Section 2 – Introduction to Harley-Davidson EFI Systems

How It Works

Before discussing how the Screamin' Eagle Pro Super Tuner software works, it is important to understand how the Electronic Fuel Injection system functions. It is assumed that the user of this product has a thorough understanding of internal combustion engine operation.

Harley-Davidson Electronic Sequential Port Fuel Injection System (ESPFI)

This completely new engine management system was released starting with select 2001 model year Softail motorcycles. This system is a speed/density, open loop, sequential port fuel injection design that also controls spark timing and spark intensity.

Speed/Density System – When the ECM monitors manifold air pressure, air temperature, throttle position and engine RPM to manage fuel delivery.

Open Loop Control – When the ECM monitors sensors positioned on the intake side of the engine and does not monitor the end result of internal combustion at the exhaust.

Sequential Port Fuel Injection – When the injector nozzle is positioned in the manifold near the intake valve and is precisely timed to deliver fuel to each cylinder.

Current ESPFI Components

The following is a list of the major components of Harley-Davidson's current ESPFI system. It is important to have an understanding of what these components do before learning how the ESPFI system functions. Refer to the appropriate Harley-Davidson Service Manual for the vehicle you are working on for additional information on component design and function and for the physical location and testing procedures for each individual component.

ECM – Electronic Control Module – This is the brain of the system that collects input signals from multiple sensors, makes decisions and sends output signals to deliver fuel and spark to the engine.

CKP – Crank Position Sensor – This sensor provides input signals to the ECM that indicate engine RPM, (how fast the engine is running in Revolutions Per Minute). The ECM also uses these inputs to determine what stroke the engine is in so it can deliver the fuel and spark at the desired time.

MAP - Manifold Absolute Pressure – This sensor provides input signals to the ECM and reacts to intake manifold pressure and ambient barometric pressure. Intake manifold pressure reflects changes in engine speed and load. Ambient barometric pressure reflects changes in atmospheric pressure caused by weather conditions or changes in altitude. The ECM uses the inputs from this sensor to help calculate how much air is entering the engine.

IAT – Intake Air Temperature – This sensor provides input signals to the ECM as it reacts to the temperature of the air entering the engine. For example, hot air has less oxygen in it than cool air. The ECM uses the inputs from this sensor to help calculate how much oxygen exists in a quantity of air.

ET – Engine Temperature – This sensor provides input signals to the ECM as it reacts to the engine temperature of the front cylinder head. The ECM uses the signals from this sensor to determine if the engine is at operating temperature, or warming up.

TP – Throttle Position – This sensor provides input signals to the ECM as it reacts to throttle shaft rotation, telling the ECM throttle position, if the throttle is opening or closing, and how fast it's opening or closing.

VSS – Vehicle Speed – This sensor provides input signals to the ECM to indicate if the bike is moving or sitting still. It is used mostly to assist the control of idle speed.

BAS – Bank Angle Sensor – This sensor is located in the turn signal module and it sends a signal to the ECM if the bike leans over more than 45° from vertical. If the ECM gets this signal for more than one second it assumes the bike fell over and it shuts down both the fuel management and ignition circuits.

Ion Sensing System – This system uses ion-sensing technology to detect detonation or engine misfire in either the front or rear cylinder by monitoring the electrical energy at the spark plug following every timed spark. If an abnormal level of energy is detected across 2 or 3 spark firings the ECM responds by retarding spark timing in the problem cylinder as needed to eliminate it.

Fuel Injectors – The fuel injectors are electric valves that open and close to deliver a high-pressure spray of fuel directly at the intake valve. They are controlled by output signals from the ECM to deliver fuel at a precise moment. If more fuel is needed, the ECM will signal the injector to remain open for a longer period of time. The period of time is known as the injector "pulse width" and is measured in milliseconds. One method of rating fuel injectors is by their flow rate – such as in gm/sec, or grams per second.

Electric Fuel Pump– A 12-volt high-pressure fuel pump, (located in the fuel tank) supplies fuel under pressure to the fuel injectors.

Fuel Pressure Regulator – A mechanical device that controls fuel pressure to 55-62 PSI by returning excess fuel from the fuel pump back to the fuel tank.

IAC – Idle Air Control – An electric valve that's threaded, (each rotation is a "step") and controlled by output signals from the ECM to open and close as needed to allow enough air into the engine for starting and idle operation. The greater the number of IAC steps, the greater the amount of air enters the engine through the IAC passages. **Note:** ETC vehicles do not use the IAC system.

Twist Grip Sensor (for ETC Vehicles) – A sensor that provides information to the ECM about the position of the twist grip.

As mentioned, the ECM is the brain of the ESPFI system. And, like our own brain, it has memories and it makes decisions. The ECM memories are located in Look-up tables. Th uses several different Look-up tables to make decisions on fuel and spark management. Look-up tables that are in constant use by the ECM are the VE, (Volumetric Efficiency), (Air Fuel Ratio) and Spark Advance tables.

