the coating fails because of age or initial method of installation. Additional design issues are end seal design, space between the carrier pipe and the casing, the likelihood of stress on the carrier pipe at the entry point, etc.
3	Corrosion History on Adjacent Buried Pipe Segments	R		Casings that are in a pipe segment with known corrosion problems and are influenced by the same CP system shall be placed in a separate cased region.	Corrosion history on a pipe segment may be an excellent indicator for corrosion in a casing if there is a short or an electrolytic contact. Per NACE RP 0502, Table 1, these need to be in separate regions from areas that do not promote corrosion. Leak and rupture history can be dependent on corrosion history, which according to NACE RP 0502 need to be identical for each ECDA region.

Table B.1 Guidelines for Establishing ECDA Regions for Cased Pipe

Item	Attribute	R	C	Comments	Additional Guidance Material
4	Each carrier pipe must have a similar cathodic protection maintenance history	R		Cased crossings that reside in areas that are found during the Pre-Assessment to have had intermittent or inadequate cathodic protection must be considered for a specific cased region.	Cathodic protection maintenance histories are important to determine the susceptibility of the carrier pipe to external corrosion and may provide additional information on the likelihood of past, present and future corrosion.
5	Past knowledge of metallic or electrolytic contacts	R		Casings that are found to have been metallically shorted or electrolytically contacted in the past (even seasonally) and have not passed a Subpart O integrity assessment shall be placed in a separate cased region.	Cased crossings with metallic shorts or electrolytic contacts may have undergone external corrosion in the past and may be susceptible to external corrosion in the present and future and thus must be in separate regions.
6	Each carrier pipe must have similar exposure to microbiologically influenced corrosion (MIC)	R		If the cased crossing is in an area of the operator's system that is known to have a high rate of MIC related corrosion, then the casing must be placed in a separate region.	MIC can cause the corrosion growth rate to be accelerated and may require a higher level of CP. Areas that are prone to MIC must be in a separate region.
7	Casing Construction Techniques		C	Different construction techniques that result from changes in construction crews/contractors and installation procedures may require separate cased regions.	Some construction techniques and crews may produce poor quality construction or specific construction deficiencies, e.g., pushing centralizers together, damaging the pipe coating, etc.
8	Each carrier pipe should have a similar time in service		C	Different pipe vintages may require different regions. Operators should rely on their experience and follow the protocols established in their ECDA procedures for buried pipe.	Time in service may be an indication of the extent of atmospheric corrosion or corrosion from shorted conditions and electrolytic contacts. Date of installation can also assist in determining construction techniques used.
9	Casing and Carrier Pipe Environment		C	Different environments surrounding the casing may require designation as separate regions, which should be consistent with the operator's ECDA procedure for buried pipe. A separate region is needed for each area with similar drainage characteristics and each area with similar soil corrosivity properties.	The environment may play a large role if there are electrolytic contact issues and shorted conditions. Some environments are more prone to causing shorts than others. Environment may play a significant role in corrosion growth rates.
10	Carrier Pipe Stress Level		C	The operating stress levels (e.g., 20% as compared to 72%) must be considered when establishing regions.	The stress on a carrier pipe can determine the consequence of a failure. Low stress carrier pipes will tend to leak rather than rupture while the converse is true for high stress pipes. Pipe stress levels must be considered when determining casing regions.
11	Carrier Pipe Seam		C	Operators should follow their ECDA procedure for buried pipelines.	Selective seam corrosion can be a threat to some older pipelines with specific seam types, and thus should be in a separate region.

Table B.1 Guidelines for Establishing ECDA Regions for Cased Pipe

Item	Attribute	R	C	Comments	Additional Guidance Material
12	Land Use		C	Areas where the land use may increase corrosion due to the corrosiveness of the environment (such as processing plants) should be considered for a separate region.	Land use can impact the threat of external corrosion to the carrier pipe within the casing. For example, cased crossings near major highways that have snow and ice could be subject to salt contamination, i.e., low resistivity of the surrounding ground. There are other areas which could subject the pipeline to large soil loads from above, etc.
13	Protection System on Carrier Pipe		C	Operators should consider the type of CP system used on the cased pipe and follow their ECDA procedure for buried pipelines.	Galvanic and impressed current CP systems will behave differently and cased crossings should have the same type of CP systems in the same region.
14	Stray Current and Induced AC on Carrier Pipe		C	Operators should follow their ECDA procedure for buried pipelines regarding stray current and induced AC history.	Stray currents, either DC or AC, can accelerate corrosion or cause corrosion, and thus cased crossings with potential stray current issues should be in separate regions.
15	Temperature on Carrier Pipe		C	Different operating temperatures may require separate regions, especially if high operating temperatures, coupled with moist environments, could cause degraded coatings by creating a steaming effect or causing moisture to condense in the annulus. Additionally, high operating temperatures that can accelerate corrosion should be considered when establishing cased regions.	High temperatures can accelerate atmospheric corrosion by allowing additional moisture and humidity to permeate the casing annular space. Additionally, fluctuations in temperature can cause condensation which could cause atmospheric corrosion to form on the carrier pipe.
16	Carrier Pipe Exposure to Humid/Dry Air		C	If the casing resides in an area that the operator has identified as an atmospheric corrosion monitoring area, such as salt marine environments, the casing should be placed in a separate region.	See the above guidance material. Cased crossing in dry air regions should be less prone to atmospheric corrosion and thus be in a separate region.

Table B.1 Guidelines for Establishing ECDA Regions for Cased Pipe

Item	Attribute	R	C	Comments	Additional Guidance Material
17	Carrier Pipe Design		C	Operators should follow their ECDA procedure for buried pipelines. Each carrier pipe should have a similar type pipe design: maximum allowable operating pressure, diameter, class location, end loading stresses and other design factors	Dissimilar designs with regard to piping design, MAOP, diameter and other issues can affect both the likelihood and consequence of failure and thus should be in separate regions.

