Formulating an Engine Oil

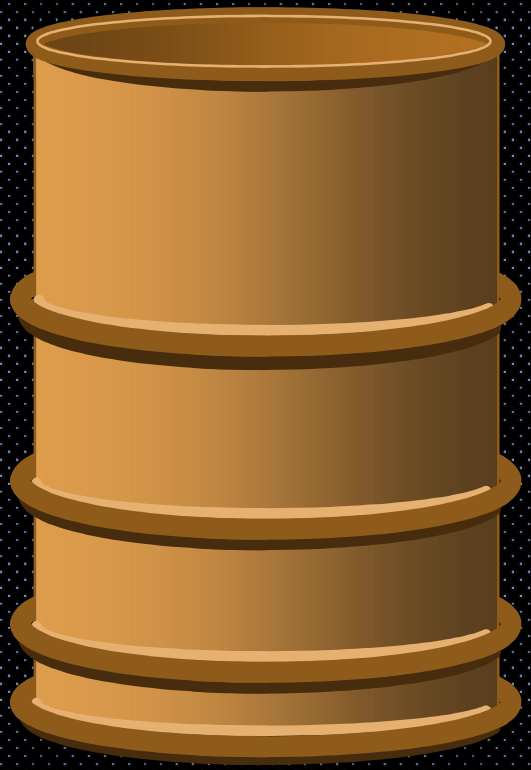
STLE Toronto Section Meeting

Nov 10 2015

Paul Sampson – Lubrizol Canada

Formulating an Engine Oil

Typical Motor Oil Composition



Base Oils: 70-95%

Performance Package: 5-20%

Viscosity Modifier: 0-20%

Pour Point Depressant: 0-1%

Formulating an Engine Oil

Must Meet Many Needs...

- What the Vehicle Needs
- What the Government Requires
- What the OEM Wants (Perceptions)
- What the Owner Wants to Use
- What the Oil Company Wants to Market
- What the Additive Company Wants to Make

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What the Engine Needs from a Motor Oil...

- Metal-to-Metal Friction Reduction
- Contaminant Containment
- Heat Transfer
- Rust Protection
- Sealing
- Cleaning
- Proper flow

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What the Government Requires…

- Reduced Emissions
- Increased FE
- Safety
- Environmental impact – Disposal etc.

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What the OEM Wants from a Motor Oil...

- Confidence of Performance
- Engine Durability (No Warranty Claims)
- Low Price (for Factory-Fill and Service-Fill Oils)
- Reduced Emissions
- Improved Fuel Economy
- Enabling technology

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What the Consumer Needs/Wants...

- Low Cost
- Longer Drain Intervals
- Confidence they are taking good care of the Engine - Durability
- Premium Performance for Premium Engines
- Dedicated versus Universal Oils for Heavy Duty Diesel Oils
- Fuel Economy
- Environmental Responsibility

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What the Oil Marketer Needs/Wants...

- Performance
- Differentiation
- Low Cost/High Price
- Ease of Blending
- Avoid Conflict with OEMs
- Regulatory Compliance

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What the Additive Company Wants...

- Meet Requirements of Wide Range of Applications
- Differentiation
- Minimal Test Costs
- OEM plans – to produce enabling technology
- Ease of Regulatory compliance
- Low cost raw materials

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Oil Company Decisions

Base Oils

- Supplier: Imperial Oil, Petro-Canada, Chevron etc.
- Viscosity Grade: 100N, 150N, 240N, etc.
- Grouping: I, II, III, IV or V
- Processing: Solvent, Hydrotreated, Rerefined, or Unconventional

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Oil Company Decisions

Viscosity Grades

- Geographical Location
- Marketing Strategies - Differentiation
- OEM Requirements

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Oil Company Decisions

Performance (Detergent Inhibitor) Package

- Supplier: Lubrizol, Oronite, INF, Afton
- Performance Targets
- OEM Requirements
- Ability to Rationalize
- Treat Rate
- Robustness
- Cost Effectiveness

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Oil Company Decisions

Viscosity Modifier

- Supplier: Lubrizol, Oronite, INF, Afton, Evonik etc.
- Class: OCP, PMA, SBR, StarIP, etc.
- Type: Dispersant or Non-Dispersant
- Form: Solid or Liquid
- Shear Stability: High, Medium or Low

