

Fire Management Tech Tips

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DIESEL AFTERTREATMENT SYSTEMS

by

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Key Points

- Most 2007 and newer Forest Service diesel-powered vehicles use advanced technologies to meet new emissions requirements.
- Improper maintenance of these new systems could lead to severe engine performance limitations.
- Diesel particulate filters require periodic self-cleaning (regeneration).
 - Regeneration occurs automatically if driving for extended periods at highway speeds.
 - If you do not regularly drive at highway speeds, you might need to prompt the vehicle to perform this function manually, while parked (if available).
 - Exhaust surfaces and gases will be very hot during regeneration.
- Selective catalytic reduction systems require the use of diesel exhaust fluid, which must be refilled every 1,000 to 8,000 miles, depending on operating conditions.
 - The vehicle will warn drivers when diesel exhaust fluid is running low. Failure to refill eventually leads to engine derate and vehicle immobilization.
 - Emergency responders or those working in remote or hazardous environments should store a small container of diesel exhaust fluid onboard for emergency situations.

INTRODUCTION

In 2001, the U.S. Environmental Protection Agency drafted new standards for diesel engine emissions, to be phased in gradually beginning in 2007. These requirements, developed to reduce the amount of particulate matter and oxides of nitrogen produced by diesel engines, have led manufacturers to pursue new emissions technologies. Aftertreatment systems, devices which modify the chemical and/or physical composition of exhaust gases, have emerged as the leading technology. Though designed to require a minimal amount of driver intervention, most aftertreatment systems require some form of periodic maintenance. The purpose of this Tech Tip is to inform readers on the identification, operation, and maintenance of these new systems to ensure they do not hinder operations.

AFTERTREATMENT SYSTEM COMPONENTS

Aftertreatment systems consist of a diesel particulate filter and a selective catalytic reduction system. Though they appear similar, both devices perform different functions and have different maintenance requirements.

Diesel Particulate Filter

The purpose of the diesel particulate filter is to prevent soot from escaping through the exhaust system. The diesel particulate filter is a ceramic filter composed of long, narrow channels, which are plugged at alternating ends. These porous channels trap particulate matter, but allow gases to flow through undisturbed.

Selective Catalytic Reduction

The purpose of selective catalytic reduction is to transform oxides of nitrogen into less harmful byproducts. The selective catalytic reduction catalyst is similar to the diesel particulate filter in general size and appearance, but it operates in a different way. Before exhaust gases reach the catalyst, a special fluid (diesel exhaust fluid, commonly called urea, AdBlue, or smurf juice) is injected into the gas stream. The fluid and exhaust gases then react with the catalyst, producing nontoxic nitrogen and water vapor.

HOW DO I KNOW IF I HAVE A DIESEL PARTICULATE FILTER AND/OR SELECTIVE CATALYTIC REDUCTION?

As of 2010, all heavy-duty and some light-duty diesel powered on-road vehicles (utility trucks, fire engines, and so forth) are required to have aftertreatment systems. Due to the various tiers and classifications in the U.S. Environmental Protection Agency requirements, some smaller diesel pickups, vans, or other vehicles may or may not use an aftertreatment system. See appendix A for a listing of Forest Service vehicles, which use new aftertreatment systems. **As of 2011, vehicles manufactured by International (Navistar), including type 3 and 4 wildland fire engines, water tenders, and crew carriers, are equipped with diesel particulate filters only.**

Identifying Vehicles with a Diesel Particulate Filter

The presence of a diesel particulate filter is not outwardly obvious. The filter is part of the exhaust system and typically is hidden by chassis/body components. The only way to verify if your vehicle is equipped with a diesel particulate filter is by reviewing the owner's manual and/or diesel engine supplement, which should be supplied with the manual.

Identifying Vehicles with a Selective Catalytic Reduction System

Vehicles with selective catalytic reduction systems are identified easily by the presence of a diesel exhaust fluid filler cap, which looks similar to a conventional fuel filler cap, but is blue (figure 1). The location of the diesel exhaust fluid filler depends on chassis and body configuration, but typically it is placed directly behind the cab or near the fuel filler cap.



Figure 1—Diesel exhaust fluid filler cap located on 2011 Ford F-450 with utility body (selective catalytic reduction systems only).

MAINTENANCE OF AFTERTREATMENT SYSTEMS

Diesel Particulate Filter Maintenance

Soot collected within the diesel particulate filter must be removed periodically. This self-cleaning process is called regeneration. During the regeneration process, the exhaust temperature is increased, which burns off the accumulated particulate matter.

