Evaluation of IDEAL-CT Testing Equipment

Nathan Moore, NCAT

National Center for Asphalt Technology
NCAT
at AUBURN UNIVERSITY

IDEAL-CT Question - Equipment

- Can I run the IDEAL-CT on my current Marshall/load press?
- Different types of devices:
  - Screw-drive -> Pine, Humboldt, Instrotek, Karol Warner, etc.
  - Servo-hydraulic -> TestQuip, MTS, etc.
  - Data acquisition -> Smart-Jig
- Do these devices give the same results?

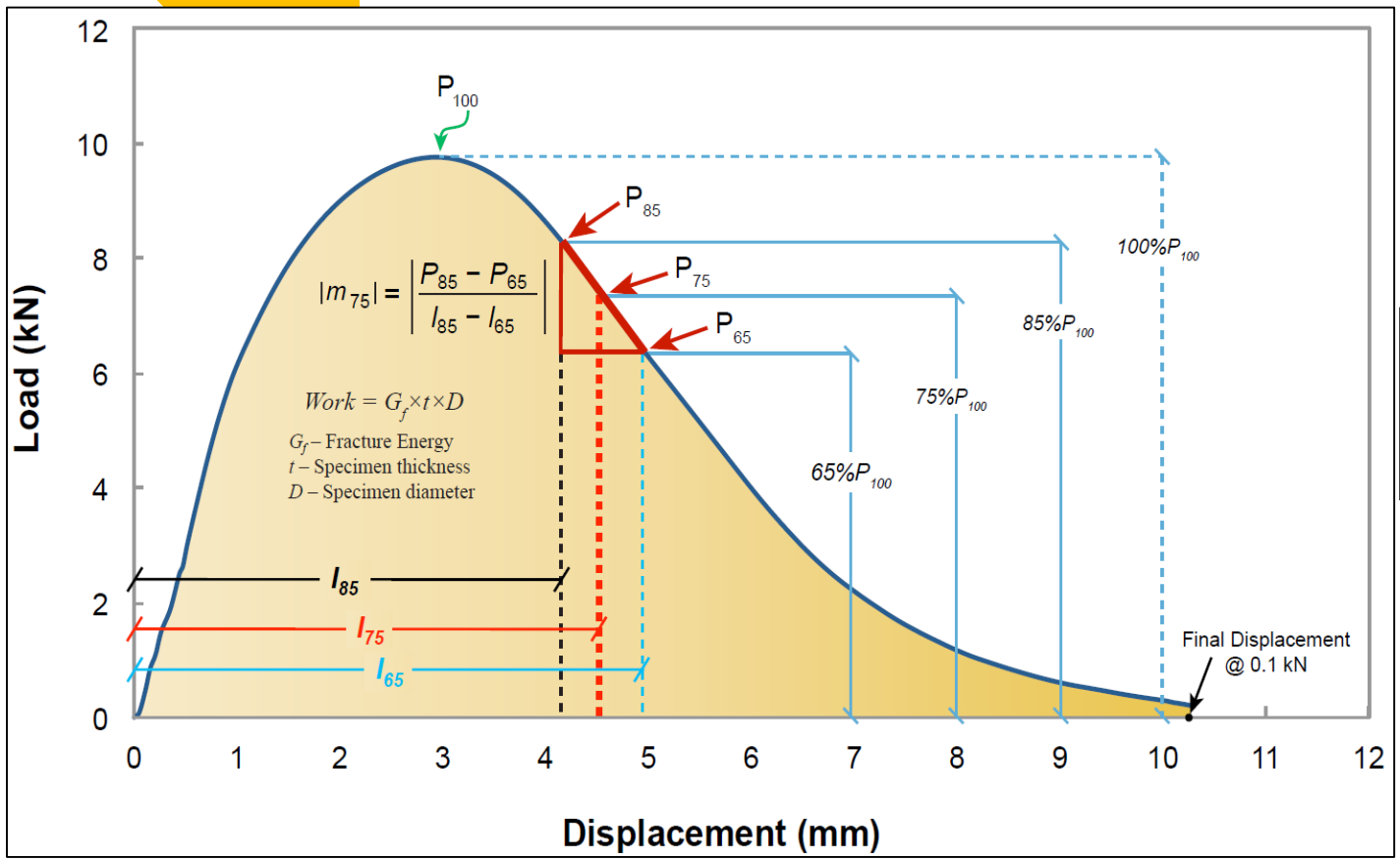
Objectives & Questions

1. Does a given device meet the current ASTM specification?
2. Do different devices produce the same results?
3. Are the any trends regarding equipment comparisons?
4. How should we move forward with this test given the variety of loading devices?

Current Work

- Three mixes from 2018 Test Track
  - Low CT-Index – Volumetric design, 100 gyr, 76-22
  - Medium CT-Index – BMD, 70-28
  - High CT-Index – BMD, 70-22
- Reheated PMLC specimens (split samples)
  - 62 mm height
  - 7.0 ± 0.5% air voids (Group averages between 6.8 and 7.1% Va)
- Group A – Test Quip
- Group B – Pine Press (digital recorder)
  - InstroTek Smart-Jig used as jig

IDEAL-CT Overview



$$CT_{index} = \frac{t}{62} \times \frac{G_f}{|m_{75}|} \times \frac{l_{75}}{D} \times 10^6$$

(Zhou et al., 2017)

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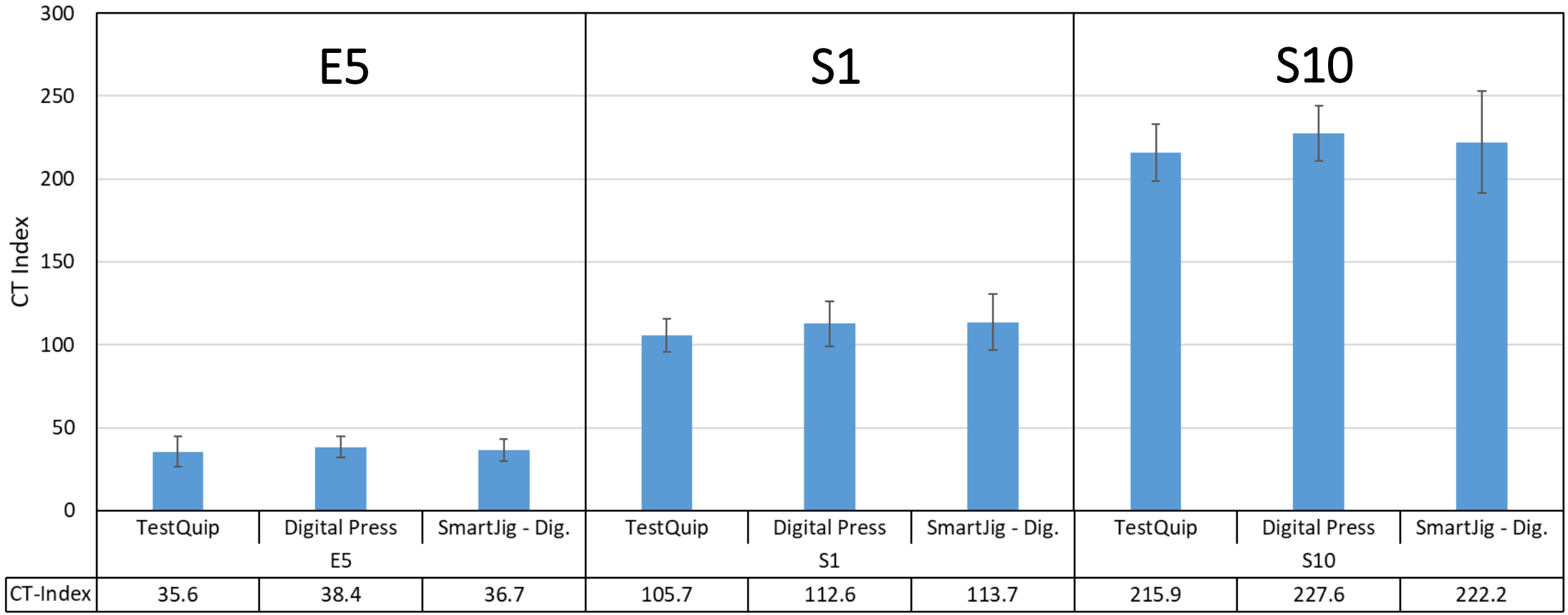
Lab Testing Results



