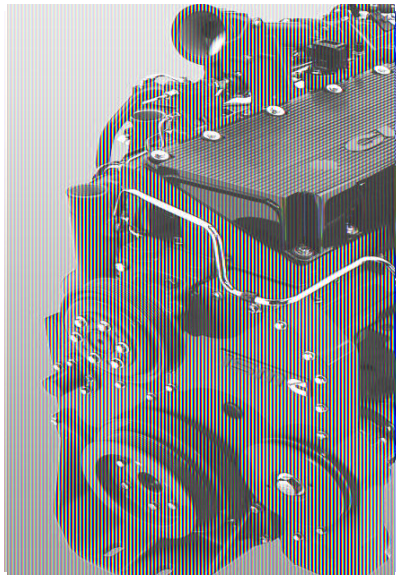
Bosch Airless SCR System

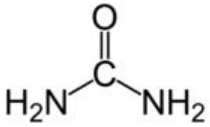


Selective Catalytic Reduction

- The DEF dosing system operates on the principle of Selective Catalytic Reduction (SCR).
- Selective catalytic reduction is a NOx control method for diesel engine exhaust.
- The process involves the injection of Urea into the exhaust over a catalyst.
- The ammonia reacts with NOx and produces harmless nitrogen (N_2) and water (H_20).

1 Urea Injection

- Small quantity of urea injected
- Proportional to NOx rate
- $(NH_2)_2CO$



2 Hydrolysis

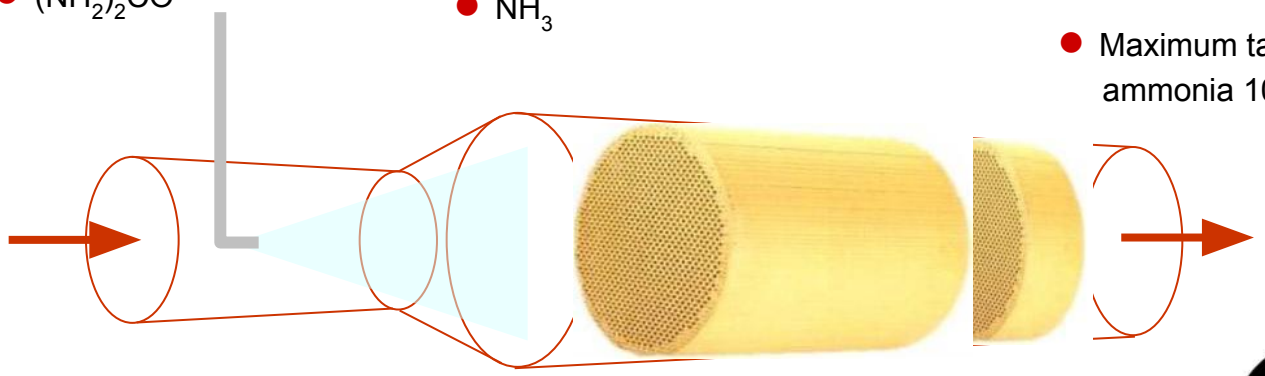
- Urea breaks down by hydrolysis to form ammonia
- NH_3

3 NOx Catalysis

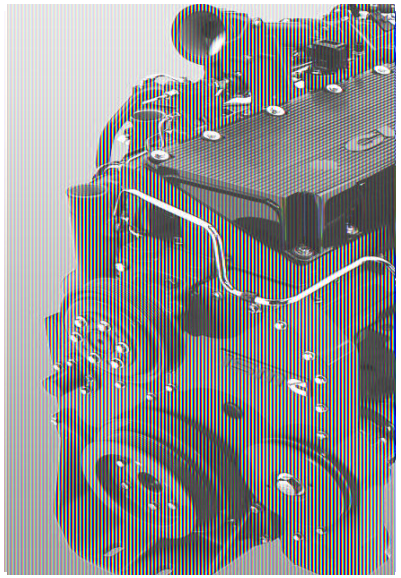
- NO and NO_2 react with ammonia over a catalyst to form nitrogen and water vapor

4 Ammonia Slip

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



DEF - Diesel Exhaust Fluid



Diesel Exhaust Fluid (DEF)

- Diesel Exhaust Fluid (DEF) is 32.5% strength urea water solution with high purity requirements.
  - Nontoxic and nonpolluting
  - Nonflammable
  - Stable and colorless
  - Weak ammonia smell
  - Leaks are easy to find
    - Water evaporates and urea crystals remain
  - DEF freezes at approximately -11°C [12°F]

WARNING

It is unlawful to tamper with or remove any component of the aftertreatment system. It is also unlawful to use diesel exhaust fluid (DEF) that does not meet the specifications provided or to operate the vehicle/equipment with no diesel exhaust fluid (DEF).

WARNING

Diesel exhaust fluid (DEF) contains urea. Do not get the substance in your eyes. In case of contact, immediately flush eyes with large amounts of water for a minimum of 15 minutes. Do not swallow internally. In the event the diesel exhaust fluid is ingested, contact a physician immediately. Reference the Materials Safety Data Sheet (MSDS) for additional information.

For further information, reference the diesel exhaust fluid manufacturer's Material Safety Data Sheet.

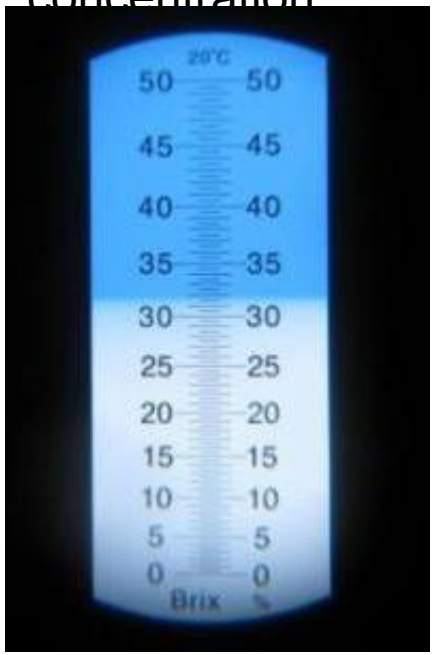
DEF Specification

- DEF must meet the International Standard ISO 22241-1 for diesel engines. There is no acceptable substitute.
  - Some locations may reference the DIN 70070 standard. Diesel exhaust fluid specification limits of this standard are identical to ISO 22241-1.
- For engines using SCR operating in the United States and Canada, it is also strongly recommended that the DEF used be certified by the American Petroleum Institute (API). This would be indicated by a symbol on the container/dispensing system, as shown.

- Service Bulletin 4021566: Diesel Exhaust Fluid Specifications for Cummins® Selective Catalytic Reduction Systems
  - The purpose of this bulletin is to help the user understand correct specifications, usage, and handling of DEF.

DEF Service Tool

- To test the concentration of the diesel exhaust fluid, use the Cummins® DEF refractometer, Part Number 4919554.
- When using the DEF refractometer service tool, the acceptable DEF measurement specification is 32.5 +/- 1.5 percent.
  - This specification takes into consideration the refractometer tool tolerances, variability, and calibration when measuring DEF concentration



Service Manual 4310608

011-056 Exhaust System Diagnostics

CAUTION

Never attempt to create diesel exhaust fluid by mixing agricultural grade urea with water. Agricultural grade urea does not meet the necessary specifications required and the aftertreatment system may be damaged.

CAUTION

Never add water or any other fluid besides what is specified to the diesel exhaust fluid (DEF) tank. The aftertreatment system may be damaged.

CAUTION

Do not add any chemicals/additives to the diesel exhaust fluid in an effort to prevent freezing. If chemicals/additives are added to the diesel exhaust fluid, the aftertreatment system may be damaged.

