
TECHNICIAN
TRAINING
DORMAN
Training Seminar Series
Presents
Introduction Diesel Emissions
Usage
Diagnosis Part 2

1


DORMAN
Aftermarket Innovators

2

## *Your Instructor For This Webinar*

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- **ATTP Master Instructor, New York State**
- **Author, "Medium/Heavy Duty Truck Electricity and Electronics"**
- **Training provider for various Associations, industry and various NY State agencies**
- **Developed trainings that range from four hours to multiple days, specializing in brakes, electrical, regulations and many other subjects relating to our industry.**
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# Emissions 101

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## Did we put the cart before the horse in emissions Part 1?

### Yes and No

- Part 1 dealt with understanding emissions and the major components and systems to reduce emissions with post-combustion.
- Part 2 will put the horse before the cart.
- We will look at pre-combustion major components and systems
- We will look at their role in reducing emissions.
- Understanding how they operate will help us diagnose emissions related issues.





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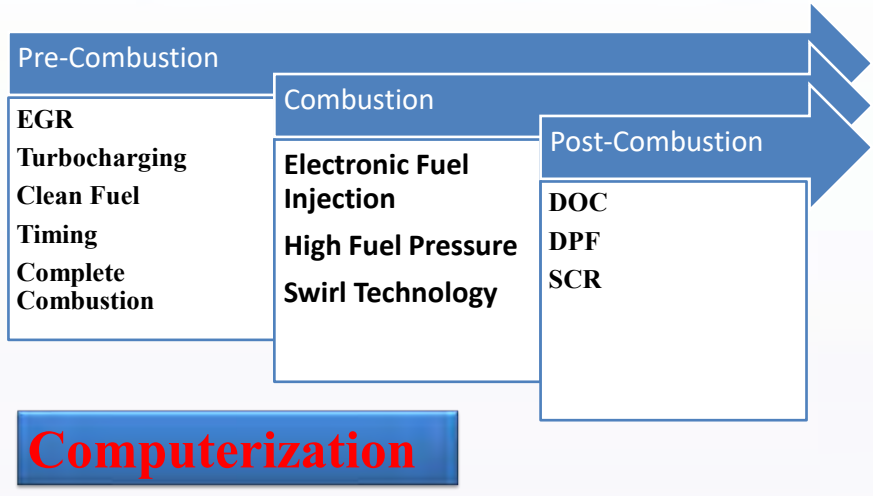
## Emissions Reduction





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## Turbocharging:

- ***Came before Exhaust Gas Recirculation (EGR).***
- ***EGR came before SCR.***

**Air Induction for Diesel Engines**

- **It's all about " Volumetric Efficiency"**
- **Diesel engines have suffered from low specific power output (maximum output per unit weight)**
- **Main reason for that is power output is limited by how much fuel can be burned efficiently in each combustion chamber.**
- **The amount of air inducted is important for efficient combustion.**
- **Typically, a diesel engines capacity to induct air is fixed.**
- **The maximum amount of air inducted is dependent upon intake filter restriction, pressure drops through the intake ducts, manifold, ports and valves.**
- **Inducting air to higher density than ambient air allows for more fuel that can be added in proportion to the additional mass of air inducted.**
- **With the added fuel and air, power output would increase.**
- **Where and how can we get this added air?**





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## Forced Air Induction

**The easiest way to improve volumetric efficiency is to add an external device such as a turbocharger or a supercharger (boosting the charge air). We will stick to turbocharging. Basically, these units force as much air as possible into each cylinder.**

- **The turbocharger is an air pump.**
- **It provides higher pressure and density than ambient air.**
- **Benefits:**
  - **Higher concentration of oxygen for improved combustion resulting in;**
  - **More power**
  - **Improved engine torque output**
  - **Cleaner emissions.**





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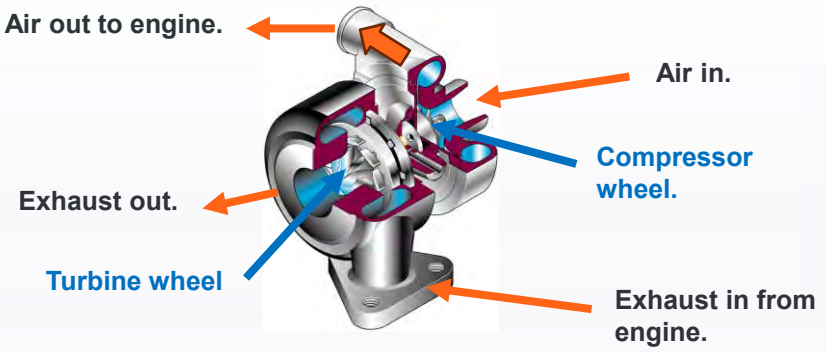
**Forced Air Induction :** Turbocharger

- **Advantage**
  - Using the exhaust energy to increase engine power by;
    - Directing exhaust gas to rotate a ***turbine,*** which drives another turbine ***(compressor)*** to pump fresh air into the combustion chambers at a pressure higher than normal atmosphere.







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Exhaust turbine using exhaust energy to spin turbine shaft

Oil in from engine.

Oil out to engine (drain)

Compressor turbine spun by exhaust turbine/shaft to induct compressed dense air to engine.




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## The Real World

What happened?
How would you find it?
**Could this have been prevented?**







- **Turbos can rotate at 150,000 rpm to more than 300,000 rpm.**
  - Oil is a crucial component for the life of a turbo.
  - Air in must be clean.

**Failure to adhere to those two simple concepts can lead to;**

- Worn, broken turbine tips.
- Turbine shaft wear, allowing play between bushing/bearing/shaft and housing.
- Shaft play allows the end of tips to grind around the housing.

- **When replacing a turbo, always check to make sure oil is getting to turbo and make sure oil is draining from turbo.**
  - Basically, watch for those two actions while cranking the engine.
  - This can verify possible root cause of a turbo failure and prevent failure of a newly installed turbo.

**Note: As a rule, turbos are designed to withstand a lot of extreme conditions such as huge temperature differences between the hot exhaust turbine side and the cooler compressor side.**




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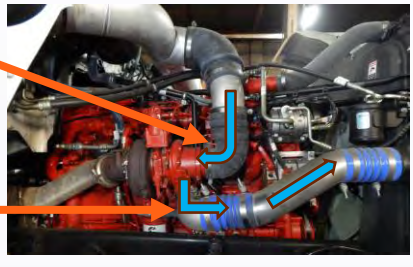
## Charge Air

- **Charge air due to compressing tends to get hot.**
  - Hot air is less dense than cold air.
  - Dense air is more desirable for efficient combustion.
- **That's why it is typically passed through "an inter cooler"**
- **Inter coolers are like radiators( minus liquid coolant).**
  - Ambient air is passed from the outside of the moving vehicle across the surface of hollow tubes to cool the "charged air" passing through the hollow tubes.
  - The effect is to increase the density of the "charge air".

