Composite Structure Engineering Safety Awareness Course

“Real Life” Data Analysis and Problems

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“Real Life” Data Analysis and Problems

AGENDA

- Data problems
- Data on more batches
- Material specification limits
- Data does not meet specification limits
- Reduced testing
- Re-qualification

Data Problems

- When the data appears perfect, be very suspicious
- Look at the actual test specimens
  - Failure modes, layup, machining
  - Separate data by failure modes
- Report must include all measured data
  - Width, thickness, load, load-strain curves, etc
- DO NOT accept data files with stress/modulus values only
  - Data files must contain the calculations (formulas) using measured data

Data Problems

- High variation (CoV)
  - If due to high scatter with no batch variation, look at specimen preparation and test methods
  - If have batch variation, review material and panel fabrication process
  - When setting spec limits
    - Reduce the CoV to avoid low requirements and lack of control
    - Test additional batches and reset spec limits
  - Allowables
    - Test additional specimens and/or batches

Data Problems

- Batch variability
  - Fiber / prepreg variations
  - Resin content, areal weight variations
    - Review batch cert data, panel thickneses
  - Panel cure variations
  - Testing variations
    - Not likely but could occur if different labs, operators, machines used for different batches
  - Don’t blindly believe the “statistics”!
    - Plot the data

Data Problems

- Batch variability
  - Qualification data
    - Compare supplier to purchaser test data
    - Reject qualification batches
    - Test more batches
    - Do not set low spec limits to cover variability
  - Allowables data
    - Need minimum of 5 batches for ANOVA basis values (per CMH-17)
    - Test more batches, or
    - Reject the material qualification for lack of control

Data Problems

- Outliers
  - Use STAT17 analysis to detect
  - Compare values to expected results
  - Check failure modes carefully
  - Discard only for an assignable cause
    - Known testing error or deviation
    - Known error or deviation in the material that would be rejected by the applicable process spec
    - Clearly separate failure mode – but this requires that allowables be developed for each mode
    - Otherwise low values are hard to exclude
  - High outliers can be excluded if value is clearly outside of the expected range
    - Modulus values sometimes, rare for strength values

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When is Data on More Batches Needed?

- Suspected batch to batch variability
- Qual batch material process or raw materials are not representative of production material
- Anomalous failure modes
- Cure problems (porosity, Tg variation, etc)
- Too many batches failing material batch certification/acceptance tests
- Need higher design allowables
  - But there is no guarantee!

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Material Specification Limits

- Intended to “control” material and catch “bad” batches
- Not intended to “allow all material to pass”
- High CoV’s – reduce CoV in calculations
- Low CoV’s – increase (carefully) CoV to avoid excessive rejections
  - See CMH-17 guidelines
- Reset specification limits for batch tests after:
  - a) ~ 10 batches, b) ~ 30 batches, c) Re-Qual

Material Specification Limits

- Cured ply thickness, resin content, areal weight, Tg, etc
  - Max and min average values
- Volatile content, void content, etc
  - Max average values
- Modulus
  - Max and min average values
- Strength
  - Lower limits on average and individual
  - Should have upper limits (see previous presentation)
  - Use SPC controls on batch test data in lieu of hard upper spec limit

Material Specification Limits

- Use CMH-17, Volume 1, Chapter 8 equations
  - For strength properties:

$$\text{MinAverage} = \bar{x} - k_n^{\text{Mean}} S$$

$$\text{MinIndividual} = \bar{x} - k_n^{\text{Indv}} S$$

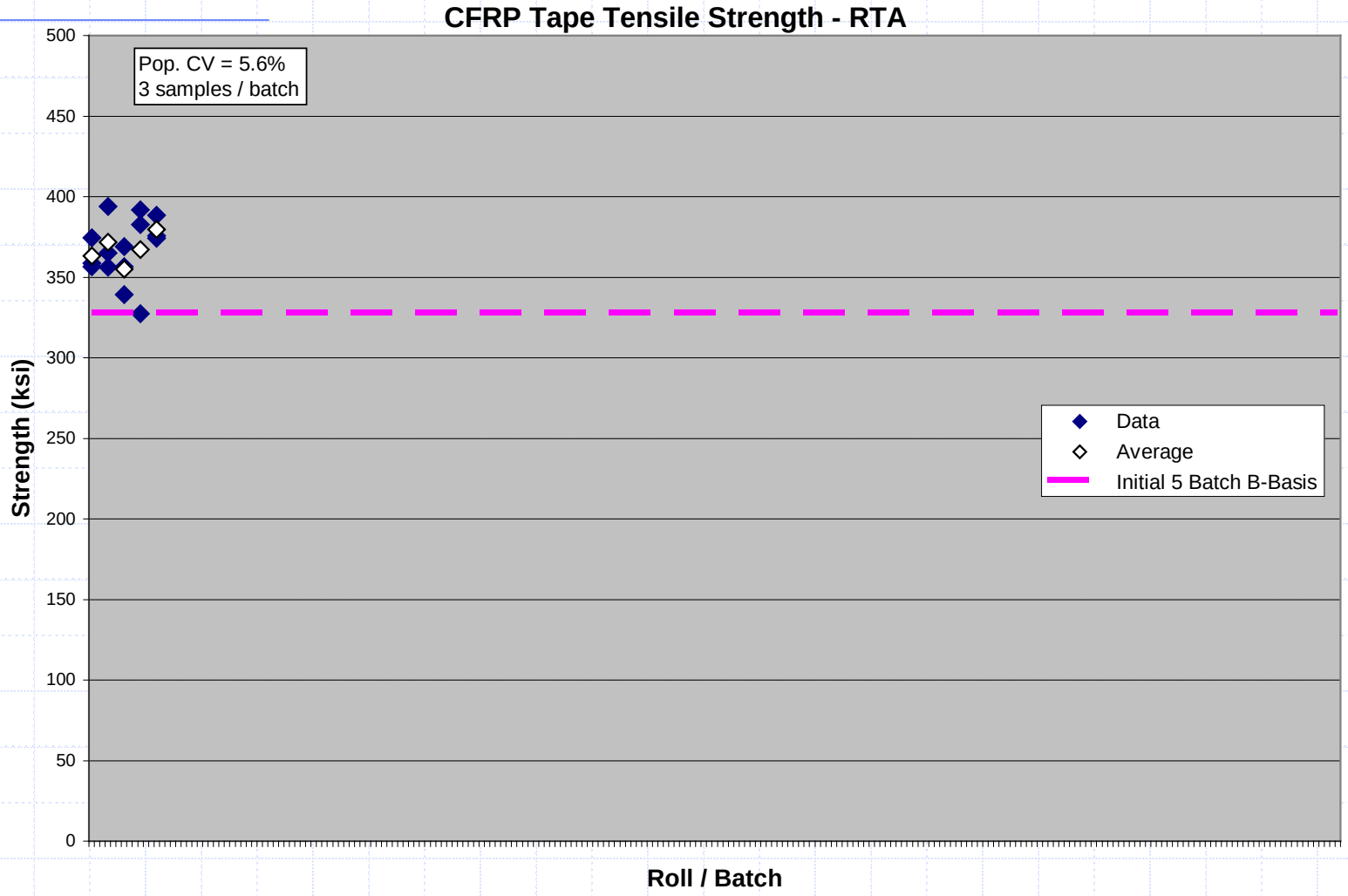
  - Where k_n is a function of:
    - Number of test replicates in roll/batch sample
    - Probability of rejecting "good" material, α
      - For specification limits use α = 0.01 with provision for retests

Material Specification Limits

- The following slides illustrate
  - Using actual tension data for a typical CFRP prepreg material
  - Relationship between specification limits and basis values
  - Sample versus population basis values
  - Specification limits set using CMH-17 equations versus process capability Cpk

