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The Tricks of NOx : Oxides of Nitrogen

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OXIDES OF NITROGEN
TRICKS OF NOX

Presentation by Tim Janello

The Gasoline Equation

- HC = Hydrogen (H) + Carbon (C) + Oxygen (O2) + Nitrogen (N) + Compression + spark

=

- Heat + H2O + Carbon Monoxide (CO) + Carbon Dioxide (CO2) + HydroCarbons (HC) + Oxides of Nitrogen (NOx).

Intake

- Gasoline (HC) = Hydrogen & Carbon
- Oxygen (O2) = Reactant for Combustion
- Nitrogen (N2) = 78% of Air

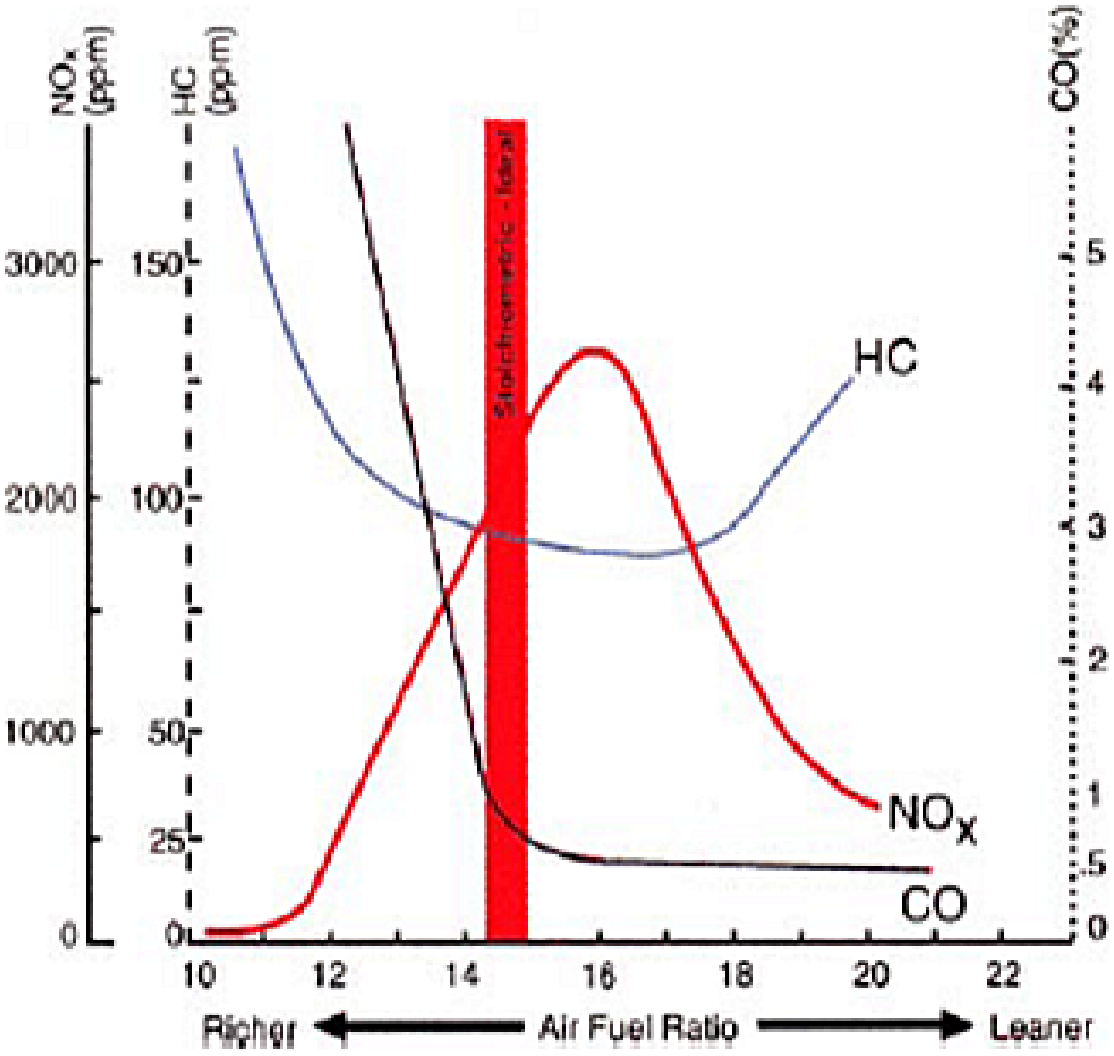
Combustion

- Intake Gases
- Compression
- Spark
- Heat is Produced (Expansion)

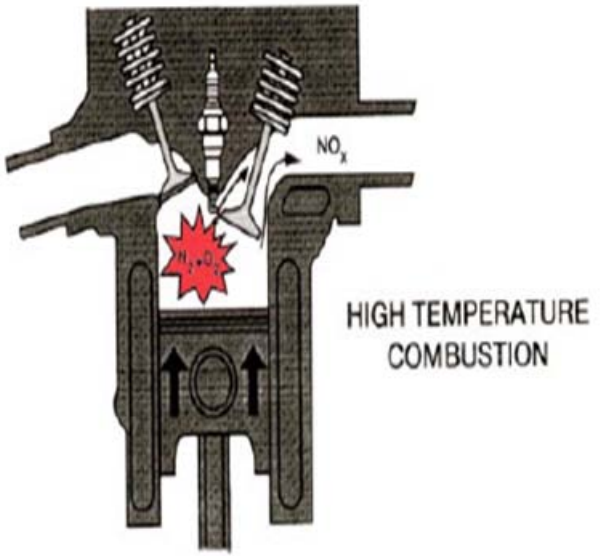
Combustion Gases

- H2O = Water
- Carbon Dioxide(CO2) = Combustion Efficiency
- Carbon Monoxide(CO) = Rich Condition
- Some HC Left Over = Gasoline
- Some O2 Left Over
- N & O Combine = NOx

