Exhaust Aftertreatment

Advanced Emission Controls

Filtration

Content/Objectives

1. To understand engine and vehicle technology relating to emissions.
2. To understand Diesel Oxidation Catalyst (DOC) and Diesel Particulate Filter (DPF).
3. To understand Regeneration.
4. To understand DPF cleaning.
5. Summary.

Objective 1: To understand engine and vehicle technology relating to emissions.

- Cummins has made a large investment in the development of advanced combustion systems that reduce engine-out emissions at the source – inside the combustion chamber.

Filtration

Objective 1: To understand engine and vehicle technology relating to emissions.

One of Cummins' unique advantages is integrating critical subsystems.

Cummins Filtration

Cummins Turbo Technologies

Cummins Emission Solutions

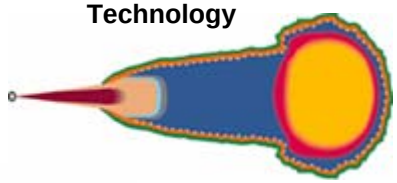
Cummins Fuel Systems

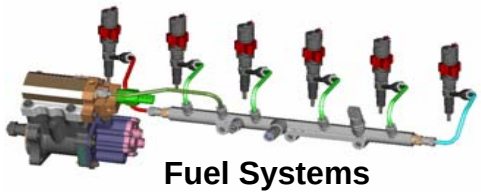
Objective 1: To understand engine and vehicle technology relating to emissions.

Cummins core in-house technologies include:

- Combustion technology
- Fuel systems
- Electronics
- Air handling
- Filtration
- Aftertreatment

Combustion Technology





Fuel Systems

Filtration

Air Handling

Aftertreatment

Filtration

Objective 1: To understand engine and vehicle technology relating to emissions.

The introduction of cooled Exhaust Gas Recirculation (EGR) technology in 2002 to meet the 2.5-g/hp-hr NOx standards created the foundation for our 2007 products.

Objective 1: To understand engine and vehicle technology relating to emissions.

The EGR system takes a measured quantity of exhaust gas and passes it through a cooler before mixing it with the incoming air charge to the cylinder.

During combustion, EGR has the effect of reducing flame temperatures, which in turn reduces NOx production--since NOx is proportional to flame temperature.

Filtration

Objective 1: To understand engine and vehicle technology relating to emissions.

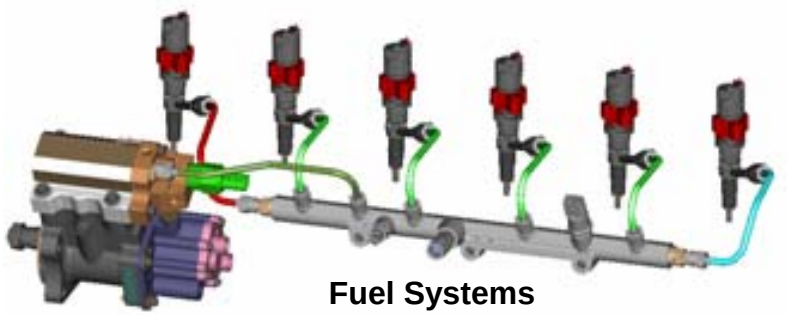
Air Handling

A key component to the Cummins EGR system is its Variable Geometry Turbo. It features a unique patented one-piece sliding nozzle which moves continuously to vary the power of the turbine and the amount of air delivered to the engine.

Cummins Turbo Technologies

Objective 1: To understand engine and vehicle technology relating to emissions.

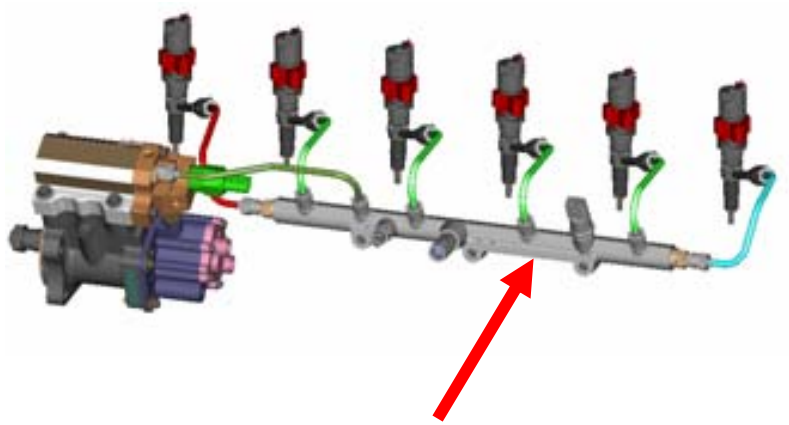
Another key component is the
- High Pressure Common Rail fuel system, used on Cummins Midrange and High Horsepower engines.



