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PRCI Research Exchange

A Data-driven Process to Determine CVN Based on Comparable Pipe Attributes

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Overview of Crack Assessment

Pipe geometry: OD, WT
Pipe material: YS, UTS, CVN
Operation: MAOP (or MOP)

Crack size: depth and length
Sizing uncertainty: tool tolerance
Crack growth: growth rate

Burst Pressure Model

(e.g., CorLAS)

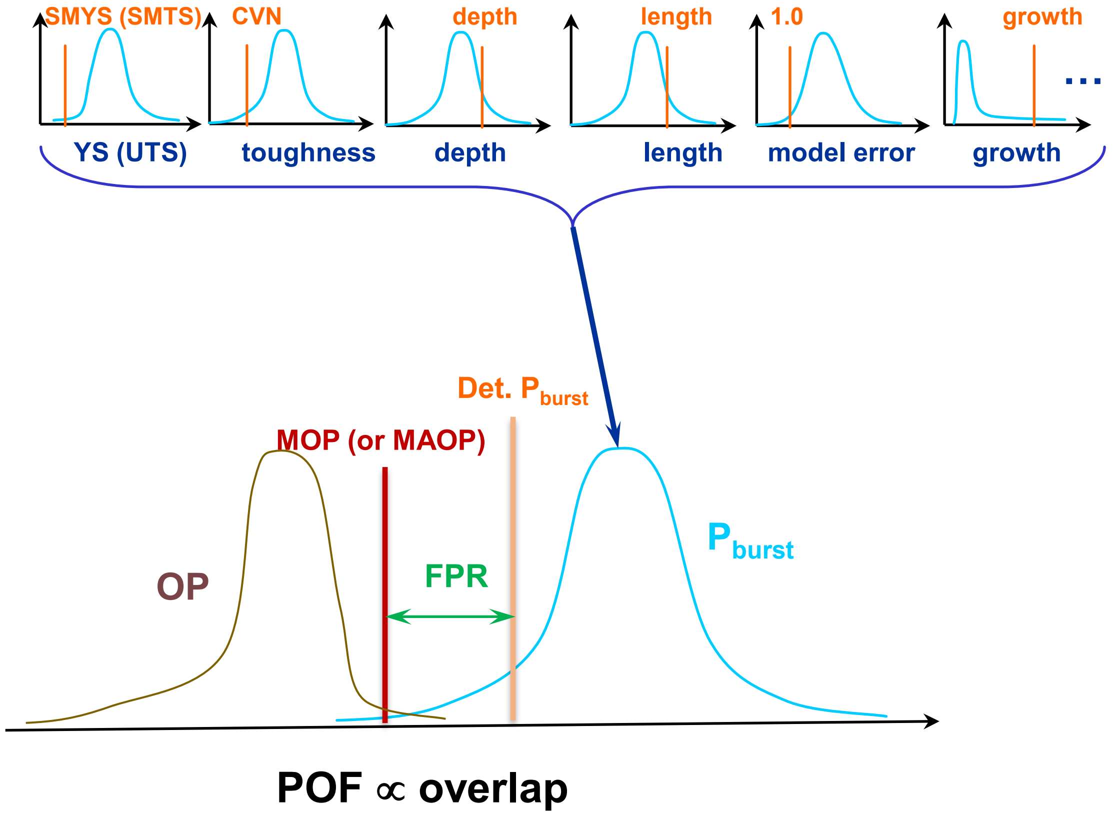
Predicted burst pressure, P_b

$P_b < SF \times MAOP$?

Integrity Decision

How to Provide Safety?

- **Uncertainties associated with input variables**
- **Conservatism in deterministic assessments**
  - **conservative constant characteristic value of inputs (e.g., SMYS) – *accounts for uncertainty in variables***
  - **further conservatism with safety factors (SF) – *accounts for different consequences, human error etc.***



$$FPR = P_{burst\ Det} / MOP > SF \Rightarrow POF < \text{acceptable POF}$$

How to determine the characteristic Value of CVN?

