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- How to test a HO2S Sensor
- What is a AFR sensor
- How to test a AFR sensor
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- How to use STFT and LTFT to assist your diagnosis
- How an AFR/HO2S has effect on Catalytic Converter Function
- Ethanol Blended Fuels and how they may affect your diagnosis

How does an HO2S work?

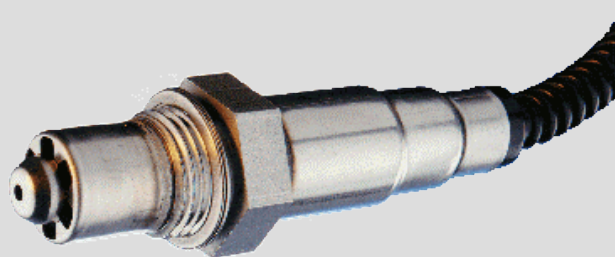
H02S

- An HO2S – Heated Oxygen Sensor
 - Is used to ensure the air fuel ratio is correct for Catalytic Converter operation

- HO2S

0.0 Lean

Rich 1.0



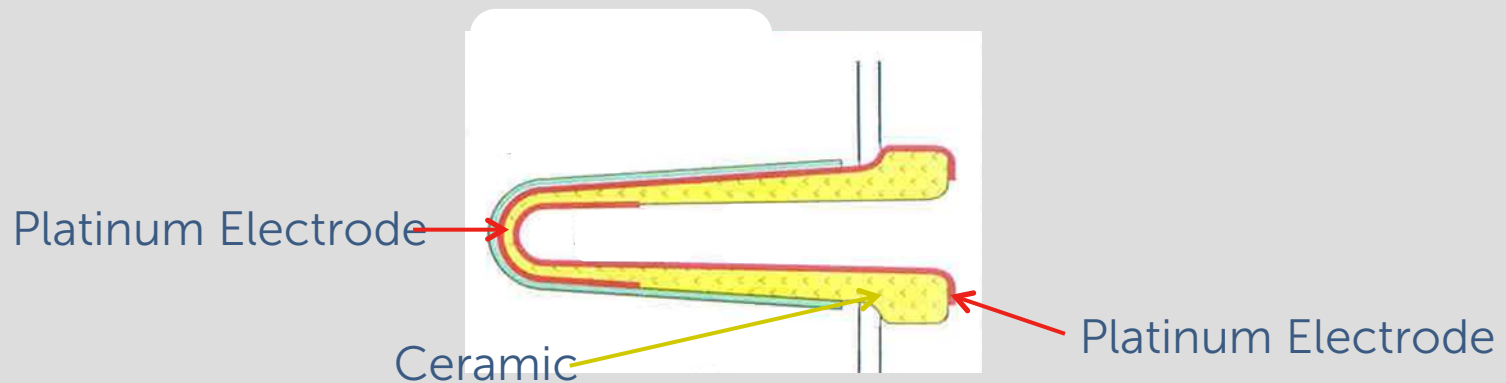


H02S

- HO2S sees 0.0 volts lean
 - IPW will be wide
 - Providing CO - Carbon Monoxide to cause the oxidation process to begin
- HO2S see 1.0 volt rich
 - IPW will be narrow
 - Providing O₂ – Oxygen to replenish the O₂ used during the Oxidation process

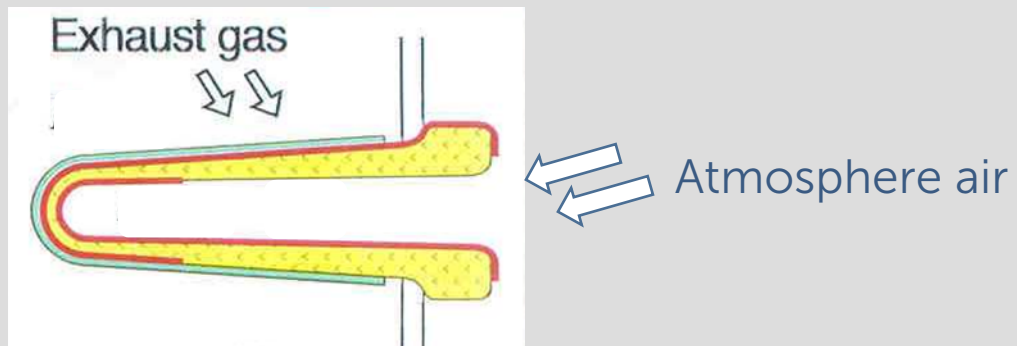
H02S

- HO2S consist of Ceramic made of Zirconium Dioxide and Platinum Electrodes
- Ceramic has attached 2 Platinum Electrodes
- The HO2S generates a voltage based on comparison of Oxygen in the Exhaust as compared to the Oxygen in the Atmosphere



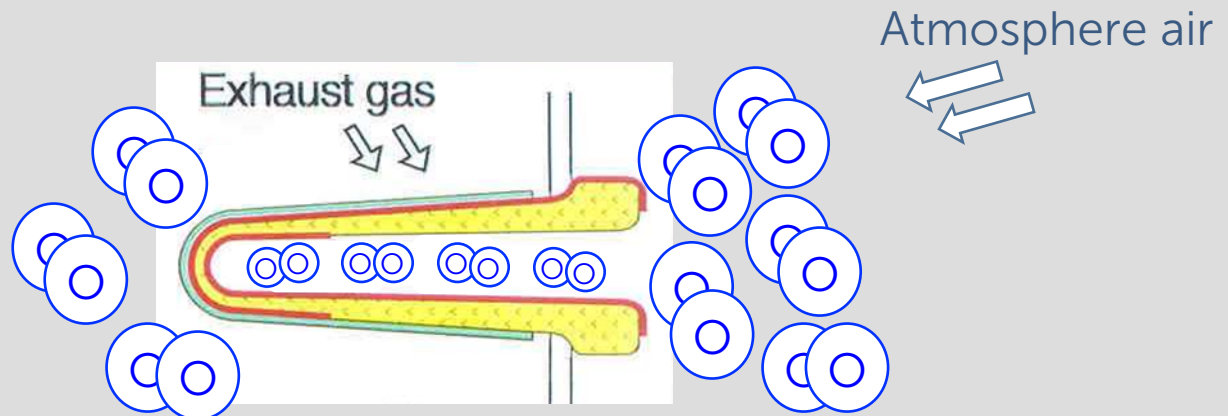
H02S

- One end of the Ceramic/Platinum combination is exposed to the Exhaust
- The other end of the Ceramic/Platinum combination is exposed to the Atmosphere



