

Girth Weld Failures and Industry Responses

Keynote Address



Center for Reliable Energy Systems

Yong-Yi Wang, Ph.D.

ywang@cres-americas.com

614-419-2366

IPG 2025

11/7/2025

Bogota, Colombia

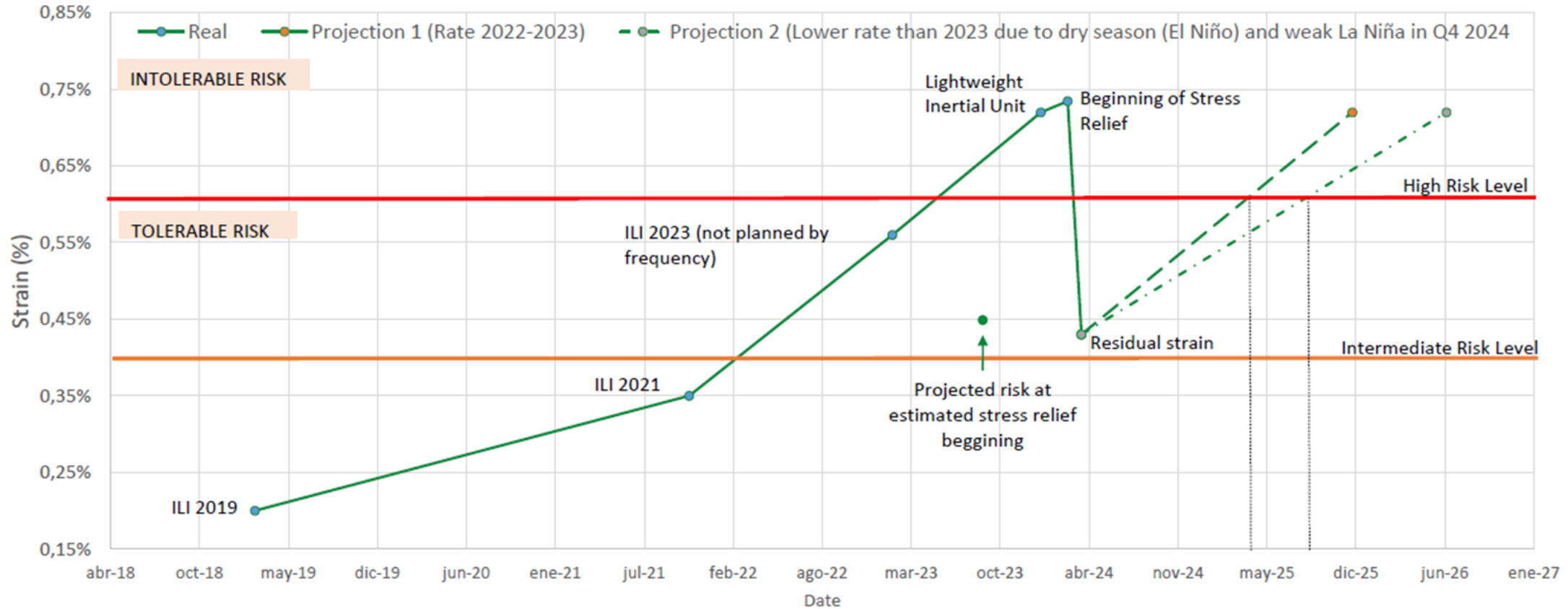
Overview

- ❑ Goal of this presentation
- ❑ A brief bio of the presenter
- ❑ Incidents and major contributing factors
- ❑ Mitigative measures
- ❑ Screening for existing assets
- ❑ Concluding remarks

Goal of this Presentation

- ❑ Set appropriate strain limit thresholds
- ❑ Increase strain limit

Risk behaviour between 2019 and 2024 and projections to 2025



Presenter – Dr. Yong-Yi Wang, Person

- ❑ Grew up in a small town in northern China.
- ❑ Undergraduate education in Shanghai, China
- ❑ Graduate education in the US
- ❑ S.M. and Ph.D. at MIT
 - ❖ Major: Mechanics and Materials
 - ❖ Minor: Business administration
- ❑ Hobbies
 - ❖ Swimming
 - ❖ Rock climbing
 - ❖ Running
 - ❖ Gardening



Yong-Yi here

Presenter – Dr. Yong-Yi Wang, Professional Life

- ❑ 30+ years of experience in consulting/research for the pipeline industry
 - ❖ Work with almost all stakeholders: regulators, standards committees, operators, service providers
- ❑ Founded CRES in 2007
- ❑ Industry leadership
 - ❖ Chair, Fracture Mechanics subcommittee of API 1104
 - ❖ Chair, Geohazards Management and Strain-Based Design and Assessment Track, IPC
 - ❖ Chair, Work Group on the Management of Circumferential Cracks, API RP 1176
 - ❖ A lead author for several PRCI, JIP, INGAA, and API documents on the management of geohazards
- ❑ Authored over 180 technical papers on pipeline integrity assessment, geohazards management, materials, welding, and fracture mechanics.
- ❑ Most known for strain-based design and assessment
- ❑ Awards
 - ❖ Honoree of distinguished lecture series, IPC 2018
 - ❖ Distinguished researcher, PRCI