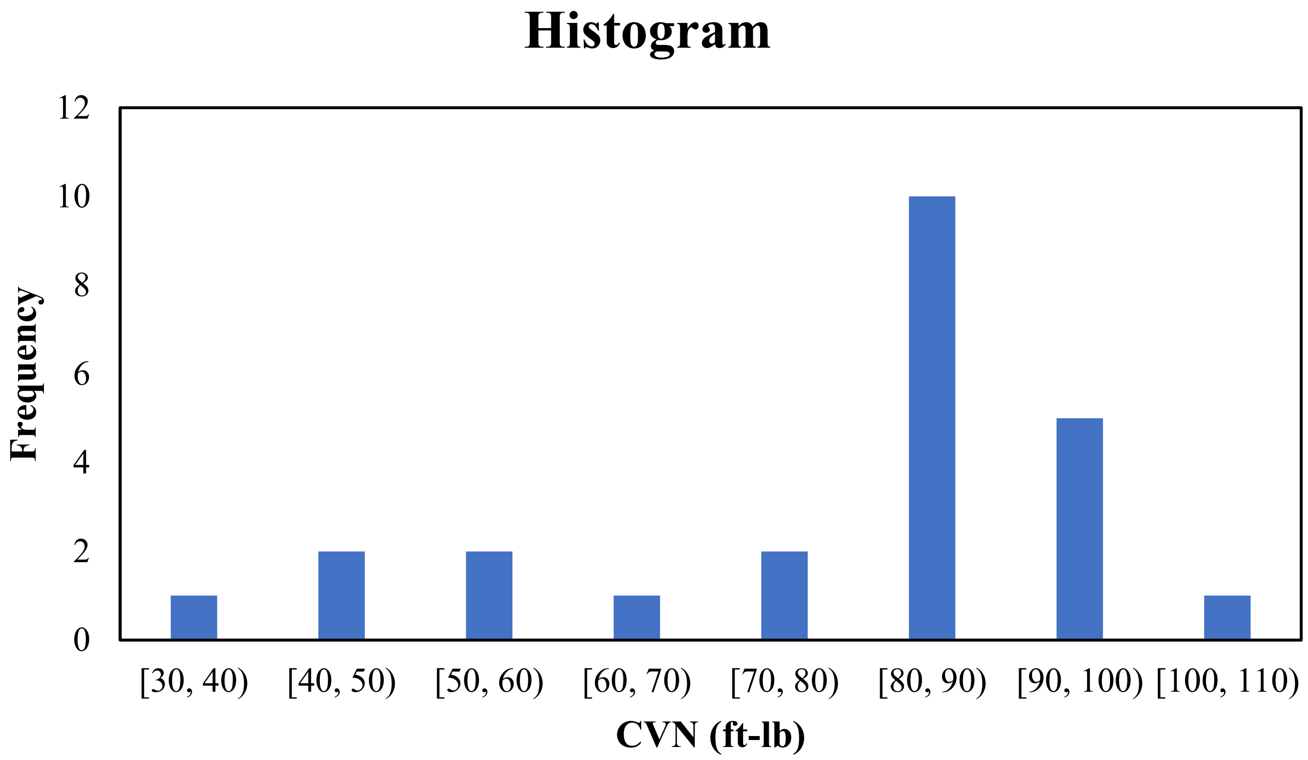
- **TCE developed a material database**
- **CVN Values in 49 CFR § 192.712e(2)(i)**
  - (A) *Charpy v-notch toughness values from* ***comparable pipe*** *with known properties of the same vintage and from the same steel and pipe manufacturer;*
  - (B) *A conservative Charpy v-notch toughness value to determine the toughness based upon the ongoing material properties verification process specified in* ***§ 192.607****;*
  - (C) *If the pipeline segment does not have a history of reportable incidents caused by cracking or crack-like defects, maximum Charpy v-notch toughness values of* ***13.0 ft-lbs****. for body cracks and* ***4.0 ft-lbs****. for cold weld, lack of fusion, and selective seam weld corrosion defects;*
  - *(D) If the pipeline segment has a history of reportable incidents caused by cracking or crack-like defects, maximum Charpy v-notch toughness values of* ***5.0 ft.-lbs****. for body cracks and* ***1.0 ft.-lbs****. for cold weld, lack of fusion, and selective seam weld corrosion;*

Objective

- Develop criterion for determining the characteristic value
- Identify key parameters for defining comparable pipe
- Develop data collection process as per comparable pipe attributes