	E5			S1			S10		
	TestQuip	Digital Press	SmartJig - Dig.	TestQuip	Digital Press	SmartJig - Dig.	TestQuip	Digital Press	SmartJig - Dig.
CT-Index	35.6	38.4	36.7	105.7	112.6	113.7	215.9	227.6	222.2

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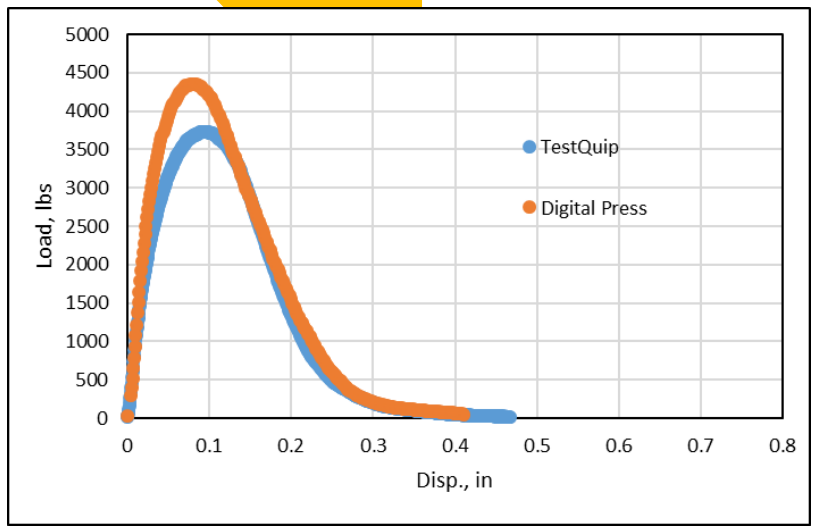
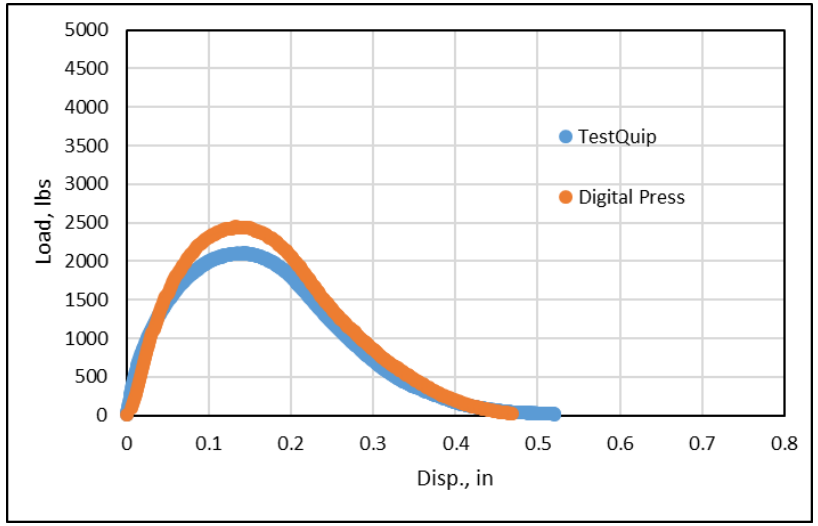
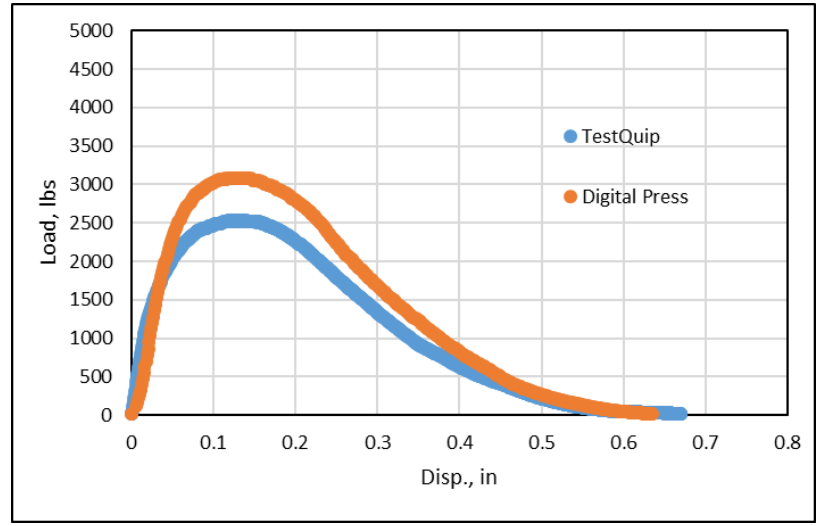
Comparison of Load Curves