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Oil Company Limitations

- Base Oil Availability / Cost factors
- Ability to Handle Solid Polymers
- Ability to Handle Viscous Materials
- Ability to Store Large Volumes / Number of tanks etc
- Ability to Handle Several Components
- Blending capabilities
- Environmental Concerns

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Additive Company Decisions

Formulation Limitations

- Phosphorus Level for Passenger Car Motor Oils
- TBN Level for Heavy Duty Diesel Engine Oils
- Sulfated Ash Level
- Base Oil Coverage / Licensable products
- Viscosity Grades to Be Covered
  - Determines test strategy
- Global or Regional Requirements
- HTHS

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Additive Types

- Metallic Detergent
- Ashless Dispersant
- Antioxidant
- EP & Antiwear Agent
- Rust / Corrosion Inhibitor
- Friction Modifier
- Antifoam Agent

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Detergent Function

- High Temperature Deposit Control
- Receptor for Solids Contamination
- Neutralize Acids / TBN
- Rust Inhibition

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Metallic Detergents

Function:

- Provide High Temperature Cleanliness
- Control Corrosive Wear

Types:

- Metallic Soaps; Normally Na, Ca, or Mg
- "Soap" Substrates:
  - Sulfonates (Natural/Synthetic)
  - Salicylates
  - Phenates
  - Carboxylates

Mechanism:

- Suspend Soot via Micelle Formation
- Neutralize Acids from Engine Blow-By

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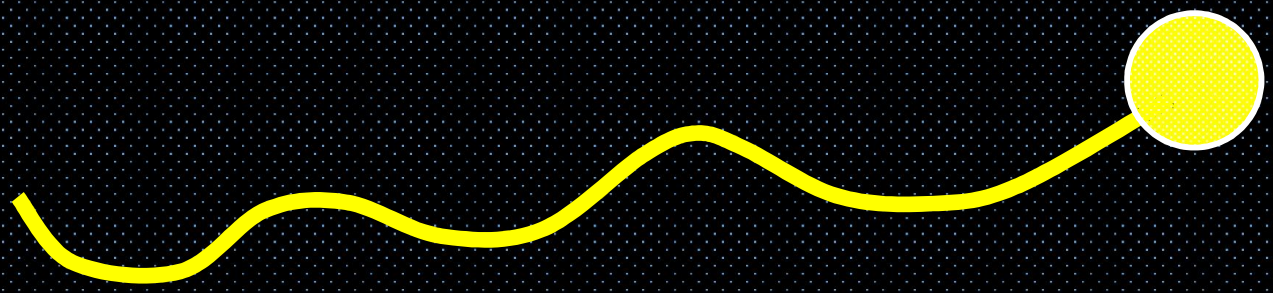
Detergent Structure

Metal Carbonate
(Overbasing)

Polar Head
(Metal)



Hydrocarbon Tail
(Substrate)

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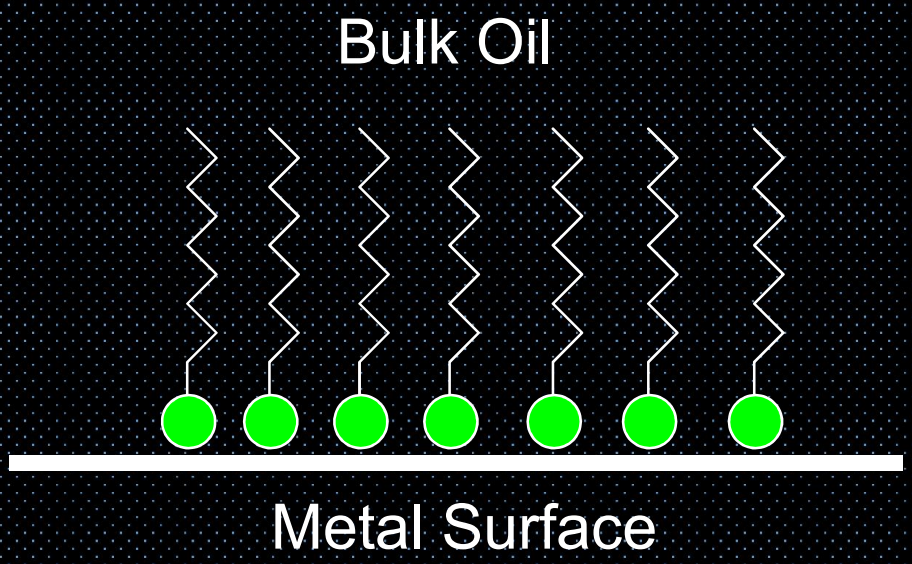
Detergent Mechanism



