

ISB Camshaft and Tappet Test for Lubricant Evaluation



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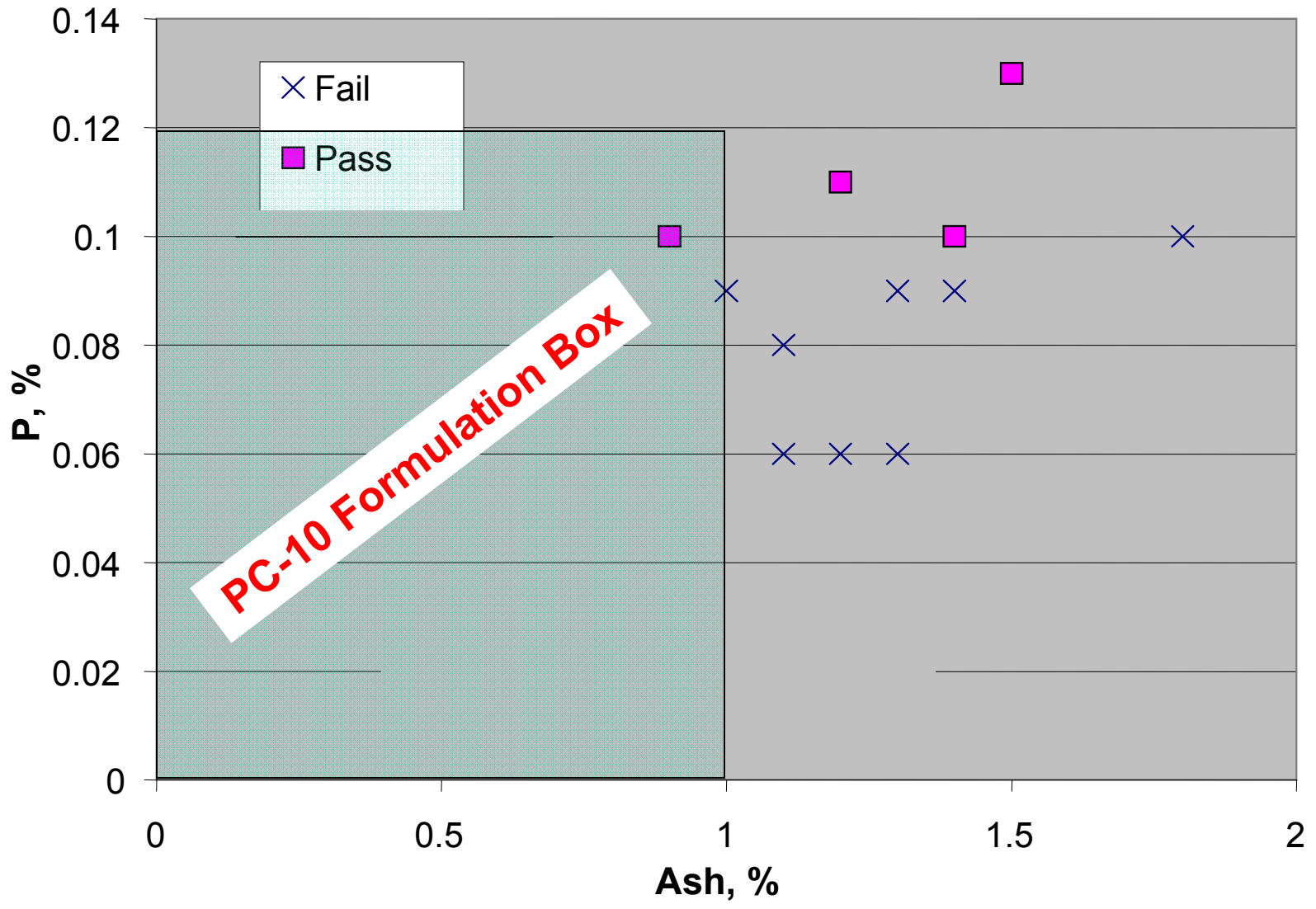


Historic Field Problem

- ISB cams have sliding contact
- Field and test cell studies showed sensitivity to lubricant phosphorous levels
- PC-10 will limit phosphorous to protect after-treatment devices.
- A sliding wear, sooted oil test was needed to protect engines in the field

