FW MURPHY™
PRODUCTION CONTROLS

AFR-64L

Lean Burn Air/Fuel Ratio Controller

Installation and Operations Manual

Please read manual for hazard and safety advisement.

00-02-0707

2013-05-22
Section 40

Warranty - A limited warranty on materials and workmanship is given with this FW Murphy product.
A copy of the warranty may be viewed or printed by going to http://www.fwmurphy.com/warranty

Please read the following information before installing.

BEFORE BEGINNING INSTALLATION OF THIS FW MURPHY PRODUCT:

- Read and follow all installation instructions.
- Please contact an FW Murphy U.S. Master Distributor immediately if you have any questions. http://www.fwmurphy.com/where-to-buy/us-sales-distributors
- Additional contact information is located on the back page of this document.

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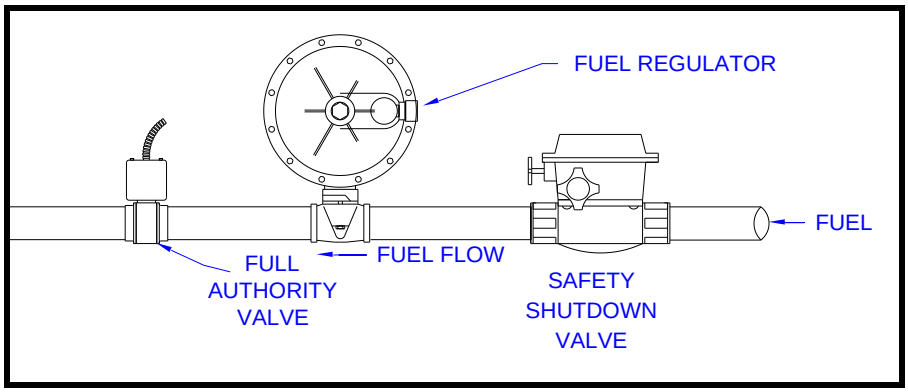
Safety

- **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.**



Butterfly Valve shown properly installed downstream of automatic fuel shutoff valve

- **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 FW MURPHY 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 FW Murphy.

Introduction

This manual describes the basic installation, setup, operation and maintenance of the FW Murphy Lean Burn Air/Fuel Ratio Control System; the AFR-64L is used to control lean-burn, four stroke, spark-ignited, gaseous fuel engines.

The system is designed to maximize the efficiency, maintenance, and emissions of the engine by maintaining a constant air/fuel ratio in relation to varying engine load, speed, fuel quality, ambient temperature and barometric pressure. This is done without operator intervention after the initial program setup.

The FW Murphy AFR-64L air/fuel ratio controller represents cutting edge technology in many areas: hardware, microprocessor power, control system software, operator interface options, adaptability to variable engine conditions and control requirements, software upgrade capability, in addition to comprehensive on-board diagnostics system (OBD).

Parts and Supplies

AFR-ND-L-64L-11-FA## – Full Authority Valve (Single O2 Sensor – Single Fuel Valve)

Quantity	Part #	Model #	Description
(2)a	47050835	ADAPTER,2" FT Flange Assy	One 2" NPT Flange, Gkt & Hdwr for FT-33, 60, & 68
(2)a	47050834	ADAPTER,3" FT Flange Assy	One 3" NPT Flange, Gkt & Hdwr for FT-75
(1)	00020707	AFR-64L Manual	AFR-64L I/O Manual
(1)	47000470	AFR-64R/L-CD	AFR-64R/L PC Software
(1)u	47700330	AFR-ND-L-64L Control Unit	Enclosure; ECM; TCB; Display & Hdwr
(1)u	47700329	AFR-WD-L-64L Control Unit	Enclosure; ECM; TCB; Display & Hdwr
(1)c	47000016	FL Cable 50	FL Valve Cable - 50' Length
(2)a	47000001	FL-25-Flange Assy	One 1" NPT NPT Flange, Gkt & Hdwr for FL-25
(2)a	47000003	FL-50-Flange Assy	One 2" NPT NPT Flange, Gkt & Hdwr for FL-50
(1)c	47050836	FT Cable 50	FT Valve Cable - 50' Length
(1)v	00031008	FT-33	33mm Full Authority Fuel Control Valve
(1)v	00031009	FT-60	60mm Full Authority Fuel Control Valve
(1)v	00031010	FT-68	68mm Full Authority Fuel Control Valve
(1)v	00031011	FT-75	75mm Full Authority Fuel Control Valve
(1)	00031022	MAG PU	Magnetic Pick-up 4" Length
(1)	00031023	MAG PU Cable-50	Magnetic Pick-up Cable 50'
(1)	47050819	MAP Cable - 50	MAP Sensor Cable 50'
(1)	00030997	MAP Sensor	Intake Manifold Press Sensor
(1)	00031024	MAT Cable-50	MAT Sensor Cable 50'

