Case Studies: What's New in Pipeline Integrity Management

Northeast Gas Association

June 8, 2022

MMT

AGENDA

Review of CFR 192.607

Applicability in Other Sections

Compliance Timeline

Case Studies

§192.607 Overview

What is the Mega Rule?

PHMSA regulation requiring pipeline owners and operators to update and maintain records of gas transmission assets with the **goal of improving pipeline safety**.

Overarching Goals

Pipeline Safety

Compliance

Maintain MAOP

Material Verification: Key Points

§192.607(b): Operators are required to have traceable, verifiable and complete (TVC) records.

§192.607(c): If an exposed line does not have associated TVC records, operators must verify

§192.607(c): Material verification can be achieved destructively or nondestructively

§192.607(d): Nondestructive verification must also:

- Utilize SME validated tools
- Conservatively account for tool tolerance
- Equipment must be properly calibrated

Operators testing frequency can be:

- The lesser between one sample per mile and 150 samples; or
- An alternative sampling plan with a valid statistical bases

Population Sampling

Operators are permitted to use a sampling program to verify material properties.

§192.607(e)(2): "[...] operator must determine material properties [...] until completion of the lesser of the following:

(i) One excavation per mile [...]; or

(ii) 150 excavations if the population is more than 150 miles."

Results identifying inconsistent samples are subject to an expanded sampling program.

§192.607(e)(5): "An operator may use an alternative statistical sampling approach [...] The alternative sampling program must use valid statistical bases designed to achieve at least 95% confidence [...]"

Applicability for Other Sections

§192.619 – MAOP Determination

Determining Maximum Allowable Operating Pressure for pipelines of each class location.

§192.619(a)(4): "[...] the maximum safe pressure [...] including material properties verified in accordance with §192.607"

§192.619(e): "[...] pipelines that meet the criteria specified in §192.624(a) must establish and document the maximum allowable operating pressure in accordance with §192.624."

§192.624 – Reconfirming MAOP

Reconfirming MAOP can be completed using:

- Pressure test
- Pressure reduction
- ECA
- Pipe replacement
- Alternative technologies

§192.624(c)(1)(iii): " If any records [...] are not documented in traceable, verifiable, and complete records, the operator must obtain the missing records in accordance with §192.607"

§192.632 – ECA for MAOP

When establishing strength and MAOP via ECA, operators must assess:

- Threats
- Relevant loading and operational circumstances
- Relevant mechanical and fracture properties
- In-service degradation or failure processes
- Initial and final defect size relevance

§192.632(a): "If any material properties required to perform an ECA [...] are not documented [...] verify the undocumented information in accordance with §192.607."

§192.712 – Predicted Failure Pressure

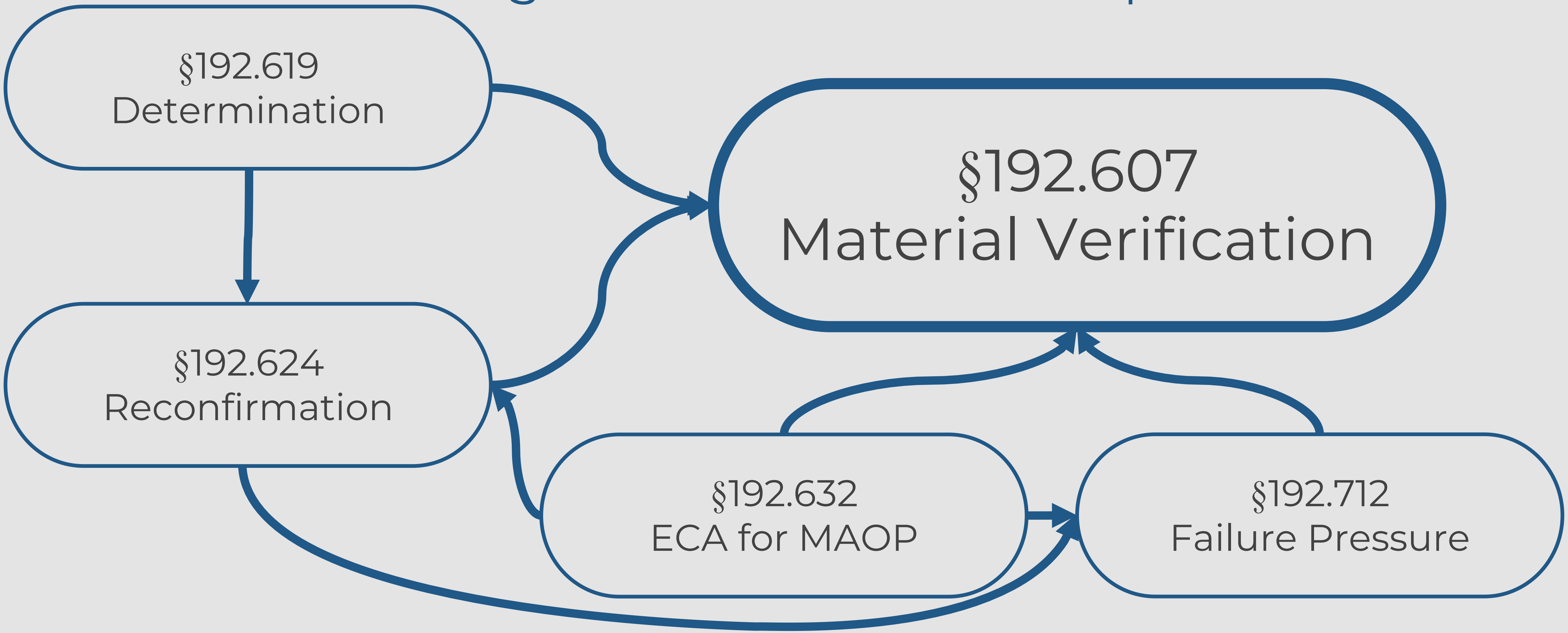
Operators must analyze anomalies and defects to determine a predicted failure pressure and remaining life.