Test History – B Camshaft Pitting

Phosphorus and Ash Effects

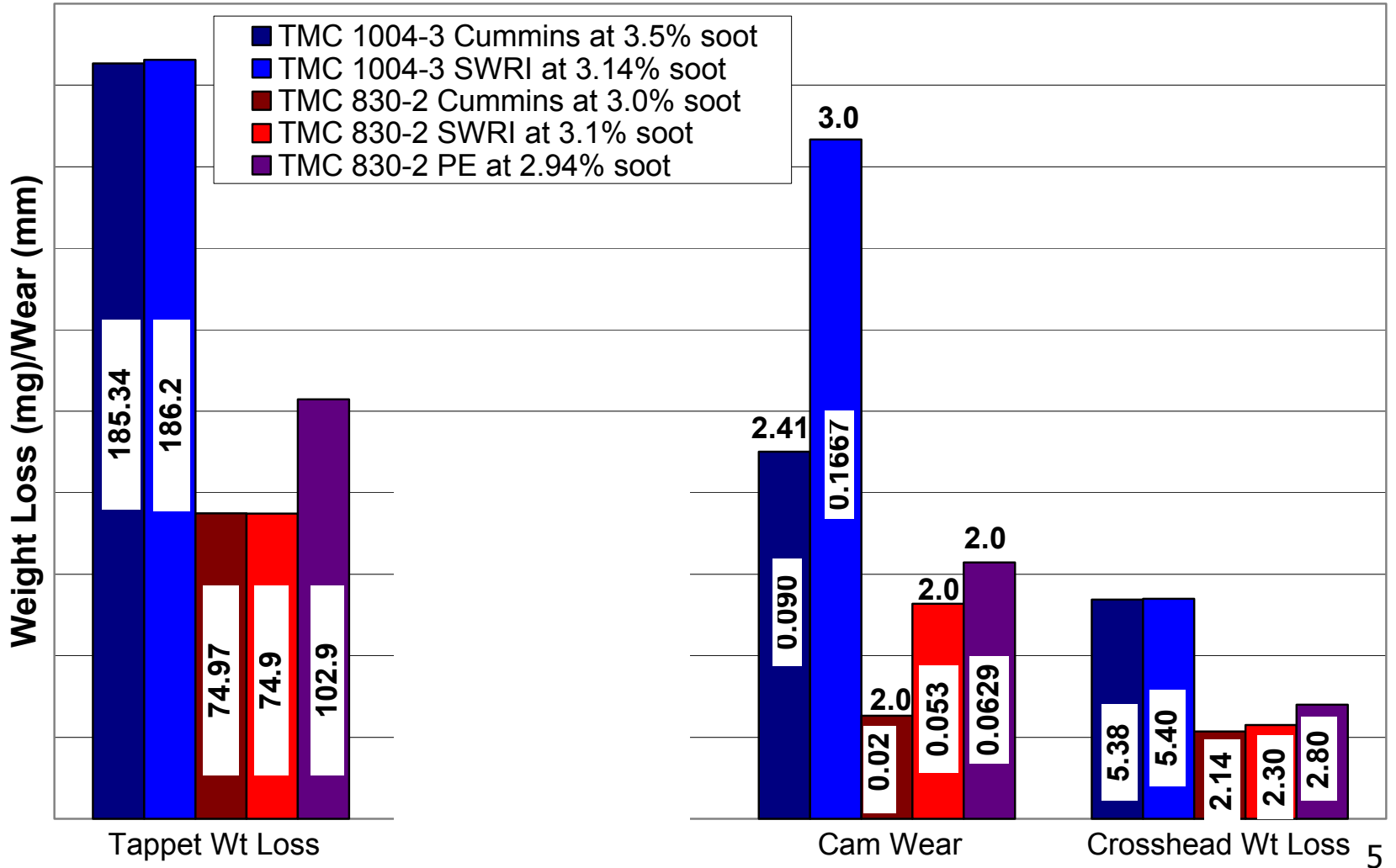


ISB Test Overview

- **2004 EPA Compliant engine rated at 300 HP and 600 ft-lbs lbf-ft torque**
- **The engine is run through a series of warm-up cycles to flush the engine oil with reference or candidate oil**
- **Stage I consists of a 100 hour soot generation steady-state cycle at 1600 RPM and 325 ft-lbs torque. The soot window at 100hours is 3.25 +/- 0.25% soot.**
- **Stage II consists of a repeating 28 second accelerated wear cycle for 250 hours. The oil pan level is verified as full by the dipstick before starting this stage.**
- **The wear components and other test parameters are evaluated upon successful test completion.**

