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What Truck Stop Operators Need to Know about Diesel Exhaust Fluid (DEF)

By Chad Johnson, Chad.Johnson@gilbarco.com

Overview

Since January 1, 2010, the US Environmental Protection Agency (EPA) has required diesel vehicles to reduce nitrogen oxide emissions significantly. Because of the stringent requirement, most trucks have committed to using Selective Catalytic Reduction system (SCR). SCR reduces nitrogen oxide emissions by converting it into harmless nitrogen through the use of a special catalytic converter and a non-explosive, non-toxic, non-flammable, water-based urea solution called Diesel Exhaust Fluid (DEF).

As a result of the new EPA regulation, all truck OEMs have been using a form of NO_x emission reduction for their fleets since 2010. Two methods have been deployed to meet the stringent requirements: Exhaust Gas Recirculation (EGR) and Selective Catalytic Reduction (SCR) – with SCR having been the most widely used application.

Selective Catalytic Reduction (SCR)

SCR reduces tailpipe nitrogen oxide emissions by treating the exhaust stream with a spray of DEF, along with a catalyst that converts NO_x into nitrogen and water, which are harmless and present in the air.

To reduce NO_x, a small amount of DEF is injected directly into the exhaust upstream of a catalytic converter. The DEF vaporizes and decomposes to form ammonia (NH₃), which in conjunction with the SCR catalyst reacts with NO_x to convert the pollutant into nitrogen (N₂) and water (H₂O).

Exhaust Gas Recirculation (EGR)

NO_x formation is a function of the high combustion temperature in diesel engines. The hotter the combustion temperature, exponentially more NO_x is created from oxygen and nitrogen molecules. EGR reduces some of the nitrogen molecules by introducing cooled exhaust gas, which is lower in oxygen, into the intake system; thereby reducing the combustion temperature and lowering NO_x production.

Selective Catalytic Reduction (SCR):

- > Is a proven technology in Europe, Japan, and Australia and three years in North America
- > Delivers more power and a better torque than EGR technology does
- > Improves fuel economy (see table)
- > It requires less maintenance, and does not affect vehicle servicing and oil change intervals

SCR - The engine choice in 2013

When OEM engine manufacturers pursued compliance with the NO_x emission standards, SCR was the preferred alternative. One manufacturer, Navistar continued to explore the EGR solution. In mid-2012, the following announcement was made highlighting their plans for meeting the regulations moving forward.

Almost all of North America's Class VIII diesel trucks manufactured in 2013 will utilize the SCR technology further expanding the adoption and usage of DEF.

"Navistar announced in August 2012 that it will use Cummins engines and SCR technology to meet the U.S. EPA 2010 emissions regulations. International ProStar+ truck models with MaxxForce 13 engines and Cummins Emission Solutions SCR devices are expected to enter regular production in April 2013. The remaining line-up of Navistar heavy-duty trucks will move to using SCR technology throughout 2013."

Characteristics of DEF:

- > Weight = 9.2lbs/gallon
- > It is nontoxic, colorless, and odorless mixture of 32.5% urea and purified water.
- > It freezes below 12 degrees Fahrenheit; it must be protected from extreme cold during storage.
- > It is relatively stable at storage temperature of up to 84 degrees Fahrenheit.
- > It will last 1 year when stored between 10 and 90 degrees Fahrenheit. Exposing DEF to heat for an extended period of time will reduce its shelf life – if stored continuously at 90 degrees Fahrenheit, DEF shelf life is reduced to 6 months. Refer to the table below.
- > Approved and non-approved materials with DEF:
- > It does not form stable emulsions with fuel oils
- > It is a stable solution, even under extended time periods, if it is stored properly.

