

Cased Pipe Risk Assessment and Inspection Technologies

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Background

- Differences between Cased Pipe & Line Pipe
 - Corrosion is a different time-dependent threat inside a casing
 - Time independent threats might be lower inside a casing
 - ECDA difficult to apply inside a casing
- Risk is a basis to compare cased and uncased pipe allowing resource optimization

Vision for Cased Pipe Integrity Assurance Model

- Operators are collecting data on cased pipe
- Need to separate casings into categories on basis of threat or risk
- Cased Pipe Integrity Assurance model designed to be
 - Thorough and defensible to regulators
 - Flexible to allow for available data
 - Conservative and able to accommodate input by SMEs
 - Robust

PHMSA 'Serious' Incident Data

- Avoidance of threats (gas transmission)
 - Third party damage (34.4% of all incidents)
 - Other external forces plus natural forces (4.6%)
 - Material failure (10.6%)
 - some of these would be avoided since activation requires external force
- Cased pipe might be ~40% lower PoF than uncased

Specific Threats by Category

Category	Example
Time Dependent	<u>External Corrosion</u> , Internal Corrosion, <u>SCC</u> , Erosion, <u>Fatigue</u>
Static or Resident	<u>Manufacturing</u> , <u>Welding/Fabrication</u> , and <u>Equipment Defects</u>
Time Independent or Random	<u>Mechanical Damage</u> , Incorrect Operations, Weather and <u>Outside Forces</u>

Cased Pipe Integrity Assurance Model

- Objective
 - Develop an overall risk assessment algorithm to support risk and integrity management of encased pipe
- Benefits
 - Allow threats within casings to be evaluated differently than threats outside of casings; helps to balance opportunity to reduce risk and prioritize threats
 - Provide a means for assessing cased pipe that would otherwise not be possible or would be cost prohibitive
 - Provide a formal, technically defensible consensus-based process for assessing risk on cased pipe

Applicability of Model

1. Low Risk

- Risk insignificant

2. Susceptible

- Work to put casing in 'Low Risk' category
 - Collect additional data to determine if categorization is from uncertainty (i.e., conservative assessment was assumed)
 - Perform action to stop atmospheric or external corrosion
 - Mitigate or eliminate corrosive environment
 - e.g., remove short, dry annulus and repair end seals, use dielectric wax

3. At risk

- Examine or inspect pipe
- Possible repair
- Possible P & M measures
- Mitigate or eliminate corrosive environment

Corrosion Mechanisms in Casings

- Oxygen corrosion in liquid water
- Oxygen corrosion in condensed water
- MIC in liquid water

Estimate Risk Using Prob of Failure & Consequence of Failure

- Utilize three concepts for PoF
 1. Exposure (corrosivity) = *likelihood of an active pipe failure reaching the pipe when no mitigation applied*
 2. Mitigation (CP and Coatings) = *reduces likelihood or intensity of the exposure reaching the pipe; keeps mechanism off the pipe*
 3. Resistance (Pipe Wall Thickness and/or SMYS) = *ability to resist failure given presence of exposure/threat*
- Probability of Damage (PoD) determined by #1 and #2
- Probability of Failure (PoF) determined by PoD and #3
- $\text{Risk} = \text{PoF} \times \text{CoF}$

The Cased Pipe Integrity Assurance Process



The Result: Calculate Risk from PoF and CoF for Each Casing

Microsoft Excel - Casing Risk v5.4.xls

FileEditViewInsertFormatToolsDataWindowHelp

Type a question for help

85%

Arial

10

B I U

Security...

Reply with Changes... End Review...