Variation of CVN

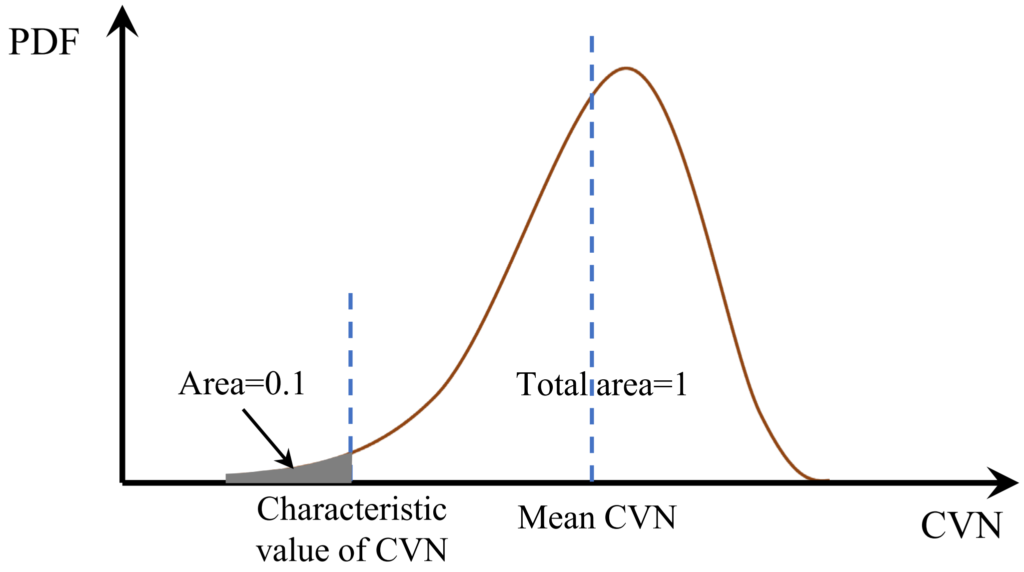
- Inherent variation
- Limited number of data samples -> biased estimate



Characteristic value

- Minimum or average of three (or a few) data points
- API 579 approach (see Table below): ~20th perc. value
- INGAA research: 10th perc. value of industry data
- TCE Approach: 10th perc. value of adequate data samples from TCE's database considering comparable pipe attributes

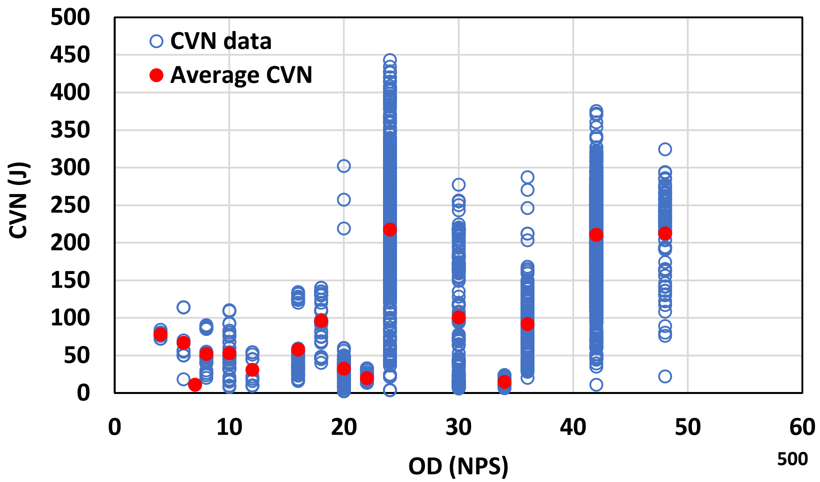
Number of fracture toughness tests	Equivalent to the minimum of three tests
3 to 5	lowest value
6 to 10	second lowest value
11 to 15	third lowest value
16 to 20	fourth lowest value
21 to 25	fifth lowest vale
26 to 30	sixth lowest value