Exhibit C Above-Ground Survey Techniques for Carrier Pipe in Casing Using ECDA Indirect Inspection Tools

C.1 Introduction

This section contains guidance on the differences between doing an ECDA assessment on regular line pipe and a carrier pipe in a casing. This guidance addresses:

- The tools that are available,
- A brief description of how the tools work,
- Guidance surrounding the use of the tools (e.g., is access to the pipe required?),
- How actual indications are measured and directly examined,
- Limitations such as interferences, etc.,
- The different types of contacts and shorts that can be detected, and
- Proper interpretation of indirect inspection tool readings when used for cased pipe.

C.2 Definitions:

Electrolytic Contact (also known as an Electrolytic Short or Couple) – Ionic contact between two metallic structures via an electrolyte
Metallic Short – Direct or metallic (electronic) contact between two metallic structures

C.3 References:

NACE RP 0200-2000 – Steel Cased Pipeline Practices
NACE RP 0502-2002 – Pipeline External Corrosion Direct Assessment Methodology

C.4 Indirect Inspection – Casing to Pipe Tests

There are several types of tests that can be used to determine if a carrier pipe is likely to be in metallic or electrolytic contact with a casing. Some of them use the same principles and equipment as the ECDA indirect inspection tools, though specific techniques and interpretation may differ. They are as follows:

a) Direct Current Voltage Gradient (DCVG)
b) AC Current Attenuation (PCM)
c) Alternating Current Voltage Gradient (ACVG) – PCM A-Frame
d) Potential Surveys
   1. Potential Surveys (CIS, No Interruption)
   2. Potential Surveys (CIS, Interrupted)
e) Pipe/Cable Locator
f) Panhandle Eastern Test
g) Internal Resistance Test
h) Casing/Pipe Capacitance
i) Current Span Test – Four Wire Drop Test
j) Temporary Intentional Short

Operators who use these types of tests must have a procedure for the test that is specific to applying the tool to cased pipe. Operators must ensure that the personnel performing the test are properly trained and qualified and that the results are properly interpreted and documented.

C.4.1 Direct Current Voltage Gradient- DCVG

DCVG surveys are used to evaluate the coating condition on buried pipelines. In a DCVG survey, a DC signal is typically created by interrupting the pipeline's cathodic protection current, and the voltage gradient in the soil above the pipeline is measured. Voltage gradients are the result of current pickup/discharge at holiday locations. Shorted or contacted conditions can occur only when there is a holiday in the coating.

A typical DCVG system consists of a current interrupter, a voltmeter, connection cables and two copper-copper sulfate electrodes. On sacrificial anode systems a temporary rectifier needs to be installed. Ideally, the interrupter is installed at a rectifier. The electrodes are held 3 to 6 feet apart either perpendicular to the pipe or, more commonly, over the pipe. The magnitude of the shift between the "on" and "off" readings and the direction of the meter are recorded. When a coating holiday is approached, a noticeable signal swing can be observed on the voltmeter at the same rate as the interrupter switching cycle. A metallically shorted bare casing would behave as an extremely large holiday on the pipe from both ends of the casing. The DCVG may also be able to detect electrolytic contact which may present themselves as a smaller holiday. In either situation, DCVG can give a positive indication that a short or contact exists, but will not be able to locate the short or contact in the casing.

Since the DCVG method measures the difference between two copper-copper sulfate reference cells, each cell must make good contact with the ground and the surface must be conductive (wet). Since the cells are wired to a volt meter, no connection to either the casing or carrier pipe is needed. There are no trailing wires or other attachments, except for an interrupter at the rectifier.

C.4.2 AC Attenuation - PCM

This type of survey is often used for ECDA of uncased pipe because it is normally an assessment of the condition of the pipeline coating. A signal (4Hz AC) is applied to the pipeline, and coating damage is located and prioritized according to the magnitude and change of current attenuation.

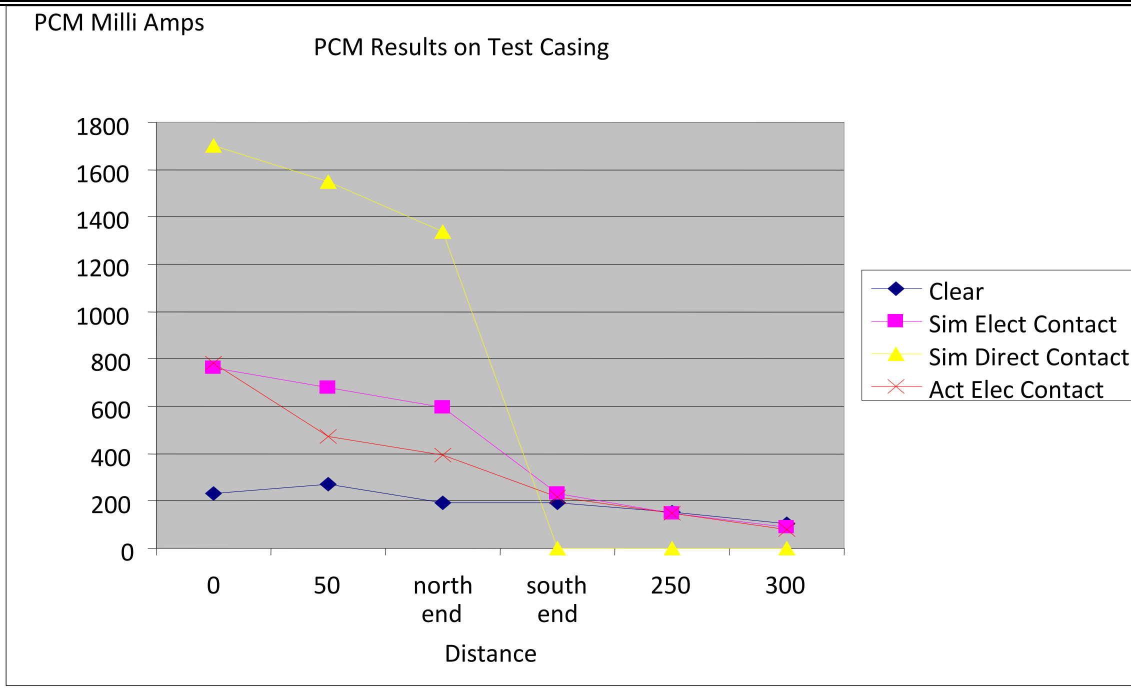
The test is set up by first connecting the signal generator to the pipe, typically through a test lead. A cycled AC signal is produced and transmitted along the pipe. The transmitter is energized and adjusted. Signals along the pipe are then measured with the detector/receiver unit array, which is sensitive to the electromagnetic field radiating from the pipeline.