(1)	00031025	MAT Sensor	Intake Manifold Temp Sensor
(1)	00031029	NM-10	Null Modem Cable 10' Length
(1)	00031030	O2 NUT	18mm x 1.5 Threaded, Coupling for O2 Sensor
(1)	00031039	UEGO Cable-50	UEGO Sensor Cable 50'
(1)	00031040	UEGO Sensor	Heated Wideband Oxygen Sensor
(1)v	47700033	Valve Assy,FL-25	25 MM Full Authority (FA) Butterfly Valve
(1)v	47700034	Valve Assy,FL-50	50 MM Full Authority (FA) Butterfly Valve

(1)c	*Indicates only 1 cable Assy style is used, depending on the valve type used*
(1)v	*Indicates only 1 of the valve types are used*
(1)u	*Indicates only 1 of the Control Units are used, depending on the display option*
(2)a	*Indicates only 1 flange adaptor style is used, depending on the valve type used*

AFR-ND-L-64L-21-FA## – Full Authority Valve (Single O2 Sensor – Dual Fuel Valve)

Quantity	Part #	Model #	Description
(4)a	47050835	ADAPTER,2" FT Flange Assy	One 2" NPT Flange, Gkt & Hdwr for FT-33, 60, & 68
(4)a	47050834	ADAPTER,3" FT Flange Assy	One 3" NPT Flange, Gkt & Hdwr for FT-75
(1)	00020707	AFR-64L Manual	AFR-64L I/O Manual
(1)	47000470	AFR-64R/L-CD	AFR-64R/L PC Software
(1)u	47700330	AFR-ND-L-64L Control Unit	Enclosure; ECM; TCB; Display & Hdwr
(1)u	47700329	AFR-WD-L-64L Control Unit	Enclosure; ECM; TCB; Display & Hdwr
(2)c	47000016	FL Cable 50	FL Valve Cable - 50' Length
(4)a	47000001	FL-25-Flange Assy	One 1" NPT NPT Flange, Gkt & Hdwr for FL-25
(4)a	47000003	FL-50-Flange Assy	One 2" NPT NPT Flange, Gkt & Hdwr for FL-50
(2)c	47050836	FT Cable 50	FT Valve Cable - 50' Length
(2)v	00031008	FT-33	33mm Full Authority Fuel Control Valve
(2)v	00031009	FT-60	60mm Full Authority Fuel Control Valve
(2)v	00031010	FT-68	68mm Full Authority Fuel Control Valve
(2)v	00031011	FT-75	75mm Full Authority Fuel Control Valve
(1)	00031022	MAG PU	Magnetic Pick-up 4" Length
(1)	00031023	MAG PU Cable-50	Magnetic Pick-up Cable 50'
(1)	47050819	MAP Cable - 50	MAP Sensor Cable 50'
(1)	00030997	MAP Sensor	Intake Manifold Press Sensor
(1)	00031024	MAT Cable-50	MAT Sensor Cable 50'
(1)	00031025	MAT Sensor	Intake Manifold Temp Sensor
(1)	00031029	NM-10	Null Modem Cable 10' Length

