The Road to Improved Heavy Duty Fuel Economy

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Directions in Engine-Efficiency and Emissions Research Conference 2010

The Pressure to Improve HD Fuel Economy Increases

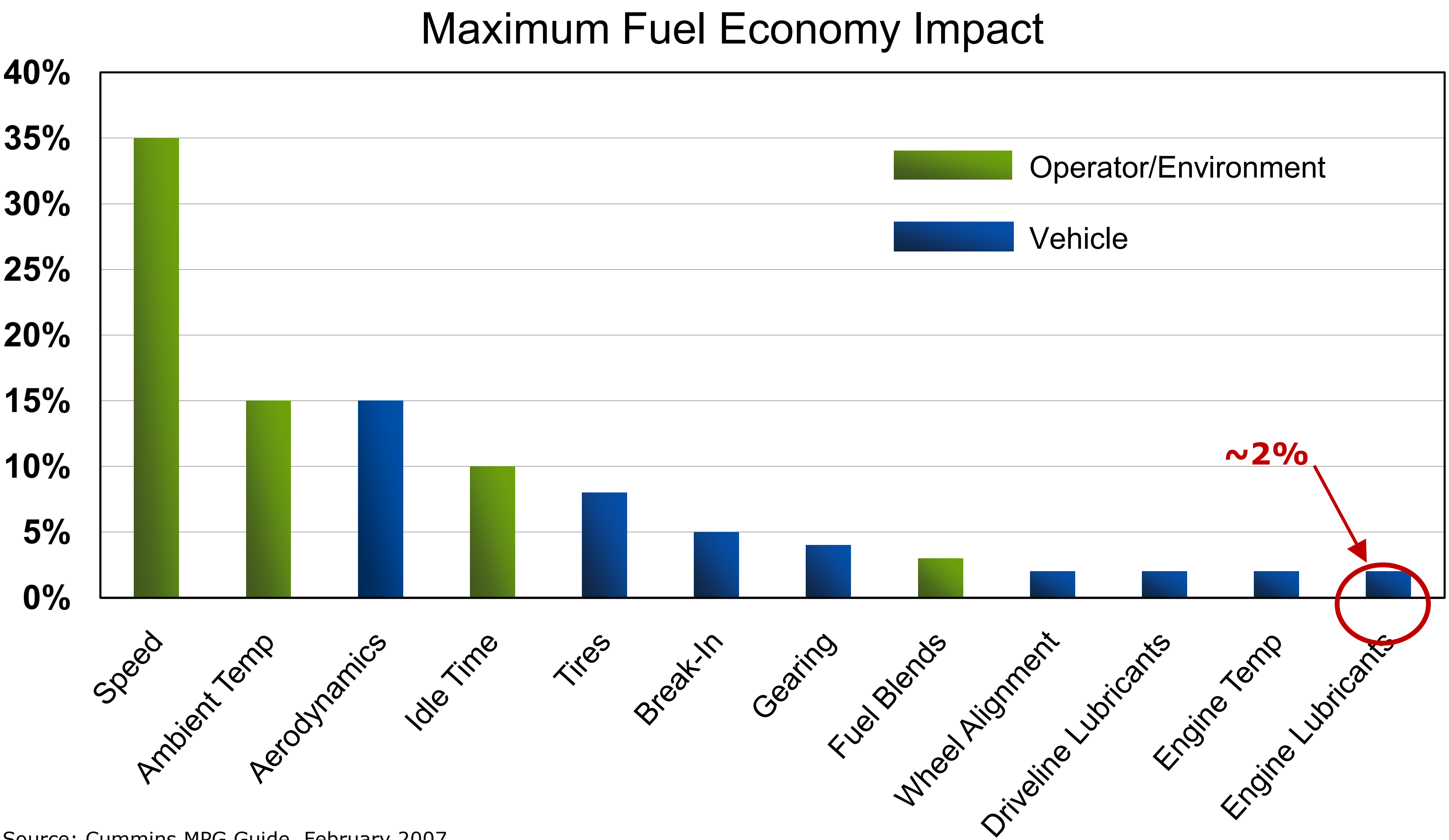
Reduce CO_2 Emissions

Fuel Economy Legislation

Improve Fuel Economy for Heavy Duty Diesel Engines

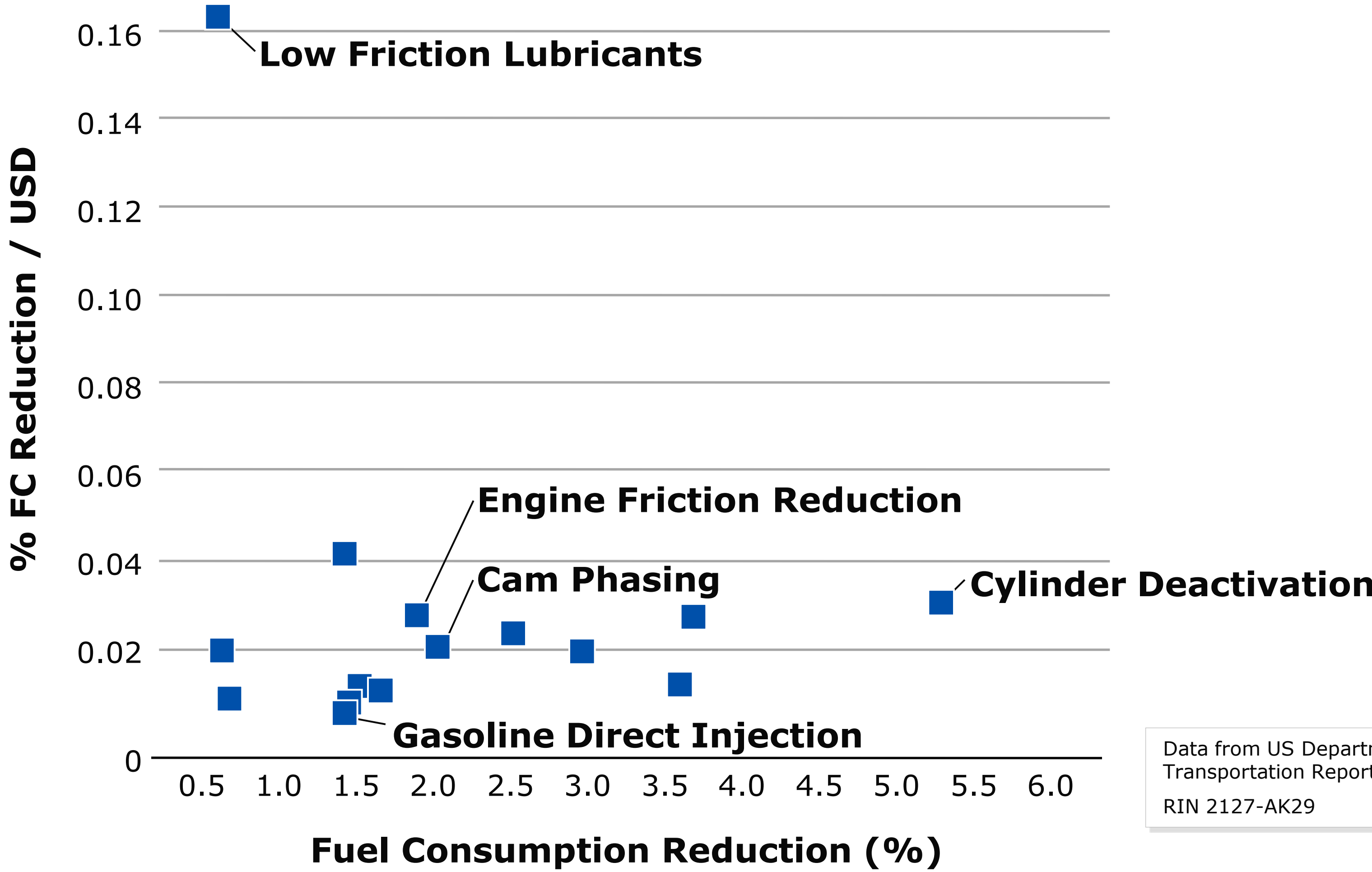
Rising Fuel Cost

Truck Fuel Economy Contribution by Area
Engine Oil Impact is Relatively Small



Source: Cummins MPG Guide, February 2007

Engine Lubricant is an Inexpensive Method to Improve Fuel Economy



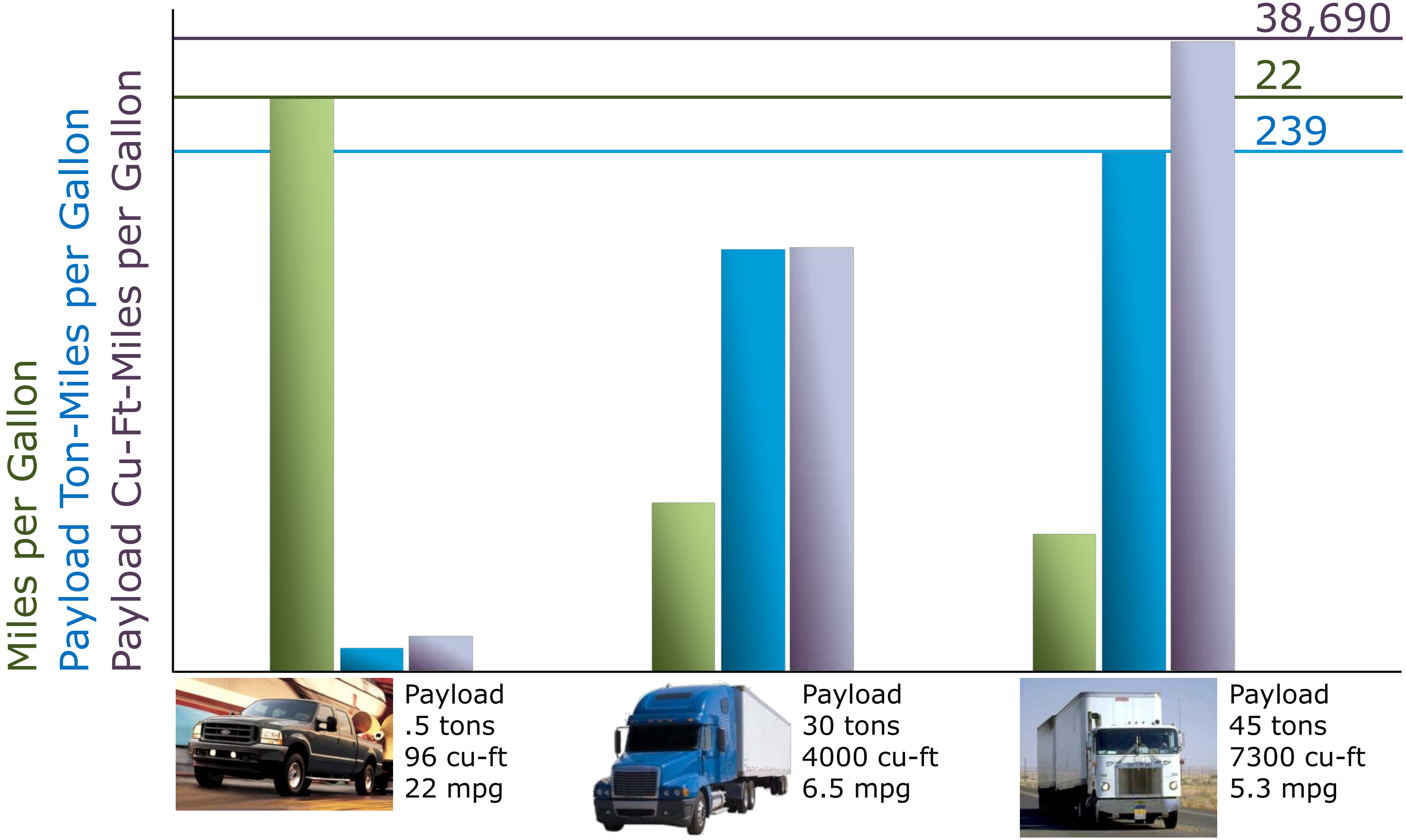
