

Oil-Water Emulsion in API CJ-4 Engine Oil

ASTM Section D.02
Heavy-Duty Engine Oil Classification Panel
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Caterpillar Inc.
H. Abi-Akar
J. Katinas

- ☀ Background of Emulsion Issue
- ☀ Cat O-WEST emulsion bench test
- ☀ Emulsion Task Force Updates

Request to HDEOAP & EMA in August, 2008:

Modify the water emulsification properties of engine oils to reduce the potential of emulsion formation and/or diminish emulsion stability

Identification & Impacts



- ☀ Oil-Water emulsion found with many engine technologies:
 - ☀ Pre-2004 Off-Highway
 - ☀ 2007 EGR
 - ☀ 2007 CGI

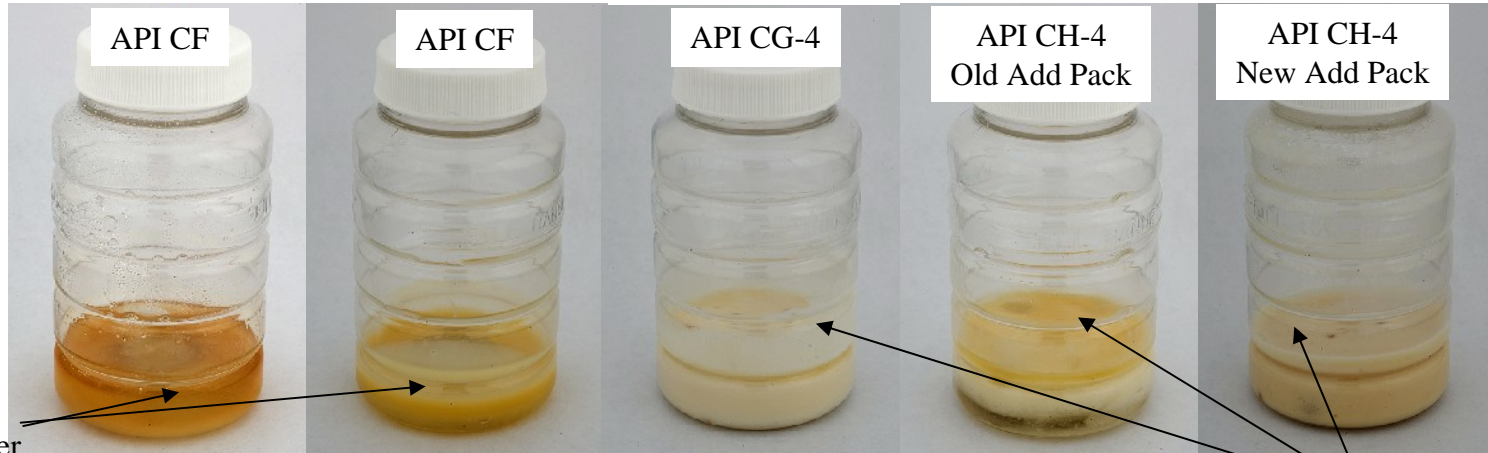
- ☀ Emulsion can cause metal components to rust
- ☀ Customer may perceive emulsion as head gasket failure
- ☀ Emulsion formation may negatively impact customer perception
 - ☀ Unnecessary downtime
 - ☀ Excessive diagnostic costs
 - ☀ Concern about engine durability



