REX2024

PRCI Research Exchange

Importance and Usage of PRCI Material Property and Burst Testing Database

Based on PRCI EC-2-11 and NDE-4-17A projects

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LEADING PIPELINE RESEARCH

Pipeline Research Council International

Background

- Pipeline material property record is one of the important datasets required for effective pipeline integrity management
- PRCI material property database has recently been enhanced as part of NDE-4-17A project

- Burst testing is one of the best methods for validating defect assessment and model development or improvements.
- A lot of burst tests have been conducted in previous projects by PRCI, DOT and member companies dealing with corrosion, crack, dent etc. PRCI EC-02-11 project developed a burst testing database

- The material property and burst testing databases are hosted in PRCI Virtual Technology Development Center (VTDC).
- PRCI member companies can access the database from VTDC

Motivation

- Material and Burst tests are expensive and time consuming
- Finding appropriate pipe samples for testing is challenging
- Historical burst test data contains valuable information which were not captured in a systematic way in the past
- This often led to duplicative testing
- Address PHMSA's FAQ-23 and build an industry resource to compile properties of representative pipeline materials

PHMSA FAQ-23. Is there a process to compile comparable pipe material properties across the industry?

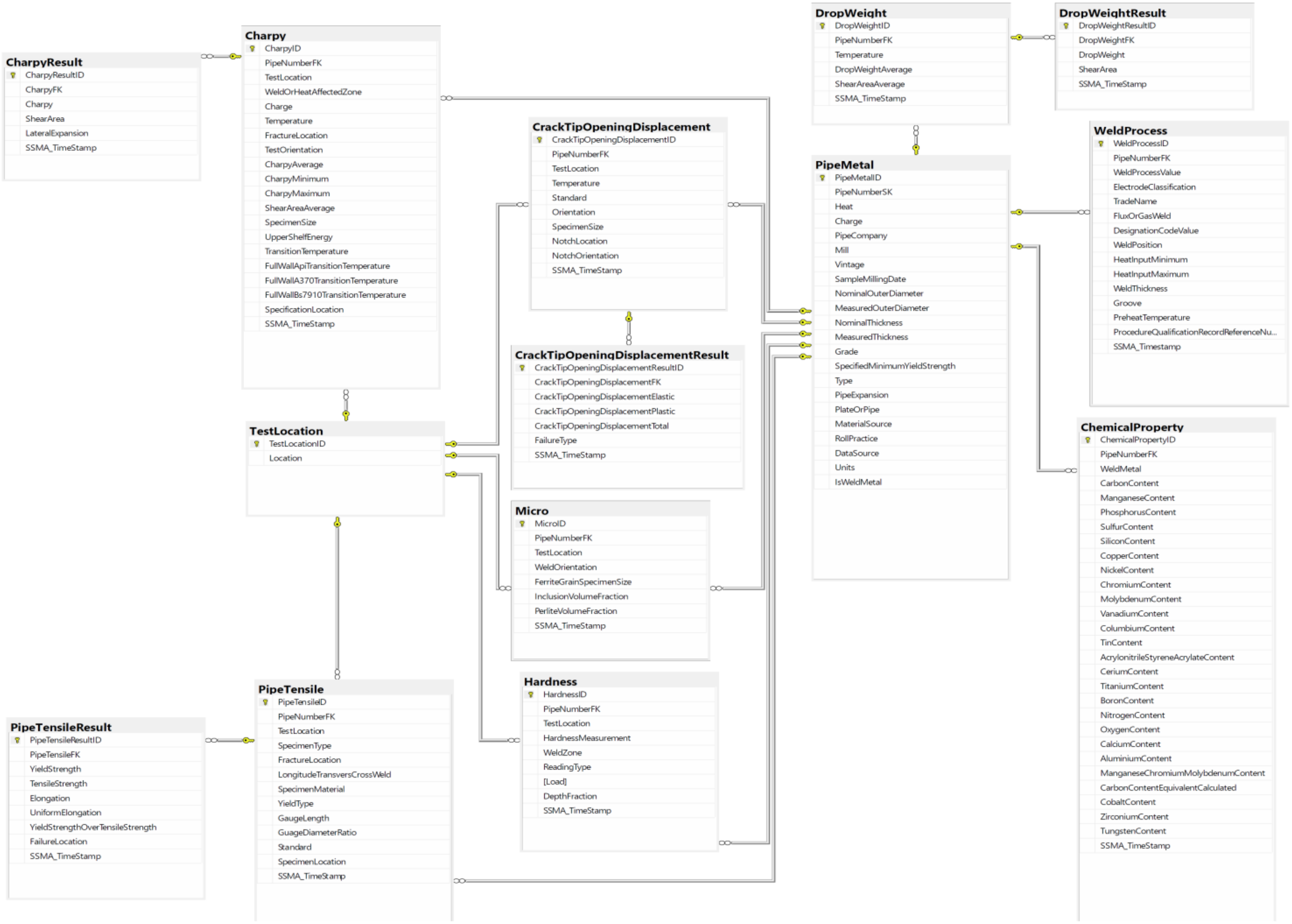
No process currently exists to compile pipe material property information. Material properties can vary greatly during the manufacturing process. PHMSA expects operators to verify pipe material used within their system.

Value to Pipeline Community

- Readily available burst testing and material property records for future PRCI projects or PRCI members in-house projects
- Support pipeline integrity of systems that do not have available material test records in demonstrating regulatory compliance
- Saving time and money in future PRCI projects by leveraging data from the database
- Recovery of huge testing campaign done in the past and build the foundation to capture records from material and burst testing performed in future PRCI projects
- Strong material for validation of new/improvement of assessment criteria or modelling effort
- Ability to compare and improve upon NDE material verification results, especially grade determination, collected in the field under 192.607
- Ability to see predicted ranges of destructive results to support decision making around cutouts or NDE results – making it less likely to force operators to use expanded sampling