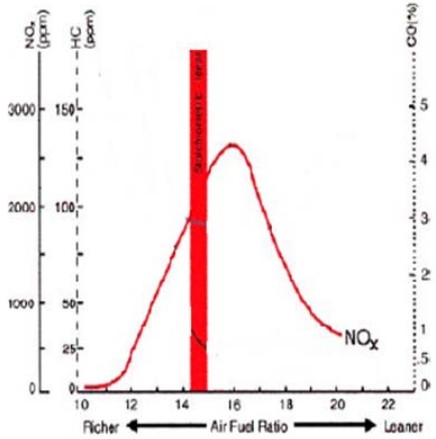
Here is the Problem.
NOx is inverse to HC & CO



Forming NOx



- Nitrogen (N2)
  - 78% of Atmosphere
  - Very Stable Molecule
  - Becomes Ions at High Temperatures (>2300°F)
  - O2 become Ions
  - Forced Together NOx (multiple Os)



High Combustion Temperatures

- 2300°F
  - Increase Compression Pressure
  - High Throttle Angles
  - Increase Compression Ratio
  - Cooling System Temps
  - Carbon in Combustion Chamber
  - Lean A/F
  - Cylinder Quench Areas

Engine Load

- Normal Rise with Power Demand
- Throttle Angle Increase
- More Air in Cylinder
- Compression Pressure Rises
- Compression Temperature Increases
- Combustion Temperature >2300°F
- Rich A/F Reduces Combustion Temp

Making NOx

- Pressure = Heat (molecule expansion)
- Heat
  - Hydrogen & Carbon Separate
  - O2 separate into single atoms
  - CO2 & H2O (increase cylinder pressure)
  - >2300°F N2 separate
  - N + O = NOx
  - High Temp Areas in Cylinder (quench)

Causes of NOx (1)

- Overheated Engine
  - Coolant Flow
    - Thermostat
    - Radiator
    - Fans
    - Coolant mixture
      - Too much water = Air pockets around cylinder
      - Too much Antifreeze = Insulates cylinder
      - Rust = Hot spots

Tricks of NOx

- Consumes O2
- HC left over
- Several Condition = Same Results
- Lack of HCs to cool down the mix to make CO.
- CO molecules not created to help catalyst reduce NOx to N & CO2.

- Cats can mask.
  - High CO = Low NOx

High NOx / Pre-ignition

- High Cylinder Temperature (heat retention)
- O2 – HC prematurely oxidize.
- Less O2 for A/F at Spark
- Less O2
  - HC not separated
  - Limited CO2
- Reading:
  - HC = High
  - CO = Low
  - CO2 = Low
  - O2 = Low
  - NOx = High

High NOx / Knock

- Result of Pre-Ignition
  - Compression Fighting Expansion
  - Piston Slapping Cylinder
  - High Ignition Firing Line
  - 2 Flame Fronts Collide
  - Low Horse Power – High Engine Load
  - Knock Sensors Retard Timing
- Readings:
  - HC = High
  - CO = Low
  - CO2 = Low
  - O2 = High (Misfire)
  - NOx = High

Causes of NOx (2)

- Faulty EGR System (Think Variable Displacement)
  - Not opening
    - No cooling affect
    - More Air = High Combustion Pressure
    - PCM not adding Fuel (no cooling)
      - No Power Loss
      - O2 Sensor May Not Go Lean (O2 used in NOx)
    - Timing Advancing
  - Insufficient Opening
    - Same only not as drastic.

High NOx / EGR

- High Cylinder Air Volume
  - No cooling of mixture
  - Compression Ratio up
  - Combustion Temperature up
  - Less Engine Load
    - Leaner A/F Ratio (not loaded)
    - O2 Senor not Going Lean
    - No fuel Cooling Affect
    - Advanced Timing
- Readings:
  - HC = High
  - CO = Low
  - CO2 = Low
  - O2 = Low
  - NOx = High

Causes of NOx (3)

- Lean air/fuel mixture
  - Vacuum Leak
  - Low Fuel Pressure
  - Plugged Injector
  - Pre-Ignition
  - Engine Knock
    - Retarded Timing
    - High MAP or Load Calculation (bad MAP/BARO)
    - O2 Sensor Low (bad?)

High NOx / Lean

- High O2
  - High Compression Temperature
    - Premature Oxidation of HC (separate)
    - High Combustion Pressure/Temperature
    - N separate & combine with O
    - Oxygen is used up leaving unused HC
    - Slight Misfire Condition
    - MAP or MAF & TPS Calculating Less Air/Load
- Readings:
  - HC = High
  - CO = Low
  - CO2 = Low
  - O2 = High
  - NOx = High

Causes of NOx (4)

- High Temperatures:
  - Small mass
  - Easy to Ignite
    - Pre-Ignition?
  - Higher Engine Load
    - Calculations
- Excessive Spark Advance (Not pinging)
  - Early Flame Front
  - High Combustion Temperature
  - Early Oxidation

Causes of NOx (5)

