Final Report

On

Improvements to the External Corrosion Direct Assessment (ECDA) Process (WP # 360)

Cased Pipes
(Project #241)

for

Pipeline and Hazardous Materials
Safety Administration (PHMSA)

U.S. Department of Transportation

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by

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Executive Summary

On June 28, 2007, PHMSA released a Broad Agency Announcement (BAA), DTPH56-07-BAA-000002, seeking white papers on individual projects and consolidated Research and Development (R&D) programs addressing topics on pipeline safety program. Although, not specifically suggested by PHMSA, three Direct Assessment projects were proposed by Corrpro based on in-house gap-analysis of the External Corrosion Direct Assessment (ECDA) process. A white paper was submitted for a consolidated Research and Development (R&D) program entitled "Improvements to the External Corrosion Direct Assessment (ECDA) Process". It was eventually approved for implementation by PHMSA with the following 3 projects:

- Cased pipes
- Severity ranking of ECDA indirect inspection indications
- Potential measurements on paved areas

The ultimate goal of each of the program was to present the results and recommendations to the applicable Standards Development Organizations (SDOs) to ensure the strengthening of industry consensus standards and the timely implementation of research benefits for improved safety, environmental protection, and operational reliability. It was also to expand DA applicability and increase the knowledge of the DA methodology.

The accomplishments and conclusion of Cased Pipes are summarized as follows:

- An effective ECDA methodology was developed as another assessment option for cased pipes.
- The methodology makes use of ECDA Indirect Inspection surveys being used on uncased, buried pipe as part of the process for identifying and ranking Direct Examination priorities and selecting the most effective assessment tools
- The completed methodology will include guidelines produced by the CASQAT committee.
- The completed methodology will be provided to industry organizations for development of consensus standards.

Introduction

A Government and Industry Pipeline R&D Forum was held in New Orleans on February 7 and 8, 2007, by the U.S. Department of Transportation (DOT), Pipeline and Hazardous Materials Safety Administration (PHMSA). The 2-day event included approximately 240 representatives from Federal, State and international government agencies, public representatives, research funding organizations, standards developing organizations, and pipeline operators from the U.S., Canada and Europe. The R&D Forum led to a common understanding of current research efforts, key challenges facing government and industry, and potential research areas where exploration can help meet these challenges, and should therefore be considered in developing new research and development applications. On June 28, 2007, PHMSA released a Broad Agency Announcement (BAA), DTPH56-07-BAA-000002, seeking white papers on individual projects and consolidated Research and Development (R&D) programs addressing topics on pipeline safety program areas identified at the R&D Forum, namely:

1. Excavation Damage Prevention Technologies
2. Direct Assessment Methods for Transmission and or Distribution Pipelines
3. Defect Detection/Characterization
4. Defect Remediation/Repair/Mitigation
5. New Fuels Transportation

Several specific R&D projects were suggested in the BAA. Although, not specifically suggested by PHMSA, three Direct Assessment projects were proposed by Corrpro based on in-house gap-analysis of the External Corrosion Direct Assessment (ECDA) process. Over several years, ECDA has been used to assess the condition of thousands of miles of natural gas pipelines. Corrpro's gap analysis identified three key areas of opportunity to enhance application of the technology. A white paper was submitted for a consolidated Research and Development (R&D) program entitled "Improvements to the External Corrosion Direct Assessment (ECDA) Process". It was eventually approved for implementation by PHMSA. One of the three components of the consolidated R&D program is as follows:

Cased pipes: Technologies that are currently used to assess cased pipes include in-line inspection, guided wave ultrasonic, electromagnetic wave, pulsed eddy current, conformable array, bore scope, pressure testing and visual inspection. The three most promising in-line technologies presently in use or being developed are: In-Line Inspection (ILI), Guided Wave Ultrasonic Inspection (GWUT) and Electromagnetic Wave Inspection (EMW). Several other technologies are under development, some of which have the potential to be better for inspecting cased pipe than these three tools. While these technologies are recognized as the best minimally invasive technology presently available for identifying and quantifying corrosion and other metal-loss defects, they can not easily or economically be used on many pipelines.

The ultimate goal of each of the projects is to present the results and recommendations to the applicable Standards Development Organizations (SDOs) to ensure the strengthening of industry consensus standards and the timely implementation of research benefits for improved safety, environmental protection, and operational reliability. It is also to expand DA applicability and increase knowledge of DA methodology.

1.1 Project Objectives

The goals of the Cased Pipes Project are:

- To obtain, evaluate and utilize the results of industry surveys related to cased pipes
- To Identify, analyze and determine applicability of existing and emerging technologies for assessing cased pipes for external corrosion damage
- To develop and verify a new assessment methodology (that makes use of existing ECDA methodologies, existing and emerging technologies, and best practices of pipeline operators) for assessing pipelines in casings under electrically (metallically) shorted, electrolytically coupled and electrically isolated conditions
- To convey new methodology and application guidelines to industry organizations for development into consensus standards
- To produce project report, and conduct web-based workshop and public presentations

The project is designed such that its results parallel PHMSA program elements, namely: pipeline assessment, defect characterization, improved design of data collection systems, human factors and safety.

1.2 Cased Pipes and ECDA Methodology

Although modern horizontal directional drilling construction techniques tend to eliminate benefits of casings, the legacy reasoning for the use of cased crossing was to provide the capability to remove or replace carrier pipeline without disturbing the road or rail-crossing. Casings accommodate higher dead loads (overburden for deep pipe), live loads (traffic) and prevent third-party damage to the pipeline. On the other hand, greater strength and/or pipeline wall thickness, concrete coatings and other methods could provide protection to the pipeline from mechanical damage and external loads.

The downsides to the use of casings are numerous, namely: additional design and construction costs, additional maintenance and monitoring of electrical isolation and the problems associated with electrical shorts, including remediation, and increased loads on the cathodic protection (CP) systems. If the annular space between the pipe and casing becomes filled with an electrolyte, possible corrosion mechanisms include electrical shielding, crevice corrosion associated with nonmetallic casing spacers and pipe corrosion at coating flaws.

Although it is possible for CP current to get to the pipe through the casing containing electrolyte, mud or debris deposits in contact with the pipe may interrupt a continuous electrical path to the casing. If there is an electrical short between the pipelines and casing, the casing may appear as a large coating flaw on the pipeline, consume the available CP current and reduce CP effectiveness at other locations along the pipeline.

While uncased road and railroad crossings are becoming common with the use of concrete-coated pipe for damage protection and/or modern horizontal directional drilling construction techniques, aging cased pipelines still pose significant corrosion problems. Several pipeline failures caused by external corrosion on cased pipe in the past have injured members of the public, damaged property and/or the environment. More failures are likely to occur in the future on account of aging cased pipes. It is simply not practical to assess many cased pipes for external corrosion damage using standard assessment methods for the following reasons:

- Service interruption required for pressure testing is unacceptable particularly for natural gas pipelines,
- Pipeline excavation required for attachment of equipment used to propagate an inspection signal along the pipeline in the casing is either not possible or impractical,
- Introducing water into the pipeline for pressure testing is unacceptable, particularly for natural gas pipelines,
- Pipeline configuration prevents the use of in-line inspection tools, and
- Pipeline operating conditions preclude the use of in-line inspection tools.

There is a real need for an economic, effective ECDA methodology that can be employed at cased crossings where ILI, pressure testing, or excavating the pipeline are either not possible or impractical. The technology needs to be minimally intrusive to limit disruption of pipeline operations and road and railroad use. NACE SP0502 and SP0200 provide some guidelines and methods but there is no specific standard that provides detailed procedures for assessing cased pipelines using ECDA.

Conventional aboveground indirect inspection tools used in ECDA are not effective for cased pipes if there is no electrical path in the annulus between the casing and the pipeline. Even when an electrolyte is introduced into the annulus, the casing may still act as a shield such that the results from most indirect inspection tools regarding the CP level or coating condition may not be particularly meaningful.

The primary goal of this project is to develop a new ECDA methodology that can be used to assess cased pipes which can not be assessed by standard methods. This new ECDA methodology will fill the assessment gap, enhance safety and protect the environment.

1.3 Existing Cased Pipes Assessment Technologies

Although, the focus of the present work is to develop a Cased Pipes External Corrosion Direct Assessment methodology, it is instructive to examine the major methodologies that have been used so far for inspecting cased pipes. These existing technologies and methodologies are well grounded and are well accepted by the pipeline industry. Examples include:

Pressure testing: Pressure Testing (PT), illustrated in Figure 2-1, is an important integrity verification method. When used for pipeline testing, hydrocarbons are removed and the pipeline is completely filled with water. Hydrostatic pressure is increased until the required pressure is achieved. The required pressure is held for a period while the pipeline is visually inspected for leaks. Testing is mandated to be performed at 125% of the maximum operating pressure (MOP) for at least 4 continuous hours and an additional 4 hours at a pressure at least 110% MOP if the piping is not visible. The use of hydrotesting for integrity verification purposes is based on the supposition that, after defects that fail above MOP are removed, the line is safe to operate at MOP and below.

A special type of pressure test, a spike test, is used to detect stress corrosion cracking. During a spike test, the pipeline is maintained at the elevated pressure for a short period to induce stress corrosion cracking. If failure occurs, the pipeline is replaced. If failure does not occur, the elevated pressure imparts surface compressive stresses on the pipe, providing an important stress corrosion cracking control mechanism.

When pressure testing is used as a verification method, the tests are conducted on a repeated frequency for the lifetime of the pipeline, or until an alternative verification method is selected. Water is preferred as the pressure medium to limit safety hazards and environmental damage in the event of a leak or rupture while testing. After hydrotesting, the pipeline is safely emptied in accordance with the prevailing regulation. The pipeline is dried to ensure it is free of all moisture before it is placed in service. Some companies run a slug of biocide between two sealing pigs for laying a tenacious film on the inner circumferential surface of the pipe wall to reduce the risk of microbiologically induced corrosion (MIC).

Pressure testing has a few significant disadvantages for pipeline operations.

First, it is a destructive test.

Secondly, it requires an interruption in service, which can be a problem when a single pipeline is feeding a plant or an entire city.

It is a pass or fail test with integrity conclusions that are relevant only at the time of the test. For example, the size of the anomalies that remain can be very large and no information is provided regarding non-critical flaws that might soon become critical cracks.

In the event of a failure, the cost of repairing a rupture due to a defect on the pipeline can be substantially more than the cost of repairing a defect if it was discovered through non-destructive verification method.

Dewatering, cleaning, and drying a pipeline after hydrostatic testing can be both time consuming and costly.

In-line Inspection: In-Line Inspection (ILI) technology has existed for more than 40 years and is recognized as a mature technology for inspecting pipelines in a manner that is minimally disruptive for pipeline operations when compared to pressure testing and other highly disruptive technologies. ILI is capable of identifying and quantifying many pipe defects such as external corrosion damage, internal corrosion damage, dents, gouges and hard spots. Specialty ILI tools are capable of identifying and quantifying cracking defects such as stress corrosion cracking, selective longitudinal seam corrosion and circumferential weld defects. It is widely accepted by the pipeline industry that ILI technology is capable of obtaining sufficient information to allow full assessment of pipe condition for many pipe defects; particularly for corrosion damage and other metal-loss defects.

Some limitations of ILI are as follows:

While ILI is recognized as the best minimally invasive technology presently available for identifying and quantifying corrosion and other metal-loss defects, it can not easily or economically be used on many pipelines. Pipelines where ILI can easily and economically be used are those that are constructed in manners that allow insertion and removal of the inspection tools (launchers and receivers), allow passage of the inspection tools through the pipelines (full-opening valves, uniform pipe diameter and long radius bends), and operating conditions that satisfactorily propel the inspections tools through the pipelines (product flow rates within the ranges required by the tools for both liquid and gas pipelines, and adequate pressure to prevent surging for gas pipelines). Most liquid and many gas transmission pipelines were either built or can be relatively easily and economically modified to accommodate ILI tools. Unfortunately, not all liquid and a significant portion of gas transmission pipelines were not constructed to allow ILI, and most gas distribution systems were not constructed and do not have operating conditions (flow rates and pressures) that allow ILI.

Guided Wave Ultrasonic Inspection: Guided Wave Ultrasonic inspection technology (GWUT) has been used to inspect difficult-to-access pipeline segments for approximately 10 years. Over the past 3 to 5 years GWUT has seen widespread use for inspecting cased pipe segments. GWUT is minimally disruptive for pipeline operations because, unlike ILI, it does not require pipe to be opened for insertion/removal of inspection devices, does not require pipe modifications (such as for valves that are not full opening, pipe of varying diameter, and short radius bends), and is not appreciably affected by product flow or pressure. The GWUT transmitter/receiver sensors are mounted on a collar that simply wraps around the pipe being inspected.

Other than pressure testing, ILI and visual inspection, GWUT is the only other inspection technique for inspecting cased pipe formally recognized by PHMSA at the present time. This acceptance is conditional upon a set of 18-point GWUT requirements/restrictions. While not yet considered a mature technology for inspecting pipe, significant improvements to GWUT over the coming years are likely. It is reasonable to assume that GWUT technology will develop into a mature inspection technology much like ILI technology.

Even though GWUT is limited to short lengths of pipeline, it is capable of inspecting a significant percentage of cased pipe segments. Casings that are too long to be inspected from one setup location at one end of the casings often can be inspected by setting up the GWUT equipment at both ends and inspecting into the casings.

Some present limitations of GWUT are as follows:

To be acceptable to PHMSA for inspecting cased pipe, GWUT inspections must follow a strict 18-point inspection protocol. Even if the protocol is followed and GWUT inspection meets the restrictions, it is still considered to be a Go/No Go inspection technique for pipe defects with additional assessment requirements in No Go situations.

GWUT technology for pipe inspection is at this time in its infancy when compared to ILI technology. It is not presently capable of identifying and quantifying pipe defects to the same degree as ILI, and information obtained by GWUT is not sufficiently detailed to allow full assessment of pipe defects.

For all practical purposes, GWUT is now only capable of detecting gross metal loss defects and is not extremely reliable for discriminating between metal loss defects and acceptable cased pipe discontinuities such as casing spacers.

The primary inconveniences with use of GWUT technology are that buried pipe segments must be excavated to allow mounting of the sensor collar on the pipe and most types of external coatings must be removed from the area of the pipe where the sensor collar is mounted.

Additionally, the inspection range of GWUT equipment is limited by conditions that cause rapid attenuation of ultrasonic sound such as external coatings, contact with soil and water, pipeline appurtenances such as valves and flanges, and products in liquid pipelines.

