

# Selective Catalytic Reduction (SCR) and Diesel Exhaust Fluid (DEF)

Training Module



**Filtration**



Filtration

CUMMINS FILTRATION

## DEF – SCR Training Module

Welcome to the Cummins Filtration DEF – SCR training module.

DEF & SCR systems are key to Cummins meeting the 2010 On-Highway emissions requirements.

Many other engine manufacturers have selected SCR as their 2010 emission strategy.

Consequently, DEF will be an integral part of their solution as well.



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FILTERS. PUMPS. SYSTEMS.

## DEF – SCR Training Module

The following training module will introduce you to the basic aspects of SCR technology, providing an overview of the Selective Catalytic Reduction (SCR) system and Diesel Exhaust Fluid (DEF).

## DEF – SCR Training Module Objectives:

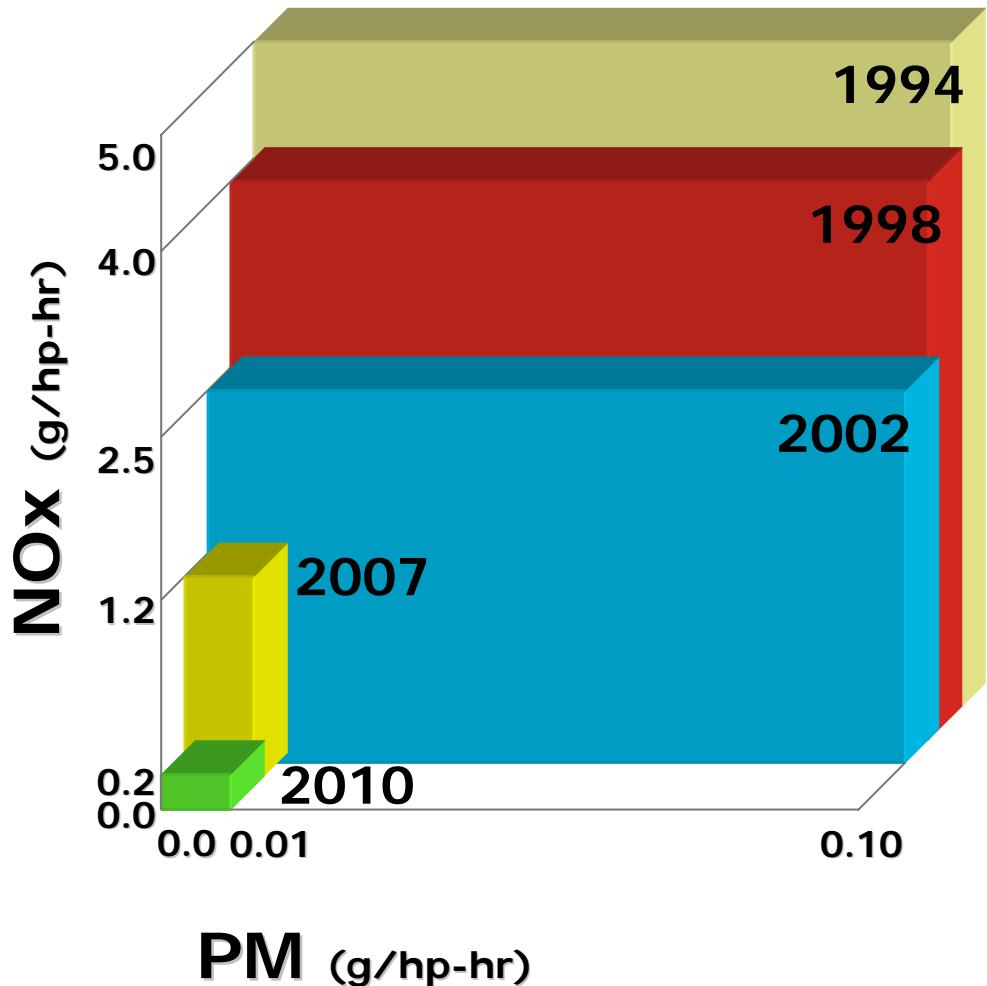
- Objective 1: Become familiar with DEF and SCR systems
- Objective 2: Gain further knowledge of DEF
- Objective 3: Understand Cummins Filtration's role in DEF supply

