



# Biodiesel Validation in Caterpillar Engines

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Orlando, Florida

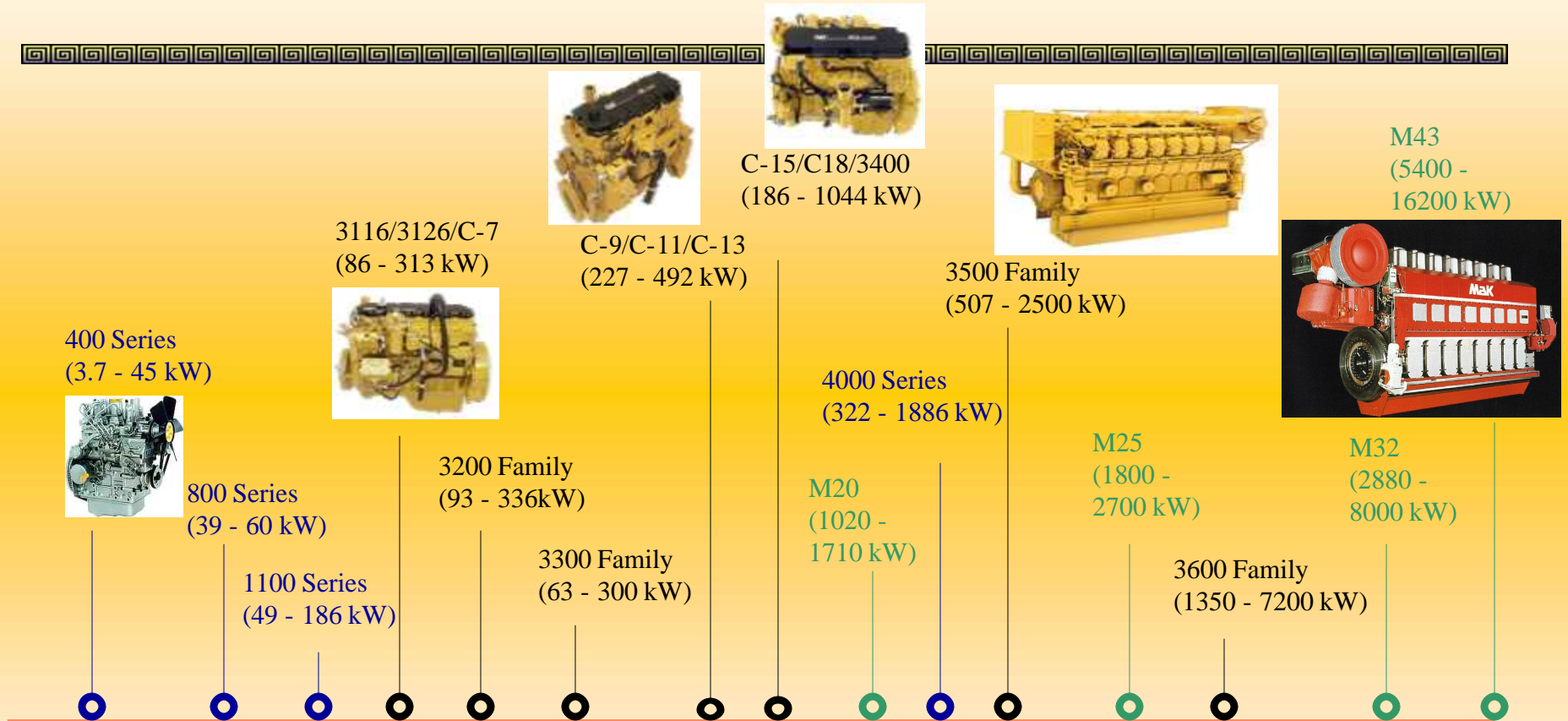
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# Caterpillar Diesel Engines - Product Line



# Caterpillar Engine Applications



# New Product Introduction



- ❖ Diesel Engines and new product, for worldwide applications, are validated on diesel fuels per ASTM D975 or EN590
- ❖ Emissions Certification is conducted using EPA prescribed certification fuel
- ❖ Fuels other than diesel present a challenge for design and validation efforts
  - The fuels must be viable, available, and of consistent characteristics

# Validation of Biodiesel



## Approach to validation:

- ❖ Analysis: Risk assessment, modeling
  - Rigorous 6 Sigma methodology; FMEA for potential applications and blends
  - Development of analysis and testing procedures characterize the fuel and understand its potential performance and interactions
- ❖ Bench tests: Accelerated tests for stability, compatibility, etc.
- ❖ Engine tests: Accelerated cycles and Detailed assessment of components
- ❖ Field testing: Assessment of performance and analysis of components
- ❖ Testing programs with the industry: EMA, NBB, NREL, ASTM, etc.

