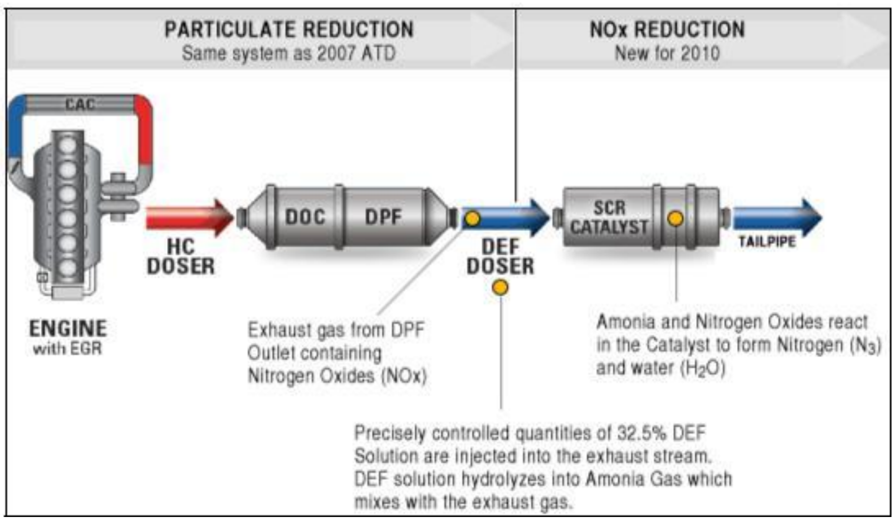
MANCHACA FIRE/RESCUE

Understanding and Maintenance of Emissions Aftertreatment Systems

Emissions Standards Background

In 2007, The Environmental Protection Agency enacted standards designed to limit the nitrogen oxide and particulate emissions from diesel engines. The EPA07 standards called for a 90% reduction in allowable particulate emissions. Diesel engine manufacturers met this standard by introducing a filter in the exhaust system that would capture the majority of soot and other particulates. This device is known as the diesel particulate filter (DPF). In 2010, the EPA enacted additional standards on diesel emissions. The EPA10 standard focused on the reduction on NOx emissions from diesel engines. To meet this standard, the diesel engine industry added an additional chamber in the exhaust system downstream of the DPF. This device sprays a fine mist of “diesel exhaust fluid” (DEF) into the exhaust stream. The DEF mixes with the exhaust gases and converts to ammonia. It then enters a chamber where, in the presence of a catalyst; the DEF reacts with the nitrogen oxides to create nitrogen gas and water vapor. The EPA standards do not exempt emergency vehicles from regulation. However, in 2012; the EPA issued an announcement that they would exempt emergency vehicles from some “derating” conditions. This will be discussed in more detail later.

Components and Function of Diesel Emissions Systems



Starting at the engine, one of the first emissions components is the **Exhaust Gas Recirculation system (EGR)**. The EGR takes a portion of the exhaust gas, cools it through a heat exchanger, and recirculates it to the cylinders. The cooler exhaust, along with its reduced oxygen content, results in lower engine combustion temperatures. The lower temperature results in lower NOx emissions.

Between the engine and the DPF filter are the **HC Doser** and the **Diesel Oxidation Catalyst (DOC)** components. The HC doser injects a fine mist of diesel into the exhaust stream. This mist then enters the DOC and reacts with a catalyst material. The result is a high heat output that is used to clean the DPF filter through a process called active regeneration. The HC doser does not operate continuously. It only operates when sensors indicate that the DPF filter needs to be cleaned and the vehicle is allowed to go into active regeneration mode.

The **Diesel Particulate Filter (DPF)** is a ceramic filter designed to capture particulate emissions (soot) from the engine exhaust. As soot accumulates in the filter it can begin to restrict air flow in the exhaust system. In order to clear the filter and maintain low emissions, heat is used to clean the filter by oxidizing (burning) the soot buildup. This process yields carbon dioxide, water vapor, and ash. The oxidizing of the soot in the DPF is known as regeneration. Regeneration will be covered in detail later.

Downstream from the DPF is the **Diesel Exhaust Fluid Doser (DEF Doser)** and the **Selective Catalytic Reduction** system **(SCR)**. **Diesel Exhaust Fluid (DEF)** is an aqueous solution of 32.5% urea and 67.5% deionized water. It is introduced to the exhaust stream by the DEF doser where it decomposes into ammonia and carbon dioxide. Along with the NOx in the exhaust stream, the ammonia and carbon dioxide enter the SCR. The catalyst material in the SCR causes further chemical reactions yielding water vapor, carbon dioxide, and nitrogen. These gases are then released from the tailpipe of the apparatus.