- Carbon Deposits (rich condition)
  - Top of Piston
    - Higher Compression Ratio
    - Hot Spots (Pre-Ignition)
    - Insulate Piston or Head
  - Intake Valves
    - Absorb HC = Lean Mix
- Catalytic Converter Failure
  - Rhodium Coated (sulfur or carbon)
  - May not be a TWC (Lacks Reduction Section)

High NOx / Carbon

- Result of Rich Condition:
  - Repair High CO
  - Intake Valve Carbon
  - Absorbs HC = Lean Mix
  - High O2 = Low O2 Sensor Voltage
  - Simulated Lean Misfire
- Readings
  - HC = High
  - CO = Low
  - CO2 = Low
  - O2 = High
  - NOx = High

High NOx / Cam Timing

- Later Compression Temp Rise,
  - Longer Oxidation Period
  - High Combustion Temperature
- MAP low
  - Add fuel
  - CO up
- Reading:
  - High HC
  - High CO
  - Low O2
  - Low CO2
  - High NOx.

High NOx / Valve Unseated

- No Heat Transfer:
  - Hot Spot
  - Valve and Seat Hot
  - Pre-ignition?
- Reading:
  - High HC
  - Low CO
  - High O2
  - Low CO2
  - High NOx

Trouble Areas!

- CO = Fuel Control (@ idle <2%)
- HC = Unburned Fuel
  - Leanness
  - Misfires
  - Extremely Rich
- NOx:
  - High Temp / High Pressure
  - EGR
  - Lean
  - Timing
- CO & HC lower when lean = NOx up
- NOx down when rich = CO & HC up

MAP Errors

- Baro Reading Low
  - More Air in Cylinder than Expected = Lean
- MAP Reads Higher Vacuum than Expected
  - ECM Thinks Less Air = Less Fuel = Lean
- TPS Reads Less Throttle Angle
  - ECM Thinks Less Air/Load
  - Less Fuel = Lean
  - ECM Advances Timing

MAF

- Rule of Thumb
  - 1 Liter Displacement
  - 1 Gram per Second
  - @600 RPM Free Idle (calculate % over)
- Reads less Air = Lean A/F
  - Fuel Trims High Positive
  - 15% + or – (MIL on)
  - Trims are NOT Perfect

Exhaust Gas Recirculation (EGR)

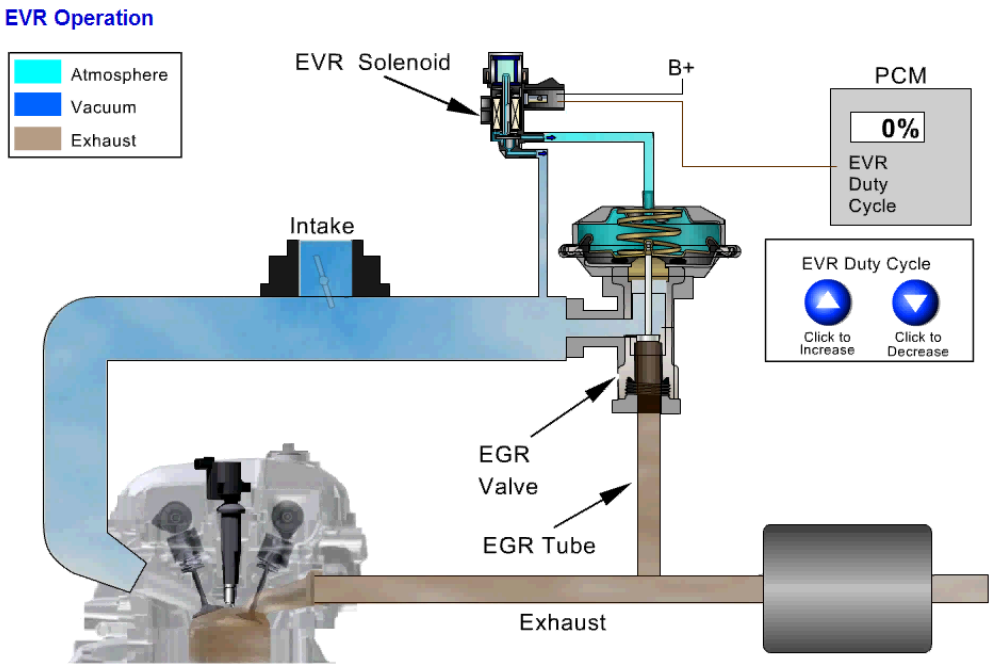
- Reduce fresh air cylinder charge.
  - Reduces combustion temperature.
  - Variable Cylinder Displacement?
  - Better fuel economy?
  - Added EGR :
    - Increases cylinder charge with no Throttle Angle change.
    - Throttle Angle is reduced to reduce torque.
    - Less air /less fuel = less emissions/better economy.
- Integral to lean burn concept. (GDI)
  - Lowers NOx
  - Diminishes need for rich mode. (CO to Cat)

EGR Tests

- EGR on
  - O2 Change
    - MAP Adds Fuel
    - MAF Subtracts Fuel
    - Trims Should Not Change IF ECU is Expecting
  - MAP Voltage UP
  - MAF g/s Down
- May Pass Tests BUT?
  - 4.2 V6 Ford Intake Tube?

EGR Systems

- Mixes exhaust gas (inert) with the A/F charge:
  - During cruise and off idle.
  - Less A/F, lower temp.
  - Typically 8% of A/F
  - Dependent on exhaust back pressure- orifice - intake vacuum.
  - Not proportional to Duty Cycle!



