Regeneration of the DPF

As per Mercedes-Benz, {{The normal regenerating intervals of the BlueTec Diesel Particulate Filter (the driving distance between two regeneration periods) is 130 miles of City driving, & 320 miles of Highway driving. }} The problem is, very few people drive strictly City or Highway. The regeneration interval is actually decided by pressure sensors which tell the ECU how much soot is stored in the DPF. {{The duration of a regeneration period generally lies between 15 & 25 minutes.}} In other words, the regeneration of the DPF takes 15 minutes on the Highway & 25 minutes in City driving. In order to burn off the soot trapped in the DPF, the regeneration of the DPF requires an exhaust temperature of 1600F. High RPM's while Highway driving makes the regeneration go quicker, with fewer regeneration cycles. Vehicles primarily driven on the Highway have fewer problems, because the DPF needs fewer regeneration cycles.

So how does the the DPF get to 1600F? Your Turbocharger is driven by hot exhaust gas. It's only cooling is your engine oil and the air going through it. Better Turbo's are water cooled. As the air and oil moves through the Turbo it gets very hot. When the DPF is full of soot and oil sludge, the ECU injects additional fuel into the combustion chamber. The extra fuel heats the exhaust to 1600F so it can clean out the DPF. Not all of the extra fuel is burnt and some washes past the piston rings. The combustion temperatures are so high, that the fuel and oil on the piston rings is burnt. This is called "coking". Over time, the piston rings become packed with burnt oil and fuel. The piston rings can't seal against the cylinder walls and compression gas goes into the crankcase. This is called "Blow-by". This also causes excessive crankcase pressure. It causes oil leaks and it causes hot oil vapor to travel through the Oil Separator and into the Turbo. The air moving through the hot Turbo is filled with oil vapor. The Intercooler's job is to cool down the air going into the combustion chamber. Over time, the oil vapor fills the Intercooler with oil sludge and the Intercooler can no longer cool the combustion chamber. As the combustion temperatures go higher, it causes even more Blow-by. The oil vapor also clogs the DPF with increasing amounts of oil sludge. The system is forced the regenerate more frequently to keep up with the Blow-by. Over time, the cycle keeps getting worse and worse. The oil in the crankcase gets so hot, that it turns into sludge.

Your driving style and maintenance will determine how many problems you have. You can help the system with high quality oil that can handle extreme temperatures. A Catch Tank diverts the oil vapor and prevents it from causing so much damage. Mercedes has modified many of the parts in the emission system to help reduce the problems caused by the DPF regeneration. Mercedes has also modified the engine computer so it doesn't inject so much fuel during regeneration. There is a number of things that have been done to get a handle on the regeneration problem. The problem is, Mercedes won't pay for these updates. Dealers don't tell owners about them, because customers would demand that Mercedes fix the problems they created. It's a classic Catch 22. Depending on a number of factors, I explain individually what each owner needs to do for their engine and emission system to work properly. The goal is to have the lowest operating cost over the life of the engine. If it's a new engine, there are specific things to be done. Diesel Break-in oil and a Catch Tank are the first step. Older engines have many updates and I look at the maintenance history to determine what needs to be done. Certain oils and additives work best in new engines and different oils and additives work in older engine with stuck piston rings. I here from a lot of owners with over 80,000 miles and the engine is burning a quart of oil every 200 miles. Their dealer has told them they need a new engine. I've lost count of how many engines that have been saved with change in the maintenance.

Practically everything I send owners originally came from Mercedes Technical Service Department. I try to send documents based on your experience and vehicle. It's easier if I give you a overview over the phone. A lot of people have the mistaken impression they can switch to a better oil and that will solve their problems. Better oil helps, but there is a lot more to this. Call or email me, and I can send you the PayPal link.

Email: tom54stephens@gmail.com
Phone: 916-715-0665

Note: The owners of newer Sprinters can look at the amount of soot stored in their DPF. If yours says it is above 90%, that will trigger a Check Engine light. Drive the engine real hard on the freeway. Kick it into passing gear. This will blow out the soot. I've had owners tell me they were at 98% and several hards runs on the freeway brought it down to 0%.

Try to find this statement in your Owners Manual. It's not there. It's found in another booklet that Mercedes doesn't include with your vehicle. "Stationary for long periods" means idling. Mercedes is 100% correct. Short trips and prolonged idling will cause engine failure. Mercedes finally put this in the 2019 Owners Manual; 12 years after they built the BlueTec diesel.

cific maintenance work must be carried out at regular intervals and in accordance with the service requirements of the dealer listed here on the inside title page. Details can be found in the Maintenance Booklet.

Short journey

! If the vehicle is predominantly used for short-distance driving or is stationary for long periods, this could lead to a malfunction in the automatic cleaning function for the diesel particle filter. This can lead to blockage of the diesel particle filter. This can also result in fuel collecting in the engine oil and cause engine failure.

Therefore, if you mainly drive short distances, drive on a highway or an inter-urban road for 20 minutes every 300 miles (500 km). This facilitates the diesel particle filter's burn-off process.

Speed limiter

⚠ **WARNING**

Exceeding the stated tire load-bearing capacity and the approved maximum speed could lead to tire damage or the tire bursting. There is a risk of accident.

Therefore, only use tire types and sizes approved for your vehicle model. Observe the tire load rating and speed rating required for your vehicle.

As the driver, you must find out about the maximum speed of the vehicle and the resulting permissible maximum speed of the tires (tire and tire pressure). In particular, also observe the tire approval regulations for each country.

You must not exceed the speed limit for the tires listed in the tire pressure tables. You can find information on tire pressures in the "Wheels and tires" section (▷ page 288).

You can permanently limit the maximum speed of your vehicle to 55 mph (90 km/h), 60 mph (100 km/h) or 75 mph (120 km/h).

We recommend that you use an authorized Sprinter Dealer for the programming of the maximum speed.

Before overtaking, take into consideration that the engine speed limiter prevents the speed increasing beyond the programmed maximum speed.

Driving abroad

Service

An extensive network of authorized Sprinter Dealers is also at your disposal when you are traveling abroad. Nevertheless, please bear in mind that service facilities or replacement parts may not always be immediately available. You can obtain a list of workshops at any authorized Sprinter Dealer.

Fuel

In some countries, only fuels with a higher sulfur content are available.

Unsuitable fuel can cause engine damage. Information on fuel (▷ page 318).

Low-beam headlamps

If you are traveling in countries where vehicles are driven on the opposite side of the road to that in which the vehicle is registered, you will need to:

- have the halogen headlamps partially masked
- have the Bi-Xenon headlamps set to symmetrical low beam

This prevents glare to oncoming traffic and no longer illuminates the edge of the road to the same height and distance.

Have the headlamps masked or adjusted at a qualified specialist workshop before you cross the border, but as close to it as possible.

After the hot oil vapor enters the Turbocharger it goes into the EGR and the intake system. The extreme heat bakes the oil into a rock hard carbon sludge. It is extremely hard for fuel system cleaners to remove this. This same sludge also clogs the DPF until it can no longer regenerate and burn it off. The DPF then needs to be professionally cleaned or replaced.

Mercedes-Benz BlueTec Diesel

From the Garrett Turbocharger FAQ section of their website:
Q. Should my turbo/exhaust manifold glow red after driving?
A. Yes, the turbo/exhaust manifold can glow red under certain driving conditions. The exhaust gas temperature can reach over 1600F under high load operating conditions; i.e. towing, extended uphill driving, or extended high rpm/boost conditions.