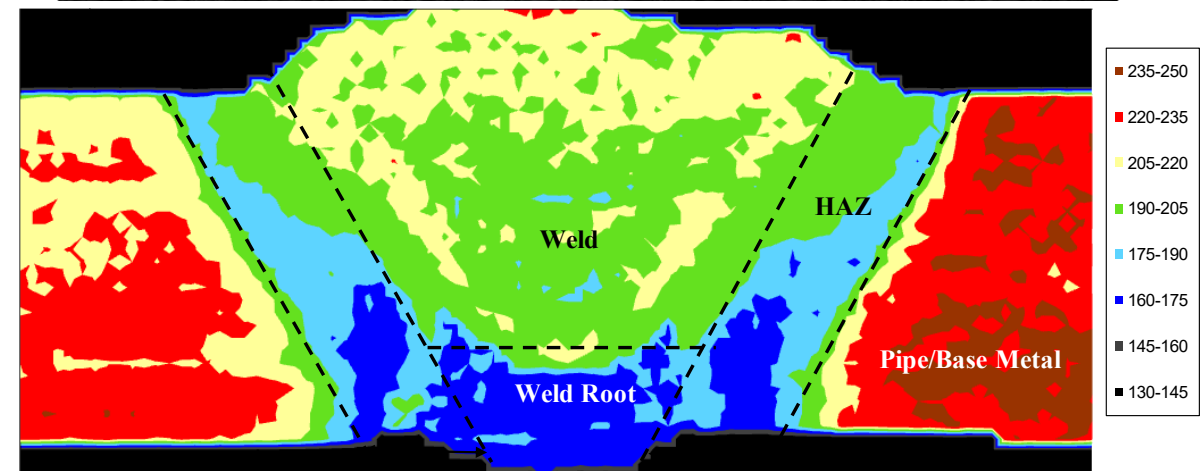
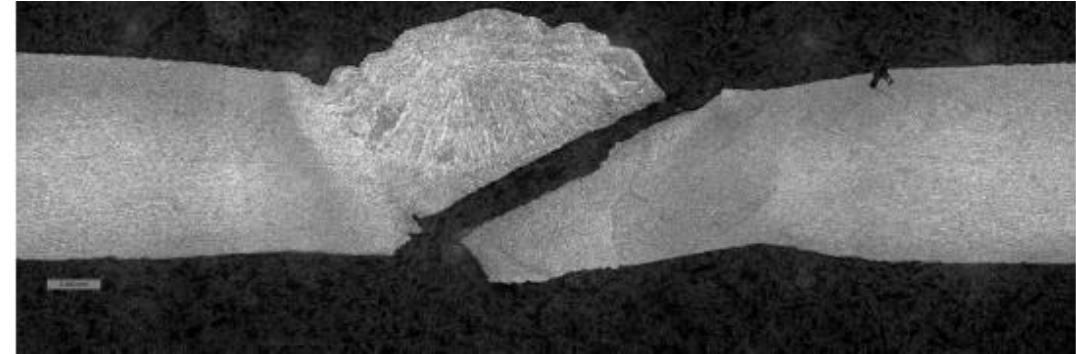
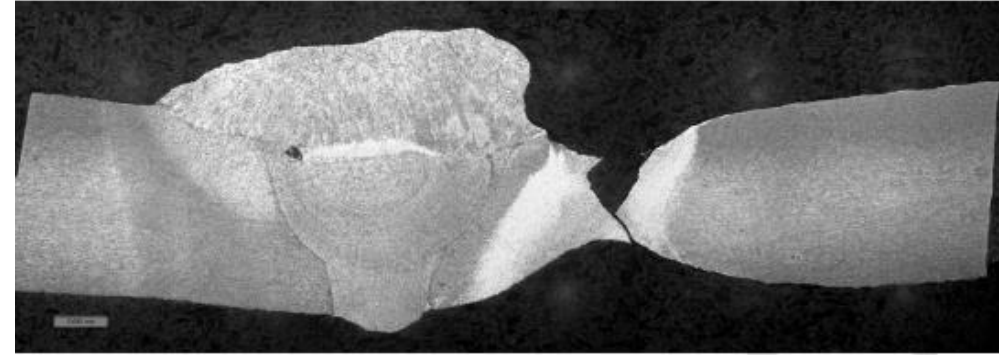
Acknowledgement

- ❑ Sponsors
 - ❖ Pipeline operators
 - ❖ PRCI
 - ❖ JIPs
 - ❖ CER
 - ❖ Pipe and steel mills
- ❑ Industry leaders
 - ❖ Steve Rapp, Russell Scoles, Marie Quintana, Dr. David Johnson
- ❑ Staff at CRES
 - ❖ Dr. Dan Jia and Mr. David Warman and many others

Example Failure Incident 1

□ Key Incident data

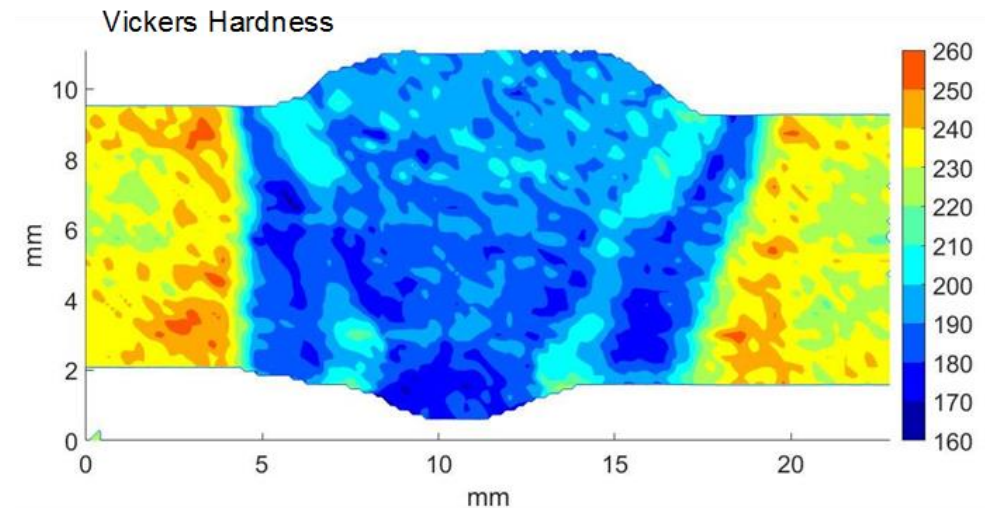
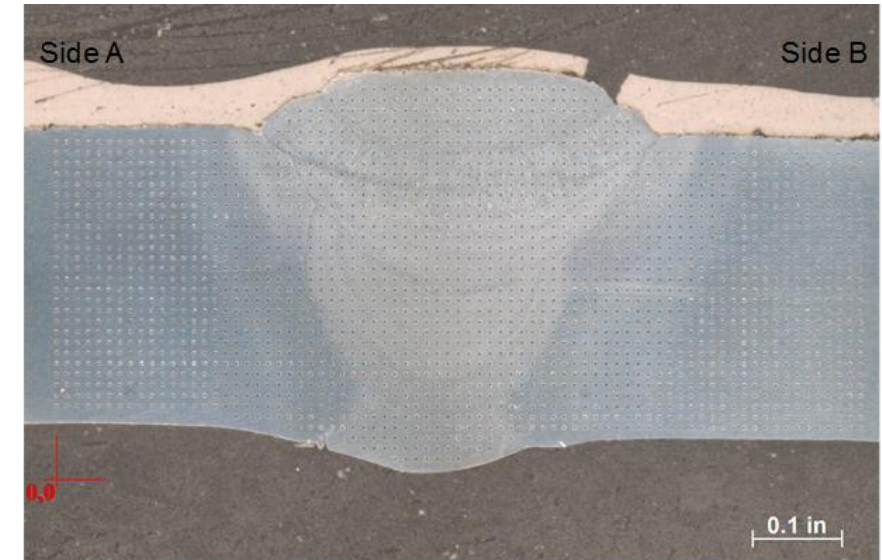
- ❖ Pipeline: X70, 20" OD HFI
- ❖ Occurred in the winter of 2014/2015
- ❖ Length of time after construction: 1 year