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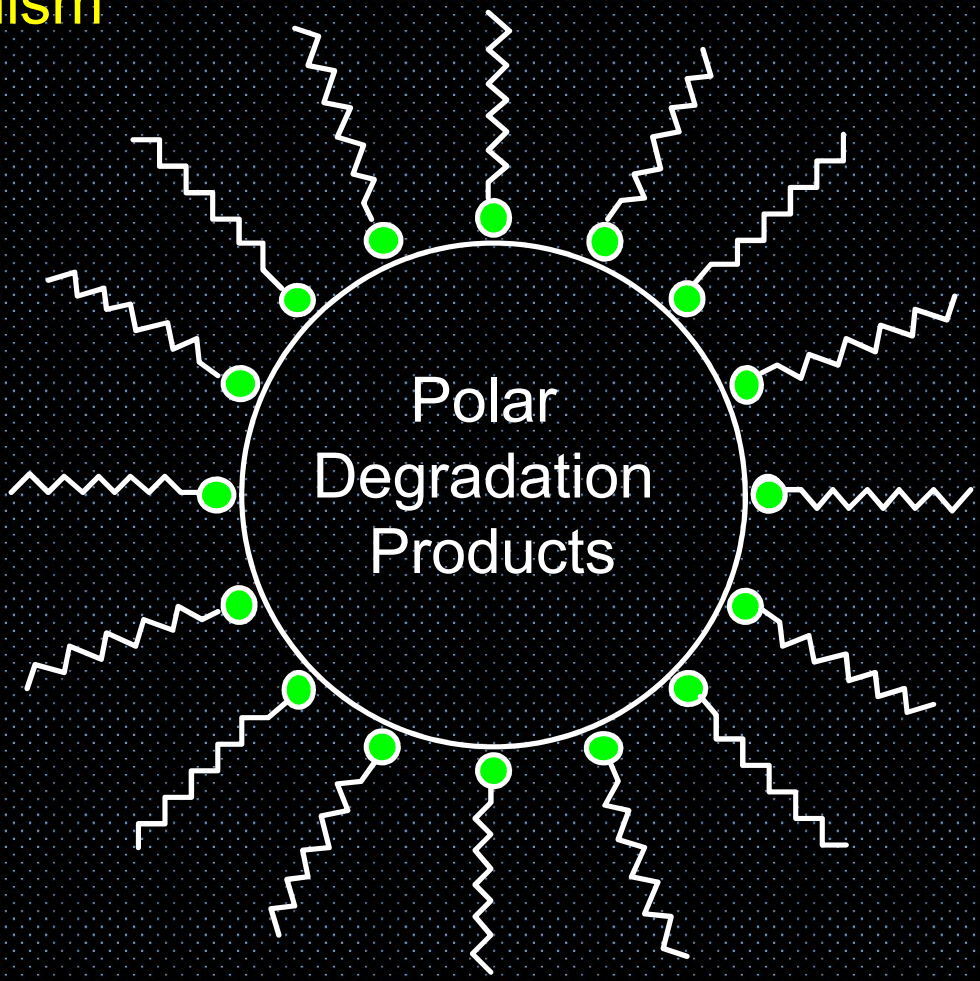
Detergent Mechanism