DEF Storage Recommendations

- Shelf Life:
  - The following conditions are ideal for maintaining diesel exhaust fluid quality and shelf life during prolonged transportation and storage:
    - Storage temperature between -5°C to 25°C [23°F to 77°F]
    - Store in sealed containers to reduce the possibility of contamination
    - Avoid direct sunlight.
  - In these conditions, diesel exhaust fluid has a minimum expected shelf life of 18 months.
    - However, each 5°C [9°F] increment above recommended temperatures reduces shelf life by 6 months
    - for example 30°C [86°F] = 12 month shelf life, 35°C [95°F] = 6 month shelf life, etc.
- Storage:
  - Long term storage in a vehicle (in excess of 6 months) is **not** recommended.
  - If long term storage is necessary, periodic testing of the diesel exhaust fluid is recommended to be performed to make sure the concentration does **not** fall out of specification. Reference the Testing section of this service bulletin.
- For detailed information on handling, transportation, and storage, reference ISO 22241-3.

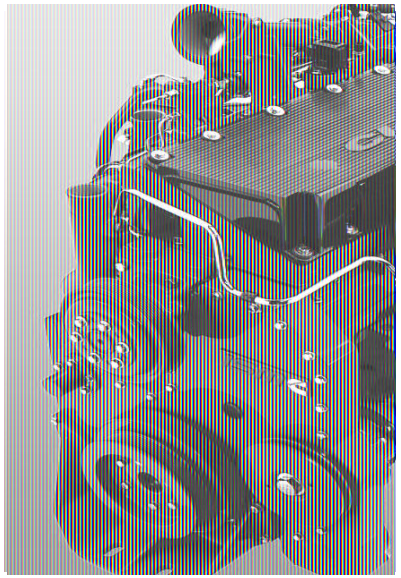
Cleanliness Practices

- Materials that come into contact with diesel exhaust fluid must be free from any contamination, oil, fuel, dust, detergents, and any other chemicals.
  - NOTE: Spilled diesel exhaust fluid, if left to dry or wiped away with a cloth only, will leave a white residue. Failure to clean the spilled diesel exhaust fluid from a surface may result in an incorrectly diagnosed leak of the diesel exhaust fluid dosing system.
- Before the use of containers, funnels, etc. that will be used to dispense, handle, or store diesel exhaust fluid, make sure to wash them thoroughly to remove any contaminants and then rinse with distilled water.
  - NOTE: Do not use tap water to rinse components that will be used to deliver diesel exhaust fluid. Tap water will contaminate the diesel exhaust fluid. If distilled water is not available, rinse with tap water and then rinse with diesel exhaust fluid.

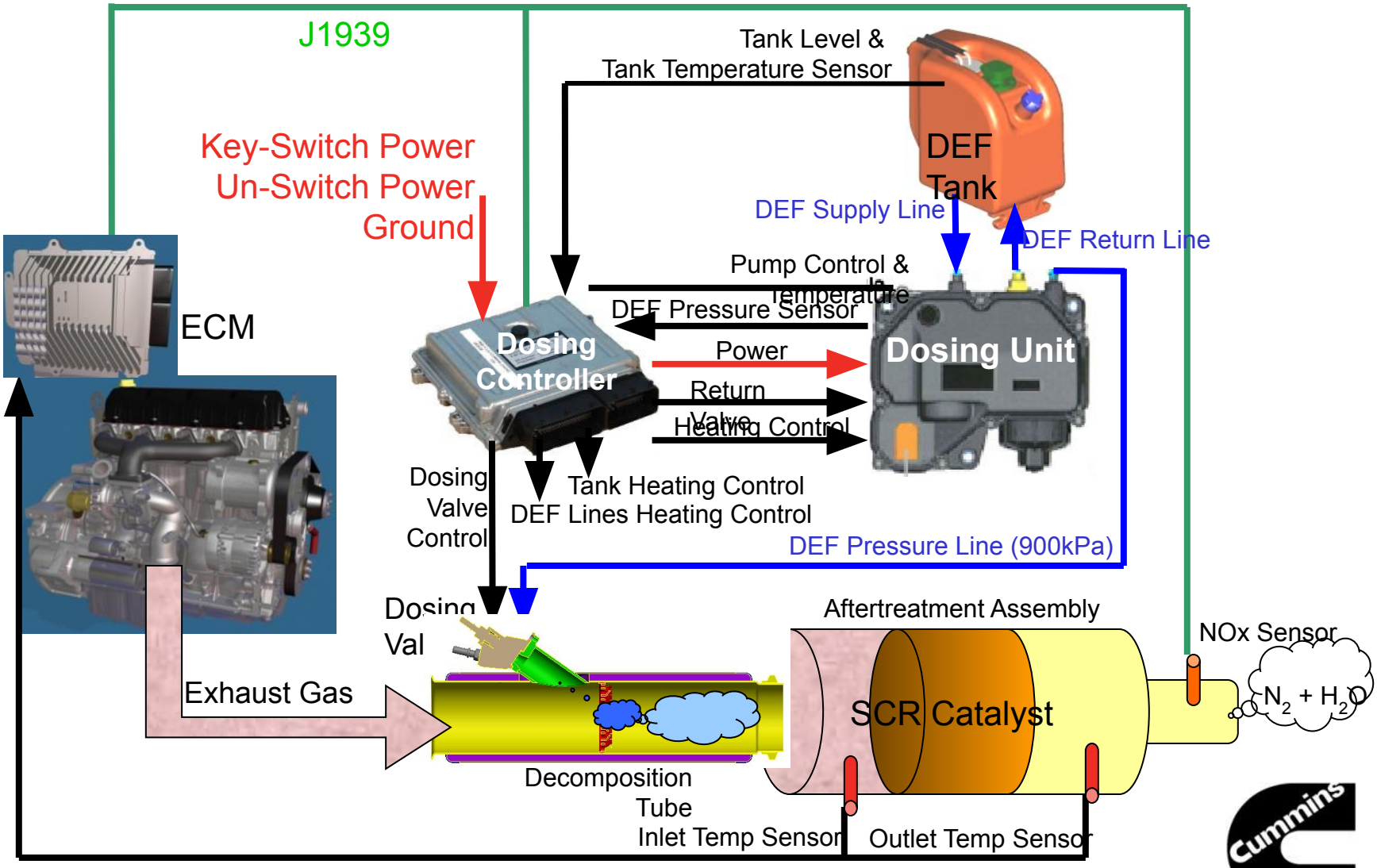
Disposal and Cleaning of DEF

- If spillage occurs, the diesel exhaust fluid should be either transferred into a suitable container, or covered using an absorbent material and then disposed of according to local environmental regulations. The container **must** be labeled correctly.
- Do **not** empty into the drainage system.
- Do **not** empty/release into surface water.
- Very small amounts of diesel exhaust fluid can be rinsed away with a large volume of water.

System Components



System Components



DEF Controller

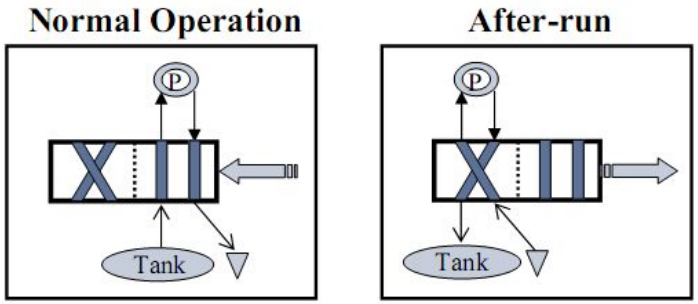
- DEF Controller controls the functions of the aftertreatment system and communicates with the engine ECM via the J1939 data link.
  - Controls dosage rates by commands the DEF dosing unit and the DEF dosing valve to purge, prime, and maintain dosing, while monitoring ambient conditions.
  - DEF Controller also controls any necessary heating to defrost the dosing system.
  - Any faults that are viewed by the aftertreatment DEF control module are communicated to the ECM.
- 86-pin and 53-pin connectors.
- Do not unplug connector when vehicle batteries are connected.

