Small-Scale Testing to Characterize ERW Seam Properties in Response to NTSB Recommendation P-09-01, Arising from the Carmichael, MS Rupture
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Task

- Identify best method for characterizing toughness properties of ERW seams
  - Literature search
    - Current and new practices
  - Charpy V-notch (CVN) impact testing
    - 5 pipe sections

Literature Search Findings

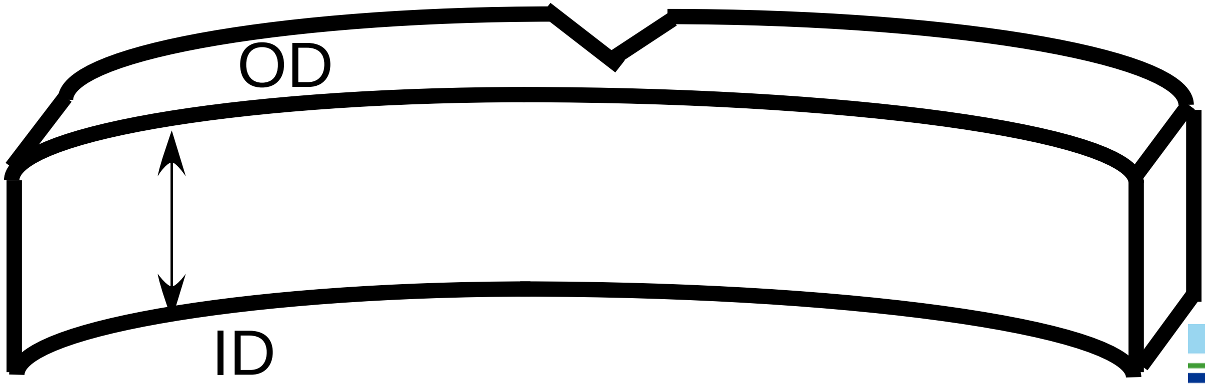
- Support use of CVN testing for the assessment of toughness of line pipe steels
  - Good correlation between CVN results and more expensive/complicated fracture mechanics type tests (J_{IC}, CTOD)
  - Integrity predictions using CVN tests consistent with full scale burst tests

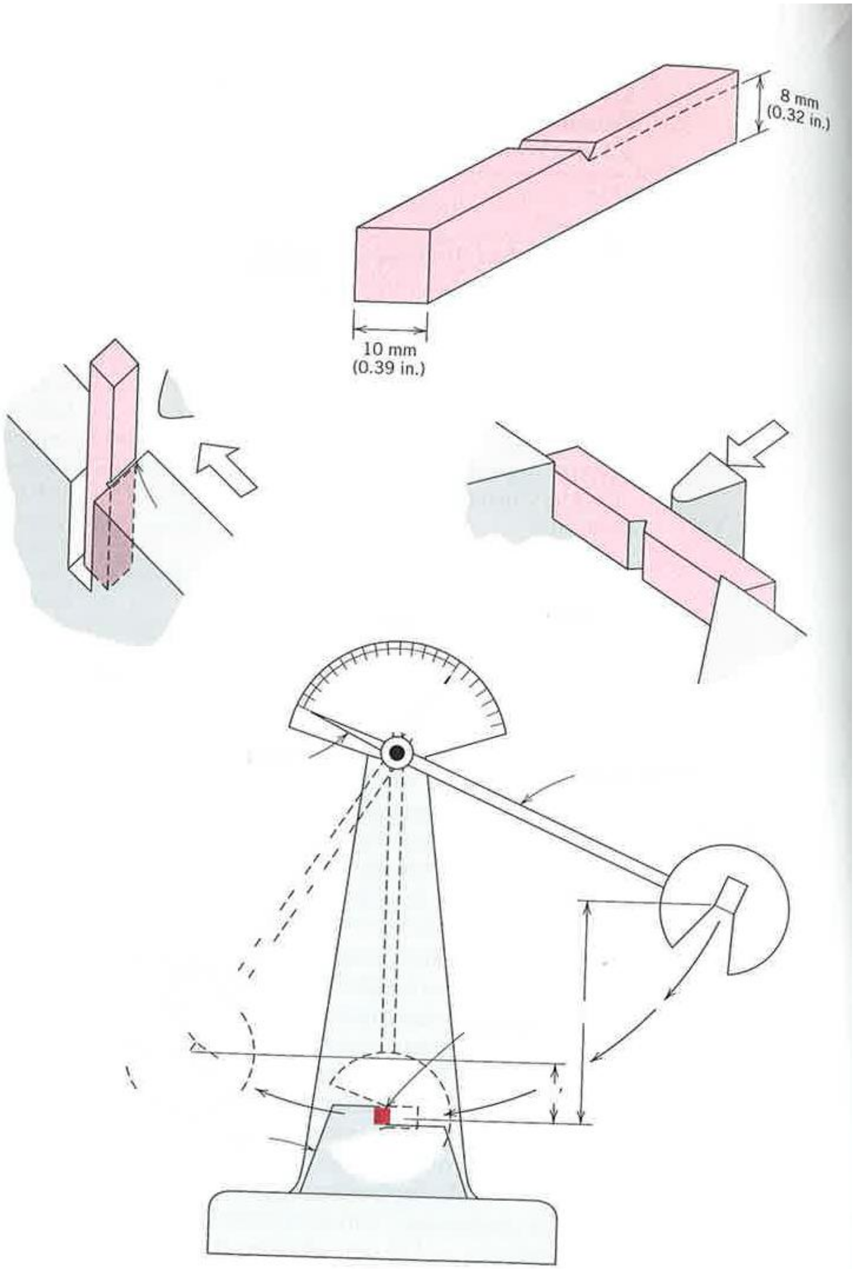
Optimize CVN Tests by

- Not flattening CVN specimens
- Use of full thickness specimens
- Locate notch with metallography
- Obtain full temperature curves
- Perform a sufficient number of tests to establish the range of scatter