$$C_{pk} = \frac{\overline{X} - LSL}{3\sigma}$$

Example Data



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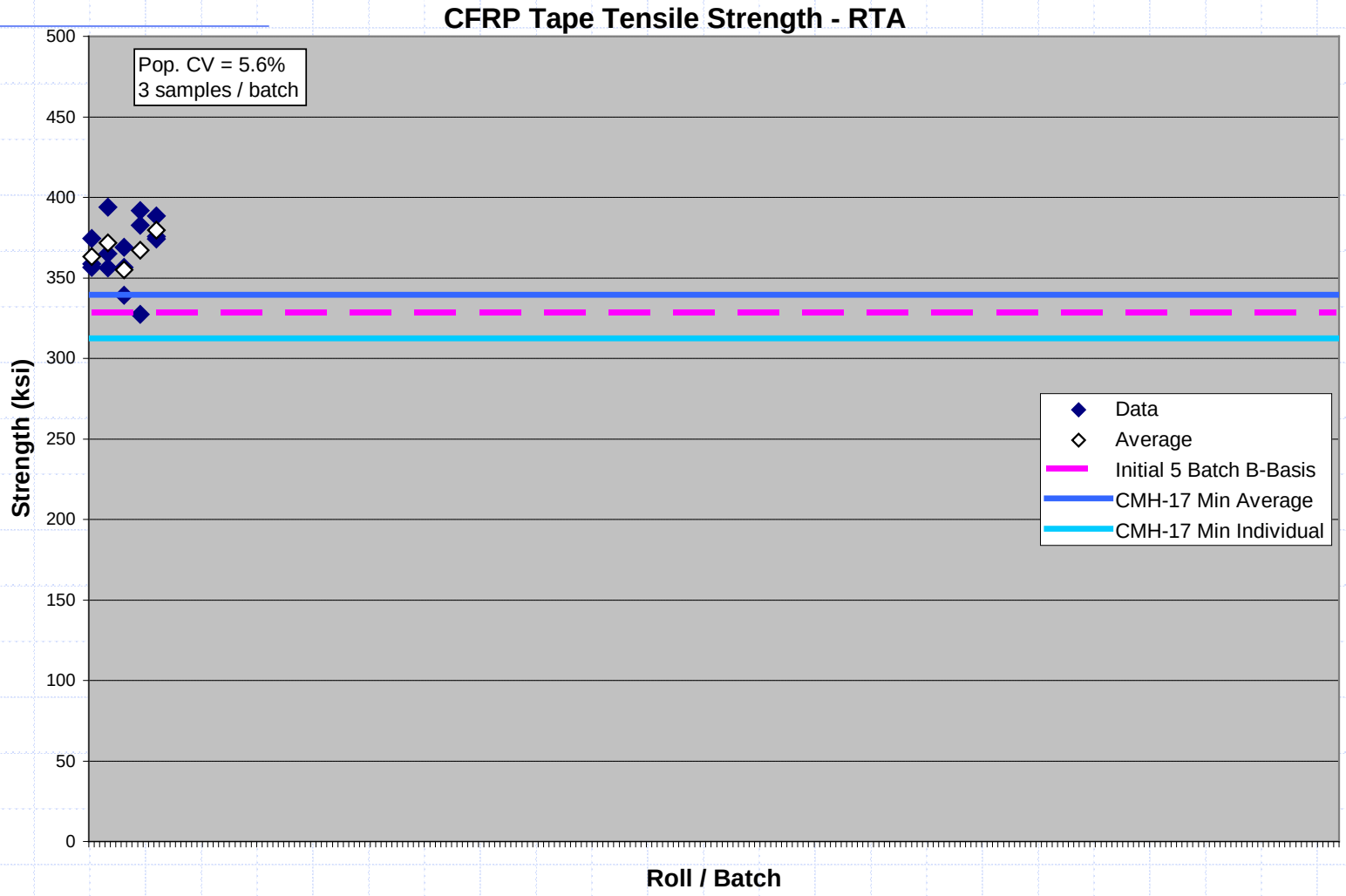