User Interactions with Emissions Systems

Diesel Particulate Filter (DPF) Regeneration

In order for the DPF to remain clear of excessive soot buildup, the filter must undergo periodic regeneration cycles. Regeneration is the process of increasing exhaust stream temperatures to burn off the soot captured in the filter. There are two general types of regeneration; passive and active. Additionally, active regeneration may be automatic or manual (parked).

Passive regeneration is the oxidation of the DPF due to the naturally occurring elevated temperatures coming from the engine when operated under load for an extended period of time. Examples include sustained driving at highway speeds and sustained pumping operations with elevated rpms. Providing an opportunity for passive regeneration to occur helps prolong the interval between active regeneration cycles. Vehicles that do a lot of stop-and-go driving or perform long periods of idling can benefit from being placed in scenarios where passive regeneration can occur.

Automatic active regeneration occurs when sensors in the emissions system determine that there is a buildup of soot in the DPF and engine operating conditions are correct to initiate regeneration. Engine load, engine speed, and exhaust temperature must be at acceptable levels in order for a regeneration cycle to start. With these conditions met, the HC doser begins to add a fine mist of diesel into the exhaust system, upstream of the DOC and DPF. The diesel reacts with the catalyst in the DOC, allowing superheated gas to enter the DPF and burn off the soot buildup. The automatic regeneration will continue until sensors determine that the filter is sufficiency clean. The automatic regeneration may also be prematurely aborted if any of the prerequisite conditions change below their threshold levels (i.e. engine load, speed, or temperature).

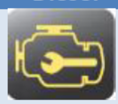
A manual or parked regeneration occurs when sensors on the vehicle indicate the need for regeneration and engine conditions are in a state to properly regenerate the DPF. A lamp on the instrument panel will indicate the need for regeneration. While this lamp is illuminated, a parked regeneration can be performed by manually operating the regen switch.

Passive Regeneration
Natural cleaning of the DPF through routine operation of the vehicle under heavy load such as highway driving or pumping operations

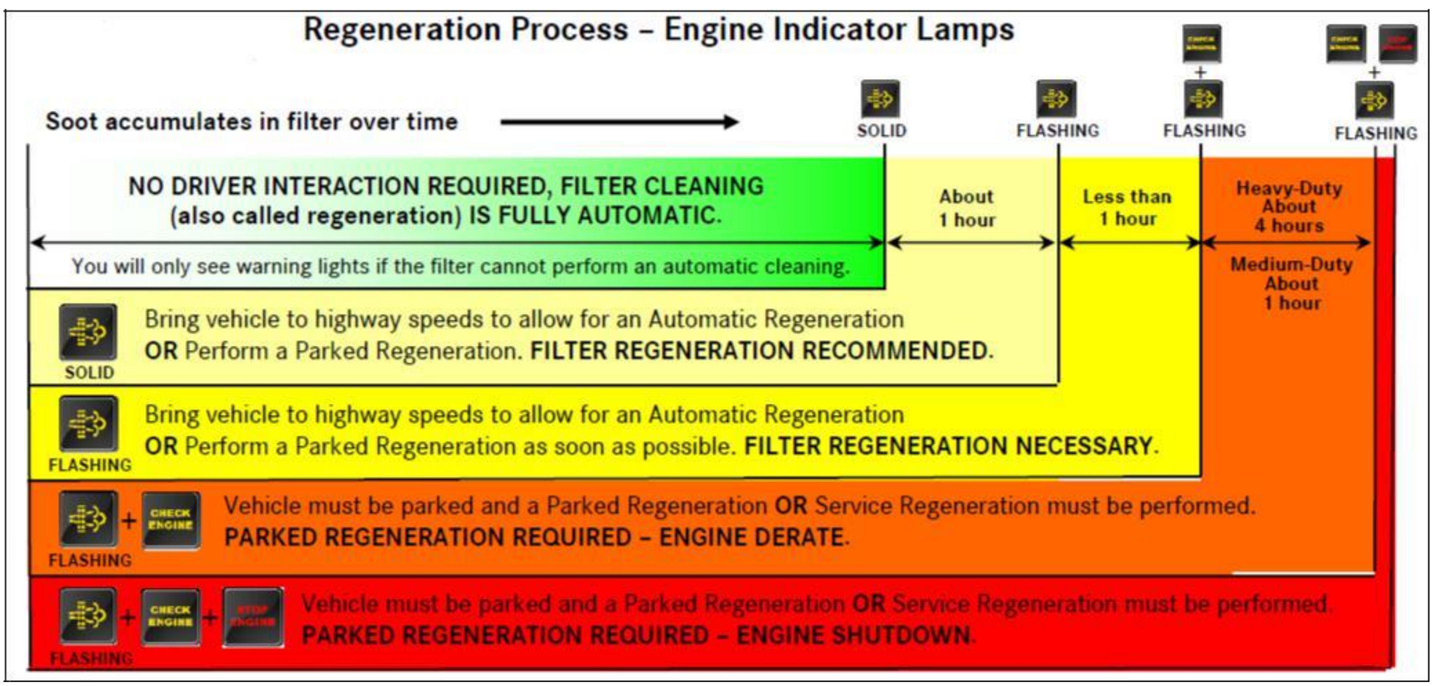
Active-Automatic Regeneration
Vehicle automatically goes into regeneration, using the HC doser to create elevated exhaust system temperatures

Active-Parked Regeneration
Vehicle has provided indicators of the need for regeneration and the driver initiates the process via the regen switch.

