

*Update on the Development of a
New Sequence VID Fuel
Efficiency Test for Engine Oils*

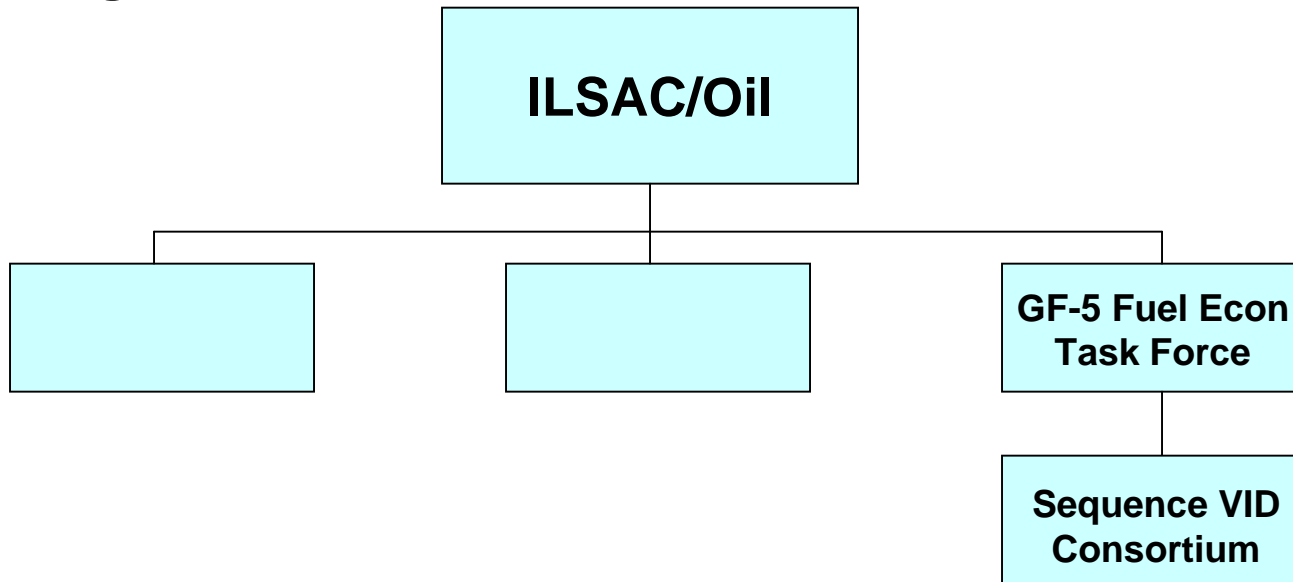
ILSAC/Oil Meeting

**Detroit, MI
September 3, 2008**

Jim Linden
General Motors R&D

Consortium to Develop A New Sequence VID Fuel Efficiency Test for Engine Oils

- **Reporting Structure**



Prior Presentations

- **Background**
- **Consortium formation**
- **Test Oil selection and description**
- **Vehicle testing (FTP)**
 - Fuel economy results
 - Used Oil analyses
- **Dyno Test Set-up**
 - Engine selection
 - Engine Modifications
 - Special Hardware
 - Selection of initial test conditions
- **VID Test Matrix Design**
 - Matrix I – Aging Conditions
 - Matrix II – Initial Stages Evaluation
 - Matrix III – Additional evaluation and stage reduction
 - Matrix IV – Fresh and Aged Oil testing
 - IVa - PCM recalibration and Dual Throttle
 - Matrix V – Prove Out - Design

Outline

- **Matrix V – Prove Out**
 - **Design**
 - **Results**
 - **Statisticians' Recommendations**
 - **Stage Weighting Evaluations**
- **Selection of Baseline and Stages Weighting**
- **Discrimination Results**

Sequence VID Consortium – Scope and Objectives

Scope

Develop an engine dynamometer-based fuel economy test for ILSAC GF-5 that will replace the ILSAC GF-4 Sequence VIB fuel economy test. The new test should represent both viscometric and friction modifier oil effects on the fuel economy of current and future North American and Japanese engines.

Objectives

- The test should be responsive to both viscometric and friction modifier effects in oils.
- Ideally, the test should show improved test precision over the current Sequence VIB fuel economy test. This will be quantified by showing that the new test has a lower standard deviation of fuel economy improvement.
- Develop a VID engine test based on the operating conditions mapped proportionally to the FTP-75 and Highway Fuel Economy tests, and which generally agrees with the FTP fuel economy data generated by the consortium. Other data may be considered, as appropriate. The test should emulate aging observed during mileage accumulation at 6500 miles from the FTP program, discriminate between Oil Z and the other matrix oils based on viscosity effects and determine FM effects.

Matrix V - Prove Out Design

additional tests

- **Oils:**
 - 3 Oils (A, B and E)
 - 1 Technology
- **8 runs at both SA labs**
 - **IAR:**
 - Oil A – 3 runs
 - Oil B – 3 runs
 - Oil E – 2 runs
 - **SwRI:**
 - Oil A – 3 runs
 - Oil B – 2 runs
 - Oil E – 3 runs
- **Effects tested:**
 - **Oil**
 - **Friction Modifier**
 - A v. B
 - (non FM v. FM)
 - **Viscosity Grade**
 - A v. E
 - (5W-20 v. 10W-30)
 - **Lab**

Option 1A

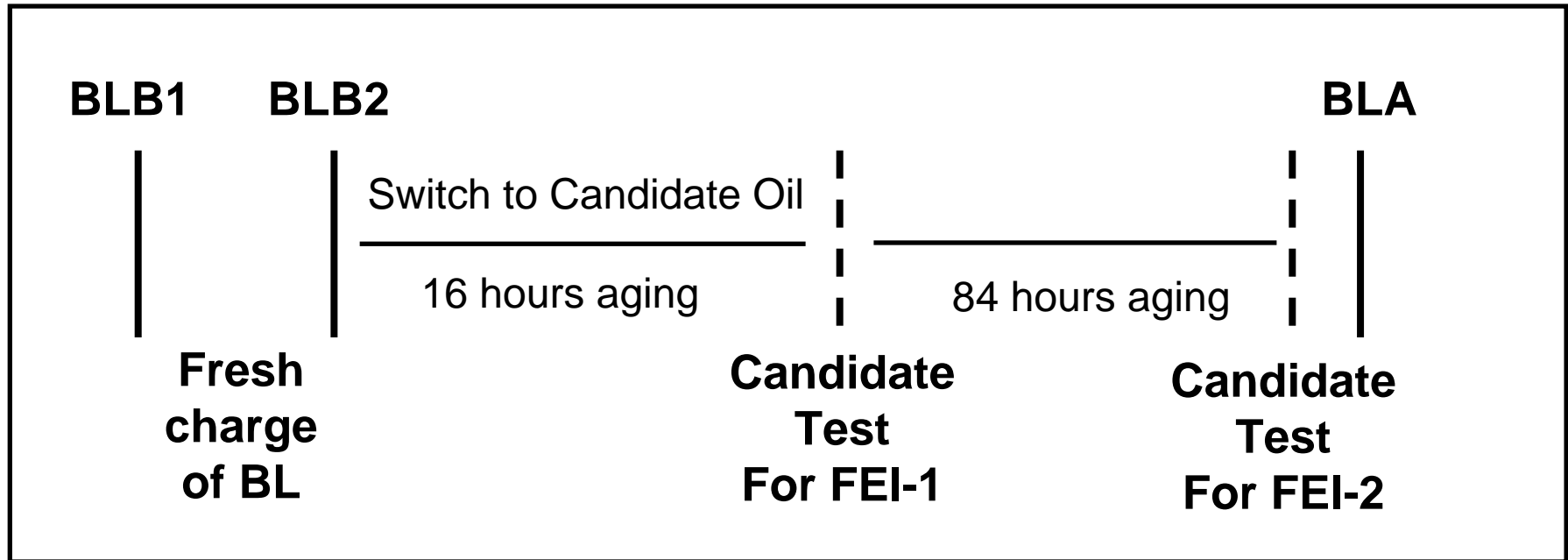
Order	IAR
1	A
2	B
3	E
4	E
5	B
6	A
7	A
8	B
9	B