Fuel Systems

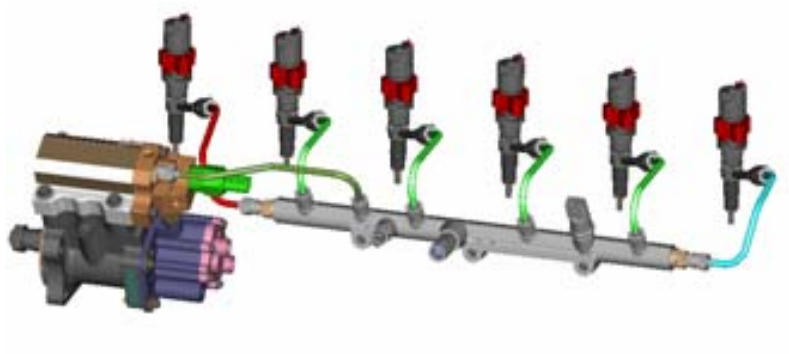
Objective 1: To understand engine and vehicle technology relating to emissions.

- A common rail injection system first stores fuel under high pressure in a common rail – pressures that exceed 25,000 psi.
- Then with the use of electronically controlled injectors, fuel is delivered into the combustion chamber.



Objective 1: To understand engine and vehicle technology relating to emissions.

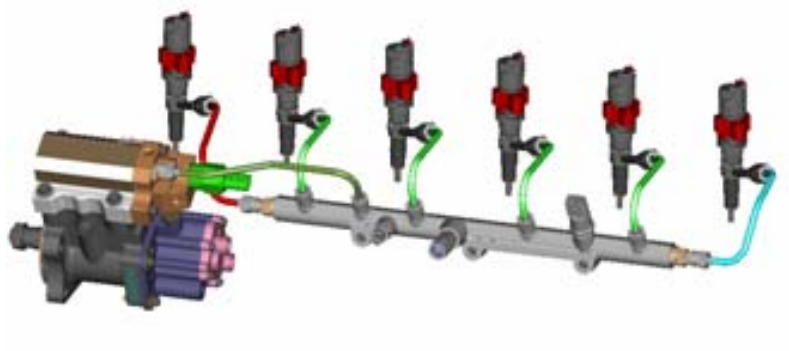
- High fuel pressure produces a fine mist of fuel that burns better and cleaner in the combustion chamber.
- In addition, for each combustion cycle, the common rail allows up to five injections per cycle.



Filtration

Objective 1: To understand engine and vehicle technology relating to emissions.

With common rail fuel systems, fuel consumption is improved, even with the use of ULSD fuels.



Because of the high system pressures and the sophisticated injection system, superior fuel and fuel/water separator filters are necessary to ensure trouble-free life.

Objective 1: To understand engine and vehicle technology relating to emissions.

In order to meet EPA 2007 emissions regulations, engine manufacturers must now use *advanced emission control devices.*

Advanced emission control devices refer to exhaust aftertreatment devices or systems.

Filtration

Objective 1: To understand engine and vehicle technology relating to emissions.

Any post combustion device, or system attached to the exhaust of the engine to reduce exhaust emissions, is an aftertreatment device or system.

Particulate Matter (PM) is a form of carbon (i.e. soot) produced by incomplete combustion of diesel fuel in the engine.

Exhaust aftertreatment can reduce NOx, remove PM, and in some applications, do both.

Objective 1: To understand engine and vehicle technology relating to emissions.

Cummins Engines use aftertreatment devices that include a Diesel Oxidation Catalyst (DOC), as well as a Diesel Particulate Filter (DPF).

A Cummins Particulate Filter is the correct name for our combination DOC and DPF aftertreatment system.

