2007 ATA / ARTSA
Technical & Maintenance Conference

Engine Innovations & Maintenance Implications

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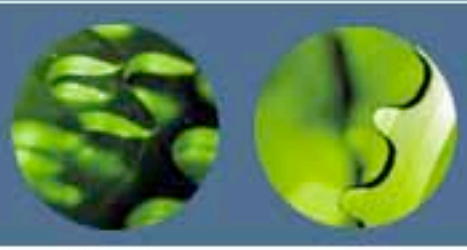
2007 Technical and Maintenance Conference

Session 1:
Sunday 11 Nov 07,
1:30 to 3:00 pm
Engine Innovations & their Maintenance Implications

2007 Technical and Maintenance Conference

Session 1 Chair:
Simon Humphries,
Isuzu Australia Limited



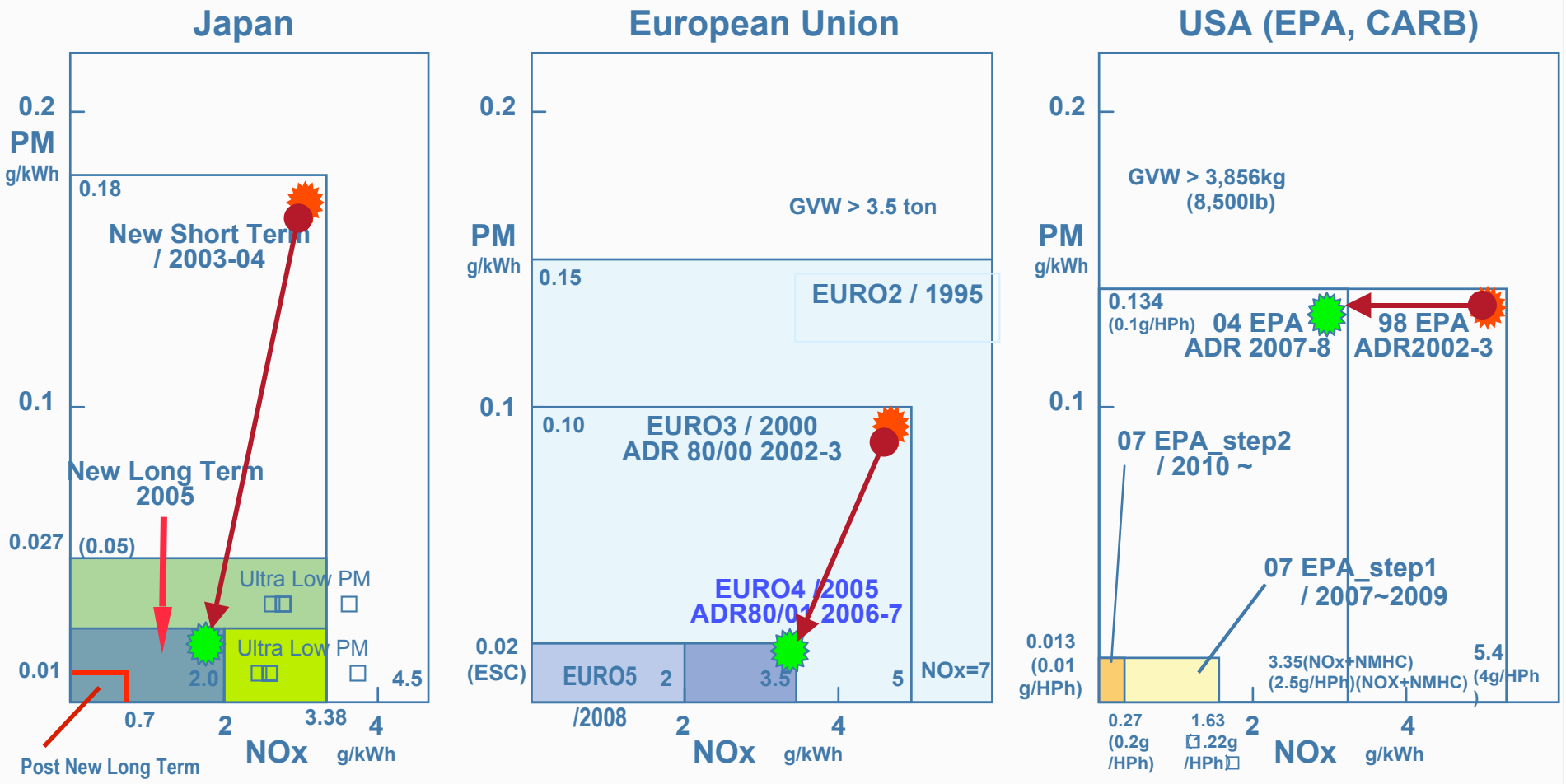
Engine Innovations: Contents

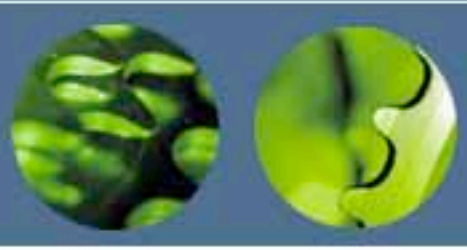
- Introduction: Simon Humphries, Isuzu Australia
- US Market (1): Ian Loy, Caterpillar
- Euro SCR: Simon Humphries
  (Material from DaimlerChrysler & Volvo)
- Euro EGR/DPF: Simon Humphries
- US Market (2): Ian Loy
- Alternative Fuels: Mark McKenzie, RARE Consulting
- Summary
- Question time for panel

Engine Innovations

- ADR 80/02 is mandatory from 1 Jan 2008
  - Euro4 is the primary standard
  - USEPA 04 is an allowable alternative
  - J-NLT 05 without OBD is another alternative
- Trucks for Australia all use engines produced for Europe, USA or Japan
  - Australia is a technology taker
  - No diesel engines designed and built in Australia

Truck exhaust gas regs (Diesel Engines)





Engine Innovations

- Euro4 is the primary standard
  - Over 80% PM reduction & 30% NOx reduction
  - Engines tuned for low PM, with Selective Catalytic Reduction (SCR) after-treatment used by many, especially in HD engines
    - Requires an exhaust catalyst that features urea solution (“AdBlue”) injection
  - Exhaust Gas Recirculation (EGR) + Diesel Particulate Filter (DPF) used by others
    - The DPF collects PM, and needs to “regenerate”

Engine Innovations

- **USEPA 04** is an allowable alternative
  - All except Caterpillar use EGR
    - EGR systems are tried and proven technology
  - Caterpillar uses ACERT
    - A suite of technologies that combine to meet the standard
- **J-NLT 05** without OBD is an alternative
  - Toughest of the three standards to comply
    - Lowest NOx and PM limits combined
  - most use EGR + DPF; UD & Fuso use SCR for HD
  - Some HD Japanese engines for Australia will adopt this standard

Isuzu Engine Solutions for Euro4

- Isuzu will comply with Euro4 for all LD and MD trucks (150 to 300 HP)
- J-NLT 05 compliance for HD trucks (325 to 520 HP)
- Common technologies adopted across all engines for 2008
  - Variable Geometry Turbo, Cooled EGR, HP Common Rail, 4V per cyl, advanced electronic controls
- New feature: the Isuzu Diesel Particulate Diffuser (DPD)

US sourced Engines

- For USEPA04 compliance, Caterpillar has chosen to adopt “ACERT”
- To discuss this, and the maintenance aspects of ACERT, please welcome Ian Loy of Caterpillar Australia

2007 Technical and Maintenance Conference

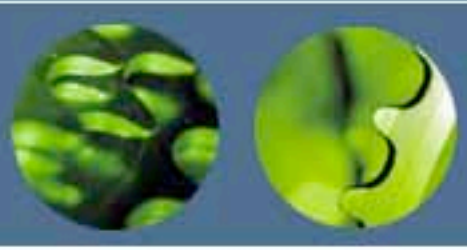
Ian Loy – Caterpillar of Australia
OEM Account Manager - Asia Pacific

Engine Innovation

The Maintenance Implications

The Challenge

Meet emission requirements and customer needs



What do customers Expect?

- Reliability
- Fuel economy
- Lifetime cost
- Durability
- Power
- Sales support
- Standardisation
- Ease of maintenance
- Warranty
- Parts availability

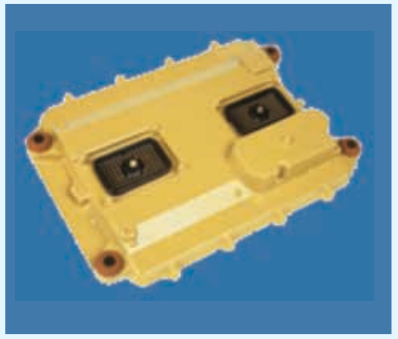
Note: Expectations Vary with Fleet Size; this is the Heavy Duty user expectations

Source : Customer Satisfaction Survey (1999)

