AFR-9R
Air/Fuel Ratio Controller

SETUP & OPERATIONS

Please read manual for hazard and safety advisement.
Read this entire manual and any other publications relevant to this project prior to installing, modifying or operating the equipment described herein. Follow safe practice standards. Observe all local, state and federal codes. Use this manual for safe, effective operation. Improper installation, operation or other use of this product could result in any combination of poor performance, equipment damage, human injury or possible death.

This manual is the sole property of Enovation Controls. Copying, faxing, e-mailing, altering or in any way reproducing this manual in whole or in part is forbidden without the express written consent of Enovation Controls.

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Safety

- The electrically actuated fuel control valves supplied with this product are designed to control fuel flow only. They are not designed to replace a fuel shut-off valve or a fuel shut-off system. Therefore the product relies on the installation and use of an automatically closing fuel shut-off valve (user supplied) to stop fuel flow during and after engine shutdown and is necessary for safe product use. Such valves are widely available.

- Automatic and/or semiautomatic fuel shut-off valves are mandated by the National Fire Protection Association’s “NFPA 37 – Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines.” We recommend reading the National Fire Protection Association’s codes and standards, NFPA 37 and NFPA 54 along with any other national, state, and local codes and standards relevant to your application.

- Do not open the controller’s enclosure when a hazardous atmosphere is present. Wiring connections that could spark are present inside the enclosure.
• Do not connect or disconnect end devices or make wiring changes while power is supplied to the product unless the area is known to be non-hazardous. Electrical sparks may occur.

• Separate non-incendive and intrinsically safe wiring from any other wiring.

• Do not share the speed signal supplied to an electronic governor or ignition system with this product.

• Do not operate components beyond their respective safety ratings (maximum/minimum pressure, voltage, current, etc.).

• All electrical connections should be performed by qualified personnel and should meet all Federal, State, Local and End User electrical codes.

• If the installer is unfamiliar with Federal, State, Local and End User electrical codes or is unable to safely complete any of the installation requirements put forth in this manual, contact your COMPLIANCE CONTROLS distributor for information on qualified installers.

Failure to follow the safety instructions of this manual could void the product warranty.

This product is often used in retrofit applications. It is the responsibility of the installer(s)/end user(s) to assess the safety and suitability of the product with regard to the end user’s or users’ specific application. This responsibility is not shared by Compliance Controls.
System Introduction and Display Navigation

Introduction
The AFR-9R is often sold as a retrofit product. As with all retrofit products, it is not possible for the manual to address every situation that may be encountered on a specific application. Consequently, it is important for both installers and users alike to understand the underlying concepts of the AFR-9R in order to address these as they arise. Keep in mind your distributor's purpose is to help in this regard.

Product Overview

There is a misconception that air/fuel ratio controllers (AFRC's) reduce emissions. Only catalysts reduce emissions. However, for every 3-way catalyst, there is a specific air/fuel ratio at which the catalyst performs best. This "sweet spot" is found by adjusting the fuel delivery to the carburetor. Maintaining this "sweet spot" is the job of an air/fuel ratio controller.

The AFR-9R controller uses a heated oxygen sensor mounted in the engine's exhaust (upstream of the catalyst) to detect drift in the engine's air/fuel ratio over time. As an engine drifts "Lean" there is less fuel to combine with oxygen during combustion leaving more "leftover" oxygen passing into the exhaust. An engine drifting "Rich" is the opposite. More fuel requires more oxygen to burn, leaving less pure oxygen passing into the exhaust.

To determine the oxygen sensor value corresponding to your catalyst's "sweet spot," you must use an Exhaust Gas Analyzer. The fuel to the engine should be adjusted while watching the analyzer until optimum emissions is achieved. The oxygen sensor reading being measured by the controller is the value you will want the controller to maintain for the long term so you will enter this sensor value into the controller as a "target." From that point on, the controller will:

1. **Measure** the oxygen sensor's value.
2. **Compare** it with the target to determine if the engine is drifting rich or lean and calculate how much.
3. **Decide** what action to take and how severe it should be (controlled by the GAIN).
4. **Act** using a valve to change the fuel flow to the engine so as to bring the air/fuel ratio back to your target.

These steps are repeated infinitely to maintain control.

Single Set Point vs. Multi-set Point Controllers

The AFR-9R is a multi-set point controller. To understand the AFR-9R, it is helpful to first consider a single set point controller. With a single set point controller, the same air/fuel set point is used regardless of engine load. This style of controller is sufficient for applications where the engine stays at a relatively constant load and/or the emissions regulations for the area are not stringent. However, an engine/catalyst combination requires different air/fuel values across an engine’s load range to achieve maximum emissions reduction.
The AFR-9R controller provides a means for entering multiple air/fuel targets to be matched with specific engine loads. The AFR-9R does this by providing the user with a two dimensional table consisting of three RPM points and three manifold pressure points creating nine possible air/fuel targets.