Data from US Department of Transportation Report
RIN 2127-AK29

From *North American Fuel Economy Testing*, T. Miller, 15th Annual Fuels & Lubes Asia Conference

Fuel Economy is Front Page News

Engine Oil Change Can Be Quickly Implemented and Has Immediate Impact on Entire Fleet

What is the Best Way to Measure Fuel Economy?

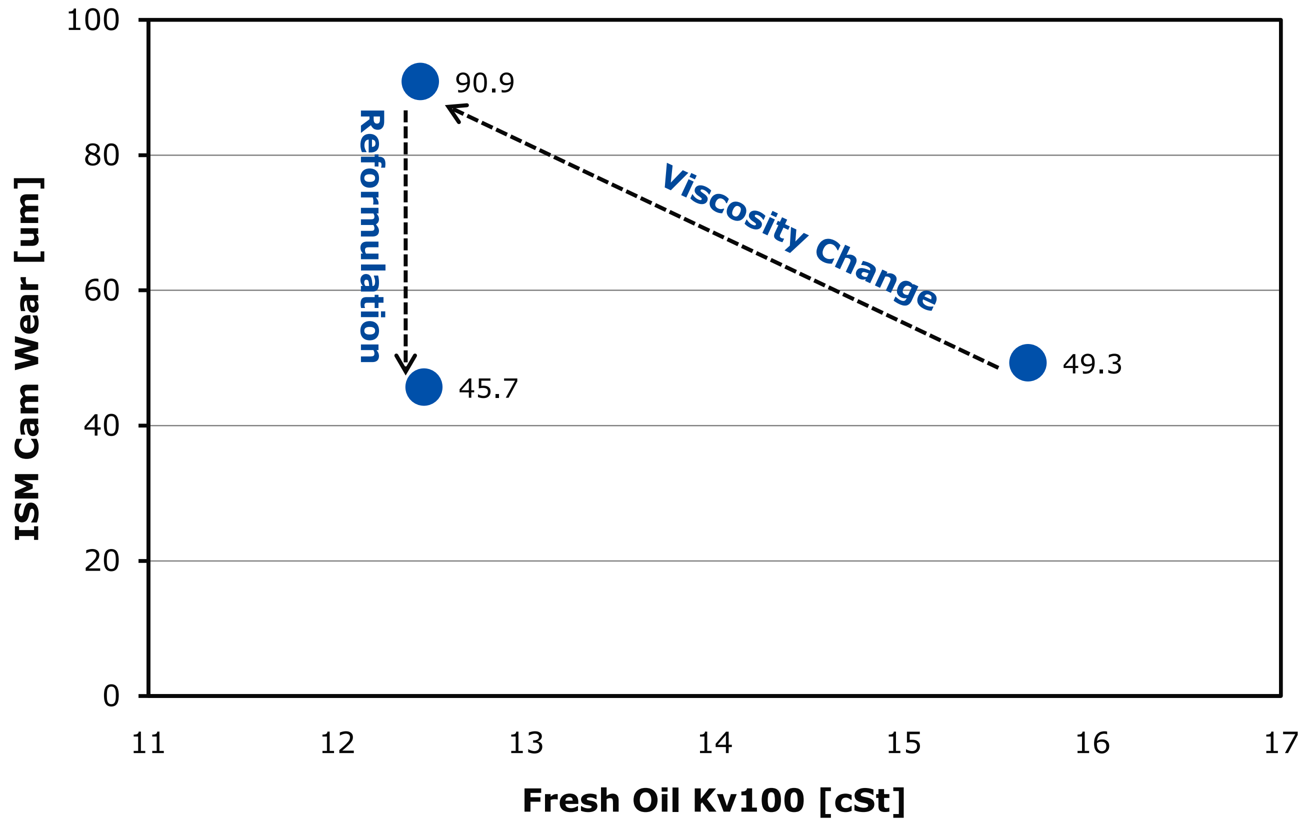


Payload
.5 tons
96 cu-ft
22 mpg

Payload
30 tons
4000 cu-ft
6.5 mpg

Payload
45 tons
7300 cu-ft
5.3 mpg

Gains in Fuel Economy Can’t Be at the Expense of Engine Durability



Achieving HD FE gains while maintaining other areas of performance from engine oil involves more than just reducing viscosity