Air in from filter.

Air to charge air cooler







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Charge Air Cooler (Intercooler)

**What are some symptoms if there are issues with the charge air portion?**

What type of issues/failures can occur with this section?



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## Smoke Machine Leak Detecting



**Ball floating indicating a leak.**





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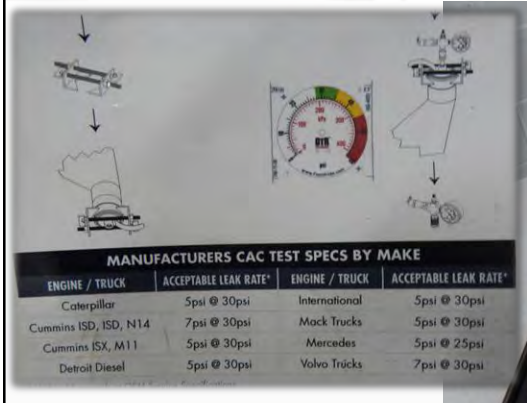

MANUFACTURERS CAC TEST SPECS BY MAKE

| ENGINE / TRUCK | ACCEPTABLE LEAK RATE* | ENGINE / TRUCK | ACCEPTABLE LEAK RATE* |
|---|---|---|---|
| Caterpillar | 5psi @ 30psi | International | 5psi @ 30psi |
| Cummins ISD, ISD, N14 | 7psi @ 30psi | Mack Trucks | 5psi @ 30psi |
| Cummins ISX, M11 | 5psi @ 30psi | Mercedes | 5psi @ 25psi |
| Detroit Diesel | 5psi @ 30psi | Volvo Trucks | 7psi @ 30psi |

**Using air pressure to check charge air cooler.**





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## Types of Turbochargers

- **Fixed (single-flow turbine-shaft compressor design)**
  - No control over speed or boost pressure.
  - Turbocharge is matched to engine with optimum turbine housing selected.
- **Waste Gate turbocharger (turbine bypass).**

Waste Gate Control using pressure from turbo compressor.





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- **Waste Gate Turbocharger cont.**
  - Used to improve turbo and engine performance.
  - Utilizes components to provide control over the *"exhaust gas bypass flow".*
  - **A waste gate valve is mounted on arm and passes through a bushing in the turbo housing.**
  - A welded crank assembly welded to the arm is controlled by either a pneumatic or electric actuator.
  - **The pneumatic actuator may be powered by air pressure or vacuum controlled by a hose from the compressor outlet or by a control valve in the vehicles vacuum circuit.**
  - An electric actuator responds to commands from the vehicles ECU (ECM, PCM).





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Waste Gate Turbo Cont.

- **Wastegate is used to control flow of exhaust gas to "*bypass*" the turbine wheel.**
  - **At higher engine speed, the turbine housing approaches its maximum flow.**
    - **The wastegate valve will open to allow some exhaust gas to *bypass* the turbine wheel and merge directly with the exhaust outlet flow.**
    - **This reduces backpressure, allowing the engine to breath freely for maximum power.**
  - **At low operating speed (low boost level) the pressure in the control valve hose and actuator is low, so the turbine bypass valve is closed.**
  - **Upon acceleration, the turbo responds to the increasing exhaust gas (energy) by speeding up and providing more boost pressure and air flow to the engine.**
  - **At a pre-determined level, the actuator rod will move and open the turbine by-pass valve.**
  - **During deceleration, the boost pressure from the turbo reduces and the by-pass valve closes again.**





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Waste Gate Turbocharger cont.

**LET'S KEEP IT SIMPLE.**

- **Driver Complaint: Lack of power.**
  - **Road test to verify**
- **Description and operation (we just did it)**
  - **Check for frozen arm/linkage.**
  - **If not froze, apply vacuum/pressure to verify if valve moves.**
  - **If it doesn't move, chances are good it is the valve.**
  - **If valve moves, check control source ( hose, fitting for leak, plugged etc.)**
  - **If electrical, check for power, ground and electric control circuit.**

**Chances are pretty good the problem will be simple on these systems.**
**Very common to these systems are frozen arm/shaft going through the housing.**





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## Variable-Geometry Turbochargers (VGT) VNT (Garrett trademark).

**Important Concept for explaining "VGT"**

- **A/R ratio (important design parameter)**
  - Defined as the smallest cross-sectional area of the passage leading to the turbine wheel divided by the distance between the center of the area "A" and the center of the turbine or compressor wheel (R).
  - A small A/R ratio increases the turbine rotational speed, resulting in a higher compressor speed.
    - The result is greater air inducted by the compressor.
  - A larger A/R ratio equates to a slower rotational speed of both the turbine and compressor wheels.

***Simplified:***

- **For greater boost, a smaller A/R ratio is required.**
- **For lower boost, a greater A/R ratio is used.**





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## Variable-Geometry Turbochargers (cont.)

**Problem:**

- If the aspect ratio (A/R) is too large, the turbo will most likely fail to create boost at low speeds.
- If the aspect ratio (A/R) is too small, the engine will likely choke (high pumping losses at high speeds, lowering power output.

**Solved by using "Variable-Geometry Turbochargers" that can alter the *geometry* of the turbine housing as the engine accelerates.**

- Aspect ratio can be maintained to minimize lag at low boost threshold.
- Provide high efficiency at higher engine speeds.





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Variable-Geometry Turbochargers (cont.)
Most Common Designs:

- **Variable-Nozzle Turbines (VNT) (Garrett)**
  - The turbine vanes rotate in unison relative to its hub, thus varying its pitch and cross-sectional area.
- **Sliding Wall Turbines (Holset/Cummins)**
  - The vanes do not rotate.
  - The effective width is changed.
  - Usually done by moving the "turbine" along its axis (retracting the vanes within the housing).
- **VGT's are also used to control the ratio of "*exhaust gas recirculating*" back to the engine inlet.**
  - Control to ***increase exhaust manifold pressure*** until it ***exceeds inlet manifold pressure***. ***This promotes exhaust gas recirculation (EGR).***
  - Ensuring a sufficient EGR rate even during gear changing (shifting) events can be sufficient to reduce NOx emission.




