Best Maintenance Practices: Diesel Particulate Filters

Presented by
Peter Tuckerman
• **DPF** = Diesel Particulate Filter

• **PM** = Particulate Matter

• **Opacity** = The Measurement of Diesel Smoke

• **OEM** = Original Equipment Manufacturer

• **SiC** = Silicone Carbide

• **BP** = Back Pressure

• **SCR** = Selective Catalytic Reduction

• **DOC** = Diesel Oxidation Catalyst

• **OC** = Oxidation Catalyst
Modern diesel aftertreatment system

Diesel Engine w/EGR

Particulate Reduction

DEF Injection

NOx Reduction
What is a DPF?

• A Diesel Particulate Filter (or DPF) is a device designed to remove diesel soot from the exhaust stream of a diesel engine.

• High efficiency Diesel Particulate Filters are a wall flow design.

• The exhaust flows into the filter through the cell walls and the soot (or PM) is caught as it passes through.
What They Do:

• Diesel particulate filters: up to 99% PM reduction.
• Must oxidize the accumulated particulates to maintain exhaust flow
  • passively, or actively.
• Heating the filter to soot oxidation temperature is known as "filter regeneration".
DPF Regeneration

• Diesel Particulate Matter burns when temperatures reach 600°C. This temperature can be reduced with the use of a catalyst.

• Every DPF manufacturer has their own process for regeneration. The actual temperature of oxidation will depend on the catalyst employed.
Passive Regeneration:

- DPF systems that are able to regenerate using the heat of the exhaust from the engine are known as passive systems.
  - Use of a DOC
  - Catalytic wash coating
Passive DPF Temp Requirement:

- HUG     200°C for 15%
- CDTi    280°C for 25%
- DCL     280°C for 30%
- ESW L’S 260°C for 25%
- 260°C for 20% plus 300°C for 5%
- ESW LV  260°C for 25%
- ESW TCat 210°C for 10%
- DON LNF 235°C for 40% or 300°C for 10%
- DON LXF 245°C for 40% or 310°C for 10%
- JM CRT  240°C for 40% or 260°C for 20%
- ADVccrt 230°C for 40% or 300°C for 10%
- Cummins 316°C no time requirement
- Detroit
- Isuzu
Passive DPF Temp Requirement:
PASSIVE/ACTIVE FILTER:

- Systems that regenerate using the engines exhaust temperature and an outside heat source. i.e. Diesel injection or electrical plug-in.
  - Most OEM equipped engines
- Meets the wide range of engine duty cycles
Active Regeneration:

- DPF systems that are not able to regenerate without using an additional heat source are known as active systems.
  - Diesel burner
  - Electrical heater coil (240 or 480 volts)
  - Diesel injection across a hot catalyst
- This type of DPF is typically not coated.
- Baking a DPF during cleaning is a type of active regeneration!
Cordierite Wall Flow Filters:

- Most OEM filters are made of cordierite.
- Cordierite filters provide excellent filtration efficiency. They are strong in large pieces, they have a low (1200° f) melting point.
Silicon Carbide Wall Flow Filters:

The other type of filter material is SiC. It has a melting point much higher than cordierite (2700° f). SiC cores are made in segments which are bonded by cement, allowing heat expansion of the core to be absorbed by the cement.
Selective Catalytic Reduction (SCR):

**SCR** is an active NOx emissions control strategy that injects a mixture of urea and water into the exhaust stream, in front of a hot catalyst, known as diesel exhaust fluid (DEF).

$$\text{NOx} + \text{Urea} \rightleftharpoons \text{Nitrogen} + \text{Water} + \text{Carbon Dioxide}$$
SCR at work

Diesel Engine

DOC

DPF

SCR CATALYST

Tailpipe

DPF Regeneration Process

DEF Injection

NOx Reduction
SCR service items:
# Data Monitoring Systems:

<table>
<thead>
<tr>
<th>Condition</th>
<th>Notification</th>
<th>Fault Code</th>
<th>Derate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correct DEF</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Incorrect DEF, at detection *</td>
<td>Check Engine Lamp Solid</td>
<td>3543</td>
<td>None</td>
</tr>
<tr>
<td>Incorrect DEF, at detection + 10 hours *</td>
<td>MIL Solid</td>
<td>3543</td>
<td>25% Torque Derate (per EPA guidance CISD-09-04)</td>
</tr>
<tr>
<td>Incorrect DEF, at detection + 20 hours, and after the engine has been shut down or in extended idle *</td>
<td>MIL Solid, Check Engine Lamp Solid</td>
<td>3543</td>
<td>25% Torque Derate and Vehicle Speed Limited to 5 mph</td>
</tr>
</tbody>
</table>