The regeneration process is designed to occur with no driver interaction. However, this requires the vehicle to be running at highway speeds for extended periods (approximately 30 minutes). If this condition cannot be met, the procedure must be performed while parked (called stationary, parked, or operator-commanded regeneration). **Failing to perform diesel particulate filter regeneration when prompted could lead to vehicle disablement. In severe cases, the filter may need to be removed and serviced or replaced by the manufacturer. This will not be covered by the manufacturer's warranty.**

Diesel particulate filter equipped vehicles are required to provide adequate notification to drivers when regeneration is necessary. A warning will be provided by an indicator lamp and/or the vehicle's message center. Indicators vary by vehicle manufacturer (see appendix B for manufacturer-specific warnings). If you are prompted to perform regeneration, but are not able to drive at highway speeds for 20 to 30 minutes, a parked regeneration will be necessary. **Do not ignore regeneration messages. Doing so will cause engine performance to become limited and eventually shutdown.** NOTE: Parked regeneration is not available on Dodge Cummins 6.7L vehicles (4500 and 5500 chassis cabs) and pre-2011 Ford models.

Parked Regeneration Precautions

During regeneration, exhaust surfaces and gas temperatures will be extremely hot and may ignite nearby flammable materials. If a parked regeneration is necessary, move the vehicle to a location clear of vegetation and obstructions. If exhaust surfaces are exposed, use a safety cone or sign to warn approaching personnel.

Parked regeneration typically takes 15 to 30 minutes. Some vehicles will not be able to operate normally until the regeneration cycle is finished. If you are planning to perform a parked regeneration, plan for the vehicle being out of service until it is complete. See appendix C for vehicle-specific procedures.

Selective Catalytic Reduction System Maintenance

Unlike the diesel particulate filter, the selective catalytic reduction system contains consumable fluid, which must be periodically replenished. **The engine will derate and may eventually shutdown if the diesel exhaust fluid tank is empty or filled with contaminated fluid.**

The distance that can be traveled on a single tank of diesel exhaust fluid is different for each vehicle, and varies based on operating conditions. In general, for heavy-duty pickups, diesel exhaust fluid is consumed at a 50:1 ratio with diesel (for every 50 gallons of diesel used, 1 gallon of diesel exhaust fluid will be consumed). Pulling heavy loads, excessive idling, or aggressive driving practices may increase diesel exhaust fluid consumption.

What Happens If I Run Out of Diesel Exhaust Fluid?

The selective catalytic reduction system is designed to provide ample warning to the driver prior to the diesel exhaust fluid dropping below critical levels. The level of diesel exhaust fluid in the tank cannot be directly monitored by the driver. During vehicle startup, the vehicle's message center may display a diesel exhaust fluid status message (figure 2). When the diesel exhaust fluid drops below a certain level, an onboard warning is provided by the vehicle's message center.



Figure 2—Normal diesel exhaust fluid status displayed on vehicle message center (2011 Ford F-450).

For most vehicles, a warning will be displayed when the diesel exhaust fluid range is less than 800 to 1,000 miles. The display may be supplemented by a chime or voice message (see appendix B for manufacturer-specific warnings). As the diesel exhaust fluid level continues to decrease, messages will become more aggressive, sometimes requiring driver acknowledgement before the vehicle can be taken out of park. Once the tank reaches a critical level, speed will be restricted. Finally, once the diesel exhaust fluid tank is empty, the vehicle will become disabled and may run in idle-only mode. The vehicle will remain immobile until the diesel exhaust fluid tank is refilled.

Purchasing, Handling, and Storing Diesel Exhaust Fluid

Although diesel exhaust fluid may be replenished during servicing, it is advised that Forest Service vehicles, which operate in hazardous or remote environments have a small amount of diesel exhaust fluid stored onboard for emergency use. One or 2.5-gallon containers of diesel exhaust fluid can be purchased from common automotive retailers (see appendix D). As of 2011, the price of diesel exhaust fluid is \$2.75 to \$5.00 per gallon, depending on the quantity and location of purchase. **Only use diesel exhaust fluid which is certified by the American Petroleum Institute.** Other sources may not be of proper quality, and could trigger contamination warnings, leading to possible vehicle immobilization.

Diesel exhaust fluid is a nonflammable substance that consists of 32.5 percent urea and water mixture. Though it is generally nonhazardous, it should be handled with care, as it can be corrosive to aluminum and low carbon steels. When using diesel exhaust fluid, use the same general precautions and personal protective equipment as you would for handling other automotive fluids or lubricants.