Some owners go along thinking they don't have any problems, why do any preemptive repairs? Not realizing the Engine ECU is constantly injecting to much fuel during the regeneration of the DPF. Mercedes knows this and has published over 50 software updates trying to reduce the fuel required for regeneration. Mercedes finally admitted that all the 2015 and older BlueTec ECU's can't be fixed with software updates. The ECU's also have a problem in their diagnostic software. If the system has a problem there is a fault code that tells the mechanic what happened. These fault codes can't be trusted. The codes are often wrong. That's why owners will often have to take the vehicle back several times for a repair. Mechanics hate the BlueTec because they get blamed for the bad repairs. The ECU must go back to Germany and be rebuilt. Mercedes does not pay for this. The excess fuel causes the coking you see on these piston rings. The excess fuel also washes into the crankcase oil and creates all the sludge. This sludge causes the oil lines to the crankshaft to clog up and starve the crankshaft for oil. Even 2019 Sprinters have software updates that are important.

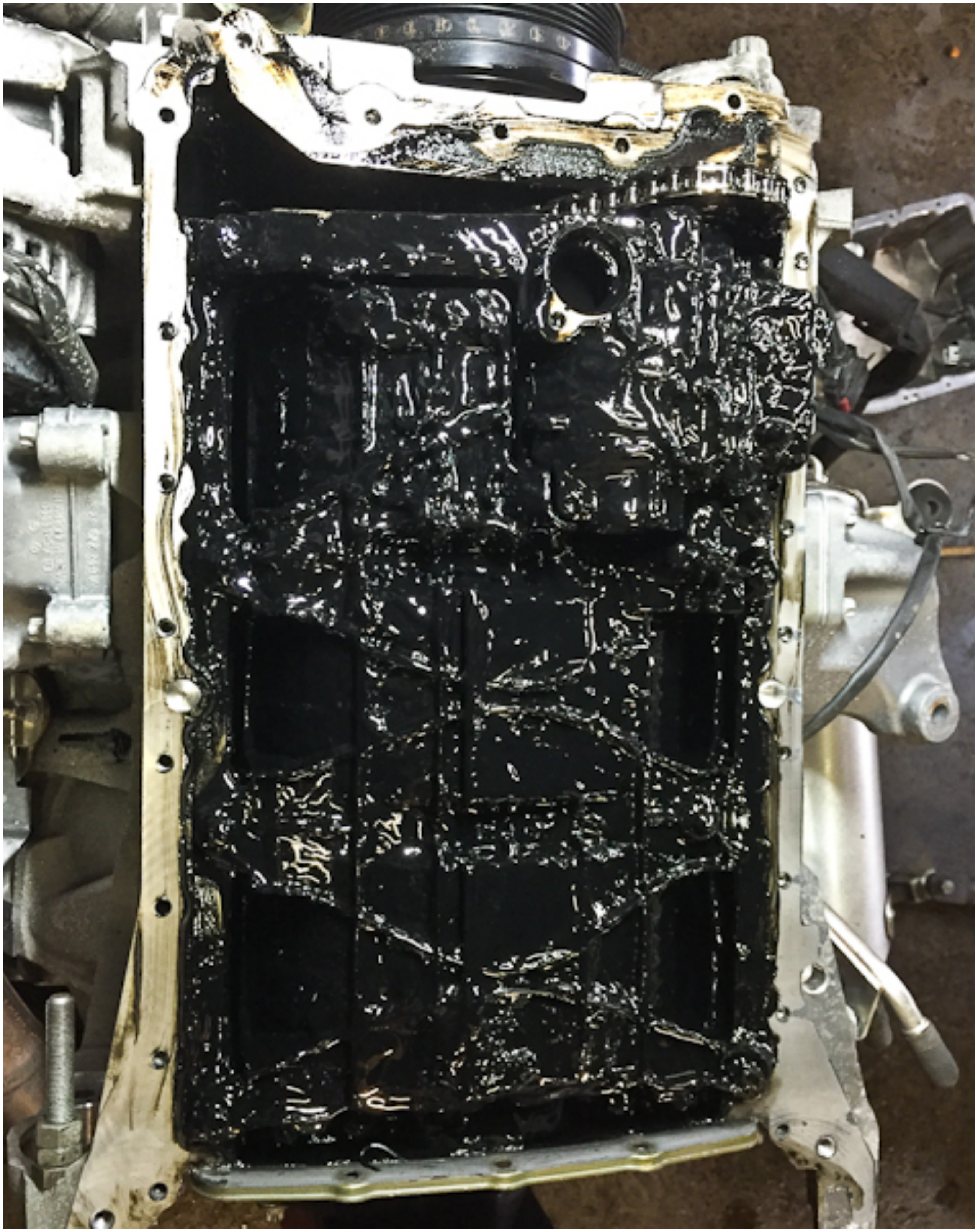
Another example of what happens without owners realizing, is the DPF pressure lines all become clogged with oil sludge. Mercedes admits this and has published modified parts to correct the problem. Owners don't know they have a problem until the DPF completely clogs up. When the pressure lines can't sense how much back pressure is building up in the DPF, the ECU never ask for regeneration.

All of the various subsections of the BlueTec system have to work together. I send owners the information on how to update and maintain each part of the system. If you skip one part, it causes another problem someplace else in the system. It has taken Mercedes 13 years to finally work out all the problems and publish the updates that make the BlueTec system actually work. Prior to this, its been a system of band aids to keep it all working.

This is what piston rings look like when they are packed with burnt oil. When the DPF goes into Regeneration the Piston Rings are so hot the oil and fuel are baked into this hard carbon crud. Over time the piston rings become stuck in their ring groves. The stuck rings can't press tightly against the cylinder walls and the engine starts to burn oil. At first owners won't notice the oil consumption because diesel fuel is washing past the piston rings and into the crankcase. As time passes, the oil level drops faster than the diesel fuel can replace the missing oil. Owners will also notice this as problems with the DPF and the EGR. The Check Engine light comes on and the engine goes into the Limp Home mode. This is a sign that the engine is very close to locking-up. There are special oil additives that will begin to clean this mess. Mercedes has updated many of the parts in the engine to reduce this problem. Some owners think a better oil will solve this problem. A better oil is only a small piece of the puzzle. There is a systematic process to solve this problem.

This is what diesel fuel (fuel accretion) in the crankcase oil looks like at 80,000 miles and 20,000 mile oil changes. The Turbocharger sucks this out of the crankcase via the Oil Separator (PCV valve). This same sludge coats the EGR, Swirl Flaps, Intercooler, EGR cooler and the DPF. As the sludge thickens over time, it finally clogs the oil check valves and starves the crankshaft for oil. The engine locks up. This is what you get with 20,000 mile oil changes and Mobil One 5W/30 ESP.

Mercedes-Benz BlueTec Diesel



BlueTec diesels are not meant for short trips & cold weather.
Mercedes is telling you this in this bulletin.

- Engine oil diluted with diesel fuel -

Topic number	LI18.00-N-054809
Version	1
Design group	18.00 General
Date	10-11-2012
Validity	Model 906 with engine OM642, OM646 and OM651 in combination with diesel particulate filter
Reason for change	Extended to include OM651

Complaint

Engine oil level above max. Oil level indicator lamp comes on.

The following points can be ruled out:

- No engine oil was refilled.
- No relevant fault entry in engine control unit.
- No mechanical defect on engine.