§192.632(a): "If any material properties required to perform an ECA [...] are not documented [...] verify the undocumented information in accordance with §192.607."

Default material properties:

Toughness – 4.0 ft-lb
Strength – 30 ksi

Mega Rule Partial Roadmap



If required to consider material properties, and records are not TVC, **testing is required**.

Implementation Timeline

Jul. 2028 - Reconfirmation 50% Complete

Jul. 2034 - 100% Predicted Failure Pressure Analysis Complete

Jul. 2035 - Reconfirmation 100% Complete

Material Verification Technologies

Methodologies

NDE

- In-Situ testing
- Techniques
  - Hardness (Mic-10)
  - Ball Indentation (Frontics)
  - Frictional Sliding (MMT)

Hydrostatic Testing

- Pressurize at or above SMYS
- Determine leaks or expansion

Not mentioned as a means of material verification in §192.607

Lab Testing

- Destructive cutout sent for tensile testing
- Repair required for cutout section

MMT HSD

Strength Properties
- Steel Grade Verification

ERW Seam Classification
- Low-Frequency, High-Frequency, Post-Weld Heat Treatment

ERW Seam Weld Toughness
- (Under Validation)

Pipe Body Toughness
- (In Development)

HSD: How it works

Frictional Sliding

1. Stylus is loaded into the sample
2. Force measurements ensure the loading conditions
3. Stylus slides across the sample surface and material response is measured

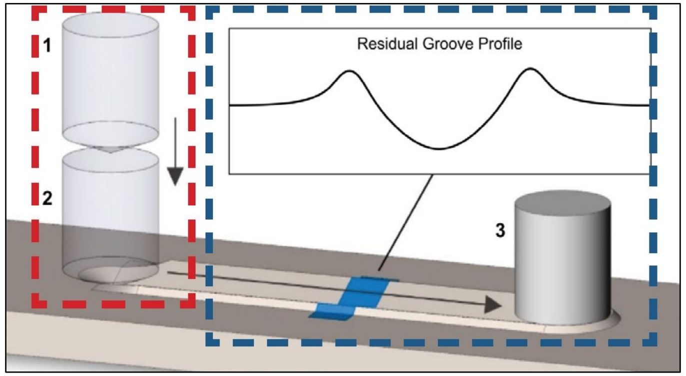
Results:

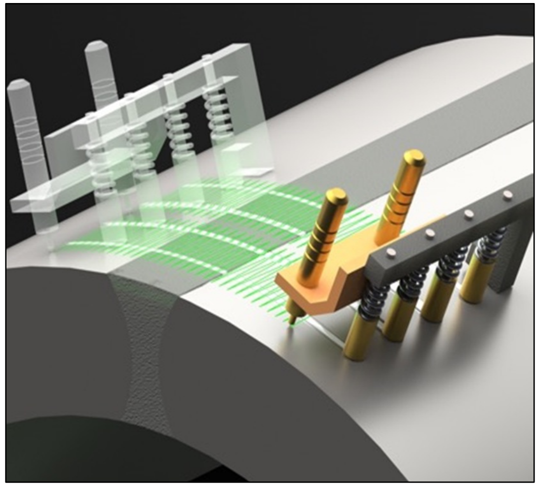
200+ hardness measurements per test

Measurement variation at locations of interest

i.e.: Across a seam

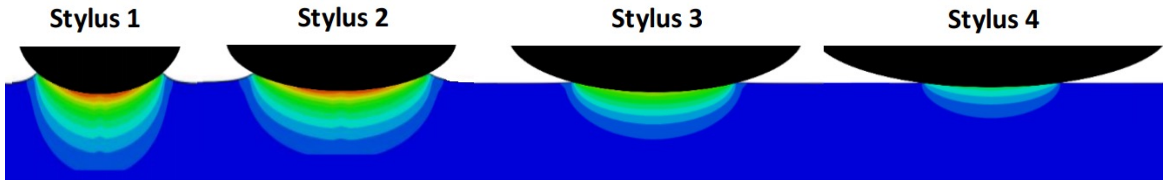
Frictional Sliding



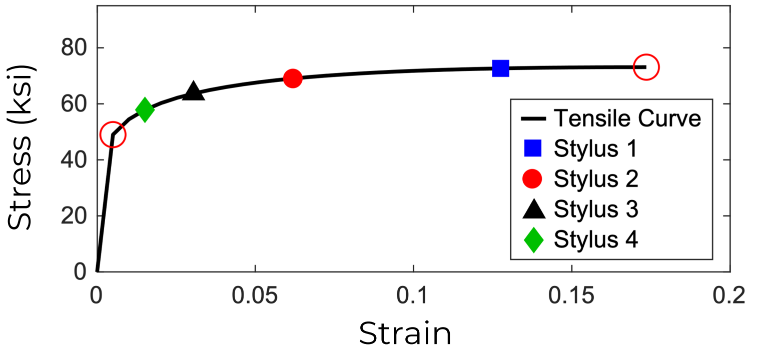


HSD TESTER – CONVERTING DATA TO PIPE MATERIAL STRENGTH PROPERTIES

- **Surface Hardness:** HSD device measures surface hardness
- **Surface YS and UTS:** Hardness data is converted to surface Yield and Ultimate Tensile Strength data through use of equations developed using FEA modeling
- **Bulk Prediction:** Surface YS and UTS is then input into prediction model which utilizes machine learning