(1)	00031030	O2 NUT	18mm x 1.5 Threaded, Coupling for O2 Sensor
(1)	00031039	UEGO Cable-50	UEGO Sensor Cable 50'
(1)	00031040	UEGO Sensor	Heated Wideband Oxygen Sensor
(2)v	47700033	Valve Assy,FL-25	25 MM Full Authority (FA) Butterfly Valve
(2)v	47700034	Valve Assy,FL-50	50 MM Full Authority (FA) Butterfly Valve

(2)c	*Indicates only 1 cable Assy style is used, depending on the valve type used*
(2)v	*Indicates only 1 of the valve types are used*
(1)u	*Indicates only 1 of the Control Units are used, depending on the display option*
(4)a	*Indicates only 1 flange adaptor style is used, depending on the valve type used*

AFR-ND-L-64L-22-FA## – Full Authority Valve (Dual O2 Sensor – Dual Fuel Valve)

Quantity	Part #	Model #	Description
(4)a	47050835	ADAPTER,2" FT Flange Assy	One 2" NPT Flange, Gkt & Hdwr for FT-33, 60, & 68
(4)a	47050834	ADAPTER,3" FT Flange Assy	One 3" NPT Flange, Gkt & Hdwr for FT-75
(1)	00020707	AFR-64L Manual	AFR-64L I/O Manual
(1)	47000470	AFR-64R/L-CD	AFR-64R/L PC Software
(1)u	47700330	AFR-ND-L-64L Control Unit	Enclosure; ECM; TCB; Display & Hdwr
(1)u	47700329	AFR-WD-L-64L Control Unit	Enclosure; ECM; TCB; Display & Hdwr
(2)c	47000016	FL Cable 50	FL Valve Cable - 50' Length
(4)a	47000001	FL-25-Flange Assy	One 1" NPT NPT Flange, Gkt & Hdwr for FL-25
(4)a	47000003	FL-50-Flange Assy	One 2" NPT NPT Flange, Gkt & Hdwr for FL-50
(2)c	47050836	FT Cable 50	FT Valve Cable - 50' Length
(2)v	00031008	FT-33	33mm Full Authority Fuel Control Valve
(2)v	00031009	FT-60	60mm Full Authority Fuel Control Valve
(2)v	00031010	FT-68	68mm Full Authority Fuel Control Valve
(2)v	00031011	FT-75	75mm Full Authority Fuel Control Valve
(1)	00031022	MAG PU	Magnetic Pick-up 4" Length
(1)	00031023	MAG PU Cable-50	Magnetic Pick-up Cable 50'
(1)	47050819	MAP Cable - 50	MAP Sensor Cable 50'
(1)	00030997	MAP Sensor	Intake Manifold Press Sensor
(1)	00031024	MAT Cable-50	MAT Sensor Cable 50'
(1)	00031025	MAT Sensor	Intake Manifold Temp Sensor
(1)	00031029	NM-10	Null Modem Cable 10' Length

(2)	00031030	O2 NUT	18mm x 1.5 Threaded, Coupling for O2 Sensor
(2)	00031039	UEGO Cable-50	UEGO Sensor Cable 50'
(2)	00031040	UEGO Sensor	Heated Wideband Oxygen Sensor
(2)v	47700033	Valve Assy,FL-25	25 MM Full Authority (FA) Butterfly Valve
(2)v	47700034	Valve Assy,FL-50	50 MM Full Authority (FA) Butterfly Valve

(2)c	*Indicates only 1 cable Assy style is used, depending on the valve type used*
(2)v	*Indicates only 1 of the valve types are used*
(1)u	*Indicates only 1 of the Control Units are used, depending on the display option*
(4)a	*Indicates only 1 flange adaptor style is used, depending on the valve type used*