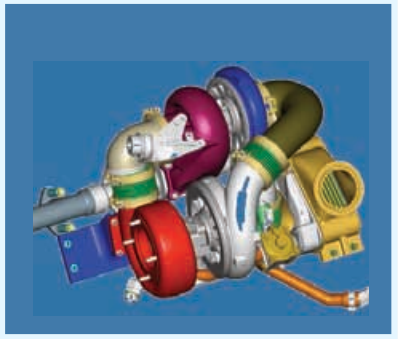
ACERT Technology

Previous, Proven Componentry

Combustion



Controls

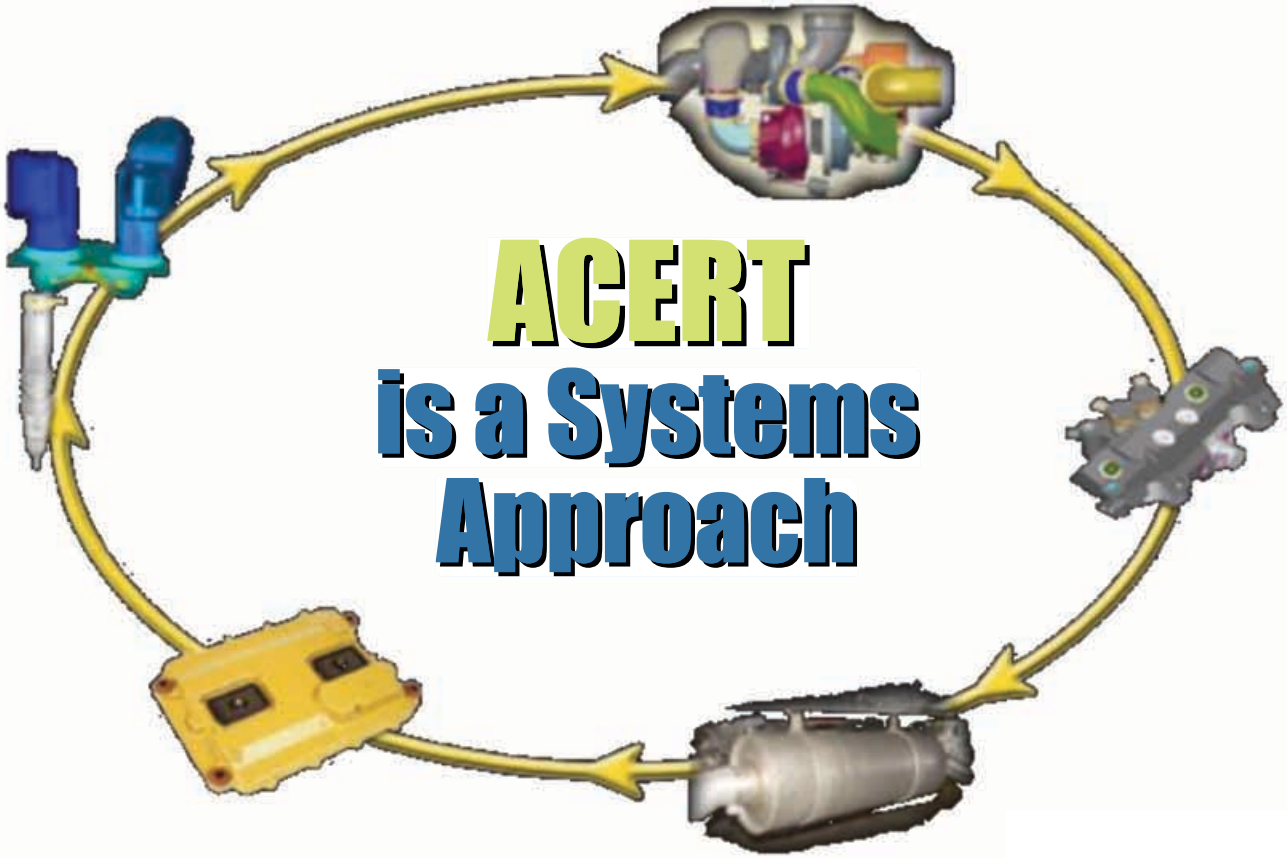


Advanced Air Systems

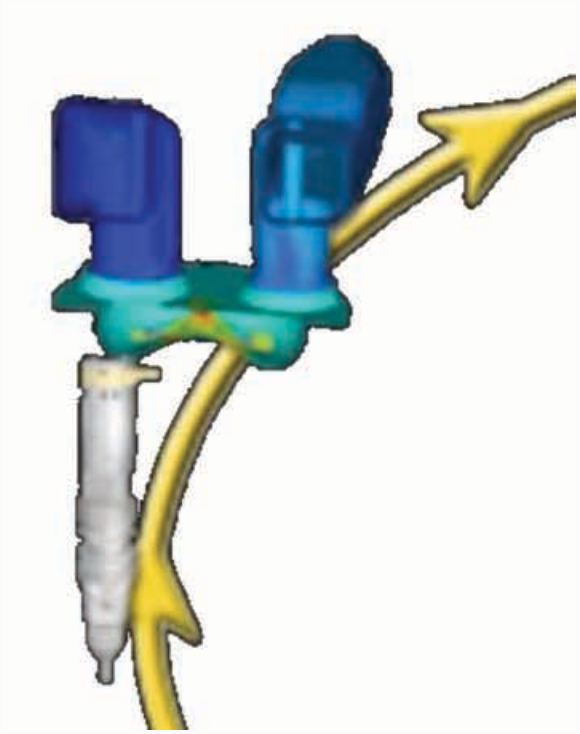
Flexible Fuel Systems

After-treatment

ACERT Technology



ACERT Technology



Injection &
Combustion Chamber

Fuel Systems Combustion Control

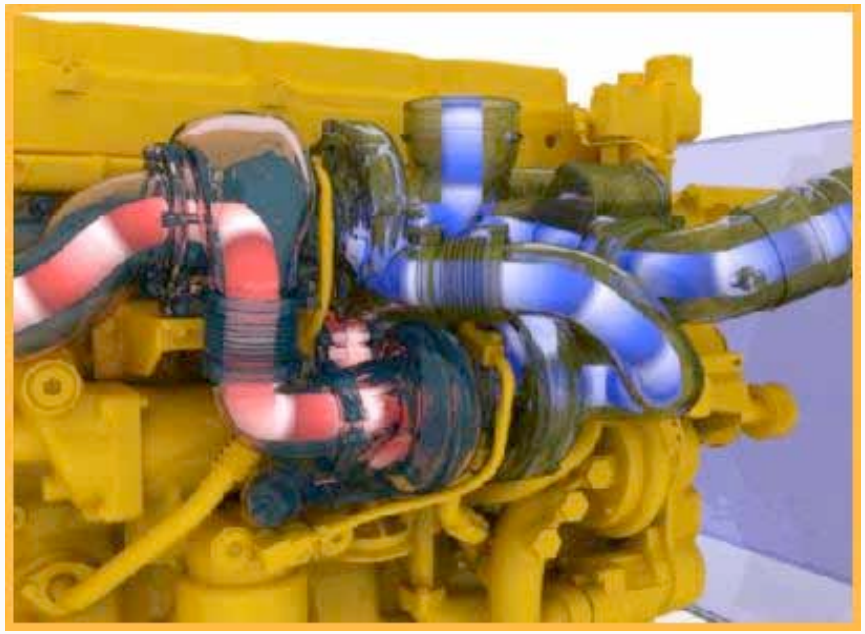
Single Injection

Multiple Injection Rate Shaping

ACERT Technology

Series Turbo-charging

Air Systems
Series Turbocharging



Reliability & Durability

- Proven, 50 years
- 20 to 40% Slower
  - Than today's

Performance

- Higher boost
- Improved response
- Emissions reduction
- Fuel economy

ACERT Technology

Variable Valve Actuation
&
Cat Brake

Air Systems
Variable Valve Actuation

Simple

- Keeps inlet valves open

Reliability

- Injector & hydraulics technology

Performance

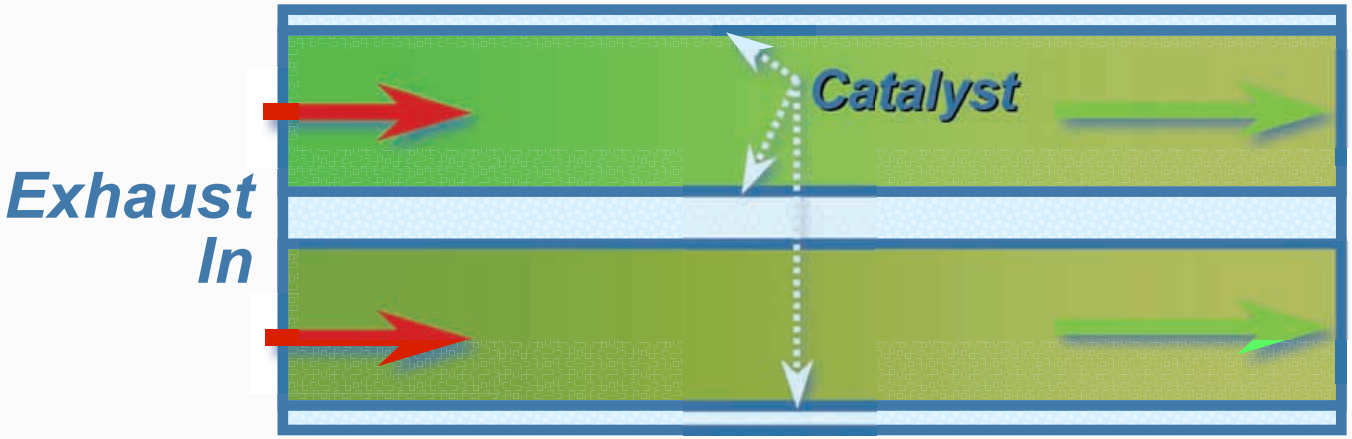
- Low emissions
- Fuel economy

ACERT Technology

Oxidation catalyst

Efficient Aftertreatment

7kg per muffler



Working Principle

CO (Carbon Monoxide) + O_2 (Oxygen) → CO_2 (Carbon Dioxide)

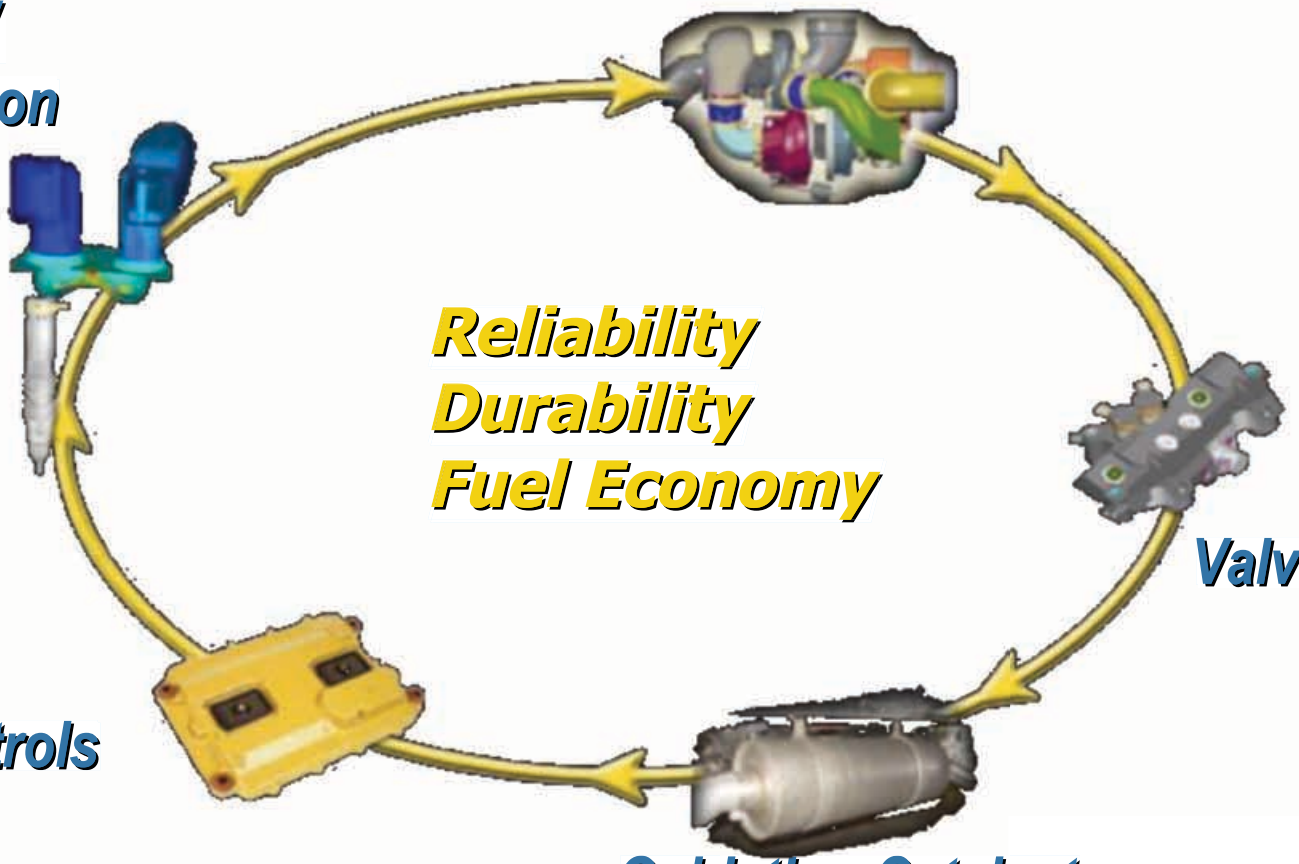
HC (Total Hydrocarbon) + O_2 (Oxygen) → CO_2 (Carbon Dioxide) + H_2O (Water)

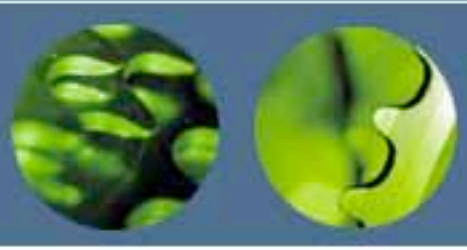
SOF (Soluble Organic Fractions) + O_2 (Oxygen) → CO_2 (Carbon Dioxide) + H_2O (Water)

ACERT Technology

Electronics

A Systems Approach





ACERT Technology

Lots of
COOL,
CLEAN
air

ACERT v Today

ACERT v Today

- 60% Longer Oil Change Interval
  - CI-4 oil
  - 15,500 liters of fuel / 500 hours (typical)

Oil Change Capacity

	Typical	Occasionally	Oil Filters
C9	35L		1
C13	40L	34L	1 or 2 (+2.5L)
C15	38L	49L	1

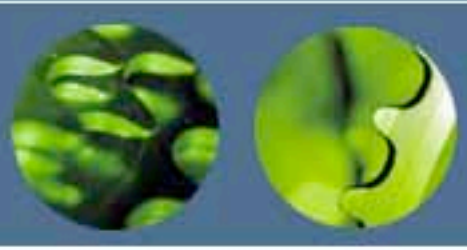
Less oil reduces change interval,
more oil increases interval

ACERT v Today

- 60% Longer Oil Change Interval
  - CI-4 oil
  - 15,500 liters of fuel / 500 hour
    Typical – C13 & C15
- Cat Air Compressor
  - built to last as long as the engine
- Cat Brake
  - no tune up kits

ACERT v Today

- Slower turbocharger speed
  - Longer turbo life
    ~ same replacement cost as VGT
- Fuel economy
  - Generally better than today
    - Up to 10% (and over) in heavy applications
  - Even longer oil change intervals



Maintenance Changes

Service Intervals

Maintenance Changes

Service

Intervals

ACERT Technology

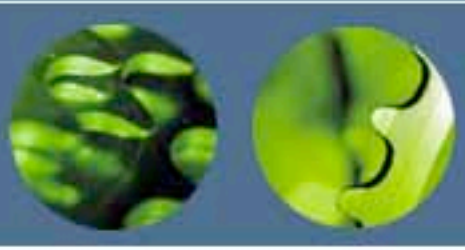
- Better reliability
- Better durability
- Better maintenance
- Better economy

