

WILSON COMMUNITY COLLEGE



The Impact of Bio Diesel Upon Late Model Diesel Engines: What Fleet Managers, Techs and Operators MUST Know

APWA North American Snow Conference

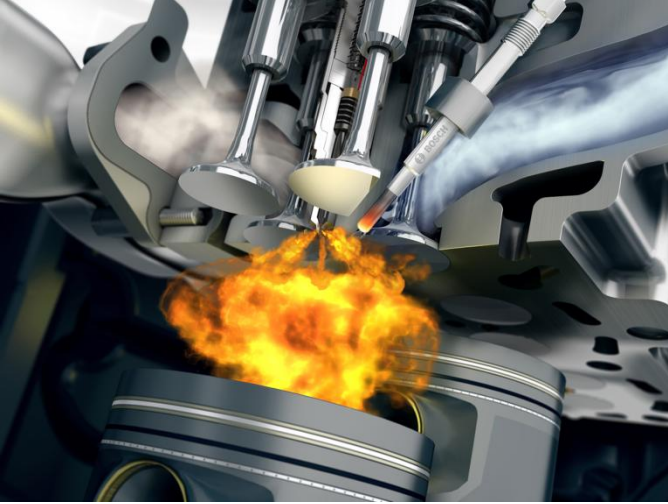
Milwaukee, Wisconsin

May 1, 2012

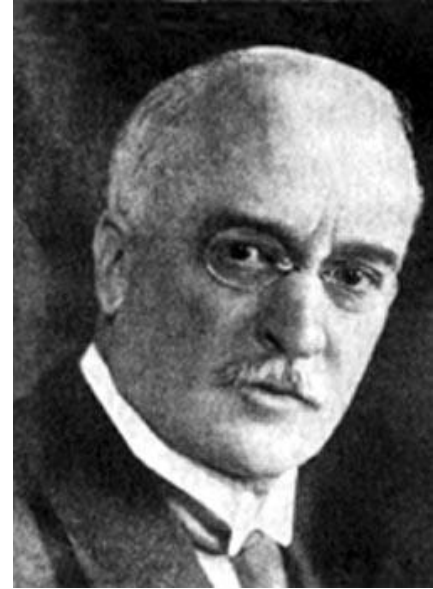
Rich Cregar

**Instructor, Department Head,
Advanced Transportation
Technologies**

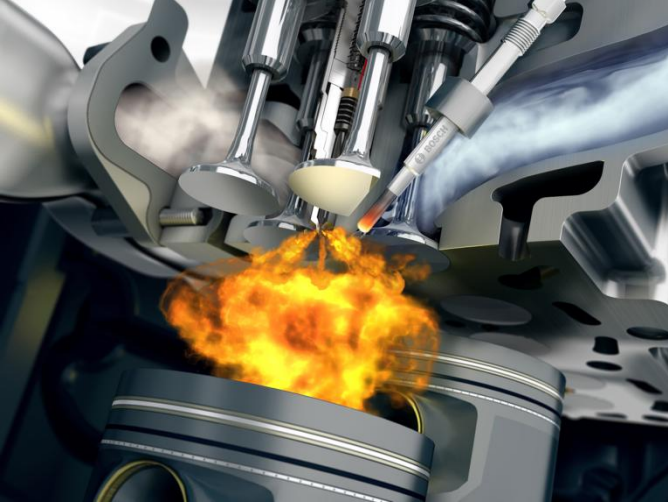
**Wilson Community College,
Wilson, North Carolina**



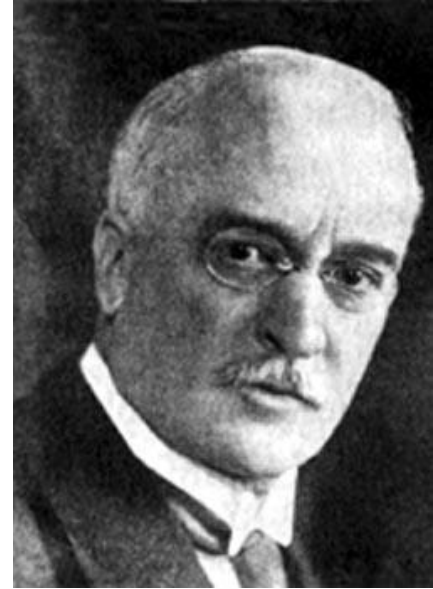
Outline



- Emission standards in the USA
- Current Diesel technologies
- Bio Diesel
- Issues with use of Bio Diesel
- Solutions, conclusions

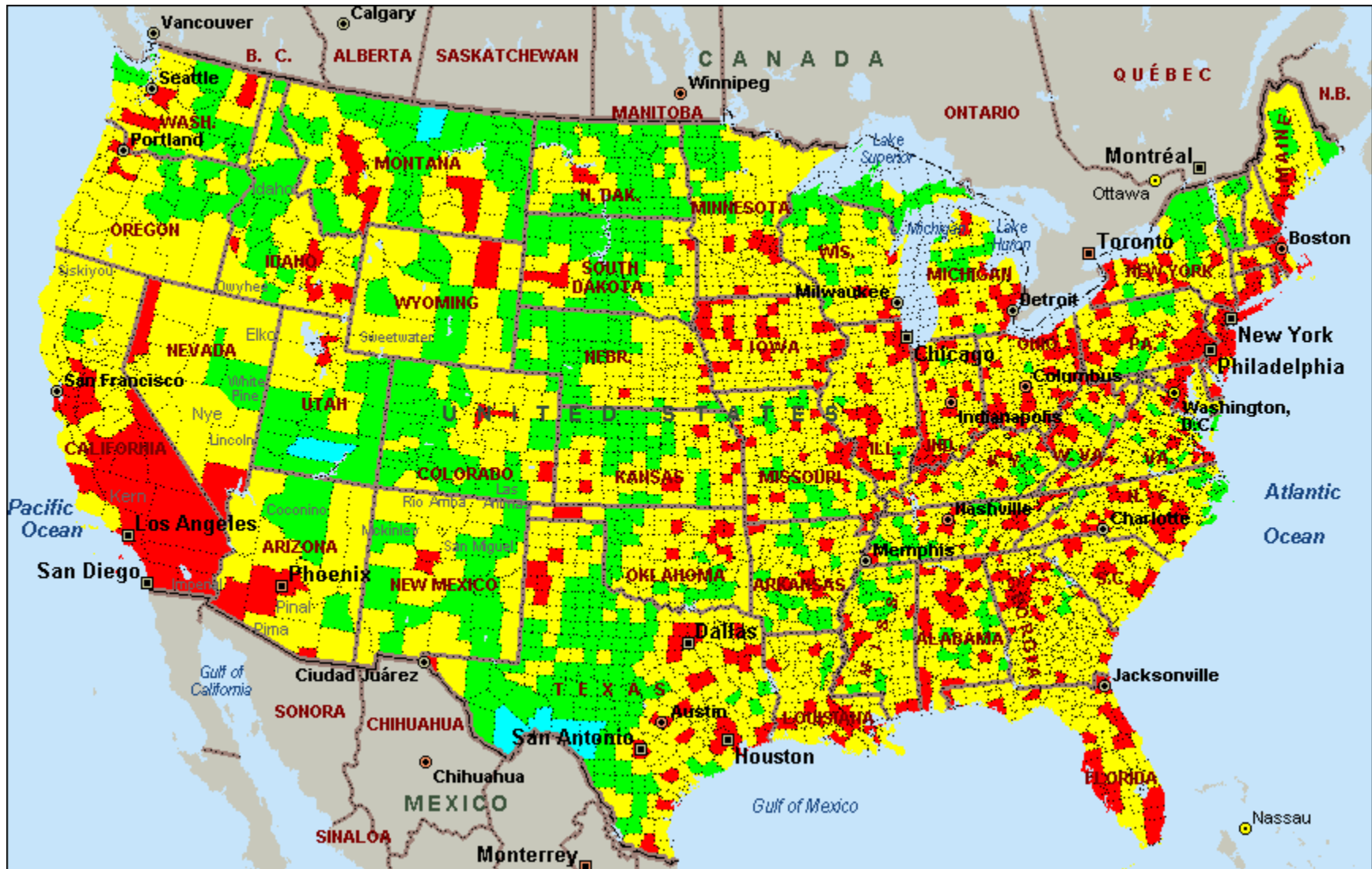


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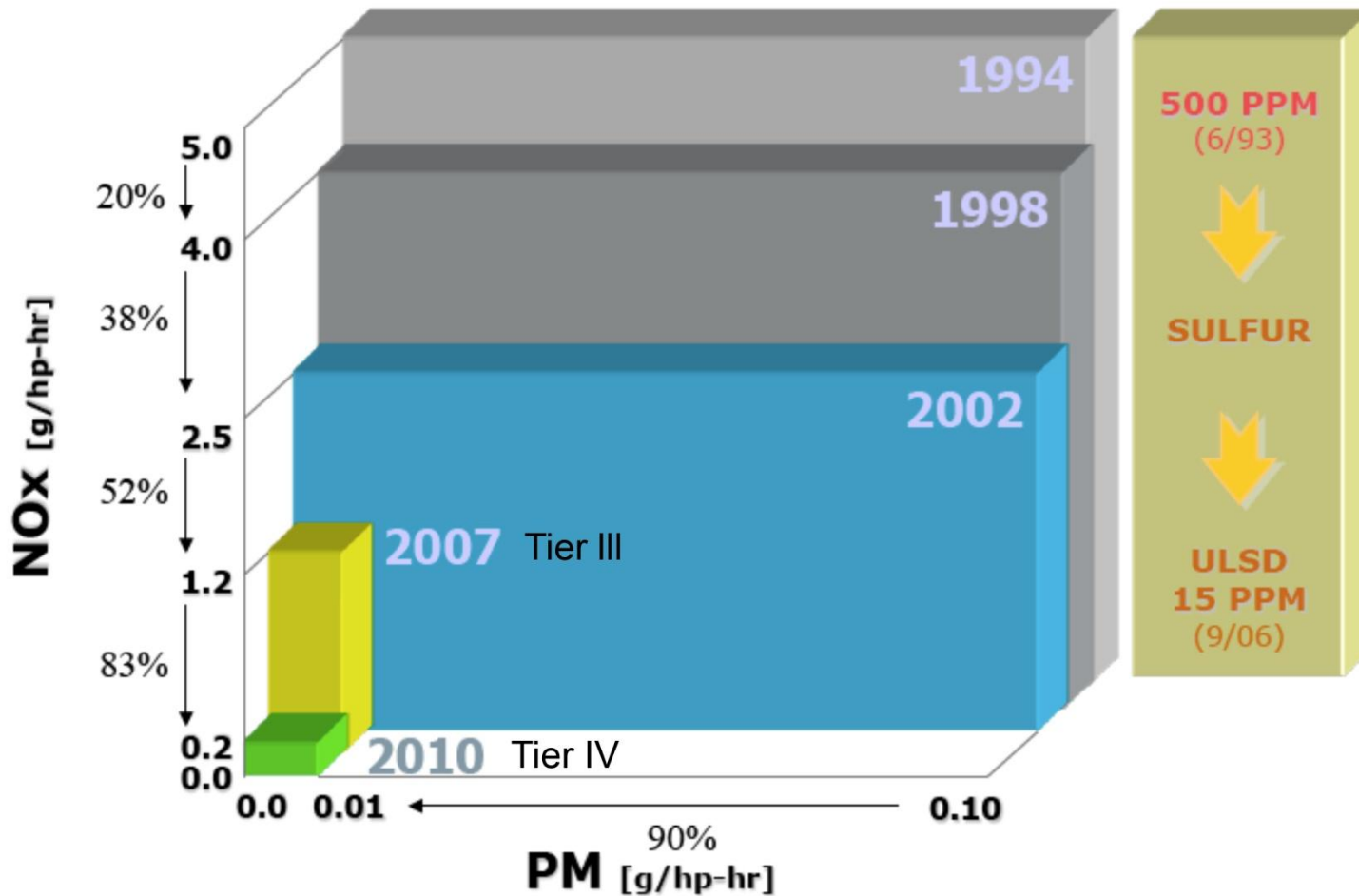
Our Air Quality



Air quality emissions are Carbon Monoxide (CO), unburned fuel (HC), Oxides of Nitrogen (Nox) and particulates (PM). Note that Ozone (O₃) is not a direct vehicle emission.

Graphic: EPRI

Federal On-Road Emission Requirements



Graphic: BMW (DOE DEER 07)

These move to all non-road by 2014

Locomotive & Marine by 2016

At present the only CO₂ regulations in the US are in the transportation sector and in the State of California (AB-32)

CAFE Standards

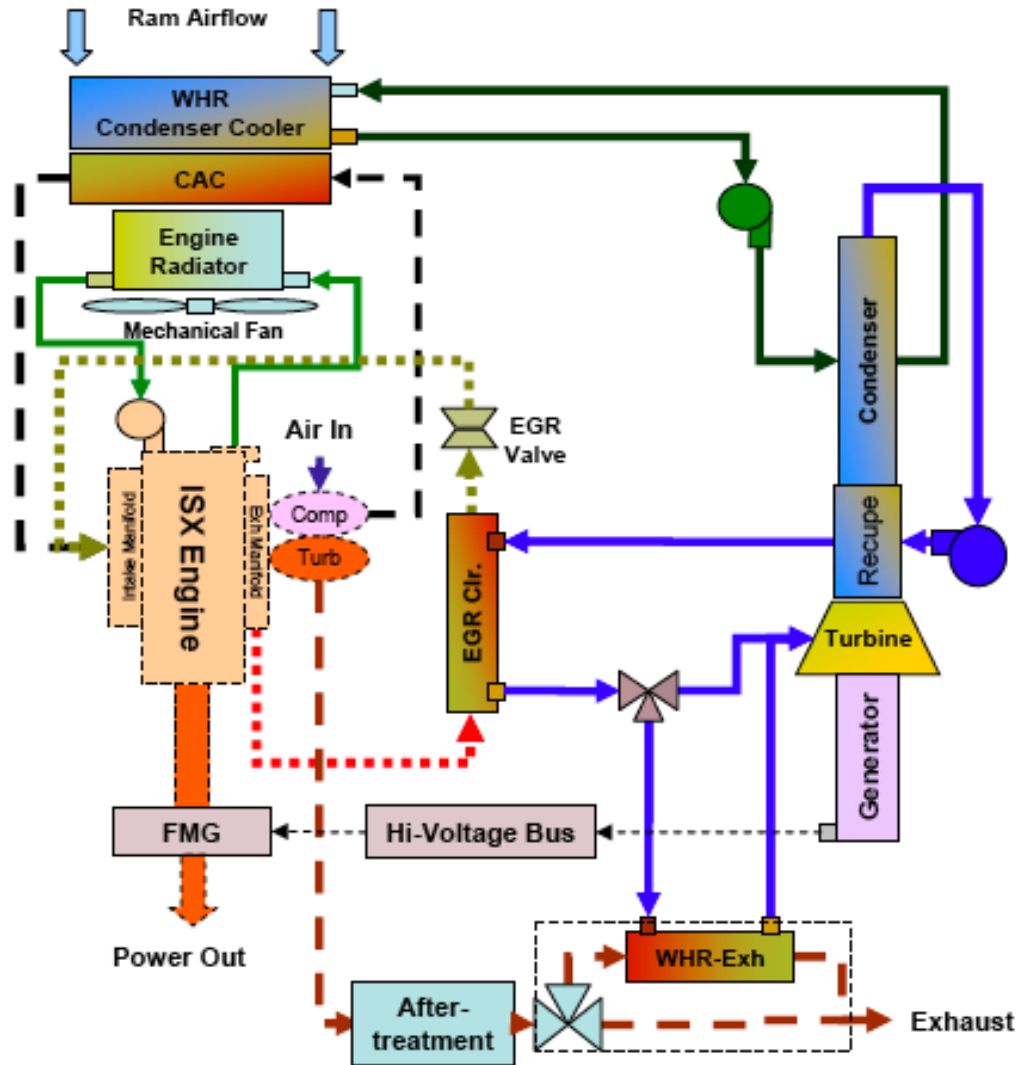
- September, 2011 Obama Administration announced the largest mandated fuel economy increase in history
- By executive order, 54.5 mpg by 2025
- Applies to the light duty fleet
- Also mandates that medium & heavy-duty on-road trucks reduce fuel consumption by 20% from 2014 to 2018
- On average this equates to reducing consumption by 4 gallons/100 miles for class 8 vehicles (semi-trucks)