The vehicle's emission control system provides a variety of indicators and warnings to the driver to communicate the status of the DPF filter. Understanding what is being requested through the indicators and warnings is essential in keeping the apparatus in service and ready for response. A key point to remember is that if there are emission system indicator lamps illuminated on the instrument panel, the apparatus is requesting action from the driver. With the possible exception of the High Exhaust System Temperature lamp (HEST), there will be no indicator lamps when the apparatus is performing passive or automatic active regeneration. Active indicator lamps are a message to the driver that it is time to perform a parked regenration or to drive the vehicle in conditions where an automatic regeneration can occur (sustained highway driving).

Detroit Diesel	Cummins Diesel	ENGINE INDICATOR LAMPS AND ASSOCIATED DRIVER ACTIONS
		**Amber Warning / Check Engine Lamp:** Fault indicted with engine controls (Vehicle can be driven to the end of shift – call for service)
		**Malfunction Indicator Lamp (MIL):** Indicates failure of a component of the emissions control system. May illuminate at the same time as the Check Engine light. (Vehicle can be driven to the end of shift – call for service)
		**Red Stop Engine Lamp:** Major engine fault indicated. Engine damage or derate of engine output could result. Shut down and call for service.
		**DPF Regeneration Lamp:** Solid yellow indicates that a parked or automatic regeneration ***should*** be performed. Flashing yellow indicates a parked or automatic regen ***must*** be performed. Ignoring this condition can lead to a physical engine derate and the unit going out of service. This lamp will go out when active regeneration is in progress.
		**High Exhaust System Temperature Lamp (HEST):** Information only. Indicates elevated exhaust temperatures that could cause damage to items near the tailpipe. This lamp illuminates when exhaust is at high temp and the vehicle is moving 0-5 mph. The HEST lamp could be due to passive regen, automatic, or parked regen.

These indicators and warnings will display in a sequential order, indicating the degree of soot accumulation in the DPF and the urgency of performing regeneration. The diagram below shows the sequence of warnings and the available resolutions.



Note that when the DPF Regeneration Lamp is illuminated by itself (solid or flashing), the driver has the option of performing an automatic regen through uninterrupted highway driving or initiating a parked regen.

When the amber Check Engine lamp is illuminated along with the DPF lamp, the only option for the driver is to perform a parked regen or to contact a mechanic to force a regen via the emissions system software.

If the red Stop Engine lamp comes on with the amber Check Engine and DPF lamp, an apparatus shutdown and/or emissions system damage is imminent. A parked regen must be performed immediately. It is possible that the system will not accept a parked regen request at this point and it will have to be forced by a mechanic through the emissions system software.

<u>Parked Regeneration Process</u>

To initiate a parked regen, the vehicle must be in the correct state:

- The DPF Regeneration Lamp must be illuminated (It is not uncommon for an active DPF lamp to go out if the apparatus is shut down and then restated later to perform a regen)
- The engine should be fully warmed up (coolant temperature >185 F)
- The engine should be at slow idle (use of the high idle switch will prevent a parked regen from starting)
- PTO/Pump Mode must be disengaged
- Cycle transmission from Drive to Neutral (i.e. must be in neutral for parked regen)
- Cycle the parking brake (parking brake off, then on – Parking Brake must be on for regen)

The DPF Switch should be held in the ON position for 5 seconds and released. If the vehicle accepts the request for the parked regen, the driver will notice the engine speed increase and the DPF lamp on the instrument panel go out.

The regeneration process will typically take 20-50 minutes, depending on the degree of soot buildup present in the DPF. If the regeneration cycle is successful, the engine rpms will return to idle and the DPF lamp will remain off. If the DPF lamp returns after the regen cycle, the process failed and the Service Center should be contacted.

During a parked regen, the apparatus should be outdoors and the area around the tailpipe should be kept clear due to elevated exhaust temperatures (10 feet of clearance is recommended). Exhaust temperatures can reach 1200 F during active regeneration.

A parked regen can be cancelled should there be a need to use the vehicle. The driver may press and hold the DPF switch for 5 seconds to cancel a regen in progress. It is also possible to stop a regen cycle by releasing the parking brake, placing the vehicle in gear, or shutting down the vehicle.