E5



S1



S10

TestQuip

Digital Press

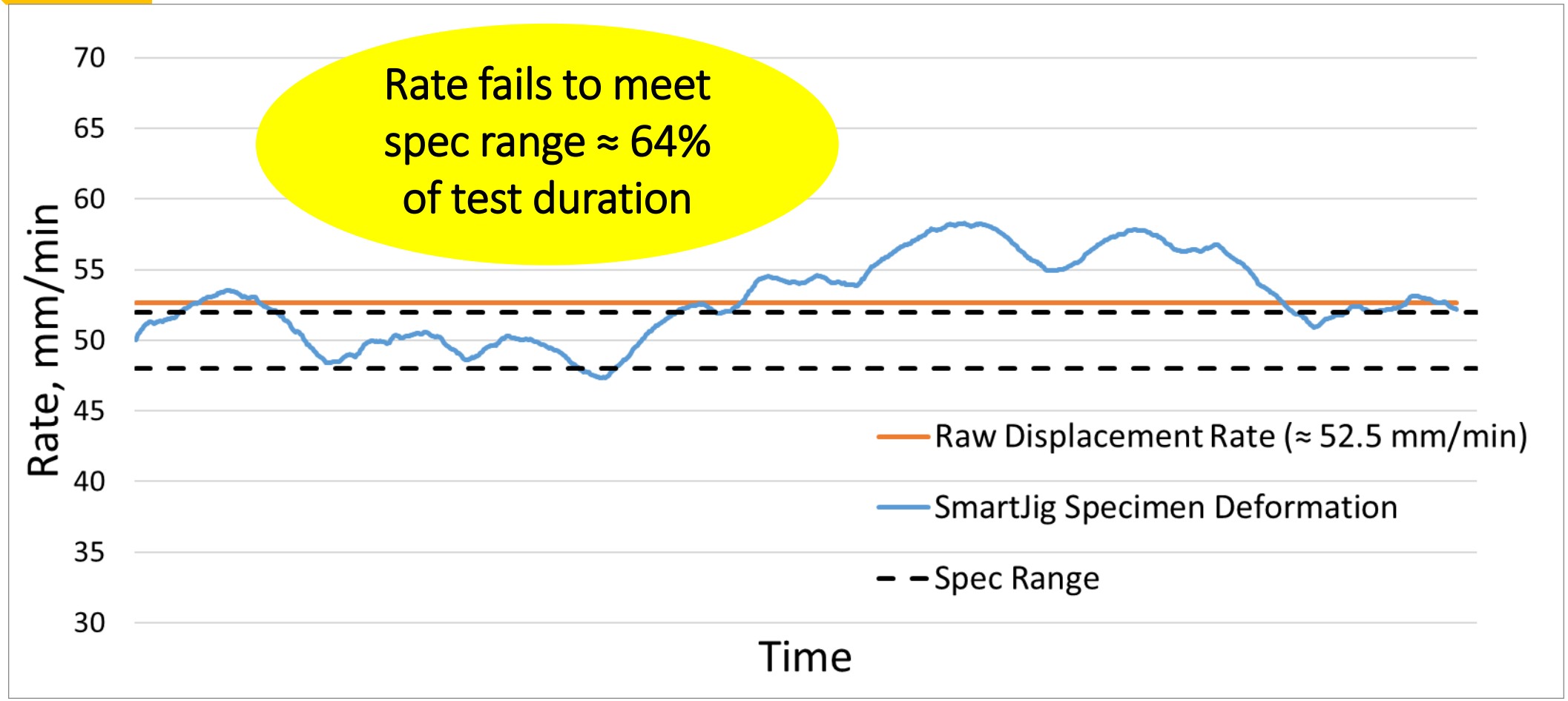
Summary

- In all 3 datasets Peak load, Fracture energy, and CT-Index is higher on digital press than on TestQuip device.

Mix	Peak Load	Fracture Energy	CT-Index
E5	8.1%	6.3%	7.8%
S1	4.3%	3.3%	6.6%
S10	7.2%	9.4%	5.4%

- Average CT-Index not ***statistically*** different but it is ***consistently*** different!
- May not represent every Pine Press or TestQuip device

Displacement vs. Deformation Rate



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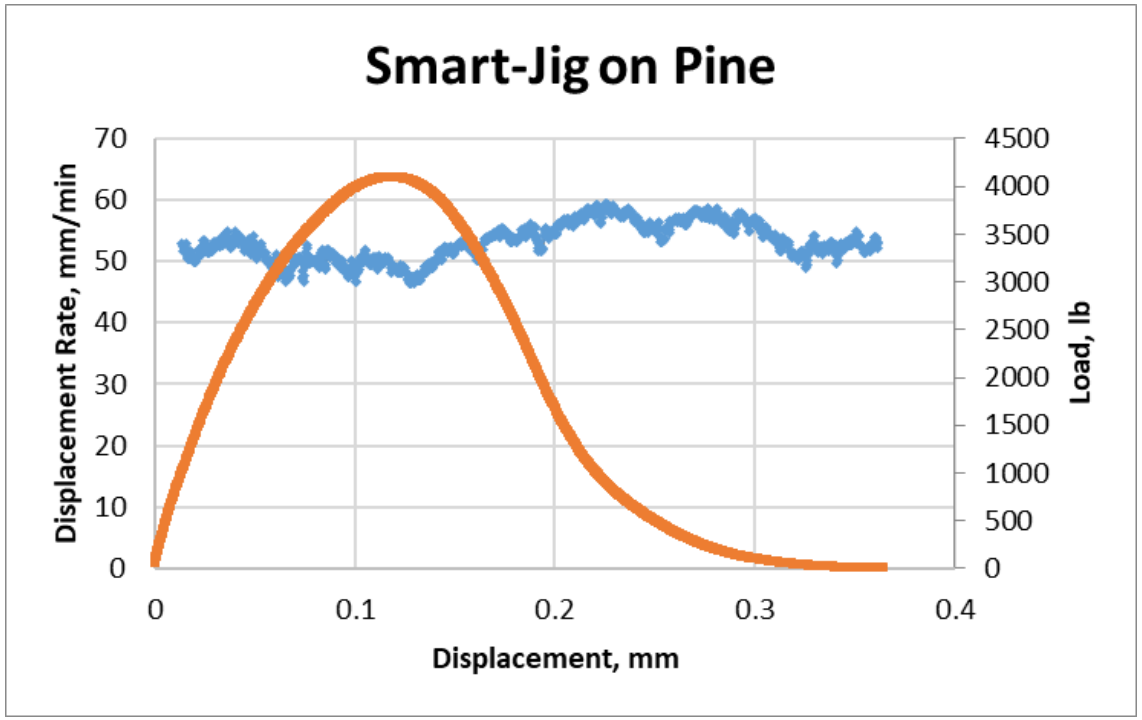
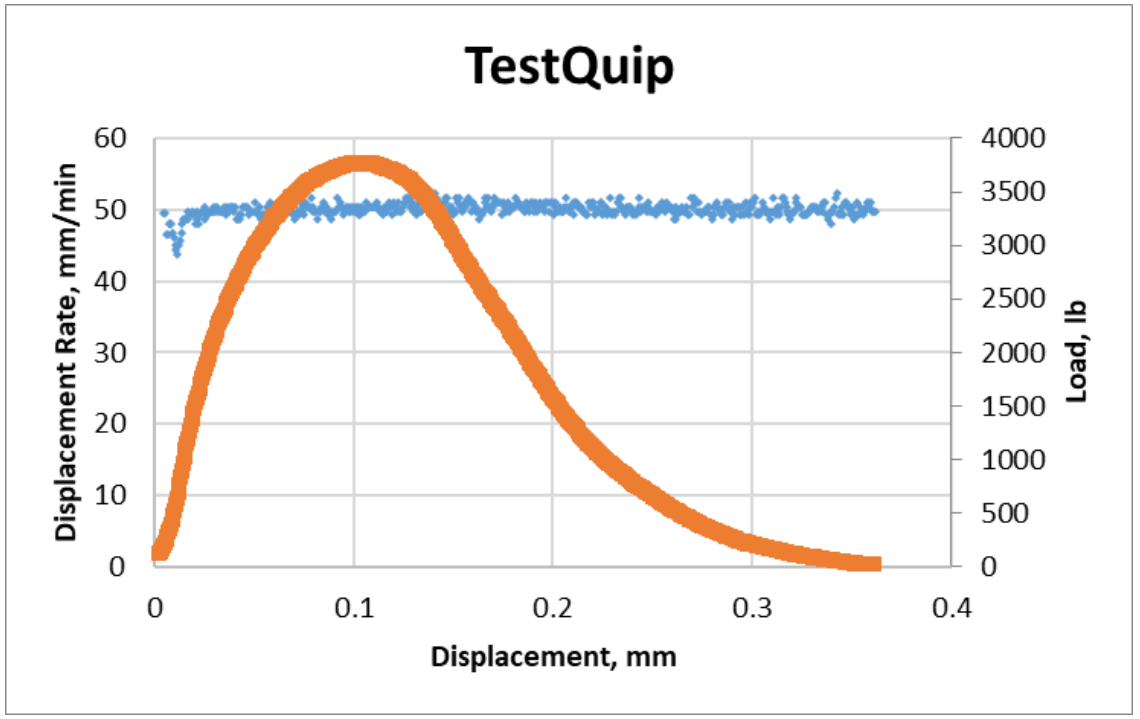
Curve Comparisons
E5





