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PIPELINE EXTERNAL CORROSION DIRECT ASSESSMENT METHODOLOGY. LESSONS LEARNED – Part 1

Angel R. Kowalski[1]

Abstract

DNV Columbus (Former CC Technologies) played a key role in the development of Direct Assessment (DA) methodologies, providing leadership in the NACE technical committees charged with development of DA standards. Since the first publication of NACE Standard RP-0502-2002, External Corrosion Direct Assessment (ECDA) has been successfully applied over a great number of pipelines to evaluate the impact of external corrosion on the pipeline integrity. This paper summarizes the results of applying ECDA over a selected number of underground pipelines and presents interesting facts about the methodology.

1. Introduction

The pipeline industry is undergoing changes because of revisions to safety regulations. These changes include developing standards, recommended practices, and guidelines that can be used by operators to develop, implement, and validate pipeline-integrity verification programs. Methods for verifying pipeline integrity include pressure testing, in-line inspection (ILI), and others, such as a method called Direct Assessment (DA). Each of these techniques has capabilities and limitations that need to be considered in developing and validating a pipeline integrity management program.

In the USA, the US Department of Transportation (DOT) Office of Pipeline Safety (OPS) has changed and is changing pipeline safety regulations. These changes affect approximately 160,000 miles of hazardous liquid pipelines and 330,000 miles of natural gas transmission pipelines in high-consequence areas (HCA). The regulations are intended to decrease the number pipeline failures affecting public safety and the environment. The final rule for hazardous liquids pipelines, dated Jan. 16, 2002, requires that all operators of hazardous liquid pipelines develop and implement integrity management programs including integrity verification of all pipeline segments within an HCA. A similar rule for gas transmission pipeline operators was implemented in December of 2003. Since the gas rule contains provisions for use of Direct Assessment, NACE developed a series of technical consensus standards guiding implementation of the approach.
The definition of an HCA is complex. For hazardous liquid pipelines, it includes unusually (environmentally) sensitive areas, highly populated areas, and commercially navigable waterways. The final rule for gas pipelines includes proximity to populated areas (including buildings such as schools and hospitals).

In-line inspection (ILI) tools, sometimes called pigs, are devices containing sensors designed to scan the pipe wall for defects. There is a wide range in type of tool and the defects they can detect. A wider range of technologies are available to liquid operators than gas operators. The interpretation of signals is complicated, and the level of accuracy depends on the type of tool, how it is run, and the type of defect. There are many advantages and disadvantage to ILI. However, ILI is considered impractical for many pipelines because the tools require construction of a launcher and receiver at the ends of an unobstructed pipe segment without changes in pipe size or bends.

Hydrotesting is a method where a pipeline is taken out of service, filled with water, and pressurized to a value greater than the operating pressure. Any defects in the pipe wall that are near failure in a pipeline result in a release of water. Hydrotesting is most often used for new pipelines (or those returned to service) to ensure that construction defects are found. There are many advantages and disadvantage to hydrotesting. However, hydrotesting is not practical for many pipelines because the service interruption is not acceptable (e.g., a single pipeline feeding gas to a city or power plant).

[1] Program Manager, Inspection & Services - DNV Columbus, Inc

Direct Assessment (DA) methods are processes to assess the condition of pipelines with respect to external corrosion (EC), internal corrosion (IC), and stress corrosion cracking (SCC). Each of the DA method uses techniques to determine the most likely locations for corrosion. These locations are excavated and directly assessed. If these locations most likely to have suffered corrosion are not a threat to pipeline integrity, the remaining section of pipe less likely to have suffered corrosion is considered to also not be a threat.

External Corrosion Direct Assessment (ECDA) is defined by NACE Standard SP0502-07. The use of DA is expected to improve the overall safety, integrity, and reliability of the pipeline infrastructure because it will allow assessment of pipelines for which other integrity verification methods are not practical. There are many advantages and disadvantages to DA, and there will be some pipelines for which DA is not appropriate.

In this article, the results obtained during the application of ECDA over a selected number of pipelines transporting gas and hazardous liquids are discussed.

2. ECDA Historical Review

DNV Columbus has been supporting pipeline operators in the application of the ECDA methodology to assess the mechanical integrity of their pipelines. ECDA is a four step process that combines pre-assessment, indirect inspections, direct examinations, and post assessment to evaluate the impact of external corrosion on the integrity of the pipeline. Twenty (20) case studies have been selected for the overall review of the ECDA process. However not in all cases the four steps have been applied by DNV Columbus, in some cases the pipeline operator completed at least one of the steps. The case studies include projects completed between 2004 and 2008 and the corresponding pipe data can be found in Table 1.

