

## **A.O. Smith Hard Spot Response and Repair Criteria**

Remedial Work Plan, Increment 2 rev. 1

PHMSA Second Amended Corrective Action Order, CPF 2-2019-1002H



July 10, 2020 (rev. 1)

A.O. Smith Hard Spot Response and Repair Criteria, CPF 2-2019-1002H

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## **Executive Summary**

Texas Eastern Transmission, LP (TETLP), a subsidiary of Spectra Energy Partners, LP, which is in turn a wholly-owned subsidiary of Enbridge Inc., owns and operates a pipeline system consisting of three (3) parallel natural gas pipelines, Lines 10, 15, and 25 located between Kosciusko, Mississippi and Uniontown, Pennsylvania. Line 15 of this system experienced an in-service failure on August 01, 2019, approximately four (4) miles downstream (south) of the Danville, Kentucky Compressor Station (Failure 1). Line 10 of this system experienced an in-service failure on May 4, 2020, roughly seven (7) miles north of TETLP's Owingsville Compressor Station near Hillsboro, Kentucky (Failure 2).

On August 08, 2019, the Pipeline and Hazardous Materials Safety Administration (PHMSA) issued a Corrective Action Order (CAO), CPF 2-2019-1002H, to require certain corrective actions in response to Failure 1, applicable to the Line 15 pipeline from Kosciusko, Mississippi to Uniontown, Pennsylvania. PHMSA issued an Amended Corrective Action Order (ACAO) on April 28, 2020 to update the CAO to address actions taken by TETLP since Failure 1. As noted in the ACAO, a 2011 hard spot in-line inspection (ILI) of Line 15 did not report any hard spot indications. Post-incident review of the underlying ILI data, however, revealed hard spots in the failed pipe joint and the Failure 1 origin coincided with the locations of two (2) newly discovered hard spot indications. On June 01, 2020, PHMSA issued a second Amended Corrective Action Order (Second ACAO) to update the ACAO to address Failure 2, while noting that the preliminary failure cause appears to be land movement. In the Second ACAO, PHMSA applied the corrective measures to Lines 10, 15, and 25 from Kosciusko, Mississippi to Uniontown, Pennsylvania (Affected Segment).

The Second ACAO corrective measures require, among other things, that TETLP prepare and submit for PHMSA approval a Remedial Work Plan (RWP) that specifies the tests, inspections, assessments, evaluations, and remedial measures that TETLP will use to verify the integrity of the Affected Segment and to address the known or suspected factors and causes of Failure 1 and Failure 2 (Second ACAO, Par. 11 and 25). TETLP submitted a Hard Spot ILI Tool Qualification Plan as an initial increment of the RWP which was approved by PHMSA on May 29, 2020.

In order to evaluate and respond to the data from the ILI hard spot tool runs on the Affected Segment, TETLP prepared this A.O. Smith Hard Spot Response and Repair Criteria for PHMSA review and approval as a second increment of the RWP. As TETLP completes the testing and remediation specified by the RWP to address the suspected causes of Failure 1 and Failure 2, it will prepare requests for temporary or permanent removal of pressure restrictions as appropriate. For requests for temporary removal of pressure restrictions, TETLP will prepare and provide an Integrity Assessment Summary (IAS) for pipeline segment(s) in support of a request for a return to a modified or normal operating pressure under the Second ACAO (Second ACAO, Par. 3(B), 17(B)). For requests for permanent removal of pressure restrictions, TETLP will prepare an Engineering Assessment Summary (EAS) which will summarize the inspections, assessments, and evaluations considering all relevant integrity threats that TETLP performed under the RWP for each pipeline segment(s) (Second ACAO, Par. 3(A), 17(A)).

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**Definitions**

Terms	Definition
Affected Segment	The seven hundred seventy-five (775) mile parallel bi-directional Line 10, 15, and 25 pipelines operated by TETLP from Kosciusko, Mississippi to Uniontown, Pennsylvania. <i>Second ACAO, p. 7.</i>
Amended CAO (ACAO)	Amended Corrective Action Order (ACAO) issued to TETLP by PHMSA on April 28, 2020 that updates the terms of the CAO to address actions taken by TETLP since the August 01, 2019 failure.
Caliper tool	An in-line inspection tool designed to record conditions such as buckles, dents, wrinkles, ovality, bend radius and angle, and occasionally, indications of significant internal corrosion by sensing the shape of the internal surface of the pipe. <i>NACE SP0102-2010 Standard Practice (SP), In-line Inspection of Pipelines.</i>
Cathodic Protection (CP)	A technique to reduce the corrosion of a metal surface by making that surface the cathode of an electrochemical cell. <i>NACE, Control of External Corrosion on Underground or Submerged Metallic Piping Systems.</i>
Corrective Action Order (CAO)	Corrective Action Order (CAO) issued to TETLP by PHMSA on August 08, 2019.
Electromagnetic Acoustic Transducer (EMAT)	Electromagnetic Acoustic Transducer (EMAT) is a non-destructive testing technology that has applications in a wide range of industrial sectors. EMAT is generally used to assess the condition of manufactured objects and the technology is particularly effective for detection of stress corrosion cracking and disbanded coating.
Expander Marks	Artifacts created when the pipe was expanded at the mill to final diameter using hydraulic expansion methods. The marks represent locations between the individual OD expansion dies where differential expansion occurs. Elevated pipe hardness at the expansion ring locations are typically between 240-280 HB and are not an integrity threat.
Failure 1	Incident that occurred on August 01, 2019 on TETLP's Line 15 located approximately four (4) miles downstream (south) of the Danville, Kentucky Compressor Station near milepost 423.4.

Terms	Definition
Failure 2	Incident that occurred on May 04, 2020 on TETLP's Line 10 located approximately seven (7) miles upstream (north) of its Owingsville Compressor Station near Hillsboro, Kentucky.
Hard spot	A localized increase in hardness through the thickness of a pipe, produced during hot rolling of a steel plate as a result of localized quenching. <i>API Standard 1163, In-Line Inspection Systems Qualification, Section 3.1.44, p. 6 (2013).</i>
Hardness Brinell (HB)	Brinell Hardness measured on the HB scale. The Brinell hardness test consists of applying a constant load of three thousand (3,000) kilogram-force (for steel), on a hardened steel ball-type indenter, ten (10) mm in diameter, to the flat surface of a workpiece. The Brinell hardness number is identified as HB.
Hardness Rockwell B (HRB)	Rockwell Hardness measured on the B scale. A designation of hardness measured by pressing a 1/16 inch hardened steel ball indenter under a total test force of one hundred (100) kgf and which is applicable to copper alloys, soft steels, aluminum alloys and malleable iron. The Hardness Rockwell B number is identified as HRB. <i>ASTM E18-19, Standard Test Methods for Rockwell Hardness of Metallic Materials, ASTM International (2019).</i>
Hardness Rockwell C (HRC)	Rockwell Hardness measured on the C scale. A designation of hardness measured by pressing a diamond-cone Brale indenter under a total test force of one hundred and fifty (150) kgf and which is applicable to steel, hard cast irons, deep case-hardened steel and other materials harder than one hundred (100) HRB. The Hardness Rockwell C number is identified as HRC. <i>ASTM E18-19, Standard Test Methods for Rockwell Hardness of Metallic Materials, ASTM International (2019).</i>
High consequence area (HCA)	Certain populated and occupied areas as defined under PHMSA integrity management regulations at 49 C.F.R. § 192.903 and TETLP SOPs implementing those regulations.
Hydrogen Embrittlement (HE)	A condition of low ductility in high strength steel resulting from the absorption of atomic hydrogen. <i>ASM Metals Handbook, Vol. 1, 8th ed.</i>
Hydrogen stress cracking (HSC)	A time-dependent failure mechanism that causes cracks to initiate and grow in high-strength steels subjected to sustained tensile