Aftertreatment

Cummins Filtration

Objective 2: To understand Diesel Oxidation Catalyst (DOC) and Diesel Particulate Filter (DPF).

Now let's discuss what a DOC and a DPF do in the exhaust system.

Objective 2: To understand Diesel Oxidation Catalyst (DOC) and Diesel Particulate Filter (DPF).

- DOC (Diesel Oxidation Catalyst) is a flow-through honey comb substrate with a catalytic coating applied to the surface.
- As exhaust passes over the catalyst, a chemical change takes place, reducing carbon monoxide (CO), hydrocarbons (HC) and soluble organic fraction (SOF) of the soot.

SOF is unburned fuel.

Precious Metal Coating

Straight through design

Exhaust flow

Filtration

Objective 2: To understand Diesel Oxidation Catalyst (DOC) and Diesel Particulate Filter (DPF).

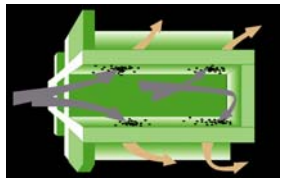
The catalytic coating is a material used to promote oxidation by increasing the speed of a chemical reaction. It is typically a precious metal, such as platinum.

The DOC oxidizes, or converts, NOx (Nitric Oxide) to NO_2 Nitrogen Dioxide.

Objective 2: To understand Diesel Oxidation Catalyst (DOC) and Diesel Particulate Filter (DPF).

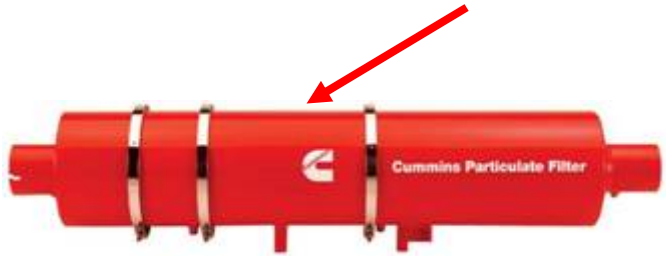
- DPF (Diesel Particulate Filter) is a device designed to physically remove soot or particulate matter in diesel exhaust.
- This matter is sometimes referred to as a “particulate trap”.

Note: Cummins refers to a DPF as a filter, not a trap.



Wall Flow Design

Diesel Particulate Filter



Exhaust flow

Filtration

Objective 2: To understand Diesel Oxidation Catalyst (DOC) and Diesel Particulate Filter (DPF).

The DPF is placed after the DOC in the system. As the oxidized NO2 passes through the DPF, it combines with the collected carbon (C) (soot) to form CO2 Carbon Dioxide, which leaves the exhaust system as a clear gas.

The DOC oxidizes, or converts, NOx (Nitric Oxide) to NO_2 Nitrogen Dioxide.

NO_2 Nitrogen Dioxide combines with C carbon and becomes CO_2.

Objective 3: To understand Regeneration.

What’s all this about “regeneration”?

Objective 3: To understand Regeneration.

- Regeneration is the controlled removal (cleaning) of Particulate Matter (soot) deposited in the diesel particulate filter.

This is known as **Passive Regeneration.**

- When operating conditions maintain sufficient exhaust temperatures, the diesel particulate filter is continually being cleaned.

Cummins engines are designed to maximize the use of passive regeneration.

Objective 3: To understand Regeneration.

- **Passive regeneration** is the continuous regeneration when operating conditions maintain sufficient exhaust temperatures.

Passive regeneration is totally *transparent* to the driver.

- Soot is continually oxidized in the Cummins Particulate Filter to from invisible carbon dioxide, so clean exhaust comes out the tailpipe.

Cummins engines are designed to maximize the use of passive regeneration.

Objective 3: To understand Regeneration.

Active regeneration occurs when there is not sufficient heat in the exhaust. Exhaust temperatures are raised by injecting a small quantity of fuel upstream of the diesel oxidation catalyst.

The resulting chemical reaction over the diesel oxidation catalyst raises exhaust temperatures high enough to oxidize the carbon from the filter.

It requires 15-20 minutes to clean the filter; it does not need to be continuous and occurs while the vehicle continues to operate.

Objective 3: To understand Regeneration.