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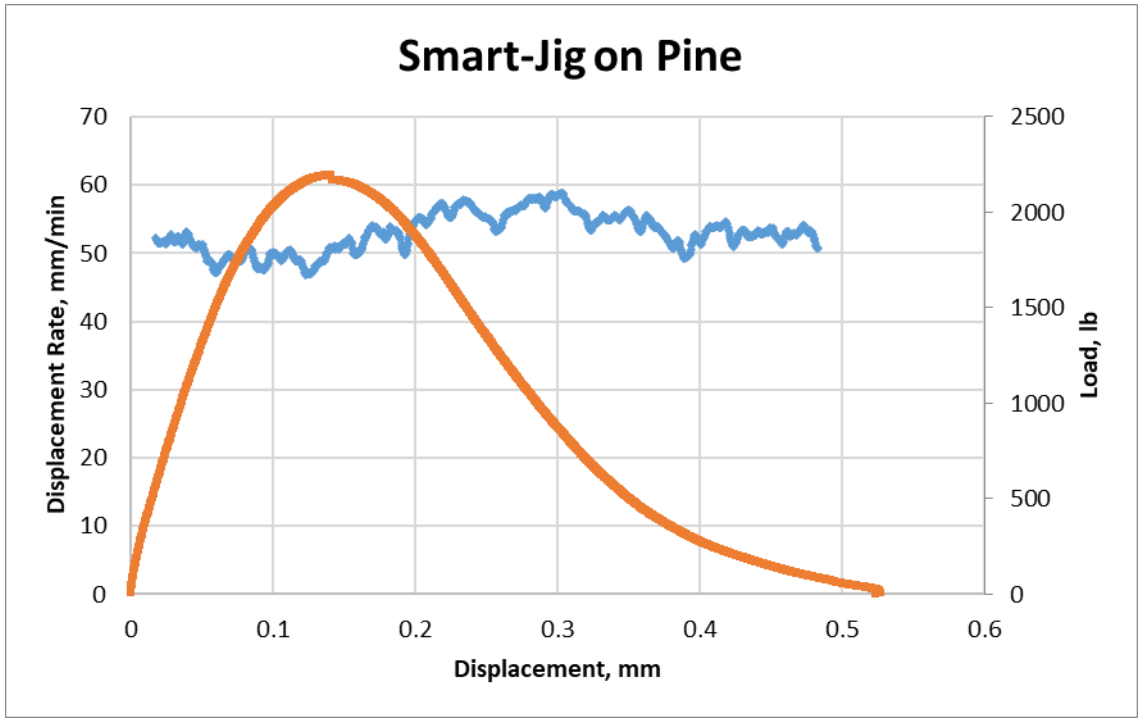
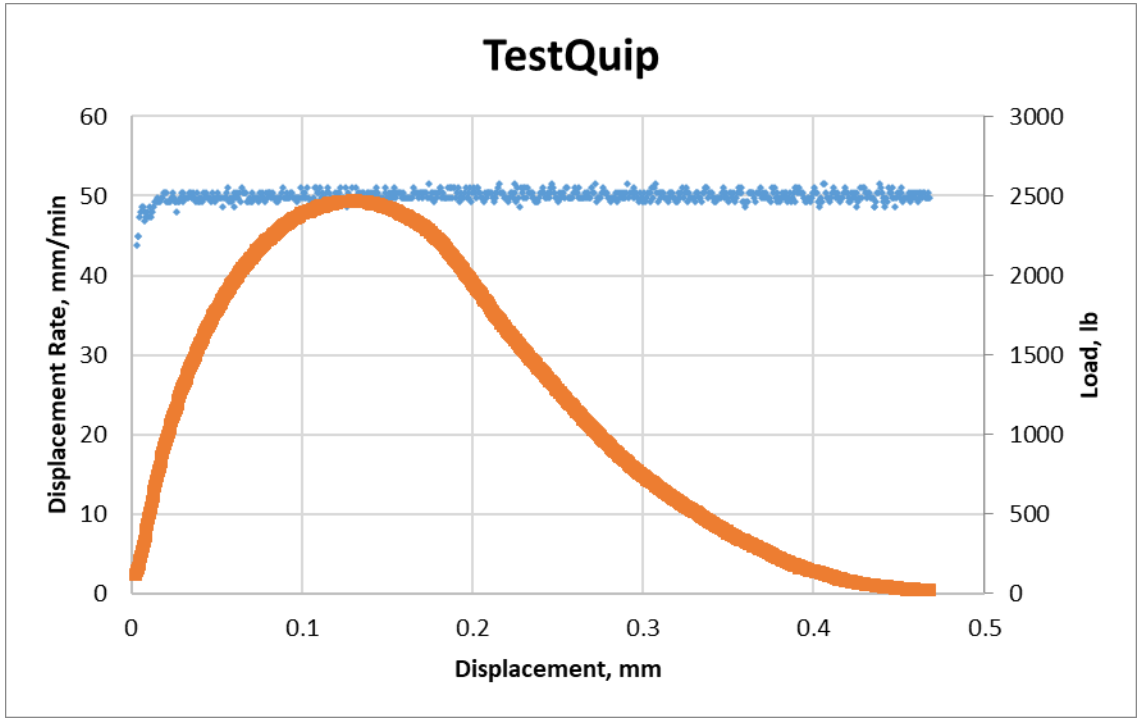
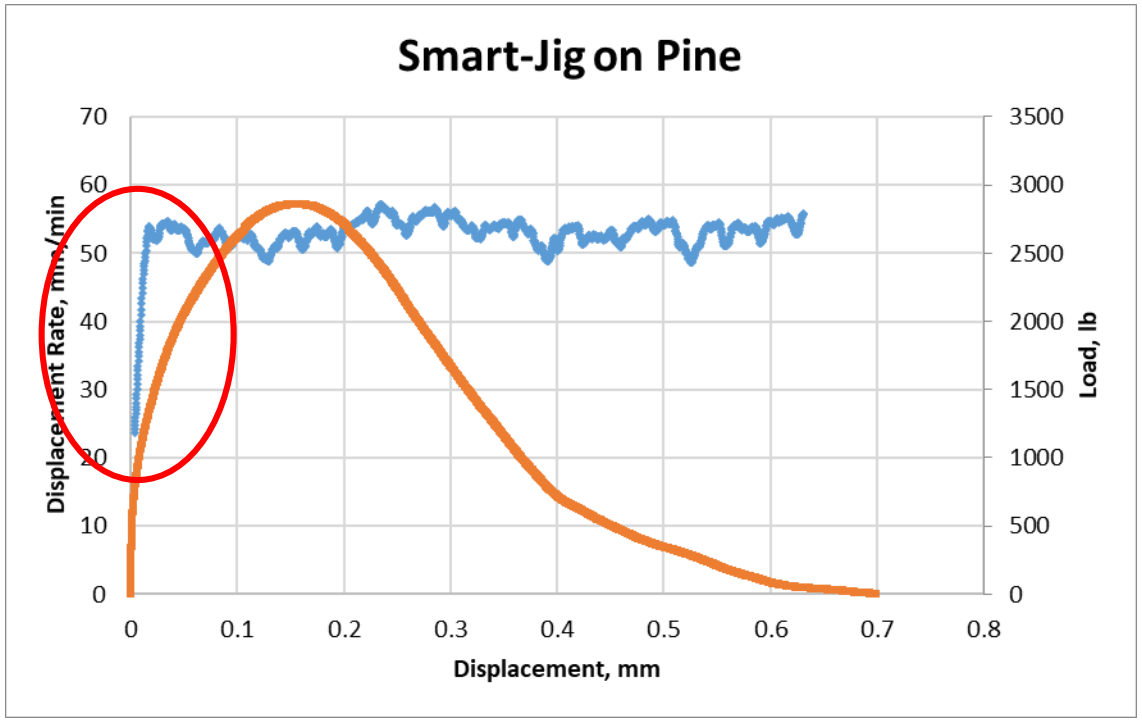
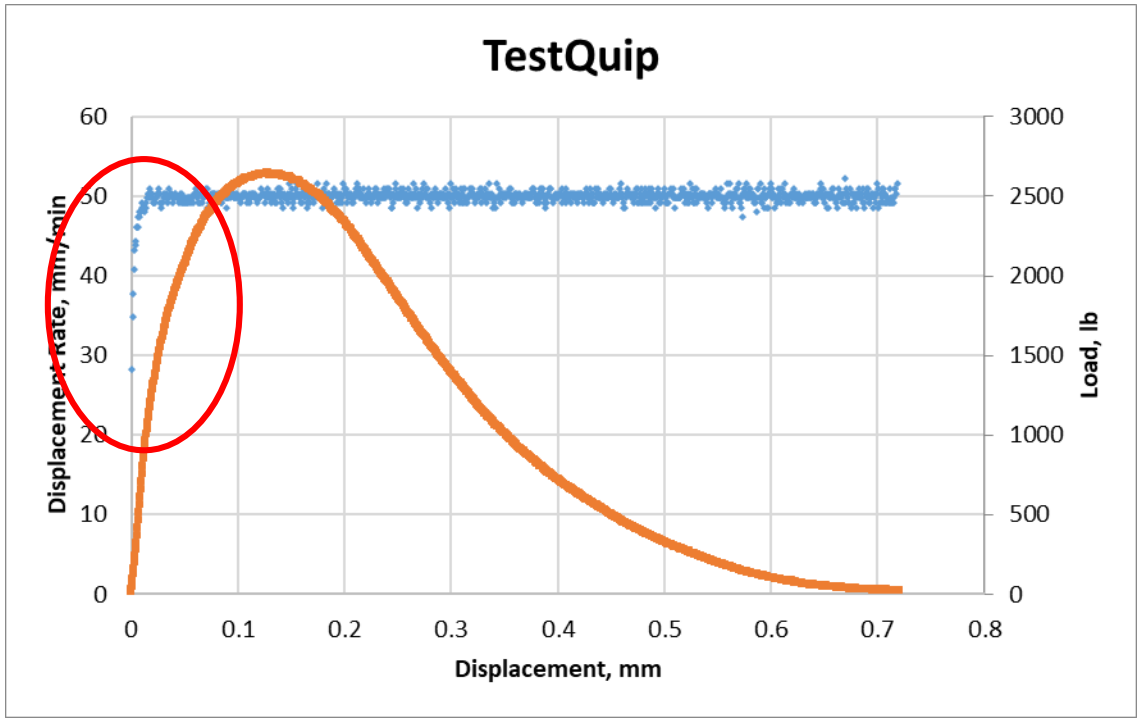
Curve Comparisons
S1