During operation, the controller determines engine load by monitoring both manifold pressure and engine speed. Using these, the AFR-9R interpolates an air/fuel set point from among the nearest corresponding points of the table.

**Post-catalyst Oxygen Sensor**

As an additional option, the AFR-9R offers the ability to run a post-catalyst oxygen sensor. In many cases, a post-catalyst oxygen sensor can enable the AFR-9R to compensate for slight changes in the system over time.

Post-catalyst control may be thought of as a separate controller unto itself. The post-catalyst control loop compares the reading from the post-catalyst sensor with the user set target (interpolated from another 9 point table not to be confused with the pre-catalyst table) and biases the pre-catalyst target rich or lean depending upon the error.

In short, the post-catalyst control loop adjusts the pre-catalyst targets in order to richen or lean the engine. The point to remember is that its ability to adjust the pre-catalyst target is limited to + or - .010. Therefore during setup and tuning, richening or leaning the air/fuel ratio of the engine by solely adjusting the post-catalyst set points can only have a limited effect. In practice BOTH pre and post-catalyst tables must be adjusted.

One may know if it is time to adjust the pre-catalyst target by looking at the Pre-catalyst Offset value located on the Main View page. If it is at .010 or -.010, then the post-catalyst loop has done all it can and the pre-catalyst target must be adjusted in the desired direction to cause further change.

**Fuel Valves Used with the AFR-9R**

The AFR-9R is a multi-set point controller that may be used with two different fuel control strategies: a proportional solenoid valve (the TK Valve) mounted in an auxiliary fuel line and a full authority (FA) butterfly valve mounted in the main fuel line.
Basic Navigation

Navigating the screens of the AFR-9R display can be performed by pressing any of the buttons next to an icon on the screen. Depending on the icon you can:

- Move the cursor on the screen up, down, left or right
- Edit a field
- Choose another menu
- Change pages
On the “Main View” screen, the user can monitor the operation of the AFR-9R air/fuel ratio controller.

Staring at the top left corner of the “Main View” screen:

**Engine Speed:** Actual engine speed is calculated by the number of pulses per revolution entered by the user during the system setup.

**Fault and Warning Indicators:** The yellow symbol is an indicator that the fault relay has been activated and an active fault is present. The red symbol is an indicator that the shutdown relay has been activated and a shutdown fault is active.

**O2 Sensor Phi Values:** These are the values read from the Left Bank, Right Bank and Post-catalyst oxygen sensors and are used to determine the air to fuel ratio of the engine by measuring the excess exhaust oxygen concentration. If the engine is setup for a single bank application, the Right Bank sensor value will read “OFF”. If the post-catalyst oxygen sensor is turned off, the Post-catalyst sensor field will also read “OFF”.

**Target Values:** These are the desired phi targets for pre-catalyst and post-catalyst control.

**PreCat Phi Offset:** This value indicates the amount of offset that has been applied to the Pre-catalyst target to achieve the desired post-catalyst target. This value is only active if the post-catalyst sensor is used.

**Catalyst Temperatures:** The pre-catalyst and post-catalyst temperatures are displayed here along with the calculated differential between the two (post-cat minus pre-cat). If the catalyst thermocouples are not used, these values show ambient temperature inside of the enclosure.

**Valve Position:** These values are the commanded positions for the Left Bank and Right Bank fuel control valves.
**Mode:** This field will indicate whether the valve control is in “Automatic” or “Manual”. While in automatic, the controller determines the valve position based on feedback from the oxygen sensors. While in manual, the user determines the valve position. Manual valve control can be accessed through the “Main Menu”. Note: Manual mode can only be entered while the engine is running.

**Press any button to access the “Main Menu”**

**Main Menu Screens**

![Main Menu Screens](image)

From this menu, every point of interest of the controller can be accessed.

**Fault Screens**

**Active Faults**

![Active Faults](image)

This screen shows all of the active or on going faults. At the top of the screen is a quick reference of the number of active and historic faults. The active fault screen will show up to eight concurrent faults. Any faults greater than eight will be hidden.

Pressing the “Clear” button will purge all active and historic faults, but all active faults will return within 10 seconds.

Pressing the “Historic” button will take you to the list of previous faults.