Regulatory Action to Limit CO₂ Emissions

- Regulations will require using a grams/mile standard of measurement and will set targets based on vehicle “footprints”
- The footprint will be the product of the vehicles wheelbase X its track width (50 sq/ft is average)

	2012	2013	2014	2015	2016
Passenger Cars (g/mi)	261	253	246	235	224
Light Trucks (g/mi)	352	341	332	317	302
Combined Cars & Trucks (g/mi)	295	286	276	263	250
Combined Cars & Trucks (mpg)	30.1	31.1	32.2	33.8	35.5

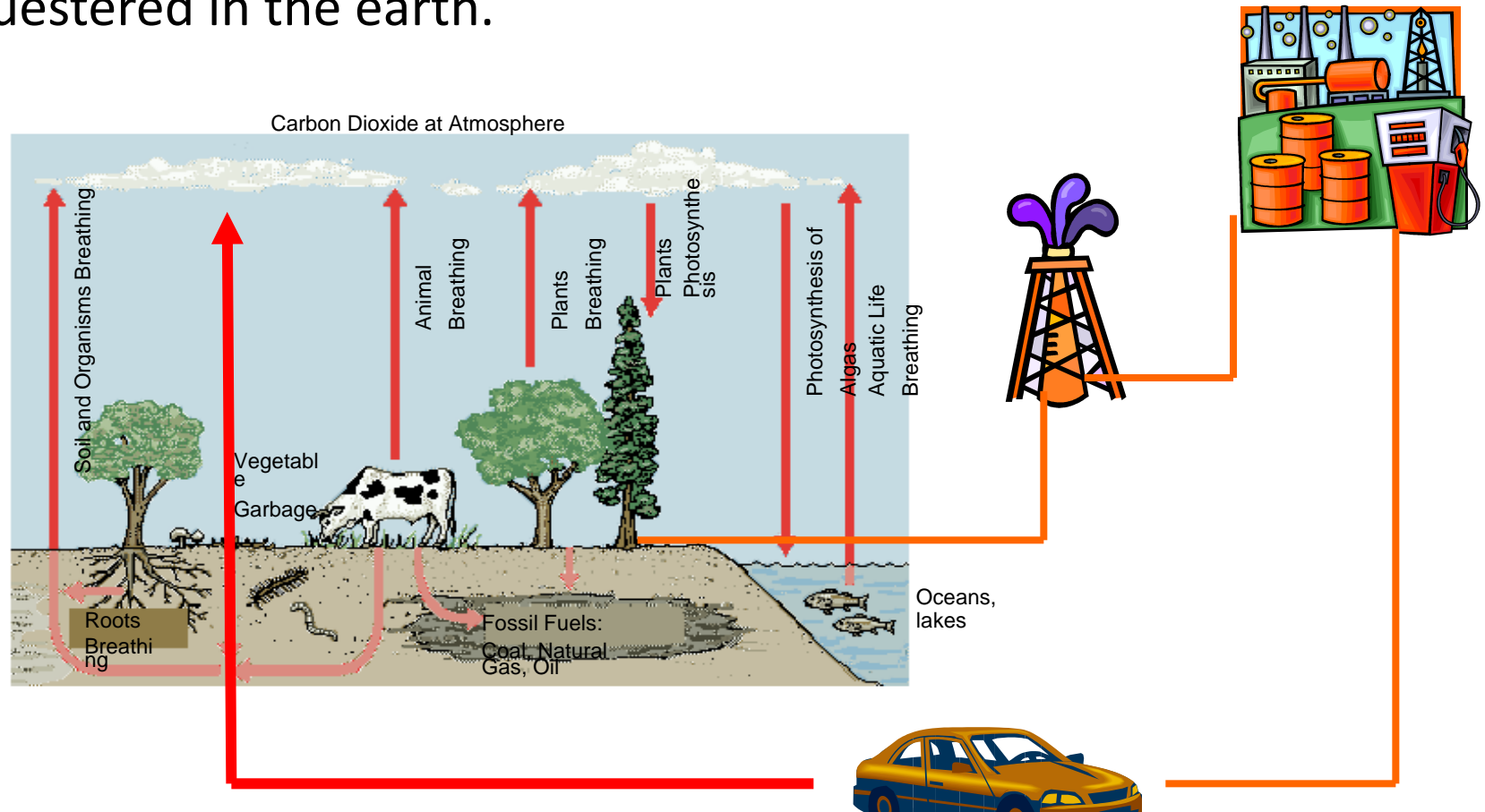
Medium/Heavy Duty Power, 2014?



Graphic: Cummins

What is Fossil vs. Renewable CO₂?

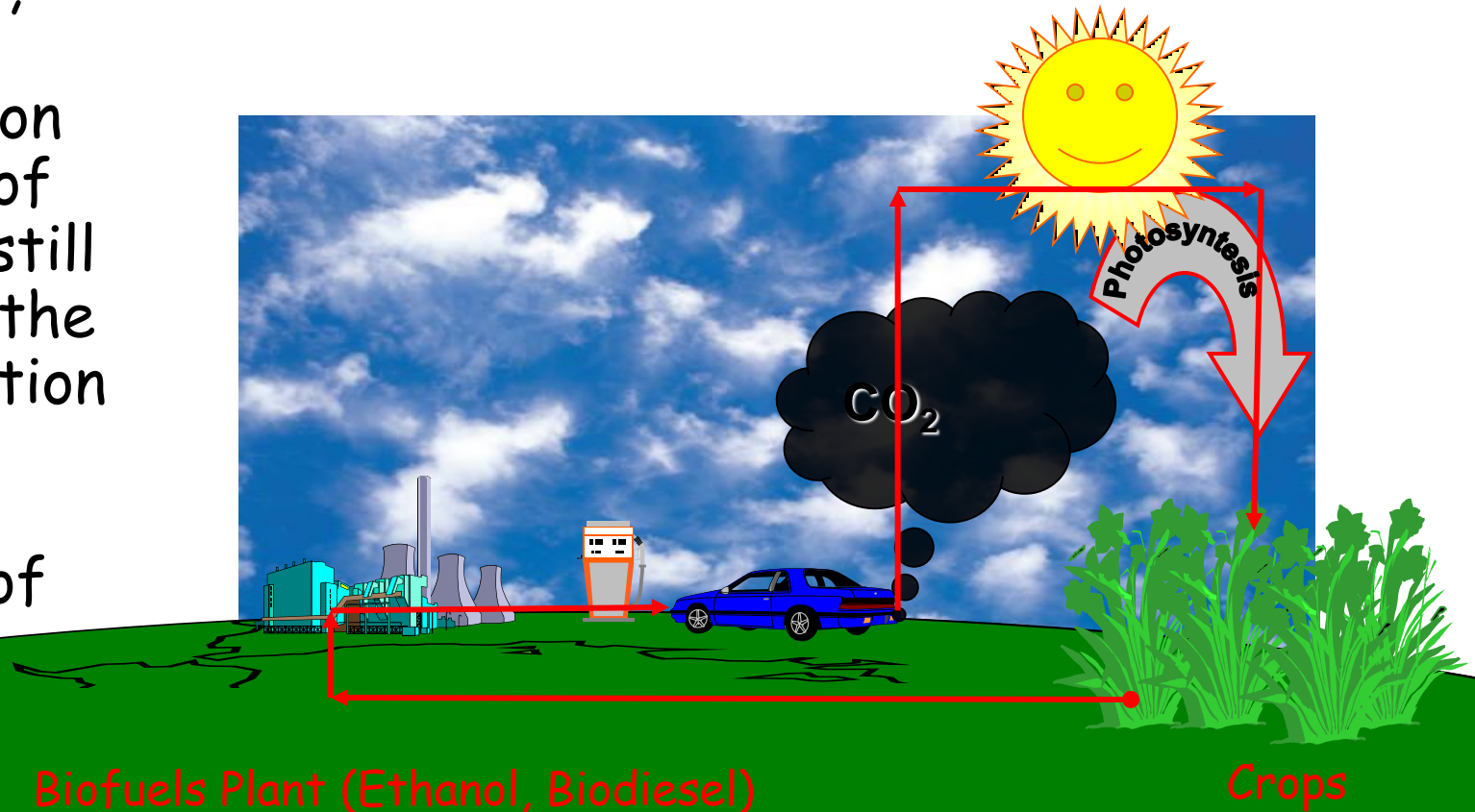
Burning fossil fuels adds CO₂ to the atmosphere otherwise sequestered in the earth.

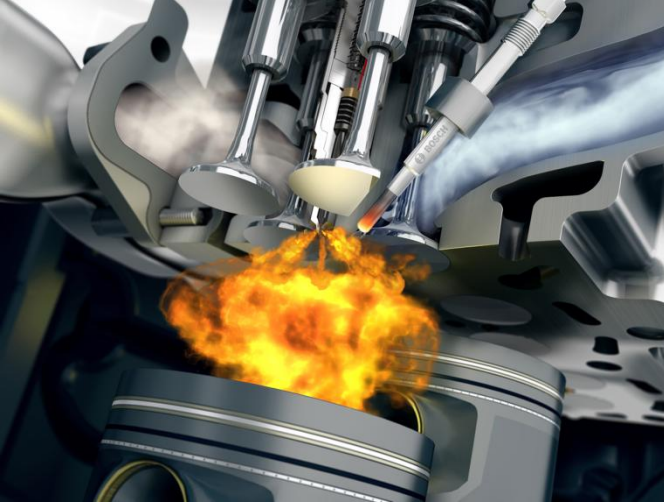


Renewable Fuels

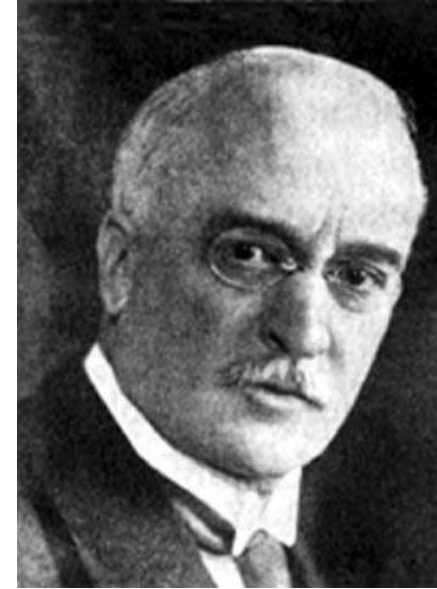
- Vehicles burning ethanol emit CO_2 into the atmosphere.
- Plants use CO_2 during photosynthesis to produce sugars.
- Ethanol is made from plant sugars.

- However, the production and use of ethanol still involves the consumption of fossil fuel and release of fossil carbon.



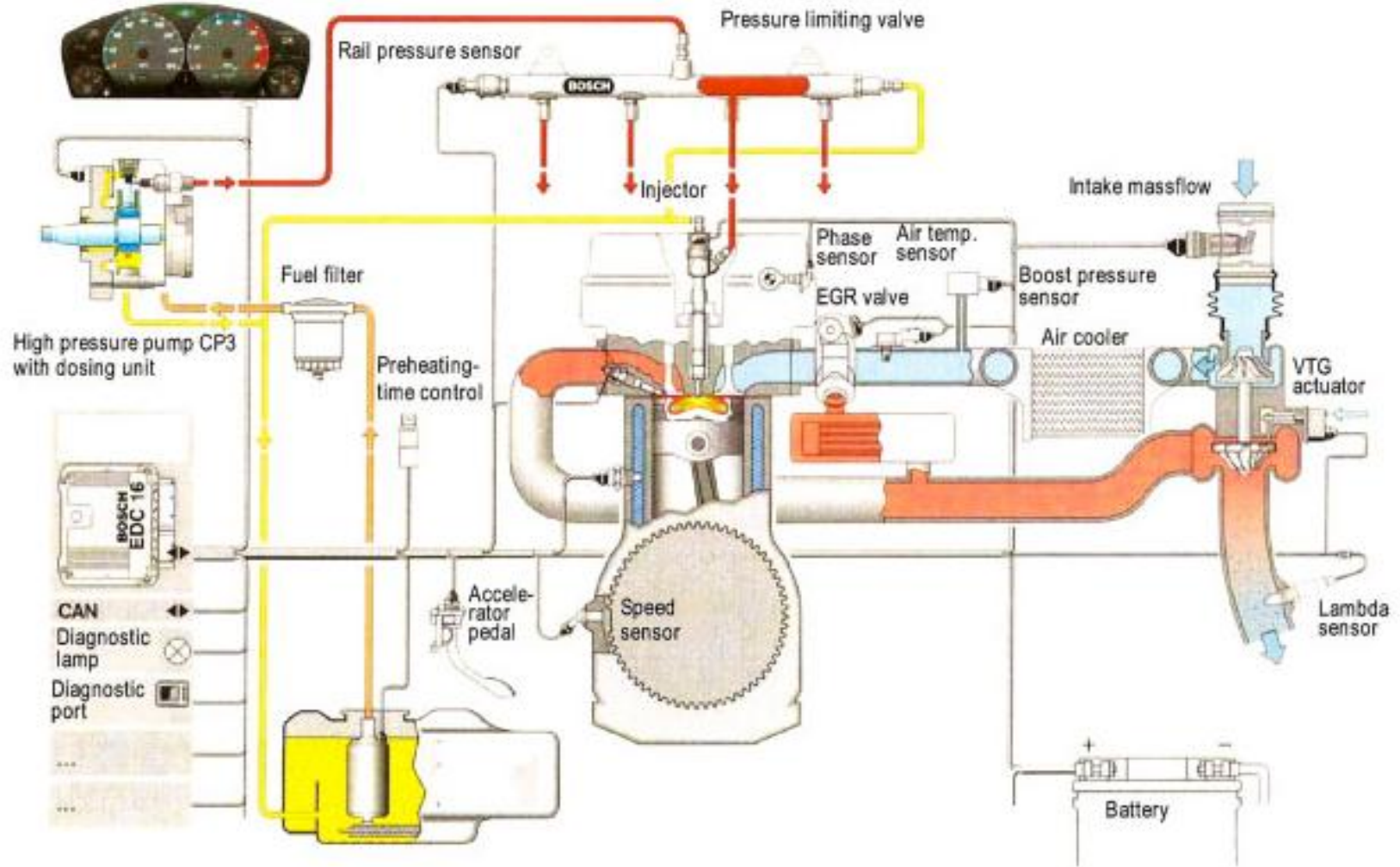


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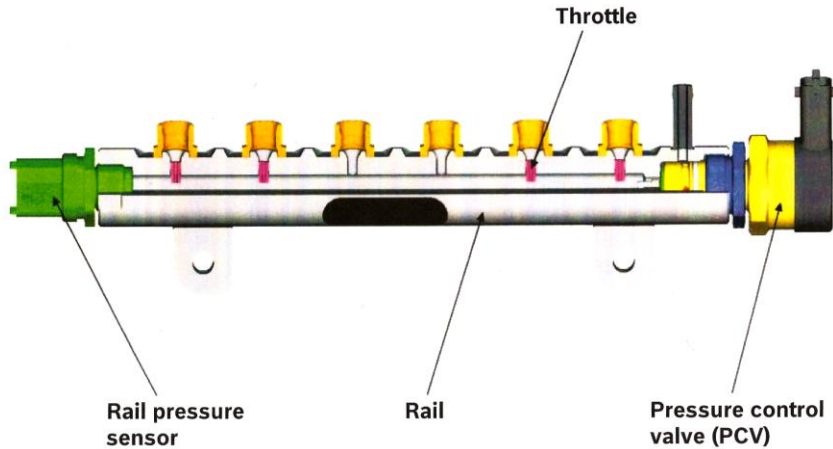
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Common rail components include a high pressure distribution rail, injectors, HP delivery pump, sensors and control circuitry

