Spectra Energy Gas Transmission

Metallurgical Services & Quality Assurance

Date: November 8, 2012

Subject: 2012 Annual Review of Spectra Energy's Hard Spot IMP Program

To: Distribution

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Conclusions

- In total 558.01 miles of pipeline have been assessed since 2004, of which 307.29 miles were considered to have high risk for hard spots based on manufacturer, diameter and vintage. With the exception of the Owingsville Line 15 failure in 2003, the hard spot features that have been detected and examined did not have any cracking, and had no interaction with mid-wall laminations.
- In general, the hard spot tool data demonstrated good agreement with the properties measured during bellhole excavations. Only one hard spot had hardness properties above 300 Brinell (308 Brinell). This hard spot was repaired with a steel sleeve per Spectra Energy procedures. All other hard spots had hardness properties below 300 Brinell, and were recoated and backfilled.

Recommendations

- Perform ILI hard spot assessment of Danville Line 15 in 2013
- Add ILI hard spot assessments for Five Points Line 3, Lebanon Line 3 and Transition to Thomaston Line 21 to the assessment plan for 2013.
- Perform excavations in 2013 at 2 locations on Kosciusko Line 15 where hard spots with estimated hardness properties of 312 Brinell were discovered on a 2011 ILI hard spot assessment.
- Hard spot ILI assessments are recommended for Barton Line 15, Gladeville Line 15, Danville Line 15, Lufkin Line 11 and Thomaston Line 21. These assessments may be performed at their next scheduled HRMFL tool run date. The results of all hard spot assessments should be used to determine if Athens Line 15 and Holbrook Line 15 require a hard spot ILI.
- Evaluate the relationship between plate supplier, pipe manufacturer, diameter and vintage. Research Moody reports to study this material. This research may result in improvement to the management of risk associated with hard spots and influence future ILI hard spot tool planning and scheduling.

Background

Spectra Energy's Integrity Management Plan (IMP 511 "Hard Spots") has been in effect since 2004. Spectra Energy (DEGT at the time) initiated the hard spot management program in response to a service failure that occurred November 2, 2003, in the 30" Texas Eastern Line 15, downstream of the Danville discharge at Mile Post 501.76 (26493+05). This failure was attributed to a hard spot that had interacted with a lamination. A hard spot is a localized region of the pipe that has high hardness properties due to accidental localized quenching during manufacturing of the steel plate. Hardness greater than 300 Brinell is generally considered high enough to be susceptible to cracking, with the primary risk associated with hydrogen induced cracking. As a result, hard spots are manufacturing defects that have been in service since original construction.

Spectra Energy's IMP program involves the assessment of the Spectra Energy system for pipe that has an elevated risk for hard spots, assessment of in-line inspection (ILI) tools for detection of hard spots, ILI assessment of selected segments with a hard spot tool, assessment of the ILI results, bellhole assessment of selected anomalies, and review of the results. IMP 511 details the assessment of materials that have a history of hard spot failures, and it was concluded that the highest risk for structurally significant hard spots was related to pipe produced by A.O. Smith between 1952 and 1958. Assessment of ILI technology concluded that Tuboscope's Linalog HRMFL tool with hard spot package had satisfactory performance for hard spot detection with an accuracy of +/- 50 Brinell. See Appendix A. The first run with the tool was performed on Owingsville to Wheelersburg Line 15 in 2004. Two sections of pipe with hard spots were excavated, removed from service and shipped to Spectra Energy's Metallurgical Lab in Houston for assessment. PHMSA representatives were invited to observe laboratory testing using field hardness testing techniques (Tellebrineller and Microdur ultrasonic impedance hardness testing). Each hard spot was assessed for location, hardness, presence of cracking using magnetic particle inspection (MPI), and the presence of laminations using straight beam ultrasonic inspection. Three hard spots were selected for metallurgical cross section and microhardness testing, and the results confirmed that the ILI tool and field hardness testing methods were in agreement with the microhardness testing values.

Since the initial hard spot assessment work in 2004, the ILI response and bellhole assessment methodology has been incorporated in SOP 9-4050 "Miscellaneous Defects". See Appendix B for details. At this time, hard spot ILI runs have been performed on the following lines:

- Owingsville to Wheelersburg Line 15
- Egypt to Barton Line 15
- Mt. Pleasant to Gladeville Line 15
- Lambertville to Stony Point M/L
- Wheelersburg to Athens Line 15
- Huntsville to Lufkin Line 11
- Kosciusko to Egypt Line 15
- Tompkinsville to Danville Line 15
- Berne to Holbrook Line 15

Tuboscope has since changed to NDT Systems and Services. Two runs have been performed successfully with NDT. In total 558.01 miles of pipeline have been assessed, of which 307.29 miles were considered to have high risk for hard spots based on manufacturer and vintage. With the exception of the Owingsville Line 15 failure, the hard spot features that have been detected and examined did not have any cracking, and no interaction with mid-wall laminations. Only one hard spot had hardness above 300 Brinell (308 Brinell), and was repaired with a steel sleeve per Spectra Energy procedures. All other hard spots were recoated and backfilled.

2012 Hard Spot ILI Assessments

In 2012, ILI was performed on Berne to Holbrook Line 15. No hard spot anomalies were reported. As a result, no excavations for hard spots were performed.

2013 Hard Spot Assessments

Kosciusko Line 15 Excavations - Two excavations are planned for 2013 on Kosciusko Line 15 in response to the 2011 hard spot tool run. One excavation is a hard spot at WC 292920.933 (Category 3, estimated hardness 312 Brinell). The second excavation is a possible hard spot (Category 3, estimated hardness 312 Brinell) at WC395721.808. All of the reported hard spots were in areas outside of HCAs.