THANK YOU

European SCR

Material from Mercedes-Benz & Volvo Truck Australia

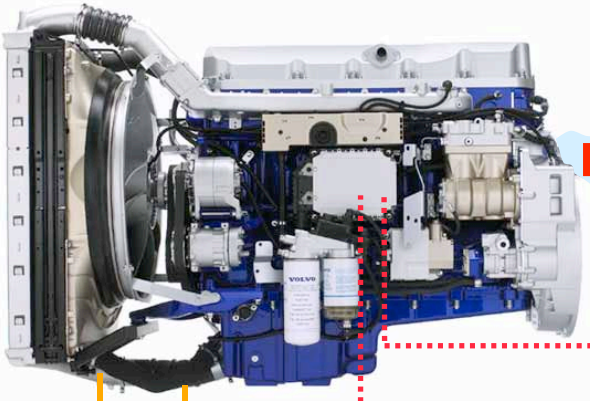
SCR – Selective Catalytic Reduction



NO_x

AdBlue in hot exhaust: NH_3+CO_2

In SCR catalyst: N_2+H_2O



Exhaust pipe

SCR catalyst in muffler

AdBlue injector

Emission sensor

Heating

Temp. sensor

AdBlue tank

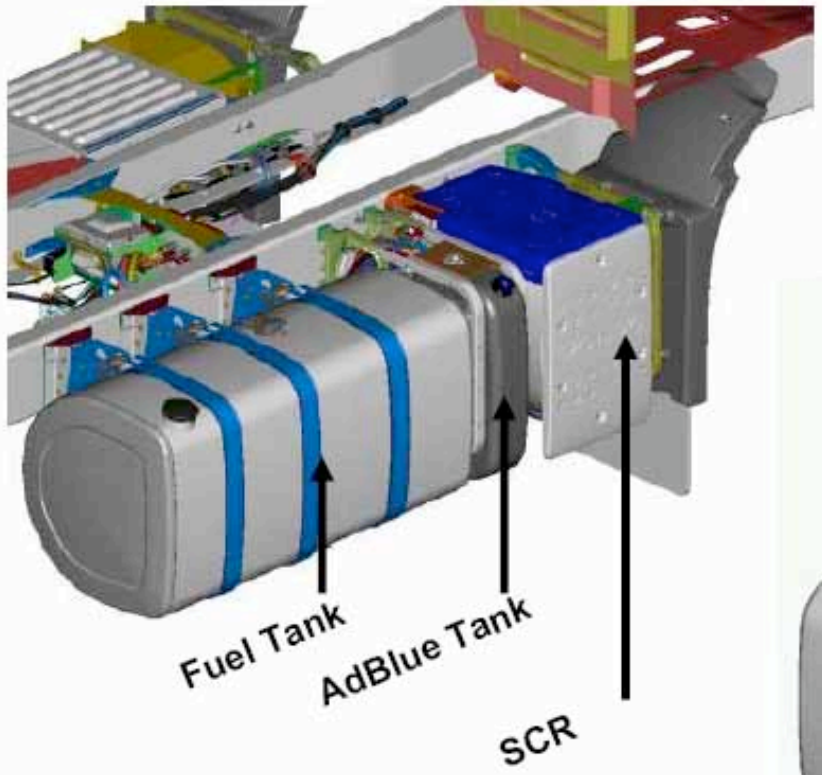
Temp. sensor

Level sensor

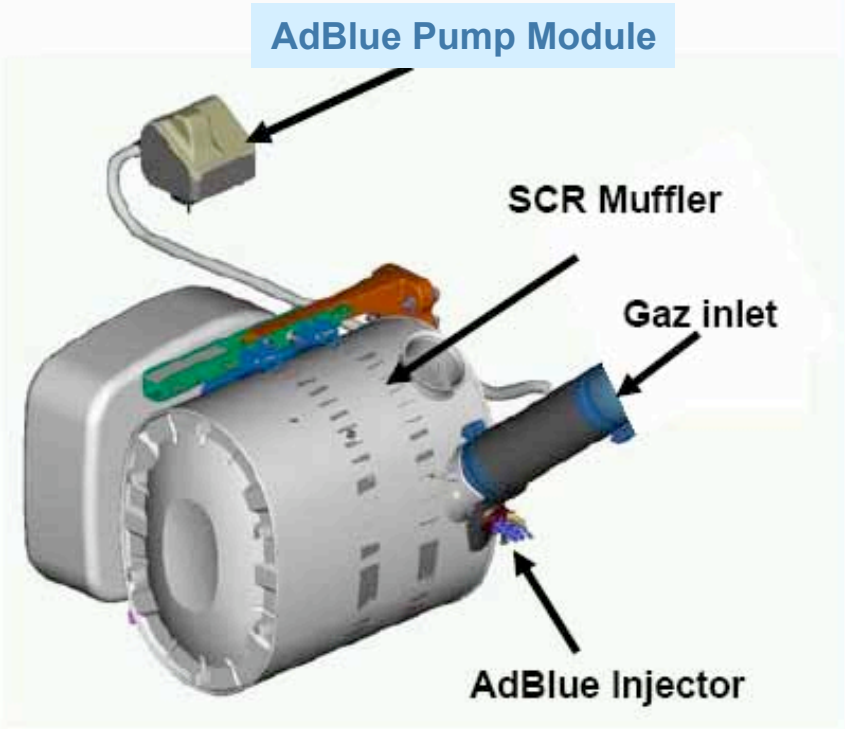
DECU Dosing Electronic Control Unit

AdBlue Pump Unit

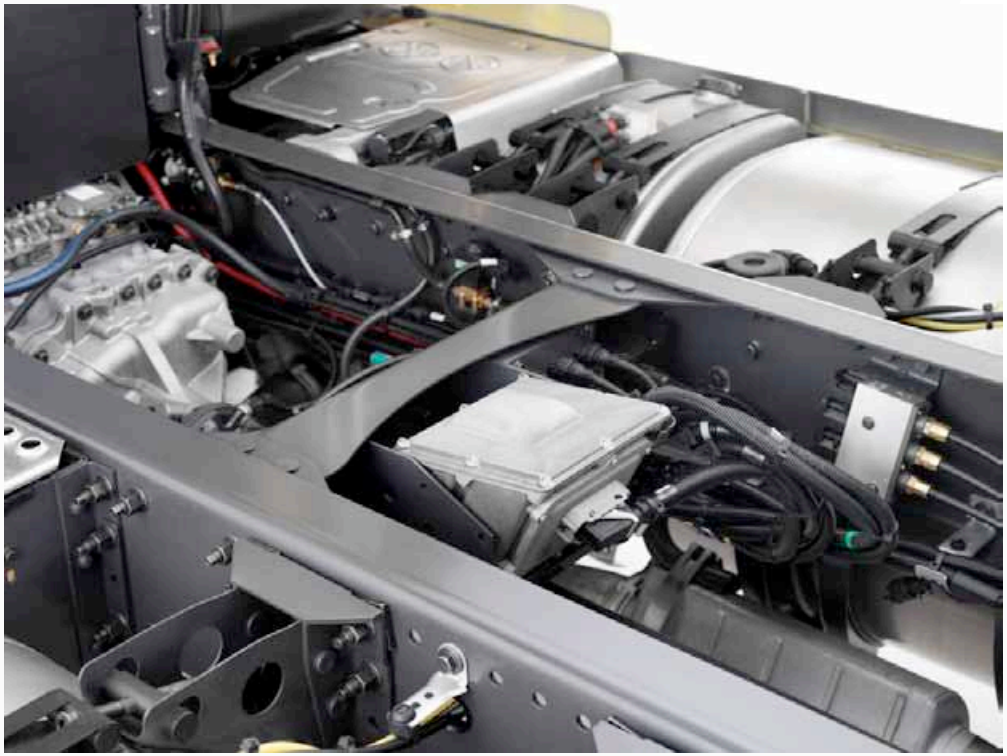
Example SCR Installation



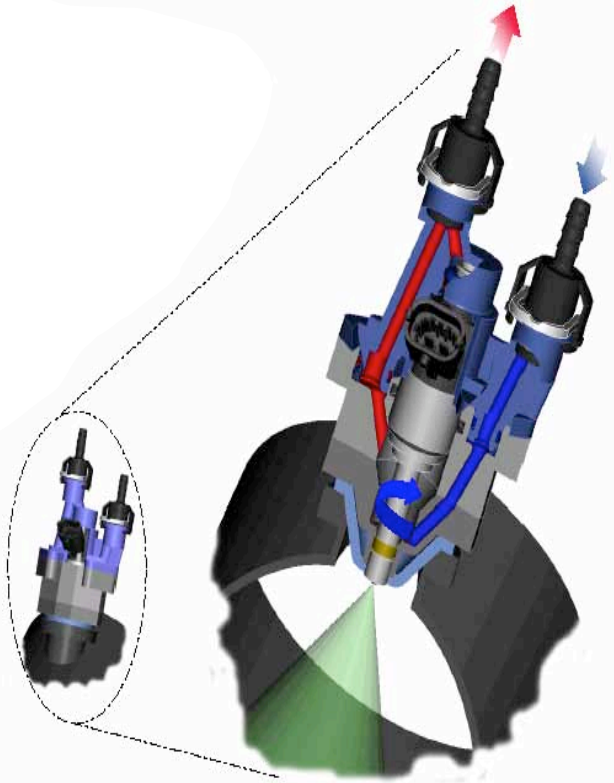
(Side Mounted Muffler Version)



AdBlue System Components

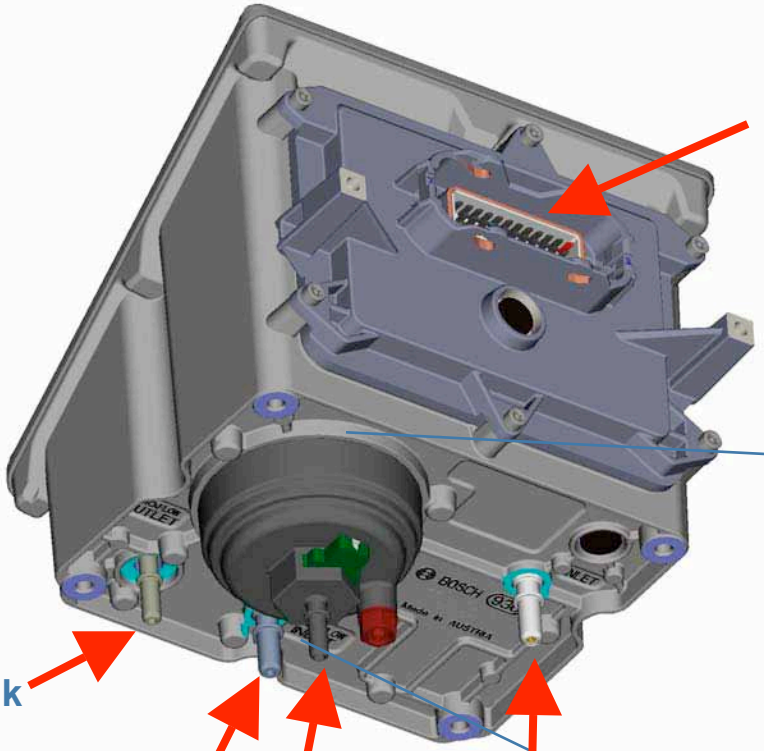


AdBlue Pump Unit



AdBlue Injector

Pump Module with Filter



Electrical Connections
Can Bus & Diagnostics

Pump return to tank

Dosing module return to pump

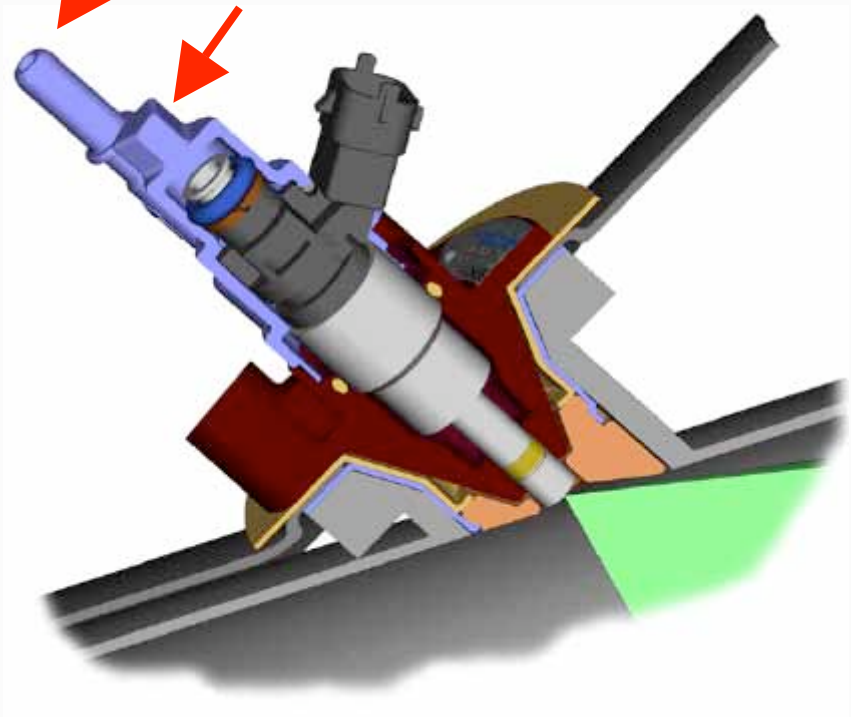
Pump filter outlet to dosing module

Inlet AdBlue tank to pump

Dosing Module

Dosing module return to pump

Dosing module inlet from pump filter



BLUETEC

SCR Diesel Technology for Commercial Vehicles

- Service & Maintenance
- Dealer requirements - Special Tools
- What the Driver Sees
- If we run out of AdBlue?

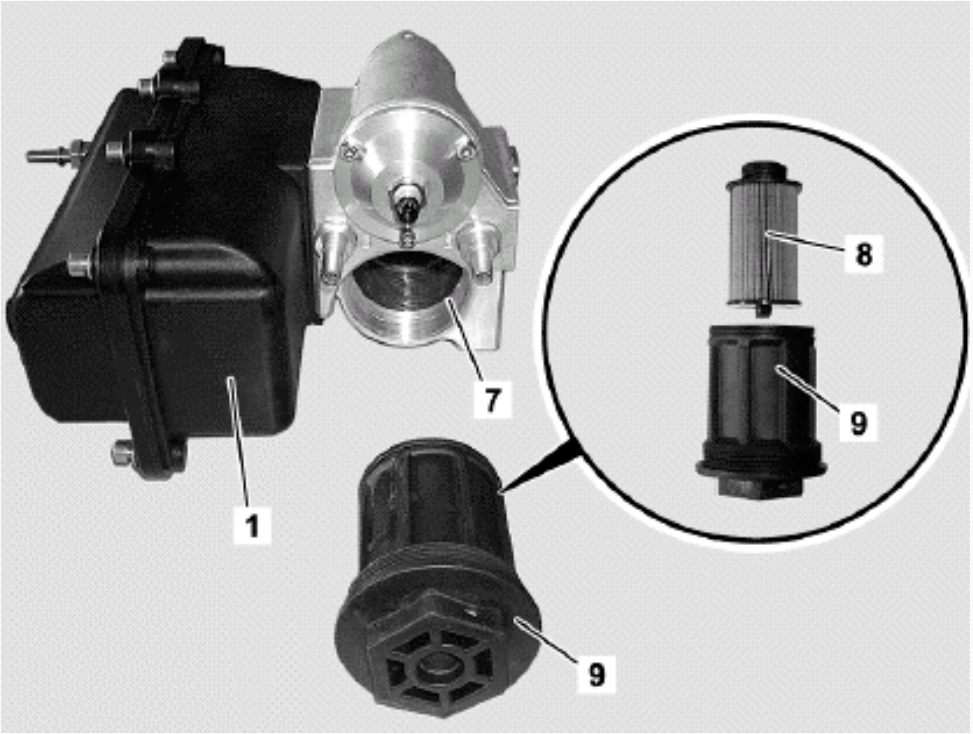
BlueTec Service & Maintenance

Below are the key components for Service & Maintenance of the BlueTec System.

- AdBlue Filter
- Pressure Reservoir
- NOx Sensor
- NOTE: NO service requirement for mufflers used with BlueTec

Service & Maintenance – AdBlue Filter

- Filter Service every 120,00kms
- Common to Truck & Bus



Service & Maintenance – Pressure Reservoir

- Maintenance Every 3 years
- Check pressure and adjust if required (3bar).
- Common to Truck & Bus

Service & Maintenance – NOx Sensor

- Service every 3 years / 360,000kms

Workshop Requirements - Special Tools

Diagnostic

- AdBlue Test Kit - Hydrometer, measuring bottle, beakers.
- Test Injection Lines
- Test Nozzle for all engines

Instrumentation Truck

Tank Content Display

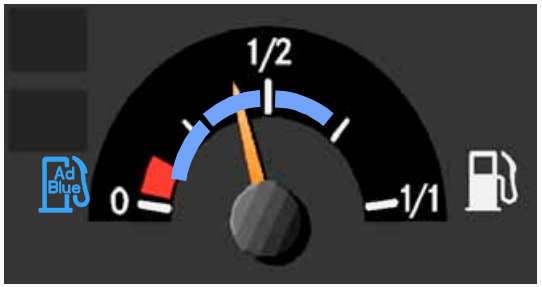
- Display of absolute AdBlue fill level

1) INS = Instrument

Fuel Reserve Message

- Warning Adblue low

Permanent Display



- Permanent display

System Display

- Malfunctio n indicator

Instrumentation Bus

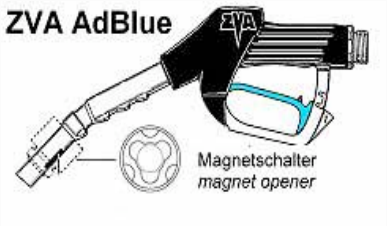
Tank Content Display	Fuel Reserve Message	No Fuel	System Display
			
• Display of absolute AdBlue fill level • (upon request)	• Warning Adblue low	• Permanent display	• Malfunction indicator

Filling AdBlue

"Filler Neck"

- Smaller diameter than for diesel
- Solenoid integrated

"Tank Filler Nozzle"



- Automatic system: Activation of flow via magnetic field

- Emergency refill always possible

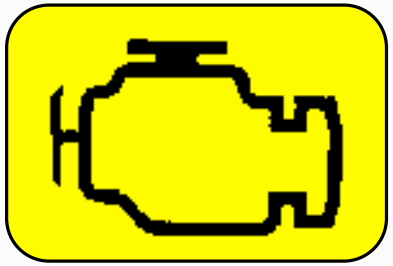
Owing to the tapered design of the filler necks and the integration of "solenoids", AdBlue fuelling can be carried out without confusion both when fuelling with a "simple" mechanical tank filler nozzle and with an automatic auxiliary tank arm"enabled" via the solenoids

What Happens if We Run Out?