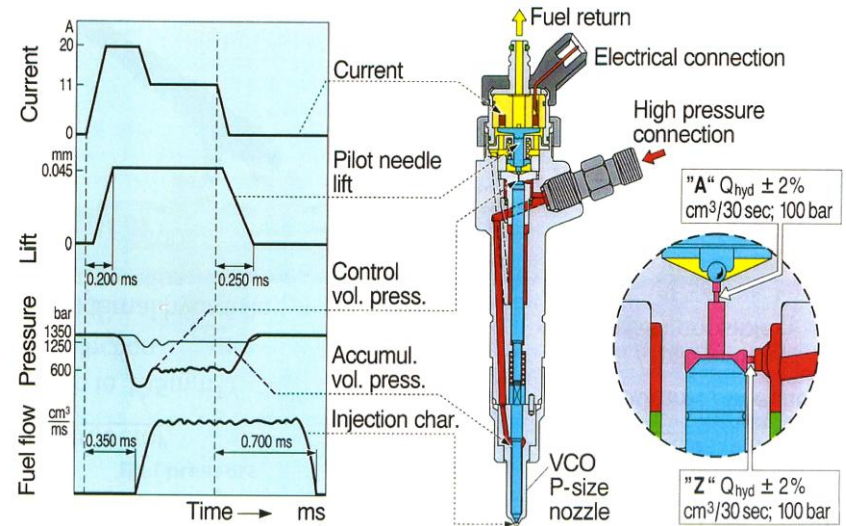


CRD Components

Hydraulic components: rails

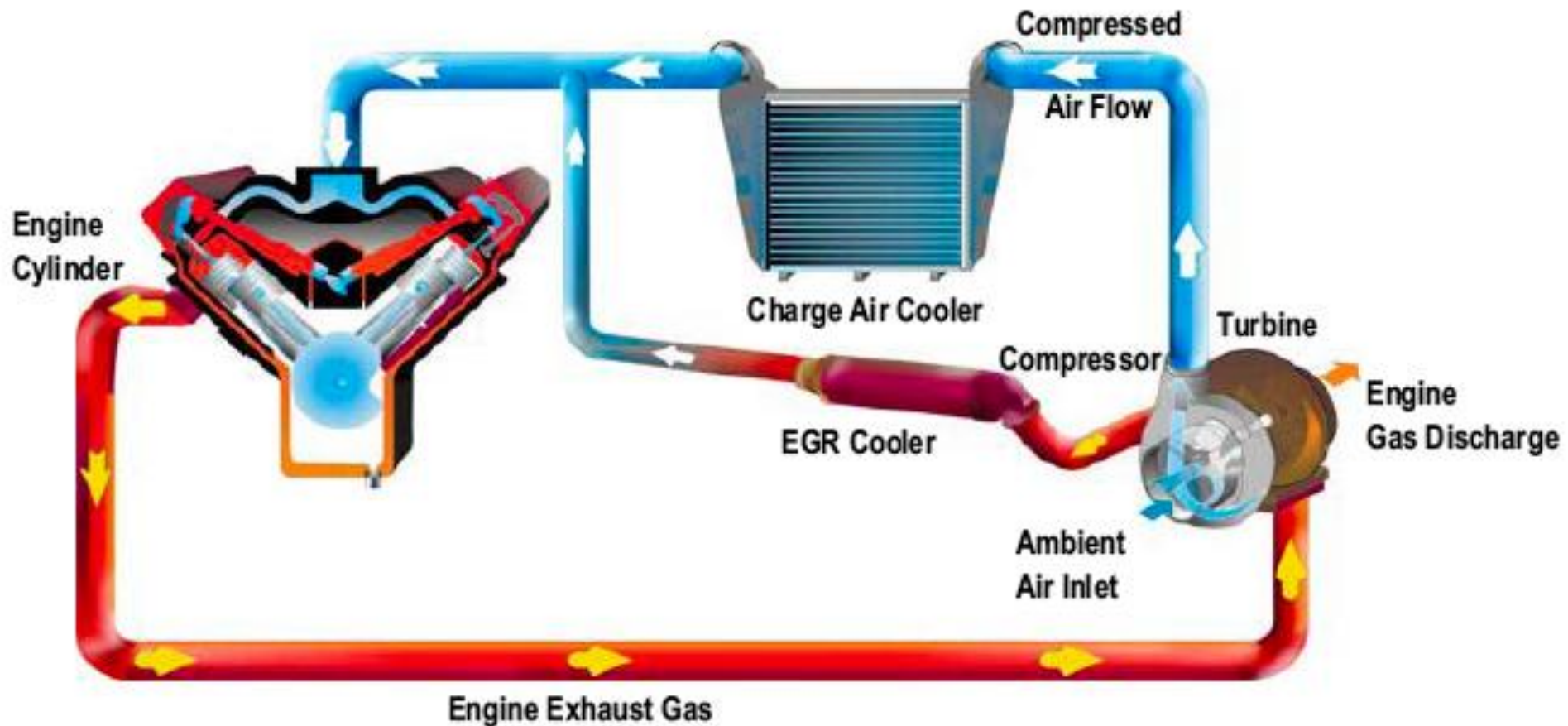


Solenoid Injector



High Pressure Fuel Pump

Turbocharger Basics - Air Supply Critical



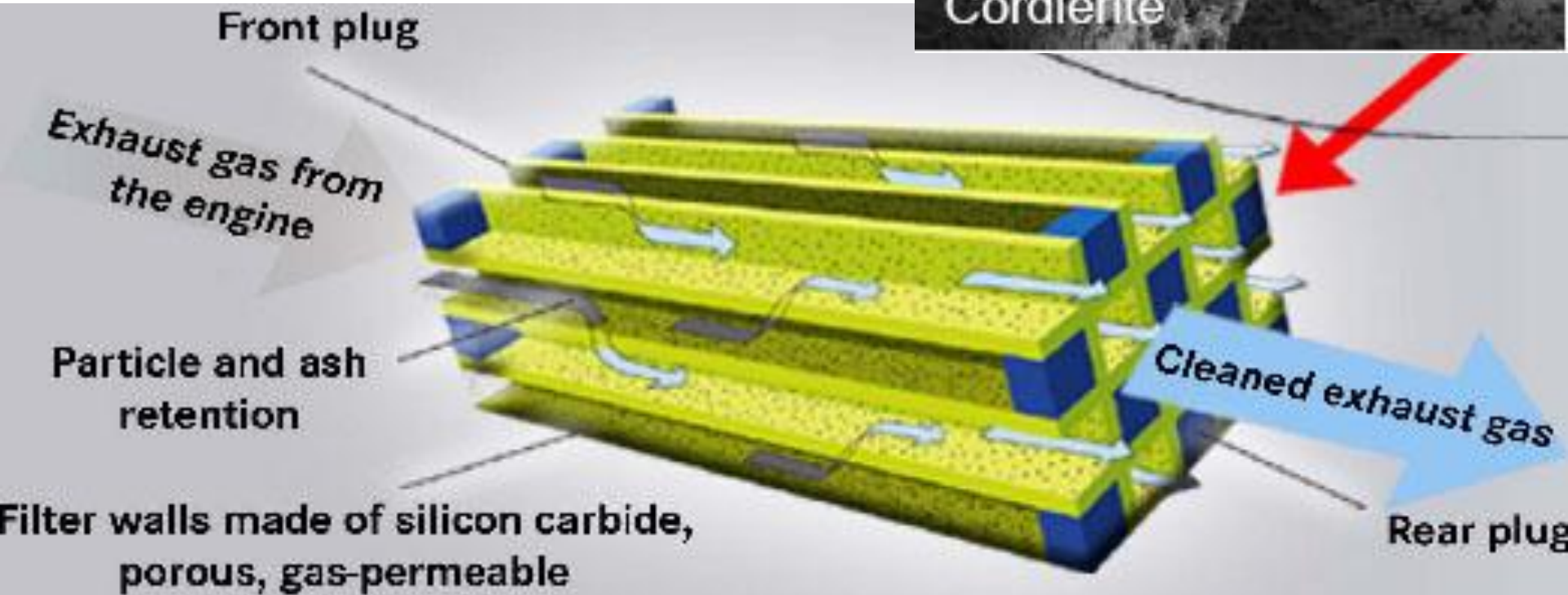
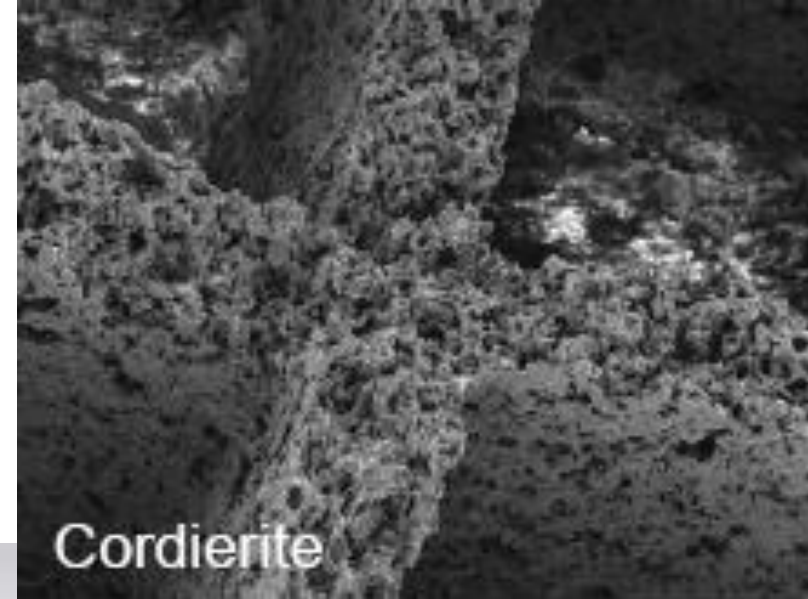
Diesel Engines - Average Air/Fuel Ratio by Volume: 20,000:1