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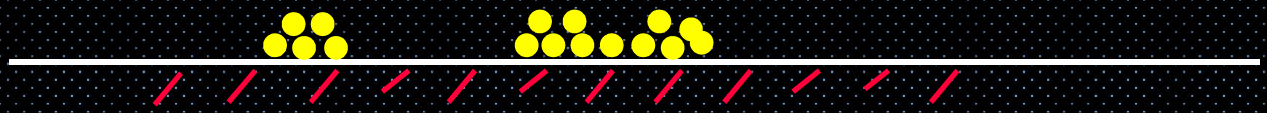
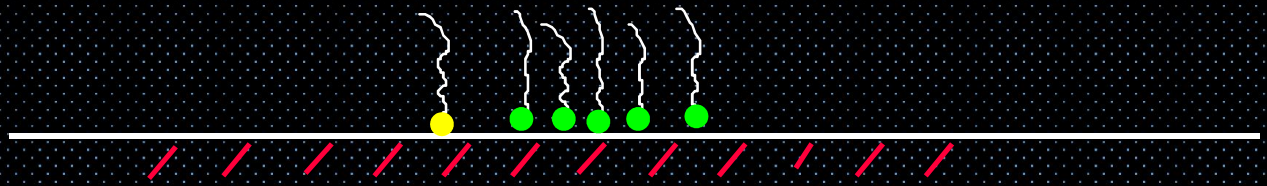
Detergency in Hydrocarbon Systems

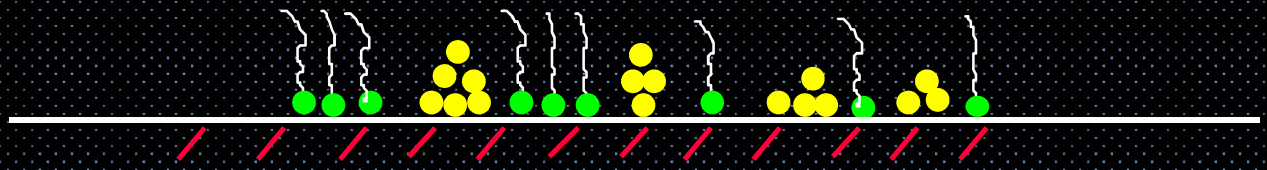
Gum being polar, sticks on polar surfaces



The polar ends of detergents also stick to polar surface



An effective detergent displaces gum (deposits)



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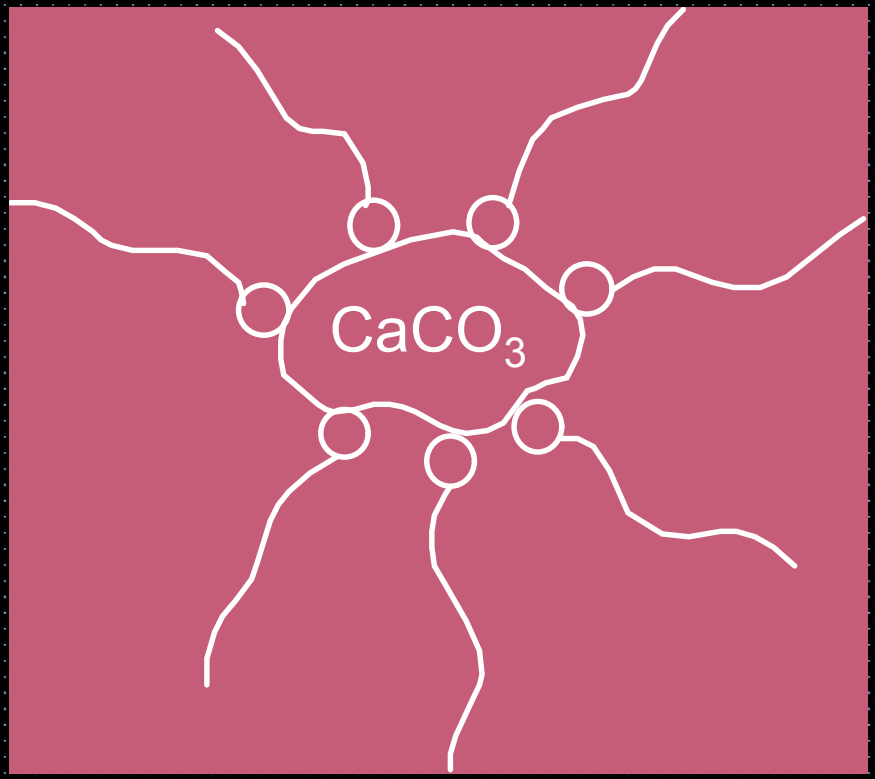
Overbased Sulfonates