One type of Look-up table the ECM always uses is for VE, which is a percentage rating much air is flowing through the engine while running as compared to its theoretical capa example, an engine with a displacement of 88 cubic inches running at 5600 RPM at full has a theoretical airflow capacity of 100% when it flows about 143 cubic feet of air per m (cfm). If the same engine flows 107 cfm at 5600 RPM it would have a VE of about 75%. the engine flows about 157 cfm at 5600 RPM it would have a VE of about 110%. That's the VE can exceed 100%, especially in high performance engines that have improved ai through the engine. VE reacts to engine speed and to anything that increases or decrea airflow through the engine. The VE Look-up tables in the Screamin' Eagle calibrations a calculated from data they gather while testing live engines on engine and chassis dynamometers, and with data acquisition equipment in conjunction with track testing.

Overview of How the Harley-Davidson ESPFI Functions

The front and rear cylinder VE Look-up tables, which are programmed into the ECM, tell the ECM how much air, (volume) is flowing into the engine at different engine RPM and throttle positions.

The ECM also monitors the intake air temperature and manifold absolute pressure, which provide it with an indication of air density, or the amount of oxygen contained in a volume of air.

The AFR (Air Fuel Ratio) table, which is programmed into the ECM, tells the ECM what AFR the engine should require under specific engine loads, (engine load is determined by monitoring manifold absolute pressure and engine RPM) to produce the performance that's desired.

The front and rear Spark Advance tables, which are programmed into the ECM, tell the ECM the spark advance desired for specific engine loads to produce the performance that's desired.

When the engine is running the series of events typically follows the process below:

- The ECM monitors the CKP, TP, IAT and MAP sensors telling it engine RPM, throttle position, intake air temperature and manifold absolute pressure.

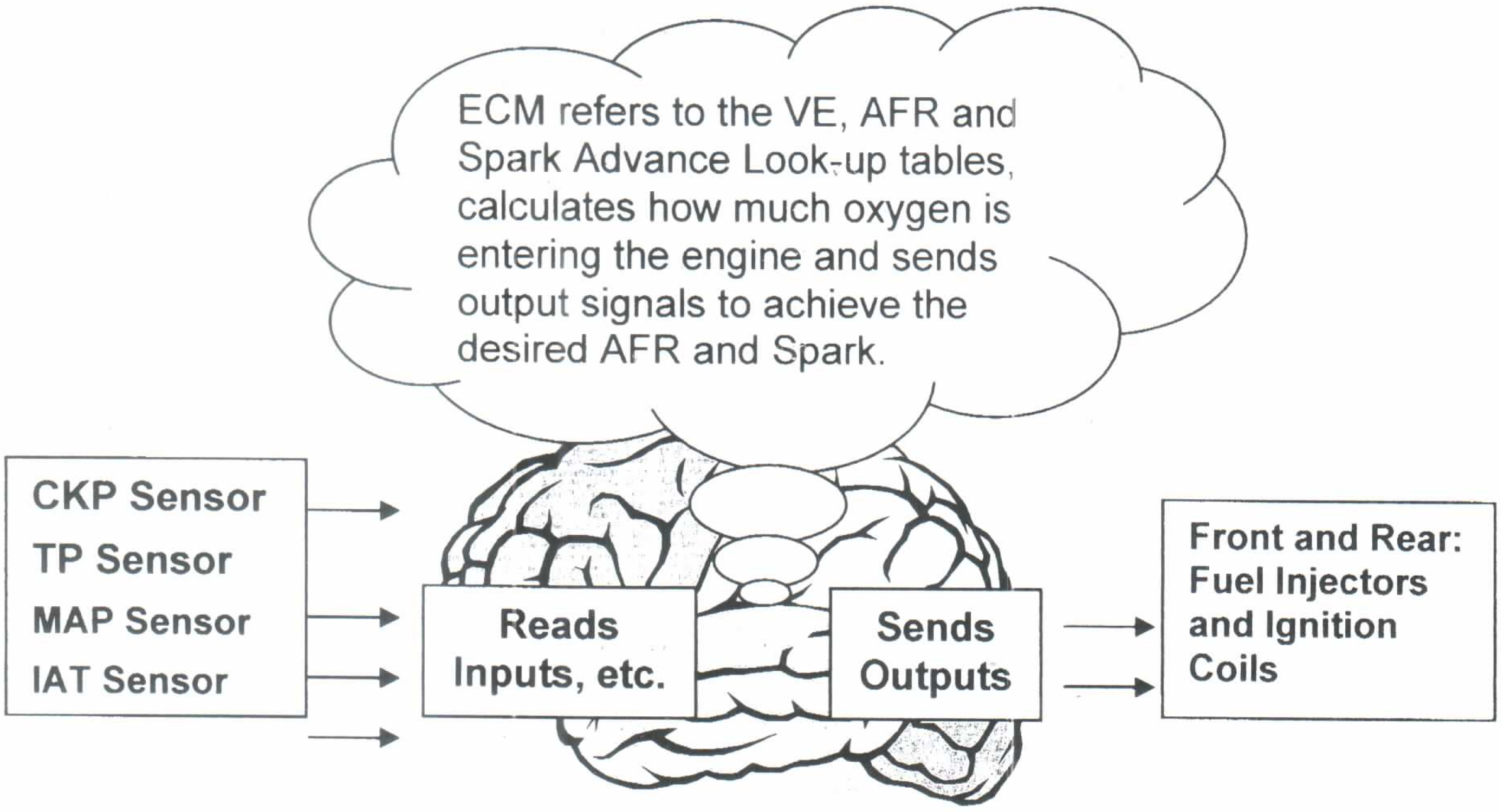
- The ECM looks at throttle position and engine RPM when it refers to the VE Look-up tables. From this information the ECM knows the volume of air that should be entering each cylinder at this moment, under these present conditions.