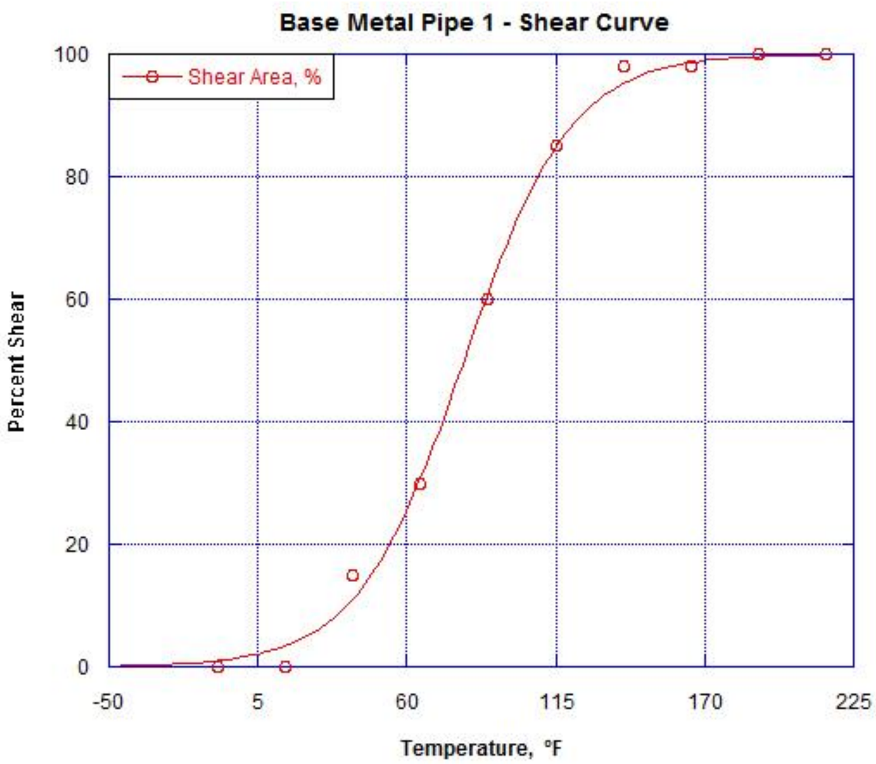
CVN Testing

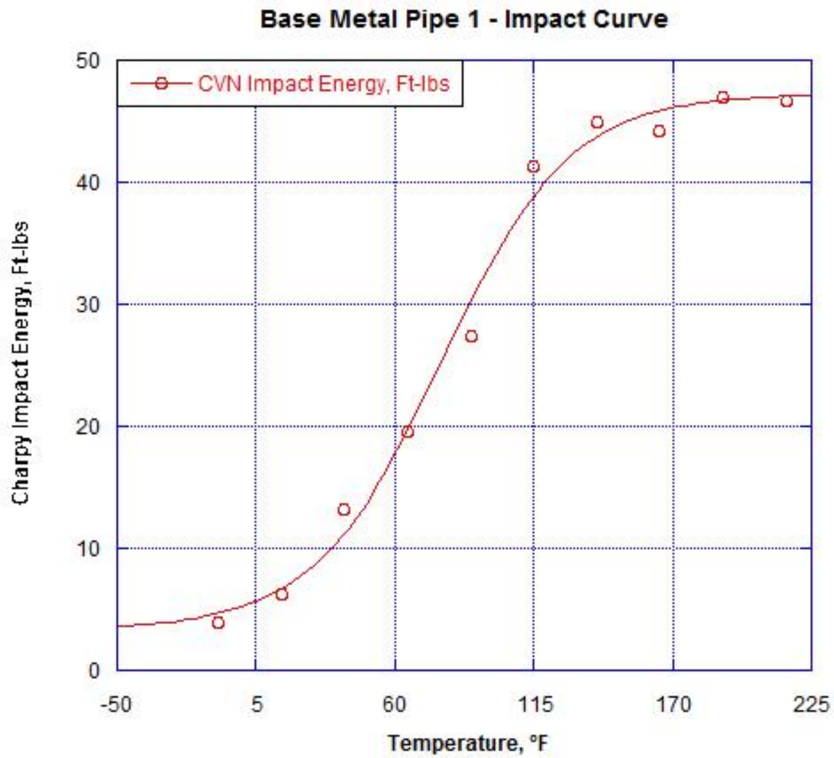
- CVN specimens machined and notched
- Hammer impacts the back side of the specimen = 3 point bend loading
- Test temperatures, impact energies, % shear, and lateral expansion reported




8 mm
(0.32 in.)
10 mm
(0.39 in.)