Failure to properly maintain the DPF filter can result in damage to the filter assembly. The DPF filter ranges in cost from $6,000 to $14,000 depending on the engine with which it is paired. Due to the expense of these items, they are not kept as regularly stocked parts at the service center. The DPF must be ordered when a failure occurs. There have been several cases of delays in getting the needed DPF parts to service an apparatus, prolonging out of service periods.

Major Cleaning of the DPF

When a DPF-equipped apparatus goes in for class B preventative maintenance (major PM, involving changing out to a reserve unit), the DPF undergoes a major cleaning. This involves removing the filter and sending it to a vendor. The vendor places the filter in an oven that operates at temperatures around 1800°F. Pressurized air forces the high temperature air through the filter and clears out any collected soot or ash.

Diesel Exhaust Fluid (DEF)

As mentioned earlier, DEF is used to convert NOx emissions to carbon dioxide, water vapor, and nitrogen before leaving the tailpipe of the apparatus. It is the responsibility of the apparatus operator to ensure that the DEF tank is kept filled. Operators should consider the maintenance of the DEF level as important as the maintenance of the fuel level in the apparatus. Pierce apparatus have a 4½ gallon DEF tank. Do NOT place DEF into the Diesel tank. DEF is not a fuel additive. Major damage can occur to the engine and fuel system if DEF is placed in the diesel tank. Other warnings occur as the tank level drops below ⅛ full.

DEF Tank Levels and Warnings	
DEF Full → ¼ full	No warnings
DEF ¼ → ⅛ full	“DEF Low” light on solid
DEF below ⅛ full	“DEF Low” light will flash
DEF below ¼ gallon	“DEF Low” flashes and “Check Engine” light on
DEF tank empty	“DEF Low” flashes; “Check Engine” and “MIL” light on

Derating of Emergency Vehicles

In an attempt to ensure compliance with emission standards, EPA rules call for the “derating” of a vehicle if its emissions fall outside acceptable parameters. Derating is the reduction of engine torque and the reduction of maximum speed. In some cases, apparatus speed can be limited to 5 mph or the apparatus will fail to start once shut down. Events such as an empty DEF tank or a failure to regenerate can trigger the derating of an apparatus.

After concerns were raised to the EPA, allowances were given to emergency services to prevent the derating of vehicles that have a dedicated use as an emergency vehicle. Current EPA rules allow emergency vehicles to continue to operate without a derate being initiated by the onboard emissions control module. However, this does not eliminate the need to properly operate the emissions control systems and keep them in good repair. There are other ways by which a vehicle may derate. Failing temperature or turbo sensors can cause an apparatus to derate. Also, there is the possibility of a “physical derating” of an apparatus. This is typically when a DPF filter has become so clogged and restricted that vehicle performance is affected by the physical restriction of soot in the DPF filter (not a signal from a sensor or action by the emissions control module). Proper care of the apparatus as described in the **User Interactions with Emissions Systems** section can prevent the occurrence of derating issues.

The EPA’s definition of “dedicated use as an emergency vehicle” refers to vehicle chassis that are typically custom built for emergency services (like Pierce fire apparatus). This exception dos not apply to common chassis like Ford, Chevy, or Dodge trucks. These vehicles are programmed to derate based on signals from the emissions control system.

Emission Systems in MFR Vehicles

No DPF or DEF: TEN501
DPF and DEF: ENG501, ENG511, and BT501

Due to the emergency vehicle allowances provided by the EPA in 2012, fire apparatus are programmed to continue operation without derating via the emissions control module. The possibility still exists for the physical derating of a vehicle that has been allowed to operate beyond its recommended regeneration cycle.

General Recommendations for Apparatus Operators

The primary issue for the apparatus operator is understanding the concept of regeneration and understanding the meaning of the messages and warnings provided via the instrument panel lamps.

Due to the nature of fire service operations, fire apparatus do a lot of stop-and-go driving and spend a lot of time idling. As a result, fire apparatus typically require more frequent regeneration cycles than other commercial diesel vehicles. Apparatus that spend more time on freeways or making extended runs will see longer periods between regeneration cycles. Apparatus that respond mostly on neighborhood streets and have a lot of idling time will see more frequent requests for regen. Apparatus that are experiencing frequent alerts for parked regeneration should consider taking their apparatus out on a freeway for uninterrupted high-speed driving on a periodic basis. These trips should be 20 to 40 minutes in duration. These highway trips allow the apparatus to passively regenerate and help to keep the DPF cleaner for a longer period of time.

For apparatus using DEF, the DEF level should be monitored and maintained.

Ultimately, the apparatus relies on its driver to recognize the signals for a parked regen and to perform the regen in a timely manner. Ignoring regeneration alerts can lead to reduced performance and decreased life of the DPF assembly. Utilizing the information and procedures in this document can go a long way in ensuring the response readiness of the apparatus and its crew.