Symptoms

- Insufficient:
  - Detonation
  - NOx Emission Test Failure
  - No MAP/MAF changes
- Excessive:
  - Unstable idle
  - Stumbles
  - Flat Spots
  - Hesitations
  - Surging
  - MAP: HC-CO-O2 increases
  - MAF: HC – O2 increases

EGR Monitoring

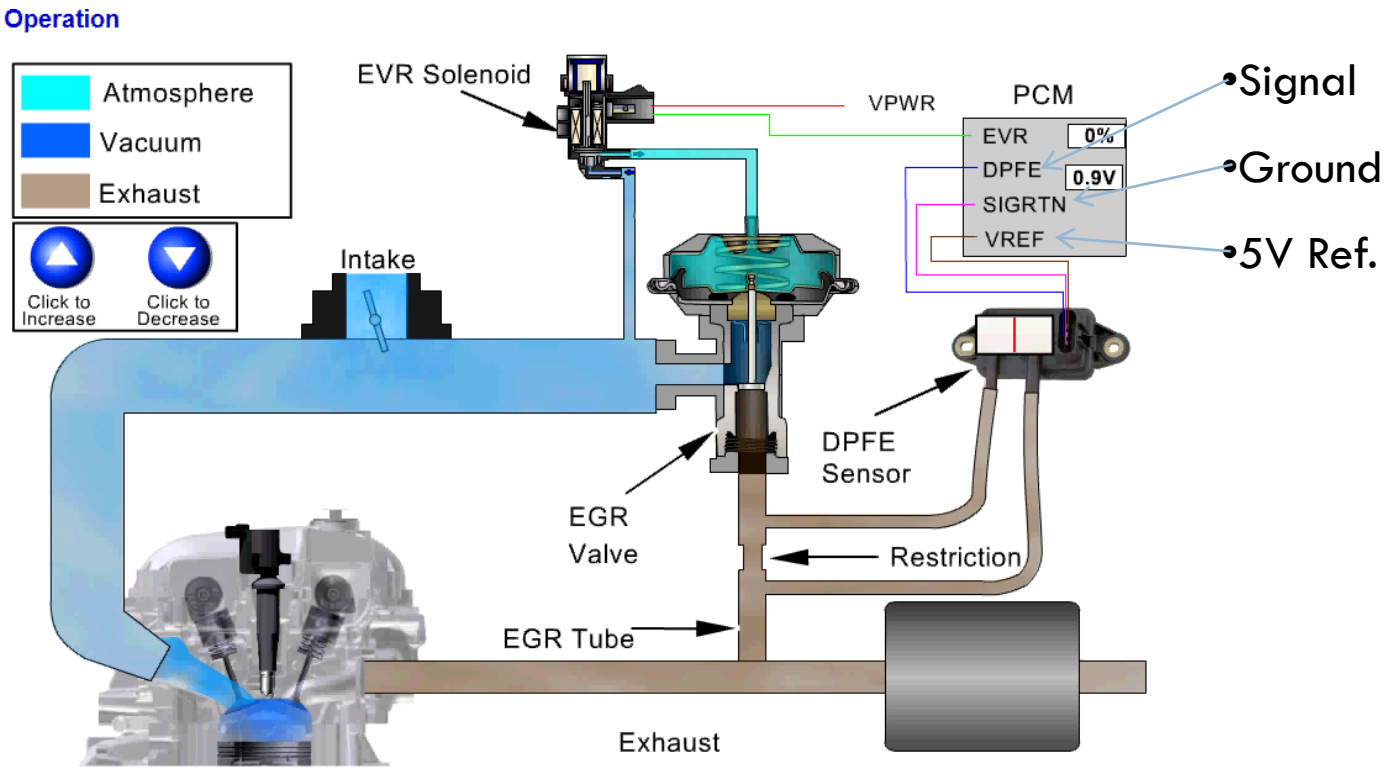
- Flow
  - Pressure feedback
  - MAP/MAF change
  - Position Sensor
  - Temperature (IAT to EGR temp sensor)
  - O2 Sensor Changes
- 2 Good Trip Failures
  - 1 Pass Erases Pending
  - P0401: Insufficient flow
  - P0402: Excessive flow

EGR Falsely Passes Tests

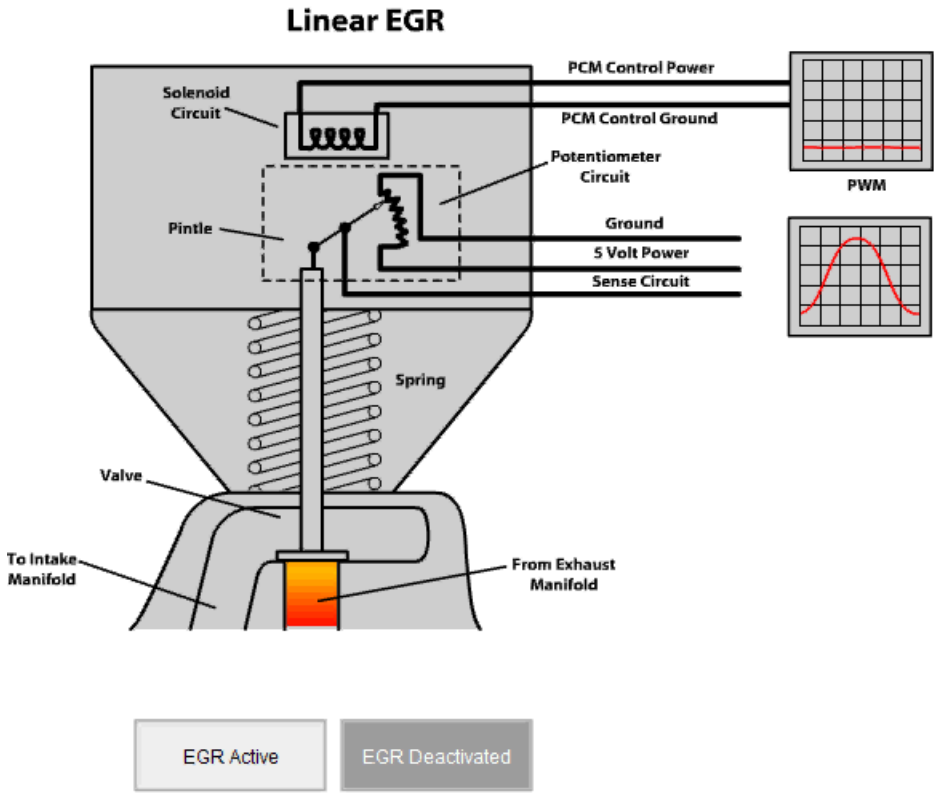
- Flow Test Passes but Distribution Un-equal
- 4.2L Ford V6
- Intake Manifold Tube Plugged for Rear Cylinders
- Front Over Flowing
- Rear Cylinders Lean
- Random Mis-Fires
- Check Mode 6 Test Results
- May be at Minimum But Still Passing