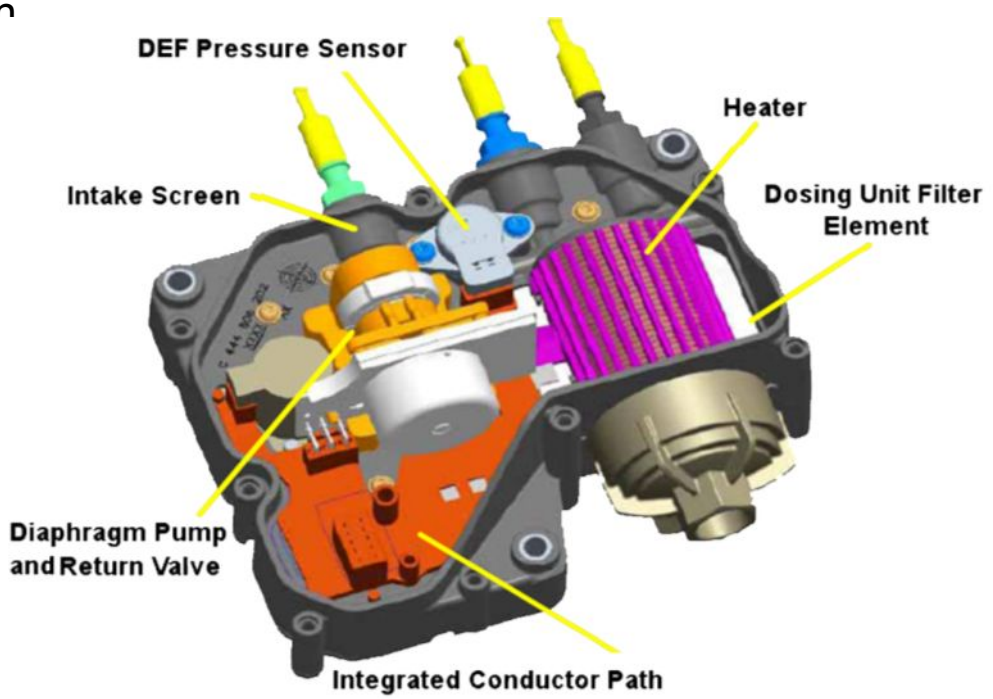
DEF Dosing Unit

- The pumping mechanism of the dosing system.
  - Draws DEF through its suction port and filters it.
  - Then pressurizes the DEF and supplies it to the DEF dosing valve at constant pressure (900 kPa).
    - It does **not** meter the amount of DEF to be dosed.
  - Any unused DEF is returned to the DEF tank through the return port.

DEF Dosing Unit (Cont.)

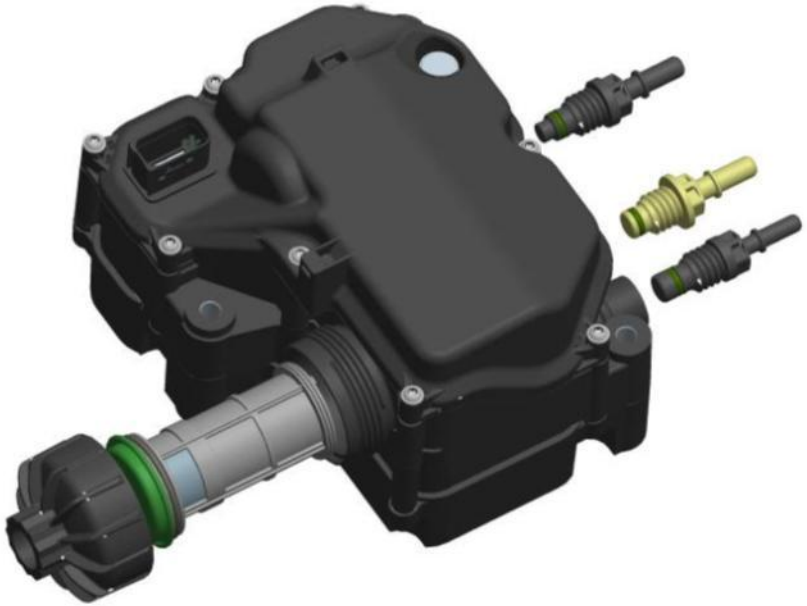
- DEF Pressure Sensor:
  - Measure actual DEF pressure.
- Diaphragm Pump:
  - Driven by electrical motor.
- Return Valve:
  - Allows purging of DEF lines with uni-directional pump.
- Temperature Sensor:
  - Same PWM signal line used to control pump flow and transmit temperature.
  - Only used before system primir
- Build in heater.





DEF Dosing Unit Filter

- A 10-micron filter designed to prevent foreign objects, that may be suspended in the DEF, from entering the dosing system.
  - Debris can cause permanent damage and premature failure to either the DEF Dosing Unit or the DEF Dosing Valve.
- DEF Dosing Unit Filter is a maintenance item.

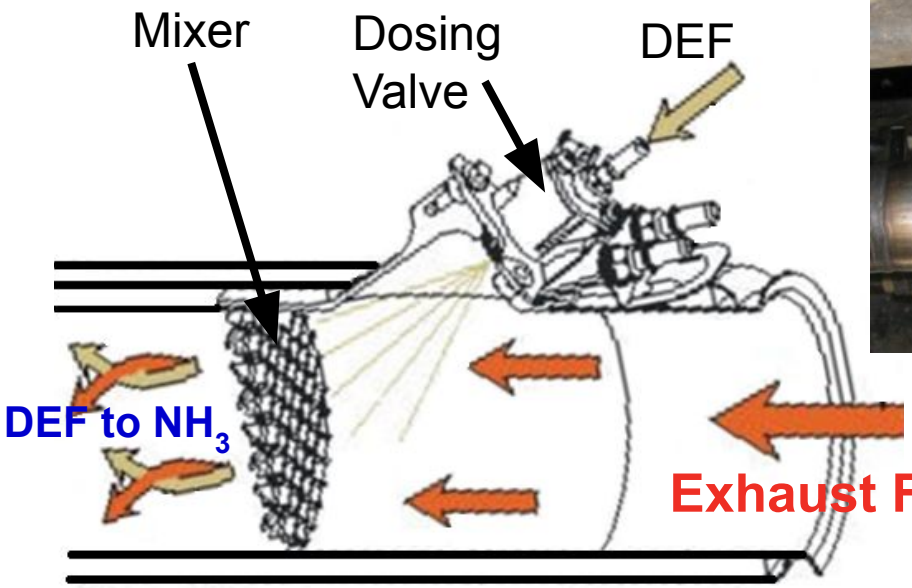


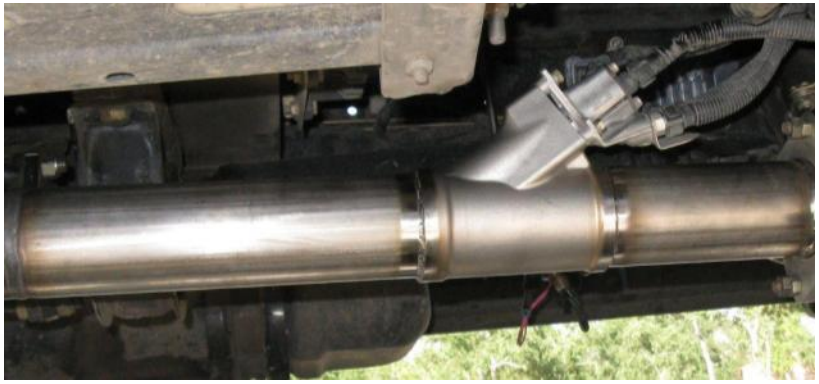
DEF Dosing Valve

- Located in the decomposition pipe.
- DEF dosing valve is controlled by the DEF controller and sprays the correct amount of DEF into the exhaust stream, as required.
- Engine coolant is supplied to the DEF dosing valve to keep the valve cool and operable.