Spare/ Loose Parts

Part #	Model #	Description
47050835	ADAPTER,2" FT Flange Assy	One 2" NPT Flange, Gkt & Hdwr for FT-33, 60, & 68
47050834	ADAPTER,3" FT Flange Assy	One 3" NPT Flange, Gkt & Hdwr for FT-75
00020707	AFR-64L Manual	AFR-64L I/O Manual
47000470	AFR-64R/L-CD	AFR-64R/L PC Software
47700330	AFR-ND-L-64L Control Unit	Enclosure; ECM; TCB; Display & Hdwr
47700329	AFR-WD-L-64L Control Unit	Enclosure; ECM; TCB; Display & Hdwr
47050823	BACK Panel SCE-12P20	Enclosure Back Plate
47050824	COM KIT AFR	UniOP Display Daughter Board for secondary Modbus
00002138	CONVERTER	12 to 24 Volts DC to DC converter
47000005	ECM-L-64L	Engine Control Module for the AFR-64L
47050831	ENCLOSURE-CSA	CSA Approved Enclosure
47000016	FL Cable 50	FL Valve Cable - 50' Length
47000001	FL-25-Flange Assy	One 1" NPT NPT Flange, Gkt & Hdwr for FL-25
47000003	FL-50-Flange Assy	One 2" NPT NPT Flange, Gkt & Hdwr for FL-50
47050832	FLOTECH 2" Gasket	2" Flange gasket only
47050836	FT Cable 50	FT Valve Cable - 50' Length
00031007	FT2 Spool Piece	2" NPT Spacer FT Valve removal
00031008	FT-33	33mm Full Authority Fuel Control Valve
00031009	FT-60	60mm Full Authority Fuel Control Valve
00031010	FT-68	68mm Full Authority Fuel Control Valve
00031011	FT-75	75mm Full Authority Fuel Control Valve
47050833	Gasket,3",FT Flange	3" Flange gasket only

00031021	KTC-12	Type “K” thermocouple (12” probe)
00031022	MAG PU	Magnetic Pick-up 4" Length
00031023	MAG PU Cable-50	Magnetic Pick-up Cable 50'
47050819	MAP Cable - 50	MAP Sensor Cable 50'
00030997	MAP Sensor	Intake Manifold Press Sensor
00031024	MAT Cable-50	MAT Sensor Cable 50'
00031025	MAT Sensor	Intake Manifold Temp Sensor
00031029	NM-10	Null Modem Cable 10' Length
00031030	O2 NUT	18mm x 1.5 Threaded, Coupling for O2 Sensor
00031012	O-RING,FL-25-FLG	FL-25 Flange o-ring
00031019	O-RING,FL-50-FLG	FL-50 Flange o-ring
00031031	PLUG,MALE,18MM	Male Plug (18mm) for a Vacant Oxygen Sensor Hole
47050841	TCB	Terminal Connector Board
47050018	UEGO Block	Lean Burn O2 Mounting Block
00031039	UEGO Cable-50	UEGO Sensor Cable 50'
00031040	UEGO Sensor	Heated Wideband Oxygen Sensor
47050859	UNIOP COM Cable	UniOP Communications Cable – 18"
47050860	UNIOP COM Cable-Panel	UniOP Communications Cable – 6'
47050861	UNIOP COM Cable-Remote	UniOP Communications Cable - 50'
47000013	UNIOP Display AFR-64L	AFR-64L Display Only
47050820	UNIOP Gasket	Gasket seal for mounting UniOP in panel
47050845	UNIOP Power Cable	UniOP Pwr Cable – 18" Length
47050846	UNIOP Power Cable - Remote	UniOP Pwr Cable - 50' Length
47700033	Valve Assy,FL-25	25 MM Full Authority (FA) Butterfly Valve
47700034	Valve Assy,FL-50	50 MM Full Authority (FA) Butterfly Valve

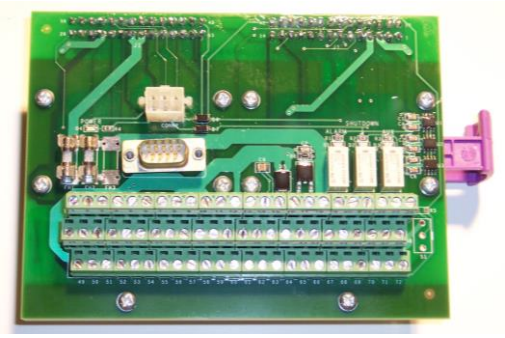
Parts Identification

Please remember your specific kit may not include all of these parts. Refer to the Installation section of this manual for a parts listing of each kit.