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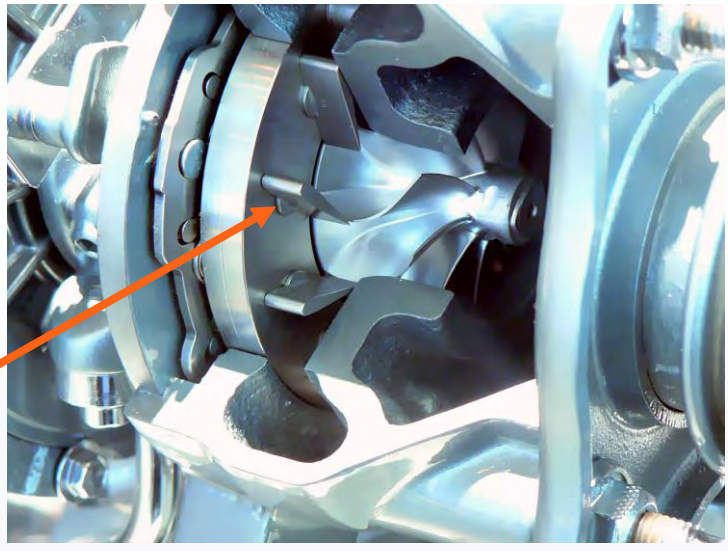
## Variable Nozzle Turbocharger (VNT)




Courtesy WikiPedia

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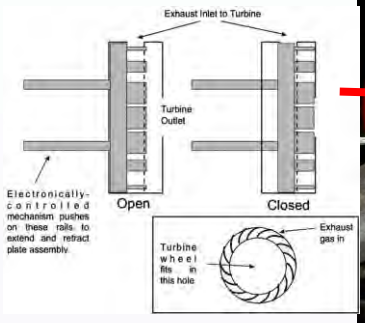
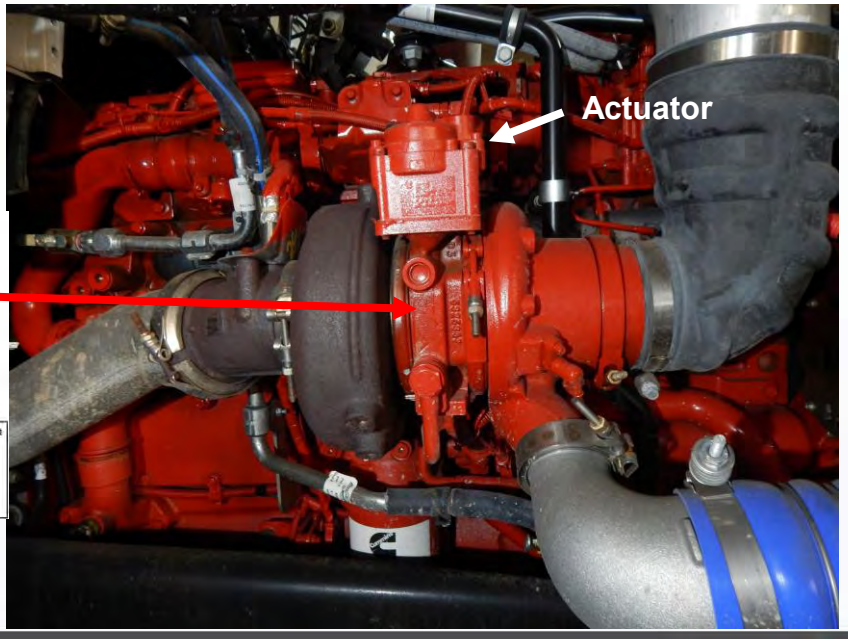
**Cummins CX15 with a Variable Geometric Turbocharger.**





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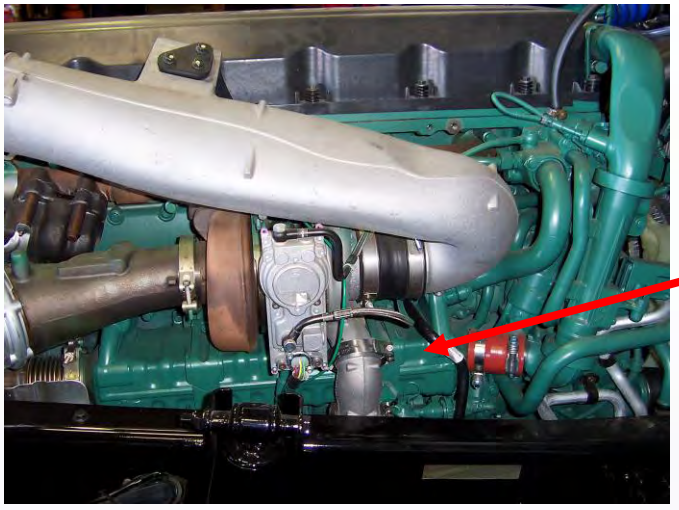

**EGR Cooler**

**Volvo FM VGT diesel engine with EGR emissions technology.**

Courtesy: Panoha via wikipedia





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VGT's (cont.)

- **VGT's are controlled by the vehicles ECM.**
  - VGT actuators have built in electronics to send information to the ECM, such as speed, travel capabilities, position of the actuator etc.
  - Provide diagnostic and fault code reporting through the ECM.

**From Cummins:**

**NOTE: If the VGT actuator must be replaced, the new device must be calibrated. New VGT actuators are not calibrated by the manufacturer?!?**

Drivers seat observations:

- Boost can vary because the ECM senses ambient air temperature and air pressure to optimize boost pressure for engine operating requirements.
- VGT's will whistle loudly in certain normal engine operating conditions.

*Usually when the ECM requests more exhaust heat for regeneration of the DPF.*

**Note: This is a normal condition even though the whistle might sound like a boost leak.**







## Cummins- VGT Calibration

- Start with a search.
- Search for:
  - ✓ Operating Procedures
  - ✓ Fault Code Instructions
  - ✓ Service Instructions
  - ✓ Bulletins
  - ✓ Parts References
- Get comfortable with all that knowledge.
- You don't want to get halfway through or most of the way to find out you are not equipped to finalize the job.
- Try to eliminate those little surprises that seem to crop up on occasion.