Example Failure Incident 2

□ Key Incident data

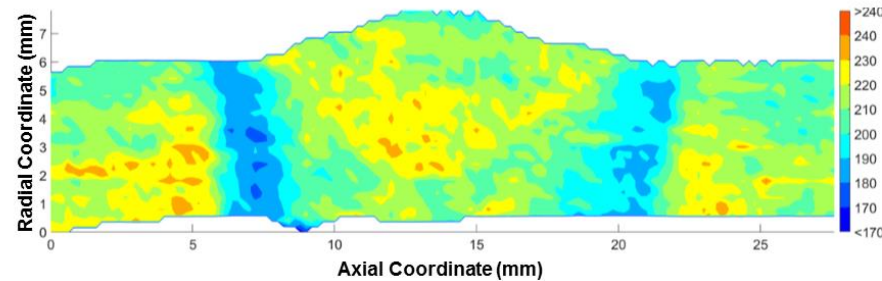
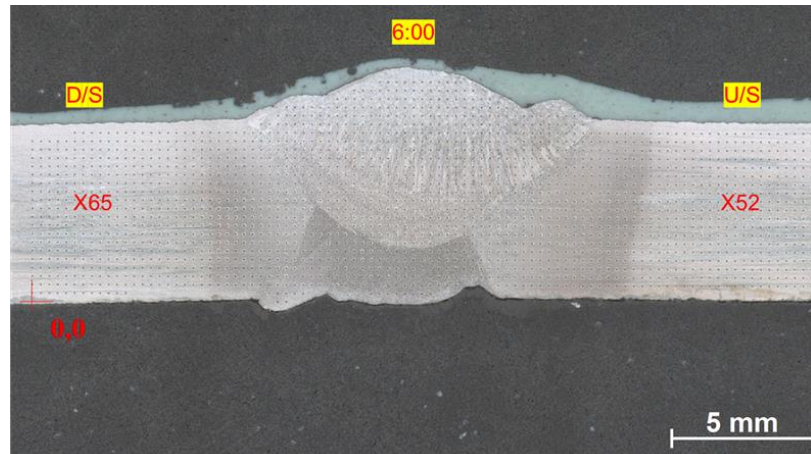
- ❖ Pipeline: X70, 24" OD HFI
- ❖ Occurred in the winter of 2017/2018
- ❖ Length of time after construction: 3.5 years



Example Failure Incident 3

□ Key incident data

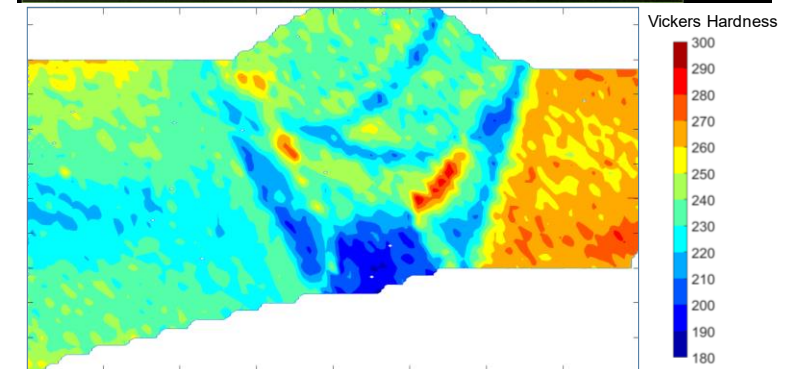
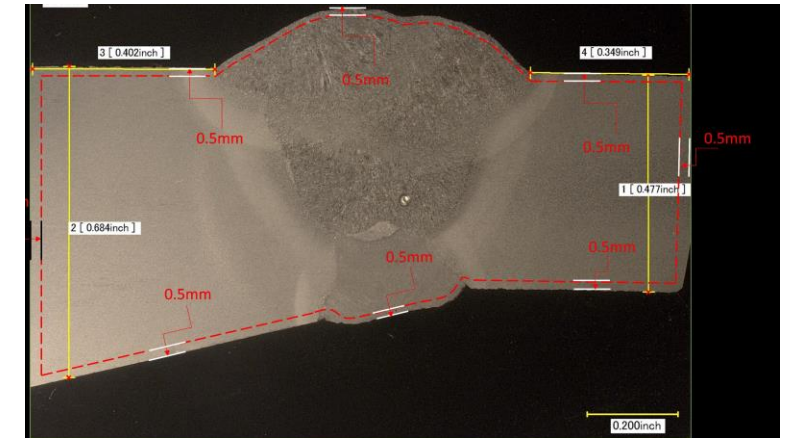
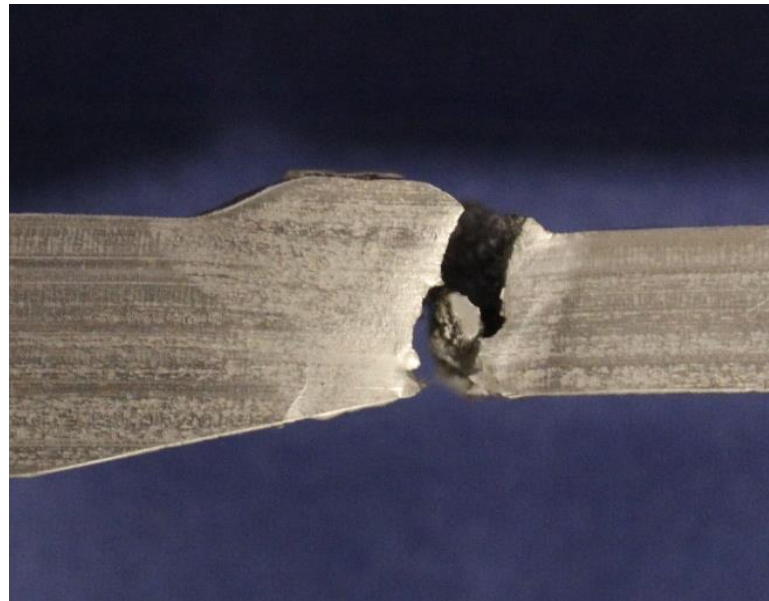
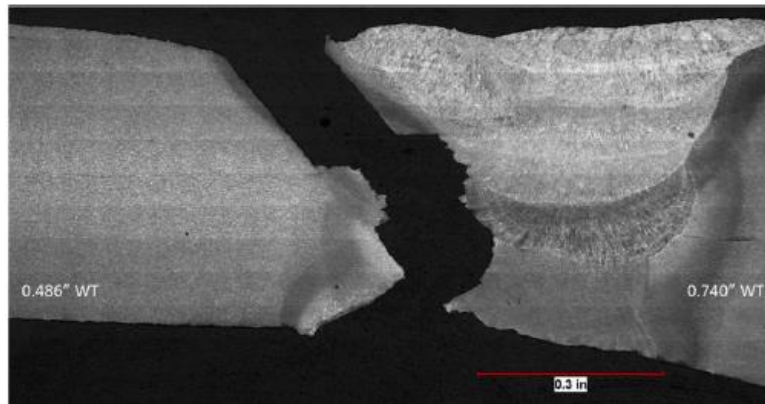
- ❖ Pipeline: X52/X65, 12" OD
- ❖ Occurred in the winter of 2015
- ❖ Length of time after construction: 4-5 years



Example Failure Incident 4

□ Key Incident data

- ❖ Pipeline: X70/X80, 30+” OD
- ❖ Occurred in the winter of 2015/2016
- ❖ Length of time after construction: 6 years



Example Failure Incident 5

- ❑ On February 22, 2020, a CO₂ pipeline ruptured in proximity to the community of Satartia, Mississippi.
- ❑ The rupture followed heavy rains that resulted in a landslide, creating excessive axial strain on a pipeline weld.