In this test, a contact should cause a noticeable drop in the AC signal strength between the readings just before the start of the casing and just after the end of the casing. If there is no contact, there should be no drop since the carrier pipe is isolated from both the casing and the ground (essentially just being suspended in air). Both electrolytic contacts and direct shorts should be detected and the relative loss of signal strength may indicate which type of contact is present.

If testing over the actual casing is permitted by available access, the signal may be shielded by the casing itself but the drop in signal strength should be apparent once the end of the casing is passed. There should be a pronounced loss in signal as compared to other areas where the coating is in good condition.

The only connection to the pipe is the signal generator which should be at least several pipe lengths away from the casing (care must be taken with the ground for the signal generator to prevent it becoming a pathway for signals to couple with the pipe). The receiver does not have to have contact with soil and since it uses the magnetic flux/field, it can read signals under paved surfaces as long as there is not significant metal reinforcement. The unit must locate the pipe so it is an excellent pipe locator and pipe depth measurement tool. The receiver must be kept perpendicular to the pipe regardless of the terrain.

For example, the following plot was taken from data on a test casing. The casing is located between the north end and south end and is 100 ft. in length. Testing was performed at 100 ft. and 50 ft. before and after the casing. This facility includes the capability of simulating metallic and electrolytic contacts with a series of test wires and rheostats. The simulated direct short shows 100% attenuation; the clear condition shows 1.5% attenuation, the simulated electrolytic contact shows 61% attenuation, and the actual electrolytic short (done by flooding the casing and having holidays on the carrier pipe) shows 45% attenuation.



C.4.3 Alternating Current Voltage Gradient - ACVG

ACVG surveys are similar to DCVG surveys, except that an AC signal is applied to the pipe by a signal generator.

The ACVG test is conducted using an A-Frame device, usually in conjunction with an AC attenuation device that measures the AC potential difference between two fixed metal pins in contact with the soil. In this survey, the device is moved above the pipeline and when the arrow changes direction, the equipment operator knows the contact has been passed. As in DCVG, if the device is moved to either end of the casing, it should point into the cased crossing. Typically, a reading cannot be obtained over the casing and thus only the readings at each end are important. One indirect inspection survey contractor uses a range of 50 to 80 dBµV as an electrolytic contact and all readings over 80 dBµV as direct shorts (direct shorts are typically 90+ dBµV with 99 dBµV not being uncommon). The ACVG (A-Frame) device does not need a rectifier but uses a signal generator (the same one as one brand of AC attenuation device) connected to the pipe and to an independent ground, which inputs a 4 HZ signal on the pipe. The signal is used as pure AC to be picked up by the two probes and to have the relative difference between the probes show the direction to the contact.

As with DCVG and AC Attenuation, the receiver does not have to be connected to the carrier pipe. The only connection is the signal generator and that should be at least several pipe lengths (or more) away from the casing. The probes on the A Frame need to make good contact with the soil, so wetting down dry surfaces is necessary. With porous and poor quality paving, good readings can be obtained provided sufficient moisture exists or is added.

C.4.4 Potential Surveys - CIS

Potential surveys of pipelines and casings are made to monitor cathodic protection potentials (voltages in volts DC) and are the initial test conducted to identify contacted casings. The presence of a contact may also be evaluated by measuring/comparing the pipe-to-electrolyte (P/S) and casing-to-electrolyte (C/S) potentials.

C.4.4.1 CIS, No Interruption (P/S and C/S Potential Differences)

This test is typically a screening tool used as part of a periodic survey. The P/S potential and the C/S potential are read with protective current applied using a voltmeter and reference electrode. A potential difference of 100 mV or less between the two readings is typically an indication of a metallic short or an electrolytic contact condition. Further testing is needed to confirm the casing condition. Protected bare and coated casings may not show the same type of changes.

C.4.4.2 CIS, Interrupted (Cycling the Rectifier)

While taking the P/S and the C/S readings, the rectifier is cycled on and off. If the shift in the potentials of both the pipe and the casing is in the same direction and of similar magnitude, a metallic shorted condition is possible. If the potential shifts are in the same direction, but of different magnitudes, an electrolytic contact condition is possible. If the potential shifts are very small or in opposite directions, the casing is probably clear and the casing may be in the gradient of a nearby ground bed. Protected bare and coated casings may not show the same type of changes when the rectifier is cycled.

A CIS can show if there is a possible contact to a casing, provided the casing is bare and is not protected separately. Typically, the CIS will dip at both ends of the casing and will recover as one goes away from the casing. In some situations, the potential drop may not be very large, especially if the pipe coating is good and the contact is electrolytic with a fairly high resistance. In these situations, other testing methods may be more appropriate.