Curve Comparisons
S10



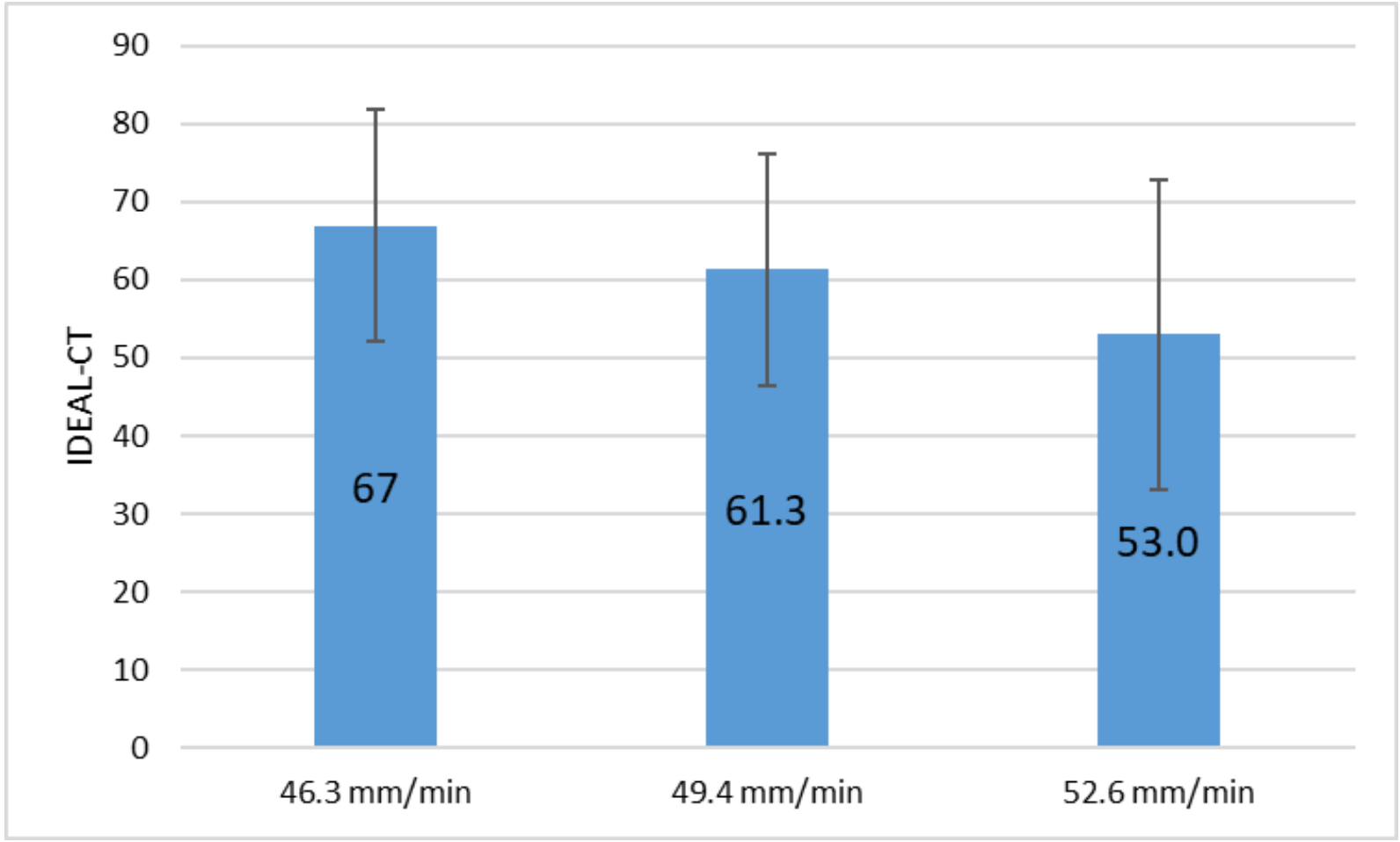


Displacement vs. Deformation Rate

- Current spec requires 50 ± 2 mm/min of *deformation*
  - Deformation ≠ Displacement
  - This often requires a closed-loop feedback system
- A single speed screw-driven device may be used *"if it can maintain the constant deformation rate." (ASTM D8225)*
- Need to verify that the screw-driven machines can meet the specification

Does rate matter…? YES!!!!