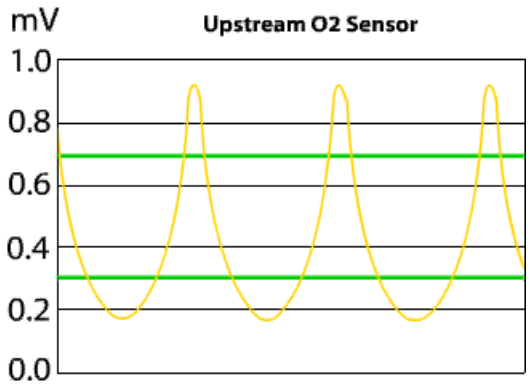
EGR Systems: Ford DPFE

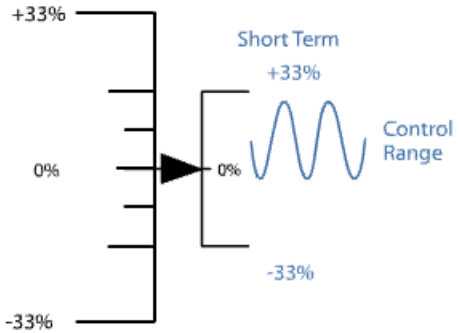
- Pressure drop across the orifice indicates flow.
  - Closed voltage .2 and 1.3V
  - DPFE should raise to 4 volts with vacuum applied
  - DPFE should drop quickly when vacuum is released