C.4.5 Pipe/Cable Locator

The presence and location of a pipe-to-casing metallic contact may be approximated by following the signal from a pipe and cable locator with the signal applied between the pipe and casing. If there was a metallic contact between the pipe and the casing, the signal from the locator would follow one structure to the point of contact and return. If a clear signal can be picked up at the opposite end of the casing on the carrier pipe, without appreciable degradation, the casing is not shorted. If there is a reduction in the signal strength without an apparent signal return location, an electrolytic contact condition is expected. This is not a very precise test and should be used for screening purposes only and may not show all electrolytic contacts.

C.4.6 Panhandle Eastern 'B' Method

The Panhandle Eastern method involves determining whether the casing is isolated or not by discharging DC current from the casing and comparing the electrically coupled response of the 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 C/S potential shifts in a positive direction. If the pipe and casing are metallically shorted, 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 contacts, 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. Additional testing must be performed to confirm if such a contact condition exists or does not exist.

C.4.7 Internal Resistance Test

This technique indicates whether direct metal-to-metal contact exists between the carrier pipe and the casing by measuring electrical resistance.

A battery is inserted in a circuit set between the pipe (cathode) and the casing (anode). With a known constant current (I) applied briefly, the potential difference between the pipe and the casing is measured and recorded ($E_{on)}$. With the test current interrupted, the pipe-to-casing potential (E_{off}) is measured.

The change in voltage between each is determined (E_{on}-E_{off}) and then divided by the current (I) so that the internal resistance is determined by Ohm's law. If the internal resistance is less than 0.01 ohm, then the casing is metallically shorted. In many situations, no conclusions concerning electrolytic contacts can be made. Therefore, this test is not recommended for determining whether or not a casing and carrier pipe is connected electrolytically. Additional testing must be performed to confirm if such a contact condition exists or does not exist.

C.4.8 Casing/Pipe Capacitance

The actual resistance between a potentially shorted casing and the carrier pipe depends on many factors, such as the environment in which the pipe is located. Checking the electrical isolation of a carrier pipe in a casing for current leakage can be a reliable test. The capacitance test looks at the electrical characteristics of the possible short. The device used and principles involved are the same as for evaluation of the effectiveness of an isolation flange. In general, the following conditions exist when effective isolation is measured:

1. Substantially different ground voltage readings are evidenced on the pipe and the casing.
2. The percentage of current leakage that the short will allow to flow through it is low, 25 percent or less.
3. The voltage drop across a pipe and casing that is not shorted is significant. The voltage drop across a shorted condition would be negligible, in the range of 10 millivolts or less.

The Isolation Checker uses the above three criteria to determine, and display, whether the pipe and the casing are shorted or clear. For electrolytic contacts no conclusion can be determined in many situations, so this test is not recommended to determine if a casing and carrier pipe are connected electrolytically. Additional testing must be performed to confirm that such a contact condition exists or not.

C.4.9 Current Span Test (Four Wire Drop Test)

This test is similar to the evaluation of current leakage through an isolation device. The test consists of measuring a current span along the casing while test current is applied in each of three circuit configurations:

1. Current is applied through an ammeter along the length of the casing from contacts just outside the ends of the current span. If the casing is clear, then all of this test current must pass through the span (in agreement with the polarity of the current circuit), and the calculated resistance (using Ohm's Law) may be employed to confirm the resistance of the span. If there is a metallic contact between the pipe and casing, part of the test current will flow along the pipe, and the measured resistance will be reduced accordingly.

2. Current is applied through an ammeter between a contact to the pipe (cathode) at one end of the casing and to the casing (anode) at the opposite end. Again, essentially no current will flow along the pipe unless there is a metallic contact between the pipe and casing, with the measured resistance reduced accordingly.

3. Current is applied between the pipe and casing at one end of the casing. If the pipe and casing are clear at that end, then all of the test current will flow along the casing span away from the location of the current circuit. If a short exists at the end where the current is applied, there will be virtually no current flowing along the span. If a short exists at the end of the casing opposite the current circuit, then current flows away from the current source along the casing and back to the source along the pipe inside the casing. If a short exists between the casing ends, then the apparent current flow along the span varies accordingly.

Often this test does not provide conclusive identification of electrolytic contacts and is not recommended for determining if a casing and carrier pipe is connected electrolytically. Additional testing must be performed to confirm if such a contact condition exists or does not exist.

C.4.10 Temporary Intentional Short

This test is done by comparing/recording the pipe-to-soil and casing-to-soil potentials with and without an external shorting jumper connected between the pipe and the casing at one end. The reference cell is located in the same location over the pipeline for both the pipe-to-soil and casing-to-soil potential measurements. Typically, the reference cell is located at least 3 feet from the casing vent over the carrier pipeline beyond the end of the casing.

The following measurements are recorded:

1. The initial pipe-to-soil and casing-to-soil potentials without the external shorting jumper connected.
2. The potential difference between the casing and the carrier pipe.

3. The pipe-to-soil and casing-to-soil shorted potentials with a shorting jumper connected between the pipeline and the casing.

Indication of a shorted condition is apparent if all potential measurements are nearly identical to those taken before the shorting jumper was connected. If possible, repeat the test by shorting the pipe to the opposite end of the casing.

Often this test does not provide conclusive identification of electrolytic contacts and is not recommended for determining if a casing and carrier pipe is connected electrolytically. Additional testing must be performed to confirm if such a contact condition exists or does not exist.