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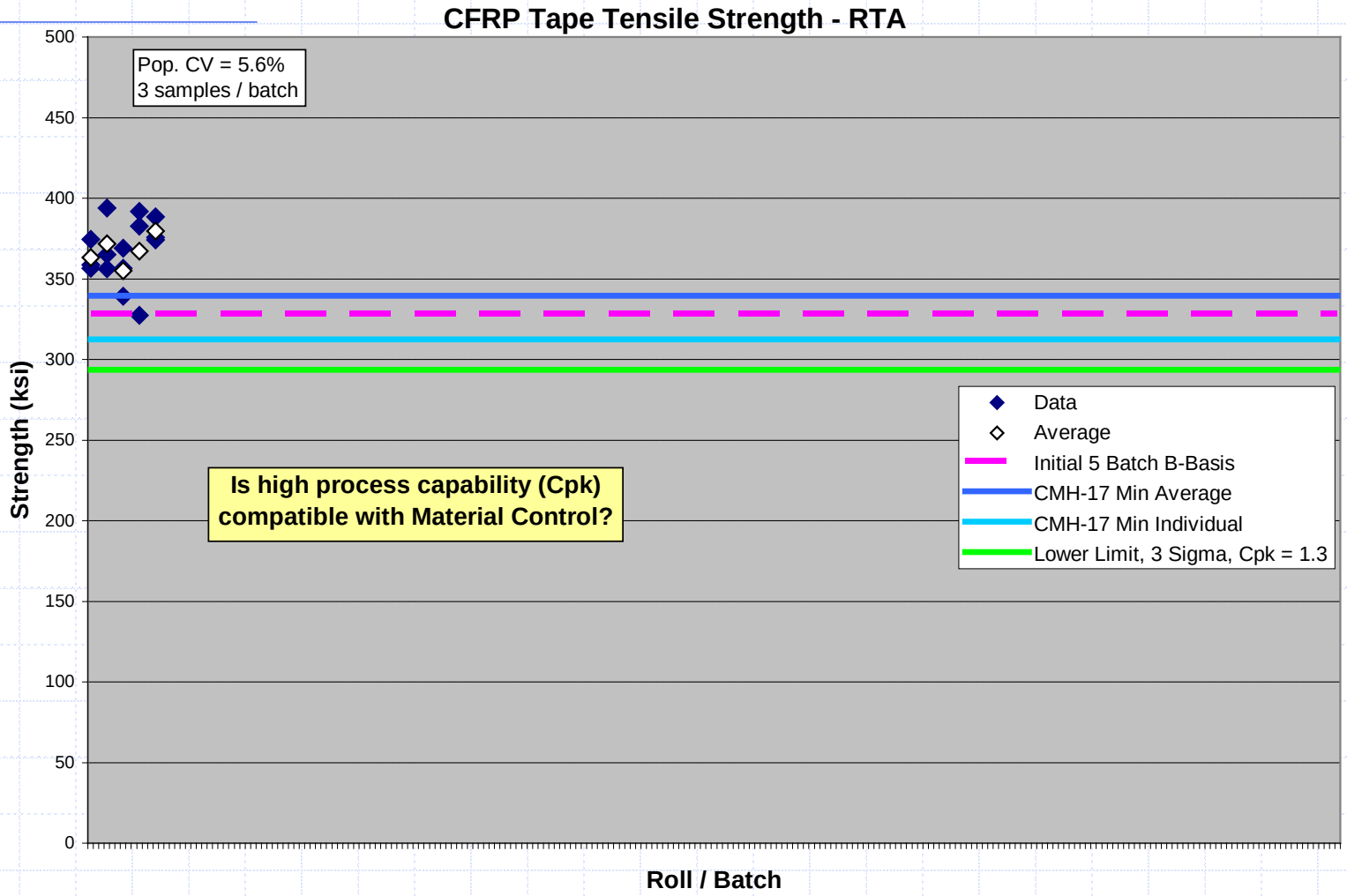

