- **AIR INJECTION SYSTEMS:** Any system or devise installed on an internal combustion engine to inject fresh air into the exhaust stream, either before or after the catalytic converter. Air injection systems (previously known as smog pumps) can dilute the test samples taken at the tailpipe and must be disabled prior to testing with a gas analyzer.

- **AFR – AIR FUEL RATIO:** The ratio of air to fuel as it is introduced into the combustion chamber. Also known as the Stoichiometric ratio. Typically shown as a number like 14.7:1 – referring to 14.7 parts (mass) of air to each part of fuel.

  AFR was a historically popular method for analyzing fuel mixtures. This is NO LONGER THE CASE TODAY (today, technicians use **Lambda** – see definition below), as different fuel mixture strategies and varying fuel blends have created an environment where ratios far below 14.7:1 and ratios up to 25:1 may be normal – depending on the computer strategy and the blends of alcohol available (E-85 for example requires more fuel to air – often as much as 25% more fuel to air than conventional gasoline).

  For pure gasoline engines, without a modified fuel strategy, a ratio with a number progressively higher than 14.7 for the first number refers to a lean mixture, with a number less than 14.7 referring to a progressively richer mixture.

  To accurately utilize AFR for diagnostics, you need to know the specific gravity of the fuel, as well as the exact blend of gasoline and alcohol, and you must have a chart of the fuel mixture strategies for that specific model of car. Since the actual correct AFR ratio can be affected by so many things, it is important to measure the **Lambda** readings for diagnostic purposes (see definition below), a far more accurate number that is unaffected by seasonal mixtures of fuel and other factors.

- **ATOMOSPHERIC or BAROMETRIC PRESSURE SENSORS:** Sensors that monitor atmospheric pressure, providing an input to the vehicles on board computer to adjust fuel mixtures accordingly

- **CATALYTIC CONVERTER:** A devise resembling a muffler in the exhaust stream with a catalyst bed that is used to convert certain exhaust emissions into a more harmless emission through a chemical process.

- **CO:** Carbon Monoxide. When measured at the tailpipe, it is a measurement of incomplete combustion typically the result of an overly rich mixture. As the numbers get progressively higher, the indication is a progressively richer mixture.

- **CO2:** Carbon Dioxide. Carbon dioxides are a leading indicator of efficient combustion. The higher the CO2 emission, the more efficient the combustion cycle.

- **ETHANOL – E85 – GASOHOL – FLEX FUEL - BIOFUELS:** As nations work towards reducing their dependence on fossil fuels, it has become popular to add a specific blend of alcohol or ethanol to regular gasoline. These alcohols can be made from corn, beets, sugar cane, switchgrass and a variety of other crops.

  Blends can be anywhere from 90% gasoline and 10% alcohol, to 85% alcohol to 15% gasoline. When alcohols are used as fuel, they tend to be slower and cooler burning than regular gasoline, as they do not have as much "stored energy". This is why a vehicle with an E-85 blend (ethanol blended at a minimum rate of 70%, and a maximum rate of 85%) will have reduced miles per gallon (KM per liter) measured fuel economy.

  The introduction of these fuels (and varying fuel mixture – "flex fuel" computer strategies) has led to the decline in popularity of using AFR (air fuel ratio) for diagnostics in favor of Lambda readings – as Lambda readings are unaffected by these fuel blends. Imagine testing a Flex Fuel using AFR, where 14.7:1 is appropriate for pure gasoline, but 14.7:1 with the presence of E-85 would indicate a lean condition – and just how lean would depend upon the mixture in the tank. If the vehicle owner buys different fuels on each fill-up, you could have a custom blend that only the vehicles on-board computer could compensate for.

- **DIRECT INJECTION SYSTEMS:** An increasingly popular design where the fuel is injected directly into the combustion chamber and all that travels through the intake system is air. In carbureted and traditional fuel injection, the mixture of air and fuel is done outside the combustion chamber, whereas in a direct injection system, the precise amount of fuel for the operating condition is introduced at the exact time for the most efficient power or economy required. Direct injection is currently a more complex and costly system, however the gains in both power and fuel economy have made it more popular in the luxury and performance car segments.