In general, the above tests are usually excellent tools for the detection of direct or metallic shorts, but lack precision when used to identify electrolytic contacts. In most cases, operators should use more than one technique to validate that the casing is clear and free from all types of shorts or contacts. If an operator cannot positively exclude the existence of an electrolytic contact, the operator should assume such a condition currently exists or has previously occurred.

Exhibit D Casing Quality and Monitoring Guidelines

Exhibit D addresses the preventive measures that must be taken to manage the threat of external corrosion on a carrier pipe within a casing and gives guidance for quality casing construction and implementation of an effective casing monitoring program. In the context of ECDA for cased pipe, the preventive measures described in this Exhibit represent the "other assessment activities" listed in NACE RP 0502-2002, Table 1. The information obtained from the effective implementation of the guidelines in this Exhibit can be used during the pre-assessment evaluation step and the direct examination step of the ECDA process, as discussed in Section 3.3. These activities are critical to the effective application of ECDA for cased pipe.

A properly designed and maintained casing can mitigate external corrosion. Casing monitoring is an important aspect of in-process evaluation and assures that casing integrity and functionality is maintained. These casing quality and monitoring guidelines are important aspects of complying with NACE RP 0502-2002, §5.7 and §5.8:

> *§5.7 Mitigation*
> *§5.7.1 The pipeline operator shall identify and take remediation activities to mitigate or preclude future external corrosion resulting from significant root causes.*
> *§5.7.1.1 The pipeline operator may choose to repeat indirect inspections after remediation activities.*
> *§5.7.1.2 The pipeline operator may reprioritize indications based on remediation activities, as described below.*
>
> *§5.8 In-Process Evaluation*
> *§5.8.1 The pipeline operator shall perform an evaluation to assess the indirect inspection data and the results from the remaining strength evaluation and the root cause analyses.*
> *§5.8.2 The purpose of the evaluation is to assess the criteria used to categorize the need for repair critically (Paragraph 5.2) and the criteria used to classify the severity of individual indications (Paragraph 4.3.2)*

D.1 Wax Filled Annulus[11]

To effectively manage external corrosion for carrier pipe in a filled casing, certain guideline conditions must be implemented and met during the assessment interval. The annulus must be adequately filled with an appropriate corrosion inhibiting casing fill material. A properly filled casing annulus prevents electrolyte from coming into contact with the carrier pipe by encapsulating coating voids along the carrier pipe with the fill material and by displacing electrolyte. Additional chemical inhibitors may be applied through the vent prior to fill application to treat any water/electrolytes that may remain in the annulus during the fill process.

When an operator demonstrates that it has achieved a successful casing fill, periodic monitoring is necessary to assure that conditions do not change. An effective monitoring program: (1) ensures that the carrier pipe remains electrically isolated from the casing and isolated from any electrolyte, and (2) ensures that the engineered systems for assuring electrical isolation and a controlled environment such as the casing, end seals, carrier pipe coating, and annulus fill remain intact and fully functional. For example, operating temperatures above the fill material melt point, may affect the stability of fill level over time and may permit fill to seep out, resulting in a fill level change which may permit the reintroduction of an electrolyte into the annulus. To ensure that external corrosion does not develop, monitoring of cathodic protection, and other conditions that impact fill level stability, is necessary.

This approach only applies to non-shorted cased pipe. Therefore, monitoring must also check for shorts.

The detailed guidance that follows is organized in the following manner:

[11] Note: Filling a casing annulus with corrosion inhibiting fill material may limit the effectiveness or the use of Guided Wave Ultrasonic Testing, as a direct or indirect method of assessment of a carrier pipe inside a casing. An operator should consider this if GWUT is a possible assessment or reassessment method to be used in the future.

Section D.1.1, Guidelines for a Quality Casing Fill
Section D.1.2, Guidance for Monitoring Filled Casings Free of Metallic Shorts and Electrolytic Contacts

D.1.1 Guidelines for a Quality Casing Fill

The annulus between the casing and carrier pipe must be completely filled, have no voids, be free of electrolytes, have no metallic shorts, be sealed to prevent leakage of fill material, use high quality non-corrosive fill, and otherwise assure that external corrosion on the carrier pipe cannot occur. The following criteria are provided as guidance to assure a quality fill that meets this objective.

D.1.1.1 Casing Preparation Procedure

1) Casing Installation Data
Pipe and casing diameter, wall thickness, coating thickness, vent size and length, spacer type and quantity used, and casing length are needed to calculate the volume of fill material required.

2) Spacers
Operators must identify type and number of insulating spacers used in the annulus to electrically isolate the carrier pipe from its outer casing. For future reference, operators should document manufacturer, model, material, and size of spacers used.

3) Pipe and Casing Support
To prevent movement that could cause a short to develop after the filling process has been completed, carrier pipe and casing must be adequately supported.

4) Flushing Annulus
Prior to filling, the casing must be excavated, end seals removed, the carrier pipe inspected, and the annulus must be flushed and dried to remove debris, contaminants, electrolytes, and other materials that could cause or contribute to the formation of a corrosion cell.

5) Casing End Seals
Operators must give consideration to type of end seals used on casings. Casing end seals should be designed to prevent ingress of water and soil into the casing annulus.

When conducting direct examinations, end seals are removed from the exposed casing end in order to inspect the annulus, drain water and flush to remove debris. Care must be taken in the replacement of these seals. A statistical study[12] of selected ILI logs of cased pipe suggests that the most severe external corrosion tends to occur nearer the end of the casing.

6) Casing Vent Pipes/Fill lines
A vent pipe shall be installed on each end of the casing, and an opening in the casing at the vent-pipe connection shall be provided. The opening shall be adequate in size to allow for the flow of casing filler into the casing. Vent pipe with a minimum diameter of 2 inches is recommended.