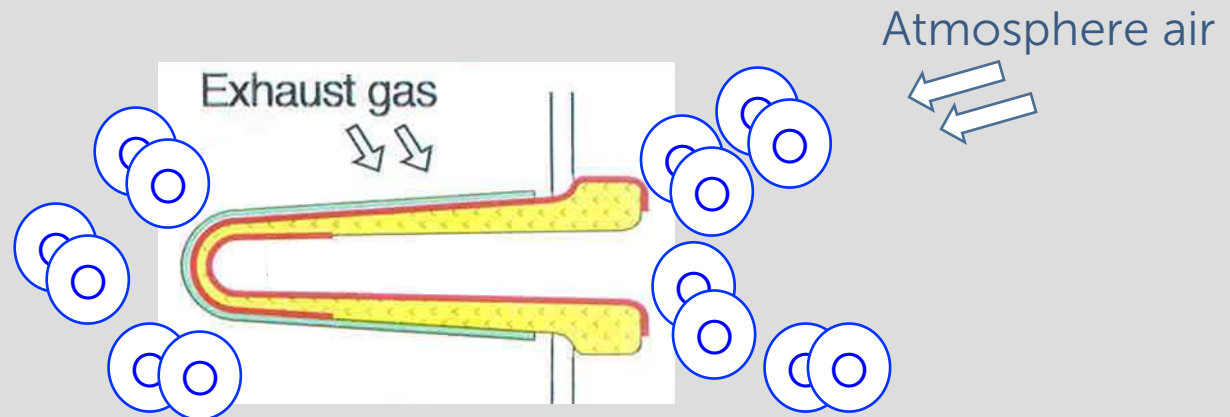
H02S

- When the O₂ in the exhaust gas is low, the sensor voltage is high indicating a Rich condition
- The greater the difference in O₂ in the Atmosphere versus the exhaust the higher the voltage
- The Atmospheric O₂ wants to travel towards the O₂ starved Exhaust, this movement of the O₂ creates a high voltage



H02S

- When the O₂ in the exhaust gas is high, the sensor voltage is low indicating a Lean condition
- The Atmospheric O₂ does not travel through the ceramic and therefore creates no or low voltage





H02S

- The HO2S is heated
- The heater brings the temperature rapidly to 650°F
 - Cold engine start up
 - Prolonged idle periods
- The ECM controls the heater by turning on and off the heater relay
 - The HO2S heater relay provides 0 to 2 amps for the heater to function



H02S

- On V engine
 - B1 S1 Bank One Sensor One
 - B1 S2 Bank One Sensor Two
 - B2 S1 Bank Two Sensor One
 - B2 S2 Bank Two Sensor Two
- S2 – Sensor Two is used to report Catalyst efficiency



How to Test an HO2S



H02S Test 1

- Graph HO2S Bank 1 Sensor 1
- Specification for Good O2 Sensor: 10 cycles from 200mv Lean to 800mv Rich and then Rich to Lean in 1 second, at 2000 RPM hot engine
- Datastream should display a minimum of four O2 Sensor cycles from 200mv Lean to 800mv Rich and then Rich to Lean, at 2000 RPM hot engine



HO2S Propane Test 2

- O2 Sensor propane enrichment test
- Graph the front O2 sensors
- Add propane to enrich the mixture
- Propane enrichment will increase the O2 voltage which will rise towards or above .8 volts
- Keep adding propane until RPM drops, to obtain maximum output
- Shut off the propane to see how fast the voltage decreases
- It should decrease rapidly towards a Lean signal



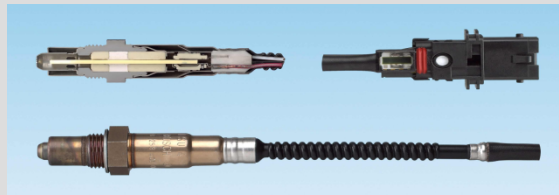
HO2S Test 3

- With the ignition ON and the engine running (KOER), allow to warm to normal operating temperature
- Upstream oxygen sensors should switch from rich to lean every few seconds
 - The voltage should toggle between 300-600 mV and never be a negative value



What is an AFR?

- An AFR – Air Fuel Ratio sensor is a wide band Oxygen sensor
 - It has a wide voltage range to make its measurements
 - This provides for more accurate calculation of fuel metering by the PCM – Powertrain Control Module
 - More points on the AFR scale gives the PCM more points to set IPW – Injector Pulse Width
 - Its design makes it fast acting allowing the PCM to make fast decision
 - An HO2S and an AFR look similar, but have different connectors



AFR





- An AFR reads 2.50 volts rich to 3.80 volts lean
 - Global OBD II 0.50 volts rich and 0.78 volts lean
 - Positive amperage rich to Negative amperage lean
- The voltage change is governed by an amperage polarity change created by a detection circuit in the PCM
- The AFR is heated to 1435°F

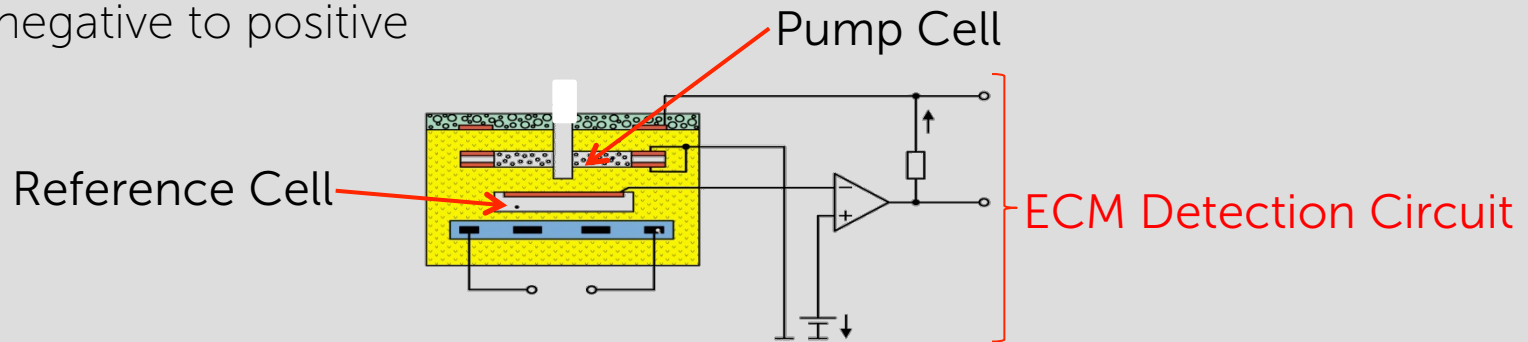
OEM PID	Global OBDII PID	Amperage
2.50 Volts	0.50 Volts	Positive