Objective 1: Become familiar with DEF and SCR systems

## Objective 1: Become familiar with DEF and SCR systems

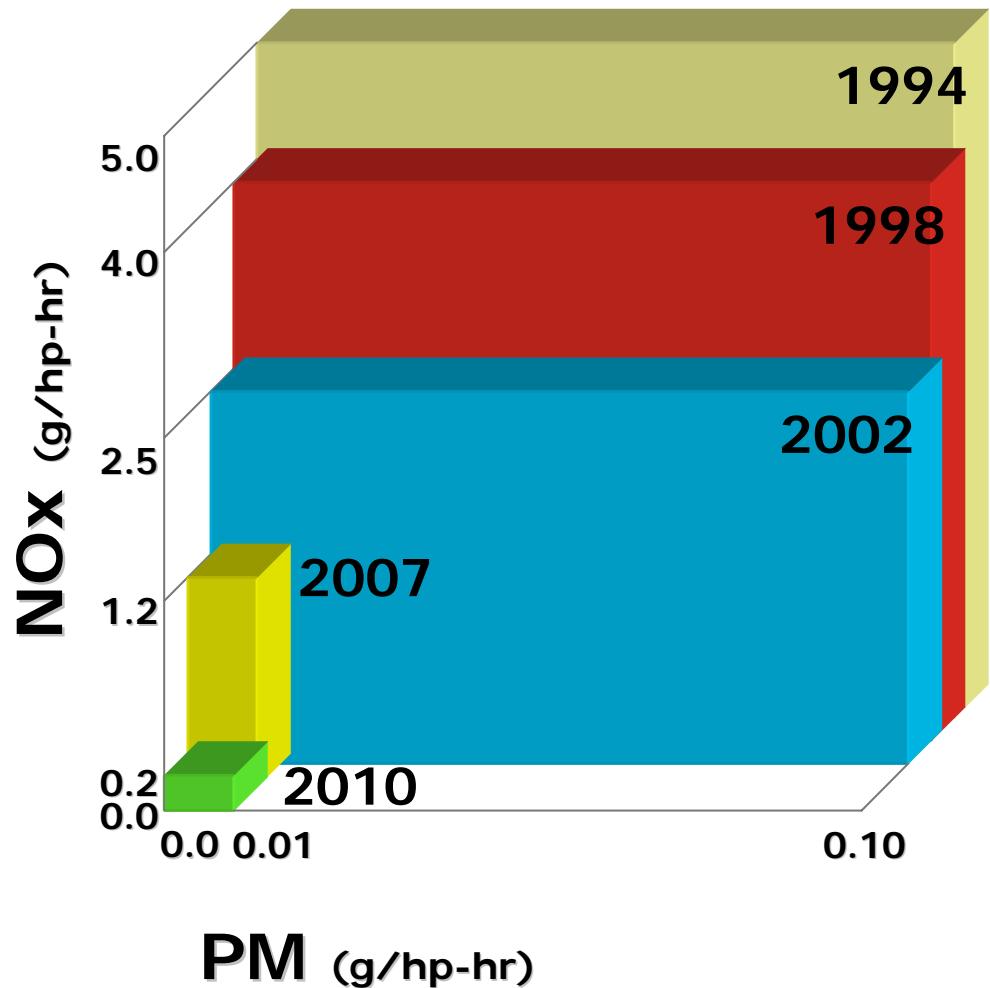
2010 heavy-duty emissions standards for North America are:

- 0.2 g/HP-hr NOx
- 0.01 g/HP-hr Particulate Matter (PM).



## Objective 1: Become familiar with DEF and SCR systems

This is a reduction of emissions by 98% since the late 1980's.





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FILTERING YOUR WORLD

## Objective 1: Become familiar with DEF and SCR systems

Cummins has committed to providing a complete lineup of certified and compliant on-highway engine products that will meet the 2010 emissions standards.



## Objective 1: Become familiar with DEF and SCR systems

For 2010, Cummins is enhancing the technology that it currently has in the marketplace. Building on its successes with cooled Exhaust Gas Recirculation (EGR) introduced in 2002 and the Cummins Particulate Filter introduced in 2007, Cummins will meet the 2010 emissions standards with the addition of Nitrogen Oxide (NOx) aftertreatment using Selective Catalytic Reduction (SCR) technology.





## Objective 1: Become familiar with DEF and SCR systems

SCR technology uses a urea based chemical called diesel exhaust fluid (DEF) and a catalytic converter to significantly reduce oxides of nitrogen (NOx) emissions.