With NOx Sensor

- Warning Lamp on Dash
- 40% Power Reduction after engine stop

System Display



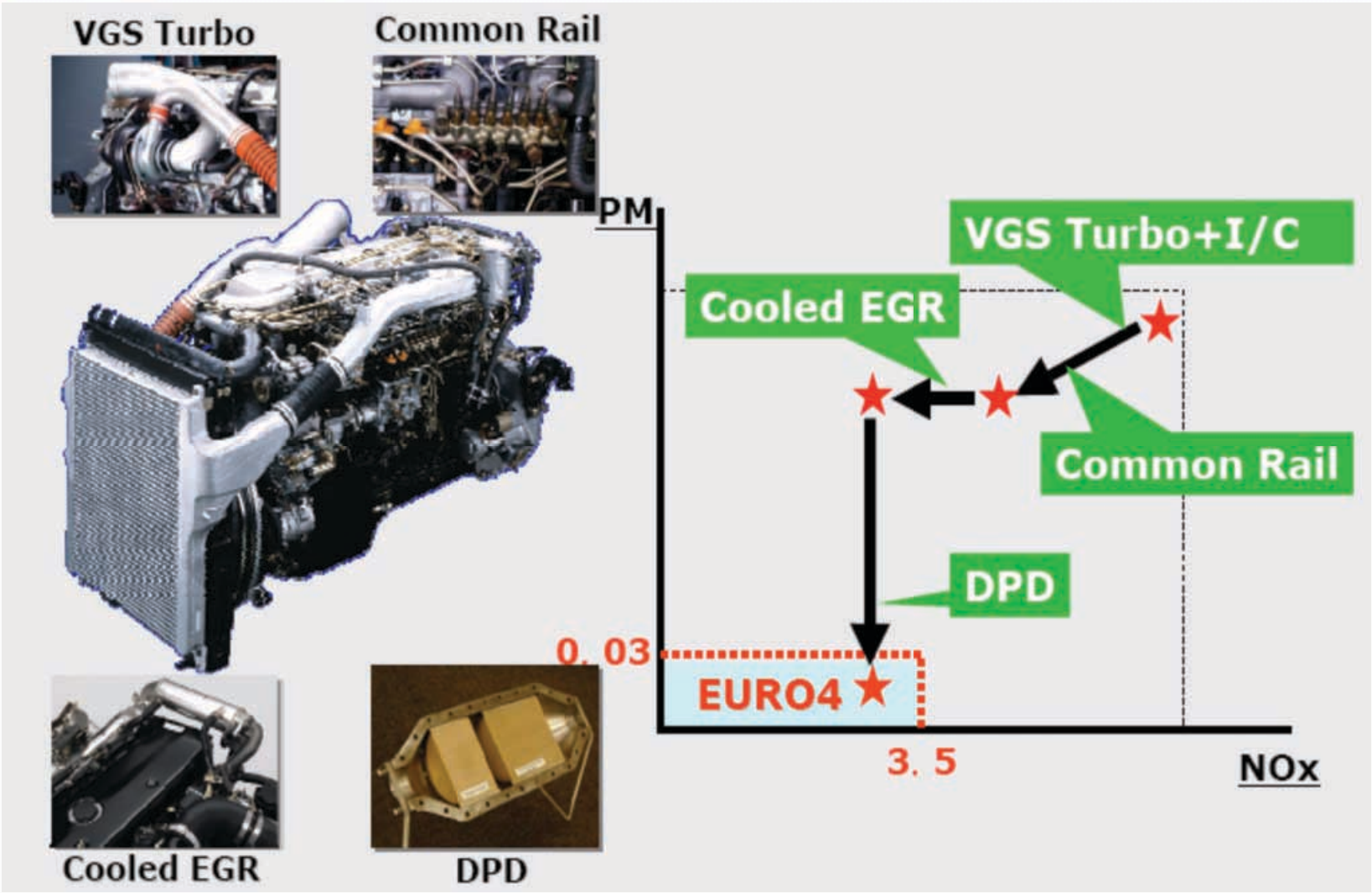
Warning Lamp

and fuel gauge reads empty!

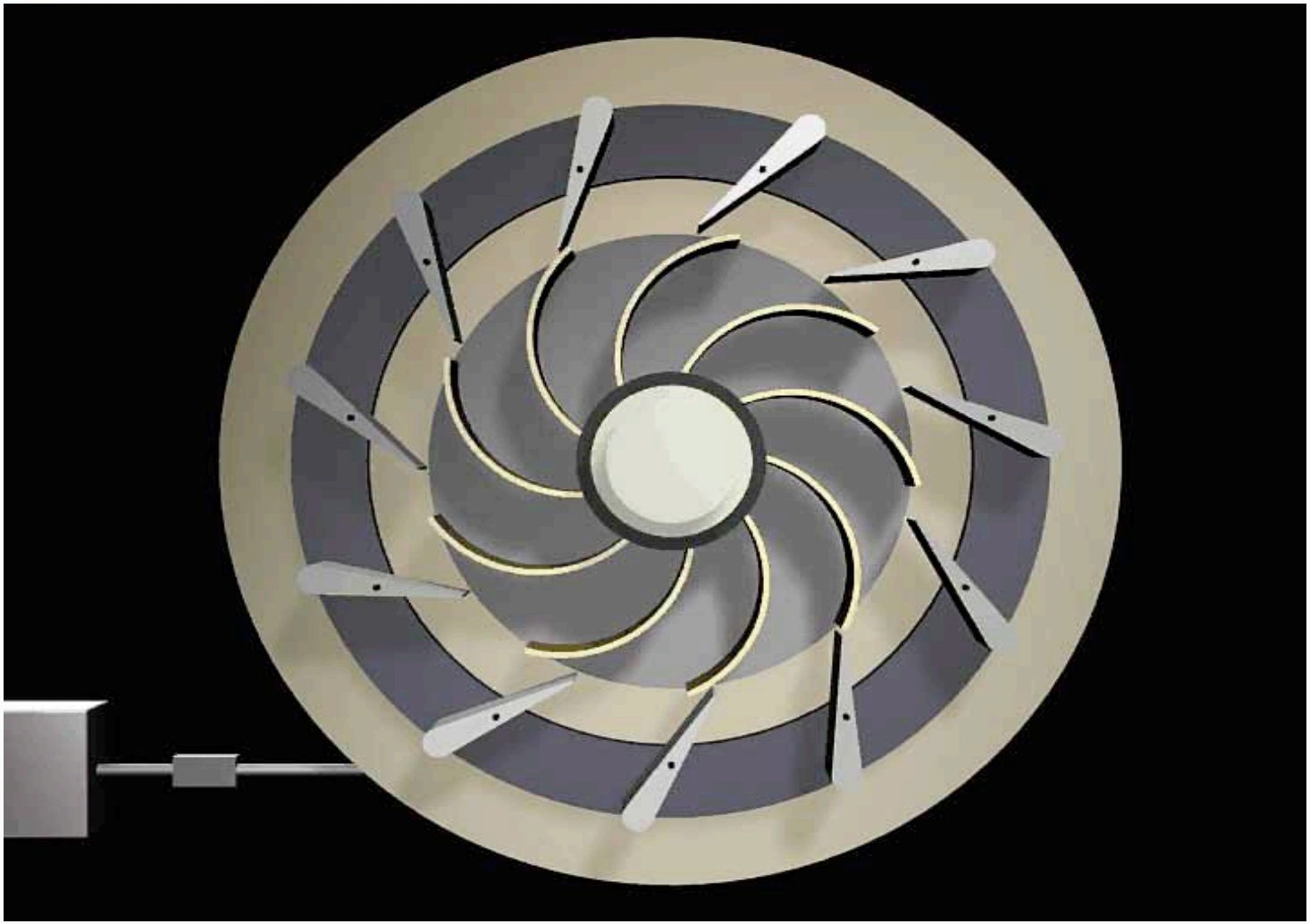
Euro EGR + DPF

Simon Humphries
Isuzu Australia Limited

Euro 4 EGR Engine Technologies



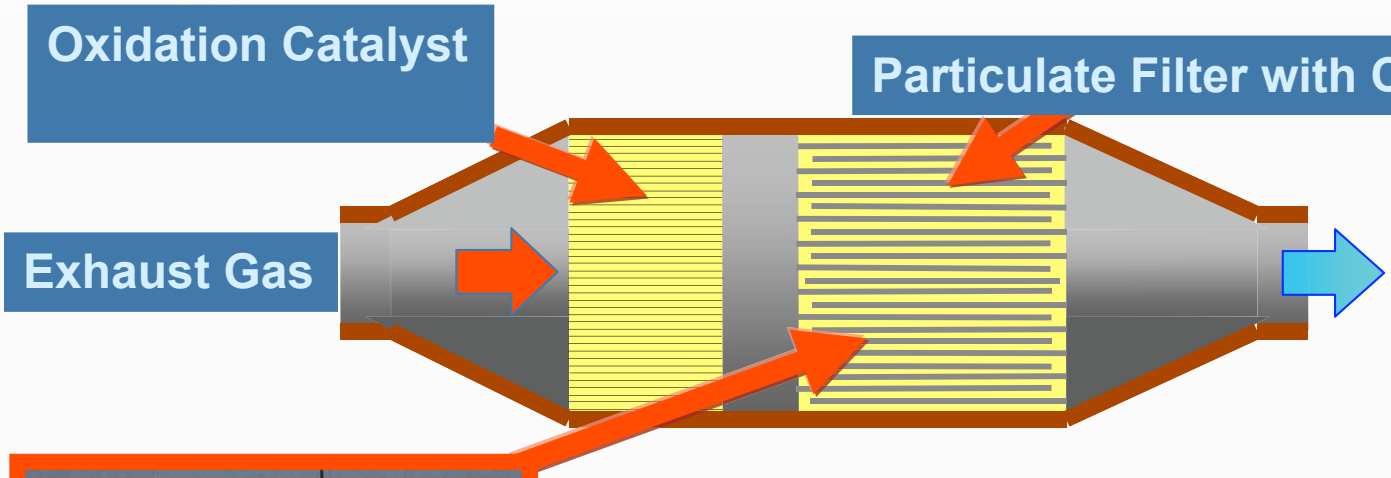
VGS Turbo-charger

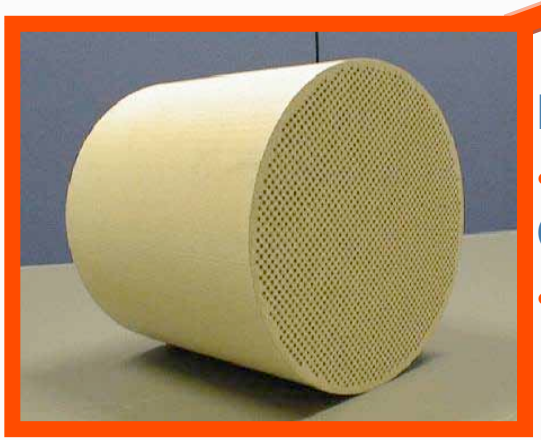


VGS Turbo-charger

- **Benefits: Variable Geometry System Turbo-charger**
  - ✓Provides both low emissions and high engine output
  - ✓The position of the turbo-charger variable vanes is controlled by the ECM, varying boost dependent upon the load requirements of the engine
  - ✓Maximises engine efficiency – creates more power and torque
  - ✓Saves fuel, and that saves money
  - ✓Does not require a “waste gate”.

Isuzu Diesel Particulate Diffuser





Ceramic filter

Regeneration process

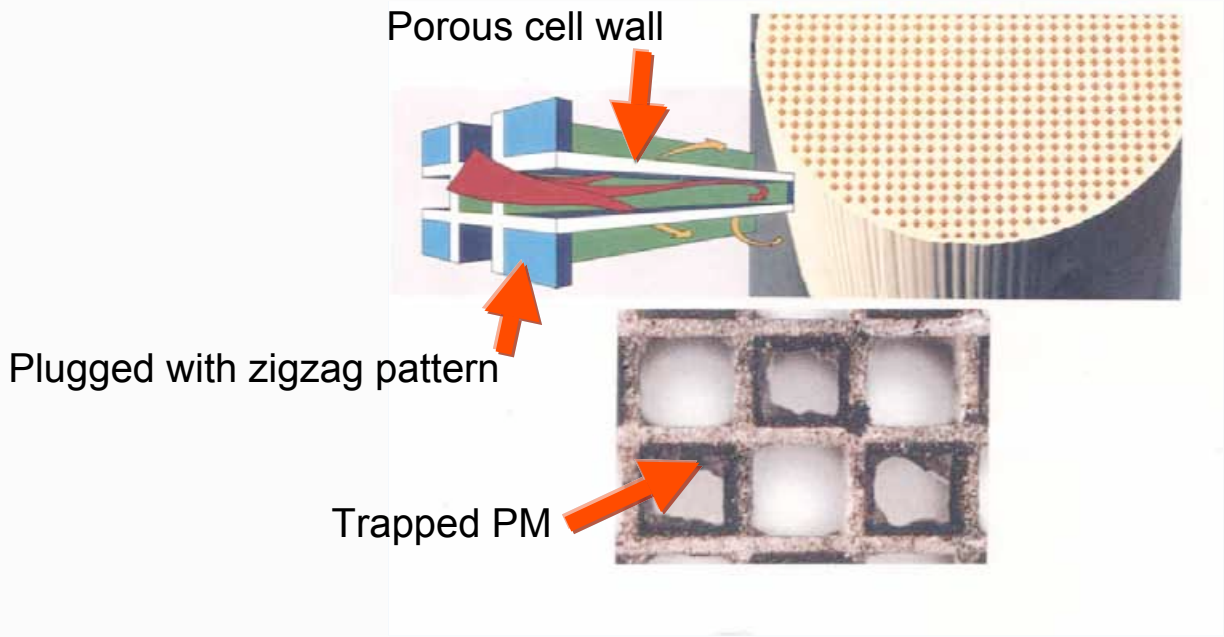
- Middle & Heavy Load: Combustion by Catalyst
- Light Load: Combustion by Post-Injection

Introduction

- April 2004 in Japan
- Many thousands in service.

DPD Regeneration

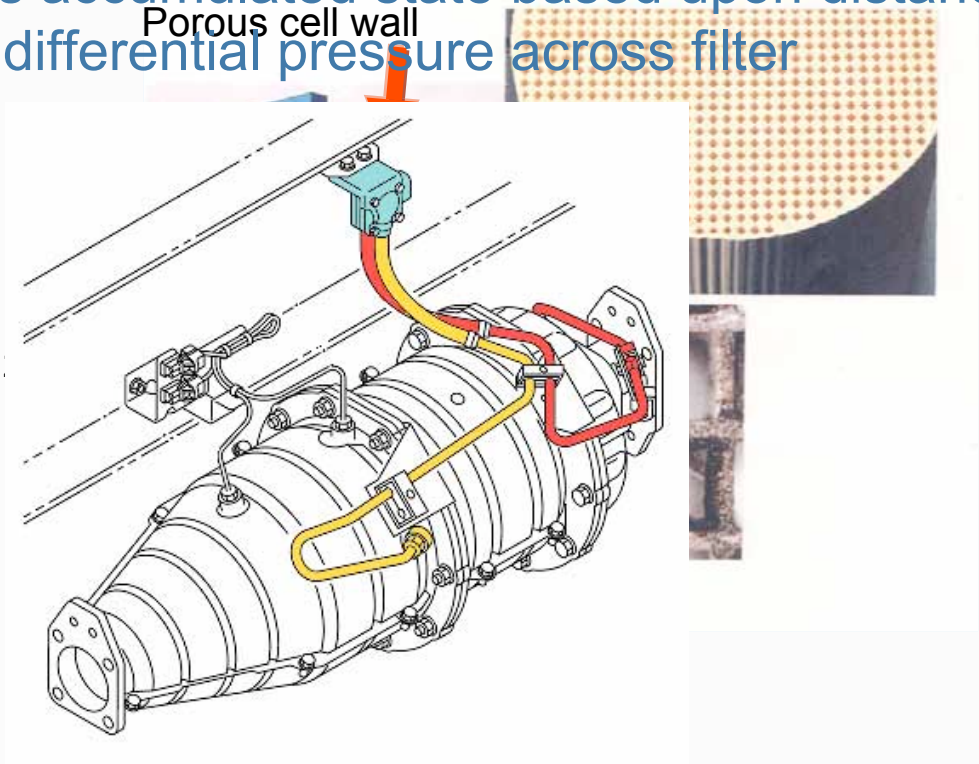
Diesel Particulate Diffuser is “regenerated” when Particulate Matter builds up in the filter



DPD Regeneration

Diesel Particulate Diffuser is “regenerated” when Particulate Matter builds up in the filter