Pressing the “Home” button will return the user to the “Main Menu” screen.
Historic Faults

This screen shows all faults have occurred but are no longer active. Up to eight most recent historic fault events can be shown. Any number of faults greater than eight are hidden.

Pressing the “Clear” button will purge all of the faults (both active and historic), but all active faults will return within 10 seconds. (The controller displays an active fault on both the active and historic pages. The difference being an active fault will disappear from the active fault page when the fault ceases while it will remain on the historic fault page until it is cleared or the number of historic faults that have accumulated have exceeded eight in number.

Pressing the “Active” button will take you to the list of active faults.

Pressing the “Home” button will return the user to the “Main Menu” screen.

Switch to “Auto/Manual” Mode Screen

Once the user enters this screen from auto mode, the controller locks the valves into position where they were when this screen was entered. The cursor will default to the left valve position and can be moved to the right valve using the right arrow button. Note: manual valve operation can only occur while the engine is running. If the engine is stopped, the controller will not allow a manual valve position to be set.

Once a desired valve is chosen, pressing the “Edit” button will take the user to the adjustment screen.

The user can adjust the valve position up or down using the + or – buttons. Once the desired valve position is achieved, pressing the “Done” button will take the user back to the “Manual Valve Control” screen.
The "Help Menu" is a quick reference to areas that the user may have questions about, covering the setup and operation of the AFR-9 controller.

Examples of Help Screens
**Default Valve**

- The final valve command is the sum of the nominal (or “ballpark”) valve command and an offset. The offset arises from the closed loop feedback action needed to move the valve from the nominal position to the actual position necessary to hit the target at the given load.

- Closed loop feedback is displayed as “Closed Loop Effort” using bar graphs. It is an indicator of how far the nominal valve command is from where it should be to hit the target. A minimum of effort (zero) is ideal.

- The Nominal Valve Table also serves as a Default Valve Position table in the event an oxygen sensor is lost.

**Controller Gain**

- Try factory setting of 20% first.

- Increase valve gain to speed up response of controller and decrease to slow controller response.

- If gain is set too high, controller may oscillate.

- Use only high enough gain to achieve satisfactory results. More is not better.

**Catalyst High Temperature**

- Ignore if not using thermocouples.

- These are the temperature limits at which the catalyst over temp alarm will be triggered.

- A catalyst over temperature alarm is the only alarm that will trigger the shutdown relay.

- All other alarms only trigger the alarm relay.

- Catalyst manufacturers advise against settings above 1350°F. Default is 1250°F.
View & Adjust Targets Screens

From this screen, the user can view the “Pre-catalyst” target table. Pressing the “Edit” button allows the user to enter the target table and adjust the desired RPM, MAP or Phi Targets.

Pressing the Right arrow button allows the user to view and/or edit the “Post-catalyst” target table. By pressing the “Edit” button the user can enter the target table field and adjust the desired RPM, MAP or Phi Targets.

Nominal Valve Table Screen

The “Nominal Valve Table” plays several key roles in the operation of the AFR-9R controller.

- The nominal valve table defines where the default valve position will be in the event of a pre-catalyst oxygen (HEGO) sensor failure. During this failure, the controller looks at the calculated mass air flow rate and defaults the valve to the position closest to that air flow rate. The air flow rate is calculated using the intake manifold absolute pressure, the engine’s speed, the number of cylinders and the engine’s total displacement in liters.

- The controller also uses this table during rapid load changes. During a load change, the controller will drop from closed loop control into open loop control. Once in open loop the controller will snap the valve(s) into the valve position corresponding to the observed air flow rate And then operate in closed loop mode from this new valve position. This speeds up controller response to load changes.
Looking at this page, top to bottom:

- **Minimum Allowed Valve Command** – Allows the user to set a minimum valve opening. This prevents the valve from going below this point under any running circumstance. We advise that this value be set to 0% in order to allow the valve the most control range.
- **Left/Right Valve Positions** – The actual valve position
- **Closed Loop Effort** – This is the total adjustment the controller has made to the valve position, comparing actual vs. default command
- **Air Flow** – This is a calculated air flow rate based on several parameters and is a reference to load.
- **Nominal Position** – This is the user defined setting for the valve at the corresponding load in the event of an oxygen sensor failure or any other issue that would force the controller into open loop.

Adjusting the table is performed by pressing the edit button and moving the cursor to the desired field and increasing or decreasing the value.

**Startup Valve Position Screen**

The “Startup Valve Position” is a user definable valve position used in assisting at engine startup. This value is in play when the engine speed is between 25 & 450 RPMs.