Cause

Fuel enters the engine oil because diesel particulate filter (DPF) regeneration is aborted several times - engine is switched off by driver or regeneration is aborted by engine control system due to insufficient temperature in the exhaust system.

Note:

Certain operating conditions (e.g. frequent short distance driving, large amounts of idling) favor repeated DPF regeneration aborts

Remedy

If possible, limit short distance driving and/or frequent idling. Drive at highway speeds for at least 20 minutes at around every 300 miles to support DPF regeneration.

If this problem occurs, change oil and perform manual DPF regeneration.

Inform customer accordingly about the technical circumstances.

Symptoms

Symptom
Power generation / Engine lubrication/oil cooling / Indicator lamp / Engine oil level indicator lamp / lit

There are several reasons why soot is a serious problem in diesel engines.

To start off, diesel fuel is 'heavier' than petrol and does not burn as readily as petrol. Secondly, the fuel/air mixture in a petrol engine is ignited by an electric discharge at the spark plug. In a diesel engine the fuel and air ignite spontaneously (auto-ignition) as a result of the high pressure and temperature in the combustion chamber. Furthermore, diesel is only injected into the compressed air in the combustion chamber towards the end of the compression stroke, resulting in poor mixing of the diesel and air. This creates fuel-dense, oxygen lacking 'pockets' that produce soot when ignited. Some of this soot comes into contact with the oil film on the cylinder liners. As the piston moves down, soot that is trapped in the oil film is scraped down into the oil sump by the oil control piston ring.

Soot can also reach the oil in the sump via blow-by, i.e. the leaking of partially burnt fuel and combustion gases past the piston rings into the crankcase. This occurs more frequently in engines with worn piston rings. Other factors that can lead to abnormal soot loading of the oil are:

Bore Polishing caused by friction modifiers.
Frequent stop/start operations.
Extended periods of idling.
Incorrect injector spray patterns.
Rich fuel/air mixtures.
Blocked air filters.
Individual soot particles are minute and impose little danger to the oil and engine. The soot particles, however, have the tendency to agglomerate (clump together) and form larger clusters. These large clumps of soot can cause damage to the engine, but the dispersant additives in engine oil prevent them from agglomerating and keep them finely suspended in the oil.

When the soot concentration in engine oil reaches a level that can no longer be dissolved by the dispersant additive, the soot particles clump together to form sludge.

The sludge attaches itself to engine surfaces, impedes oil flow through the oil filter as well as the engine and increases oil viscosity with the following devastating results:

Agglomerated soot negatively impacts the performance of anti-wear lubricant additives and leads to accelerated engine wear.
Build-up of soot and sludge in the grooves behind piston rings causes rapid wear of the rings and cylinder walls.
High viscosity results in cold-start problems and risk of oil starvation. This often results in premature engine failure.

There is a myth that modern engines are built with very tight tolerances. For that reason, they need low viscosity oil. The EPA is currently working on 0W/8 motor oil. Think about it. If engines were built with tight tolerances, it would create more drag in the engine. It would require more fuel to run a engine with tight tolerances. The engines are actually built slightly looser so they don't need as much fuel to run. This is also why you see Mercedes tell owners it is normal for the engine to use one quart of oil every 600 miles. It's in your owners manual. Mercedes uses low viscosity oil because it has less drag while the engine is running. It is also easier for the engine to burn low viscosity oil. Mercedes has finally put a viscosity oil chart in the owners manual. It says owners may use 20W/50 or 10W/60 oil in a BlueTec diesel. Higher viscosity oil is harder to burn and clog the DPF.

In order to meet EPA fuel economy standards, Mercedes-Benz recommends engine oil designed for gas engines. Obviously Mercedes doesn't tell owners the oil is not approved for diesel engines. Mercedes is trying to save themselves from paying huge financial penalties for missing the mandated fuel economy standards. The gas engine oil has extra friction modifiers for improving fuel milage. Gas engine oil does not have enough oil additives for diesel soot. The extra friction modifiers and soot cause the cylinder walls to become highly polished. This causes excessive blow-by. When the engine oil is only changed every 20,000 miles, the oil is so full of soot sludge, the crankshaft and timing chain starve for oil and fail. The engine will make it through the warranty period. After the warranty, the problems begin to grow. At first, owners don't realize what's happening. As the repair cost climb, most owners sell the vehicle. Now the problems become the second and third owners responsibility. Thinking the fault is with the emission system, they delete the emission system. If the proper oil had been used in the new engine, the repair cost would be reasonable and owners would still have a functioning emission system.

If you get any of these fault codes, it is a early warning that the engine is badly slugged. The engine will lock-up if you don't immediately address this problem.
Mercedes doesn't tell you what's actually causing the DPF to clog up and store these fault codes. The exhaust temperatures are to high and that causes Blow-by at the Piston Rings. Blow-by is also forcing hot crankcase vapor out of the PCV valve (Oil Separator). All of the Blow-by clogs the internal engine and finally ends up in the DPF. The DPF is just a symptom of a bigger problem. Mercedes tells the mechanic to check a list of obscure problems that are rarely the cause. Mercedes never tells the mechanic how to effectively clean up the sludge in the Intercooler and EGR Cooler that are always causing DPF problems.
Why doesn't Mercedes explain the actual problem? Mercedes would have to admit their oil and oil change intervals is the primary cause of this constant problem.

Fault code P245997, P246397, P245900, P246385 or P246309 stored in engine control unit

Topic number	LI49.20-N-060290
Version	3
Design group	49.20 Exhaust aftertreatment unit
Date	02-29-2016
Validity	**Model 906 with engine OM642 and OM651**
Reason for change	update cause

Complaint:

Active engine diagnosis warning lamp.
The following fault codes are stored in the engine control unit:

- Fault code P245997

The regeneration frequency of the diesel particulate filter is not OK. System function is restricted.

- Fault code P246397

The soot content of the diesel particulate filter is not OK, "The system function is restricted" is stored in the engine control unit.

- Fault code P245900

The regeneration frequency of the diesel particulate filter is not OK.

- Fault code P246309

The soot content of the diesel particulate filter is not OK. There is a component fault.

- Fault code P246385

The soot content of the diesel particulate filter is not OK. There is a signal above the permissible limit.

Cause:

The following causes may produce these fault codes.
For example:

- Deviation detected in emission sensor system or sensor wiring.
- Deviation detected in a component, which results in an excessive amount of engine soot development. (For example, intake air system, injector, HFM-SFI).

Notes:

- The fault codes for the regeneration frequency of the diesel particulate filter (DPF) appear when the vehicle is regenerated unusually often or for too long. Normal regeneration intervals (driving distances between two regeneration periods) are 250 km urban and 500 km inter city. The duration of a regeneration period generally lies between 15 and 25 minutes.
- The fault codes for the soot content of the diesel particulate filter appear when the engine timing has calculated an excessively high soot load. A high soot load does not necessarily actually exist. It could also be that faults in the sensor system erroneously detect a high soot level, although the loading of the diesel particulate filter is actually OK.

Remedy:

For these fault codes there are guided tests in XENTRY, which have to be fully processed.
The following test steps are to be processed for the above-mentioned fault codes:

1. Read out and document the fault freeze frame data for each fault code from the engine control unit.
2. Record the performance data for the CDI control unit (under "Special processes" in XENTRY Diagnostics) or the development diagnosis sheet (DAS).