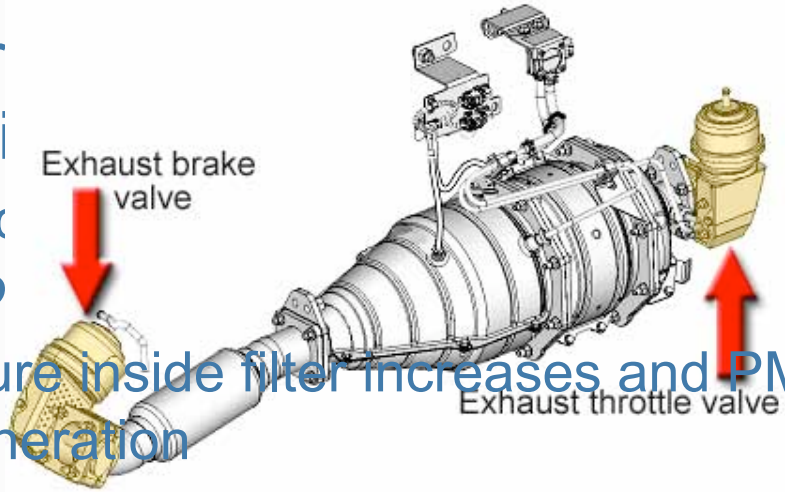
- ECM detects accumulated state based upon distance travelled ***or*** differential pressure across filter

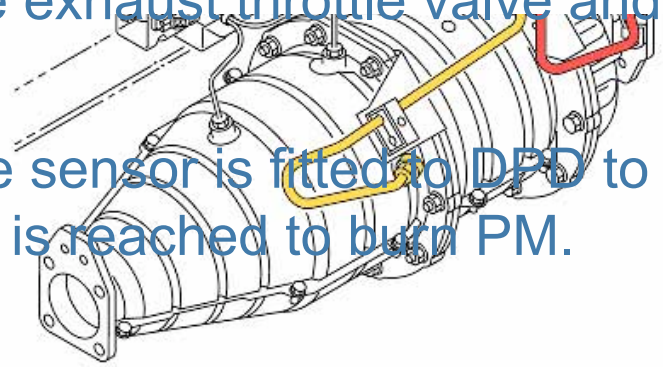


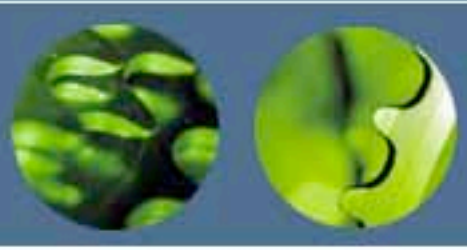
DPD Regeneration

Diesel Par ıted”
when Parti e filter

- ECM detec ı distance travelled ***o*** .
- Temperature inside filter increases and PM is burnt during DPD regeneration
- To achieve required temperature, ECM controls fuel injection, the exhaust throttle valve and exhaust brake valve
- Temperature sensor is fitted to DPD to ensure correct temperature is reached to burn PM.





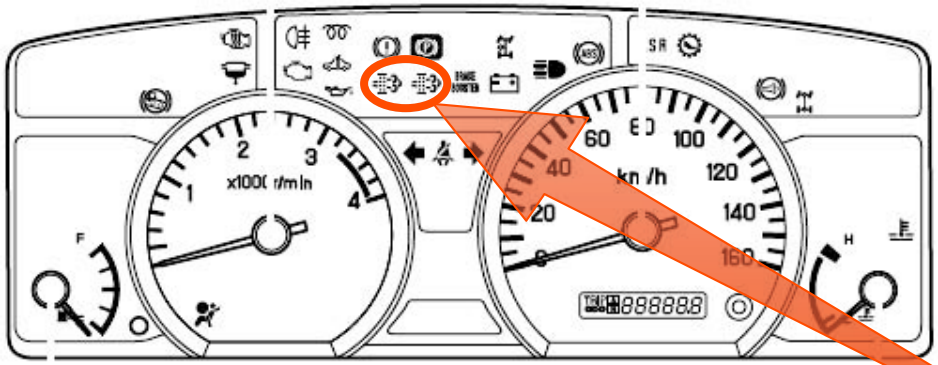


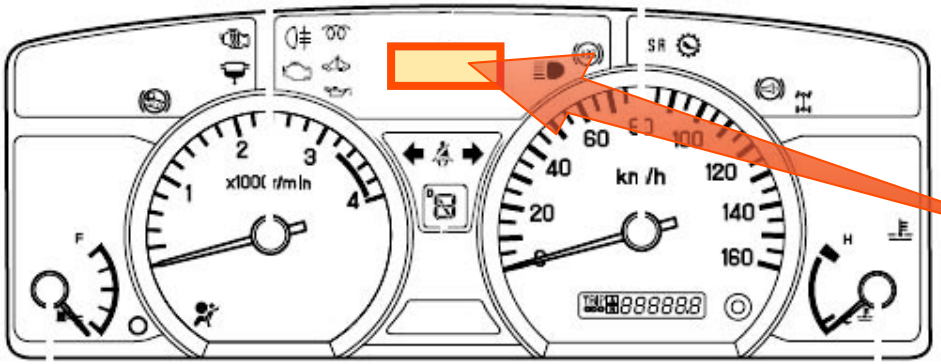
When Does Regeneration Work?

- Two patterns of regeneration:
  - ✓ automatic regeneration
  - ✓ manual regeneration
- Normally, automatic generation occurs
- Manual regeneration **only** required if conditions prevent automatic regeneration from being completed

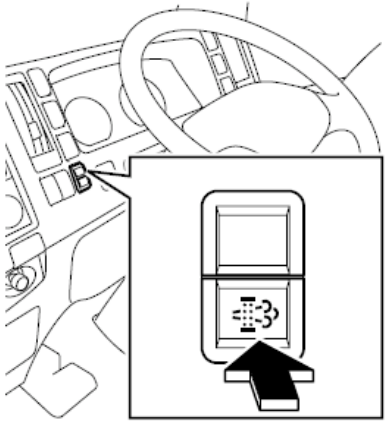
Regeneration pattern	DPD lamp	Switch operation	Condition of vehicle when regenerated	Time for regeneration
Automatic regeneration (normal condition)	GREEN	No	Regardless of whether the vehicle is moving or stationary	20-30 minutes or more
Manual regeneration (DPD lamp is flashing)	Flashing (2 stages)	Yes	**Only** when vehicle is stationary	About 20 minutes

DPD Indicator Lamps & Switches

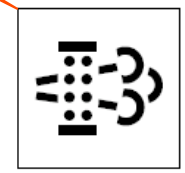




Multi Function Display
Dash



Model without multi information display



Model with multi information display

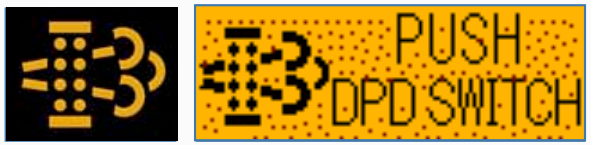
DPD Regeneration: Indicators

Green lamp or AUTO REGEN turns ON:

- Under automatic regeneration control

Orange lamp or MANUAL REGEN turns ON:

- Under manual regeneration control



Orange lamp or PUSH DPD SWITCH slow blink:

- Manual regeneration is urged
- Manual regeneration is interrupted

Orange lamp or PUSH DPD SWITCH fast blink:

- Manual regeneration is urged (higher accumulation level)
- Manual regeneration is interrupted.

DPD – Oil Requirements

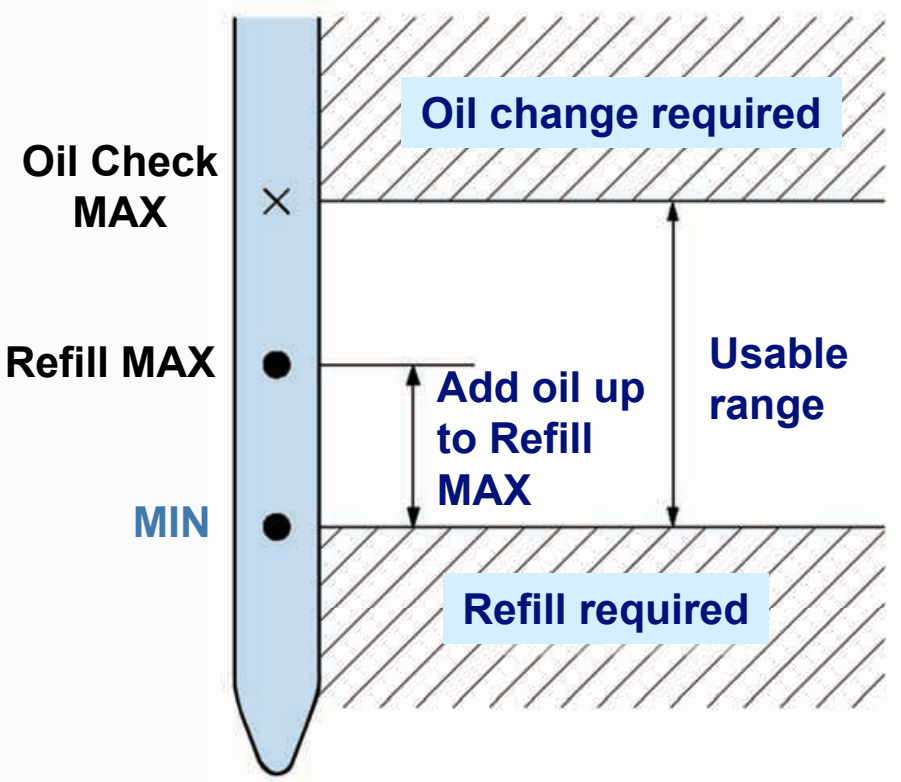
- Always use correct engine oil
  - Low sulphated ash diesel engine oil (<1%)
  - 10W-40 viscosity rating
  - Europe requirement – ACEA E7
    USA requirement – API CJ-4 / SM
  - Suitable for vehicles equipped with Diesel Particulate Diffuser.

DPD: Maintenance

- Pressure differential sensor tubes: replace every 3rd major service
  - 45,000 to 90,000 km intervals
- DPD ceramic filter:
  - Removed from casing and cleaned with high pressure air every 100,000 km (approx)
  - DPD components, including ceramic filter are designed to last the life of the vehicle

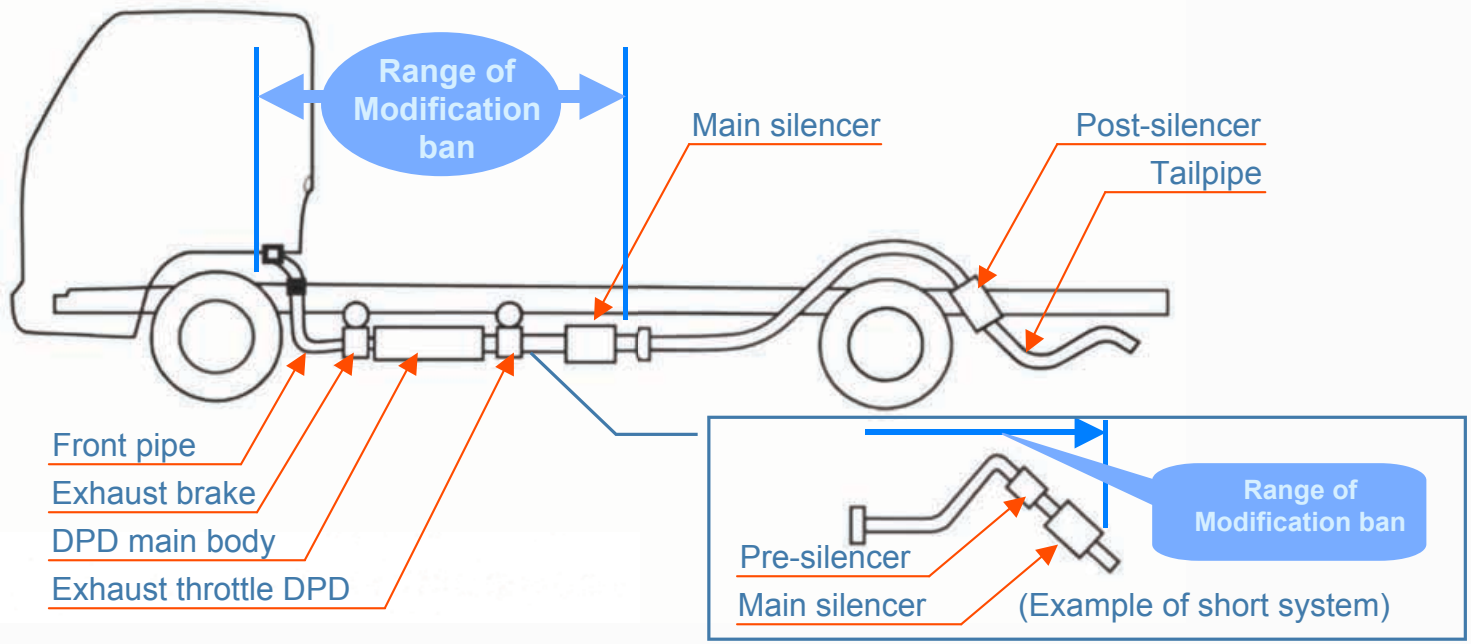
DPD - Other Precautions

- Fill oil to correct level



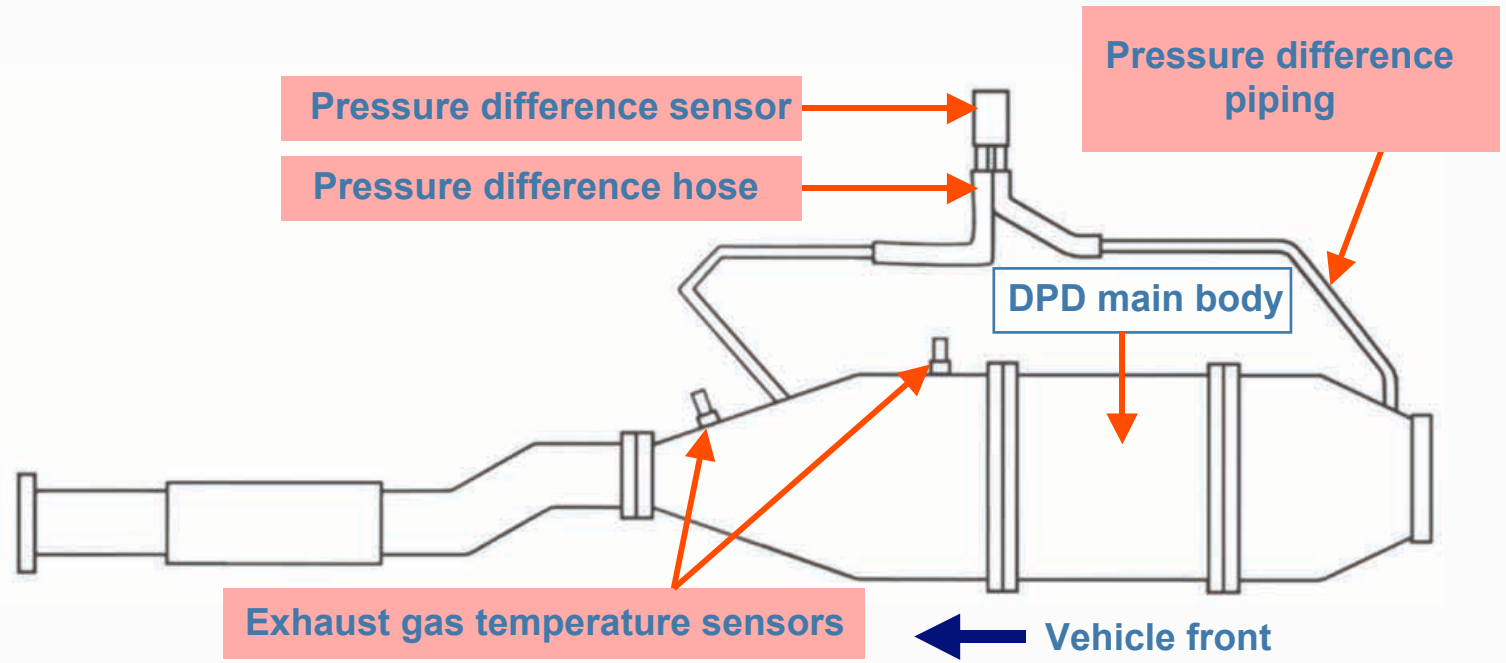
DPD - Other Precautions

Do Not Modify or Move the Exhaust System, Including the DPD.

