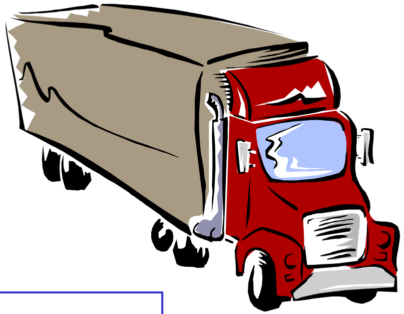
Alternative Fuels
Dimethyl Ether Rheology and Materials Studies

Performance

Cost

Without sacrificing



Engine Compatibility

Ease of Use

Goal: Quantify and characterize fuel system interactions
and
elastomer compatibility with dimethyl ether

PennState

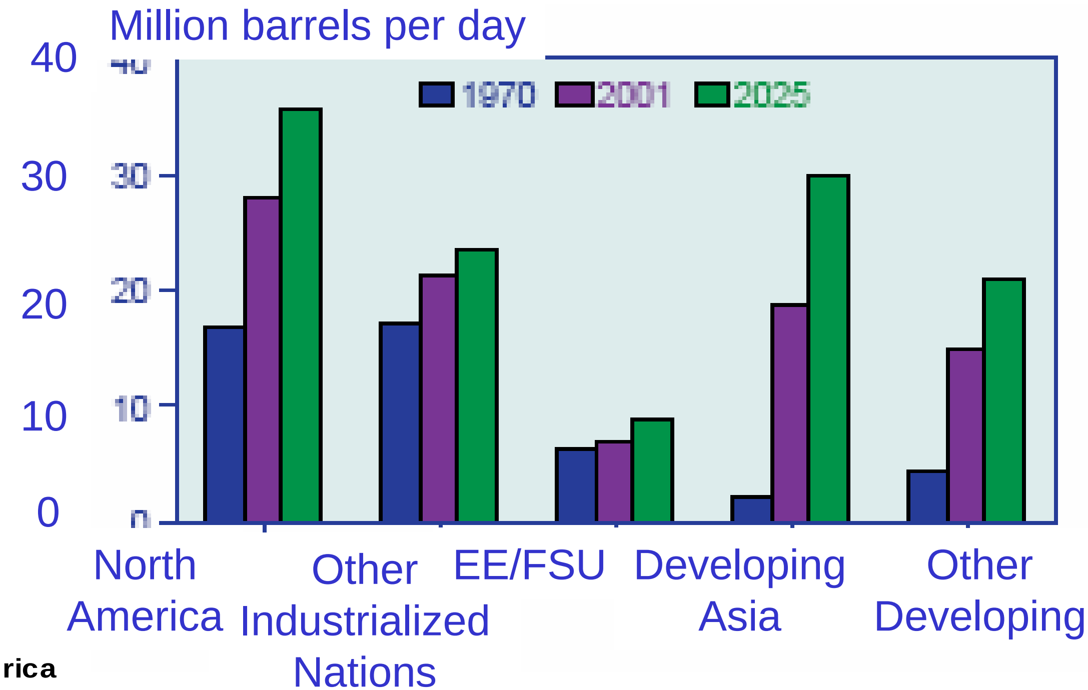
Dr. Kimberly Wain
Dr. Joseph Perez
Dr. Wallis Lloyd