3. Plausibility check of component B28/8 (DPF differential pressure sensor).
4. Check compression pressure (see AR01.00-D-1200WE for model 906).
5. Check installation height of fuel injectors (see AH07.16-P-1000-01S). Note: If there are any deviations, check whether too many sealing rings or none at all have been installed.
6. Check charge air system for leaks.
7. Check exhaust system for leaks.
8. Plausibility check of temperature sensors in exhaust system.
9. Check electrical lines and connectors for emissions sensor system.
10. Perform wipe test on the exhaust tailpipes. To do this, take a suitable cloth (e.g. a soft cleaning cloth) and check whether there are any soot deposits on the inside of the exhaust tailpipes (see attachment for example pictures).

- If the cloth becomes black or gray, open the connecting point downstream of the DPF. If the exhaust pipe at the DPF outlet is carbon-fouled, the monolith broken out or if a white crust is visible on the monolith replace the DPF.
- If no discoloration is visible on the cloth, perform a visual inspection at the DPF inlet. If the DPF inlet is oiled up or the honeycomb structure of the monolith is partly/completely sealed with soot. Check the DPF regeneration history to ensure the regeneration is being fully performed. If there is oil present locate the source of the oil (i.e. Check the turbo exhaust vanes for signs the shaft seal is leaking)

Note:

If the diesel particulate filter is replaced, this then has to undergo teach-in with XENTRY.

Regeneration while driving is not necessary.

In a warranty case all test results should be submitted along with the diesel particulate filter.

11. If no damage can be found to the diesel particulate filter, regeneration must be performed while driving, following the test instructions.

12. Acquisition of diagnostic performance data, acquisition of data on completion of repair work

Note:

Please note that for the complete repair the damage code must relate to the component causing the damage.

If no faults are found replacement of the diesel particulate filter is not permissible in this case.

Attachments	
File	Description
01.JPG	Wipe test (clean)
02.JPG	Wipe test (black)
03.JPG	Wipe test (gray)
04.JPG	Connecting point downstream of DPF outlet (clean)
05.JPG	Connecting point downstream of DPF outlet (black)
06.JPG	Connecting point downstream of DPF outlet (monolith damaged)
07.JPG	Connecting point downstream of DPF outlet (white crust on monolith)
08.JPG	Visual inspection of DPF at CAT inlet (not oiled up)
09.JPG	Visual inspection of DPF at CAT inlet (monolith clogged with soot)
10.JPG	Visual inspection of DPF at CAT inlet (monolith OK)

Control unit/fault code		
Control unit	Fault code	Fault text
CDID2Common Rail Diesel Injection (CRD2_NFZ)	P245997	The regeneration frequency of the diesel or gasoline particulate filter is not OK.The system function is restricted.

CDID2Common Rail Diesel Injection (CRD2_NFZ)	P246397	The soot content of the diesel particulate filter is not OK.The system function is restricted.
N3/33 - Motor electronics 'CDI43' for combustion engine 'OM651' (CDI) (CR43)	P246397	The soot content of the diesel particulate filter is not OK. The system function is restricted.
N3/28 - Motor electronics 'CDID3' for combustion engine 'OM651' (CDI) (CRD3NFZ)	P245997	The regeneration frequency of the diesel or gasoline particulate filter is not OK. The system function is restricted.
CDID2Common Rail Diesel Injection (CRD2_NFZ)	P246397	The soot content of the diesel particulate filter is not OK. The system function is restricted. (MOPF)
N3/33 - Motor electronics 'CDI43' for combustion engine 'OM651' (CDI) (CR43)	P246385	The soot content of the diesel particulate filter is not OK. There is a signal above the permissible limit value.
N3/33 - Motor electronics 'CDI43' for combustion engine 'OM651' (CDI) (CR43)	P245900	The regeneration frequency of the diesel or gasoline particulate filter is not OK. _
CDID2Common Rail Diesel Injection (CRD2_NFZ)	P245997	The regeneration frequency of the diesel or gasoline particulate filter is not OK. The system function is restricted. (MOPF)
N3/28 - Motor electronics 'CDID3' for combustion engine 'OM651' (CDI) (CRD3NFZ)	P245900	The regeneration frequency of the diesel or gasoline particulate filter is not OK. _
CDID2Common Rail Diesel Injection (CRD2_NFZ)	P246309	The soot content of the diesel particulate filter is too high.There is a component fault.
CDID2Common Rail Diesel Injection (CRD2_NFZ)	P246309	The soot content of the diesel particulate filter is not OK. There is a component fault. (MOPF)
CDID2Common Rail Diesel Injection (CRD2_NFZ)	P245900	The regeneration frequency of the diesel or gasoline particulate filter is not OK. _ (MOPF)
N3/28 - Motor electronics 'CDID3' for combustion engine 'OM651' (CDI) (CRD3NFZ)	P246309	The soot content of the diesel particulate filter is not OK.
CDID2Common Rail Diesel Injection (CRD2_NFZ)	P245900	The regeneration frequency of the diesel or gasoline particulate filter is not OK.

Operation numbers/damage codes

Op. no.	Operation text	Time	Damage code	Note
07-0641	ENGINE COMPONENTS:................... CHECK PER FAULT CODE			

WIS-References

Document number	Title	Note	Allocation
AR01.00-D-1200WE	Check compression pressure	MODEL 906 with ENGINE 651.955/956/957	Remedy
AH07.16-P-1000-01S	Notes on injectors	MODEL 906 with ENGINE 651	Remedy

This diesel oil is what Mercedes uses in Germany. It is an Ester synthetic, 5W/60 with all the approvals from API, ACEA and Mercedes. It cost about $30 per quart. You can't get this oil in America.

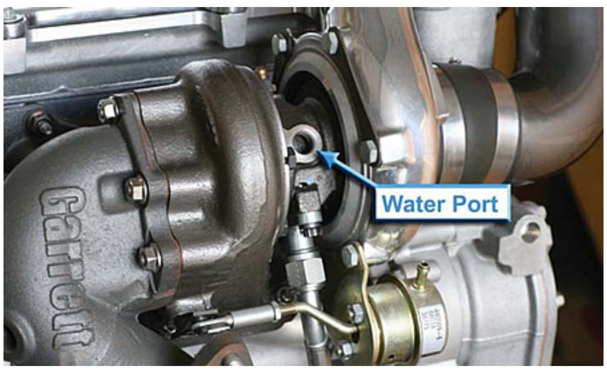
If Mobil One 5W/30 ESP is so good, why do the Mercedes dealers in Germany use this 5W/60 oil? Why isn't it available in America? Mercedes dealers in America only sell 5W/30 oil. They always tell owners that any oil with a viscosity higher than 30 is to thick. How do they explain this oil? If the MB approval MB229.52 is strictly for BlueTec diesels, how can this oil also have the MB229.52 approval? How does this oil also have the API and ACEA BlueTec approvals and Mobil One 5W/30 doesn't? This is precisely why the Mercedes approval system is worthless. It is not logical for Mobil One 5W/30 ESP to have the same MB229.52 rating as this 5W/60 oil. Your owners manual even says the approved oil must have the proper API and ACEA BlueTec diesel classifications. Both the API and ACEA only approve Mobil One 5W/30 ESP for Gas engines. That explains why Mobil One breaks down and turns into sludge.