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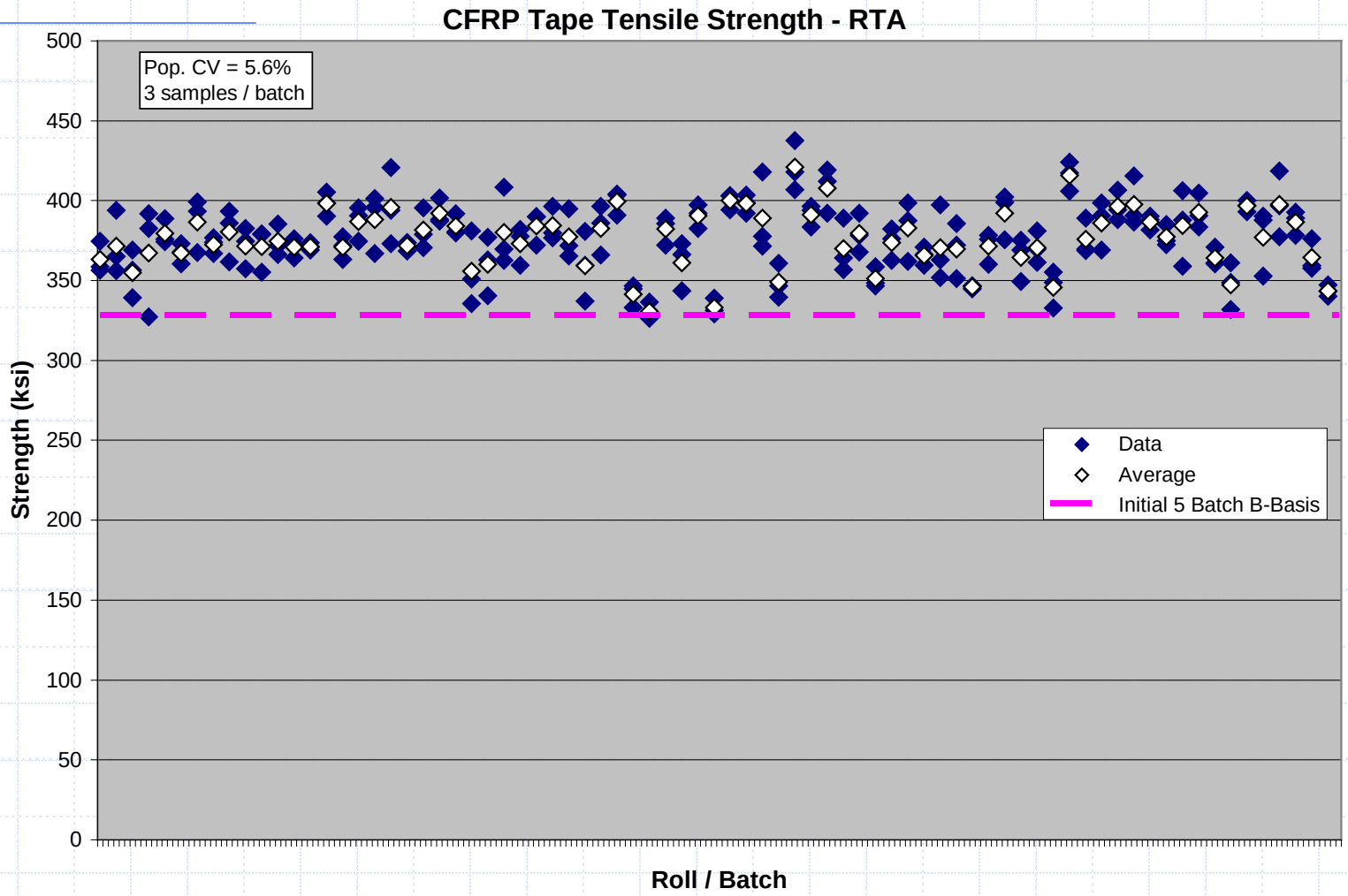