The storage life of diesel exhaust fluid depends on the environment. If stored between 10 and 90 °F, it will last a minimum of 12 months. Storage temperatures exceeding these limits will cause early breakdown of diesel exhaust fluid and should be avoided where

possible. **It is recommended that Forest Service vehicle operators replace the stored fluid annually.** Follow the manufacturer's instructions for safe disposal of the old fluid.

Diesel exhaust fluid freezes at 11 °F. However, freezing does not change the composition of the fluid, and vehicles are equipped with heating systems to thaw the fluid. **If the diesel exhaust fluid is frozen, vehicle operation will not be impacted.**

How To Fill the Diesel Exhaust Fluid Tank

In many cases, the diesel exhaust fluid tank will be filled during regular servicing (oil changes). However, it can be filled easily by anyone, using the following steps:

1. Turn off the vehicle's engine.
2. Open the diesel exhaust fluid filler cap. The cap is colored blue, and the nozzle is of smaller diameter than a standard diesel nozzle to prevent the diesel exhaust fluid tank from being accidentally filled with diesel fuel.
3. Insert the container-supplied filler nozzle into the tank. The fluid will automatically stop flowing once the tank is full.
4. Restart the engine. If a low-level warning was previously displayed, the system should clear itself within a few seconds.

A Note to Vehicle Purchasers

When ordering a chassis from the manufacturer, ensure that the parked regeneration option is included. **This is nonstandard on most vehicles, so you must ask for it. In addition, ensure vehicles do not have an idle shutdown timer.** Idle shutdown timers are used for consumer and commercial vehicles to reduce emissions, but could present safety issues for fire and other emergency response vehicles.

Where To Find More Information

Your vehicle's owner's manual and/or diesel engine supplement is the primary source for information regarding new emissions systems. If you have questions or problems not addressed in the owner's manual, contact your fleet representative or dealer.

Conclusions

Though the new emissions systems require periodic maintenance, manufacturers have done an excellent job of providing ample guidance to drivers to mitigate potential issues. By following the instructions provided by the owner's manual and onboard message systems, you will avoid the risk of your vehicle becoming disabled.

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The National Technology and Development Center's national publications are available on the Internet at <http://www.fs.fed.us/eng/pubs/>.

Forest Service and U.S. Department of the Interior, Bureau of Land Management employees also can view videos, CDs, and National Technology and Development Center's individual project pages on their internal computer network at <http://fsweb.sdtc.wo.fs.fed.us/>.

For additional information on diesel aftertreatment systems, contact Trevor Maynard at SDTDC. Phone: 909-599-1267 ext 258. Email tbmaynard@fs.fed.us.

Appendix A – Aftertreatment Systems on 2011 Forest Service Vehicles*

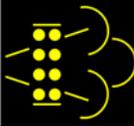
Vehicle Type	Manufacturer/ Model	Engine	DPF Equipped	SCR Equipped
Type 3 & 4 Wildland Engine	International/ Durastar 7400	Navistar (International) MaxxForce 9	X	
Type 2 Water Tender				
Crew Carrier Vehicle/Helitender	International/ Durastar 4300	Navistar (International) MaxxForce DT	X	
Type 6 Wildland Engine/ Dozer Tender/ Superintendent Truck	Ford F-450/F-550	Power Stroke 6.7L Turbo Diesel	X	X
	Dodge 4500/5500	Cummins 6.7L Turbo Diesel	X	X
Patrol/Utility pickup	Dodge 2500/3500	Cummins 6.7L Turbo Diesel	X	

*This list covers common fire vehicles used within the agency. Individual regions or forests may operate other vehicles which, are affected by new emissions systems but are not listed.

Appendix B – Diesel Exhaust Aftertreatment System Warning Indicators

Note: The specific warning indications listed below are for current (2011) models, but may differ for other model years.

International MaxxForceDT (4300 chassis) and MaxxForce9 (7400 chassis)

Diesel Particulate Filter (DPF) System Warnings		
Warning	Situation	Required Action
Solid warning lamp on dashboard 	Regeneration required as soon as practical	Drive at highway speeds (minimum of 20 minutes) or perform parked regeneration.
Flashing warning lamp on dashboard 	Exhaust filter is full. Regeneration required immediately	Drive vehicle to a safe area and perform parked regeneration to avoid engine derate.
Flashing warning lamps on dashboard and audio chime 	Exhaust filter is full – engine is derated	Drive vehicle to a safe area and perform parked regeneration to avoid engine shutdown.
Warning lamp on dashboard and audio chime 	Exhaust filter overfull – engine shutdown imminent	Pull vehicle safely off roadway and shut off engine. DO NOT ATTEMPT TO PERFORM REGENERATION. Service is required.

