

## OPERATIONS

# Bluetec - A revolution in diesel NOx emissions technology

Starting in 2007, new diesel vehicles from Mercedes and others used Selective Catalytic Reduction technology to meet stringent diesel emissions standards. Read on for a comprehensive overview of effective diagnostic procedures.

Andrew Libert Sept. 1, 2018 16 min read

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The story begins in the early 2000s, when the government laid down the law on a new generation of emissions standards, requiring manufacturers to make drastic improvements in fuel economy and emissions. Manufacturers responded by looking at a wide range of new technologies, including gasoline direct injection, [electric cars](#), hybrids, fuel cell vehicles and advanced electronic common rail diesels. Over half of the vehicles in Europe are diesels, which have excellent fuel economy and low HC/CO emissions, so German manufacturers chose to refine them and bring them to the U.S.

There was just one problem with that plan, diesel engines tend to produce very high levels of NOx emissions. NOx limits in the U.S. were always stricter than those in Europe, but the new laws slashed the limit by 90 percent. Engineers at [Mercedes](#), BMW, [Volkswagen](#) and [Bosch](#) put their heads together and began searching for the ideal NOx solution that would revolutionize modern diesels.

Research focused on three different types of solutions:

1. Decrease the amount of NOx coming out of the engine
2. Use a NOx Storage Catalytic Converter to filter it out
3. Selective Catalytic Reduction (SCR). SCR injects a liquid urea solution (called Diesel Exhaust Fluid, or "DEF") into the exhaust where it breaks the NOx down into nitrogen and water.

Each technology has different tradeoffs. Reducing the engine's NOx production is less effective and decreases power. Using a NOx Storage Catalytic Converter is more effective but requires extra fuel to be injected to burn the stored NOx off which reduces fuel economy. SCR is extremely effective and doesn't reduce fuel economy, but it requires many expensive parts and space for a large storage tank for the DEF. Another disadvantage of the SCR system is the requirement for maintenance; periodically the DEF must be refilled or the system will quit functioning.

Mercedes-Benz and BMW ultimately decided SCR was the way to go. At the time though, the government didn't like SCR — they preferred the NOx Storage Catalytic Converter technology VW was promoting because it was maintenance free. U.S. officials were concerned. SCR systems would not be maintained, and the cars would run wild with untreated NOx emissions. The [EPA](#) made sure that the Ultra Low Sulfur Diesel (ULSD) needed for these new emissions technologies would be available everywhere by the time the new laws phased in, but there was concern the supply and distribution infrastructure for DEF wouldn't be ready.

Manufacturers were required to disable the vehicles if the SCR system is not working. Ordinarily, the driver doesn't even know the system is there, but if the DEF level runs low, warnings appear in the cluster in stages, and ultimately, the vehicle goes into limited starts mode and counts down. When the count hits zero, most

vehicles will not start againake sure to refill the tank as part of your regular service on all SCR equipped diesel vehicles.

## System overview

Diesel Exhaust Fluid is 62.5 percent deionized water and 32.5 percent urea by definition, and the industry standard for its quality is ISO 22241. You can buy DEF from any manufacturer and use it in a Mercedes system if it meets the ISO standard, which should be on the product label. AdBlue is a German auto industry brand name for DEF, and I will use the term "AdBlue" when referring to DEF going forward.

Although you don't have to buy it from Mercedes they sell a special bottle I really like. You screw it onto the fill port, push it down, and the fluid will flow into the tank until it is full. Then, you release and unscrew it for a drip free job. It also makes it perfectly clear the tank is full without accidentally overfilling it and making a mess. AdBlue is corrosive so always use gloves and safety glasses and keep it away from painted surfaces. Clean up is easy, just wash it away with water.

An important first step is to make sure that the fluid is good quality. AdBlue has a limited shelf life (at least one year when stored properly), and it is also vulnerable to contamination. On Sprinters, the AdBlue fill port is under the hood and commonly gets water or washer fluid in it instead. On the 166 chassis, it is right next to the diesel fill port, so sometimes it is contaminated with diesel and vice versa **(Figure 1)**.