Database Structure

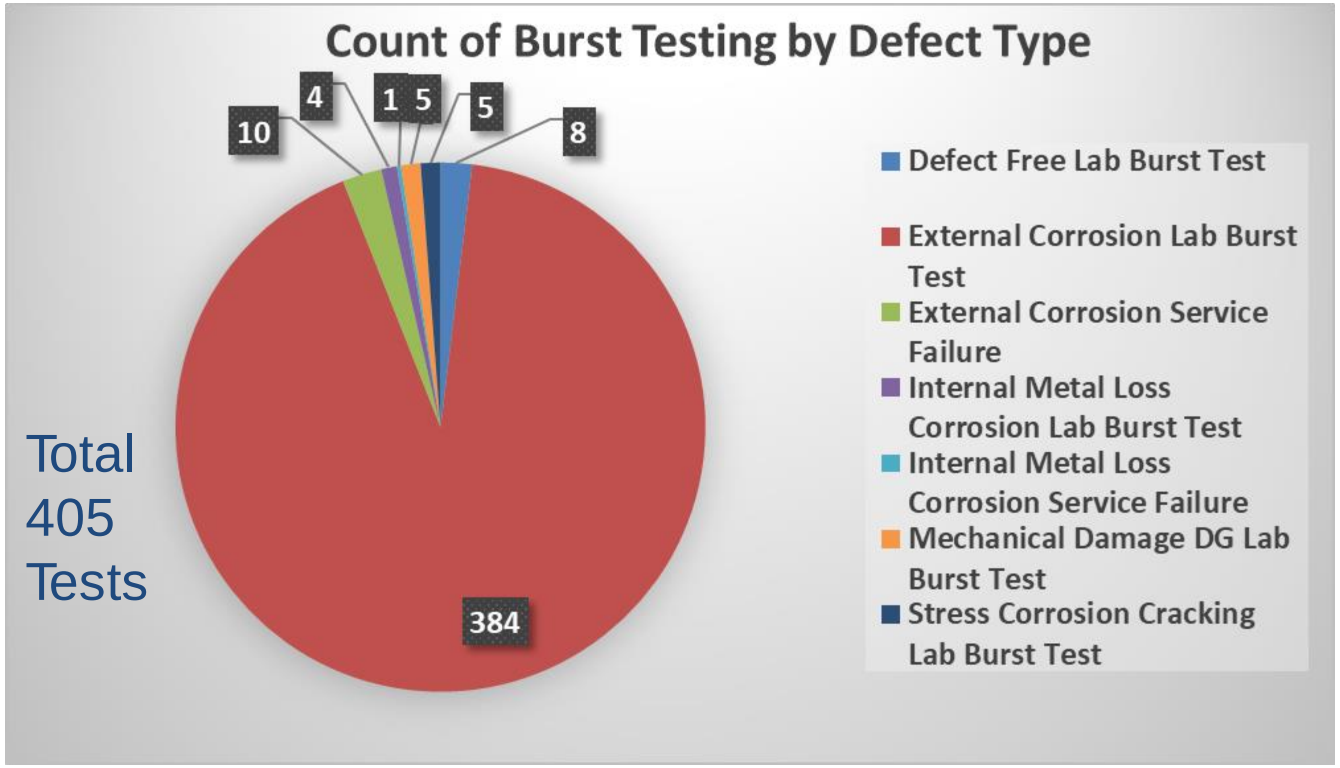
Data Tables	Number of Data Fields
BurstTest	14
BurstTestDefectGeometry	58
BurstTestLayout	11
BurstTestLoading	23
Charpy	30
CharpyResult	6
ChemicalProperty	29
CrackTipOpeningDisplacement	10
CrackTipOpeningDisplacementResult	7
DropWeight	11
DropWeightResult	6
Fatigue	13
FEA	8
Hardness	12
JRCurve	10
Micro	8
PipeMetal	35
PipeTensile	16
PipeTensileResult	10
WeldProcess	34
Total	**351**

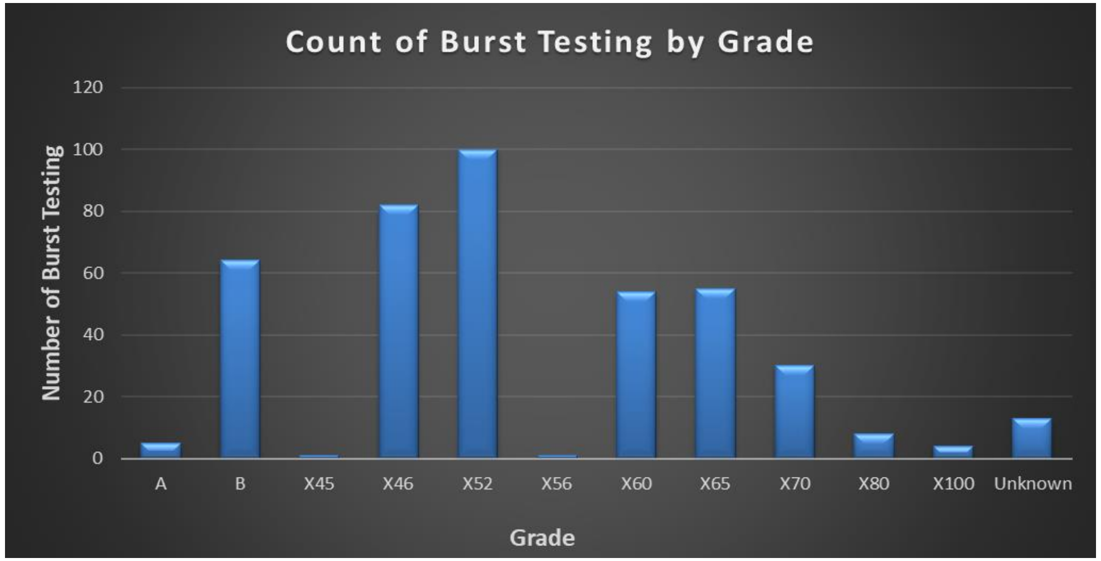


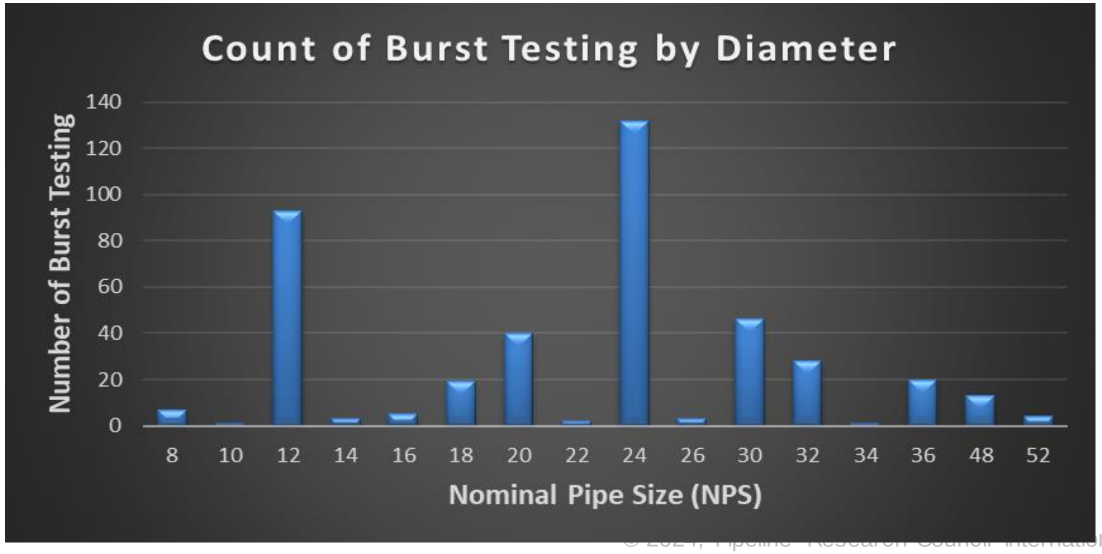
Key Features of the Database

- Provide a uniform format for material property and burst testing data collection
- Ensures data traceability and retention of the source data with supporting documents
- Records available in both imperial and metric units
- Ability to add pictures (e.g., stress-strain curve, CVN transition curve, defect profile, etc.)