The Lubricant Contribution to Improved Fuel Economy in Heavy Duty Diesel Engines

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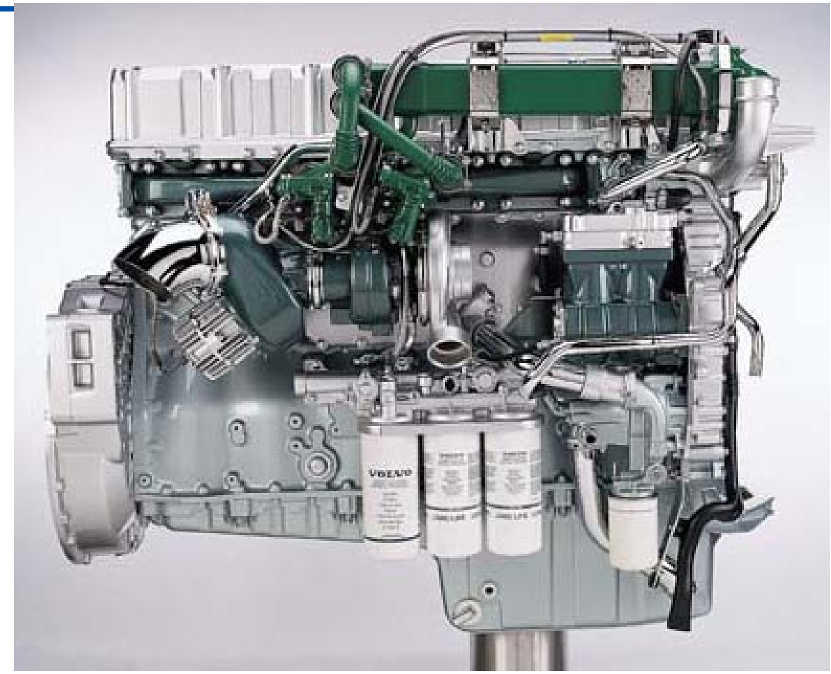
Presentation Overview

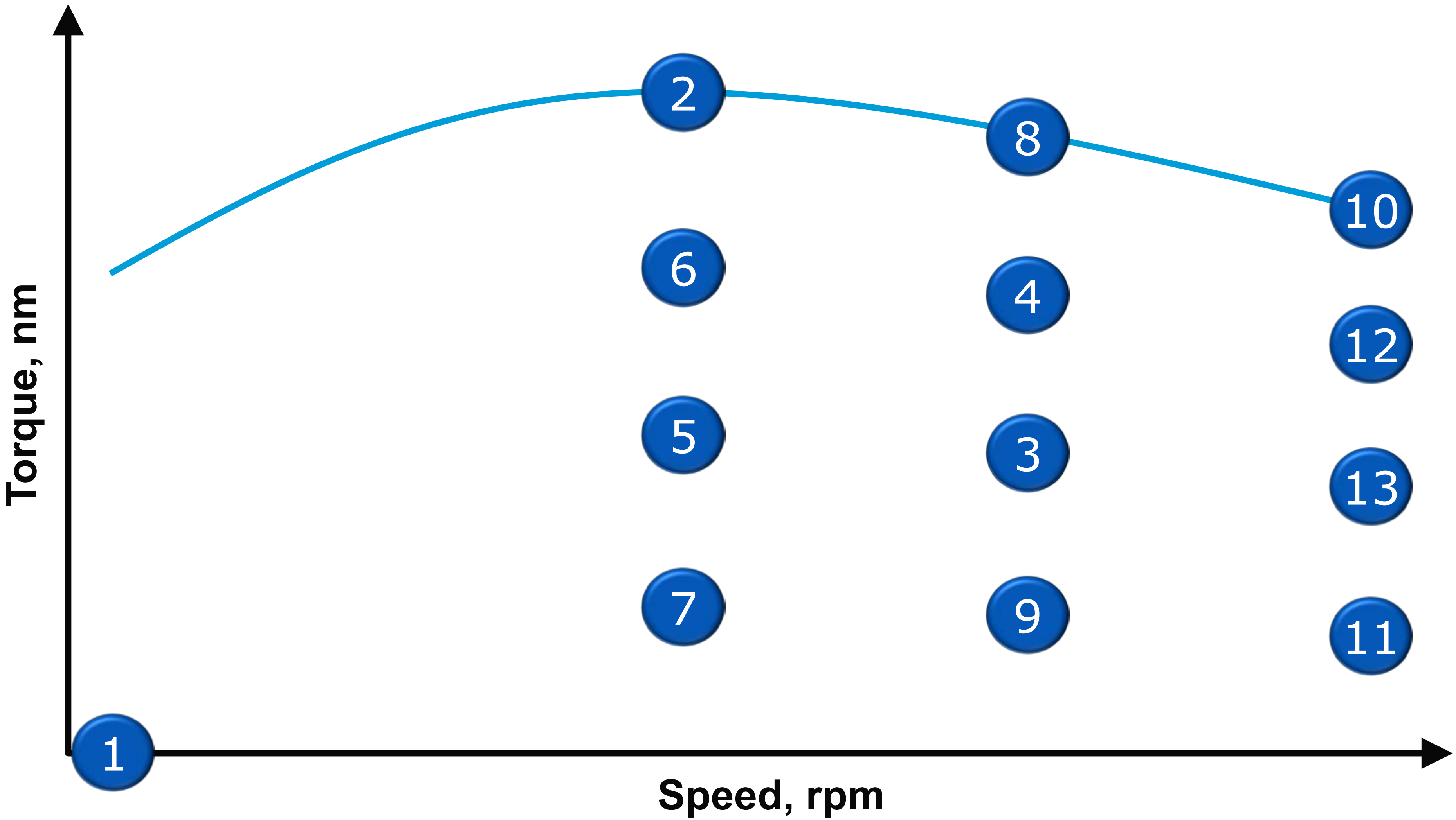


- The Volvo D12D Fuel Economy Engine Test Procedure
- An Evaluation of the Results From a Base Oil Type Comparison
- Introduction of a New Method of Analyzing the D12D FE Results
- Application of this method for
  - Viscosity grade comparison
  - Evaluation of the friction modifier impact
  - Study of the impact of soot
- Conclusions

Volvo D12D Fuel Economy Test

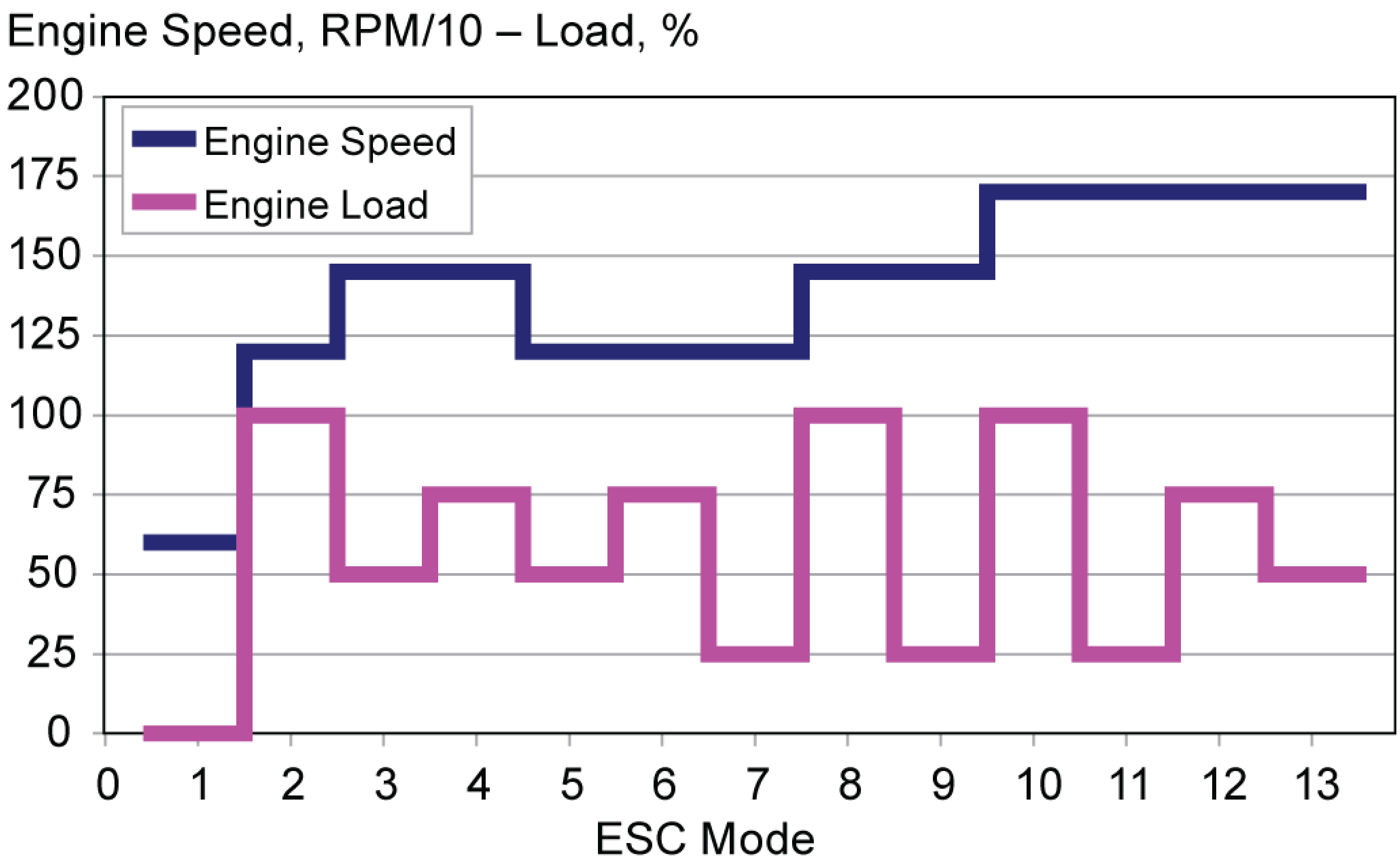
- Industry Standard Heavy Duty Fuel Economy Test
  - Test is also installed at Oronite's Rotterdam Lab
- Volvo Euro 3 Engine
  - 6-cylinder in-line configuration
  - 12.130 liter displacement
  - 338 kW at 1800 rpm
  - 2200 Nm at 1200 rpm
- Volvo D12D Fuel Economy Test Procedure
  - Laboratory engine test
  - 13-mode cycle at varying speeds/loads
  - SAE 15W-30 reference oil
  - Flush and run test procedure

