ISB Cam and Tappet Test
Industry Report Packet

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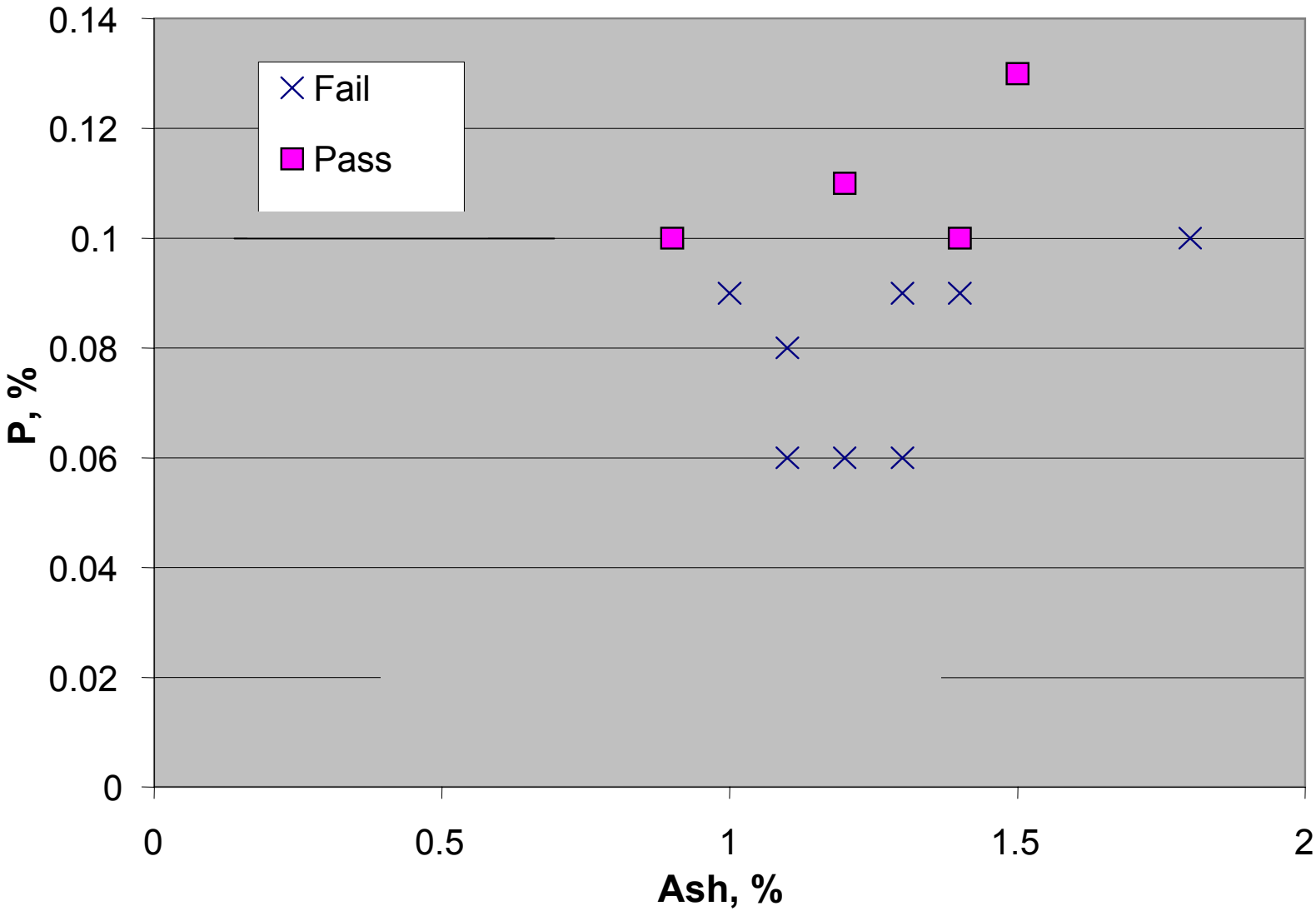
Test History

- Based upon the an internal Cummins accelerated camshaft and tappet test
- Cam lobe pitting directly correlated with oil quality
- Cam lobes and tappets are rated on a 5 point scale from good to strong pitting observed.
- 12 engine oils representing North America and SE Asia regions,
  - 6 of the oils tested failed to meet the wear criteria.
  - 20% were represented by intake cam lobes the remaining were represented by the exhaust lobes.