Terms	Definition
	stresses while atomic hydrogen is diffusing through the lattice; the stress may be below the nominal yield strength of the steel or even below the design stress. <i>Hydrogen Stress Cracking Overview and Controls, T.P. Groeneveld and R.R. Fessler (1974).</i>
In-line Inspection (ILI)	An inspection of a pipeline from the interior of the pipe with a device or vehicle that uses a nondestructive testing technique to inspect the pipeline from the inside. <i>NACE SP0102-2010, In-Line Inspection of Pipelines.</i>
Magnetic Particle Test (MT)	A nondestructive examination technique for locating surface flaws in steel using fine magnetic particles and magnetic fields. <i>API 1163, In-line Inspection Systems Qualification (incorporated by reference at 49 C.F.R. § 192.243 effective July 1, 2020).</i>
Maximum allowable operating pressure (MAOP)	The maximum pressure at which a pipeline or segment of a pipeline may be operated under 49 C.F.R. Part 192. <i>49 C.F.R. § 192.3.</i>
MFL	Magnetic Flux Leakage ILI tool for detecting metal loss from corrosion or mechanical damage.
Nondestructive Examination (NDE)	The evaluation of results from non-destructive testing (NDT) methods or non-destructive testing techniques to detect, locate, measure, and evaluate anomalies. <i>NACE SP0102-2010, In-Line Inspection of Pipelines.</i>
PHMSA	Pipeline and Hazardous Materials Safety Administration.
Remedial Work Plan (RWP)	Remedial Work Plan required with respect to Failure 1 (Second ACAO, Par. 11) and with respect to Failure 2 (Second ACAO, Par. 25).
Second Amended Corrective Action Order (Second ACAO)	Second Amended Corrective Action Order issued to TETLP by PHMSA on June 01, 2020 to address the May 04, 2020 failure (Failure 2).
Specific Minimum Yield Strength (SMYS)	Minimum yield strength of the line pipe material, as defined by relevant API 5L Specification for Line Pipe Materials.
Standard Operating Practices (SOPs)	Procedures prepared for pipeline operations.

<b>Terms</b>	<b>Definition</b>
TETLP	Texas Eastern Transmission, LP, a subsidiary of Spectra Energy Partners, LP, which is in turn a wholly-owned subsidiary of Enbridge Inc.

**Relevant Standard Operating Procedures and Guidance Documents<sup>1</sup>**

<b>Document No.</b>	<b>Title</b>	<b>Revision</b>
1-4010	Excavation and Backfill	03/26/18
1-4020	Locating Buried Pipelines Using Electronic Line Locators	11/20/19
9-2010	In-line Tool Pipeline Inspection	05/23/17
9-3010	Response to In-Line Inspection	05/28/19
9-3020	Monitoring and Mitigation (ECDA)	04/25/18
9-3040	Enhanced Survey Analysis	12/11/18
9-4010	Defect Assessment & Repair Options for Internal Corrosion	10/03/19
9-4020	Defect Assessment & Repair Options for External Corrosion	12/11/18
9-4030	Defect Assessment & Repair Options for SCC	07/28/18
9-4040	Defect Assessment & Repair Options for Dents and Mechanical Damage	05/23/17
9-4050	Defect Assessment & Repair Options for Miscellaneous Defects	05/15/18
9-4060	Magnetic Particle Inspection of Pipelines for Surface Cracks	01/12/18
9-4070	Ultrasonic Inspection of Line Pipe	12/12/17
9-4110	CorrEval Software & User’s Guide	12/05/17
9-4120	Mechanical Damage Assessment Software & User’s Guide	02/15/13
9-5010	Pipeline Repair Procedures	05/28/19
9-5020	Repair Sleeve Design	05/28/19
440	Integrity Management Threat Response Guidance, Manufacturing	12/19/19
511	Integrity Management Technical Guidance Document, Hardspots	12/20/09

<sup>1</sup> This table includes the versions of TETLP standard operating procedures (SOPs) and guidance documents in effect at the time of submission of the A.O. Smith Hard Spot Response and Repair Criteria to PHMSA. TETLP routinely revises its SOPs and guidance documents consistent with 49 C.F.R. Part 192. At all times during implementation of the RWP, TETLP will utilize the version of SOPs and guidance documents in place at the time that the work is performed. TETLP will make final updated SOPs and guidance documents available to PHMSA upon request.

## 1.0 Background

Texas Eastern Transmission, LP (TETLP)<sup>2</sup> owns and operates a pipeline system consisting of three (3) parallel natural gas pipelines, Lines 10, 15, and 25, located between Kosciusko, Mississippi and Uniontown, Pennsylvania. These pipelines are bi-directional and are approximately seven hundred and seventy-five (775) miles in length. On August 01, 2019, at 1:23 a.m. Eastern Daylight Time (EDT), Line 15 of this system experienced an in-service failure approximately four (4) miles downstream (south) of the Danville, Kentucky Compressor Station near milepost (MP) 423.4 (Failure 1). On May 04, 2020, Line 10 of this system experienced an in-service failure approximately seven (7) miles north of TETLP's Owingsville Compressor Station near Hillsboro, Kentucky (Failure 2). The pipelines were flowing from north to south at the time of each failure.

In response to Failure 1, the Pipeline and Hazardous Materials Safety Administration (PHMSA) issued a Corrective Action Order (CAO), CPF 2-2019-1002H, on August 08, 2019, to require certain corrective actions applicable to the Line 15 pipeline from Kosciusko, Mississippi to Uniontown, Pennsylvania. On April 28, 2020, PHMSA issued an Amended Corrective Action Order (ACAO) to update the terms of the CAO to address actions taken by TETLP since Failure 1. As noted in the ACAO, while a 2011 hard spot in-line inspection (ILI) of Line 15 did not report any hard spot indications, post-incident review of the underlying ILI data revealed hard spots in the failed pipe joint, of which two (2) coincided with the Failure 1 origin location (ACAO, Preliminary Findings).