Dept. of Chemical Engineering
113 Fenske Lab
University Park, PA 16802

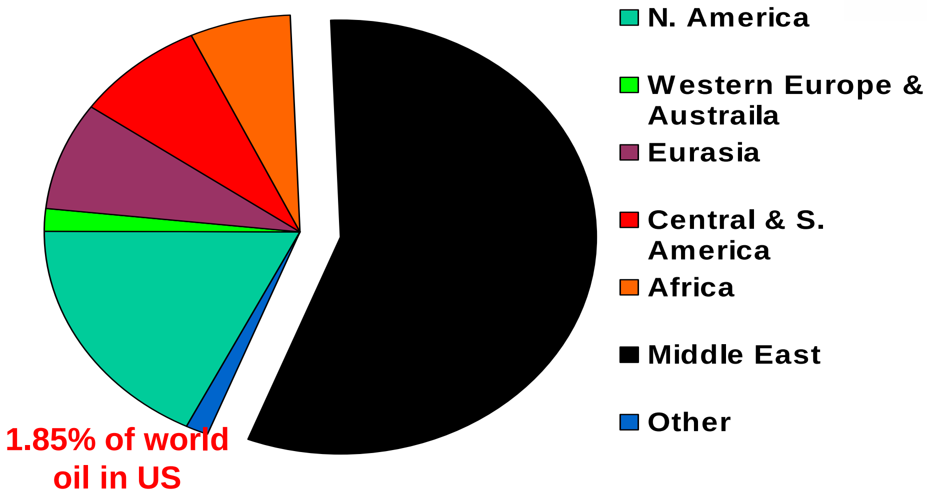
Petroleum Outlook

How much petroleum is the world consuming? According to DOE…

Developing countries will require massive resources

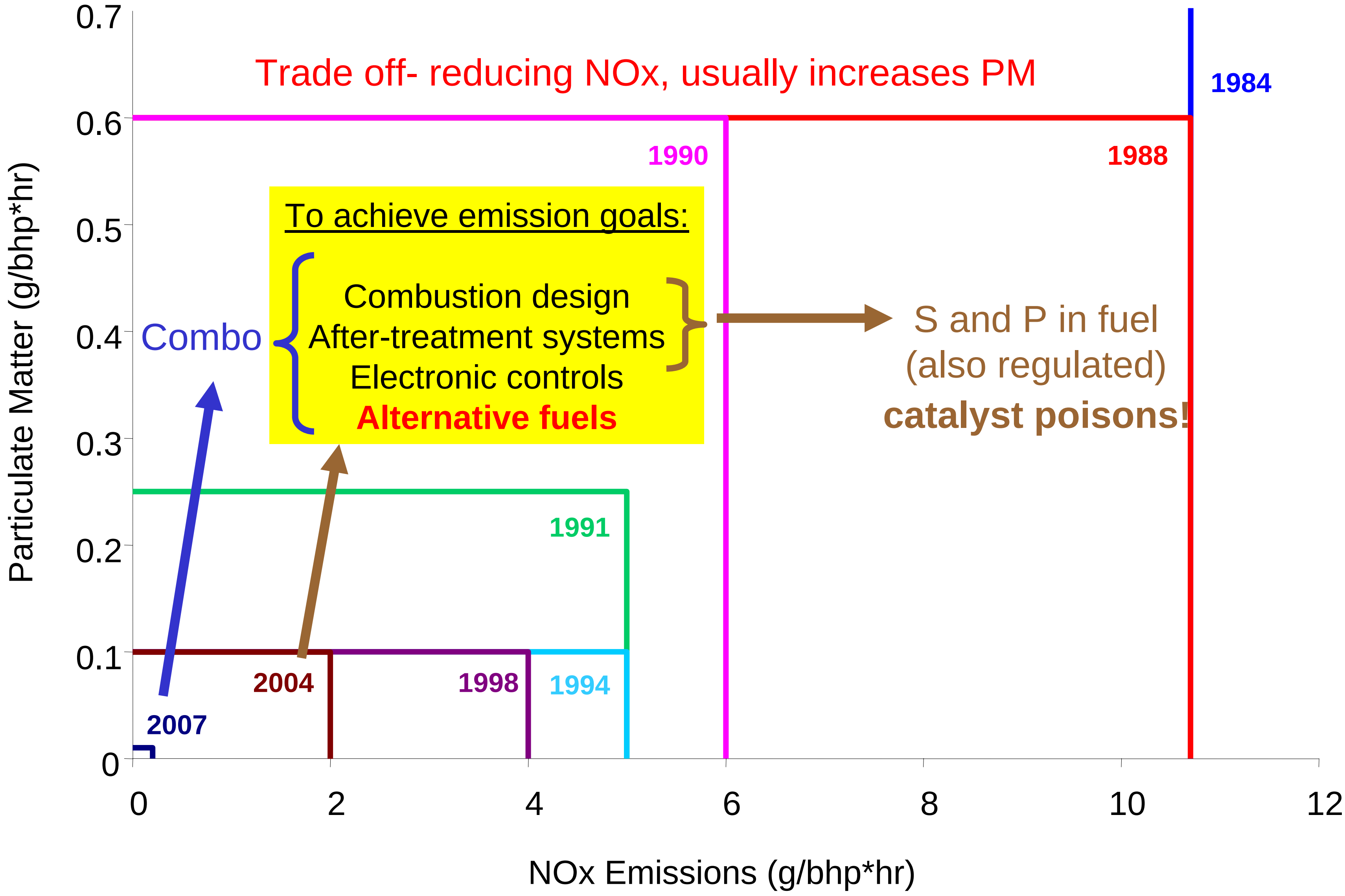


Where is the world's oil located? (proven reserves)



US has extremely limited proven oil reserves, imports

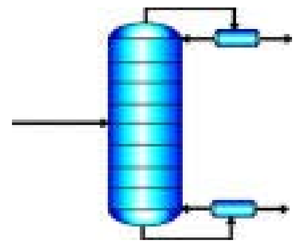
U.S. Diesel Emissions Regulations



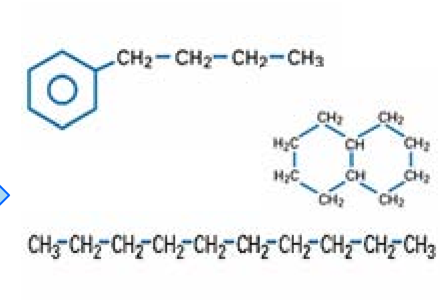
Fuel Studies at PSU

Diesel Fuels

Petroleum cut boiling
~282-338°C
LSDF 325 ppm S
ULSDF < 15 ppm S



Distillation



Hydrocarbon mixture

Soybeans

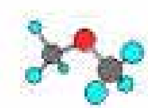
+ ROH $\xrightarrow{\text{catalyst}}$

Biodiesel Fuels

Blends of methyl esters made from vegetable oils- renewable!
No sulfur, phosphorus content

Dimethyl Ether

Converted biomass- renewable!
Zero emission fuel, gas at STP



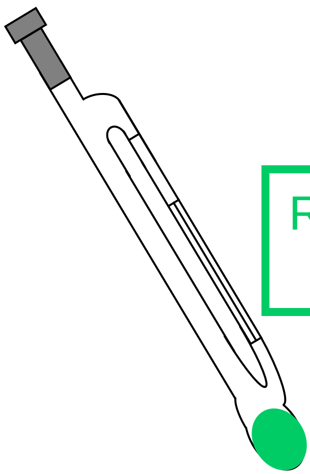
Hydrocarbon ⟶ Syngas ⟶ DME

DME Areas Investigated

Fuel Injector Lubrication

Mimic fuel injector response

Viscosity Improvement



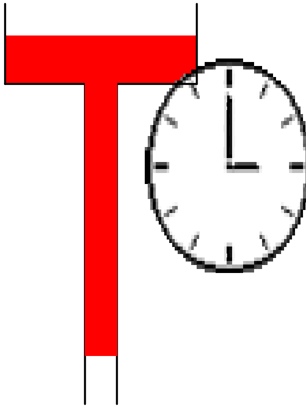
Raise to ASTM lower limit (DME)