Gasoline Engines - Air/Fuel Ratio by Volume: 9,000:1

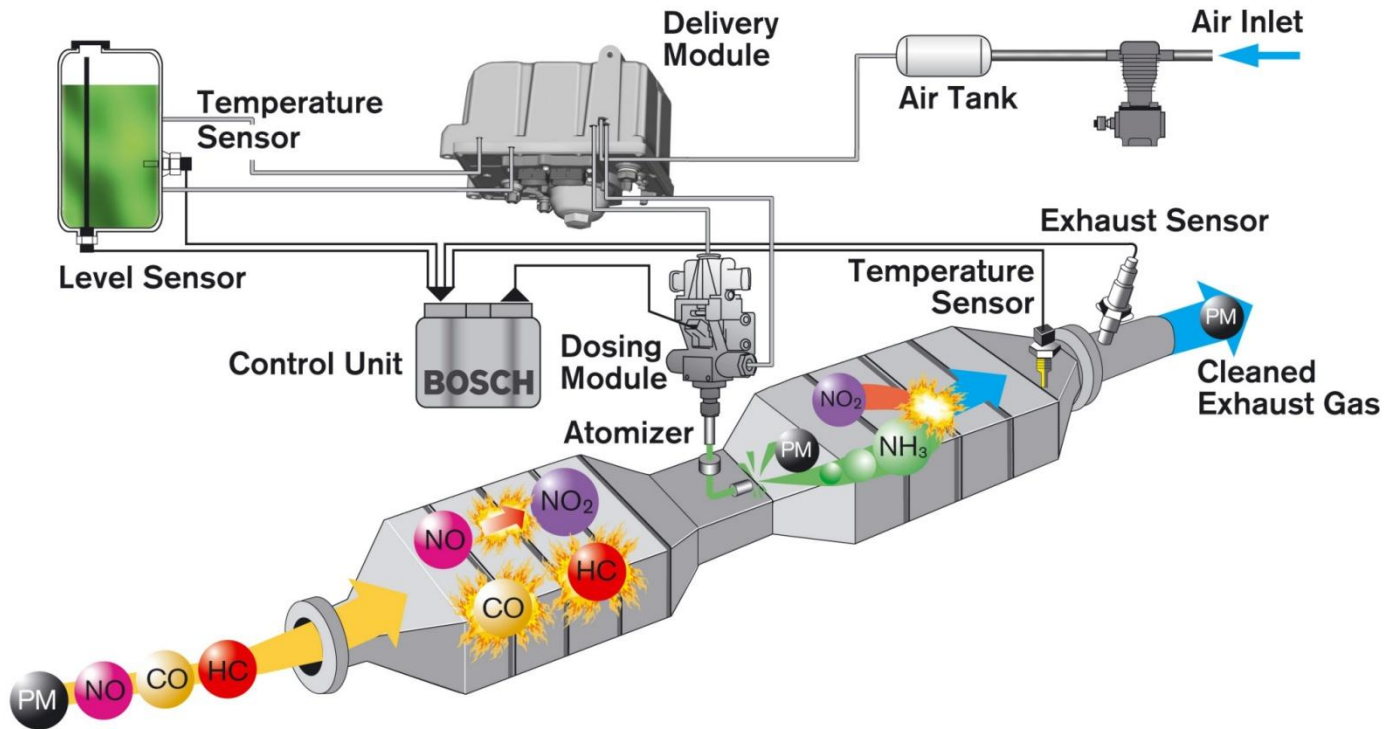
Turbocharger Uses Exhaust Energy

Turbo - a Critical Part of the Pumping Loop

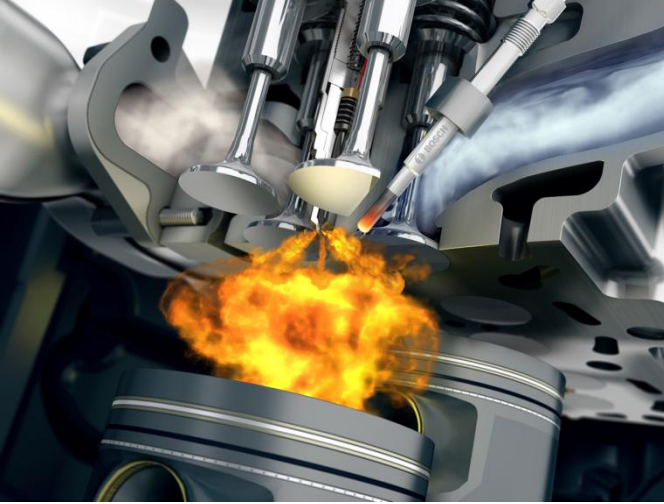
PM & the DPF



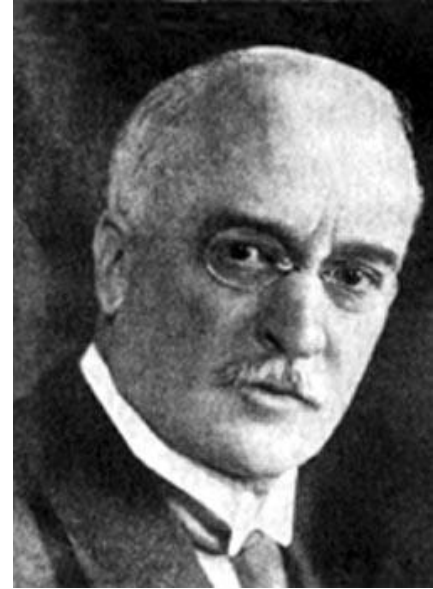
After Treatment - SCR



Courtesy of The Robert Bosch Corporation



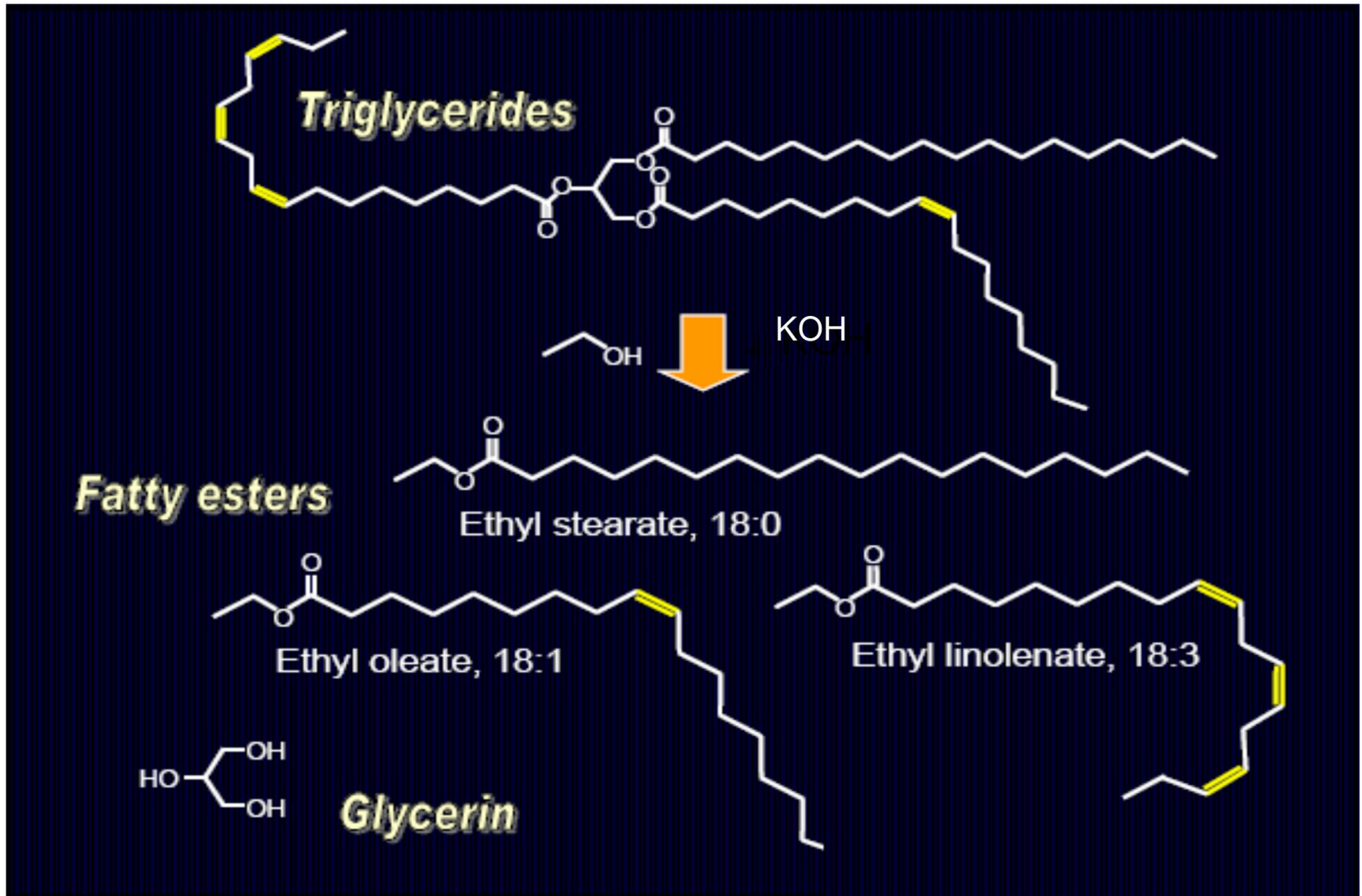
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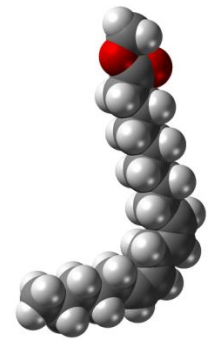


Transesterification



Why Biodiesel?

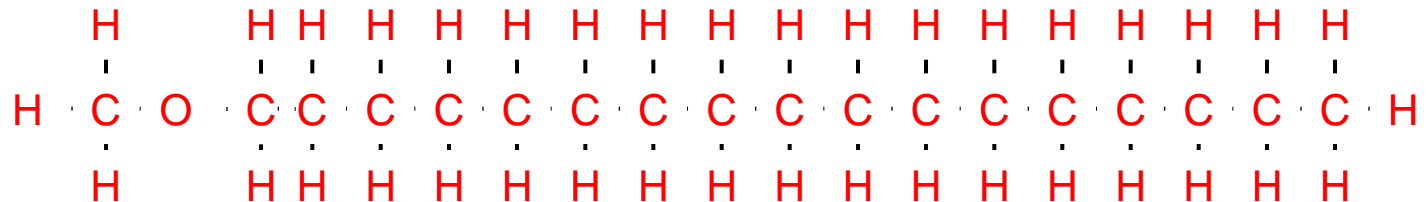
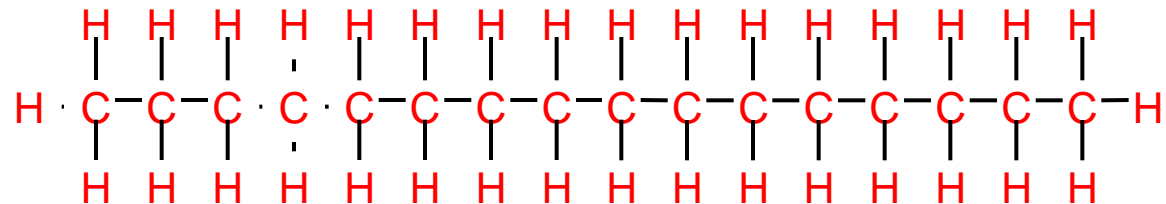
Methyl Linoleate



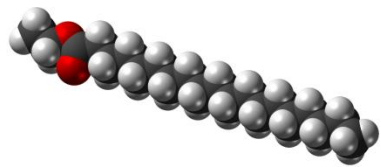
BioDiesel vs Raw
Triglycerides (SVO):

- Lower Viscosity
- Much Higher Cetane
- No Glycerin pyrolysis
- Resistance to Polymerization
- Lower Pour Point (on average 30' lower)
- Can be blended with Mineral Diesel

This represents 1 typical Molecule of Diesel Fuel

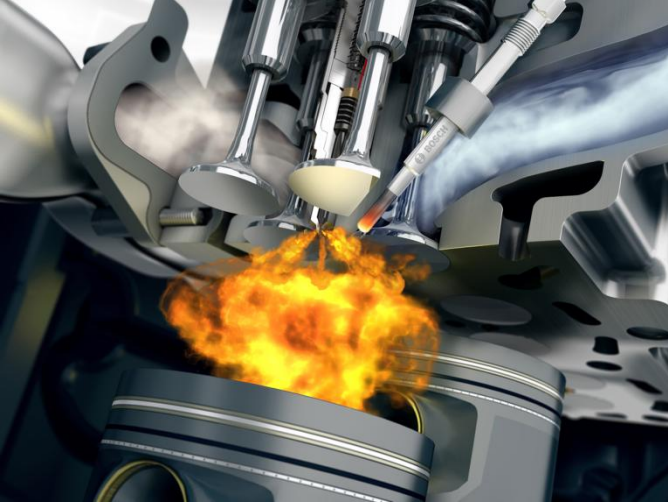


This represents 1 typical saturated molecule of BioDiesel



Ethyl Stearate

Graphics: Wikipedia

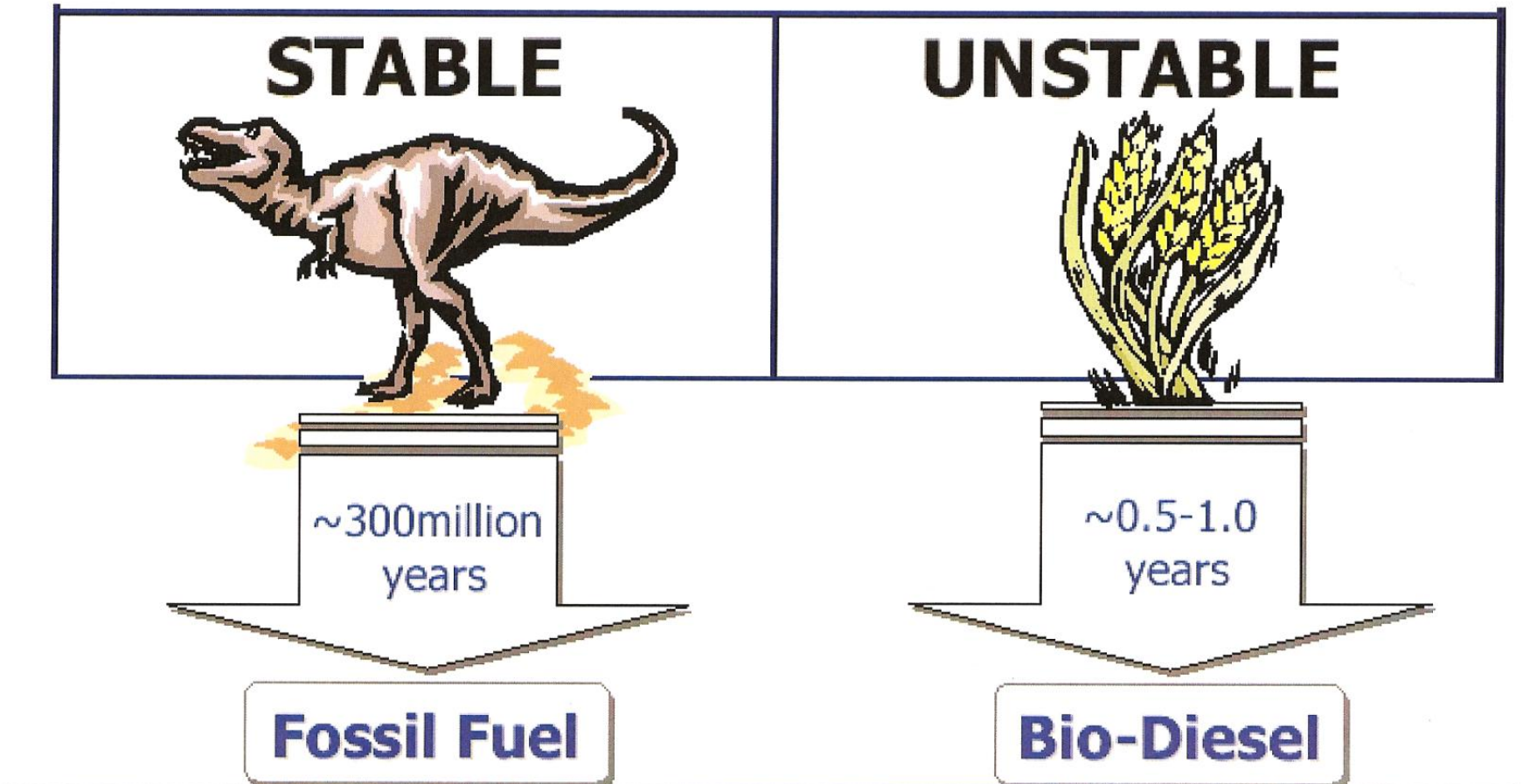


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The challenge of Biodiesel



ASTM D6751 for B6 to B20



DRAFT NBB SPECIFICATION FOR BIODIESEL BLENDS B6-B20

July 2008

Biodiesel (B100) and the petroleum diesel must meet their respective ASTM specifications before blending. This specification covers blend between 5 and 20 percent biodiesel by volume blended with petroleum diesel fuel.