Order	SwRI
1	E
2	B
3	A
4	A
5	B
6	E
7	E
8	A
9	A

+ Two invalid tests at SwRI

Sequence VID Test Procedure

Used in Prove Out Matrix



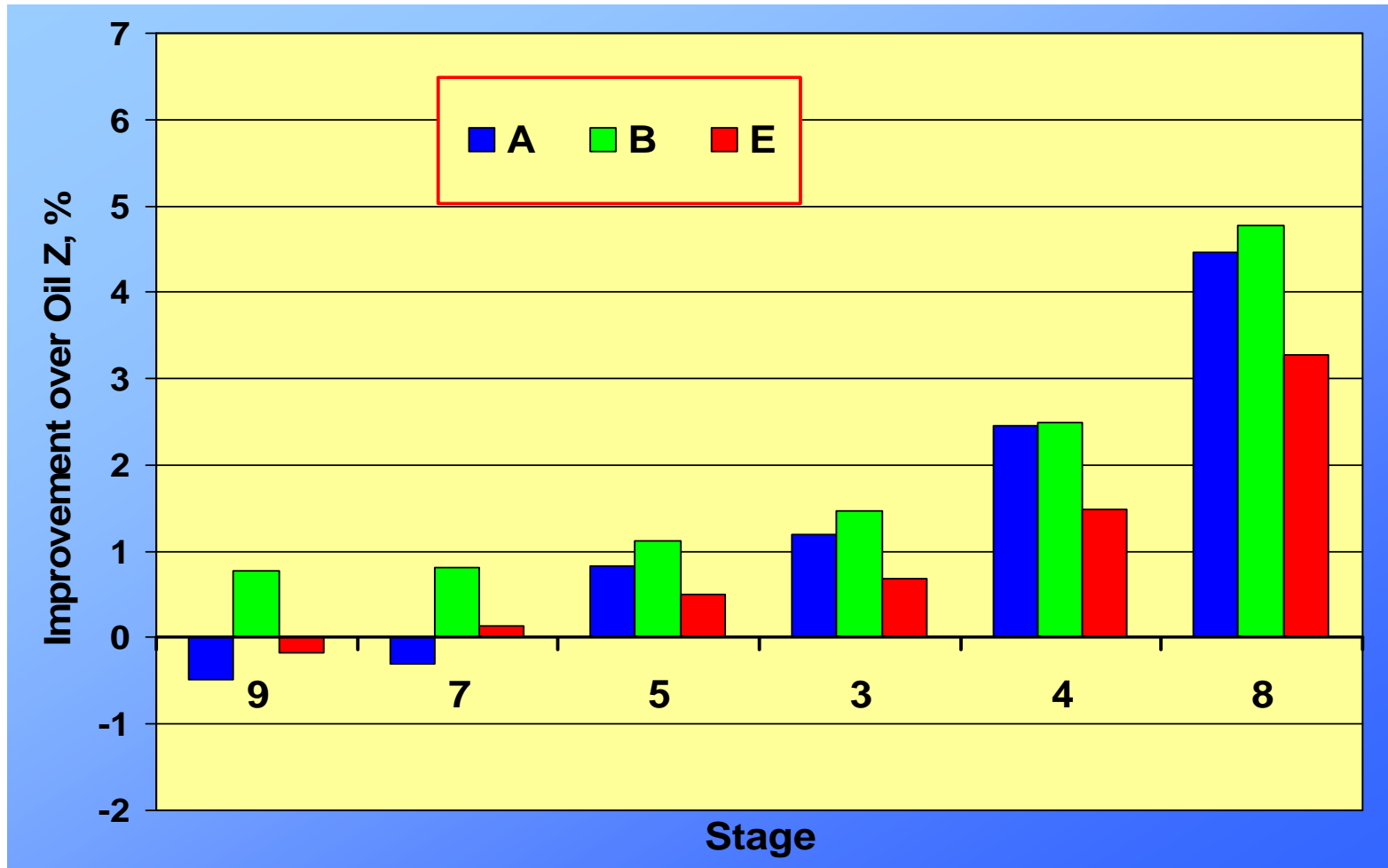
BLB1 = Baseline Test Before -1

BLB2 = Baseline Test Before -2

BLA = Baseline Test After

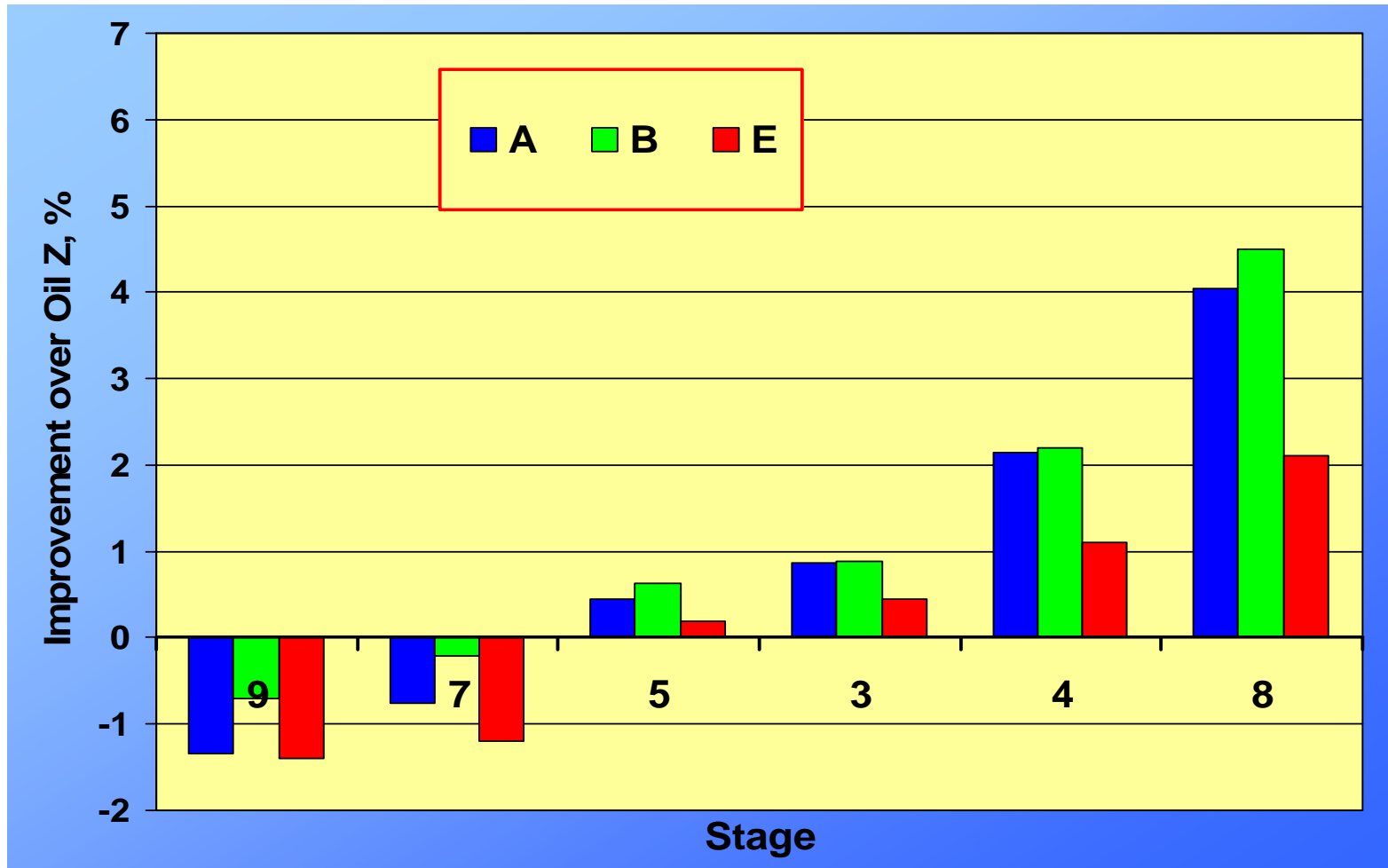
Prove Out Matrix Results - FEI 1

- Both Labs -



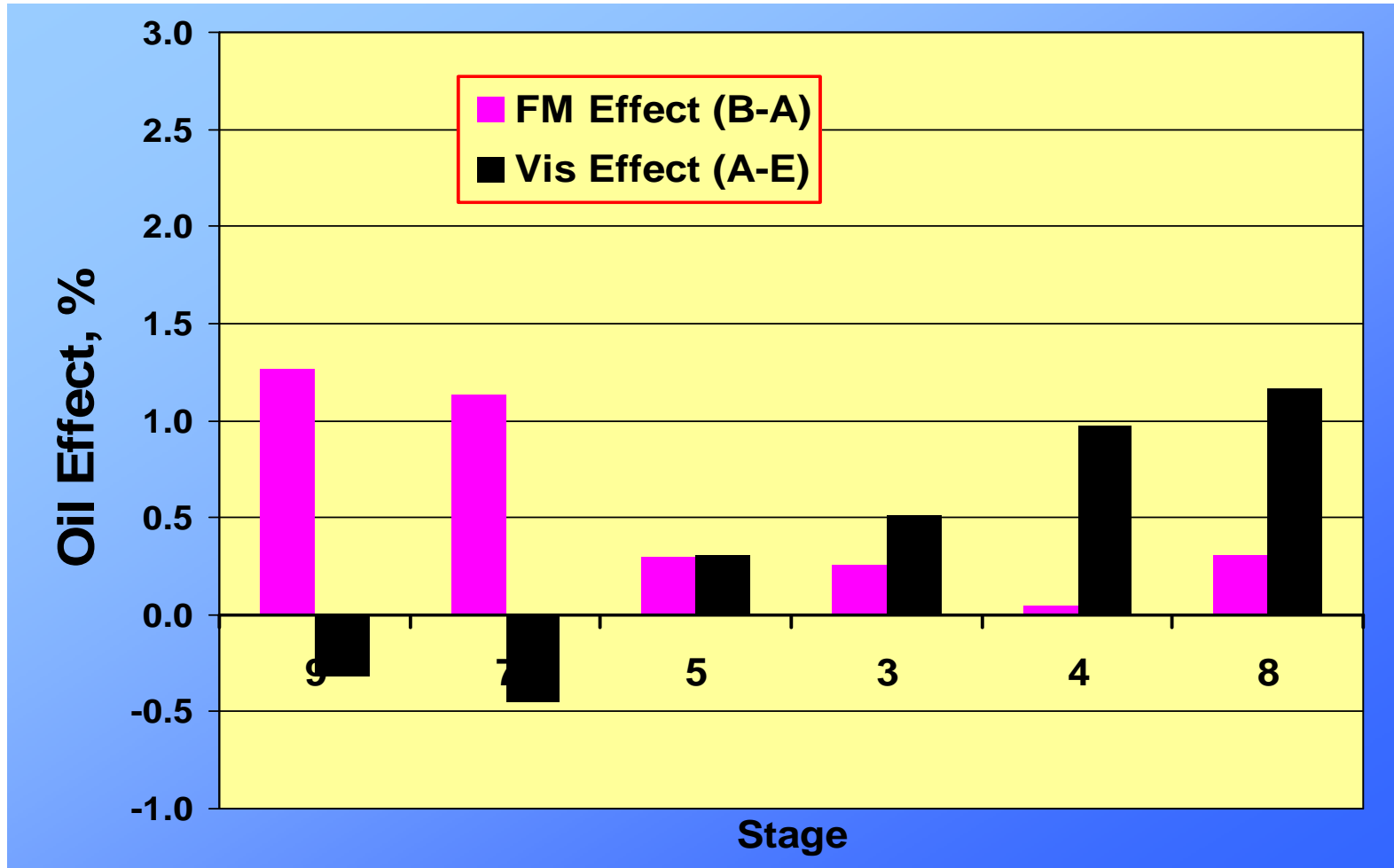
Prove Out Matrix Results - FEI 2

- Both Labs -



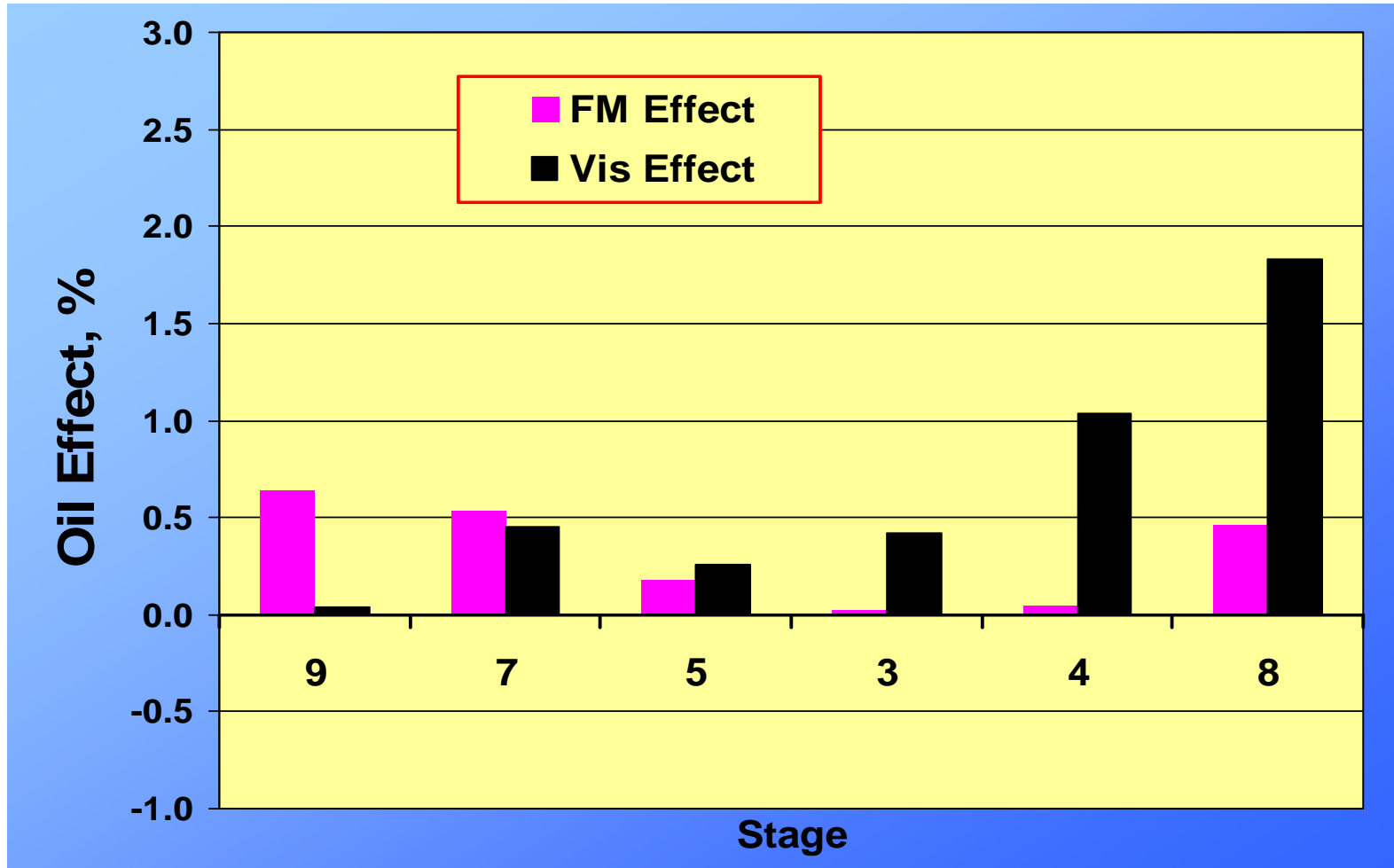
Prove Out Matrix Results - FEI 1

- FM and Vis Effects -



Prove Out Matrix Results - FEI 2

- FM and Vis Effects -



Statistical Agreements

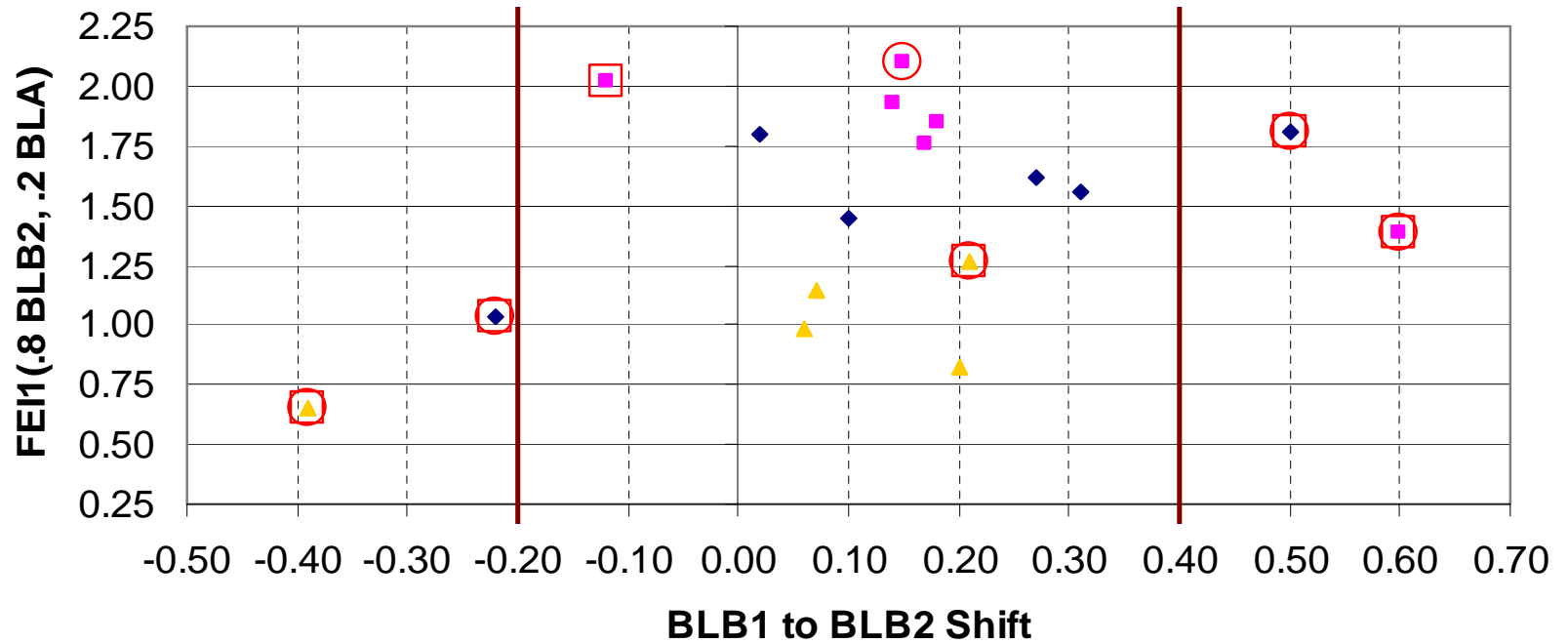
- Significant Fuel Consumption and FEI differences and Baseline variability exist between SwRI & IAR
- No FM carry-over identified. However, consecutive Baseline Fuel Consumption differences appear to be oil dependent