Elastomer Durability

How alternative fuels effect physical properties

Viscometry

Principle: Time for a certain volume of liquid to move through a calibrated capillary



$$\upsilon = \frac{10^6 \pi g D^4 H t}{128 V L}$$

Pressurizable design

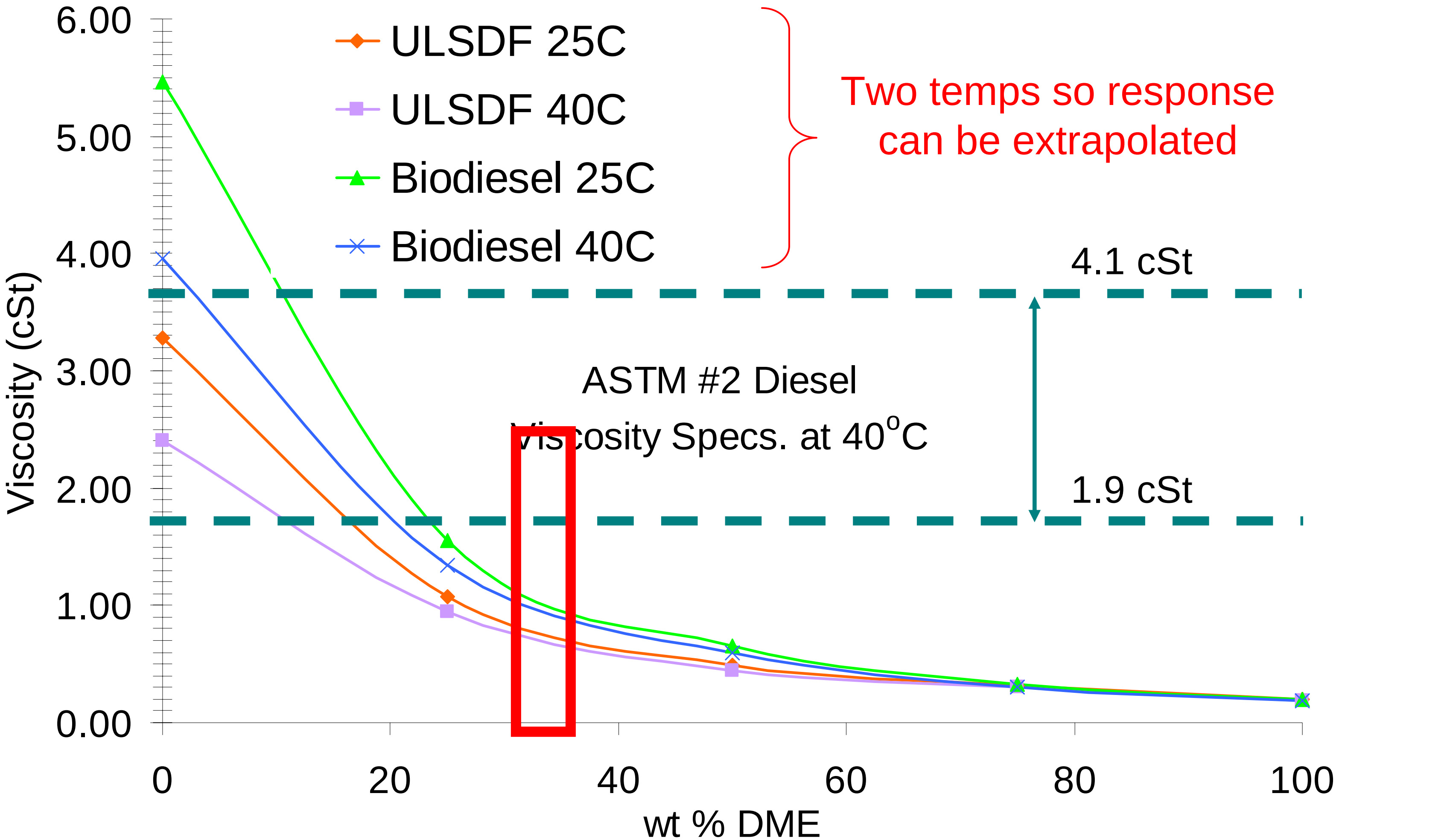
Small capillary for enhanced accuracy

Adaptable Swagelock® fitting at fill port

<u>Test Matrix</u>

Typical viscosity improving additives
Environmentally friendly additives
Blends of DME and diesel- with and without additives
Blends of DME and biodiesel- with and without additives

Viscometer Data

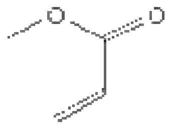


Dramatic decrease in viscosity with addition of DME in small quantities

Additives Used

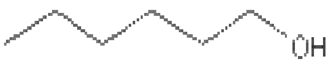
Traditional

Polymethacrylate- Long chain ester (OFM, VI)



Olefin Copolymer- Ethylene/propylene non-conjugated diene (VI)