Discrimination Testing

ISB Cam Cycle Test Data



Discrimination Testing

Analysis for Wear

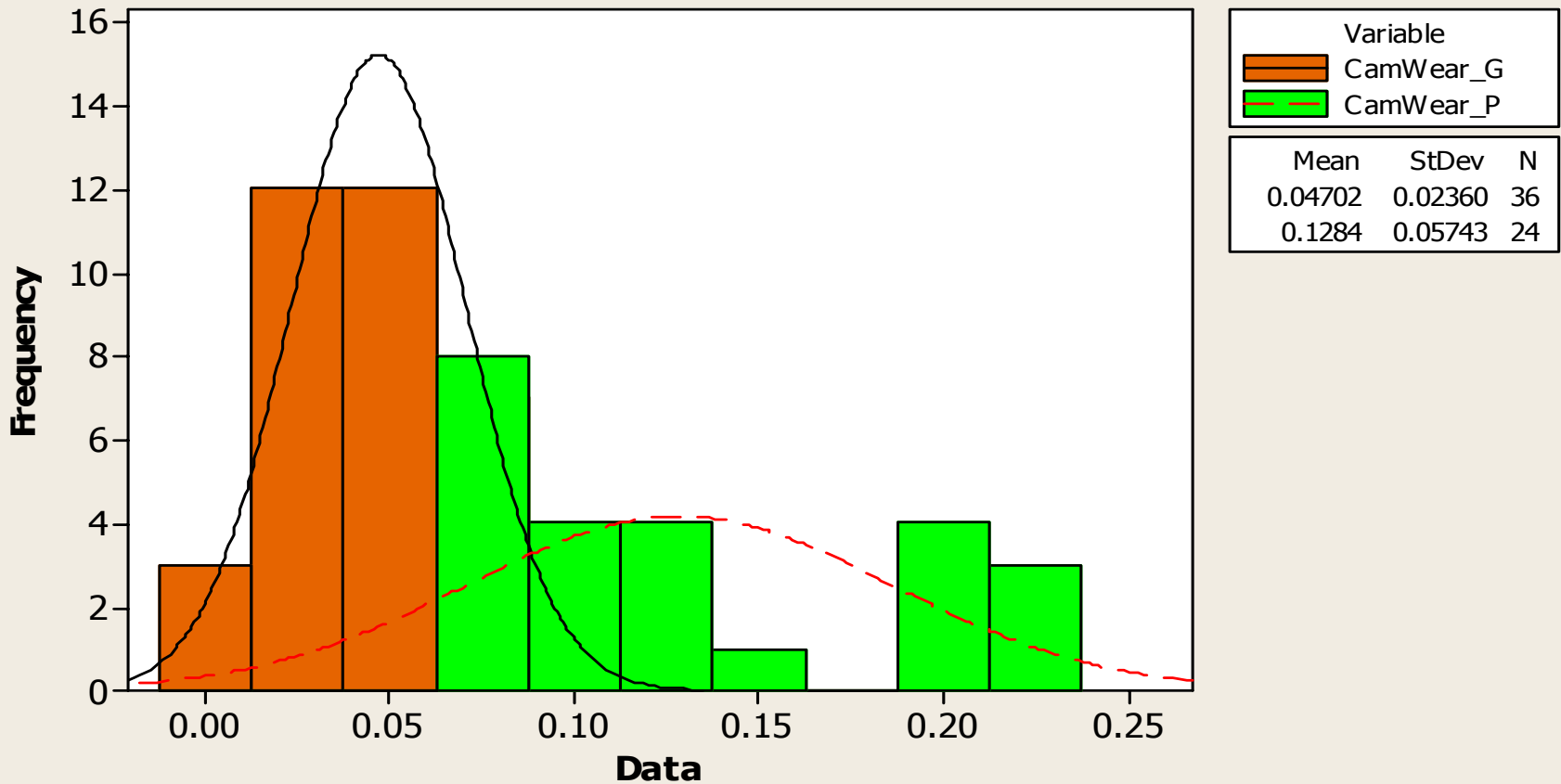
- Two sample t-test was used to evaluate the significance of the mean shift in the data (poor oil vs good oil)
 - There was a significant difference in the means of the data
 - The test can discriminate between oil quality on the accepted wear parameters