On June 01, 2020, PHMSA issued a Second Amended Corrective Action Order (Second ACAO) to update the terms of the ACAO to address Failure 2 and which requires corrective actions on Line 15 as well as Lines 10 and 25 from Kosciusko, Mississippi and Uniontown, Pennsylvania (Affected Segment). As noted by PHMSA in the Second ACAO, the preliminary failure cause of Failure 2 appears to be land movement (Second ACAO, Preliminary Findings). In relevant part, the Second ACAO requires that TETLP prepare and submit for PHMSA approval a Remedial Work Plan (RWP) that specifies the tests, inspections, assessments, evaluations, and remedial measures TETLP will use to verify the integrity of the Affected Segment and which addresses all known or suspected factors and causes of the failures (Second ACAO, Par. 11 and 25).

Based on the analyses and activities that TETLP has performed to date under the PHMSA orders, TETLP has determined that certain portions of the Affected Segment warrant further investigation to evaluate the manufacturing threat of hard spots. Accordingly, as an initial increment of the RWP, TETLP submitted a Hard Spot ILI Tool Qualification Plan to PHMSA for approval on April 07, 2020 and which was approved on May 29, 2020. As a second increment of the RWP, TETLP prepared this A.O. Smith Hard Spot Response and Repair Criteria for PHMSA review and approval. This portion of the RWP describes the inspection, evaluation, and repair criteria that TETLP proposes to use to prioritize (also described as "sentencing"), excavate, evaluate, and repair A.O. Smith hard spot anomalies on the Affected Segment. Subsequent RWP increments will be forthcoming consistent with the requirements under Second ACAO Paragraphs 11 and 25.

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<sup>2</sup> TETLP is a subsidiary of Spectra Energy Partners, LP, which is a wholly owned subsidiary of Enbridge Inc.

## 1.1 Affected Segment A.O. Smith Pipe

The section of Line 15 involved in Failure 1 is comprised of 30-inch nominal diameter 0.375-inch wall thickness API 5L X-52 pipe that contains a flash welded longitudinal seam. The pipe was manufactured by A.O. Smith in 1957 and it was coated with coal tar enamel coating. Based on reviews that TETLP has performed to date under the Second ACAO, ACAO, and CAO, TETLP determined that the Affected Segment contains pipe manufactured by A.O. Smith that may be susceptible to hard spots.<sup>3</sup> Table 1.0 summarizes the relevant A.O. Smith pipe segments<sup>4</sup> on the Affected Segment based on pipe data for Lines 10, 15, and 25, comprising approximately three hundred and fifty-three (353) miles of pipeline.

**Table 1.0 – Affected Segment A.O. Smith Pipe**

Segment	Line 10		Line 15		Line 25	
	A.O. Smith Year of Manufacture	Length (feet)	A.O. Smith Year of Manufacture	Length (feet)	A.O. Smith Year of Manufacture	Length (feet)
KOSC-EGYP	1969	12	1957, 1958	333,114	1969	22
EGYP-BART	NA	0	1957	336,252	NA	0
BART-MTPL	NA	0	1957, 1958	188,890	1965	1,692
MTPL-GLAD	1967	24	1957, 1958, 1966, 1967, 1968	234,136	NA	0
GLAD-TOMP	NA	0	1957	109,643	NA	0
TOMP-DANV	NA	0	1957, 1958, 1965	212,995	1965	43
DANV-OWSV	1967	23	1957	141,020	NA	0
OWSV-WHEE	NA	0	1957, 1958	129,337	NA	0
WHEE-ATHE	NA	0	1957, 1958, 1961	168,632	NA	0
ATHE-BERN	NA	0	1958	464	NA	0
BERN-HOLB	NA	0	1957	10,406	NA	0
HOLB-UNIO	NA	0	NA	0	NA	0
<b>TOTAL</b>	59 feet (or roughly 0.01 miles)		1,864,889 feet (or roughly 353 miles)		1,757 feet (or roughly 0.33 miles)	

<sup>3</sup> According to industry reports prepared by Kiefner and Associates, Inc., "hard spots have been detected in A.O. Smith flash-welded pipe made in the period between 1947 and 1960" and "[s]ome batches of AOS pipe produced between 1952 and 1957 were affected by [...] hard spots in the pipe body, owing to uncontrolled thermal events in the plate rolling mill. *Kiefner and Van Auker, Final Report, Repair/Replace Considerations for Pre-Regulation Pipelines*, p. 150 (Mar. 11, 2015); *M. Rosenfeld, Joint Efficiency Factors for A.O. Smith Line Pipe*, p. 16 (Dec. 2012).

<sup>4</sup> A "pipeline segment" is defined as the pipeline from one compressor station to the next compressor station.

## 1.2 Post-Failure Hard Spot ILI Tool Runs and Planned Pipe Replacement

In response to Failure 1, TETLP has completed ten (10) successful hard spot ILI tool runs on the Line 15 Affected Segment with qualified tools and pursuant to the schedule outlined in its Hard Spot ILI Tool Qualification Plan and TETLP Standard Operating Procedures (SOPs), including *In-line Tool Pipeline Inspection (9-2010)*. With these ILI hard spot tool runs, TETLP has completed hard spot ILI assessments on all the pipeline segments on the Line 15 Affected Segment containing A.O. Smith pipe with qualified ILI tools, except for the Athens to Berne segment where TETLP has elected instead to replace the small amount of A.O. Smith pipe. Because the Holbrook to Uniontown segment of Line 15 does not contain A.O. Smith pipe, TETLP will not perform an assessment with a hard spot ILI tool.

TETLP will not perform ILI hard spot tool assessments on Line 10 because it will conduct hard spot field evaluations of the full length of A.O. Smith pipe on the Kosciusko to Egypt, Mount Pleasant to Gladeville, and the Danville to Owingsville segments in accordance with the hard spot field evaluation and repair criteria, methods, and timeframes in this RWP increment. With respect to Line 25, TETLP performed a hard spot ILI assessment on the Barton to Mount Pleasant segment and it will conduct hard spot field evaluations of the small amounts of A.O. Smith pipe on the Kosciusko to Egypt and the Tompkinsville to Danville segments consistent with this RWP increment. As an alternative to field evaluation of the short sections of A.O. Smith pipe on Lines 10 and 25, TETLP may elect to replace the pipe. Table 2.0 summarizes the post-failure hard spot ILI tool assessments that TETLP has completed on the Affected Segment.

**Table 2.0 – Post-Failure Hard Spot ILI Runs**

Segment	ILI Hard Spot Tool Run Date		
	Line 10	Line 15	Line 25
KOSC-EGYP	NA	Jun. 5, 2020	NA
EGYP-BART	NA	Apr. 9, 2020	NA
BART-MTPL	NA	Apr. 2, 2020	Aug. 5, 2020
MTPL-GLAD	NA	Mar. 26, 2020	NA
GLAD-TOMP	NA	Mar. 18, 2020	NA
TOMP-DANV	NA	May 22, 2020	NA
DANV-OWSV	NA	Mar. 5, 2020	NA
OWSV-WHEE	NA	Oct. 2, 2019	NA
WHEE-ATHE	NA	May 29, 2020	NA
ATHE-BERN	NA	NA	NA
BERN-HOLB	NA	Mar. 11, 2020	NA
HOLB-UNIO	NA	NA	NA

## 2.0 Objective

The objective of this second RWP increment is to outline the hard spot evaluation and repair criteria for relevant portions of the Affected Segment that are comprised of A.O. Smith pipe (Second ACAO, Par. 11 and 25).