The recommended practice is to install a bottom vent pipe on the lower elevation of the casing and a top vent pipe at the higher elevation. This does not preclude alternate configurations. Top side vent fills may be an acceptable alternative for short casings provided care is taken during the fill operation to ensure that trapped air is removed and no significant voids are present.

Access must be maintained to fill line/vent to facilitate fill application and for future monitoring of the fill level, a requirement for the elimination of the threat of external corrosion.

7) Test Leads

[12] Song, F; Fassett, R; Boss, T; Lu, A; *Study Investigates Damage to Cased Pipeline Segments*; Oil and Gas Journal, April 6, 2009.

Adequate test connections must be installed on each casing, and on the carrier pipe at or in the vicinity of the casing, as needed when the casing is exposed. These test leads are used to perform monitoring tests to document that the casing is electrically isolated and clear of all metallic shorts and electrolytic contacts.

8) Backfill
To ensure the stability of the end seals after excavation and before/during fill application, the carrier pipe and casing may need to be supported with well-compacted soil or sand/soil bags under the pipe. b

9) Isolation Testing
Electrical isolation between the carrier and its casing must be confirmed prior to and after the completion of the back fill process.

D.1.1.2 *Casing Filler Material*

Operators must give consideration to the type of insulating material used in the annulus. A high dielectric non-conductive fill material appropriate for the expected operating temperatures of the pipeline is the minimum requirement. The filler should also be non-flammable. Typically, casing-filler material is composed of petrolatum wax or other petroleum-based compounds and may contain corrosion inhibitors, plasticizers, and thermal extenders. Other acceptable fill materials are available. Operators must understand fill material properties and principles of appropriate application. Fill material properties can be found in NACE RP0200-2000, Appendix A.[13]

Operators typically use either hot injected petrolatum wax or a cold injected petroleum blend casing filler. Each type of filler has particular advantages and limitations. Operators should consult with fill manufacturers for specifications.

Operating temperatures must be considered when selecting fill. It is strongly recommended that the melting temperature of the filler be above the maximum operating temperature of the pipeline. Where operating temperatures are expected to rise above the fill material melting point, operator should carefully review product information and confirm suitability of product for conditions before proceeding with fill.

D.1.1.3 *Casing Fill Procedure*

The operator must perform calculations based upon the information collected during the casing installation to determine the amount of wax needed. For existing pipelines where information about the casing is unavailable, an operator shall determine through investigation and/or excavation, the size, condition, and type of casing, carrier pipe, spacers, and casing end seals. The fill must be performed in conditions that promote success. Review procedures and recommendations with the vendor/fill contractor prior to fill application. Check for appropriate ambient temperature, vent blockage and leaky end seals. As ambient temperature can significantly affect the properties of the filling material, careful consideration must be given to the timing of the filling procedure. The supplier of the filling material will have recommendations on the temperature range required for filling the casing. When the temperature is outside the optimum range, the filling must be delayed until temperatures are acceptable.

To test for obstructions, dry air is blown through the casing vents. The vent pipes and the casing annulus must be free of restrictions to allow adequate flow of the filler material. Additionally, a test must be performed to determine if the end seals are intact. This could be accomplished by pumping low pressure air into the casing with the vents temporarily blocked. Care should be taken to not damage the end seals during such testing.

Prior to filling, the annulus should be flushed and dried to remove debris, contaminants, electrolytes, and other materials that could cause or contribute to the formation of a corrosion cell in accordance with Flushing Annulus procedure D.1.1.1 (4). If it cannot be verified that the annulus is free of electrolyte after flushing, then corrosion inhibitor should be poured into the casing through the bottom vent or introduced as an additive in the filler material, in order to passivate trapped water.

The filling material must be pumped at a rate that will allow the material to fill all voids within the casing and displace any residual fluid or air. If the filling is performed too rapidly, voids in the fill material may develop, seals

[13] NACE Standard Practice RP 0200-2000, *Steel-Cased Pipeline Practices*

may be damaged and filling material wasted. The casing filler is pumped into the casing through one vent and will discharge out the opposite vent when the casing is full. Fill is most effective when pumped through a bottom vent.

The fill level must be closely monitored during the filling procedure and after the initial fill has been completed. If the fill material level recedes, additional material can be added to the casing and the level again monitored until stabilized. If the fill level continues to recede and the appropriate fill level cannot be maintained, additional investigation must be conducted and the source of any leak repaired.

Once the fill material level has stabilized, the total volume of fill material pumped into the casing and vents must be compared to the calculated volume. The difference in fill volume should be within 10% of expected. Common reasons for discrepancies are as-built conditions may vary from design documents; incorrect spacer count; and inaccurate calculation of annulus volume, coating and casing thicknesses. If the cause of the discrepancy is not identified, operators must investigate. If the discrepancy cannot be resolved, then the fill cannot be considered acceptable for purposes of these guidelines. Operators should review fill specific information and piping configuration and data to determine if the fill is acceptable.

After the filling operation is complete, the carrier pipe and casing pipe must be checked to verify that no short or contact developed during the fill process.

D.1.2 Guidance for Monitoring Filled Casings Free of Metallic Shorts and Electrolytic Contacts

To ensure the continued effectiveness of the casing and fill material at preventing external corrosion:

- The fill material must remain in place and continue to encapsulate the carrier pipe.
- The level of fill material in the annulus of a casing must be monitored to ensure that the annulus remains effectively filled. Field verification of fill material effectiveness must include verification of casing integrity to assure that fill material is not lost through corroded or damaged casing.
- Electrical isolation of the casing from the carrier pipe must also be monitored.