- At the same time the ECM looks at intake air temperature and manifold absolute pressure to calculate the density of the air entering the engine. Air density tells the ECM how much oxygen is in the air entering the engine.

- Now the ECM knows exactly how much oxygen is entering each cylinder and it refers to the AFR Look-up table for the AFR that's desired. It then sends the appropriate output signals to the fuel injectors to achieve the AFR it has been programmed to deliver for the current engine RPM and engine load.

- The ECM also refers to the Spark Advance Look-up tables for the desired spark advance for each cylinder according to the current engine RPM and engine load. The ECM then sends output signals to the front and rear ignition coils to deliver the desired timing of the spark for each cylinder.

ESPFI System Operation



- When the engine is experiencing a temporary condition such as when the bike is be started on a cold morning, it uses additional Look-up tables that are also programm into the ECM. For example, a cold engine that's being cranked to start rotates at a v low RPM and needs additional fuel. The ECM reads the ET and CKP sensors, whic it the engine is cold, and that it's rotating at cranking speed. The ECM then refers to Cranking Fuel look-up table and directs the fuel injectors to remain open longer, (increasing their pulse width) which delivers a richer air/fuel mixture for starting. It a directs the IAC to open to its programmed number of steps to allow enough air into engine for starting and idling.

- When the engine starts to run the ECM sees the higher RPM and then refers to a Warmup Enrichment look-up table that it uses to add the additional fuel needed whi engine is still cold. The table is designed to diminish its affect, (referred to as "deca value") to zero as the engine comes up to operating temperature.

ECM Refers to:	When:	Other Factor:	Purpose:
Cranking Fuel Table	Engine is being started	Engine Temperature	To increase fuel injector pulse width and deliver more fu for starting
Warm-up Enrichment Table	Engine is colder than operating temperature		To richen AFR for c engine and diminis effect as engine wa up
Idle RPM Table	Throttle is closed	Engine Temperature	To keep idle RPM a desired speed as engine warms up
Intake Air Control Table	Throttle is closed	Engine Temperature	To allow enough ai into the engine for c engine idle

Heat Management System

The ESPFI systems also incorporate a sophisticated heat management system that operates in three-phases to keep things cool in extreme conditions.

Phase I: If the ECM detects engine temperature above approximately 300° F while moving or stationary it reduces the idle speed. A lower idle speed produces fewer combustion events per minute and that reduces engine heat.

Phase II: If the ECM detects an engine temperature that's still drifting higher while moving or stationary it richens the AFR. An increased amount of fuel in the air/fuel mixture has a cooling effect on the engine.

Phase III: If the ECM detects an engine temperature that's still drifting higher while moving or stationary it directs the fuel injectors to skip, (only when the bike is stationary) and not deliver fuel on every intake stroke. This limits the number of combustion events taking place, which produces less heat.

The three phases just described function seamlessly, and the rider may not notice the transition from one phase to the next.

Model Year 2007:

For all Big Twin vehicles there is an optional Heat Management System called the 'Engine Idle Temperature Management System' or EITMS. The Tuner software allows the EITMS to be turned ON/OFF.

For those riders who frequently find themselves in riding conditions where the vehicle is subjected to prolonged idle conditions the optional 'Engine Idle Temperature Management System' (EITMS) is available. This feature offers limited rear cylinder cooling with the vehicle stopped while the engine is left at idle.

Enabling EITMS will cause the rear cylinder to be shut OFF when ALL of the following occur:
Engine Temperature reaches ~300°F.
And the vehicle is at IDLE.
And the vehicle is STOPPED.

NOTE:
Customer benefits (for Rider Comfort) – If a customer experiences frequent riding conditions where prolonged idle conditions create excessive engine heat, EITMS offers limited rear cylinder cooling with the vehicle stopped and engine at idle. While enabled, the customer may notice a unique exhaust odor which may be objectionable. The EITMS does not address engine heat issues resulting from other operating conditions.