Property	ASTM Method	Limits	Units
Calcium & Magnesium, combined	EN 14538	5 maximum	ppm (ug/g)
Flash Point (closed cup)	D 93	52 minimum	degrees C
Water & Sediment	D 2709	0.05 maximum	% vol.
Kinematic Viscosity, 40 C	D 445	1.9 – 4.1	mm ² /sec.
Ash Content	D 482	0.01 maximum	% mass
Sulfur			
S 15 Grade	D 5453	0.0015 max. (15)	% mass (ppm)
S 500 Grade	D 5453	0.05 max. (500)	% mass (ppm)
Copper Strip Corrosion	D 130	No. 3 maximum	
Cetane	D 513	40 minimum	
Cloud Point	D 2500	report	degrees C
Carbon Residue 100% sample	D 4530*	0.05 maximum	% mass
Acid Number	D 664	0.3 maximum	mg KOH/g
Free Glycerin	D 6584	0.020 maximum	% mass
Total Glycerin	D 6584	0.240 maximum	% mass
Phosphorus Content	D 4951	0.001 maximum	% mass
Distillation, T90 AET	D 86	343 maximum	degrees C
Sodium/Potassium, combined	EN 14538	5 maximum	ppm
Oxidation Stability	EN 14112	6 minimum	hours
Cold Soak Filtration	Annex to D 6751	360 maximum	seconds
For use in temperatures below -12 C	Annex to D 6751	200 maximum	seconds

B5 is D975 spec,
same as Diesel

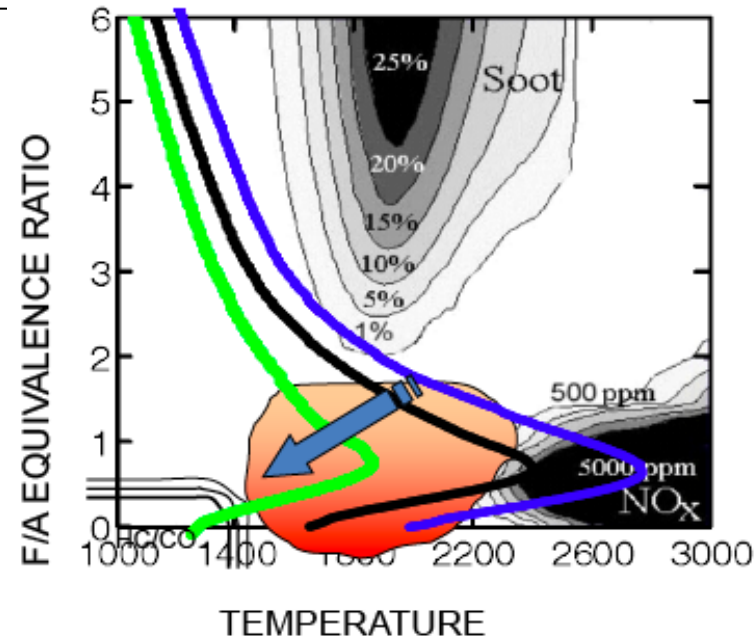
◆Oxidation
Stability is 6
hours

◆Cold Soak
Filtration Test
included

◆Acid Number
Reduction

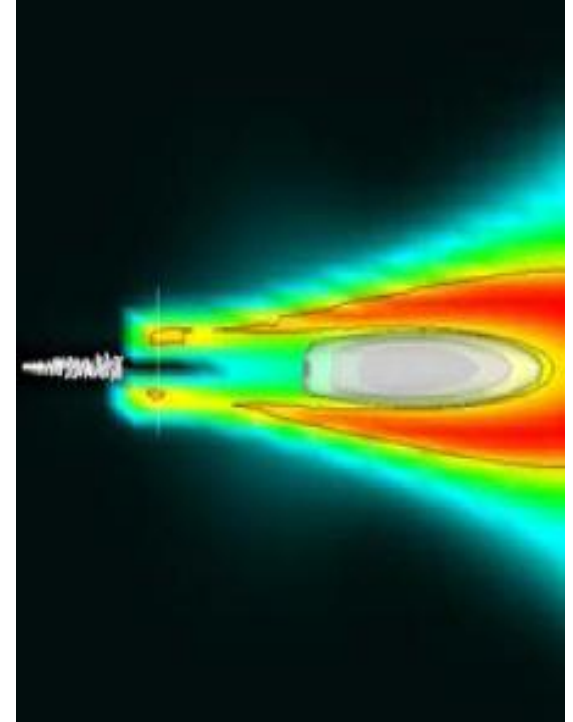
Key Challenges For Biodiesel

- **What's to worry >B5?**
- Fuel quality
 - Glycerin
 - Potassium
 - Fuel oxidation stability
 - Contamination, microbe growth
 - High cloud point
 - Materials interaction
 - Water, water separation filter efficiency
 - Contamination of lube oil

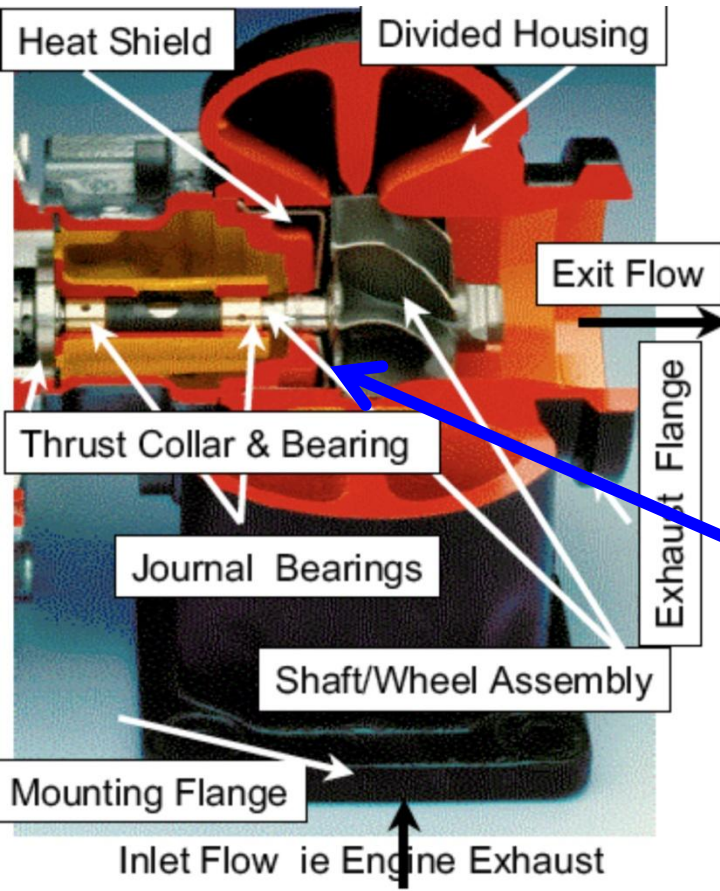


Key Challenges For Biodiesel

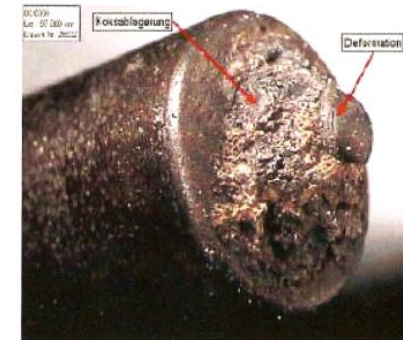
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The challenge of Biodiesel



Coking



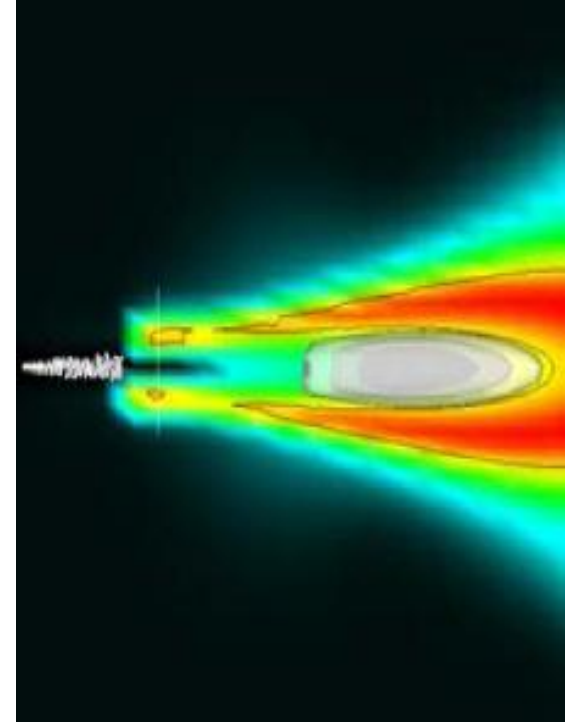
Excess Glycerin



GM BioDiesel Analysis DEERE 2010, SAE 2011

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Technical report Diesel Particulate Filter – BASF

Original DPF Code

B0

B10

B30



After being fixed in epoxy resin and cut into slice



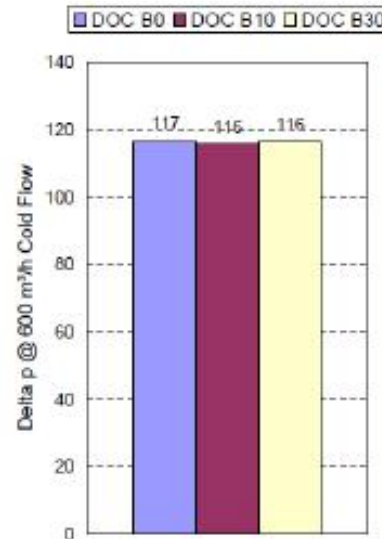
Slightly more ash stored in B10 and B30

Pictures of DPF Rear core after fixed in epoxy resin and cut into slice – Same ash Morphology for all samples

B0

B10

B30



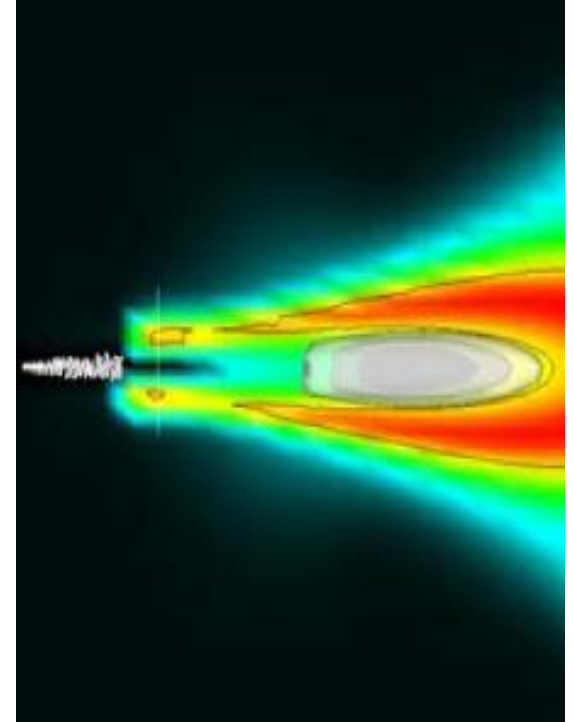
Conclusion

- There might be a small influence on the amount of stored ash if the amount of biofuels is increased from 0% to 10% (no difference b/w 10 to 30%)

This will be a big problem is the Catalyst is not fully removed from the fuel!

Key Challenges For Biodiesel

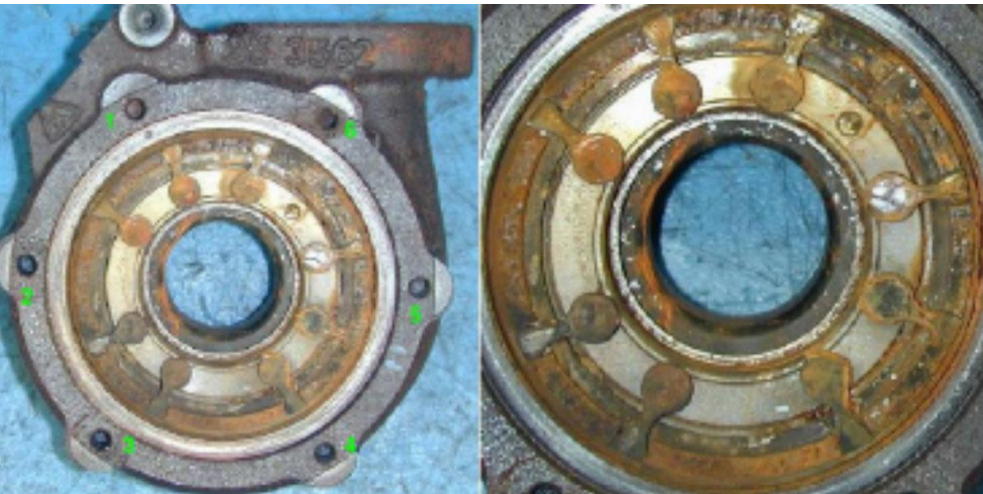
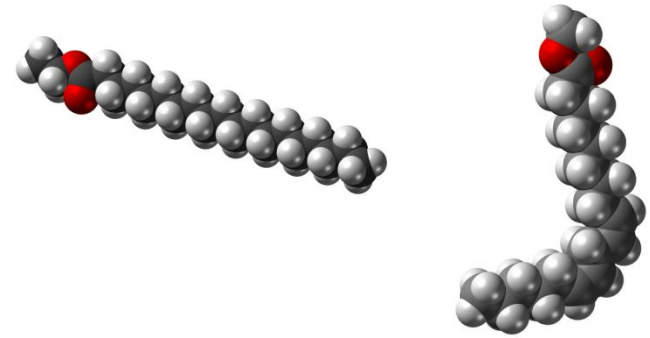
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Free Fatty Acids (Oxidation Stability)



FFA content is a function of feedstock quality (Saturation, prior use) , shelf life and storage conditions

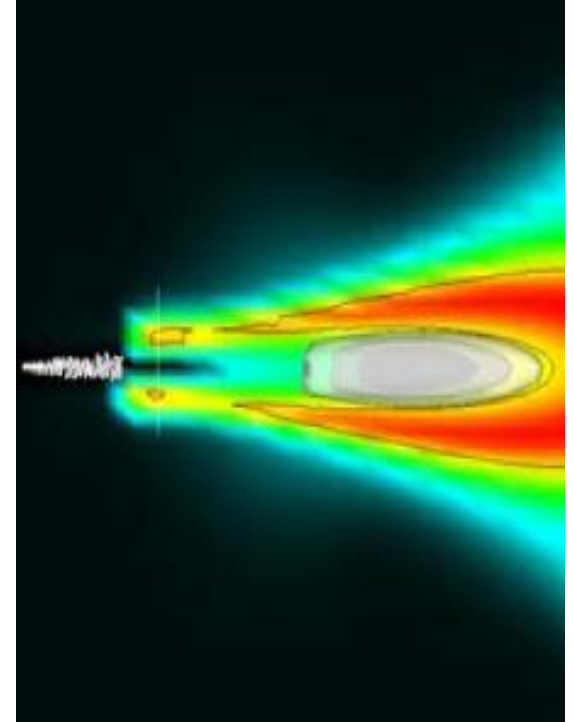


- WVO should not be used as a feedstock for modern Diesels
- Fuel should be used within 90-120 days of production
- Purge air space with inert gas