Shear and Impact Curves





Phase 1

- Established CVN toughness of BM/SW, defect free areas
- Five pipe sections, 100 specimens
- Specimens not flattened
- Only machine ID away from SW
- Transverse faces of CVN specimen polished/etched to identify bond line

Phase 1 Results

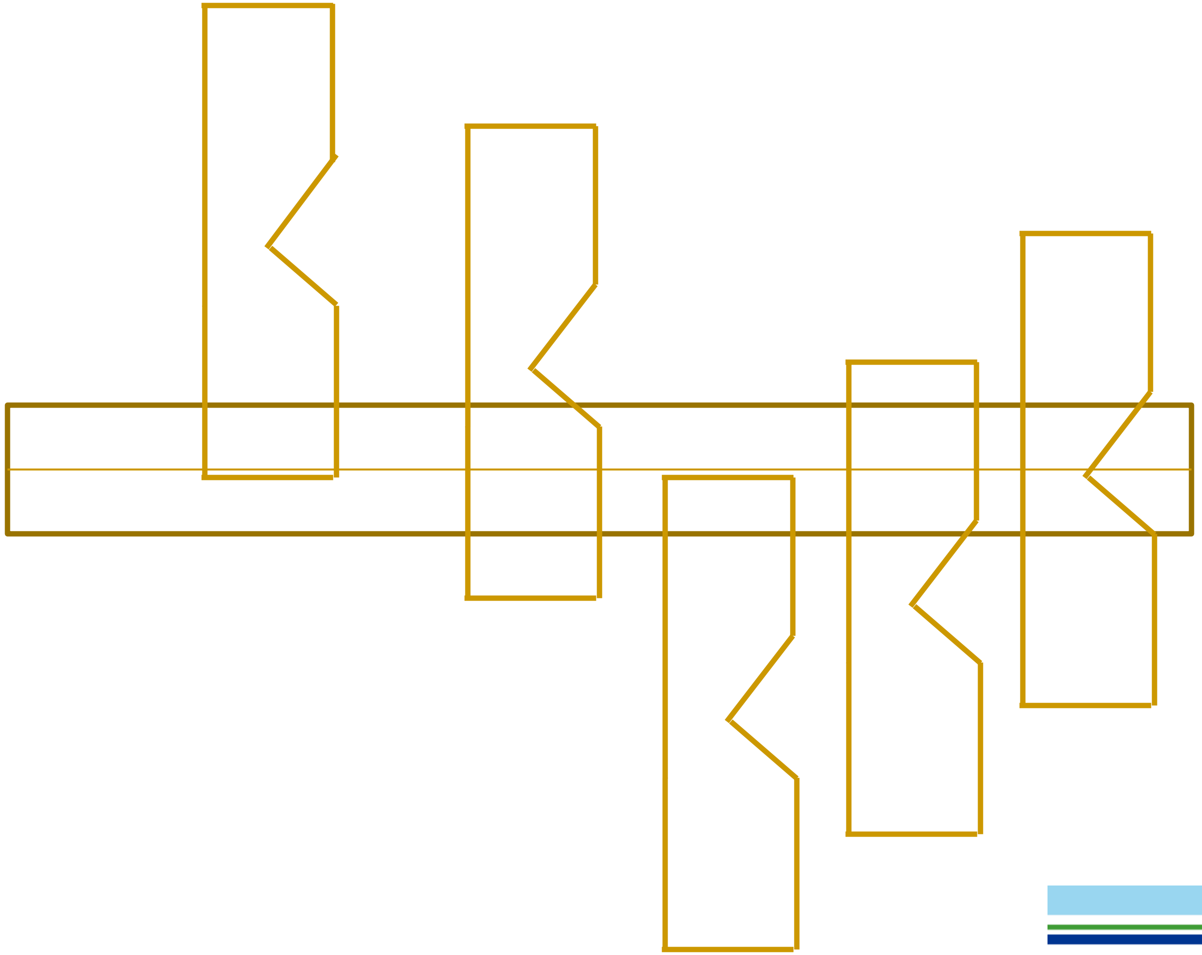
	Upper Shelf Impact Energy (Full Size), J		
	Base Metal	Seam Weld	Difference
Average	41.4	25.4	16.0
Range	22.0 – 64.0	10.0 – 34.7	–

	85% FATT, ℃		
	Base Metal	Seam Weld	Difference
Average	29.3	60.0	30.7
Range	3.33 – 57.8	29.6 – 110	–

