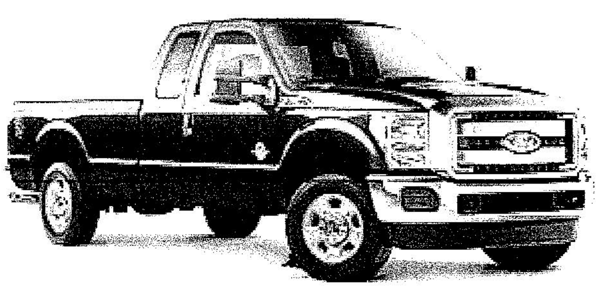
There are two approaches for reducing diesel NOx emissions:

1. **In-cylinder techniques** – this includes any method that limits NOx formation by lowering combustion temperatures. Examples include retarded injection timing, charge air cooling (CAC), and exhaust gas recirculation (EGR).
2. **Aftertreatment** – anything that is done to treat exhaust gases after they leave the engine cylinders. Aftertreatment is an effective, but expensive approach for reducing diesel NOx.

Aftertreatment of diesel NOx is unavoidable now that the 2010 EPA diesel emission regulations are in place. The 2007 regulations focused on reduction of diesel particulate matter (PM), which most OEMs could meet through the use of diesel particulate filters and EGR. The 2010 standards are tough on NOx – leaving OEMs no choice but to use aftertreatment hardware for NOx reduction.

A NOx aftertreatment solution that is gaining momentum here in the U.S. is **urea selective catalytic reduction** (urea SCR). This involves injecting a urea-water solution (also known as **diesel exhaust fluid** or **DEF**) into the exhaust stream ahead of a special catalytic converter. As the urea solution makes contact with hot exhaust gases, ammonia (NH_3) is released. With ammonia in the exhaust gases, the SCR catalyst is able to break apart NO and NO_2 molecules and "reduce" them to nitrogen, oxygen, and water.

Urea is a type of nitrogen fertilizer that is produced using natural gas as a feedstock. Diesel Exhaust Fluid (32.5% urea, 67.5% water) is carried onboard the vehicle in a separate holding tank and would be refilled at varying intervals depending on the vehicle's drive cycle. If the DEF tank goes dry, the vehicle's operation would not ordinarily be affected but NOx emissions would increase. With little incentive for the driver to refill the tank (DEF is not free), the EPA insisted that vehicle manufacturers utilize strict measures to ensure that the DEF tank was not allowed to go dry, and that the correct fluid was installed.



2011 Ford F350 Super Duty Pickup
6.7 liter PowerStroke Diesel

In the case of the 2011 Ford 6.7 liter PowerStroke, the driver is given progressive warnings as the DEF tank approaches empty. If ignored long enough, the engine will derate to the point where it will not come off idle. BMW diesels that utilize urea SCR will not start if the DEF tank goes dry. A driver that has had this happen to them once is not likely to ignore the DEF tank refill reminders the next time around.

Photo courtesy of Ford Motor Company

The following diesel-powered domestic vehicles will utilize urea SCR for the 2011 model year:

1. Dodge chassis cab
2. Ford Super Duty pickup and chassis cab
3. GM Duramax-powered vans and pickups (includes regular, extended cab, and crew cab)

Urea SCR is an excellent method for reducing diesel NOx emissions, but it is not a new technology. It has been used for many years in stationary powerplant applications and also in Europe for a number of years in mobile applications (primarily heavy trucks). The primary advantage of urea SCR is that the engine can be tuned for high temperature combustion and good overall efficiency. NOx that is generated in the engine is then dealt with downstream in the exhaust system. This results in greater fuel economy and increased engine reliability.

Urea SCR systems use diesel exhaust fluid (DEF) as a **reductant**. DEF is a blend of 32.5% urea and 67.5% deionized water. DEF is injected into the diesel exhaust stream ahead of an SCR catalyst. When the urea makes contact with the hot exhaust gases, ammonia (NH_3) is released. The SCR catalyst then uses the ammonia to initiate a reaction where NO and NO_2 molecules are broken down (reduced) into nitrogen, oxygen, and water.

One major disadvantage of urea SCR is that DEF freezes at 12° F (-11° C). This is the primary engineering challenge that had to be overcome to make urea SCR practical in diesel-powered vehicles. To overcome this, onboard DEF tanks and supply lines are designed to provide heat to the urea solution. Most often, this involves the use of electric heating elements that can quickly return frozen DEF to a liquid state. Insulation is also applied strategically to help prevent freezing of the solution during extreme cold weather operation.

The pump that is used to "dose" the DEF into the exhaust system is designed so that it will run backwards during a key-off cycle. This removes all DEF from the supply lines and thus prevents freezing in the lines during cold weather. DEF does not degrade if it freezes and thaws, and DEF urea/water percentages are set so that the concentration level does not vary as the solution changes from solid to liquid.