ILI Hard Spot Assessments in 2013 – Table 2 shows the planned 2013 ILI assessments. A hard spot tool run is currently scheduled for Danville Line 15. Review of the remaining runs has identified 3 segments with significant A.O. Smith pipe of 1950's vintage:

- Five Points Line 3 (46.09 miles of 26" OD pipe manufactured in 1951)
- Lebanon Line 3 (52.88 miles of 26" OD pipe manufactured in 1951)
- Transition to Thomaston Line 21 (32.09 miles of 16" OD pipe manufactured in 1953)

Review of industry incidents indicates that the highest risk pipe materials have the following characteristics:

- Diameter between 20" and 30"
- Pipe manufactured between 1952 and 1958
- Pipe manufactured by A.O. Smith

Based on these considerations, Five Points Line 3 and Lebanon Line 3 were manufactured outside of the high risk time period. Thomaston Line 21 was manufactured in the high risk time period, but is outside of the high risk size range. Further review of the manufacturing date risk indicates that Five Points Line 3 and Lebanon Line 3 should be considered high risk and scheduled for ILI. The OD of Thomaston Line 21 is below the high risk range in IMP 511. Given that the pipe was manufactured in 1953, it is recommended that Thomaston Line 21 should be considered high risk and scheduled for ILI. Further assessment of Moody reports and documentation is being performed by Metallurgical Services to determine if additional information that may influence the recommendation is available for Thomaston Line 21.

Hard Spot ILI Assessments After 2013

Review of Line 15 data indicates that the following segments have not been assessed:

- Barton Line 15 - 40.25 miles of 1957 A.O. Smith 30"OD
- Gladeville Line 15 – 14.74 miles of 1957 A.O. Smith 30"OD
- Danville Line 15 – 28.04 miles of 1957 A.O. Smith 30"OD
- Athens Line 15 – 0.05 miles of 1958 A.O. Smith 30"OD
- Holbrook Line 15 – 4.44 miles of 1957 A.O. Smith 30"OD
- Lufkin Line 11 – 33.59 miles of 1953 A.O. Smith 24" OD
- Thomaston (to Provident City) Line 21 – 32.09 miles of 1953 A.O. Smith 16" OD

Hard spot ILI assessments are recommended for Barton Line 15, Gladeville Line 15, Danville Line 15, Lufkin Line 11 and Thomaston Line 21. The results of all hard spot assessments should be used to determine if Athens Line 15 and Holbrook Line 15 require hard spot ILI.

Metallurgical Services has been discussing hard spot ILI experience with other operators, and is in the process of assessing GE's hard spot tool capabilities. See Appendix B for vendor information. It should be noted that the GE hard spot tool requires two runs. One run to magnetize the pipeline, and one run to detect elevated residual magnetism indicative of a hard spots. The NDT tool is performed in one run in combination with the HRMFL tool. The NDT tool loses the ID/OD discrimination capability when the hard spot package is added to the HRMFL tool.

Final Comments

Going forward, a memo documenting the annual review of the hard spot program will be issued.

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Discharge	Line	OD	Date	Report Number	A.O. Smith In-Service Date	Miles of Pipe	% A.O. Smith on Discharge	ILI Predicted Hardness (Brinell Scale) 200 to 300	301 to 400	Other	Bellhole Inspection Results Maximum Hardness (Brinell)	MPI	Lamination Interaction	Repair
Owinsville to Wheelersburg	15	30	7/3/2004	6584.01	1958	24.76	39.94%	11	0	0	255	No Cracks	None	Recoat
Egypt to Barton	15	30	4/26/2005	10008.01	1957	60.24	84.31%	4	0	0	265	No Cracks	None	Recoat
Mt. Pleasant to Gladeville	15	30	4/29/2005	10008.02	1957	54.05	63.57%	5	2	0	200	No Cracks	None	Recoat
Lambertvile to Stony Point	M/L	26	5/31/2006	12186.01	1962	1.06	2.68%	2	0	0	298	No Cracks	None	Recoat
Wheelersburg to Athens	15	30	7/9/2008	10611.01 and 14611.01	1957	29.57	56.55%	0	0	0	NA			No Excavation Required
Huntsville to Lufkin	11	30	7/20/2005	10015.01	1953	31.93	52.03%	0	0	0	NA			No Excavation Required
Kosciusko to Egypt	15	30	7/15/2011	70158.01	1957	63.32	79.43%	34	1	6*				2013 Excavation
Tompkinsville to Danville	15	30	4/5/2011	70130.01	1957	40.39	53.55%	14	2	0	308	No Cracks	None	Recoat
Berne to Holbrook	15	30	5/6/2012	70320.01	1957	1.97	4.05	0	0	0	NA			No Excavation Required

Table 1: Hard spot Assessments performed up to 2012.