Tier 3 Machines were found with emulsion after being shipped from factory

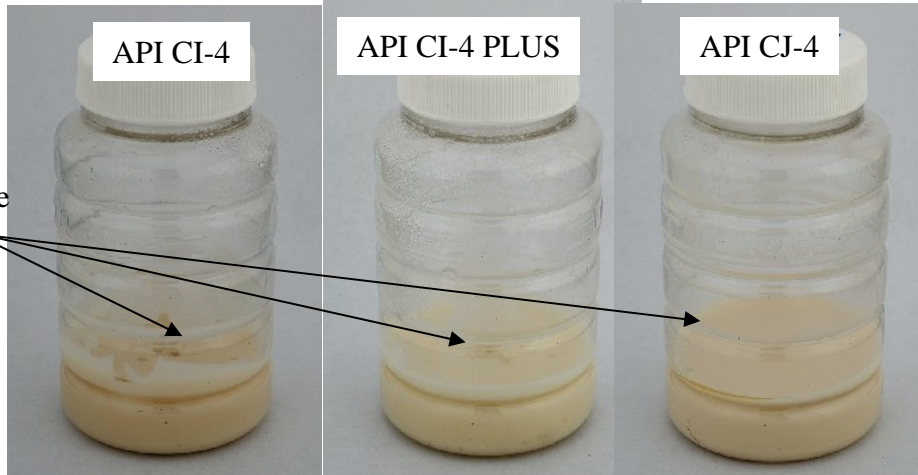
- ✿ No design changes of the engines
- ✿ Engines had <100hrs when emulsion found
- ✿ Multiple starts and stops at the factory and during the shipping process contributed to emulsion formation

API Oil Category Emulsion Effects



Oil and water
clearly separated

Oil and water clearly
separated with layer of
emulsion still visible



No oil-water layer visible
Solid emulsion

Emulsion Formation Engine Test Confirmation/Proof of Concept



**Pre-Baseline
No Emulsion**

Baseline – CJ-4 Oil

No water on valve cover – even after sitting for several min.

“Mild Fail” oil

Little water separation in valve cover after sitting for ~5min.

“Pass” Oil

Large amounts of water separated in valve cover after sitting for ~5min

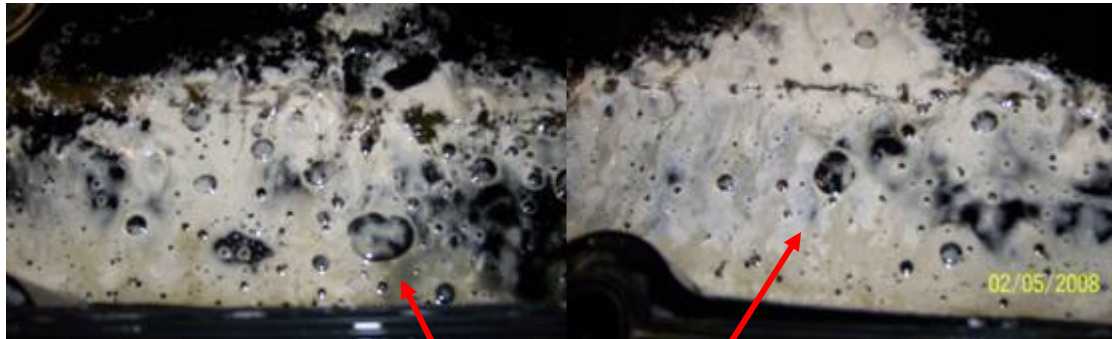
Engine Test Simulating Field Emulsion Conditions

“Pass” and “Mild Fail”: API CJ-4 oil modified to reduce emulsion

“Pass” & “Mild Fail” Oil Proof of Concept



Engine Test Parts

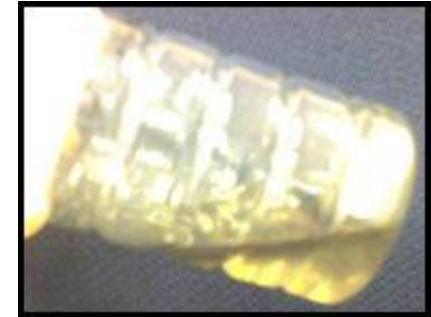


**Water began separating from emulsion
<5 minutes after test stopped**

Engine Test Simulating Field
Emulsion Conditions

Non-Emulsifying “Pass” oil successfully passed
Caterpillar Proprietary Engine testing