1300 (887 267)

The Turbocharger on the OM642 BlueTec diesel is made by Garrett. Garrett makes dozens of different types of Turbochargers. When Mercedes-Benz ask Garrett to supply the Turbo for the OM642, I'm sure Garrett tried to talk Mercedes out of putting Garrett's cheapest Turbo on the engine. Garrett & Mercedes both knew the Turbo Mercedes ask for, was not appropriate for the engine. In this technical article, Garrett explains what goes wrong. They should know, they built it. The Turbo on the OM642 is exhaust driven. The exhaust on a BlueTec diesel gets extremely hot. The Turbo on a OM642 is only cooled with the engine's own oil. The extreme heat in the Turbo breaks down the engine oil & that's why the engine oil turns to sludge. If Mercedes had used a water cooled Turbo as Garrett explains in this article; the engine would be far more reliable. Mercedes knows this, because they use water cooled Turbo's on Military vehicles with the OM642 engine. However, Mercedes will not even allow privet owners to even buy the water cooled Turbo that goes on a Military engine.

"Does my turbo really need water? Is it really that thirsty? Why should I care?" - The Garrett® engineers are asked many such questions regarding our water-cooled turbochargers. Many customers question the necessity or benefits of plumbing in those extra water lines to the sides of the turbo's center housing. Why not just leave them off? The reality is that a water-cooled turbo can be damaged irreparably without proper water line setup. With a little background and some explanation of what water cooling really does for turbochargers, this Garrett® bulletin will hopefully convince a sceptic that the benefits provided by water-cooling are worth the small effort required to properly set it up.

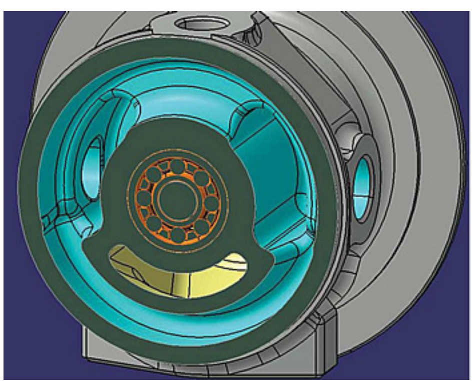
What does water-cooling really do? - Water-cooling improves mechanical durability and lengthens the turbocharger's life. Many turbochargers are designed without water cooling ports and are sufficiently cooled by air and the lubricating oil that flows through them. Other turbochargers, such as many in the Garrett® GT & GTX ball bearing line up, are designed from the beginning to be cooled by oil and water. How can we tell the difference between an air/oil-cooled turbo and an oil/water-cooled turbo?
If the turbocharger's center housing has threaded ports on either side, at 90° from the oil inlet/outlet flanges, then it is water-cooled. In order to meet durability targets defined by Garrett® engineers during its development, it needs water flowing through it. Water cooling's main benefit actually occurs after the engine has been shut down.



Mercedes-Benz did not use the water cooled Turbocharger or water cooled Intercooler on the BlueTec diesels sold in America. The European versions of the OM642 and OM651 diesel have water cooled Turbochargers and Intercoolers. Mercedes and Garrett will not send the replacement parts for a water cooled Turbo to America. I have tried many times to find a way, and Mercedes blocks every attempt. They won't even sell the parts to you if you go to Europe. Mercedes and Garrett always ask for a VIN number and proof of ownership. The only way to work around the blockade is to find a European owner of your same vehicle and order the parts through them. You also need to order all the hoses and brackets to make the conversion.

Water ports are located on either side of the turbo's center housing. Water should flow through the center housing from right to left, or left to right. If there are more than two ports to choose from, be sure to use one on either side of the center housing (don't plumb both lines in on the same side). Heat stored in the turbine housing and exhaust manifold "soaks back" into the center section of the turbocharger after shutdown. If water is not plumbed correctly, this intense heat can potentially destroy the bearing system and the oil-sealing piston ring behind the turbine wheel.

How does water-cooling work? - The physical process of turbocharger water-cooling is an interesting one, and works in a different way than what might seem obvious. It is true that during normal engine operation water flows through the turbocharger mostly due to pressure created by the engine's water pump. However, an additional phenomenon known as "thermal siphoning" pulls water through the turbo's center housing if the water lines are properly routed, even after the engine is shut off and the water pump is no longer pumping.



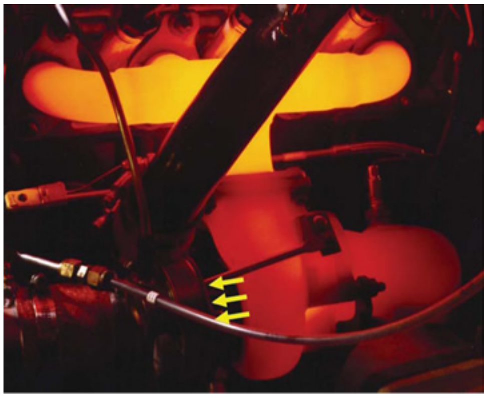
Turbo center housing shown in cutaway view, with water cavity (blue), oil cavity (yellow). Water cavity completely surrounds ball bearing cartridge (orange) and has a port on either side for water inlet & outlet.

Heat in the center housing is transferred to the water via conduction, like the cooling effect that occurs inside a typical water-cooled engine (with a water jacket surrounding each cylinder and running through the cylinder head). If the water running through a turbocharger is allowed to escape freely after absorbing heat, it will rise through the cooling system pulling cooler water into the turbocharger along with it. In this way the intense heat that has soaked back into the turbo after engine shutdown is wicked away from the bearings and seals, and prevented from causing serious damage without assistance from the engine's water pump.

How does water-cooling extend turbo life? - "Heat soakback" is a major turbo killer and must be taken seriously by turbocharger engineers and turbo users alike. This damaging heat originates in the exhaust system. During hard usage, high exhaust gas temperatures dump massive amounts of heat into the exhaust manifold, turbine housing, and turbine wheel. These components are designed to handle very high temperatures through careful design and materials selection. However, some of this stored heat will want to naturally make its way into the less-heat-tolerant center housing, bearing system and shaft of the turbocharger through conduction, since these components are all in contact with one another. While the engine is running and oil is flowing through the turbo's bearing system, most of the transferred heat will be absorbed by the oil, preventing damage to the bearings and oil seals.

Once the engine is shut down, the oil flow stops and so does the exhaust gas flow through the turbine - but all of that heat stored by the exhaust manifold and turbine housing still remains. This heat must go somewhere. Its only escape paths are either to be transferred via conduction into the turbo's center section and the exhaust downpipe, or to radiate into the surrounding air under the hood. A small amount of heat will be transferred to the surrounding air via radiation and convection, but the great majority will conduct from the turbine housing into the center housing, since the center housing is at a lower temperature. Additionally, some of the heat will travel from the turbine wheel into the shaft and out towards the bearing system. During this phase of turbine & exhaust cool down, as the heat is "soaking back" into the turbo's center section, the temperatures of the center housing, oil seal, bearings and any oil remaining in the turbo are all elevated above the normal operating temperatures that occurred while the engine was running, since the oil flow is no longer available to carry heat away. (See the Canton "Accusump Turbo After Oiler" to prevent this.)

This effect is worsened by a large turbine housing. The larger the turbine A/R (and/or the more massive the turbine housing) the more heat is stored in the housing during operation. Therefore there is a greater risk for damage to the turbo during heat soakback after shutdown.



Intense heat in the exhaust manifold and center housing will remain once engine is shut down, and travel into the turbocharger's center housing (in direction of yellow arrows) where it can wreak havoc on the bearing and seals.

You wouldn't believe how many "diesel experts" on the Mercedes owner's forums tell other BlueTec owners that it's impossible for the turbo to run red hot. You can't see that it's glowing red hot, because there is a heat shield around the turbo. The heat shield is removed in this photo. Your engine oil flows through the turbo. What do you think happens to the oil?