Discrimination Testing

Cam Wear Comparison

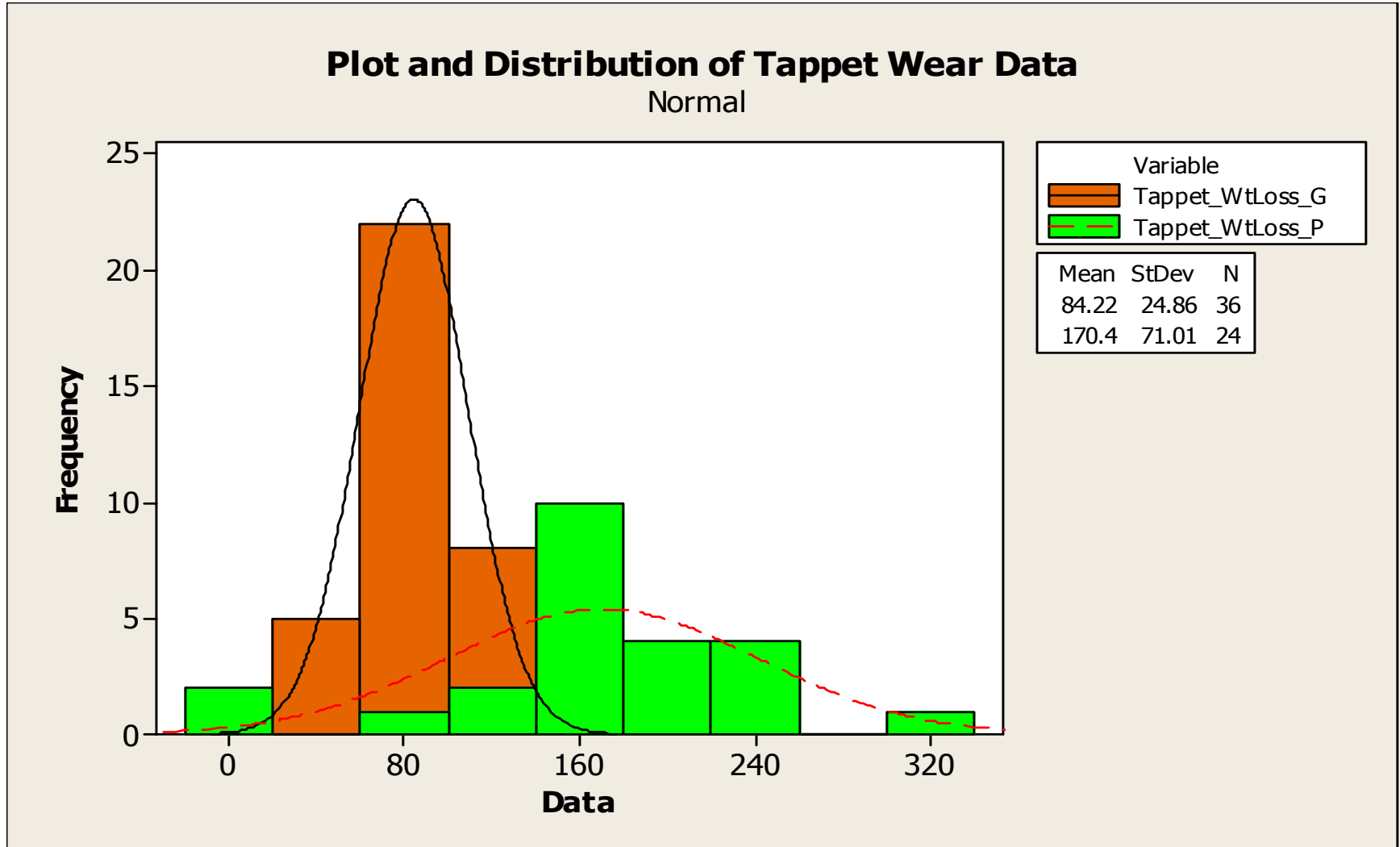
Plot and Distribution of Cam Wear Data

Normal



Discrimination Testing

Tappet Wear Comparison



Precision Summary

ISB Matrix Data 10/27

	Repeatability s (Within Stand)	Reproducibility s (Between Stand)	Reproducibility s (Between Lab)
Tappet Wear (mg) Soot Adj	8.1645 Ep=1.84	16.8574 Ep=0.89	16.9092 Ep=0.89
Camshaft Wear (um)	4.7021 Ep=3.19	7.1512 Ep=2.10	7.1512 Ep=2.10
XHead Wear (mg) Soot Adj	0.3817 Ep=1.96	0.3817 Ep=1.96	0.5221 Ep=1.44
Torque Adjstd Cam Wear (um)	5.0833 Ep=2.95	5.0833 Ep=2.95	6.3063 Ep=2.38

Target Summary

ISB Matrix Data 10/27

	Oil 830-2	PC10B	PC10E
Tappet Wear (mg) Soot Adj	LS Mean = 88.23 Mean = 85.8167 S = 16.1416	LS Mean = 93.47 Mean = 88.6833 S = 15.8176	LS Mean = 67.54 Mean = 57.86 S = 9.4796
Camshaft Wear (um)	LS Mean = 40.20 Mean = 40.2667 S = 9.2058	LS Mean = 44.85 Mean = 41.9833 S = 5.6722	LS Mean = 36.86 Mean = 34.14 S = 5.0093
XHead Wear (mg) Soot Adj	LS Mean = 2.072 Mean = 2.0833 S = 0.5345	LS Mean = 2.057 Mean = 2.0667 S = 0.4367	LS Mean = 1.940 Mean = 2.0000 S = 0.4743
Torque Adjstd Cam Wear (um)	LS Mean = 40.86 Mean = 40.86 S = 6.8895	LS Mean = 42.29 Mean = 42.2984 S = 4.7694	LS Mean = 33.94 Mean = 33.0695 S = 6.0193