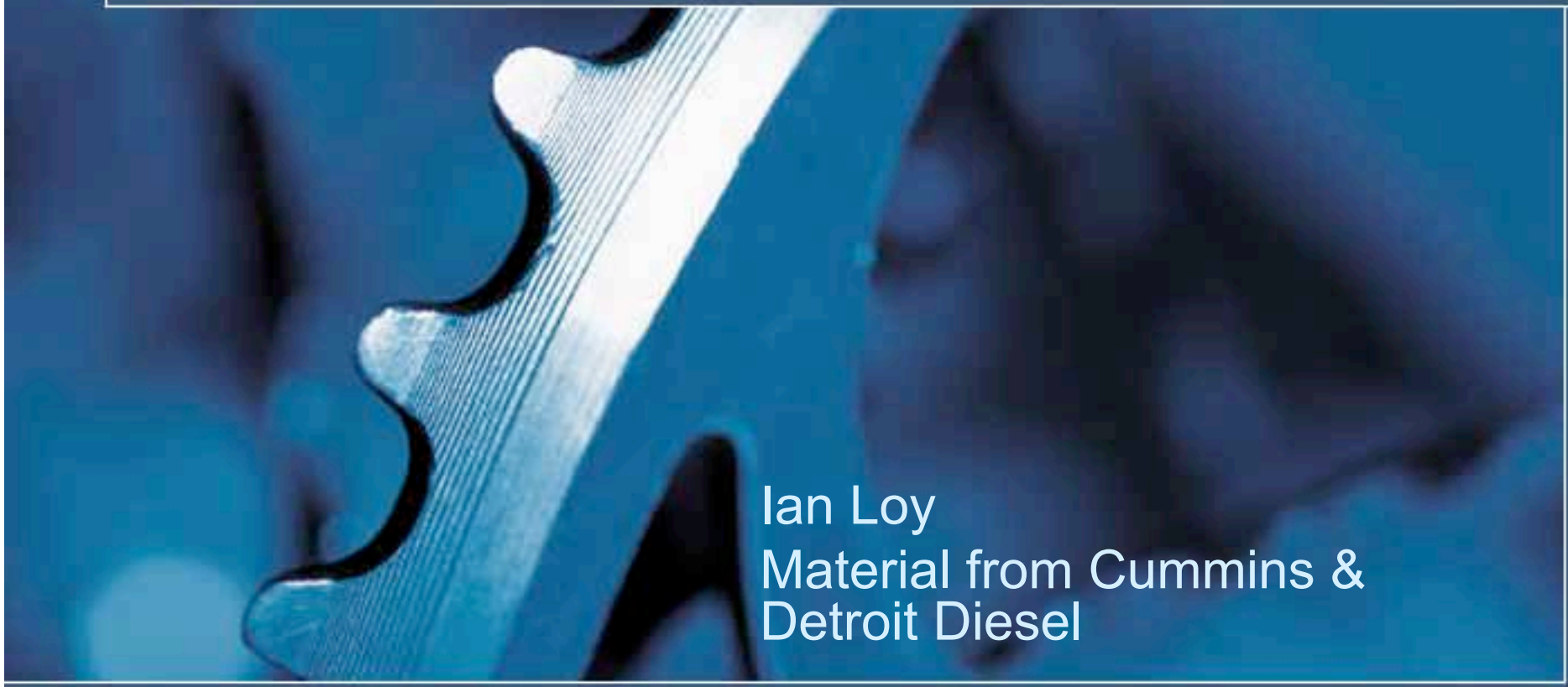


DPD - Other Precautions

Do Not Modify or Move the Sensor or the Pressure Difference Hose.



US Market EGR



Ian Loy
Material from Cummins &
Detroit Diesel

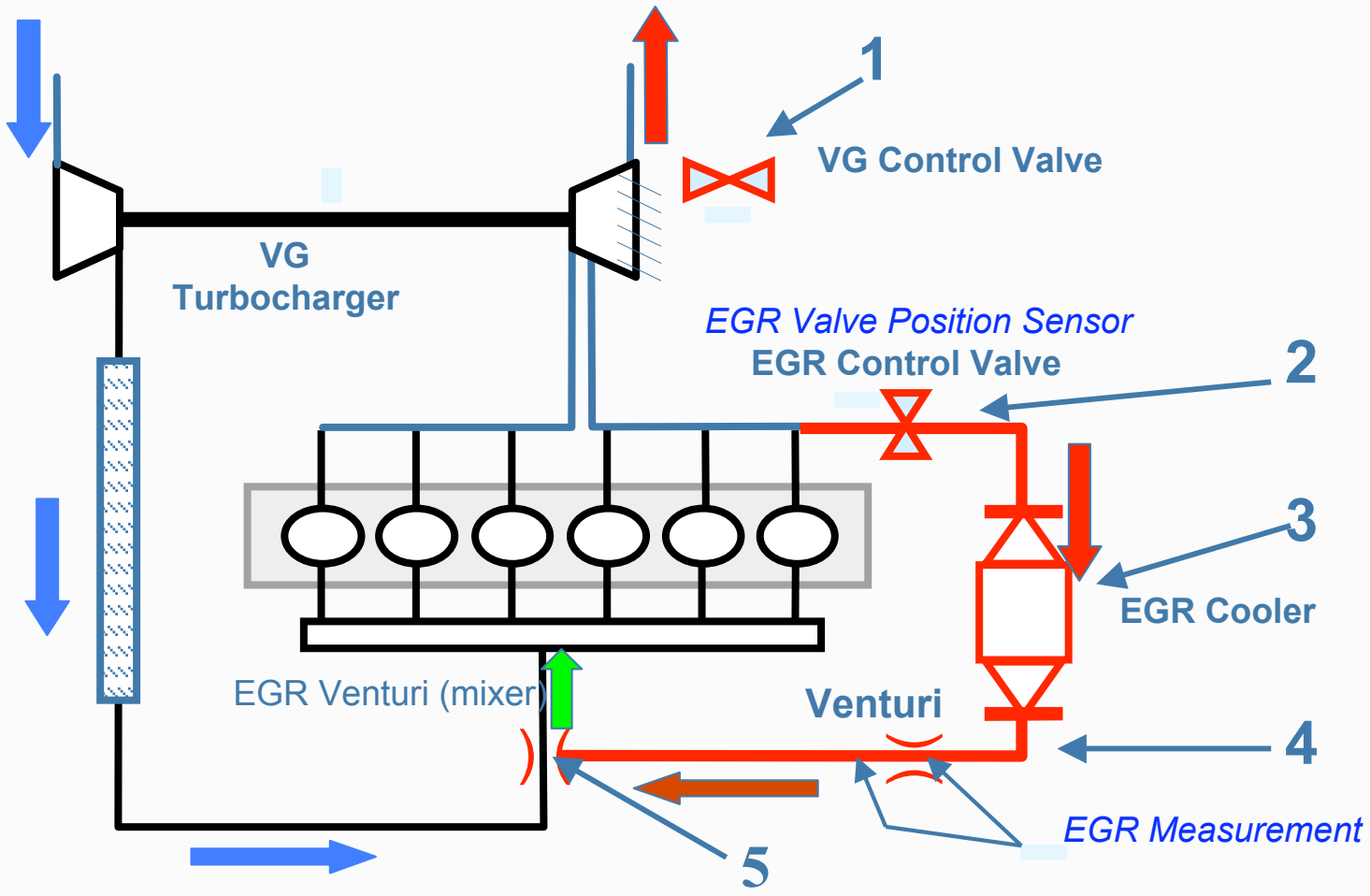
US Market: EGR

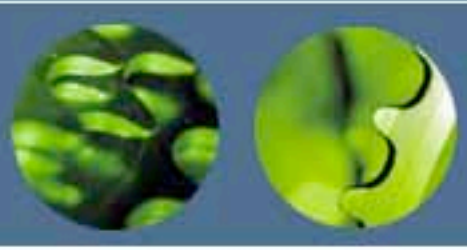
- Cooled EGR adopted
- Variable geometry turbos adopted
- Oil change intervals unchanged
- Cooled EGR systems are designed to be maintenance free

Why go with Cooled EGR?

- EGR is a simple solution in terms of:
  - Emissions
  - Cost
  - Reliability (20 year old technology)
  - Ease of installation
  - Clean installation
    - Added components include EGR cooler, EGR valve, and other valves do not change engine dimensions.

Basic EGR Gas Flow

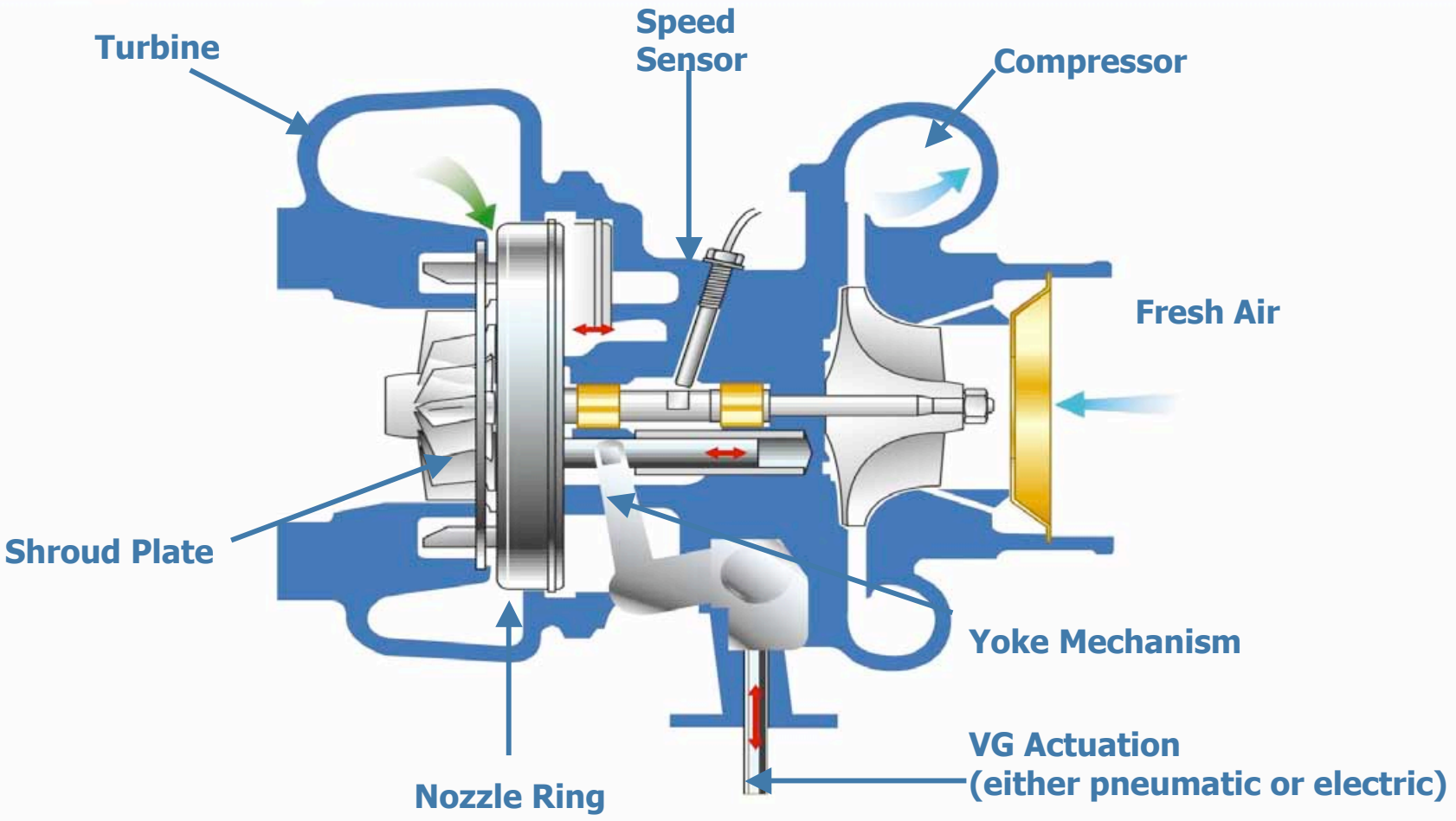




Variable Geometry Turbocharger

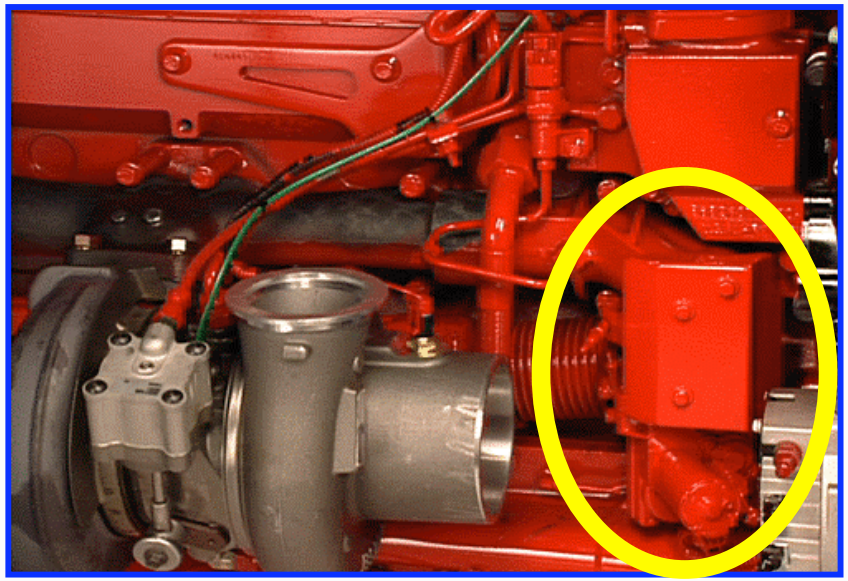
- Two primary purposes:
  - The VG turbo controls exhaust manifold backpressure to create exhaust gas flow through the EGR system.
  - The VGT controls boost pressure to improve transient response.
- Water cooled bearing & oil lubricated housings to improve durability
- Improved engine braking.