OEM PID	Global OBDII PID	Amperage
3.80 Volts	0.78 Volts	Negative

How does an AFR work?

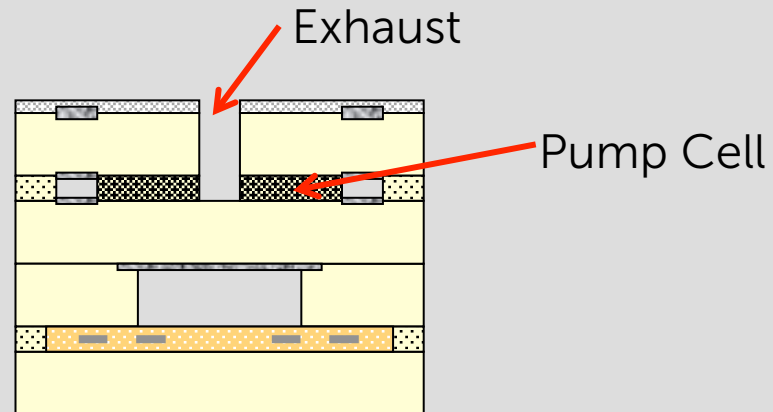
How an AFR works

- The wide band Oxygen sensor has two cells
 - Pump Cell
 - Reference Cell
- The ECM detection circuit tries to maintain 3.30 volts to the Pump Cell sensing wire at all times in order to maintain Stoichiometric
- To maintain the voltage during engine operation it will vary the amperage to the detection circuit by reversing the polarity from negative to positive



How an AFR works

- The Pump Cell current flow pushed the Exhaust in and out of the Pump Cell
- Once the analysis has been completed the Pump Cell expels the Exhaust
- This is a constant ongoing circulation
- The change in exhaust oxygen is always being detected





How an AFR works

- If the exhaust is rich containing less oxygen the voltage will fall to as low as 2.50 volts
 - The amperage will be positive to try to maintain 3.30 volts
 - Air fuel ratio as rich as 12:1
- The ECM decrease IPW based on a decision made from the amount current flowing

OEM	Global	Amperage	Condition	Lambda	A/F Ratio	IPW Correct
2.50v	0.48v	0.004	Rich	0.84	12 to 1	Lean



How an AFR works

- If the exhaust gas is at Stoichiometric the voltage 3.30
 - The amperage is 0 amps
 - Air fuel ratio Stoichiometric 14.7:1
- ECM maintains IPW based on a decision made from the amount current flowing

OEM	Global	Amperage	Condition	Lambda	A/F Ratio	IPW Correct
3.80v	0.76v	0	Ideal	1.00	14.7 to 1	None



How an AFR works

- If the exhaust is lean containing a lot of oxygen the voltage will rise to as high as 3.80 volts
 - The amperage will be negative to try to maintain 3.30 volts
 - Air fuel ratio as lean as 19:1
- The ECM increases IPW based on a decision made from the amount current flowing

OEM	Global	Amperage	Condition	Lambda	A/F Ratio	IPW Correct
3.80v	0.76v	-0.001	Lean	1.20	19 to 1	Rich



Regular Unleaded Gasoline C8 H8

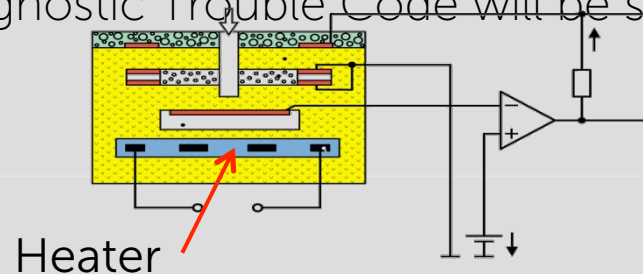
OEM PID	Global OBD II	A/F	Amperage	A/F Ratio
2.4v	.48v	Rich 0.84 Lambda	Positive +0.004	12.0
2.5v	.50v			12.3
2.6v	.52v			12.6
2.7v	.54v		0.003	12.9
2.8v	.56v			13.2
2.9v	.58v			13.5
3.0v	.60v		0.001	13.8
3.1v	.62v			14.1
3.2v	.64v			14.4
3.3v	.66v	Stoichiometric 1.00 Lambda	0.000	14.7
3.4v	.68v			15.3
3.5v	.70v			15.9
3.6v	.72v		-0.001	16.5
3.7v	.74v			17.2
3.8v	.76v			17.8
3.9v	.78v			18.4
4.0v	.80v	Lean 1.25 Lambda	Negative -0.002	19.0



The AFR Heater

How does an AFR work?