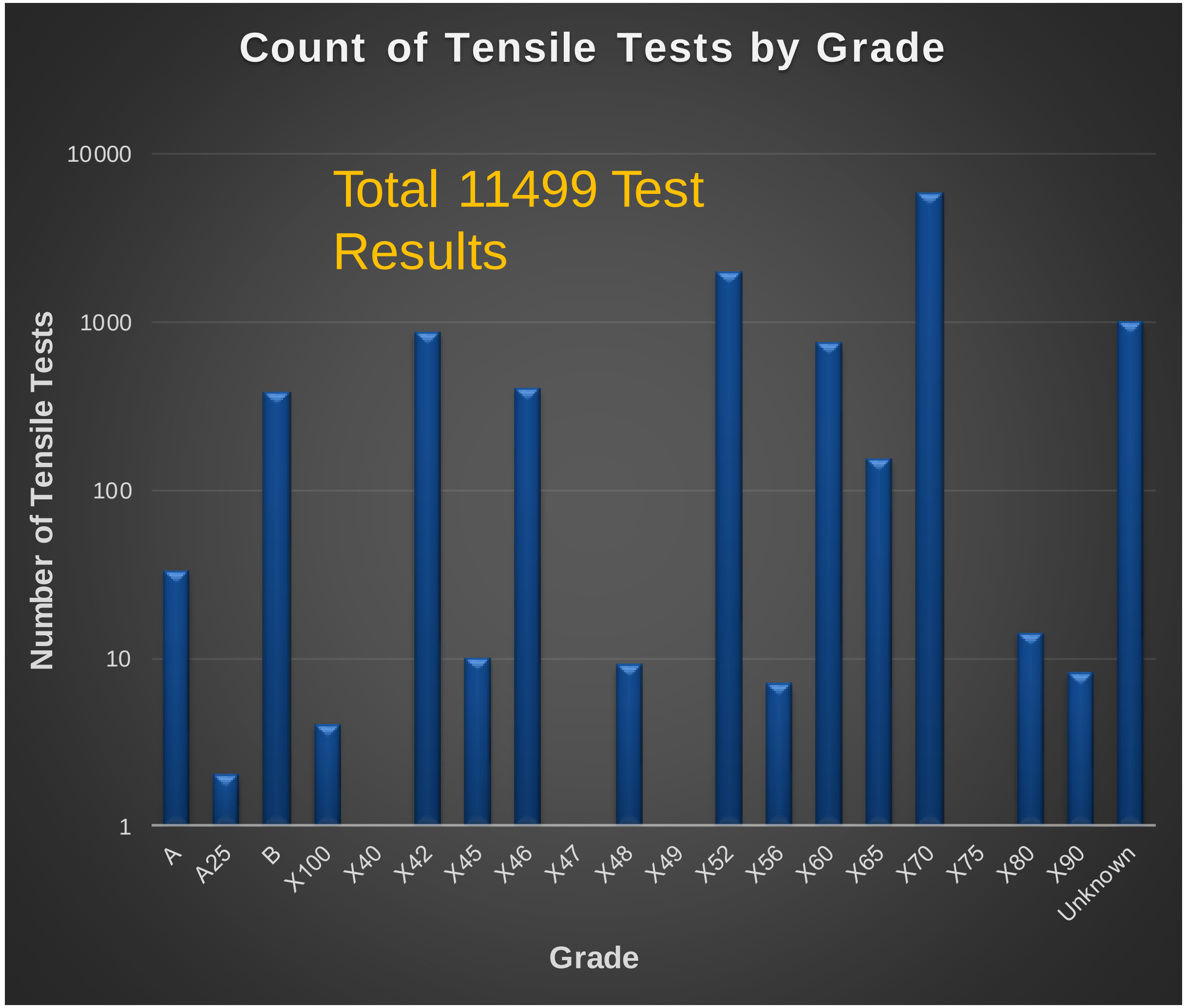
Available Burst Testing Data

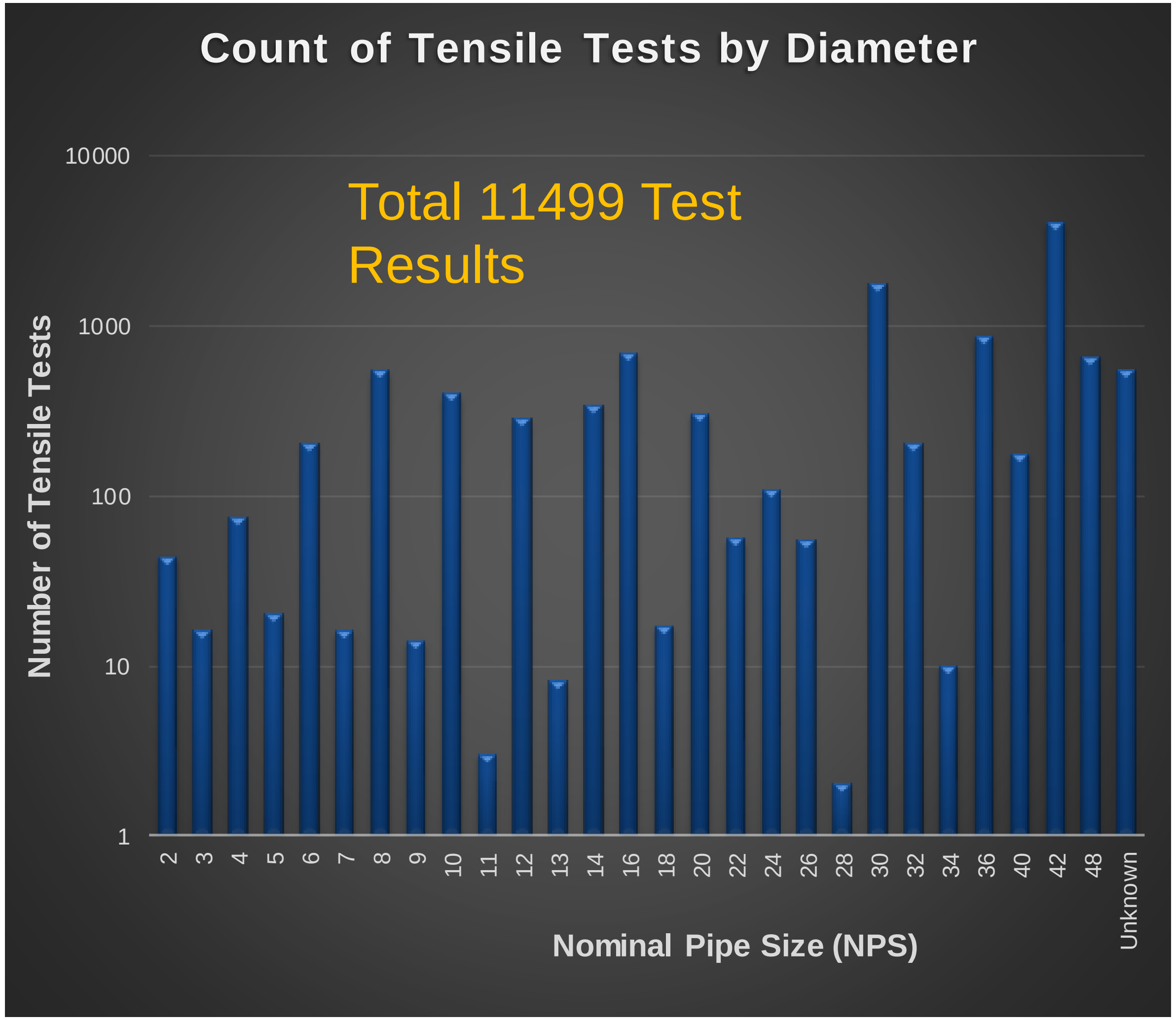






Available Tensile Test Data





Available Charpy Test Data

Vintage	Number of Test Results
1900s	21
1920s	26
1930s	269
1940s	310
1950s	1461
1960s	547
1970s	683
1980s	53
1990s	10163
2000s	97
Unknown	2703
Total	**16333**