The 13 Mode ESC Test



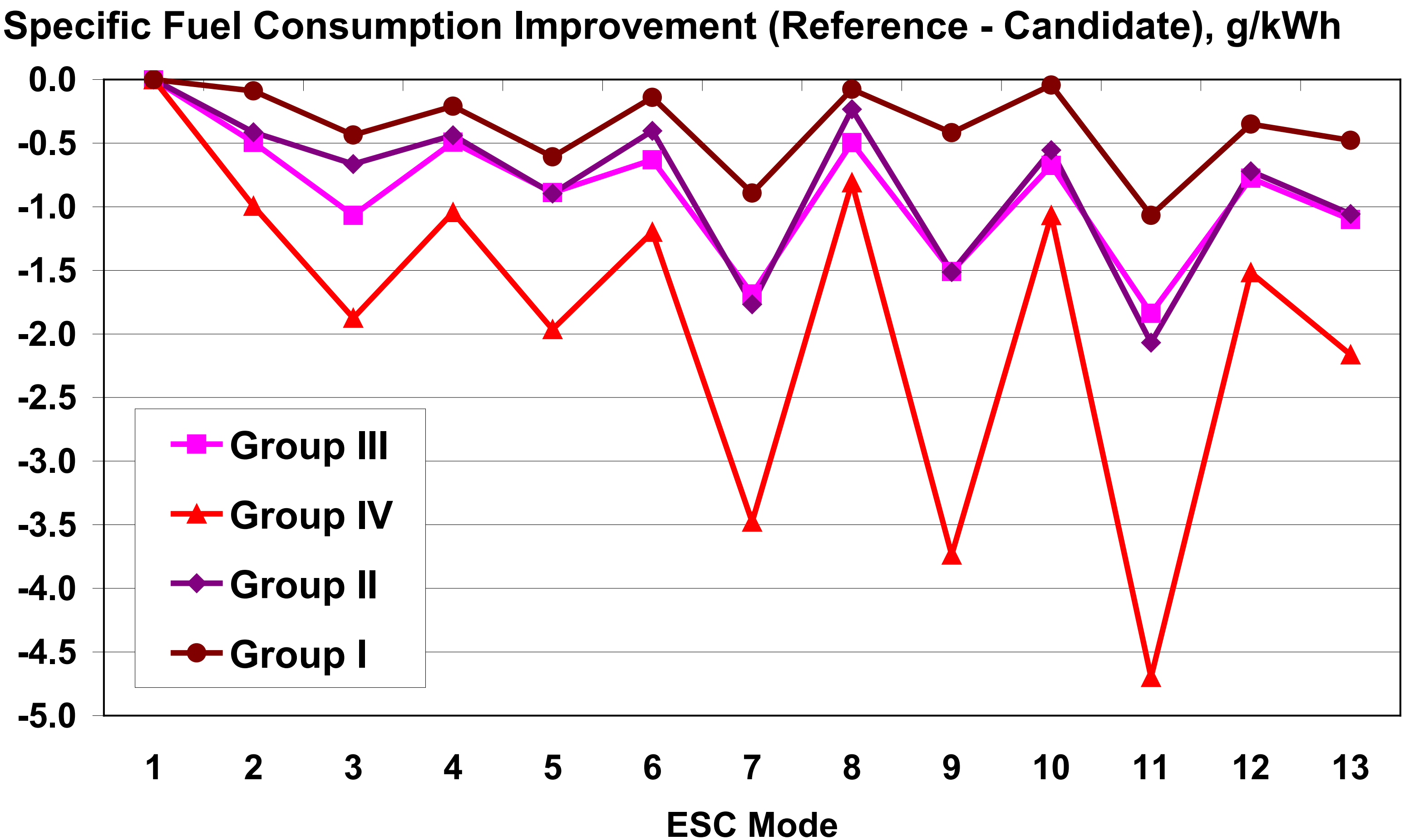
The Volvo D12D FE Operating Conditions

ESC modes 7, 9, and 11 are the low load modes

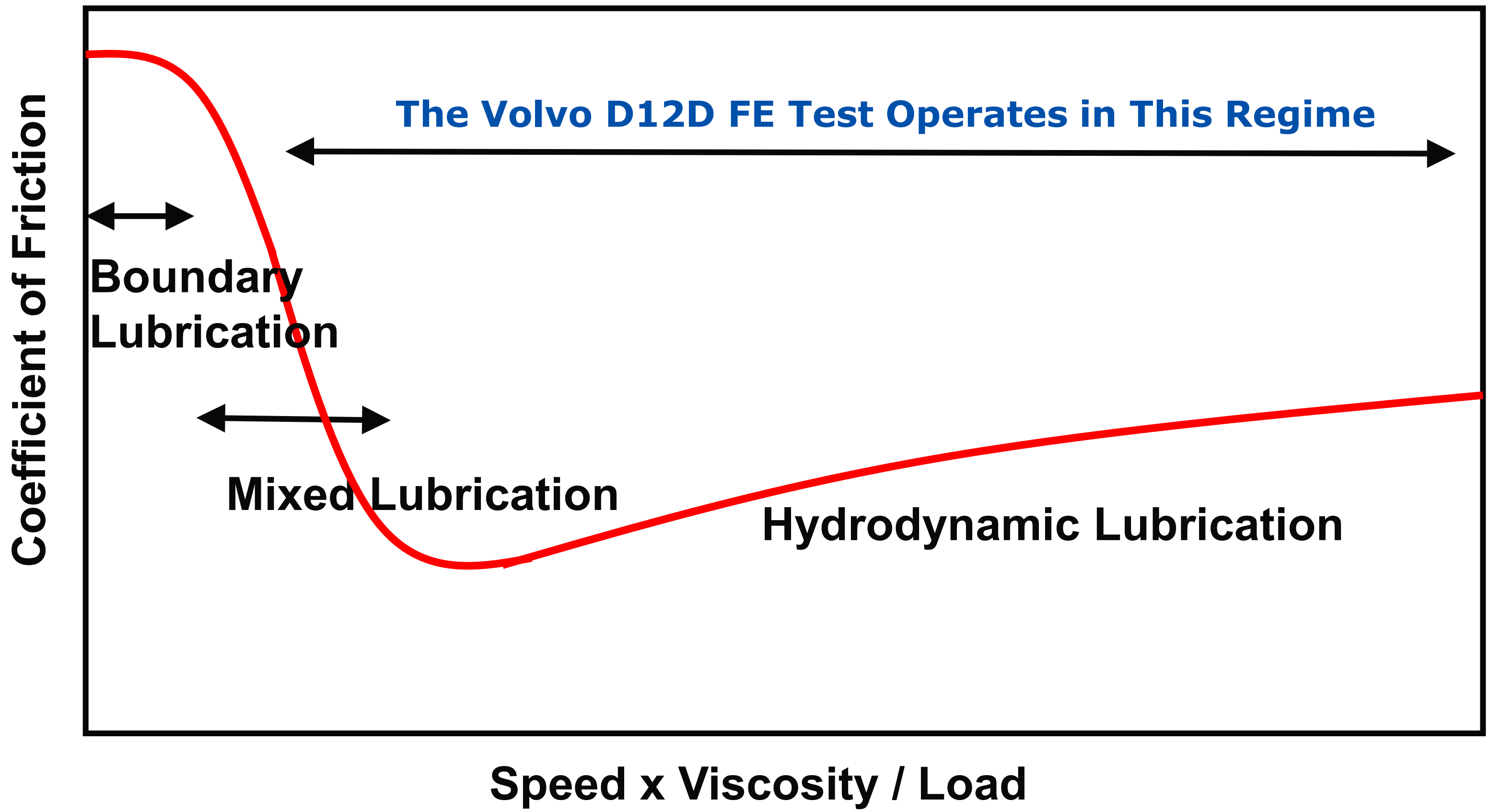


Fuel Consumption Improvements by ESC Mode