### **3.0 Approach**

In order to meet the objective, TETLP prepared this A.O. Smith Hard Spot Response and Repair Criteria for PHMSA review and approval which identifies (1) A.O. Smith hard spot inspection and defect assessment criteria, (2) field evaluation and repair criteria for A.O. Smith hard spots, and (3) a continual improvement process which includes an ILI hard spot tool and in-ditch tool validation.

### **4.0 A.O. Smith Hard Spot Inspection and Defect Assessment Criteria**

When TETLP receives the hard spot ILI data from the ILI tool service providers, it will review, analyze, and respond to the information pursuant to TETLP SOPs, including in particular *Response to In-line Inspection (9-3010)* and *Defect Assessment & Repair Options for Miscellaneous Defects (9-4050)*. Additional A.O. Smith hard spot response and repair criteria are outlined in this document that apply specifically to the Affected Segment. TETLP will review and analyze the hard spot ILI data for all integrity threats reported by the selected ILI tool technology, with a focus on potentially actionable A.O. Smith hard spot features. Hard spot sentencing results will be integrated with the most recent ILI caliper and corrosion tool results, including electromagnetic acoustic transducer (EMAT) results (where available), to identify any interacting threats. Field evaluation of the integrity of potential defects may involve dimensional measurement, visual examination, magnetic particle test inspection, nondestructive testing, acid etching, and hardness testing.

#### **4.1 Hard Spot Anomaly Characteristics**

A hard spot is a manufacturing defect caused by localized quenching of the steel skelp during the plate hot rolling process. Hard spots are not a direct cause of failure, but they potentially can be a key contributing cause to hydrogen stress cracking (HSC). Hard spots in the pipe body are susceptible to HSC if they are subjected to sufficiently high stress levels in the presence of atomic hydrogen.<sup>5</sup> The operating hoop stress levels in certain pipelines may constitute sufficient stress and atomic hydrogen can be generated at areas of damaged coating by cathodic protection (CP) current.<sup>6</sup>

The frequency of pipeline failures due to hard spots remains low, as compared to other incident causes.<sup>7</sup> A failure related to hard spots requires simultaneous exposure to four (4) elements: (1)

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<sup>5</sup> Kiefner and Van Auker, *Final Report, Repair/Replace Considerations for Pre-Regulation Pipelines*, p. 15 (Mar. 11, 2015).

<sup>6</sup> *Id.*

<sup>7</sup> See publicly available PHMSA incident data, <https://www.phmsa.dot.gov/data-and-statistics/pipeline/data-and-statistics-overview>.

an appropriate level of stress; (2) susceptible steel microstructure (*i.e.*, a hard spot); (3) a flaw in the coating coincident to the hard spot; and (4) the presence of hydrogen. A 2004 industry report found that a majority of recorded A.O. Smith pipeline failures at that time were associated with hard spots on pipelines with nominal outer diameters equal to or greater than twenty (20) inches where the pipelines operated at or above sixty (60) percent specific minimum yield strength (SMYS), had coating damage, and CP was greater than -1.2V.<sup>8</sup>

With respect to CP, historical hard spot failures demonstrate that when CP is provided at excessively high levels, the pipe may be more susceptible to hydrogen generation. Separate from the RWP, TETLP has a program underway to maintain CP levels between -850 mV and -1200 mV for pipelines containing A.O. Smith pipe. Based on more recent analysis of prior hard spot failures, mitigating CP potentials may not be as effective as initially thought to lower the risk of the HSC threat on affected pipelines depending on the circumstances.<sup>9</sup> TETLP is studying the effects that CP may have on hydrogen generation and it will incorporate any relevant findings through the lessons learned process under the Second ACAO.

As to hardness values, TETLP's review of available documented A.O. Smith pipeline failures demonstrates that in cases where hardness has been confirmed, there have not been recorded failures that occurred below three hundred and fifty (350) Hardness Brinell (HB). Industry standard API Specification 5L, Specification for Line Pipe (45<sup>th</sup> ed.),<sup>10</sup> defines a hard spot as a "defect" where (1) it is larger than fifty (50) millimeters (2.0 inches) in any direction and (2) its hardness exceeds three hundred and twenty-seven (327) HB taken using a carbide ball indenter.<sup>11</sup> For that reason, three hundred and twenty-seven (327) HB hardness is often cited in the industry as guidance for ILI hard spot response criteria. Along these lines, Enbridge, of which TETLP is a wholly owned subsidiary, has employed an ILI hard spot response criterion of three hundred (300) HB for hard spot indications of any size to account for ILI tool tolerance. As explained below, for the purposes of the RWP TETLP will also employ an additional hard spot criterion of two hundred and eighty (280) HB for hard spot indications with a size greater than four (4) square inches (including accounting for ILI tool tolerance).

#### **4.1.1. Actionable A.O. Smith Hard Spots**

Based on TETLP's review and analysis of hard spots generally and hard spots on the Affected Segment specifically, TETLP is applying this more conservative definition of actionable hard spot defects to the portions of Affected Segment comprised of A.O. Smith pipe under the RWP. TETLP

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<sup>8</sup> Clark, Leis and Eiber *Integrity Characteristics of Vintage Pipelines*, prepared for the Interstate Natural Gas Association of America Foundation, Inc. in conjunction with the American Gas Association Foundation, p. 21 & 22 (Oct. 2004).