An aftertreatment injector, also known as a ‘dosing’ injector, introduces a small amount of fuel into the exhaust stream ahead of the DPF, which increases the temperature of the exhaust, but, does not burn.

Dosing injector: Used to inject a small amount of fuel into exhaust during an “active” regeneration event.

Note: There is no actual flame or burning of the fuel that is injected into the system.

Objective 3: To understand Regeneration.

Stationary regeneration is the oxidation of soot while the vehicle is not being driven. It is performed because the normal driving cycle will not support passive or active filter regeneration (the exhaust does not get hot enough).

A few duty cycles (high idle time and short route segments) occasionally require a stationary regeneration, such as:

- Package delivery that never leaves the city
- Urban pickup and delivery trucks
- Emergency trucks
- Class 8 tractor in Canada at -20 F (or really cold Celsius) going from stoplight to stoplight

Filtration

Objective 3: To understand Regeneration.

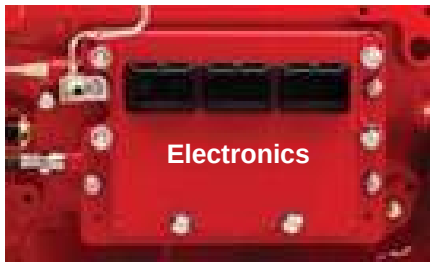
Passive Regeneration → Operate the vehicle normally.

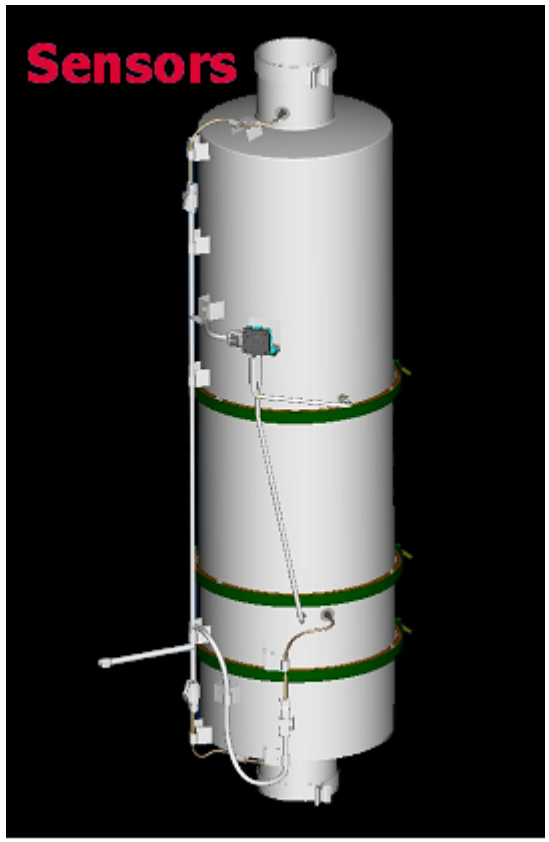
Active Regeneration → Dosing occurs – there is no operator interaction.

Change Duty-Cycle OR Stationary Regeneration → Put more load on engine – requires driver interaction.

Objective 3: To understand Regeneration.

The engine's Electronic Control Unit (ECU) monitors the DPF performance through the use of sensors and determines if the aftertreatment system is functioning properly.



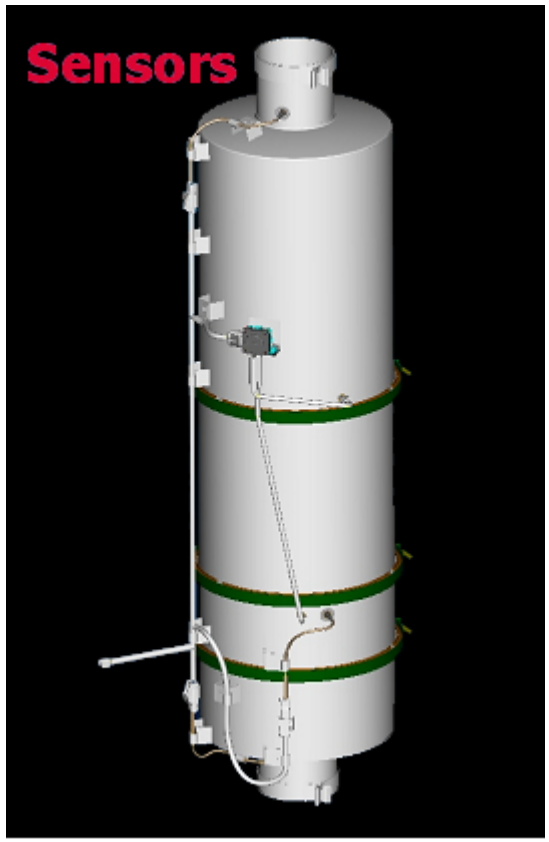


Objective 4: To understand DPF cleaning.