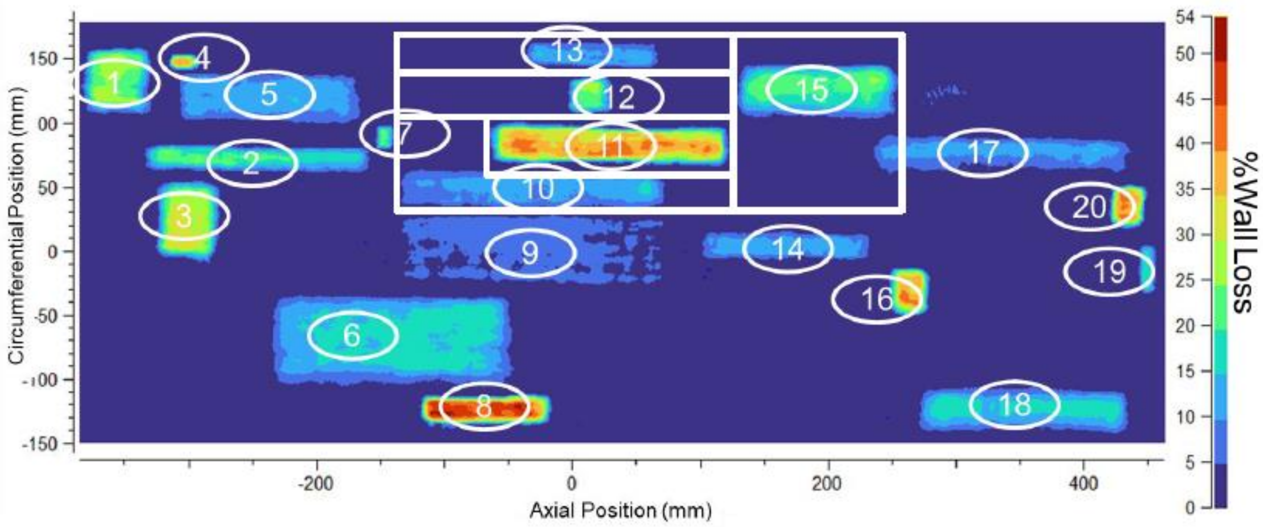
Grade	Number of Test Results
A	97
B	979
X42	777
X45	9
X46	420
X48	15
X52	2353
X56	59
X60	1439
X65	560
X70	6041
X80	1848
Unknown	1736

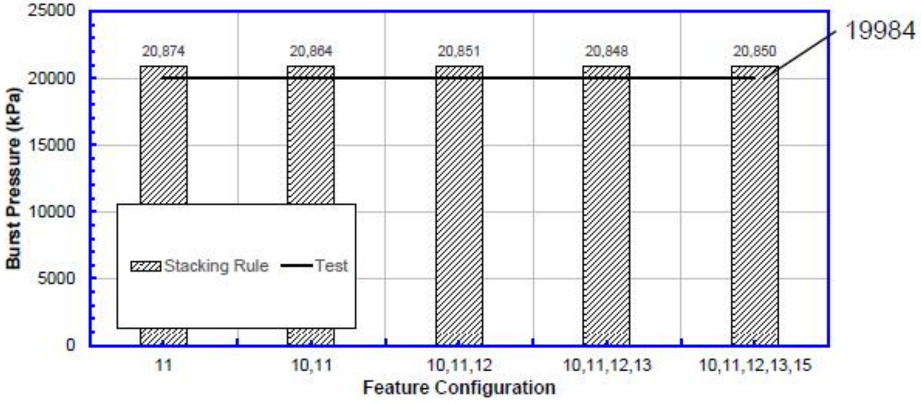
Manufacturer	Number of Test Results
AOSmith	171
Bethlehem	24
Cal-Metal	10
Camrose	5202
IPSCO	2865
J+L	30
Kaiser	293
Kawasaki	6
LoneStar	125
Napa	45
National Tube	44
Nippon	33
Page-Hersey	28
Republic	122
Shaw Group Inc.	11
Stelco	34
Stupp	158
Sumitomo	6
UK	24
USS	362
Welland	1817
Youngstown	97
Unknown	4825

Use Case 1- Model Development and Validation

Use of Burst Testing Data from PRCI EC-2-09 in EC-2-10 Project in developing a new model

Source: EC-2-10 Project Status Update by CRES on Feb 7, 2024





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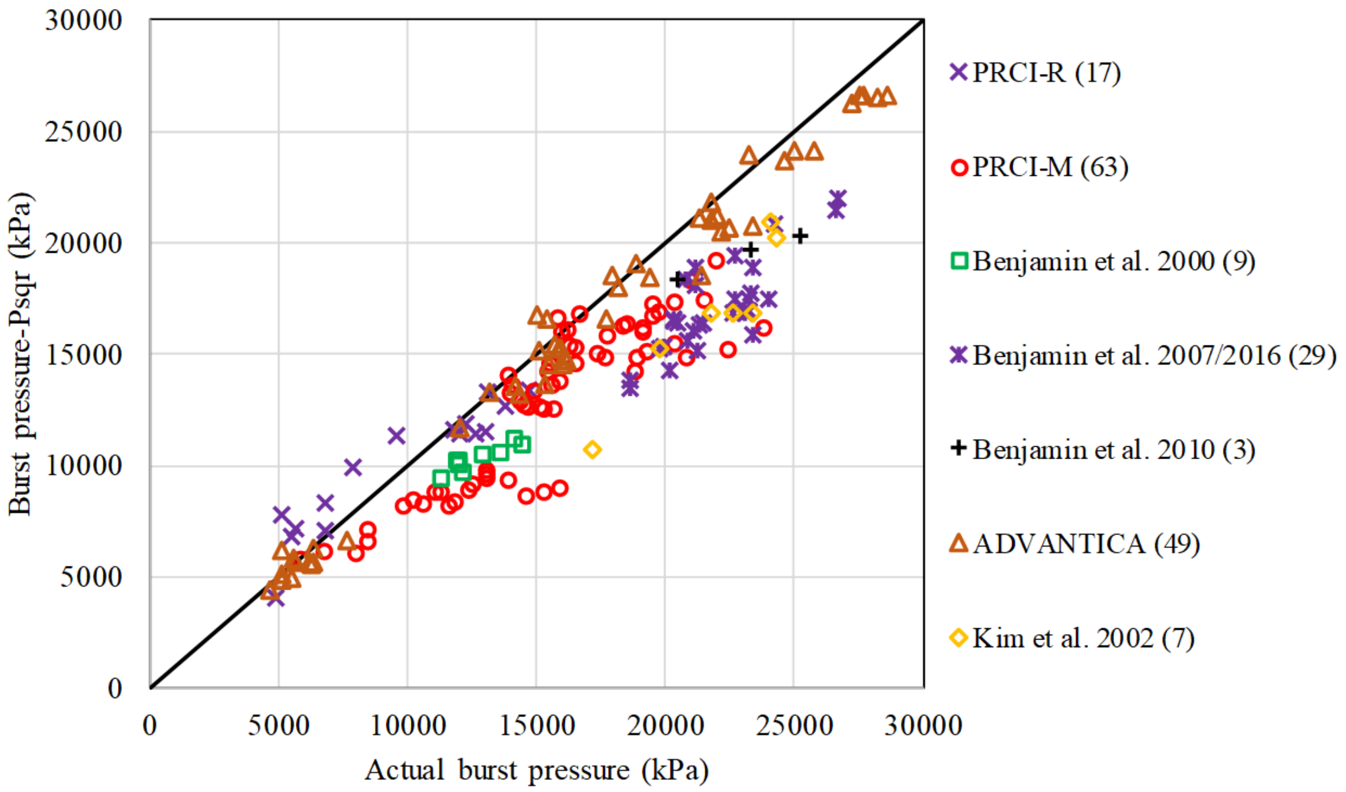
Use Case 1- Model Development and Validation