Lengths of pipeline that can be inspected by GWUT from one setup location vary widely depending on conditions, but typically range from about 50 feet to 200 feet.

Electromagnetic Wave Inspection: Electromagnetic Wave inspection technology (EMW) has much in common with GWUT inspection technology in the way that it functions and in the way that it is used. While GWUT uses ultrasonic sound waves to inspect pipe, EMW uses electromagnetic waves. EMW application to pipeline inspection is much more recent than GWUT and it is significantly more in its infancy than GWUT. Although it is not yet considered a mature technology for inspecting pipe, significant improvements to EMW over the coming years are likely. As with GWUT, it is reasonable to expect EMW technology to develop into a mature inspection technology. EMW appears to be developing much in the same manner as GWUT, but EMW is in its infancy when compared to GWUT. Its first PHMSA acceptance may be as a technique to judge the quality of filling when filling casings with wax

Some present limitations of EMW are as follows:

Testing thus far indicates that EMW is more likely to be a technique for evaluating the environment in the casing annulus rather than for evaluating cased pipes.

EMW appears to be capable of determining if the casing annulus is filled with liquids or solids (water, mud, casing filler, etc.), and the locations of liquids and solids when only partially filled.

1.4 Drivers for Cased Pipes ECDA Methodology

Although, the major methodologies that have been used so far for inspecting cased pipes are well grounded and are well accepted by the pipeline industry, there are significant drivers for Cased Pipes ECDA Methodology:

- Pipeline operators are faced with tremendous challenges when assessing cased pipe that cannot reasonably be assessed using pressure testing or in-line inspection
- The emerging cased pipe assessment technologies are promising, but will likely take years to develop into acceptable assessment techniques
- The deadline for assessing all Gas Transmission pipe, including cased pipe, is December 17, 2012 – 2-1/2 years from now
- ECDA methodology that is now accepted for uncased buried pipe can be developed, improved and/or augmented to be an acceptable assessment technique for cased pipe where pipe and casing conditions allow its use

It has long been the pipeline industry consensus that standard coating and cathodic protection surveys can not be applied to cased pipes because casings and/or lack of continuous electrolyte in casing annuli prevent electrical measurements. Both past and current Corrpro research and testing have demonstrated that cathodic protection can reach cased pipes even if the casing is electrically shorted to the pipe (GRI-05/0020 and other research). If cathodic protection current can reach cased pipes, standard coating and cathodic protection surveys can be applied to cased pipes even though application may be limited if casing is electrically shorted to pipe, if casing is coated or if no electrolyte is present in casing annulus.

Based on evaluations of information obtained from previous research, industry surveys, operator data, operator procedures, best practices, laboratory and field testing, appropriate assessment technologies and/or methodologies could be identified for various cased pipe parameters/situations. Given that cathodic protection current can reach cased pipe under certain conditions, standard coating and cathodic protection survey techniques should also be at least partially effective under these certain conditions. As a minimum, standard coating and cathodic protection survey techniques do produce pertinent data on buried pipe outside of casings that can be used to ascertain likely conditions related to coating condition and external corrosion on cased pipe. The methodology would make use of ECDA indirect inspection surveys being used on uncased, buried pipe as part of the process for identifying and ranking direct examination priorities and selecting the most effective assessment tools.

1.5 Indirect Inspection Tools

NACE SP0502 provides guidance for the selection and use of numerous Indirection Inspection tools that are capable of detecting and evaluating external coating defects and cathodic protection deficiencies on buried pipe in order to identify locations where external corrosion has occurred or may be occurring on buried pipelines.

Most of the Indirect Inspection tools depend on pipe being buried or submerged in an electrolyte that can be contacted with electrical survey devices to detect coating defects and cathodic protection deficiencies. Some of the tools do not depend on pipe being buried or submerged in an electrolyte. For this project, two tools were used that depend on the presence of an electrolyte, the DC Voltage Gradient survey and the Close Interval Potential survey, and one tool was used that does not depend on the presence of an electrolyte, the AC Current Attenuation survey. These three tools are the most common tools used by the pipeline industry for ECDA of buried pipe.

1.6 Indirect Inspection Survey Data Sources

Indirect Inspection survey data were obtained from numerous routine Indirect Inspection surveys performed during the past 5 to 6 years and from Indirect Inspection surveys performed specifically for this PHMSA project where the pipelines that were surveyed included cased pipe segments. Much of the survey data for these cased pipe segments and adjacent buried pipe were available for evaluation. More than 200 cased pipe segments have been identified for which ECDA Indirect Inspection survey data were available.

1.7 Pre-Assessment

The Pre-Assessment step of the ECDA process involves the collection and evaluation of information pertinent to external corrosion to determine if ECDA is appropriate for a given segment of pipeline, to determine which Indirect Inspection tools are to be used, and to determine how the results of Indirect Inspection will be validated. NACE RP0502 recommends a rigorous Pre-Assessment for ECDA and lists information that should be collected and evaluated to ascertain the applicability of ECDA.

NACE RP0502 does not address Pre-Assessment of cased pipe, but much of the information pertinent to ECDA of buried pipe is also pertinent to cased pipe. During this PHMSA project, all available Pre-Assessment information was collected. This information was not strictly used to determine the applicability of ECDA to cased pipe because, for the most part, ECDA Indirect Inspection surveys had already been performed on cased pipe and pipe adjacent to cased pipe. The applicability of Pre-Assessment information for cased pipe was evaluated using the results of the Indirect Inspection surveys and other inspections used to validate Indirect Inspection survey data.

1.8 Indirect Inspection

Indirect Inspection was accomplished using AC Current Attenuation, DC Voltage Gradient and Close Interval Potential surveys performed either as part of this project or during routine ECDA performed on pipelines operated by three pipeline companies participating in the project. These Indirect Inspection surveys were performed in accordance with pipeline operator and standard survey procedures, and following recommendations in NACE RP0502.

Indirect Inspection Data: Most of the Indirect Inspection survey data were collected during surveys on long sections of buried pipelines that included segments of cased pipe. For these surveys, those portions of the survey data for approximately 500 feet of buried pipe upstream and downstream of the cased pipe were evaluated. For surveys being performed exclusively for this project, the minimum lengths of buried pipe being surveyed upstream and downstream of the cased pipe was 300 feet. Based on data evaluated, it appears that data collected within 300 feet of the ends of cased pipe are sufficient to evaluate the validity of Indirect Inspection survey data for cased pipe and to evaluate the impact the casing may have on the data for adjacent buried pipe.

Other data collected routinely during ECDA Indirect Inspection surveys include cathodic protection system operating data, interference bond data, foreign structure pipe-to-soil potentials, casing-to-soil potentials, terrain and soils information, pipe depth measurements, and weather conditions. These data were used when pertinent to evaluations of coating condition and cathodic protection effectiveness.

Spatial alignment of data collected during the Indirect Inspection surveys was accomplished in two manners; 1) correlation of data with survey flags placed at 100-foot interval along the pipeline route, and 2) correlation of data with sub-meter GPS positions taken at 100-foot survey flags and physical features along the pipeline route. Examples of physical features include valves, pipeline markers, cathodic protection test stations, foreign pipeline crossings, edges of roads, casing vent pipes, fences and edges of bodies of water. Because the Indirect Inspection survey data were typically collected within 500 feet of roads and casing vents, spatial alignment of data were relatively simple and very accurate.

Indirect Inspection Data Evaluation: Indirect Inspection data for cased pipe and adjacent buried pipe were evaluated in compliance with pipeline operator and standard procedures, and following recommendations in NACE RP0502. Data were evaluated to identify external coating damage and cathodic protection deficiencies. Data collected during individual Indirect Inspection surveys were evaluated independently of data collected during other Indirect Inspection surveys, and data from all Indirect Inspection surveys were combined and evaluated in conjunction with one another.

Severity Classifications for Indications: Severity classifications for individual ECDA Indirect Inspection survey indications provide relative severity rankings for the indications. Because Severity Classifications vary widely among the pipeline operators, strict Severity Classifications have not been developed. General Severity Classifications used for this project for the Indirect Inspection survey indications may be found in Table 1.

Table 1: Example ECDA Severity Classifications for Indirect Inspection Indications on Cased Pipes

Survey Tools	Severity Classifications			
	None	Minor	Moderate	Severe
AC Current Attenuation	Uniform attenuation profile with no significant change inside or near casing	Small change in attenuation profile over short length of pipe inside or near casing	Moderate change in attenuation profile over short length of pipe inside or near casing	Large change in attenuation profile over short length of pipe inside or near casing
DC or AC Voltage Gradient	No indications on adjacent buried pipe – and – No indications on cased pipe	Few indications on adjacent buried pipe – but – No indications on cased pipe	Several indications on adjacent buried pipe – but – No indications on cased pipe	Numerous indications on adjacent buried pipe – or – Any indications on cased pipe
Close Interval Potential	Uniform potential profile with no significant depression – and – All potentials more negative than -850mV	Minor potential depression – but – All potentials more negative than -850mV	Moderate potential depression – but – All potentials more negative than -850mV	Large potential depression – or – Any potentials less negative than -850mV

Action Prioritizations for Indication: Action prioritizations for combined ECDA Indirect Inspection survey indications provide relative remedial response rankings for the combined indications. Because Action Prioritizations vary widely among the pipeline operators, strict Action Prioritizations have not been developed. General Action Prioritizations used for this project for the Indirect Inspection survey indications may be found in Table 2.

Table 2: Example ECDA Prioritization Criteria for Direct Examination of Cased Pipe Segments

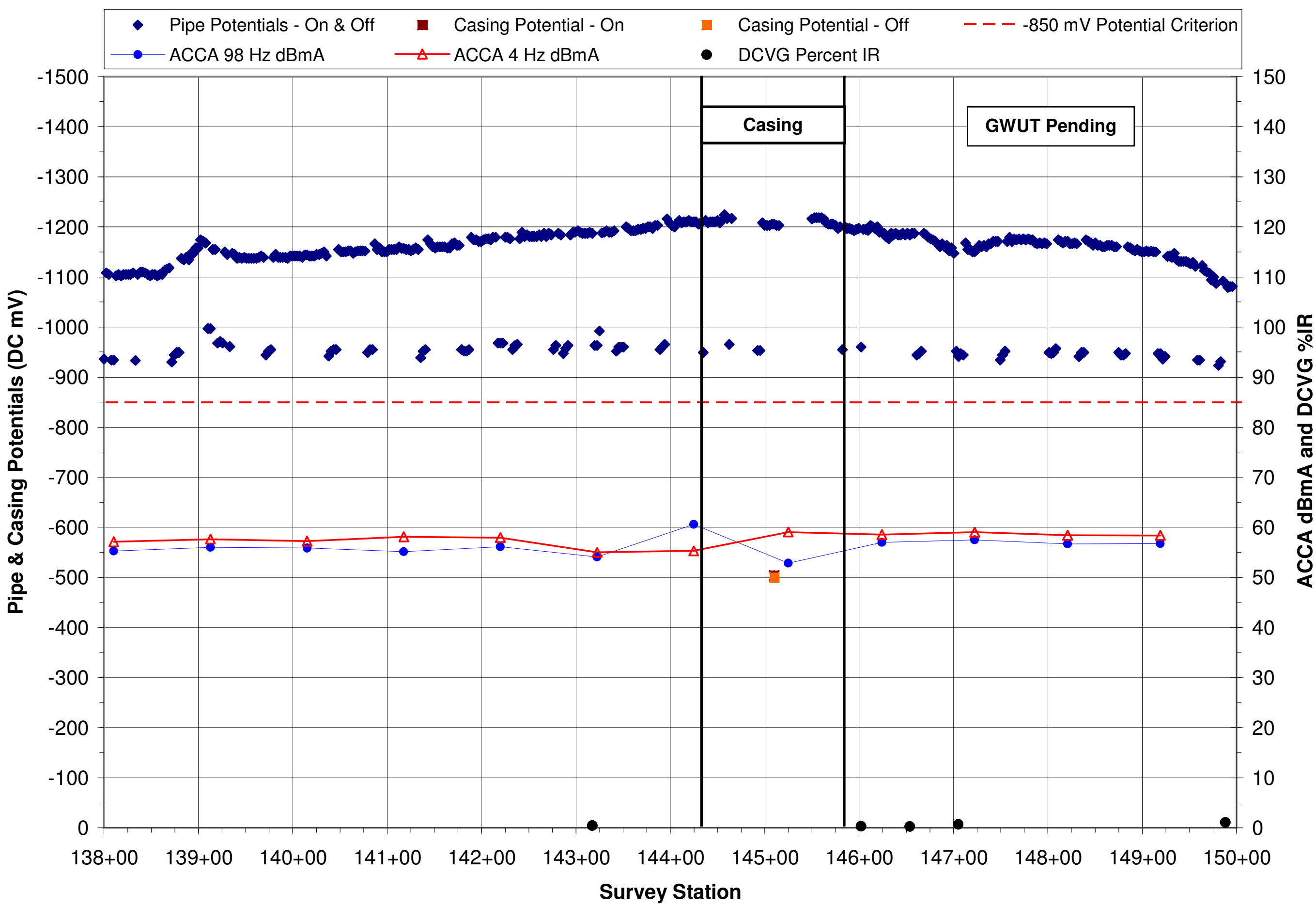
Prioritization Criteria for Cased Pipe Segments Based on ECDA Survey Severity Classifications			Cathodic Protection Severity Classifications Based on Close Interval Potential Survey Results			
			No Indications	Minor Indications	Moderate Indications	Severe Indications
Coating Condition Severity Classifications	Based on AC Current Attenuation Survey Results	No Indications	No Action	Monitor	Schedule	Immediate
		Minor Indications	Monitor	Monitor	Schedule	Immediate
		Moderate Indications	Monitor	Schedule	Schedule	Immediate
		Severe Indications	Schedule	Schedule	Immediate	Immediate
	Based on DC or AC Voltage Gradient Survey Results	No Indications	No Action	Monitor	Schedule	Immediate
		Minor Indications	Monitor	Monitor	Schedule	Immediate
		Moderate Indications	Monitor	Schedule	Schedule	Immediate
		Severe Indications	Schedule	Schedule	Immediate	Immediate

1.9 Results for 30 Example Cased Pipe Indirect Inspections

As stated previously, ECDA Indirect Inspection survey data were obtained and evaluated for more than 200 cased pipes. Because the volume of these data is extremely large, these data are provided in supplementary volumes 1 through 3 that accompany this report. Information is provided in this report for an example set of 30 of these cased pipes. The survey data were processed, integrated and plotted for these 30 cased pipes. The data plots for 4 of these cased pipes may be found in Figures 1 through 4. For all 4 of these cased pipes, the casings were electrically isolated from the cased pipes, the casings were bare, the pipelines are near the Gulf coast where the casing annuli are likely to contain some water and/or mud, and Indirect inspection surveys were performed on the cased pipes except where the cased pipes were directly under pavement. Summary results of evaluations of Indirect Inspection survey data for these 4 cased pipes are as follows:

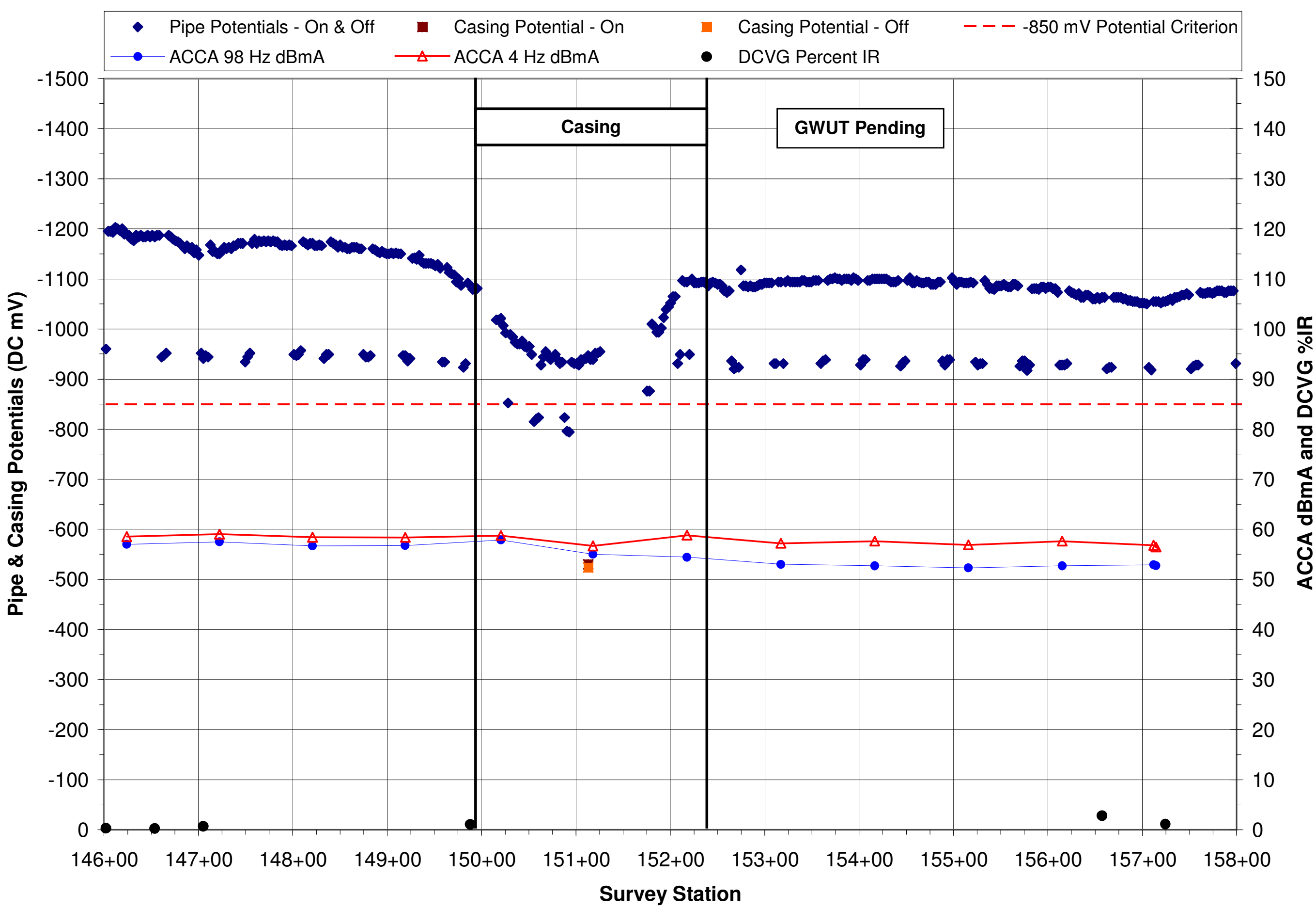
- Figure 1 - The survey data for the cased pipe segment appear to be consistent with survey data for adjacent buried pipe and there are no significant indications or variations in the data that indicate coating anomalies or cathodic protection deficiencies. While it has not been determined by other means whether or not the survey data represent actual coating and cathodic protection conditions for the cased pipe, it appears that this cased pipe is a low priority for further integrity assessment.

Figure 1: ECDA Survey Data - Pipeline 11 - Casing 1



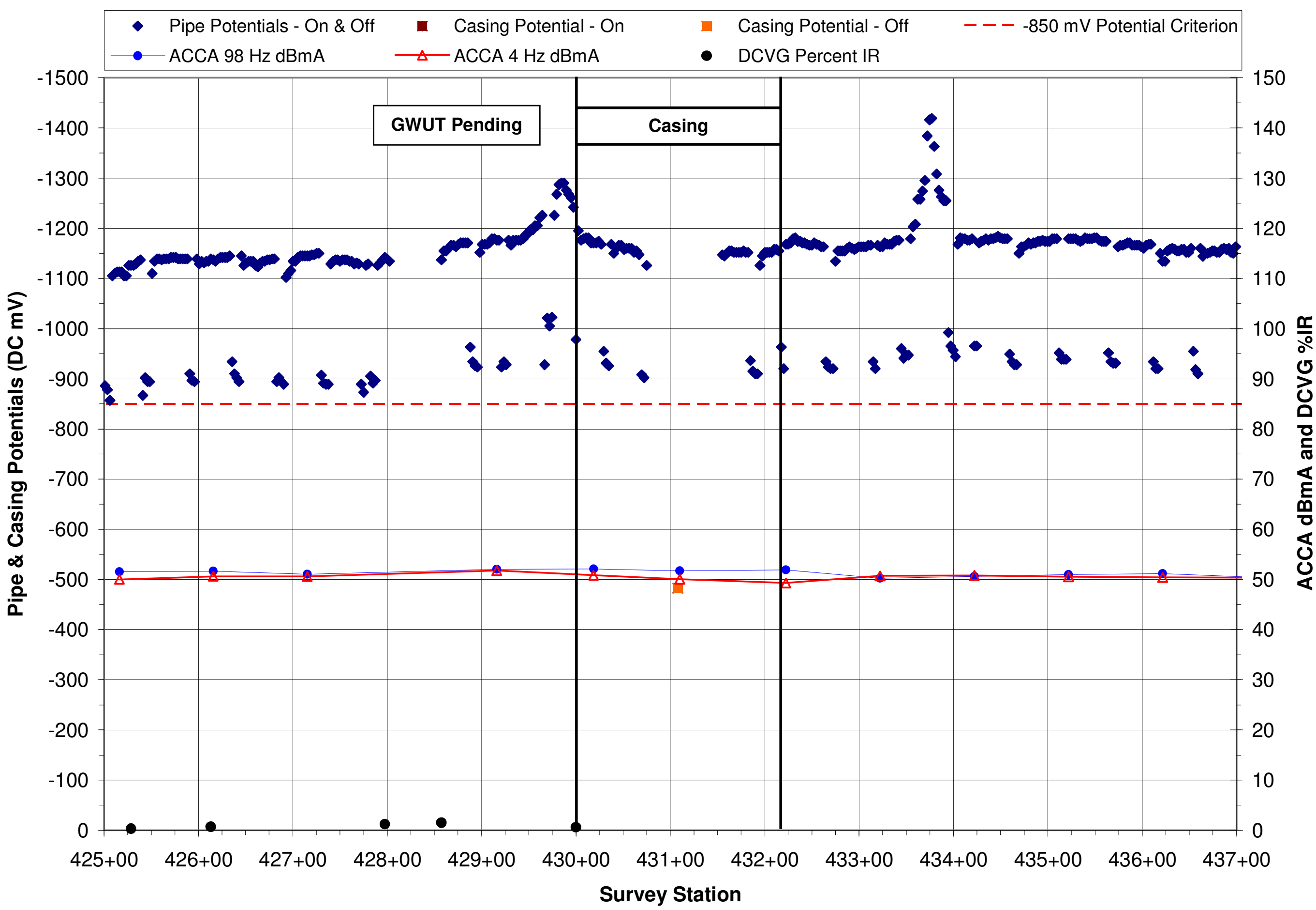
- Figure 2 - The survey data for the cased pipe segment appear to be consistent with survey data for adjacent buried pipe. While the AC Current Attenuation and DC Voltage Gradient survey data show slight, but no significant indications or variations in the data that indicate coating anomalies or cathodic protection deficiencies, the Close Interval Potential survey data indicate a significant decrease in cathodic protection near the middle of the casing. This cased pipe is a high priority for further integrity assessment.

Figure 2: ECDA Survey Data - Pipeline 11 - Casing 2



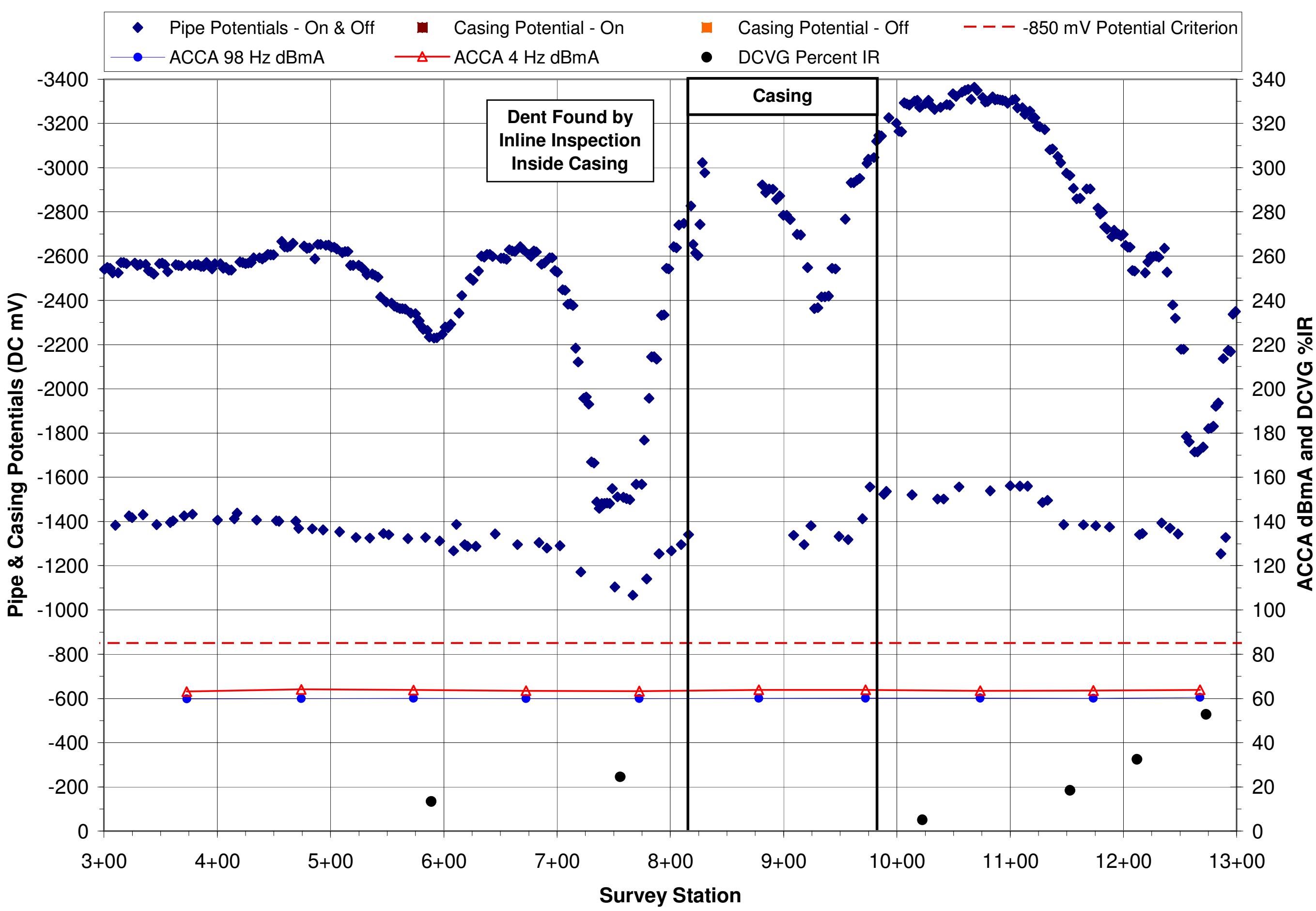
- Figure 3 - The survey data for the cased pipe segment appear to be consistent with survey data for adjacent buried pipe. While the AC Current Attenuation and DC Voltage Gradient survey data show no significant indications or variations in the data that indicate coating anomalies or cathodic protection deficiencies, the Close Interval Potential survey data indicate a moderate decrease in cathodic protection near the middle of the casing. This cased pipe is a moderate priority for further integrity assessment.

Figure 3: ECDA Survey Data - Pipeline 15 - Casing 5



- Figure 4 - The survey data for the cased pipe segment appear to be consistent with survey data for adjacent buried pipe. While the AC Current Attenuation and DC Voltage Gradient survey data show no significant indications or variations in the data that indicate coating anomalies or cathodic protection deficiencies, the Close Interval Potential survey data indicate a significant decrease in cathodic protection near the middle of the casing. This cased pipe is a high priority for further integrity assessment. (The Close Interval Potential and DC voltage Gradient survey data also indicate coating anomalies and cathodic protection deficiencies on adjacent buried pipe that warrant further investigation.)

Figure 4: ECDA Survey Data - Pipeline 18 - Casing 1



After processing, integrating and plotting the survey data for the 30 cased pipes, the data were evaluated using the Severity Classification guidelines provided in Table 1 and using the Action Prioritization guidelines provided in Table 2. A listing of Severity Classifications and Action Prioritizations for the 30 cased pipes may be found in Table 3.