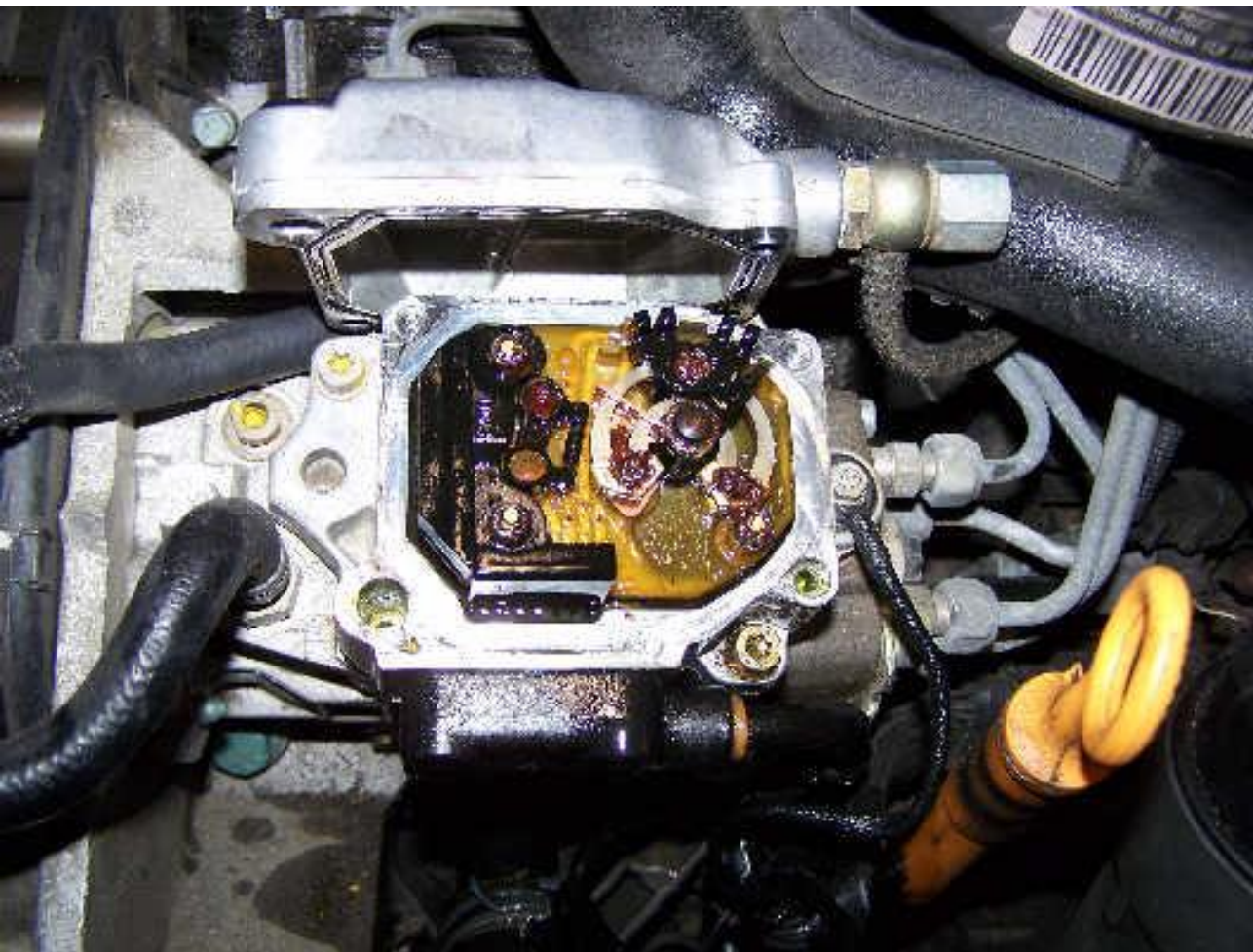
GM BioDiesel Analysis DEERE 20

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Microbial Contamination



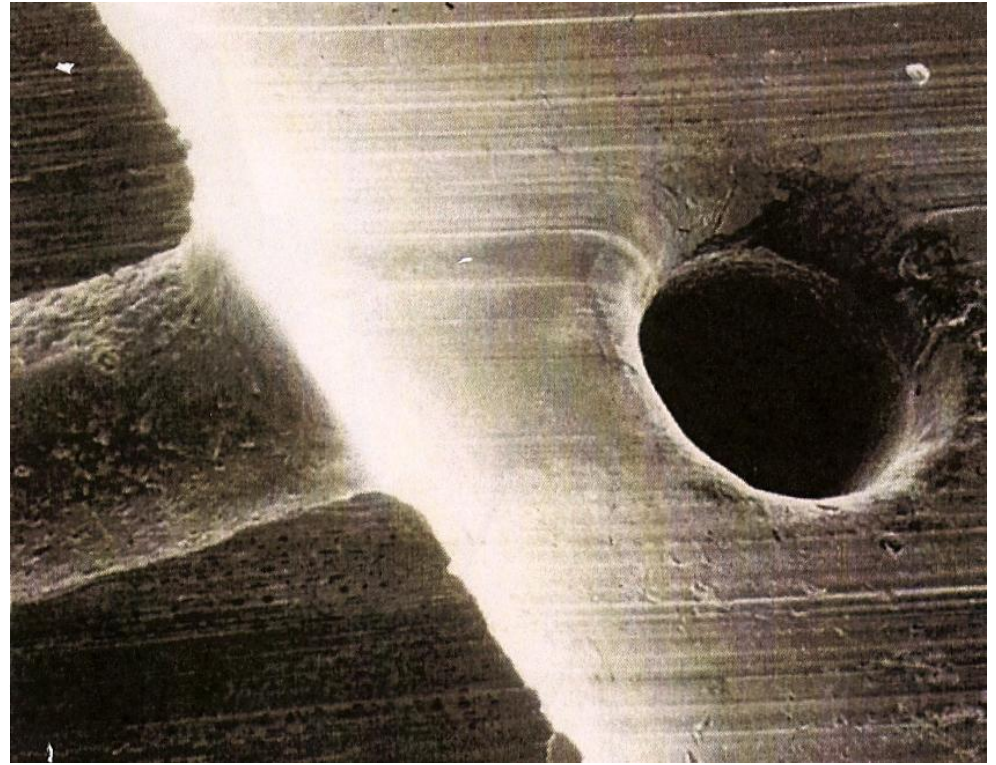
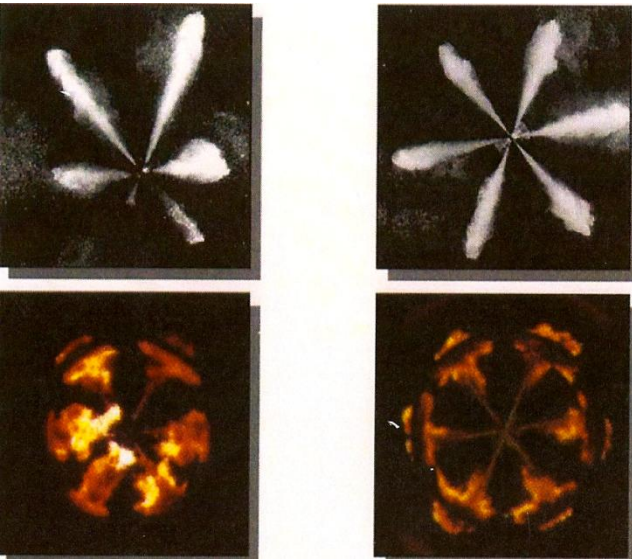
Since the last stage of transesterification is the destruction of the monoglyceride this is the most common remnant of incomplete conversion

Monglycerides will promote microbial growth in the fuel tank and water retention

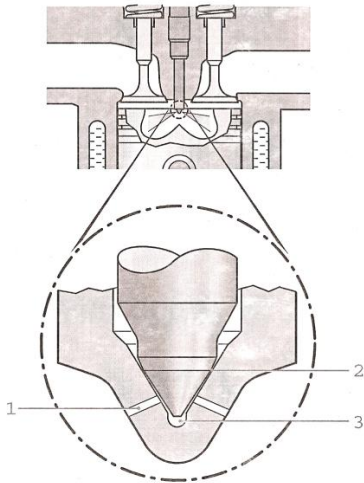
It is critical to use high quality filtration, closely monitored!

Photos courtesy of the Robert Bosch Corporation

Effects of dirt/water



Hydraulic components: nozzle tip in cylinder head

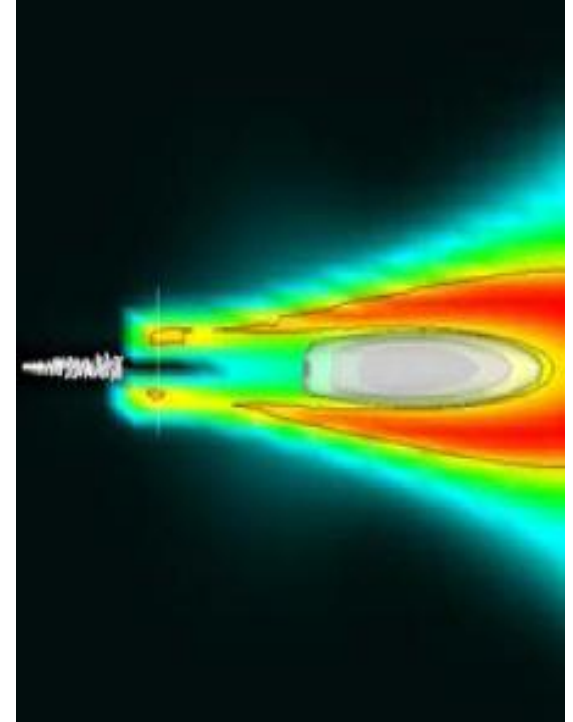


1. Injection-orifice geometry
2. Seat geometry
3. Sac-hole geometry

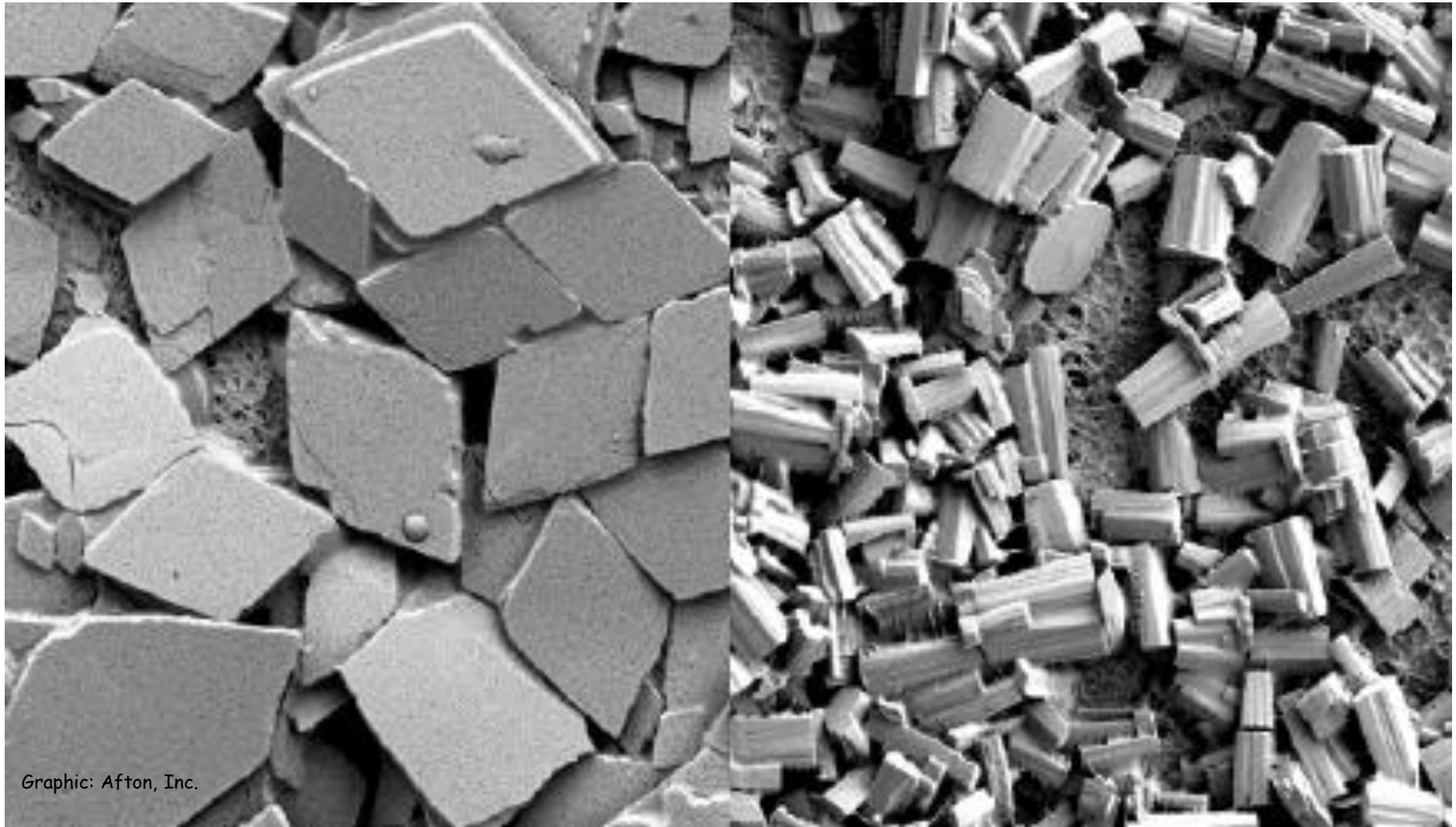
Source: Bosch Diesel Engine Management, 4th edition

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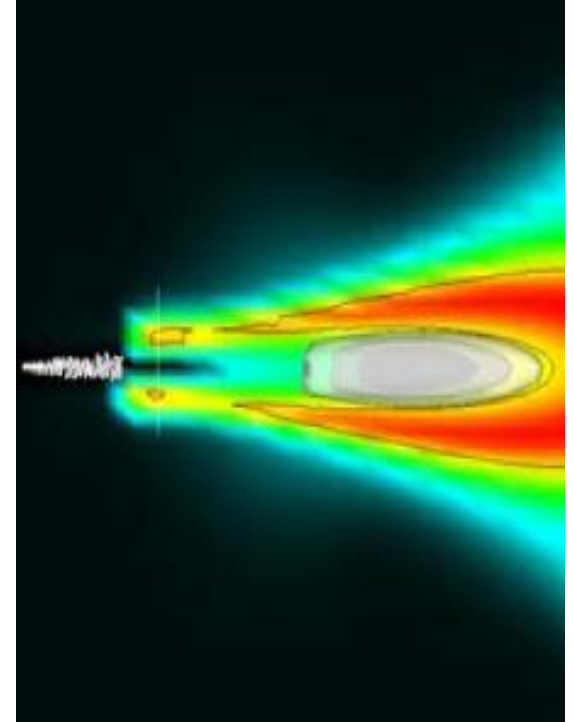
Cold Flow (Clouding) & Anti-Gel Agents



Graphic: Afton, Inc.

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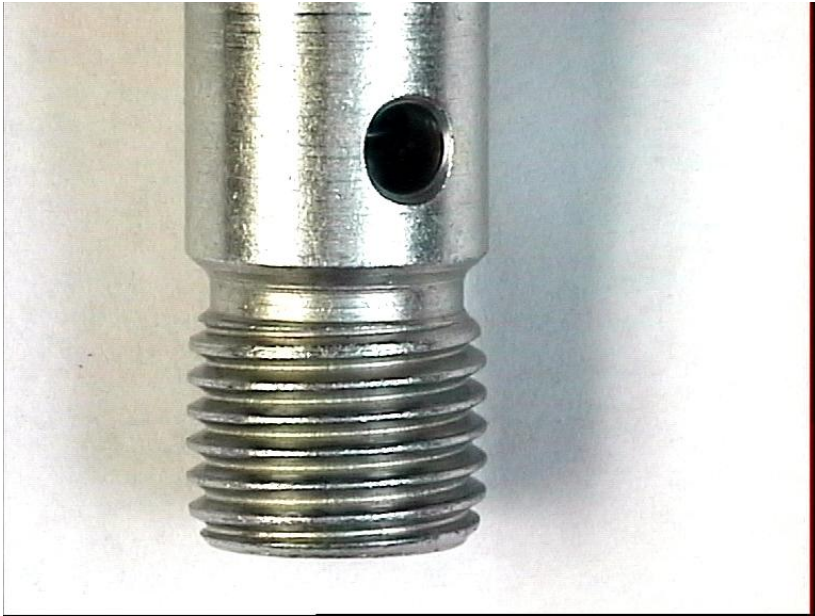


Materials Interaction

- Biodiesel causes degradation/swelling of elastomers (natural and nitrile rubber), Nylon 6.6
Attacks brass, bronze, copper, lead, tin and zinc

Bosch pump overpressure valve, removal of zinc coating after 1 yr stand-by genset operation with B20 (300 hrs):