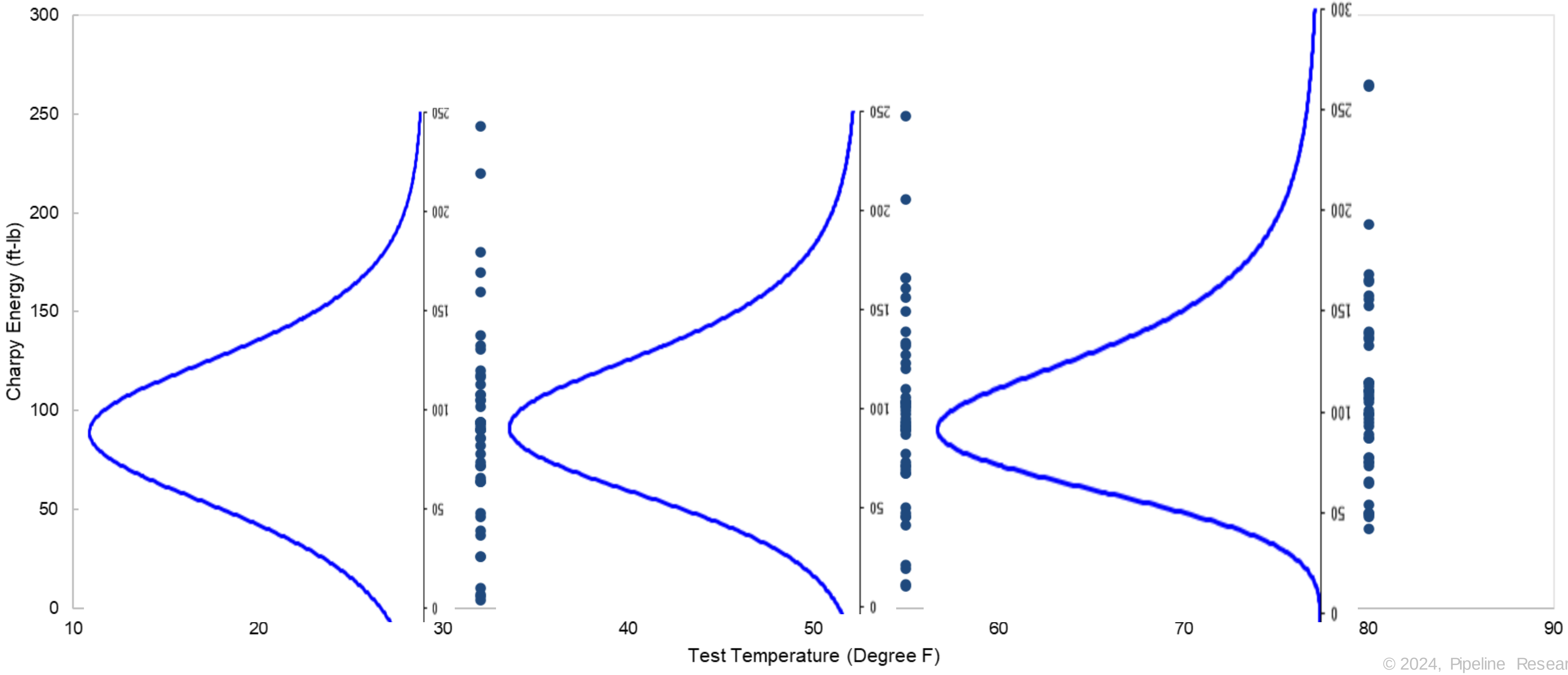
Validation of Psqr Corrosion Assessment Model using Public Data



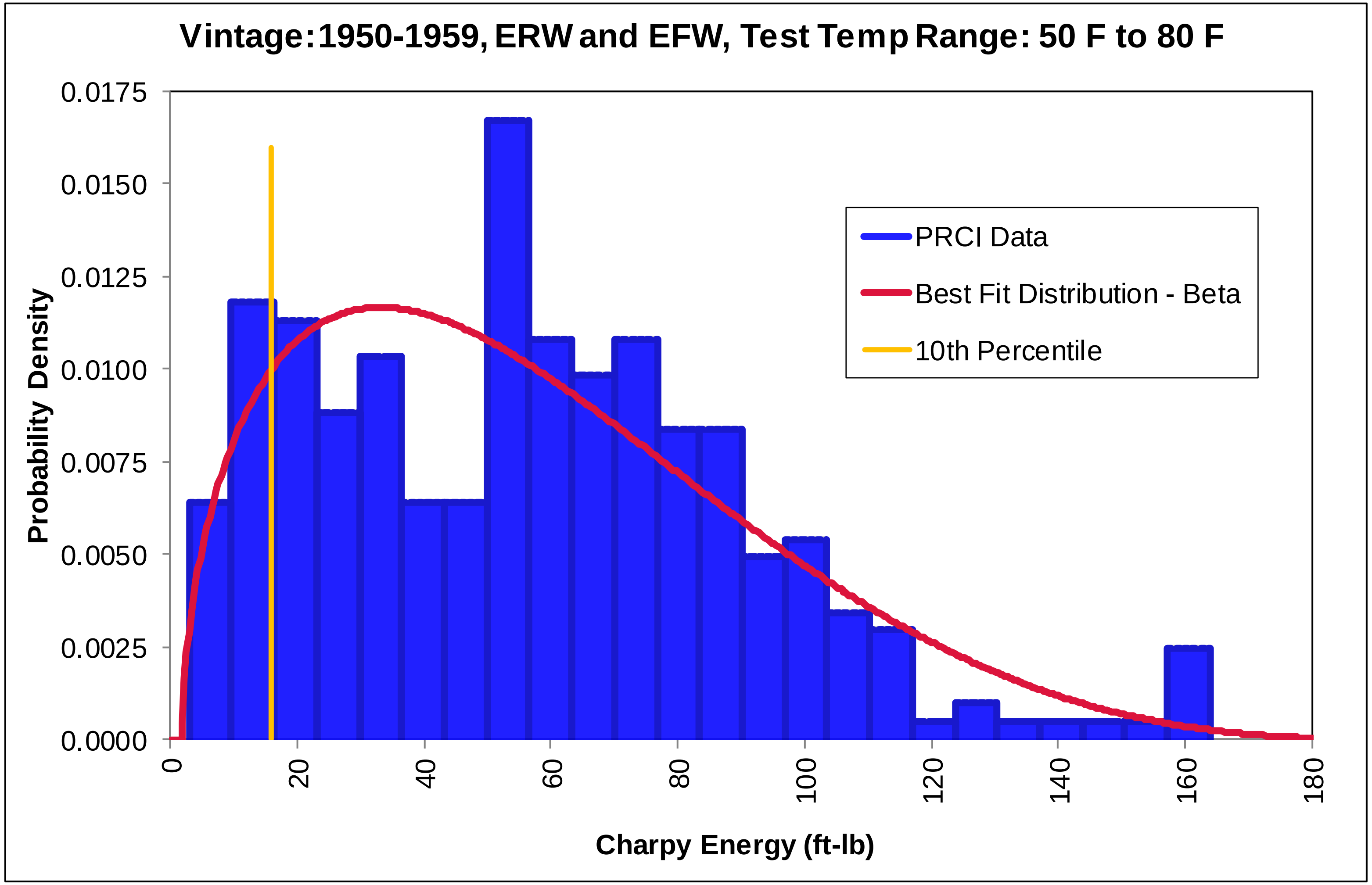
Use Case 2 – Use to Toughness from Similar Pipe

CFR 192.712 (e) (2) (A) Charpy v-notch toughness values from comparable pipe with known properties of the **same vintage** and from the **same steel and pipe manufacturer**;

ERW, Gr. X52, 1973 Stupp pipe



Use Case 3 –Other Default Toughness from Similar Pipe



CFR 192.712 (e) (2)

(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;

(E) Other **appropriate values** that an operator demonstrates can provide conservative Charpy v-notch toughness values of crack-related conditions of the pipeline segment.