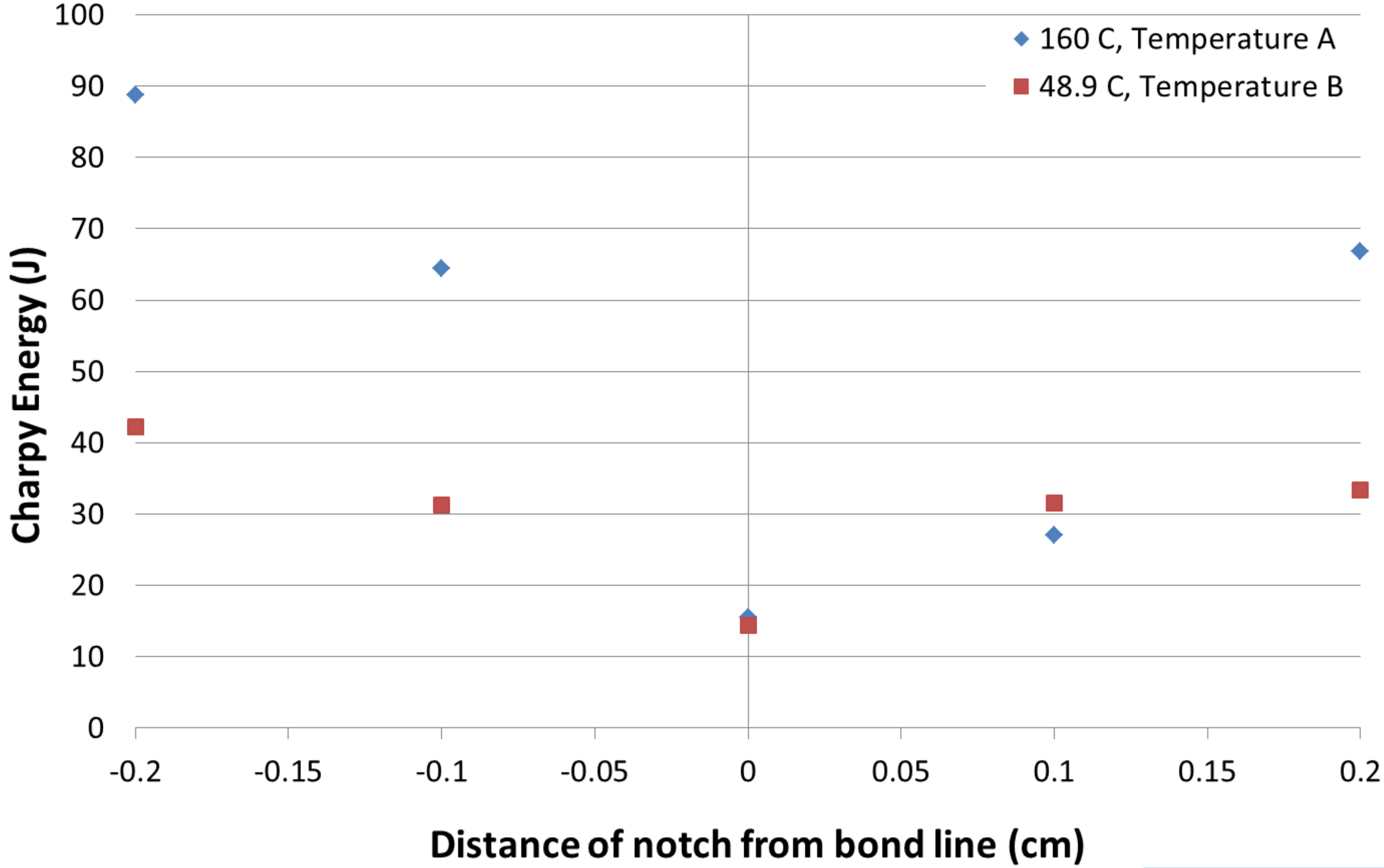
Phase 2 – Varying Specimen Location

- Chose A and B temperatures based on Phase 1 Energy vs Temp curves
  - A Temp in upper shelf region for BM/SW
    - 160, 50, 93, 160 C
  - B Temp in upper shelf for BM and lower shelf for SW – more sensitive to location
    - B Temp actually near or above 85% FATT of the BM – 50, 27, 4, 60 C

