REX2024
PRCI Research Exchange

PRCI- REX 2024-073: Enbridge's Experience of Managing Hard Spots on Natural Gas Transmission Pipeline System

Gary Vervake
Debartha Bag
Samuel Kindel
Brady Bolf

San Diego, California
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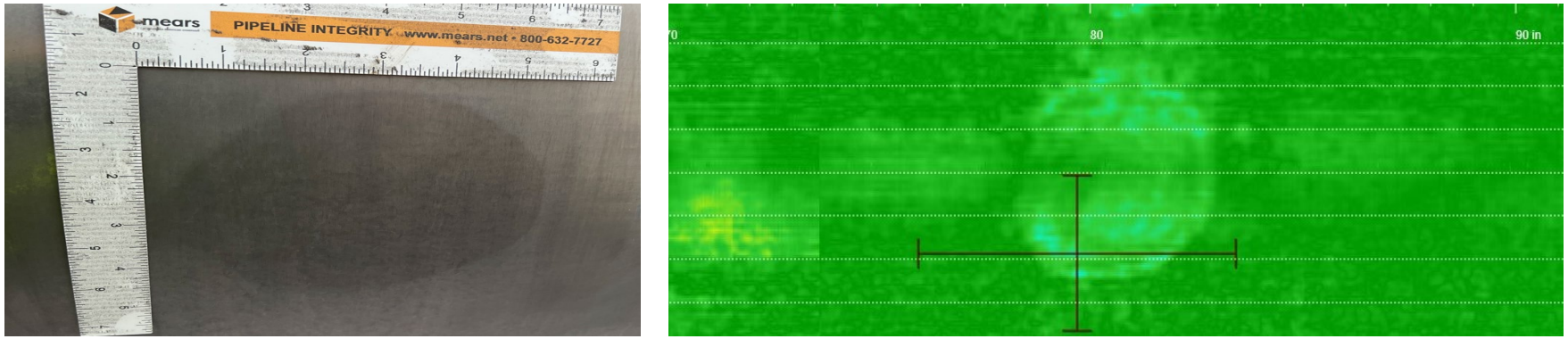
Overview

- Hard Spots and Enbridge Hard Spot Program
- GTM Pipeline Overview
- ILI Hard Spot Response
- Hard Spot Inspection and Repair Methods
- Pipe Cutout Assessments and Learnings from 2019 (CMA)
- Results from ILI and Dig Assessments
- Reliability Assessments
- Conclusions and Recommendations

Background

- Hard Spots are manufacturing defects of localized high hardness due to inadvertent quenching during final hot rolling of steel plates.
- API 5L criteria for hard spot: >327 HB and larger than 2” in any direction.
- Enbridge Criteria: Hard Spot > 280 HB without any length restriction.
  - Conservative criteria considers ILI tool tolerance of ± 50 HB.
- Injurious Hard Spots: Pipe body features with through-wall hardness > 300 HB, martensitic microstructure, prone to hydrogen embrittlement.
- Hard Spots with relatively lower hardness, intact coating, and isolated from exposure to corrosion or excessive CP generally remain stable and non-injurious.

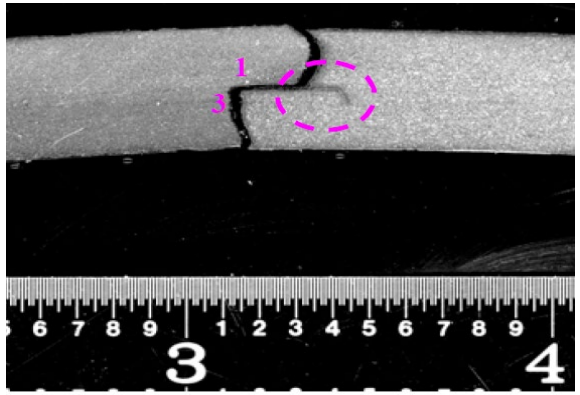


ECT Scan and Etching of AO Smith Pipe Body Hard Spot (338HB).