Test History – B Camshaft Pitting

Phosphorus and Ash Effects



Test History
Lessons Learned

- **Test cycle limits lubricant entrainment.**
- **Pre-sooting the oil prior to the accelerated cam cycle test provides for the most severe wear scenario.**

Test Development

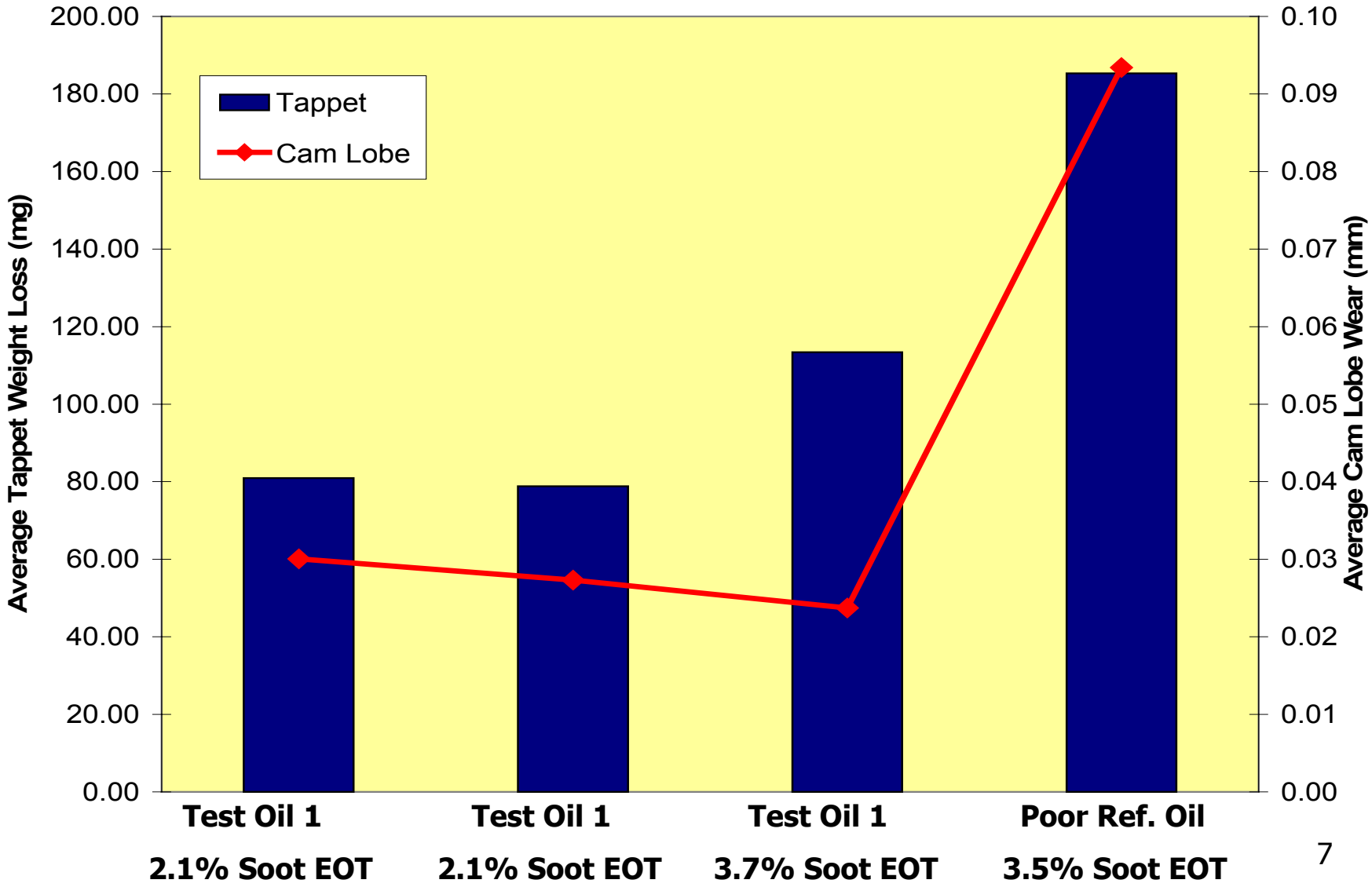
- Quantify end of test measurements from internal cam and tappet test.
- Test procedure was proposed, drafted and developed with Cummins support.
- Procedure is now being finalized with the help of the industry through the ASTM ISB Task Force.
  - Six labs participating on the task force.
    - One actively running data
    - Two preparing stands will be up by end of May
    - Remaining three running in June.