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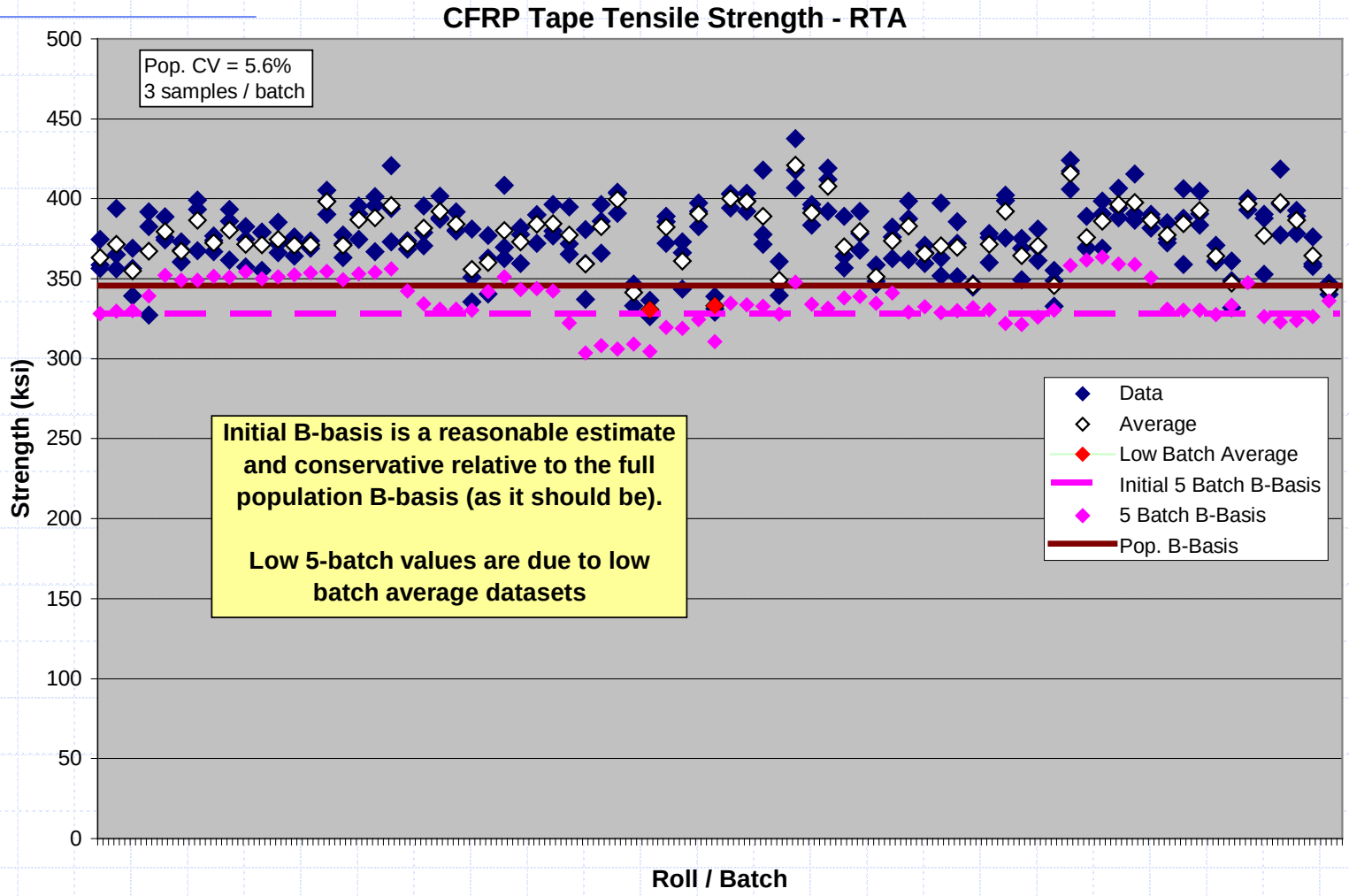

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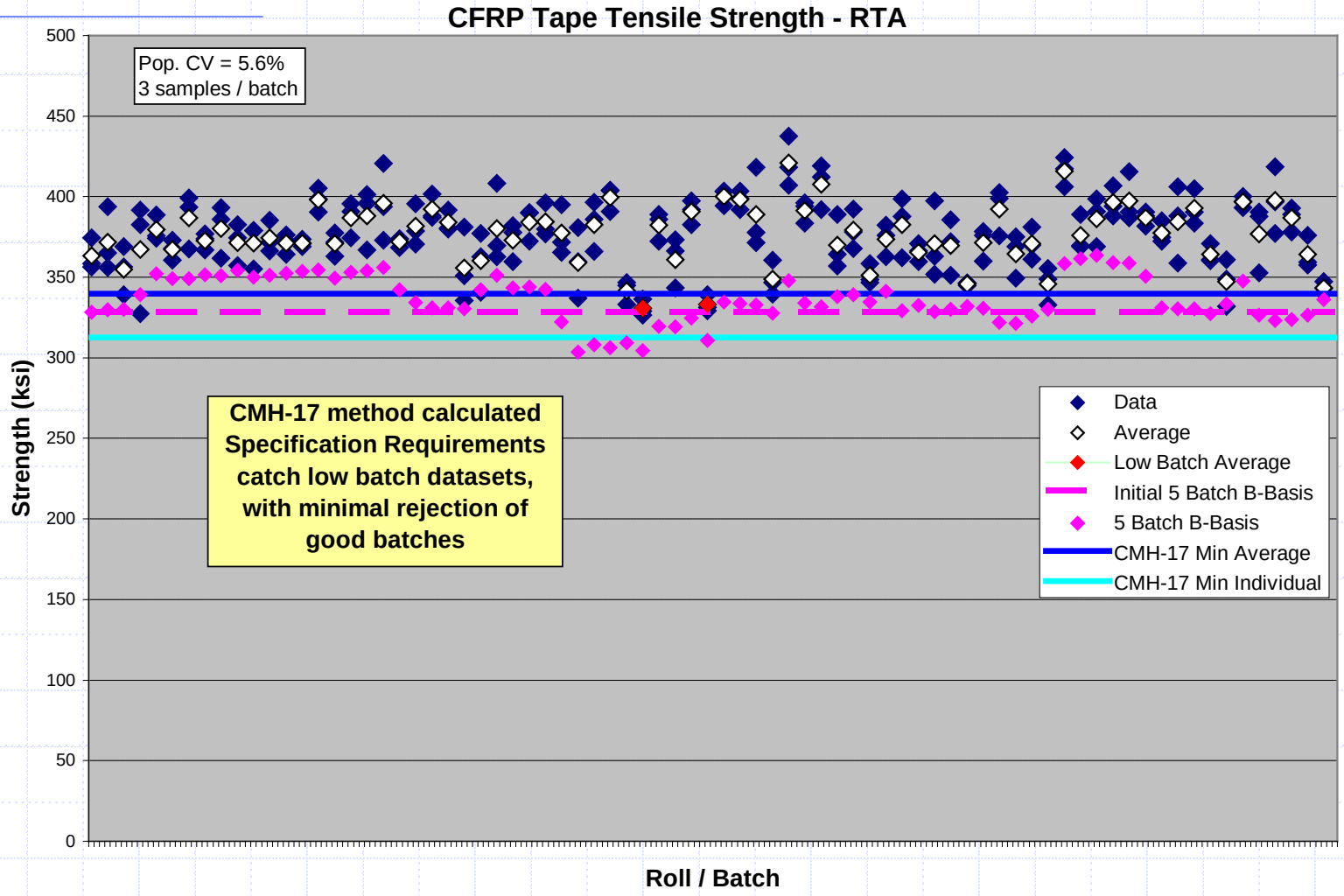