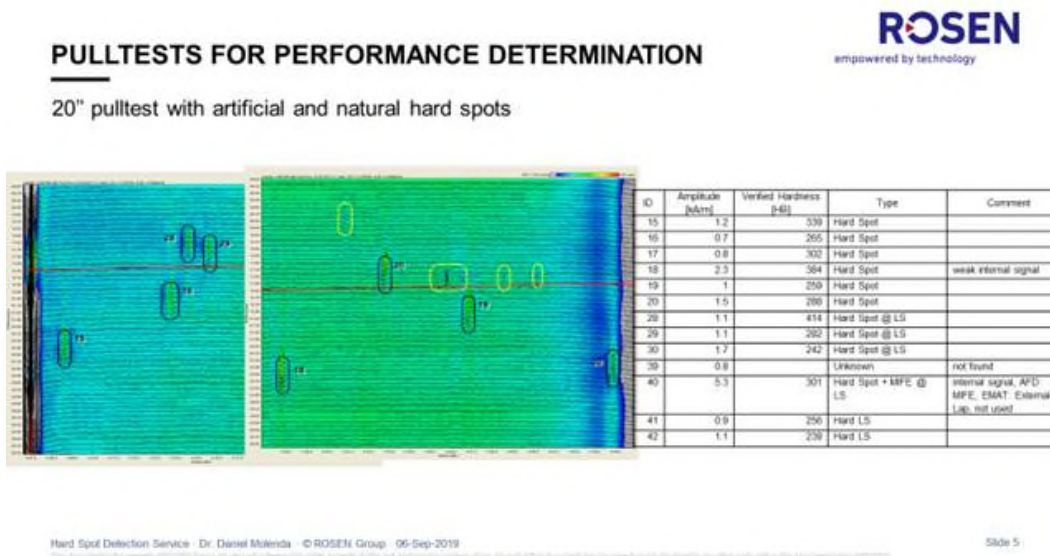
<sup>9</sup> See *e.g.*, TETLP *Integrity Management Program Technical Guidance Document 511, Hardspots* (Dec. 20, 2009) (detailing 2006 Review of DEGT Hard Spot Management Activities prepared by CC Technologies, Inc.).

<sup>10</sup> API Specification 5L is incorporated by reference under PHMSA's 49 C.F.R. Part 192 construction regulations (*i.e.*, 49 C.F.R. §§ 192.7, 192.55(e), 192.112(a)-(e), 192.113).

<sup>11</sup> The standard includes the following equivalent hardness values under different measurement methods: thirty-five (35) Hardness Rockwell C (HRC) and two hundred and forty-five (245) Hardness Vickers (HV).

is focusing on the hardness value and surface area of hard spot features. Figure 1.0 below depicts hard spot ILI data of the quenched martensitic microstructure associated with a hard spot.

**Figure 1.0, Rosen Image of Hard Spot Features**



TETLP will excavate and evaluate the following hard spot defects: (1) with a hardness of three hundred (300) HB or more regardless of surface area and (2) with a hardness of two hundred and eighty (280) HB to two hundred and ninety-nine (299) HB with a surface area equal or greater than four (4) inches sqr. These values are considered to be conservative estimates based on hardness levels observed in previous documented failures.<sup>12</sup> To ensure more reliable detection and characterization of hard spots, these values also account for the sizing accuracy from the hard spot ILI tool service provider and the results of the pull-through testing under TETLP’s Hard Spot ILI Tool Qualification Plan (approved by PHMSA on May 29, 2020). *Appendix A, Rosen Romat DMG, In-line High Resolution Hard Spot Detection and Sizing Service Performance Specification (Oct. 11, 2019).*

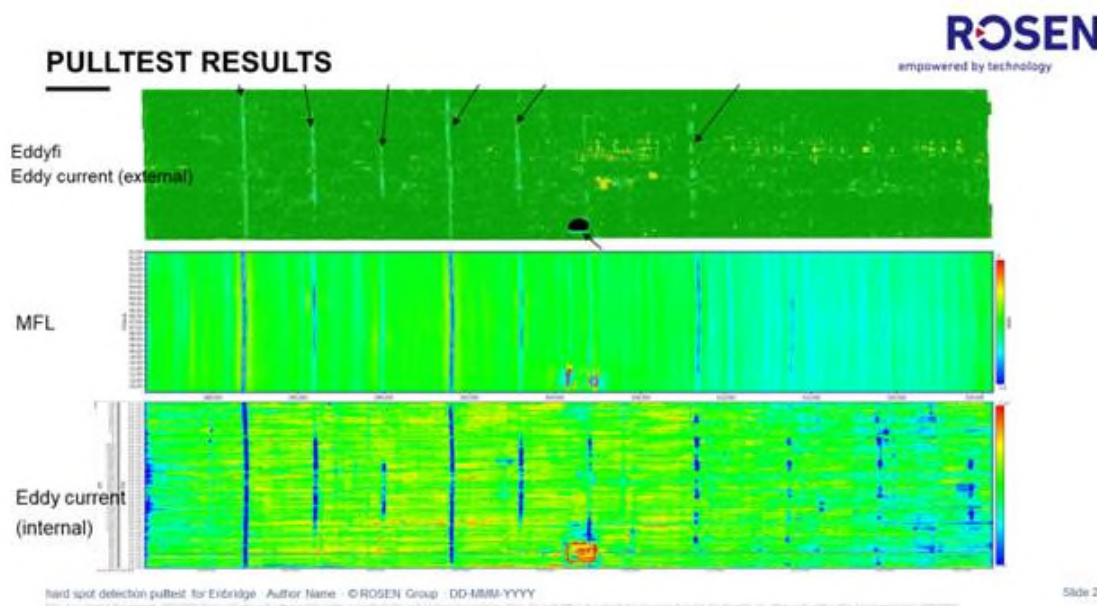
As explained in Sections 5.0 and 6.0, TETLP will provide information from the hard spot evaluations to the ILI tool service provider(s) to improve the calibration of their tool(s). TETLP is also undertaking additional analysis of hard spot measurements. Based on this information, TETLP will update its A.O. Smith hard spot response and repair criteria applicable to the Affected Segment , if necessary, and with notice to PHMSA.

<sup>12</sup> TETLP Integrity Management Program Technical Guidance Document 511, Hardspots (Dec. 20, 2009) (detailing 2006 Review of DEGT Hard Spot Management Activities prepared by CC Technologies, Inc.); R. J. Eiber, *Field Failures Investigation, L30174 Fifth Symposium on Line Pipe Research* (1974); T. P. Groeneveld, *Hydrogen Stress Cracking, L30174 Fifth Symposium on Line Pipe Research* (1974).

#### 4.1.2. Non Actionable ILI Features

As described above, hard spots with hardness properties of less than two hundred and eighty (280) HB are not an integrity threat and are not actionable. In addition, low field magnetic flux leakage (MFL) ILI tools can detect other magnetic anomalies within the pipe that are not hard spots. In relevant part, MFL tools frequently detect expander mark features. Expander mark features were created when the pipe was expanded to a final diameter using expander rings. This resulted in localized areas of higher hardness as compared to the rest of the pipe body. Expander marks typically have hardness between two hundred and forty (240) HB and two hundred and eighty (280) HB. This elevated hardness is caused by cold work hardening, however, and does not present a microstructure change. Figure 2.0 below depicts expander marks.

**Figure 2.0, Rosen Image of Expander Marks**



A hard spot has a quenched martensitic microstructure and high hardness susceptible to hydrogen embrittlement and HSC. In contrast, expander marks have material microstructure that is not susceptible to HSC, and therefore there are no integrity issues associated with expander marks. The expander marks can be reliably identified as nonactionable ILI features based on the following characteristics: (1) alignment in the circumferential direction; (2) equidistant at approximately every three (3) feet;<sup>13</sup> and (3) a distinct magnetic signature. Expander marks are not typically reported by ILI tool service providers because they do not impact pipeline integrity. The detection of expander marks on the Affected Segment, however, may be used to further demonstrate that the ILI hard spot tool functioned within the relevant parameters for hard spot

<sup>13</sup> TETLP has not identified patterns between hard spots and low level metal loss, small dents, or ground repaired seam.

detection. Specifically, the detection would confirm that a hard spot ILI tool is capable of identifying features that may exhibit a higher hardness value in the range of two hundred and forty (240) HB to two hundred and eighty (280) HB, but which are not ultimately hard spot features.