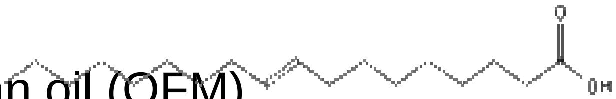
Alcohol- Ethoxylated long chains (OFM)



Synthetic

Poly-a-olefin- PAO-40 “40” refers to kinematic viscosity at 100 ^{o}C (VI)

Environmentally Friendly

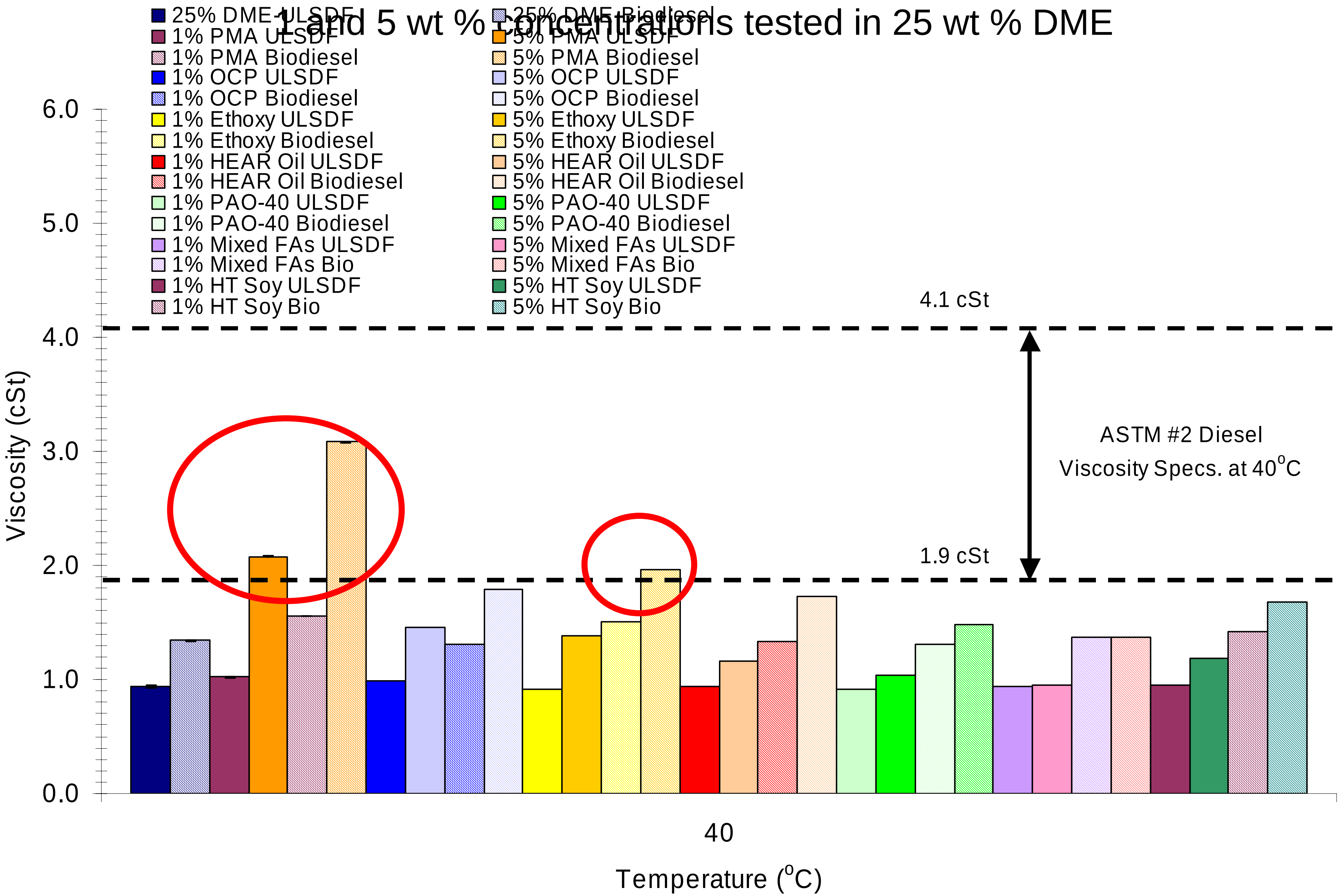


Vegetable Oil- Heat modified (polymerized) soybean oil (OFM)

Vegetable Oil- Mixed fatty acids (OFM, VI)

Vegetable Oil- Oleic acid alternative (OFM, VI)

Additive Effect



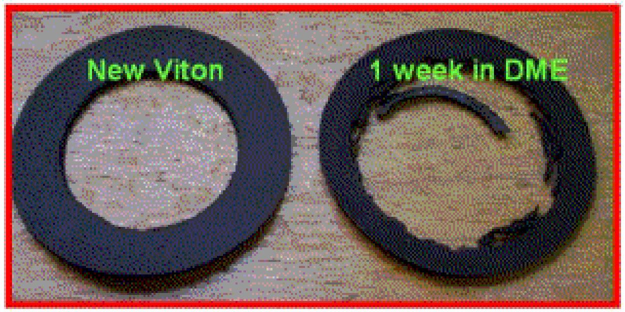
Material Compatibility

Fuel-Elastomer Interaction

Throughout the engine elastomers such as gaskets and o-rings provide proper seals and maintain the appropriate fuel environment

What happens with Dimethyl Ether?