When using the TK style proportional valve this value should be set to 0% and should not be changed.
When using the butterfly (full authority) valve, a position must be defined. Through experience we have found that Caterpillar and Cummins engines like to start lean, so a good starting point for these engines is around 25% or less. On the other hand, Waukesha and White engines like to start rich so a good starting point for these is 50%. After attempting to start the engine, this value may need to be changed until the engine starts easily.

To edit this field, press the “Edit” button and step the valve position up or down using the + and – buttons. Press the “Done” button when you are finished.

**Display User Setting Screen**

![Display User Settings Screen](image)

From this screen the user can adjust the “Ambient Light” and “Brightness” to their desired setting.

**Diagnostic Values Screens**

![Diagnostic Values Screen 1](image)

![Diagnostic Values Screen 2](image)

On these screens, the user can view key values of the controller, such as:

- Left Bank, Right Bank and Post-catalyst oxygen sensor voltages
- Left Bank, Right Bank and Post-catalyst oxygen sensor health
- Left Bank, Right Bank and Post-catalyst oxygen actual phi values
- Left Bank, Right Bank and Post-catalyst oxygen phi targets
- Left Bank and Right Bank valve positions
- Engine RPM and Intake Manifold Pressure
- Battery voltage at the ECM
- Basic operational state of the system as well as the ECM run hours (Note: this is not an engine hour meter.)
**Initial Setup Screens**

On this screen, the user sets up the controller to match their particular engine. Fields include:

- Catalyst temperature shutdown limits
- Number of pre-catalyst sensors – Single bank (1), Dual Bank (2).
- Turning the post-catalyst feedback off or on
- Choosing the valve type – Butterfly or proportional
- Adjusting the controller reaction gain
- Changing the engine run signal input type  
  Note: Ground=Run is only for troubleshooting purposes.
- Changing the number of pulses per revolution (used to determine engine speed)
- Number of cylinders (used to calculate engine air flow)
- Engine displacement in liters (used to calculate engine air flow)

To edit any of these fields, arrow up or down until the desired field is highlighted then press the "Edit" button. Use the + or – buttons to increase or decrease the field. Press the “Done” button when you are completed adjusting that field.

**Software Version Screen**

This screen informs the user of the software that is loaded on the ECM and on the PV display.

The ECM serial number is also displayed.
### Section 40

**AFR-9R Wiring Termination**

#### Upper (short) Tier

| Terminal | 72 | 71 | 69 | 68 | 67 | 66 | 65 | 64 | 63 | 62 | 61 | 60 | 59 | 58 | 57 | 56 | 55 | 54 | 53 | 52 | 51 | 50 | 49 |
|----------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| DEVICE   | NOT USED | NOT USED | NOT USED | NOT USED | NOT USED | NOT USED | MAP SENSOR SIGNAL (+) | NOT USED | MAP SENSOR SIGNAL (+) | NOT USED | NOT USED | NOT USED | RIGHT BANK HEHO SIGNAL (+) | LEFT BANK HEHO SIGNAL (+) | RIGHT BANK HEHO SIGNAL (+) | LEFT BANK HEHO SIGNAL (+) | LEFT BANK HEHO HEATER (-) | LEFT BANK HEHO HEATER (-) | LEFT BANK HEHO HEATER (-) | LEFT BANK HEHO HEATER (-) | NOT USED | BATTERY NEG (-) | BATTERY POWER (+) |
| WIRE COLOUR | X | X | X | X | X | X | X | X | X | X | X | X | BLACK | BLACK | BLACK | BLACK | BLACK | BLACK | BLACK | BLACK | BLACK | BLACK |

#### Middle Tier

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**NOTE:** If system is setup for “Single Bank” operation, only the Left Bank oxygen sensor and control valve is active.

**NOTE:** Either the Magnetic Pickup or the G-Lead connection is used, not both.

**NOTE:** All cable shields/drain wires should be connected to the earth ground termination lug located on the ECM/TCB’s back plate (lower right hand corner).
Initial Setup

Controller Configuration

The first step required for the successful operation of the AFR-9 Air/fuel Ratio Controller is properly matching the controller to the engine.

To match the controller to a specific engine, follow the prescribed steps below.

From the “Main View” screen, press any button to enter the “Main Menu” page 1.

Press the lower right hand button “Continue” to go to the “Main Menu” page 2.
Press the second button from the top on the right hand side “Initial Setup” to enter the setup mode.

![Initial Setup](image)

Using the yellow Up/Down arrow buttons on the right side of the screen, move to the field that you wish to change and press the top right hand button “Edit”.

![Initial Setup](image)

In the Editing mode, use the blue up down arrow buttons to select the desired change for the field. Once you have completed your editing of the field, press the “Done” Button in the upper right corner.