Table 1 Case Studies Pipe Data

Case #	NPS (inch)	Survey Length (ft)	Installation Year	Coating Type	CP	Seam Weld	Grade	Wall Thickness (inch)
1	8	20,170	2001	FBE	ICCP	ERW	X-42	0.219 / 0.250
2	8/12	16,430	1981	CTE/OW/PET	ICCP	ERW	X-42	0.219 / 0.250
3	10	2,760	1985	FBE	ICCP	ERW	X-42 & B	0.365
4	10	580	1989	FBE	ICCP	ERW	B	0.365
5	10	2,952	1985	FBE	ICCP	ERW	B	0.365
6	10	3,130	2003	FBE	ICCP	ERW	X-42	0.307
7	8	1,749	2004	FBE	ICCP	ERW	X-42	0.277
8	10	948	1985	FBE	ICCP	ERW	B	0.365
9	2,4 & 6	29,198	-	CTE	ICCP	-	-	0.340
10	16	26,878	1985	PET	ICCP	DSAW	X-65	0.625
11	20/24	36,607	1954	PET, CTE	ICCP	Seamless, ERW	B, X-52, X-60	0.375, 0.312
12	24	11,900	1969	CTE	ICCP	ERW	X-60	0.312
13	6	9,012	1992	FBE	ICCP	ERW	-	-
14	12	3,980	1960	CTE	Galvanic	Seamless	B	0.216
15	8	7,182	1964	CTE	ICCP	ERW	X-42	0.188
16	6	7,182	1950	PE CTE	ICCP	ERW	-	0.125
17	24	26,400	1965	CTE	ICCP	SAW	X-42	0.312
18	24	35,139	1956	CTE	ICCP/Galvanic	SAW/ERW	X-42	0.312
19	24	17,983	1965	CTE	ICCP/Galvanic	ERW	X-42, X-56	0.312, 0.375
20	8	7,700	1970	X-TRU	-	Seamless	B	0.419

2.1. Pre-assessment Step

The objectives of the Pre-assessment step are to determine whether ECDA is feasible for the pipeline to be evaluated; select indirect inspection tools; and identify ECDA Regions. DNV Columbus conducts a rigorous review of the historical data available following the guidelines of NACE SP0502 and pipeline operator's procedures (when available).

On all case studies ECDA was found practical and feasible as an integrity assessment tool to evaluate the impact of external corrosion. In relation to ECDA Regions, in fifteen (15) of the twenty (20) case studies (75%) the pipeline segments were considered as one (1) ECDA Region; in two (2) of the case studies (10%) the pipeline segments were considered as two (2) ECDA Regions and in three (3) of the case studies (15%) the pipeline segments were considered as three (3) ECDA Regions.

The number of indirect inspection tools varied from case to case, in 14 of the total twenty (20) case studies (70%), three (3) indirect survey tools were selected; in 5 of the case studies only two (2) aboveground survey tools (10%) were selected; and in one (1) case study four (4) indirect survey tools were chosen to conduct the indirect inspection step.

Close Interval Potential Survey (CIS) and Direct Current Voltage Gradient (DCVG) were selected in all the case studies; Alternating Current Voltage Gradient was selected in one (1) case, soil resistivity measurement was selected in eleven (11) cases and Electromagnetic Current Attenuation (EM) in 4 cases. The corresponding Pre-assessment data can be seen in Table 2.

Table 2 Case Studies Pre-assessment Step Data

	PRE-ASSESSMENT						
			Indirect Inspection Tools Selected				
Case #	Feasibility	# ECDA Regions	CIS	DCVG	ACVG	EM	Soil Resistivity
1	✓	3	✓	✓			✓
2	✓	3	✓	✓			✓
3	✓	1	✓	✓			✓
4	✓	1	✓	✓			✓
5	✓	1	✓	✓			✓
6	✓	1	✓	✓			✓
7	✓	1	✓	✓			✓
8	✓	1	✓	✓			✓
9	✓	1	✓	✓			
10	✓	1	✓	✓			
11	✓	2	✓	✓			✓
12	✓	1	✓	✓			✓
13	✓	1	✓	✓			✓
14	✓	1	✓	✓			
15	✓	1	✓	✓			
16	✓	1	✓	✓			
17	✓	2	✓	✓		✓	
18	✓	1	✓	✓		✓	
19	✓	1	✓	✓		✓	
20	✓	3	✓	✓	✓	✓	

2.2. Indirect Inspection Step

The objective of the Indirect Inspection Step is to identify and define the severity of coating faults, other anomalies, and areas at which corrosion activity may have occurred and may be occurring. This step requires the use of at least two aboveground survey tools over the entire length of each ECDA Region. The indirect inspections should be conducted using intervals spaced closely enough to permit a detailed assessment. The distance selected must be such that the inspection tool can detect and locate suspected corrosion activity on the segment. The data obtained from each survey tool needs to be aligned and compared. After identifying and aligning indications, the Indication Severity Classification was established. NACE Standard SP0502 defines the classification as the process of estimating the likelihood of corrosion activity at each indication under typical year-round conditions and suggests the use of the following classification: "Minor": indications that the pipeline operator considers inactive or as having the lowest likelihood of corrosion activity; "Moderate": indications that the pipeline operator considers as having possible corrosion activity; and "Severe": indications that the pipeline operator considers as having the highest likelihood of corrosion activity.