### SCR Catalyst

- Very high efficiency
- Thermal stability





## Objective 1: Become familiar with DEF and SCR systems

SCR technology is not new to Cummins or Cummins Filtration. In 2006, Cummins launched its midrange engines certified to the Euro 4 standard using SCR for commercial vehicle applications in Europe.



### SCR Catalyst

- Very high efficiency
- Thermal stability



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## Objective 1: Become familiar with DEF and SCR systems

Cummins has built and shipped over 50,000 SCR engines to date.

Cummins Emission Solutions has built and shipped over 250,000 SCR systems.



### SCR Catalyst

- Very high efficiency
- Thermal stability





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## Objective 1: Become familiar with DEF and SCR systems

Cummins Filtration has offered DEF for stationary applications for over 5 years.



### SCR Catalyst

- Very high efficiency
- Thermal stability

## Objective 1: Become familiar with DEF and SCR systems

DEF is injected into the hot exhaust gas stream where it vaporizes and decomposes to form ammonia and carbon dioxide. Ammonia ( $\text{NH}_3$ ) is the desired product which in conjunction with the SCR catalyst, converts the NOx to Nitrogen ( $\text{N}_2$ ) and water ( $\text{H}_2\text{O}$ ).



### SCR Catalyst

- Very high efficiency
- Thermal stability

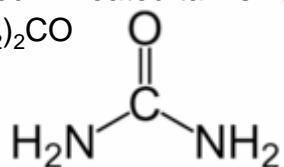
# Selective Catalytic Reduction Components And The Chemical Process That Occurs Inside The SCR Device

## ■ Chemistry is well understood and controllable

**1**

### DEF Injection

- Small quantity of DEF injected
- Proportional to NOx rate
- 32.5% solution in water, freezing point = 11° F
- Stored in heated tanks
- $(\text{NH}_2)_2\text{CO}$

**2**

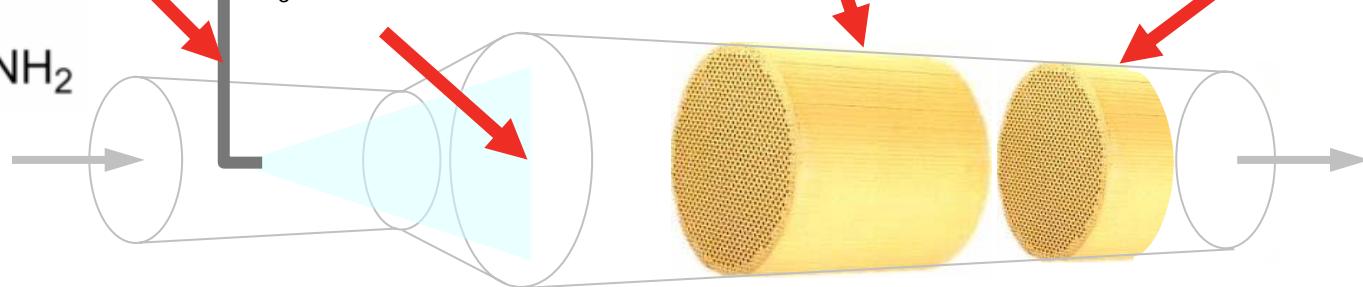
### Hydrolysis

- When the DEF is injected into hot exhaust gas, it vaporizes and decomposes to form ammonia and carbon dioxide

**3**

### NOx Catalysis

- NO and  $\text{NO}_2$  react with ammonia over a catalyst to form nitrogen and water vapor

**4**

### Ammonia Slip

- Any trace amounts of ammonia remaining after reaction with NOx is broken down to nitrogen
- Maximum tailpipe ammonia 10PPM