Table 3: ECDA for 30 Cased Pipe Segments - Severity Classifications & Action Prioritizations Based on Results of Indirect Inspections (Highlighted Data Corresponds to Indirect Inspection Survey Data Figures 1 through 4 in Body of Report)

Seq. No.	Pipeline Number	Casing No.	Electrical Isolation Status	AC Current Attenuation		DC Voltage Gradient		Close Interval Potential			Action Prioritization	Other Integrity Assessments Performed to Date	
				Data Results	Severity Classification	Data Results	Severity Classification	Data Results	Pipe Meets CP Criteria	Severity Classification		Method	Results
1	1	1	Shorted	Moderate Change	Moderate	Indications at Both Casing Ends	Severe	Moderate Depression	Yes	Moderate	Immediate	GWUT	No Indications
2	2	1	Isolated	Uniform Profile	None	Few Indications Near Casing	Minor	Uniform Profile	Yes	None	Monitor	GWUT	No Indications
3	3	1	Isolated	Moderate Change	Moderate	Indications at and Near Casing	Severe	Uniform Profile	Yes	None	Schedule	GWUT	No Indications
4	4	1	Possibly Shorted	Moderate Change	Moderate	Indications at and Near Casing	Severe	Uniform Profile	Yes	None	Immediate	GWUT	No Indications
5	5	1	Isolated	Moderate Change	Moderate	Few Indications Near Casing	Minor	Uniform Profile	Yes	None	Monitor	GWUT	No Indications
6	6	1	Unknown	Significant Change	Severe	Several Indications Near Casing	Moderate	Uniform Profile	Yes	None	Immediate	GWUT	No Indications
7	7	1	Isolated	Minor Change	Minor	Few Indications Near Casing	Minor	Uniform Profile	Yes	None	Monitor	GWUT	No Indications
8	7	2	Possibly Shorted	Moderate Change	Moderate	No Indications Near Casing	None	Uniform Profile	Yes	None	Schedule	GWUT	No Indications
9	8	1	Isolated	Minor Change	Minor	Few Indications Near Casing	Minor	Uniform Profile	Yes	None	Monitor	GWUT	No Indications
10	8	2	Possibly Shorted	Moderate Change	Moderate	Few Indications Near Casing	Minor	Uniform Profile	Yes	None	Schedule	GWUT	No Indications
11	9	1	Isolated	Minor Change	Minor	No Indications Near Casing	None	Uniform Profile	Yes	None	Monitor	GWUT	No Indications
12	9	2	Isolated	Minor Change	Minor	No Indications Near Casing	None	Uniform Profile	Yes	None	Monitor	GWUT	No Indications
13	10	1	Isolated	Uniform Profile	None	Many Indications Near Casing	Severe	Minor Depressions	Yes	Minor	Schedule	None	GWUT Pending?
14	11	1	Isolated	Moderate Change	Moderate	Few Indications Near Casing	Minor	Uniform Profile	Yes	None	Schedule	None	GWUT Pending?
15	11	2	Isolated	Minor Change	Minor	Indications at and Near Casing	Severe	Significant Depression and Low Off Potentials	No	Severe	Immediate	None	GWUT Pending?
16	12	1	Isolated	Moderate Change	Moderate	Indications at and Near Casing	Severe	Significant Depression	No	Severe	Immediate	None	GWUT Pending?
17	13	1	Isolated	Minor Change	Minor	No Indications Near Casing	None	Minor Depressions	Yes	Minor	Monitor	None	GWUT Pending?
18	13	2	Isolated	Minor Change	Minor	No Indications Near Casing	None	Uniform Profile	Yes	None	Monitor	None	GWUT Pending?
19	13	3	Isolated	Uniform Profile	None	No Indications Near Casing	None	Uniform Profile	Yes	None	No Action	None	GWUT Pending?
20	14	1	Isolated	Moderate Change	Moderate	Indications at and Near Casing	Severe	Uniform Profile	Yes	None	Schedule	None	GWUT Pending?
21	14	2	Isolated	Minor Change	Minor	Indications at Both Casing Ends	Severe	Uniform Profile	Yes	None	Schedule	None	GWUT Pending?
22	15	1	Isolated	Uniform Profile	None	No Indications Near Casing	None	Significant Depression and Low Off Potentials	No	Severe	Immediate	None	GWUT Pending?
23	15	2	Unknown	Minor Change	Minor	No Indications Near Casing	None	Uniform Profile	Yes	None	Monitor	None	Excavation Pending?
24	15	3	Isolated	Uniform Profile	None	No Indications Near Casing	None	Marginal Off Potentials	No	Moderate	Schedule	None	GWUT Pending?
25	15	4	Isolated	Minor Change	Minor	Indications at and Near Casing	Severe	Marginal Off Potentials	No	Moderate	Immediate	None	GWUT Pending?
26	15	5	Isolated	Uniform Profile	None	Indications at and Near Casing	Severe	Minor Depressions	No	Minor	Schedule	None	GWUT Pending?
27	16	1	Possibly Shorted	Uniform Profile	None	Indications at and Near Casing	Severe	Minor Depressions	Yes	Minor	Immediate	None	Other Pending?
28	17	1	Unknown	Uniform Profile	None	Few Indications Near Casing	Minor	Uniform Profile	Yes	None	Schedule	None	Other Pending?
29	18	1	Unknown	Uniform Profile	None	Several Indications Near Casing	Moderate	Significant Depressions	Yes	Severe	Immediate	ILI	Dent Inside Casing
30	19	1	Isolated	Minor Change	Minor	Indications at and Near Casing	Severe	Minor Depressions	Yes	Minor	Schedule	None	Other Pending?

Tables 4 and 5 provide summaries of the numbers of Severity Classifications for the ECDA Indirect Inspection indications and the numbers of Action Prioritizations for the 30 cased pipes. It is given that these Severity Classifications and Action Prioritizations can not be strictly applied to cased pipe as they would be for ECDA of buried pipe, these Severity Classifications and Action Prioritizations are useful for ranking or prioritizing cased pipes for further integrity assessment and/or remedial action.

Table 4: Numbers of Indications by Severity Classification for 30 Cased Pipes

Severity Classification	AC Current Attenuation	DC Voltage Gradient	Close Interval Potential
Severe	1	12	4
Moderate	9	2	3
Minor	11	7	5
None	9	9	18
Totals	30	30	30

Table 5: Numbers of Action Prioritizations for 30 Cased Pipes

Immediate	Schedule	Monitor	No Action	Total
9	11	9	1	30

1.10 Possible Improvements to Technologies

Possible improvements to technologies that have been identified thus far for Cased Pipe ECDA methodology over the technologies addressed by buried pipe ECDA methodology are as follows:

- More specific data requirements, data integration and data evaluation to improve identification of corrosion threats to cased pipe

- Modifications to existing Indirect Inspection survey techniques or development of new Indirect Inspection survey techniques that address requirements and peculiarities of cased pipe

- More specific definition of Severity Classification categories to improve assignment of severity ratings to Indirect Inspection indications

- More specific definition of Action Prioritization categories to improve selection of types and timing of remedial action responses required for cased pipe corrosion threats

1.11 PHMSA Committees

In late 2008, PHMSA formed a joint PHMSA/Industry advisory committee with Corrpro as a member. The committee is charged with developing guidelines for pipeline operators and regulators on cased pipe assessments. The goals are:

- to provide guidance that will be used during regulatory inspection activities
- to address all present and developing cased pipes assessment methods (including ECDA)

In January 2009, PHMSA formed a Casing Quality Action Committee (CASQAT) committee to develop guidelines for use by regulatory auditors and pipeline operators for cased pipe assessments. The CASQAT committee work independently of the Joint PHMSA/Industry Advisory committee. It is comprised of about 20 people - 9 from regulatory agencies, 5 from pipeline operators, 4 from industry organizations and 2 from service companies. Some of its members are also on the Joint PHMSA/Industry Advisory committee.

1.12 Enhanced ECDA Methodology for Cased Pipes

The draft guidelines for the External Corrosion Direct Assessment (ECDA) of Cased Pipeline Segment are provided in the appendix to this report.

1.13 Prospective Future Research Project

Our current activities so far have indicated the need for in-depth research projects in the following specific areas related to cased pipes:

- Development of quantitative models for predicting the condition of cased pipe in casings that are not filled,
- Condition assessment of cased pipe in wax-filled casings, and
- Filling pipeline casings with polymerized structural materials to improve or ensure structural integrity of cased pipes.

1.14 Conclusion

Based on the results of evaluations of ECDA Indirect Inspection surveys performed on cased pipe segments and adjacent buried pipe, the following conclusions have been drawn.

- Standard Indirect Inspection surveys on cased pipe **may** produce definitive data for evaluating the condition of the coating and the effectiveness of cathodic protection, and for predicting the likelihood of corrosion, but only under specific conditions. As a minimum, specific conditions include electrical isolation of the pipe from the casing, a conductive electrolyte in the casing annulus, and a bare casing.

- Standard Indirect Inspection surveys on cased pipe **will not** produce definitive data for evaluating the condition of the coating and the effectiveness of cathodic protection, or for predicting the likelihood of corrosion, where:

  a. the pipe is electrically shorted to the casing,
  b. there is not a conductive electrolyte in the casing annulus, or
  c. where the casing is coated.

- The results of standard Indirect Inspection surveys on cased pipe **are** useful for ranking and prioritizing cased pipes for further integrity assessment and/or remedial action.

- Additional research and testing is required to develop methods for ascertaining the validity of standard Indirect Inspection survey data collected on cased pipe.

1.15 References

1. External Corrosion Direct Assessment, NACE SP0502-2008, NACE International (Houston, Texas: NACE 2008)

2. Steel-Cased Pipeline Practices, NACE SP0200-2008, NACE International (Houston, Texas: NACE 2008).

3. External Corrosion Probability Assessment for Carrier Pipes Inside Casings (Casing Corrosion Direct Assessment--CCDA), GRI-05/0020, Gas Technology Institute.

4. L. Rankin, J. Carroll, D. Kroon, D. Lindemuth, M. Miller, O. Olabisi, *PHMSA-Sponsored Research: Improvements to ECDA Process – Cased Pipes*, CORROSION/2010, San Antonio TX, NACE International, 2010

5. J. Carroll, D. Kroon, D. Lindemuth, M. Miller, O. Olabisi, L. Rankin, *PHMSA-Sponsored Research: Improvements to ECDA Process – Potential Measurements in Paved Areas*, CORROSION/2010, San Antonio TX, NACE International, 2010

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7. PHMSA – Pipeline Corrosion Final Report – Michael Baker Jr., Inc. – July 2008

8. PHMSA - Applying External Corrosion Direct Assessment (ECDA)In Difficult-to-Inspect Areas DTRS56-05-T-0003 - E. B. Clark, B. N. Leis, and S. A. Flamberg – March 2007

9. PHMSA - Demonstration of ECDA Applicability and Reliability for Demanding Situations DTPH56-06-T-000001 - Daniel Ersoy – August 2008

10. PHMSA - Improvement of External Corrosion Direct Assessment Methodology by Incorporating Soils Data DTRS56-03-T-0003 - B. N. Leis, E. B. Clark, M. Lamontagne, and J. A. Colwell - November 2005

Appendix

Draft Recommended Guidelines for External Corrosion Direct Assessment (ECDA) Of Cased Pipeline Segments

Draft Recommended Guidelines

for

External Corrosion Direct Assessment (ECDA)
of Cased Pipeline Segments

to

Pipeline and Hazardous Materials
Safety Administration (PHMSA)

U.S. Department of Transportation

Contract No. DTPH56-08-T-000012

Improvements to the External Corrosion Direct Assessment (ECDA) Process
(WP # 360)

Cased Pipes
Project No. 241

by

CORRPRO COMPANIES, INC.
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June 2010

Foreword

These recommended guidelines closely follow the format used by NACE International in its standard practice SP0502-2008, Pipeline External Corrosion Direct Assessment Methodology. The guidelines are written in this manner because NACE SP0502-2008 is widely recognized, accepted, and used by the pipeline community for assessing external corrosion on buried ferrous pipelines. Additionally, it is expected that PHMSA will provide these guidelines to NACE for consideration and perhaps use during development of a standard practice. If this happens, having these guidelines in a format that follows the NACE standard practice should reduce the time and effort required to develop a standard practice for cased pipes.

The guidelines provided in Appendices B, C and D of these recommended guidelines are the work product of the PHMSA Casing Quality Action Team (CASQAT) committee. This committee was comprised of PHMSA employees, pipeline operator personnel and pipeline service company representatives.

Improvements to the External Corrosion Direct Assessment (ECDA) Process

Recommended Guidelines for Cased Pipes

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Appendices

Section 1: General

1.1 Introduction

1.1.1 These guidelines address the External Corrosion Direct Assessment (ECDA) process for onshore segments of buried, externally coated, ferrous pipelines that pass through buried ferrous casings. These guidelines are intended to provide guidance for applying the ECDA process on typical pipeline systems, and in typical cased pipe situations. These guidelines assume that external corrosion is a pipeline integrity threat that is to be evaluated. They are not intended for use on pipelines that were not provided with an external coating at the time of construction.

1.1.2 ECDA was developed as a process for improving pipeline safety by providing a method for evaluating external corrosion activity on buried ferrous pipelines that cannot realistically be evaluated by other means such as in-line inspection and pressure testing.

1.1.3 Unlike many assessment methods that only identify where external corrosion has already occurred, ECDA provides the benefit of identifying locations where external corrosion may have already occurred, may be occurring, and may occur in the future.

1.1.4 ECDA applications can include but are not limited to the following situations or activities:

1.1.4.1 Cased pipes that cannot realistically be assessed by other means.

1.1.4.2 For establishing priorities for assessments by other means.

1.1.4.3 Where the desire is to identify conditions conducive to future external corrosion so that proactive measures can be taken to prevent future external corrosion.

1.1.4.4 When there would be benefits from establishing baselines from which future external corrosion assessments could be evaluated.

1.1.4.5 When there is the need to establish reassessment intervals that cannot be established by other means.

1.1.5 ECDA may assist with the detection of other pipeline integrity threats under specific conditions. Other threats may include mechanical damage, stress corrosion cracking (SCC), microbiologically influenced corrosion (MIC), and electrical interference from outside sources. ECDA is not intended to facilitate evaluation of threats other than external corrosion, so when conditions indicative of other threats are detected, assessments and/or inspections appropriate for the other threats are to be performed.

1.1.6 These guidelines were written to provide flexibility for tailoring the ECDA process to specific pipeline and cased pipe situations.

1.2 The ECDA Process

1.2.1 ECDA is a four step process. The steps are as follows:

1.2.1.1 Pre-Assessment: During this step, pertinent information is collected, integrated and evaluated, ECDA feasibility is determined, ECDA regions are identified, and Indirect Inspection tools are selected. Details of these activities can be found in Section 2 of these guidelines.

1.2.1.2 Indirect Inspection: During this step, the Indirect Inspection tools are employed to detect external coating defects and cathodic protection deficiencies, the coating defect and cathodic protection deficiency indications are evaluated and classified with respect to severity, and the classified indications are prioritized to determine the need and establish the priority for evaluation or inspection. Details of these activities can be found in Section 3 of these guidelines.