Closed-Loop Operation

Background

In closed loop operation the ECM uses one or more oxygen sensors as a feedback loop order to adjust the fuel mixture. This gives the name 'closed loop' from the closed feedb loop. The ECM does not run in a closed feedback loop all the time, so 'open loop' is use describe the operation of the ECM when the mixture is not being adjusted in this way (u when the engine is cold or when running under high load).

In closed loop operation the ECM uses the oxygen sensor to tell if the fuel mixture is ric lean. However, due to the characteristics of the oxygen sensor it can't tell exactly how r lean, it only knows that the mixture is richer or leaner than optimum. The ECM will enric mixture if the oxygen sensor shows that the mixture is lean, and lean the mixture if it loo The result of this is that the mixture will swing back and forward around the stoichiomet or the set point of that particular O2 sensor.

Harley-Davidson Motor Company started using O2 sensors with the 2006 EFI Dyna mo today all Harley's use O2 sensors and can operate in 'Closed Loop' mode. Harley uses called a narrow band or switching sensor which controls over a very narrow range that i stoichiometric (14.6 AFR). In some circumstances the tuner may want to move this con point, and the ability to do this is accomplished with the Super Tuner by adjusting the C Loop Bias table. This table will allow moving the O2 set point by about ± 0.5 AFR. Tryin skew the set point by more than ± 0.5 AFR causes the sensor to become inaccurate.

Tuning with Closed-Loop

If a large part of the original calibration's AFR table reads 14.6 AFR (the numbers in the will be in bold font) then that calibration is indeed closed loop.

The AFR table controls the operating conditions in which the ECM will enable closed-lo AFR cell must equal 14.6 for the ECM to enable closed-loop operation. This allows the control if and when the bike is in closed-loop using the AFR table.

Lambda based calibrations will be in closed loop for lambda values between .976 and 1

Advanced Tuning

Use both Basic and Advanced Tuning to make edits to calibrations, save the edited file, and then program ("Reflash") the ECM with the new calibration.

TIP: Create a log that lists the calibrations you have modified, and for what purpose.

The Advanced Tuning tables allow much greater control over ECM operation, and separate out the front and rear cylinder functions into individual tables. Advanced Tuning tables display the actual absolute data values.

There are a total of eleven calibration tables available:

- **Air Fuel Ratio** – This table affects the Air-Fuel Ratio Target for BOTH Front & Rear Cylinders simultaneously. This table charts AFR vs MAP and Engine RPM.
    - Increases make the AFR Target leaner (leaner = less fuel).
    - Decreases make the AFR Target richer (richer = more fuel).

  Changing the values within the Air Fuel table to a value other than 14.6 will remove the vehicle from operating in closed loop mode. This will limit the engine's ability to adjust automatically based on O2 sensor feedback. Cells that are set to closed loop mode are indicated by bold text.

- **Volumetric Efficiency (VE) Front and Rear Cylinders – The VE Tables tell the ECM** the air flow efficiency of each cylinder in percent. This table charts VE percent vs. throttle position (TPS) and engine RPM. These tables can be adjusted independently, or in tandem.
    - Increases raise the VE, implying there is more air entering the cylinder.
    - Decreases lower the VE, implying there is less air entering the cylinder. Lambda based calibrations have VE tables based on MAP and engine RPM.

  TIP: If the VE table values are set at 125 or higher (max value of 127.5), you may want to change the engine displacement to allow the VE table adjustments to compensate for the increased air flow of the engine. Remember, if any engine parameters are changed, new recordings must be made before using the Smart tune function.

- **Spark Advance Front and Rear Cylinders – The Spark Advance Tables control the** spark timing of each cylinder independently. This table charts ignition Timing in degrees Before Top Dead Center vs. MAP and engine RPM.
    - Increases Advance the spark timing.
    - Decreases Retard the spark timing.

- **Warm-up Enrichment – The Warm-up Enrichment Table tells the ECM to deliver** additional fuel to both cylinders as the engine is warming up. This table charts AFR adjustment to the target value vs. engine temperature.
    - Increases add fuel during warm up.
    - Decreases remove fuel during warm up.

  TIP: Use Warm-up Enrichment Table to adjust the cold engine to warm engine performance. Increase fuel to correct engine coughing and surging during engine warm-up. Decrease fuel to correct overly rich conditions evidenced by black exhaust smoke during engine warm-up.

- **Cranking Fuel** – The Cranking Fuel table controls the fuel injector pulse width (Bl
both injectors while the engine is being started. This table charts injector pulse wid
engine temperature.
    - A longer pulse delivers more fuel.
    - A shorter pulse delivers less fuel.

  TIP: Use Cranking Fuel Table to correct hard starting problems of engines in warr
mode by increasing/decreasing the fuel delivered for starting. Engines that are ha
starting usually require more fuel.