- **EGO SENSOR:** Exhaust Gas Oxygen Sensor. Also commonly referred to as an O2 sensor or Lambda sensor. There have been various designs of this type of sensor over time in response to different emission regulations and on-board computer systems.

  Typically installed up stream of the catalyst (many newer cars use as post catalyst sensor to validate the effectiveness and life of the catalyst) in the exhaust system, these sensors are one of the most critical to proper performance of the modern internal combustion engine. Ultimately, the primary role of the sensor is to measure the Oxygen content of the exhaust flow and provide an input to the computer that allows it to adjust the air fuel ratio for optimum performance and emissions in real time.

  Often forgotten as an "out of site, out of mind" part of the system, many subtle and not so subtle drivability problems can be traced back to this sensor. Simply put, the computer system in the car expects a real time and accurate input from the sensor in order to constantly adjust the air fuel ratio correctly. The sensor, however, has a finite life and slows down over time, and should be replaced between 50,000 and 100,000 miles (80,000 – 160,000 KM), depending upon the model and type of sensor, as part of any tune up performed on the car.

In addition, the presence of oil deposits (from engine wear), silicates (from gasket sealing compounds or antifreeze), and periods of misfire, can cause a coating on the sensor that will slow down the response to changes in oxygen content of the exhaust and the sensor will send an erroneous reading to the computer, resulting in an incorrect mixture response.

A simple rule of thumb: If replacing spark plugs, replace the EGO / Lambda / O2 sensors at the same time. You can test the sensor for speed of response and proper function with a high impedance lab scope or digital graphing multi-meter to validate your diagnosis, but if the sensor has over 50,000 miles (80,000 KM) on it, you should replace it regardless – as is likely at the end of its useful life and will likely fail sometime soon. The proper "tune-up" of today is typically the combination replacement of spark plugs, O2 sensor(s), fuel and air filters, often combined with any necessary cleaning of the fuel system and intake system.

- **EGR VALVE:** Exhaust Gas Recirculation Valve. One of the earliest and most effective methods of reducing NOX emissions, the EGR valve takes a small amount of the exhaust gas and returns it to the combustion chamber. Contrary to popular thought, this exhaust gas is not "re-burned" – as there is no longer enough fuel or oxygen. The spent exhaust gas effectively takes up space in the combustion chamber (as an inert gas), and helps to COOL the combustion chamber and promote a more efficient burn of the air fuel mixture by helping to prevent premature detonation of the new air fuel mixture.

- **EXCESS BACKPRESSURE – EXHAUST:** Backpressure in the exhaust system has a significant effect on engine performance and on the accuracy or validity of sample readings at the tailpipe. Engine performance is dramatically affected, since the restriction on the exhaust side prevents the engine from pulling air into the engine on the intake side – simply put, if you cannot let the air out, you cannot bring any more air in.

  The common symptom of a severe exhaust restriction is a total lack of power and an inability to increase RPMS. When testing at the tailpipe with a gas analyzer, the readings mimic a severe exhaust leak, and a reading that is not valid for tuning purposes. This happens because there is not sufficient exhaust flow to "push out" the O2 that the atmosphere pushes in the end of the tailpipe.

  The software system on this site uses the readings from the gas analyzer to calculate a probable or possible restriction in the exhaust and suggests to the operator to test for an exhaust restriction by removing an O2 sensor upstream of the catalyst to perform an exhaust back pressure test.

- **EXHAUST PROBE:** The exhaust probe included with the gas analyzer is a calibrated, stainless steel test probe designed to produce accurate measurements of the exhaust sample. Modifications to this probe or not fully inserting the probe into the tailpipe will result in a warning message that the operator does not have a valid reading, and will suggest that you test for proper insertion, and / or perform a leak test on the sample probe and hose used by the gas analyzer.

- **HC:** Hydrocarbons. Measured in PPM (parts per million), this is a measurement of unburned fuel. It is the hydrocarbons in all fossil or man-made fuels that provide the energy for an internal combustion engine.