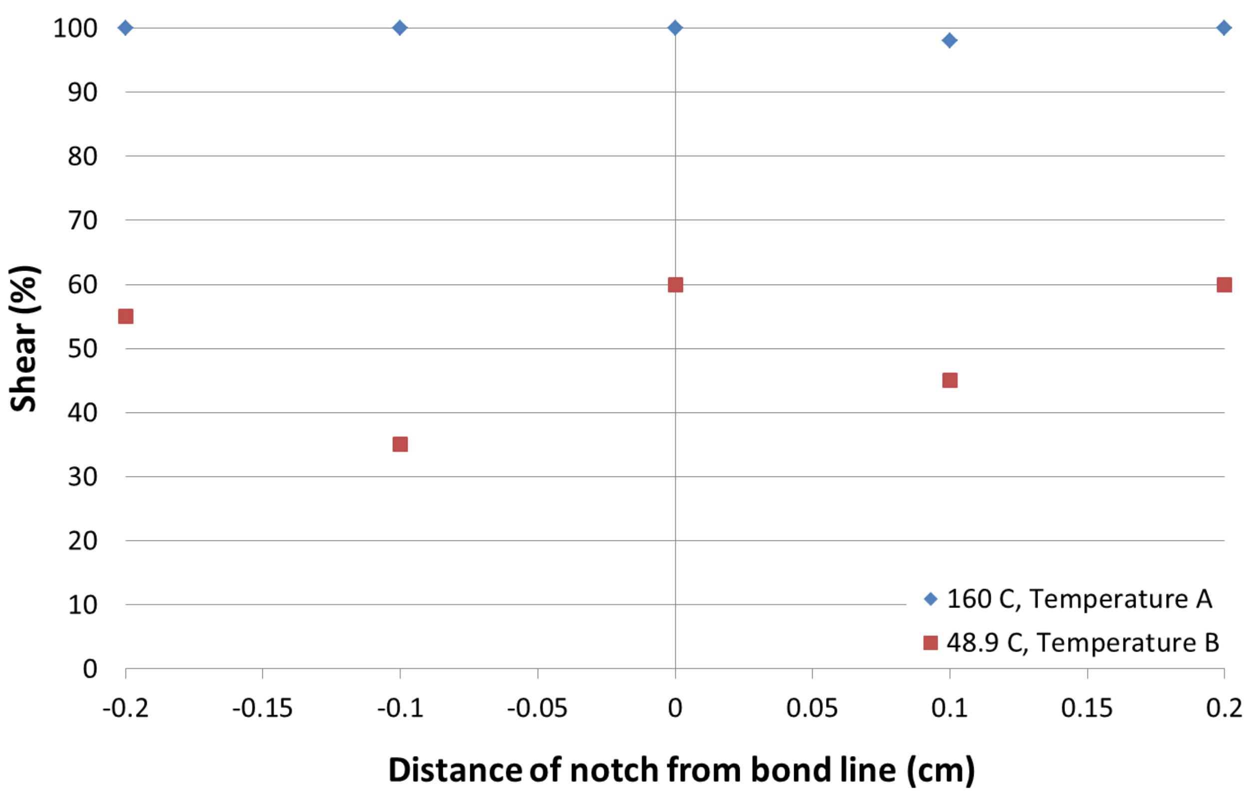
Varying Notch Circumferentially



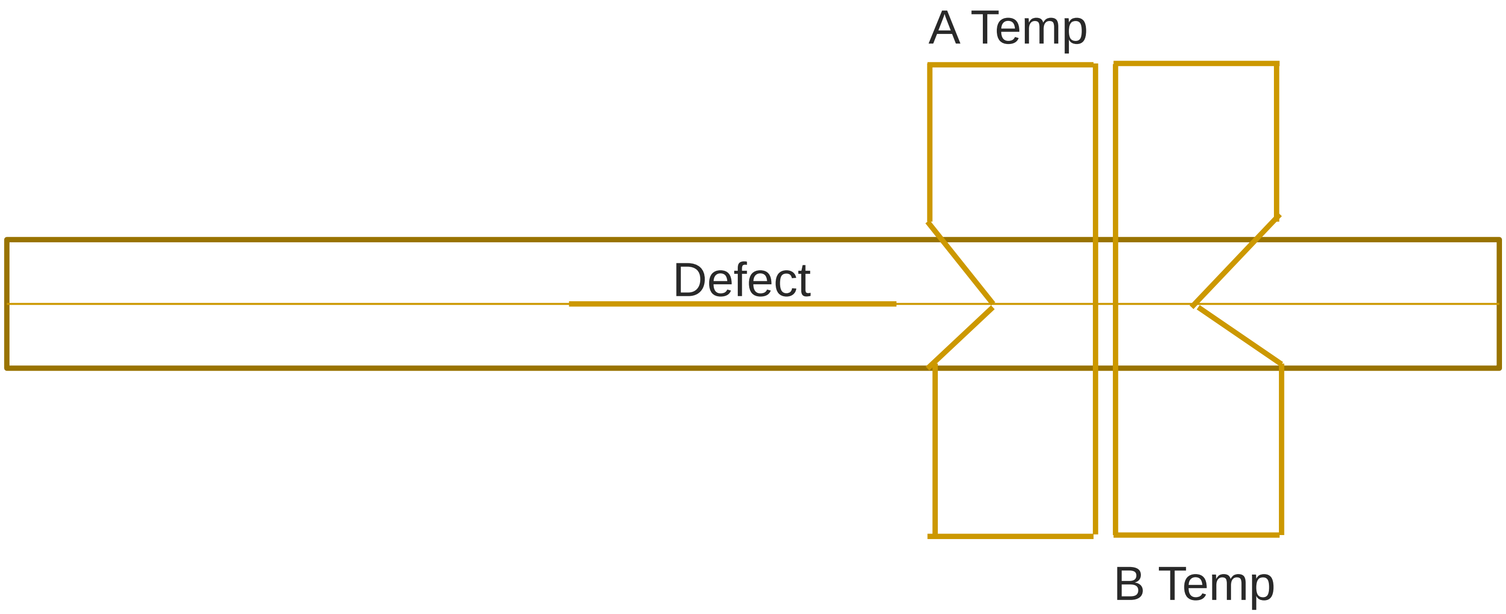
CVN vs. Distance from BL



Shear % vs. Distance from BL