Some ESC modes magnify the impact, but the ranking of oils remains the same

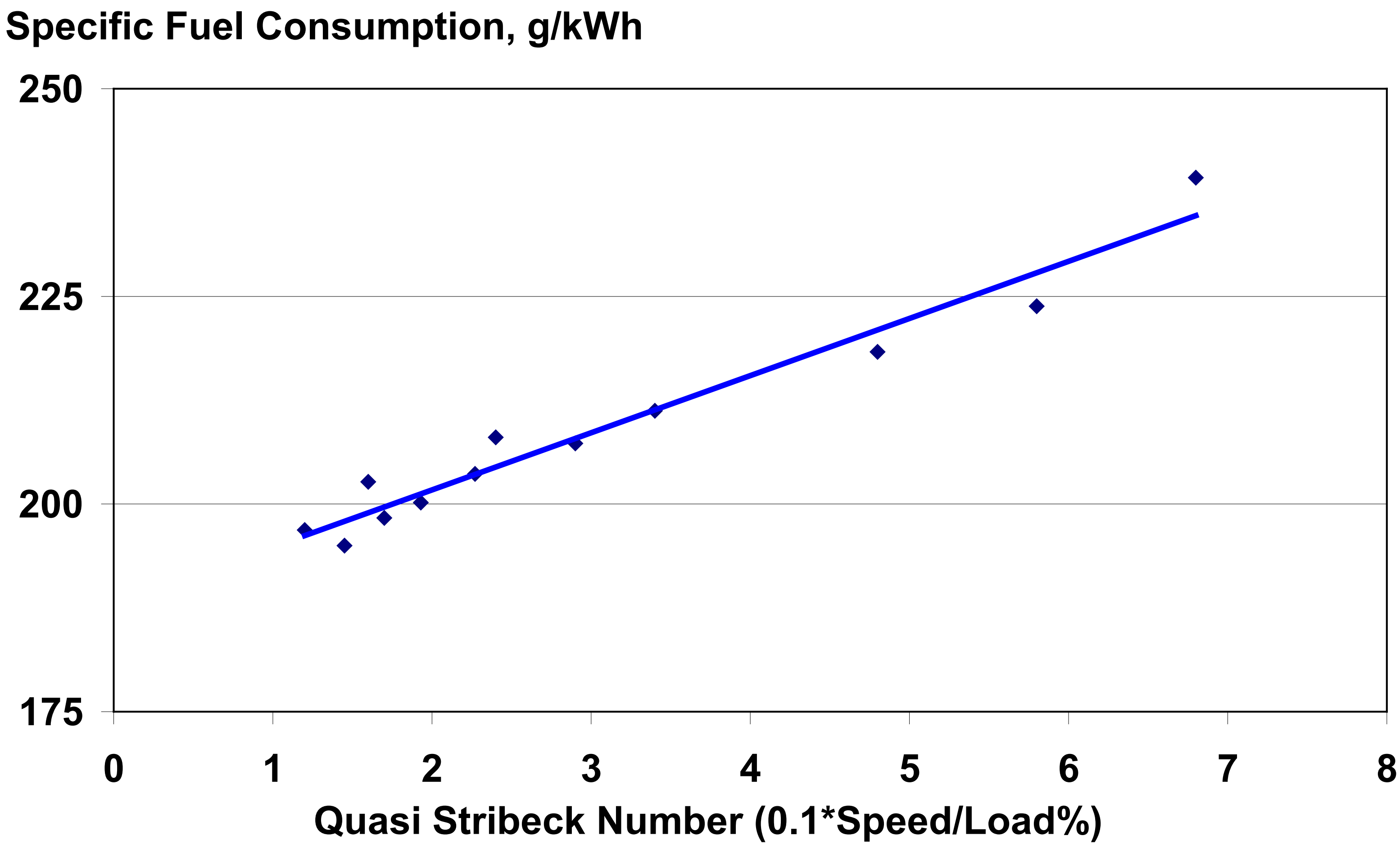


Different Sources of Friction

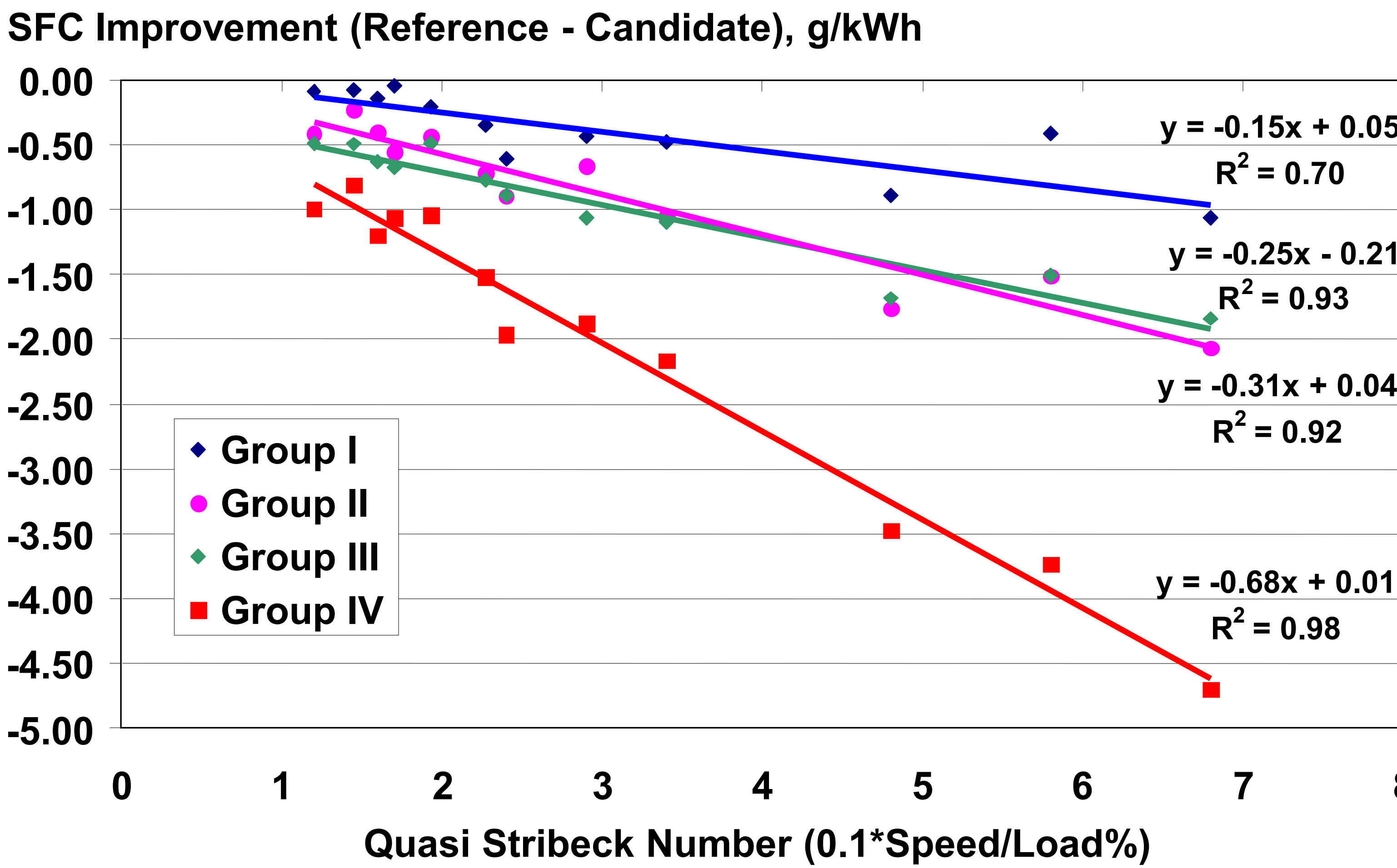


The Volvo D12D FE Operates Mostly in the Hydrodynamic Lubrication Regime