**The following slides are an example of need to know from Cummins relating to VGT.**
**(Consult Cummins For Complete Information)**

## VGT Calibration

**This engine uses a variable geometry turbocharger (VGT) actuator.**

- The electric VGT ***actuator*** is not a serviceable component of the turbocharger assembly. If it is determined that the electric VGT ***actuator*** requires replacement during troubleshooting, the entire turbocharger assembly must be replaced.
- The electric VGT ***actuator*** calibration can be updated if an update is available. If troubleshooting indicates to update the electric VGT ***actuator*** calibration, see the following procedure.

**Refer to Procedure 010-150 in Section 10.**





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## 010-150 Turbocharger Actuator Calibration Code-1

**Note: Downloading a calibration code into the turbocharger actuator is only required if directed by a Campaign, Temporary Repair Practice, or warrantable repair.**

- Turbocharger actuator calibration code downloads can be performed with "INSITE" electronic service tool.
- "Insite" electronic service tool connects to the turbocharger actuator through the engine control module (ECM) by using the J1939 data link.
- The "Install" and 'Calibrate" sections must be performed after the calibration code download process if the actuator is not yet installed onto the turbocharger.
- See the following procedure for ISL9 CM2350 engines. Refer to Procedure 010-134 in Section 10. See the following procedure for ISB4.5 CM2350 engines. Refer to Procedure 010-134 in Section 10.

**NOTE: This is the Operating procedure for calibrating the VGT actuator, which must be done every time a VGT is installed or removed. But it can also be done with the VGT left in place.**





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## 010-150 Turbocharger Actuator Calibration Code-2

- If the turbocharger actuator is not removed during calibration code download, no further steps are required.
- The turbocharger actuator calibration code download process occurs with the key switch turned ON. Always follow the instructions on the service tool screen.

NOTE: If the tool will not communicate with the key switch in the ON position, cycle the key switch and try again.




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## 010-150 Turbocharger Actuator Calibration Code-3

NOTE: Although either the engine-mounted service tool connector or the vehicle mounted service connector can be used for the software installation, Cummins Inc. recommends that the engine-mounted service connector be used for the software installation process, whenever possible.

- Connect the “INSITE” electronic service tool to the J1939 data link, located on the engine or in the vehicle cab.
- Follow the steps in “INSITE” electronic service tool screens to complete the turbocharger actuator code download.
- Once completed, use “INSITE” electronic service tool to clear all fault codes. Turn the key switch *OFF* for 30 seconds. Turn the key switch *ON* and check for fault codes.




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## Temperature Sensor Commonalities

### Air Temperature Sensor

- **This sensor is a thermistor.**
  - **Used to measure changes in air temperature.**
  - **This sensor has many different names. For example: *Air Charge Temperature Sensor, Manifold Air Temperature Sensor and Inlet Air Temperature Sensor.***
  - **The thermistor receives a 5V reference voltage through a set of pull-up resistors inside the ECM.**
  - **The sensor signal will vary from approximately 4.7V cold to.4V hot.**
  - **The ECM provides the sensor ground.**




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| Scan Data | | |
|---|---|---|
| Intake Air (°F) | Intake Air (°C) | Intake Air (V) |
| 194°F | 90°C | 0.60V |

**Parameters for Setting Codes:**
**Most vehicles have a minimum and maximum temperature operating range. If the ECM detects sensor readings out of these parameters, a code will set for an open or short in that circuit. As an example, an air temperature sensor that is unplugged will result in a 5V signal to the ECM. As this is out of the allowable operating range, the ECM will set a code for an open circuit.**
**(This is a nice quick way to determine if the computer is capable of sensing)**
**NOTE: *The electric circuit connector must be tested to ensure for sufficient voltage and ground. The reference voltage must be 5V, and the ground voltage must be less than 100mV.***




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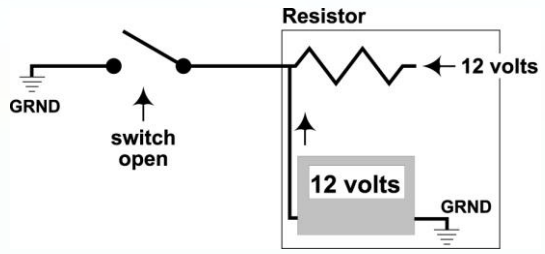
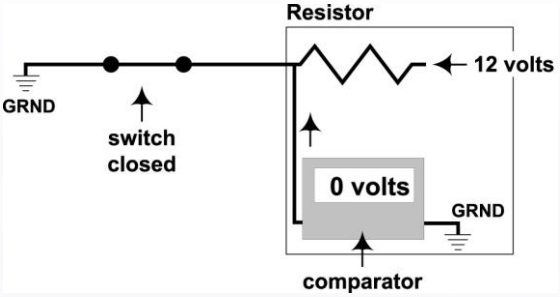
## Pull-Down Circuit

- In the pull-down circuit, the computer sends a voltage out through an internal resistance. When switch is open, the computer sees the voltage.




- When the input device switch closes, the voltage is sent to ground and the computer senses no voltage due to the voltage drop across the internal resistor







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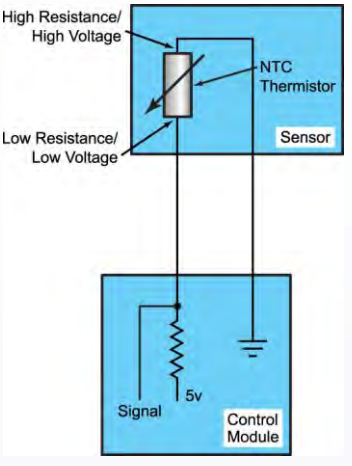
## Two-Wire Sensor Circuit

- A two-wire sensor, such as the engine intake air/coolant sensor receives a reference voltage signal through a current limiting resistor in the control module on one lead wire.
- The second lead wire is simply a ground from the control module.
- The circuit inside the control module can be termed a "pull-down" circuit.
- The engine CTS/IAT is a Negative Temperature Coefficient (NTC) type of sensor and as the sensor warms up, the internal resistance lowers, and voltage drop across a reference resistor in the control module will change.
- When the temperature sensors resistance lowers, voltage drop across the reference resistance increases.