Use Case 4 – Better Understanding of Material Property Variability

- API 1176 Annex D provides statistics of yield strength and ultimate strength by pipe grade
- API 1176 assumes normal distribution in providing the upper and lower quantile values
- Source of the API 1176 data is not provided
- PRCI Database contains more data than API 1176 Annex D; hence, can better represent similar pipeline characteristics

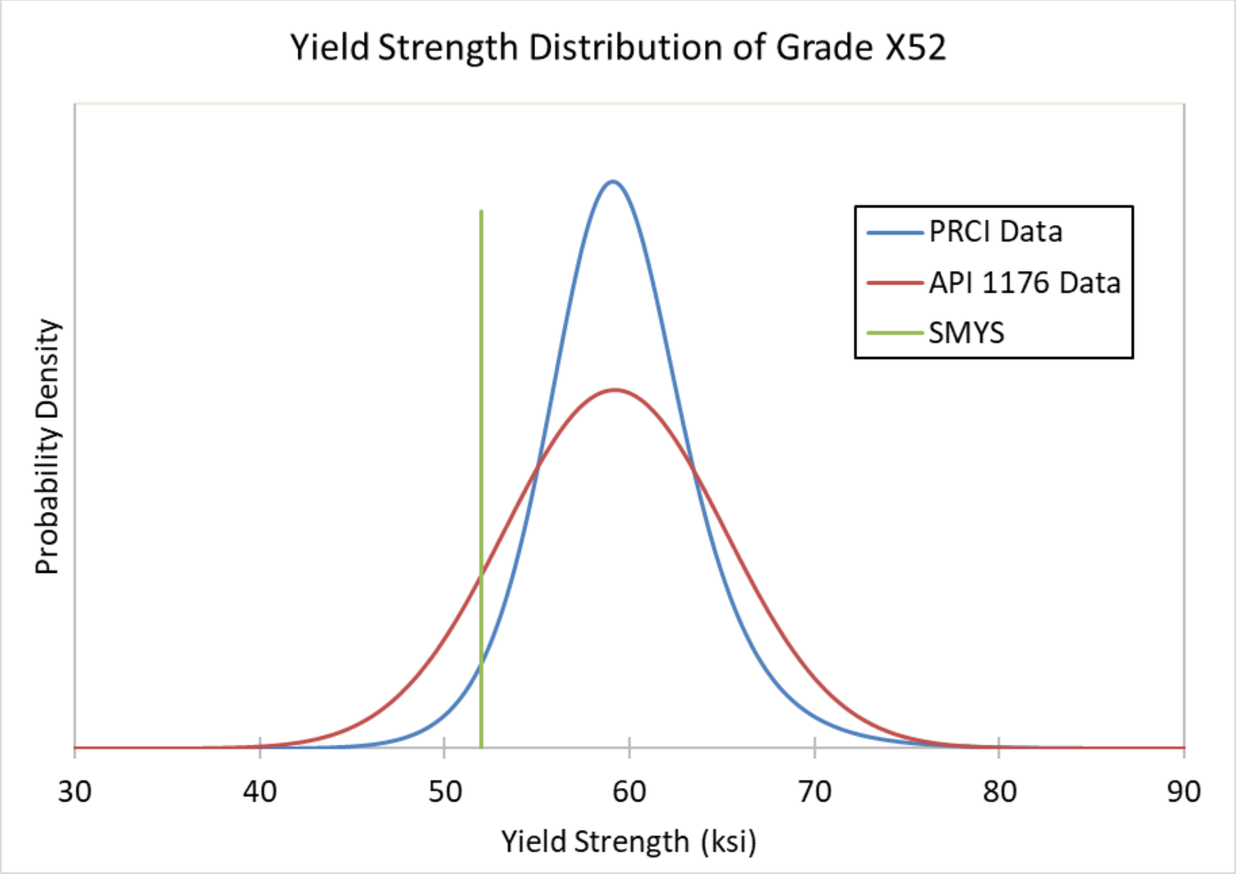
Table D.1—Database Yield Strength (YS) Properties by Grade

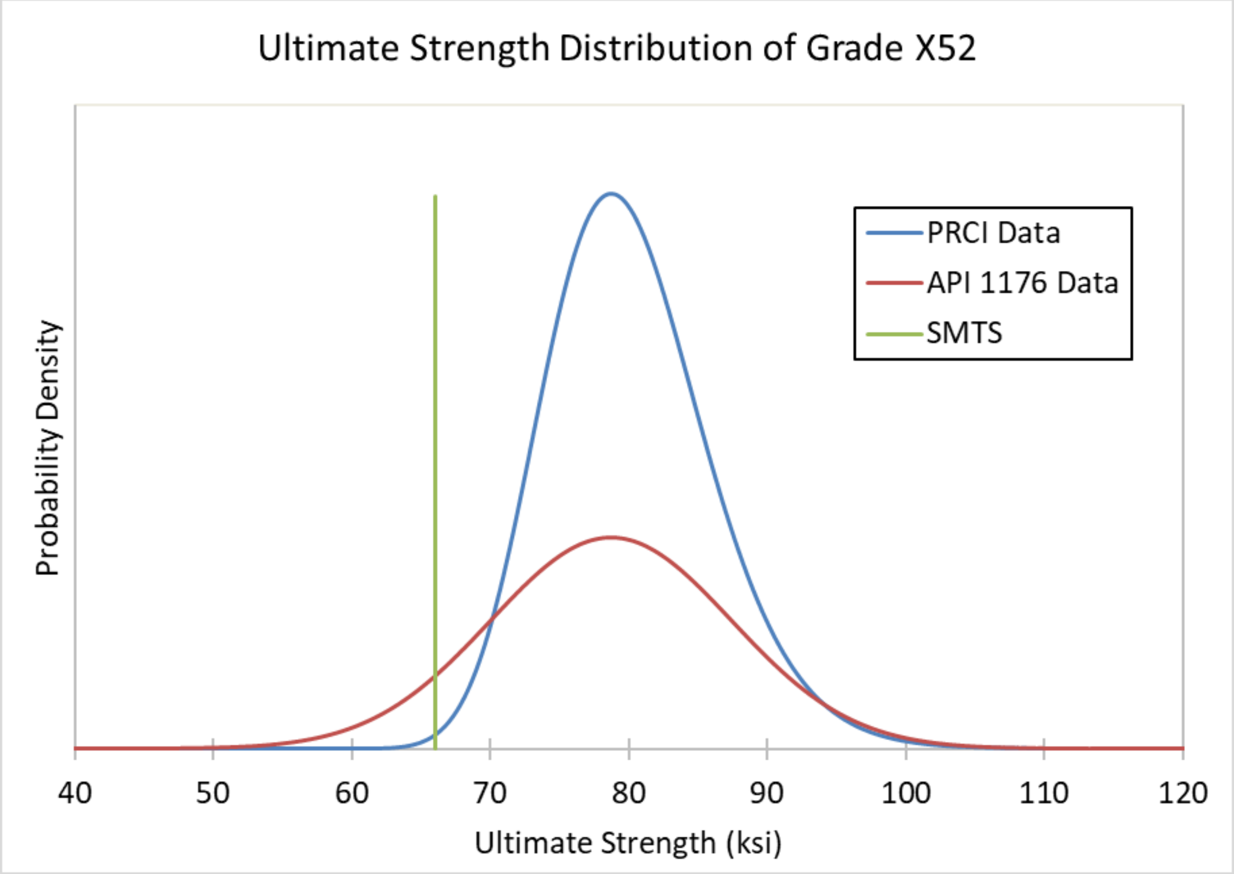
Grade	SMYS lb/in.^{2} (MPa)	Mean YS lb/in.^{2} (MPa)	StdDev lb/in.^{2} (MPa)	SD/Mean	U95 YS = AvgYS+1.64sd lb/in.^{2} (MPa)	L5 S = AvgYS–1.64sd lb/in.^{2} (MPa)
A/Bsmr/OH	30,000 (210) [a]	39,997 (275.77)	4,535 (31.267)	0.113	47,434 (327.04)	32,560 (224.49)
B	35,000 (245)	48,641 (335.37)	7,795 (53.744)	0.160	61,425 (42[illegible])	35,857 (247.22)
X42	42,000 (290)	52,228 (360.1)	6,396 (44.09)	0.122	62,[illegible]17 (432.[illegible]2)	41,739 (287.78)
X46	46,000 (320)	53,723 (301.46)	5,96[illegible] ([illegible])	[illegible]	63,502 (437.83)	43,944 (302.98)
X52	52,000 (360)	[illegible]9,19[illegible] ([illegible]8.11)	[illegible],98[illegible] (41.25)	0.101	69,004 (475.77)	49,380 (340.46)
X56	56,000 (390)	62,833 (433.22)	8,704 (60.01)	0.139	77,108 (531.64)	48,558 (334.79)
X60	60,000 (415)	68,660 (473.39)	5,390 (37.16)	0.079	77,500 (534.34)	59,820 (412.44)
X65	65,000 (450)	72,003 (496.44)	2,884 (19.88)	0.040	76,733 (592.05)	67,273 (463.83)
X70	70,000 (485)	80,438 (554.60)	4,996 (34.45)	0.062	88,631 (611.09)	72,245 (498.11)