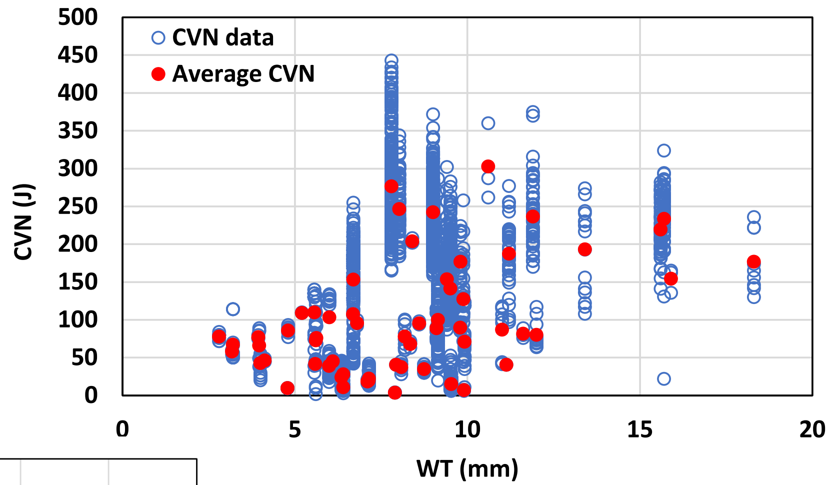


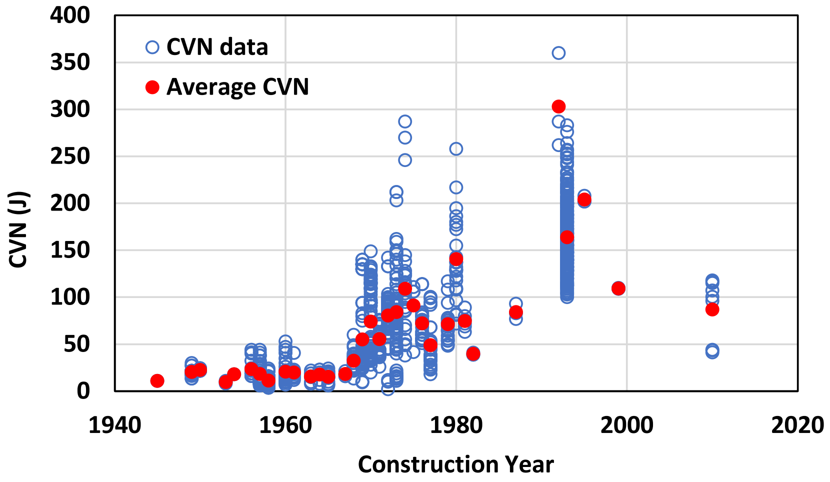
How to define comparable pipe?

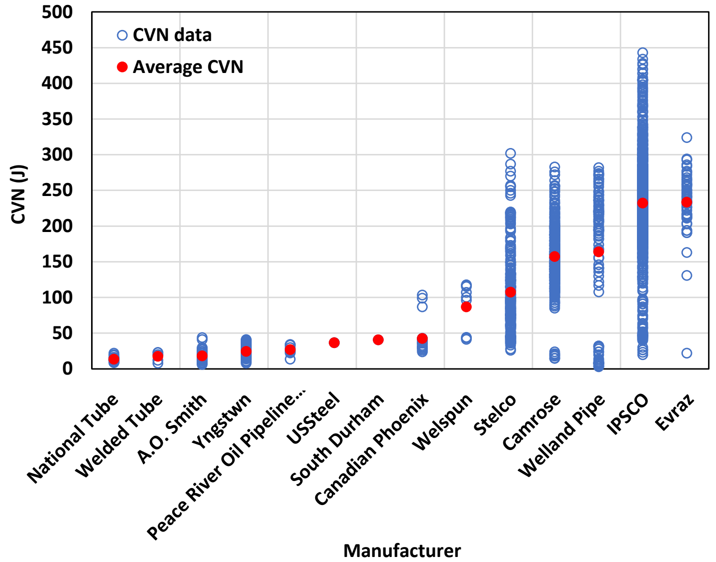
- 192.712 e(2)(i)(A) Charpy v-notch toughness values from <u>comparable pipe</u> with known properties of the same vintage and from the same steel and pipe manufacturer;
- The key parameters were identified through data analysis