Objective 1: Become familiar with DEF and SCR systems

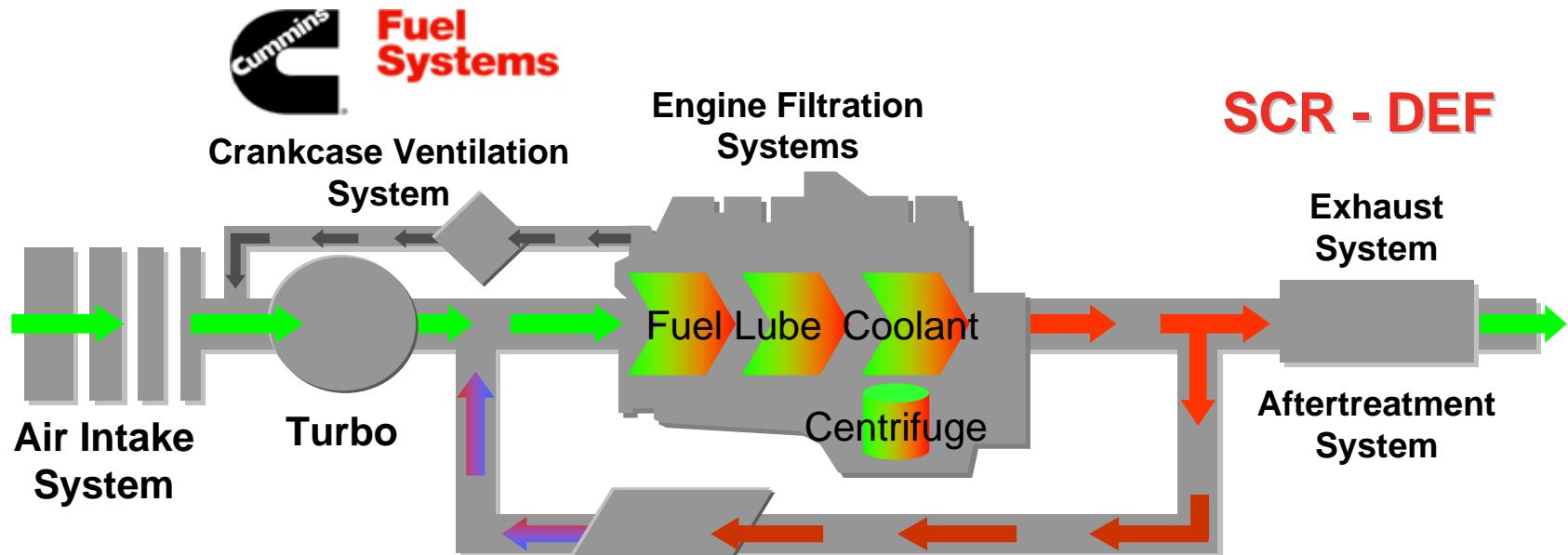
**SCR maximizes combustion efficiencies allowing the engine to be fully optimized, providing:**

- Improved engine performance and drivability
- Up to 5% fuel economy advantage over '07 Cummins Heavy Duty engines
- Lower contaminants in both exhaust and lube system
- Fewer Diesel Particulate Filter (DPF) regenerations



## Objective 1: Become familiar with DEF and SCR systems

The combination of combustion design, fuel systems, air handling, aftertreatment, filtration and electronic controls, all in-house core technologies, puts Cummins in a very unique and strong market position.



**Turbo  
Technologies**



**Emission  
Solutions**

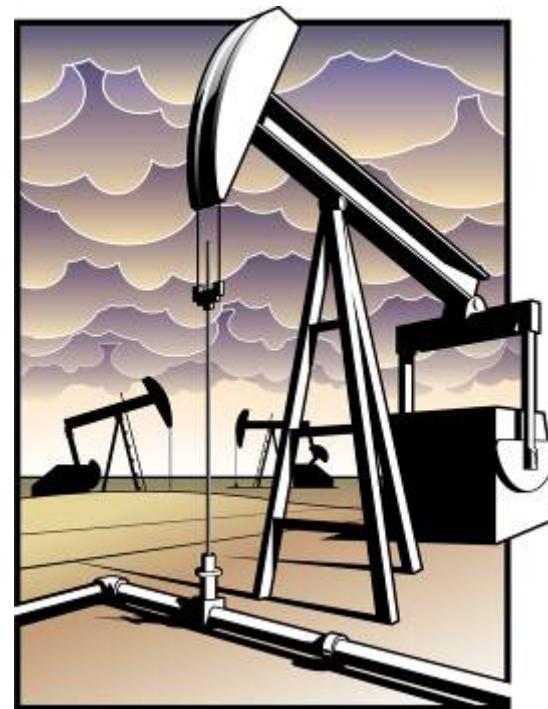


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Objective 2: Gain further knowledge of DEF

## Objective 2: Gain further knowledge of DEF

Diesel exhaust fluid (DEF) is the reactant necessary for the functionality of the SCR system.



DEF is produced from natural gas, coal or other petroleum products.

## Objective 2: Gain further knowledge of DEF

Pure urea is solid at room temperature. DEF is prepared by dissolving solid urea to create a 32.5% solution in deionized water.