- Pine device
- Medium rate available with sprocket change
- Clear trend in the load curve slopes too



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Future Testing

- Four devices:

Manufacturer	Device	Type
Pine Test Equipment	850T Test Press	Screw-Drive
Instrotek Inc.	Auto-SCB	Screw-Drive
Humboldt	HM-5125	Screw-Drive
Troxler (formerly Test Quip)	IDEAL Plus	Servo-Hydraulic

- Six mixes:

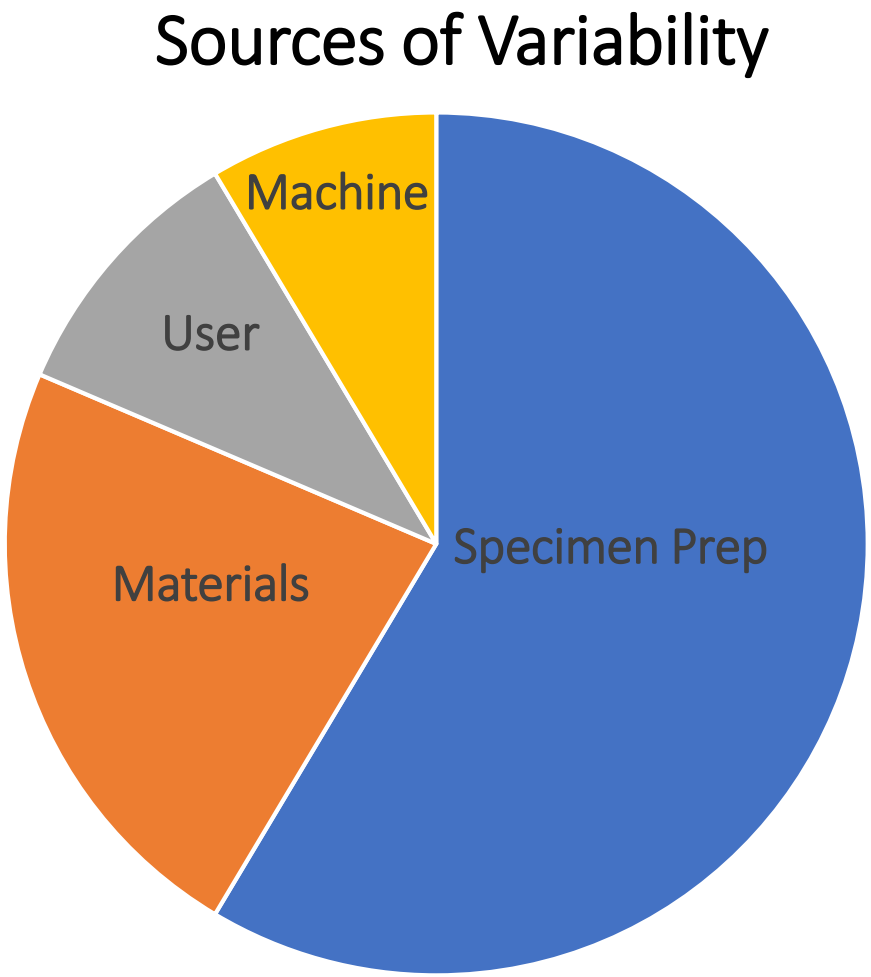
CT-Index Range	No. of Mixes
0 to 25	1 mix
25 to 50	1 – 2 mixes
50 to 100	1 – 2 mixes
>100	1 – 2 mixes

Future Testing

- Evaluate machine-to-machine differences
- If no differences occur…
  - *"Much ado about nothing"*
- If differences do exist…
  - Identify potential causes
  - Make recommendations to manufacturers
  - Propose a framework for state-specific comparison testing

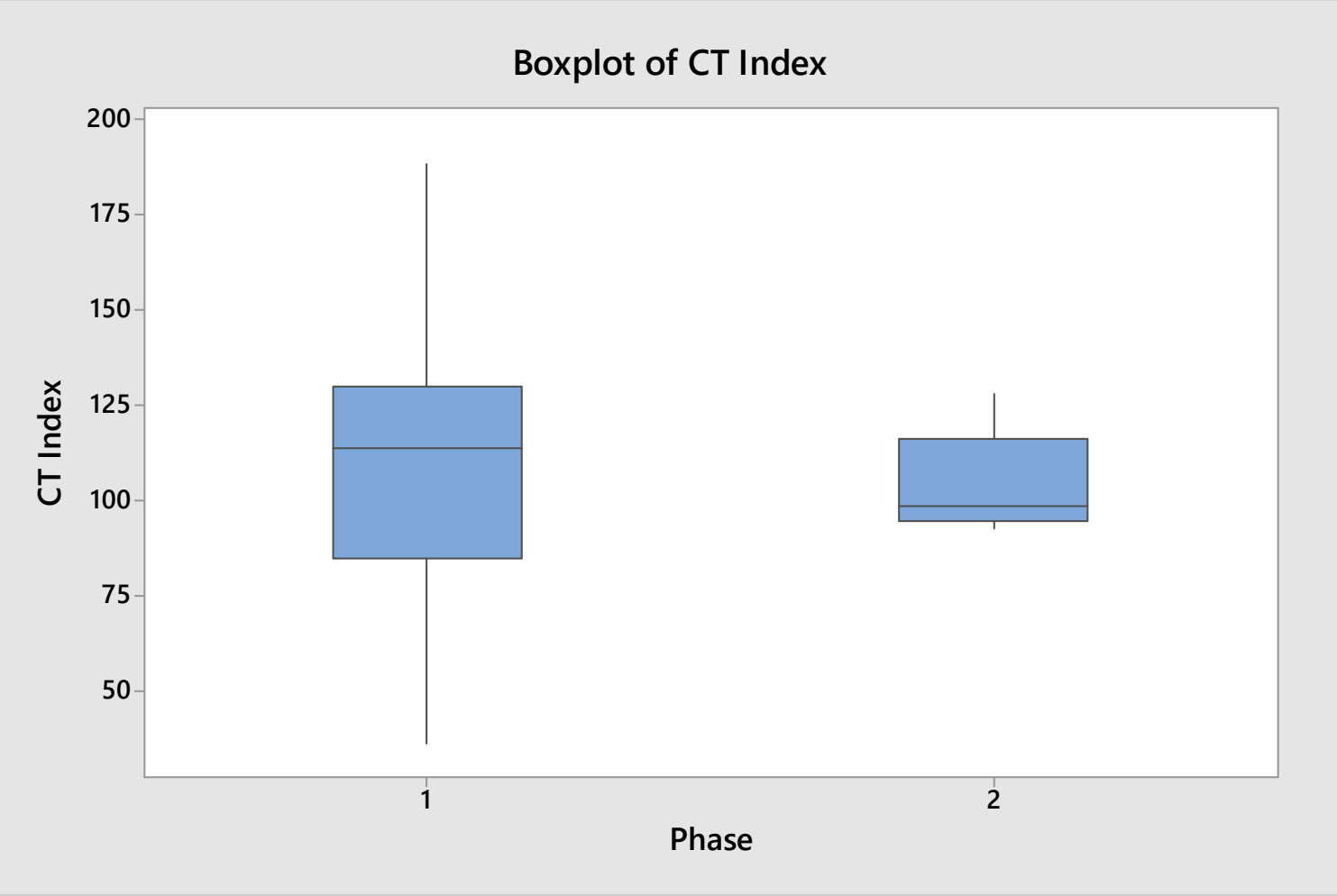
Why even do this?