1.2.1.3 Direct Examination: During this step, the indications that were identified as needing to be evaluated or inspected are evaluated or inspected, repair and/or remedial measures are taken where required, and the need to evaluate or inspect additional indications is determined. Details of these activities can be found in Section 4 of these guidelines.

1.2.1.4 Post Assessment: During this step, information obtained during the first three steps is evaluated to determine the effectiveness of the ECDA process, to determine reassessment intervals, and to generate information to be used for planning and performing remedial activities. Details of these activities can be found in Section 5 of these guidelines.

1.3 Additional Considerations for the ECDA Process

1.3.1 ECDA is a continuous improvement process. Through successive applications, ECDA should identify locations where corrosion activity has occurred, is occurring, or may occur. Comparing the results of successive ECDA applications will facilitate the evaluation of ECDA effectiveness and demonstrate that pipeline integrity is continuously improving.

1.3.2 For correct application of these guidelines, the guidelines should be considered in their entirety and applicable guidelines used where appropriate. Using only part of the guidelines without considering the guidelines in their entirety can lead to misinterpretation or misapplication of the guidelines.

1.3.3 Because of the variety and complexity of cased pipes, these guidelines may not accommodate every situation or condition related to external corrosion that could exist. ECDA has limitations and not all cased pipes can be successfully assessed using ECDA. Just as with all other assessment methods, precautions should be taken when applying these ECDA guidelines.

1.3.4 When ECDA is used for the first time on cased pipes, more stringent application of the guidelines should be employed to ensure that ECDA is appropriate for the situations or conditions. This is particularly true when material, construction, environment, operation, maintenance and corrosion control information required for effective application of ECDA may be lacking. More stringent application may include but is not limited to additional data collection, Indirect Inspection surveys, Direct Examination inspections, and Post Assessment evaluation.

1.3.5 These guidelines should be applied under the direction of competent persons who, by reason of knowledge of the physical sciences and the principles of engineering and mathematics, acquired by education and related practical experience, are qualified to engage in the practice of corrosion control and risk assessment of buried ferrous piping systems. Such persons may be registered professional engineers or persons recognized by appropriate industry organizations as specialists, engineers or technicians with suitable levels of education and experience.

Section 2: Pre-Assessment

2.1 Introduction

2.1.1 The objectives of the Pre-Assessment step are to collect data pertinent to the ECDA process, to determine if ECDA is feasible for the cased pipes that are to be assessed, to identify ECDA regions, and to select Indirect Inspection tools. The Pre-Assessment step must be comprehensive and thorough.

2.1.2 The Pre-Assessment step is to include the following activities:

2.1.2.1 Data collection;

2.1.2.2 Data integration;

2.1.2.3 Data evaluation;

2.1.2.4 ECDA feasibility determination;

2.1.2.5 ECDA regions identification; and

2.1.2.6 Indirect Inspection tools selection.

2.2 Pre-Assessment Data

2.2.1 A sufficient amount of data needed to determine ECDA feasibility, to identify ECDA regions, and to select Indirect Inspection tools is to be collected. Collected data are to include historical and contemporary data for the cased pipes and for adjacent buried pipe where pertinent. Categories of data to be collected are as follows:

2.2.1.1 Line pipe, casing pipe and associated materials;

2.2.1.2 Construction;

2.2.1.3 Environment;

2.2.1.4 Operation;

2.2.1.5 Maintenance; and

2.2.1.6 Corrosion control.

2.2.2 A list of example Pre-Assessment data can be found in Appendix A. The list provides guidance for data to be collected. Not all data may be required for all cased pipes, and other data not on the list may be required for some cased pipes. Minimum data requirements are to be established by evaluating individual data to determine its relevance to the occurrence of external corrosion. Those data that are essential to the success of the ECDA process are to be identified and extra effort made to collect the data. As a minimum, the following data are to be considered essential:

2.2.2.1 Construction information for cased pipe and casing;

2.2.2.2 Coating type and condition information for cased pipe and adjacent buried pipe;

2.2.2.3 Data related to the historical status of electrical isolation between the cased pipe and casing;

2.2.2.4 Historical pipeline operating temperatures, particularly if in excess of 120º F;

2.2.2.5 Operating stress level, particularly if above 60% SMYS;

2.2.2.6 Data relevant to ECDA region identification;

2.2.2.7 Data relevant to Indirect Inspection tool selection; and

2.2.2.8 For cased pipes where the casing annulus has been filled with high dielectric material, information for the type of fill material, date of fill, and fill condition monitoring.

2.3 Data Integration

The collected data are to be integrated in a manner that facilitates accurate and thorough evaluation. Data integration may be accomplished by any suitable means appropriate for the specific data to be integrated, including but not limited to lists, tables, spreadsheets and electronic data bases. The means selected for integrating the data are to provide for easy recognition of data types, a clear understanding of the data, and logical evaluation of the impact the data has on the ECDA process.

2.4 Data Evaluation

The integrated data are to be evaluated to determine if sufficient data are available to determine ECDA feasibility, identify ECDA regions and select Indirect Inspection tools. In the event it is determined that sufficient data cannot be collected for some cased pipes or ECDA regions, ECDA is not to be used for those cased pipes or ECDA regions.

2.5 ECDA Feasibility Determination

2.5.1 The ECDA feasibility determination is to consider all conditions that may prevent the effective application of ECDA on cased pipes. The following conditions may prevent the effective application of ECDA on cased pipes:

2.5.1.1 Casings electrically shorted to the cased pipe by direct metallic contacts;

2.5.1.2 Casings that cannot be contacted for electrical measurements;

2.5.1.3 Casings coated externally or internally with effective high dielectric coatings;

2.5.1.4 Coatings on cased pipes or on buried pipe adjacent to cased pipes that cause electrical shielding;

2.5.1.5 Backfill on casings or on buried pipe adjacent to casings with rock content or rock ledges that would interfere with collection of reliable Indirect Inspection data;

2.5.1.6 Certain ground surfaces or surface conditions that prevent surface electrical measurements (such as pavement and frozen ground) unless actions can be implemented to eliminate or minimize the effects of these surface conditions (such as drilling holes through pavement or waiting until the ground is not frozen);

2.5.1.7 Situations that prevent the collection of above ground measurements within a reasonable time frame;

2.5.1.8 Locations with adjacent buried metallic structures that prevent the collection of valid above ground measurements;

2.5.1.9 Areas that are not accessible for performing above ground measurements; and

2.5.1.10 Any other conditions on casings, cased pipes or adjacent buried pipe that prevent the successful use of ECDA Indirect Inspection tools.

2.5.2 If it is determined that ECDA is not feasible for an individual cased pipe or for cased pipes in an ECDA region, other acceptable methods of assessing integrity are to be used.

2.6 ECDA Regions Identification

2.6.1 An ECDA region for cased pipes is those cased pipes that have similar material and construction characteristics, environmental conditions, operation and maintenance histories, corrosion and corrosion control histories, expected future corrosion conditions, and that can be assessed using the same Indirect Inspection tools.

2.6.2 A single ECDA region can include numerous cased pipes, does not need to be contiguous along a single pipeline or pipeline section, and can include cased pipes on more than one pipeline providing that the region criteria are met and that all of the cased pipes can be assessed using the same Indirect Inspection tools.

2.6.3 All cased pipes are to be included in an ECDA region, even when situations and conditions for one cased pipe require it to be in a region of its own.

2.6.4 Criteria for region identification are to be identified and defined. Criteria are to take into account all conditions that could significantly affect external corrosion. Example Pre-Assessment data in the list in Appendix A may be used as guidance for identifying the criteria. The data collected during Pre-Assessment are to be analyzed to define the criteria.

2.6.5 The identification of ECDA regions may need to be modified during the application of the ECDA process based on the results of Indirect Inspection and Direct Examination.

2.6.6 Additional guidelines for establishing ECDA regions for cased pipes can be found in Appendix B.

2.7 Indirect Inspection Tools Selection

2.7.1 A minimum of two Indirect Inspection tools are to be selected and used for all cased pipes where ECDA is being applied. Consideration should be given for using more than two tools for the first application of ECDA on cased pipes, for cased pipes where Pre-Assessment data are limited, or for cased pipe situations or conditions that are not typical.

2.7.2 The Indirect Inspection tools are to be selected based on their ability to reliably detect external coating defects, cathodic protection deficiencies, and other conditions indicative of external corrosion under the specific cased pipe conditions to be encountered.

2.7.3 The Indirect Inspection tools that are selected should be complementary such that strengths of one tool compensate for limitations of the other tools.

2.7.4 If more than one ECDA region is identified for cased pipes along a pipeline segment, the same Indirect Inspection tools do not have to be used for all cased pipes along the pipeline segment. Using different tools for some of the cased pipes along a pipeline segment may provide the benefit of obtaining other valuable information than can be applied to other cased pipes along the pipeline segment. If other tools are used, the tools are to be selected based on their ability to reliably detect external coating defects, cathodic protection deficiencies, and other conditions indicative of external corrosion under the specific cased pipe conditions to be encountered.

2.7.5 Guidelines for selecting Indirect Inspection tools can be found in Appendix C. The guidelines indicate situations and conditions under which individual tools are likely to be reliable and situations and conditions under which individual tools are not likely to be reliable. Additional guidelines and other information for Indirect Inspection tools can be found in Appendix D.

2.7.6 The Indirect Inspection tools discussed in the guidelines in Appendix C are not the only tools available for Indirect Inspection. Other technologies presently exist and new technologies are being developed that will detect external corrosion and/or conditions relevant to the occurrence of external corrosion. Use of these other technologies may be considered for situations and conditions where the tools discussed in Appendix C are not appropriate or where these other technologies can provide cased pipe condition information that is superior to the information that can be obtained from using the tools in the table.

2.7.7 In the event it is determined that none of the available Indirect Inspection tools are capable of reliably detecting coating defects, cathodic protection deficiencies or other conditions indicative of external corrosion, other means may be employed to determine the condition of the cased pipe. Other means include in-line inspection, pressure testing and other technologies that provide an equivalent understanding of the condition of the cased pipe. These other means do not necessarily have to be used on all casings in an ECDA region, and can be used on a sampling of cased pipes. When only a sampling of cased pipes are evaluated by other means, the number of cased pipes evaluated must be adequate to ensure that the evaluations are representative of the remaining cased pipes that are not evaluated. In this situation, actions in the Pre-Assessment and Post Assessment steps are still required to effect a full and acceptable application of the ECDA process.

Section 3: Indirect Inspection

3.1 Introduction

3.1.1 The objectives of the Indirect Inspection step are to detect areas on cased pipes where external corrosion may have occurred, may be occurring, or may occur in the future, and to classify the detected areas with respect to severity.

3.1.2 The Indirect Inspection tools selected in the Pre-Assessment step are to be used to collect external corrosion related data on cased pipes. The Indirect Inspections are to be performed in all ECDA regions identified in the Pre-Assessment step.

3.1.3 A minimum of two Indirect Inspection tools are to be used during Indirect Inspection. Use of more than two tools should be considered for the first application of ECDA on cased pipes, and may be necessary for cased pipes where Pre-Assessment data are limited, or for cased pipe situations or conditions that are not typical.

3.2 Indirect Inspections

3.2.1 The Indirect Inspections are to be performed and analyzed in accordance with generally accepted industry practices. Typical procedures for some of the Indirect Inspection tools discussed in Appendix C of these guidelines can be found in NACE SP0502-2008 in Appendix A.

3.2.2 Indirect Inspections are to be performed on all cased pipes in ECDA regions where cased pipes are to be assessed by ECDA. For those cased pipes where Indirect Inspections cannot be performed, other assessment methods are to be used.

3.2.3 The cased pipe and adjacent buried pipe on which the Indirect Inspections are to be performed are to be identified, located with pipe location equipment, and clearly marked prior to performing the Indirect Inspections. The boundaries of the cased pipe and adjacent buried pipe on which the Indirect Inspections are to be performed are also to be identified and clearly marked.

3.2.4 Ideally, the Indirect Inspections should be performed on the full lengths of the cased pipes and sufficient lengths of adjacent buried pipe as is required to facilitate a thorough evaluation of coating defects, cathodic protection deficiencies, and other conditions related to external corrosion on the cased pipe. Realistically, this is not always possible because of conditions and restrictions created by land surface use at the cased pipes. When conditions and restrictions exist that prevent Indirect Inspection on the full lengths of the cased pipes, every effort is to be made to perform Indirect Inspection on as much of the cased pipes as is practicable and/or allowable.

3.2.5 All of the Indirect Inspections performed in an ECDA region are to be performed in a reasonable period of time so that conditions that could affect the results of the Indirect Inspections do not change significantly. Significant changes of conditions can cause the data to be difficult to evaluate and, in extreme situations, render the data invalid. Conditions that could affect the results include changes in soil moisture content and temperature, changes in operations of cathodic protections systems, changes in piping configuration, and changes of the ground surface over and near the pipelines.

3.2.6 Distances or intervals between Indirect Inspection measurements are to appropriate for the individual Indirect Inspection tools and sufficiently short to facilitate a detailed assessment. The distances or intervals are to be such that the Indirect Inspection tools can detect and locate coating defects, cathodic protection deficiencies and other conditions indicative of external corrosion.

3.2.7 Indirect Inspection measurements are to be collected in a manner that facilitates spatial reference to at-grade and above-grade features located along the cased pipes and adjacent buried pipe. Distances or intervals between these features are to be sufficiently short to allow accurate alignment of data from the Indirect Inspections and to allow future identification of locations of Indirect Inspection indications within distances that are satisfactory for Direct Examination requirements. Where features are not sufficiently close, flags may be placed or marks may be painted to establish sufficient spatial references. Incorporating global positioning system (GPS) location measurements with the individual Indirect Inspections has proven to be invaluable for establishing locations of Indirect Inspection indications, for aligning data from several Indirect Inspections, and for resolving spatial errors.

3.2.8 When ECDA is applied for the first time, actions are to be taken to verify accuracy and consistency of the Indirect Inspection measurements. These actions may include repeating portions of the measurements, spot checking measurements with other instruments, and any other means that verifies accuracy and consistency of the measurements.

3.3 Data Evaluation and Severity Classification

3.3.1 After completing the Indirect Inspections, the data from the individual Indirect Inspections are to be evaluated to identify indications specific to the individual Indirect Inspections. Criteria for identifying indications are to be defined.

3.3.2 After identifying indications for the individual Indirect Inspections, the indications are to be classified according to severity. Classifying indications according to severity is the process of defining the likelihood of corrosion activity at each indication under typical year-round conditions. The following are examples of classifications typically used in ECDA:

3.3.2.1 Severe: Indications that are considered to have the highest likelihood of corrosion activity.

3.3.2.2 Moderate: Indications that are considered to have a likelihood of corrosion activity that falls between “severe” and “minor”.