Diesel Exhaust Fluid (DEF)

The Product

Diesel Exhaust Fluid (DEF) is a urea-based solution that will be used by SCR systems. DEF is produced to an international standard (ISO 22241). It consists of 32.5% automotive-grade urea and 67.5% de-ionized water. The difference between agricultural-grade urea and DEF centers upon purity and concentration. Purity is essential to performance and working life of the SCR after-treatment system. Proper concentration is essential to the efficacy of the NO_x reduction process. DEF is less toxic than other automotive fluids, and not a hazardous substance under EPA regulations. It is safer to handle and transport.

Fuel Economy of Diesel Trucks, Pre-2010 Regulations (Miles per Gallon)*

	Class 4	Class 5	Class 6	Class 7	Class 8
2007-2009	14.3	12	9.7	7.4	6.1

Fuel Economy of Diesel Trucks, SCR-Equipped (Miles per Gallon)*

	Class 4	Class 5	Class 6	Class 7	Class 8
2009-2015	15	12.6	10.2	7.7	6.4

*Source: *Frost & Sullivan*

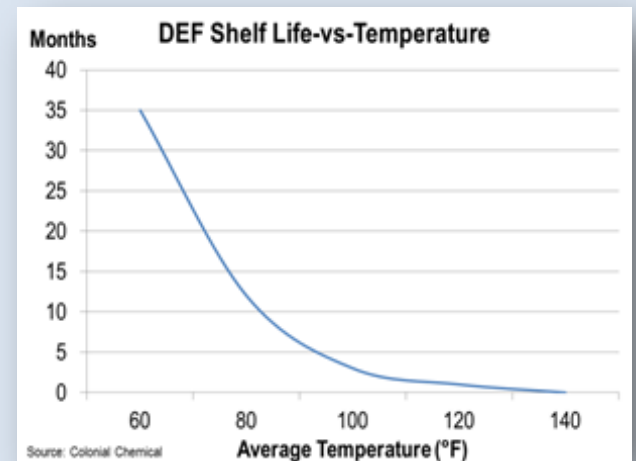
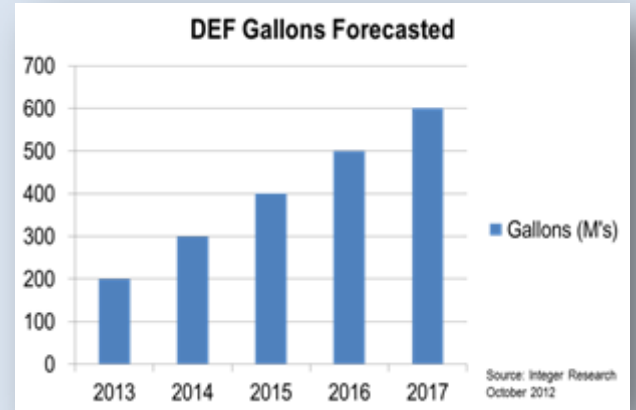


DEF Consumption

DEF consumption in North America continues to grow exponentially as new trucks come on-line with the SCR technology. Dosage rates for DEF continue in the 3-6% rate of diesel consumption and truck growth in the Class VIII segment has contributed to overall DEF growth. The graph highlights the total consumption of DEF projected through 2017 in millions of gallons.

The vast majority of DEF sales have come from bulk dispensing of DEF at travel plaza and local refueling locations. DEF is also available for sale in different size containers (*e.g.*, bulk, IBCs, or in palletized drums and jugs).

DEF costs are driven by the price of urea and the quantity of DEF purchased. Bulk DEF prices have ranged from \$2.50/gallon to \$3.25/gallon in 2012 with smaller size container prices ranging from \$4 - \$8 per gallon.



Application

SCR vehicles have been fitted with a tank to house DEF. At retailing sites, the filling procedure will be similar to that of diesel but with a lesser quantity, given that the dosing rate is 3-6% of diesel consumption.

DEF Storage can be done with underground storage tanks or above ground containers. The dispenser and the piping to each dispenser must be designed for the climate the dispenser is located. The space on the forecourt can be minimized by looking for equipment that combines the diesel and DEF fueling at a single point of fueling. This minimizes the footprint and increases the traffic flow at existing locations.