Mercedes recommends using a refractometer to measure the quality of AdBlue. Refractometers work by measuring the way light bends as it passes through a liquid. When the chemicals or their concentrations change, the way they affect light changes as well.

You want a refractometer made specifically for DEF testing because it will show a scale corresponding to the percentage of Urea; an [OTC 5025](#), for example. Regardless of which one you use, be sure to follow the instructions for proper calibration and testing. Mercedes simply specifies the exact standard of 32.5 percent, but good fluid generally tests within 32 percent to 33 percent **(Figure 2)**.

If the urea percentage is incorrect, the fluid is low quality or it was contaminated. In either case, it will be necessary to flush the system and replace the fluid. It's also not a bad idea to verify the quality of your own shop supply to avoid creating unnecessary contamination problems for yourself and your customer.

The AdBlue tank is designed to store enough to make it to the next service, but with aggressive driving, it may have to be topped off before then. AdBlue's freezing point is 12 degrees F and unlike windshield washer fluid, there are no compatible anti-freezing additives. As a result, the entire storage and supply system is heated, and there are no moving parts in the tank. Instead of a float to measure the level, an electronic sensor uses three switches to indicate full, reserve and empty.

There are three heaters as well:

1. One in the tank,
2. One inside the pump
3. One on the pressure line to the metering valve

The pump is mounted on top of the tank but it has to pull from the bottom, so it has a hard time priming, unlike a fuel pump which is submerged. When the engine is shut off, the metering valve is held open, the pump switches into reverse, and empties the line, so that it doesn't freeze.

The exhaust portion of the SCR system includes:

- The SCR catalyst
- The AdBlue metering valve
- A temperature sensor
- Upstream and downstream NOx sensors

The SCR module monitors the storage, supply and heating systems, and the CDI module controls the metering valve and monitors the emissions performance via the NOx sensors.

## Troubleshooting

Start diagnosis by checking with the customer about service history and any previous diagnostic or repair attempts, it's common for these vehicles to make their way around the block and take some bruises before arriving at your doorstep. Where you go next depends on whether the vehicle was towed in or driven in. Diagnosis will require a few road tests, so you need to deal with any count down or limited starts condition first.

Hook up the [Autologic](#) (or equivalent scan tool), do a complete vehicle scan, and record the results.

### Do not clear the codes

Clearing [DTCs](#) on some models will cause the system to go into a "Tampering Mode" and get stuck in the start countdown even after repairs are completed. If you have zero remaining starts, you will need to reset the data that resulted in the system shutdown. Check the fill level of the AdBlue — if it is empty, you will need to completely fill it and perform the tank reset adaptation. In order for the tank adaptation to succeed all of the level, sensors need to read WET, and there cannot be any ambient temperature sensor faults.

If the tank is full but does not read WET across the board, you need to disconnect the SCR module and check resistance across each level switch. They should be within approximately 3.8 – 4.2 kOhms. After successful adaptation of the tank, try again to reset the start countdown.

If it works, go straight to diagnosis. If not, perform the metering valve adaptation reset in the CDI module and try again. If you are still stuck, reset the adaptations of the AdBlue Quality, both NOx sensors and the SCR catalyst.

Due to the large number of variations/revisions of the CDI, SCR, and NOx sensor module software and hardware, each vehicle performs a little differently. Sometimes, reprogramming and SCN coding the CDI and SCR modules is necessary to get everyone on the same page or even to escape limited starts. The NOx sensors have a Q code printed on the back which indicates their version, with the latest being Q5. Q1 and Q2 sensors are not compatible with newer ones, so if you have to replace one, you must do them both.

Q3 and on is supposed to be compatible with later versions, but as a support specialist with Autologic, I have sometimes seen issues when only one is replaced. The sensors are very expensive, so it may be best to advise the customer that you will start with the faulty sensor and replace the other as needed, but ideally you would replace them in sets.