ECM-L-64L CONTROL MODULE

The ECM (Engine Control Module) consists of a molded enclosure designed to protect the Printed Circuit Board. The Printed Circuit Board (PCB) includes the microprocessor controller and all associated electronics for power regulation, signal inputs, filtering, controlled outputs and communications.

TERMINAL CONNECTOR BOARD

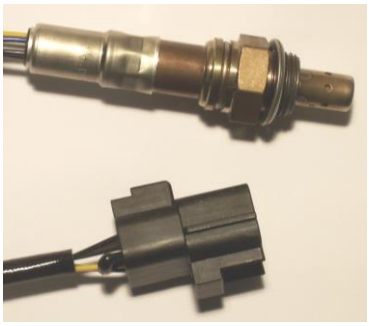


The terminal connector board consists of:

- three (3) tier screw terminal strip where all systems connections are made
- status indicator light (green) located above the fuses on the connector circuit board to indicate the controller has power
- relays
- fuses

UEGO SENSOR

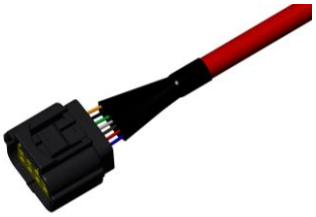
Universal Exhaust Gas Oxygen



The UEGO (Universal Exhaust Gas Oxygen) sensor is a Zirconia-type wide band sensor used in conjunction with the AFR-64L to calculate the excess exhaust oxygen concentration in the exhaust stream. The UEGO sensor is a five (5) wire, heated sensor used to provide the primary signal to the controller in a closed loop mode. This electrically heated sensor provides a constant temperature to allow a precise control target for various engine loads and conditions. The heating of the thimble increases the stability of the sensor's sensitivity to its optimum operating temperature of 990°F (550°C). The sensor has a maximum ambient temperature rating of 250°F (121°C) with a meltdown point of 500°F (260°C). The maximum thimble temperature is rated at 1300°F (704°C).

UEGO Cable

7 Wire Oxygen Sensor Cable



The UEGO sensor cable assembly is a 20 gauge, seven (7) conductor, shielded cable (10 turns per foot), with a standard length of 50 feet, terminated on one end with a modular connector for the UEGO sensor. The maximum recommended length of this cable is 50 feet. Harness sheath color is Red.

UNIOP DISPLAY

The UniOP is a 4 line x 20 character, 24 volt DC, panel mounted, user interface display system.

BUTTERFLY VALVE

Full Authority Fuel Control Valve

Available in 33mm, 50mm, 60mm, 68mm & 75mm

Warning: Not a fuel shut-off valve!

An electronically actuated, full authority valve, controls fuel flow to the carburetor or mixer. The valve position responds proportionally to the valve command.

The full authority fuel valve is available with a variety of bore sizes for various applications. One control valve is needed per control bank.