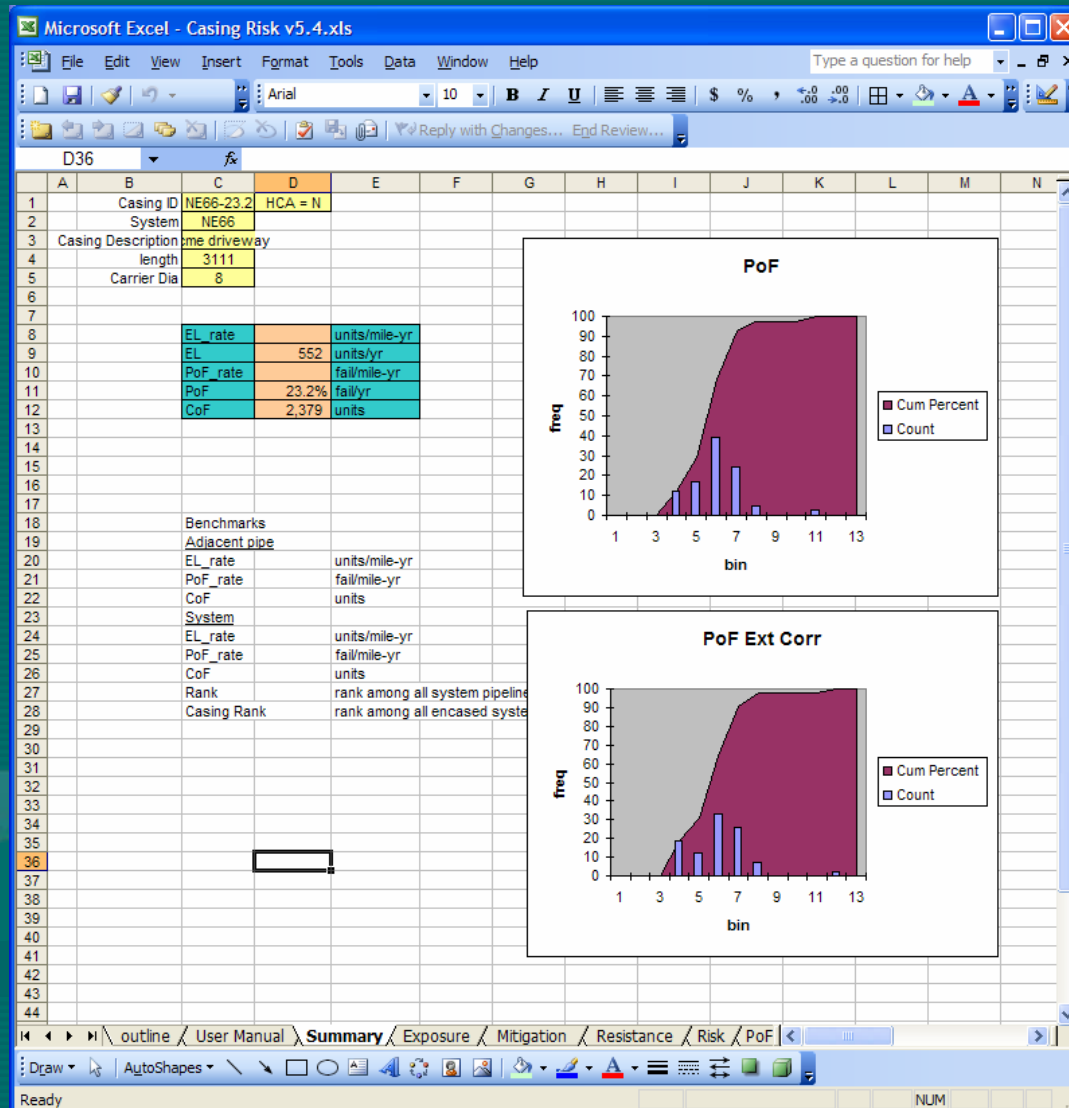
C4

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
2					Min	58	0	0.034705	1,667	0.2%	1.3%	0.002%	0.002%	0.002%	0.8%	0.002%	0.002%	11,080	1,480						
3					Avg	2,392	0	0.256876	9,909	16.9%	5.8%	0.03%	0.03%	0.03%	6.0%	0.03%	0.03%	48,928	7,739						
4					Max	12,412	0	0.934479	22,245	88.1%	42.3%	0.12%	0.12%	0.12%	80.0%	0.12%	0.12%	109,400	13,300						
5									CoF	PoF															
6	System	Segment	Length	HCA	EL_rate	EL	PoF_rate	PoF	composite	ext corr	int corr	thd pty	weather	geohaz	fatigue	SCC	IncOps	rupture	pinhole	PIR (NOP)					
			ft		units/mil e-yr	units/yr	fail/mile- yr	fail/yr	conseq units	fail/yr	fail/yr	fail/yr	fail/yr	fail/yr	fail/yr	fail/yr	fail/yr	conseq units	conseq units	ft					
8	NE12	NE12-44.1	234	Y		3,004		18.0%	16,673	11.1%	3.4%	0.00%	0.004%	0.004%	4.5%	0.00%	0.00%	67,820	10,990	135.2					
9	NE12	NE12-67.9	100	Y		12,412		93.4%	13,282	88.1%	42.3%	0.00%	0.002%	0.002%	4.5%	0.00%	0.00%	67,820	10,990	85					
10	NE12	NE12-82.6	234	N		2,878		70.5%	4,082	58.2%	18.2%	0.00%	0.004%	0.004%	13.8%	0.00%	0.00%	27,820	2,990	63.5					
11	NE12	NE12-71.2	244	N		1,198		37.5%	3,191	31.5%	6.7%	0.00%	0.005%	0.005%	2.3%	0.00%	0.00%	18,910	2,495	85					