- All three BL runs are required
 - For minimum RMSE and maximum discrimination
- Baseline Weight
 - FEI1: 0-20 BLB1, **80 BLB2** & 0-20 BLA
 - FEI2: **0 BLB1**, 10-50 BLB2 & 50-90 BLA
- Discrimination
 - Practical stage weights exist that discriminate FM & VG for FEI1
 - The same stage weights discriminate for VG for FEI2, FM is directionally correct

Statistical Agreements (con't)

- Guidelines for oil pressure, MAP, and/or baseline fuel consumption, should be established for test validity (BLB1, BLB2), and interpretability (BLB2, BLA) before the precision matrix. Propose:
 - BLB1-BLB2 Fuel Consumption shift: -0.20% to 0.40%
 - If outside range, run BLB3 and compare with BLB2
 - ASTM Sequence VI Surveillance Panel to investigate test-to-test variability in baseline fuel consumption and report findings before start of precision matrix
- report findings before start of precision matrix
- before precision matrix
- precision matrix
- L weights or stage weights – deferred to Consortium

BLB Shift

BLB1 to BLB2 Shift vs. FEI1(.8 BLB2, .2 BLA)



- ◆ A
- ◆ B
- ◆ E
- Min/Max FEI1 Values
- Min/Max Shift Values
- Suggested Limits

Baseline Weighting

- Agreed to the need for three Baseline runs,
 - BLB1, BLB2, BLA
- Variety of Baseline weighting proposals
- Effects of Baseline weighting on precision for FEI-1 and FEI-2 determined
- Baseline weights that minimize RMSE & maximize discrimination do not differ greatly from current Sequence VIB:
 - 80-20 FEI-1 and 10-90 FEI-2

Baseline Weighting

- Three Baseline runs will be run for each test
 - BLB1, BLB2, BLA
- BLB2 must be within -0.20% to +0.40% of BLB1, otherwise BLB3 needs to be run
- Baseline weighting for FEI-1 will be:
 - 0% BLB1, 80% BLB2, 20% BLA
- Baseline weighting for FEI-2 will be:
 - 0% BLB1, 10% BLB2, 90% BLA