Ford PowerStroke 6.7L (F-450 and F-550)

Diesel Particulate Filter (DPF) System Warnings		
Warning	Situation	Required Action
“DRIVE TO CLEAN EXHAUST FILTER” displayed on message center 	Regeneration required as soon as practical	Drive at 30+ mph or perform parked (operator-commanded) regeneration until “EXHAUST FILTER DRIVE COMPLETE” message is displayed (approximately 20 minutes).
“REDUCED ENGINE POWER” displayed on message center and warning lamp displayed on dash 	Exhaust filter is full – engine derate imminent	Drive at 30+ mph or perform parked (operator-commanded) regeneration until “EXHAUST FILTER DRIVE COMPLETE” message is displayed (approximately 20 minutes).

<p>“REDUCED ENGINE POWER” displayed on message center and warning lamp displayed on dash</p> 	<p>Exhaust filter is full – engine is derated</p>	<p>Engine power limited. Service is required.</p>
<p>Selective Catalytic Reduction (SCR) System Warnings*</p>		
<p>Warning</p>	<p>Situation</p>	<p>Required Action</p>
<p>“EXHAUST FLUID RANGE XXX MILES”</p>	<p>DEF tank will be empty in XXX miles</p>	<p>Refill DEF as soon as practical.</p>
<p>“SPEED LIMITED XXMPH IN XX MI EXHAUST FLUID EMPTY”</p>	<p>DEF tank nearly empty engine is derated</p>	<p>Drive vehicle to a safe area and refill DEF tank.</p>
<p>“XX MPH MAX UPON RESTART DIESEL EXHAUST FLUID EMPTY”</p>	<p>DEF tank empty - engine is derated</p>	<p>Refill DEF tank immediately.</p>
<p>“SPEED LIMITED TO XX MPH EXHAUST FLUID EMPTY”</p>	<p>DEF tank empty - engine is derated</p>	<p>Drive vehicle to a safe area and refill DEF tank.</p>
<p>“ENGINE IDLED UPON REFUEL EXHAUST FLUID EMPTY”</p>	<p>DEF tank empty – VEHICLE DISABLED</p>	<p>Drive vehicle to a safe area and refill DEF tank.</p>
<p>“ENGINE IDLED SEE MANUAL EXHAUST FLUID EMPTY”</p>	<p>DEF tank empty – VEHICLE DISABLED</p>	<p>Refill DEF tank immediately. At least 0.5 gallons required to exit idle only mode. Vehicle will still run in speed-limited mode until tank is completely refilled.</p>

*NOTE: If DEF is contaminated, messages similar to those above will be displayed, but with the words **“EXHAUST FLUID CONTAMINATED.”**

Diesel Particulate Filter (DPF) System Warnings		
Warning	Situation	Required Action
<p>“Exhaust System – Regeneration Required Now” displayed on message center</p>	<p>DPF at 80% capacity. Regeneration required as soon as practical.</p>	<p>Drive at highway speeds for a minimum of 45 minutes until “Exhaust System – Regeneration Completed” is displayed.</p> <p>NOTE: Parked regeneration is not possible on the Cummins 6.7L engine.</p>
<p>“Exhaust Filter XX% Full” displayed on message center</p>	<p>DPF at XX% capacity. Regeneration required as soon as practical.</p>	<p>Drive at highway speeds for a minimum of 45 minutes until “Exhaust System – Regeneration Completed” is displayed.</p>
<p>“Exhaust Filter Full – Power Reduced See Dealer” displayed on message center</p>	<p>Exhaust filter is full – engine is derated.</p>	<p>Engine power limited. Service is required.</p>
Selective Catalytic Reduction (SCR) System Warnings		
Warning	Situation	Required Action
<p>“DEF Fluid Level XX%” displayed on “System Info” menu of message center</p>	<p>DEF tank at XX%.</p>	<p>None</p>
<p>“Low DEF Refill Soon” displayed on message center, audio chime</p>	<p>2 gallons remaining in DEF tank.</p>	<p>Refill DEF as soon as practical.</p>
<p>“Refill DEF Engine Will Not Restart in XXX Miles” displayed on message center, audio chime, warning lamp</p> 	<p>1 gallon remaining in DEF tank (approximately 500 miles).</p>	<p>Refill DEF as soon as practical.</p>
<p>“Refill DEF Engine Will Not Restart” displayed on message center, audio chime, warning lamp</p> 	<p>DEF tank empty - engine will not restart after shutdown.</p>	<p>Refill DEF immediately. At least 2 gallons required.</p>

Appendix C – Parked Regeneration Procedures

International MaxxForceDT (4300 chassis) and MaxxForce9 (7400 chassis)