3.3.2.3 Minor: Indications that are considered to have the lowest likelihood of corrosion activity or to be corrosion that is not active.

3.3.3 Criteria for classifying indication severity are to be defined. Defining the criteria is to take into account the capabilities of the individual Indirect Inspection tools, the unique conditions within an ECDA region, and the experience level of persons evaluating the Indirect Inspection data.

3.3.4 For initial ECDA applications, severity classification is to be made more stringent. For example, when uncertainty exists about the specific classification that should be applied, the next higher classification is to be applied.

3.3.5 Table 1 provides example severity classifications for several Indirect Inspection tools. These example severity classifications are general in nature and are not absolute criteria.

Table 1: Example ECDA Severity Classifications for Indirect Inspection Indications on Cased Pipes

Survey Tools	Severity Classifications			
	None	Minor	Moderate	Severe
AC Current Attenuation	Uniform attenuation profile with no significant change inside or near casing	Small change in attenuation profile over short length of pipe inside or near casing	Moderate change in attenuation profile over short length of pipe inside or near casing	Large change in attenuation profile over short length of pipe inside or near casing
DC or AC Voltage Gradient	No indications on adjacent buried pipe – and – No indications on cased pipe	Few indications on adjacent buried pipe – but – No indications on cased pipe	Several indications on adjacent buried pipe – but – No indications on cased pipe	Numerous indications on adjacent buried pipe – or – Any indications on cased pipe
Close Interval Potential	Uniform potential profile with no significant depression – and – All potentials more negative than -850mV	Minor potential depression – but – All potentials more negative than -850mV	Moderate potential depression – but – All potentials more negative than -850mV	Large potential depression – or – Any potentials less negative than -850mV

3.4 Data Alignment and Comparison

3.4.1 After completing evaluation of individual Indirect Inspection data and classifying severity of individual Indirect Inspection indications, the data and indications from each of the individual Indirect Inspections are to be aligned with one another and compared.

3.4.2 Spatial alignment of Indirect Inspection data and indications is to be accomplished using locations of at-grade and above-grade features identified during the Indirect Inspections and/or flags that were placed or marks that were painted during the Indirect Inspections. If GPS location measurements were taken during the Indirect Inspections, this information can be used to accomplish or improve spatial alignment of data and indications.

3.4.3 Aligned Indirect Inspection data and indications are to be compared to determine if indications from one Indirect Inspection align with indications from other Indirect Inspections. Particular attention to possible spatial alignment errors is to be given to indications from multiple Indirect Inspections that are close to one another but that do not align to determine if these indications do in fact exist at the same location.

3.4.4 Indications from multiple Indirect Inspections that align with one another are indicative of external corrosion conditions that are likely to be more severe than external corrosion conditions that are indicated by only one Indirect Inspection tool. The probable increase in severity is defined and evaluated in the Direct Examination step.

3.4.5 After the Indirect Inspection data and indications are aligned and compared, the aligned data and indications are to be evaluated to determine if the results from the individual Indirect Inspections are consistent with one another.

3.4.6 If the results from the individual Indirect Inspections are not consistent with one another or if two or more Indirect Inspections indicate significantly different sets of locations for Indirect Inspection indications, and the differences cannot be explained by the inherent capabilities of the Indirect Inspection tools or by spatial alignment errors caused by specific localized pipeline features or conditions, additional action is to be taken in an effort to correct the inconsistency.

> 3.4.6.1 Additional action generally is to involve repeating one or more of the Indirect Inspections or performing additional Indirect Inspections. Data from these Indirect Inspections are to be evaluated, classified, aligned and compared as described in this section.
>
> 3.4.6.2 If the results from these Indirect Inspections are also inconsistent, or if these Indirect Inspections are not performed for any reason, the validity of ECDA for the involved cased pipe is to be reassessed. If it is determine that ECDA is not valid for an individual cased pipe or for cased pipes in an ECDA region, another integrity assessment method is to be used to assess the integrity of the individual cased pipe or cased pipes in the ECDA region.

3.4.7 After evaluation, classification, alignment and comparison of Indirect Inspection data and indications have been completed, and after any inconsistencies have be resolved, the results of Indirect Inspection is to be compared with the results of the Pre-Assessment and prior corrosion history for each ECDA region to determine if all results are consistent. If all results are not consistent, ECDA feasibility and/or ECDA region definitions are to be reassessed.

3.4.7.1 If reassessment of ECDA feasibility indicates that ECDA is not feasible, another integrity assessment method is to be used to assess the integrity of the cased pipes in the ECDA region.

3.4.7.2 If the ECDA region cannot be redefined to produce consistent results, another integrity assessment method is to be used to assess the integrity of the cased pipes in the ECDA region.

Section 4: Direct Examination

4.1 Introduction

4.1.1 The objectives of the Direct Examination step are to evaluate Indirect Inspection indications to determine the severity of the indications with respect to their need for inspection, and to perform inspections at appropriate locations to collect data needed to assess coating damage, cathodic protection adequacy and corrosion activity. Typically, Direct Examination requires that the pipe and casing be excavated to facilitate inspection.

4.1.2 The Direct Examination step is to include the following activities:

4.1.2.1 Prioritization of all Indirect Inspection indications to establish pipe inspection priorities;

4.1.2.2 Excavation and inspection of pipe and coating at an appropriate number of locations where corrosion activity is most likely;

4.1.2.3 Measurements of environmental factors, cathodic protection, and coating damage;

4.1.2.4 Measurements of corrosion damage and evaluations of remaining pipe strength at areas of corrosion damage;

4.1.2.5 Root cause analyses for coating damage and corrosion damage; and

4.1.2.6 Process evaluation.

4.1.3 During pipe inspection, conditions other than external corrosion may be found. Other conditions may include but are not limited to mechanical damage, stress corrosion cracking (SCC), microbiologically influenced corrosion (MIC), and electrical interference from outside sources. When found, these conditions are to be inspected and remediated in manners appropriate for the conditions.

4.2 Prioritization of Indications

4.2.1 Prioritization is the process of determining the need for Direct Examination of each of the indications detected during Indirect Inspection. Prioritization is to be based on the likelihood of past, present and future corrosion activity.

4.2.2 Definitive criteria for prioritization are to be established. When establishing criteria, consideration is to be given for the history of prior corrosion, year-round environmental and operating conditions, Indirect Inspection tools used, and criteria used for identification and classification of indications.

4.2.2.1 Different criteria may be required for different pipelines, ECDA regions, operating conditions, maintenance practices, corrosion and cathodic protection histories, and other differences.

4.2.2.2 For initial applications of ECDA, prioritization criteria is to be made more stringent.

4.2.3 Table 2 provides example prioritization criteria for several Indirect Inspection tools. These example prioritization criteria are general in nature and are not absolute criteria.

Table 2: Example ECDA Prioritization Criteria for Direct Examination of Cased Pipe Segments

<table>
<tr><th colspan="3" rowspan="2">Prioritization Criteria for Cased Pipe Segments
Based on ECDA Survey Severity Classifications</th><th colspan="4">Cathodic Protection Severity Classifications
Based on Close Interval Potential Survey Results</th></tr>
<tr><th>No Indications</th><th>Minor Indications</th><th>Moderate Indications</th><th>Severe Indications</th></tr>
<tr><td rowspan="8">Coating Condition Severity Classifications</td><td rowspan="4">Based on AC Current Attenuation Survey Results</td><td>No Indications</td><td>No Action</td><td>Monitor</td><td>Schedule</td><td>Immediate</td></tr>
<tr><td>Minor Indications</td><td>Monitor</td><td>Monitor</td><td>Schedule</td><td>Immediate</td></tr>
<tr><td>Moderate Indications</td><td>Monitor</td><td>Schedule</td><td>Schedule</td><td>Immediate</td></tr>
<tr><td>Severe Indications</td><td>Schedule</td><td>Schedule</td><td>Immediate</td><td>Immediate</td></tr>
<tr><td rowspan="4">Based on DC or AC Voltage Gradient Survey Results</td><td>No Indications</td><td>No Action</td><td>Monitor</td><td>Schedule</td><td>Immediate</td></tr>
<tr><td>Minor Indications</td><td>Monitor</td><td>Monitor</td><td>Schedule</td><td>Immediate</td></tr>
<tr><td>Moderate Indications</td><td>Monitor</td><td>Schedule</td><td>Schedule</td><td>Immediate</td></tr>
<tr><td>Severe Indications</td><td>Schedule</td><td>Schedule</td><td>Immediate</td><td>Immediate</td></tr>
</table>

Note: The example prioritizations in Table 2 are for cased pipe segments that do not have construction or operation characteristics that increase the likelihood for external corrosion. If a cased pipe segment has construction or operation characteristics that increase the likelihood for external corrosion, the prioritization rating is to be increased to a higher rating appropriate for the characteristic that causes the rating increase. Construction or operation characteristics that may require a rating increase include, but are not limited to, pipe electrically shorted to casing, pipe exposed to high temperature, pipe known to have coating damage under similar conditions, pipe known to be essentially bare, pipe at locations where the likelihood for atmospheric corrosion is high, older pipe, and pipe for which construction or operation characteristics are generally unknown.

4.2.4 Minimum prioritization categories are as follows:

4.2.4.1 Immediate Action Required: Indications that are considered as being likely to have ongoing corrosion activity and that are considered to pose an immediate threat to pipeline integrity under normal operating conditions. Immediate Action Required indications include but are not limited to the following examples:

4.2.4.1.1 Multiple severe indications from one or more Indirect Inspection tools in close proximity to one another;

4.2.4.1.2 Individual severe indications from more than one Indirect Inspection tool that are essentially at the same location;

4.2.4.1.3 Other severe indications if significant prior corrosion activity is likely at or near the indications;

4.2.4.1.4 Indications for which prior corrosion or the likelihood of ongoing corrosion activity cannot be determined; and

4.2.4.1.5 For initial ECDA applications, locations at which inconsistencies between Indirect Inspection results were identified and could not be resolved.

4.2.4.2 Scheduled Action Required: Indications that are considered as possibly having ongoing corrosion activity but are not considered to pose an immediate threat to pipeline integrity under normal operating conditions. Scheduled Action Required indications include but are not limited to the following examples:

4.2.4.2.1 Severe indications that were not placed in the Immediate Action Required category;

4.2.4.2.2 Multiple moderate indications from one or more Indirect Inspection tools in close proximity to one another;

4.2.4.2.3 Individual moderate indications from more than one Indirect Inspection tool that are essentially at the same location; and

4.2.4.2.4 Other moderate indications if significant prior corrosion activity is likely at or near the indications.

4.2.4.3 Suitable for Monitoring: Indications that are considered to be inactive or to have the lowest likelihood for prior or ongoing corrosion activity. Suitable for Monitoring indications include but are not limited to the following examples:

4.2.4.3.1 Moderate indications that were not placed in a higher priority category; and

4.2.4.3.2 Minor indications.

4.3 Direct Examination Methods

4.3.1 Methods that may be used to accomplish Direct Examination pipe and coating inspections include but are not limited to the following:

4.3.1.1 Visual Pipe and Coating Inspection

4.3.1.2 Guided Wave Ultrasonic Inspection

4.3.1.3 In-line Inspection

4.3.1.4 Pressure Testing

4.3.1.5 Other Technology

4.3.2 It should be understood that not all of these inspection methods provide definitive information, such as corrosion damage dimensions and coating condition, that may be used later in the ECDA process to determine remaining life and reassessment intervals. Additionally it should be understood that it may not be practicable to perform pipe and coating inspections on the full lengths of all segments of cased pipes. In such instances, it will be necessary to apply sound engineering analyses to make determinations or decisions regarding the condition of cased pipe segments that have not be fully inspected.

4.4 Number of Direct Examinations

4.4.1 Direct examinations are to be made based on the prioritization categories determined earlier in the Direct Examination step. A minimum of one direct examination is required for each ECDA region regardless of the results of the Pre-Assessment and Indirect Inspection steps.

4.4.2 When more than one direct examination is performed, the order in which the direct examinations are performed is to take into account safety and related issues.

4.4.3 The following are guidelines for determining the number of direct examinations based on prioritization categories of Indirect Inspection indications.

4.4.3.1 Immediate: All indications prioritized as Immediate require direct examination. If an Immediate indication is reprioritized from Immediate to a lower prioritization before direct examination is performed, direct examination of the indication may follow the guidelines for the lower prioritization. Reprioritization of indications is not to be performed for initial application of ECDA.

4.4.3.2 Scheduled: If there are any indications prioritized as Scheduled, some will require direct examination as follows:

4.4.3.2.1 At least one Scheduled indication in each ECDA region requires direct examination. This Scheduled indication is to be the one considered to be the most severe in the ECDA region. For initial application of ECDA, an additional indication requires direct examination. This indication is to be the next most severe in the ECDA region.

4.4.3.2.2 If a direct examination at a Scheduled indication reveals corrosion damage that is deeper than 20% of the original pipe wall thickness or that is deeper or more severe than at an Immediate indication, at least one more direct examination is to be performed at the next most severe indication in the ECDA region. For initial application of ECDA, an additional indication requires direct examination. This indication is to be the next most severe in the ECDA region.

4.4.3.3 Monitored: If there are any indications prioritized as Monitored, some will require direct examination as follows:

4.4.3.3.1 If there are not any Immediate or Scheduled indications in an ECDA region, at least one Monitored indication in the ECDA region requires direct examination. This Monitored indication is to be the one considered to be the most severe in the ECDA region. For initial application of ECDA, an additional indication requires direct examination. This indication is to be the next most severe in the ECDA region.

4.4.3.3.2 If there are not any Immediate or Scheduled indications in multiple ECDA regions, at least one Monitored indication in the ECDA region identified as the most likely for external corrosion in the Pre-Assessment step requires direct examination. This Monitored indication is to be the one considered to be the most severe in the ECDA region. For initial application of ECDA, an additional indication requires direct examination. This indication is to be the next most severe in the ECDA region.

4.4.3.4 No Indications: In the event that no Indirect Inspection indications are identified in an ECDA region, a minimum of one direct examination is required at the location identified as the most likely for external corrosion in the Pre-Assessment step. For initial ECDA applications, an additional location requires direct examination. This additional location is to be the next most likely location for external corrosion identified in the Pre-Assessment step.