Decomposition Tube

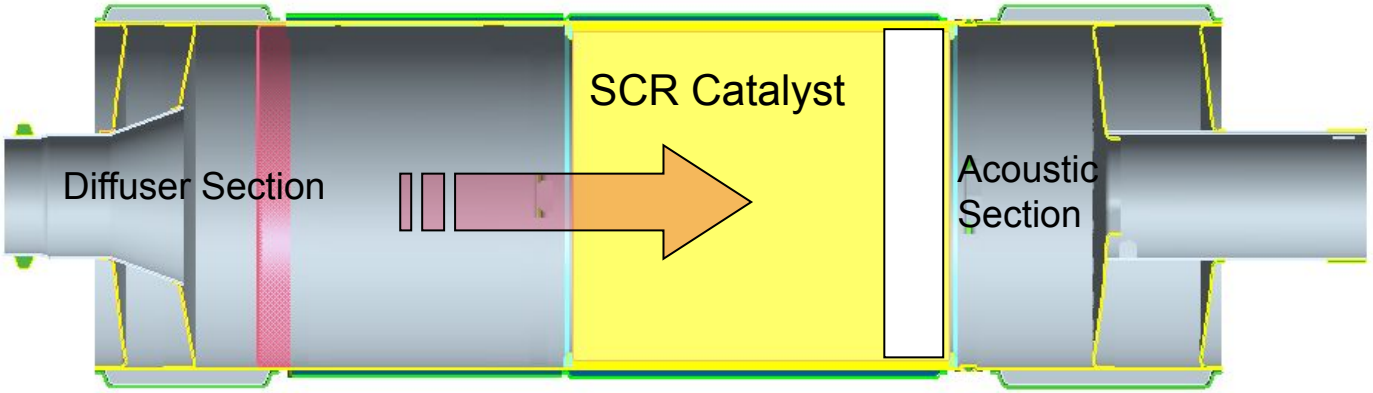
- Provides the mounting of Dosing Valve, and converts DEF into ammonia.
  - Contains a mixer to help distribute the DEF evenly in the exhaust stream, to convert DEF into ammonia.





Aftertreatment Assembly (SCR Catalyst)

- Sometimes referred to as the Exhaust Gas Processor (EGP).
- Different sizes available to suit application.
- Contains:
  - Diffuser & Acoustic sections.
  - SCR Catalyst
  - NH_3 Slip Catalyst (Only for E5 application)
  - Mounting bosses for inlet, outlet temperature and NOx sensors
- Handle with care – catalyst is ceramic



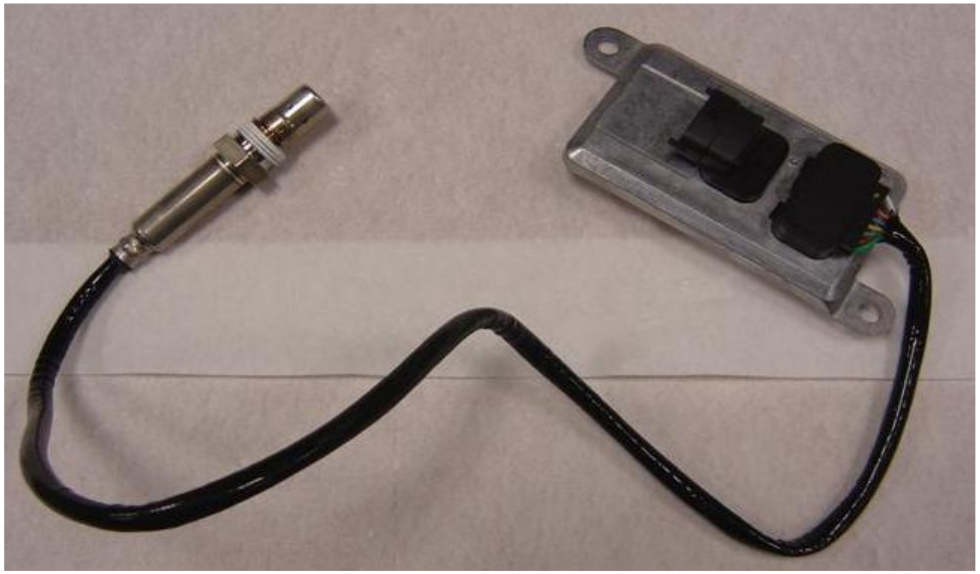
NH_3 Slip Catalyst (Only for E5)

SCR Catalyst

- A ceramic catalyst substrate with precious metal wash coat.
  - Vanadium Pent-oxide - V_2O_5
    - Vanadium Pentoxide has been determined by the State of California to cause cancer.
    - Always wear protective gloves, dust mask, and eye protection when handling the catalyst assembly.
  - Tungsten Tri-oxide - WO_3
  - Titanium Di-oxide - TO_2

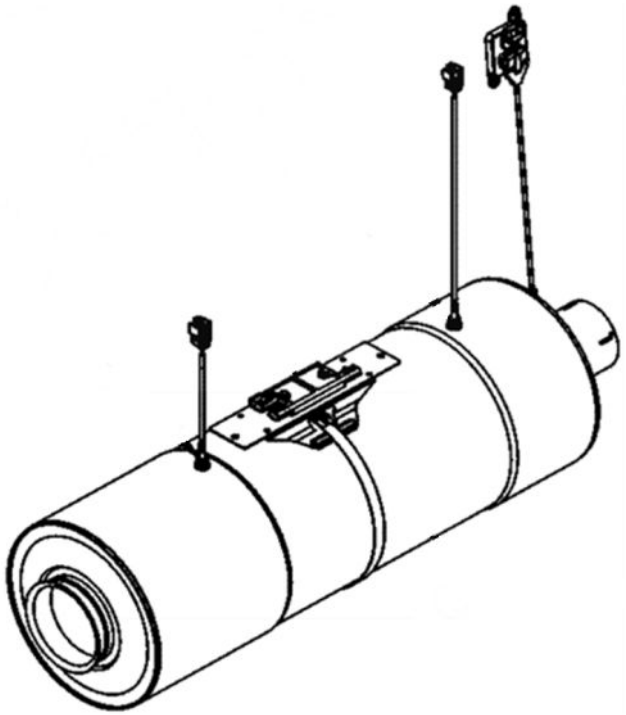
NOx Sensor

- The NOx sensors at the outlet of the SCR catalyst monitor the NOx output of the exhaust system and relay this information back to the ECM via SAE J1939.
- Processor mounting is critical
- Not serviceable



Inlet & Outlet temperature sensors

- The exhaust gas temperature sensors are located in the exhaust muffler, on either side of the catalyst brick.
  - Some SCR catalysts will contain two temperature sensors and other applications will only contain one temperature sensor.
- The temperature sensors are used to monitor the catalyst intake and outlet temperatures.

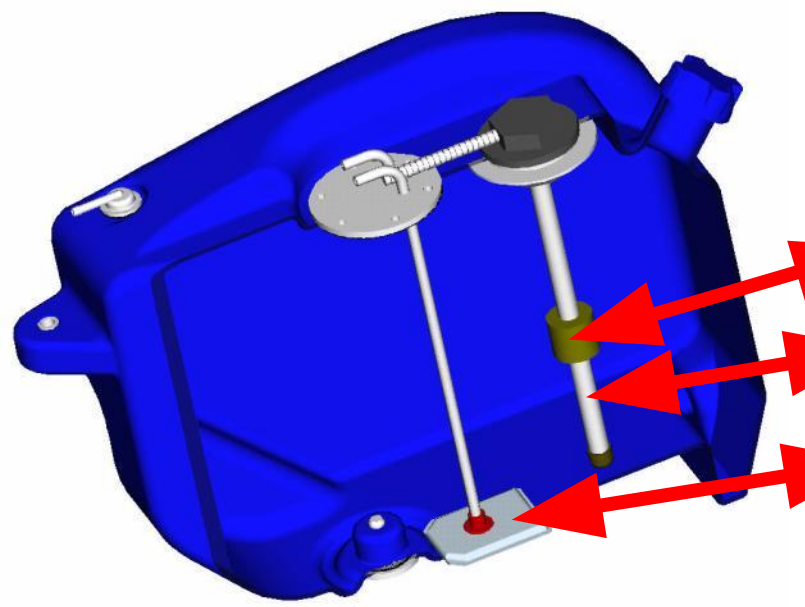


DEF Tank

- DEF tank is designed to store DEF and monitor the DEF tank level and the DEF tank temperature to the DEF controller.
- OBD requires a rationality check of urea/AdBlue consumption from the tank.
- DEF tanks vary in size and shape.