HSD Test Surface Strength Predictions

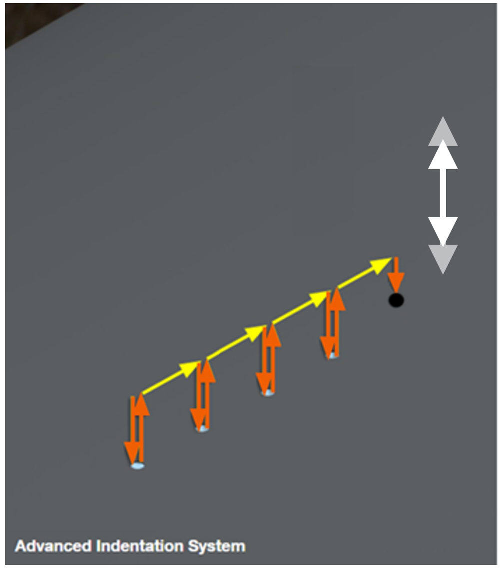


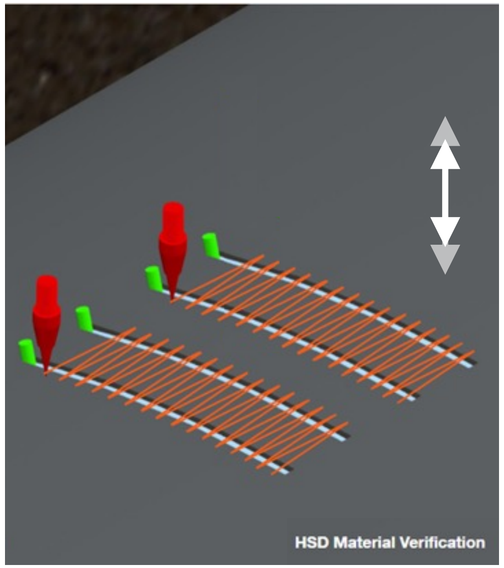
Bulk material strength prediction model

HSD: Unique Technology Feature

No Vibrational Effect

Longitudinal vs Radial Measurements

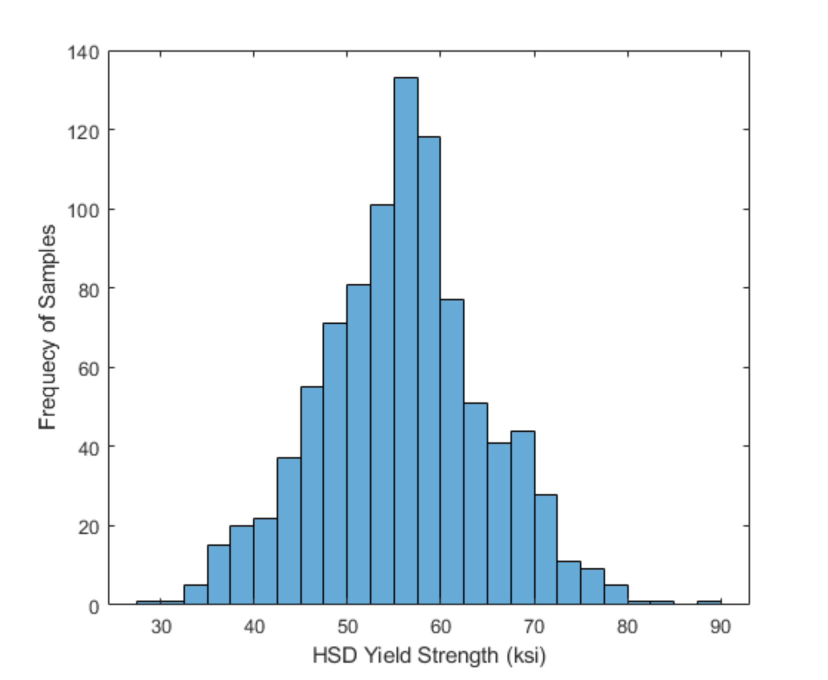




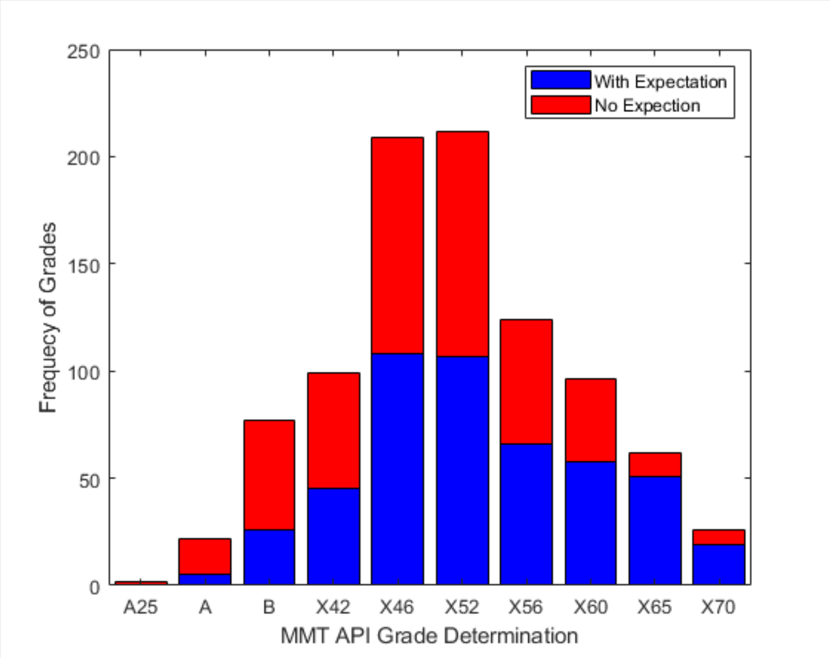
Case Studies

Observed Data