NTC Sensor Circuit







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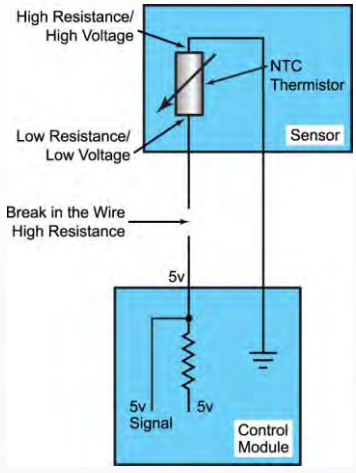
**There are 4 possibilities for an open circuit or high input type fault.**

- **Open inside the temp sensor.**
- **Open in the sensor wire.**
- **Open inside the control module.**
- **Open in the ground circuit or a bad ground.**

- **When the control module detects, a voltage signal above 4.8 volts from this sensor, it identifies this as a non-plausible signal and will suspect that the circuit is either open or shorted to power as a result of the high voltage input.**

Open NTC Sensor Circuit







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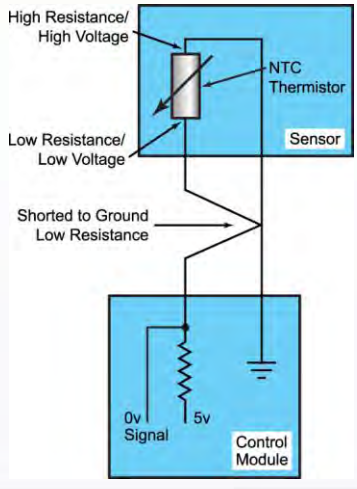
**There are 2 possibilities where it may be shorted.**

- **Shorted to power in the sensor wiring.**
- **Short to power inside the control module.**
- **If the control module sees a signal of 200mV or less from this sensor, the control module will identify this as a non-plausible signal and will suspect that the circuit is either shorted to ground or a loss of voltage has occurred due to the low voltage input.**

Shorted NTC Sensor Circuit







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## Two-Wire Summary

- A two-wire thermistor can be tested with the electronic tool (scan tool) and a multi-meter.
- First the scan tool should display ambient temperature after the vehicle has sat overnight with the engine off.
- **Then disconnect the sensor, with the key-on engine-off; the reading on your scan tool or meter will indicate a value that is equivalent to a high voltage reading (Low temperature). This indicates reference voltage is available.**
- If not, look for a ground fault in the signal wire. A grounded signal wire (low resistance) pulls the reference voltage down.
- If a ground fault can not be found in the signal wire, check for reference voltage at the PCM. When checking for reference voltage , it can prove beneficial to remove the signal wire from the PCM connector. This will prevent a grounded circuit (signal wire) that may have been missed in the previous test from influencing this check.




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## Two Wire Summary –cont.

- If the scan tool or meter indicates the value that is equivalent to a high voltage reading, the ground circuit needs to be checked next.
- Using a suitable jumper wire, connect the signal wire to the ground wire at the connector. With the key-on engine-off, the reading on your scan tool or meter will indicate a value that is equivalent to a low voltage reading. This indicates that a good ground is available. If not. That portion of the circuit is at fault.

**Tip: Intermittent faults are common also. Knowing that and you might suspect an intermittent issue, wiggle the wiring harness and connectors while checking for faults.**




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**Fault Code 2641 Turbocharger Turbine Intake Temperature:** ***Voltage above normal or shorted to high source.***

- **High signal voltage is detected at the turbocharger intake.**
- **Engine performance may be reduced.**

**Note: Engine protection is not available for the engine turbocharger turbine intake temperature.**

**Component DESCRIPTION: This temperature sensor is a variable resistor sensor used to measure the temperature of the exhaust entering the turbocharger's turbine.**

**The ECM determines the temperature of the exhaust entering by supplying a 5-volt reference voltage to the intake temperature signal circuit, and then monitors the change in voltage caused by the changes in the resistance of the sensor.**

- **When the engine is started, the diagnostic runs continuously after a 2-minute warm-up period.**

***Conditions for setting the fault code:***

- **The turbocharger turbine intake temperature signal voltage is higher than 4.95 Volts for more than 1 second, as detected by the ECM**







**Action Taken When Fault Code Becomes *"Active"***

**When the diagnostic runs and fails, the ECM:**

- **Turns ON the amber Check Engine lamp, the Malfunction Indicator Lamp (MIL), or both.**
- **A default value is used for the engine turbocharger turbine intake temperature and;**
- **Engine protection is disabled for the turbocharger turbine intake temperature.**

**The default value is a strategy for "Engine Protection".**

**Conditions for Clearing Code:**

- ***Repair the fault.***

***To validate the repair, the following conditions must occur simultaneously for 5 seconds:***

- ***Engine coolant temperature must be above 32ºF (0ºC).***
- ***Turbocharger compressor intake air temperature and intake manifold air tempe3rature must be higher than 41ºF (5ºC).***
- ***The engine must run for more than 120 seconds.***
- ***The engine must not be motoring.***

**Checking Turbocharger Turbine Intake Temperature Sensor Circuit Response**

- Ignition "OFF"'
- Unplug turbo intake temp. sensor connected to the engine wiring harness.
- Check for damage in pins and connectors.
- Connect a jumper wire from the signal pin of the turbine intake temp. sensor to the return pin of the of turbine intake temp. sensor at the connector of the engine wiring harness.
- Turn ignition ON.
- Connect scan tool. Wait approximately 2 minutes and check for fault codes.
- If the fault code 2642 became active the turbine intake temperature sensor is faulty.

**If No Fault Code 2642.**

- Repeat above steps, but this time connect a jumper wire from the signal pin of the turbo intake3 temp. sensor to the return pin of turbo intake temp. sensor at the "ECM".
- Turn ignition ON.
- If Fault Code 2642 came on, chances are good you have a problem in the engine wiring.

**IF NO Fault Code 2642, the recommendation is a possible ECM fault.**

**Note: Check ECM calibration/update**







**VGT (or any) Turbo Failures**

**If a turbo fails, ask yourself *why did it fail?***

**Possible causes:**

- Blocked crankcase filter causing excessive pressure, pushing oil ou of the turbo.
- Hot shutdowns.
- Oil contamination (carbon)
- Carbon buildup in the engine.

**Preventive Maintenance:**

- Timely oil changes.
- Using correct oils.
- Clean/replace DPF filters.

## Exhaust Gas Recirculation System (EGR) (Explained Generically)

- EGR routes and controls the flow of exhaust gases into the intake manifold.
- EGR directly affects combustion.
- EGR is counter-productive to the combustion process.
- Recirculating of exhaust gases should occur only when conditions are right such as steady state, while the vehicle is under a moderate load.
- Engine performance may be adversely affected if the system operates at the incorrect time or has the incorrect flow rate.
- The EGR system is not designed to operate below a specific temperature.