  In perfect combustion, all of the HC should be consumed, and you should have a zero (0), PPM reading for HC at the tailpipe. The presence of HC at the tailpipe in increasing numbers from zero indicates progressively higher levels of misfire. This misfire can be mechanical, spark related or related to an overly rich or lean condition. This software system will direct the operator to the most likely cause.

- **INPUT SENSORS:** These sensors recognize inputs from the driver or outside conditions and adjust engine performance accordingly. An example would be the TPS (throttle position sensor / switch), which adjusts the engine performance based on inputs from the driver. These sensors and adjustments are designed to initiate a process.

- **LAMBDA:** Considered the most accurate, dimensionless measurement of Air Fuel ratios based on calculations from the exhaust sample. The Lambda number is calculated by the 4 or 5 gas analyzer by comparing all of the gases (with particular attention to the carbons and oxygen) to determine how efficiently combustion has taken place with regard to air / fuel ratios.

  Lambda is the preferred method to determine relative richness or leanness of the mixture as it is virtually unaffected by a catalytic converter (your readings for Lambda would be the same before or after a catalytic converter), variations in fuel additives or mixtures, the use of oxygenated fuels, the presence of NOX and other variables that make reading a 4 or 5 gas analyzer more complex. Lambda is presented as a number where 1.000 (unloaded use) is considered a perfect air fuel ratio (14:7 – 1), with progressively higher numbers indicating a progressively leaner mixture, and progressively lower numbers indicating a progressively richer mixture.

  Accurate samples at the tailpipe are required for correct calculation of Lambda, as any dilution of the sample due to an exhaust leak, or the failure to properly disable an air injection system, or to properly leak test your gas analyzer sample hose will result in an incorrect diagnosis of a potentially lean air fuel ratio.

  There is a direct relationship to the size of the leak and the error in the Lambda reading – Example: A 10% leakage factor in the exhaust or sample hose will result in a Lambda reading of +.1, or 10%. The effect will be an incorrect diagnosis. Imagine a correct reading of Lambda of .900 (an overly rich condition), with a 10% leakage factor will show as 1.000, or a perfect mixture. The same would hold true for a correct reading of 1.000 with a 10% leakage factor resulting in a Lambda reading of 1.100 – an excessively lean mixture. The software system on this site calculates the validity of the sample and the possible presence of a leak or dilution of the sample and warns the operator to check for leaks and retest the vehicle.

- **LAMBDA SENSOR.** Also commonly referred to as an O2 or EGO sensor. There have been various designs of this type of sensor over time in response to different emission regulations and on-board computer systems.

Typically installed upstream of the catalyst (many newer cars use as post catalyst sensor to validate the effectiveness and life of the catalyst) in the exhaust system, these sensors are one of the most critical to proper performance of the modern internal combustion engine. Ultimately, the primary role of the sensor is to measure the Oxygen content of the exhaust flow and provide an input to the computer that allows it to adjust the air fuel ratio for optimum performance and emissions in real time.

Often forgotten as an "out of site, out of mind" part of the system, many subtle and not so subtle drivability problems can be traced back to this sensor. Simply put, the computer system in the car expects a real time and accurate input from the sensor in order to constantly adjust the air fuel ratio correctly. The sensor, however, has a finite life and slows down over time, and should be replaced between 50,000 - 100,000 miles (80,000 – 160,000 KM), depending upon the model and type of sensor, as part of any tune up performed on the car.

In addition, the presence of oil deposits (from engine wear), silicates (from gasket sealing compounds or antifreeze), and periods of misfire, can cause a coating on the sensor that will slow down the response to changes in oxygen content of the exhaust and the sensor will send an erroneous reading to the computer, resulting in an incorrect mixture response.

A simple rule of thumb: If replacing spark plugs, replace the EGO / Lambda / O2 sensors at the same time. You can test the sensor for speed of response and proper function with a high impedance lab scope or digital graphing multi-meter to validate your diagnosis, but if the sensor has over 50,000 miles (80,000 KM) on it, you should replace it regardless – as is likely at the end of its useful life and will likely fail sometime soon. The proper "tune-up" of today is typically the combination replacement of spark plugs, O2 sensor(s), fuel and air filters, often combined with any necessary cleaning of the fuel system and intake system.