- The AFR heater operates at 1435°F
- The heater circuit carries 7 amps
- The heater circuit is PWM – Pulse Width Modulated
 - When the AFR is cold the heater circuit PWM is at higher frequency to obtain 1435°F
 - When the AFR is at 1435°F operating temperature the PWM is at lower frequency to maintain the 1435°F
- Because the AFR requires more heat than an HO2S (650°F) the heater is on longer and usually on full time while driving
- If a malfunction occurs in the heater circuit is turned off
 - A DTC – Diagnostic Trouble Code will be set





How to Test an AFR



AFR Sensor Test 1

- Engine at operating temperature
- No DTC's present for AFR or AFR Heater circuit
- From idle raise engine to 2500 RPM
- AFR should read 3.30 volts
- Snap the throttle to 4000 RPM
 - AFR voltage will fall Rich
- After throttle is closed and at return to idle
 - AFR voltage should rise Lean
- If no change check AFR heater circuit
- Always verify AFR specification with Identifix

OEM PID	Global OBDII PID	Amperage
2.50 Volts	0.50 Volts	Positive

OEM PID	Global OBDII PID	Amperage
3.80 Volts	0.78 Volts	Negative



AFR Sensor Test 2

- Engine at operating temperature
- No DTC's present for AFR or AFR Heater circuit
- Create a Vacuum Leak
 - Lean condition
 - Voltage should rise
 - Amperage should drop



AFR Sensor Test 3 Toyota

- Engine at operating temperature
- No DTC's present for AFR or AFR Heater circuit
- Special Tests
 - AFR Test
 - Activate
 - IPW will increase automatically
 - AFR voltage should drop with IPW increasing
 - IPW will then decrease automatically
 - AFR voltage should rise with IPW decreasing



What is Fuel Trim?



What is Fuel Trim?

- Fuel Trim is the corrections the PCM is commanding
- Specification: $\pm 5\%$
- STFT – Short Term Fuel Trim – immediate correction about 20 times per second
 - change rapidly in response to the HO₂S/AFR inputs and or MAF and or RPM
 - These changes fine tune the engine fueling
- LTFT – Long Term Fuel Trim – long term correction about 2 times per second
 - The Long Term Fuel Trim values change in response to trends in Short Term Fuel Trim
 - The Long Term Fuel Trim makes coarse adjustments to fueling in order to re-center and restore control to Short Term Fuel Trim



What is Fuel Trim?

- +10, + plus numbers on STFT means the PCM has received a lean signal from the AFR or HO2S
 - PCM will command the Injector Pulse Width to widen for a rich correction
- -10, - minus numbers on STFT means the PCM has received a rich signal from the AFR or HO2S
 - PCM will command the Injector Pulse Width to narrow for a lean correction



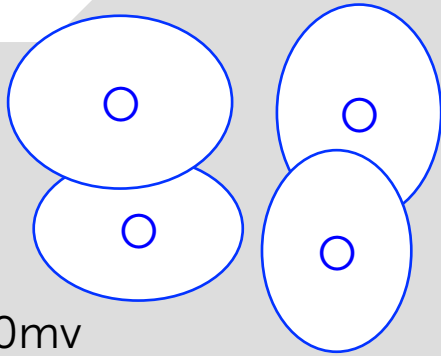
Diagnosing with Fuel Trim

Fuel Trim Diagnostics

Idle	2500 RPM	Possible Causes
+ 5% and Up	0%	Vacuum Leaks
0%	+ 5% and Up	Low Fuel Volume
+ 5% and Up	+ 5% and Up	Low Fuel Pressure
-5% and lower	0%	Contaminated Crankcase
-5% and lower	-5% and lower	Injectors

