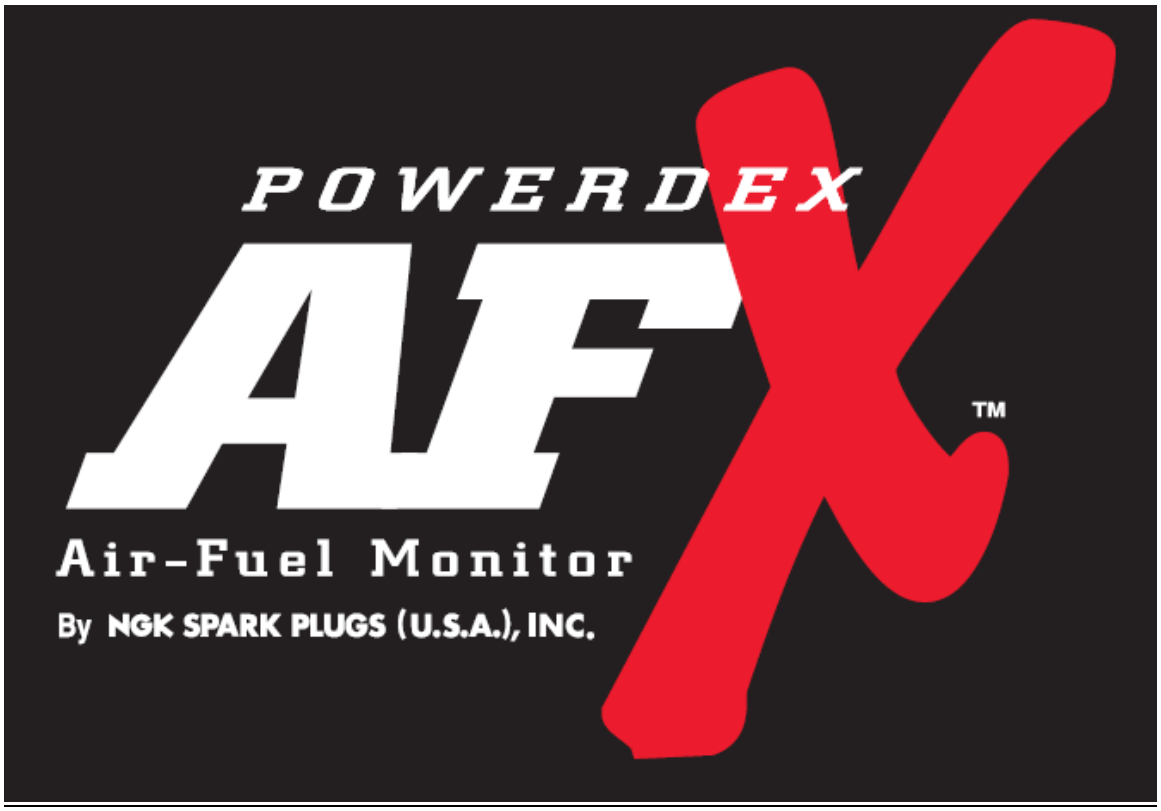
AIR-FUEL RATIO



TUNING MANUAL

Rev.04

WARNINGS

- **The AFR sensor gets very hot when power is applied and it stays hot for a while after power is disconnected. It can burn you and potentially ignite combustible vapors. Be careful when handling the sensor.**

- Do not open or modify the controller.

- Do not apply excessive voltage (more than 28V DC) to the harness.

- Do not modify the wiring harness.

- If the wiring harness is damaged, do not use it. Replace it.

- Do not open or modify the AFR sensor.

Tuning Engines with the AFX

Introduction

The AFX is a tool to measure the air-fuel ratio (AFR) delivered to carbureted and fuel injected performance engines. Its measurement range is 9.00 to 16.00 AFR for gasoline. For maximum AFR sensor life, the sensor must be powered when in the exhaust of a running engine.

AFX Installation

The AFR sensor should be located between 12" and 48" from the engine, upstream of any catalyst device if so equipped. The closer the sensor is to the engine, the more likely it will be overheated, possibly shortening its life. The further it is from the engine, the more likely condensed water will get into the sensor and thermally shock it, again possibly shortening its life. The sensor should be mounted at least ten exhaust diameters upstream of the exhaust exit (ex. for a 3" exhaust pipe, that is 30"). If the sensor is mounted between one and ten exhaust diameters from the exhaust exit, the AFR measured will be leaner than the actual AFR by as much as 2 AFR at low engine speeds (i.e. less than 3000 rpm).

In turbocharged applications, it is recommended that the sensor be installed downstream of the turbine. This is due to the fact that the high pressures before the turbine can distort the AFR reading. Apply the same installation guidelines as described above, but take into consideration that the sensor needs to be downstream of the turbine.

Make sure there are no leaks in the exhaust system, as this will create an artificially lean (higher) AFR reading. Also, install the sensor upstream of any factory air-injection if so equipped, as this too will cause a false lean reading.