Step	Action
1	Pull vehicle safely off of roadway. Park vehicle at least 50 feet from flammable materials. If exhaust surfaces are exposed, place a safety cone or warning sign to alert nearby personnel.
2	Allow engine to run until coolant temperature has reached at least 170 °F.
3	Set parking brakes and place the transmission in Park or Neutral. Do not touch the accelerator, brake, or clutch pedals during regeneration.
4	<p>Press and hold the PARKD REGEN switch (below instrument cluster on right side) for 2 seconds. An orange lamp above the switch will illuminate, indicating the cycle has started. Engine speed will increase to a pre-determined RPM. The high exhaust temperature lamp will be displayed (this is normal):</p>  <p>NOTE: If the vehicle must be moved after starting regeneration, press the PARKD REGEN switch down to interrupt the cycle. This should only be done in emergency situations. Regeneration may need to be performed again.</p>
5	Regeneration will last approximately 20 minutes. When the cycle is complete, engine RPM will return to idle and all warning lamps will extinguish. The vehicle can now be operated normally. NOTE: exhaust surfaces will still be extremely hot!

Ford PowerStroke 6.7L (F-450 and F-550)

Step	Action
1	Pull vehicle safely off of roadway. Park vehicle at least 50 feet from flammable materials. If exhaust surfaces are exposed, place a safety cone or warning sign to alert nearby personnel.
2	<p>Start engine with vehicle fully warmed. Set parking brake and place the transmission in Park. Disengage PTO (if equipped). NOTE: If “service engine soon” light is illuminated, operator-commanded regeneration cannot be performed.</p> 
3	Press the INFO button on the steering wheel until the “ EXHAUST FILTER XX% FULL CLEAN Y/N ” message is displayed. Select “ Y ”.
4	<p>Engine speed will increase to 2000-2400 RPM. The cycle will last for 10-25 minutes. “CLEANING EXHAUST FILTER” may be displayed in the message center.</p> <p>NOTE: If the vehicle must be moved after starting regeneration, press the brake, accelerator, or shut off the engine. This should only be done in emergency situations. Regeneration may need to be performed again.</p>
5	When regeneration is complete, the engine will return to normal RPM. NOTE: exhaust surfaces will still be extremely hot!

Appendix D – Diesel Exhaust Fluid (DEF) Manufacturers and Retailers

DEF Information Web sites		
Site Name	URL	Features
U.S. Department of Energy DEF Locator	http://www.afdc.energy.gov/afdc/locator/def/	Interactive map of DEF retailers in North America
FindDEF	http://www.finddef.com	Interactive map of DEF retailers in North America
DiscoverDEF	http://www.discoverdef.com	Interactive map of DEF retailers in North America
Facts About SCR	http://www.factsaboutscr.com	Information about SCR systems and DEF

DEF Manufacturers (API Certified)	
Manufacturer / Brand	Web site
Air1 DEF	http://us.air1.info/en/
AirBlue Fluids DEF	http://www.airbluefluids.com/
AIRx Airgas DEF	http://www.airgasspecialtyproducts.com/products/dieselExhaustFluid.aspx
Cummins Filtration/Valvoline AirShield DEF	http://www.fleetguard.com/html/en/products/fuel/diesel_emission/air_shield.html
Kost DEFendal	http://www.kostusa.com/def/
Kruse AdBlue	http://adbluebluesky.de/
Motorcraft (Ford) DEF	http://www.fordparts.com/
NOxBlue DEF	http://www.noxblue.com/
Pilot Travel Centers Pilot DEF	http://www.pilottravelcenters.com
PolyFreeze Certified DEF	http://www.certifieddef.com/
Purus DEF	http://www.purusproducts.com/def.html
Terra Environmental Technologies TerraCair	http://www.tet-terra.com/def/
Victory Blue DEF	http://www.victorybluedef.com/
Warren Oil Lubrigard Skyblue DEF	http://www.warrenoil.com/

North American DEF Retailers	
Retailer	Container Sizes
Pilot Travel Center	1 gal, 2.5 gal, bulk
Flying J	1 gal, 2.5 gal, bulk
Love's Travel Stops	1 gal, 2.5 gal, bulk
NAPA Auto Parts	1 gal, 2.5 gal, 55 gal, 330 gal
O'Reilly (Kragen) Auto Parts	1 gal, 2.5 gal, 55 gal, 275 gal
Advance Auto Parts	1 gal, 2.5 gal, 55 gal, 275 gal
Ford Dealerships (Motorcraft)	1 gal, 2.5 gal
Chrysler/Dodge Dealerships (Cummins)	1 gal, 2.5 gal

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