4.5 Direct Examination Data

4.5.1 Data to be collected during Direct Examination inspection of pipe are to be adequate to allow assessment of the condition of the cased pipe with respect to coating condition, external corrosion damage, cathodic protection, and environmental parameters that affect external corrosion. Additionally, data are to be collected regarding the condition of the casing and casing appurtenances (end seals, spacers, vent pipes, etc.).

4.5.1.1 Because Direct Examination methods for cased pipe may include visual inspection, guided wave ultrasonic inspection, in-line tool inspection, or inspections using other technologies, the types of data that are to be collected may vary widely. The types of data collected are to be appropriate for the specific type of Direct Examination method used and in agreement with standard industry practices.

4.5.1.2 Minimum data requirements are to be established before performing pipe and casing inspections. Minimum data requirements should include the types and accuracies of data to be collected and take into account the conditions expected to be encountered, the types of corrosion activity expected, and the availability and quality of historical data.

4.5.1.3 If the Direct Examination method requires the excavation of the pipeline and casing, data collection will need to occur in three phases as follows:

4.5.1.3.1 Data collected prior to any excavation work to include but not be limited to pipe-to-soil potentials, casing-to-soil potentials, casing isolation test data and surface soil resistivities.

4.5.1.3.2 Data collected during or immediately after pipe and casing excavation, but before any pipe coating or casing appurtenance removal, to include but not be limited to sample collections of soil, water, and corrosion and cathodic protection products, coating type and thickness, assessment of coating condition and adhesion, dimensions of coating defects, under-film liquid pH, MIC samples, and photographic documentation.

4.5.1.3.3 Data collected after pipe coating and casing appurtenance removal to include but not be limited to locations and dimensions of corrosion damage, other parameters required for remaining pipe strength calculations, and photographic documentation. (Prior to measuring dimensions of corrosion damage, all damaged and disbonded coating is to be removed and the pipe surface cleaned to expose native pipe steel.)

4.6 Other Data, Observations and Considerations

4.6.1 The lengths of excavations are to be increased if conditions are found that indicate coating defects or corrosion damage are likely to extend beyond the original limits of the excavation.

4.6.2 Consideration is to be given to performing other pipe integrity assessments unrelated to external corrosion while the pipe and casing are exposed. Other integrity assessments include but are not limited to stress corrosion cracking, longitudinal seam defects, circumferential weld defects, and internal corrosion damage.

4.7 Remaining Strength Evaluation at Corrosion Damage

4.7.1 At locations where corrosion damage is found on cased pipe, the remaining strength of the damaged pipe is to be evaluated using industry standard methods such as ASME B31G, RSTRENG, and Det Norske Veritas (DNV) Standard RP-F101.

4.7.2 If the remaining strength of the cased pipe at corrosion damage is less than the established level for the pipeline, the damaged pipe is to be replaced or repaired, or the operating pressure decreased to a level appropriate for the severity of corrosion damage.

4.7.3 Unless corrosion damage can be shown to be isolated and unique in a root cause analysis, alternative methods of assessing pipeline integrity are to be considered for the entire ECDA region.

4.7.3.1 While the ECDA process facilitates finding representative corrosion damage in an ECDA region, it may not find all corrosion damage in the ECDA region.

4.7.3.2 It should be assumed that other corrosion damage may be present elsewhere in the ECDA region that is similar to corrosion damage that was found by the ECDA process.

4.8 Root Cause Analysis

4.8.1 The root cause of significant corrosion activity is to be identified. Root causes of corrosion activity for cased pipe includes but is not limited to the following:

4.8.1.1 Most corrosion activities that are typical for uncased pipe buried in soil or submerged in water;

4.8.1.2 Cathodic protection shielding caused by an electrically shorted casing;

4.8.1.3 Cathodic protection shielding caused by a coated casing;

4.8.1.4 Cathodic protection shielding caused by the cased pipe coating being disbonded;

4.8.1.5 Cathodic protection shielding caused by casing centralizers, end seals or other cased pipe construction materials or devices; and

4.8.1.6 Atmospheric corrosion, particularly for pipelines operating at elevated temperatures where humidity or soil moisture content is high.

4.8.2 If a root cause is identified for which ECDA is not well suited, such as cathodic protection shielding caused by an electrically shorted casing, an alternative method of assessing the integrity of the pipeline segment is to be considered.

4.9 External Corrosion Mitigation

4.9.1 Remedial actions are to be taken to mitigate corrosion that may result from identified root causes. Remedial actions for cased pipe include, but are not limited to, removing the casing, electrically isolating the casing from the cased pipe, filling the casing annulus with a high dielectric material, repairing or replacing the cased pipe, repairing the coating on the cased pipe, and providing supplemental cathodic protection.

4.9.2 Consideration is to be given for repeating Indirect Inspections or using other assessment means after remedial actions are taken to verify the effectiveness of the remedial actions.

4.9.3 It may be acceptable to reclassify and/or reprioritize Indirect Inspection indications as a result of remedial actions. If remedial actions result in the elimination of corrosion activity or conditions that caused an Indirect Inspection indication, the indication is no longer a threat to the cased pipe and no longer needs to be considered for the current assessment. However, future assessments are to include techniques that are capable of detecting a recurrence of the corrosion activity or conditions that caused the Indirect Inspection indication.

4.10 Reclassification and Reprioritization of Indications

4.10.1 Reclassification of an Indirect Inspection indication may be acceptable and may be required depending on corrosion activity found during pipe inspection.

4.10.1.1 Except for initial application of ECDA, if corrosion activity is less severe than classified, the classification may be downgraded to be more representative of actual corrosion activity. Classification is not to be downgraded for initial applications of ECDA.

4.10.1.2 If corrosion activity is more severe than classified, the classification is to be upgraded to be more representative of actual corrosion activity. If repeated pipe inspections reveal corrosion activity that is more severe than initial classifications, ECDA feasibility is to be reevaluated.

4.10.2 Reprioritization of an Indirect Inspection indication may be acceptable and may be required depending on corrosion severity found during pipe inspection.

4.10.2.1 Except for initial application of ECDA, if corrosion severity is less severe than prioritized, the prioritization may be downgraded to be more representative of actual corrosion severity. Prioritization is not to be downgraded for initial applications of ECDA.

4.10.2.2 If corrosion severity is more severe than prioritized, the prioritization is to be upgraded to be more representative of actual corrosion severity. If repeated pipe inspections reveal corrosion severity that is more severe than initial prioritizations, ECDA feasibility is to be reevaluated.

4.10.3 When corrosion activity classifications and/or corrosion severity prioritizations are upgraded as the result of pipe inspections that reveal more severe corrosion activity and/or corrosion severity, the root causes of corrosion activity are to be identified. After identifying these root causes, all other Indirect Inspection indications in the cased pipe region where similar root-cause conditions may exist are to be evaluated to determine if there is a need to upgrade classifications and/or prioritizations for these indications.

4.11 In-Process Evaluation

4.11.1 An evaluation is to be performed to assess the criteria used to classify and prioritize Indirect Inspection indications. This assessment is to include results from the Indirect Inspection data, the remaining pipe strength evaluations, and the root cause analyses.

4.11.2 Assessing and Modifying Classification Criteria

4.11.2.1 Corrosion activity at each pipe inspection is to be assessed to determine if the classification criteria are accurately representing the severity of corrosion damage.

4.11.2.2 Except for initial application of ECDA, if corrosion activity is less severe than classified, the classification criteria may be downgraded to be more representative of actual corrosion activity. Classification criteria are not to be downgraded for initial applications of ECDA.

4.11.2.3 If corrosion activity is more severe than classified, the classification criteria are to be upgraded to be more representative of actual corrosion activity. Additional Indirect Inspections may be necessary to obtain information needed to make appropriate upgrades to classification criteria. If repeated pipe inspections reveal corrosion activity that is more severe than upgraded classification criteria, ECDA feasibility is to be reevaluated.

4.11.2.4 If classification criteria are modified, all Indirect Inspection indications that have not been evaluated are to be reclassified using the modified classification criteria.

4.11.3 Assessing and Modifying Prioritization Criteria

4.11.3.1 Corrosion severity at each pipe inspection is to be assessed to determine if the prioritization criteria are accurately predicting the need and response time for pipe repair.

4.11.3.2 Except for initial application of ECDA, if corrosion severity is less severe than prioritized, the prioritization criteria may be downgraded to be more appropriate for actual corrosion severity. Prioritization criteria are not to be downgraded for initial applications of ECDA.

4.11.3.3 If corrosion severity is more severe than prioritized, the prioritization criteria are to be upgraded to be more appropriate for actual corrosion severity. If repeated pipe inspections reveal corrosion severity that is more severe than upgraded classification criteria, ECDA feasibility is to be reevaluated.

4.11.3.4 If prioritization criteria are modified, all Indirect Inspection indications that have not been evaluated are to be reprioritized using the modified prioritization criteria.

Section 5: Post Assessment

5.1 Introduction

5.1.1 The objectives of the Post Assessment step are to define reassessment intervals and assess the effectiveness of the ECDA process.

5.1.2 The Post Assessment step is to include the following activities:

5.1.2.1 Remaining life calculations;

5.1.2.2 Determination of reassessment intervals;

5.1.2.3 Assessment of ECDA effectiveness; and

5.1.2.4 Feedback.

5.2 Remaining Life Calculations

5.2.1 Remaining life calculations are calculations made to determine the period of time required for continuing corrosion activity to result in a failure. The calculations require identification or selection of the worst remaining corrosion damage and the determination or selection of a corrosion growth rate. If no corrosion defects are found, remaining life calculations are not required and the remaining life can be considered the same as for a new pipeline.

5.2.1.1 Worst Remaining Corrosion Damage

5.2.1.1.1 At this point in the ECDA process, all Indirect Inspection indications prioritized as Immediate will either have been or will be addressed. Therefore, identification or selection of worst remaining corrosion damage may be based on the worst remaining Indirect Inspection indication.

5.2.1.1.2 The most severe corrosion damage found at the most severe Indirect Inspection indication with a prioritization less than Immediate is to be used as the maximum remaining flaw size for remaining life calculations. If root-cause analyses indicate that the most severe Indirect Inspection indication is unique, the size of the next most severe indication may be used for remaining life calculations.

5.2.1.1.3 As an alternative to using the most severe corrosion damage found, a value based on sound engineering analysis may be used. This analysis may be based on a statistical or a more sophisticated analysis of corrosion damage found at pipe and casing inspection sites.

5.2.1.2 Corrosion Growth Rate

5.2.1.2.1 Determinations or selections of corrosion growth rates are to be based on sound engineering analyses.

5.2.1.2.2 Corrosion growth rates measured using corrosion rate measurement methods or equipment may be used if these rates are applicable to the ECDA region being evaluated.

5.2.1.2.3 Corrosion growth rates may be determined using the methods and values provided in Appendix D of NACE SP0502.

5.2.1.2.4 Corrosion growth rates may be determined using evaluations and analyses of actual corrosion damage found during pipe and casing inspections.

5.2.2 Remaining Life Calculation

5.2.2.1 Remaining life may be calculated using sound engineering analysis of the worst remaining corrosion damage and conservative corrosion growth rates. The analysis is to assume that corrosion damage grows continuously and is to take into account typical sizes and geometries of corrosion damage.

5.2.2.2 Remaining life may also be calculated using the equation that follows. This equation is based on corrosion damage that grows continuously and takes into account typical sizes and geometries of corrosion damage.

$$RL = C \times SM \times t / GR = C \times (FPR - MR) \times t / GR$$

Where: RL = Remaining Life (years)

C = 0.85 (dimensionless calibration factor)

SM = Safety Margin = Failure Pressure Ratio – MAOP Ratio

Failure Pressure Ratio (FPR) (dimensionless) $= \dfrac{\text{Calculated Failure Pressure}}{\text{Yield Pressure}}$

MAOP Ratio (MR) (dimensionless) $= \dfrac{\text{MAOP}}{\text{Yield Pressure}}$

t = Nominal Pipe Wall Thickness (mm [in])

GR = Corrosion Growth Rate (mm/y [in/y])

5.3 Reassessment Interval Determination

5.3.1 The reassessment interval is to be determined using a sound engineering analysis and conservative determinations or selections of remaining corrosion damage sizes, corrosion growth rates, and corrosion growth periods. To ensure that the reassessment interval is not unreasonably long, a maximum reassessment interval that cannot be exceeded regardless of the findings of the ECDA is to be established. Guidance for establishing the maximum reassessment interval may be found in pipeline industry standards such as ASME B31.4, ASME B31.8, and API 1160.

5.3.2 The reassessment interval is to be determined using the half-life method commonly used in engineering practice. The half-life method involves determining or estimating the true life and setting the reassessment interval to be one-half of the true life. The remaining life determination made in section 5.2.2 is to be used as the true life for determining the reassessment interval.

5.3.3 Because ECDA regions may have different corrosion mechanisms, severities of corrosion damage and corrosion growth rates, remaining life determinations are to be made for each ECDA region.

5.4 Assessment of ECDA Effectiveness

5.4.1 ECDA is a continuous improvement process. Successive applications of ECDA will enhance the ability to identify locations where corrosion activity has occurred, is occurring, or may occur. Assessment of ECDA effectiveness during each application of ECDA, and during mitigation activities between ECDA applications, is crucial to improving the likelihood that ECDA will identify locations of past, present and future corrosion activity.

5.4.2 Criteria are to be established for assessing the effectiveness of the ECDA process. The criteria may be for the application of ECDA, for the results of the ECDA process, or absolute criteria. These criteria include but are not limited to the following:

5.4.2.1 Criteria that track the reliability or repeatability of the application of ECDA - An example of this is tracking the number of instances where Indirect Inspection indications needed to be reclassified or reprioritized. If the number of reclassifications or reprioritizations is significant, the original classification or prioritization criteria probably need to be modified.

5.4.2.2 Criteria that track the application of the ECDA process – An example of this is tracking the number of inspections made to investigate suspected problems. Increases in the number of inspections indicate more aggressive corrosion monitoring.

5.4.2.3 Criteria that track the numbers of cased pipes that are subjected to multiple applications of Indirect Inspections - Increases in the number of cased pipes that are subjected to multiple applications of Indirect Inspections indicate more aggressive corrosion monitoring.

5.4.2.4 Criteria that track results of the various Indirect Inspection methodologies to identify the more effective methodologies – Making more use of the more effective methodologies and less use of methodologies with lesser effectiveness indicates a more focused application of ECDA.

5.4.2.5 Criteria that track the frequency at which Immediate and Scheduled indications arise – A reduction in this frequency indicates an improved management of corrosion.

5.4.2.6 Criteria that track the extent and severity of corrosion damage – A decrease in the extent and/or severity of corrosion damage indicates an improved management of corrosion.