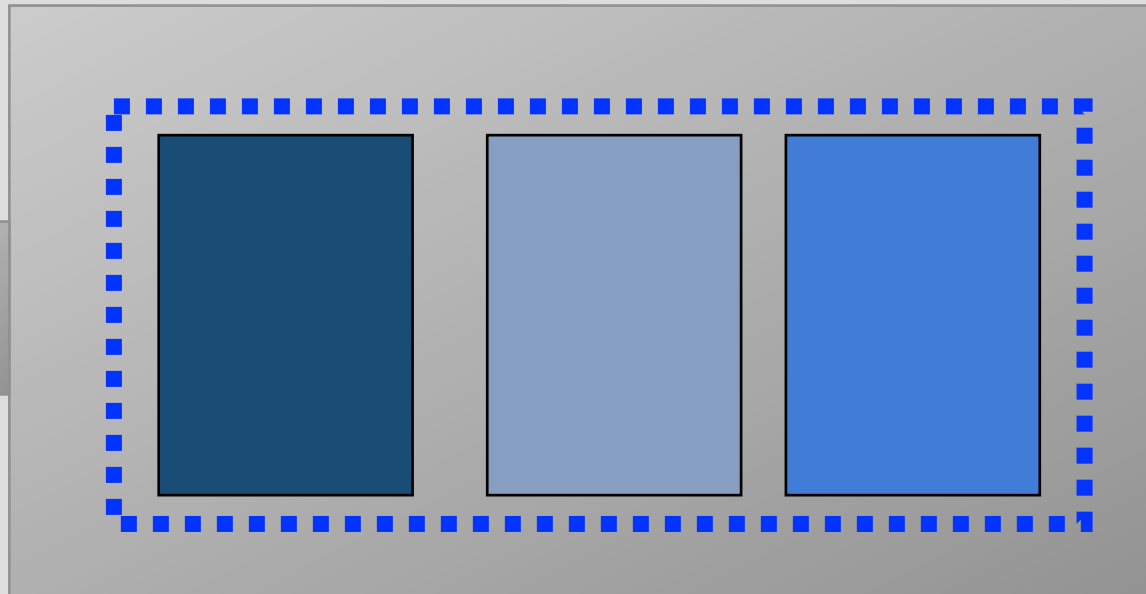


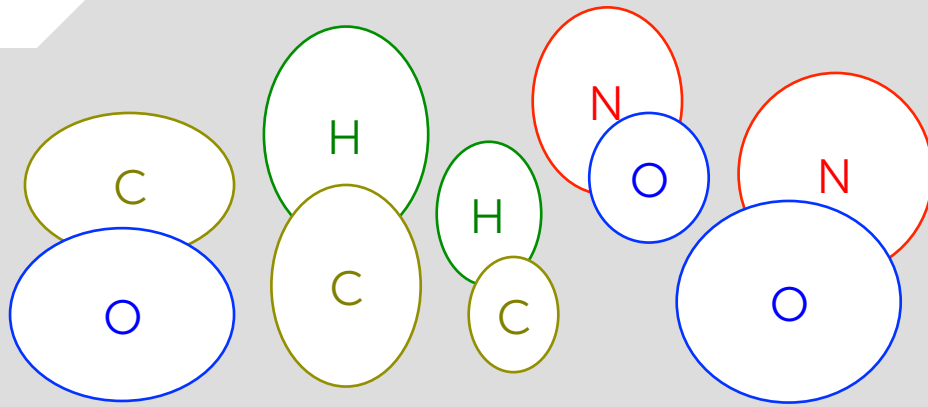
Catalytic Converter



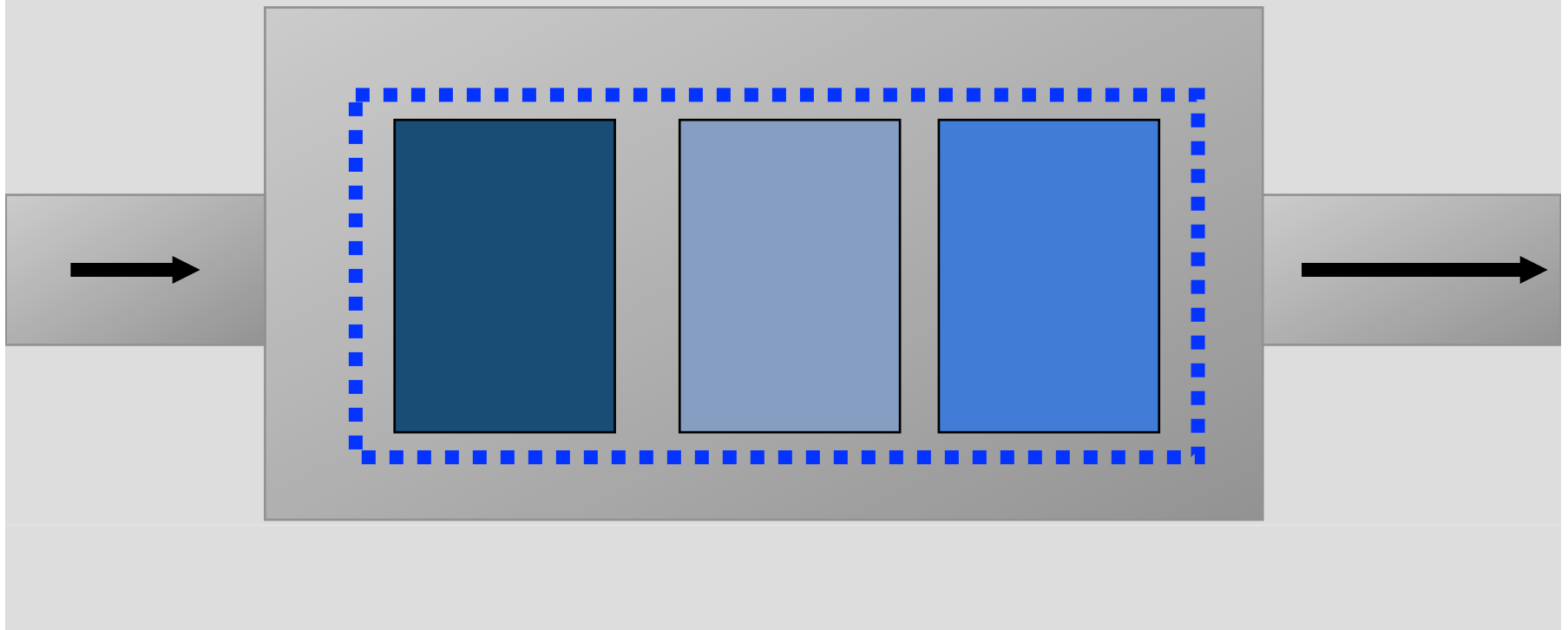
O₂ SENSOR READS LEAN, PCM
COMMANDS RICH, INCREASING CO

