What is the Future for Diesel?

AUGUST 20, 2020
Welcome and Announcements

ALL PARTICIPANTS PHONES ARE MUTED.

PLEASE SUBMIT YOUR QUESTIONS AT ANY TIME VIA THE CHAT FEATURE.

BE SURE TO SELECT KRISTEN GIFFORD (HOST)

SLIDES AND RECORDED PRESENTATION WILL BE AVAILABLE.

INSTRUCTIONS ON ACCESSING THE SLIDES WILL BE EMAILED TO YOU.

PLEASE COMPLETE OUR SURVEY ABOUT TODAY’S EVENT.

THANK YOU FOR JOINING US!
Introduction
About The Diesel Technology Forum

Education
Research
Outreach
Collaboration
Communications

DTF is a 501 ©(6) Not-For-Profit Educational Association
Members of the Diesel Technology Forum - Leaders in Clean Diesel Engines, Equipment, Components, Fuels
What is the Future of Diesel?
Why Diesel?

- Most energy-efficient internal combustion engine
- Proven - Continuous improvement over 100 years
- Available - more than 2/3 of all fuel retailers have diesel; extensive service and parts network nationwide
- Durable – > 1 M miles
- Reliable – key to uptime requirements in trucking, construction, emergency back up power
- Powerful - most energy density
- Now low-emissions
- Renewable–fuel compatible existing and new engines
Driving Forces

- Lowering Greenhouse Gases
- Lower Emissions
- Greater Productivity
- Increased Durability
- Lower Operating Costs
- Lower Fuel Consumption
- Compete with Alternatives
DIESEL'S ROADMAP TO THE FUTURE

- Emissions Closer to Zero: NOx, PM, CO₂
- Increasing Energy Efficiency
- Expanded Use of Renewable Fuels
- Hybridization Where it Makes Sense
Today's Program

Welcome Panelists

HOW CAN WE BALANCE COMPETING FORCES OF GREATER EFFICIENCY AND LOWER EMISSIONS?

WHAT ARE THE TECHNOLOGIES AND POLICIES THAT WILL DETERMINE THE FUTURE FOR DIESEL?
Alexander Freitag
VP Diesel Powertrain Solutions, Robert Bosch LLC
The Bosch Group

Four business sectors

Mobility Solutions
- One of the world’s largest suppliers of mobility solutions

Industrial Technology
- Leading in drive and control technology, packaging and process technology

Energy and Building Technology
- One of the leading manufacturers of security and communication technology
- Leading manufacturer of energy-efficient heating products and hot-water solutions

Consumer Goods
- Leading supplier of power tools and accessories
- Leading supplier of household appliances

Bosch Mobility Solutions is closely connected with all divisions. Cooperation across the Bosch Group enables a valuable exchange of knowledge and synergies.
The Bosch Group
Facts and figures

Sales in billions of euros
78.5

Associates
410,000

Associates in engineering
68,700

Manufacturing locations
268

Engineering locations
130

Business Sector Mobility Solutions

Sales in billions of euros
47.6

Associates
237,000

Associates in engineering
53,000

Manufacturing locations
127

Engineering locations
67
Keri Westbrooke
VP Chief Technology Officer,
Tenneco Powertrain

Dmitri Konson
VP Engineering
Tenneco Clean Air
Greg Garr
Director, Market Creation,
Technical Center,
Umicore Autocat USA Inc.
Topics for Discussion

1. IN PURSUIT OF GREATER ENGINE EFFICIENCY & ACHIEVING LOWER EMISSIONS
2. THE FUTURE FOR DIESEL
IN PURSUIT OF GREATER EFFICIENCY AND LOWER EMISSIONS
In pursuit of greater efficiency and lower emissions.

- Where are we today and where are we headed with diesel engine efficiency?
- How are engine components evolving, or perhaps even changing significantly, to improve the efficiency of the diesel engine, and prolong the operating life?
- *From a high level,* where are we with HD diesel emissions control today and what are the major considerations for further reductions in the future? - as envisioned in this next round of regulations now under consideration; ones that will further reduce allowable levels?
Keri Westbrooke
VP Chief Technology Officer, Tenneco Powertrain

Dmitri Konson
VP Engineering
Tenneco Clean Air
Four component groups contribute over half of the friction in an engine.

Solutions:
- IROX® Polymer Bearing Coatings
- DuroGlide® DLC Ring Coatings
- EcoTough® Piston Skirt Coatings
- MicroTorq® Seals
Today’s commercial vehicle truck pistons are 100% steel. Typically constructed from two steel forgings, welded together to form a closed gallery at the top of the piston. This gallery is filled with a continuous flow of engine oil, to cool down the piston crown.