$Ca_6(OH)_1(CO_3)_6(RSO_3)_1$



Neutralize Acids, Prevent Corrosion Due to Acid Attack

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Detergent Selection

- Balance Cost and Performance
- Too Much May Hurt Wear Performance
- Phenates Good at High Temperatures
- Sulfonates Good at Low Temperatures
- May Use up to Six Detergents

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Dispersant Functions

- Prevent Solids Agglomeration and Oil Thickening
- Control Engine Sludge
- Control Engine Varnish
- Viscosity Index Builder

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Ashless Dispersants

Function:

- Control Sludge and Varnish Formation at Lower Operating Temperature
- Control Soot Thickening
- Viscosity Index Builder

Types:

- High Molecular Weight Succinmides and Succinate Esters

Mechanism:

- Keep Sludge, Carbon, and Deposit Precursors Suspended in Oil

Differences between PCMO & HDEO

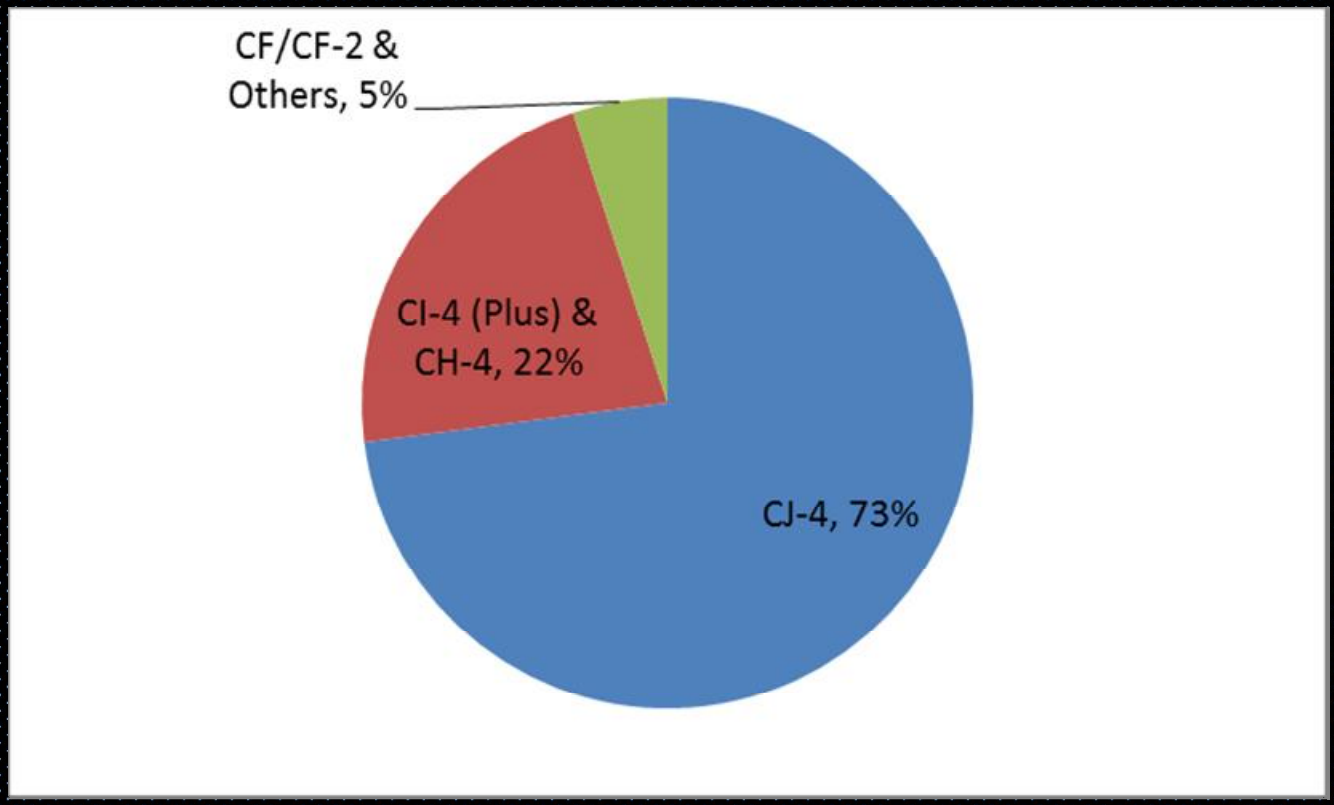
Soot, RPM, Fuel type, displacement, torque, engine braking, Higher loads, longer distances, greater idling, emission controls (SCR, EGR, PTF), Off-Hwy (slopes), larger sump sizes, oil cooling systems, longer drains