As a result of the application of the Indirect Inspection Step on the pipeline segments part of this study, a total of nine hundred and forty two (942) indications have been identified over a total survey length of approximately 51 miles (81.6 Km). The number of indications classified as "Minor" is seven hundred and three (703), which represents 74.6 % of the total number of indications. The number of indications classified as "Moderate" is two hundred and eleven (211) which represents 22.4% of the total number of indications. Finally, a total of twenty eight indications were classified as "Severe", which represents 3% of the total number of indications. The corresponding Indirect Inspection Step data is presented in Table 3.

Table 3 Case Studies Indirect Inspection Step Data

Case #	INDIRECT INSPECTION Total # of Indications	Total # of Minor Indications	Total # of Moderate Indications	Total # of Severe Indications
1	111	105	6	0
2	127	117	6	4
3	0	0	0	0
4	1	1	0	0
5	32	32	0	0
6	0	0	0	0
7	0	0	0	0
8	0	0	0	0
9	1	1	0	0
10	49	49	0	0
11	94	89	4	1
12	25	19	4	2
13	4	4	0	0
14	92	75	17	0
15	27	0	26	1
16	72	0	69	3
17	34	30	3	1
18	81	27	45	9
19	107	75	26	6
20	85	79	5	1
Total	942	703	211	28

2.3. Direct Examination Step

The objectives of the Direct Examination Step are to determine which indications from the Indirect Inspection Step are most severe and collect data to assess corrosion activity. The Direct Examination Step requires excavations to expose the pipe surface so that measurements can be made on the pipeline and in the immediate surrounding environment. The Direct Examination Step was performed following the guidelines from NACE Standard SP0502 and the pipeline operator procedures. The prioritization of indications was completed and a list of sites for excavation and direct examination was determined for each case. Prioritization is the process of estimating the need for direct examination based on the likelihood of current corrosion activity plus the extent and severity of prior corrosion.

Indications may be prioritized as: for “Immediate action required”, which includes the indications that the pipeline operator considers as likely to have ongoing corrosion activity and that, when coupled with prior corrosion, pose an immediate threat to the pipeline under normal operating conditions; as for “Scheduled Action Required”, which includes the indications that the pipeline operator considers may have ongoing corrosion activity but that, when coupled with prior corrosion, do not pose an immediate threat to the pipeline under normal operation conditions; and indications “Suitable for monitoring”, which include indications that the pipeline operator considers inactive or as having the lowest likelihood of ongoing corrosion or prior corrosion activity.

A total of one hundred and twenty one (121) direct examinations were completed as part of the application of the ECDA methodology on the 20 pipe segments, which represents and average of 6 direct examinations per case study. Of the total number of indications, seventy nine (79) were conducted over indications identified during the Indirect Inspection Step; this represents 65.3% of the total direct examinations. The additional forty two (42) direct examinations (34.7% of the total direct examinations) are associated with first time application and process validation requirements (part of the post assessment).

A total of twenty six (26) direct examinations were completed over indications prioritized as for immediate action required, which represents 21.5% of the total number of direct examinations. Pitting corrosion (with measurable wall loss) was identified in eight (8) of the sites excavated for direct examination. The detailed information of this findings and its comparison with the prediction from the indirect inspection tools will be presented in a future article (Part 2) of this study.

A significant fact obtained during the application of ECDA on this pipe segments, is that anomalies were found on all the direct examinations conducted at sites where the indirect inspection tools identified indications. The corresponding Direct Examination Step data is presented in Table 4.

Table 4 Case Studies Direct Examination Step Data

	DIRECT EXAMINATION (DE)							
				Total # of DE where corrosion was found				
Case #	Total # of Direct Examinations	Total # of DE at Indications	Total # of DE where holiday(s) were found	Pitting	General	Total # of DE at Immediate Indications	Total # of DE at Scheduled Indications	Total # of DE at Monitoring Indications
1	5	4	4	0	0	0	3	1
2	10	8	9	2	1	4	4	0
3	4	0	0	0	0	0	0	0
4	4	1	0	0	0	0	0	1
5	5	4	4	0	0	0	0	4
6	4	0	0	0	0	0	0	0
7	4	0	0	0	0	0	0	0
8	4	0	0	0	0	0	0	0
9	8	1	1	0	0	0	0	1
10	4	3	3	0	0	0	0	3
11	8	7	7	0	0	1	2	4
12	4	3	3	0	0	0	3	0
13	4	3	3	0	0	0	0	3
14	4	3	3	1	0	0	3	0
15	5	4	4	0	0	1	3	0
16	7	6	6	0	0	3	3	0
17	9	7	7	0	0	1	4	2
18	13	12	12	0	0	9	3	0
19	10	9	9	1	0	6	3	0
20	5	4	4	4	0	1	3	0
Total	121	79	79	8	1	26	34	19