How can a turbo be damaged by insufficient cooling? - Now that we have seen how turbo water-cooling works and what it is up against, we can begin to understand the consequences of insufficient cooling. Both the bearing systems and the oil sealing systems can be damaged by being overheated. Ball bearing cartridges are very robust and stand up to repeated abuse, but there are limits to the extremes that they can survive. Ball bearing cartridges are composed of a set of inner races, two sets of balls and retainers, and an outer race. Both the inner and outer races are made of various grades of steel that are very strong and hard under normal operating conditions, but which are reduced when temperatures get too high. The strength and hardness of a typical ball bearing race starts to rapidly degrade at temperatures above 300°F (150°C). This may seem low considering that exhaust gas temperatures can get as high as 1800°F (980°C) in a typical high-output turbocharged gasoline engine, but the bearing is heavily protected by several lines of defense: a heat shroud behind the turbine wheel, reduced contact area between the center housing and the turbine housing (reducing heat transfer rates), oil & water cooling during operation, and finally, water-cooling after hot shutdowns.

(Don't forget, to save money Mercedes chose NOT to use a water cooled Turbo.)

Examining water-cooling specifically, the water jacket inside the turbocharger's center housing wraps around the ball bearing cartridge and is designed to keep ball bearing temperatures below the limits to prevent bearing failure. When water is not used or not plumbed correctly, bearing temperatures can easily go over the intended limits and result in increased bearing play, turbine and compressor wheels rubbing in their respective housings, and ultimately catastrophic turbo failure. In addition to this material degradation, high bearing temperatures cause the internal clearances to decrease in a steel ball bearing cartridge. If temperatures get too high and the turbocharger is run at higher than rated turbo speeds, a steel ball bearing cartridge can physically lock up or seize, causing catastrophic turbo failure.

High speeds occurs hand-in-hand with very high boost pressures, so turbo users running a high-boost system should be extremely conscious of the setup and condition of the turbo's water-cooling lines. "High boost" varies from turbo to turbo, but can generally be considered anything above 25psig (1.7 bar).

Ball bearing races damaged by intense heat and high turbo speeds. The ball bearings had a tough time rolling over these surfaces!

This is what happens in the OM642 turbo. The luberacating oil gets so hot, it turns into a hard tar that causes the turbo bearing to fail. The impeller starts wobbling & the impeller blades hit the sides of the turbo housing. That destroys the turbo.

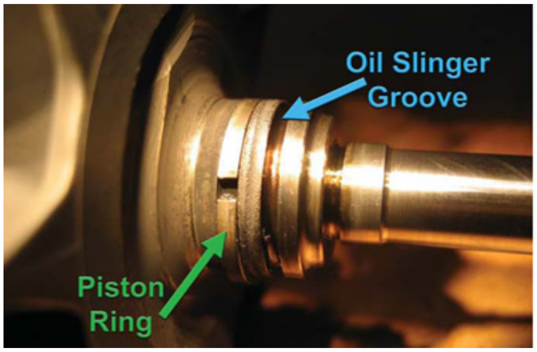
Each individual ball bearing inside the Garrett® dual ball bearing cartridge is held in place by a retainer, and there is one retainer per set of balls: one on the compressor side of the turbo and one on the turbine side. Elevated temperatures can also damage these retainers, which can lead to severe shaft motion (or play), wheels rubbing in housings, and again - catastrophic turbo failure. Keep your bearing retainers happy - don't over-cook them!

Overheated ball bearing cartridge, disassembled showing damaged retainer at lower left. Bearing races are blued and damaged as well. Excessive play is the result of retainer and race damage, often culminating in wheel to-housing rubbing and total turbo failure.

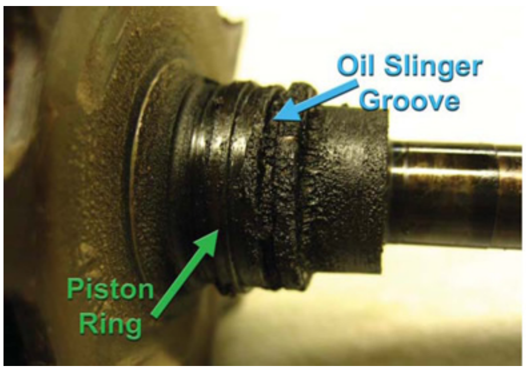
When a turbo fails, the engine often locks up shortly after.

Insufficient cooling and very high temperatures not only risk the health of the bearing system; they can potentially destroy the oil seals as well. When oil is overheated, it will oxidize and produce "coke," a solid carbon-based residue that appears as a black caked-on sooty substance. Turbocharger oil seals are not conventional rubber shaft seals like on an engine's crankshaft because rubber seals or o-rings would not be able to maintain their sealing properties at the high temperatures inside turbochargers. Instead, they are steel "piston rings" that ride in grooves in the turbo shaft. They are springy and designed to press against a bore in the center housing, just like piston rings in an engine cylinder. They also need to have some freedom of motion to work properly - a small amount of axial movement is necessary (in & out, in the direction of the shaft).

If overheated oil turns to coke in the seal area, the piston ring seal groove can be filled with coke and will over-constrain the ring. This can lead to the ring rubbing on the shaft, which it should not do. This constraint of free motion coupled with overheating will cause the ring to deform plastically as it expands outwards into the seal bore in the center housing.



Oil-sealing piston ring with gap visible, facing camera. Turbine wheel is at left, shaft is at right. These parts are used but in good condition – they have not been overheated and no coked oil is visible.



Similar turbine wheel & shaft assembly, but this one has been repeatedly overheated. Piston ring groove and oil slinger groove both contain coke. If this piston ring has not yet collapsed, it is only a matter of time before it does. Severe bluing (discoloration) of the steel shaft on right is also visible, indicating the turbocharger has not been properly cooled or has operated above the maximum rated temperatures.

The plastic (irreversible) deformation is known as ring collapse, and once the turbocharger cools down the piston ring seal has lost its springiness and cannot function as an oil seal any longer. In this way, the lack of functional water cooling can cause severe oil leakage from the center housing into the turbine housing, which will generate smoke as the oil is burned by the hot exhaust gasses.

WHY DOES PROLONGED IDLING CAUSE A TURBOCHARGER TO FAIL?