Varying Axial Location of Specimens



Plot of CVN Energy wrt Distance from Features/Defect

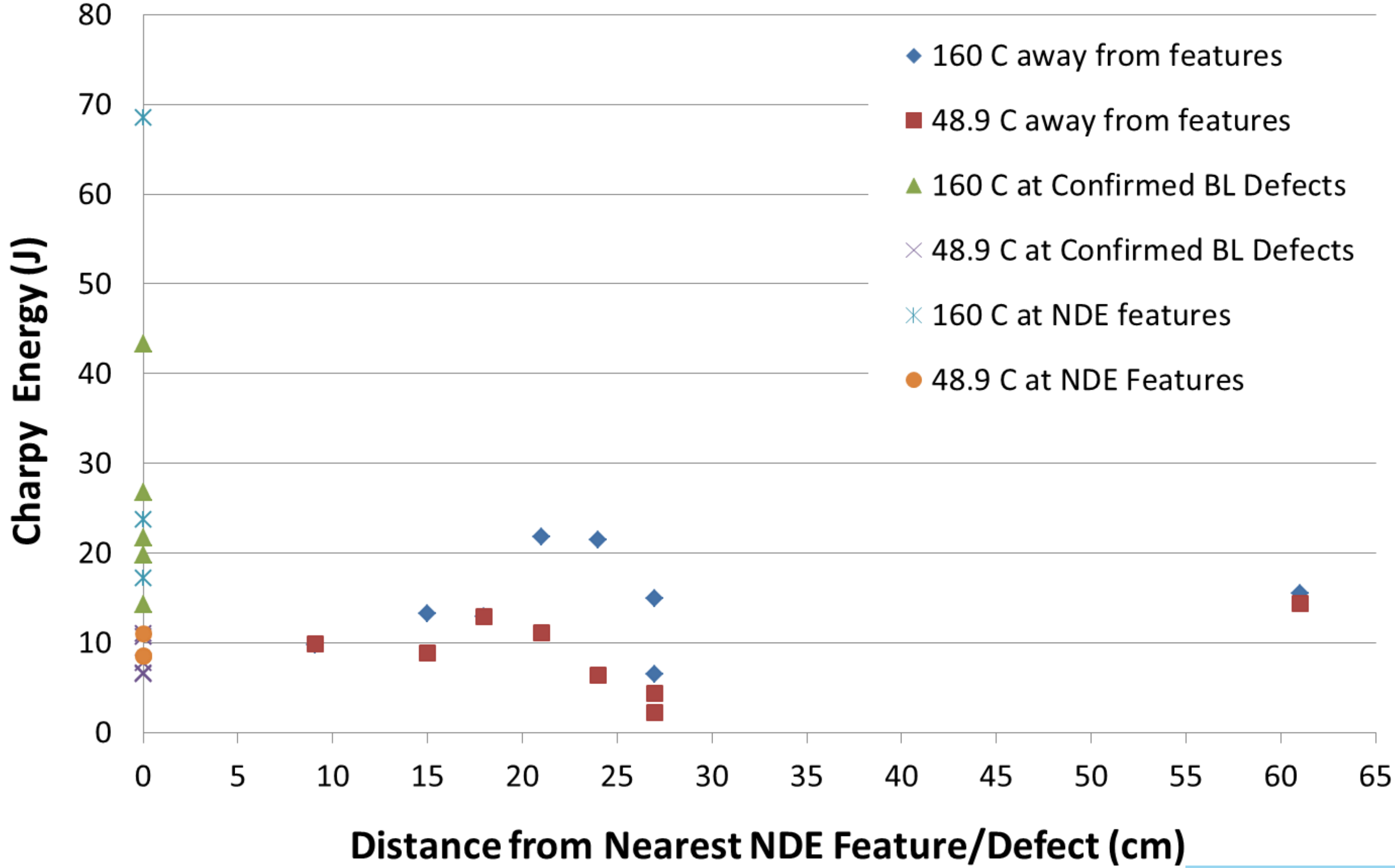
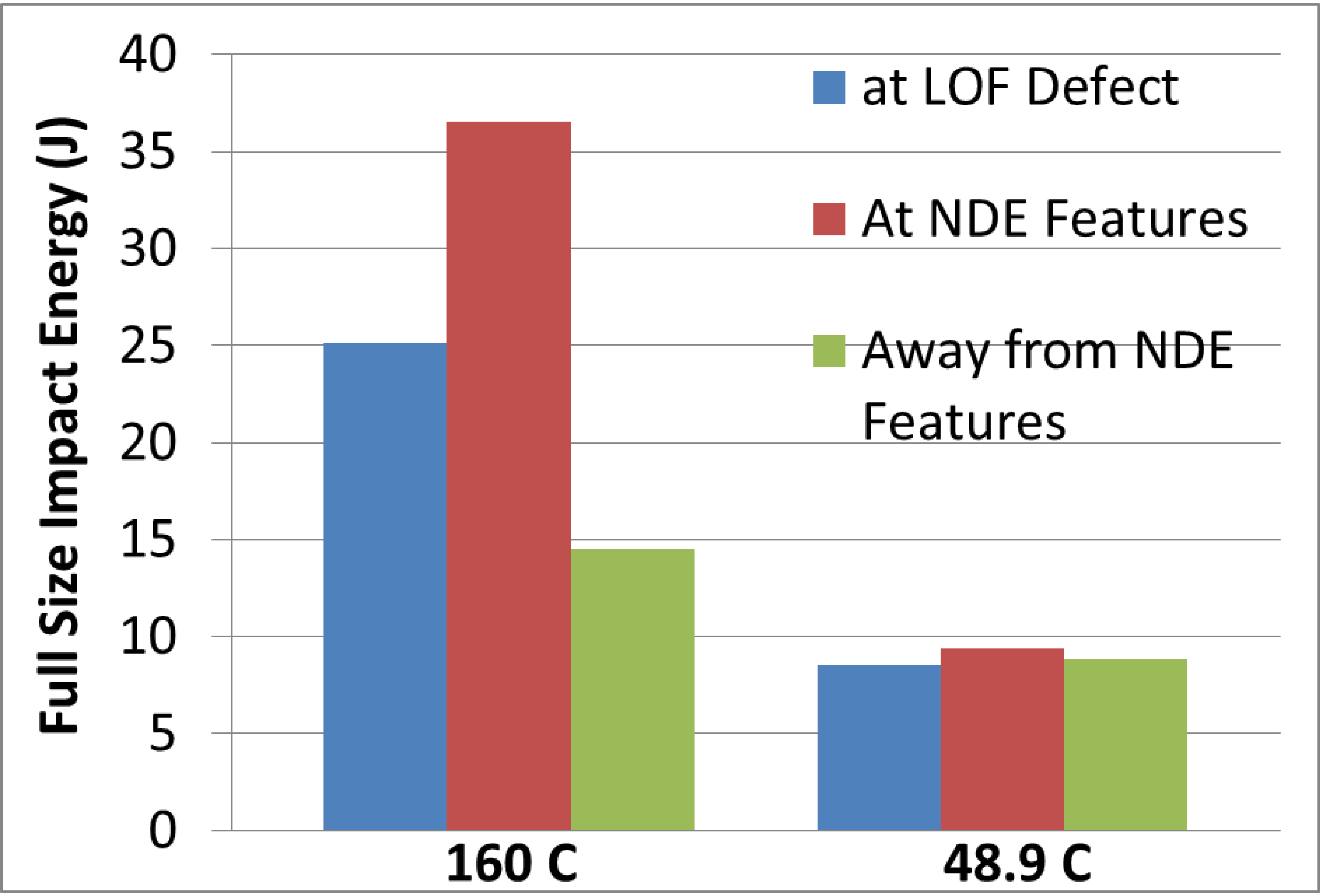