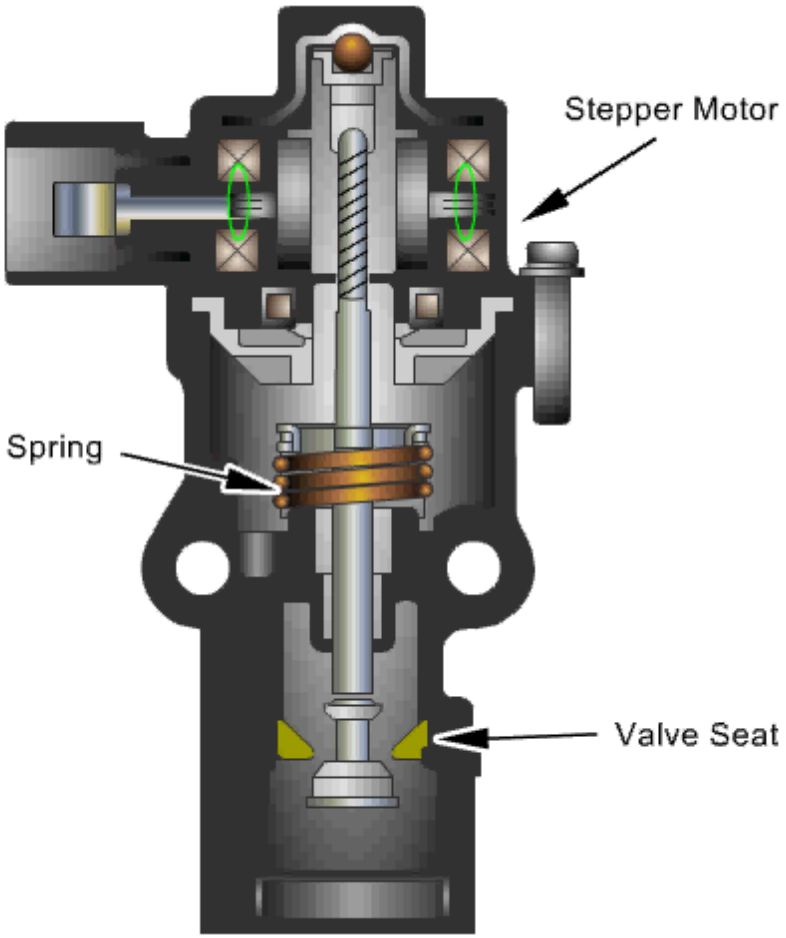
EGR Function Monitoring O2 Response



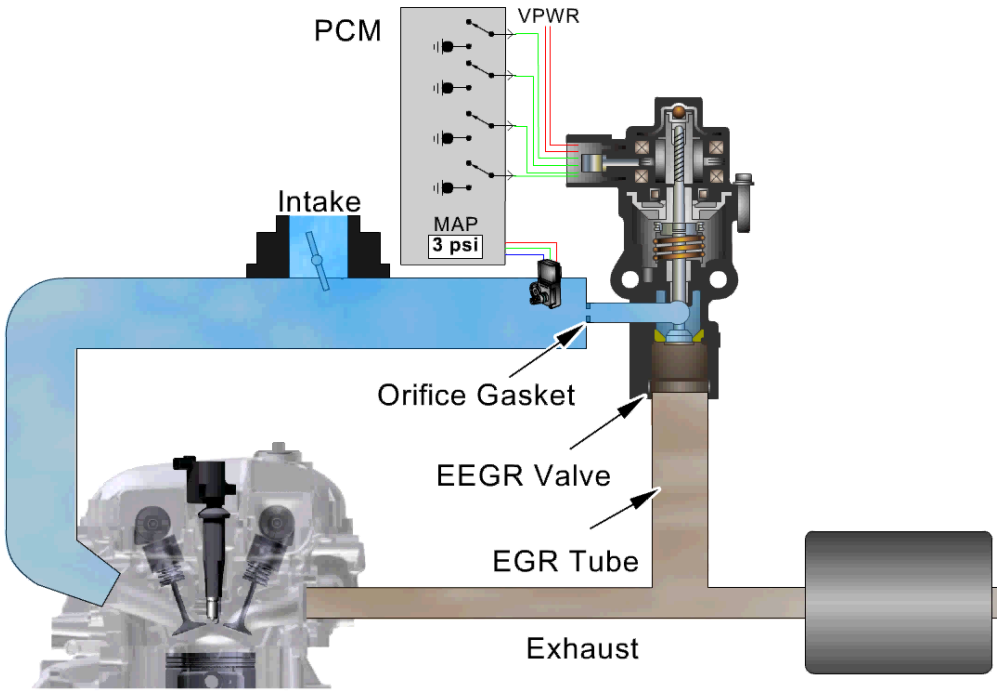




Ford Electric EGR System



- Stepper Motor
- 52 steps (Toyota 60)
- Cooled: water or air
- Smaller CID engines



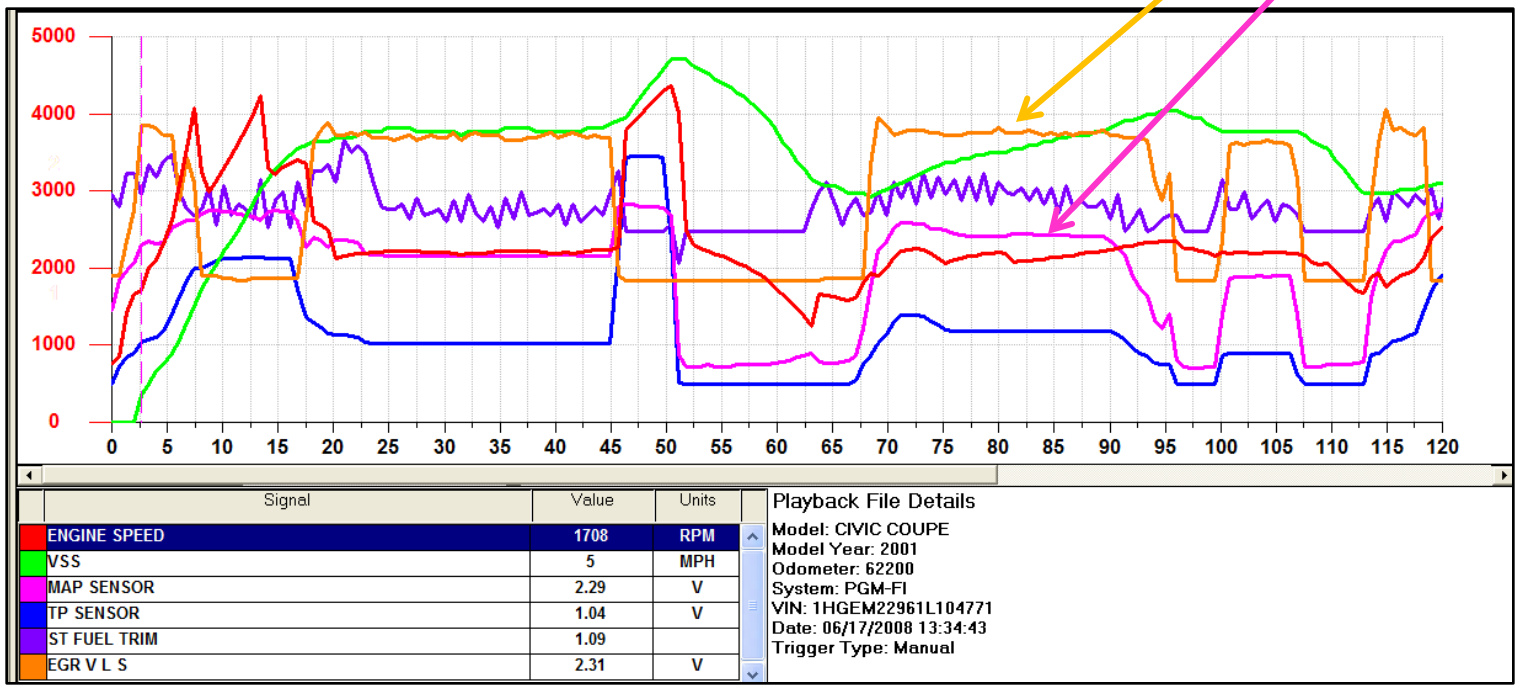
EGR Systems

- Digital EGR
  - PWM Controls Coil Magnetic Field
    - Pintle Movement
  - Position Sensor Determines Pintle Movement
  - Flow Monitors:
    - MAP: Vacuum Change During Deceleration
    - MAF: Air Flow Volume Decreases
  - Electrical Monitors