Looking Forward
Meeting the Timing

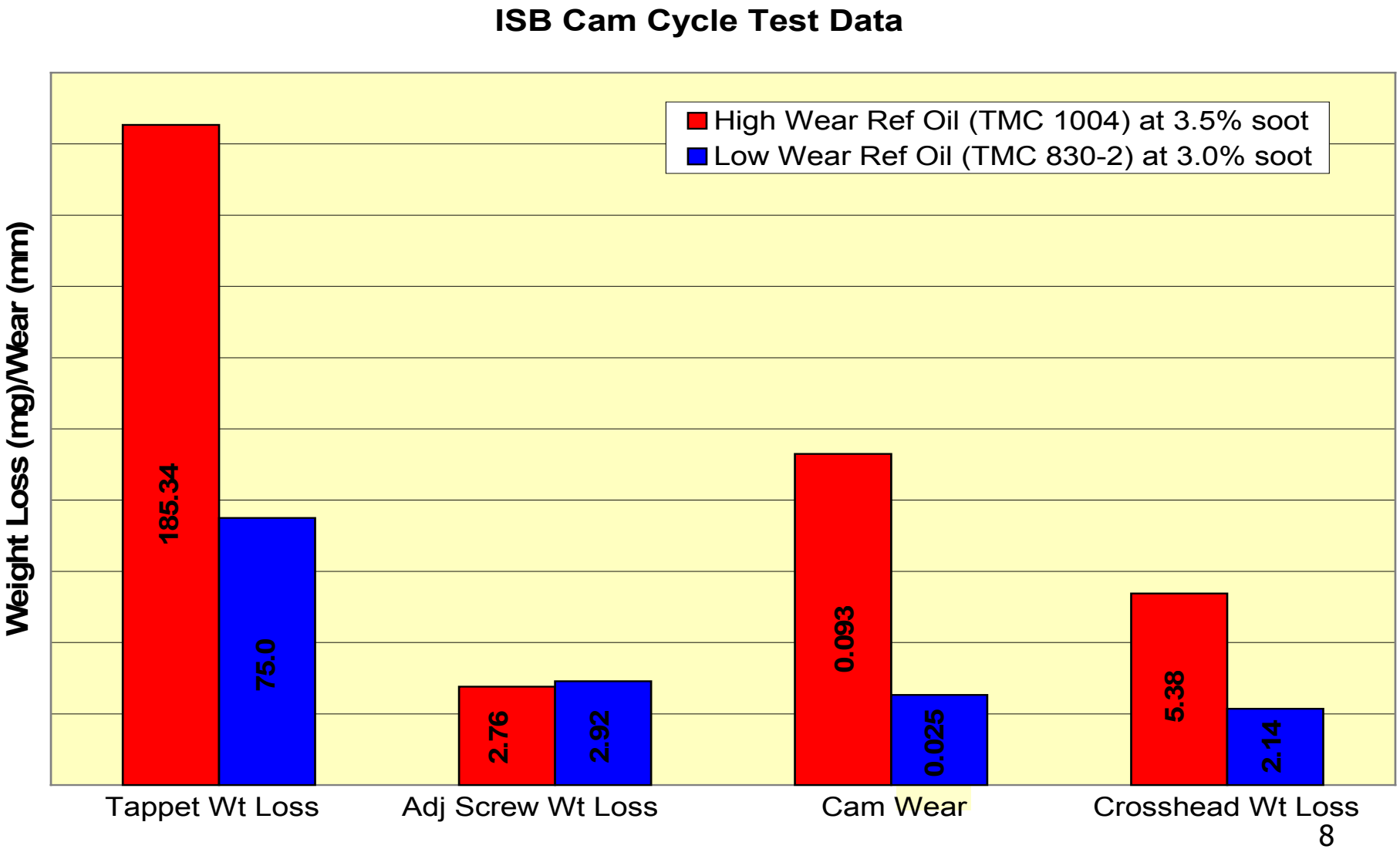
- Cummins proposes that the matrix testing begin on the ISB test as soon as the test is ready.
- First, proof of concept data indicating test discrimination and repeatability must be presented to the HDEOCP.
- This data is included in the presentation.
- When remaining stands are on line, and
- Operation and Hardware subgroup of the ISB Task Force indicates all test stands are ready
- Cummins will move that the ISB matrix begin.