- **Idle RPM** – The Idle RPM table controls the idle speed as the engine warms up. T
table charts idle RPM vs. engine temperature.

- **IAC Warm-up Steps** – The IAC Warm-up Steps table is used to provide an additi
amount of air to the engine for its first several minutes of operation.
    - Higher numbers increase airflow to the engine at idle.
    - Lower numbers decrease airflow to the engine at idle.

  TIP: Use IAC Warm-up Step Table to improve engine idle performance during wa
If engine RPM increases and then decreases just after start up, IAC steps may be
high for this engine temperature. If engine RPM dips and then increases just after
up, IAC steps may be set too low for this engine temperature.

- **Acceleration Enrichment (AE)** – The Acceleration Enrichment table allows the a
of a small amount of fuel during an increase in throttle position, or during an incre
manifold pressure. This fuel gets added to the base pulse width calculation.
    - Larger values increase the fuel added.
    - Smaller values decrease the fuel added.

- **Deceleration Enleanment (DE)** – The Deceleration Enleanment table allows the
removal of a small amount of fuel during a decrease in throttle position, or during
decrease in manifold pressure. This fuel gets subtracted from the base pulse widt
calculation.
    - Larger values increase the fuel removed.
    - Smaller values decrease the fuel removed.

- **Closed Loop Bias** – The Closed Loop Bias table skews the AFR from the nomin
AFR value. AFR can be skewed approximately ± 0.5 AFR.
    - Lower values will cause a leaner AFR.
    - Higher values will cause a richer AFR.

  Closed loop bias is not used with lambda based calibrations.

- **Throttle Progressivity** – Throttle Progressivity is a variable that allows you to ad
how closely the throttle plate follows the twist grip. You will be able to program
progressive throttle opening with this feature. The table column headings represe
twist grip position in percent. The table row headings represent engine RPM. The
in the table are the "Progressivity" values in percent.

Additionally, the user can adjust the **ECM Tuning Constants**:

- edit Engine Displacement setting (if you have changed bore or stroke);
- adjust Fuel Injector rate (if you have changed or modified injectors);
- set engine RPM limit;
- toggle the Knock Sensor ON/OFF;
- turn Temperature Management ON/OFF;
- enable/disable Active Exhaust Control;
- enable/disable Active Intake;
- enable/disable ACR (Active Compression Release).

NOTE: Edits to the Engine Displacement or Injector Size shift the entire fuel calculation.

Section 6 – Toolbox

Data Items

Data Items allows you to select specific items of data to view such as spark advance, eng speed, battery voltage and so forth.

Examine these items as numerical values in the Data List, and on a graph. The data items displayed in "real time" as the motorcycle is running.

You may also "record" the data as it is retrieved from the motorcycle's ECM and displayed may then playback the recording, stepping forward or back through the data a "frame" at a When viewing recorded data, you may also use the Quarter Mile and Speed/Distance calculators.

Use the information in Data Items to diagnose tuning opportunities, or as a tool to identify anomalies that may have occurred during the recorded event that may be contributing to p performance.

The Data Items are as follows:

- Acceleration Enrichment – Acceleration Enrichment ('AE') is a measure of how muc additional fuel is added during vehicle acceleration. AE is generated by increasing injector pulse width slightly. The resolution is 0.01 mS, and the range is 0 to 262 m
- Adaptive Fuel Values (Front & Rear) – The Adaptive Fuel Value (AFV) is how the e compensates for changes to the environment, such as riding up mountains, or swa the exhaust silencer. When the bike is ridden in closed -loop mode, the ECM monit the O2 sensor to learn the appropriate AFV value to apply to the fuel maps. This A value is applied across the entire fuel map range, hence it is critical that the AFV is accurate.
- Air Fuel Ratio (AFR) – Air-fuel ratio determines how rich or lean the engine is runni 14.6:1 is considered the most efficient AFR, while more power will be produced for (richer) values. The AFR resolution is 0.1, and the range is 0 to 25.5. Note that a co engine requires a lower (richer) AFR to operate smoothly. The typical operating ran 12.5 to 14.6, although during cold start-up the mixture may be momentarily a low a Lambda based calibrations will report lambda units. The typical operating range is good power to 1.0 for highest efficiency. Lambda during cold start-up may be as lo .55.
- Battery Voltage – Battery Voltage (Volts) is monitored at the ECM. The resolution is volts, and the range is 0 to 25.5 Volts. The nominal value will vary depending on temperature, load, and battery condition, and should be in the range of 12.6 to 15 v

Deceleration Enleanment – Deceleration Enleanment (DE) is a measure of how much fuel is removed during vehicle deceleration. DE fuel is typically removed during coasting or engine overrun to improve fuel efficiency and reduce emissions. DE is generated by decreasing the injector pulse width slightly. The resolution is 0.01 mS, and the range is 0 to 262 mS. Note that under some conditions, fuel may be entirely cut-off.