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## "Cooler Combustion"

- NOx forms in high-temperature combustion.
- The solution is "cooler combustion".
  - Lean mixture reduces HC and CO (*Revisit Emissions Part 1)* and increases temperature and therefore NOx.
- NOx can be controlled through the displacement of a portion of the air/fuel charge with inert exhaust gases (known as dilution).
- The exhaust gas dilutes the incoming air, displacing some of the oxygen in the air.
- Less oxygen results in a slower burn and reduced peak cylinder temperature reducing NOx formation.
- Another benefit is that the cooled exhaust gas absorbs some of the heat generated during combustion.

***"The hot exhaust gas/air needs to be cooled before entering intake"***




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**EGR Components**

**Typical Components:**

**Engine throttle valve, EGR cooler assembly, Temperature sensor, Oxygen sensor, EGR valve and Delta Pressure Sensor (Pressure Differential Sensor).**

**EGR cooler**

- **Primary purpose is to cool the exhaust gases.**
  - **Provides a coolant flow to remove heat from the gas side of the core.**

**Delta Pressure Sensor (pressure differential sensor).**

- **Monitors the pressure difference across the venturi in the transfer pipe.**

**EGR Temperature Sensor**

- **Measures the exhaust gas temperature exiting the EGR cooler.**

**Note: The ECM uses delta pressure and exhaust temperature to determine the rate of EGR flow.**

**EGR Valve (Mixer in some systems)**

- **Used to control of exhaust gas through the EGR system.**





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## Government Regulations

- **EPA Legislation around emissions reduction began in 1997**
- **Key Changes:**
  - 2004: Exhaust Gas Recirculation (**EGR**) introduced
  - 2007: Diesel Particulate Filters (**DPF**) and low-sulfur fuel introduced
  - 2012: Selective Catalytic Reduction (**SCR**) and Diesel Exhaust Fluid (**DEF**)
  - 2013: OEM required to have on-board diagnostics for emissions
  - 2021: Shifting focus to improving fuel economy by 24%
- **Result for the End User**
  - Top spend at Fleets since 2019
    - Greater than Fuel and Tires!
  - A fleet of 500 trucks spends **$27,000** every month on emissions repairs*

*American Trucking Associations, Inc.





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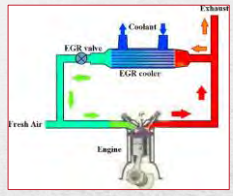
## EGR Coolers

- **Function**: An EGR Cooler dilutes the air-fuel mixture in the cylinder with cooled exhaust gas, lowering the combustion temperature
- **Failure Mode:**
  - Internal Leaking
    - Coolant Leaks into exhaust stream
  - Soot Packing
    - Insulates cooler and prevents lowering of air temperature

**Failure will lead to additional downstream issues!

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## Highlight SKUs

All SKUs Include Clamps and Gaskets!

- **904-5175**
- **Make:** Cummins
- **OE:** 4352365RX
- **Apps:** 2017-13 Cummins ISX 11.9G (Natural Gas Engines)

- **904-5510**
- **Make:** Mack, Volvo
- **OE:** 85136427
- **Apps:** 2023-08 Mack and Volvo models with MP7, D11 engines

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Recommended Service Interval: 80,000 miles/1 Year

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**EGR Components (cont.)**

**Coolant Control Valve (as per Navistar)**

- **Consists of a "*Coolant Flow Valve*" and a "*Coolant Mixer Valve*".**
- **The coolant flow valve (CFV) regulates the coolant flow through the "Low-Temperature EGR Cooler" along with the Low-Pressure Charge-Air-Cooler (LPCAC).**
- **The Coolant Mixer Valve (CMV) controls the amount of coolant that passes through the Low-Temperature Radiator (LTR)**

**Cummins uses a Mass Measurement Flow assembly.**





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**The next set of slides is a walk through of how a generic EGR flow occurs. However, we need to know about the two types of EGR systems that are used. A *"high-pressure"* and *"low recirculation".***

***High-pressure EGR:***

- **Exhaust gas is recirculated on the high-pressure side (upstream of the turbocharger turbine).**
- **The advantage is that the pressure difference to move the exhaust gas from the exhaust side to the intake side is higher and can be altered at the turbocharger by using "wastegate" or "variable turbocharger geometry" technology.**
- **Another advantage is having a short EGRT section for quick filling and emptying (faster response time).**
- **Another advantage is, the "intercooler" and the turbocharger compressor are not fouled by the exhaust gas because the recirculated exhaust gas is not mixed with fresh air until downstream of the intercooler.**

**Drawback: Greater demands are placed on the EGR cooler on the high-pressure side due to higher pressures and temperatures.**





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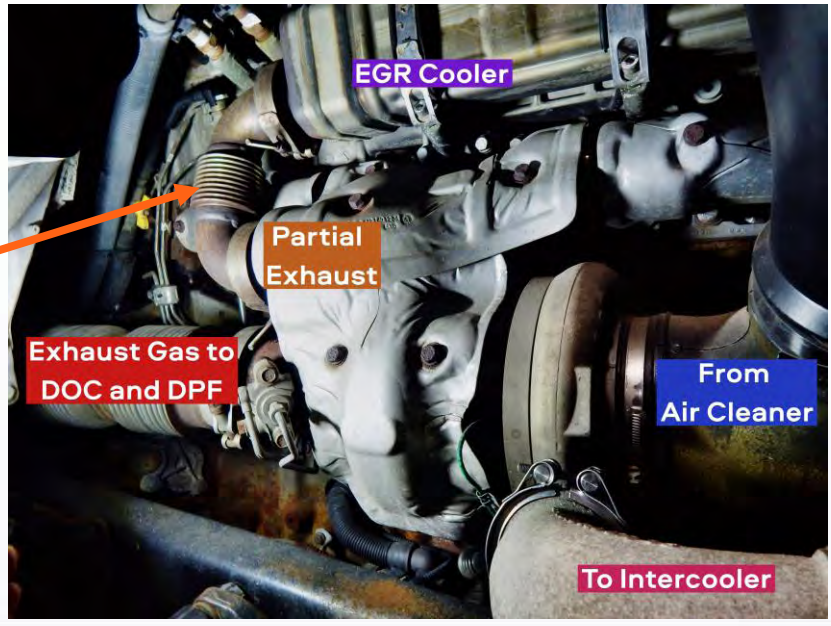
## DD 15

EGR Hot Pipe
"High Pressure"
EGR System

- Pipe runs from Exhaust manifold to EGR cooler.