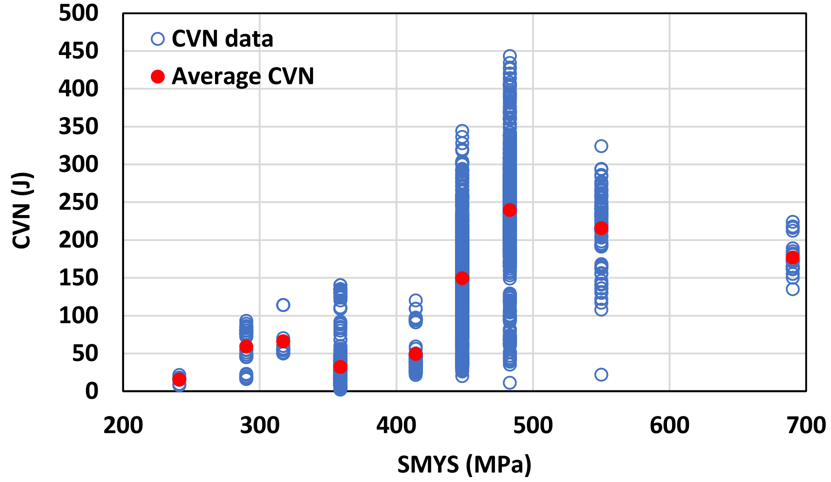
CVN vs pipe attributes for base material





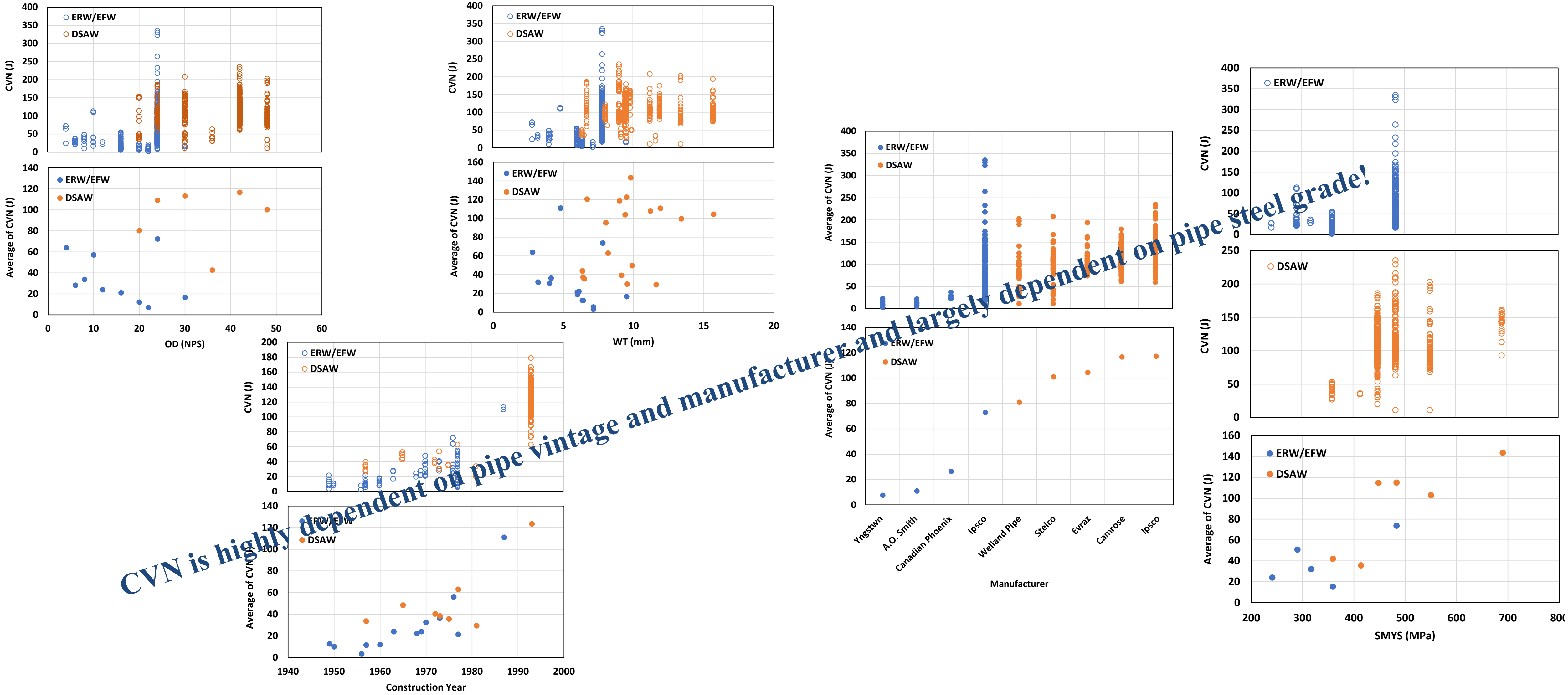






CVN is highly dependent on pipe vintage and manufacturer and largely dependent on pipe steel grade!