Desired Idle – The table value for Idle RPM at that engine temperature.

Engine RPM – The engine RPM reads out with a resolution of 1 RPM.

Engine Temperature – Engine Temperature is measured at the cylinder head and is displayed in both degrees Centigrade and Fahrenheit. The resolution is 1 degree C, and the range is -16 to +239 degrees C.

Idle Air Control Position – Idle Air Control (IAC) position is measured in steps. The value will range form 0 to 255 steps depending on engine operating mode.

Injector Pulse Width (Front and rear cylinders) – Injector Base Pulse Width (BPW) is measured in milliseconds (mS, 0.001 seconds). The resolution is 0.01 mS, and the range is 0 to 262 mS. The BPW directly affects the fuel mixture, and may be different for the front and rear cylinders.

Intake Air Temperature – Intake Air Temperature (IAT) is measured at the intake manifold and is displayed in both degrees Centigrade and Fahrenheit. The resolution is 1 degree C, and the range is -16 to +239 degrees C.

Knock Retard (Front and rear cylinders) – Spark Knock Retard is a measure of how much timing was REMOVED due to engine knock being detected. The resolution is 0.5 degrees, and the range is 0 to 20 degrees. Typically, you do not want to see more than 2-3 degrees here, values higher than this indicate either:

- The engine is too hot.
- The gas octane is low.
- The mixture is too lean.
- The timing is too far advanced or retarded.

Manifold Pressure – Manifold Pressure (MAP) is analogous to 'engine vacuum'. For EFI engines, MAP is measured in absolute units of pressure, kPa (kilo Pascals). The resolution is 0.4 kPa, and the range is 10.3 to 104.4. Note that 0 kPa is a perfect vacuum, while 100 kPa is approximately atmospheric pressure.

- Barometric Pressure – Barometric Pressure (BARO) is measured by the MAP sensor immediately before engine startup and under various conditions while the vehicle is running. It is a measure of the absolute air pressure (just like the weather report). BARO is measured in absolute units of pressure, kPa (kilo Pascals), the resolution is 0.4 kPa, and the range is 10.3 to 104.4 A typical value at sea level is 100 kPa, while 80 kPa is possible at high altitudes.

Spark Advance (Front and rear cylinders) – Spark Advance is reported in degrees before Top Dead Center (BTDC). The resolution is 0.25 degrees, and the displayed range can be -4 to +99 degrees. Typical operating range is 0 to 50 degrees. Note that the fr rear cylinders may use different timing values!

- Throttle Position – The throttle position is displayed in Volts (0 to 5.00) and in pe open (0 to 100 percent).

- Throttle Position Sensor – The Throttle Position (twistgrip) is displayed in percen

- Vehicle Speed – The vehicle speed is displayed in both MPH and in km/hr. The resolution is 1 km/hr and the range is 0 to 255 km/hr.

- Volumetric Efficiency (Front and rear cylinders) – Volumetric Efficiency (VE) is a measure of how efficiently the engine can pump air. The resolution is 0.5 percen the range is 0 to 127.5 percent. VE as reported by Tuning is the value the ECM currently using to calculate fuel delivery. Engine speed, camshaft profile, cylinde design, and intake/exhaust manifold design all influence this value.

- Warm-up Fuel – Warm-up Fuel is added when the engine is first cold started, ar reduced as the engine warms up. It is measured as units of air fuel ratio (or unit lambda), subtracted from the target AFR (or lambda) to enrichen the mixture. Th resolution is 0.1 AFR (or .002 lambda) and the range is 0 to 25.5 AFR (or 0 to .4 lambda).

- Twistgrip Position – The Twistgrip Position is displayed in percent (%).

With oxygen-sensor equipped vehicles, six additional data items are recorded:

- O2 Integrator Value (F & R cylinders) – For Oxygen-sensor equipped vehicles, Integrator indicates the deviation from the ideal fuel mixture over a few seconds 100% value means the AFR is exactly as expected, while higher values indicat mixture is Lean and lower values indicate the mixture is Rich.

- O2 Sensor Voltage (F & R cylinders) – For Oxygen-sensor equipped vehicles, sensor voltage is reported. This will be a value between 0 and 5100 mV.

- VE New Value (F & R cylinders) – For Oxygen-sensor equipped vehicles, VE N what the Volumetric Efficiency table value should be, based on A/F feedback.

Quarter Mile and Speed/Distance Calculators

NOTE: The Quarter Mile and Speed/Distance calculators are only available if you are recorded data.

The Quarter Mile time estimator calculates the times to 60 feet, 1/8 and 1/4 mile durin acceleration run, as well as zero-to-60 times. This calculator uses a linear interpolatio speed data between sample points to improve the accuracy of the time to speed and values.

...cklist of Consistency Concerns

The motorcycle must be track-worthy – for the rider's safety and the safety of others a pre-ride inspection must be performed following the guidelines provided in the Harley-Davidson Factory Service Manual for the bike being tested.