B Engine Camshaft and Tappet Testing

Repeatability and Discrimination



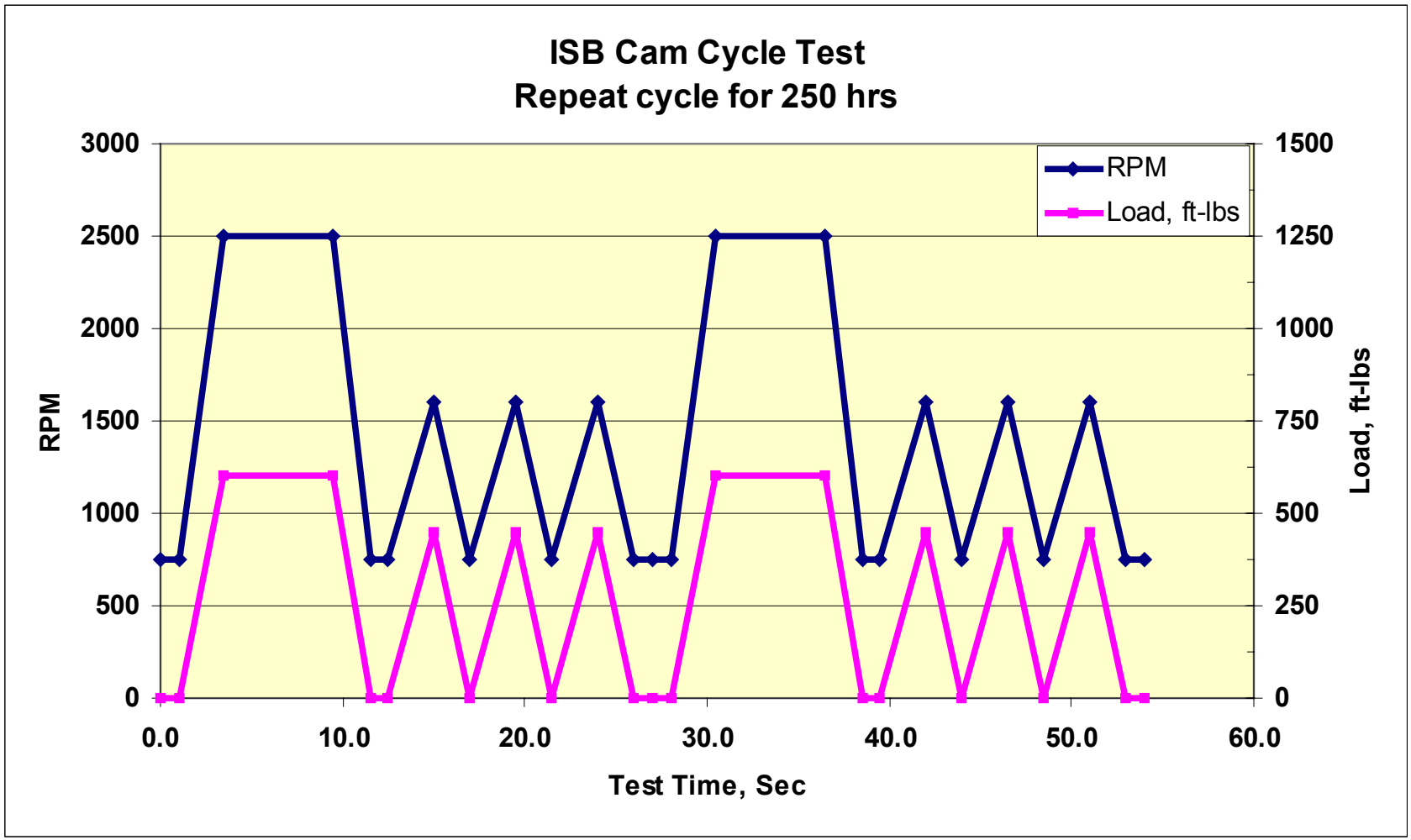
ISB '02 Camshaft and Tappet Data
Discrimination