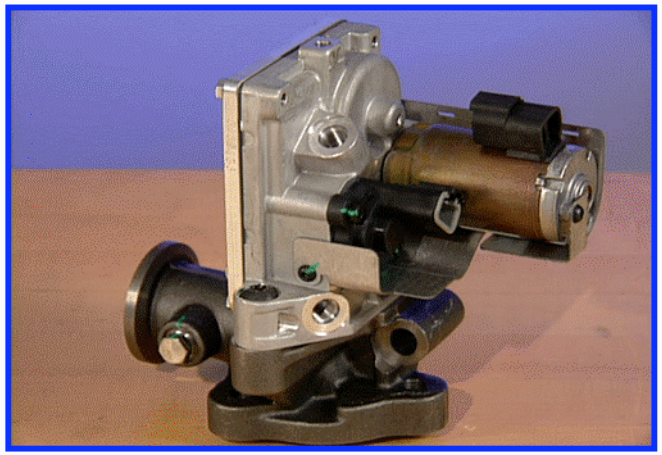
Variable Geometry Turbocharger (Cummins)



EGR Hardware: EGR Valve

- EGR valve regulates amount of exhaust gas recirculated into the intake system
- It is an outwardly-opening poppet valve that opens into the exhaust manifold
- It is controlled by a high speed electric motor with a gear reduction system

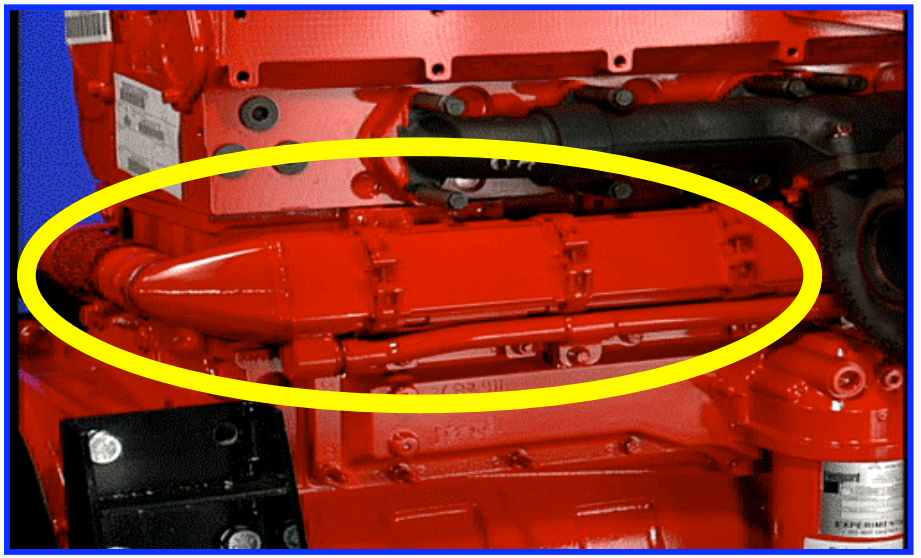




EGR Cooler

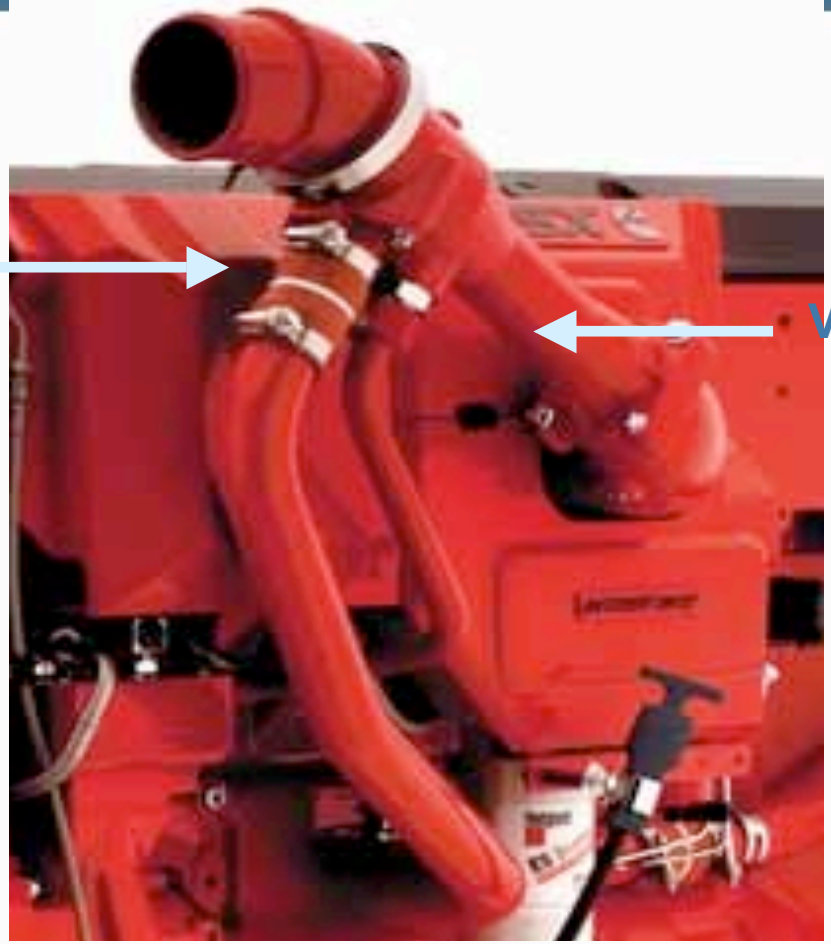
- Primary function is to reduce exhaust gas temperature recirculated into the intake system.

- Cooler is self-cleaning and will not require routine maintenance



Venturi Type Mixer

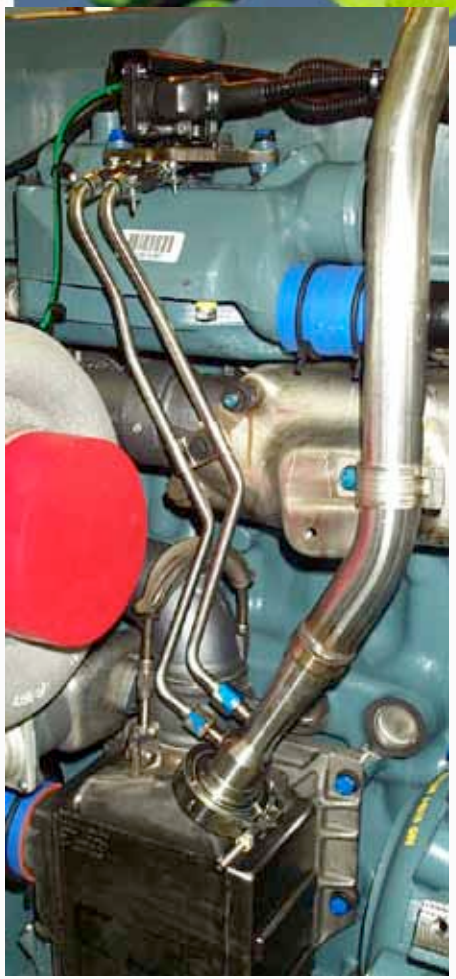
Recirculated exhaust gas inlet



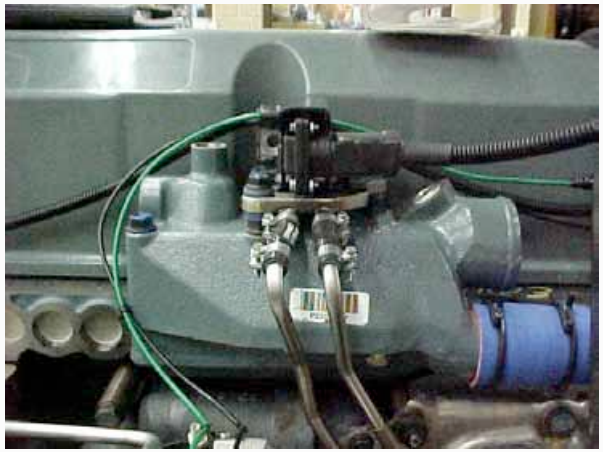
Venturi Throat

Series 60 EGR System

EGR Rate Measurement



Venturi



Differential Pressure Sensor

Temperature Sensor

EGR Maintenance

Item	Signature today	ISX EGR	Change
Oil drain intervals	Based on load/fuel burn	Based on load/fuel burn	No change
Overhead adjustment			No change
EGR components	N/A		No maintenance required

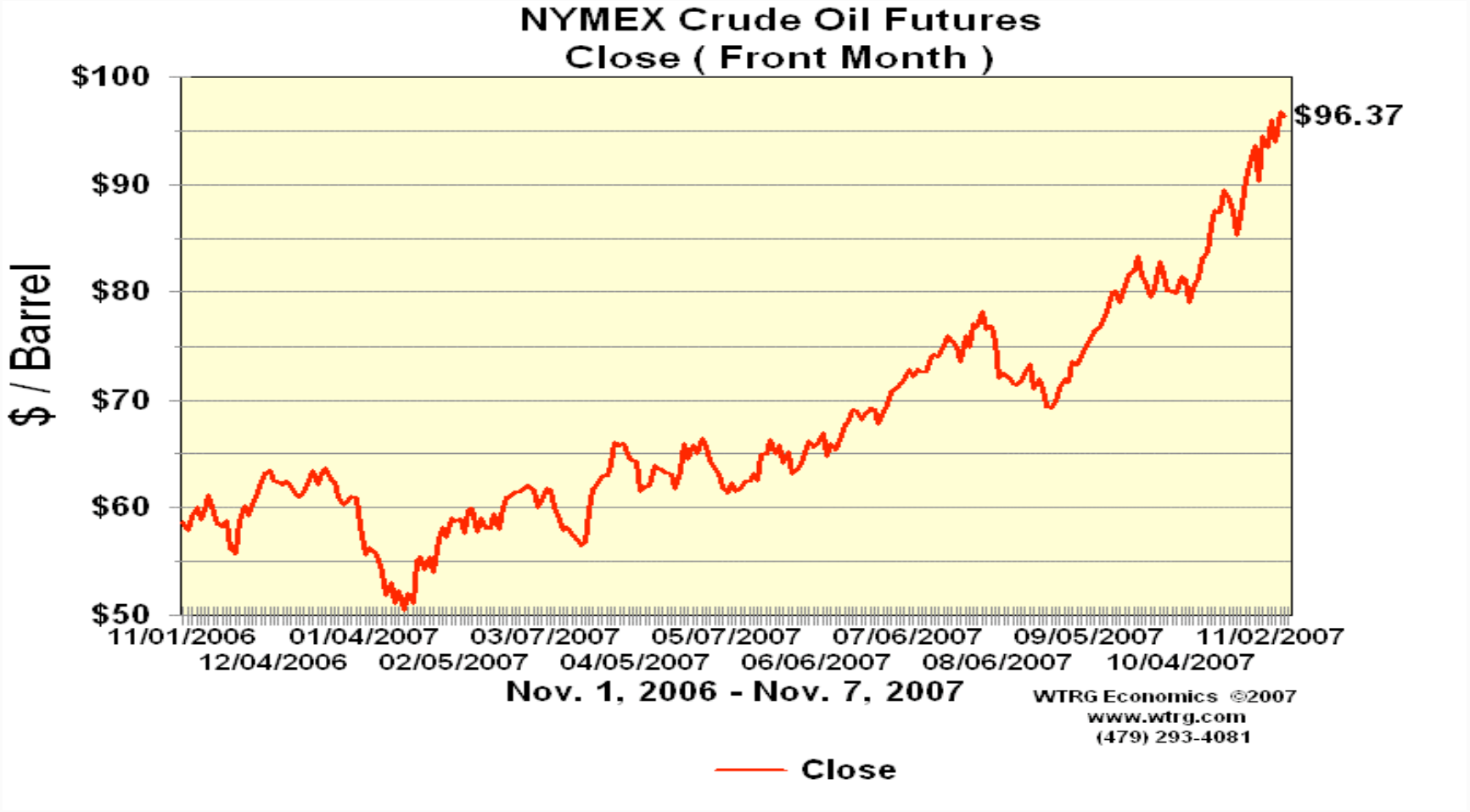
Thank you

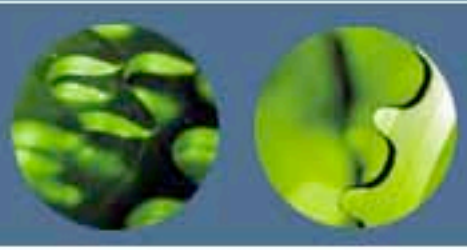
2007 Technical and Maintenance Conference

Mark McKenzie

The case for alternative fuels: What is the bottom line?

Global Oil prices

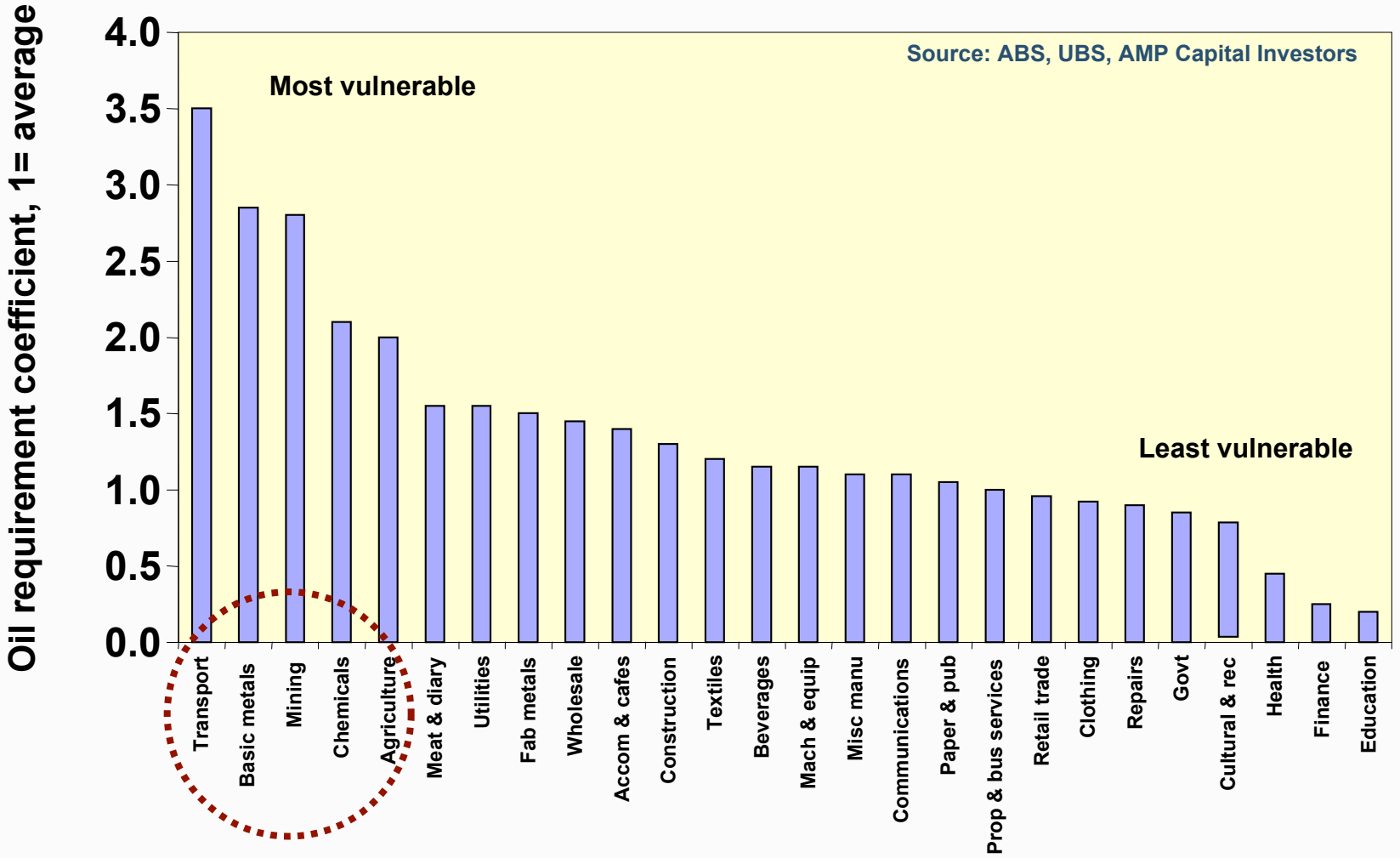


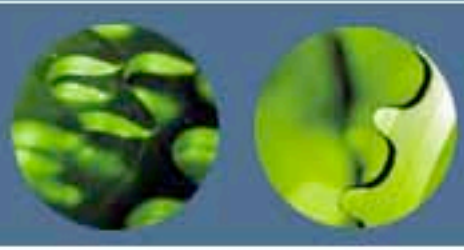


A decreasing level of oil self-sufficiency means that there is an economic imperative to develop alternative transport fuels

- Our national demand for oil is forecast to increase by 50% between 2000 and 2020, while national production is forecast to decline sharply.
- Australia's oil self-sufficiency is forecast to **decline from 85% to 40%** by 2020 (CSIRO 2002).
- This reduction in self-sufficiency will have a negative balance of trade impact of **$7-$8 billion per annum by 2020** (ABARE 2002).
- This cost is considered to be conservative as it was developed at a time when global oil prices were forecast to be between $20 and $30 per barrel.
- The forecast balance of trade impact will potentially have flow-on implications in terms of Australia's competitive position in the global economy.