- **Delhi Pipeline**

- Installed in 2009
- 24" OD X80 ERW pipes
- 77 miles
- CO₂ is used for enhanced oil recovery (EOR)

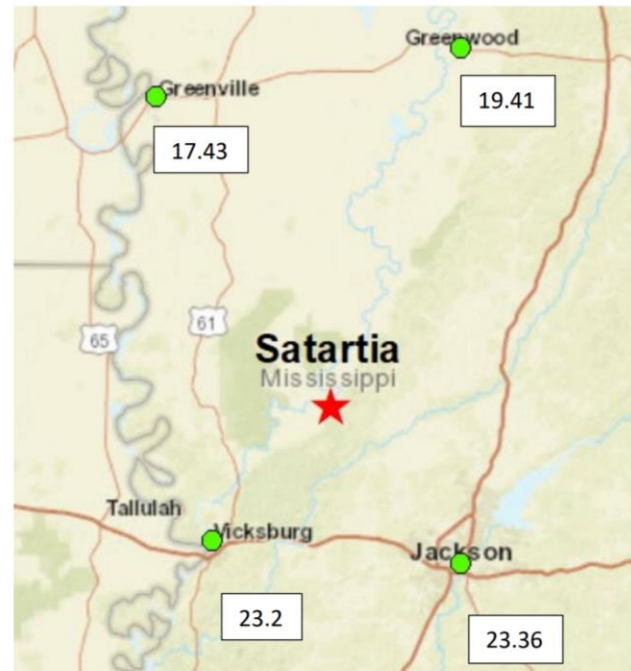


Figure 2: Vehicle is Parked on HWY 433 - The White is Ice Generated by the Release of CO₂ - The Blue Arrow Points North
(Aerial Drone Photograph Courtesy of the Mississippi Emergency Management Agency)

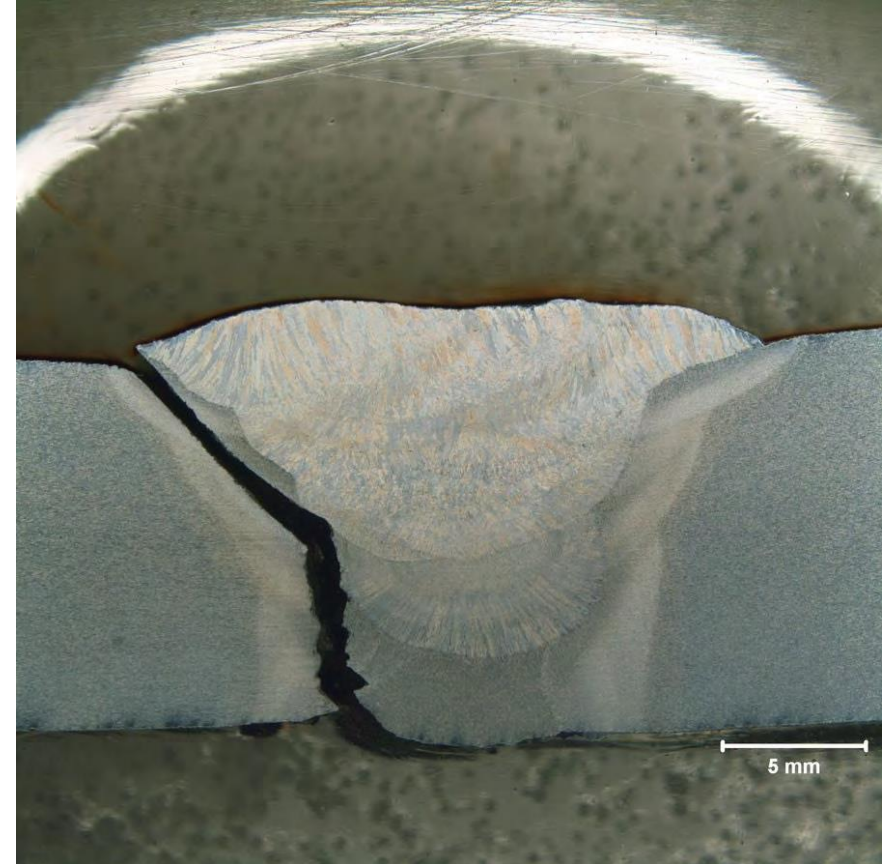
Wesley Mathews, "Failure investigation report – Denbury Gulf Coast Pipelines, LLC – Pipeline Rupture / Natural Force Damage," US DOT PHMSA OPS, May 26, 2022.

Example Failure Incident 5



Wesley Mathews, "Failure investigation report – Denbury Gulf Coast Pipelines, LLC – Pipeline Rupture / Natural Force Damage," US DOT PHMSA OPS, May 26, 2022.