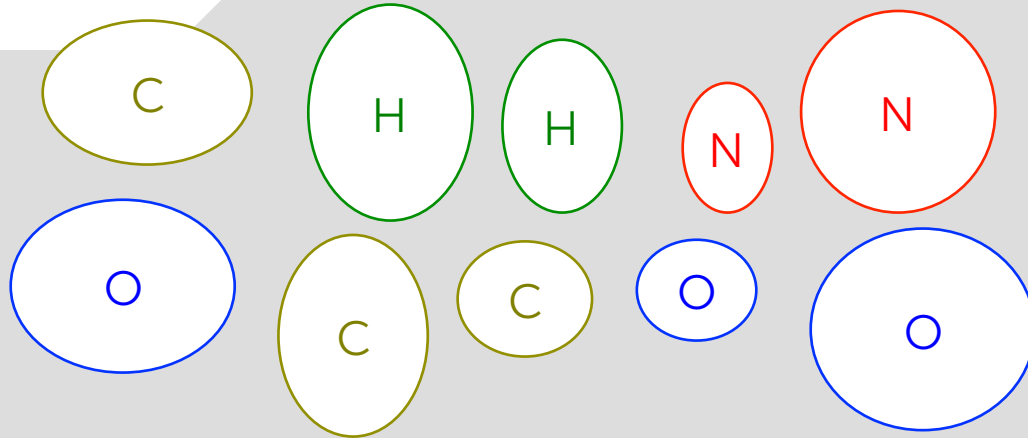
200mv
SWITCH
<100ms



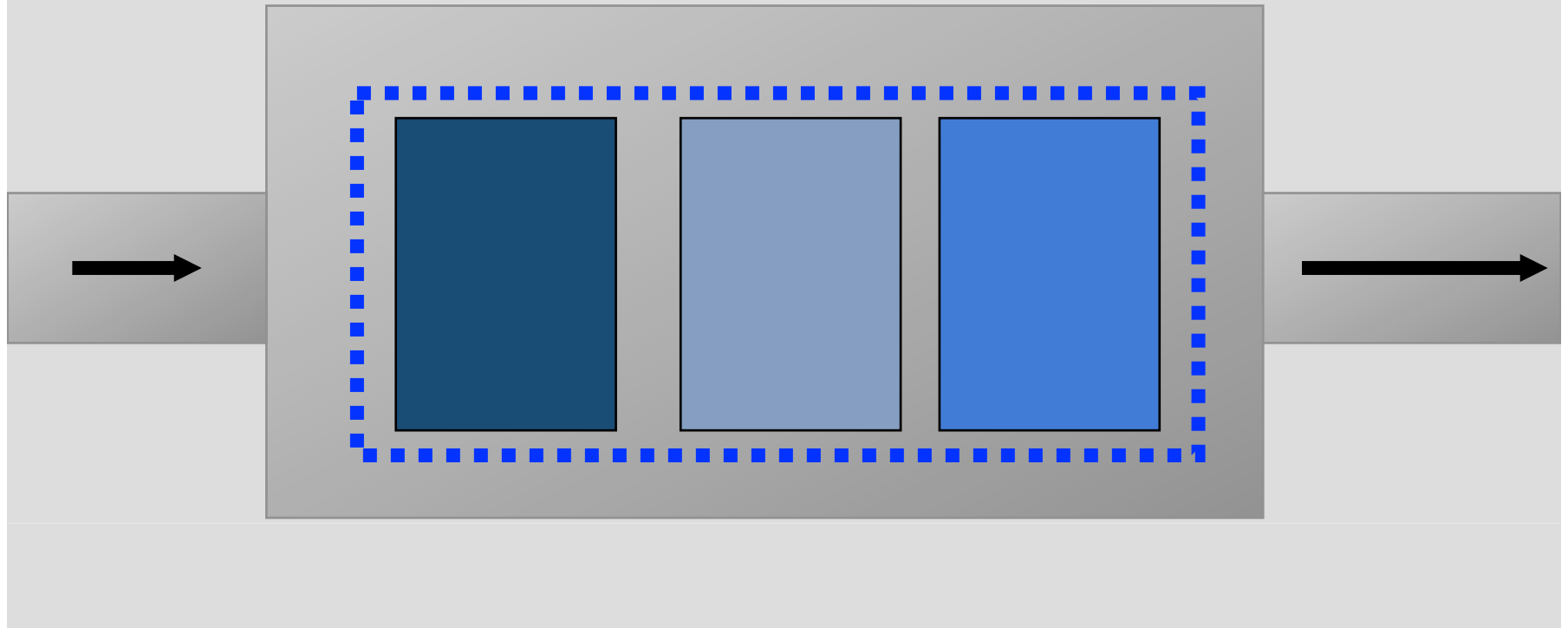


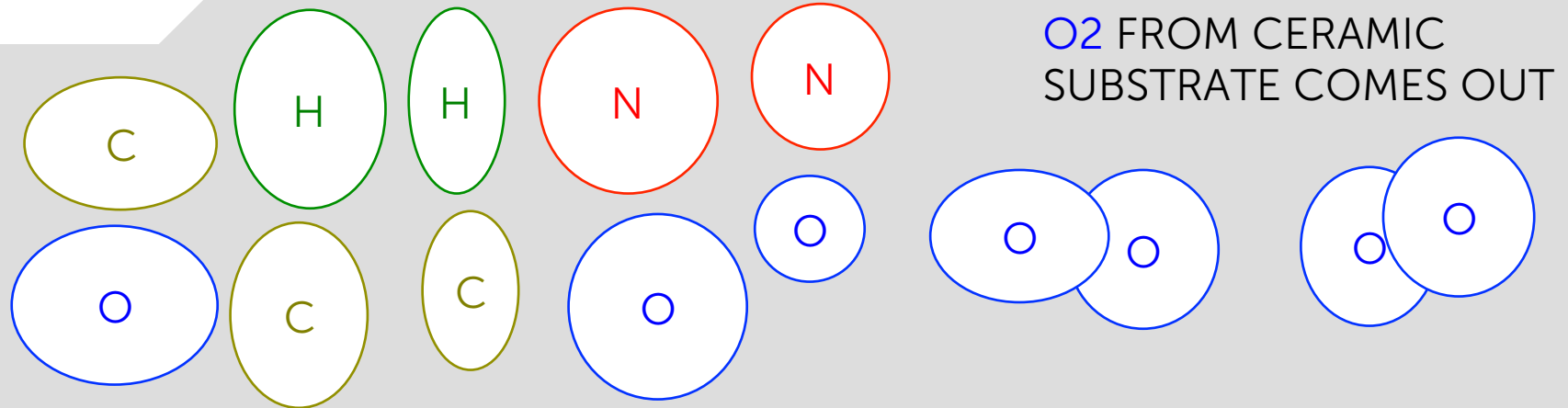
CO CAUSE THE CATALYST TEMPERATURE TO RISE