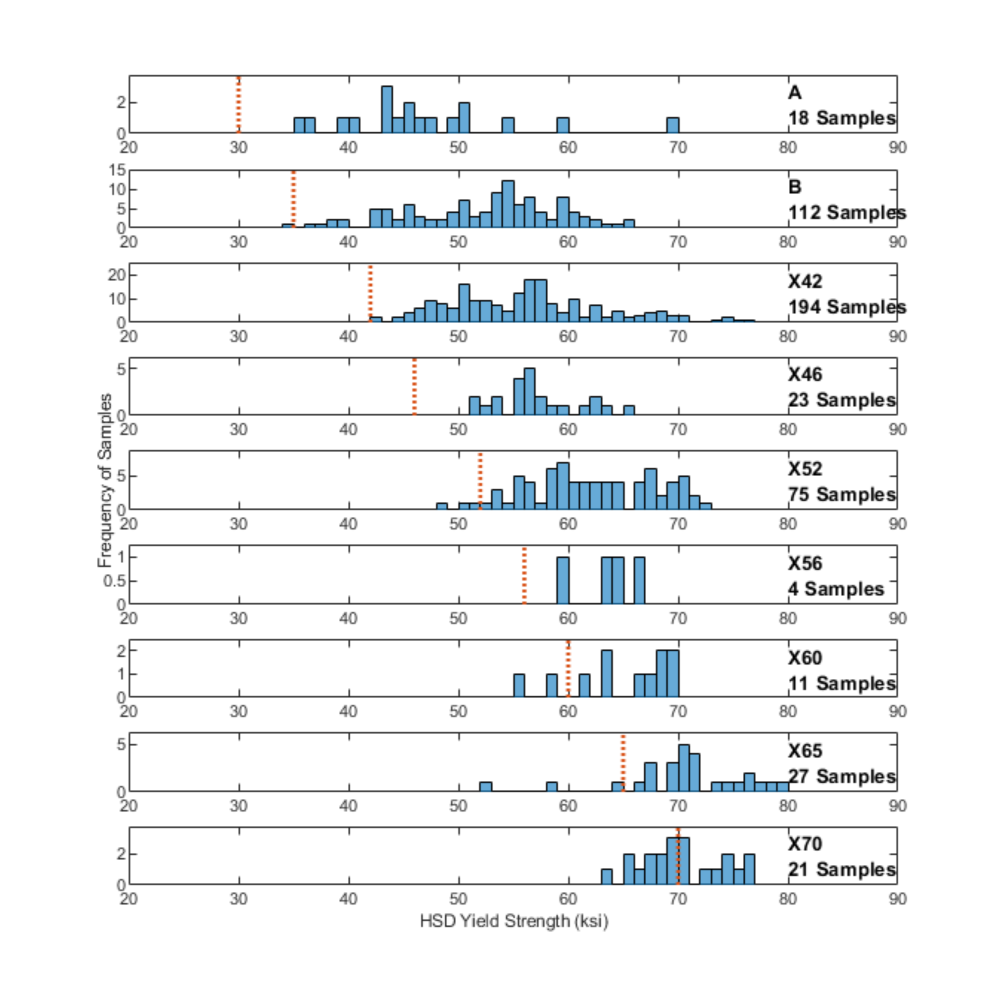
Yield Strength



Expected Grade



Meeting Grade Expectations



Samples have largely met grade expectations

485 samples with expected grade prior to testing

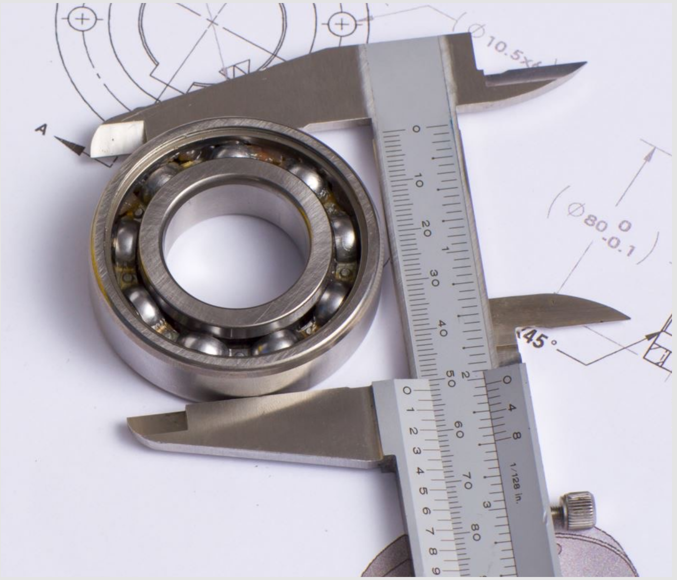
19 tested below grade

The lower the uncertainty, the more accurate the measurement to reality

Understanding Tool Uncertainty: Single Measurement

What is it?