Let’s start setting up the system to match your engine. Starting from the top and working down:

**Pre-Catalyst and Post-catalyst High Temperature** – These are settings that allow you to shut your engine down in the event of an elevated catalyst temperature. It is important to point out here that the AFR-9 will not shut down the engine on its own in the event that these values are exceeded. The AFR-9 will only shuttle the shutdown relay. The AFR-9 will need to be intergraded with the engines shutdown system. Refer to the wiring termination for the proper implementation of this feature.

In general, most catalysts have a thermal destructive point of 1350°F. Stay as far from this point as possible. The default value on a New AFR-9 is 1250°F. This is a good starting point but this value can be adjusted to whatever value you desire. A good rule of thumb would be to set this value at 150°F above the normal operation of the engine, but never above the 1250°F setting. Keep in mind that there will be a rise across the catalyst between 25°F and 125°F.
To adjust this field, use the arrow buttons to the right and press the “Edit” button. This field can be increased or decreased in steps of 10°F. When completed, press the “Done” button.

**Number of Pre-Cat O2 Sensors** – This field will determine how many independent control banks the AFR is setup to control. Engines can be classified into two groups – those with a single bank of cylinders and those with two banks of cylinders (dual bank).

A single bank engine will use one valve and one pre-catalyst oxygen sensor. In this case the valve should be connected to the left bank valve output and the pre-catalyst oxygen sensor to the left bank O2 sensor input. The number of pre-catalyst oxygen sensors should be set to Single. Once this selection is completed, press the “Done” button and move to the next parameter.

In the majority of dual bank engines 2 fuel valves and 2 pre-catalyst oxygen sensors will be used. This is because the engine has separate intake and exhaust manifolds allowing the exhaust from each bank to be sampled and controlled independently. An example of this configuration is the Waukesha L7044GSI. However, there are other variations of dual bank engines requiring a different control strategy. Here is a list:

- **Dual**
  - Bank Engine, 2 carburetors, **BUT** Common Exhaust Manifold: Uses 2 fuel valves but one pre-catalyst oxygen sensor. Both valves should be connected to the controller’s left bank valve output and the pre-catalyst oxygen sensor connected to the left bank input. This field is then set to Single and the engine is treated by the controller as a single bank engine.

- **Dual**
  - Bank Engine, **BUT** 1 Carburetor (Exhaust Manifold may be separate or common. It does not matter.): Uses 1 fuel valve and 1 pre-catalyst oxygen sensor. The valve should be connected to the left bank valve output and the pre-catalyst oxygen sensor to the left bank input. This field is then set to Single and the engine is treated by the controller as a single bank engine.

- **Dual**
  - Bank Engine, 2 Carburetors, **BUT** no room for 2 pre catalyst sensors in exhaust: Uses 2 fuel valves and 1 pre-catalyst sensor. Both valves should be connected to the controller’s left bank valve output and the pre-catalyst oxygen sensor connected to the left bank input. This field is then set to Single and the engine is treated by the controller as a single bank engine.

The Appendix of the Installation Manual contains diagrams of the many dual and single bank configurations. Once the selection for the number of pre-catalyst sensors is completed, press the “Done” button.

**Post-Catalyst O2 Sensor (On/Off)** – If you have decided to use the optional Post-catalyst control feature of the AFR-9, the sensor will be turned on or off from here. When commissioning...
the controller for the first time, leave this feature turned off. We will return to this screen later to turn it on.

**Valve Type Being Used** – The AFR-9 has 2 valve options, the TK/Solenoid (default) and the FA/Butterfly. Refer to the Installation Manual for details of these valves. Choose the valve type on your engine application.

**Controller Gain Setting** – This setting adjust the reaction of the valve to a change in the exhaust oxygen (O2 sensor). The higher the setting, the faster the response. In general, the higher the engine speed the faster the controller will need to respond. The controller is capable of operating on engines with speeds up to 4,000 RPMs. On a typical 1,200 to 1,800 RPM engine the gain setting should not be adjusted below 10 or above 30. The default setting of 20 is typically good for most mid-range (900-2,000 RPM) speed engines.

**Engine Rune Signal Input Type** – This field is typically left at the default setting of MPU/Ignition. There is a troubleshooting feature built in to the system that allows the user to simulate an engine speed with the engine stopped, by choosing the “Gnd=Run” option. This should only be used for troubleshooting and not for normal system operation.

**Number of Pulsed per Revolution** – This number is require to correctly calculate the engine’s operating speed. If the engine is setup to read the engine’s G-lead from the ignition, this is typically ½ the number of the engine’s cylinders. If the system is setup to read the engine’s flywheel teeth, refer to the back of this book in the “Engine Data” section for a list of the most common engines and most common flywheels.