## Objective 2: Gain further knowledge of DEF

DEF has high purity requirements which are defined by the German Institute of Standardization DIN 70700 and the International Organization for Standardization ISO 22241-1.

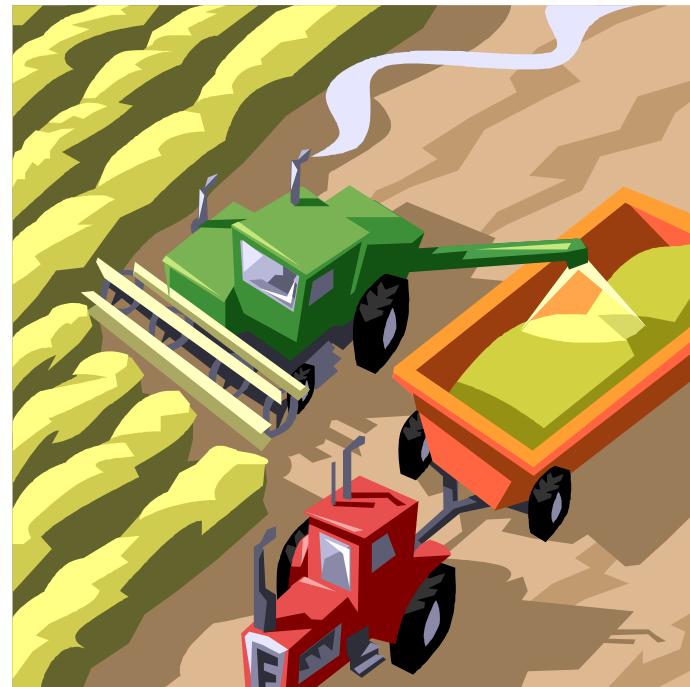


There is also an American Petroleum Institute (API) certification.

## Objective 2: Gain further knowledge of DEF

While urea is used commonly in agriculture, the formula used in an SCR system as DEF is a highly purified specially made liquid.

End-users and operators will not be capable of producing their own DEF to these strict standards.



## Objective 2: Gain further knowledge of DEF

A 32.5% solution of DEF will freeze at 12 degrees F, (-11 C).

This is the ideal solution as it allows the lowest freeze point. In the event the solution does freeze, the urea and water will thaw at the same rate, ensuring the solution does not become diluted.



## Objective 2: Gain further knowledge of DEF

The installation of an SCR system will provide for heating of the DEF tank by temperature controlled coolant heat. The DEF line from the tank to the doser will be heated by temperature controlled electrical heat tape.

The system is designed to operate properly in cold climates.



Cummins has seen  
unaided cold starts at -40°  
in under 2 seconds!

## Objective 2: Gain further knowledge of DEF

It is important to note, that even in the event that the DEF supply is frozen, (in a vehicle) it will NOT impact the operators ability to start up and continue normal operation of the vehicle.



**Note: If DEF freezes, it can be thawed and used. DEF is not damaged or destroyed from being frozen**

## Objective 2: Gain further knowledge of DEF

- Shelf life of DEF is a function of ambient storage temperature
  - Not a concern even in the harshest climates
- ISO Spec 22241-3 details the Storage, Handling and Shelf Life minimum expectations