Stage Weighting

- Stage Weighting should be based upon meeting the Objectives of the Consortium
 - Discrimination with FM and Vis Grade
 - Improved test precision
 - FTP Correlation
- Several stage weighting proposals considered by Consortium
- Final selection based upon meeting the above three Objectives

Stage Weighting

- Based upon statistical analysis of Stage conditions and FTP and Highway conditions, ability to discriminate for FM and for Viscosity effects, and to improve test precision the following stage weighting was selected:

Stage	3	4	5	7	8	9
Weight, %	30	3.2	31	17.4	1.1	17.2

- Using the above Stage weighting and the agreed upon Baseline weighting
 - For FEI-1: FM and Vis effects were statistically significant (p-Value of 0.025 and 0.015, respectively, with RMSE at 0.225)
 - For FEI-2: Vis effect was significant (p-Value of 0.029), FM effect was directionally correct (p-Value of 0.279) with a RMSE of 0.264)

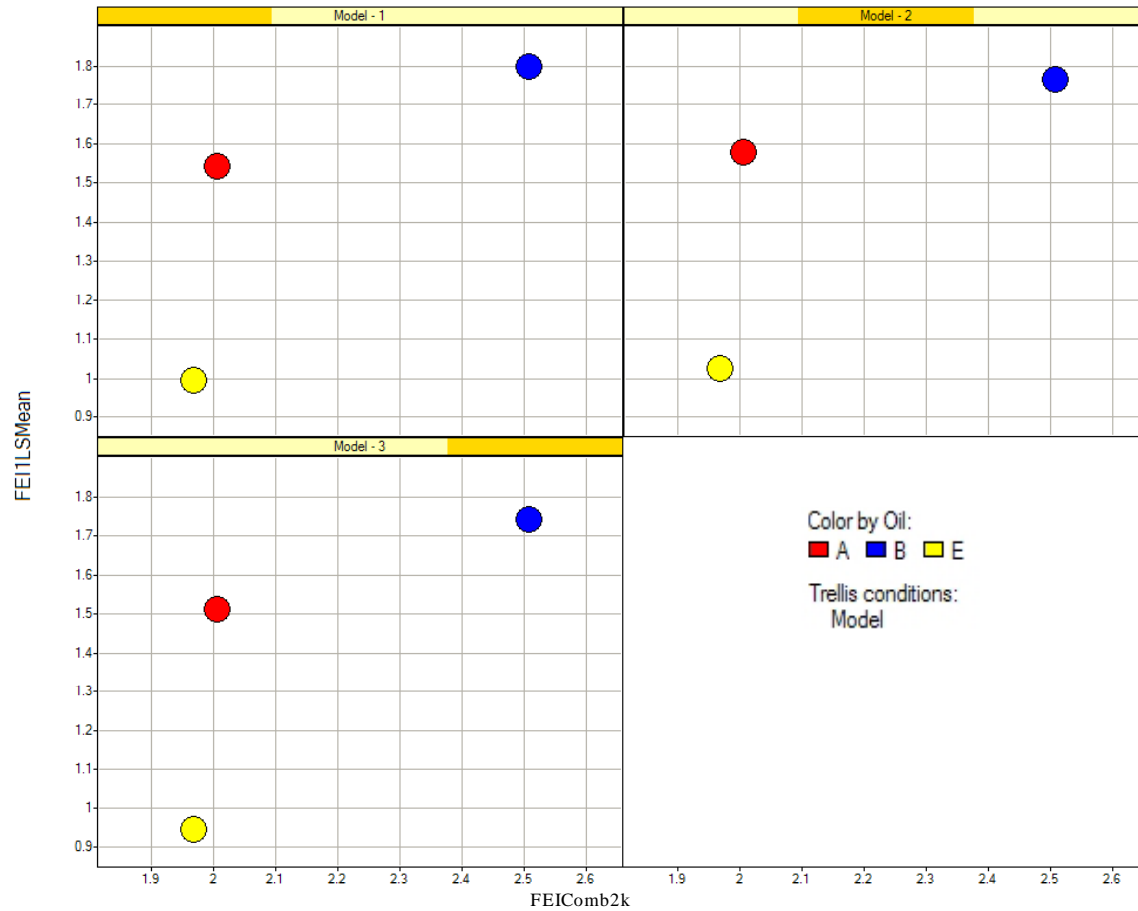
Prove Out Matrix Summary

- Test matrix designed to show discrimination of FM and Viscosity effects
- Baseline weighting established
- Stage weighting established
- FEI-1 - FM and Vis Discrimination (0.05 Significance)
- FEI-2 - Vis Discrimination (0.05 Significance) FM directionally correct

Summary

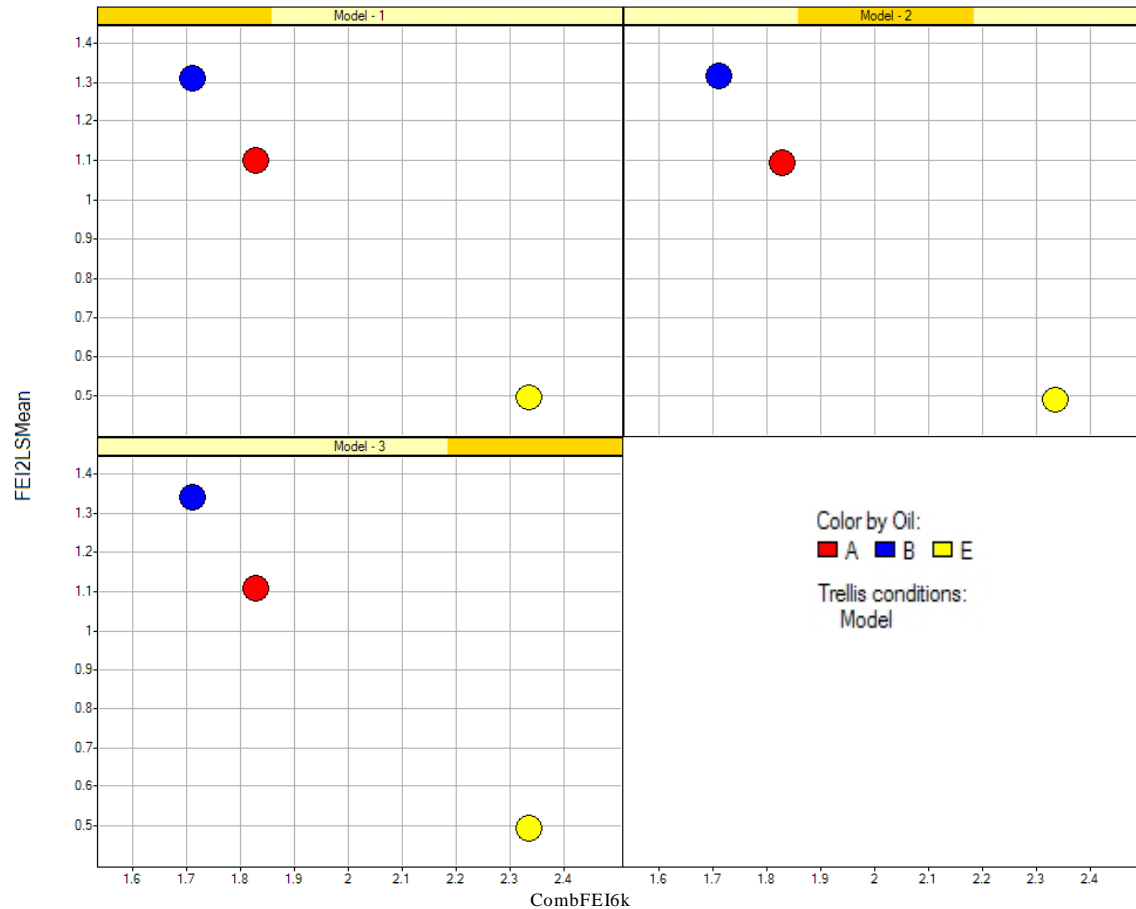
- FTP Fuel Economy Task Force charged with developing replacement for Sequence VIB fuel economy test
- Consortium formed to fund and oversee development of the new test, Sequence VID
- Vehicle testing completed