Example Failure Incident 5

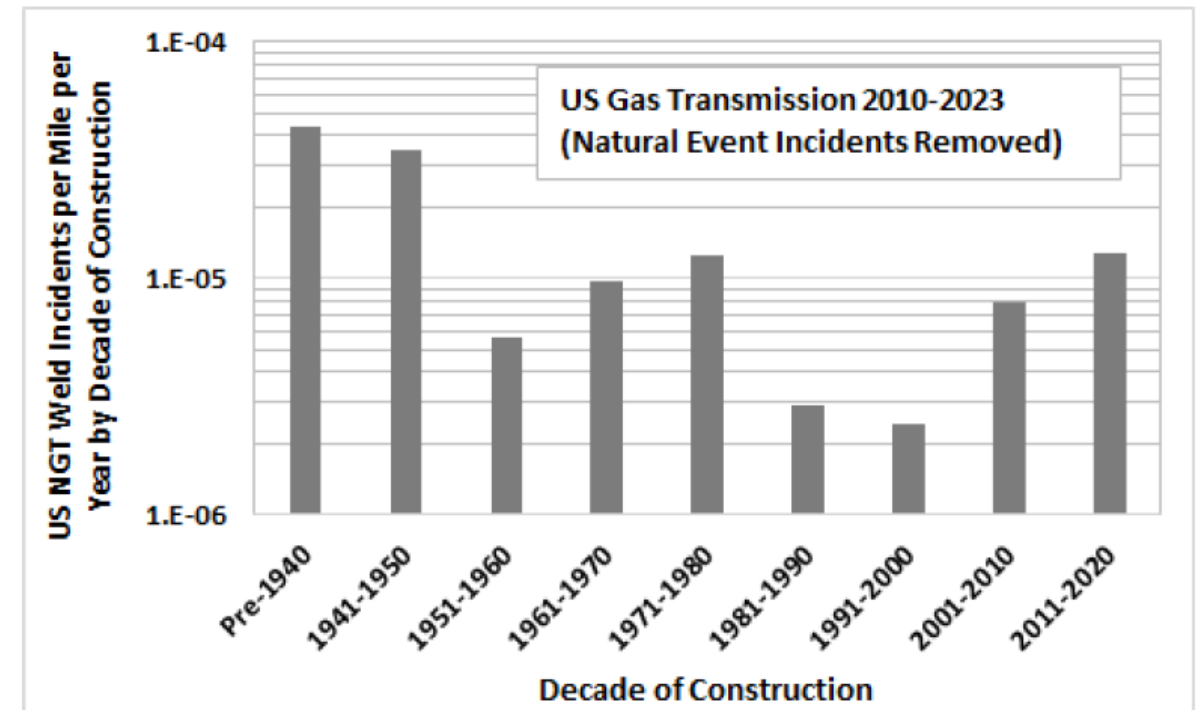


Wesley Mathews, "Failure investigation report – Denbury Gulf Coast Pipelines, LLC – Pipeline Rupture / Natural Force Damage," US DOT PHMSA OPS, May 26, 2022.

PHMSA Reportable Incidents in Natural Gas Transmission Pipelines

- ❑ Girth welds, branch welds, fab welds
- ❑ 2010-2023
- ❑ Natural force events and other external force events removed
- ❑ “Welds made post-2000 are worse, per mile per year, than welds made in the 1950s.”

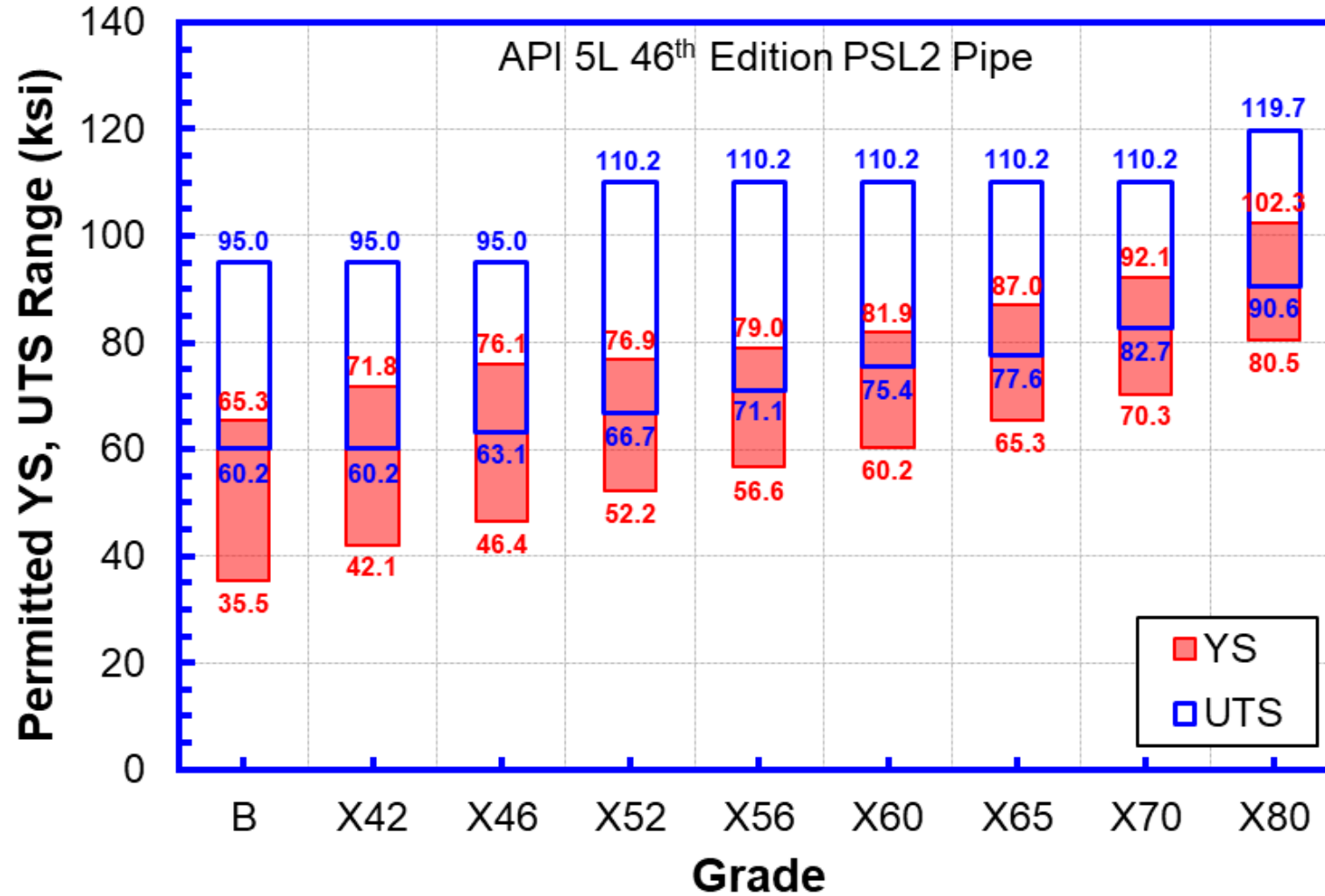
Rosenfeld, M., “B31.8 Welding Revisions Status Report,” presentation to API 1104 Committee, February 4, 2025