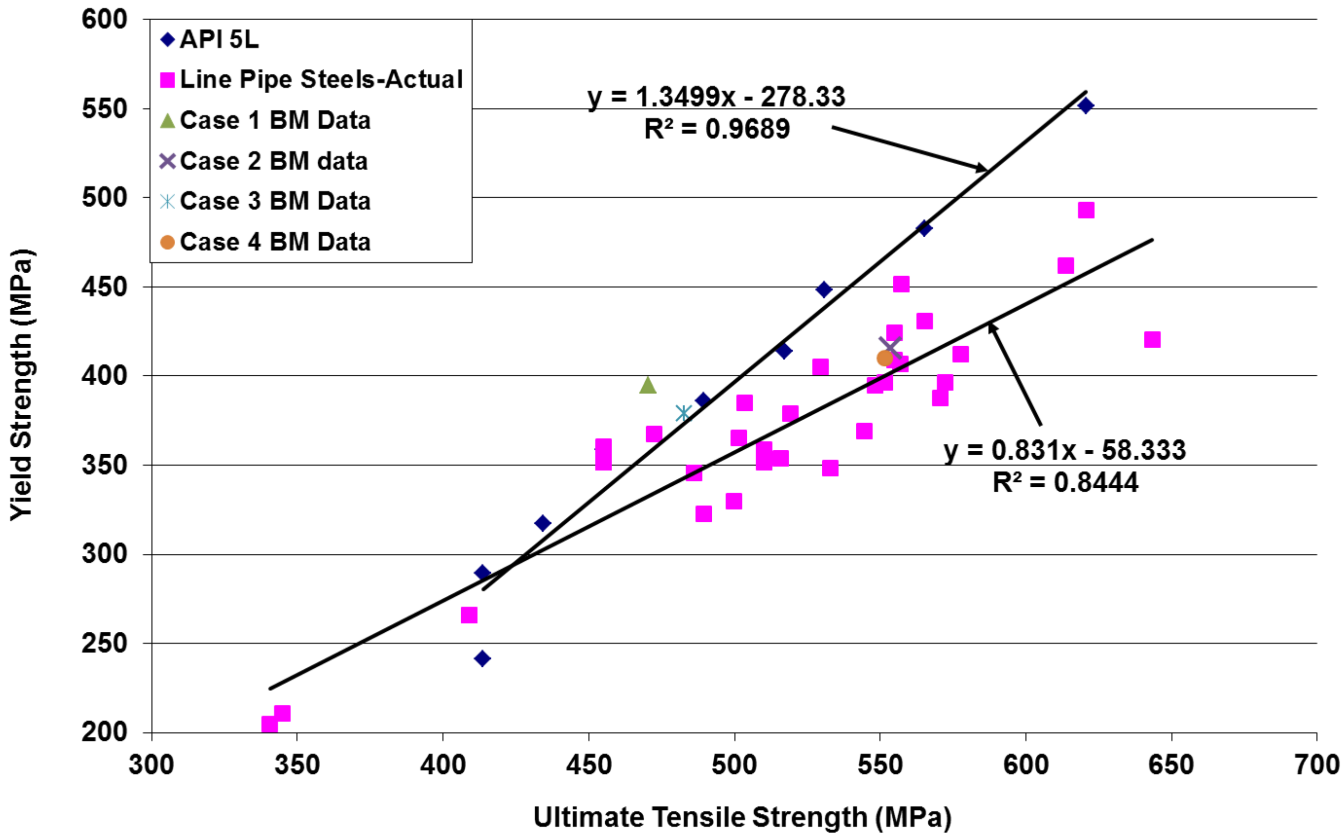
Chart of CVN Energy Regarding Relation to Features/Defect



Three Main Factors in Burst Pressure Analyses

- Pipe Geometry
- Flaw Size
- Mechanical Properties
  - Tensile Properties
  - Toughness Properties