* Once incorrect DEF has been detected the vehicle must be taken in for a service event to deactivate the warning lights and derates.
Data Monitoring Systems:

**Response to SCR System Faults**
(Non-Special Cause SCR system faults that result in SCR-off)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Notification</th>
<th>Derate</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Normal</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>SCR system fault detected *</td>
<td>Check Engine Lamp Solid</td>
<td>None</td>
</tr>
<tr>
<td>SCR system fault detected, (detection + 20 hours) *</td>
<td>Check Engine Lamp Solid</td>
<td>Torque Derate (per EPA guidance CISD-09-04)</td>
</tr>
</tbody>
</table>

* Once the condition that drove the SCR fault has been resolved the warnings and derates will immediately deactivate. The MIL will deactivate based on OBD regulations.

** MIL illuminates when required by OBD regulation.
# Data Monitoring Systems:

## Response to Special Cause SCR System Faults

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<tr>
<td>System Normal</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Special cause SCR system fault detected</td>
<td>Check Engine Lamp Solid</td>
<td>MIL Solid or Check Engine Lamp Solid</td>
<td>Varies</td>
</tr>
<tr>
<td>Special cause SCR system fault detected, at detection + 10 hours</td>
<td>Check Engine Lamp Solid</td>
<td>MIL Solid or Check Engine Lamp Solid</td>
<td>Varies 3714</td>
</tr>
<tr>
<td>Special cause SCR system fault detected, at detection + 40 hours, and after the engine has been shut down or in extended idle</td>
<td>Check Engine Lamp Solid, Red Stop Engine Lamp Solid</td>
<td>MIL Solid or Check Engine Lamp Solid, Red Stop Engine Lamp Solid</td>
<td>Varies 3714 3712</td>
</tr>
</tbody>
</table>

* Once the condition that drove the SCR fault has been resolved the warnings and derates will immediately deactivate. MIL lamp will deactivate based on OBD regulations.

** MIL illuminates when required by OBD.
DPF Service:
The cleaning process starts with:
• Inspect & Test dirty DPF
• Removal of excess soot & ash
• Regeneration of residual soot
• Removal of remaining ash
• Inspect & Test Clean DPF
DPF Service:

Fuel consumption vs engine load means.....What?

i. Most OEM suggest cleaning filters between 200,000 and 300,000 miles or 4500 hrs.

ii. Most Aftermarket suggest cleaning filters between 50,000 and 70,000 miles or 1000 hrs.

iii. Service DPF light is active on the dash.

iv. Noticeable loss of power.

v. Any major engine repair.
DPF Service:

- **DES** recommends cleaning filters annually at a minimum.
- Typically if a filter is not pulled and de-ashed at least once a year the ash that has accumulated in the filter can harden and restrict the flow, this is called sintering.
Sintering occurs in filters where ash has accumulated for an extended period of time: Exposed to high heat, pressure, and time converts to a solid restriction.

Reduction in DPF capacity and flow - increase in back pressure more quickly.
DPF Inspection:

- Inspect the filter for internal and external damage. (*No damage is too small to note* i.e. cracked welds, Broken brick, and dents). If a filter is damaged it should not be cleaned, a replacement is necessary.
Wet filters:

• Never bake a filter that is “wet” on standard cycles.
• Use caution when servicing “wet” or soaked filters
• Run them through the dry out cycle
• re-inspect
• Only bake on a general cleaning cycle.
Weight:

• Remove any and all road grime off of the filter.
• Weigh the filter using the appropriate scale (g).
• Record the information.
Wire Test:

- Insert .030 stainless wire into the filter inlet, note how far the wire travels in the cell and what kind of resistance there is in the filter.
  
  *(i.e. ash hardening, soot, or white ash).*
Flow And De-Ash:

- Flow bench is critical to consistent results – but every brand has different rates of flow: keep records!!
- De-ashing machines come in all types and a quality inspection is important.

FSX inc  Donaldson  Enviromotive  OTC
Bake the filter using the appropriate settings.

- Every substrate has a different ramp rate and temperature tolerance
- Complete regeneration of the DFP allows soot to release the sidewalls
- Ensure your cleaning facility records the temperature settings
  - Failures may not be immediately evident
  - RECORDS, RECORDS, RECORDS!

**Use adequate PPE at all times during the cleaning process**
Wire Test and Weight:

• After the de-ashing and baking process is complete.
• Insert the .030 stainless wire into the filter’s inlet, note how far the wire travels in the cell and what kind of resistance there is in the filter.
• Weigh the filter using the appropriate scale.
Dirty Filters:

Normal

Face plugged
Engine Maintenance for DPF systems
If its smokin’ its broken!

Beginning July 1, 1999, SAE J1243 smoke opacity meters became obsolete. Any smoke test performed with a SAE J1243 smoke opacity meter on or after January 1, 1999 is invalid.