Candidate oils will be compared with this line for the 15W-30 reference oil

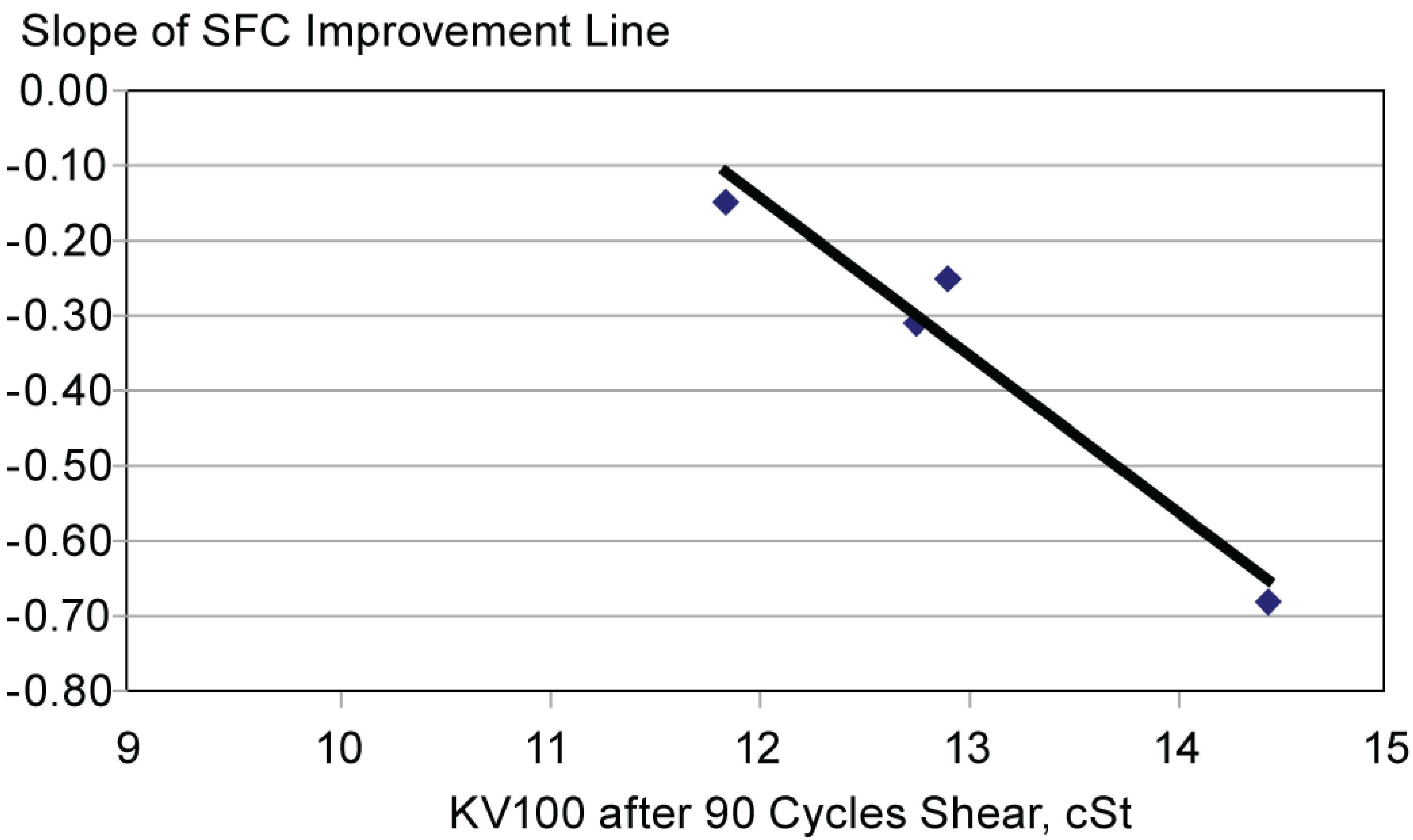


Fuel Consumption Effects are Magnified at Low Load/High Speed

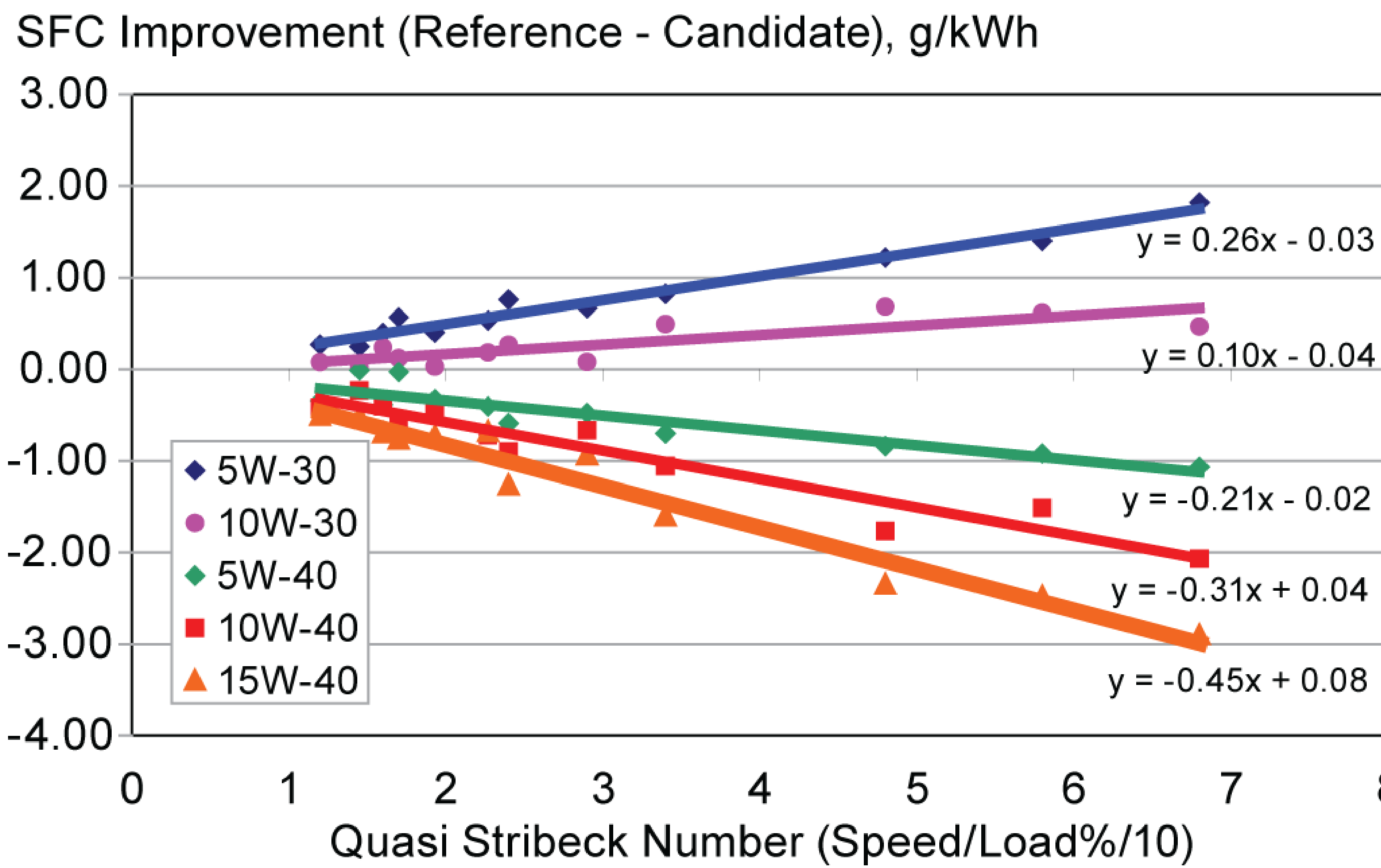


Fuel Economy Differences are Driven by Viscosity