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## DD 15






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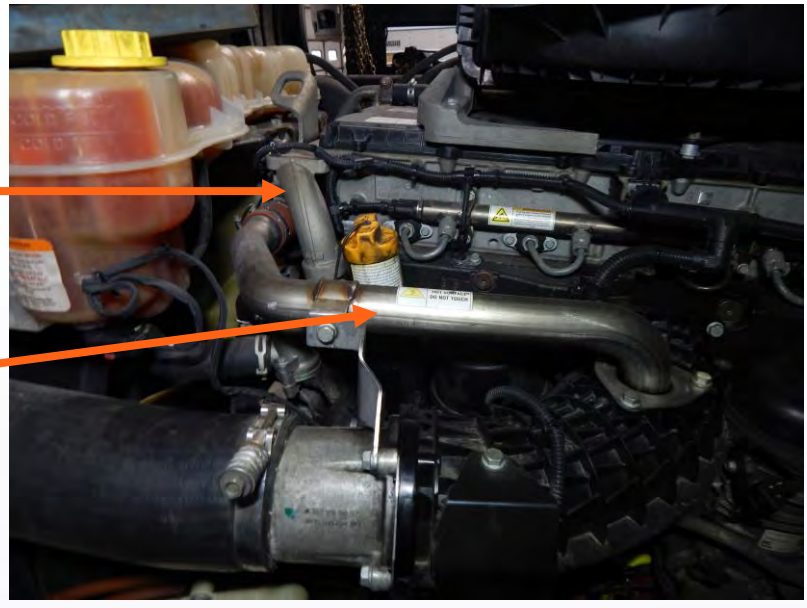
DD 15

Coolant Connector Pipe.

Mixer Pipe







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DD 13

EGR Ventura





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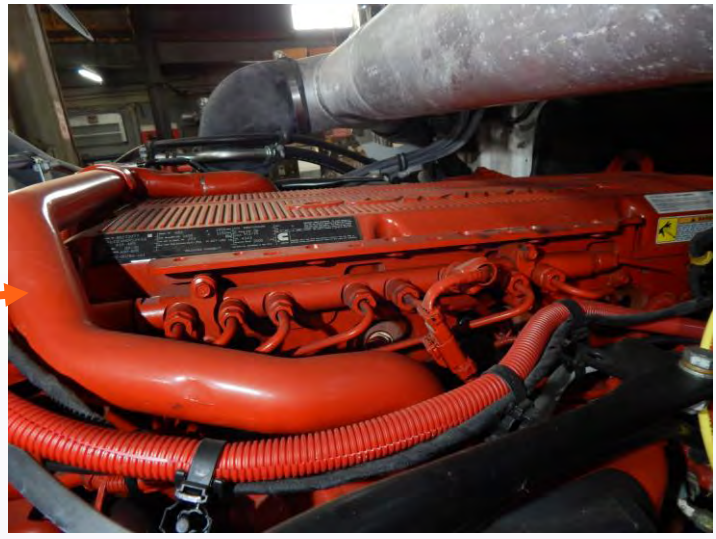
## Cummins CX15

EGR Crossover Tube







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## Cummins CX15

EGR Valve





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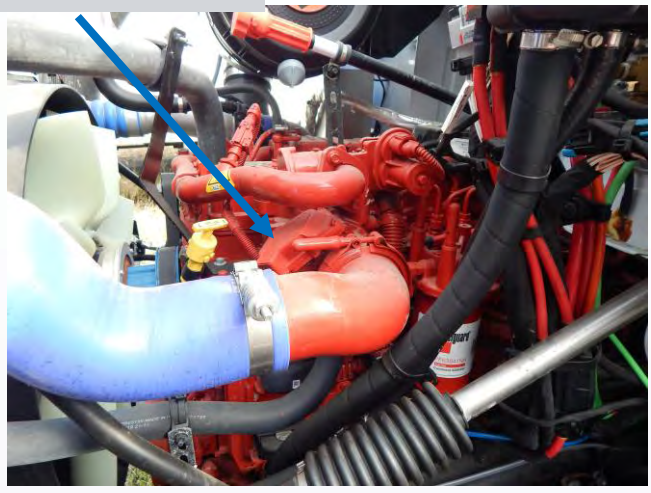
## Cummins 6.7

- **This intake throttle actuator is used on midrange engines to provide better air control for EGR mixing.**
- **It acts as an EGR assist to reduce pumping losses to EGR flow and exhaust restriction.**
- **Allows for greater optimization of engine timing. For example, closing the intake throttle limits the intake (boost) air and reduces the pressure the EGR flow works against.**
- **"ITA closes" when EGR and VGT are not capable of providing the commanded EGR flow without assistance,**

## Intake Throttle





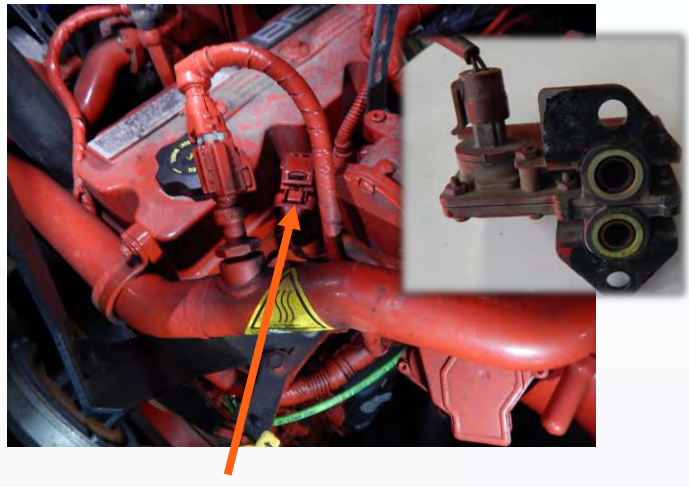




## Pressure Differential Valve

- **The EGR Differential Pressure Sensor is a three-wire pressure sensor used to compare the pressure differential between the exhaust and intake manifold to maintain proper flow.**
- **It is common for the ports to accumulate water/moisture and get packed with carbon, creating downstream issues in aftertreatments.**
- **The ports can be cleaned and blown out with low pressure shop air.**

**Note: An EGR cooler can coat the sensor with ethylene glycol, creating additional issues.**



**Pressure Differential Valve**

**Checking Calibration (keeping it simple and generic):**

- Engine needs to be under load (Stall).
- Back probe sensor.
- Measure voltage on signal and return and return pins.
- Confirm there is 5V reference .
- Confirm calibration by comparing voltage drop measurements with known good values for actual pressure.