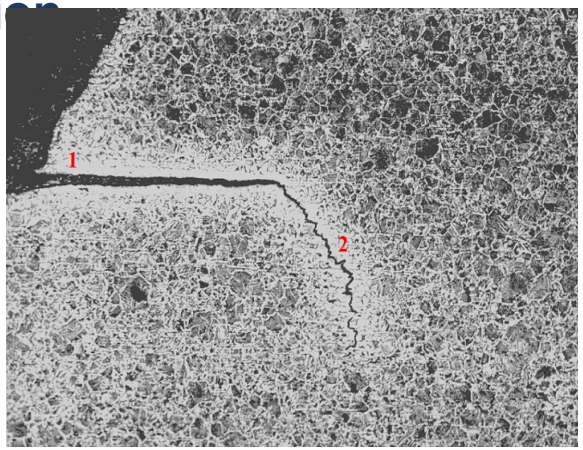
Background (Contd.)
Evolution of Enbridge Hard Spot Program

- **Hard Spot incidents data suggests susceptibility factor for hard spot is strong for pipe manufacturer, seam type, OD and pipe vintages.**

Seam Type	Manufacturer	Pipe Production Year	Number of Incidents
Flash Welded	A.O. Smith	1951-1957	26
DSAW	Consolidated Western Bethlehem Kaiser Republic	1947-1962	17
ERW	Youngstown Sheet & Tube	1947-1960	6



- **2003 Enbridge US GTM in-service failure at a hard spot interacting with laminati**
  which prompted company's research on hard spot failures and initiation of company's ILI hard spot management program.

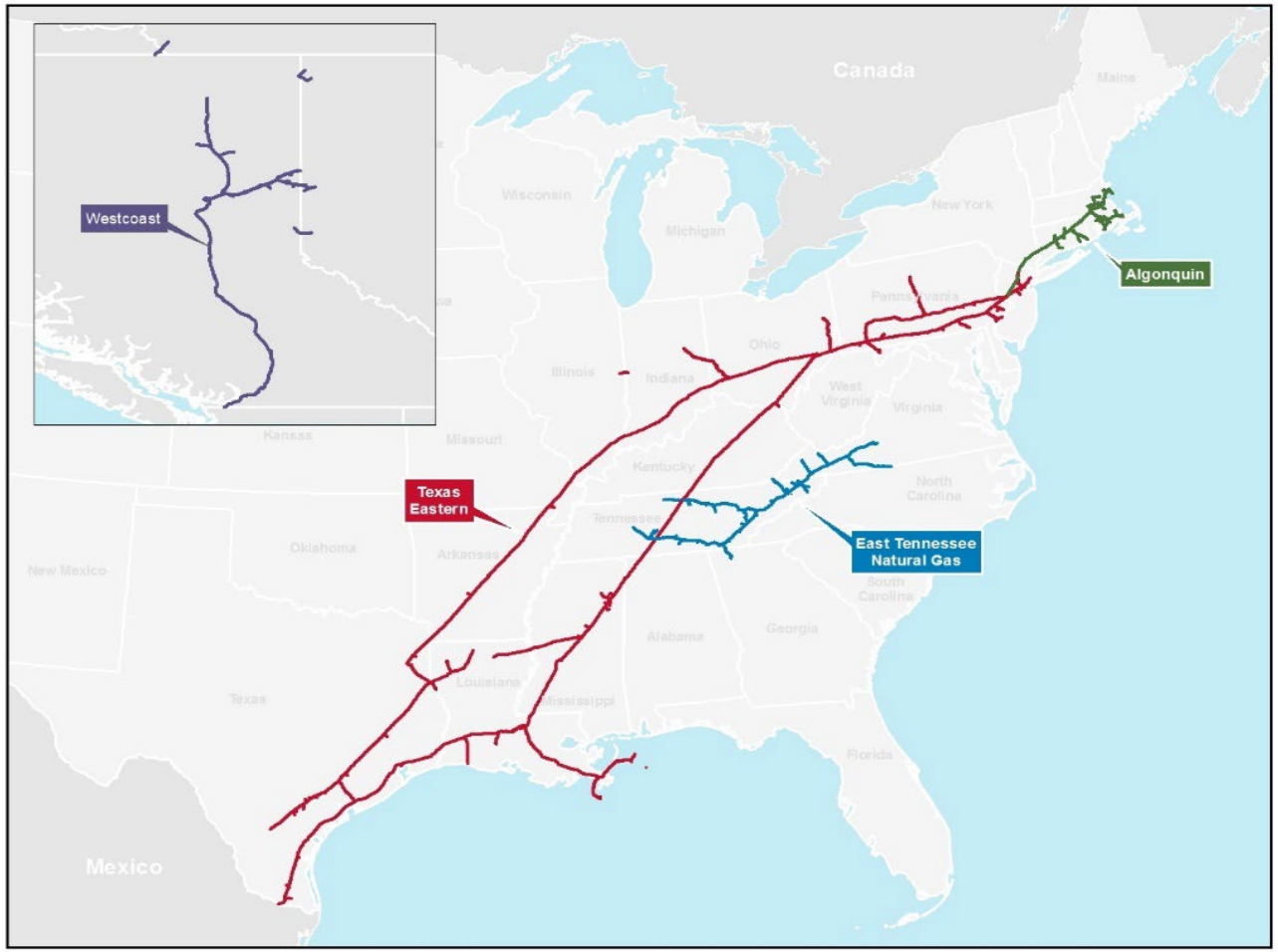


- **In 2019, USGTM had in-service failure at a hard spot**
  - Hard spot was not identified by previous ILI tool run.
  - Hard spot management program revised
  - New ILI hard spot tool campaign, rigorous bell hole NDE assessment, Risk and Reliability assessment.