EGR Systems

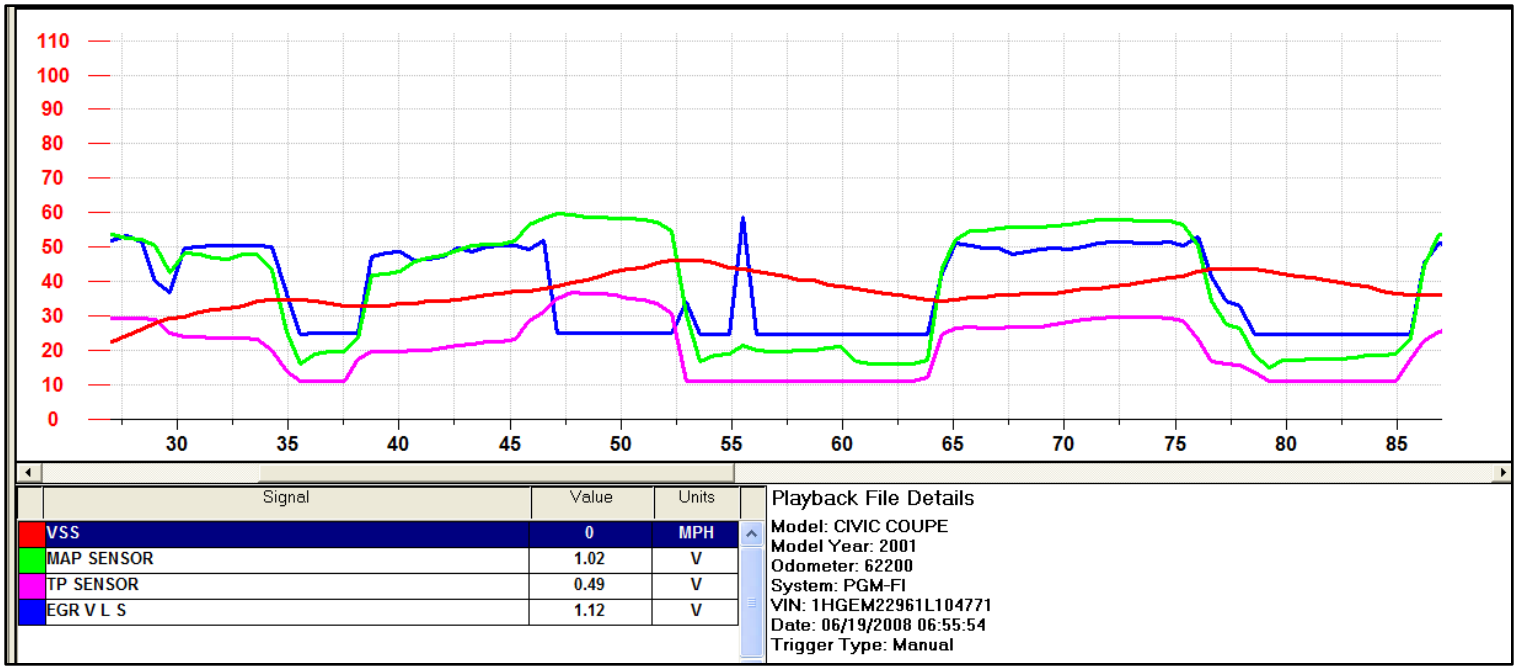
Compare EGR and MAP/ST Fuel Trim
Cruise :EGR is Modulated ON
High TPS: EGR is removed.
O2 Sensor Reaction Shown By ST Trim