There are a number of different solutions on the market from hand pump type solutions to full bulk dispenser options combined with diesel in the same dispenser. It is imperative that the product has been designed for DEF compatibility and meets the needs of the climate it operates

A typical bulk dispenser for use at a truck stop or large central refueling facility can cost between \$15,000 and \$35,000 dollars. Diesel with DEF at the same fueling location has been the most common type of fueling dispenser minimizing the forecourt time for drivers as they complete their transactions.

Approved Material^{***}

Composite plastic (polyethylene or PVC)

Stainless steel

Non-recommended Materials

Aluminum, Bronze

Carbon Steel

Copper, Iron

Nickel, Zinc

^{***}ISO 22241 for more information on compatible materials, *Source: Integer Research October 2012*

Concerns

Mis-fueling has been a concern for some truck drivers and truck stop operators, but has to date been handled via driver education and the usage of optional nozzle adapters. These optional magnetic nozzle interlock solutions mandated in some countries, but not in the United States.

Truck drivers should also keep in mind that failure to refuel the DEF tank will cause the truck to exceed allowable NOx emissions. The EPA requires OEMs to ensure a visual or audible warning that alerts the driver when the DEF tank is running low (i.e., less than 2.5% of the DEF tank capacity). Once the tank is empty a de-rating of engine power will occur and eventually the truck will be restricted to travel at a maximum speed of 5 mph.

Lastly, if the SCR system detects poor quality DEF that inhibits the system from reducing NOx to the levels mandated by EPA, a warning lamp or message will illuminate. If the driver fails to remedy the problem within 500 miles or 10 hours, the maximum available engine torque will be reduced by 25%. If the driver fails to remedy the problem within 1000 miles or 20 hours, the vehicle speed will be restricted to no more than 5 mph. Similar driver inducements will be triggered by tampering activities (*e.g.*, disconnected DEF sensor or dosing valve, SCR wiring harness, NOx sensor or DEF quality sensor).

Mass Flow Meter

- > Universally accepted principle for measuring the mass flow of liquids and gases
- > Higher accuracy and repeatability than most flow meters
- > Measurement independent of viscosity and density changes
- > No filter necessary to protect meter
- > No moving parts – no wear and tear
- > No leakage possible inside the meter
- > Capable of measuring hot and cold fluid flow



Dispenser Considerations

When you get ready to invest in DEF dispensing equipment you should look at the following attributes before making your decision:

Corrosive nature of DEF:

Make sure the material is ISO 22241 compatible in order to prevent corrosion and thereby increase equipment uptime.

Crystallization of DEF at low temperature:

Choose equipment with heated-hose cabinet and specialized heater design. This will prevent the DEF from freezing up and/or clogging up.

Ease of payment (retail channel):

Look for payment integration. This will reduce the transaction time for the truck driver.

Enhanced system accuracy and reliability:

Look for equipment with a **mass flow meter**. It has no moving parts and therefore the wear is minimal. You will have maximum uptime and reduced service costs.

Installation Examples



Above Ground piping to Dispenser



Retrofit kit to existing dispenser



Below ground submersible



Below ground piping to dispenser

Sources & Informational Sites:

SCR Facts <http://truthaboutscr.com>

DEF Locator <http://afdcdev.nrel.gov/afdc/locator/index.php?apptype=def&mode=basic>

Dept. of Energy <http://www.afdc.energy.gov/afdc>

EPA Clean Diesel Campaign Funding <http://www.epa.gov/otaq/eparecovery/index.htm>

Diesel Technology Forum <http://www.dieselforum.org>

SCR & DEF Information <http://www.factsaboutscr.com>

SCR Information <http://truckscr.com>

DEF demand: <http://www.discoverdef.com>

American Trucking Associations: <http://www.truckline.com>