FEI1-FTP FEIComb 2k-mile Correlation



VID Consortium Report
ILSAC/Oil Meeting
Sept 3, 2008

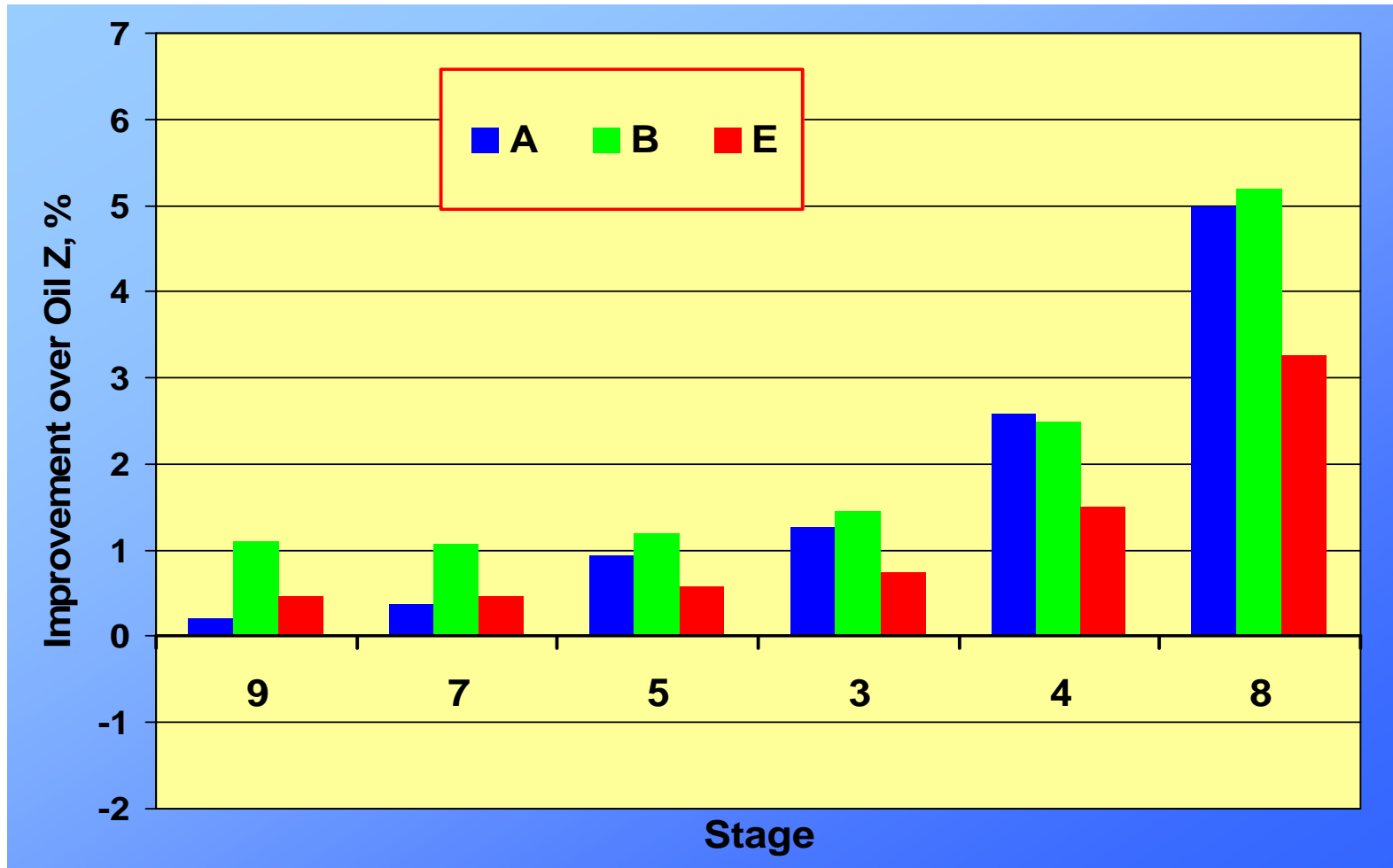
FEI2-FTP FEIComb 6k-mile Correlation



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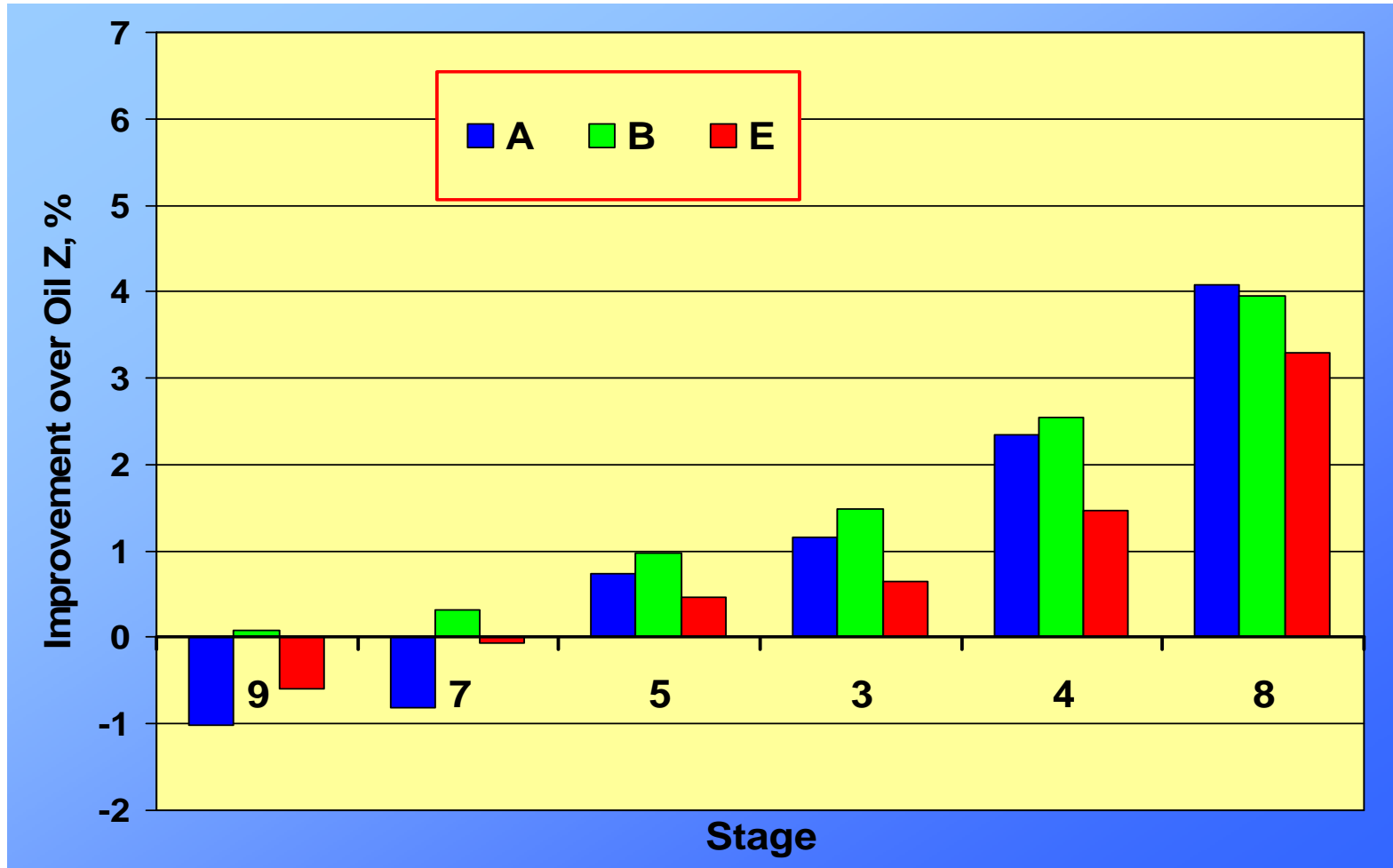
Prove Out Matrix Results - FEI 1