EGR Opens
MAP Increases



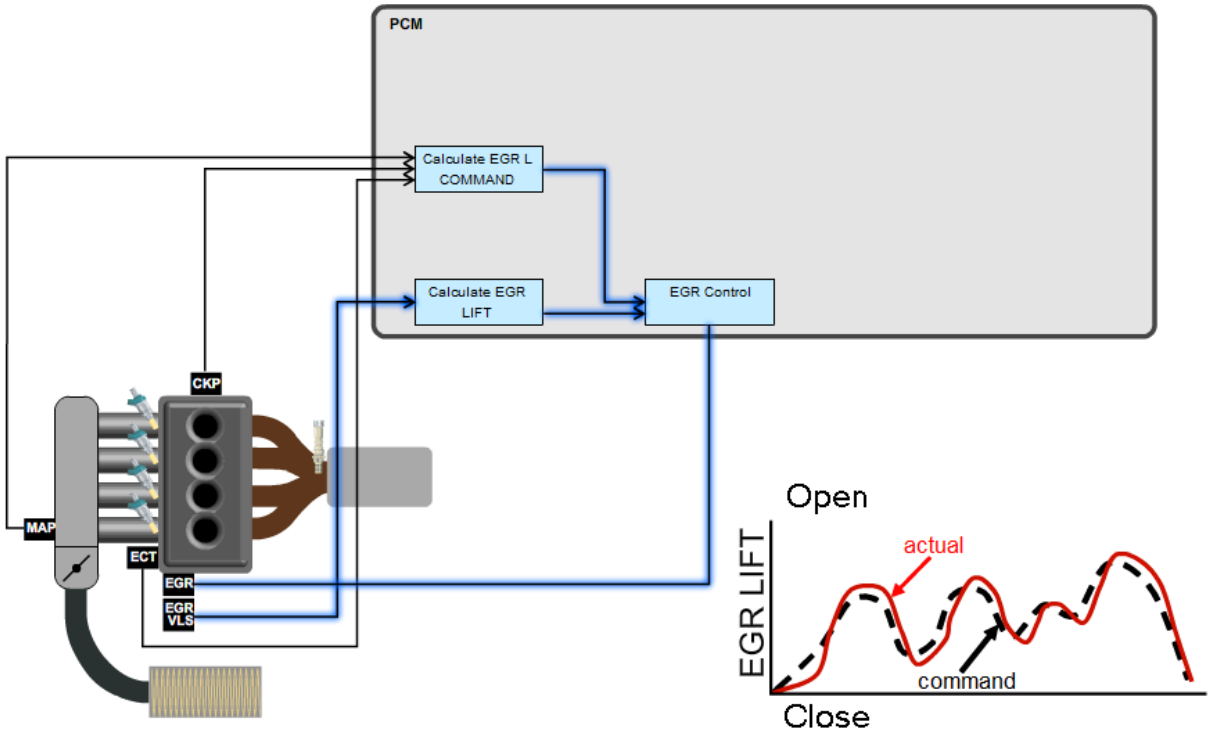
EGR Systems

Can you tell where the diagnostic monitor for flow took place?



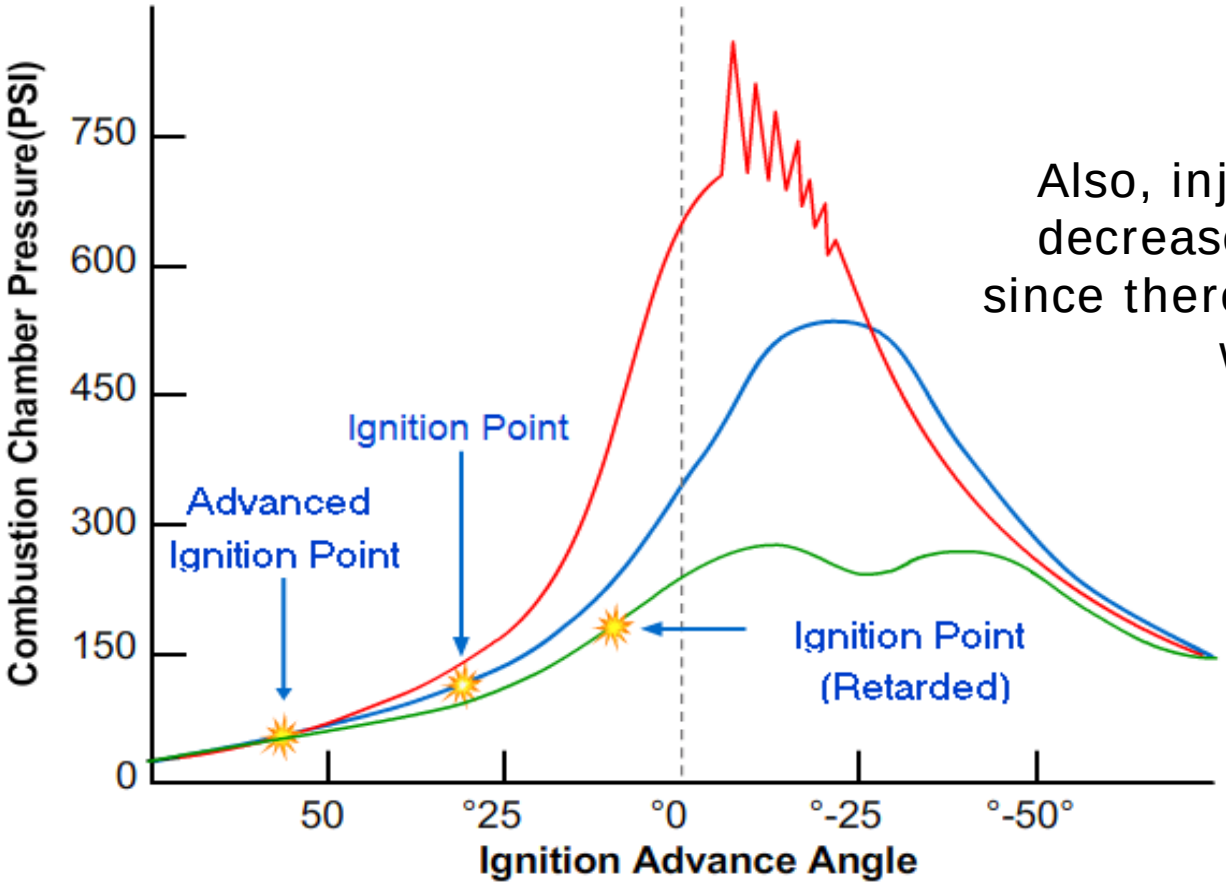
EGR Systems

PCM commands the EGR and monitors the position sensor to see if it achieve the desired lift. If not, it adjusts it's PWM until it does.



EGR Systems

With EGR, the ignition timing can be advanced a bit, since there's less A/F in the cylinder and lower pressure and combustion pressure rise.



Also, injector pulse width is decreased during EGR flow, since there's less oxygen to mix with the fuel

Questions?

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