Region	Area	Bus Unit	Proj Mgr	Caliper Insp Company	MFL Insp Company	ILI Segment ID	Length	OD	AO Smith	Date Constructed	Line #	OD
SE	Baytown	TETLP	Liles			ANGL_2-A-1	3.00	---	---	---	2-A-1	8
NE	Westwood	AGT	Bradley			JSYS_J-1_SEC1	9.98	24 & 26	2.49 miles	1953	J-1	24/22/26
C	Stanford	TETLP	Kutschinski			ATHE_25	56.75	---	---	---	25	36
NE		MNC	Bradley			GOLD_SJLT_SEC1	17.24	---	---	---	SJLT	16
NE		MNC	Bradley			GOLD_SJLT_SEC2	2.29	---	---	---	SJLT	16
NE		MNC	Bradley			GOLD_BRDR_PTLA_SEC1	10.66	---	---	---	PTLA	8
C	Lebanon	TETLP	Kutschinski			BATE_1	54.69	24	23.33 miles	1943, 1958	1	24
NE	Eagle	TETLP	Bradley			BECH_27	39.99	---	---	---	27	36
NE	Eagle	TETLP	Bradley			BERV_BECH_19	69.33	---	---	---	19	30
NE	Cromwell	AGT	Bradley			BURR_M/L	35.16	24	2.7		M/L	24
NE	Eagle	TETLP	Bradley			CJCT_1-A-1	6.28	---	---	---	1-A-1	14/16/14
SE	Clinton	TETLP	Liles			CLIN_18	58.97	---	---	---	18	30
NE	Cromwell	AGT	Bradley			CSYS_C-7	1.18	---	---	---	C-7	12
C	Stanford	TETLP	Kutschinski			DANV_15 (MFL + Hard Spot Tool)	75.05	30	28.04 miles	1957	15	30
NE	Chambersburg	TETLP	Bradley			ENTR_27	26.90	---	---	---	27	36
C	Lebanon	TETLP	Kutschinski			FIVE_2	48.11	---	---	---	2	20
C	Lebanon	TETLP	Kutschinski			FIVE_3	48.16	26	46.09 miles	1951	3	26
SE	Lake Charles	TETLP	Liles			GILL_18	62.72	---	---	---	18	30
NE	S. Plainfield	AGT	Bradley			HANA_M/L		26	30.84 miles		M/L	26
SE	Portland	TETLP	Liles			HEMP_11-O	1.65	---	---	---	11-O	12
SE	Baytown	TETLP	Liles			HUNT_11-AUX-2	0.16	---	---	---	11-AUX-2	16
SE	Baytown	TETLP	Liles			JOQN_11-AUX-1		---	---	---	11-AUX-1	16
SE	Portland	TETLP	Liles			KARO_22	52.96	14	0.02	1953	22	14
SE	Clinton	TETLP	Liles			KOSC_25	50.71	---	---	---	25	30
NE	S. Plainfield	AGT	Bradley			LAMA_L30A/L30B	83.484	---	---	---	L30A/L30B	30
NE	S. Plainfield	AGT	Bradley			LAMA_M/L		26	1.06	Unk	M/L	26
C	Lebanon	TETLP	Kutschinski			LEBA_2	57.87	---	---	---	2	20
C	Lebanon	TETLP	Kutschinski			LEBA_3	57.83	26	52.88 miles	1951	3	26
SE	Baytown	TETLP	Liles			LGVW_1-N_SEC2	21.57	---	---	---	1-N	10.75
NE	Chambersburg	TETLP	Bradley			LILL_28	4.21	---	---	---	28	36
SE	Baytown	TETLP	Liles			LUFK_11-AUX-1	1.10	---	---	---	11-AUX-1	12
NE	Eagle	TETLP	Bradley			MARI_1	47.84	---	---	---	1	36
C	N Little Rock	TETLP	Bell			NLRK_1	54.93	---	---	---	1	24
SE	Portland	TETLP	Liles			PRCY_11-AUX-1		---	---	---	11-AUX-1	16
SE	Portland	TETLP	Liles			PRCY_17	46.55	24	1.46 miles	1957	17	24
NE	Eagle	TETLP	Bradley			SHER_28	14.63	---	---	---	28	36
C	Fort Smith	TETLP	Bell			SRCY_1	127.52				1	20
SE	Opelousas	TETLP	Liles			STFR_31	22.11	---	---	---	31	36
C	Abingdon	ETNG	Kutschinski			BOYD_3305A-100	8.05	---	---	---	3305A-100	12
SE	Portland	TETLP	Liles			THOM_21 (Transition to Thomaston)	32.19	16	32.1	1953	21	16
SE	Portland	TETLP	Liles			TRNS_22	24.05	14	1.54	1953	22	14
SE	Clinton	TETLP	Liles			UCHC_18	64.37	---	---	---	18	30
NE	Uniontown	TETLP	Bradley			UNIO_1	62.52	---	---	---	1	36
C	Tuscumbia	ETNG	Bell			LOBE_3200-1_SEC3	30.61	12.75	26.76 miles	1950	3200-1	12
C	Fort Smith	OGT	Bell			LEQU_1	25.73				1	20
C	Abingdon	ETNG	Kutschinski			GLDE_3700-1	31.24				3700-1	20
NE	Uniontown	TETLP	Bradley			UNIO_2	59.05	---	---	---	2	36
C	N Little Rock	TETLP	Bell			WALN_1	52.58				1	24
C	Tuscumbia	ETNG	Bell			LOBE_3200-1_SEC2	26.52	16	38.59	1950	3200-1	16
SE	Opelousas	TETLP	Liles			WMON_26	53.08	---	---	---	26	20
C	Abingdon	ETNG	Kutschinski			WART_3100-1-2	11.61	---	---	---	3100-1/3100-2	16

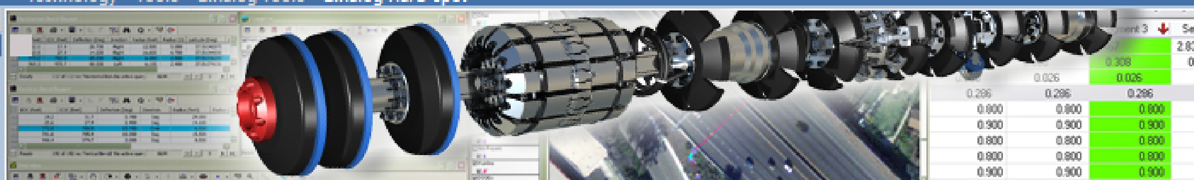
Table 2: The planned ILI runs for 2013.