[a] Actual range was YS = 25 ksi to 30 ksi (172 MPa to 207 MPa), UTS = 45 ksi to 50 ksi (210 MPa to 345 MPa).

API 1176 Annex D

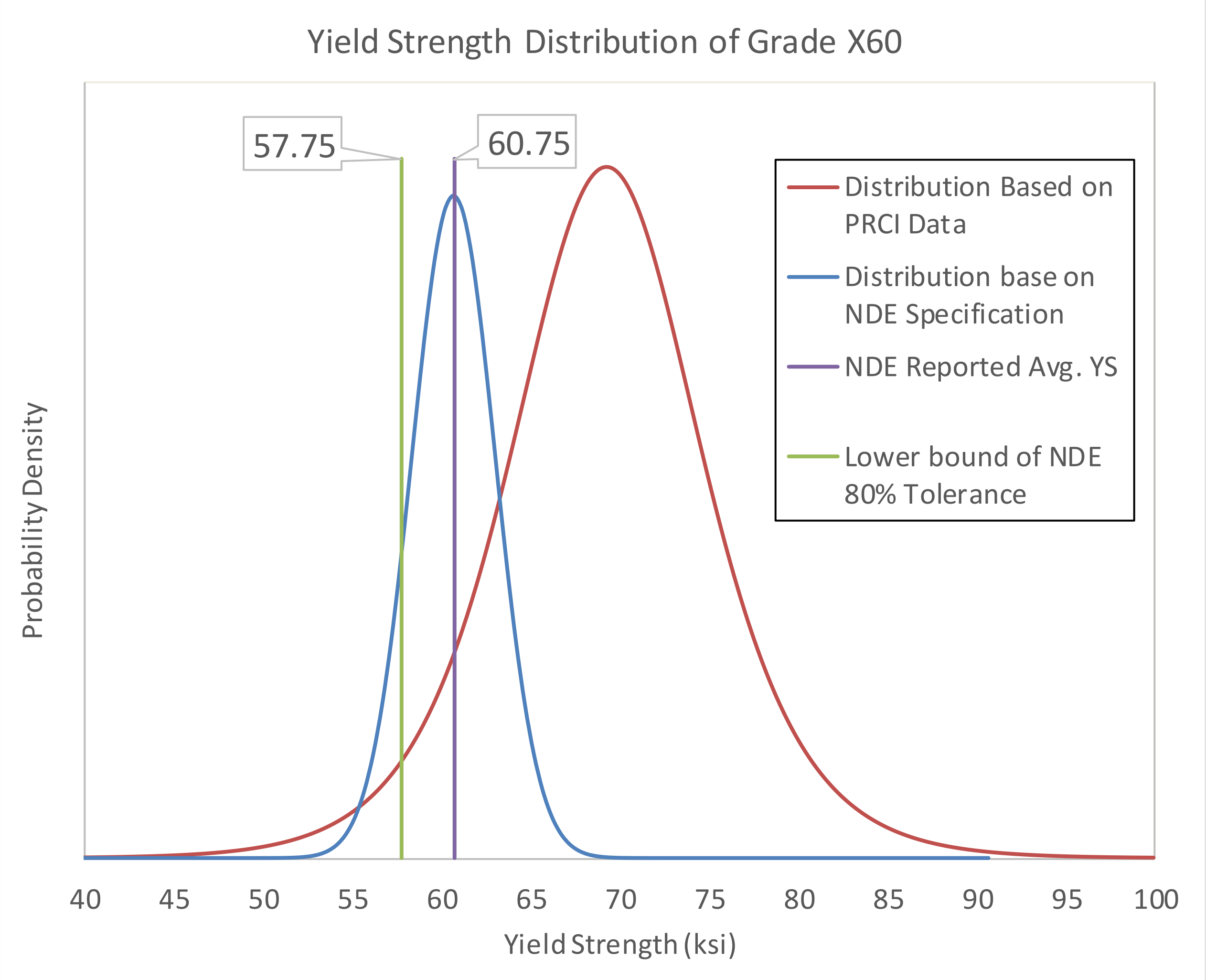
Use Case 4 – Better Understanding of Material Property Variability





Use Case 5 – Material Verification Testing Results Evaluation

- **Use PRCI database to compare material properties obtained from in-situ NDE**
- **Example Case:**
  - Non-TVC pipe grade X60
  - NDE performed in opportunistic dig
  - NDE reported an average yield strength of 60.75 ksi
  - NDE specification for yield strength is ±3 ksi 80% of the time
  - Should this pipe grade be X60 or X56 based on the NDE result?



Use Case 6 – Probabilistic Defect Assessment

- Probability distributions of mechanical properties of pipeline are critical inputs in probabilistic defect assessment
- Distributions from CSA Z662 Annex O are commonly used
- CSA Z662 Annex O distributions are developed mostly based on data for higher grade (X60 and above)
- Jiao et al. data represents pipe used in offshore operation
- PRCI Database can be leveraged to develop probability distributions of mechanical properties to better represent pipe used in onshore application for a wide range of grade, vintage and manufacturer

O.2.7.3 Mechanical properties

Table O.6 summarizes available statistical data and distributions for yield strength, tensile strength, flow stress, ultimate tensile strain, Charpy V-notch impact energy, CTOD fracture toughness, and Young's modulus.