Specification development  
Guides and information  
Communication with dealers

# Biodiesel Early Testing



- ❖ 1997 Field test, 3406 on-highway truck application using B50 blend of soy methyl ester and #2 diesel fuel
  - ❑ >240,000 miles
  - ❑ Emissions and BSFC measurements
  - ❑ Engine power and performance assessment
  - ❑ Component Wear and deposits
    - No adverse effects were found
- ❖ 2002: Program to assess seal materials compatibility in B50 soy methyl ester
  - ❑ Quantification of the adverse effects on Nitrile rubber materials
  - ❑ Identification of appropriate seal materials

# Analysis – Quality Function Deployment

		9=strong, 3=Moderate, 1=weak																									
		Biodiesel percentage	Biodiesel property/quality	Biodiesel feedstock	Biodiesel percentage	Biodiesel percentage	Biodiesel percentage	Biodiesel percentage	Biodiesel percentage	Biodiesel percentage	Biodiesel property/quantity	Biodiesel feedstock	Biodiesel percentage	Biodiesel property/quantity	Biodiesel feedstock	Biodiesel percentage	Biodiesel property/quality	Biodiesel feedstock	Biodiesel percentage	Biodiesel percentage	Biodiesel percentage	Biodiesel property/quality	Biodiesel feedstock	Biodiesel percentage	Biodiesel property/quality	Biodiesel feedstock	Biodiesel percentage
	<b>Customer / Business needs</b>																										
Performance																											
Emissions																											
Fuel system		X	X	X	X									X	X												
					X	X	X	X																			
					X				X	X	X	X	X	X													
Aftertreatment															X	X	X	X	X	X	X						
																						X	X	X	X	X	X
Lubrication system																											
Components																											



# Analysis – Failure Modes and Effect Analysis (FMEA)



Process Step/Input	Potential Failure Mode(s)	Effects	S e v	Potential Cause(s)	P r o b	Current Controls	D e t	R P N	Recommended Action(s)	Action(s) Taken	S e v	P r o b	D e t	R P N
											X	X	x	x
											X	X	x	x

# Analysis – Failure Modes and Effect Analysis (FMEA)



Process Step/Input	Potential Failure Mode(s)	P	S	P	D	R	P	N
			Sev	Prob	Det	RPN		
	<ul style="list-style-type: none"> <li>❖ Detailed analysis of potential failures on B30 and other blends</li> <li>❖ Validation, Tests and corrective actions                             <ul style="list-style-type: none"> <li>☐ Identify test engines: engine models and fuel blends</li> <li>☐ Bench tests:                                     <ul style="list-style-type: none"> <li>➤ Pistons and valves deposits</li> <li>➤ Fuel systems compatibility</li> <li>➤ Oxidation stability of biodiesel</li> <li>➤ Seals and hoses compatibility and life</li> <li>➤ Compatibility and effects on engine oils</li> <li>➤ Emissions</li> <li>➤ Etc.</li> </ul> </li> </ul> </li> </ul>							
			X	X	x	x		
			X	X	x	x		