The primary and secondary drives must be adjusted to Factory specification and at the same tension for every test. Differences in primary or secondary drive adjustment can vary the amount of frictional losses between tests and cause inconsistent performance measurements.

The front and rear tire pressure should be set to the Factory specification and must be the same pressure for every test or the frictional losses may vary and cause an inconsistent performance measurement.

The engine must be at operating temperature and the Warmup Enrichment mode must be inactive or the performance measurements will vary from test to test.

The fuel the bike is running on should be fresh and it is recommended that the same type of fuel is used for comparison tests or the performance measurements may vary.

Wind and road surface conditions on the closed-course track being used for testing should be the same for every test or the performance test measurements will be inconsistent. The closed-course track environment should allow for a safe testing event.

If a chassis dynamometer is used for testing it should be operated according to the instructions provided by the chassis dynamometer manufacturer to produce consistent performance measurement results.

...laining Air-Fuel Ratio

...Air-Fuel Ratio (AFR) of an engine is determined as the weight ratio of the air entering the ...ne in relation to the amount of fuel being mixed with the air that creates a combustible ...ure. The stoichiometric AFR is 14.6 to 1 (14.6 grams of oxygen to 1 gram of fuel). ...chiometric means that a ratio of 14.6 grams of oxygen to 1 gram of fuel, when burned, will ...retically result in complete combustion. Stoichiometric isn't the only AFR that supports ...bustion. Most engines, including Harley-Davidson Twin Cam models, will run with rich ...s of about 8 to 1 (more fuel) up to lean AFR's of about 15 to 1 (less fuel).

...en does an engine need a rich fuel mixture? It needs a rich fuel mixture to start a cold ...ine and to achieve peak power under heavy load. Cold engines need extra fuel because it's ... the fuel vapor that will ignite and burn, not the fuel liquid. When the engine is cold the fuel ...ds to condense on the walls of the intake manifold and cylinders (like water condensation on ...old window). Additional fuel is needed to provide enough fuel in vapor form to start and run ...engine. The cold air also contributes to the need for more fuel because the gases in the air ...tract when it's cold and that means there's more oxygen in a given volume of air entering ...engine, creating a leaner mixture than normal. Engines under heavy load create more heat ...neir combustion chambers because of the additional stress. Heavy loads also lower the ...gine's intake manifold vacuum, which can cause some of the fuel to drop out, or puddle in the ...nifold. The extra fuel of a rich mixture helps to cool the engine and to provide enough fuel to ...port combustion when some of the fuel drops out.

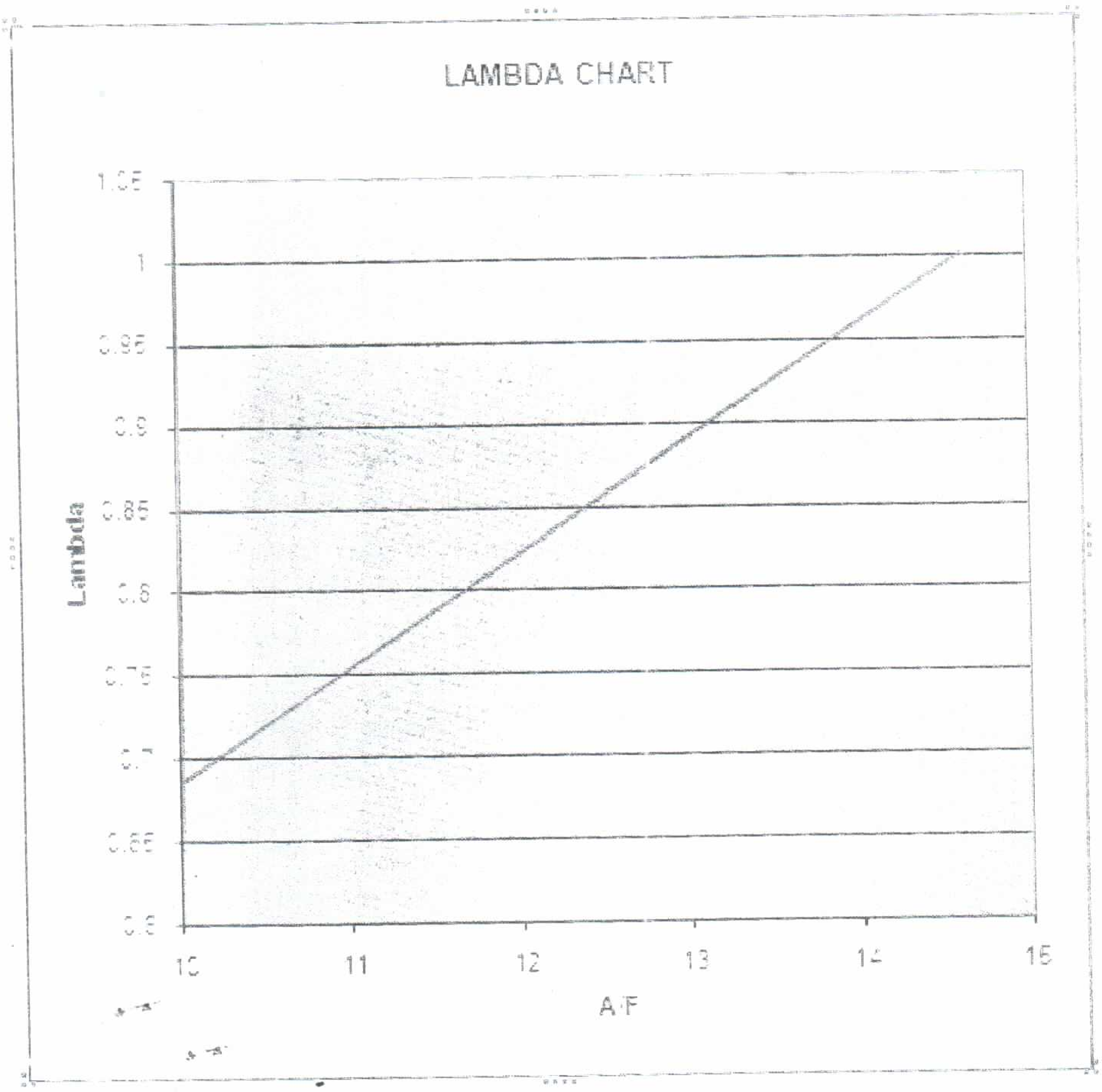
When can an engine run on a lean mixture? The engine can run on lean mixtures of say
1, when the engine is fully warmed up and being operated under light loads, such as wh
holding a steady throttle, steady speed on a flat stretch of track. A hot engine though, ur
severe load, (such as in top gear, and accelerating for a speed record), could have a tou
running on a lean mixture, and could overheat to the point of causing itself severe dama
a rule of thumb, for:

- Peak power a 12.5 to 1 AFR is preferred;
- Severe loads a 11.0 to 1 AFR is preferred;
- Cruising under light load a 14.0 to 1 AFR is preferred.

These AFRs are all approximate and your results may vary slightly.

Lambda Based Air-Fuel Tables

Beginning in Model Year 2010 certain calibrations utilize a Lambda based Air-Fuel table
Lambda is a direct indicator of whether a mixture is rich or lean. It is a calculated measu
based on the actual air/fuel ratio divided by the Stoichiometric air/fuel ratio of 14.6. The
shows the relationship between Lambda and Air/Fuel Ratio. The Stoichiometric air/fuel
14.6 is for gasoline with no ethanol content.



If the gasoline you are using has a different Stoichiometric value, 14.6 may not apply.
Stoichiometric values are selectable in the Air Fuel table when viewing Lambda values
Fuel Ratio. Changing the values within the Air Fuel table to a value outside of the app
Lambda range will remove the vehicle from operating in closed loop mode. This will lir

engine's ability to adjust automatically based on O2 sensor feedback. Cells that are within the approved range and are set to closed loop mode are indicated by bold text.

- A Lambda reading of 1 is equal to an air/fuel ratio of 14.6:1.
- A Lambda value of 1.0 indicates an ideal air/fuel mix of 14.6:1.
- A Lambda range of 0.8 - 1.1 is the most practical range for vehicle operation.
- A Lambda value of 0.856 is preferred for peak power.
- A Lambda value of 0.753 may be used under severe loads
- A Lambda range of 0.924-0.984 is preferred for light load cruising.

Why Would I Want to Adjust the AFR?
Each motorcycle (and each cylinder of an engine) has its own unique requirement for the amount of fuel that would achieve maximum performance. That's where the Screamin' Eagle Pro Super Tuner system comes in. It provides the tools necessary to adjust the AFR in the exact engine RPM and engine load needed to unleash the potential of virtually any performance-enhanced Harley-Davidson Twin Cam engine.

Symptoms of a Rich or Lean AFR
The tuner should be familiar with the symptoms of an overly rich or overly lean AFR. The symptoms are the signal to us that we have not achieved maximum performance – that we need to adjust the EFI.

Lean running symptoms
- Bike hesitates when throttle is increased
- Bike runs jerky or surges at steady throttle openings
- Engine detonates, (knocks) when accelerating
- Engine spits back or coughs through intake system
- Bike runs poorly when cold – engine runs better as it warms up to operating temperature
- Spark plug color is white
- Fuel consumption is abnormally low

Rich running symptoms
- Engine blubbers when throttle is increased
- Bike emits black exhaust smoke, (a little black exhaust smoke is normal when accelerating hard or operating engine when cold)
- Engine blubbers at steady throttle
- Engine fouls spark plugs
- Bike runs well when cold – engine runs worse as it warms up to operating temperature
- Spark plug color is black
- Fuel consumption is abnormally high