- **LEAN MIXTURE:** A condition where there is an insufficient ratio of fuel to air in the combustion chamber. Typically, as slightly lean mixture results in a loss of power and minimum fuel consumption, a progressively leaner mixture means more power loss and higher cylinder temperatures (pre-ignition or knock occurs), and in very lean conditions there is not enough fuel to maintain the combustion process and the engine stops performing.

- **MAF SENSOR:** Mass Air Flow sensor. An input sensor commonly used in a fuel-injected engine to measure the amount of air entering the intake manifold system. Often used in conjunction with an Air Temperature sensor, the inputs are used by the onboard computer to insure a proper air fuel ratio, based on the availability of air.

- **MAP SENSOR:** Manifold Absolute Pressure sensor. This sensor detects the demand load of the engine based on the pressure or negative pressure in the intake manifold and provides an input to the vehicles on-board computer that helps it make the right decision for the amount of fuel to add to the air.

- **MIL** – Malfunction Indicator Lamp - previously known as the Check Engine Light. This is a light on the dash that indicates the vehicle on board computer has detected a fault.

- **MISFIRE:** Any condition that occurs in the combustion process that results in a reduction of power, and unused fuel and oxygen being released into the exhaust system. Misfire can occur due to mechanical, ignition system or fuel mixture related problems. The software on this site analyzes the result of the combustion process and will offer the technician suggestions as to the most likely area of concern.

- **NOX:** Nitrogen Oxides. NOX emissions are considered a harmful tailpipe emission that contributes to acid rain and other harm to the environment. To the technician however, they are an indicator of a combustion process where the cylinder temperatures have exceeded the design limits of the engine and are likely to cause damage to the engine itself. Extended periods of operation at high cylinder temperatures associated with NOX production can lead to severe engine damage, such as melted piston surfaces.

  It is important to note that NOX is only formed UNDER LOADED CONDTIONS, and to properly test for NOX requires the use of a dynamometer or the use of a portable 5-gas analyzer that can be taken on a road test.

- **OUTPUT SENSORS:** These sensors are designed to recognize an output or a failure, and make adjustments accordingly. An example would be the Lambda or O2 sensor, which adjusts the fuel mixture according to what has already happened in the combustion cycle. Often these sensors cover up minor problems.

- **O2:** Oxygen. An essential element of combustion, O2 and HC are the two primary ingredients combined in the combustion chamber to provide the chemical reaction which results in power delivery. In perfect combustion, 100% of the O2 will be used in the combustion process, and at the tailpipe, there should not be a measurable presence of oxygen.

- **O2 SENSOR:** Also commonly referred to as an EGO or Lambda Sensor. There have been various designs of this type of sensor over time in response to different emission regulations and on-board computer systems.

  Typically installed up stream of the catalyst (many newer cars use as post catalyst sensor to validate the effectiveness and life of the catalyst) in the exhaust system, these sensors are one of the most critical to proper performance of the modern internal combustion engine. Ultimately, the primary role of the sensor is to measure the Oxygen content of the exhaust flow and provide an input to the computer that allows it to adjust the air fuel ratio for optimum performance and emissions in real time. Often forgotten as an "out of site, out of mind" part of the system, many subtle and not so subtle drivability problems can be traced back to this sensor.

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- **PCV:** Positive Crankcase Ventilation. One of the earliest emission controls, and one of the most beneficial, the PCV system directs the harmful vapors present in the crankcase into the intake manifold and the combustion chamber. This process removes condensation, fuels and other contaminates in the engine oil (extending the life of the oil), while preventing the release into the atmosphere of harmful vapors that may be present in the crankcase.