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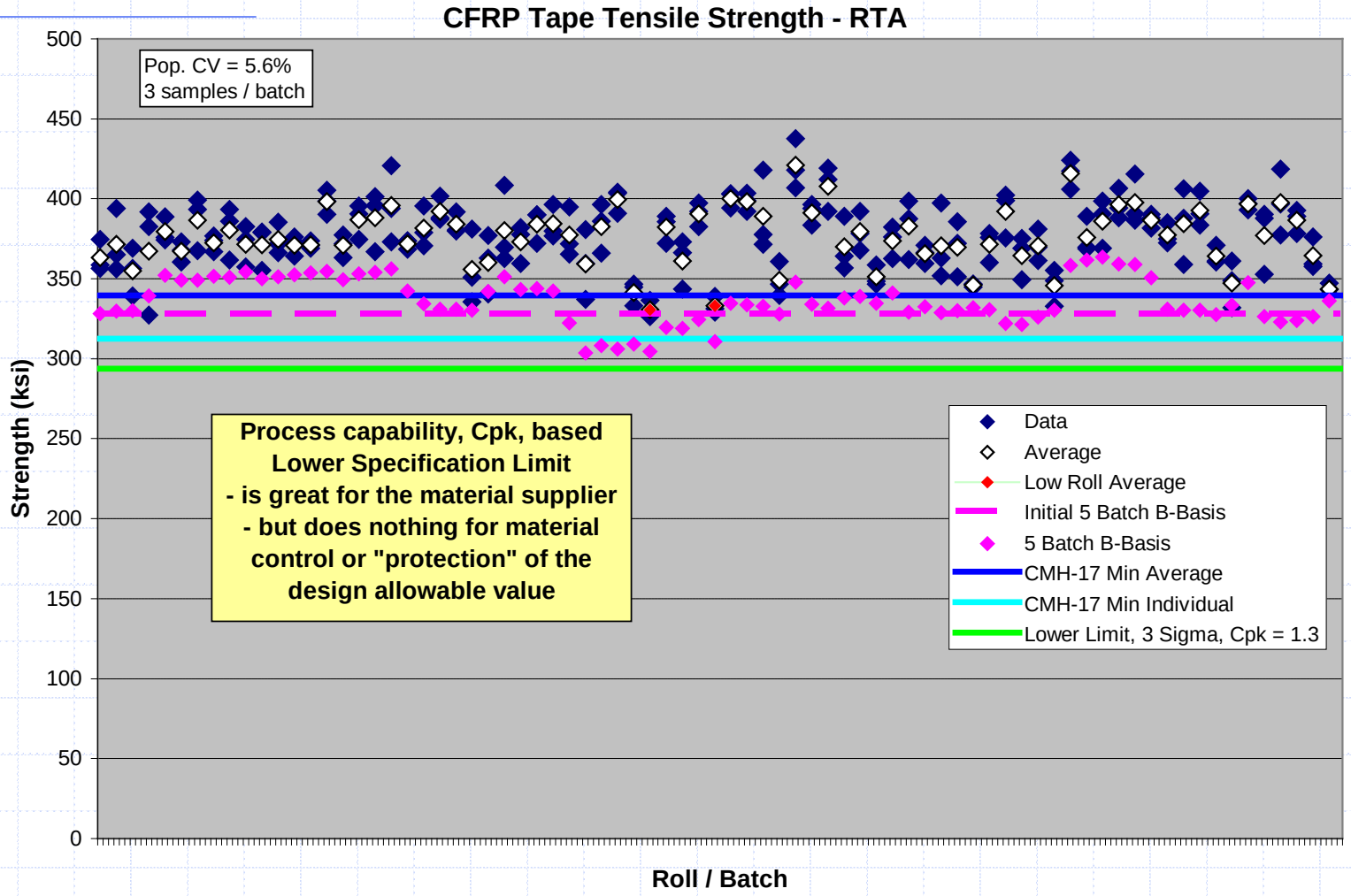