Emulsion Samples

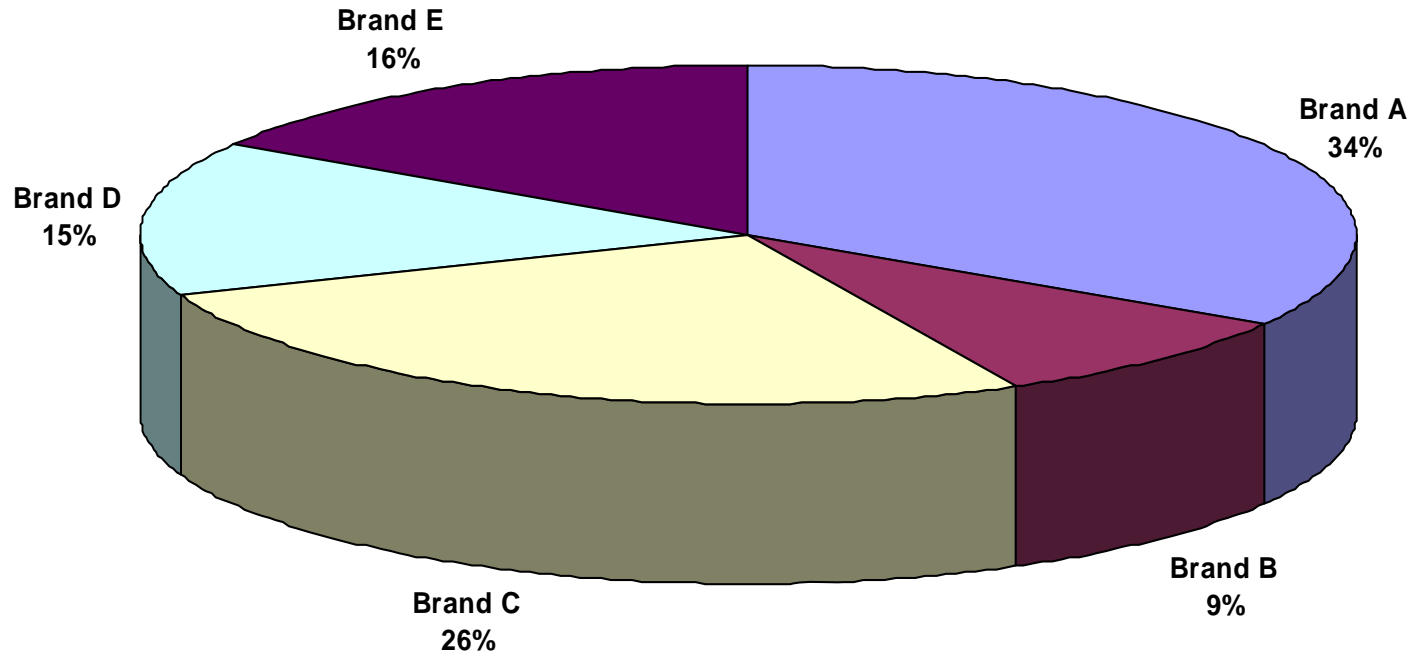


2hrs after sample taken
Oil and water separated
Considered a “Passing” Oil



(Photo at 2hrs after sample taken)
Water separated after 4 days
Considered a “Mild Fail” Oil

Field Data - Reported Oil Emulsion



Note: All values are percentages of a sample size

Oil-water emulsion forms when water becomes dispersed in oil

Two methods can be used to create thick emulsions (70-90% water)

1. Slowly adding water to oil while mixing
2. Condensing water into thin oil film layer

Condensation of water onto oil layer is believed to be cause of engine emulsion

O-WEST Bench test was developed to simulate emulsion formation as seen in engines

Bench Capabilities:

- ✿ Controlled environmental factors
- ✿ Controlled fluid supply
- ✿ Automated runs

Test Procedure:

- ✿ Form emulsion
- ✿ Centrifuge sample for set amount of time
- ✿ Evaluate water separation

Pass/Fail Criteria:

- ✿ Based on emulsion stability over time
- ✿ Amount of water separated

Emulsion Formation Test Parameter Development



Test Parameters Development: % Water with Karl-Fischer Titration

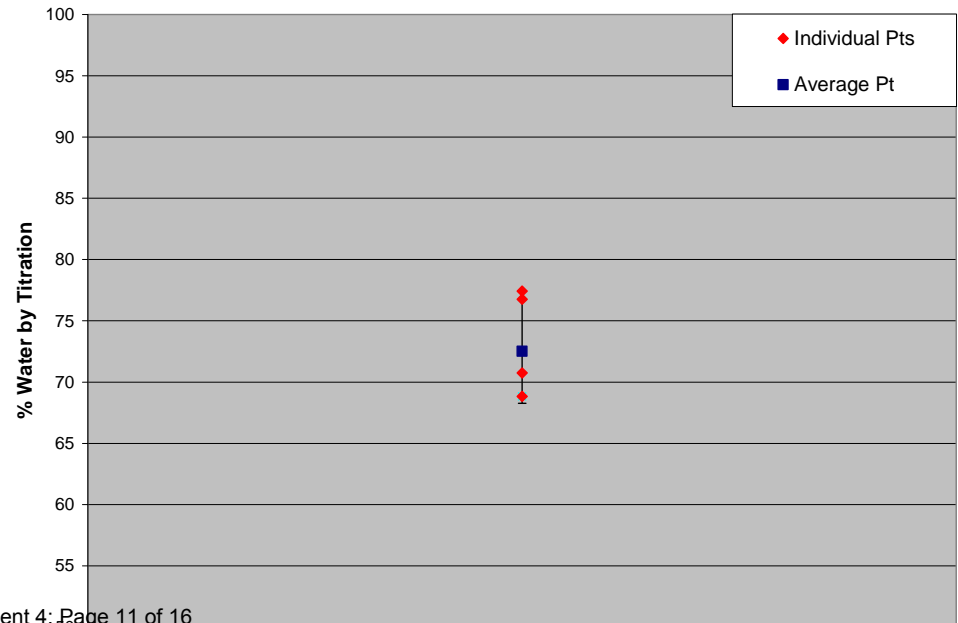
Field Data - Emulsion Characterization			
Maximum Range		Minimum Range	
85%	water	69%	water
15%	oil/fuel	31%	oil/fuel