12	NE12	NE12-13.7	267	N		3,296		26.6%	12,391	20.9%	6.1%	0.01%	0.005%	0.005%	1.3%	0.01%	0.01%	58,910	10,495	136.3					
13	NE12	NE12-3.8	292	N		2,999		24.5%	12,243	19.5%	5.4%	0.01%	0.006%	0.006%	0.8%	0.01%	0.01%	57,425	10,413	150					
14	NE12	NE12-21.1	319	N		745		24.5%	3,043	19.1%	5.0%	0.01%	0.006%	0.006%	1.8%	0.01%	0.01%	17,425	2,413	163.3					
15	NE12	NE12-85.5	348	N		672		17.8%	3,785	13.9%	3.6%	0.01%	0.007%	0.007%	0.8%	0.01%	0.01%	24,850	2,825	175					
16	NE12	NE12-59.1	380	N		3,064		19.5%	15,686	15.2%	4.2%	0.01%	0.007%	0.007%	0.9%	0.01%	0.01%	64,850	10,825	163.3					
17	NE12	NE12-74.2	414	N		628		17.8%	3,536	13.3%	3.6%	0.01%	0.008%	0.008%	1.6%	0.01%	0.01%	19,850	1,825	175					
18	NE12	NE12-18	452	N		269		7.6%	3,536	0.7%	4.2%	0.01%	0.009%	0.009%	2.8%	0.01%	0.01%	19,850	1,825	163.3					
19	NE12	NE12-62.2	494	N		1,026		6.5%	15,686	0.9%	3.6%	0.01%	0.009%	0.009%	2.2%	0.01%	0.01%	64,850	10,825	175					
20	NE12	NE12-67.3	539	N		1,246		7.9%	15,686	1.1%	4.2%	0.01%	0.010%	0.010%	2.8%	0.01%	0.01%	64,850	10,825	163.3					
21	SW44	SW44-9	588	N		1,050		6.7%	15,686	1.0%	3.6%	0.01%	0.011%	0.011%	2.2%	0.01%	0.01%	64,850	10,825	175					

outline / User Manual / Exposure / Mitigation / Resistance / Risk / PoF / Data / equations / equat-old / variables / VBA / ROC / sample / data2