ISB Test Overview

- The ISB Cam and Tappet Test is:
  - Based upon a 2004 EPA Compliant engine
  - Rated at 300 HP and 600 ft-lbs torque.
- First portion; a 100 hour soot generation cycle:
  - 1600 RPM and 325 ft-lbs torque.
  - Timing retarded
  - Soot window of 3.25 +/- 0.25%.
- Oil level is verified as full.
- Continues on a 28 second accelerate wear cycle for 250 hours.
- Wear components and other test parameters are evaluated at EOT.

Second Phase Cycle



Scope

To develop a lubricant performance test on a Cummins ISB test platform that can discriminate and provide a quality assessment of motor oils in a sliding tappet engine under cyclic conditions. The ISB test development will consider the following parameters for lubricant quality evaluation:

Primary Parameters

Tappet Weight Loss

Cam Lobe Wear

Cam Journal Wear

Secondary Parameters

Push tube scuffing

Sludge

Oil filter delta P

Adjusting screw wt. loss

Crosshead weight loss

Objectives

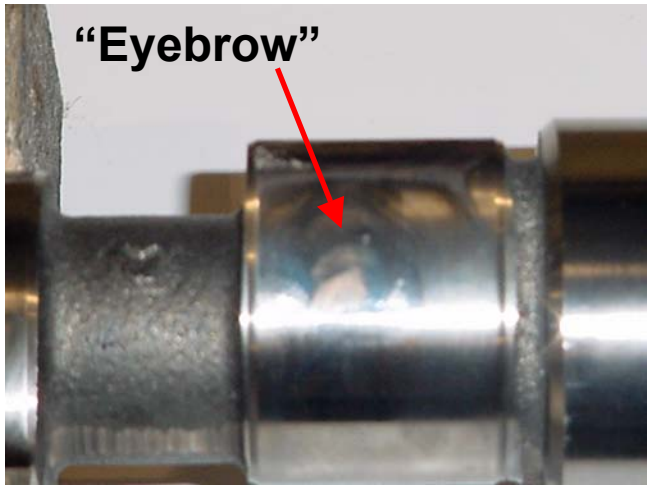
- Draft of test procedure 12/03
  - **Preliminary draft completed 01/04**
  - **Work continues within the ISB Task Force to refine and standardize the procedure**