  It is important to understand the function of the PCV system, as there can be an effect on the air fuel ratio as measured at the tailpipe under certain conditions. Example: The vehicle has been hard to start, with extended periods of cranking time. This has allowed raw fuel to be introduced into the cylinders, and that fuel has made its way past the rings and is now mixed into the engine oil in the crankcase. As the engine warms up, the gasoline in the oil vaporizes, and the PCV system begins burning that fuel vapor (the computer will "see" a richer condition than the amount of fuel that has directed into the engine, and will attempt to compensate for that by sending a more lean command in an attempt to achieve a correct air fuel ratio) as part of the combustion process until such time as all of the gasoline in the fuel has been vaporized and consumed.

  Testing with a scan tool at this time may show everything acceptable, with the exception of a consistent leaner than usual command that could be potentially interpreted as a failure of some other system. It is important for the technician to both insure that the testing performed is on a fully warmed up engine, and that the PCV is allowed to breathe fresh air anytime an incorrect fuel mixture condition is suspected, to confirm whether there is contamination in the oil affecting the performance of the engine. The simple rule, if allowing the PCV to breathe fresh air "corrects" any fuel mixture problems, replace the PCV valve and change the engine oil.

- **PERFECT EMISSIONS:** With a perfect blend of air, fuel and internal combustion (before any catalyst in the exhaust stream), only be H2O (water), CO2 (carbon dioxide) and N (nitrogen) would be measurable in the exhaust. There would be zero (0) HC (hydrocarbons), zero (0) CO (carbon monoxide), zero (0) NOX (nitrides of oxygen) and zero (0) O2 (oxygen) – as these gases commonly found in the exhaust are all the result of imperfect combustion.

- **PROACTIVE DIAGNOSTICS:** Use of advanced diagnostic techniques and software (such as a 4 or 5 gas analyzer and this site), to spot problems in advance, before they cause a hard fault and create a problem for the customer. Proactive diagnostics coupled with an informative sales approach allow the customer to make a buying decision, rather than forcing a buying decision. The shops that practice this method tend to have fewer comebacks and a higher overall profitability.

- **REACTIVE DIANGOSTICS:** Many technicians today rely on the check engine light and a scan tool for all drivability diagnostics, waiting for a problem severe and consistent enough to trigger a fault in a vehicles on-board diagnostics. The end result, high levels of "comebacks"-- as correcting the fault alone fails to uncover the underlying problems that led to the failure, and decreased sales of preventative maintenance services as shops behave as "repair facilities", not "automotive service" facilities.

- **RICH MIXTURE:** When the ratio of air to fuel is lower than 14:7:1 (unloaded) or 12.5 - 13.3:1 (loaded), the mixture is characterized as rich – and is using more fuel than necessary, a wasteful condition that can also lead to premature engine wear. Maximum power under load requires additional fuel to be efficient, hence the lower number for a loaded condition. When using Lambda for testing in an unloaded condition, numbers progressively lower than one (1) are considered richer – and when testing under load, numbers progressively lower than .850 (maximum power is created when the Lambda reading is between .900 and .850)

- **TPS:** Throttle Position Sensor (Switch). A sensor that provides input to the vehicles on board computer relative to the position of the accelerator pedal.

- **ULTRA LEAN BURN SYSTEMS:** A lean burn technology (with air fuel ratios as high as 25:1) that promises gains in fuel economy and emission control have been introduced in recent years. With the technology of today, ultra lean burn systems are suitable for light load and throttle down conditions, as the limits imposed by the physics of an internal combustion engine preclude this strategy for performance applications that meet current and proposed emissions standards. Those limits are based on the conditions required for the "stratified charge" approach and others that require higher compression and a swirling technology to accomplish a complete burn at very lean air fuel ratios.

  One of the first technical challenges observed is the formation of NOX due to the higher than normal combustion temperatures, requiring a special catalyst to reduce emissions. While it is likely that many systems employing this technology are likely in the future, it is important for the technician to understand that when testing these systems they may see a higher than normal reading for Lambda, and/or higher O2 content in exhaust sample.

- **VALID READING:** Before a diagnostic decision can be made, the technician needs to verify that the reading is valid. This software system automatically tests for the validity of the reading and directs the operator to re-test when a sample is not considered valid for diagnostic purposes. This is determined in part by a mathematical equation that confirms a sample is not diluted by air injection, or affected by a restriction in the exhaust system.