High piston temperatures, particularly on the top rim of the piston crown, present a challenge (metal oxidation), but hotter pistons can also provide benefits to both in-cylinder efficiency, and exhaust temperature energy.

Tenneco Monosteel® truck diesel piston

Piston crown temperatures can exceed 500°C, 930°F

Tenneco EnviroKool™ piston.
Decouples the cooling media in the gallery from the engine oil. A metallic coolant formulation, provides a rapid temperature rise rate in cylinder and in the exhaust stream. Reduces oil pump capacity (parasitic loss reduction), and prolongs oil life. Production 2023.

Tomorrow’s commercial vehicles will be challenged to emit much less NOx (oxides of nitrogen)

The NOx emissions control technology NH₃-SCR has proven to be very capable, but pushing it beyond its current limit will require the catalyst to heat up faster, and to remain hot under sustained low-load operation:

- Additional SCR sub-system upstream allows catalyst’s temperature to align more closely with that of the engine’s exhaust

- Addition of heat to the exhaust within the exhaust system, either with a fuel burner, a fuel-oxidizing catalyst, or an electric heater

**Tenneco’s system concept for the Class 8 truck**

The additional, upstream SCR sub-system is integrated into the current aftertreatment packaging envelope in this prototype system developed for the EPA ULNOx Demonstration

**Tenneco’s concept for exhaust heating**

The CSTU (cold start thermal unit) provides the most heating power and thus enables the fastest warm-up, and can also be used to maintain the aftertreatment system temperature during low-load operation
## Diesel Technology Breakthrough

### Bosch Development Platform Vehicle

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>Displacement</td>
<td>1.7 l / 4 cyl</td>
</tr>
<tr>
<td>Power</td>
<td>110 kW</td>
</tr>
<tr>
<td>Torque</td>
<td>340 Nm</td>
</tr>
<tr>
<td>FIE</td>
<td>CRS2 (2200 bar)</td>
</tr>
<tr>
<td>EGR</td>
<td>LP + HP-EGR</td>
</tr>
<tr>
<td>CAC</td>
<td>Water cooled</td>
</tr>
</tbody>
</table>

**System approach required to meet future requirements**
Commercial Vehicle - Engine Study

System Setup

- CRaN Modular System
  - Moderate nozzle flow
  - Faster injector opening setting
  - Up to 2500 bar

- Improved fuel-injection

- Adjusted Cold NOx raw emissions

- Efficient temperature management

- Enhanced exhaust-gas treatment

- Improved turbocharging

- Extended software functions

Extended functions:

- 7.8 l / 6 cyl.
- Power: 230 kW
- Torque: 1400 Nm
- Fuel injection equipment: CRIN C
- Pressure: 2500 bar
- Exhaust gas recirculation: HP-EGR

COMPREHENSIVE SYSTEM APPROACH. UTILIZE KNOW HOW GAINED FROM PC SEGMENT

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NO\(_x\) reduction

Progress hits the road

No rocket science but symbiosis of
- engine
- temperature management
- exhaust aftertreatment

Record readings under some real driving conditions

13 mg/km NO\(_x\)

*Record reading with refined Bosch technology on urban, extra-urban, freeway driving in certain circumstances

*Results from European tests, results may vary
Commercial Vehicle - Engine Study

Key Feature: EGT System Layout with DI-SCR

MD engine 7.8l
HP-EGR only

Condition: degreend (hydrothermal in oven)
Commercial Vehicle - Engine Study

Results: HD FTP

NH₃ tailpipe emissions are below 10ppm (mean value at cold and hot test)
What is the Future of Diesel?

August 20, 2020

Greater Efficiency and Lower Emissions
Where Are We Today and What Might the Future Be for Emission Headed Towards **Near-Zero** in 2027 from 0.2 to 0.02 g/bhp/hr

![Graph showing emission levels](image)

- Current FTP Standard: 200 mg
- 2024 System: 50-100 mg
- 2027 System with Twin-SCR and Cylinder Deactivation: 10-30 mg

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[Graph image section with emission levels]
Emissions Policies

EPA Cleaner Truck Initiative CTI (ANPRM Update)

- Standard similar to CARB: 10-30 mg/bhp/hr
- Low Load Cycle (LLC): TBD
- Warranty: 435,000 miles
- Full Useful Life (FUL): 600,000 miles
- In-Use Operation Monitoring
- PEMS systems in operation to measure real driving
- Implementation 2027 with deterioration factor through 2035 TBD
- NPRM delayed until early 2021 with final expected in Summer 2021
Emissions Policies