YS vs. UTS Plot



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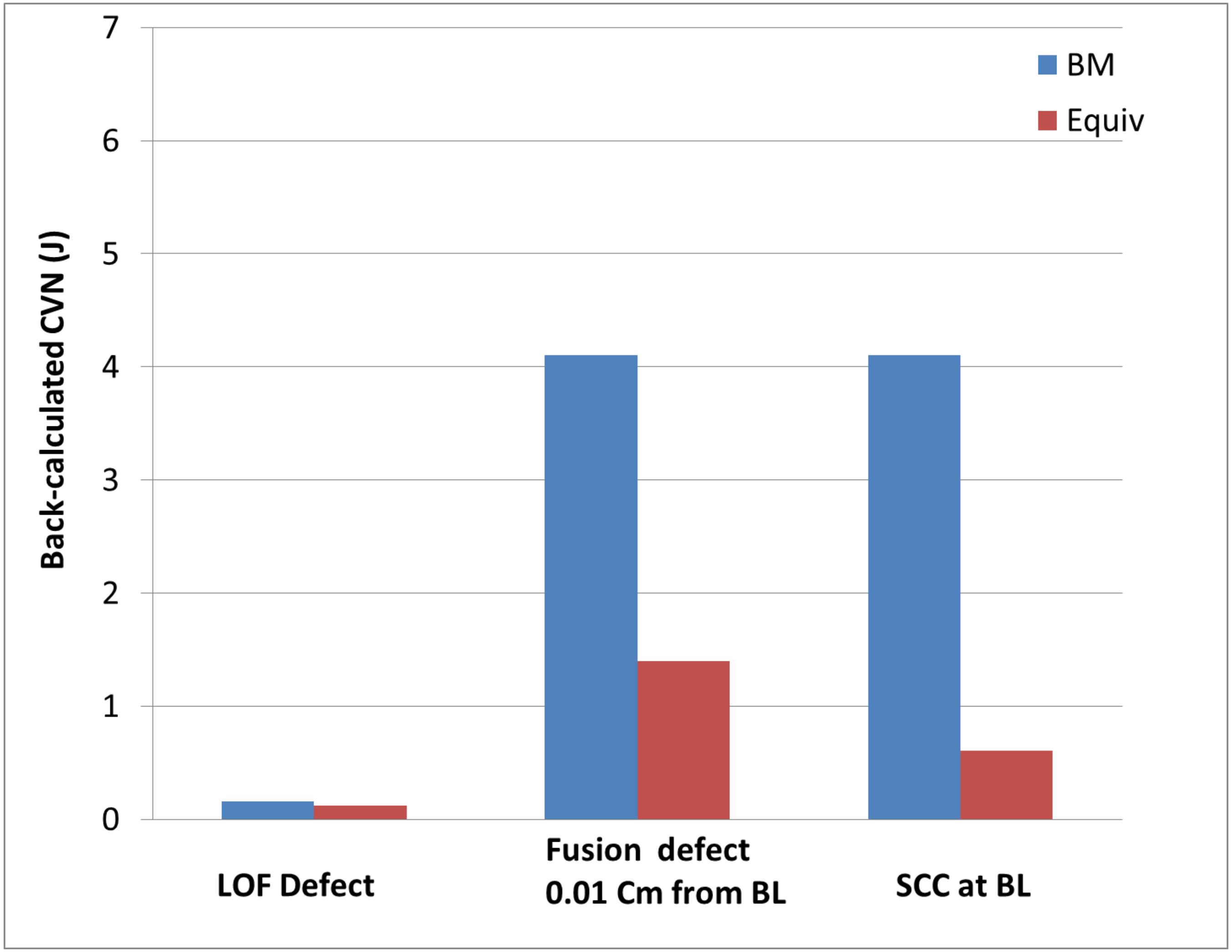
CorLAS™ Calculations

#	Flaw Length (cm)	Flaw Depth (cm)	Hydrotest Failure Pressure (kPa)	Upper Shelf CVN Impact Energy (J)	Base Metal YS (MPa)	Base Metal UTS (MPa)	Back-Calculated CVN to cause failure Based on BM Tensile Properties (J)	Equiv. YS of Overload Region from Hardness Testing/ Archive Tensile Data (MPa)	Equiv. UTS of Overload Region from Hardness Testing (MPa)	Back-Calculated CVN to Cause Failure Based on Equiv. Tensile Properties (J)
1[1]	9.7	0.15	6,929	43.3	359	471	0.16	469	634	0.12
2[2]	48	0.340	9,446	12	416	554	4.1	490	689	1.4
3[3]	13	0.25	9,570	13	379	483	4.1	534	710	0.61
4[4]	18	0.450	10,030	42.7	410	552	Back-calculation was not necessary since the calculated failure pressure was 9,770 kPa.			

1. Lack-of-fusion defect.
2. Fusion defect within 0.01 cm of the BL.
3. Stress corrosion cracking at the BL.
4. A majority of the flaw was a hook crack (within 0.2 cm of the BL) with an average depth of approximately 0.19 cm. A short portion of the flaw was a lack-of-fusion defect with a maximum depth of 0.450 cm.

Chart of Back-calculated CVN Values from CorLAS™



Burst Pressure Analyses Examples

- Failure pressure calculations for flaws associated with LF/DC ERW failures
  - Overestimate pressures compared to actual when using upper shelf CVN
  - Very low (<1.4 J, back-calculated) CVN energies are needed to cause failure

Conclusions

- Findings support use of CVN testing for assessing toughness of line pipe steels
- Best way to run CVN tests of ERW pipe
  - Not flatten CVN specimens
  - Use full thickness specimens
  - Locate notch with metallography
  - Obtain full temperature curves

Conclusions (continued)

- CVN energies decreased when circumferential distance from BL decreased
- CVN tests near defects did not capture the low toughness values that are commonly back calculated

Conclusions (continued)

- Establish range of bond line energies
  - Perform a series of hydrotests
  - Measure the pipe geometry and initiating flaw (length and depth)
  - Measure the tensile properties of the pipe
  - Use CorLAS^{TM} or other FM model to back calculate CVN energy to cause failure