Enbridge US and Canada GTM System

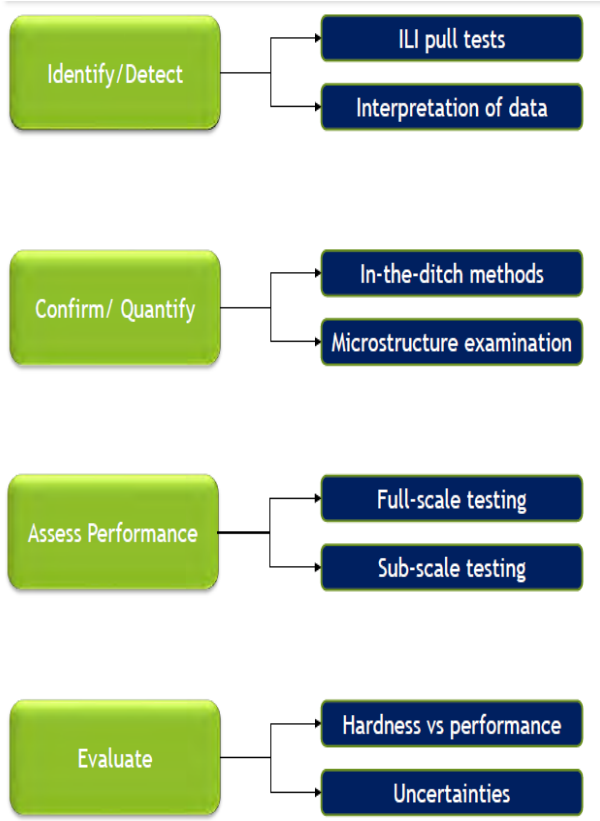
- **US GTM**
  - Mexico boarder to NE Canadian Border
  - Large Dia. pipeline- 24”, 30”and 36” OD
  - Class 1 (NWT 0.375”), X52
  - Predominantly coal tar and asphalt coating
  - Predominantly 1950s AO Smith EFW and DSAW pipes.
  - Predominantly operating stress at 72% SMYS with some grandfathered segments operate above 72% SMYS.
  - Reverse flow enacted in 2014-time frame.

- **West Coast GTM**
  - US Boarder to Fort Nelson
  - Large Dia. pipeline- 30” (762 mm)and 36” (914 mm) OD
  - Class 1 (NWT 0.375”/9.5mm, 0.390”/9.9 mm) X52 and X60
  - Predominantly Tape or asphalt coating
  - 1950s AO Smith EFW and DSAW pipes.



Enbridge 2019 Hard Spot Pipe Cutouts Assessments – Circumferential Magnetic Anomalies (CMA)

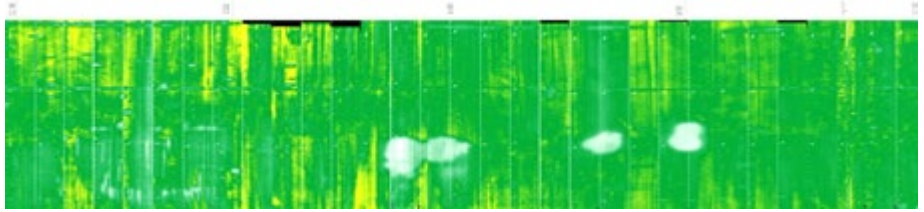
- In the Fall of 2019, Enbridge took up an extensive hard spot evaluation campaign on 13 pipe cutouts of AO Smith 30" 0.375" WT X 52 pipes, suspected of having hard spots based on 2011 hard spot ILI run.
- This project involved a comprehensive assessment of:
  - Pull tests involving multiple ILI providers
  - NDE campaign with several NDE providers
  - Laboratory metallurgical assessment with full scale and sub scale testing.
- This project helped shaping Enbridge's current hard spot program with the understanding of:
  - different types of hard spots (next slide)
  - NDE assessment methods
  - performance and uncertainties of ILI tools.
- These learnings were also shared with ILI providers which helped improve current industry hard spot ILI identification algorithms.