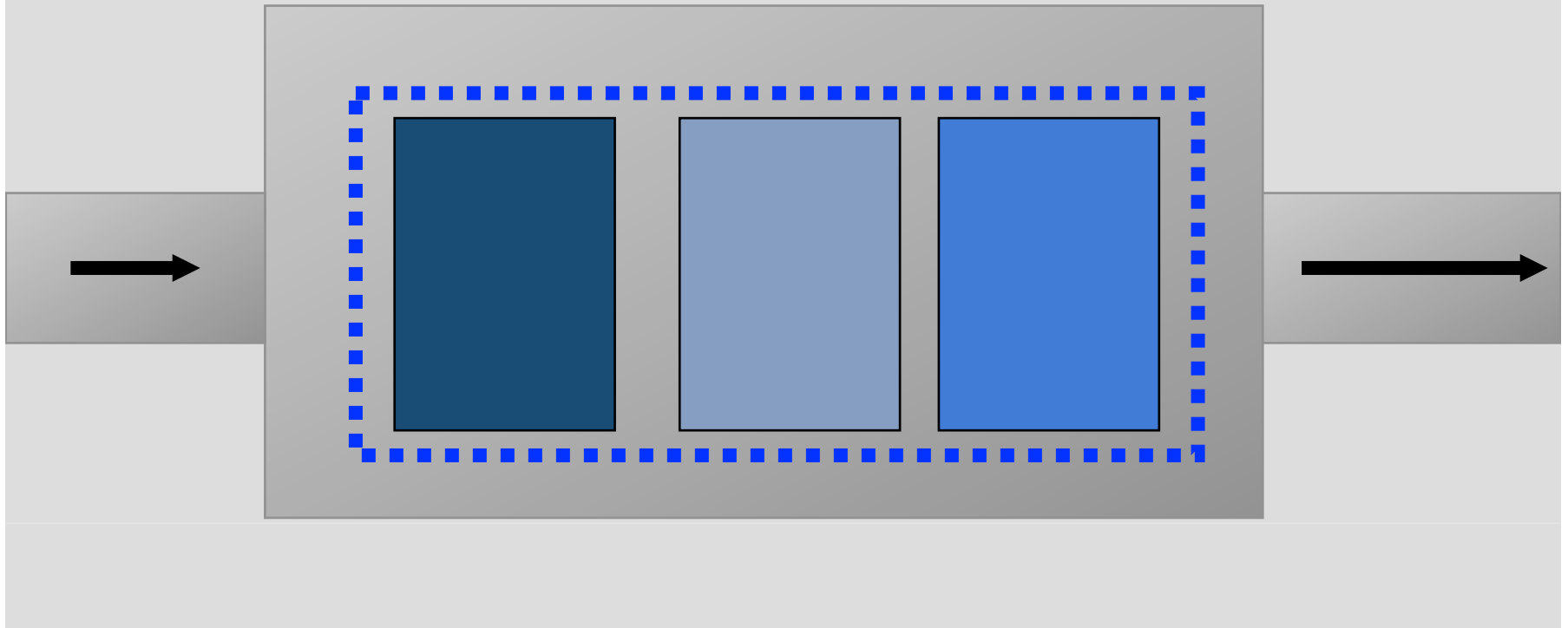


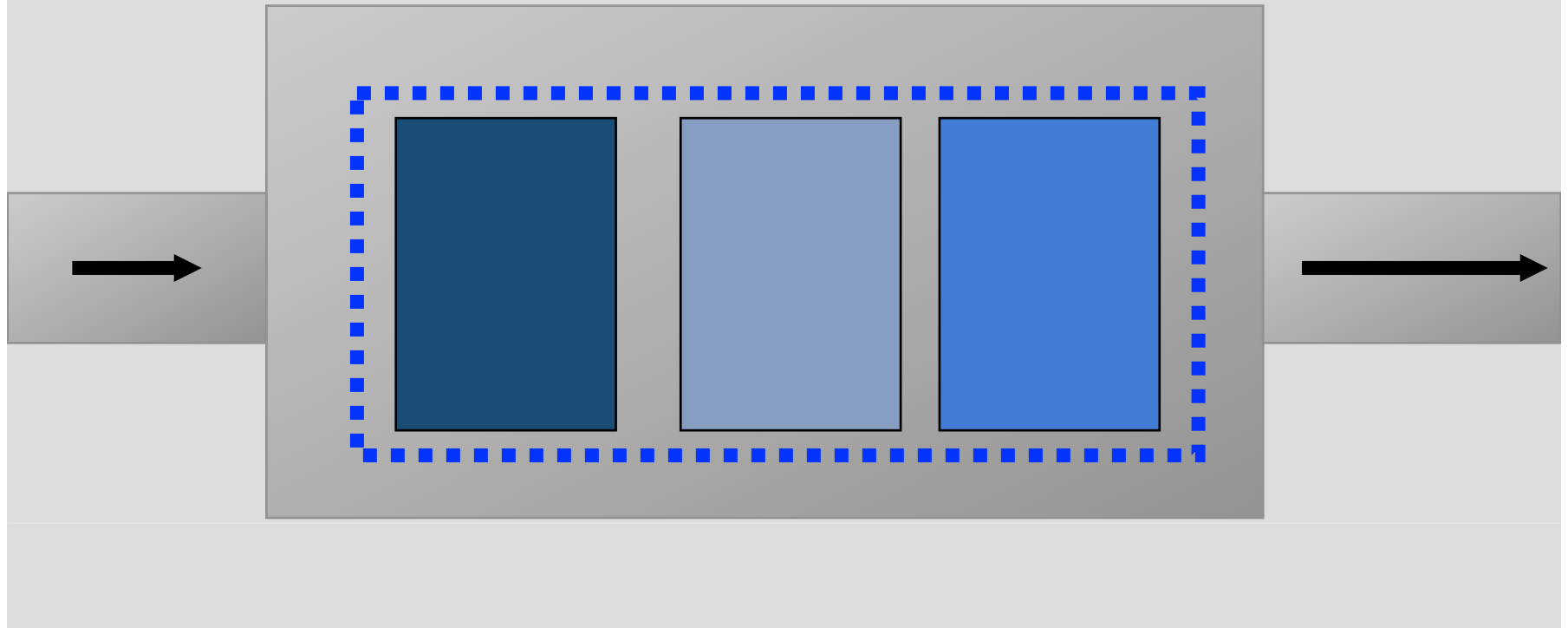
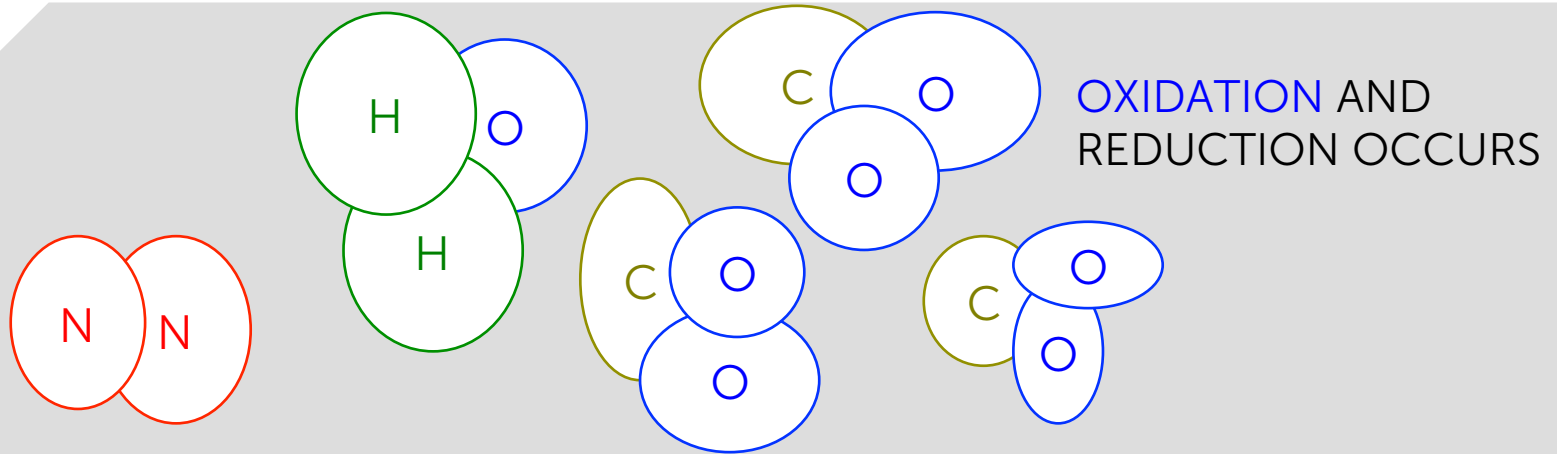
HIGH CATALYST TEMPERATURE
CAUSES ELEMENTS TO
SEPARATE