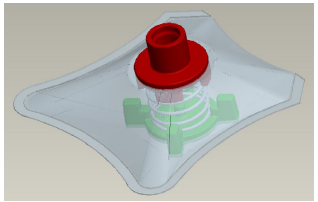
DEF Tank Level & Temperature Sensors

- Level sensor has defined “resistance steps” operated by reed switches – it is important to reference “top” and “bottom” resistor for calibration. Different ECM fit different sensor.
- Tank should also clearly show capacity in litres.



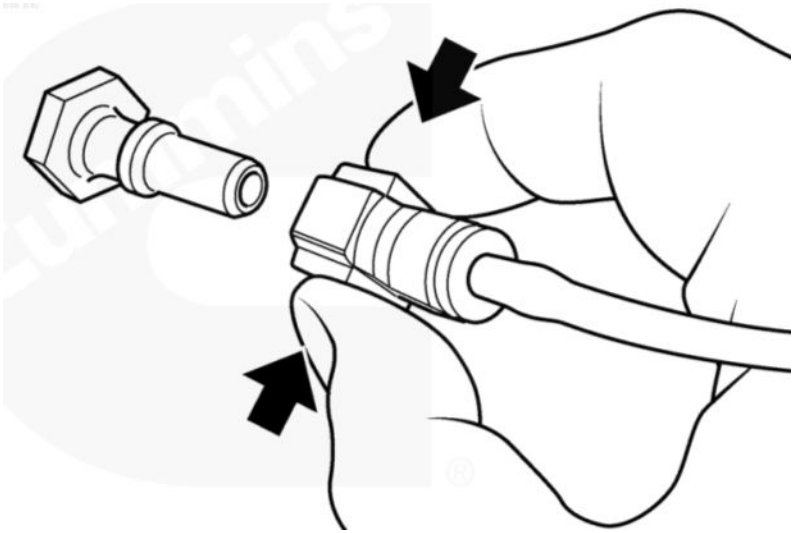
Level (Magnetic Float)
&
Temperature (Thermistor) Sensor

DEF Tank Filter (Teabag)



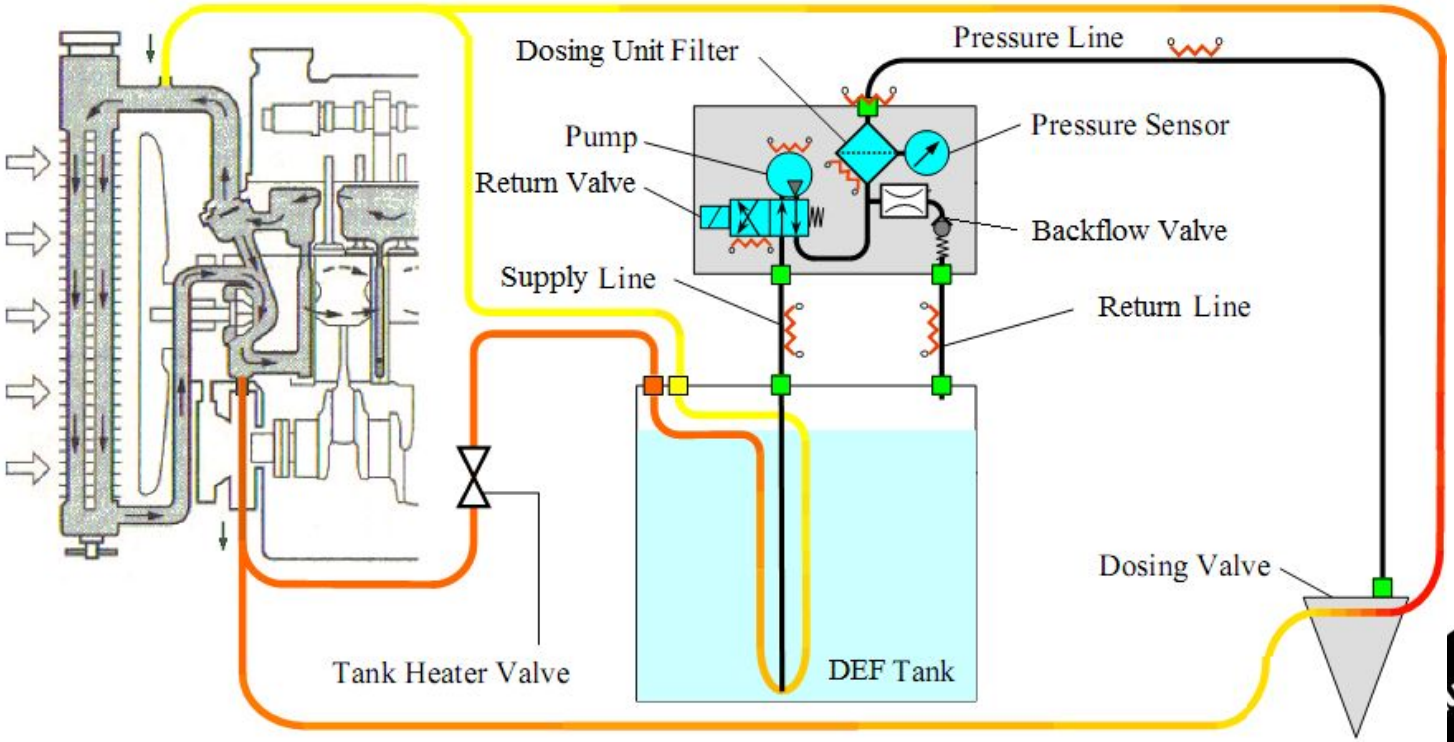
DEF Lines

- The aftertreatment DEF lines carry the DEF to and from the DEF tank, aftertreatment DEF dosing units, and the aftertreatment DEF dosing valve.
- DEF will fill the lines during a prime or operating state and then be removed in a purge state to prevent freezing of the system.
- DEF line connectors, length, and design will vary by vehicle manufacturer.



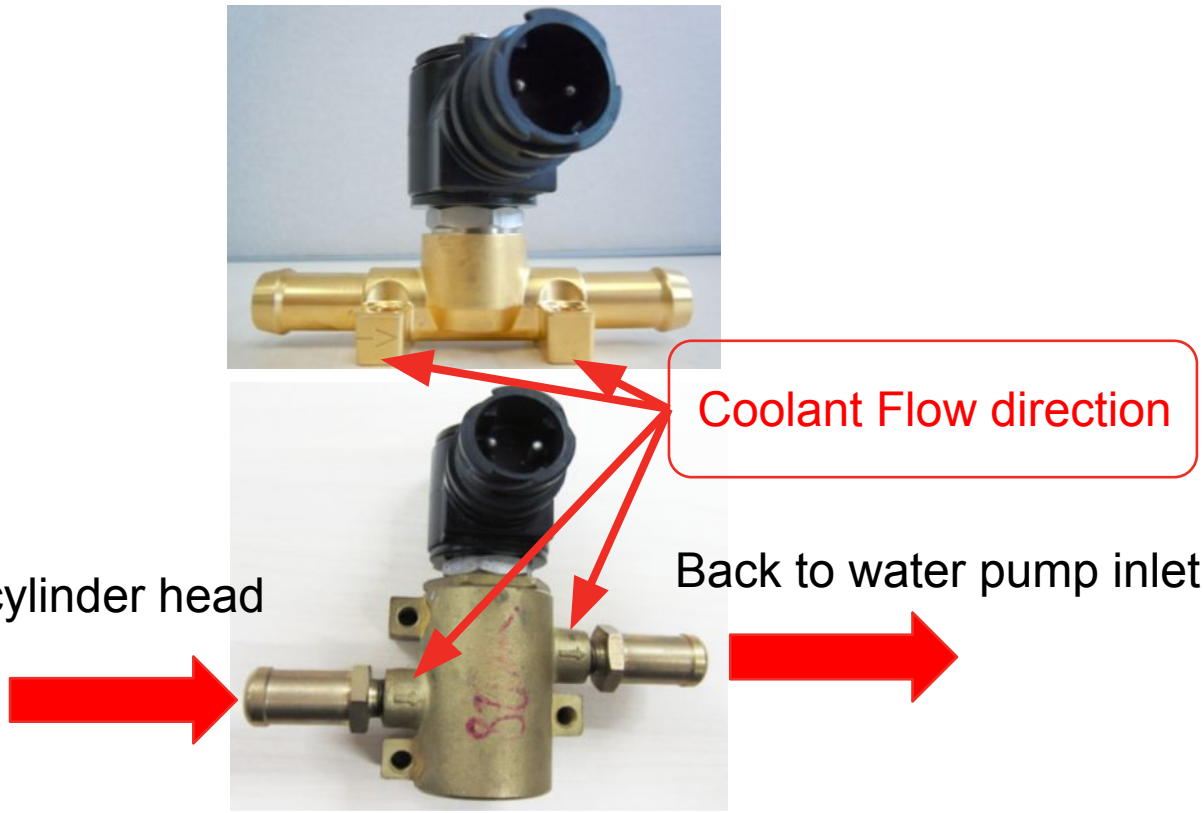
Heating of SCR system

- Dosing Unit has internal electrical heater, controlled by Dosing Controller.
- DEF lines usually incorporate electrically heated elements, controlled by the Dosing Controller.
- DEF tank is heated by engine coolant.
  - DEF tank heating valve is controlled by Dosing Controller.