**Number of Cylinders** – This is the total number of cylinders of the engine. This value is used in the calculation of the engine air flow.

**Engine Displacement** – This is the total engine displacement in liters. If the displacement in liters is not known, refer to the “Engine Data” section of this manual. If the cubic inch displacement (CID) is known, divide the CID by 61 to get the liters displacement.

At this point the basic set up of the engine is completed. Press the “Home” button in the top left corner to return to the “Main Menu”. When the “Home” button is pressed you will be prompted to save changes. Save your changes at this point. If you choose not to save the changes and the power is lost to the controller, all changes will be lost.

When the screen returns to the “Main Menu” page 2, you will choose the “Startup Valve Position” button (3rd from top, left hand side).

**Startup Valve Position** – When using the TK/Solenoid option, the startup valve position will remain at 0%. This option is locked out and no adjustments can be made

If using the FA/Butterfly valve is used, a starting position is required to assist in the starting of the engine. This value will differ from engine type to engine type. A general recommendation is:

- Caterpillar and Cummins engines like to start with a lean air/fuel mixture. A good starting position for these engines is around 25%. This could be less for some engines and more for others. The user will determine this during the initial startup.
- Waukesha, Arrow and White engines typically like to start with a rich air/fuel mixture. A good starting position for these engines is around 50%. This could be less for some engines and more for others. The user will determine this during the initial startup.

To adjust this set point, press the “Edit” button and increase or decrease the field to the desired setting. Press the “Done” button when completed.

Once these parameters are set you are ready to start commissioning the AFR system.
Controller Commissioning

Verify Engine Condition First!

IMPORTANT! It cannot be overly stressed that an Air/Fuel ratio controller will not solve engine related issues. Moreover, Air/Fuel ratio controllers, in general, can actually magnify underlying engine problems such as slight misfires. Tuning for emission with a problematic engine is futile. Simply put, proceeding beyond this section with a poorly running engine is a waste of your time.

Verify the engine and all of its components are in good working order:

- All cylinders have good compression
- Engine cylinder head valves are adjusted to factory specifications
- Spark plugs are in good condition, properly gapped and torqued
- Ignition system is in good working condition (coils, plug wires, magneto, etc.)
- Exhaust gaskets and expansion joints are in good condition and no exhaust leaks are present
- Ignition timing is set at factory specifications for the site specific fuel quality
- Carburetor/mixer & regulators are in good working order and the fuel pressures are set to factory specifications.

Finally, keep in mind that most catalyst manufacturers recommend that new or freshly overhauled engines to be run through a break in period before installing the catalysts. Consult your catalyst manufacture for their specific recommendations.
Tools needed for commissioning

To successfully commission the AFR system and to tune it for emissions, certain specialized tools will be required. Short of mentioning the basic hand tools needed for everyday engine work, below is a list of specialized tools that will be required.

- Manometer – Digital, U tube or slack tube capable of measuring differential pressure in inches of water up to 20”.
- Multi-meter – capable of measuring ohms resistance and DC voltage up to a minimum of 36 VDC.
- Exhaust gas analyzer – Capable of measuring CO, NOx and O2 at a minimum. Should be capable of measuring at least 1 ½ times your permitted limits. Ideally, but not required, should be capable of reading CO in excess of 6,000 PPM and NOx in excess of 4,000 PPM.
- Ignition timing light

Fuel Pressure Check

1. As a reference, the fuel pressure supplied to the regulator(s) and carburetor(s) should be checked prior to the commissioning of the system. In most cases, the fuel pressures should be adjusted to the engine manufacturer’s recommendations. There will be instances where the fuel pressure may need to deviate from the OEM settings in order to better meet the desired exhaust emissions control. These pressure readings will be read at different points depending on whether the Butterfly (full authority) or the TK (supplemental) valves are used.
   a. If the Butterfly – Full Authority (FA) Valve is used, the fuel pressure will be measured between the final cut regulator and the Butterfly (FA) Valve. The fuel pressure will always be measured between the fuel pressure before the valve and the air pressure applied to the regulator. On turbocharged engine, the manometer will be connected to the regulator’s outlet side and the air side will be connected to the carburetor’s inlet air somewhere between the turbocharger and the carburetor air horn. On naturally aspirated engines (non-turbo charged), there are two possible measurement styles depending on whether the regulator is equipped with a balance line between the carburetor’s air inlet and the air side of the regulator or whether the engine is equipped with a non-balanced regulator. On units without a balance line, the fuel pressure is compared to ambient air. On units with a balance line, the fuel pressure should be compared to the air entering the carburetor/mixer like you would do on a turbo charged engine.
   b. If the TK Valve is used, several different measurement methods can be used depending on whether the engine is turbocharged, naturally aspirated with balanced regulator or naturally aspirated without a balanced regulator. (See the separate AFR Installation Manual for TK Valve pressures.) On turbocharged engine, the manometer will be connected to the regulator’s outlet side and the air side will be connected to the carburetor’s inlet air somewhere between the
turbocharger and the carburetor air horn. On naturally aspirated engines (non-turbo charged), there are two possible measurement styles depending on whether the regulator is equipped with a balance line between the carburetor's air inlet and the air side of the regulator or whether the engine is equipped with a non-balanced regulator. On units without a balance line, the fuel pressure is compared to ambient air. On units with a balance line, the fuel pressure should be compared to the air entering the carburetor/mixer like you would do on a turbo charged engine.
Engine Startup & Pre-catalyst Targeting