- There are numerous sources of potential variability or bias
- We know how to minimize other sources:
  - Specimens prep – Proper sampling, avoid segregation, consistency, etc.
  - Users – Training, attention to detail, etc.
- We should investigate every known source of variability



For illustrative purposes only.
Not real data.

NCAT Round Robin Phase I & II



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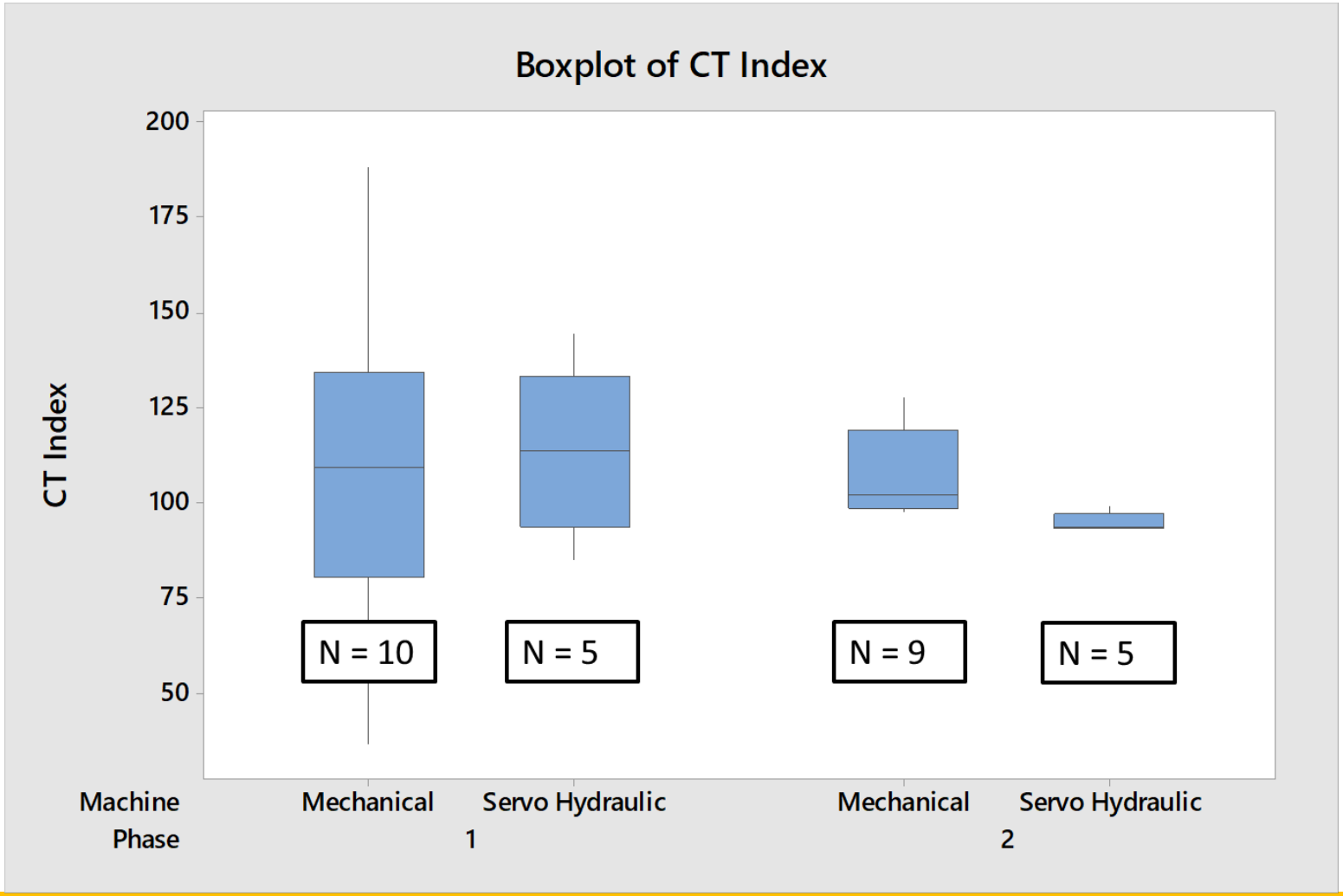
NCAT Round Robin Phase I & II

- ASTM E691-19 Precision Estimates
- Almost identical within-lab variation for Phase I and Phase II
- Significant drop in between-lab CV for Phase II versus Phase I
  - Effect of Sample Fabrication

Phase	Within-Lab CV (%)	Between-Lab CV (%)
I	19.5	35.2
II	18.7	20.1

IDEAL-CT Machine Effects



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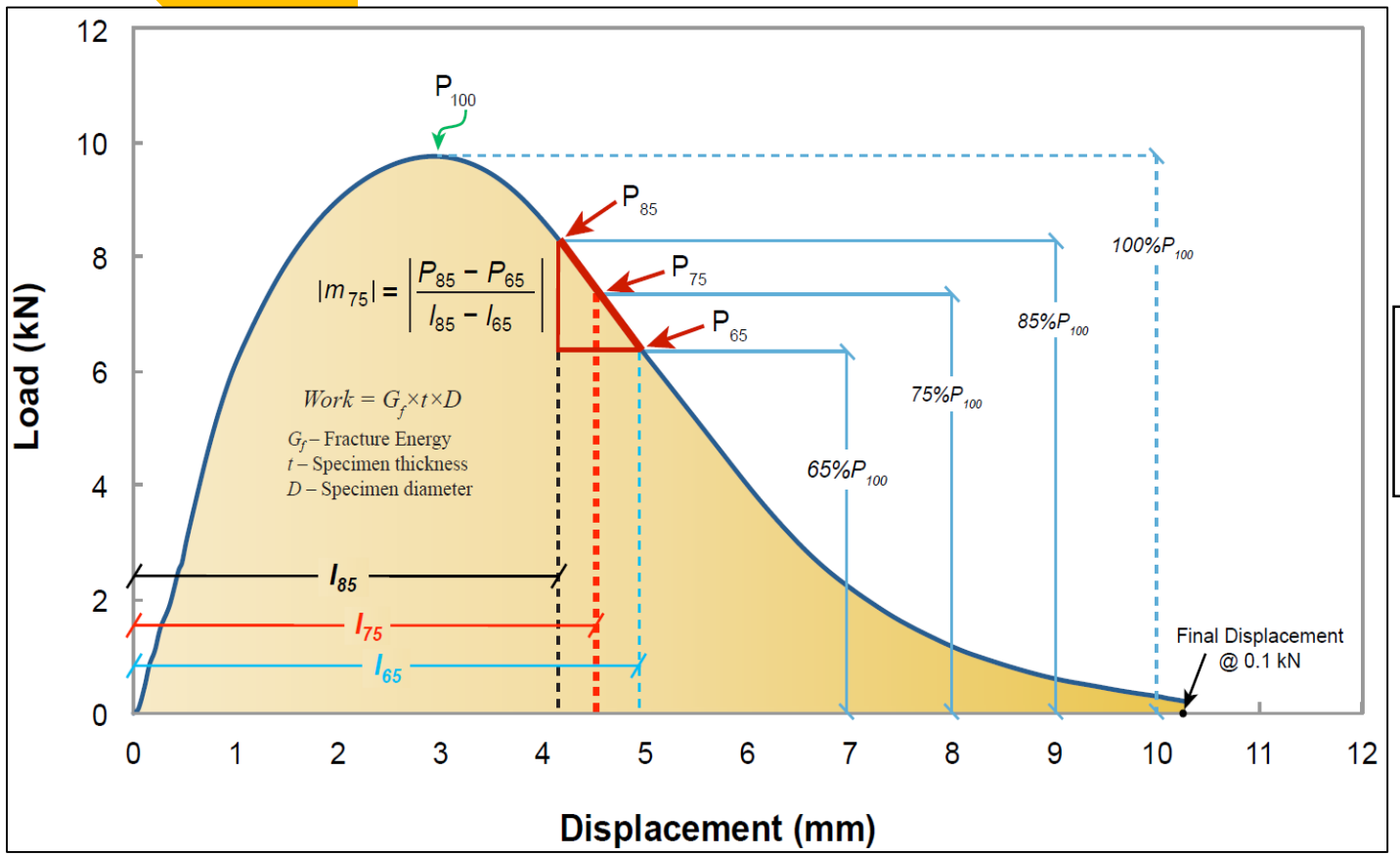
IDEAL-CT Overview