**DEF stored at a constant temperature of 95 deg F had a shelf life of over 6 months!**

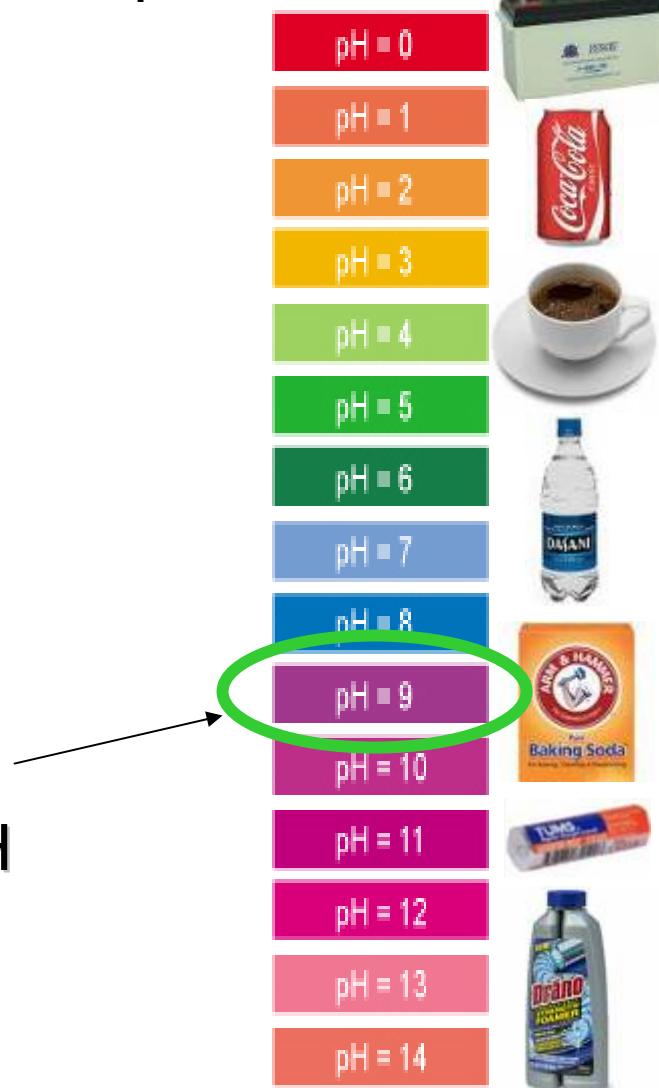
## Objective 2: Gain further knowledge of DEF

- In order to maintain maximum shelf life, Cummins recommends DEF be stored at under 86° F (30° C)
- In order to avoid freezing, Cummins recommends DEF be stored at above 12° F (-11° C)



# Diesel Exhaust Fluid - Properties

- DEF is safe to handle and store
  - Non-toxic and non-polluting
  - Non-flammable
  - Stable and colorless
  - Non-hazardous
  - Does not require special handling
- When stored at extreme temperatures, neither DEF nor Urea become toxic
- DEF is slightly alkaline with a pH of approximately 9



## Objective 2: Gain further knowledge of DEF

DEF consumption is expected to be approximately 2% of fuel consumption, dependant on vehicle operation, duty cycle, geography, ratings etc.



# Diesel Exhaust Fluid - Operation

## Example: Heavy Duty

- Annual miles for average truck = 120,000
- mpg for average truck = 6 mpg
- $120,000 / 6 \text{ mpg} = 20,000 \text{ gallons diesel fuel per year}$
- DEF usage @ 2% of fuel consumption = 400 gallons of DEF/year
- $400 \text{ gallons} / 20 \text{ gallon tank (average size)} = 20 \text{ DEF fill-ups/year}$



# Diesel Exhaust Fluid - Operation

## Example: Medium Duty

- Annual miles for average truck = 50,000
- mpg for average truck = 8 mpg
- $50,000 \text{ miles} / 8 \text{ mpg} = 6,250 \text{ gallons}$   
diesel fuel per year
- DEF usage @ 2% of fuel consumption  
= 125 gallons of DEF/year
- 125 gallons / 10 gallon tank (average size) = **13 DEF fill-ups/year**



A truck averaging 8 mpg can  
expect to travel approximately 400  
miles on 1 gallon of DEF!

# Diesel Exhaust Fluid - Operation

- DEF level gauge incorporated with all fuel gauges
- Multiple step notification system as to remaining DEF
- At no time is the vehicle ever shut down due to no DEF remaining





Filtration

# Diesel Exhaust Fluid - Operation

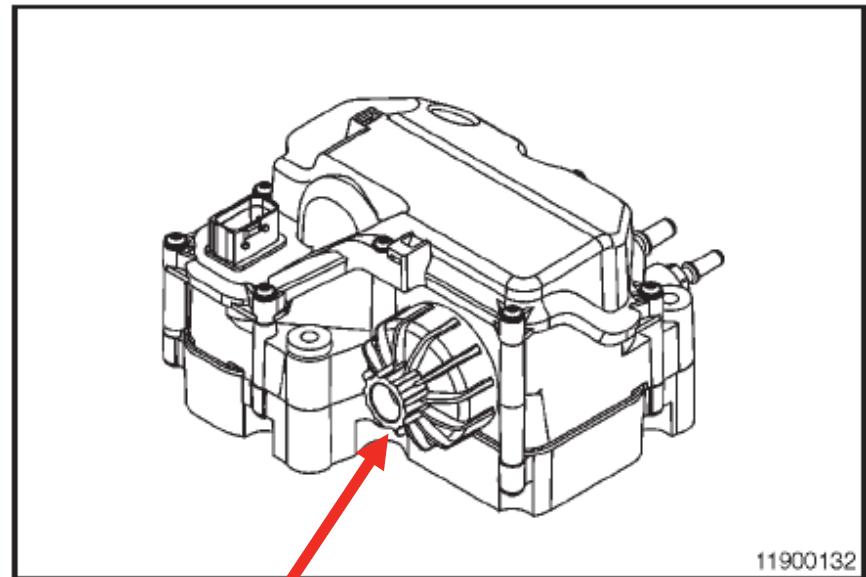
The function of the SCR system is dependant on a high quality, 32.5% DEF solution:

- NOx sensors are in place to ensure good quality DEF is always used

**NOx  
Sensors**

# Diesel Exhaust Fluid - Maintenance

- On Cummins engines, maintenance is a simple filter change every 200K miles, 322K kilometers or 5000 hours.
- This DEF dosing unit filter will be available for order from your local Cummins Distributor.

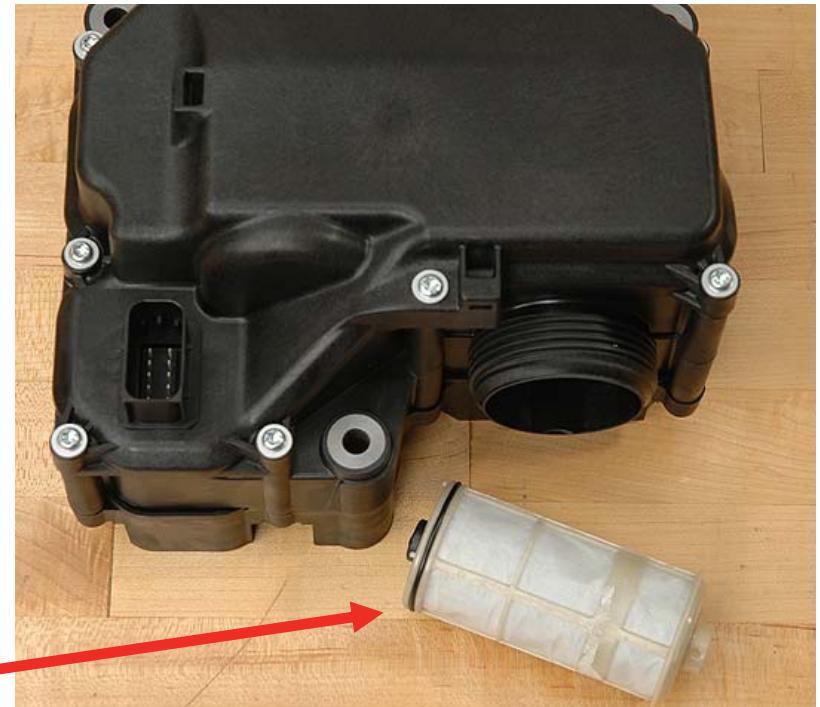
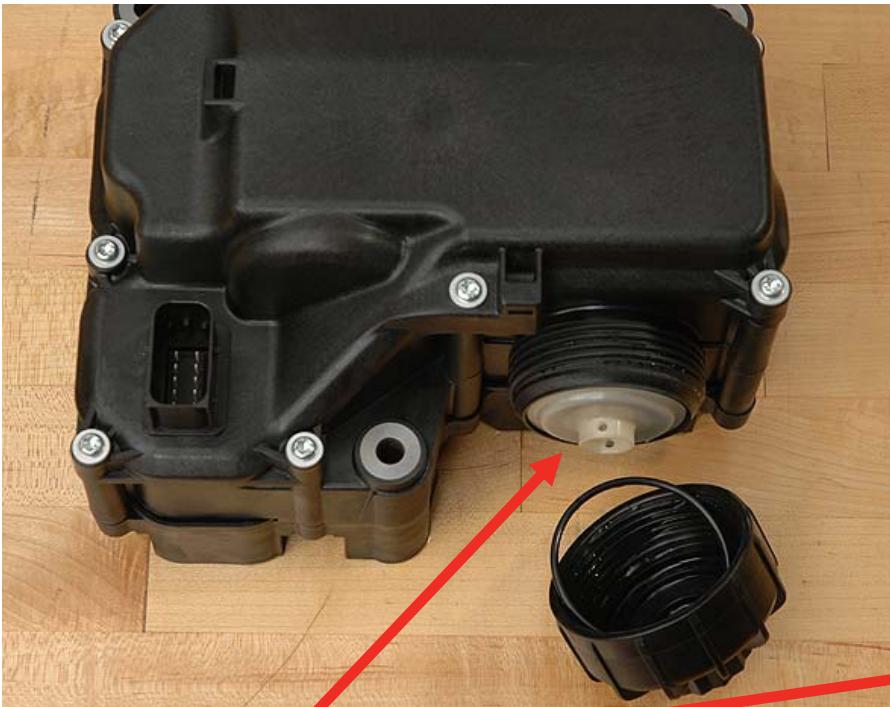