Running an engine under low loads (idling) causes low cylinder pressures. The piston rings need higher RPM's to increase the sealing pressure on the piston rings. The higher combustion pressure forces the piston rings against the cylinder walls to form a tight seal. Idling doesn't push the piston rings tight enough against the cylinder walls and that increases the Blow-by at the rings.
This poor combustion leads to soot formation and unburnt fuel residues which clogs and gums piston rings, causing a further drop in sealing efficiency and exacerbates the initial low pressure. Glazing occurs when hot combustion gases blow past the poorly-sealing piston rings. This causes the lubricating oil on the cylinder walls to 'flash burn'. Cylinder walls have a intricate pattern of honing marks machined into the hardened surface. The fine pattern is there to hold oil and return it to the crankcase via the scraper rings. When the cylinder walls become glazed from the oil and diesel fuel "flash burning", the combustion gas blows right past the piston rings and into the crankcase. This hot vapor is pushed out the Oil Separator and eventually gets into the DPF. The pressure sensors sense the oil sludge and ask the ECU to regenerate the DPF. Since the engine is idling, the exhaust temperature will need to stay hotter longer to burn off the oil sludge in the DPF. The Turbocharger is driven by the hot exhaust gas. Because the engine is idling, the turbo will stay hotter longer. The extreme heat causes the oil in the turbo bearings to fail. This is exactly how prolonged idling causes the turbo to fail.
Hard carbon (soot) also forms from poor combustion and is highly abrasive. As the soot scrapes along the honing marks on the bores it leads to what is called "bore polishing". This leads to increased oil consumption (blue smoking) and a further loss of pressure. The oil film trapped in the honing marks is intended to maintain the piston seal and pressures. This is actually one of the test performed by the ACEA and API. The E9 or CK-4 diesel oil approval means the oil will not "flash burn" on the cylinder walls. Mobil One 5W/30 ESP cannot not pass this test and is the reason engines with the factory recommended oil have so many problems related to oil failure. The very best diesel oils will also score particularly well on the NOACK Volatility test. The lower the NOACK Value, the better the oil can resist "flash burning" on the cylinder walls. As the piston rings gradually become packed with the residual waste from the "flash burning", the rings become intermittently stuck in the rings groves of the pistons. Poor combustion causes the injectors to become clogged with soot, causing further deterioration in combustion and black smoking. The stuck piston rings cause intermittent rough idle fault codes which are often miss diagnosed as bad injectors. The actual problem is a intermittent drop in compression.
Driving the engine at high rpm's forces the piston rings to make better contact with the cylinder walls.

Critics on various BlueTec diesel owners forums are saying I don't provide actual proof supporting my recommendations for different types of oil. The critics say my opinion is outdated and they'll stick with the oil Mercedes-Benz recommends. The following pages are a short exert from a technical article about the effects of soot in diesel oil and what type of oil is the most effective. The critics think motorcycle oil with the API "CF" diesel approval is total nonsense. API "CF" is the older diesel approval for high soot diesel fuel. Not all motorcycle oils have the "CF" rating. The "CF" oils have higher Ash. Theoretically, Ash contaminates the DPF. It is much cheaper to clean a dirty DPF than it is to replace the Timing Chain and stuck Piston Rings. I invite doubters to read the article and provide their proof that Mobil One ESP doesn't need any API or ACEA diesel approvals. I remind the critics that Mobil One 5W/30 does not have any API or ACEA diesel approval. Mobil One ESP is only approved for Gas engines. If the critics could provide any test data from Mercedes to support the factory approval system? Or is it that consumers should just trust Mercedes and Exxon Mobil? Mercedes has never published any test data that supports their recommendations. ZERO. I can also send you the independent oil test from real BlueTec diesels running on various oils. Mobil One ESP fails miserably when compared to other diesel / motorcycle oils.

The effects of soot-contaminated engine oil on wear and friction

Soot is the black nasty smoke that comes out of a diesel exhaust. Make no mistake about it, the soot coming from a diesel is loaded with nitros oxides (NOx) and other cancer causing chemicals. The days of half hearted attempts at reducing nitros oxides and deleting the emission system when no one is looking are over. Soot is the number one enemy of your engine and the air you breath.

The effects of Soot Contaminated Engine Oil on wear and friction

During the diesel engine combustion process, soot particles are produced and are either exhausted into the atmosphere or absorbed by the engine's lubricant. Soot contaminated lubricant has been shown to produce significant amounts of engine wear. The main mechanism of soot-related wear is through abrasion, but, at increased levels of soot content in the lubricant, starvation of the contact can occur, which can increase wear further. High concentrations of soot can increase the local acidic level and, around the piston where high temperatures and volatile gases coexist, corrosion may also occur. Car, engine, and lubricant manufacturers are facing increasing pressure to lengthen service intervals and therefore oil life in order to reduce lifetime vehicle costs for the customer and the overall impact that the vehicles have on the environment, i.e. a reduction in the amount of engine oil discarded. Increasing sump drain intervals, however, means that oil is becoming contaminated with high levels of soot and increasingly more degraded. (Note: The older API "CF" diesel oil approval is still available and consist of higher levels of the chemical additives that are better at neutralizing the acidic soot contamination found in used diesel oil. The only negative side effect of API "CF" diesel oil is an increase in the Ash contained in the oil. The EPA states that any Ash levels above 0.8 will contaminate the DPF and reduce its effectiveness. API "CF" diesel oil currently has 1.0 Ash. This is a minor side effect for a oil that is better at fighting the wear caused by soot and the increased acidic levels in the used diesel oil.)

On top of this, the use of exhaust gas recirculation (EGR) is increasing; this is where a portion of the exhaust gases are recirculated into the inlet manifold. This acts to reduce the peak combustion temperature and therefore to reduce the nitrogen oxide (NOx) emissions. (This is precisely why abnormally high exhaust temperatures caused by a sludge filled EGR cooler causes frequent NOx sensor failures.) EGR also causes combustion products to be recirculated, rather than to pass out of the engine in the exhaust gases, which leads to further oil contamination. Wear problems are arising from demands for improved fuel economy, performance and lower oil consumption. Which leads to many component contacts within an engine operating under higher loads with thinner lubricant films.

The problem of increasing soot levels or particulate matter levels less than 10 mm in diameter can be partially solved through further understanding of the formation of soot during fuel combustion and investigating how the amount that is produced can be reduced. This is an area of work that has already attracted much research interest.

The problem has also been investigated from a lubricant viewpoint, in terms of designing lubricants that will disperse particles within the lubricant and keep them in suspension. Vehicle service intervals are currently dictated by the length of time that lubricants can maintain their physical properties, but also, and possibly more importantly, by the length of time that they can hold soot particles in suspension. The soot particles are contained within the lubricant by dispersant additives (Soot Scatter). (This is why the older API "CF" High Sulfur Fuel diesel oil approval is superior to the current API "CK-4" Ultra Low Sulfur Fuel diesel oil.) Current lubricant technology, however, has reached a limit on the amount of dispersants that can be added, as too much will result in a corrosion problem in the engine due to the free amines associated with the dispersant.

A different approach to addressing the problem, which has already received some research interest, is to investigate how engine components and their interfaces are actually affected by soot. This has involved looking at what wear mechanisms occur with soot-contaminated engine oil, and under what conditions they occur, and also investigating how much soot the components can tolerate.

The aim of this paper was to collate all the knowledge to date relating to the soot contamination of automotive lubricants. An explanation is given of what soot is and its formation mechanism in an internal combustion engine. The overriding issues caused by soot are highlighted, as are current and future legislation covering engine emissions. Methods that have been used to test sooty oil are described and the use of soot simulates is assessed. The main causes of engine component wear that have been proposed are outlined and the theories that have been developed over the last 30 years are explained. Potential research areas and opportunities to minimize the effect of soot are also discussed.