→ Severe breakdown
Loss of elasticity
Swelling

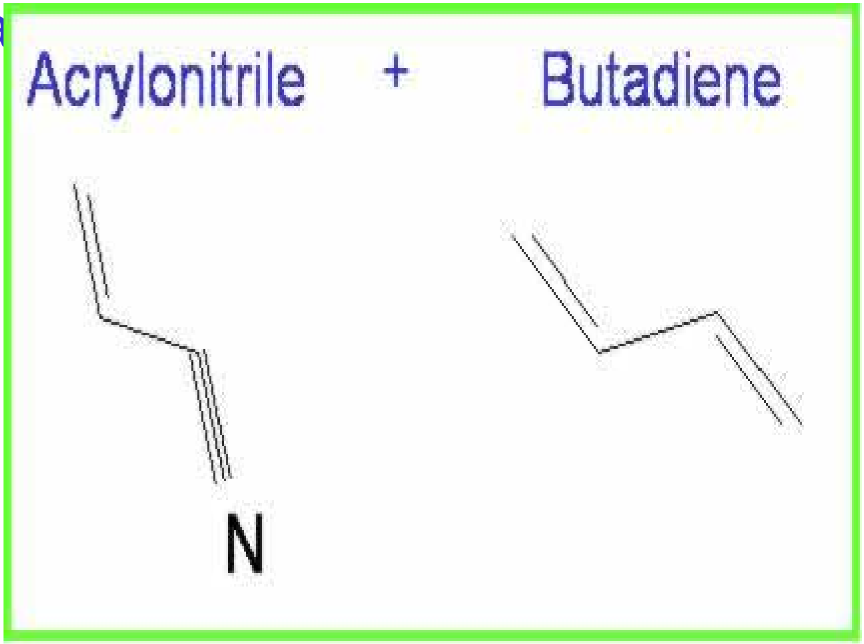


Result: Seal failure during operation and/or storage

Approach: Soak o-rings in DME and test physical properties (mass, volume, diameter) and elastic response (tensile properties). Deduce trend and formulate a failure mechanism.

Elastomer Durability

Chosen materials represent ma



Buna-n

Silicon

Viton

Polyurethane

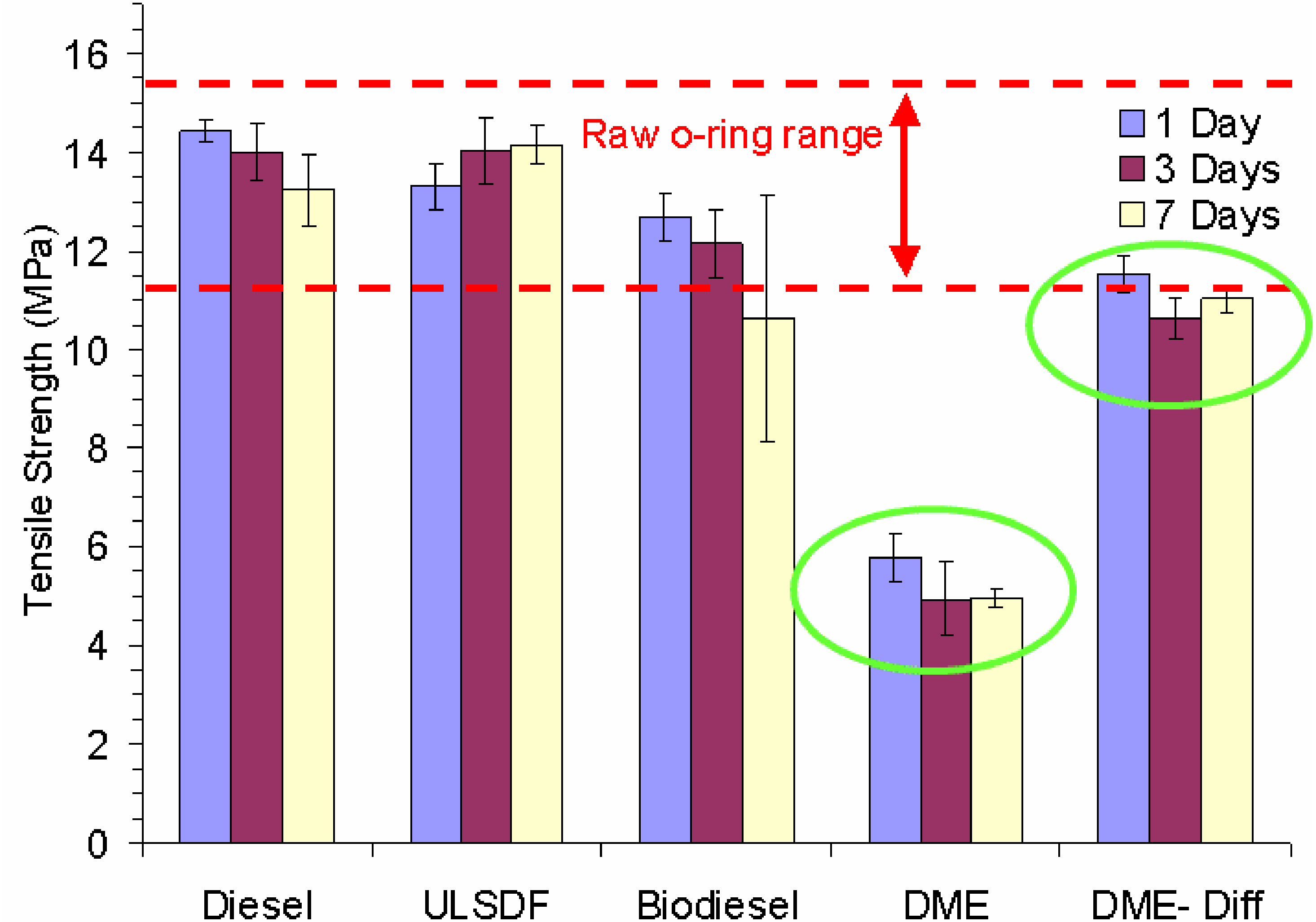
Teflon

Kalrez (fluoro-polymer)