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## Possible Intake Throttle Actuator Codes:

**Actuator Codes**

- 175- Electronic Throttle Control Actuator Driver Circuit – "Voltage above normal, or shorted to high source.
- 176- Electronic Throttle Control Actuator Driver Circuit – " Voltage below normal, or shorted to low source.
- 177- Electronic Throttle Control Actuator – Mechanical system not responding or out of adjustment.

**Position Sensor Codes**

- 3539- Engine Intake Throttle Actuator Position Sensor Circuit – Voltage above normal, or shorted to high source.
- 3541- Engine Intake Throttle Actuator Position Sensor Circuit – Voltage below normal, or shorted to low source.
- 3542- Engine Intake Throttle Actuator Position Sensor – Data erratic, intermittent or incorrect.




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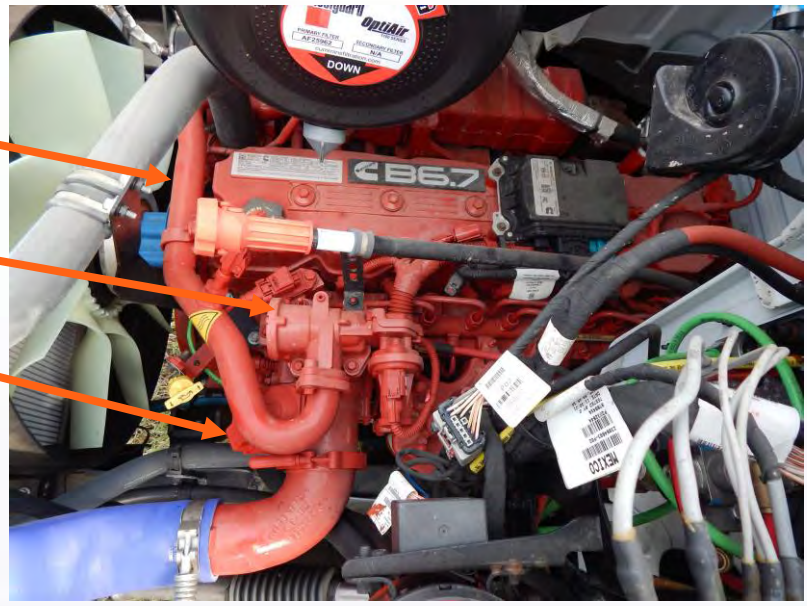
Cummins 6.7

Exhaust Gas Crossover Tube

EGR Valve

Engine Intake Throttle





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**Low-Pressure EGR:**

- Exhaust gas for recirculation is routed only “downstream” of the turbine through the EGR cooler and mixes with the inducted fresh air upstream of the turbocharger compressor.
- The exhaust gas passes through the diesel particulate filter (DPF) before arriving at the EGR cooler (soot removed).
- The benefit is a non-fouled EGR cooler. Also, lower temperature in this area results in lower temperature stresses in the EGR cooler.

**Objective**

- By having lower inlet temperature, the cooler outlet temperature will be lower than with a high-pressure recirculation.
- Lower temperature can reduce NOx emissions and, in some cases, sufficient to eliminate SCR system.

**Drawback**

- Reduced dynamic response as compared to the high-pressure EGR.

EGR rates are set lower to prevent the engine from being “flooded” with exhaust gas.





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## The EGR Journey Generically and Simplified.

- Starts with ambient air passing through the air filter (suffering a drop in pressure).
- The pressure reduced air enters the inlet duct/plenum going to the turbocharger "compressor".
- Air exiting the "compressor" has a different makeup of density, temperature and flow characteristics going to the "air-to-air intercooler".
- At the intercooler this air recovers density as it exchanges heat with the cooling media.
- The cooled (denser) "charge air" passes through an "EGR valve" on its way to the intake manifold.
- "Exhaust Gas" recirculated from the exhaust manifold enters the "EGR valve" where it is metered and mixed (partially) with the fresh air prior to entering the intake manifold as a mixture.
- Once in the intake manifold, the mixture of air and exhaust gas continues to mix.

"Where did the Exhaust Gas come from?





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## The EGR Journey Generically and Simplified.

Exhaust Gas

- Depending on the pressure differential between the exhaust and intake manifolds;
  - EGR flows from the exhaust manifold through the "EGR Cooler", where it loses some pressure and exchanges with some coolant medium.
- It then proceeds to the EGR valve as described in the intake air journey.

This describes in general what the components of an EGR system are and what impacts each of the components, not to mention how each component impacts others.

**Now we have a general idea of the various systems and components utilized for emissions reductions.**

**Next month we are going to look at issues and symptoms and how to troubleshoot and diagnose.**





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## EGR Cooler Diagnosing (in general)

**Symptoms related to EGR cooler issues:**

- Increased smoke emissions.
- Poor engine performance.
- Reduced power.

**Inspection:**

- Visually inspect the EGR cooler for any visible signs of damage.
- Check for leaks, and or carbon buildup.
- Check for coolant leaks (fittings, cracks etc.)

**Pressure Test:**

- Perform a pressure test on the EGR cooler for leaks.
- Apply pressure to the coolant side of cooler while monitoring for drops in pressure which could indicate a leak.

**Diagnosing:**

- Use an electronic service tool (scan-tool) to retrieve error codes related to the EGR system such as insufficient flow or excessive temperature.







## EGR Cooler Diagnostics (in general)

**Note: EGR coolers tend to have two failures:**

- Plugged with soot (restricting exhaust gas flow) and
- Cracks (fractures) inside the cooler due to thermal cycling and constant pressure.

**EGR Valve Diagnosing (in general)**

EGR valves are prone to wear and tear due to the complex environment they operate in. A major cause of failure tends to be buildup of carbon particles from the exhaust gases in the EGR and intake system passages. The results are:

- Clogged tubes and exhaust channels.
- Valves plunge mechanism stuck in in closed or open position.

**Symptoms:**

- Engine performance- For example: A stuck open valve will affect the vehicles air/fuel ratio causing performance issues such as reduced power, rough idle and poor acceleration.

**NOTE: The open valve could produce turbo boost pressure leaks, causing the turbo to to work harder.**

- Check Engine light (MIL) comes on indicating a problem with the EGR valve.
- Increased NOx emissions when the EGR valve remains closed.

**NOTE: The result will be a higher combustion temperature, increasing NOx emissions reduce fuel efficiency.**





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