Soot Generation

Soot is a microscopic carbonaceous particle that is a product of incomplete combustion of hydrocarbons (in this case, diesel fuel). It consists of carbon, ash, and unsaturated (un- burned) hydrocarbons. The unsaturated hydrocarbons are essentially acetylene and polycyclic aromatic hydrocarbons. These components have particularly high levels of acidity and volatility. Measurements have shown that it typically contains 90 per cent carbon, 4% oxygen, and 3% hydrogen with the remainder consisting of nitrogen, sulphur, and traces of metal.
Individual or primary soot particles from diesel combustion have been measured to be approximately 40 nm. Because of soot's colloidal properties, the particles agglomerate up to a maximum of approximately 500 nm, with a mean soot agglomerate size of 200 nm.
Soot particles tend to be more prevalent in diesel engines than in gasoline engines owing to the differences in the combustion mechanisms. Diesel engines are operated at higher air-to-fuel ratios, which tend to produce greater levels of engine soot.
The Mercedes-Benz OM642 and OM651 diesel engines operate using direct fuel injection and swirl within the combustion chamber to assist fuel–air mixing. Combustion initiates close to the injection point and occurs very rapidly as a diffusion flame. At this point, the air and fuel mix well, but the mixture is very fuel rich, causing very high levels of soot to be produced. After diffusion burning, the combustion process progresses through the rest of the combustion chamber by pyrolysis burning, which slowly burns the majority of the remaining fuel. This slow burning produces more particulates (soot) and un- burned hydrocarbons at the end of the combustion process.
Throughout the combustion process, soot particles are produced and destroyed. They are created by the process explained above and destroyed by oxidation. Oxidation is a mechanism that occurs when soot or soot precursors come into contact with various oxidizing species. When this happens, the hydrocarbons that are trapped inside the soot are burned out and the particle size reduces.
During the diffusion burning stage of the combustion process, the soot particles produced in the initial phase of the combustion process come into contact with a much higher volume of air compared with fuel, and a large proportion of the soot particles are oxidized.
Further oxidation is required to reduce the amount of soot finally exhausted. When the exhaust valve (EGR) opens, the combustion products are emitted to the exhaust system, which contains more oxidizing species. Oxidizing catalytic converters (SCR) are used to reduce further the amount of soot emitted from the tailpipe. The majority of the soot formed is oxidized prior to exhaust. By comparison, this is possibly why most soot particles are absorbed by the lubricant and relatively little is exhausted.
It has been shown that, of the soot produced within the engine, only 29% reaches the atmosphere through the exhaust pipe, with the remainder being deposited on the cylinder walls and piston crown. Of the soot that is retained in the engine (mainly in the lubricant), 3% is attributable to blow-by gases; the remainder results from piston rings scraping away soot deposits in the cylinder, which then end up in the sump. Soot is then transported around the engine where it can be entrained into component contacts (the Piston Rings being the most effected).

Proposed Soot Wear Mechanisms

Three different wear mechanisms due to soot contamination have been proposed. Chemical adsorption of the anti-wear components in the lubricant by the soot reduced the lubricant's ability to protect the surfaces. Other researchers have suggested that soot wear could occur because of starvation of lubricant in the contact. This is where soot agglomerates to dimensions greater than the oil-film thickness and blocks lubricant entry to the contact. The final mechanism proposed suggests that wear of the surfaces occurs by three-body abrasion, where the soot acts as the third body. As agglomerates, soot is reasonably soft, but, as individual particles, soot is thought to be hard enough to wear metal surfaces.

It is understood that sulphur used in fuels and lubricants is a corrosion inhibitor; therefore, current legislation to reduce the amount of sulphur in fuels and lubricants could lead to the occurrence of higher rates of corrosion, especially as such a region in the engine contains high levels of acid products post combustion. Lubricants therefore need to have a sufficient neutralizing ability in that region to prevent the occurrence of corrosion. Research has developed in more recent years to investigate the physical and mechanical actions of soot particles in lubricants.

Studies have highlighted wear mechanisms such as bore polishing on a macroscopic level, microscopic abrasion, and lubricant contact starvation due to the soot contained within the lubricating oil. Initial investigations were carried out from a purely chemistry point of view, as soot was known to be one of the contributing factors to long- term oil degradation. Observations showed that, as the oil degraded, the amount of engine component wear increased.

The restriction on the amount of particulates emitted introduces the need for exhaust particulate filters (DPF) to be fitted, with the result that soot particles are contained onboard the vehicle. Particulate filters may, however, have an effect on the efficiency of the engine, as they gradually trap increasing amounts of exhaust soot, and the engine's back pressure will be detrimentally affected.

Another impact on the quality and ability of the oil to perform its function is the level of stress that it is under, increasing the degradation of the lubricant through shearing and heating. Oil stress has been increasing for the last 10 years and is expected to rise at an increasingly faster rate in the future. Therefore, significant further development is required to help to maintain lubricant performance under these expected conditions.

The earliest investigations into soot wear were performed with a four-ball wear test machine, using base oils with various additives, mixed with carbon black and centrifuged engine soot. The wear tests demonstrated an increase in specimen wear with increasing contamination level. The wear test concluded that increasing wear was due to the carbon black and soot particles preferentially adsorbing anti-wear species within the lubricant, e.g. zinc dialkyldithio-phosphate (ZDDP).

A study using a valve train wear test showed that, during engine tests, ZDDP decomposes quickly initially, but the lubricants still retained their anti-wear properties. Analysis of diesel soot showed that it adsorbs compounds containing zinc, but very few compounds containing phosphorus, with the phosphorus compounds being retained within the lubricating oil, maintaining the oil's performance. Further test suggested that the soot acts to strip off the anti-wear film on the surface of the metal surface, leaving it exposed, which results in increased wear. This study proposes that the anti-wear film is removed through abrasion and not adsorption, as analysis of the centrifuged oils show very little sign of zinc and phosphorus depletion, as would be expected if the ZDDP had been adsorbed. The test results concluded the ideal ZDDP level in diesel motor oil should be between 1600 ppm and 2000 ppm to protect the hardened surfaces from soot abrasion.

Soot size relative to the oil-film thickness also produced oil degradation, which may help to explain the differences in the results seen. Oil-film thickness measurement indicated that soot contamination of a lubricant affected the oil film produced and therefore influenced the frictional characteristics of the contact, especially when the primary soot particle diameter was greater than the film thickness.

Effects of Soot in Lubricants

Various studies have been carried out to attempt to understand the properties of soot-contaminated lubricants. Early work carried out by investigating the shear rate rheometry of used oils; the study showed that soot contamination of oil increases the viscosity and therefore reduces its ability to perform its function, particularly at lower operating temperatures. One investigation has shown that, below 1% (by weight) soot concentration in the lubricant, the viscosity increase is linear. However, above 1%, the viscosity rose rapidly. The work also suggests that soot suspended in oil is thixotropic, meaning a contaminated lubricant's properties are dependent on their shear histories.

Investigations looked at the increase in the viscosities of oils from the field, specifically Sprinter's equipped with the OM642 V6 engines operating under 'taxi-cab' conditions, including 'stop and go' and idling situations (which would promote soot production). Oil sampling and testing was performed at 4,000 km operating periods, up to 16,000 km.

At the end of the tests, viscosities had risen to between 300 and 350cS (mm^2/s) from an initial viscosity of approximately 60cS.

Engine valve trains (i.e. Timing Chains) have been shown to be the most susceptible to soot-related wear because the type of motion (generally reciprocating) creates interrupted oil films, low lubricant flow-rates, and related design issues. The effect of soot contamination around the piston rings has also proven to create significant wear. Abrasive wear occurs to a lesser degree as the reciprocating motion in that region of the engine is more effective in creating oil films, but, owing to the extreme temperatures, volatile gases, and the presence of oxygen, corrosive wear is highly likely to occur.

Soot-contaminated lubricants have been shown to increase the wear of many engine components. An engine's valve train has proven to be the most seriously affected because of the thin oil-film thicknesses experienced in many of its reciprocating contacts. The film thicknesses produced in such contacts have been shown to be less than the diameter of the soot particles contained within the lubricant.

Finally, improvements in lubricant technology can assist in the retention of soot particles and anti- wear performance through additive improvements. Also, increased wear protection can be achieved through the very high viscosity indices possible with modern synthetic lubricants.