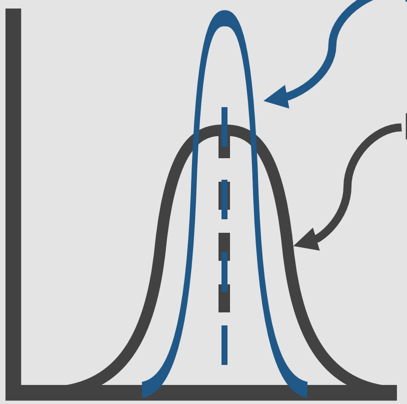
The statistical dispersion of values attributed to a measured quantity



What's the impact?

Operators need a measured value, yet measurements give a range of possible actual values (uncertainty)

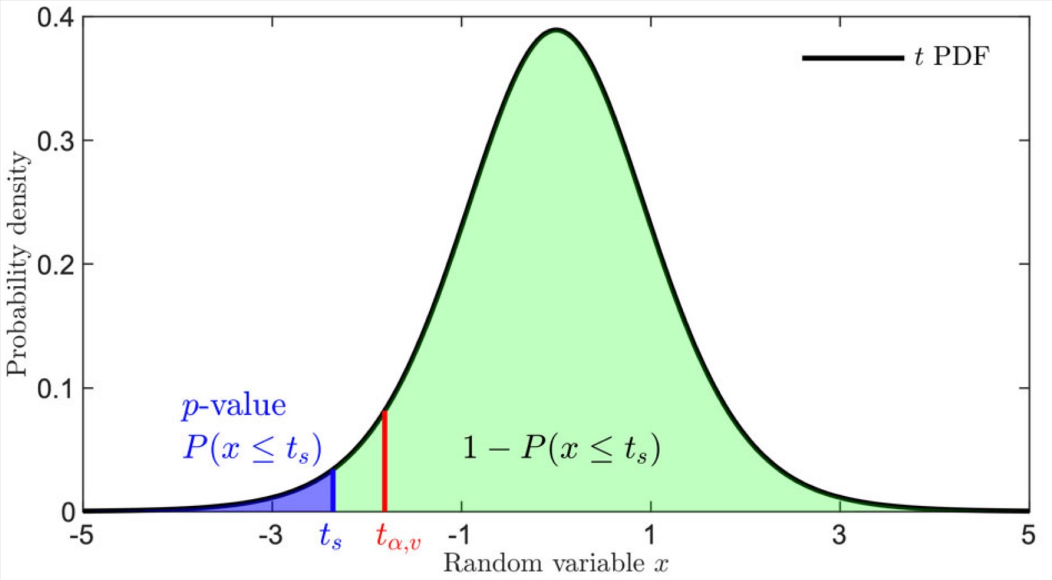
The lower the uncertainty, the more accurate the measurement to the actual



Understanding Tool Uncertainty: Multiple Measurements

Population Uncertainty

Measurements will not provide the exact same results

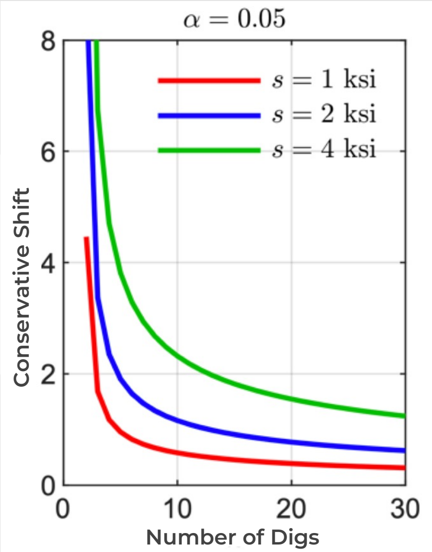


Goal

Understand the probability that the overall system exceeds the conservative estimate of strength required by §192.607

Impact of Tool Uncertainty

Mean population values vary with uncertainty



S. Palkovic, et al. "A statistical approach to material verification of expected grade through opportunistic field measurements." *Pipeline Pigging and Integrity Management conference, Houston, February 2020* .