Average water in emulsion is ~77%

Oil data from field engines included API CI-4, CI-4 PLUS, and CJ-4 oils

Test bench settings were developed to create emulsion with a range of water

API CJ-4 oil showed consistent water between 68-78%



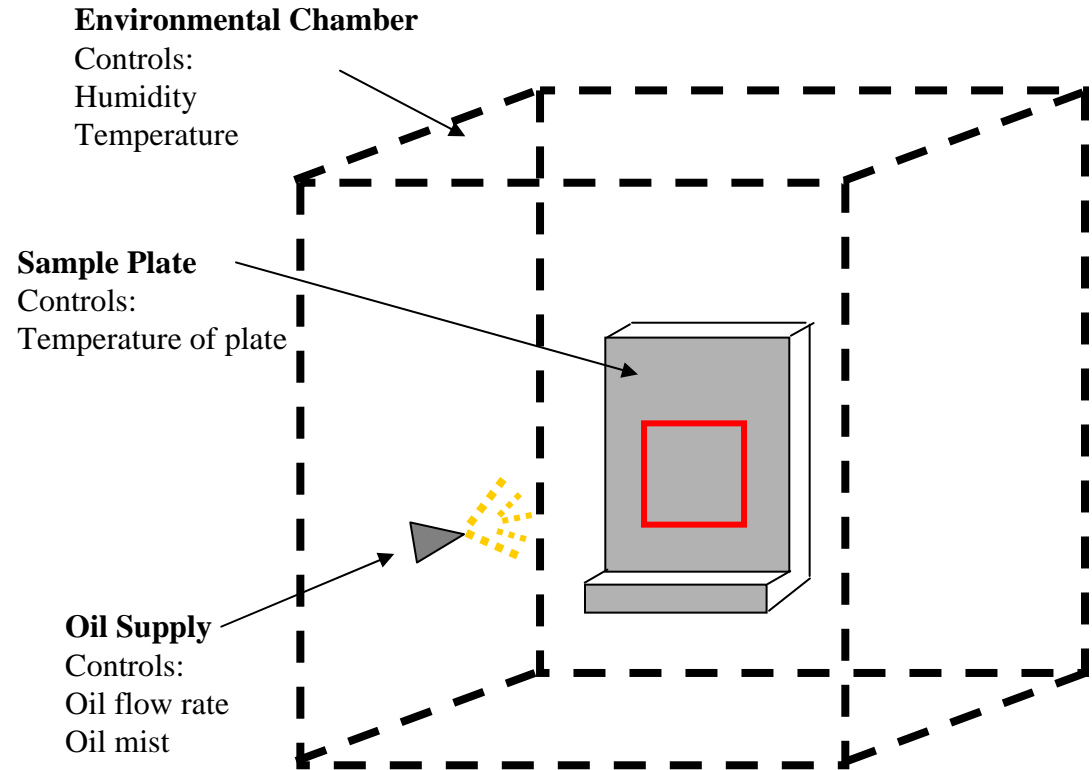
Oil-Water Emulsion Stability Test (O-WEST)



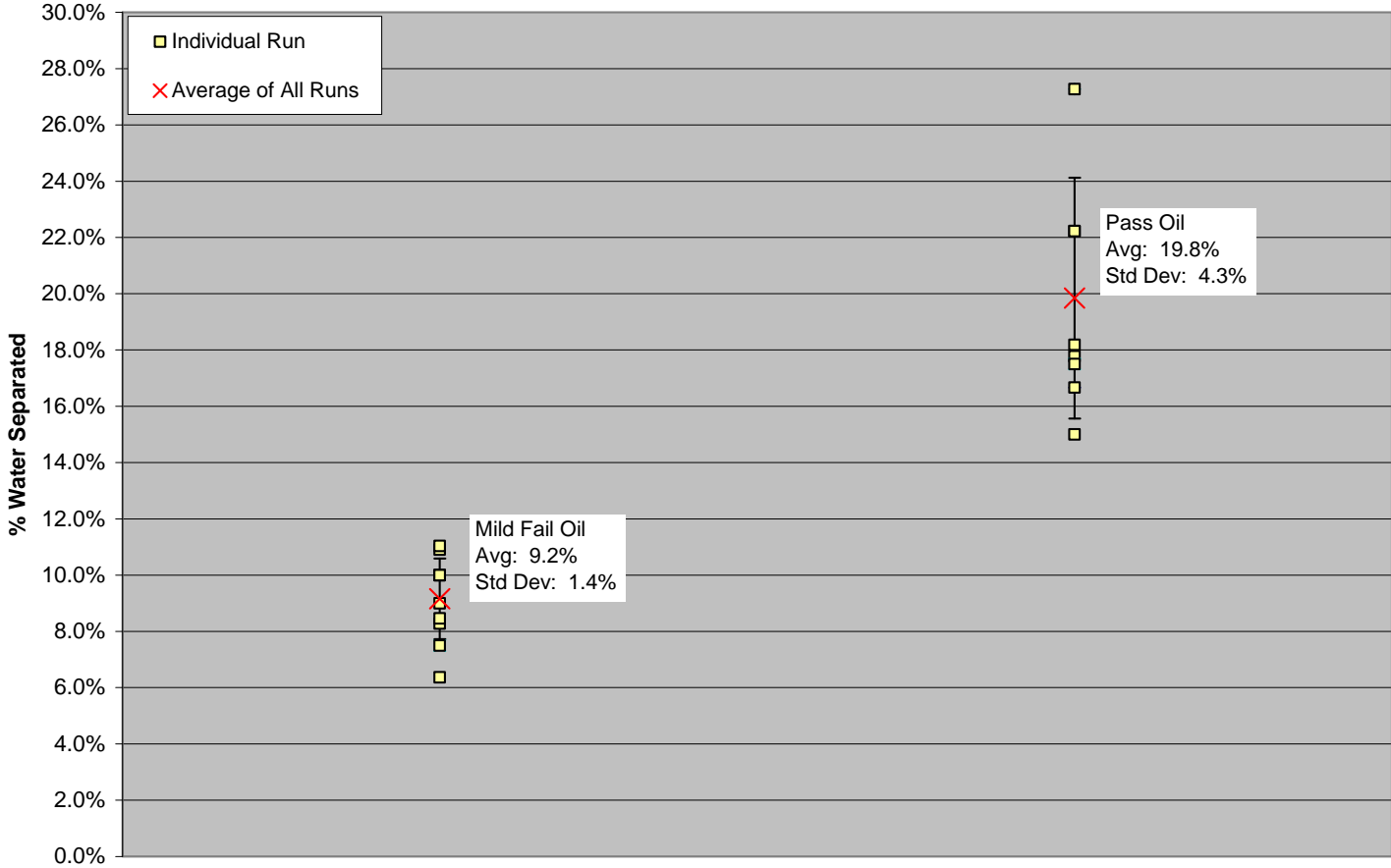
Emulsion Formation:

All aspects of the test bench are controlled by a common computer and a single program

- ✿ Environmental chamber is held at a specific temperature and humidity
- ✿ Oil is sprayed onto the sample plate
- ✿ Sample plate temperature is controlled to condense water onto the surface



"Pass" & "Mild Fail" O-WEST Data



O-WEST Data – Different Brands



	Avg Water Separated	Std Dev
API CJ-4	3.30%	1.10%
"Mild Fail" oil	9.20%	1.40%
"Pass" oil	19.80%	4.30%

	Avg Water
Brand A	1.11%
Brand B	0%
Brand C	3.20%

Emulsion formation is NOT dependent on Brand or Viscosity Grade

Commercially available oils

Emulsion Task Force Update



An Emulsion Task Force has been formed

Members include representatives from:

- ☀ Afton Chemical
- ☀ BP
- ☀ Caterpillar
- ☀ Chevron Oronite
- ☀ ExxonMobil
- ☀ Infineum
- ☀ Intertek
- ☀ John Deere
- ☀ Lubrizol
- ☀ Shell
- ☀ Southwest Research Institute
- ☀ Volvo

- ☀ Members of the Task Force have visited Caterpillar for an O-WEST Bench demonstration
- ☀ Caterpillar shared test details with the Task Force, including O-WEST parameters and emulsion formation information
- ☀ Oil and additive companies have supplied samples for testing, which includes a by-hand screening and/or O-WEST evaluation
- ☀ Caterpillar is planning a field evaluation of the “pass” engine oil that is expected to be complete by Spring, 2009

Emulsion Task Force Update



Task Force Concerns/Future Work:

- ☀ **Effects of water separation on engine** – Caterpillar is planning to run a field test to evaluate water separation with the “pass” engine oil
- ☀ **Passenger car oils requirements** – Caterpillar will evaluate the “pass” oil in the auto Emulsification test. Caterpillar will also contact ILSAC to better understand the needs and help determine a way to maintain universal oils.
- ☀ **Continued improvement and refinement of O-WEST** – Caterpillar will evaluate additional parameters such as emulsion viscosity or total percent water in emulsion as part of test data requirements. Cat will analyze separated water to determine composition.
- ☀ **Identify tests needed to validate impact on performance characteristic of the oil** - Task Force will need to review individual solutions and determine what tests would be needed.
- ☀ **O-WEST data will be shared with the Industry** – EMA will support data presentation to ensure anonymity.