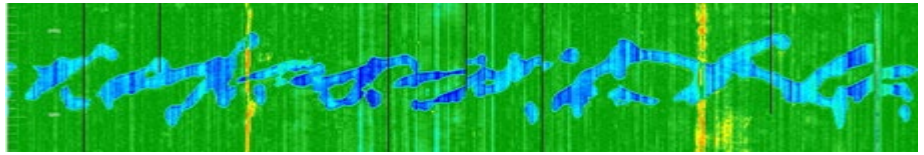
Circumferential Magnetic Anomalies (CMA)

- a) Typical saw tooth pattern, ID dominant

- b) Distributed hard spots, can be through wall



- c) Atypical pattern, OD dominant



Eddyfi scans revealing various hard spot types.

CMAs revealed from ID etching, corresponds to item a) saw tooth pattern in ID. Pattern discontinuous across seam weld.

- CMAs are generally considered non-injurious:
- Found to contain bainitic microstructures instead of martensitic in conventional hard spots.
- Less susceptible to hydrogen embrittlement
- Generally recorded to have lower hardness values~ 250-300 HB
- PHMSA seems to be in agreement that CMA's are non-injurious

Enbridge Hard Spot ILI Response

- ILI Response for Hard Spots > 280 HB
- Addresses Interactive Threats – Corrosion, Cracks, Dents
- Distinguishes hardness levels 280HB, 340HB and 400HB.
- Includes Surface Area Consideration
- Considers HCA and Outside of HCA.
- Priority 1 – Immediate
- Priority 2 – Scheduled
- SOP defines safe excavation pressures sentenced hard spot features.
- Sentenced ILI features are considered possible hard spots and require direct examination confirmation.

Table 4: Hard Spot Sentencing Criteria

HARD SPOT EVALUATION CRITERIA		ANOMALY EVALUATION*	
Hardness	Surface Area	HCA	Outside of HCA
Any Hard Spot greater than or equal to 280 Brinell™ Hardness (HB) interacting with another defect[1] or Greater than or equal to 400 HB	All	Priority 1[2]	Priority 1[2]
Between (and including) 340 HB and 399 HB	All	Priority 1[2]	Priority 2[3]
Between (and including) 300 HB and 339 HB	All	Priority 2[3]	Priority 2[3]
Between (and including) 280 HB and 299 HB	Greater than or equal to 4 inches square	Priority 2[3]	Priority 2[3]

Notes:

[1] *"Another Defect" includes dents, metal loss ≥10%, crack field or crack-like defects.*

[2] *"Priority 1" anomalies will be excavated and evaluated as soon as practicable, subject to the 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.*

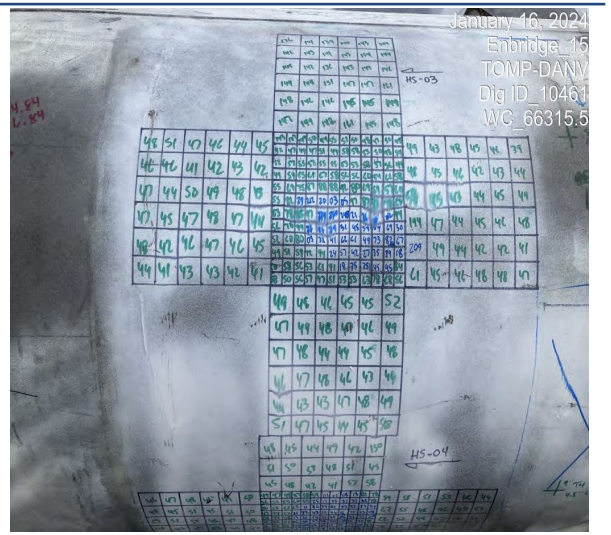
[3] *"Priority 2" anomalies will be scheduled for excavation and evaluation, subject to the receipt of necessary permits and right-of-way access. All Priority 2 evaluations and necessary repairs within a pipeline segment will be completed before requesting approval to return that segment to normal operation.*