The sensor boss requires a ¾" (19mm) hole in the exhaust. A step drill or hole saw may be used. Weld the sensor boss to the exhaust so that it will position the sensor in the upper half of the exhaust between the 10 o'clock and 2 o'clock locations. This is to avoid liquid fuel or condensed water from getting inside the sensor and thermally shocking it.

The electrical connector for the sensor must be clean and dry. Do not use any dielectric compounds or contact sprays on the electrical terminals.

After welding the sensor boss to the exhaust, run an M18 x 1.5mm tap or thread cleaner (KD Tool P/N 730 or equivalent) through the boss to remove any thread distortion. If this is not done, the sensor's threads may be damaged during installation or removal. Apply a small amount of anti-seize on the threads and tighten the sensor to 15~20 lb.-ft. Caution must be taken not to over-tighten the sensor. Unless you are permanently installing the unit as a constant AFR monitoring device, you will be installing and removing the sensor frequently. The more you over-tighten the sensor, the more the threads will deform each time and make it that much more difficult to reinstall the next time. During a reinstallation, if the sensor shows any resistance to being screwed back into the boss, run the tap or thread cleaner through the boss, clean the threads of the sensor with a fine wire brush, and apply a small amount of anti-seize on the threads before installation. If the threads on the sensor are damaged, run the sensor into a die.

The controller has an operating temperature range of -40 to 185º F and is splash-proof but not 100% water-proof. Mount it accordingly. The controller and the harness should be kept away from ignition systems and the harness should be routed away from the exhaust system and moving engine components.

The quality of the AFR measurement depends on the quality of the power you supply the AFX with. The ground terminal should be connected directly to the battery's negative terminal or the body of the vehicle (if metal). The power terminal should have 11 to 28V DC attached (via a switch or relay) whenever the engine is running. If the sensor is not powered when the engine is running, sensor life will be shortened. The AFX (including sensor) draws less than 2 amps.

Before the AFX is used for the first time, or for the first time before a new AFR sensor is used, it should be calibrated.

AFX Calibration

The procedure to calibrate the AFX is as follows:

1. Connect the harness to the control module and the AFR sensor. With power disconnected from the harness and the sensor removed from the exhaust, hold the sensor by its wires letting it hang free in air. You cannot reliably calibrate the AFX with the sensor mounted in the exhaust of an engine, even if the engine has been off for several days.

2. Attach power to the harness. In about 10 seconds, you will start to notice the AFR sensor getting hot. **Use CAUTION, the sensor can burn you**.

3. Wait three minutes. This is to allow the sensor to reach operating temperature.

4. Turn the calibration knob on the back of the display head until the display reads "CAL-". If the display reads "Air_" when the sensor is in air, turn the knob clockwise until the display reads "CAL-". If the display reads "Air¯" when the sensor is in air, turn the knob counterclockwise unit the display reads "CAL-".

5. Disconnect the power from the harness. When the AFR sensor cools down, install it in the exhaust and do not touch the calibration knob until the next time you calibrate the AFX.

It is impossible to predict how often the AFX needs to be calibrated without knowing the conditions under which the AFR sensor was used. However, here are some calibration guidelines:

- The first time before a new sensor is used: calibrate.
- For every 3000 ft. change in altitude: calibrate.
- For race engines: calibrate before every tune session.
- For wild, street performance engines: calibrate once every week of use on the street.
- For mild street engines: calibrate once every month of use on the street.
- For use with leaded fuel: calibrate once every hour.

Experience will teach you if you need to shorten or lengthen these times by how much you had to turn the calibration knob to recalibrate. If you did not have to turn the calibration knob at all, try lengthening the time between calibrations.

The AFX has been designed to extend the AFR sensor's life as long as possible. However, since sensor life depends on sensor operating conditions, it impossible to predict sensor life without knowing the conditions under which the AFR sensor was used. Certainly, leaded fuel will shorten the sensor's life. However, there is a statistical component to sensor life. For example, a spark plug may foul and the sensor may be sprayed with raw fuel and thus be thermally shocked. Therefore, the AFR sensor should be considered an expendable part; a cost of tuning, just like gasoline and your time. Some tuners will never kill a sensor. Some tuners will kill two sensors a race season. You may use the AFX as a constant AFR monitoring tool, but keep in mind that this will consume the sensor faster. If you are not using the sensor to tune the engine, we generally recommend you take it out. It may be a good idea to keep a backup sensor on hand if you tune constantly or if you tune at the track.

Replacement AFR sensors are available from your nearest AFX distributor.

Using the AFX to Tune Engines for Racing Applications

People who tune spark ignition engines for racing applications are concerned with decreased lap times, faster e.t.s, and higher speeds. Once an engine is physically built, the fuel delivery (i.e. jetting or fuel pulse duration), and spark timing are the two principle tuning parameters used to optimize the engine for the type of racing it will participate in.

One way to tune the fuel delivery is to do a lot of track testing. However, because the relationship between AFR measurements and maximum horsepower, best throttle response, engine life, and best fuel economy are well known, it is faster to first tune to specific AFRs and then to use actual track performance for final fuel delivery adjustments.