Confidence $= 1 - \alpha$

i.e.: 95% Confidence $\Longrightarrow \alpha = 0.05$

Findings:

- Approach diminishing returns with more accurate tools
- Fewer digs maximize impact

PROPOSED STATISTICAL ANALYSIS

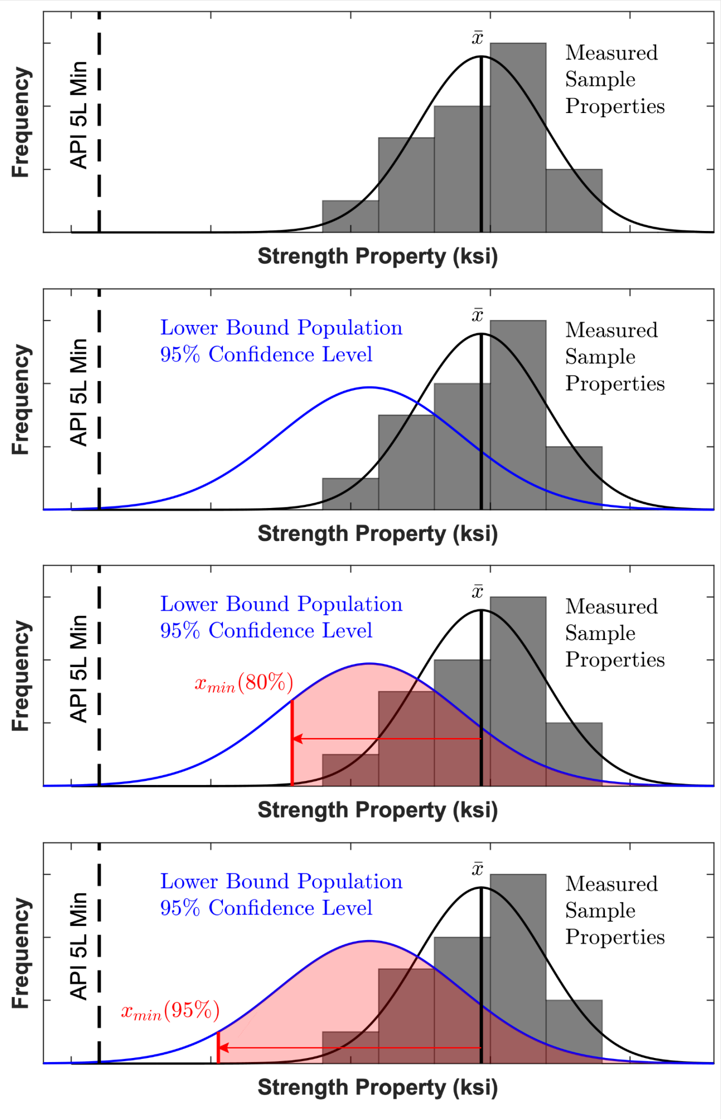
Measured – Tool Uncertainty – Sampling Uncertainty > Grade Minimum

Measured Distribution

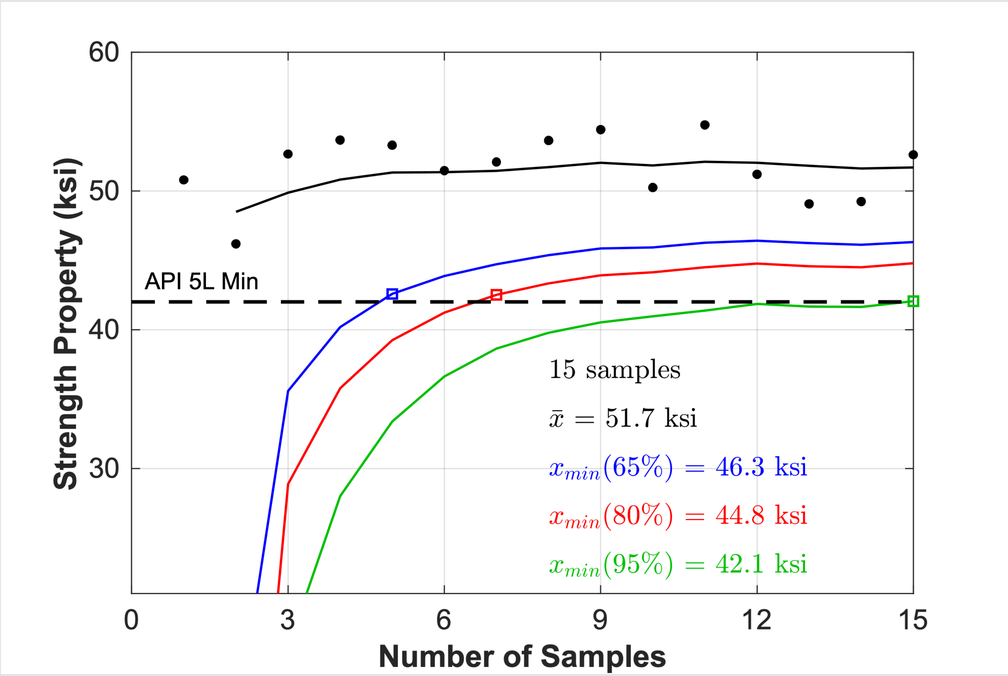
Lower Bound Population Distribution (95% Confidence Level)