Appendix A – NDT Hard Spot Tool Overview and Specifications

NDT Systems & Services

Company | NDT Systems | NDT Services | Contact | Info | Impressum

>> Technology > Tools > Linalog Tools > **Linalog Hard Spot**



Linalog® Hard Spot

Hard spots caused by local quenching, cold working and welding are areas of elevated hardness in relation to the surrounding pipe surface. They have high coercivity and a high saturation point, which means they are harder to magnetize and demagnetize than normal pipe steel. It is this physical characteristic which the Hard Spot tool exploits to survey the pipeline by comparing data collected by corrosion hall sensors in the active magnetic field and data collected by the trailing residual field hall sensors.

There are three commonly accepted mechanisms that lead to the condition known as localized hard spots within a section of pipe.

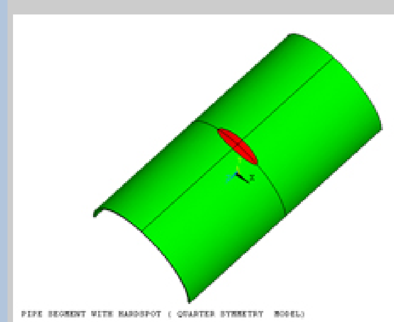
Local quenching - caused in the pipe mill where localized areas of heated steel in the austenitic state are quenched by uncontrolled cooling water at an accelerated rate versus the surrounding plate steel in the same state forming localized regions of marten site. Typically found in certain mills during the 1950's and 1960's.

Cold working - steel is stressed beyond its elastic limit and the shape of the material is deformed permanently. This can be caused by Expander Marks created during the rounding process by pressure from the expanding machine mandrel, during the formation of Field Bends where work hardened areas are created by the mandrel during the bending process and by Mechanical Damage such as gouging.

Welding - superheating of the pipe surface may be caused by arc burns. Although the mechanisms involved in the creation of residual stresses in mill (quenched) hard spots, cold working (plastic deformation) and HAZ (localized superheating) are different, all exhibit a measurable coercivity that is greater than within the surrounding parent metal. As a consequence, all are readily detected by the hard spot inspection tool.

Quick Info:

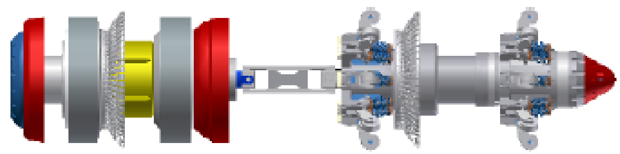
API specification 5L section 9.10.6 defines a repairable hard spot as an area greater than 2 inches (50mm) in any direction with a hardness greater than or equal to 327 Brinell, 35 Rockwell C, or 345 Vickers. NDT typically reports hardness over 250 Brinell in bands of 50 Brinell.



Pipe Segment with Hard Spot (Quarter Symmetry Model)

2 Tool Specifications

30" LINALOG® Max w/INS



387904

Lengths	Imperial (in.)	Metric (mm)
Section 1	55.0	1397
Section 2	66.0	1676

	Imperial	Metric
Overall Tool Length	121.0 in.	3073 mm
Tool Mass	4100 lb.	1860 kg

TYPICAL INSPECTION SPECIFICATION

DETECTION PARAMETERS
(Grading @ 90% Confidence)

Minimum Detectable Thresholds

t < 0.380 in. (10 mm)	= 0.380 in. (10 mm)
t ≥ 0.380 in. (10 mm)	≥ 1t (t = wall thickness)

Dent	1 in. L x 1 in. W	(25 x 25 mm)
Ovality	1 in. L x 2 in. W	(25 x 50 mm)

Minimum Sizeable Depth

Pitting Corrosion	15% Pipe Body	25% HAZ
General Corrosion	10% Pipe Body	20% HAZ
Deformation	0.10 in. (2.5 mm)	

SIZING ACCURACY
(Grading @ 80% Confidence)

Depth	Pitting	General Metal Loss
Pipe Body	± 10%	± 10%
Heat-affected Zone (HAZ)	± 15%	± 15%

Pitting	Length	± 0.25 in. (6.4 mm)
	Width	± 0.75 in. (19 mm)
General Metal Loss	Length	± 0.75 in. (19 mm)
	Width	± 1.00 in. (25 mm)
Deformation	Length	± 0.10 in. (2.5 mm)
	Width	± 1.00 in. (25 mm)

LOCATING ACCURACY

Axial
± 0.3% General
± 1 in. (25 mm) Localized

Circumferential
± 5°

Sensor Count

186 Corrosion
‡ 62 Deformation
62 ID/OD
‡ 186 HardSpot/ Reduced Field

TOOL PARAMETERS

	Imperial	Metric
Temperature Range	32° to 160° F	0° to 71° C
Inspection Speed Range	<0.5 to 9.0 mph	<0.2 to 4.0 m/s
Optimum Speed Range	3.0 to 7.0 mph	1.3 to 3.1 m/s
Maximum Operating Pressure	3250 psi	22.41 MPa