For most spark ignition engines, there is a specific small window of AFR in which maximum horsepower and best throttle response will be found. For gasoline, that range is 12.5 to 13 AFR. For reasons such as engine life and fuel economy, some engines are not operated within that range. Here are some examples:

- At high load conditions, air-cooled engines are often operated at an AFR as low as 10 in order to reduce engine temperatures that may lead to engine damage.

- At high load conditions, turbocharged engines are often operated at an AFR as low as 10 (sometimes even less) in order to reduce engine and turbocharger temperatures which may lead to engine and turbine damage. When mounting the sensor on a turbocharged application, it is recommended that the sensor be installed downstream of the turbine.

- Engines operated at loads beyond their original design or at their maximum load for periods longer than they were designed for may be operated at an AFR as low as 10 in order to reduce engine temperatures that may lead to engine damage.

- In racing where fuel stops are made, engines can be operated at an AFR greater than 13 at light loads in order to improve fuel economy. Fuel economy is maximized at an AFR of about 16. However, at these leaner AFRs (i.e. higher numbers), internal engine temperatures will increase and this may lead to engine damage at high loads.

- With low octane fuels, engines are often operated at an AFR less than 12.5 in order to suppress detonation that may lead to engine damage.

- Engines that have a centralized fuel delivery system (i.e. a carburetor) may have some cylinders operating at an AFR greater or less than the engine average. The fuel delivery and induction should be tuned so that the average of the cylinders is between 12.5 and 13, and to avoid a specific cylinder(s) from operating at a lean AFR that could lead to overheating or detonation.

- For engines equipped with nitrous oxide and/or other chemical intercoolers like water methanol injection systems, the true AFR reading will be altered by these chemicals that have different characteristics than your primary fuel. It is difficult to determine the magnitude of the effect on AFR. A safe starting point is around 12.5 AFR.

In summary:

If you have a water-cooled, naturally aspirated engine, start with an AFR of 12.5 and tune from there. For forced induction, start at 10 and tune from there. "Tune from there" means adjusting the AFR and then testing for benefits such as decreased lap times, faster e.t.s, and higher speeds while watching for issues leading to unsatisfactory engine life or fuel economy. Always keep in mind that leaner AFRs (i.e. higher numbers) increase engine temperatures and if caution is not taken, can lead to engine damage at high engine loads.

The preceding discussion pertains to race engines operating under race conditions. When race engines are idling, an AFR less than 13 can lead to spark plug fouling or unhappy pit neighbors (the smell). Often increasing the idle AFR will eliminate spark plug fouling. At idle, the engine is operating far below its maximum temperature and pressure limits, so increasing idle AFR is unlikely to lead to engine damage at idle unless the engine is wildly misfiring. With carburetors, idle AFR adjustments will influence off-idle AFR and may cause detonation during initial throttle opening. Therefore and especially with carburetors, the choice of idle AFR will be based on tradeoffs between spark plug fouling, idle smoothness, off-idle AFR, and detonation. The final choice of idle AFR may be between 13 and 16. Often it is closer to 13 than 16.

Using the AFX to Tune Engines for Performance Street Applications

Performance street engines should be tuned the same way as race engines are except during non-WOT (non-wide open throttle) operation, the AFR should be increased. The reasoning here is that it makes no sense to pollute the air and waste fuel unless maximum engine power is required. For non-WOT and non-idle conditions, an AFR of about 14.5 will often give satisfactory performance, will pollute less, and will use less fuel.

AFX Troubleshooting

If you cannot calibrate the AFX or if the display shows "Sen#" ("#" is a trouble code number), you should:

1. Check if the sensor is attached

2. Check if the wiring harness is damaged

3. If steps 1. and 2. show no problems, replace the AFR sensor. It has reached its limit for useful life.

If the display shows "Bat_", the supply voltage is too low (below 11V).

If the display shows "Bat‾", the supply voltage is too high (above 28V).

If the display reads "9.00", the AFR is 9.00 or less.

If the display reads "16.00", the AFR is 16.00 or more.

AFX Specifications

Measurable AFR Range	9.00 ~ 16.00 AFR
Accuracy	Within 0.1 AFR
Supply Voltage	DC 11V ~ 28V
Sensor Tightening Torque	15 ~ 20 lb.-ft.
Absolute Maximum Exhaust Temperature	1650º F (900º C)
Compatible Fuel Types	Gasoline (leaded or unleaded), Methanol

AFX Kit Parts

For replacement parts, please contact your nearest AFX distributor.

Distributor Information, Technical Support

NGK Spark Plugs (U.S.A.), Inc.
1-877-473-6767 Option 2

AFX Product Warranty

NGK Spark Plugs (U.S.A.), Inc. warrants that the products, which it sells to the Distributor, seller, reseller, or customer, shall be free from defects in workmanship and materials within a period of sixty (60) days from the delivery thereof to the aforementioned parties. This does not apply to products that have been modified, altered, abused, damaged during transit, or subjected to conditions in excess of their intended environment. Due to the nature of the product, there is no warranty on AFR sensor life.

NGK Spark Plugs (U.S.A.), Inc. shall not be liable for any economic damages or losses resulting from the improper use of its products.