ReadyNUM

Explore Relative Risk of Single Casing Compared to Others

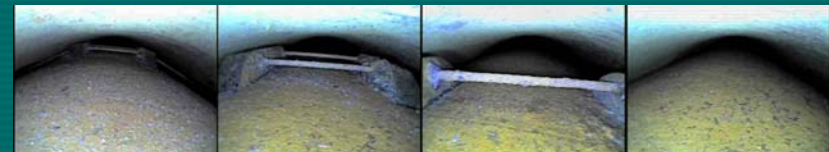


Status of Cased Pipe Integrity Assurance Model

- WKM/Muhlbauer and CCT/DNV completed model in 2009
- Spreadsheet deliverable and user manual provided to funders
- User-friendly graphical version of model available through licensed commercializer; New Century Software
(rich.arata@newcenturysoftware.com)
- NYSEARCH funders working on independent validation (by WKM) of model based on casing job data

Annular Space Direct Inspection Robot

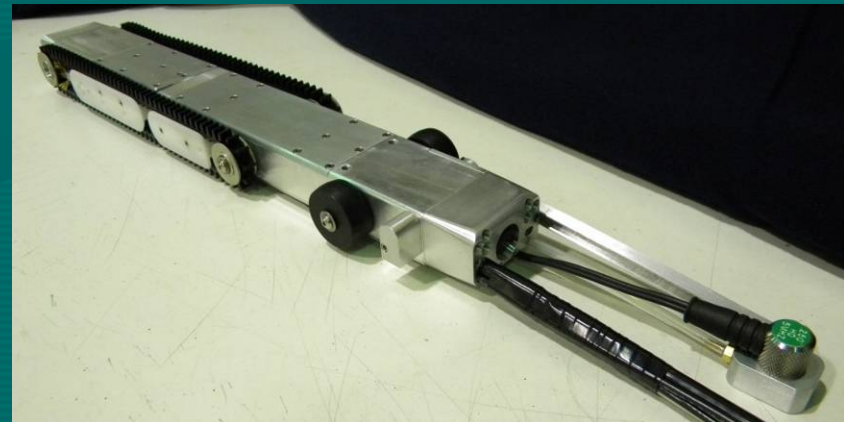
- Purpose: To develop a platform for inspection of the carrier pipe in the annular space
- Ph I: development, testing & implementation of visual inspection camera
- Video Inspection can provide data
 - Integrity of Coating
 - Physical placement & condn of insulators
 - Presence of Electrical contacts
 - Environmental Conditions
 - Risk Assessment



Casing Camera passing over casing spacer

Annular Space Direct Inspection Robot

- Phase II Objectives
 - Enhance System Reliability and Availability
 - Develop functionality to assess carrier pipe integrity
- Phase II system enhancements include:
 - Spot pipe wall thickness measurement sensor
 - Humidity sensor for direct readings of humidity level inside the casing
 - Inclinometer for on screen display of radial positioning
 - Video measuring tool for precision measurement of features and defects



Development Status of Annular Space

Direct Inspection Robot

- Field test inspections continue with first generation robot
- Additional prototypes available to accommodate more jobs and spares
- Ultrasonic metal loss sensor, moisture sensor and inclinometer developed and tested in lab; field testing pending
- Commercial service offering is likely to be available in 2010; currently assessing market interest



Overall Data Collection Efforts related to Projects & Casings

- ILI data, casing inspection data, casing history and construction information being collected where possible
- Direct information from Annular Space Inspection Robot can also provide condition of coating, location/position of spacers, presence of moisture and location of anomalies
- Direct information from robot can be used to complement other information

Overall Data Collection Efforts related to Projects & Casings (cont.)

- Through scientific methods established by CCT/DNV, we are quantifying the boundaries of corrosion rates in annular space (Corrosion Rate Estimation Project)
 - Benchscale testing
 - Full laboratory testing
 - NYSEARCH/NGA test bed controlled tests
 - Member field tests
- All this information can further substantiate calculations made through cased pipe integrity assurance model

Summary

- The external corrosion threat on pipelines differs when the pipe is within a casing
- The principles of corrosion and risk are the same both inside and outside of the casing
- Methods are being developed that apply existing tools to cased pipelines
- Inspection tools are being developed that can navigate in the annular space