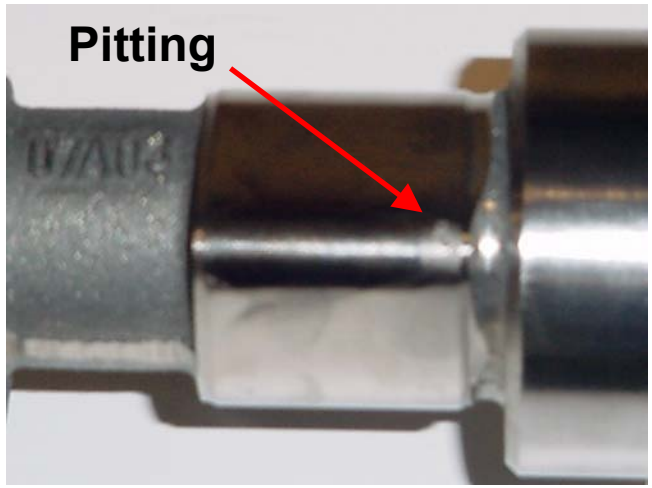
- Test engines to six labs 1/04
  - ExxonMobil, Lubrizol, PerkinElmer, SwRI, Valvoline
  - Ethyl engine 5/04

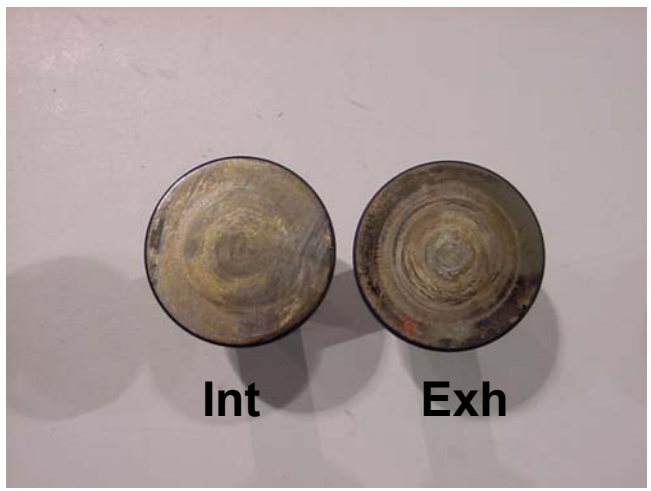
3. Initiate matrix design 1/04
   - **Preliminary proposal based upon 4 labs attached**

4. Begin matrix testing To meet API timing

Cam and Tappets After Test







ISB Test Parameters

- Parameters to be rated
  - –Primary Parameters
    - •Tappet Wear
      - –mg wt loss
    - •Cam lobe wear
      - – mm wear
        - »ADCOLE measurement
        - »Cams will be pre and post measured by CPD
        - »The O&H Sub-group is evaluating alternative wear measurement methods
    - •Cam journal wear
      - – mm wear
        - »ADCOLE measurement

ISB Test Parameters

- Parameters to be rated
  - –Secondary Parameters
    - •Overhead wear
      - –Crosshead Weight Loss, mg loss
      - –Adjusting Screw Weight Loss, mg loss
      - –Push Tube Scuffing
    - •Other parameters
      - –Oil Filter Delta Pressure, kPa
      - –Sludge, rocker cover and oil pan

Precision ISB Matrix Design

Reducing the costs

Ideas

- Each test stand will demonstrate similar wear performance as the Cummins test stand
  - based on comparison to historical data (mean and standard deviation)
- Cost effective matrix based on 4 oils.
- 3 DI/VI combinations, 1 base oil, and 1 Reference Oil
- Each successful test generates 12 tappet, cam and crosshead wear points
- No VGRA or BOI included in matrix design

Hardware Modifications