Proposed Limit

Tappet Weight Loss

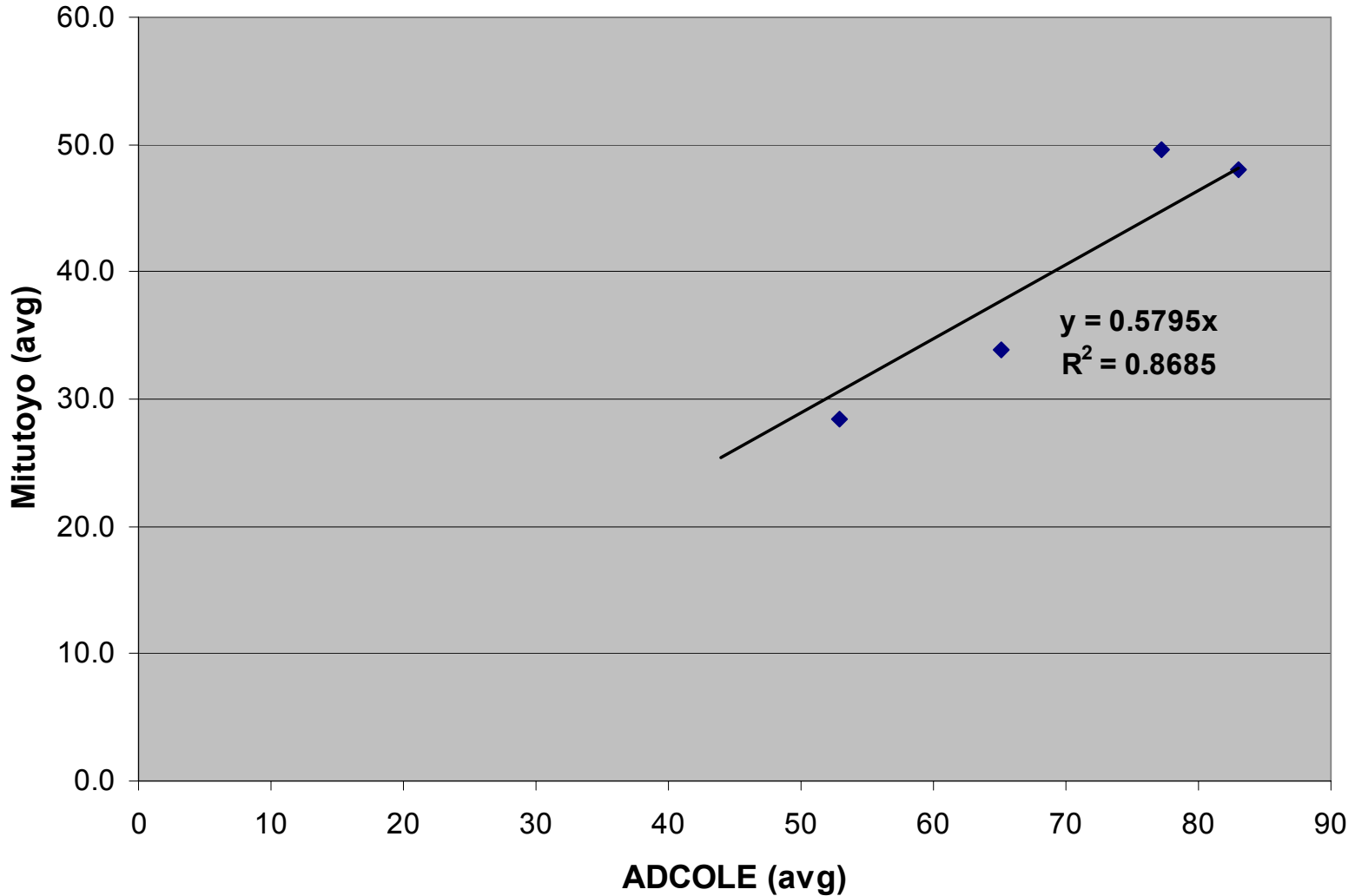
- Based upon matrix data the tappet weight loss limit is 75 mg
- 95% CI for the mean of the parameter is 65 – 86 mg

Cam Wear Issues

- Cummins uses a visual inspection scale to rate cam distress
- Cummins established a correlation between the “service rating” and the Adcole wear profile results
- Following the matrix, the Surveillance Panel adopted a Mitutoyo snap gauge measurement
- To set limits we need to relate Mitutoyo to the service rating