Expensive specialty polymer with high chemical resistance

ME tested 1) right out of pressure vessel and 2) after diffusion of DM
out of o-ring (temporary versus permanent damage)

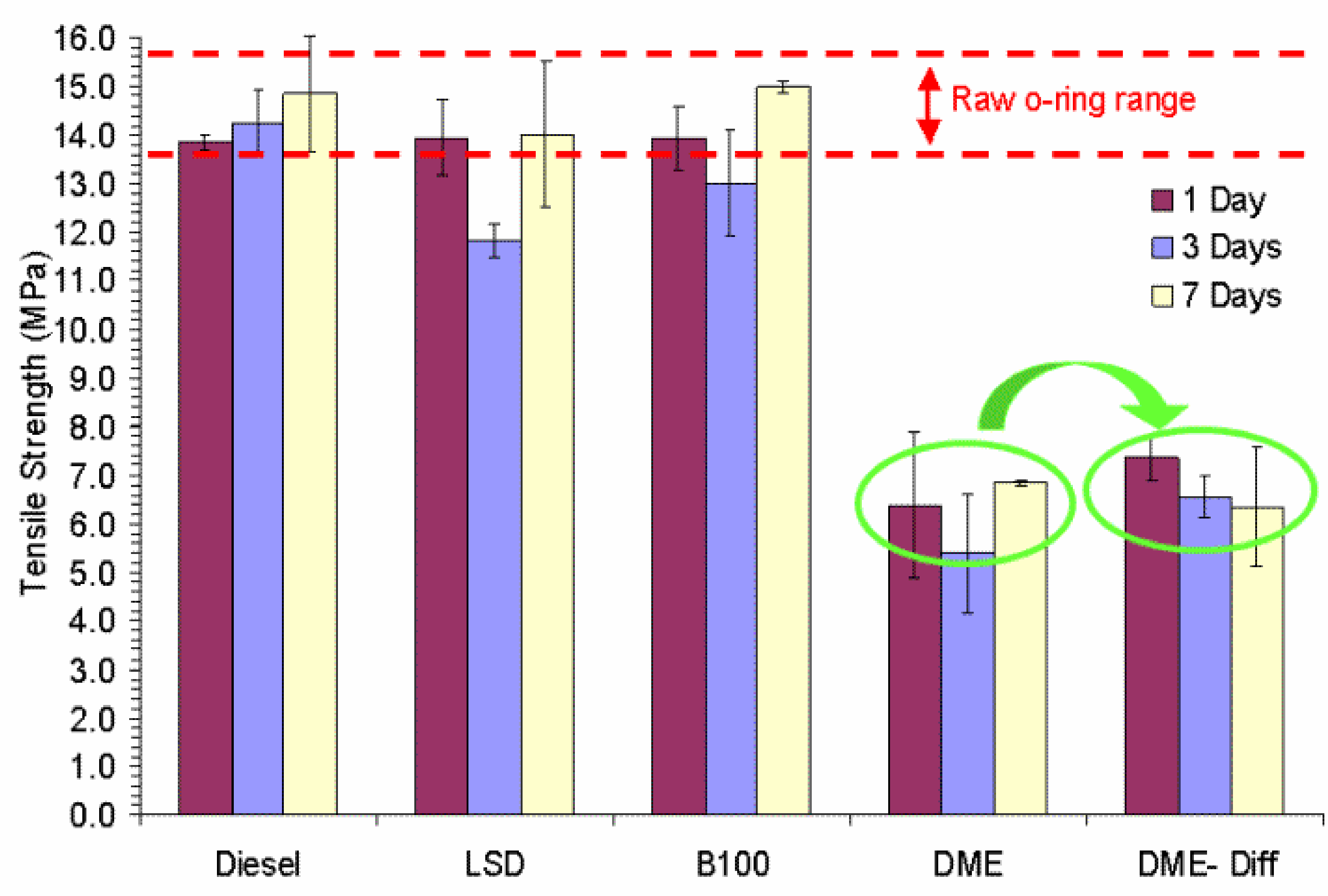
Buna-N Fuel Response



Strength loss is temporary and likely due to partial solvency of fuel in elastomer

Extended exposure leads to performance compromise in DME

Kalrez Fuel Response



Strength loss is permanent and likely due to rupture of crosslinking

Extended exposure leads to deterioration in DME

Fuel Injector Wear

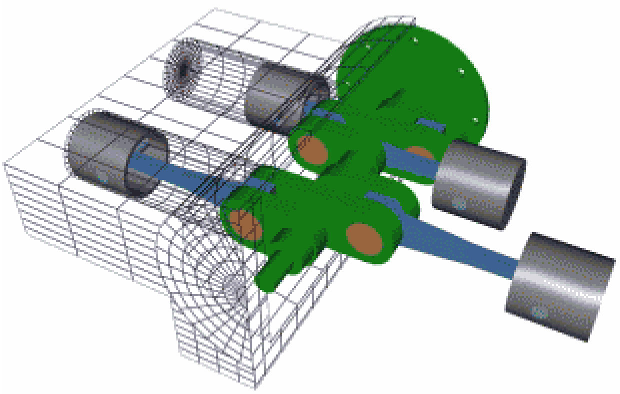
Bench Testing

Goal: Faster, less expensive test that accurately predicts fuel injector behavior

Modified Cameron-Plint wear tester

Pressurizable housing

Utilizes parts duplicating actual injector parts:
- Same geometry as diesel injector
- Same surface roughness and materials
- Operates at typical or higher frequency



Total costs per test: ~$250 vs. $5000 for full engine test
Total operational time: 3 hrs. vs. weeks for engine test

→ Significant savings!