CVN vs pipe attributes for weld material

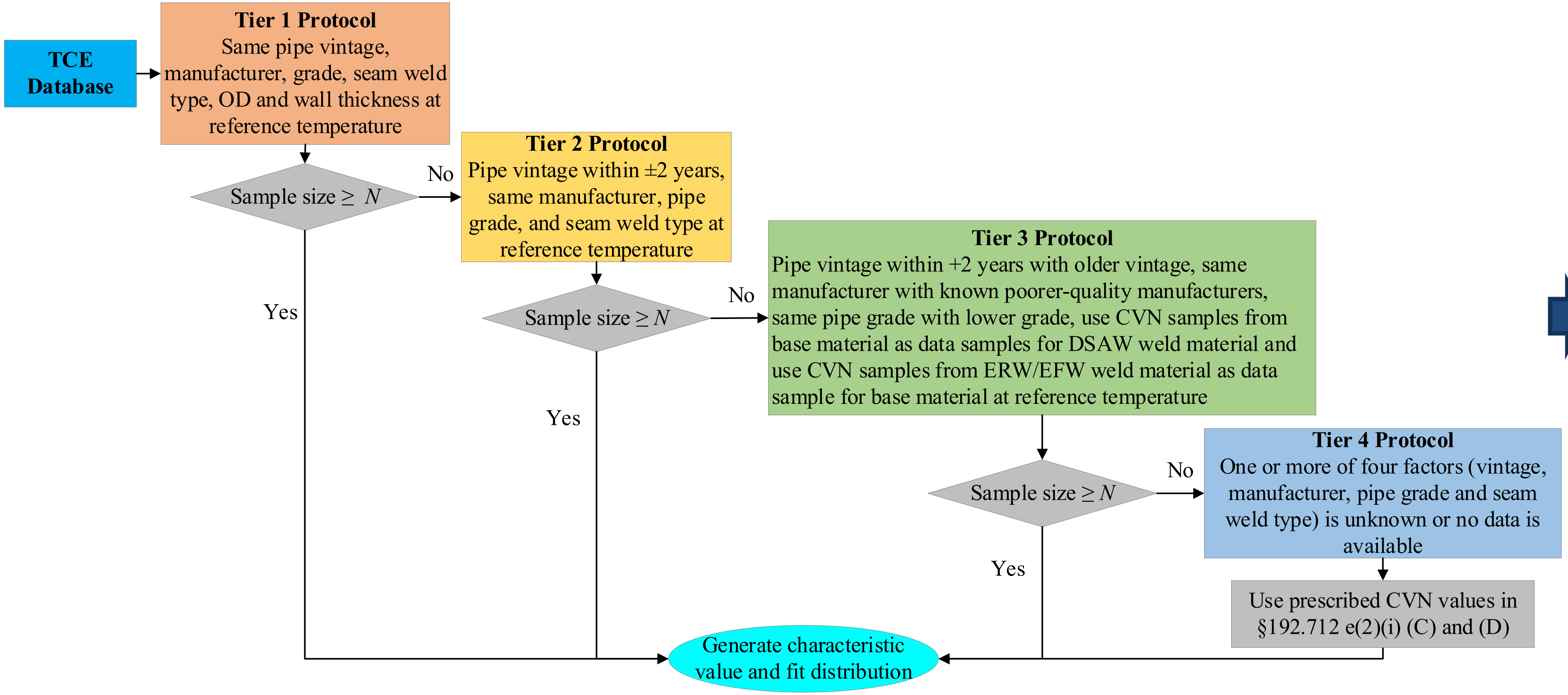


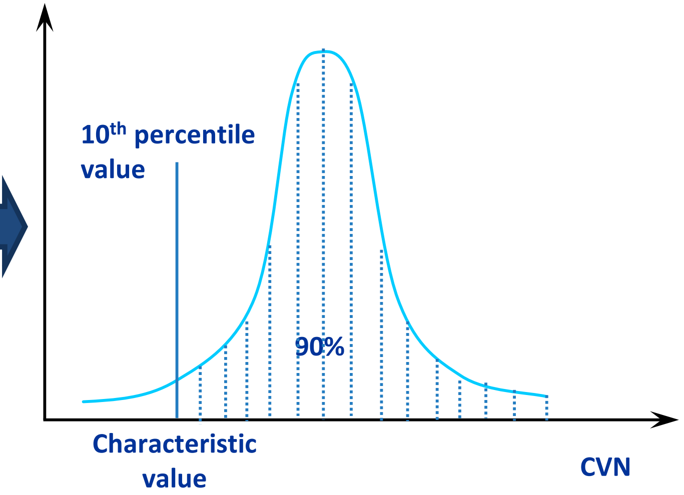
Comparable pipe

- Vintage
- Manufacturer
- Pipe grade
- Weld type

Tier	Classification	Criteria	Data Source
1	Same pipe	• Same vintage • Same pipe grade • Same manufacturer • Same weld type • Same OD • Same wall thickness • Reference temperature	TCE CVN database
2	Comparable pipe	• Vintage is identical or within ±2 years • Same pipe grade • Same manufacturer • Same weld type • Reference temperature	TCE CVN database
3	Comparable pipe with embedded conservatism[1]	• Vintage within +2 years plus older vintage • Same pipe grade plus lower grade • Same manufacturer plus known poorer-quality manufacturer(s) based on SME's judgement • Use CVN samples from base material as data samples for DSAW weld material and use CVN samples from ERW/EFW weld material as data samples for base material • Reference temperature and lower	TCE CVN database
4	Unknown pipe	• One or more of four factors (vintage, pipe grade, manufacturer, and seam weld type) is unknown • No data available	Prescribed default CVN values for pipe body and weld in accordance with §192.712(e)(2)(i)(C) – (D)

Four-tier data collection process for determining CVN





Demonstration

- **5 pipeline sections, API 5L X52 ERW pipe**
- **A.O. Smith (Pipelines # 1-4) and Youngstown (Pipeline #5)**

Pipeline ID	Vintage	Material Type	Sample Size	CVN Value (ft-lb)				Distribution Type
				Min	Max	Mean	Std	
1	1949	base	36	10.0	22.0	15.7	3.0	Weibull
		weld	28	3.0	16.0	7.5	2.7	Weibull
2	1950	base	36	10.0	22.0	15.7	3.0	Weibull