There’s a lot of discussion regarding cleaning of the DPF – what does this all mean?
How is cleaning different from regeneration?

Objective 4: To understand DPF cleaning.

Cummins is ready with technology to meet the 2007 emission standards. Not only have we conducted extensive fleet testing – we're already demonstrating our filter-cleaning equipment and procedures.



Objective 4: To understand DPF cleaning.

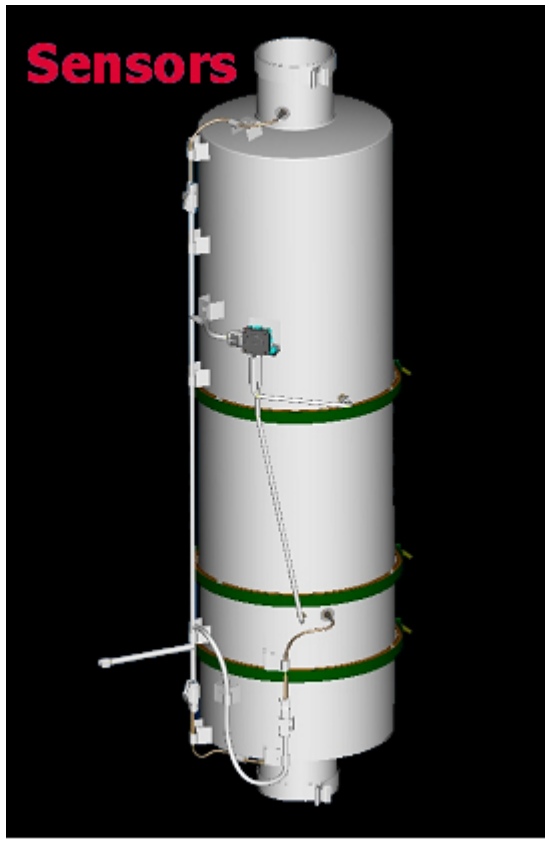
As the exhaust stream flows through the Cummins Particulate Filter, the particulate matter gets oxidized and oil particles are trapped and converted into ash, while clean air travels through the walls and out the exhaust stack.

Ash: Incombustible material, found in oil additives, that can only be removed by cleaning.

- Ash comes from the oil
- Soot or particulate matter (PM) comes from the combustion process
- PM is oxidized (regeneration) in the DPF, while ash will need to be removed (cleaned)

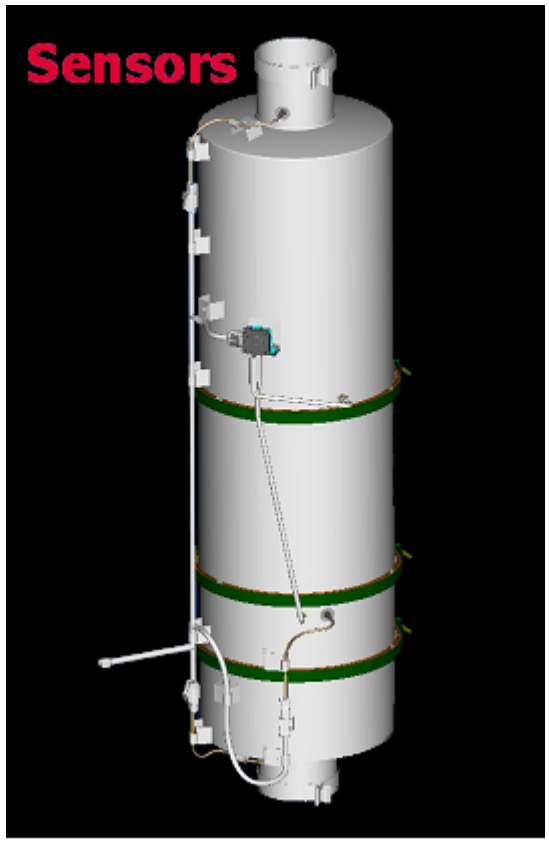
Objective 4: To understand DPF cleaning.