Cameron-Plint Device

Modified Cameron-Plint

Matching outer cylinder per pin

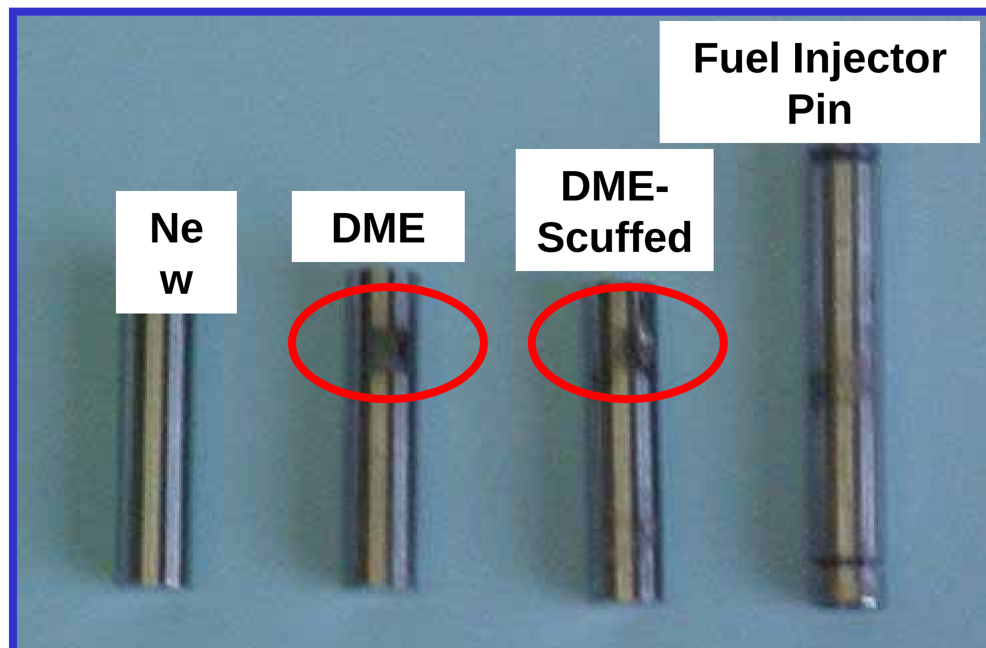
Capable of 2 tests /cylinder
1 per pin

Variable speed motor, 0-50 Hz

Fully simulates injector motion

Pin travel distance: 1mm

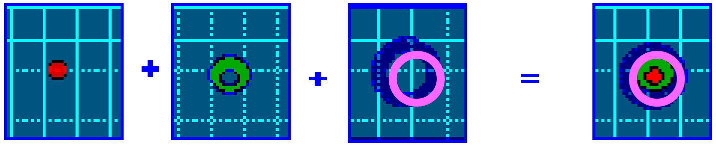
Test Pins



Wear Scar Mapping

Wave/light interference generates a horizontal light plane which is used as a surface probe

Successive intersections between the probe plane and the sample are the relief level curves



MicroXAM™ Surface Mapping Microscope

Pros: Fast image acquisition
Easy to use
Robust technique

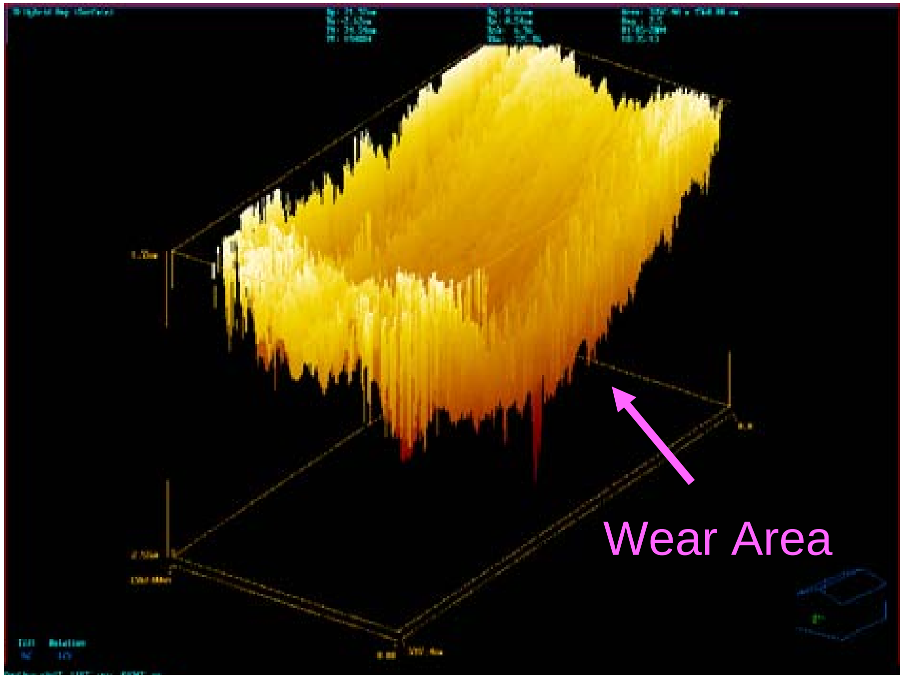
Cons: Res. limit ½ wavelength of light source
Curvature problematic