	Time	Distance
Run Duration	210 hr.	210 mi.
		338 km

*Wall Thickness Inspection Range

0.188 in.	To	0.500 in.
4.8 mm	To	12.7 mm

PIPELINE CONDITIONS

Bend (90°)	Back to Back Transition inch	Back to Back Transition mm	Minimum ID in Bend inch	Minimum ID in Bend mm
1.5D	0	0	29.0	737
3D	0	0	26.0	660
5D	0	0	25.5	648

Straight Pipe (Fittings)	25.5	648
Straight Pipe (Continuous)	27.5	699

Comments

*Increased wall thickness inspection available
‡Optional inspection services available

INS/GPS available
Contact NDT Sales person for details

This information is intended for the use of NDT Systems & Services LLC customers only. The above data is standard specification only. If pipeline requirements or conditions are not within these parameters, please contact NDT Systems & Services LLC at 713-799-5430 for specific applications. This information is subject to revision without notice and is not to be construed as a warranty or guarantee of any nature.
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3 Feature Specifications

24" to 42" LINALOG® Max

MFL Table 1 : Identification of Features

Feature	Yes POI>90%	No POI<50%	Maybe 50%<=POI<=90%
Int./ext./midwall discrimination (Not Midwall)	X		
Additional metal / material			
- debris			X
- touching metal to metal			X
Anode			X
Anomaly			
- arc strike			X
- artificial defect	■		
- buckle			▲
- corrosion	X		
- corrosion cluster	X		
- crack			■
- dent			▲
- dent with metal loss			▲
- gouging			▲
- grinding			▲
- girth weld crack			■
- girth weld anomaly	X		
- HIC		X	
- lamination			■
- longitudinal weld crack		X	
- longitudinal weld anomaly	X		
- ovality		X	
- pipe mill anomaly			X
- pipe mill feature anomaly			X
- SCC		X	
- spalling			■
- spiral weld crack		X	
- spiral weld anomaly			X
- wrinkle			▲
Crack arrestor			X
Eccentric pipe casing			X
Change in wall thickness	X		
CP connection			X
External support	X		
Ground anchor			X
Off take	X		
Pipeline fixture	X		
Reference magnet	X		
Repair			
- welded sleeve repair	X		
- composite sleeve repair			X
- weld deposit			X
- coating		X	
Tee	X		
Valve	X		
Weld			
- bend	X		
- diameter change	X		
- wall thickness change (pipe/pipe connection)	X		
- adjacent tapering			X

■ This will be reported as an anomaly but accurate identification depends upon the size and shape of the item.

▲ Mechanical anomalies do not represent simple metal losses and therefore do not lend themselves to definable limits of detection and identification. These anomalies can represent sites of metal displacement, metallurgical changes, and localized work hardening. While mechanical anomalies are typically detected by the NDT system, the primary constituent in setting operating parameters for NDT MFL tools is optimal corrosion detection and characterization.

MFL Table 2 : Detection and Sizing Accuracy for Anomalies in Body of Long Seam Welded Pipe*

	General Metal Loss		Pitting		Axial Grooving		Circumf. Grooving	
Depth at POD = 90%	0.05t		0.08t		0.15t		0.05t	
	80%	90%	80%	90%	80%	90%	80%	90%
Depth sizing accuracy at 80% and 90% confidence	± 0.10t	± 0.13t	± 0.10t	± 0.13t	± 0.10t	± 0.13t	± 0.10t	± 0.13t
Width sizing accuracy at 80% and 90% confidence	± 1.00"	± 1.29"	± 0.75"	± 1.00"	± 0.75"	± 1.00"	± 1.00"	± 1.29"
Length sizing accuracy at 80% and 90% confidence	± 0.75"	± 1.00"	± 0.25"	± 0.32"	± 0.25"	± 0.32"	± 0.25"	± 0.32"

*Specifications for seamless pipe are dependent on the magnitude of the seamless noise.

MFL Table 3 : Detection and Sizing Accuracy in Girth Weld or Heat Affected Zone

	General Metal Loss	Pitting	Axial Grooving	Circumf. Grooving
Depth at POD = 90%	0.20t	0.25t	0.30t	0.20t
Depth sizing accuracy at 80% confidence	± 0.15t	± 0.15t	± 0.15t	± 0.15t
Width sizing accuracy at 80% confidence	± 1.00"	± 0.75"	± 0.75"	± 1.00"
Length sizing accuracy at 80% confidence	± 0.75"	± 0.25"	± 0.25"	± 0.25"

MFL Table 4 : Detection and Sizing Accuracy for Crack or Crack-like Defects

	Axial Crack	Circumf. Crack	Spiral Crack
Depth at POD = 90% of crack with L = 10"	N/A	0.25t	N/A
Minimum crack opening	N/A	0.004"	N/A
Depth sizing accuracy at 80% confidence	N/A	± 0.15t	N/A
Length sizing accuracy at 80% confidence	N/A	± 0.50"	N/A

MFL Table 5 : Detection and Sizing Accuracy for Dents and Ovalities

	Dent	Ovality*
Depth at POD = 90%	N/A	N/A
Depth sizing accuracy at 80% confidence	N/A	N/A
Width sizing accuracy at 80% confidence	N/A	N/A
Length sizing accuracy at 80% confidence	N/A	N/A
Ovality at POD = 90%	N/A	N/A