**DEF Dosing Unit  
Filter Location**



Filtration  
DEF Filter Maintenance

# Diesel Exhaust Fluid - Maintenance



The filter is located under a twist off cap in the DEF tank



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Cummins Filtration

Objective 3: Understand Cummins  
Filtration's role in DEF supply

## Objective 3: Understand Cummins Filtration's role in DEF supply

Cummins Filtration has been providing DEF for use in stationary engines since 2003, formerly sold under the StableGuard Urea name.



## Objective 3: Understand Cummins Filtration's role in DEF supply

Cummins Filtration offers DEF through our extensive distribution network, which includes over 20,000 locations with nearly 8,000 retailers in North America.

**Fleetguard DEF is available for OEM first-fill as well as Aftermarket sales.**



## Objective 3: Understand Cummins Filtration's role in DEF supply

Fleetguard DEF meets ISO22241 specifications and is certified by API.





Filtration

Cummins Filtration

## Objective 3: Understand Cummins Filtration's role in DEF supply

Fleetguard DEF is available in bulk, plastic and disposable totes, plastic drums, and smaller container sizes.



## Objective 3: Understand Cummins Filtration's role in DEF supply

Bulk delivery is available directly from our blending facilities for added convenience, and will be available throughout North America.



Minimum tanker loads  
are 5,000 gallons, FOB  
blending location.

**Objective 3: Understand Cummins Filtration's role in DEF supply**

## **DEF Products include:**

- CC36057 – Bulk
  - CC36056 – Plastic 330 gal. tote
  - CC36055 – Disposable 275 gal. tote
  - CC36054 – Plastic 55 gal. drum
  - CC36053 – 5 gal. bottle
  - CC36052 – 2.5 gal. bottle
  - CC36051 – 1 gal. bottle
  - 3918034S – Valve/Cutter Kit (for disposable tote)





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DEF Dispensing Kits

## Cummins Filtration DEF

All-in-One Kits for DEF Dispensing  
include motor, pump, nozzle, hose, and  
adapter

- 3970399 – Tote Electric Kit
- 3970398 – Tote Air Kit
- 3970403 – Drum Electric Kit
- 3970402 – Drum Air Kit
  
- Optional flow meter - 3970397

All materials meet ISO requirements for  
DEF compatibility





# Diesel Exhaust Fluid Pricing

- DEF pricing is driven by various market factors
  - Natural gas prices are only one driver of DEF pricing
  - Current pricing is based on low volume
  - The growing demand and increasing availability for DEF will influence competitive pricing
- Pricing of bulk DEF will be around the price of diesel, in the \$2 - \$3 per gallon range
- Smaller package pricing will vary based upon size and delivery method



Filtration

# Learn More about DEF

- To learn more about DEF, there are several helpful tools on [cumminsfiltration.com](http://cumminsfiltration.com):

- Brochure, LT15618
- DEF Usage Calculator
- DEF Fact Sheet, MB10033
- DEF Informational Video
- DEF MSDS Sheet

- Or visit these websites:
  - [everytime.cummins.com](http://everytime.cummins.com)
  - [factsaboutscr.com](http://factsaboutscr.com)
  - [truthaboutscr.com](http://truthaboutscr.com)
  - [truckscr.com](http://truckscr.com)

The screenshot displays three main sections of the Cummins Filtration website:

- DEF Product Page:** Shows a large image of DEF packaging (barrels and jugs) with the heading "Fleetguard Diesel Exhaust Fluid (DEF) Aqueous Urea Solution for Your SCR NOx Reduction Systems".
- DEF Facts Sheet:** Titled "Fleetguard Diesel Exhaust Fluid (DEF) Facts", it includes a diagram of an SCR system and answers to frequently asked questions.
- DEF Usage Calculator:** A form-based calculator for estimating DEF consumption and fill-ups per year, requiring inputs like vehicle type, number of vehicles, annual miles, average MPG, average DEF tank size, and DEF consumption per gallon.