#2 Diesel



B20 blend

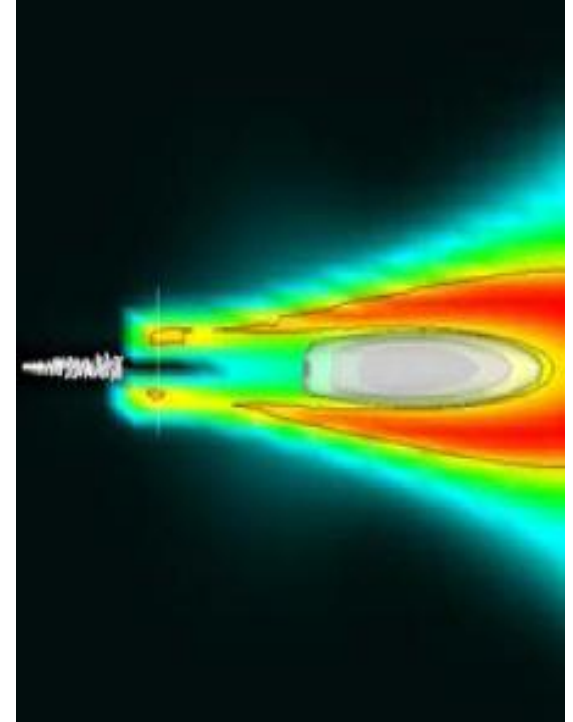


Materials Interaction

- Biodiesel will aggressively clean & scour the fuel system
- This includes storage tanks, lines, hoses, etc.
- It will carry the lacquers & solids to the fuel filter, which will plug the filter
- Once it has done so it will keep the system clean
- In service vehicles converted to Biodiesel **IN ANY PERCENTAGE** will likely require initial filter change outs

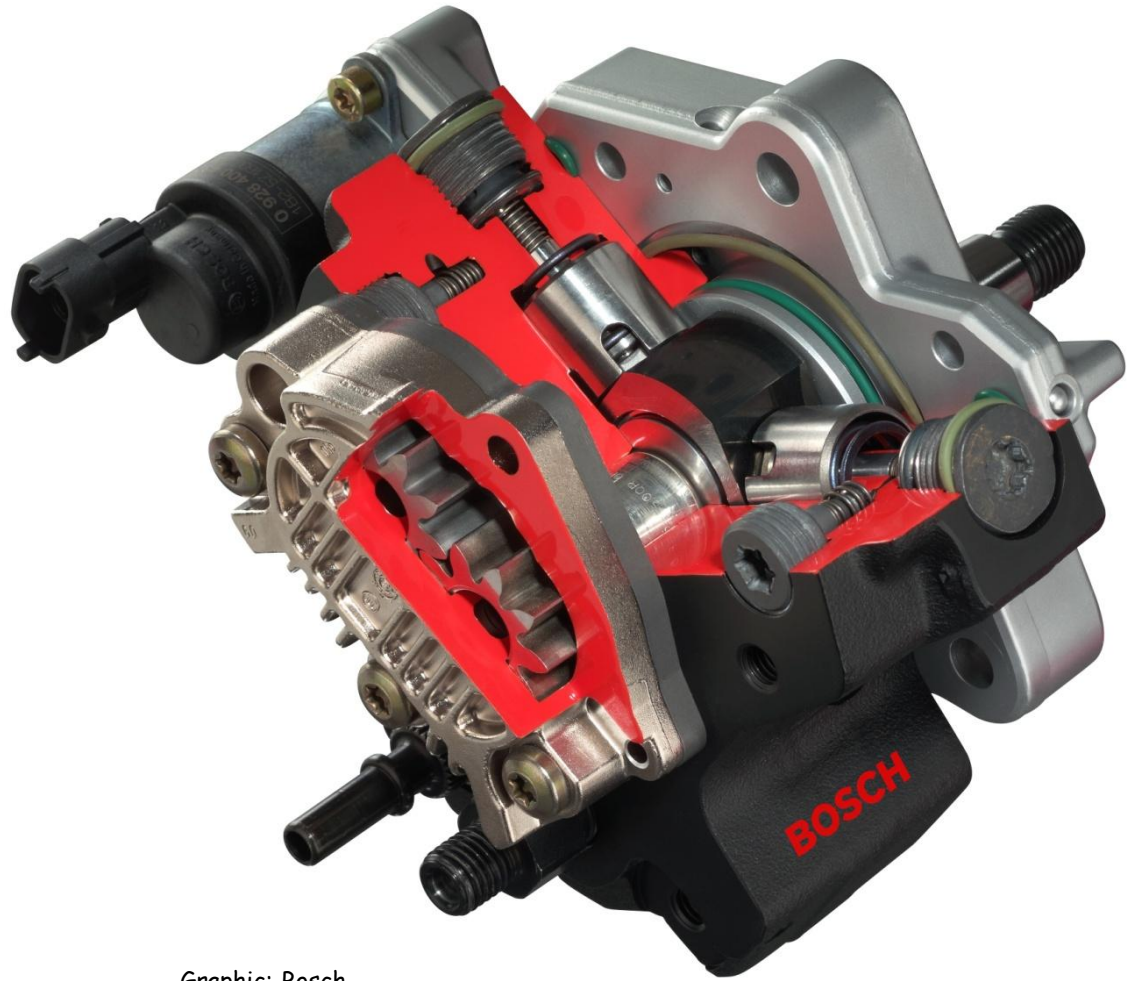
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Biodiesel & Water

- ASTM Specification:
<500PPM
- Good quality petro diesel has a water content in the range of 50ppm
- Biodiesel will retain up to 1500 ppm of water!
- If you are using Biodiesel use a water separator!



Graphic: Bosch

Biodiesel & Water

USE A WATER SEPERATOR!

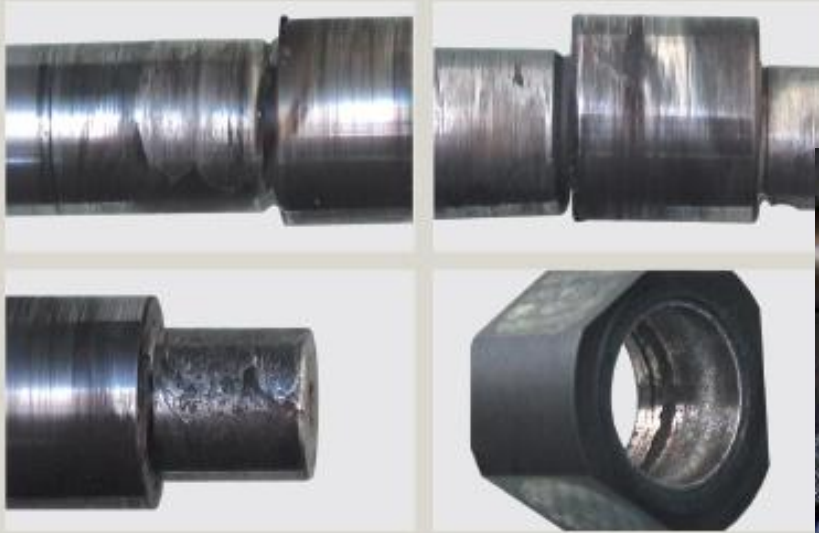
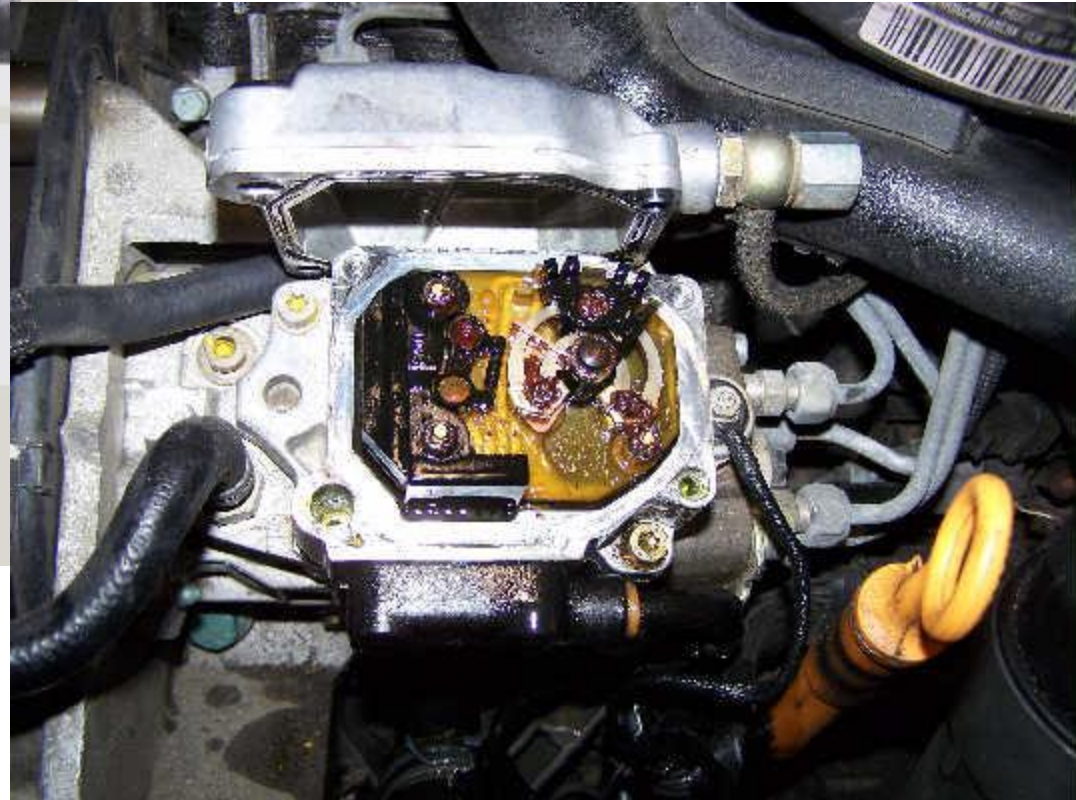


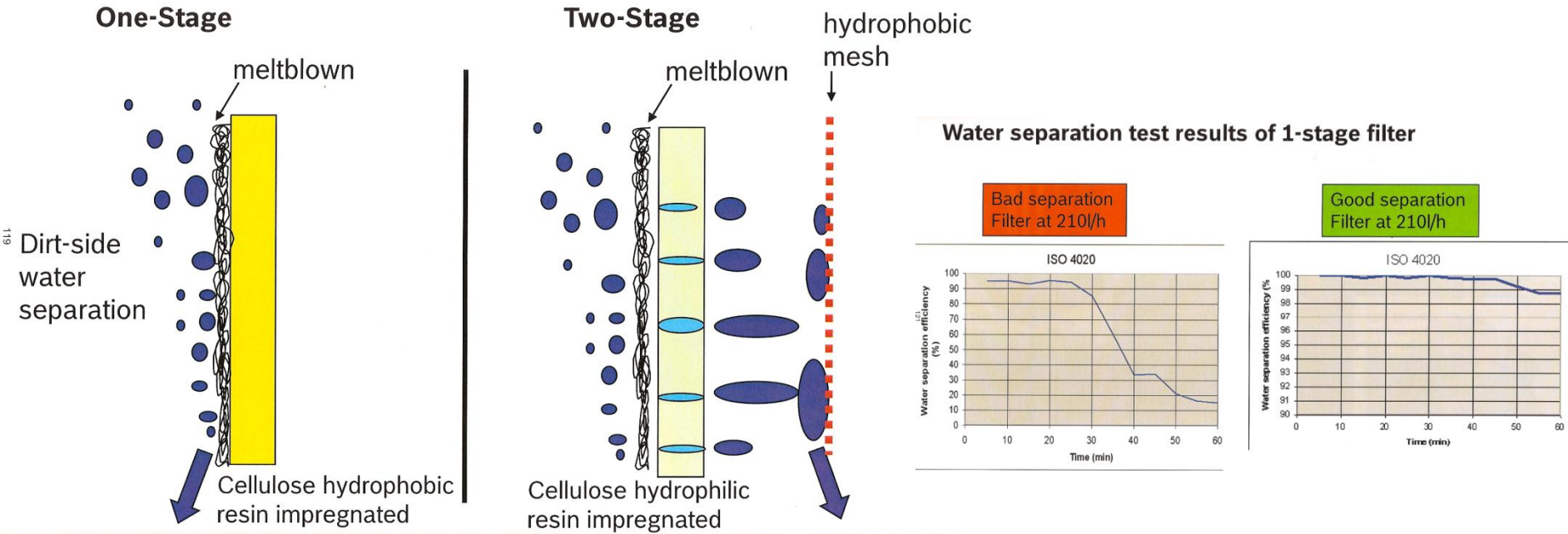
Figure 20: Wear and seizure on the eccentric shaft and roller of a Common-Rail high-pressure pump after only 189 hours endurance test wit F35

Graphic: Bosch



Photos courtesy of the Robert Bosch Corporation

Filtration-How does a Filter work?

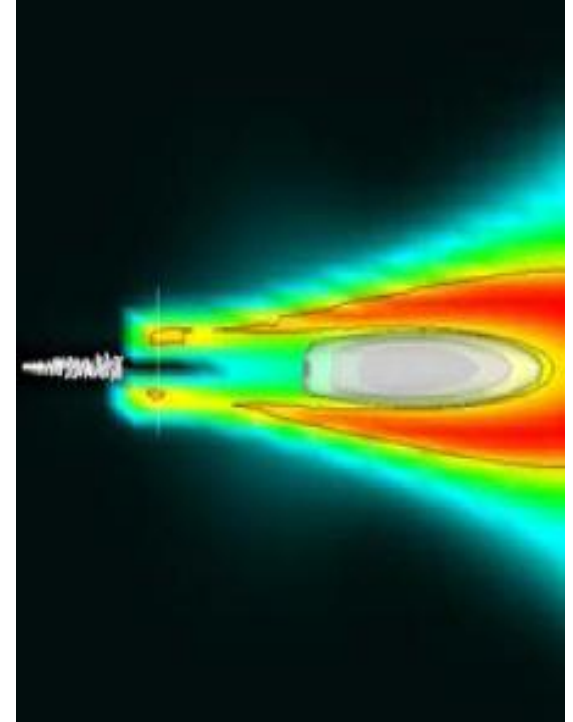


Graphic: Bosch

Use a high quality water separator!