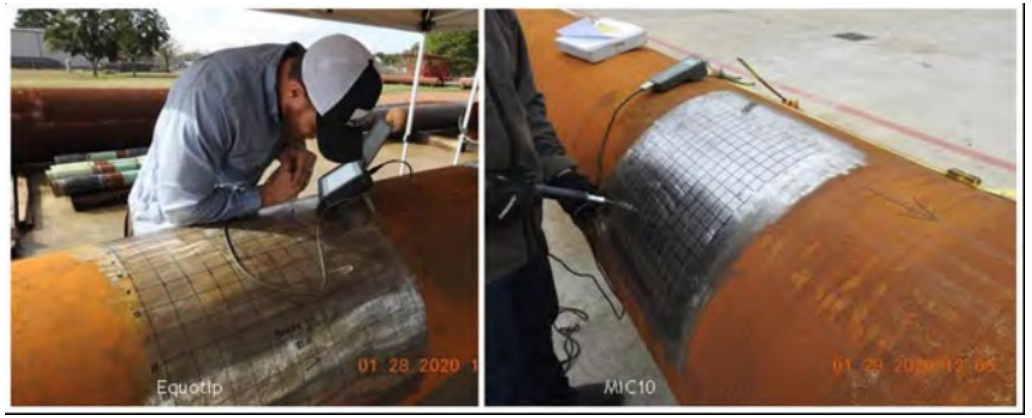
**Anomaly evaluation timeframe runs from the date of confirmed discovery under Enbridge GTM procedures. This priority scheme considers the current pressure restrictions on the affected segment.*

Enbridge Hard Spot Bell Hole NDE Program

Hard Spot field assessment :

1. Document coating type and coating condition
2. Remove coating & perform visual inspection of exposed pie for flat spots, ext. corrosion, and other features
3. Eddy Current Assessment (ECA) (entire exposed pipe)
4. MT (pre-surface polishing) – ECA and HS ILI Features
5. Ultrasonic testing (UT) lamination scan and actual WT measurements (pre-surface polishing)
6. Surface polishing
7. UT actual WT measurements (post surface polishing)
8. Acid etching
9. Portable hardness testing
   - *In pipe body*
   - *In seam weld**





179	182	176	188	211	254	283	286	278	264	201	212
197	183	183	210	289	291	294	308	274	289	273	200
189	182	199	250	301	307	305	324	315	296	294	281
182	195	242	187	317	295	332	336	297	305	297	294
188	203	245	288	308	305	338	331	328	316	306	301
209	207	225	258	294	307	306	316	326	316	316	294
210	203	217	242	285	301	311	307	294	273	293	267
186	198	190	208	259	264	272	285	272	291	229	192
176	197	189	193	200	237	282	265	240	191	184	179
176	172	174	169	185	179	183	186	263	184	175	166
174	174	172	173	178	164	168	187	172	171	168	171
176	175	173	175	171	171	179	173	162	169	175	169

Hardness Testing

- Leeb D portable hardness testing using a qualified and Enbridge GTM approved technician

Enbridge Hard Spot Repair Criteria

- Enbridge Hard Spot Repair Strategy is conservative:
- Type B Sleeve or cutouts are only permitted repairs for interactive hard spots (corrosion or cracks) and elevated hardness levels > 400HB. Composite reinforcements are not allowed for these hard spot repairs.
- Reinforcement composite wraps such as CS-NRI Atlas wrap is only approved repair method for non-interactive hard spots with hardness level <400 HB

Anomaly 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 Or Type B Sleeve**
Hard spot greater than or equal to 400 HB	**Replacement or Type B Sleeve**
Hard spot between (and including) 280 HB and 399 HB	**Reinforcement** or **Replacement** *(reinforcement by either Carbon Fiber Wet Wrap Composite or Type B pressure containing sleeve)*
Less than 280 HB**	**Recoat**

** Type B sleeve is a permanent repair for External Corrosion, and Temporary for Internal Corrosion upon approval by PI Engineering.*
*** The only hardness indications eligible for recoat and backfill are 280 HB or below hardness with no evidence of cracking as determined by MT*