O_2 FROM CERAMIC
SUBSTRATE COMES OUT

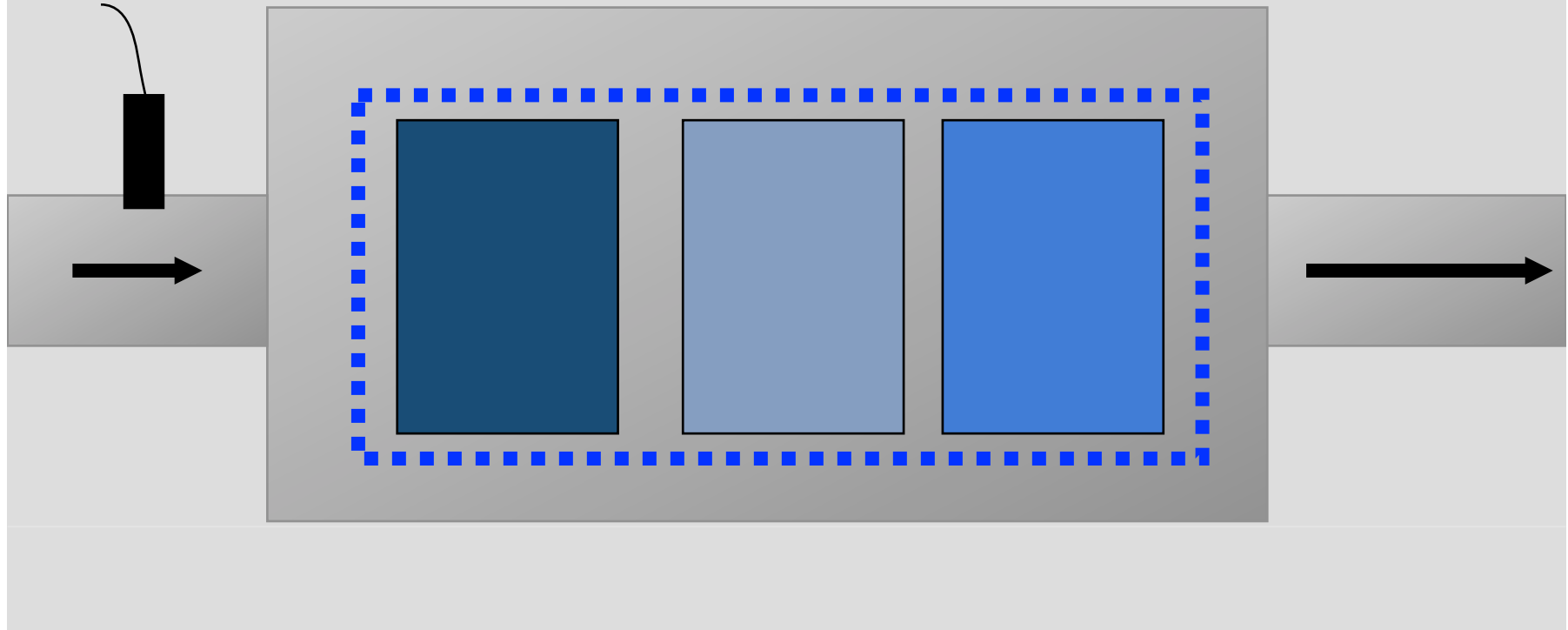






O₂ SENSOR READS RICH , PCM COMMANDS
LEAN, REPLENISHING CATALYTIC CONVERTOR
WITH O₂

800mv
SWITCH
<100ms





Ethanol Blended Fuels



Air Fuel Ratio for Ethanol Blended Fuels

- Most of North America uses Ethanol blended fuel
 - Reduces America's foreign dependence on Oil
 - Typically used is a 10% blend of Ethanol – E10
 - C_2H_5OH
 - Octane 95



Air Fuel Ratio for Ethanol Blended Fuels

- Air Fuel Ratio
 - Stoichiometric Air Fuel Ratio for 100% Ethanol is 9.00:1
 - Stoichiometric Air Fuel Ratio for Gasoline is 14.7:1
- If you blended volume of Ethanol is 10%, then to calculate your AFR use the following formula:
 - 90% Gasoline $14.7 \times 0.90 = 13.23$ AFR
 - 10% Ethanol $9.00 \times 0.10 = 0.90$ AFR
 - $(14.7 \times 0.90) + (9.00 \times 0.10) = 14.13$ AFR
 - Rounded up to 14.2 AFR

Condition	Lambda	A/F Ratio	IPW Correct
Ideal	1.00	14.2	None



Air Fuel Ratio for Ethanol Blended Fuels

- To calculate WOT AFR:
 - Ethanol blended fuel 14.2 AFR
 - Lambda at WOT 0.84
 - AFR would be $14.2 \times 0.84 = 11.928$ AFR
 - Round up to 11.9 AFR at WOT

Condition	Lambda	A/F Ratio	IPW Correct
Rich	0.84	11.9	Lean



Air Fuel Ratio for Ethanol Blended Fuels

- To calculate lean AFR:
 - Ethanol blended fuel 14.2 AFR
 - Lambda when lean 1.25
 - AFR would be $14.2 \times 1.25 = 17.75$ AFR lean
 - Round up to 17.8 AFR lean

Condition	Lambda	A/F Ratio	IPW Correct
Lean	1.25	17.8	Rich



What have we learned?

- What is a HO₂S and how does it work
- How to test a HO₂S Sensor
- What is a AFR sensor
- How to test a AFR sensor
- How a AFR Heater works
- What is STFT and LTFT
- How to use STFT and LTFT to assist your diagnosis
- How an AFRHO₂S has effect on Catalytic Converter Function
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