Cam Rating Data

ADCOLE vs Mitutoyo - Average



Proposed Limit

Average Cam Lobe Wear

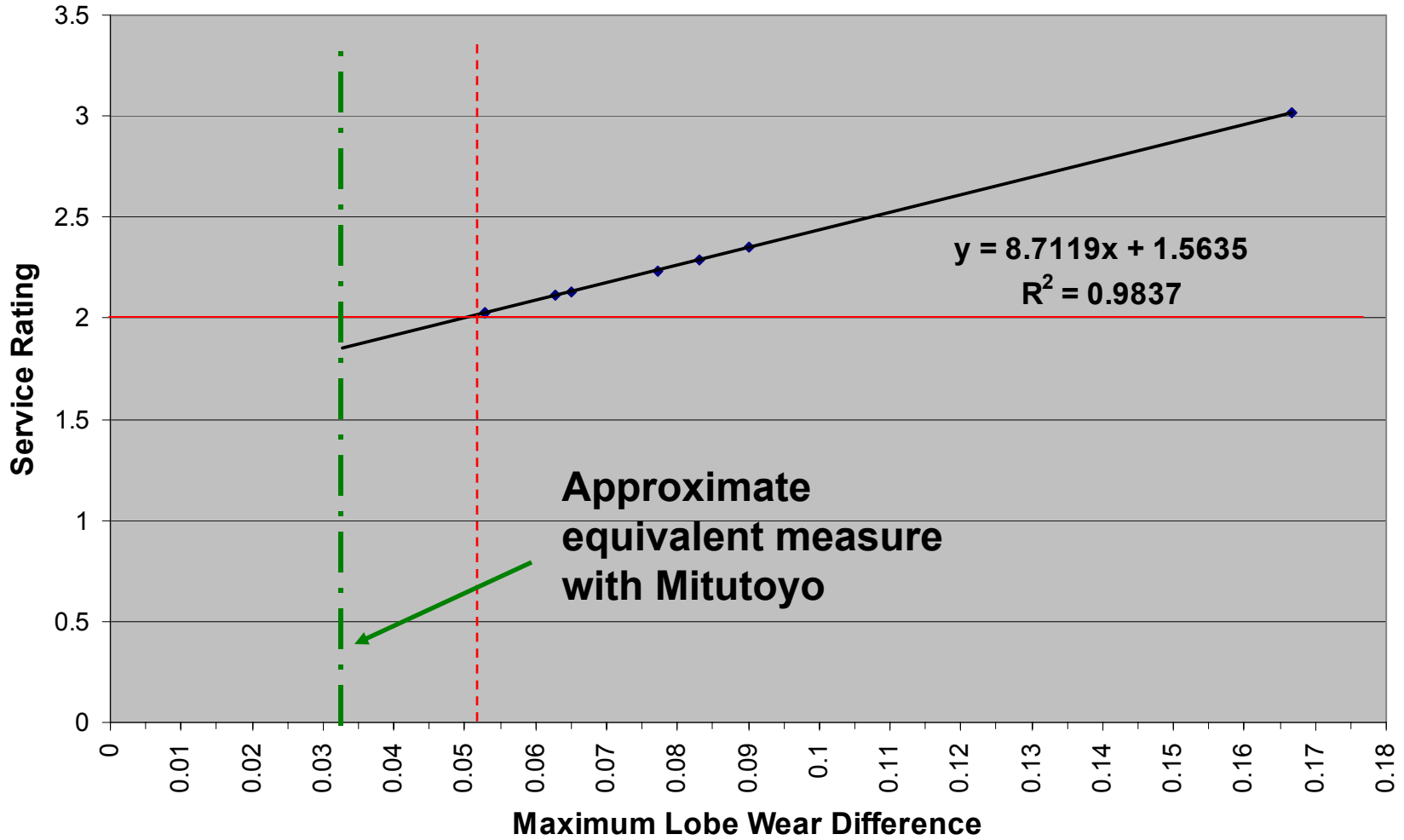
- **Need all of the remaining ADCOLE data from the matrix to insure correlation**
- Based upon data received and the correlation the relationship between ADCOLE and Mitutoyo is:

$$\text{ADCOLE} = 1.725 \times \text{Mitutoyo}$$

- Recommendation for passing cam is a rating of 2.0
- Based upon data a 2.0 correlates to a **50** μm ADCOLE rating or a **30** μm Mitutoyo
- 95% CI for the parameter is 44 – 66 ADCOLE or 25 – 38 Mitutoyo