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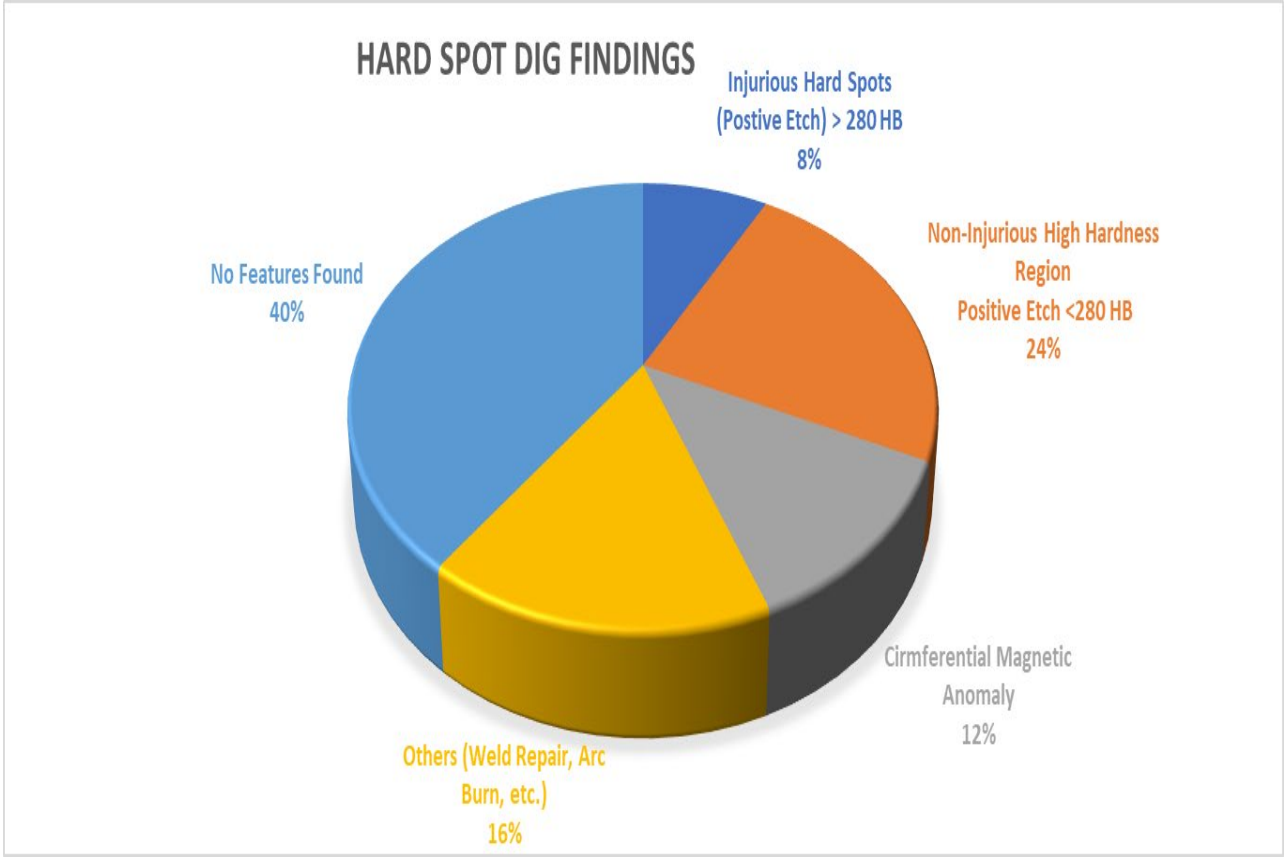
Hard Spot ILI Dig results- 2019-2024

- Enbridge GTM has inspected more than 2200 miles of pipeline in 2019 through 2024. Almost 1000 miles of these pipeline were AO Smith pipes.