Aside from codes for NOx performance and adaptations, diagnose any and all engine performance faults first, then diagnose SCR faults. Diagnosing NOx performance requires a solid foundation. Everything from the tank, to the injection, must be verified first.

Use the Autologic to test each heater with actuations. It's not necessary for NOx diagnosis, but it only takes five minutes and will help you to build familiarity with typical values, find failed heaters, and find borderline heaters that could result in a comeback. Usually the heaters will fail with high resistance or as an open circuit, generally the tank heater tends to read a little lower. If you have to drop the tank for repairs, check the harness for AdBlue contamination and replace it as necessary. Also, make sure to fill the pot all the way to the top, or the pump may fail to prime and in the worst case scenario the motor can burn up **(Figure 3)**.

Next, use the Autologic to perform the leak test. The pump will run automatically and hold the pressure at 5 bar (about 72 psi). Look for leaks, especially at the pressure line and metering valve. Remove the metering valve and check the nozzle for leakage and clogging, keeping in mind some crusty white deposits are normal.

Perform the metering valve test; watch the spray, and look for a finely atomized three cone pattern. Collect the AdBlue and weigh it. The Autologic will provide the specification (It is normally around 15 grams).

Suitable electronic scales can be found online for \$10-\$15. Just like the refractometer it's best not to wait until you need it to buy one. Even if the spray is bad, or the valve seems clogged, you should not clean it yet, but simply reinstall it because we want to see exactly what the control module saw when it decided the system had failed before we change anything.

Take that fluid sample and put it on your refractometer and check the quality. If your AdBlue is just reading marginally off, it's good enough for some test driving, but if it is contaminated, flush it out, refill it properly, and

reset the tank adaptation. You can also pull a sample from the tank's fill port.

## Evaluating the SCR system performance

Now that the storage and supply system is verified, it's time to test the NOx sensors and NOx reduction performance. NOx sensors need to be heated to about 800 degrees C (1,472 degrees F) to operate, but at this temperature, they can easily be damaged by a thermal shock if moisture or condensation hits them. Therefore, the NOx sensors are not turned on until the CDI module calculates that the exhaust temperature is high enough to vaporize the water.

It's typical for this to take 5-15 minutes from a cold start depending on ambient conditions and drive cycle. It seems to occur around an SCR temp of about 300 degrees C (572 degrees F).

**Note:** It's unlikely the exhaust will get hot enough for the sensors to work if the engine is only idling, so you must drive the vehicle.

Before they've come online, the sensors could read 0, 1000, 2000, or even "Not Operational" (**Figure 4**).

The SCR catalyst also needs to heat up and light off in order for the NOx reduction reaction to work properly, so you will need to drive the vehicle. Find someone to drive you for an SCR System Performance Road Test. I'm personally aware of a couple of technicians who have crashed doing it alone.

Before you take off, check the exhaust temperature sensors for rationality. If the vehicle is cold, there should be no more than 20 degrees C (68 degrees F) between the lowest and highest readings. During the drive, while you're waiting for the NOx sensors to come online, monitor your exhaust temperatures again.

A bad temperature sensor can upset both engine and SCR systems. Look for a sensor that suddenly jumps to an implausible value (**Figure 5**).

When the NOx sensors come online, you want to drive at about 55-60 miles per hour (85-95 kilometers per hour) with a steady engine load. Do your best to avoid braking, hills, acceleration and coasting. NOx production increases when accelerating and decreases when slowing down, so for this performance test, you need a stable NOx feed to the SCR catalyst, and the catalyst temperature needs to be stable.

Monitor the upstream and downstream values. Readings vary by application, but the reduction on a working system will be 30 percent to 50 percent.

For the 906 Sprinter, 251 R-Class, 164 ML-Class, 164 GL-Class with the OM642 engine, the upstream will usually read anywhere from 200-300 ppm, and the downstream will usually read from 75-100 ppm. The 221 S-Class, 166 ML-Class, and 166 GL-Class use an updated version of the OM642 engine, so for these vehicles, and for any vehicle with the OM651 engine (166, 204, 205, 253, 212, 906, 907), the ppm readings should be 50-150 upstream and 0-50 downstream.