At this point, the engine is ready for startup. Start the engine and let the engine settle out. Enter the “Main Menu” and navigate to page 1.

Press the “Switch to Manual Mode” button (3rd from top, right side). At this point the valves will lock into the position where they were when you entered manual mode.

Navigate to the valve that you want to adjust. Remember, if you are operating as a single bank controller only the left valve will be active. Press the “Edit” button.

1) Adjust the valve to 50% open.
2) Load the engine and bring it up to the desired speed and load.
3) Once the load has stabilized and the catalyst temperature has obtained a temperature above 750°F, insert the exhaust gas analyzer probe into the exhaust stream after the catalyst and into the exhaust pipe to a depth at least 1 ½ times the diameter of the exhaust pipe.
4) While monitoring the exhaust analyzer, adjust the load screws on the carburetor/mixer until the desired emissions levels are achieved. If you are working on a dual bank controller, adjust the load screws on both carburetor/mixers evenly while watching left bank and right bank phi values on the Manual Valve Control screen. Keep both banks adjusted equally.
5) Once the desired emissions are reached, leave the controller in manual and press the home button.
6) Press the “View & Adj Targets” button

7) At this point you will start setting up the controller’s targeting table. The controller uses measured engine speed and measured manifold pressure as inputs to this table to locate the sensor target value you have entered for the engine’s operating conditions. Since engine speed and manifold pressure will fall somewhere between two rows and two columns, the controller interpolates among the four nearest target values to calculate the setpoint for the controller at any given instant. Before you begin adjusting setpoints, you first modify the engine speed and manifold pressure values to suit your engine’s application. A few points to consider at this time:
   a. What is the engine applications minimum speed, the lowest point where you want the controller to operate?
   b. What is the maximum speed that the engine application will operate?
   c. From the point where the engine is operating at this time, will the load increase, will the load decrease?
8) With these questions answered we can start filling in the table in relation to speed and manifold pressure.
9) Navigate the green cursor to the field that you wish to adjust then press the “Edit” button.
10) Fill in the RPM row with the expected RPM ranges. Keep in mind that the engine speed should never go below the lowest setting and never above the highest setting. The center value can be adjusted to a mid-point between these two. If for some reason the engine speed goes off of this table on either the high side or the low side, the controller will drop into...
open loop and will lock the valves into a pre-determined opening. A good rule of thumb would be to add 50 RPM above the highest expected speed and subtract 50 RPMs from the lowest expected speed to prevent falling off of the table.

11) Looking at the manifold pressure, fill in the MAP row with the lowest manifold pressure that you expect and also the highest manifold pressure that you expect. The center value can be adjusted to a mid-point between these two. If for some reason the manifold pressure goes off of this table on either the high side or the low side, the controller will drop into open loop and will lock the valves into a pre-determined opening. A good rule of thumb would be to add 0.5 psia to the high side value and to subtract 0.5 psia from the load side value to prevent falling off of the table.

12) Looking at the Manifold pressure and the Speed on the left side of the page, determine the 4 target cells closest to these values.

13) Look at the actual Pre O2 values on the left center of the screen and enter this number into the desired fields corresponding to the observed Speed and Intake Pressure. Keep in mind that there will be more than 1 field that needs to be edited, typically as many as 4 fields. If the left bank and right bank values are different, average the two as a starting point.

14) Once the fields have been edited, press the “Home” button to return to the Main Menu page 1.

15) Once you enter the Main Menu page, press the “Switch to Auto Mode” button. This will return the controller to automatic operation and the valve position will begin to change.