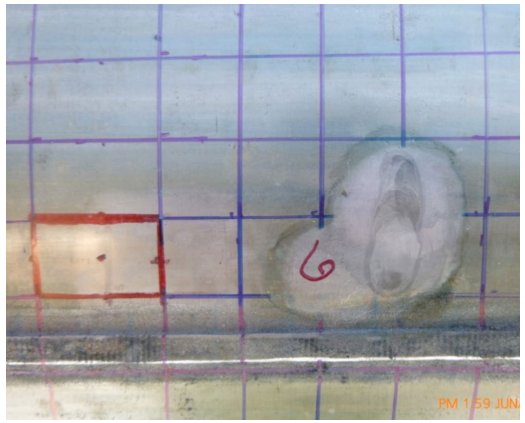
- 280 digs performed

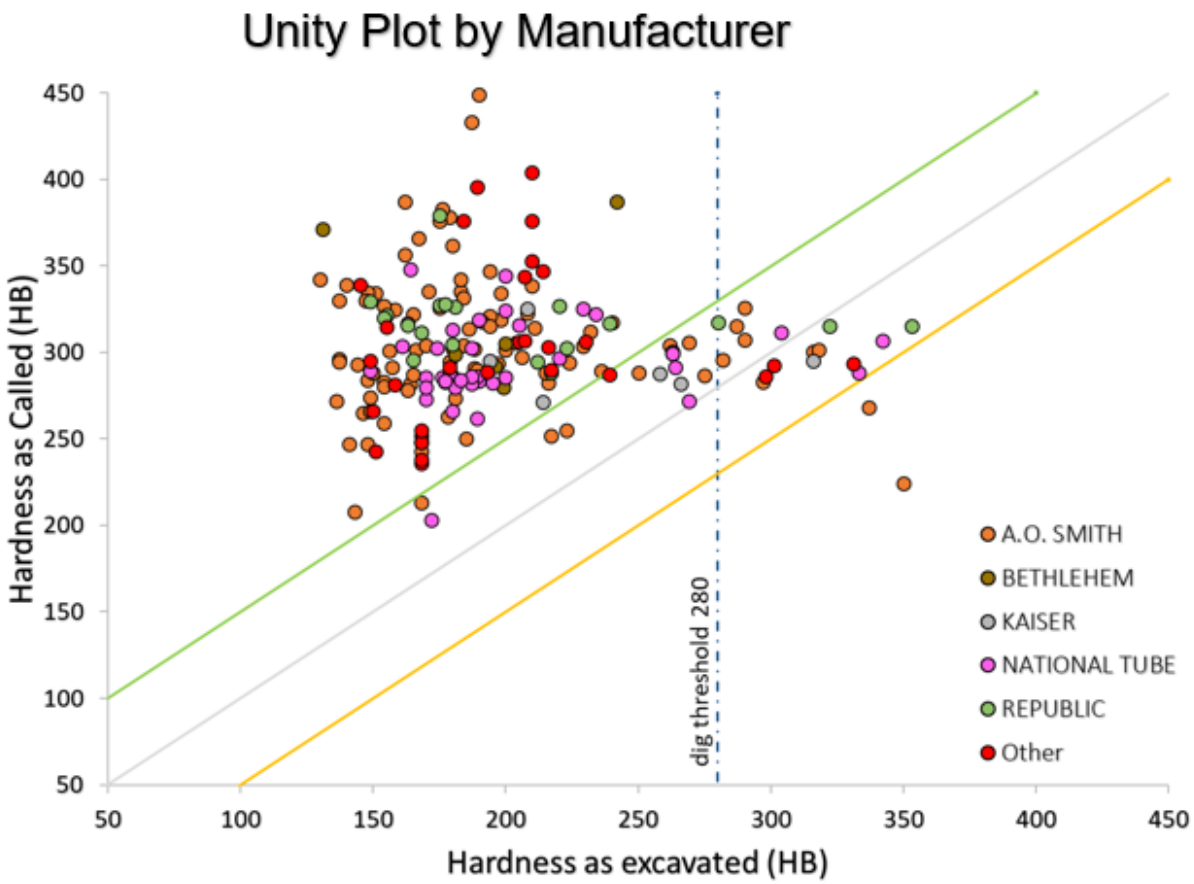
- Only 8-10 % of the ILI features were confirmed as injurious hard spots with hardness >280 HB and positive etching. A vast majority of other features were characterized as either CMAs, non-injurious hard spots with hardness < 280HB, localized weld repairs, or no features at all.



Enbridge GTM Hard Spot ILI Dig results- 2019-2024

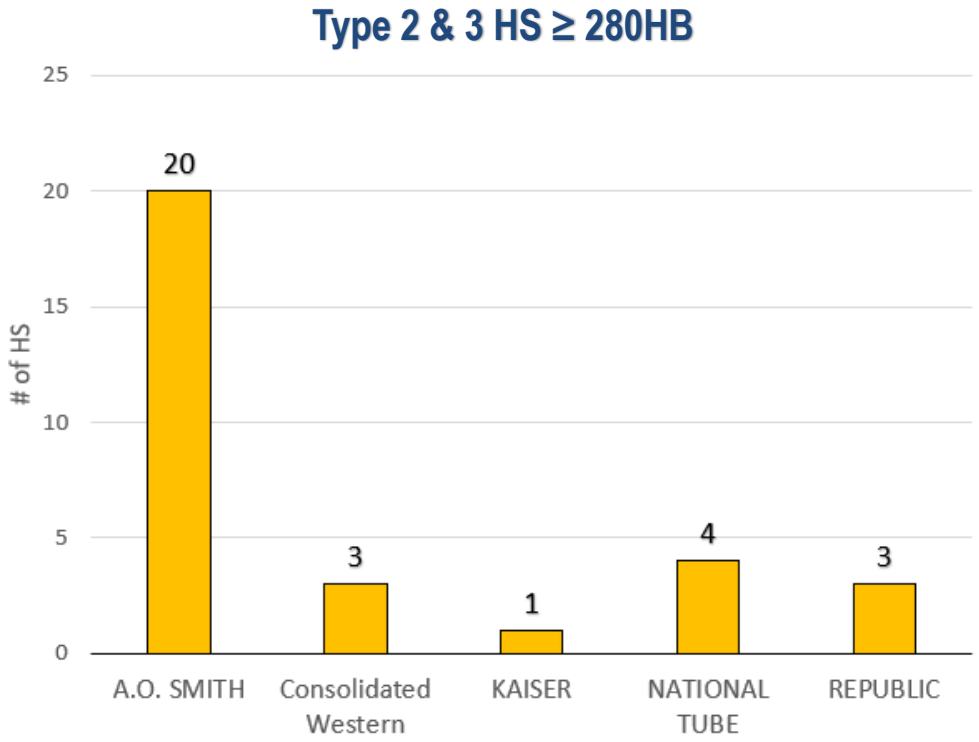
- Of the 205 features shown, 28 Hard Spot features had hardness ≥ 280 HB (13.7%)
  - A.O. Smith (FW) – 17 Hard Spots
  - National Tube (DSAW) - 4
  - Consolidated Western (DSAW) - 3
  - Republic - 3
  - Kaiser - 1
  - Bethlehem - 0