D.1.2.1 Filled Casings Monitoring Program Considerations

Operators must consider the following to develop monitoring program procedures for their filled cased pipe locations. With respect to previously filled casings, operators must have records adequate to demonstrate compliance with these guidelines regarding the initial fill, fill material, fill quality, and the adequacy of fill monitoring. Operators must also have records to demonstrate compliance with code requirements regarding operating conditions, CP, and electrical isolation. Records documenting the casing design and construction, vent configuration and type of end seals are also required. Operators must put together the best information available for previously filled casings and provide documentation of this information. For new fill locations, this information must be obtained when planning for the fill to be installed.

1) Fill product used
2) Fill material properties
3) Fill type hot or cold applied
4) Fill material application temperature
5) Operating Temperatures
6) End seal type
7) End seal properties that may impact effectiveness
8) Original fill volume vs. casing annulus volume
9) Access to and maintaining access to fill/vent line for a physical inspection and level measurements
10) Other means to monitor fill level or stability (probes, sensors, etc.)
11) Vent configuration
12) Casing fabrication (design and construction, weld types, original length or extended, split sleeve, smooth or corrugated, etc.)
13) Casing age
14) Cathodic protection levels on the carrier pipe near the casing ends
15) If the casing itself is bare or coated
16) If the casing has its own cathodic protection separate and isolated from that of the carrier pipe
17) Casing potential

18) Whether or not casing to carrier is metallically shorted or electrolytically contacted
19) Historical data of the carrier and casing pipe as available
20) History of external corrosion on the carrier pipe at (and around) the casing

Properties of fill materials vary (such as insulating properties (dielectric strength), melt/pour point, flash point, specific gravity etc.) There are several different high dielectric fill materials available to choose from for use as casing fill.

To mitigate the threat of external corrosion, a quality fill using a high dielectric insulating fill is necessary as per Section 3.1.1"Guidelines for a Quality Casing Fill". It is important to know which fill material or type was used in order to develop a proper monitoring process.

It is important that operators be cognizant of the specific fill product type used in a filled casing and fill material properties and limitations. It is important to consider the effect of environment and operating conditions on the proper selection, use, and application of casing fill material. When material type and manufacturer are known, consultation with the manufacturer is possible for clarification of any specific considerations for the fill material in use.

D.1.2.2 Considerations for Different Case Fills

Typically casing fill products are designated as hot or cold type based upon the temperature at which it is installed.

Hot fills are heated over their melting point when installed and will normally be used in applications where the fill will harden when the temperature cools below the pour point. Since a hot fill flows more freely during application, these fills are applied at very low pressures so the possibility of end seal over pressure is very low. Prior to filling, air is forced through the annulus as part of the air test which displaces water that may be in the annulus. Typically a corrosion inhibitor should be added to further mitigate corrosion.

Cold fills are applied at ambient temperatures. They are more viscous than the hot fills. Operators must ensure that ambient temperatures during filling allow the fill product to flow freely in order to completely fill the annulus without voids. During installation, pressure is required to pump the fill into the annular space. It should be noted that these fills are much heavier than water and will flow to the bottom of the casing and displace water. Water should rise to the top of the annulus and exit the casing through the vent during such installations.

The fill material melting/pour point temperature is one of the fill material properties that must be considered regarding the installation process and for developing a monitoring program.

D.1.2.3 Operating Temperature Issues

When implementing a monitoring program of the fill within a casing annulus, particular consideration must be given to the pipeline operating temperatures. Operators must be aware that fill can melt or become less viscous at operating temperatures above the fill material pour/melting point (see fill manufacturer's material specifications). Such operating temperatures may increase the likelihood of seepage from the annulus. Consult material specifications or fill manufacturer for temperature guidance (when fill material is known) and develop means to monitor fill appropriately if operating temperatures exceed the fill material melting point.

At or above the fill material pour point (melting point) temperature, the casing fill material will begin to flow and eventually liquefy, resulting in the potential for the fill material to seep out of the casing. In such cases, operators must monitor for leakage of the fill material from the annulus. The fill material could leak at breaches in the casing itself (such as those caused by corrosion or poor construction techniques), joints in the casing (such as locations where joints may have been tack welded instead of continuously welded), or ineffective end seals. Loss of fill material can lead to a reduction in the corrosion resistance that is provided by a properly filled annulus.

Therefore, pipeline operating temperatures at filled casing locations must be considered. When operating temperatures exceed the fill product melting point, measures must be taken to ensure that the fill material continues to fill the annulus as was originally intended and installed. Where operating temperatures remain below the melting point of the fill material, e.g., pipeline systems far downstream from compressor stations, fill liquefaction may not be an issue. In this case, monitoring is relatively simple as per visual inspection below.

Where pipeline temperature exceedance of the fill melt point is a concern, implementation of additional monitoring steps shall be required. Operating temperatures must be compared to fill material melt points and exceedances identified. If the melting point of the fill material has been exceeded, measures must be taken to ensure that the casing system has not been compromised.

D.1.2.4 Fill Monitoring Techniques

Access to vent (fill) line for physical monitoring of the filler level is desired and should be maintained for fill level monitoring by inspections.

Visual inspection is one way of monitoring the fill material level in the annulus.

Visual inspection at the vent line could be accomplished utilizing a boroscope, dip stick, or flashlight. Whatever the method of inspection, the level of fill material in the casing annulus must be verified. A baseline level is determined and recorded when annulus is first filled or when monitoring under this guidance begins. This could be accomplished by making a permanent mark on the vent pipe, by measuring and recording a reference from grade level or by referencing the distance from the top of the vent. Photographic representation is recommended and would be useful for future comparison. Each time the level is monitored a new reading must be taken and compared to previous reading(s) to determine if level has changed. Removal of solid fill material in the high side vent pipe in order that visual inspection can be conducted at the top of the casing pipe is one possible way to monitor fill levels. Fill monitoring must also verify the integrity of the casing to assure that fill is not lost through corroded or damaged casing.