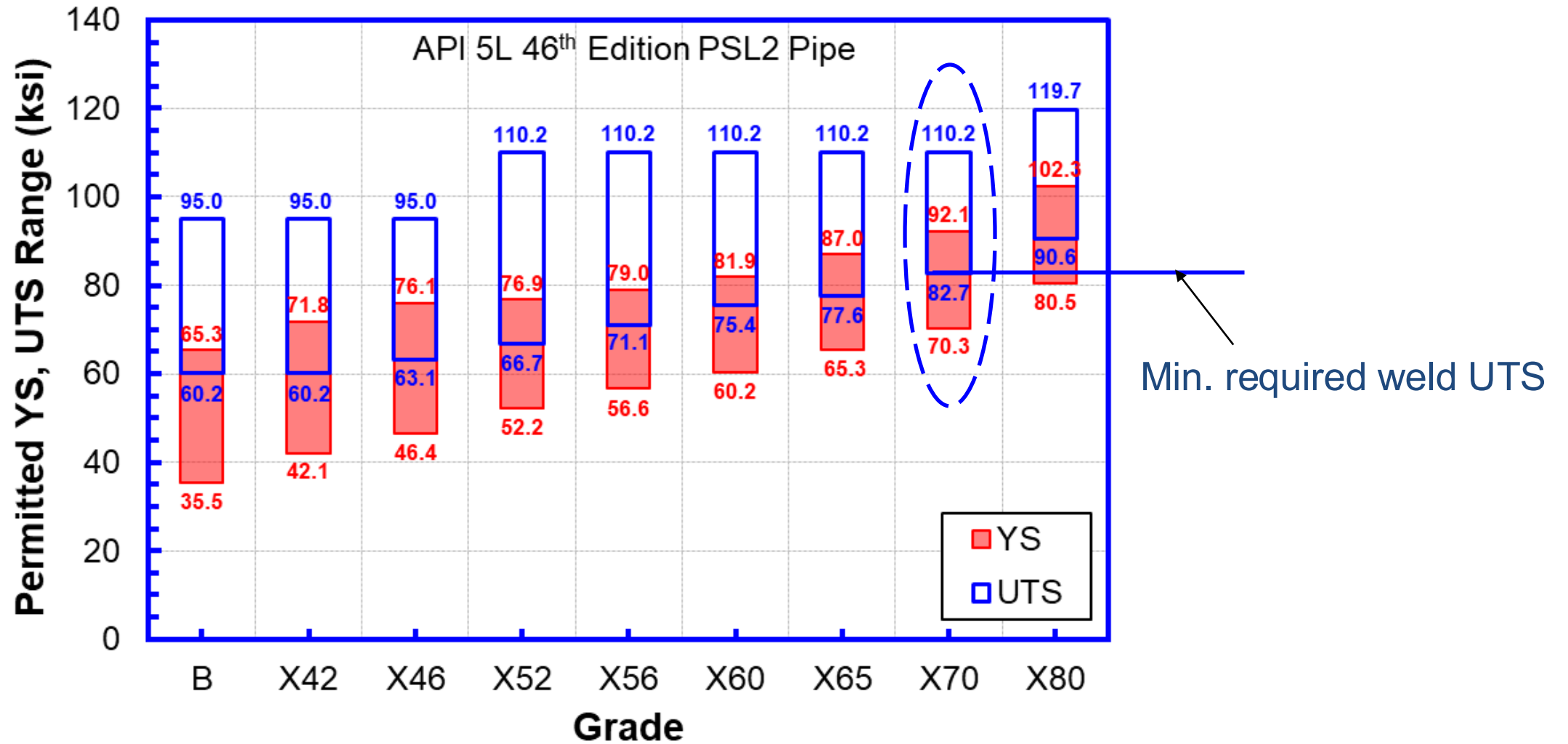
Major Contributors

- ❑ Weld strength undermatching
 - ❖ Strength of deposited weld metal lower than the strength of the pipe
- ❑ HAZ (heat-affected zone) softening
 - ❖ HAZ has lower strength than that of the pipe
- ❑ Elevated longitudinal/axial stress – sources
 - ❖ Construction
 - ❖ Post-construction settlement
 - ❖ Land movement
- ❑ Both weld strength undermatching and HAZ softening are permitted by most major pipe construction standards, such as API 1104.

Required Weld UTS Relative to 5L Pipe Specifications



Required Weld UTS Relative to 5L Pipe Specifications



Mitigative Measures

- ❑ Reduction in weld strength undermatching
 - ❖ Limiting upper end of pipe strength distribution
 - ❖ Pipe longitudinal tensile test
 - ❖ Increase weld strength
 - ▶ Low-hydrogen welding processes
 - ▶ Low heat input
- ❑ Reduction in HAZ softening
 - ❖ Steel composition relative to as-delivered strength
 - ❖ Low heat input

Mitigative Measures

- Reduction in longitudinal/axial stress
 - ❖ Raise design requirement in ASME B31.4 and B31.8
 - ▶ Standard design
 - ▶ High-strain design
 - ❖ Managing construction stress (PRCI project CNST-2-2A)
- Overall awareness and approach
 - ❖ ASME B31.8, general awareness language about
 - ❖ Weld strength undermatching
 - ❖ HAZ softening
 - ❖ Hydrogen assisted cracking
 - ❖ INGAA guidance, 2023
 - ❖ Construction of strain-resistant pipelines

Updated Linepipe Specifications by US Operators

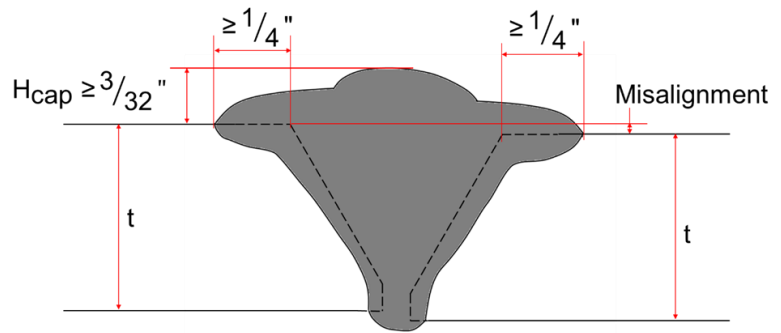
- ❑ Longitudinal tensile tests
- ❑ Limiting upper end permissible strength for high grade pipes (X65, X70)
- ❑ Put minimums on carbon and P_{cm}

Updated Girth Welding Procedure Qualification by US Operators

- ❑ New welding procedures
 - ❖ Moving away from E6010/E8010 for X70 construction in US
 - ▶ Low hydrogen SMAW
 - ❖ More mechanized processes when possible.
 - ▶ Mechanized GMAW
 - ▶ Mechanized FCAW-S
- ❑ Updated requirements for welding procedure qualifications