16) From the “Main Menu” page press the “View Adj Target” button.

17) While monitoring this page and also the emissions analyzer, allow the controller to stabilize and the emissions analyzer to stabilize.

18) Once the emissions analyzer has stabilized, compare the readings to your desired emissions target. If the CO level is high, your targets are adjusted too rich. Decrease the phi targets in the table to decrease the CO levels (i.e. – 1.028 change to 1.027). If the NOx level is high, your targets are adjusted too lean. Increase the phi targets in the table to decrease the NOx levels (i.e. – 1.027 change to 1.028). Be careful not to make too big of a change. Overshooting of the desired emissions targets can be seen if you give the engine and
23) The Nominal Valve Position table will now be adjusted.
   a. The Nominal Table is divided into two columns (Air Flow & Nominal Pos.) and three rows which represent three different load ranges. The upper most is the low load range, the center is a mid-load range and the lower is a high load range. All of these values are configurable by the user. NOTE – The Air Flow should be filled in with the lowest number at the top and the highest at the bottom. These values should always be increasing from top to bottom (see example above).

24) Consider at this point where your engine is operating, low load range, mid-load range or high load range.

25) Look at the Calculated value to the left of this table. This is where the engine is running at this point. Scroll down to the field that you wish to edit and then press the “Edit” button. Change the air flow to match closely to the Calculated value, press “Done” then arrow to the right and change the nominal valve position to match the actual valve position. If the left bank and right bank valves are at different positions, average the two positions and enter this average into this field.

Once this load point is completed, change the load and repeat steps 9 through 25 for this load point. Change the load again and repeat steps 9 through 25 again.

NOTE: DO NOT make any further adjustments to the carburetor/mixer load screw or the engine’s fuel pressure regulator. The AFR is in control and any adjustments made will be compensated for by the controller.

At this point, the setup with the controller has been completed with Pre-catalyst only Control. If you are not using the Post-catalyst control option, press the “Home” button then press the “Save All Changes” Button. The commissioning has been completed.
Post-catalyst Targeting

If you have chosen the Post-catalyst control option, at this point we will commission this feature.

1) Return to the Main Menu page 2 and press the “Initial Setup” button.
2) Scroll down and highlight the “Post-catalyst O2 Sensor (On/Off) and turn the post-catalyst sensor on.
3) Return to the “View & Adj Targets” page.
4) Press the Right Arrow button (lower right side). This will take you to the Post-catalyst Target Table.
5) Considering the speed and the intake manifold pressure that the engine is operating in, adjustments will be made to these fields similar to the way the pre-catalyst table was adjusted. Note that the RPM and MAP values of the table are the same as those set for the pre-catalyst table.
6) You will adjust these targets based on the Pre Offset value found in the lower left corner.

7) The Pre Offset number is the total adjustment the controller has made to the pre-catalyst targets so that the post-catalyst target could be met. We know that the pre-catalyst numbers are correct so we will adjust the post-catalyst numbers - until an average zero offset is achieved at all loads.
   a. If the Offset is a positive (+) number, this is an indication that the post-catalyst target is biasing the previously set pre-catalyst targets rich which we do not want since the pre-catalyst numbers have been adjusted until correct in earlier sections. Lowering the post-catalyst target will cause this offset number to decrease. Do this slowly until an average value of zero offset is achieved.
   b. If the Offset number is a negative (-) number, this indicates that the post-catalyst target is biasing the pre-catalyst target lean. Increasing the post-catalyst target will cause this offset number to increase. Do this slowly until the offset tracks at an average of zero.
   c. In a perfect world, the offset number would run at 0. The closer you can get this to 0, the longer the controller will compensate for the catalyst aging. Over days and
weeks, the offset may stray from zero. This is okay because the controller is compensating for catalyst aging as it is intended.
d. Only make small changes to the targeting table to prevent overshooting of the desired target.
e. Allow the exhaust and the engine to stabilize between adjustments.
8) Change the speed and/or load and repeat step 7 for each area on the grid.

Once you have completed this section, the controller is now in control of the air/fuel ratio of the engine.

Return to the Main Menu page 1 and press the “Save All Changes Button”
After all of the changes have been saved, press the “Main View” button.

The commissioning of your new AFR-9 with the Power View (PV) display has been completed. Relax and know that you now have the most sophisticated multi-point, user programmable air/fuel ratio controller on the market today.
## Engine Data

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<th>Engine Model</th>
<th>Number of Cylinders</th>
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White 12G825 12 162 230 2
White 16G825 16 216 230 2

Liters = Cubic Inch Displacement divided 61
This list is based on the most common engine flywheels
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