As ash builds up in the DPF, engine backpressure will increase. When the backpressure gets to a level where engine performance is close to being inhibited, a signal will be sent to the operator that it is time to clean the DPF, at the next scheduled service interval.



Objective 4: To understand DPF cleaning.

Over time (200,000–400,000 miles [320,000-640,000 km] in a typical line-haul operation), ash will build up and need to be removed in a simple maintenance procedure that's quick and convenient.



Objective 4: To understand DPF cleaning.

Equipment has been designed to clean the filter by forcing compressed air through the filter in a sealed system, vacuuming the ash into a plastic collection device.

Objective 4: To understand DPF cleaning.

To change the collection device, simply disconnect the vacuum, put a lid on the container and dispose of it according to local regulations.

Objective 4: To understand DPF cleaning.

Depending on the size and the ash load in the particulate filter being cleaned, the collection device will last up to a couple of months.

Objective 4: To understand DPF cleaning.

- The time required for the actual cleaning process varies, but on average it should take less than 30 minutes (less than the time for a normal engine servicing).
- The total procedure, including disconnecting and removing the Cummins Particulate Filter from the vehicle, cleaning the particulate filter element, then re-installing the entire unit should take about 2.5 hours or less, depending on how accessible the mounting of the Cummins Particulate filter is on the vehicle.

* While actual costs may vary, Cummins estimates that a particulate filter cleaning costs $300, which includes removal and installation.

Objective 4: To understand DPF cleaning.

- The particulate filter cleaner runs on standard 110-volt power and uses standard shop air.

- Attachments are available to fit every size of particulate filter from Cummins and most other engine manufacturers.

*This is a real benefit to service departments, since regardless of how many different types of engines they service, they only need to use one type of cleaning machine.

Objective 4: To understand DPF cleaning.

Caterpillar states that their DPF, which does not include a DOC, can be cleaned on the vehicle – it does not have to be removed.

This type of cleaning would have to occur where the proper equipment is in place – i.e., Caterpillar authorized centers.

OEMs take different approaches with dealers regarding cleaning equipment and services. Volvo–Mack for example, does not require dealers to provide DPF cleaning services.

Objective 4: To understand DPF cleaning.

While proper maintenance is key, engine manufacturers expect the exhaust aftertreatment systems to last the life of the engine.

Engine life is defined as “to the first rebuild”.

Objective 4: To understand DPF cleaning.

The particulate filter must be periodically cleaned due to ash build- up. Does this relate to the low ash oil being recommended for 2007 engines?

Objective 4: To understand DPF cleaning.

Low ash oil has lower amounts of trace elements in the lube oil additives, including calcium, zinc and phosphorous which, when burned, form ash.

Low Ash Oil, identified as CJ-4, is being required by engine manufacturers for use in their 2007 certified engines.

Objective 4: To understand DPF cleaning.

Using the higher ash CI-4 oil will shorten the DPF cleanout interval.

Note: We will discuss in further detail the use of CJ-4 and CI-4 lube oils in the Engine Lubrication module.

Summary.

- Exhaust aftertreatment is required on 2007 certified engines to meet the EPA emission regulations for NOx and PM.
- Aftertreatment devices may include a Diesel Oxidation Catalyst (DOC), a Diesel Particulate Filter (DPF), or both.
- Cummins uses a combination DOC and DPF, which is called a Cummins Particulate Filter.

Summary.

- DDC, MBE, and Volvo-Mack use combination DOC and DPF devices.
- Caterpillar uses a DPF only.
- The use of a DOC ensures better soot regeneration, at lower temperatures, meaning less time in active regeneration.
- Service intervals (off-engine cleaning) for the DPF can vary and are estimated by engine manufacturers to be between 200,000 - 400,000 miles for line haul operation.

Summary.

It is critical to learn about the aftertreatment systems, terminology and service requirements to understand the diesel engine lubrication system and recommended service interval strategies.