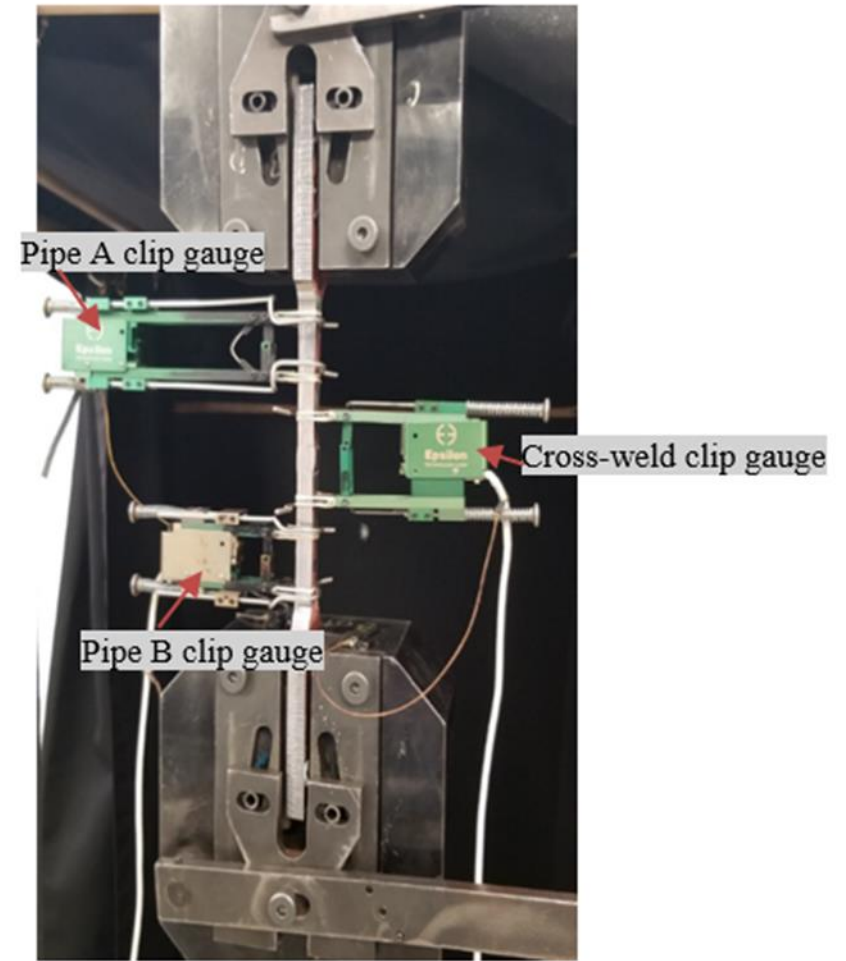
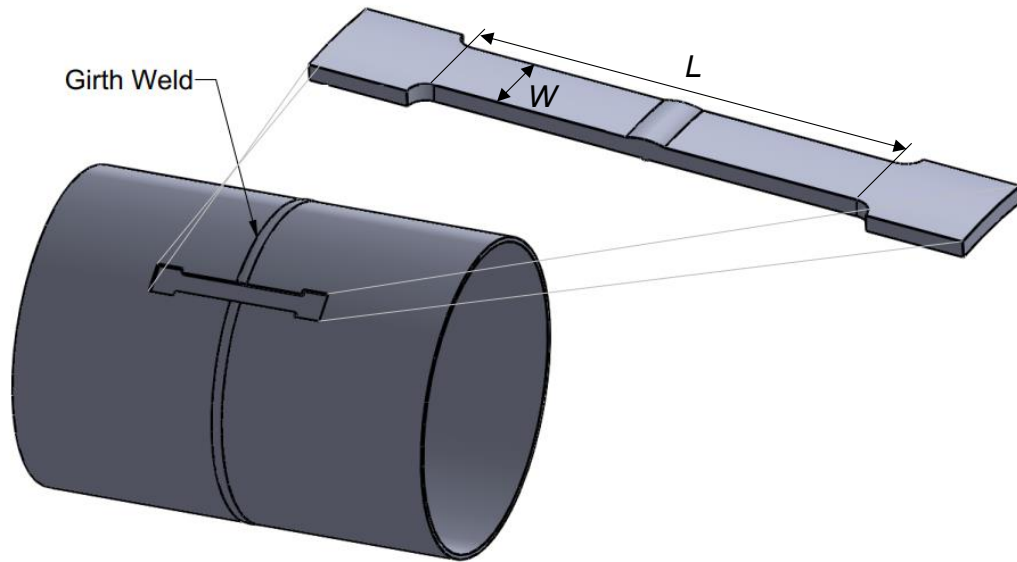
Mitigative Measures- Selection of Girth Welding Procedures

Pipe Properties	Pipe UTS (ksi)	≤ 94		> 94			
	Pipe Carbon (%)	≥ 0.050	< 0.050	≥ 0.040		< 0.040	
	Pipe Pcm	≥ 0.160	< 0.160	≥ 0.140		< 0.140	
Welding options, when the UTS first and then C% or Pcm condition is met	Filler Metal - Root Pass	E8010 or E7010					
	Filler Metal - Hot Pass	E8010					
	Filler Metal - Remaining Passes	E8010	E8010	E8010	E9018 E9045 E90T-XX	E8010	E9018 E9045 E90T-XX
	Cap Reinforcement	Regular	Regular	Wide width	Regular	Wide width	Regular
	Target Heat Input*	40 kJ/in max	30 kJ/in max	30 kJ/in max	40 kJ/in max	30 kJ/in max	30 kJ/in max

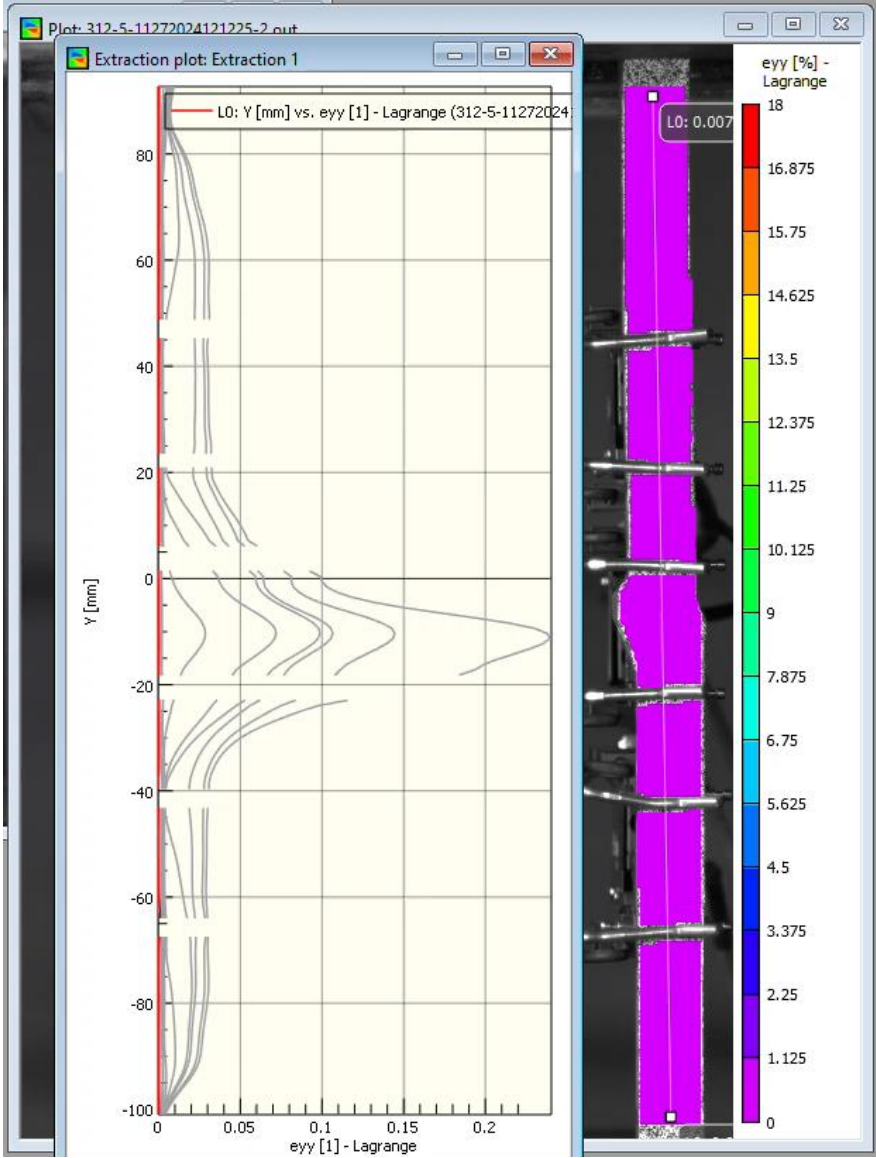


Instrumented Cross-Weld Tensile (ICWT) Test

- ❑ Must start with purposeful selection of pipe
- ❑ Follow API 1104 for specimen extraction location and test frequency