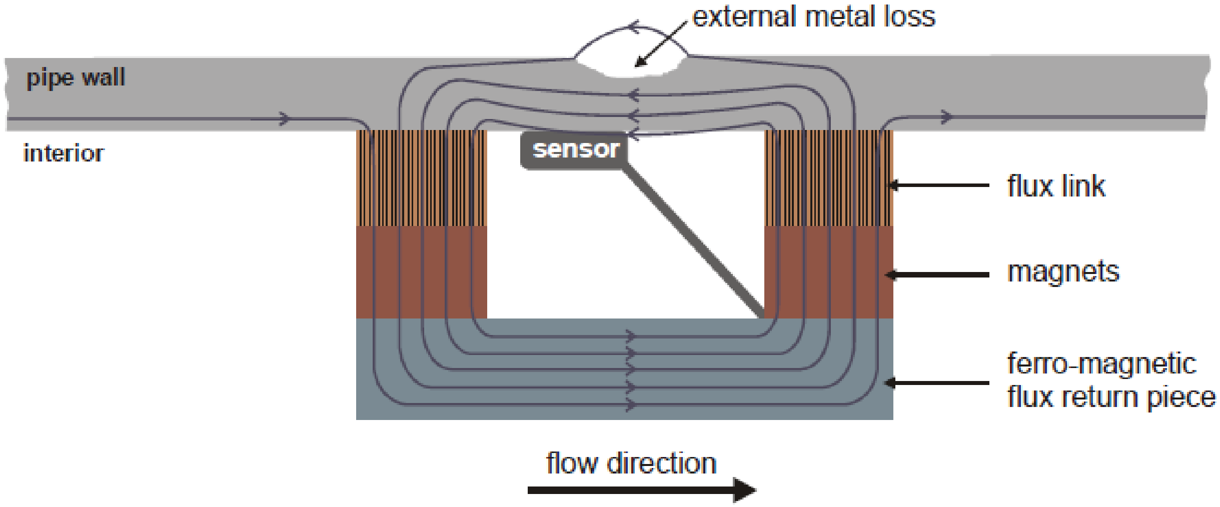
*Ovality = (IDmax-IDmin)/(IDmax+IDmin)

MFL Table 6 : Location Accuracy

	Location
Axial from girth weld	± 1.00"
Axial from marker	± 0.3% distance traveled from marker
Circumferential	± 5° for all tools except for tool statements below; ± 10° for 42" and 28" diameter tools; ± 15° for 30" LF and 40" diameter tools.

4 Notes on MFL Technology

The pipe wall is magnetized in the axial direction with the help of permanent magnets and flux conducting parts. Together with the pipe wall, this builds a magnetic circuit. The capability of the pipe wall to conduct magnetic flux depends on its permeability and its cross section. If the cross section is reduced by metal loss, the flux can no longer be conducted through the steel wall. Instead, a portion of the flux will now be diverted through the ambient non-magnetic medium. This leads to an increased magnetic stray field in the vicinity of the metal loss. The magnetic stray field is measured by a Hall sensor. The Hall sensor is always positioned close to the internal surface of the pipe. The principle of operation is depicted below.



Measurement of the Magnetic Stray Flux at an External Metal Loss

With increasing cross section, i.e. increasing depth and width of the metal loss, more flux is diverted into the ambient space. Hence, a relationship between the magnitude of the stray flux and the geometry of the anomaly can be established. Trial measurements on metal loss anomalies with known size are made in comparable pipe joints. With these measurements, a calibration model is created. Using this model, the results of an inspection run can be used to calculate true flaw profiles for anomalies that the tool has detected.

Flaws may be found on the inside as well as on the outside of the pipe. For both types, a flux increase on the inside is found by the Hall sensor. Additional sensors are used to distinguish between internal and external flaws. This type of magnetic sensor is positioned outside the magnetic circuit and will measure a possible lift-off. If the sensor detects a lift-off, it is concluded that a flaw is found on the internal surface. If no lift-off is detected, although the Hall sensors in the magnetic circuit have found a stray flux, it is concluded that the flaw is external.

Analysis specifications

This technical and commercial proposal is based on the following Standard Analysis Specifications.

Hard Spot

Tool detection & sizing specification

PII offers the following specifications based on previous experience on a reasonable endeavors basis.

Detect hard spots greater than 100 mm (or 4") in diameter with a hardness value greater than 300 brinell, this is relative to a typical parent metal hardness of 150 to 200 brinell.

Sizing accuracy: Length +/- .75"
Width +/- .75"

Deliverables

The final deliverable will consist of the following:

1. Executive Summary
2. A Supplemental Listing of hardspots
3. A Revised features listing with integrated hardspot data.
4. An Extended MFL Hardspot Inspection report with additional chapter on Hardspots

The delivery of this segment is anticipated to be within 3 weeks after delivery of the MFL Corrosion Inspection report, or 6 weeks after the residual field tool run if this is later.

Technology	Delivery date of Preliminary Report (calendar days following receipt of inspection data at PII's analysis center)	Delivery date of Final Report (calendar days following receipt of inspection data at PII's analysis center)	Comments
MagneScan 3.0	**14** days for less than 80km; **20** days for greater than 80km	**30** days for less than 80km; plus **15** days per 80km	

Appendix B: Hard Spot Assessment Plan as Detailed in SOP 9- 4050 "Miscellaneous Defects"

The following details are provided in SOP 9-4050 for hard spots:

Outline

1. Log Interpretation
    a. Description of data provided by ILI tool
        i. Site Data
        ii. Hard Spot data
        iii. Criteria for Assessing Severity of Hard Spot
            1. Hardness, Distribution (Cluster or Isolated) and Location (Inside Waiver Area, Outside Waiver Area).
2. Selection and Prioritization of Dig Sites
    a. Ranking Criteria
3. Bell Hole Examination Procedures for Hard Spots
    a. Prior to Excavation
        i. Reduce Operating Pressure 80% of past 90 day MOP.
        ii. Pipe-to-Soil Potential Measurements
    b. Hard Spot Evaluation Procedure After Excavation
        i. Excavate
        ii. Record Field Site Data
        iii. Coating Removal
        iv. Visual Inspection
        v. Magnetic Particle (MT) Inspection
        vi. Ultrasonic Wall Thickness Survey
        vii. Hardness Testing and Dimensional Documentation
    c. Hard Spot Repair Recommendations
        i. Pipe with Hardness Properties Less Than 300 HB
            1. Carefully Re-Coat
        ii. Hard Spots with Hardness Between 301 and 400 HB (No Cracking)
            1. Replacement
            2. Pressure Containing Sleeve
            3. Reinforcing Sleeve
        iii. Hard Spots with Evidence of Cracking (301 and greater)
            1. Replacement
            2. Pressure Containing Sleeve
        iv. Hard Spots with Hardness Greater than 401 HB with No Cracking Present
            1. Replacement
            2. Pressure Containing Sleeve
4. Technical Support

1. Log Interpretation

The inspection log shall reference the following:

- Pipeline Section Surveyed
- Line Size and Number
- Survey Date
- Vendor Job Number
- Run Number
- Tuboscope Pipeline Inspector
- Tuboscope Survey Analyst

The inspection log shall identify each anomaly by wheel count (feet) and clock position. It shall also note the distance to the upstream and downstream girth welds.

The ILI HS tool log will provide pipe hardness values using the Brinell scale (HB). According to the vendor, all hard spots with hardness equal to or greater than 235 HB, with an accuracy tolerance of +/-50 HB will be reported. The hardness data will then be graded by the ILI contractor and reviewed by DEGT personnel according to the scale shown below:

b. Grade 3 = Hardness of 301 Brinell (HB) and above
c. Grade 2 = Hardness of 251 to 300 HB
d. Grade 1 = Hardness of 235 to 250 HB (24HRC)

Metallurgical Services personnel will then evaluate grading assessment and determine if the proposed criteria appropriately discriminates the data, and if further refinement of the criteria may be needed.

The grading criteria shown above is based on API 5L requirements and PRCI research. API 5L states that any hard spot greater than 2" in any direction and a hardness greater than or equal to Rockwell 35 HRC (327 Brinell) shall be rejected.[1] Also, the PRCI Repair Manual states that hardness properties less than Brinell 327 (Rockwell 35 HRC) can be recoated and backfilled.[2] Hardness properties of 150 to 200 HB are consistent with the normal hardness properties that are to be expected for the API Grade X52 line pipe. API 5L specifies a minimum tensile strength of 66,000 psi (131 HB) for API Grade X52. Hardness properties of Rockwell 93 (207 HB) have been documented for the pipe body, in regions away from hard spots, for A.O. Smith, API 5L Grade X52 line pipe of similar vintage.[3] This information indicates that the grading criteria shown is a conservative assessment of the ILI data. The highest grade will be associated with regions that have hardness properties, as detected by the ILI tool, that exceed API 5L requirements and industry research limits.

2. Selection and Prioritization of Dig Sites

The ILI reports are to be delivered to Region Technical Staff, and Houston Pipeline Integrity in Houston. Houston Metallurgical Services must be consulted to review the data, prioritize the hard spot anomalies, and recommend excavations of selected hard spot anomalies.

Experience using the Tuboscope Linalog ILI HS tool in Spectra's BC Pipeline system indicated that there was a high degree of correlation between ILI data for clusters of hard spots that were detected and the physical presence of a hard spot at the specified location. In comparison, the ILI data that indicated the presence of isolated hard spots were found to be less reliable based on bell hole examination results. Based on the criteria shown in

Section 4, the following criteria is proposed, in the order shown, to prioritize suspected hard spot sites for bell hole inspection:

1) Waiver Site, Cluster, Grade 3
2) Waiver Site, Cluster, Grade 2
3) Waiver Site, Individual, Grade 3
4) Outside Waiver Site, Cluster, Grade 3
5) Outside Waiver Site, Cluster, Grade 2
6) Outside Waiver Site, Individual, Grade 3

The results of bell hole examinations of the hard spot anomalies will be compared to the log from the ILI HS tool run. At any time, the bell hole examination results may be assessed to determine if continued bell hole investigation of hard spot anomalies is warranted.

3. Bell hole Examination Procedures for Hard Spots

Excavation and bell hole examination of the pipeline will be performed in accordance with company SOP and safety policy. Each task will be performed by personnel qualified for the specific tasks discussed below.

a. Prior to Excavation
    i. Pressure Reduction – The operating pressure shall be reduced to 80% of past 90 day MOP when the bell hole inspection is for the purposes of hard spot anomalies detected by ILI. If cracks or other types of defects are detected in a suspected hard spot region, Metallurgical Services shall be consulted to determine pressure reduction requirements.
    ii. Pipe-to-Soil (electrolyte) Potential Measurements – Pipe to electrolyte potential measurements are to be performed at the suspect hard spot location in accordance with SOP #2-2010 "Structure-to-Electrolyte Potential Measurements".
b. Hard Spot Evaluation Procedure After Excavation – Pipe that is exposed for the purposes of investigating ILI hard spot data should be inspected using the procedure described in this section. Inspection results are to be recorded on the appropriate company forms listed in SOP section 1-7.
    i. Excavate - Excavation shall be performed using safe digging practices in accordance with SOP 1-4010, "Excavation and Backfill".
    ii. Record Field Site Data – Record the site features in accordance with the appropriate Company forms listed in SOP section 1-7.
    iii. Coating Removal – Remove coating for a distance of 5 feet either side of the hard spot using standard company practices. Grit blasting of the surface to a commercial finish is recommended. The surface should be free of material that might interfere with the application and movement of the MT suspension or powder during inspection.
    iv. Visual Inspection – Visually inspect the pipe external surface for evidence of flat spots or any other unique features in accordance to company SOP 1-3010. Features such as a relatively flat region with rounded edges may indicate the presence of a hard spot. All relevant anomalies and defects must be documented.
    v. Magnetic Particle (MT) Inspection – Personnel performing the inspection must have current ASNT Level II qualification for MT. NDT contractors