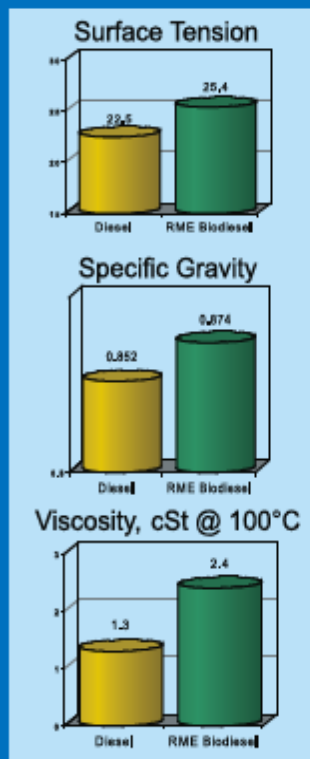
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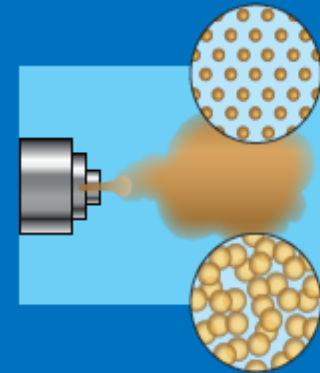


Lube oil Issues

- Accumulation of Biodiesel in lube oil causes:
 - Dilution
 - Viscosity increase
 - Oxidation
 - Polymerization (sludge)
- Shorten change intervals!
- Bio Fuels industry lobbying for DPF Doser instead of late post injection

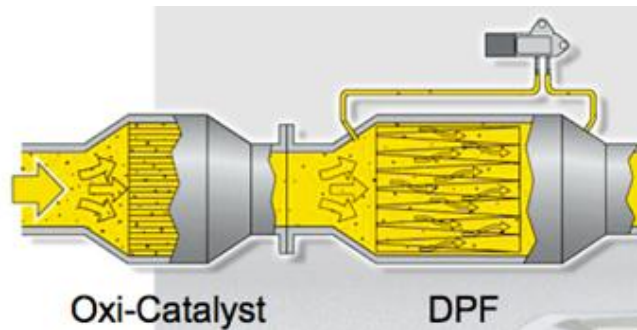


Diesel – normal droplet size



Larger fuel spray droplet size

Late or post injection leads to higher levels of fuel dilution



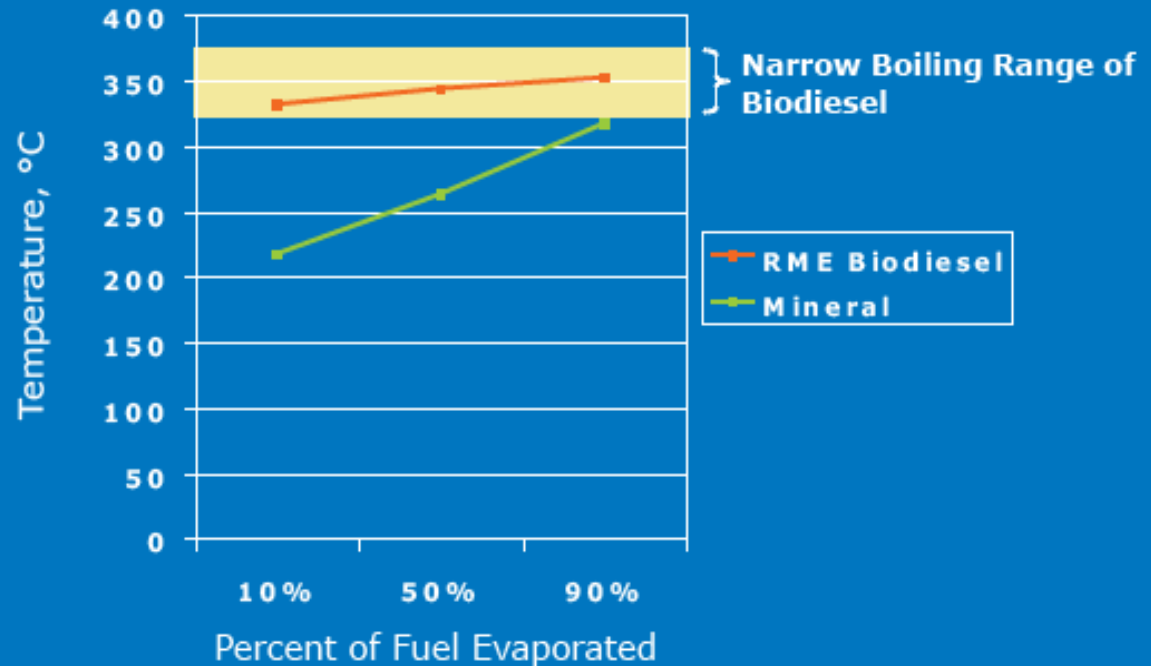
Lube Oils

**Using Biodiesel
requires
increasing the
frequency of lube
oil changes**

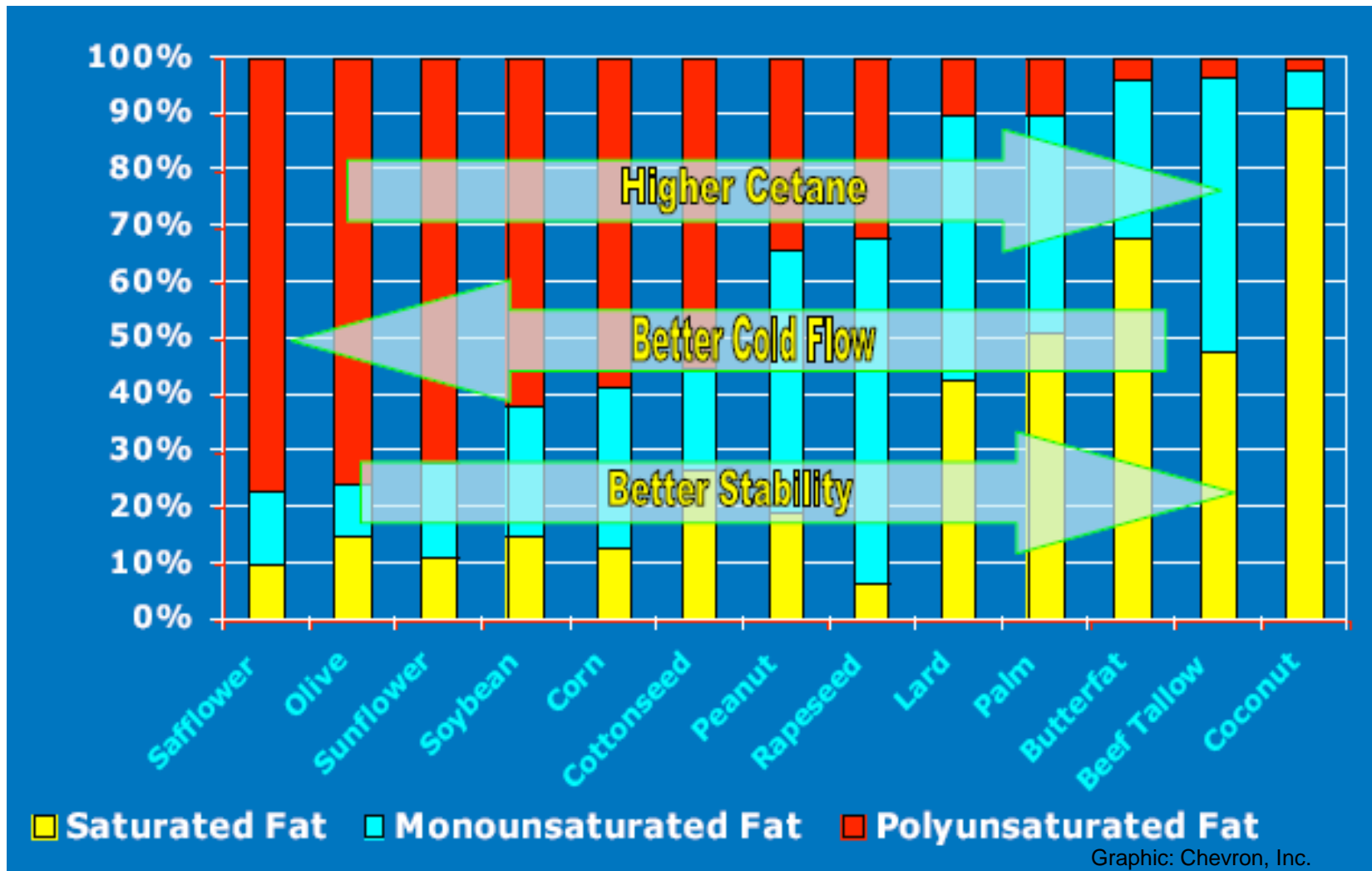
**Establish a
baseline with
initial oil analysis**

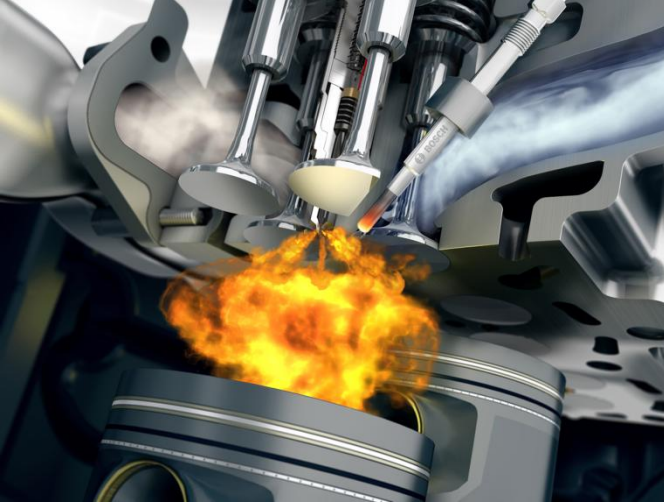
Graphic: Chevron Oil Co.

Higher and Narrower boiling range of biodiesel makes it more persistent once it enters the crankcase

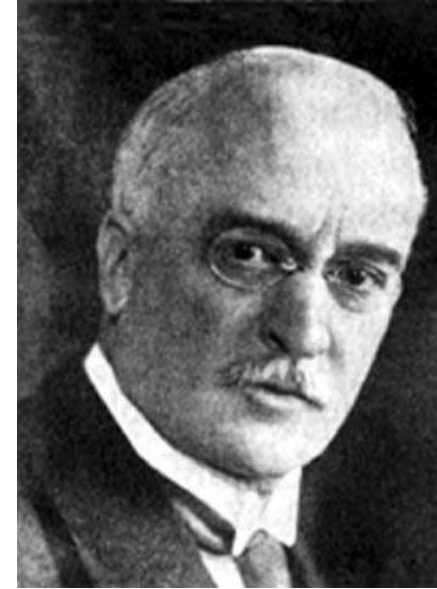


Summary of Biodiesel Properties





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- Issues with use of Bio Diesel
- *Solutions, conclusions*

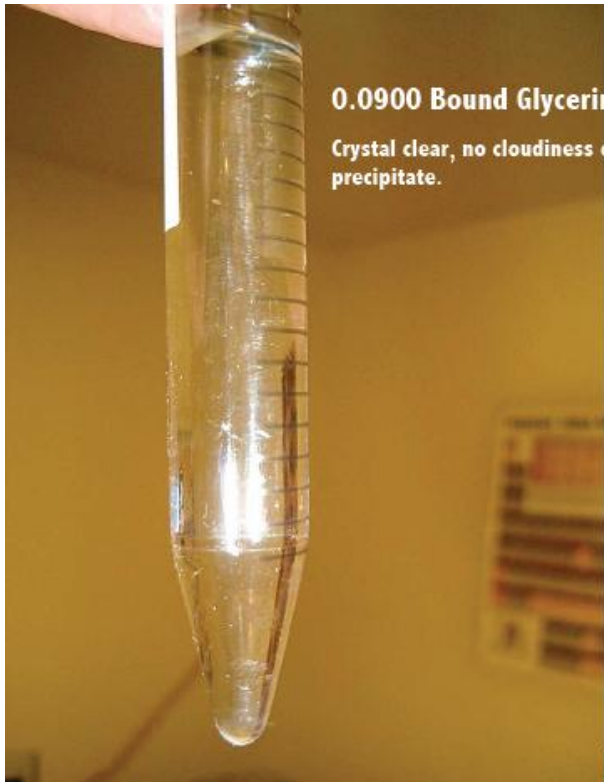
Summary: Biodiesel & Maintenance

- *Producers must be trained*
- Shippers must be trained
- Handlers/Retailers must be trained
- Operators must be trained
- *Technicians must be trained*



Summary: Biodiesel & Maintenance

- Insist on ASTM certification for every batch
- DIY test kits widely available

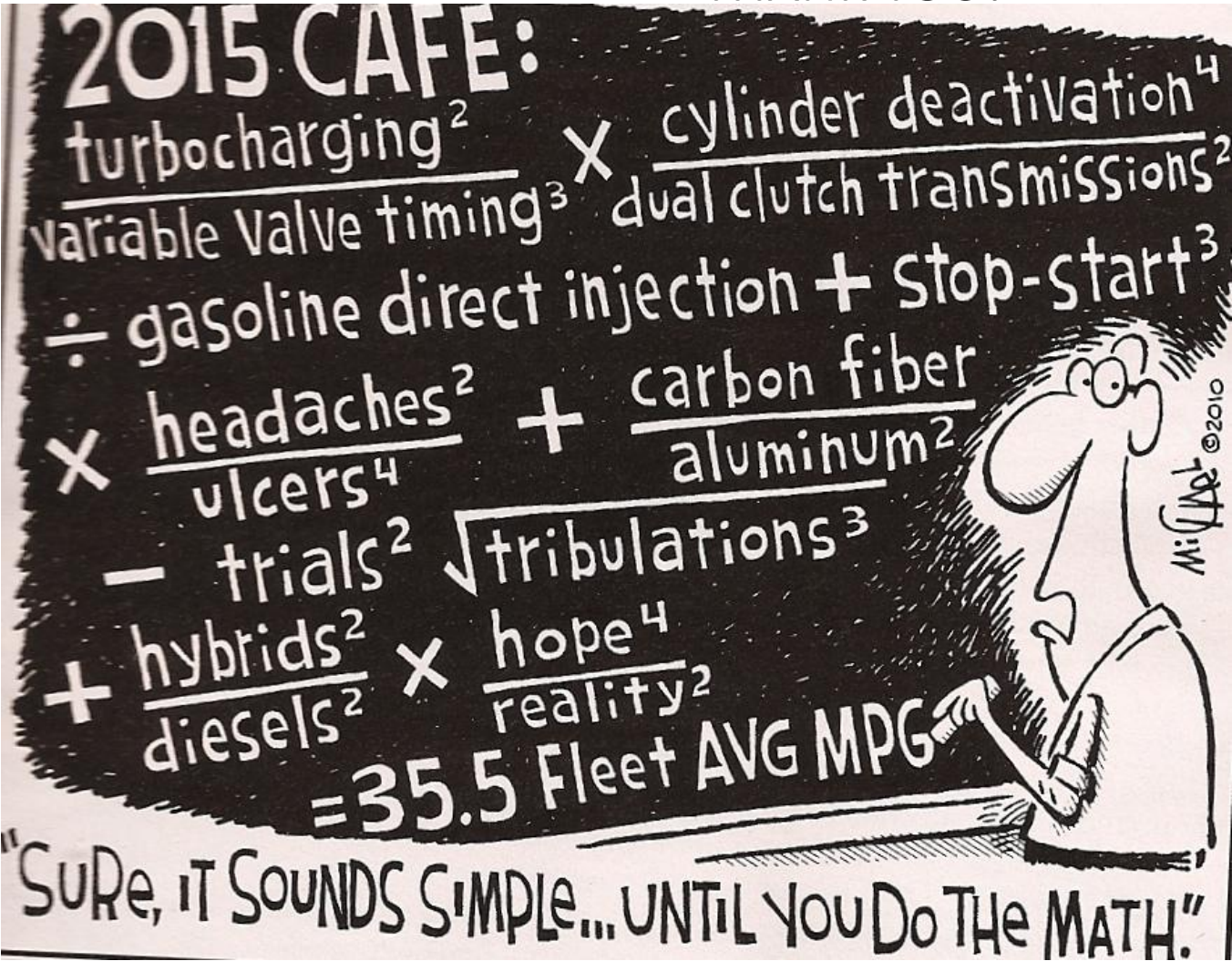


Summary: Biodiesel & Maintenance

- *Control* shelf life. Inventory a 90 day supply, purge air space, keep as cool/dry as possible. Test tanks for water regularly
- High Cloud Point: Be mindful of feedstock, ambient temperature & duty cycle of the vehicle
- Materials interaction should not be a significant issue in modern engines, update soft parts, Copper & Zinc components in older engines. Monitor filters when converting used vehicles/equipment
- All vehicles should be equipped with a water separator such as: www.racorfilters.com
- Lube Oil: Need to shorten change intervals, establish a baseline with initial oil analysis

Questions?

THANK YOU!



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