## **Diagnosing a malfunctioning system**

What you do next depends on what you found in the earlier tests. If the metering valve was leaking, you need to replace it and see if it corrects the problem, but you also need to explain you can't diagnose the SCR cat or the NOx sensors with a metering valve that is leaking into the system. It's common to have to replace more than the metering valve to fix the vehicle, so set expectations appropriately. The downstream sensor, for example, can be skewed by the excessive AdBlue leaking onto it. If you had some marginally poor quality AdBlue, go ahead and replace it now.

If the metering valve was just a bit clogged or not spraying well, you can wash it off with warm water, put it back in, and re-run the performance test. If you see a substantial improvement, you should still recommend replacing the metering valve to ensure a lasting repair. Metering valves often clog up because they are slowly leaking, and while cleaning it may restore its function temporarily, in the long run, this may result in a comeback.

All parts of this system are expensive, so when repairs seem like they might or might not be necessary, it's best to make the complete repair, or let the customer make an informed decision. Don't forget to reset the metering valve adaptation after replacement and before quality check road testing.

Bad readings (**Figure 6**) could be caused by bad sensors or by a system malfunction. Here, the next step is to verify the NOx sensors are reading correctly and compatibly with each other. Disconnect the metering valve and go drive the vehicle hard for 20-30 minutes.

The SCR catalyst is like a sponge, and it stores a lot of ammonia, so there is always some available even if the metering valve is not spraying, or there is a sudden increase in NOx (hard acceleration). You need to drive it and heat the exhaust up to burn all of that stored ammonia off. Once that happens, the upstream and downstream sensors should match pretty closely.

We know the engine out NOx on a steady cruise is around 200-300 ppm (or 50-150 ppm). A bad sensor reading will generally contrast pretty sharply.

The last piece of the puzzle (and the least likely to fail) is the SCR catalyst. The job of the SCR catalyst is to absorb and store ammonia and to help it react with the NOx to produce nitrogen and water.

What it needs most of all is a good amount of real estate (That is, a lot of surface area). Adblue deposits can build up on the SCR catalyst causing it to "deactivate," or they can collect on the mixing element after the metering valve and restrict exhaust flow.

The top three things that can ruin the SCR cat are:

1. Poor quality diesel fuel, especially with excessive sulfur
2. AdBlue contamination/deposits
3. Failures of the DPF (Diesel Particulate Filter), allowing soot leakage into the SCR cat.

Normally when the DPF is regenerated, the SCR cat is also heated up and burned clean, starting anew. If DPF regeneration stops because of a malfunction, the SCR catalyst is not regenerated either. Sometimes the SCR cat

melts due to engine malfunctions, and sometimes it breaks apart due to the harsh operating conditions. You can try to do a visual inspection with a bore scope, or you can check the exhaust back pressure reading with and without the SCR temp sensor removed, but ultimately, it is a matter of probability and process of elimination.

Look for evidence of DPF leakage by checking the SCR temp sensor for soot stains, checking inside the exhaust pipe when removing the metering valve, or checking the tail pipe with a clean white cloth. When DPF failure is suspected to have damaged the SCR catalyst, Mercedes replaces the DPF and SCR together.

Late-model Mercedes diesels can be very challenging to diagnose, but with the right information, tooling, and training, that service can be very profitable for your shop. Sprinter vehicles in particular are working vehicles, keeping businesses running every day, and their owners are often quick to open the wallet but even faster to ask for the keys.

Don't be afraid to jump into the electronic diesel market. After all, this discussion of AdBlue has already got your feet wet.

For more information on Mercedes Diesels and much more, visit [www.autologic.com/news](http://www.autologic.com/news)

*P.S. Stay tuned for more developments on Diesel Emissions Technology, "clean diesel" isn't dead yet as Bosch has recently announced dramatic breakthroughs in the NOx management technology.*

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## About the Author



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Andrew Libert attended Palm Beach State College's vocational automotive program, worked for GM at Chevrolet and then at Cadillac where he began specializing in...

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