Wear Scar Examples

75 wt % DME/25 wt % ULSDF

Scar flattened, curvature removed

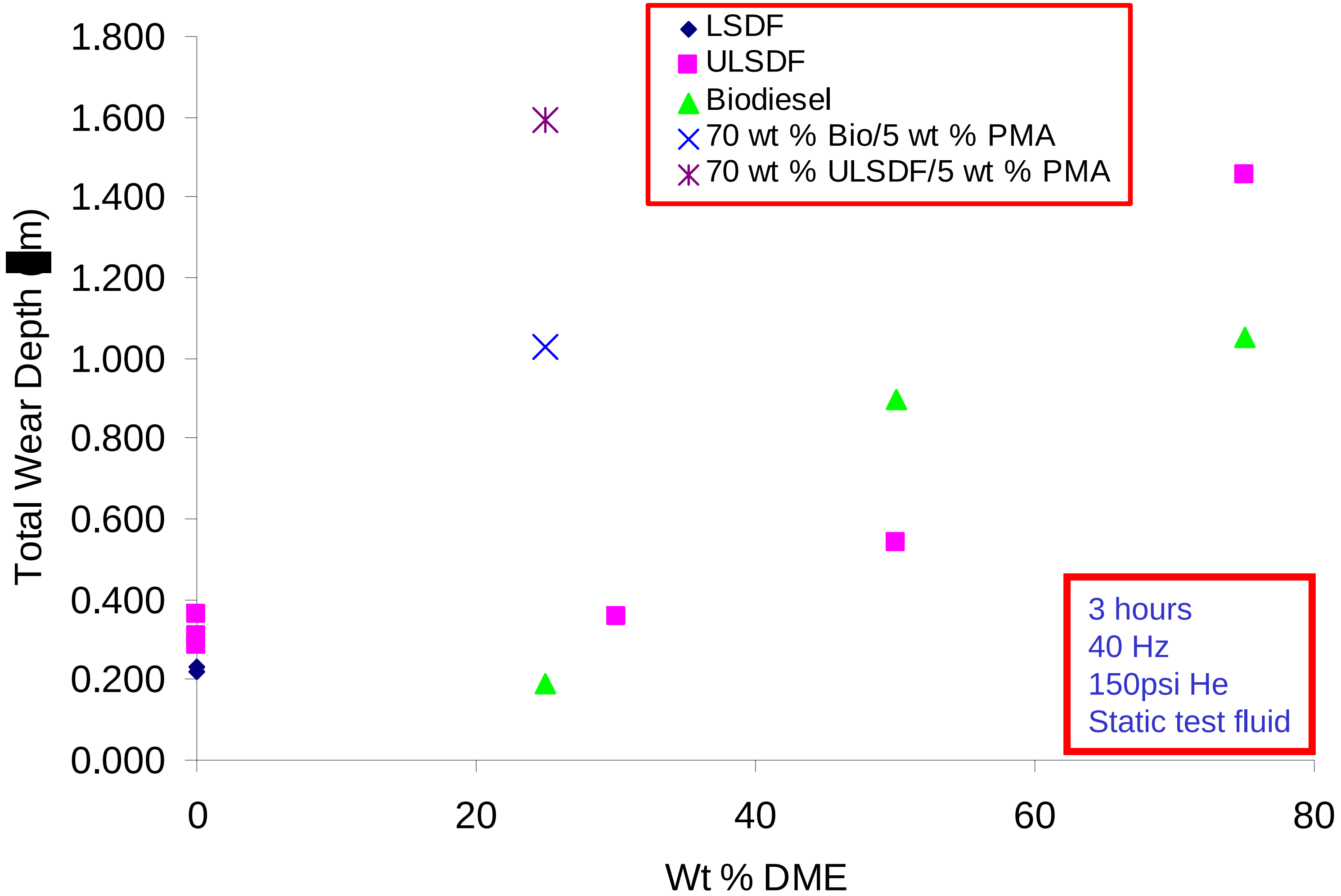
Depth of scar α severity of wear



Data confirms trend of incr. wear with incr. [DME]

Discrimination between ULSDF and biodiesel blends possible

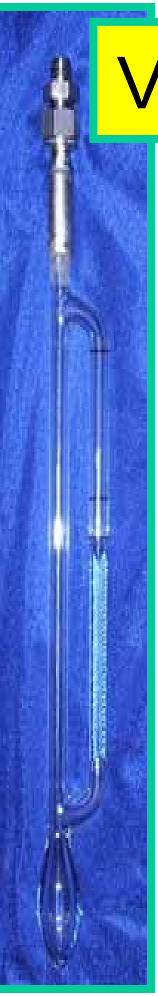
Cameron-Plint Data



Increasing wear scar depth with increasing [DME]

Additives caused deeper scar: cycled fuel mixture=shearing of additives chemical corrosion; 3 body wear

Summary



Viscosity

Material Compatibility

Alternative Diesel Fuel Understanding

Fuel Injector Wear

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THANKS - CAPTAIN JOHN
CAPTAIN – Is Port Left or Right?