The potential negative impact of rising oil prices is likely to be greatest in the transport, mining and agriculture sectors



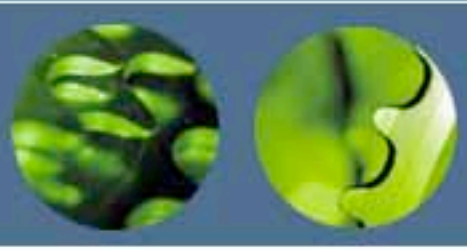


There is also an environmental imperative associated with the need to halt the growth in total emissions from road transport

Vehicle	% of Australian fleet *	GHG contribution to road transport †	PM contribution ‡
Passenger vehicles	**77.9%**	**60%**	**48%**
Commercial vehicles (LCV and trucks)	**18%**	**38%**	**51%**
Other	**4.1%**	**2%**	**1%**

* ABS 2006b † AGO 2006b ‡ BTRE 2005

- Growth in GHG from commercial vehicles is likely to be far more significant than passenger vehicles in the future with commercial vehicles accounting for 11 Mt CO_2eq (or 50%) of the forecast total growth in GHG emissions from road transport between 1990 and 2010 (AGO 2006b)



When can a potential transport fuel be considered as a genuine alternative for road transport in Australia?

A new fuel can only be considered as a substitute when it:

a) can be brought to market relatively easily

b) is both indigenous and abundant

c) delivers good economics of operation (whole-of-life operation, not just fuel savings)

d) delivers operating performance that is at least equivalent to that of conventional fuels

e) delivers environmental performance that is at least equivalent to that of conventional fuels

f) is price stable

Any alternative fuel will also need to be economically competitive with traditional fuels under the new Commonwealth fuel tax regime

Fuel type	Removal of ECGS (by July 2010)	Addition of fuel excise (2011 – 2015)	Total increase (above July 2007 prices)
Biodiesel	11.106	19.1	**+19.63** [2]
Ethanol	12.485	12.5	**+19.63** [2]
LPG [1]	7.155	12.5	**+19.63** [2]
LNG [1]	4.878	10.0	**+14.878**
CNG [1]	7.570	15.2	**+19.63** [2]

Notes

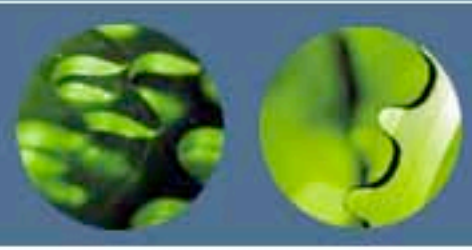
1 Equivalency factors for LPG (x 1.3), LNG (x 1.7) and CNG (x 1.1)

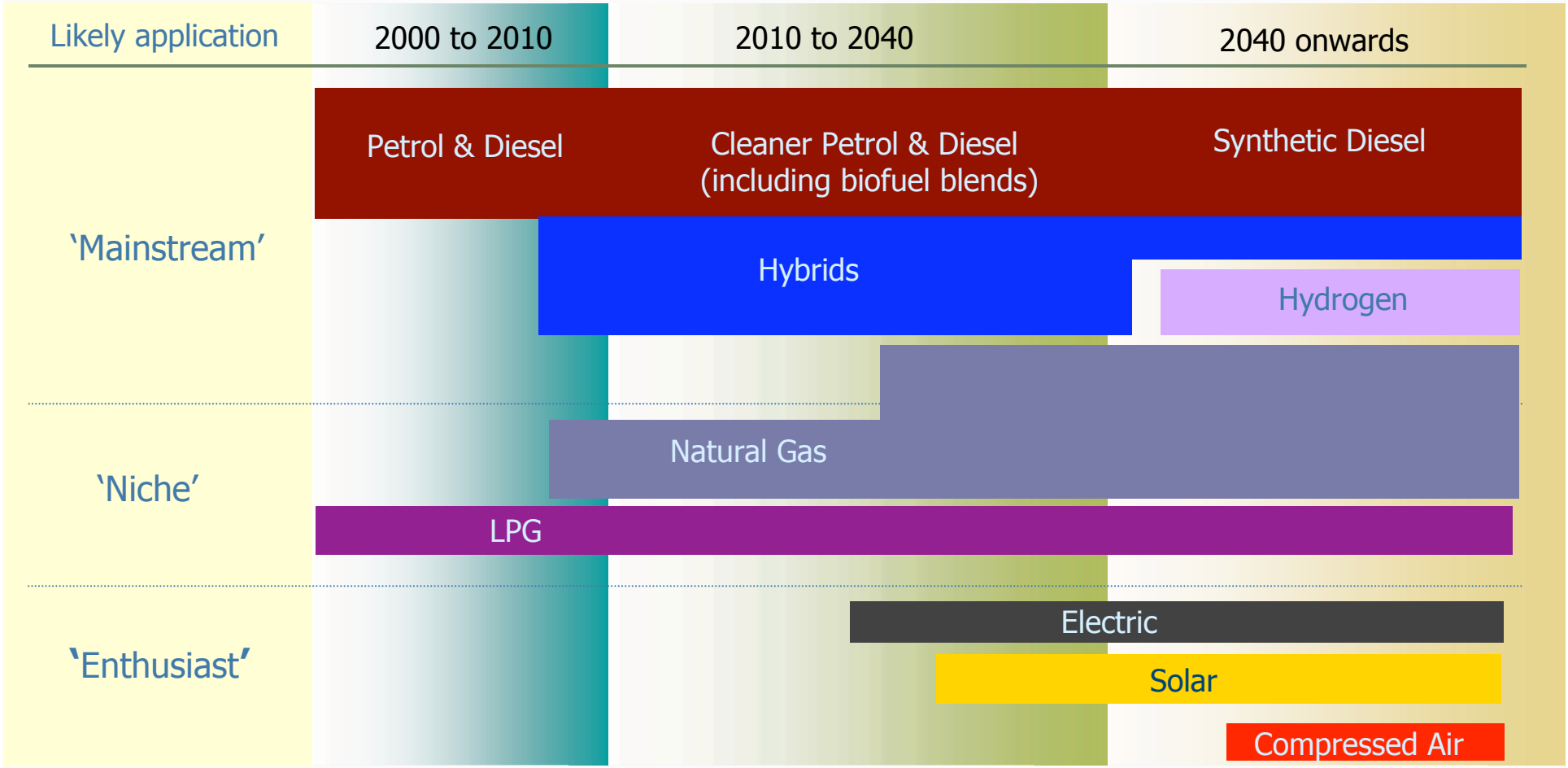
2 Transport businesses will be eligible for a rebate equivalent to the difference between the excise rate and the road user charge (currently 19.63 cpl)

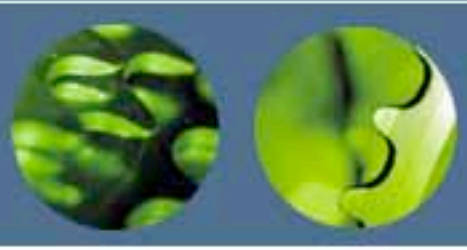
Alternative fuels for Australian road transport: A strategic perspective

	Entry level (US$ / barrel)	Start-up costs	Market ready vehicles	Indigenous fuel	Abundance	Price stability	Economic performance	Environmental performance
LPG	$45-50							
NATURAL GAS	> $50							
BIODIESEL	> $80							
ETHANOL	$45-50							
SOLAR	?							
HYDROGEN	?							
ELECTRIC	?							
FUEL CELLS	?							

Natural gas is likely to find a niche market in the heavy transport sector, while biofuels are likely to be an extender of traditional fuels

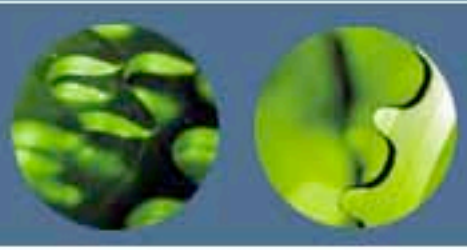






Six key challenges will limit future growth in the use of biodiesel for heavy vehicles in Australia and around the world (OECD 2007)

- Variation in fuel quality
- 'Food vs Fuel' challenge issue for 1st generation fuels
- Total greenhouse performance is likely to be worse than conventional fuels (1st generation fuels)
- Large-scale commercialisation challenges for 2nd generation fuels:
  - will require technological breakthroughs
  - are likely to be at least a decade away
- Unlikely to be developed as a large-scale substitute for conventional fuels:
  - less than 13% of total fuel demand (1st and 2nd generation combined)
- Likely to be non-economic following introduction of fuel tax excise



Three key challenges will need to be addressed for natural gas to gain a significant share of the Australian fuels market

- **Mixed performance of existing dual-fuel engine technologies**

  Currently the subject of a major R&D project being undertaken by the Australian Government in partnership with key industry stakeholders.

- **Limited engine product range**

  The Australian government is currently working with Westport Innovations and three Australian fleet operators to trial the Cummins Westport HPDI Technology (trial results are expected to be available in early 2008).

- **Severe restrictions on LNG availability**

  This issue will only be resolved by significant investment in LNG production facilities and refuelling infrastructure.

Some concluding thoughts

- Biodiesel is likely to be useful as an extender of conventional fuels only. Economics will be questionable following the introduction of fuel excise from 2011.
- Post-2015, natural gas is one of the few (if not the only) alternative fuels that is likely to remain economically viable under the fuel excise regime.
- A number of Australian fleet operators have proven that natural gas can deliver substantial economic savings and environmental benefits.
- While natural gas heavy duty engine technology has improved substantially in recent years, there is still some work to do in this area.
- For the natural gas HDV market to grow beyond its current infancy, there is an urgent need for significant investment to:
  - increase the range of gas engine products
  - improve availability of LNG on the east coast of Australia.

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Summary

Simon Humphries

Summary

- New emissions rules mean adopting new technologies
- Euro4, USEPA04 and JNLT05 are not the same, but we will see all three types on the road in 2008
- Nothing arriving in Australia that hasn't been tried, proven and developed elsewhere

Summary

- EGR components require very little maintenance
- DPF (and DPD) are designed to last the life of the vehicle, and require some attention, but will “self clean” in most circumstances
- SCR components need some attention, but not on a regular basis (unless you don’t fill up with AdBlue!)

Summary

- Alternative fuels are still a niche:
- Diesel is the dominant heavy commercial vehicle fuel, and will be for a long time
- BUT…as prices go up, others will attract attention.
- Natural Gas seems to be a viable solution for some operators
- What about Hybrids?

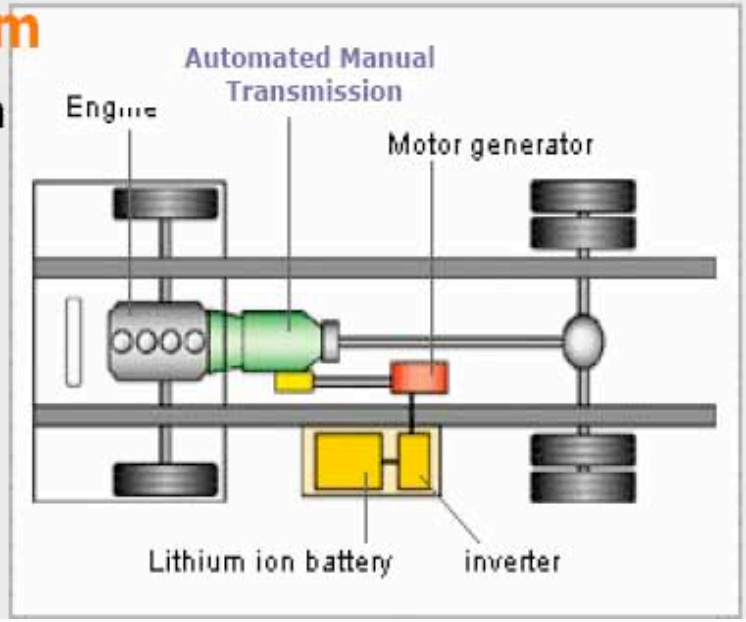
Isuzu Hybrid Electric Vehicle (HEV)

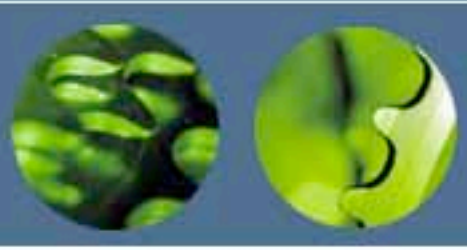
Basic CV requirements		Expectations to an HEV
·Economy ·Durability & reliability ·Safety	ISUZU HEV: Satisfying both	·Better fuel economy ·Reduced CO2

ISUZU unique HEV system

- PTO-type parallel drive system
- Highly efficient regeneration by combination with AMT
- Long life Lithium ion battery

- Best-in-class fuel economy
- Clean exhaust gas





Summary

- Hybrids are being developed that will save about 30% fuel under stop-start conditions
- Like biodiesel, another way to extend the life of diesel (or any fossil fuel)
- Cost is still an issue, but products are appearing on the market
- Still no clear viable alternative to diesel for the mainstream?
- Thank you

Question time...

Panel:

Simon Humphries

Ian Loy

Mark McKenzie