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Specification Limit Not Met

- Case of batch certification or acceptance test value not meeting specification limit
- Examine specimen
  - Failure mode, specimen quality, layup/cure process
  - Testing problem
    - Misalignment, grip slippage/damage
- Avoid by
  - Using robust, well documented test methods
  - Not testing at inappropriate (e.g., wet) conditions

Specification Limit Not Met

- Retest more specimens
  - Only for low/high average value
  - Typically 2X number of original replicates
  - Add data to original set
  - Do not discard original data except for assignable cause unrelated to material
- Test other rolls within the same batch
- Conduct testing “round-robin” program between supplier and purchaser

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Purchaser Skip Lot Reduced Testing

- Depends on application and certifying agency
- Some general guidelines
  - 3+ years full material production
  - 3+ years full part production and purchaser testing
  - Material under SPC control for all production parameters and tested properties
  - No batch certification/acceptance failures
  - No part fabrication issues related to material
  - Supplier and purchaser test results equivalent

Source Acceptance – No Purchaser Testing

- See guidelines on previous slide for Purchaser Skip Lot Testing
- May not be appropriate for primary structure applications
- See also AC 21-26

Supplier Skip Lot Reduced Testing

- See guidelines on previous slide for Purchaser Skip Lot Testing
- May only be appropriate for certain tertiary / secondary structure applications
- Requires use of SPC to monitor:
  - Prepregging process (KPPs)
  - Material properties (KCs)
- Some tests may be skipped if correlation can be shown to other tests
- Generally not appropriate to skip all tests for a batch
- Sampling plans for rolls within a batch/lot are often used

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Re-Qualification

- CMH-17 Rev G Volume 1 Chapter 2 guidance is not appropriate for primary structure material
- Material change levels per DOT/FAA/AR-02/109

0	No effect on material	No notification of end users or FAA is required
1	Minor change evaluated at supplier	Current end users are notified, but approval by end user and FAA not required
2	Partial equivalency test program	Notify current end users and obtain FAA approval
3	Full equivalency test program	Full equivalency testing and FAA approval
4	Full qualification test program	New product specification

Re-Qualification

- Level 0 (Minor Change)
  - Change in ingredient name, company name, correction of typos
- Level 1 (Minor Change)
  - Change in release paper, changes to packaging materials
  - Alt vendor for chemically and physically identical raw materials
- Level 2 (Major Change)
  - Change in resin ingredient supplier, change in resin ingredient precursor, modifications of process equipment, addition of new similar equipment.
  - New source for chemically and physically similar raw materials

Re-Qualification

- Level 3 (Major Change)
  - Change in fiber manufacturing process, fiber size or finish
  - Change in resin chemistry, viscosity of resin components
  - Change in resin mixing, filming and prepregging equipment, change in resin or fiber manufacturing site.
  - Change in cure cycle
- Level 4 (Major Change)
  - Change in fiber type, areal weight, tow count, manufacturer
  - Change in fabric weave
  - Change in resin formulation, large change in resin content

Questions?