California Approves Advanced Clean Truck (ACT) Rule

- Mandates truck manufacturers sell a certain percentage of ZEV trucks each year considers ZEV trucks BEV or FC, PHEV receive partial credits
- Takes effect 2024 and fully implemented by 2035
- Requires at least 40% of all tractor trailers,
- 55% of all medium-duty pick-ups
- 75% of all delivery trucks and vans
- Board estimates at least 15% of the 1.2 million trucks on the road would run on electricity when fully implemented
Emissions Policies

CARB Propose Heavy-Duty Low NOx Omnibus Regulation

- Lower NOx: 50mg/bhp/hr 2024-2026, 20 mg for 2027
- New NOx standard on a new low load certification cycle (LLC)
- In-use testing, new three-bin moving average windows (MAW)
- Warranty 435k miles, Full Useful Life: 600k-800k miles
- Powertrain certification test procedures for HD hybrid vehicles
- Revisions to the on-board diagnostic (OBD) requirements
- Optional 50-state certification program for MY 2024-2026
  - 0.1 g/bhp-hr on FTP and 0.3 g/bhp-hr on the LLC
- Planned board approval August 27, 2020
Evolution of Heavy-Duty Exhaust Control Technology

A natural optimization has resulted in 2019 systems being 60% smaller, 40% lighter, and cheaper than 10 years ago.

US2010

US2019

Repackaged

US2013

Downsized
Can We Get to *Near Zero*? Yes

2027 Low NOx Emission Control System with Twin-SCR ensures ultra-low emissions over all driving conditions

- Technologies on passenger cars for cold-start and in low load operation
- Low temperature active catalysts with thermal management
- Front SCR and dual and/or heated urea dosing for start-up and low load operation
- Systems integration with OEs and suppliers – more driven than in the past
REMINDER

SUBMIT YOUR QUESTIONS VIA THE CHAT FEATURE AT ANY TIME
THE FUTURE FOR DIESEL
What will the diesel engines of the future look like? How will they be different than today?

How are the customer, policy, technology drivers changing and what will be the main determinants for diesel’s future?
Alexander Freitag
VP Diesel Powertrain Solutions,
Robert Bosch LLC
CO₂ Reduction Potential
Technology Comparison

Baseline: Diesel 2019

Several paths show potential to fulfil CO₂ neutrality goal

CO₂ reduction potential

Diesel SING NGDI „Tailpipe CO₂-free“


Provided for informational purposes strictly on a non-reliance basis.

HEV = Hybrid Electric Vehicle | PHEV = Plug-in HEV | BEV = Battery Electric Vehicle | SING = Spark Ignited Natural Gas Engine | NGDI = Natural Gas Direct Injection
CO₂, a Driver for Transport Sector
Different paths towards CO₂-neutral transport goal

<table>
<thead>
<tr>
<th>Today</th>
<th>Intermediate</th>
<th>Future</th>
</tr>
</thead>
<tbody>
<tr>
<td>crude oil based</td>
<td>increasing share of renewable energy</td>
<td>CO₂-neutral</td>
</tr>
<tr>
<td>Diesel</td>
<td>Diesel + Alternative fuels R33, CARE etc.</td>
<td>100 % renewable e-fuels</td>
</tr>
<tr>
<td>ICE conventional</td>
<td>Battery electric</td>
<td>100 % renewable electricity</td>
</tr>
<tr>
<td></td>
<td>Fuel Cell</td>
<td>100 % CO₂ neutral H₂</td>
</tr>
<tr>
<td></td>
<td>H2-ICE</td>
<td></td>
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Keri Westbrooke  
VP Chief Technology Officer,  
Powertrain Tenneco

Dmitri Konson  
VP Engineering  
Tenneco Clean Air
Alternate fuels for ICE are already here – natural gas, biofuels and hydrogen, are in production, or in development for imminent use.

These fuels pose their own challenges when replacing diesel – e.g. durability of the running surfaces, and require alternate emissions control technologies.

Tenneco is a world leader in diesel engine components and emissions control systems.

We expect ICE to be the predominant powertrain for many years to come.

Our products have a direct and positive impact on engine durability, fuel economy and emissions.

Our global presence, experience, technology and engineering services drive our commitment to finding solutions.
Greg Garr
Director, Market Creation, Technical Center, Umicore Autocat USA Inc.
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OR ALLEN SCHAEFFER TO DIRECT YOUR QUESTIONS.

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SEND ANY FOLLOW UP QUESTIONS TO dtf@dieselforum.org
Join us for Future Insight Sessions – 2020

• **Future of Diesel Part 2: Fuels and Hybridization** – September Date TBA

Regional Insight Events

• Southwest
• Southeast
• California
Thank you for joining us!

Attendees will receive an email with a link for access to the materials from today’s session AND a link to a short survey.

*Please complete our attendee survey!*

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