#### **4.2 A.O. Smith Hard Spot ILI Tool Run Analysis**

TETLP will conduct hard spot anomaly evaluation and monitoring on applicable portions of the Affected Segment in accordance with *SOP Response to In-Line Inspection (9-3010)* and the A.O. Smith hard spot response and repair criteria outlined in this document. This includes evaluating anomalies that are detected by hard spot ILI tools, determining which anomalies will be selected for direct examination, and prioritizing a schedule for conducting an evaluation of the anomalies in the ditch. TETLP subject matter experts (SMEs) will review and confirm the ILI tool service provider's report, categorization, and sentencing consistent with TETLP procedures and the hard spot response and repair criteria specified in this RWP increment. If necessary, TETLP will make adjustments to the A.O. Smith hard spot anomaly categorization and sentencing.

As explained above, hard spot ILI tool tolerance is incorporated in the definition of the ILI hard spot response criteria. TETLP will compare field results of confirmed hard spots ("as-found") to the reported ILI results ("as-called") and the hard spot response criteria in this document will be updated as necessary. If the information indicates that the ILI hard spot tool tolerance should be more conservative (as compared to the ILI hard spot tool service provider specifications), TETLP will review the ILI report to identify if any additional features fail the adjusted criteria. TETLP will then prepare a schedule for evaluation in the ditch and further analysis of the defects (referred to as a "dig package").

A prioritized schedule will be completed for each Affected Segment pipeline segment inspected by a hard spot ILI tool. This prioritized schedule will include the location of the anomaly and if it is within a high consequence area (HCA), the reason for the in the ditch evaluation, and the hard spot HB hardness value and surface area.

#### **4.3 A.O. Smith Hard Spot Sentencing Criteria**

The Affected Segment is currently operating at restricted pressures. A majority of Line 15 is operating at eighty percent (80%) of the pressure at the time of Failure 1 (Second ACAO, Par. 2). Lines 10 and 25 and the remaining portions of Line 15 are operating at a modified pressure restriction based on eighty percent (80%) of the highest pressure experienced at the discharge of each compressor station for the period of ninety (90) days prior to Failure 2 (Second ACAO, Par. 15 as modified by PHMSA on June 10, 2020). The ILI hard spot response criteria described in Section 4.1.1 establishes the threshold for when an A.O. Smith hard spot feature is selected for in the ditch evaluation on the Affected Segment. A.O. Smith hard spots meeting these criteria on the Affected Segment will be prioritized for evaluation on an accelerated schedule.

TETLP's conservative criteria for scheduling and excavating A.O. Smith hard spot defects on the Affected Segment is summarized below in Table 3.0. Anomaly evaluation timeframes are based

on: (1) the correlation of HSC susceptibility with high hardness values; (2) whether an A.O. Smith hard spot is located in an HCA; (3) whether an A.O. Smith hard spot is interacting with any other defect; and (4) the restricted operating pressure of the Affected Segment. TETLP will address all actionable A.O. Smith hard spots on a pipeline segment within the Affected Segment, prior to requesting approval to return that pipeline segment to service up to normal operating pressure, consistent with the hard spot response and repair criteria in this document and its SOPs.

**Table 3.0, A.O. Smith Hard Spot Sentencing Criteria**

A.O. Smith Hard Spot Evaluation Criteria		Anomaly Evaluation <sup>14</sup>	
Hardness	Surface area	HCA	Outside of HCA
Any hard spot greater than or equal to 280 HB interacting with another defect or Greater than or equal to 400 HB	All	Priority 1	Priority 1
Between (and including) 340 HB and 399 HB	All	Priority 1	Priority 2
Between (and including) 300 HB and 339 HB	All	Priority 2	Priority 2
Between (and including) 280 HB and 299 HB	Greater than or equal to 4 inches square	Priority 2	Priority 2
Notes:			
<ol style="list-style-type: none"> <li>1. "Priority 1" anomalies will be excavated and evaluated as soon as practicable, subject to receipt of necessary permits and right-of-way access. All Priority 1 evaluations and necessary repairs within a pipeline segment will be completed before requesting approval to return that segment to normal operation.</li> <li>2. "Priority 2" anomalies will be scheduled for excavation and evaluation, subject to receipt of necessary permits and right-of-way access. All Priority 2 evaluations and necessary repairs within a pipeline segment will be completed before requesting approval to return that segment to normal operation.</li> <li>3. The Affected Segment is currently operating at restricted pressures under the Second ACAO. A majority of Line 15 is restricted to 80% of the pressure at the time of the Failure 1. Lines 10, 25, and the remaining portions of Line 15 are restricted to 80% of the highest pressure experienced at the discharge of each compressor station for the period of ninety (90) days prior to Failure 2.</li> </ol>			

Repair criteria and further action for A.O. Smith hard spots on the Affected Segment are determined once the anomaly has been evaluated in the field (as set forth under Section 5.0 below). In the event that an ILI hard spot tool does not identify any hard spot features, TETLP will confirm the accuracy of the ILI service provider report and the validation of the ILI tool as outlined in *API Standard 1163, In-line Inspection Systems Qualification*. All other actionable anomalies that are identified by the ILI tool service provider and confirmed by TETLP SMEs on

<sup>14</sup> Anomaly evaluation timeframe runs from the date of confirmed discovery under TETLP SOPs. This priority scheme takes into account the current pressure restrictions on the Affected Segment.

the Affected Segment will be planned for field investigation consistent with 49 C.F.R. Part 192 and TETLP SOPs.

## **5.0 A.O. Smith Hard Spot Anomaly Field Evaluation and Repair Criteria**

### **5.1 Field Evaluation Criteria**

To evaluate A.O. Smith hard spot defects in the field,<sup>15</sup> TETLP will perform a full joint excavation. As demonstrated in the first RWP increment, Hard Spot ILI Tool Qualification Plan, TETLP has performed testing of various ILI and field inspection tools and techniques, including EddyFi Spyne tool mapping, acid etching, and Equotip hardness testing, to determine the most reliable equipment to identify and characterize hard spots. This testing was completed on pipe with known hard spots.<sup>16</sup> A.O. Smith hard spot anomalies will be evaluated in the ditch and prepared for further evaluation pursuant to TETLP SOPs, including *Excavation and Backfill (1-4010)* and *Locating Buried Pipelines Using Electronic Line Locators (1-4020)*. TETLP will review the pipe coating condition for damage or disbondment prior to coating removal. TETLP will then evaluate targeted A.O. Smith hard spot defects and other exposed defects using the following six (6) methods (pursuant to applicable TETLP SOPs, including *Defect Assessment & Repair Options for Miscellaneous Defects (9-4050)*, and Sections 5.1.1 – 5.1.6 of this document):

- Pipe-to-soil potential measurements;
- Visual examination for evidence of flat spots or unique features;
- Magnetic Particle Test (MT) inspection to identify cracking;
- Ultrasonic wall thickness measurement survey and EddyFi Spyne tool mapping;
- Acid etching; and
- Hardness testing.