Table O.6
Parameter distributions for pipe mechanical properties
(See Clause O.2.7.3.)

Variable	Units	Distribution Type	Mean	COV, %	Source
Yield strength/SMYS	—	Normal	1.11	3.4	Jiao *et al.* (1997) API 5L X60*
		Normal	1.08	3.3	Jiao *et al.* (1997) API 5L X65*
		N/A	1.07–1.10	2.6–3.6	Jiao *et al.* (1995b) API 5L X80†
		Lognormal	1.08	4	Sotberg and Leira (19[illegible])‡
		Normal or lognormal	1.1	3.5	Proprietary data§
Tensile strength/ SMTS	—	Normal	1.1[illegible]	[illegible].0	Jiao *et al.* (1995b) API 5L X60 hoop**
		Normal	1.12	3.5	Jiao *et al.* (1995b) API 5L X65 hoop**
		Normal	1.07	2.6	Jiao *et al.* (1995b) API 5L X60 axial**
Pipe body Charpy V-notch impact energy	J	N/A	30–70	Formula‡‡	Leewis (1997)§§
		Lognormal	149–259	18–24***	Jiao *et al.* (1995b) API 5L X60 & X65†††
		N/A	110	13***	Hillenbrand *et al.* (1999) API 5L X80†††
		N/A	176–183	16–18***	Gartner *et al.* (1992)

CSA Z662 Annex O

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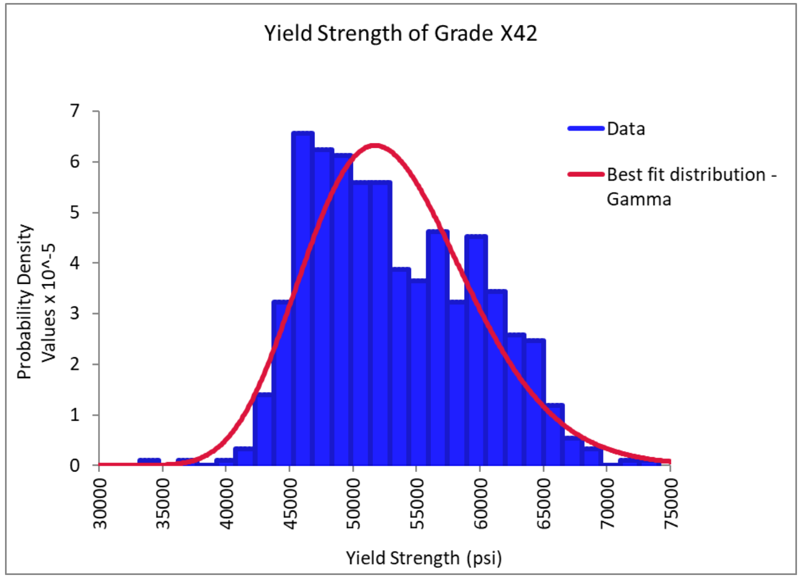
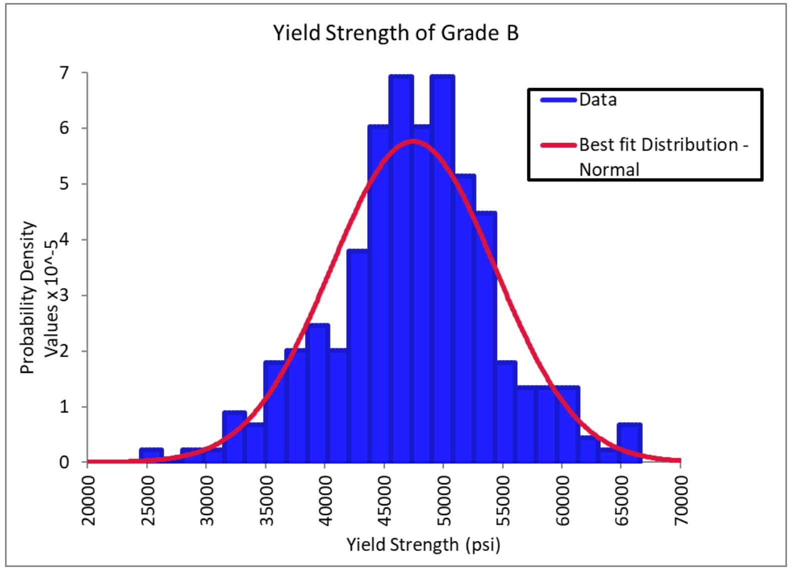
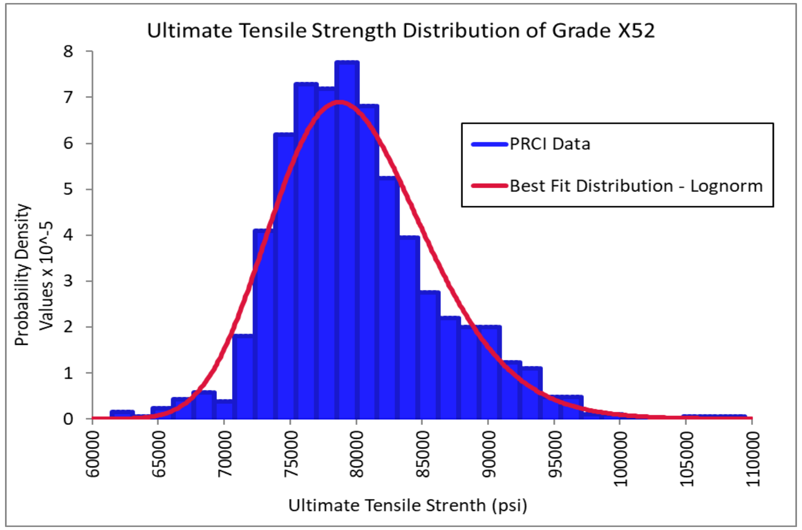
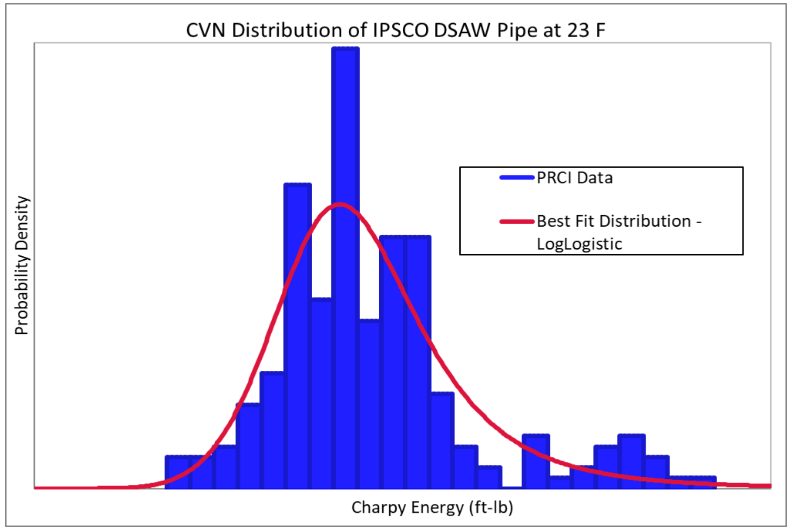
Use Case 6 – Probabilistic Defect Assessment (Example Probability Distributions)









thank you

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