DEF Tank Heating Valve

- Tank heating valve should serial connection in the tank heating tube.
- Tank heating valve should installed on upstream of DEF tank.
- Coolant flow direction have to same with direction of arrow on valve body.



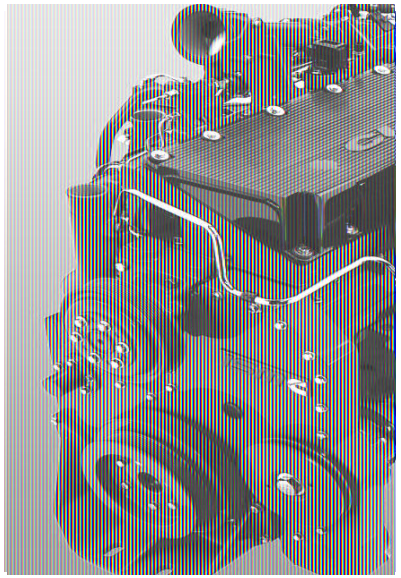
Name of Heaters in Insite

- Heater 1: DEF Pressure Line heater.
- Heater 2: DEF Supply Line heater.
- Heater 3: DEF Return Line heater.
- Heater 4: DEF Dosing Unit heater.

Turbocharger Compressor Intake Air Temperature Sensor

- This sensor is located on the air intake of the turbocharger or near the air filter.
- ECM use this sensor to read ambient air temperature, for SCR system heating.

System Operation



System Operation

- The SCR system is comprised of many components but **only** requires a minimal amount of servicing or driver intervention.
- The SCR system is comprised of states:
  1. Initialization
  2. Priming
     - 2.1. Build up DEF pressure
     - 2.2. Dosing Valve test
  3. Dosing
     - 3.1. Ready to dose
     - 3.2. Actually dose
  4. Purging
  5. Heating

1. Initialization Stage

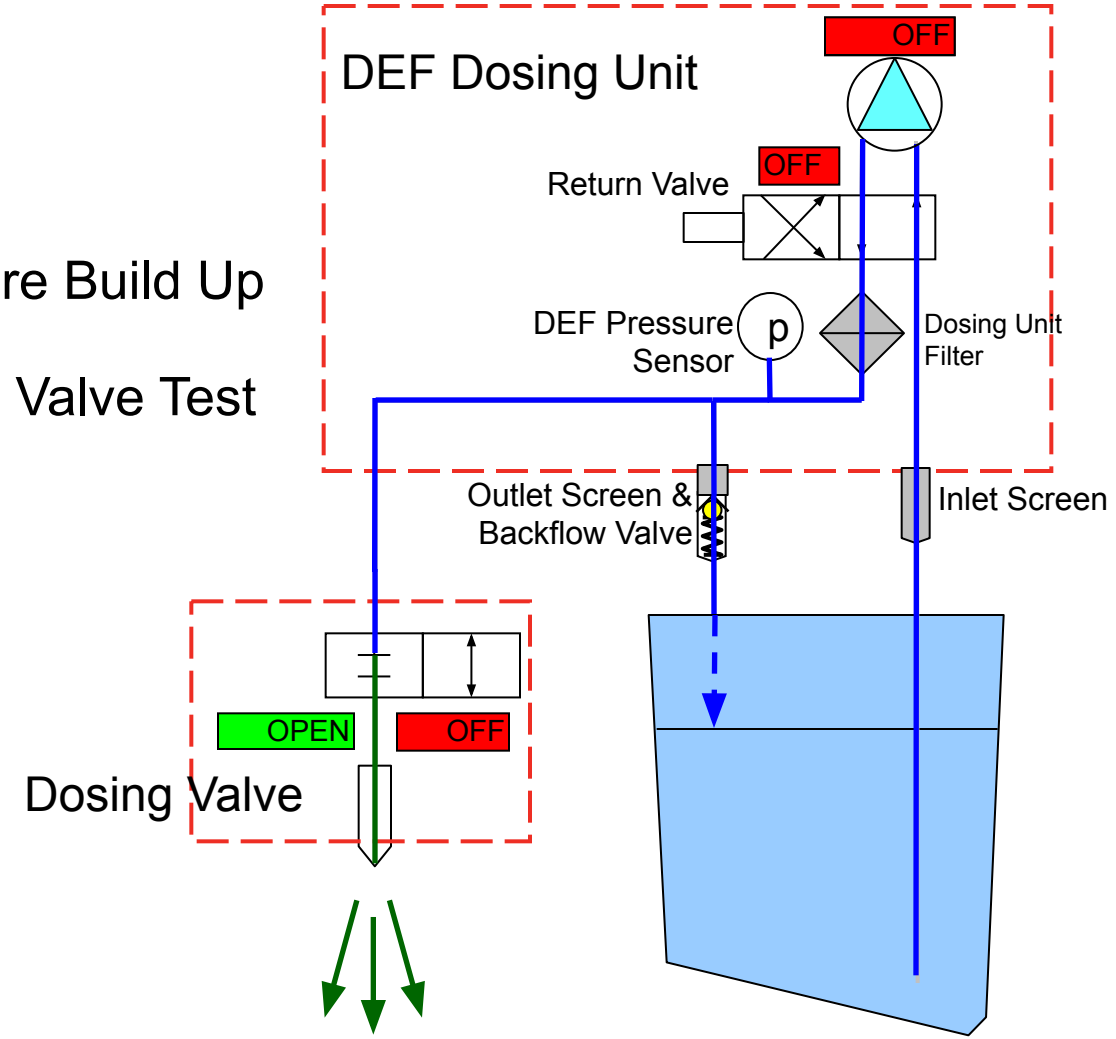
- Beginning:
  - Engine ignition switch is turned on but not start engine.
- Action:
  - System initialization and self-test.
- Ending:
  - Priming stage is begin.