shall have the materials for performing wet MT (fluorescent and contrast) inspection prior to arrival at the inspection site. These methods are the preferred methods for MT inspection, and either method shall be acceptable. NDT contractors shall perform the specific MT method that is specified by DEGT representatives.

1. General Instructions - Perform MT inspection over the entire exposed pipe surface in accordance with generally accepted industry standards such as ASTM E1444-01. Metallurgical Services shall be consulted if any linear indications are detected.
2. Magnetizing Procedure – For MT inspection of the pipeline using a magnetic hand yoke, a magnetic field is produced that is oriented longitudinal between the two poles. Magnetizing current can be either A.C. or half-wave rectified D.C. For detecting surface cracks, the A.C. method is preferred. Linear defects oriented transverse to the magnetic field can be detected. In order to detect defects oriented in either direction on the pipe surface, MT inspection must be performed in both the circumferential and longitudinal directions with the hand yoke. Full coverage of a region larger than the pole spread is achieved by performing MT inspection using multiple passes, with each pass overlapping the other by approximately 1" or more.
3. MT Methods – The following methods are preferred for performing MT inspection of the pipe surface for the purposes of finding surface breaking defects such as cracks, seams, and laminations open to the O.D. surface.
    a. Wet Fluorescent MT – This method uses finely divided magnetic particles suspended in a liquid medium that is applied by spraying. Water based medium is recommended. The particles fluoresce when inspected under black light. Excessive background fluorescence during inspection shall require additional surface cleaning or a change to a different medium or method. This method is preferred except in bright light conditions.
    b. Wet Non-Fluorescent MT - This method uses finely divided magnetic particles suspended in a liquid medium (water or non-oil based medium is recommended) that is applied by spraying. White contrast paint is applied to the pipe surface and the applied particles (red or black) are visible under normal lighting conditions.

    The following method is acceptable for performing MT inspection, if the preferred methods are deemed not suitable due to operational and environmental conditions:

    a. Visible Dry MT – This method uses a colored powder that is selected to achieve maximum contrast to the pipe surface. A bubble blower is typically used to apply a light dust of powder to the pipe surface in the area being inspected while the current is being applied. Excessive application of the powder should be avoided because this may mask any indication present. Excess powder can often be removed by lightly blowing the surface while performing the inspection with current being applied.

vi. Ultrasonic Wall Thickness Survey – Perform an ultrasonic wall thickness measurement survey of the suspected hard spot region. Ultrasonic measurements shall be made by personnel with previous experience taking UT measurements. For the purpose of wall-thickness measurement using ultrasonic techniques, an ASNT certification is not required. Metallurgical Services shall be consulted if lamination or wall loss is detected.

vii. Hardness Testing and Dimensional Documentation – Prior to testing, the pipe surface should be thoroughly cleaned of surface deposits and debris. Test locations should be ground to a depth of 0.010" and finish ground using a 240 grit flapper wheel. Perform hardness testing over a 2" grid using a Microdur hardness tester that has current calibration documentation. Where areas of high hardness are detected a ½" or smaller grid shall be used to determine the shape of the hard spot. Isolated high hardness readings must be verified. Further investigation of elevated hardness locations may require additional grinding to depths of approximately 0.015" to 0.020". The contractor performing the hardness testing must have a process for addressing scatter in the hardness test results. The hardness test data should be reported as an attachment to the "Pipe and Coating Inspection Report" (7T-33).

c. Hard Spot Repair Recommendations - Repair of hard spots, and other defects located during bell hole examination, will be performed in accordance with SOP 1-3010 "Pipeline Repair". **Grinding removal of cracks in hard spots is not an acceptable or approved repair process.** The available repair options are provided for each type of hard spot that would require repair.

i. Pipe with Hardness Properties Less Than 300 HB
   1. Carefully Re-Coat and Backfill.

ii. Hard Spots with Hardness between 301 and 400 HB with No Cracking Present.
   1. Replacement
   2. Pressure Containing Sleeve (Type "B" Welded Ends)
   3. Reinforcing Sleeve with Filler (Type "A" or Type "B" Non-Welded Ends)

iii. Hard Spots with Evidence of Cracking (301 and greater)
   1. Replacement
   2. Pressure Containing Sleeve (Type "B" Welded Ends)

iv. Hard Spots with Hardness Greater than 401 HB (No Cracking)
   1. Replacement
   2. Pressure Containing Sleeve (Type "B" Welded Ends)

7. Technical Support

Contact the Metallurgical Services Section if additional detail or technical assistance is needed.

1. API 5L, "Specification for Line Pipe", 41st Ed., April 1, 1995.

2. PRCI Report PR-218-9307, "Pipeline Repair Manual" by J.F. Kiefner, W.A. Bruce, D.R. Stephens. Page 57 and Figure 20.

[3.] PRCI NG-18, Report 131, “Summary of Field Failure Investigations”, Field Failure No. 6, “Hydrogen Cracking in 30” x 0.375” , X52 Pipeline”.