ICWT Test – Demonstration of Strain Concentration



Screening for Existing Assets – New Pipelines with Records

❑ Data/information needed

- ❖ Pipe MTRs
- ❖ Purchase records of fittings
- ❖ Girth welds
 - ▶ Welding procedures (WPS)
 - ▶ PQR
 - ▶ Inspection practice (X-ray or UT records, flaw acceptance criteria)

❑ Outcome

- ❖ Ranking of resilience (capacity)

Screening for Existing Assets – Old Pipelines w/o Records

- ❑ Data/information – starting point
 - ❖ Internal
 - ❖ External experts, consultant
- ❑ Data/information – continued collection
 - ❖ Collect cutouts
 - ❖ Perform tests
 - ▶ Weld flaws
 - ▶ Mechanical properties

Comprehensive State of Art TSC Tool: Gwise®-TSC

- ❑ A software tool commercially available to pipeline operators with a license agreement.

Comprehensive State of Art TSC Tool: Gwise®-TSC

- ❑ A software tool commercially available to pipeline operators with a license agreement.

- ❑ Vintage / year of construction
 - ❖ 1930's – present day

- ❑ Pipe grade: Grade B – X70/X80

- ❑ OD: 8.625" – 48"

- ❑ WT: 0.181" – 1.25"

Comprehensive State of Art TSC Tool: Gwise®-TSC

- ❑ A software tool commercially available to pipeline operators with a license agreement.

- ❑ Vintage / year of construction
 - ❖ 1930's – present day
- ❑ Pipe grade: Grade B – X70/X80
- ❑ OD: 8.625" – 48"
- ❑ WT: 0.181" – 1.25"

- ❑ Linepipe steels: vintage normalized and modern TMCP
- ❑ Girth welds joining pipes of nominally equal wall thickness

Comprehensive State of Art TSC Tool: Gwise®-TSC

- ❑ A software tool commercially available to pipeline operators with a license agreement.
- ❑ Vintage / year of construction
 - ❖ 1930's – present day
- ❑ Pipe grade: Grade B – X70/X80
- ❑ OD: 8.625" – 48"
- ❑ WT: 0.181" – 1.25"
- ❑ Linepipe steels: vintage normalized and modern TMCP
- ❑ Girth welds joining pipes of nominally equal wall thickness
- ❑ Girth welding processes
 - ❖ Vintage
 - ▶ Standard bevel
 - Manual SMAW
 - ❖ Modern
 - ▶ Standard bevel
 - Manual SMAW (cellulosic or low hydrogen electrodes)
 - Semi-automatic FCAW-S
 - Mechanized FCAW-G and FCAW-S
 - ▶ Narrow groove
 - Mechanized GMAW

Gwise®-TSC User Interface

- ❑ Interactive input collection and output display

The screenshot displays the Gwise TSC Version 2.0.0 (73356a128586) user interface. The window is titled "Gwise TSC Version 2.0.0 (73356a128586)" and includes a "Help" menu and a "Notes" field. The interface is organized into several sections, each highlighted with a red border:

- Module Selection:** Includes "Selection Method" (radio buttons for Auto and Manual), "Welding Process" (dropdown menu showing "FCAW mechanized"), "Construction Year" (text input), "Carbon Content (%wt)" (text input), and "Selected Module" (displayed as "None").
- Basic Pipeline Characteristics:** Includes "Pipe OD" (text input with "0" and radio buttons for in and mm), "Pipe WT" (text input with "0" and radio buttons for in and mm), "Pipe Grade" (dropdown menu), and "Operating Pressure" (radio buttons for Internal Pressure and Pressure Factor (% SMYS), with a text input for the value).
- Pipe Strength:** Includes "Manual" (radio button) and "Default" (radio button) options, "YS" (text input with "0" and radio buttons for psi and MPa), and "UTS" (text input with "0" and radio buttons for psi and MPa).
- Heat-Affected Zone Characteristics:** Includes "HAZ Softening (%)" (text input), "Girth Weld Strength" (text input), "UTS Mismatch Ratio" (text input), "Girth Weld Misalignment" (text input), and "High-Low Misalignment" (text input with radio buttons for in and mm).
- Flaw Dimensions:** Includes "Flaw Length" (text input with "0" and radio buttons for in and mm) and "Flaw Depth" (text input with "0" and radio buttons for in and mm).
- Toughness:** Includes "CTODa" (radio button) with a text input and radio buttons for in and mm, "Upper-shelf full-size Charpy" (radio button) with a text input and radio buttons for ftlb and J, and "3-point bend CTOD" (radio button) with "Average" and "Minimum" text inputs and radio buttons for in and mm.

At the bottom of the interface, there are three buttons: "Calculate", "Create batch template...", and "Run batch input...". Below these buttons is a large empty rectangular area for output display.

Gwise®-TSC User Interface

- ❑ Interactive input collection and output display
- ❑ Batch analysis
 - ❖ API provided for interfacing with corporate software, e.g., ILI screening

Gwise TSC Version 2.0.0 (73356a128586)

Help

Notes

Module Selection

Selection Method Auto Manual

Welding Process FCAW mechanized

Construction Year

Carbon Content (%wt)

Selected Module None

Basic Pipeline Characteristics

Pipe OD 0 in mm

Pipe WT 0 in mm

Pipe Grade

Operating Pressure

Internal Pressure 0 psi MPa

Pressure Factor (% SMYS)

Pipe Strength

Manual Default

YS 0 psi MPa

UTS 0 psi MPa

Heat-Affected Zone Characteristics

HAZ Softening (%)

Girth Weld Strength

UTS Mismatch Ratio

Girth Weld Misalignment

High-Low Misalignment in mm

Flaw Dimensions

Flaw Length 0 in mm

Flaw Depth 0 in mm

Toughness

CTODa in mm

Upper-shelf full-size Charpy ftlbf J

3-point bend CTOD

Average in mm

Minimum in mm

Calculate Create batch template... Run batch input...

Concluding Remarks

- ❑ The minimum requirements in current pipeline standards are inadequate for building resilient pipelines against geohazards.
- ❑ A key component of geohazards management should be having strain-resistant pipelines.
 - ❖ New construction
 - ❖ Pipe replacement
- ❑ Screening and risk assessment for existing pipelines are possible.
- ❑ Software tools are available for

Thank you!

Yong-Yi Wang, Ph.D.

CRES

614-419-2366

ywang@cres-americas.com

Q&A