2. Priming Stage

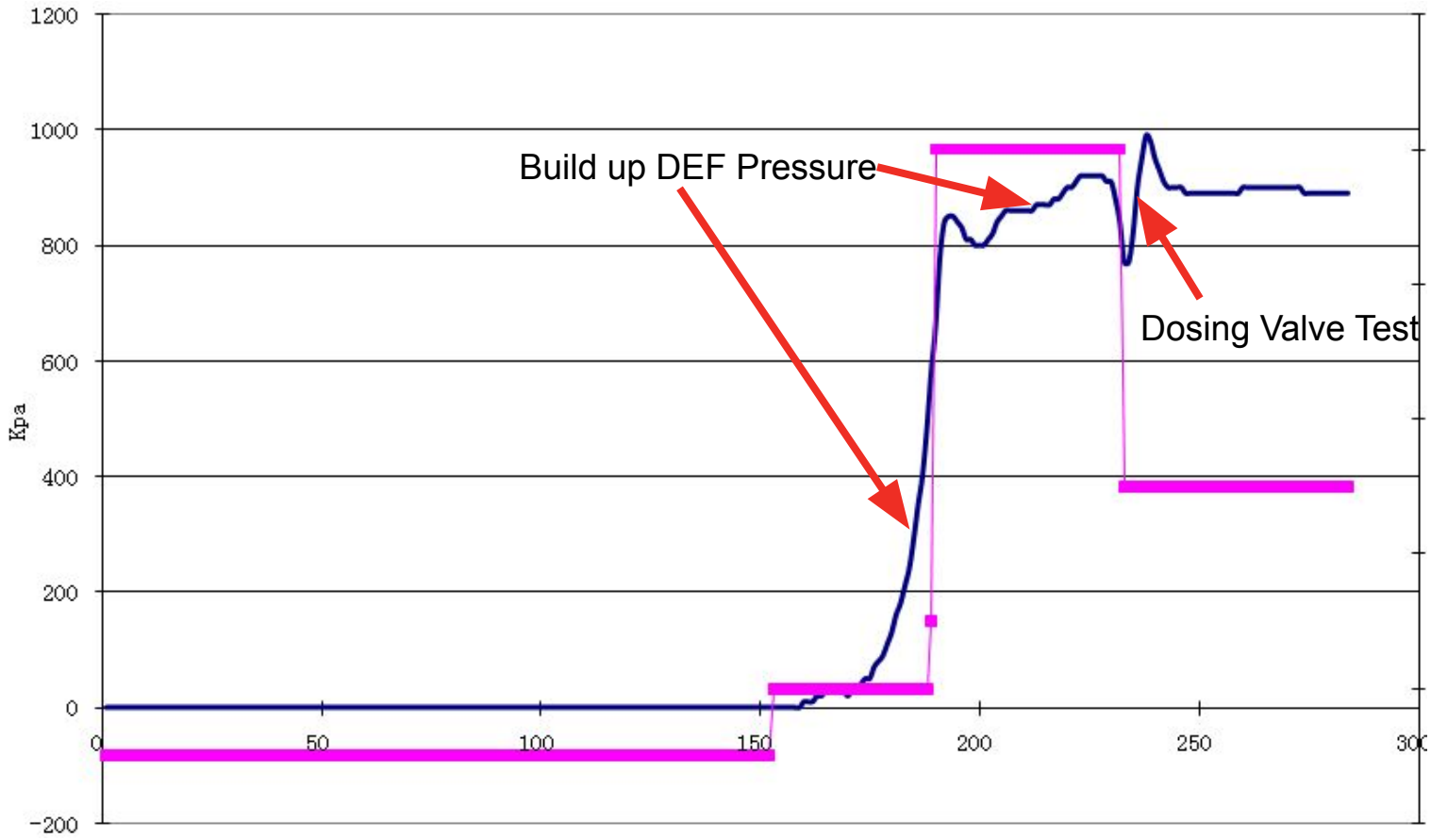
- Beginning:
  - Engine start successfully.
  - And exhaust temperature is higher than preset value.
- Action:
  - Pump running to build up constant DEF pressure.
    - Can be monitored by Insite.
  - Dosing Valve Test.(Dosing valve will open 2 seconds)
    - DEF pressure should decrease and should recover quickly.
- Ending:
  - DEF pressure is OK and dosing valve is OK.

Priming Stage - 2

- Refill
- Pressure Build Up
- Dosing Valve Test



Priming Stage - 3



Fault Codes of Abnormal Priming

- 3574: DEF pressure is too low in priming or dosing stage.
- 3575: DEF pressure is too high
- 3596: unable to maintain the commanded DEF pressure
  - Backflow Valve or return pipe
- 3568: Detect a mechanical malfunction of dosing valve
  - There is no DEF pressure drop when the dosing valve is being commanded on.
- 1682:
  - System is unable to successfully prime itself for a calibratible number of attempts.

3.1 Dosing Stage – Ready for Dose

- Beginning:
  - After priming success, the system is ready for dose.
- Pump runs continuously, and dosing valve is closed. No DEF spray into exhaust.
  - DEF pressure is kept in 900 kPa.
  - DEF that is supplied by pump is returned to the DEF tank through backflow valve.

Required Conditions for Dosing

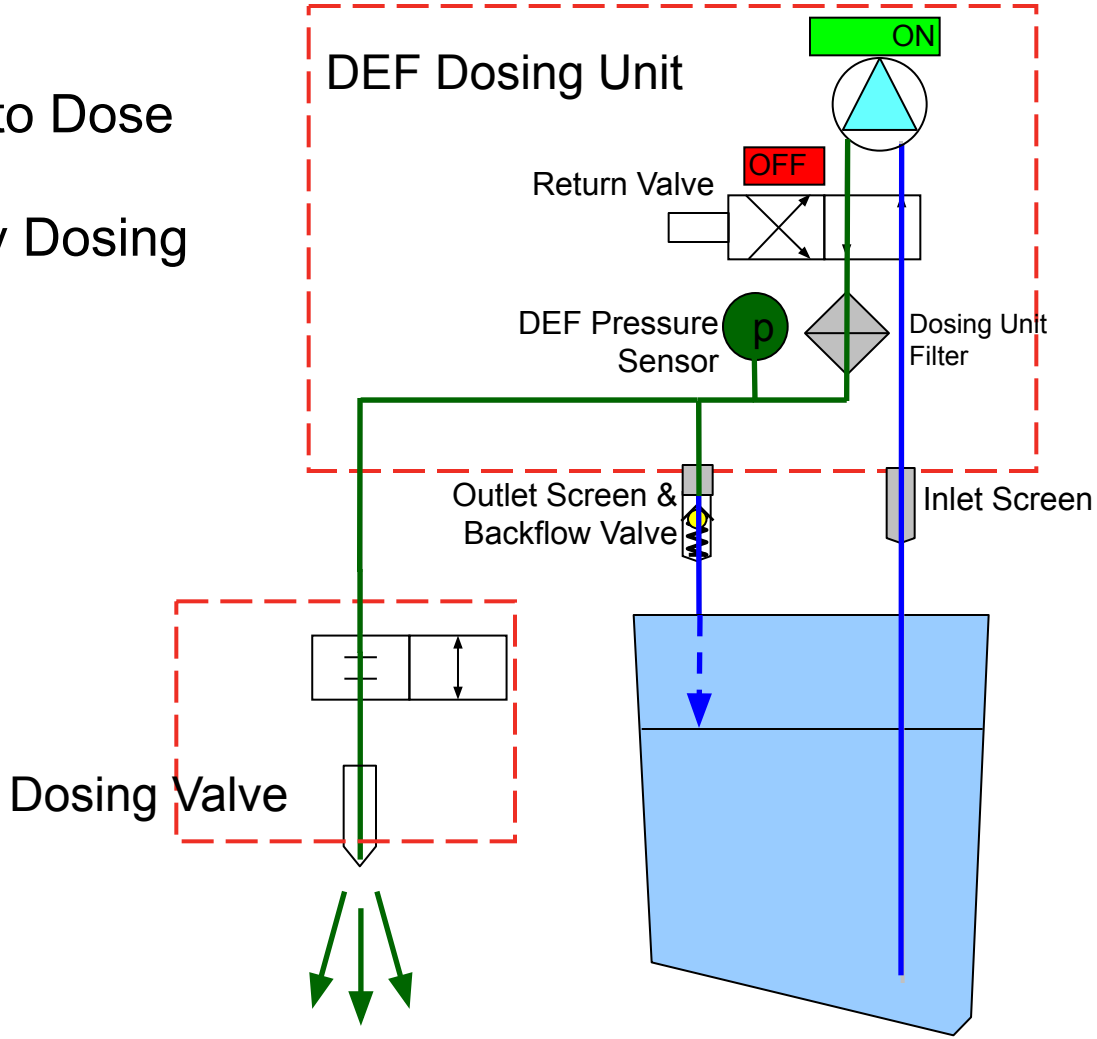
- After meet all of required conditions, ECM will command DEF dosing, allows DEF to be sprayed into the exhaust stream.
- Required Conditions for Dosing
  1. 200 degrees C @ both Catalyst Inlet and Outlet
  2. No ACTIVE SCR System Relatied Fault codes
  3. DEF Tank Level above **6%**
  4. **- 3** degrees C (DEF temp)
  5. Cummins NOx Calibration

3.2. Dosing Stage – Actually Dosing

- When the engine ECM commands DEF dosing, the DEF controller sends a PWM signal to the dosing valve, which opens the dosing valve and allows DEF to be sprayed into the exhaust stream.
  - DEF controller receives a dosing rate message from ECM.
    - DEF dosing rates are dependent on vehicle duty cycle.
  - Dosing unit runs continuously to keep DEF pressure to 900 KPa.
    - Any DEF that is not used by DEF dosing valve is returned to the DEF tank.
  - The amount of DEF to be dosed is metered by DEF dosing valve.
    - The command to dosing valve is a PWM signal, frequency is 1 Hz. (Valve open duration plus valve close duration is 1 second in 1 cycle.)
    - DEF controller adjust the duty cycle of this PWM signal to change the dosing amount.
- The DEF is then converted to ammonia and is passed over the diesel exhaust catalyst, which creates a reaction to reduce nitrogen oxides to nitrogen and water.