The field technician will evaluate the results and consult with SMEs as necessary.

#### **5.1.1. Pipeline to Soil Potential Measurements**

Pipe to electrolyte potential measurements will be performed at the suspected hard spot location in accordance with TETLP SOP, *Structure-to Electrolyte Potential Measurements (2-2010)*. The pipe-to-soil measurement data is used to investigate the cause of any cracking that may be found at the hard spot.

#### **5.1.2. Visual Examination**

The external surface of the pipe will be visually inspected for evidence of flat spots or any other unique features. Features such as a relatively flat region with rounded edges may indicate the

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<sup>15</sup> Because the Affected Segment is currently operating at restricted pressures, it is not necessary to implement an additional pressure reduction prior to the in-ditch evaluation of a hard spot anomaly.

<sup>16</sup> Remedial Work Plan Increment 1: Hard Spot ILI Tool Qualification Plan, Section 5.2 ILI Tool Benchmarking, pg. 7.

presence of a hard spot. All relevant anomalies and defects will be documented, and all defects or anomalies within the boundaries of the hard spot will be considered during the hard spot evaluation. Defects or anomalies outside of the hard spot will be assessed independently.

### **5.1.3. Magnetic Particle Test Inspection**

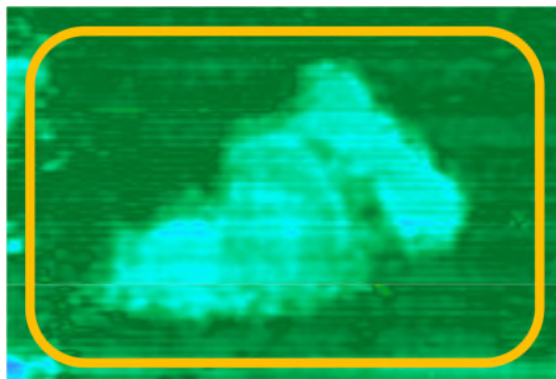
TETLP will perform MT inspection to identify evidence of cracking in accordance with TETLP SOP *Magnetic Particle Inspection for Surface Cracks (9-4060)*. MT will be performed over the entire region of the hard spot, and at any areas of disbonded coating, corrosion, deformation, and mechanical damage. If cracks or other types of defects are detected in a suspected hard spot region, TETLP will address it consistent with its SOPs and the hard spot repair criteria in Section 5.2.

### **5.1.4. Nondestructive Testing**

An ultrasonic wall thickness measurement survey will be performed on the suspected hard spot region using ultrasonic straight beam technology. TETLP will address any lamination or wall loss identified with this method consistent with Section 5.2 below and its SOPs.

The entire exposed area will be scanned using the EddyFi Spyne tool. The tool is able to detect potential hard spots for investigation because it is designed to detect changes in magnetic permeability of the material using an Eddy current array. In addition, this mapping will provide additional information on the feature and it will confirm whether the hard spot ILI tool reports any false negative findings (*i.e.*, hard spot confirmed in the ditch but not reported by the ILI tool). To ensure consistent results, the EddyFi Spyne tool will typically be calibrated before initial use, every four (4) hours, and at the end of each day. Figure 3.0 below depicts a hard spot using EddyFi Spyne tool hard spot mapping.

**Figure 3.0 – EddyFi Spyne Tool Hard Spot Mapping**



### **5.1.5. Acid Etching**

Any potential A.O. Smith hard spot areas identified by the hard spot ILI tool or the EddyFi Spyne

tool will be etched. TETLP will use acid etching to confirm if the feature is a hard spot. Pursuant to TETLP SOPs, the pipe surface will be cleaned and the surface polished in order to remove surface oxides and to obtain a relatively smooth surface. Acid etching with five percent (5%) or ten percent (10%) nital acid solution will be used to evaluate hard spot indications and locations of features to identify detailed microstructure variations. TETLP will identify and document any surface variations that occur as a result of the acid etching process. Figure 4.0 below depicts acid etching of the same hard spot that is represented in Figure 3.0 using the EddyFi Spyne tool mapping.

**Figure 4.0 - Acid Etched Hard Spot**



#### **5.1.6. Hardness Testing**

TETLP will perform hardness testing with the Equotip rebound portable hardness tester consistent with *ASTM A956, Standard Test Method for Leeb Hardness Testing of Steel Products*. Pursuant to TETLP SOPs, the pipe surface will be cleaned and a power grinder will be used to polish the surface in order to remove surface oxides and to obtain a relatively smooth surface. Prior to taking hardness measurements on the pipe, TETLP will verify the Equotip tool accuracy by taking hardness measurements on test blocks with known hardness levels. Hardness testing will be performed on the hard spot area as confirmed by etching using a one half (1/2) inch grid over the hard spot area that will extend outside the hard spot limits for six (6) inches using a coarser grid of one (1) inch.

The hardness mapping will be used to estimate the distribution of hardness levels across the hard spot, identify the highest hardness reading as compared to the ILI results, and provide feedback to the hard spot ILI service provider for continual learning and improvement as necessary. The individual location within the grid with the highest hardness value will be used to grade and classify the overall hard spot hardness level. Figure 5.0 depicts Equotip hardness measurements.

In this example, the highest hardness measurement is two hundred and forty-four (244) HB, therefore, this hard spot would be graded as two hundred and forty-four (244) HB for field evaluation purposes. Correlation of the hardness measurements over the hard spot will be compared to the measurements outside of the hard spot to validate if there is a difference of fifty (50) HB, which is required for proper ILI hard spot detection.

**Figure 5.0 - Equotip Hardness Measurements**

161	172	171	186	174	164	173	170	174	163	169	179	171	178	172	170	165	167
165	165	165	163	172	175	173	170	173	174	188	206	191	168	174	164	166	163
162	171	175	174	167	163	164	173	177	177	190	213	220	195	180	174	167	168
165	165	165	173	170	183	174	175	180	194	195	219	230	212	188	176	179	178
165	159	169	173	170	167	175	173	191	214	195	199	217	218	203	180	178	182
166	169	166	176	184	174	183	186	200	220	230	200	195	208	221	193	183	171
162	173	164	169	174	177	184	197	208	215	212	220	198	193	225	223	215	177
170	180	172	174	179	193	199	214	228	241	215	222	195	185	207	235	226	191
173	170	191	173	196	193	195	212	229	227	228	211	188	177	185	207	193	174
169	165	188	208	237	235	229	207	214	231	244	219	186	187	180	186	182	173
169	169	190	219	221	230	229	206	204	219	220	204	184	169	181	170	188	176
171	178	201	217	222	225	213	191	206	188	189	188	181	169	169	171	177	173
171	175	191	206	220	203	184	191	181	194	180	176	183	171	174	168	167	171
167	167	174	170	184	186	177	179	179	180	171	175	172	175	173	175	173	177

## 5.2 Repair Criteria, Methods, and Timeframe

A.O. Smith hard spot defects will be repaired pursuant to the criteria, methods, and timeframes set out below and in accordance with TETLP SOPs and associated guidance, including *Pipeline Repair Procedures (9-5010)* and *Defect Assessment & Repair Options for Miscellaneous Defects (9-4050)*.