Tolerance Interval with 80% Probability of Exceedance

Tolerance Interval with 95% Probability of Exceedance



Example: Verifying Yield of a Population



References

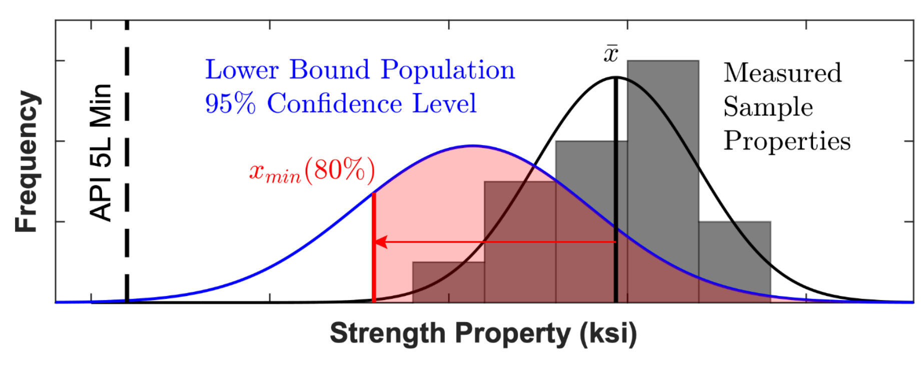
Clark and Amend, “Applications guide for determining the yield strength of in-service pipe by hardness evaluation,” *ASME CRTD Vol.* 91, 2009.

Palkovic et al., “A statistical approach to material verification of expected grade through opportunistic field measurements,” PPIM, 2020.

Palkovic et al., “Advancements in nondestructive methods using frictional sliding for direct assessment of steel pipelines and welded seams,” *IPC2020-15062*, 2020.

APPLICATION ON X42 POPULATION

Lower Bound Tolerance Interval



Clark and Amend, "Applications guide for determining the yield strength of in-service pipe by hardness evaluation," *ASME CRTD Vol.* 91, 2009.

Palkovic et al., "A statistical approach to material verification of expected grade through opportunistic measurements," *PPIM 2020*.

Case Study: In-ditch HSD testing of X42 line segment

Dig #	Measured NDE Strength		Lower Bound Strength	
	Yield (ksi)	UTS (ksi)	Yield (ksi)	UTS (ksi)
1	54.2	66.4	---	---
2	52.9	65.7	34.1	55.2
3	58.6	71.4	36.1	49.0
4	52.9	66.3	41.8	55.8
5	48.7	63.6	40.0	56.2
6	53.2	65.9	42.2	57.9
7	53.1	66.7	43.6	59.0
8	54.7	69.8	44.6	59.6
9	53.8	64.3	45.3	59.6
10	52.8	66.3	45.7	60.1

	Yield (42 ksi min)	UTS (60 ksi min)	Grade (Yield & UTS)
Digs to Verify	6 digs	10 digs	10 digs

Sampling for Grade Verification

Alternative Sampling Plan Steps

1. Define population
2. Acquire Data
3. Calculate Uncertainty
4. Compare to Expected Grade

Data analysis using 100 populations

Tolerance Interval Probability	Required Digs		
	+/- 3 ksi	+/- 4 ksi	+/- 5 ksi
70%	4.5	6.0	10.0
80%	6.5	10.0	22.0
90%	10.5	27.0	150
95%	20.5	113.5	150

Findings:

- Less accurate methods require more digs
- Tolerance Interval can be overly conservative

Key Takeaways

- Complete material verification is required in new regulations and referenced throughout.
  - NDE is a viable route
- The timeline is closer than it appears, the best approach is to start quickly and take advantage of opportunistic testing.
- Statistical approaches provide the cleanest path to TVC and full compliance, minimizing verification digs.
- Tolerance of verification tools has a large impact.

Thank You