Dosing Stage

- Ready to Dose
- Actually Dosing

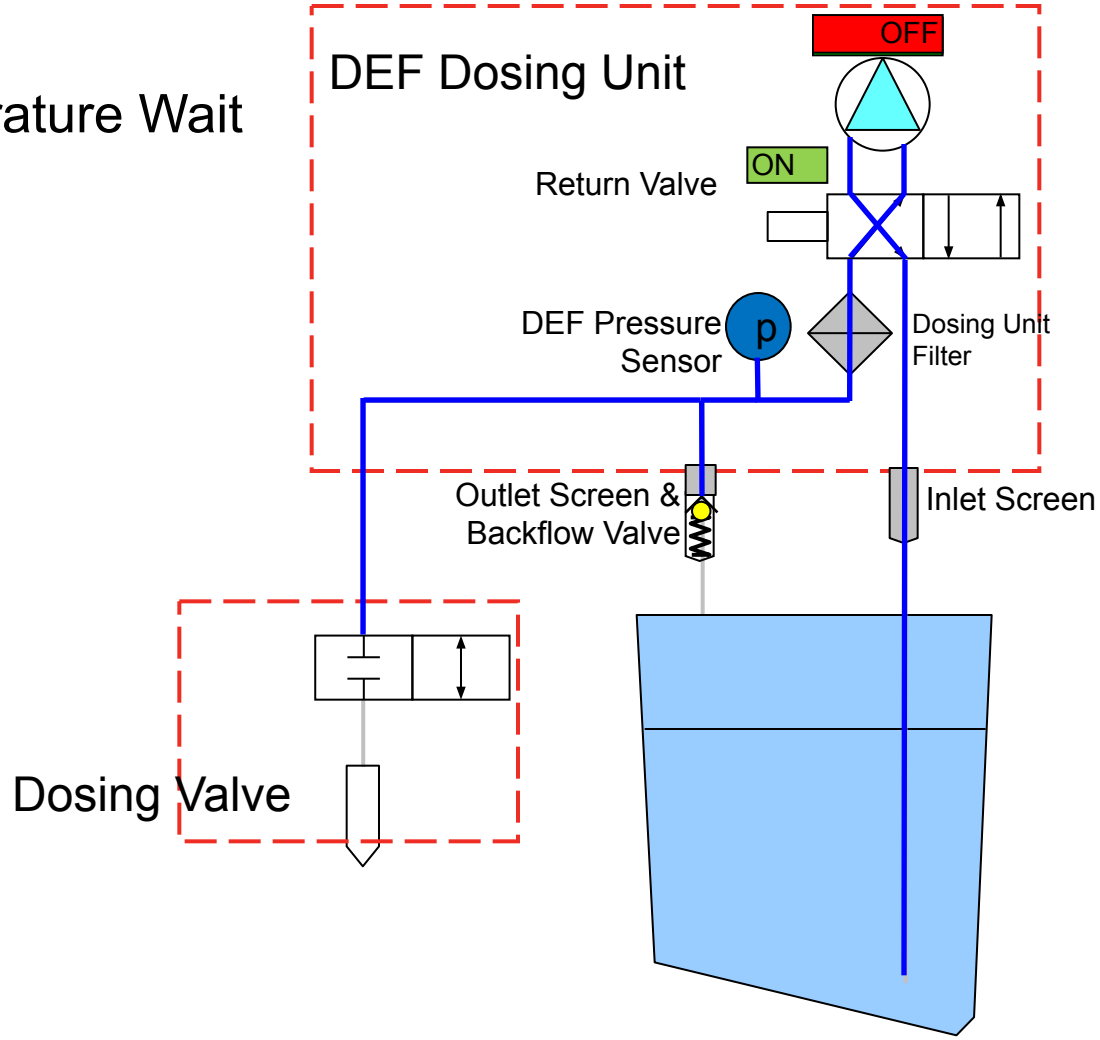


4. Purging Stage

- When the driver turns the key OFF, the dosing system will shut down with a purge cycle to prevent DEF from being left in the system and in cold climates, potentially freezing.
- After a complete purge, the majority of the system will be free of any remaining DEF.
  - The DEF dosing unit slides its internal return valve and causes a change in the flow direction of the DEF control.
  - The DEF dosing unit pulls all of the DEF out of dosing valve and the lines then return the unused DEF to the DEF tank.
  - In this process, the dosing valve will open, eliminating the vacuum created in the lines for a more complete purge process.
- If the main power to DEF controller was removed (via battery cut off or other means) before the purging state was competed, an internal fault will be logged in the ECM.
  - The incomplete purge counter can be viewed in INSITE™.

Purging Stage

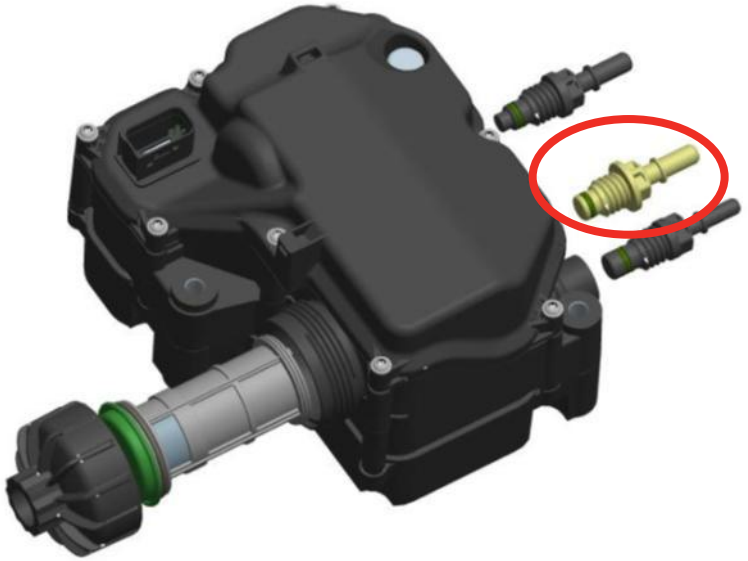
- Temperature Wait
- Purge



About DEF Unit Filter

- In the purging stage, the pump draw exhaust gas to DEF tank. The particulate matter in exhaust pipe will deposit on the inner side of DEF unit filter.
- In next priming stage, the PM may block backflow valve. So DEF pressure will higher than desired pressure.
  - Backflow valve is serviceable.

DEF Dosing Unit Filter - Normal Use



5. Heating State

- If the ambient air temperature is below -4º C [25º F], the DEF controller will command the dosing system to go into the defrost state.
  - The dosing unit will turn on its internal heater to defrost any remaining DEF inside it.
  - If the application has the DEF line heating option, the heated DEF lines will also be commanded on.
  - If the DEF tank temperature drops below -5º C [23º F], the DEF tank coolant valve will be commanded open by the DEF controller, engine coolant will flow through the tank to defrost the frozen DEF.
- The system will not prime until every component is defrosted.
- If ambient conditions continue to be cold after the system has primed, the DEF controller will command a maintenance heating feature to prevent the system from freezing again.
  - This feature will cycle the heating ON and OFF to the DEF lines, DEF tank and DEF dosing unit.

Question and Discussion