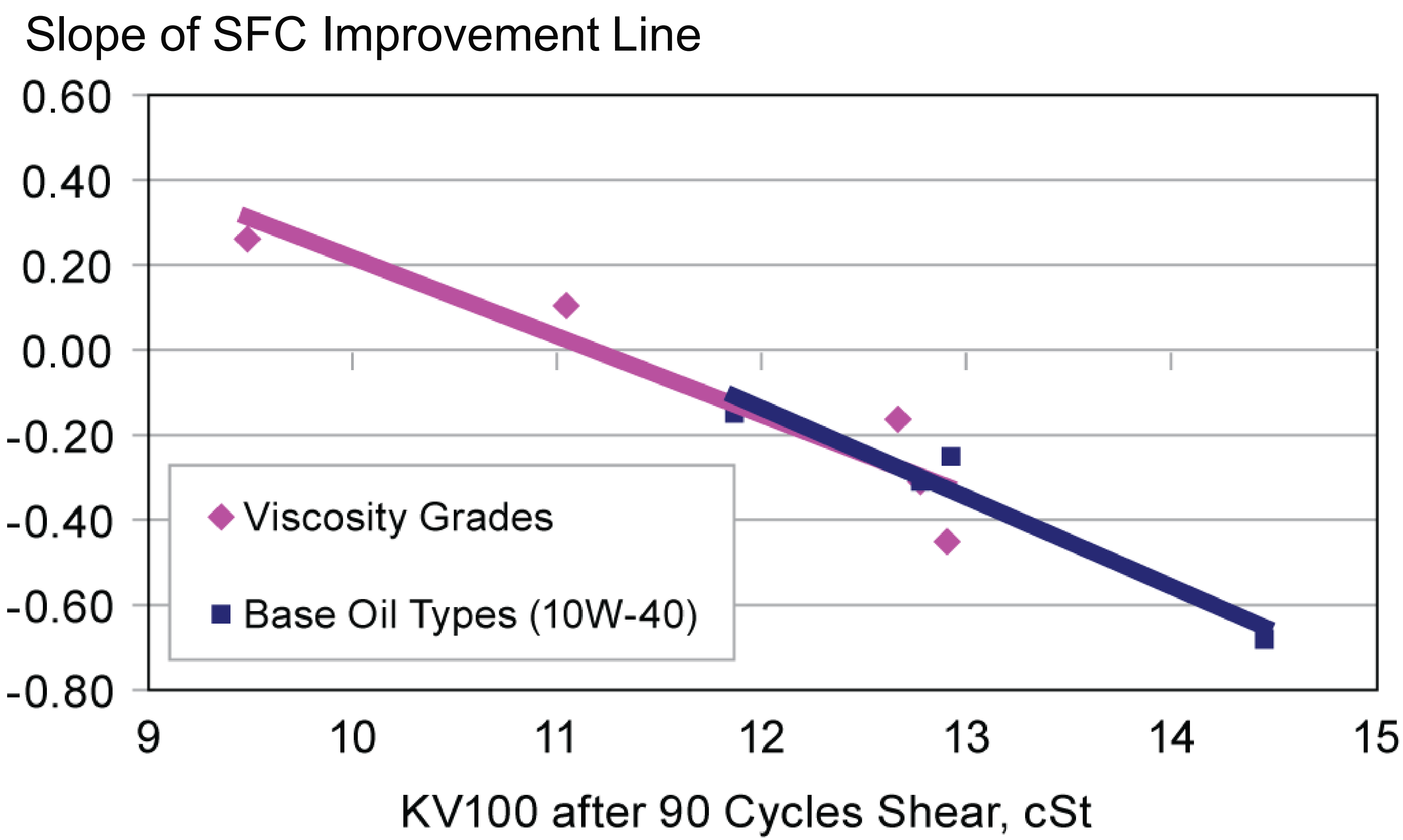
Fuel economy is determined by viscosity after accounting for permanent shear loss



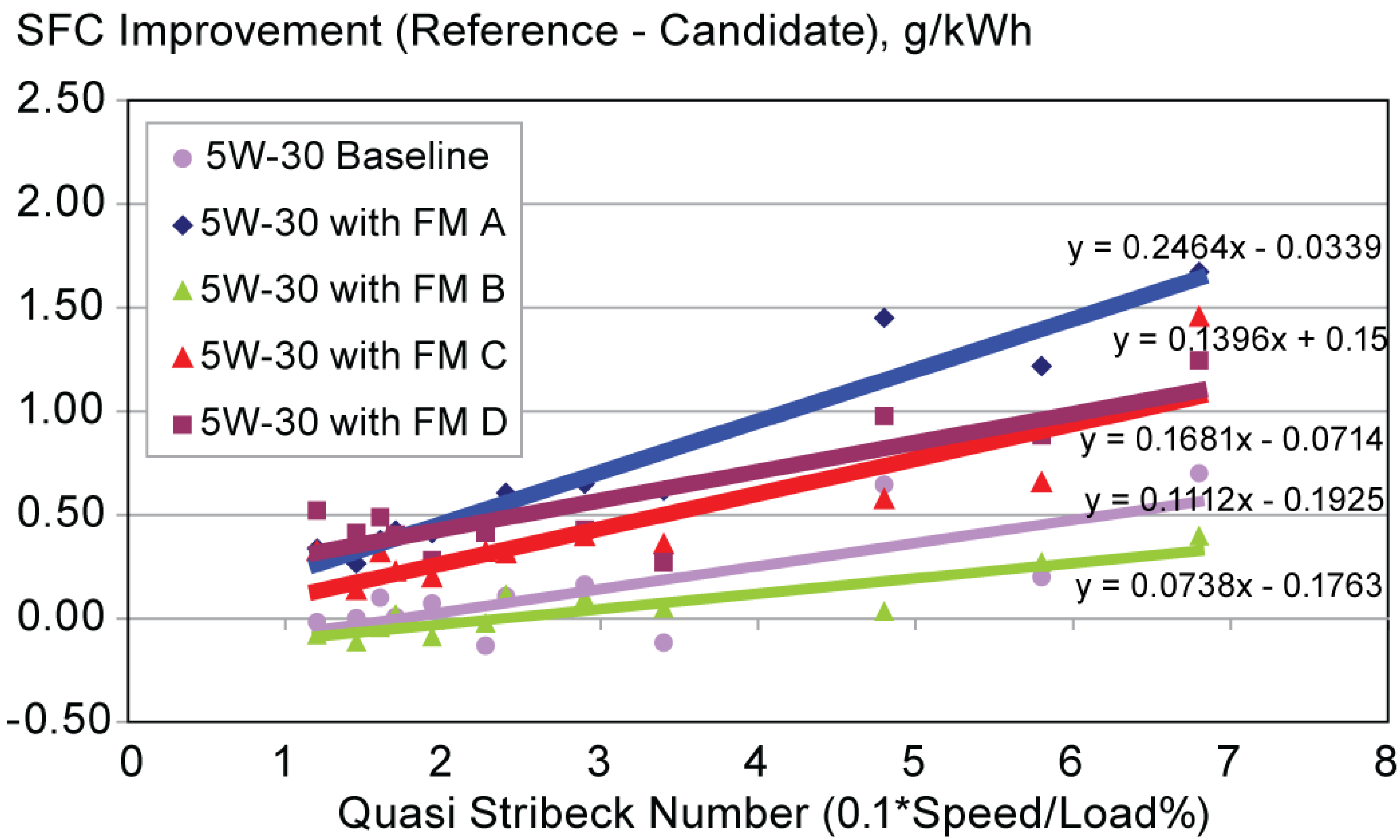
Lowering the High Temperature Viscosity Has the Biggest Impact on Fuel Economy