If the monitored pipeline operating conditions do not exceed the liquefying point of the fill material, the operator may infer that the fill material is still in solid form. When operating temperatures exceed the melting point of the filler material used, additional inspection steps must be implemented. For example, solid fill material scooped out of the high side casing vent can be visually inspected to determine if molten fill exists below the vent line. This type of verification could be used to determine the state of the fill material at different levels and would satisfy the monitoring requirements for high operating temperatures.

Other technologies or techniques that can verify fill material levels will be acceptable as long as they can be proven valid, applicable and equivalent to the methods described above.

D.1.2.5 Periodic Monitoring

After the integrity assessment of the carrier pipe and casing has been completed, the operator must periodically monitor casing integrity as described below.

- Structural integrity of the casing and end seals (i.e., that the casing pipe and end seals are not leaking) must be monitored.
- Fill quantity and fill level must be monitored (i.e., that fill material is not leaking out or melting).
- Electrical isolation of the casing from the carrier pipe must also be monitored. The electrical isolation condition of the casing pipe to the carrier pipe must be in the clear or isolated condition. Testing techniques commonly utilized include Panhandle Eastern “B”, Internal Resistance, DCVG, ACVG, Current Attenuation, etc.

The operator must perform the periodic monitoring on the schedule[14] described below.

To document that conditions have not changed on a pipeline operating at temperatures at or above the fill melting point, operators must quarterly test the carrier pipe for isolation from the casing and verify wax fill level is stable.

To document that conditions have not changed on a pipeline operating at temperatures below fill melting temperatures, operators must periodically test the carrier pipe for isolation from the casing. Quarterly testing is

[14] Annually means once each calendar year, not to exceed 15 months between any two consecutive occurrences.
Quarterly means four times each calendar year, not to exceed 4 ½ months between any two consecutive occurrences.

required during the first year, seventh year, and every seven years thereafter to periodically check for seasonal variations; annual testing is required in all other years.

To document that conditions have not changed on a pipeline operating at temperatures below fill melting temperatures, operators must periodically verify that the fill level is stable. Quarterly testing is required during the first year, seventh year and every seven years thereafter to periodically check for seasonal variations; annual testing in all other years should be sufficient once a stable level of fill has been confirmed.

Documentation of these quarterly, annual or periodic tests for isolation between the carrier and casing pipe and fill level stability is required. The information must be used in the next reassessment as described in Section 3.

Carrier pipe, inside filled casings, that is metallically shorted or electrolytically contacted to the casing, is believed to be at risk of the threat of external corrosion, even if the casing is filled with an approved high dielectric casing filler and the pipe is cathodically protected. Periodic monitoring must be designed to identify this circumstance.

D.2 Unfilled Annulus

Many of the guidelines in Exhibit D.2 were developed on the premise that a properly designed, constructed, sealed, and maintained unfilled casing provides sufficient control of the environment within the annulus to preclude the development of corrosion cells on the carrier pipe. While atmospheric corrosion is still possible, the restricted environment in the annulus limits the extent and speed of corrosion metal loss due to atmospheric corrosion. Therefore, the guidelines focus on requirements that operators demonstrate that this is the case. The guidelines address the preventive measures that must be taken to manage the threat of external corrosion on a carrier pipe within an unfilled casing and give guidance for implementation of a monitoring program that ensures that external corrosion remains mitigated at cased pipe locations.

To effectively manage external corrosion for carrier pipe in an unfilled casing, certain conditions must be met. The casing end seal must be intact and the casing must be electrically isolated from the carrier pipe. Also, the carrier pipe must be coated; bare pipe is not allowed.

After an operator demonstrates that it has achieved a successful casing installation that controls the environment in the annulus, periodic monitoring is necessary to assure that conditions do not change.

An effective monitoring program ensures that:

- The carrier pipe remains electrically isolated from the casing and isolated from any electrolyte.
- The engineered systems for assuring electrical isolation and a controlled environment, e.g., the casing, end seals, and carrier pipe coating, remain intact and fully functional.

This approach only applies to non-shorted cased crossings and the carrier pipe within such a casing. Therefore, monitoring procedures must also check electrical isolation.

Following are detailed guidelines for monitoring unfilled casings.

D.2.1 Guidance for Monitoring Unfilled Casings Free of Metallic Shorts and Electrolytic Contacts

After the integrity assessment of the carrier pipe and casing has been completed, the operator must periodically monitor casing integrity as described below.

- Structural integrity of the casing and end seals (i.e., that the casing pipe and end seals are not leaking) must be monitored.
- Electrical isolation of the casing from the carrier pipe must also be monitored. The electrical isolation condition of the casing pipe to the carrier pipe must be in the clear or isolated condition. Testing techniques commonly utilized include Panhandle Eastern “B”, Internal Resistance, DCVG, ACVG, Current Attenuation, etc.

The operator must perform the periodic monitoring on the schedule[15] described below.

[15] Annually means once each calendar year, not to exceed 15 months between any two consecutive occurrences.
Quarterly means four times each calendar year, not to exceed 4 ½ months between any two consecutive occurrences.

To document that conditions have not changed, operators need to periodically test the carrier pipe for isolation from the casing. Quarterly testing is required during the first year, seventh year, and every seven years thereafter to periodically check for seasonal variations; annual testing is required in all other years.

Documentation of these quarterly, annual or periodic tests for isolation between the carrier and casing pipe and fill level stability is required. The information must be used in the next reassessment as described in Section 3.

Carrier pipe inside unfilled casings that are not electrically isolated, are believed to be at risk of the threat of external corrosion. Periodic monitoring needs to be designed to identify this circumstance.