- IAR -



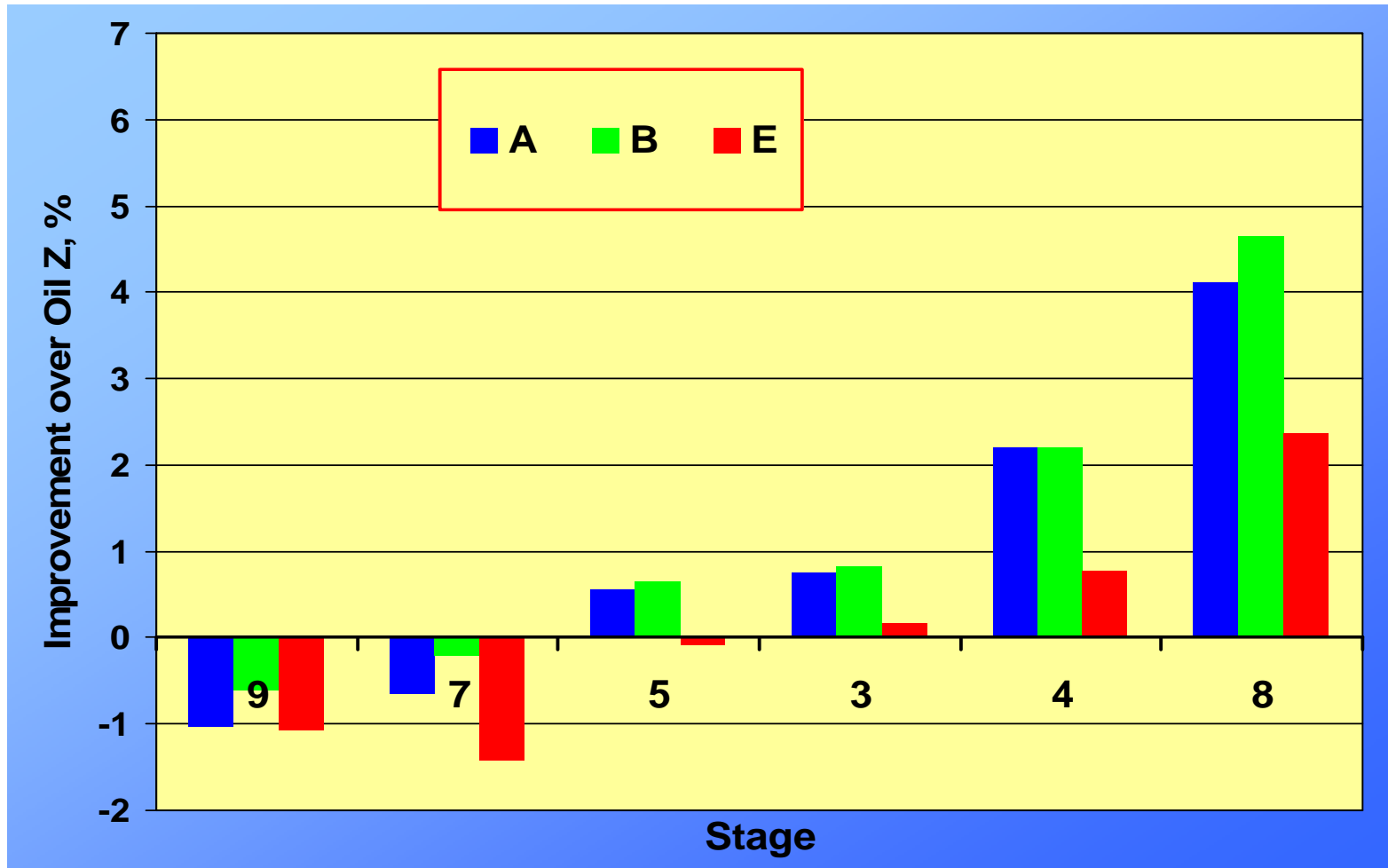
Prove Out Matrix Results - FEI 1

- SwRI -



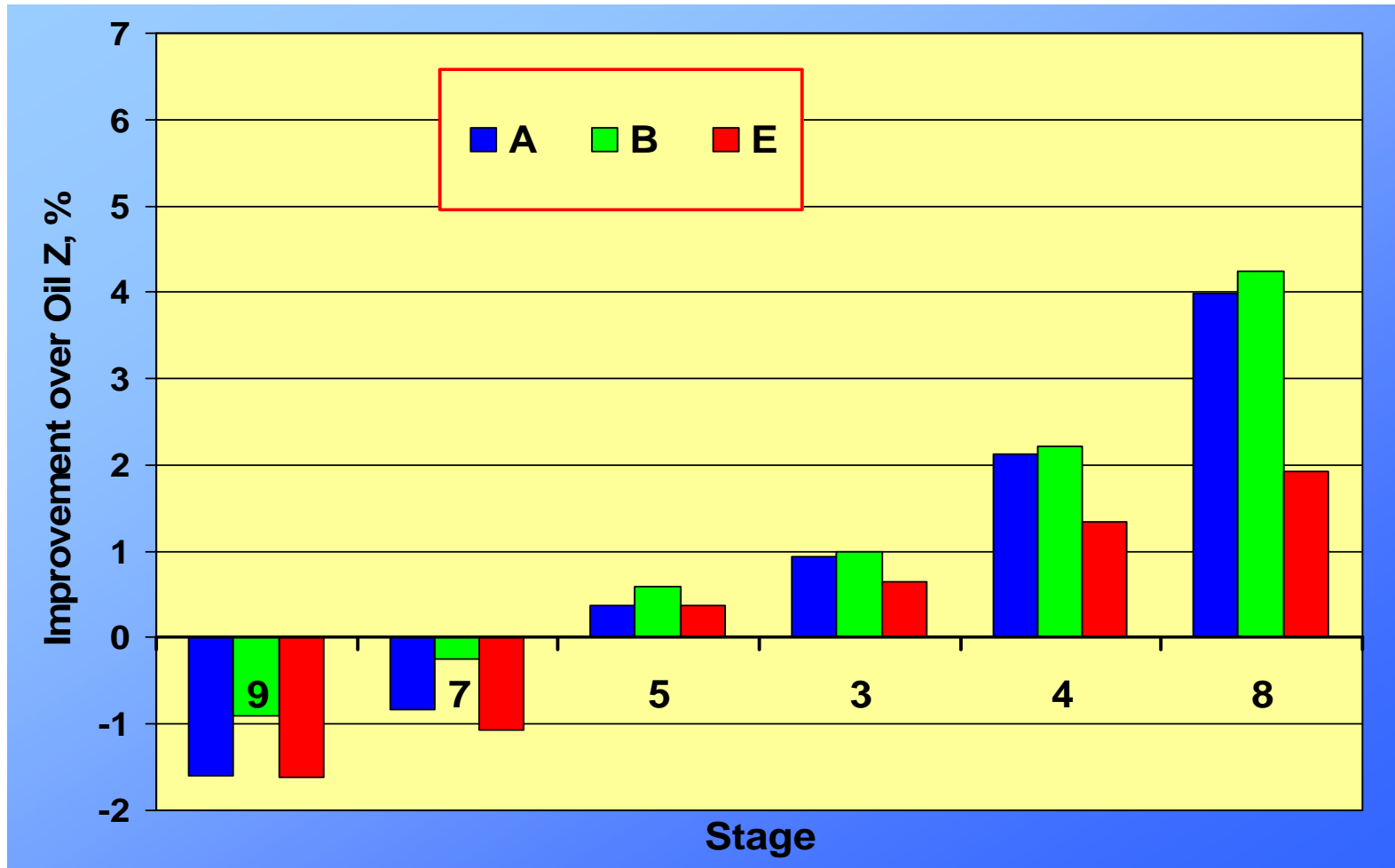
Prove Out Matrix Results - FEI 2

- IAR -



Prove Out Matrix Results - FEI 2

- SwRI -



Sequence VID – Initial Stage Conditions

Based upon engine operating conditions measured during FTP testing, the following initial 10 stages were selected – later reduced to 6 stages

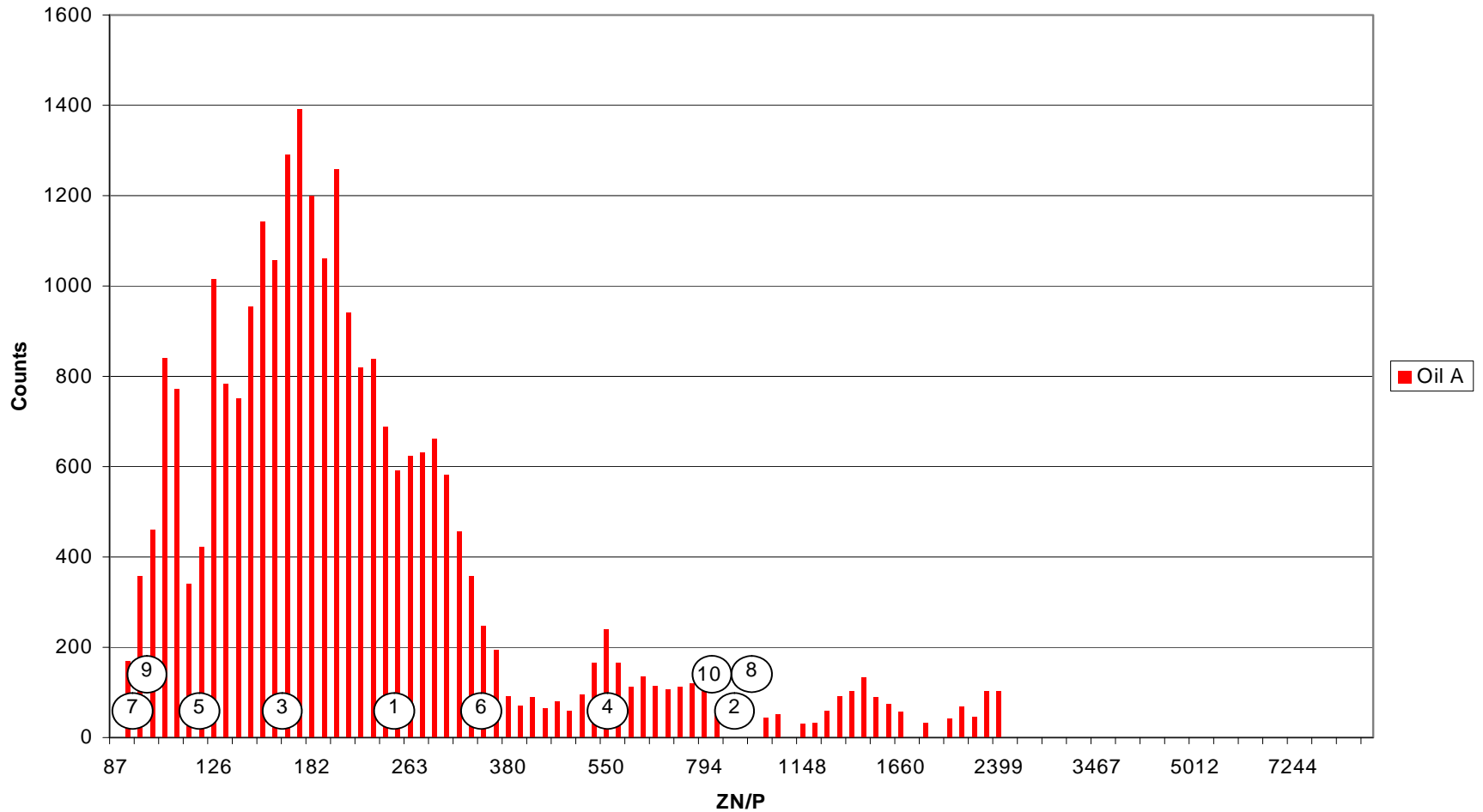
		Stage 3	Stage 4	Stage 5		Stage 7	Stage 8	Stage 9	
Speed, rpm		2000	2000	1500		695	695	695	
Torque, NM		105.0	105.0	105.0		20.0	20.0	40.0	
Power, kw		22.0	22.0	16.5		1.5	1.5	2.9	
Oil Temp, °C		115	65	115		115	35	115	
Coolant In Temp, °C		109	65	109		109	35	109	

Matrix I - Oil Aging Conditions

- **Based upon matching 6,500 miles of vehicle use, Aging conditions set at:**
 - **2,000 rpm**
 - **110 Nm load**
 - **120°C Oil temperature**
 - **100 hours**
 - **Oil volume reduced by 0.5L**

ZN/P

FTP Stribeck - Oil A



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Matrix V - Prove Out

- **Goal: Demonstrate test's ability to discriminate**
- **Testing using final test conditions and procedure**
- **Statistically designed to show discrimination**
 - between viscosity grades
 - presence of friction modifier
- **All testing at IAR and SwRI**
- **Total of 16 tests**
- **Expected completion: August 1, 2008**

Sequence VID Test Status

- Vehicle Testing is complete
- Engine/dyno/stand set-up finalized
 - Draft of Test Procedure released to the industry
 - Hardware available to the industry
- Oil aging study completed, aging conditions finalized
- Evaluation of initial stages complete - number of stages reduced from 10 to 6
- Fresh and aged oil evaluation using reduced number of stages complete
- Prove Out Matrix underway
- Research Report in process

Questions ?