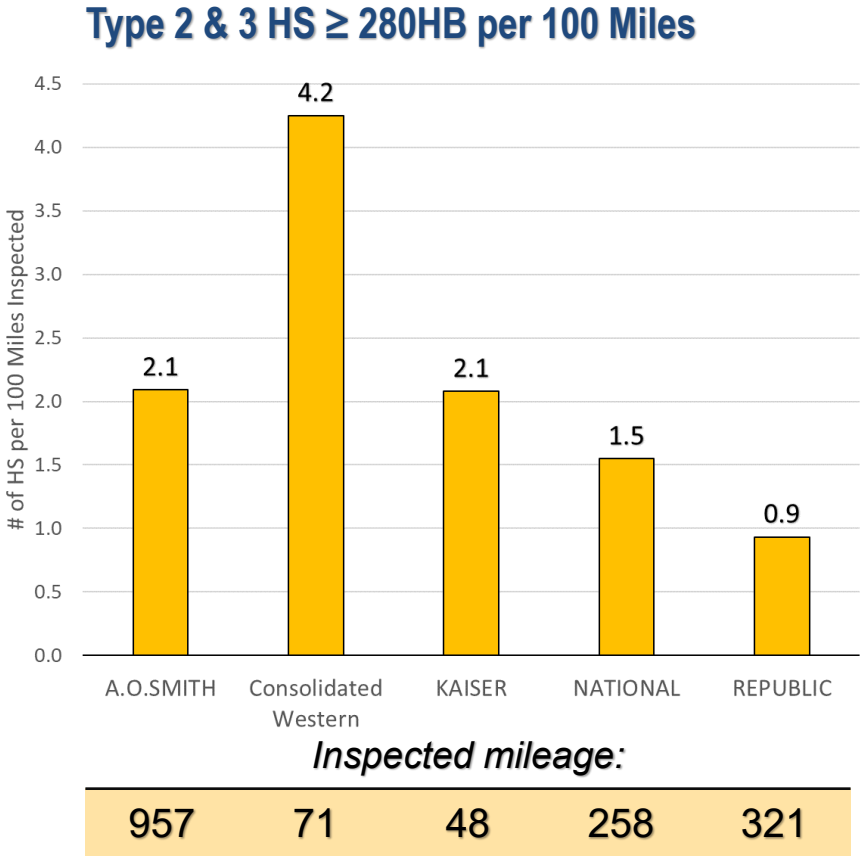




Oleg Shabarchin, PRCI Fall Meeting Presentation, September 2023.

Enbridge GTM Hard Spot ILI Dig results- 2019-2024





Inspected mileage:

957	71	48	258	321

- More than 290 digs performed since 2019
- 115 HS Features examined with positive etch.
- 31 features had field-confirmed hardness > 280 HB.

Oleg Shabarchin, PRCI Fall Meeting Presentation, September 2023.

Conclusions

1. Industry understanding of different types of hard spot, their susceptibility criteria and inspection capabilities (ILI and NDE) have been evolving, however there remains challenges for management of the threat.
2. Collaboration with the hard spot ILI vendor and operators is critical for improving hard spot integrity management.
3. Portable hardness testing technology provides useful data for managing hard spots and risk assessments. However, further development may improve accuracy and repeatability.
4. New hard spot features are being studied, and ILI vendors are improving their signal interpretation methods. Data interpretation and reanalysis of prior hard spot tool runs may result higher confidence.
5. For new types of hard spots, ILI vendors may not estimate of hardness properties. operators accustomed to the hardness values may need to have response criteria based on hard spot size dimensions.
6. Pipe replacement samples with hard spots provide extremely valuable for research.
7. PRCI research programs MAT-7-2 and MAT-7-2A will provide improvement for understanding of hard spot susceptibility and hard spot ILI performance.
8. Hard spots may be an integrity concern for operators considering transporting bended hydrogen.

thank you

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