### 5.2.1. Repair Criteria and Methods

As outlined in Table 4.0, TETLP will replace pipe containing any A. O. Smith hard spot that is: (1) interacting with cracking or corrosion that is greater than ten percent (10%) nominal wall loss; (2) interacting with another defect and where hardness is greater than or equal to two hundred and eighty (280) HB; and (3) where hardness is greater than or equal to four hundred (400) HB. Where there are no other interacting features, hard spots with a hardness between two hundred and eighty (280) HB and three hundred and ninety-nine (399) HB will be repaired by reinforcement or replacement. As explained above, hard spot features with a hardness of less

than two hundred and eighty (280) HB (as confirmed through field evaluation) are not an integrity threat and those features will be recoated.

Repair by reinforcement of the pipeline will be performed by Miliken Wet Wrap (also referred to as an Atlas Wrap) consistent with TETLP SOPs. Type B full encirclement sleeves will be used as reinforcement where necessary. Any pipe replacements will be performed with pretested pipe, consistent with 49 C.F.R. Part 192. Recoating will be conducted using a two-part liquid epoxy coating, such as Special Polymer Coatings SP-2888 coating systems as outlined in TETLP SOPs.

**Table 4.0, A.O. Smith Hard Spot Repair Criteria**

Hard Spot Characteristics	Repair Method
Any hard spot interacting with (1) cracking and/or (2) corrosion greater than 10% nominal wall loss  or  Any hard spot greater than or equal to 280 HB interacting with another defect	Replacement
Greater than or equal to 400 HB	Replacement
Between (and including) 280 HB and 399 HB	Reinforcement* or Replacement (*reinforcement by either Miliken Wet Wrap or Type B full encirclement sleeve)
Less than 280 HB	Recoat

**5.2.2. Repair Timeframe**

All A.O. Smith hard spot anomalies on the Affected Segment will be evaluated in the ditch pursuant to the schedule under Table 3.0. Repairs, whether by replacement, reinforcement, or recoating will be performed during the field evaluation and consistent with TETLP SOPs and the criteria in this document. All pipe replacements, repairs, or recoating will be performed for an Affected Segment pipeline segment prior to requesting return of that segment to normal operating pressure. Summary results will be provided in monthly reports under the Second ACAO, including ILI indications of hard spots, evaluation results (“as-called” as compared to “as-found”), and repair methods employed. The detailed inspection results for each Affected Segment pipeline segment will be submitted to PHMSA as part of TETLP’s request to return to normal operation up to the segment’s MAOP (see Section 7.0).

## **6.0 Continual Improvement**

As TETLP implements the A.O. Smith Hard Spot Response and Repair Criteria (as approved by PHMSA) on the Affected Segment A.O. Smith hard spots, TETLP will provide hard spot ILI tool service provider(s) with relevant information and findings from the actual in the ditch hard spot evaluations, including “as-called” versus “as-found” hardness values and sizing. TETLP will align the data in unity plots and it will investigate any outliers to identify the cause of the discrepancy. As a further means of confirming and/or calibrating the ILI tool probability of detection and field measurement equipment accuracy, TETLP will select hard spots identified for replacement from in the ditch assessments for testing to further characterize the hard spot in a laboratory environment. TETLP will track and analyze ILI results as compared to actual in the ditch findings to provide for improved ILI hard spot tool calibration and, as necessary, request that the ILI tool service provider reissue a report to account for the adjusted calibration. TETLP will also review all data gathered for any pattern in A.O. Smith hard spot distribution on relevant Affected Segment pipe joints.

In addition, TETLP will continue to perform additional confirmatory testing and analysis to further validate hard spot measurements (*e.g.*, hardness level, length, surface area, etc.). If necessary, TETLP will further refine the A.O. Smith Hard Spot Response and Repair Criteria in light of this information. TETLP will notify PHMSA of any revisions to this A.O. Smith Hard Spot Response and Repair Criteria RWP increment and will seek approval before any changes are implemented.

## **7.0 Request to Remove Pressure Restriction**

As TETLP completes the testing and remediation specified by the RWP to address the suspected causes of Failure 1 and Failure 2, it will prepare requests for temporary or permanent removal of pressure restrictions as appropriate. For requests for temporary removal of pressure restrictions, TETLP will prepare and provide an Integrity Assessment Summary (IAS) for pipeline segment(s) in support of a request for a return to a modified or normal operating pressure under the Second ACAO (Second ACAO, Par. 3(B), 17(B)). Specifically, the IAS will include results of the testing, field assessments, and repairs upon mitigation of the relevant threat whether hard spots, land movement, or both. For requests for permanent removal of pressure restrictions, TETLP will prepare an Engineering Assessment Summary (EAS) which will summarize the inspections, assessments, and evaluations considering all relevant integrity threats that TETLP performed under the RWP for each pipeline segment(s) (Second ACAO, Par. 3(A), 17(A)). The EAS will be based on a reliable engineering analysis which demonstrates that the pressure increase is safe considering all known defects, anomalies, and operating parameters of the pipeline. In some instances, TETLP may prepare and submit an EAS without taking the interim step of submitting an IAS.

## **8.0 Conclusion**

Once the work under Section 6.0 is completed, TETLP will have identified and removed or remediated all remaining A.O. Smith hard spots in the Affected Segment. Based on the results of the ILI hard spot assessments, repairs, and continual improvement process, TETLP will prepare

revisions to its existing hard spot program as appropriate to provide for the continued integrity of the Affected Segment. Toward that end, TETLP will continue to study the effects that CP may have on hydrogen generation and it will incorporate any relevant findings through the lessons learned process. In the meantime, and separate from the RWP, TETLP has a program underway to maintain CP levels between -850 mV and -1200 mV for pipelines containing A.O. Smith pipe.

TETLP respectfully requests that PHMSA review and approve this A.O. Smith Hard Spot Response and Repair Criteria as the second increment of the RWP, as provided in Second ACAO, Paragraphs 11(B) and 25(B). If approved, TETLP will provide updates on the repairs and summary results in monthly reports under the Second ACAO. Additional increments of the TETLP RWP will be forthcoming for PHMSA review and approval, including with respect to other activities that TETLP will perform under Second ACAO Paragraphs 11 and 25.