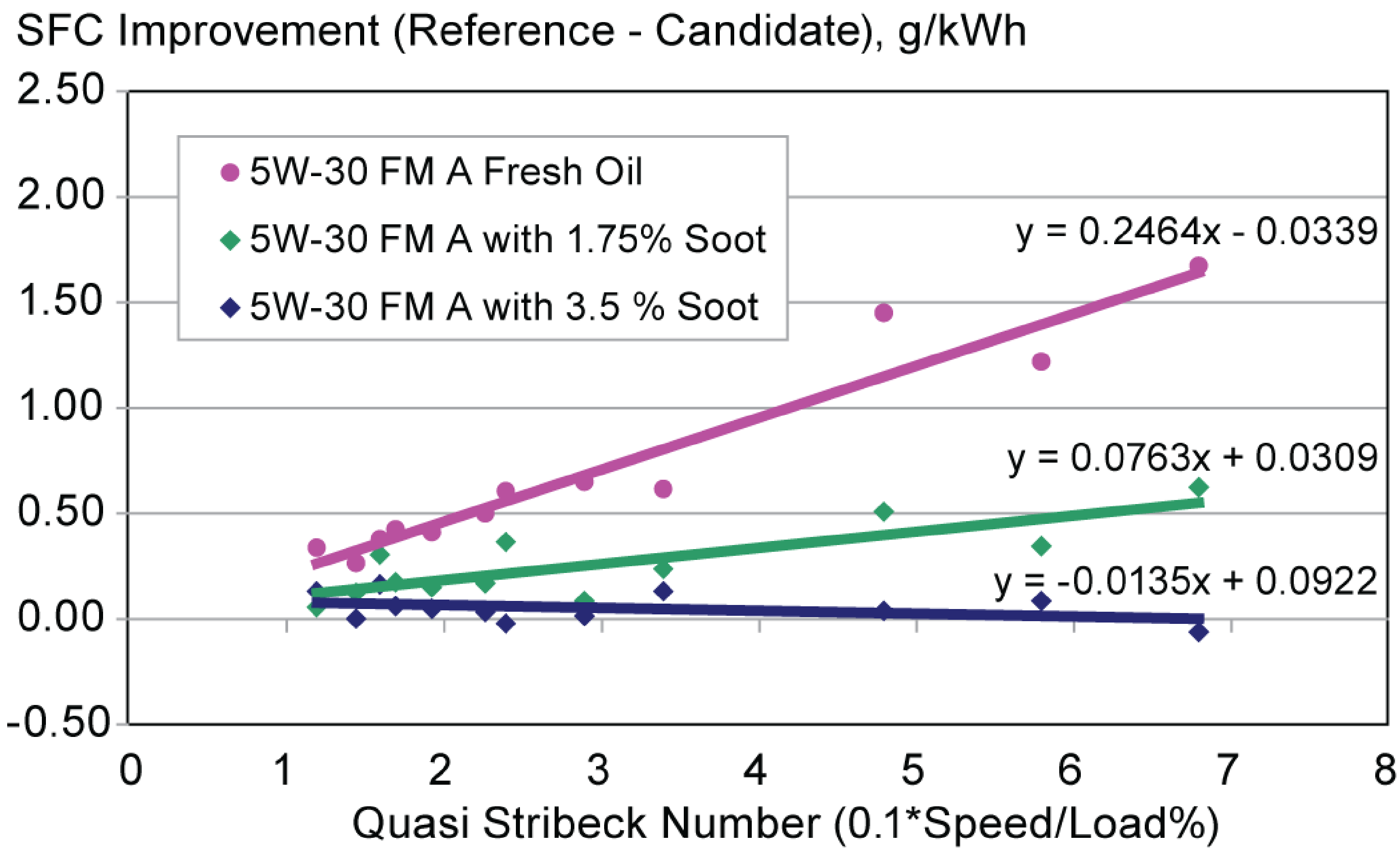
The Correlation is Valid Across Viscosity Grades



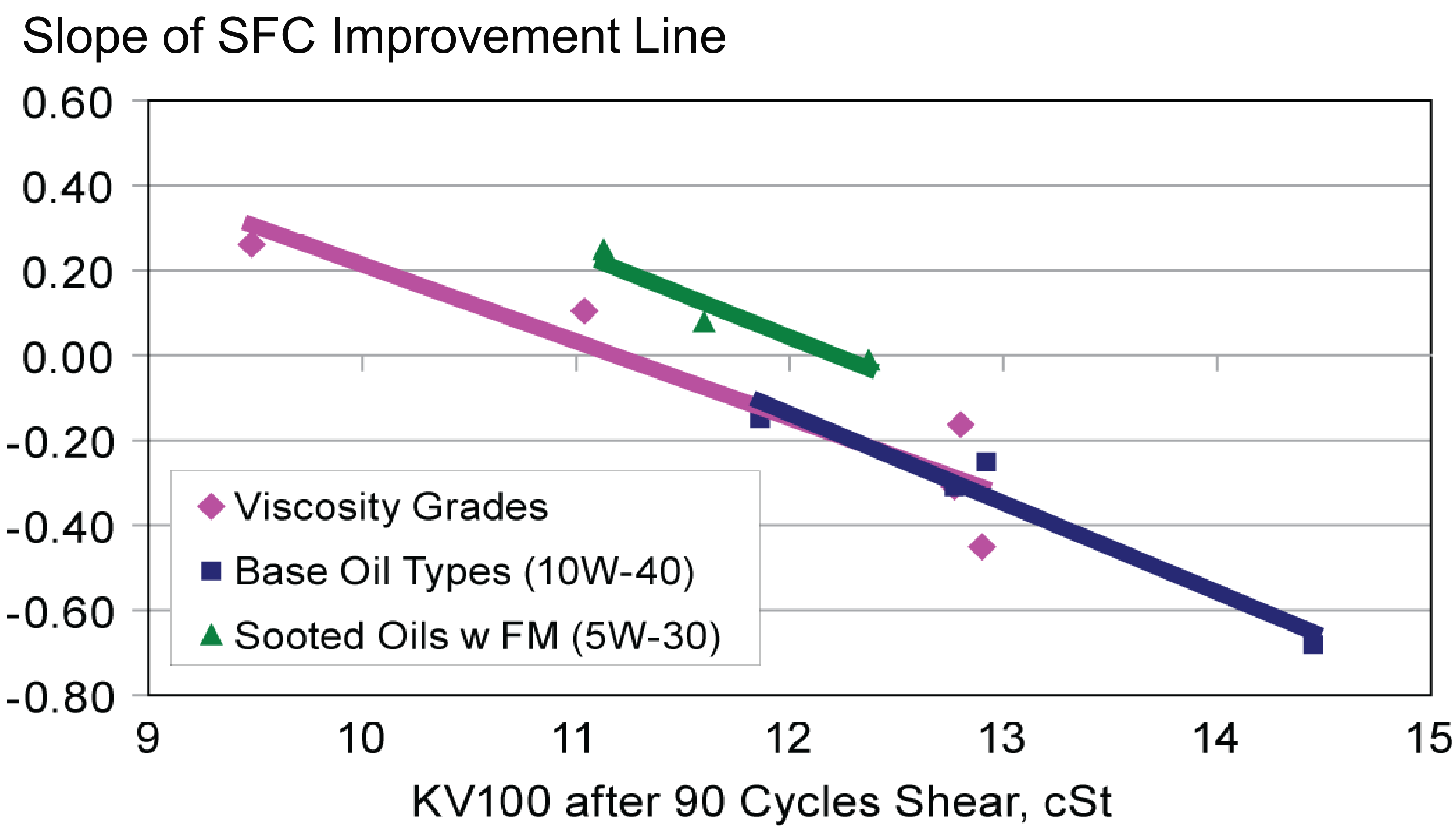
Friction Modifiers Can Impact HD Fuel Economy



Oil Aging/Soot Contamination Hurts Fuel Economy



FE Deterioration Caused by Viscometric Changes
FM Effect Remains



Conclusions

- Fuel economy in heavy duty diesel engines can be improved by lowering the viscosity of the engine lubricant

- The observed impacts are magnified when either the engine speed is increased or the load is decreased, conditions representative of long distance on-highway driving

Conclusions

- The lubricant in the engine is exposed to high shear, but the conditions that show the biggest response are assumed to be conditions where hydrodynamic lubrication prevails, which explains why the best correlation with fuel economy is found with the sheared high temperature viscosity

- Engine lubricant additives such as friction modifiers, traditionally known to improve fuel economy in passenger car engines, have shown a response in heavy duty diesel engines

Conclusions

- Aging and contamination of the engine lubricant with soot particles results in a viscosity increase which causes a deterioration of fuel economy that can be many times greater than the fuel economy benefits that can be achieved with lubricant modifications

- Controlling soot, oxidation, and evaporation-related viscosity increase remains a critical factor for optimizing heavy duty diesel engine lubricants, its impact on maintaining fuel economy control until now, has not been fully recognized