2.4. Post Assessment Step

The objectives of the Post Assessment Step are to define the reassessment intervals and assess the overall effectiveness of the ECDA process. The reassessment intervals were determined following the guidelines presented in NACE Standard SP0502. When corrosion defects where found during direct examinations, the maximum reassessment interval for each ECDA region was taken as one-half of the calculated remaining life. If no corrosion defects were found, no remaining life calculation was needed and the remaining life of the pipeline segment was taken as the same as for a new pipeline. However, state and federal regulations in the USA specifies maximum reassessment intervals based on the pipeline’s operating stress and the product transported. The reassessment interval adopted on all the case studies was the lesser of the two and in all, except one case, the reassessment interval adopted was the established by the regulatory entity.

In relation to the effectiveness of the ECDA process, on all 20 cases the direct examination results were consistent with the indication severity classification and prioritization established during the Indirect Inspection Step. No indication prioritized as for “Scheduled action required” presented a higher likelihood for ongoing corrosion than an indication prioritized as for “Immediate action required” for each individual case study. The excavations and direct examinations conducted at process validation digs did not identify anomalies on the pipe.

Corrosion was not observed on every indication prioritized as for “Immediate action required”, which indicates the conservatism of the models used to classify and prioritized the indications. However, because ECDA is a continuous improvement process, through successive applications the classification and prioritization criteria may be optimized to increase the effectiveness of the ECDA process. The corresponding Post Assessment Step data is presented in Table 4.

Table 4 Case Studies Direct Examination Step Data

Case #	POST ASSESSMENT			
	Calculated Remaining Life (Years)	Re-assessment Interval Adopted (Years)	Half of Remaining Life	ECDA Effectiveness
1	Design	15		✓
2	132	10		✓
3	Design	20		✓
4	Design	20		✓
5	Design	20		✓
6	Design	20		✓
7	Design	20		✓
8	Design	20		✓
9	Design	5		✓
10	Design	5		✓
11	Design	20		✓
12	Design	10		✓
13	Design	20		✓
14	17.7	8.8	✓	✓
15	Design	20		✓
16	Design	15		✓
17	Design	20		✓
18	Design	20		✓
19	156.9	20		✓
20	23.2	5		✓

3. Findings and Conclusion

The historical review of the data associated with the application of the ECDA methodology over 20 pipeline segments, indicates the effectiveness of ECDA in identifying and differentiating areas that are likely to have ongoing corrosion activity and pose an immediate integrity threat, areas that may have ongoing corrosion activity but do not pose an immediate integrity threat, and areas having the lowest likelihood of ongoing corrosion or prior corrosion activity.

The application of the ECDA process allows pipeline operators to improve the understanding of the external corrosion mechanism affecting their line and also allows the safe and cost effective operation of the pipelines. The analysis and comparison of historical data from the Pre assessment, with the data collected during the Indirect Inspection and Direct Examination steps is consistent and validates the application of the ECDA methodology on all 20 case studies.

As seen in Table 1, the data associated with the piping segments part of this study, indicates the wide range for application of this integrity assessment tool. Pipelines with nominal pipe sizes from 2 and up to 24 inches; different vintages, from the 1950's and up to 2004 and also different coatings systems, fusion bonded epoxy, polyethylene tape, coal tar enamel and extruded polyethylene were part of the study.

The selection of CIS and DCVG as the principal tools for locating and prioritizing indications proved to be effective; all direct examinations conducted on areas where an indication was reported showed the exposed steel. In the next article (Part 2 of this study) a detailed comparison of the indirect inspection results and the direct examination will be presented. Not all indications were associated with holidays, some were related to bare fittings and other anomalies connected to the pipeline.

The application of the ECDA methodology identified additional integrity threats such as mechanical damage. The Direct Examination Step identified mechanical damage (e.g. dents, gauges and lamination). Stray current interference was also identified in one of the case studies.

The historical review and analysis of the ECDA results indicates the reliability of the tool as an integrity assessment methodology. It was applied under a great number of different piping configurations (e.g. dynamic stray current, congested right of ways, galvanic and impressed CP systems) and proved to be effective in identifying and prioritizing the pipeline integrity threat.

The results of the ECDA process will be improved in the future as the application of the indirect inspection tools is improved and new technology is made available.

4. References

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