5.4.2.7 Criteria that establish absolute performance requirements – An example is requiring that no corrosion leaks or ruptures occur between subsequent applications of ECDA. Meeting such a requirement demonstrates improved integrity with regard to corrosion.

5.4.3 In the event that evaluation does not show improvement between ECDA applications, the ECDA process is to be reevaluated and modified as found necessary, or alternative methods of assessment are to be considered.

5.5 Feedback and Continuous Improvement

5.5.1 Throughout the ECDA process, as well as during scheduled activities and reassessments, ECDA applications are to be improved by incorporating feedback at all appropriate opportunities.

5.5.2 Opportunities for which feedback is to be incorporated include but are not limited to the following:

5.5.2.1 Identification and classification of Indirect Inspection indications;

5.5.2.2 Data collection from Direct Examination pipe inspections;

5.5.2.3 Remaining pipe strength analyses;

5.5.2.4 Root-cause analyses;

5.5.2.5 Remediation activities;

5.5.2.6 In-process evaluations;

5.5.2.7 Process validation pipe inspections;

5.5.2.8 Criteria for monitoring long-term ECDA effectiveness; and

5.5.2.9 Scheduled monitoring and period reassessments.

Section 6: ECDA Documentation

6.1 Introduction

This section addresses information that documents in a clear, concise, and organized manner the data and activities pertinent to the Pre-Assessment, Indirect Inspection, Direct Examination and Post Assessment steps of the cased pipe ECDA process.

6.2 Pre-Assessment

6.2.1 All Pre-Assessment actions and data are to be recorded, including but not limited to:

6.2.1.1 Data elements collected for the cased pipes being assessed.

6.2.1.2 Methods and procedures used to integrate collected data to determine when Indirect Inspection tools can and cannot be used.

6.2.1.3 Methods and procedures used to select the Indirect Inspection tools.

6.2.1.4 Characteristics and boundaries of cased pipe regions and the Indirect Inspection tools used in each region.

6.3 Indirect Inspection

6.3.1 All Indirect Inspection actions and data are to be recorded, including but not limited to:

6.3.1.1 Geographically referenced locations of the beginning and ending points of each cased pipe Indirect Inspection and fixed points used for determining the locations of Indirect Inspection measurements.

6.3.1.2 Dates and weather conditions during which the Indirect Inspections were conducted.

6.3.1.3 Indirect Inspection results at sufficient resolution to identify the location of each indication.

6.3.1.4 Procedures for aligning Indirect Inspection measurements and expected errors for each Indirect Inspection tool.

6.3.1.5 Procedures for defining the criteria used in classifying and prioritizing the severity of Indirect Inspection indications.

6.4 Direct Examination

6.4.1 All Direct Examination activities and other pertinent information are to be documented. Documentation includes, but is not limited to, the following:

6.4.1.1 Procedures and criteria for classifying and prioritizing Indirect Inspection indications.

6.4.1.2 Data collected during Direct Examination inspections.

6.4.1.3 Results of root-cause identifications and analyses.

6.4.1.4 Descriptions and explanations for reclassification and reprioritization of Indirect Inspection indications.

6.4.1.5 Planned mitigation activities.

6.5 Post Assessment

6.5.1 All Post Assessment activities and other pertinent information are to be documented. Documentation includes, but is not limited to, the following:

6.5.1.1 Remaining life calculations to include descriptions of methods of estimating remaining life, remaining life calculation results, and determinations of maximum remaining flaw sizes and corrosion growth rates.

6.5.1.2 Reassessment interval determination and scheduled related activities.

6.5.1.3 Criteria used to assess ECDA effectiveness and results from assessment of ECDA effectiveness to include criteria and metrics, and data from periodic assessments.

6.5.1.4 Feedback related to assessment of criteria used in each ECDA step and any modifications of these criteria.

References

1. External Corrosion Direct Assessment, NACE SP0502-2008, NACE International (Houston, Texas: NACE 2008)

2. Steel-Cased Pipeline Practices, NACE SP0200-2008, NACE International (Houston, Texas: NACE 2008).

3. External Corrosion Probability Assessment for Carrier Pipes Inside Casings (Casing Corrosion Direct Assessment--CCDA), GRI-05/0020, Gas Technology Institute.

4. PHMSA – Pipeline Corrosion Final Report – Michael Baker Jr., Inc. – July 2008

5. PHMSA - Applying External Corrosion Direct Assessment (ECDA)In Difficult-to-Inspect Areas DTRS56-05-T-0003 - E. B. Clark, B. N. Leis, and S. A. Flamberg – March 2007

6. PHMSA - Demonstration of ECDA Applicability and Reliability for Demanding Situations DTPH56-06-T-000001 - Daniel Ersoy – August 2008

7. PHMSA - Improvement of External Corrosion Direct Assessment Methodology by Incorporating Soils Data DTRS56-03-T-0003 - B. N. Leis, E. B. Clark, M. Lamontagne, and J. A. Colwell - November 2005

8. PHMSA Casing Quality Action Team (CASQAT) Committee – Guidelines for Integrity Assessment of Cased Pipe for Gas Transmission Pipelines in HCAs – March 2010

- End of Body of Guidelines -

Appendix A

List of Example Pre-Assessment Data

Appendix A: Pre-Assessment Data for Cased Pipe ECDA

The following is a listing of data that may be needed for Pre-Assessment of cased segments of pipelines. Not all data listed may be required for all cased pipes, and other data not listed may be required for some cased pipes. Minimum data requirements are to be established by evaluating individual data to determine its relevance to the occurrence of external corrosion. Those data that are essential to the success of the ECDA process are to be identified and extra effort made to collect the data.

Pipe Related Data

- Material (steel, cast iron, etc.)
- Diameter
- Wall thickness
- Year manufactured
- Seam type
- External coating type on pipe
- External coating type on joints

Casing Related Data

- Material (steel, cast iron, etc.)
- Diameter
- Length
- Year manufactured
- Locations
- Construction techniques and practices
- External and internal coatings
- Casing spacers
- Casing end seals
- Casing vent pipes

Construction Related Data

- Year installed
- Changes and modifications
- Alignment sheets, route maps and aerial photos
- Construction techniques and practices
- Locations of appurtenances (valves, taps, flanges, etc.)
- Depth of cover
- Proximity to other pipelines and utilities

Soils and Environment Data

- Soil characteristics
- Soil types
- Drainage
- Topography
- Land use
- Frozen ground

Corrosion Control Data

- CP system types
- CP test stations
- Stray electrical current sources and locations
- Electrical isolation devices (isolation flanges, etc.)
- CP evaluation criteria
- CP maintenance history
- Periods without CP
- External coating condition
- CP current demand
- CP survey data
- CP history
- Casing electrical isolation tests
- Casing filling records

Operational Data

- Pipeline operating temperature
- Operating stress levels and fluctuations
- Leak monitoring programs
- Pipe and casing inspection reports
- Leak and rupture history
- Repair history
- MIC corrosion tests
- Mechanical damage types and locations
- Previous CP surveys
- Pressure test information
- Other integrity related activities

Appendix B

Guidelines for Establishing ECDA Regions for Cased Pipe

Appendix 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 coupling. 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 contacts or electrolytic couplings	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 couplings 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 couplings. 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 coupling 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.
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.

Appendix C

Guidelines for Selecting Indirect Inspection Tools for Cased Pipe

Appendix C: 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 coupling.
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 C.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	Electro-lytic	Clear	Short	Electro-lytic				
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 at the ends of the casing, at casing spacers with metallic components or at other locations along the cased pipe segment	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 coupling or metallic short.
2	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
3	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 coupling	HVAC power lines

Table C.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**	**Electro-lytic**	**Clear**	**Short**	**Electro-lytic**				
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 consideration. Complement-ary 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 consideration

Table C.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**	**Electro-lytic**	**Clear**	**Short**	**Electro-lytic**				
6	Pipe/Cable Locator 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 coupling 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 < 0.01 ohms confirming a metallic contact.	0.01 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 coupling.

Table C.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	Electro-lytic	Clear	Short	Electro-lytic				
8	Internal Resistance Electrical Resistance NACE RP 0200	Yes	Yes	U	A	U	U	A	U	Pipe-to-casing metallic or electrolytic coupling	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. Complement-ary tool. Can determine metallic shorts only.
9	Casing-Pipe Capacitance Ref: N/A	Yes	Yes	U	A	U	U	A	U	Pipe-to-casing metallic contact	Uses flange isolation checker to indicate clear or shorted condition based on pipe-to-casing capacitance		Electrolytic range not established. Complement-ary 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.

Appendix D

Indirect Inspection Survey Techniques for Cased Pipe

Appendix D: Above-Ground Survey Techniques for Cased Carrier Pipe Using ECDA Indirect Inspection Tools

D.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, shorts and electrolytic couples that can be detected, and
- Proper interpretation of indirect inspection tool readings when used for cased pipe.

D.2 Definitions:

Electrolytic Couple – Ionic path between two metallic structures via an electrolyte
Metallic Short – Direct or metallic (electrical) path between two metallic structures

D.3 References:

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

D.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 contact or electrolytic couple 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 (ACCA)
c) Alternating Current Voltage Gradient (ACVG)
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.

D.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. Electrically shorted and electrolytically coupled 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 DC power supply 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 couples which may present themselves as a smaller holiday. In either situation, DCVG can give a positive indication that a short or couple exists, but will not be able to locate the short or couple 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.

D.4.2 AC Current Attenuation - ACCA

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.

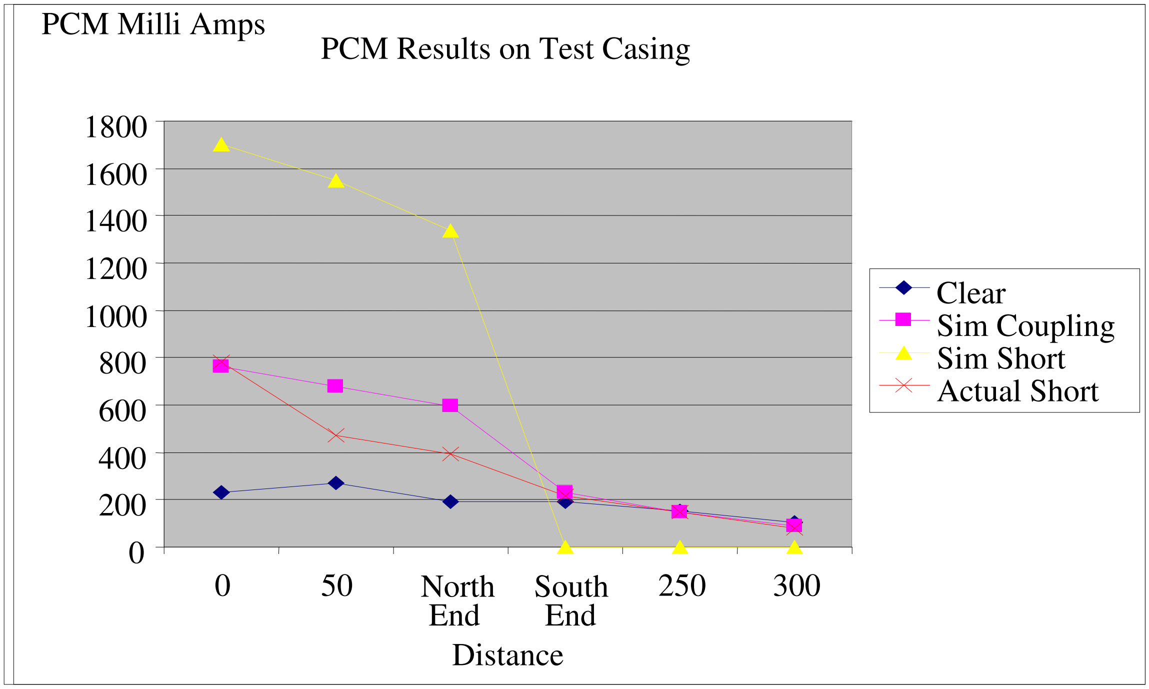
The test is set up by first connecting the signal generator to the pipe, typically through a test lead. A cycled AC signal is produced and transmitted along the pipe. The transmitter is energized and adjusted. Signals along the pipe are then measured with the detector/receiver unit array, which is sensitive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

In this test, a short 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 short, 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 couples 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 couples 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 couple shows 61% attenuation, and the actual electrolytic couple (done by flooding the casing and having holidays on the carrier pipe) shows 45% attenuation.



D.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 two metal pins fixed in a proprietary frame device, usually in conjunction with an AC attenuation device, that measure the AC potential difference between the 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 couple and all readings over 80 dBµV as direct shorts (direct shorts are typically 90+ dBµV with 99 dBµV not being uncommon). The ACVG device does not need a rectifier but uses a signal generator 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 two fixed metal pins 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.

D.4.4 Potential Surveys

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

D.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 couple condition. Further testing is needed to confirm the casing condition. Protected bare and coated casings may not show the same type of changes.

D.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 short is possible. If the potential shifts are in the same direction, but of different magnitudes, an electrolytic couple 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 short 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 an electrolytic couple with a fairly high resistance exists. In these situations, other testing methods may be more appropriate.

D.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 short 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 couple is expected. This is not a very precise test and should be used for screening purposes only and may not show all electrolytic couples.

D.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 couples, no conclusion can be determined in many situations, so this test is not recommended for determination of electrolytic couple between a casing and carrier pipe. Additional testing must be performed to confirm if an electrolytic couple exists or does not exist.

D.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 considered metallically shorted. If the internal resistance is greater than 0.08 ohm, then the casing is considered electrically isolated. If the internal resistance is between these two values, then no conclusion can be drawn regarding electrical isolation and additional testing is required. In many situations, no conclusions concerning electrolytic couples can be made. Therefore, this test is not recommended for determining whether or not a casing and carrier pipe is coupled electrolytically. Additional testing must be performed to confirm if an electrolytic couple exists or does not exist.

D.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 couples no conclusion can be determined in many situations, so this test is not recommended to determine if a casing and carrier pipe are coupled electrolytically. Additional testing must be performed to confirm whether or not an electrolytic couple exists.

D.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 short 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 short 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 couples and is not recommended for determining if a casing and carrier pipe are electrolytically coupled. Additional testing must be performed to confirm whether or not an electrolytic couple exists.

D.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 couples and is not recommended for determining if a casing and carrier pipe are electrolytically coupled. Additional testing must be performed to confirm whether or not an electrolytic couple exists.

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 couples. In most cases, operators should use more than one technique to validate that the casing is clear and free from all types of electrical shorts. If an operator cannot positively exclude the existence of an electrolytic couple, the operator should assume such a condition currently exists or has previously occurred.