Differences to formulating

More dispersant, more chemistry, Higher tbn?, different EP / Anti-wear agents? / More AO? Longer drain intervals / Antifoams

NA HD Engine Oils by API credential

NA HDEO Volume ~ 440 Million Gal (1.5 Million MT)



CJ-4 penetration has been accelerated by simple logistics

Source : Lubrizol

Engine Design Changes:

Diesel engine design is undergoing a period of significant change, driven by new CO_2 and fuel economy regulations.
Changes include:
Diesel engine downsizing – 15L to 13L
Down speeding – 1,600 rpm to 1,200 rpm
Advanced combustion design
Active oil temperature control
Variable valve timing
Start/Stop technology

Diesel engine oils have a vital role:

Enabling new advancement in diesel engine hardware designs
Increasing fuel economy through lighter viscosity grade and friction modifiers
Improving engine durability with new advanced additive chemistry and base oil selection

Example 5W-20 formulation in NEXBASE (API Group III) base stocks

All treat rates are given as % weight.

Oil Code	OS289186
Viscosity Grade	5W-20

Formulation

Lubrizol® PV1122	DI	8.62
Lubrizol® PV610	Booster	0.16
Lubrizol® 7075F	VM	4.90
Lubrizol® 6662A	PPD	0.15
NEXBASE 3043	Group III	60.32
NEXBASE 3080	Group III	25.85

Performance Claim

API	SN
ILSAC	GF-5

Example 15W-40 formulation in PURITY (API Group II) base stocks

All treat rates are given as % weight.

Oil Code OS246868
Viscosity Grade 15W-40

Formulation

Lubrizol® 40007	DI	16.50
Lubrizol® 7075F	VM	5.10
VISCOPLEX 1-3009	PPD	0.20
PETRO-CANADA PURITY 2302	Group II	78.20

Performance Claim
API CJ-4 SN
CUMMINS CES 20081
DAIMLER V2009.1 MB228.31
DDC 93K218
MACK EO-O PREMIUM PLUS 07
RENAULT RLD-3
VOLVO VDS-

PC-11 Overview

- PC-11 is major performance upgrade with involving
  - Enhanced HD Diesel Engine Oil technology beyond CJ-4
  - Significant development resources due to challenging new test requirements and the need for wider (lighter) viscosity grade coverage
  - Accelerate shift towards lighter grade for HD Diesel Engine Oil
- Target first licensing Dec 1, 2016
- Complexity management will be issue for industry
  - Various grades & universal oils. What about CI-4 plus and CJ-4?
- Split Category
  - High HTHS (3.5 min) backwards compatible
  - Low HTHS (2.9-3.2) forward looking

PC-11 Addresses Lower Viscosity and Engine Changes for Fuel Economy

What's PC-11?

- **New category split by HTHS:**
  - **High HTHS (PC-11A, CK-4) – Backwards compatible to upgrade CJ-4**
  - **Low HTHS (PC-11B, FA-4) – Fuel Economy grade for new engines.**
- **Key drivers:**
  - **Fuel efficiency and green house gas emissions**
  - **Higher engine operating temperatures : Mack T-13 test**
  - **Scuffing (adhesive wear) protection : DDC Scuffing test – not accepted into API category**
  - **Oil Aeration concerns : CAT Aeration test**
  - **Oil shear down**
  - **Bio-diesel fuel (dropped)**

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