# Accelerated Engine Tests



HD, MD and smaller engines



HD engine test, B20



Equivalent to 100,000 miles



# Characterization



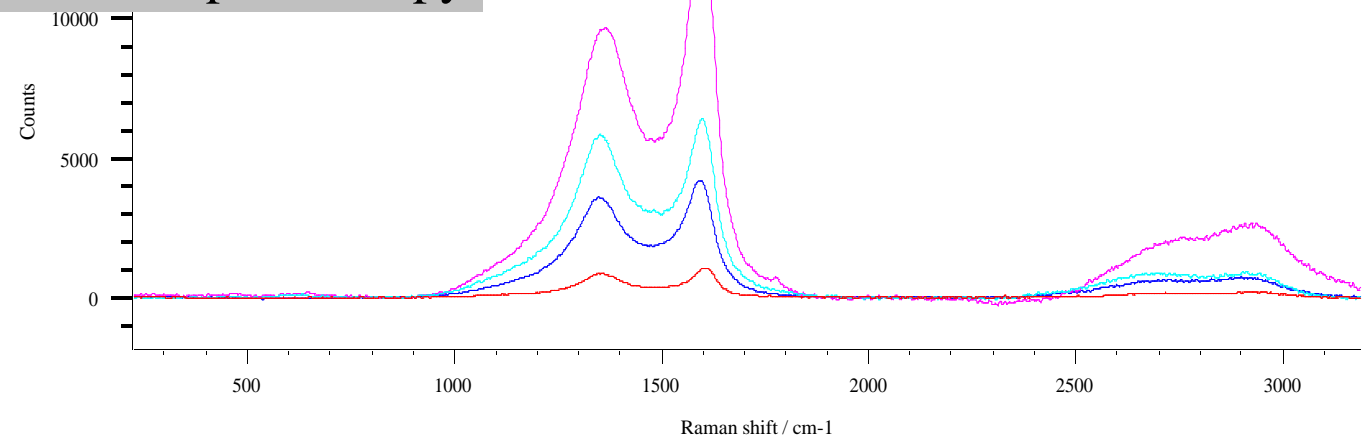
## Chemical analysis

Development of new testing methods

Understanding the mechanisms of chemical interactions

- ❖ Impact on oils
- ❖ Impact on emissions
- ❖ Impact on deposits
- ❖ Developing procedures for measurements

## Soot analysis Raman Spectroscopy



# Field Testing



## ❖ Mine applications

- ❑ B100, RME
- ❑ B20: Engine power, fuel consumption, oil analysis, general observations
- ❑ Multiple sites using biodiesel – communication with customers

## ❖ Construction sites

- ❑ Various blends
  - Engine power, oil analysis

## ❖ Bus applications

- ❑ Successively increasing blend levels
  - Monitor performance, components, power, etc.





# Biodiesel Use in Caterpillar Engines

Engines manufactured in 2006 and earlier:

1. Up to B30 maximum blend level acceptable for:
  - ACERT Technology: C7, C9, C11, C13, C15, C18, C27, C32
  - 3114, 3116, 3126, 3176, 3196, 3208, 3306, C-9, C-10, C-12, 3406, C-15, C-16, C-18, 3456, 3408, 3412, 3500 Series, C175 Series, 3600 Series, C280 Series, CM20, CM25 and CM32
2. Up to B20 maximum blend level acceptable for:
  - C0.5 through C2.2 and C4.4 mechanical fuel injection equipped engines that meet Tier3/Stage 3a emissions regulations
3. Up to B5 maximum blend level acceptable for:
  - C0.5 through C2.2 and C4.4 mechanical fuel injection equipped engines that meet Tier2/Stage 2 or earlier emissions regulations
  - C4.4 and C6.6 ACERT and C3.4, 3003-3034, 3044, 3046, 3054, 3056, 3064 and 3066 engines

# Biodiesel Use in Caterpillar Engines



## Engines manufactured in 2007

1. Requirements for Non-Road 2007 model engines:
  - No change relative to 2006
2. Requirements for On-Highway 2007 model engines:
  - Finalized extensive tests of 07 engines, HD, MR, on-truck, etc.
  - Expected announcement of up to B20
  - Biodiesel must meet Cat and/or Industry specifications and BQ900 Quality requirements





# Biodiesel Requirements for use in Caterpillar engines

**Biodiesel: Esterified vegetable oils** from a variety of feedstocks including soybean, rapeseed (primary base stocks), animal tallow, waste cooking oil, etc.

- ❖ Biodiesel blend stock must meet requirements listed in the Caterpillar biodiesel specification,\* ASTM D6751, or EN 14214
- ❖ Final biodiesel blend must meet requirements for distillate diesel fuel published by Caterpillar, ASTM D975, or EN590
- ❖ Distillate diesel used for blending must meet Caterpillar requirements, ASTM D975, or EN590

**For blends above B5, oil analysis is strongly recommended. For blends above B20 oil analysis is required to ensure oil change intervals are appropriate**

# Warranty Coverage with Biodiesel



- ❖ Warranty covers material and workmanship defects:
  - ❑ Failures caused by other factors, including lack of proper maintenance (use of improper fuel, oil or filters, lubricants and coolant) are not covered by warranty.
- ❖ Use of acceptable biodiesel blends does not affect Caterpillar warranty for materials and workmanship

Failures that result from the use of any fuel are not Caterpillar factory defects. Therefore, the cost of repair would not be covered by Caterpillar warranty.



## Position on Industry specifications

- ❖ Caterpillar supports the development of B20 Biodiesel specification
- ❖ Caterpillar supports the strengthening of B100 specification ASTM D6751: addition of the oxidation limits and limits on the alkali metals
- ❖ Caterpillar is working with the industry to develop tests and to better understand the impact of biodiesel on engines

# Sustainability



- ❖ Support of biodiesel aligns with Caterpillar sustainability initiatives
- ❖ Biodiesel is an option to expand America's production of renewable fuels and lessen our dependence on imported energy
  - ❑ Farming practices have a major impact on the life cycle sustainability contribution of biodiesel and other alternative fuels
- ❖ Support continued efforts to strengthen biodiesel technical fuel standards
- ❖ Support efforts to increase quality and consistency of biodiesel fuels

Thank You!