		weld	38	2.0	20.0	7.3	3.8	Gamma
3	1956	base	28	4.4	23.8	11.7	5.1	Weibull
		weld	28	3.0	16.0	7.5	2.7	Weibull
4	1959	base	40	4.4	23.8	11.6	4.4	Gamma
		weld	31	4.1	14.7	7.5	1.9	Gamma
5	1957	base	30	11.8	30.3	24.3	4.1	Weibull
		weld	30	1.0	17.0	4.2	3.6	Weibull

Pipeline ID	Material Type	Characteristic value of CVN (ft-lb) determined by			
		Prescribed approach [1]	Proposed approach	API approach	Regular approach [2]
1	base	13 (5)	10.0	14.0	11.4
	weld	4 (1)	4.0	4.0	4.0
2	base	13 (5)	10.0	14.0	12.0
	weld	4 (1)	4.0	4.0	8.0
3	base	13 (5)	5.9	6.5	21.5
	weld	4 (1)	4.0	4.0	12.7
4	base	13 (5)	5.9	8.1	15.3
	weld	4 (1)	5.9	6.0	7.3
5	base	13 (5)	19.3	20.7	24.4
	weld	4 (1)	2.0	2.0	3.3

Note:
1. the maximum CVN value equals the value outside of the bracket if the pipeline segment does not have a history of reportable incidents caused by cracking or crack-like defects, and the value in the bracket otherwise.
2. the value was determined by the average of CVN measured from three coupons

Summary

- A data-driven process considering comparable pipe attributes
- Less biased, more appropriate and more conservative CVN values than those derived from a small dataset CVN values
- The proposed CVN determination process in accordance with 49 CFR §192.18 and 192.712(e)(2)(i)(E) can be used as alternative material toughness that differs from the prescribed methods in §192.712(e)(2)(i)(A) – (D).
- Any new development (e.g., PRCI IM-1-08) can be a supplement to this approach
- Heavily dependent on data

thank you

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PDF of CVN for Pipeline #4