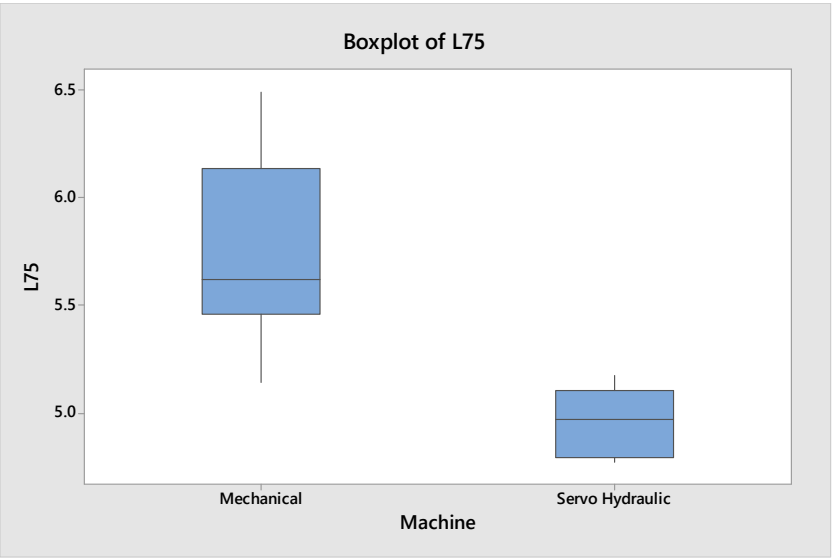


$$CT_{index} = \frac{t}{62} \times \frac{G_f}{|m_{75}|} \times \frac{l_{75}}{D} \times 10^6$$

(Zhou et al., 2017)

IDEAL-CT Machine Effects – Phase II

L75



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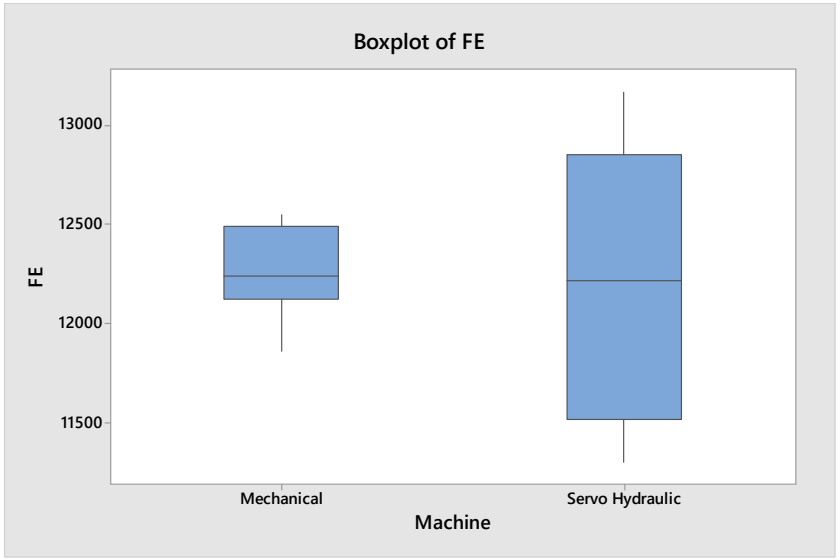
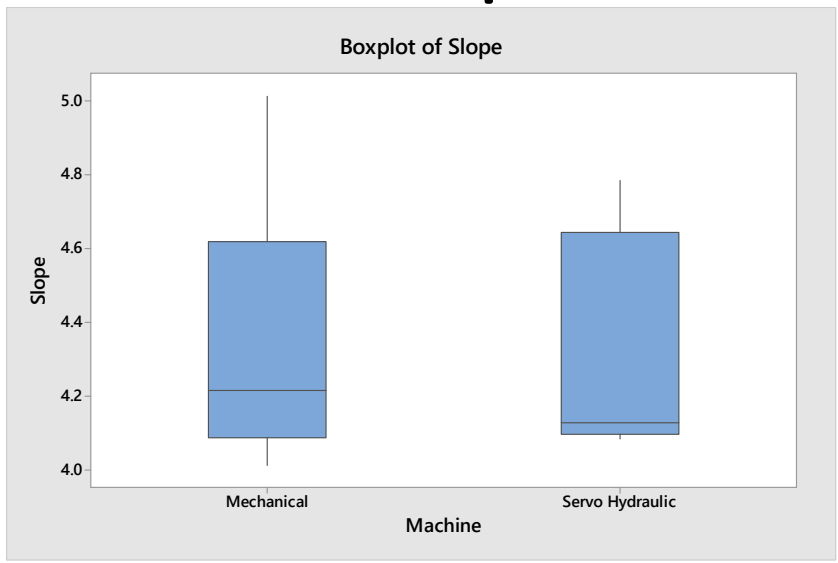


Slope



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Summary of RR Phase II

- COV of IDEAL-CT ≈ 20%
  - Both phases had essentially the same within-lab repeatability

- In general, servo-hydraulic devices have lower variability than screw-driven devices.
  - However, not all screw-driven devices are equal

Summary of Equipment

- Bias probably exists between testing devices.
  - Friction?
  - Compliance?
  - Loading acceleration/deceleration?
- Decision makers need to be aware of the extent of any differences before implementation.
- Loading rate absolutely matters.

Thoughts Moving Forward

- How to account for the fact that some machines operate differently than others?
- Equipment comparison study should be complete by summer 2020
- State-specific Round Robin studies will provide information to contractors about their equipment vs. others

Thank You

Nathan Moore
nathanmoore@auburn.edu

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