Visual Cam Rating

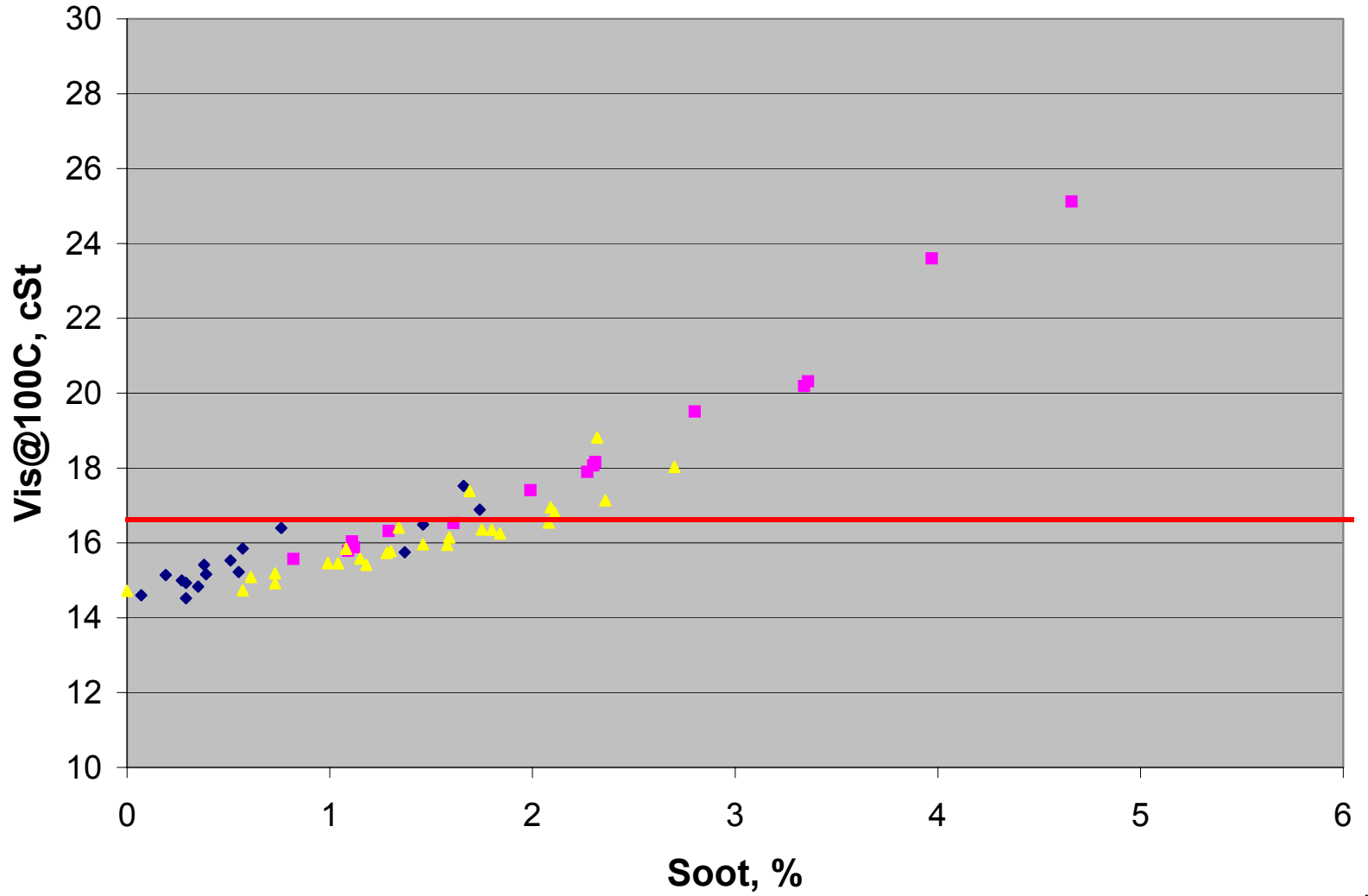
Average Cummins Rating vs Average Lobe Wear by ADCOLE



Cam Rating Issues

- The Surveillance Panel felt that the data correlating the Adcole and Mitutoyo to Service rating was sparse.
- All Matrix and Cams are being sent to Cummins along with Adcole data.
- They will be rated on the Service Rating scale
- The correlation between Service Rating and the wear measurement methods will be improved

ISB02 EGR, CI-4



Proposed Limit

Viscosity Increase Control

- Stay in grade requirement at the 100 hour soot window (3.25% +/- .25%)

Summary of limits

- **Tappet wear limit**
 - Target limit 75 mg weight loss
- **Cam wear limit**
 - Target limit 30 μm wear by Mitutoyo snap gauge
- **Viscosity limit**
 - Target limit “stay in grade” at the 100 hour soot window 3.25% +/- 0.25%

Summary of limits

- **Tappet wear limit**
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- **Cam wear limit**
 - Target limit 30 μm wear by Mitutoyo snap gauge
- **Viscosity limit**
 - Target limit “stay in grade” at the 100 hour soot window
3.25% +/- 0.25%
- **ISB was recommended for inclusion in PC10 at recent HDEOCP meeting**
- **MOTION: Exit Ballot these limits for the ISB**