Emergency vehicles and vehicles with Special Equipment (SE) identification plates issued by the Department of Motor Vehicles (DMV) are subject to PSIP.

ARB recommends owners of non-California registered fleets that operate within the State of California to also comply with PSIP. Smoke opacity tests will alert a fleet owner of potential engine and/or diesel particulate filter issues that otherwise may go unnoticed.

Also, all heavy-duty diesel powered vehicles equipped with a diesel particulate filter shall not have any visible smoke. If any visible smoke is detected, the engine and diesel particulate filter shall be inspected and repaired to manufacturer’s specifications by authorized service facilities.
Opacity:

• Diesel smoke can be measured in **Percent Opacity** which is the percent of light that is blocked when passing through an exhaust plume.
• Measured by an Opacity Machine
Why Do We Measure Opacity?

- Opacity is a quick indicator of engine health.
- Particulate matter coming from the engine has a direct impact on the performance of the DPF.
- Easy, 5 min test, to identify failed DPF systems.
When to Measure Opacity:

• Annually, for records (PSIP in CA) with the DPF in place.
• Troubleshooting: As needed, to inspect the engine condition, with the DPF removed.
• Troubleshooting:
  • When DPF warning lights are frequent.
  • Driver complains of low power.
Preventive Maintenance
Effective Diesel Engine Maintenance:

• Engine air and fuel filters
• Monitor fuel and oil consumption
• Repair exhaust leaks
• Valve adjustments
Engine Idling

• Avoid excessive idling — Excessive idling can cause the cylinder block to become scored. This is especially a problem in the warm weather when truck drivers keep the engine idling for hours on end to keep the cab cool. When an engine is idled continuously a lack of lubrication can lead to the piston scoring the cylinder block.
Fuel

• **Beware of using fuel additives** — Fuel additives may impact the durability of the engine or emission control system. *It is no longer necessary for fleet drivers to add fuel additives to highway diesel fuel.*

• **Monitor engines and fuel systems for leaks** — Before you install new parts, make sure you inspect the engine and fuel. Fix any fuel or oil leaks before making changes or repairs.
EGR & Exhaust

Inspection and cleaning of After-treatment system components:

• Regular cleaning can reduce carbon buildup on the injector tip ensuring good atomization of fuel and efficient regeneration performance.

• EGR cleaning and inspection, including exhaust leak detection:

• Cleaning the EGR cooler helps maintain EGR flow rate and reduces high intake temperatures to ensure proper combustion. Poor combustion can lead to increased PM output from the engine.
Air delivery system

- Leaks in the charge air system – changes in air-to-fuel ratio make excess soot for the DPF!
  - Turbo
  - Charge Air Cooler
  - Hump hoses
  - Dirty Air filter

- Air, EGR, & Exhaust testing:
  - “smoke” or Vapor testing equipment
  - Redline, FSX inc, Bosh
Service Interval

Cleaning Intervals:

• Decreasing the amount of time between cleaning intervals can increase the life expectancy of the filter, over time ash buildup in the filter can become sintered, this problem is more prevalent the longer ash remains in the filter. Decreasing the interval will help reduce this buildup. Sintered ash cannot be cleaned from a filter.
Coolant Systems

Coolant system Inspection:

• Proper bleeding of the coolant system and inspection for leaks help reduce air in the coolant system. Air in the coolant system can lead to overheating of engine components. The EGR cooler is very susceptible to high temperatures and is one of the most common failures in the EGR system.
Dirty or Plugged Air Filters:

- High opacity
  - Opacity higher than the DPF manufacturer specification.

- Improper combustion
  - Air fuel ratio incorrect.

- Plugged DPF
  - DPF light active.
Fuel and Filters:

- Contaminated fuel
- Dirty fuel filters
- Bad fuel injectors
Contaminated Fuel:

• How clean is your source?
• Water, oil, and fuel contaminates in diesel fuel often cause your DPF to plug; damaging injectors, pistons, and/or EGR components.

Do not use additives.

• Fuel additives can damage the coating on the DOC or DPF and void some filter system warranties.
Lubricating oil:

• Before DPFs upwards of 0.5% (w) of the engine oil was additives.

• Sulfated Ash: Engine oil products that do not burn and form solid particles

• New CK-4 or CJ-4 API oil standards are required for DPF quipped engines.
  • 0.05% sulfur

![Eng. Oil impact at 220,000km](chart.png)
Check Engine Light:

- Check the gauges.

- Check engine for visible issues.

- Just because the fault code is inactive does not mean there is no issue. It means there is no issue present, inspect and troubleshoot issues as they arise.
THANK YOU Green Transportation Summit & EXPO: Portland!

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