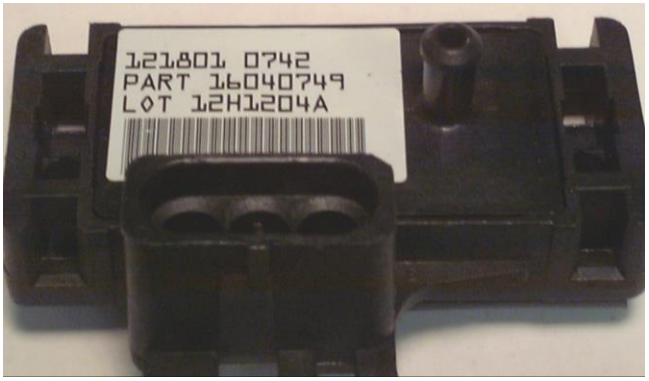
Butterfly Full Authority (FA) Valve Cable Assembly

Full Authority Fuel Control Valve Wiring Harness – 50'

The fuel valve cable assembly is a 16 gauge, four (4) conductor, shielded (10 turns per foot), with a standard length of 50 feet, terminated on one end with a modular connector for the fuel valve connection. 50 feet is the maximum recommended length for this cable. Harness sheath color is green.

MAP SENSOR

Manifold Absolute Pressure sensor

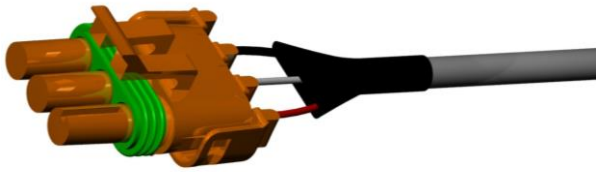


A pressure transducer that is connected to the intake manifold, used to measure the pressure of air in the intake manifold prior to induction into the engine. The sensor is a 5-volt reference type sensor capable of measuring the intake manifold pressure from 0 to 43 pounds per square inch absolute (0-3 bars absolute). The pressure reading is used for the mapping of the UEGO sensor targets and is also used in conjunction with other inputs to calculate the airflow rate to the engine, which is

used to estimate an engine load for the default valve positions in the event of sensor failure.

MAP CABLE ASSEMBLY

Manifold Absolute Pressure sensor cable assembly



The cable assembly is a 18 gauge, three (3) conductor, shielded cable (10 turns per foot), with a standard length of 50 feet, terminated on one end with a modular connector for the sensor. On applications requiring longer lengths, the cable is also available in 75 feet and 100 feet options. The maximum recommended length of this cable is 100 feet. Harness sheath color is gray.

MAGNETIC PICKUP (MPU)

5/8” x 18 thread x 4” long

Used to measure the speed of the engine A magnetic pickup (instead of G-Lead) reduces the chances of RF noise interference. Typically installed in the flywheel housing, over the center of the flywheel ring gear, but can be installed on any rotating item on the engine that can produce a minimum of 2 pulses per crankshaft revolution. A 5/8” – 18 UNF thread is tapped into the flywheel housing, perpendicular to the center of the ring gear with a 0.040” air gap. The MPU sends the pulses to the controller, which calculates the engine speed. The engine speed is necessary for the proper operation of the controller.

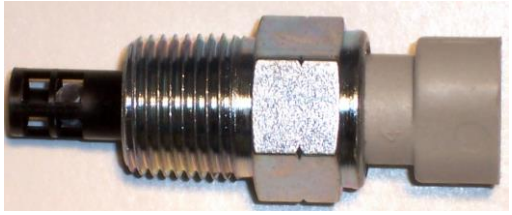
MAGNETIC PICKUP Cable

Cable assembly is a 20 gauge, two (2) conductor, shielded cable (10 turns per foot), with a standard length of 50 feet, terminated on one end with a military style Cannon Plug type connector for the Magnetic Pickup. The maximum recommended length of this cable is 100 feet. Harness sheath color is Black.

THERMOCOUPLE – Type “K” (Optional)

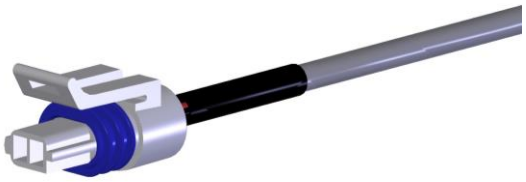
This thermocouple with its ungrounded design, is used by the controller to monitor the catalyst inlet, outlet and differential temperatures. The type “K” non-grounded thermocouple readings can be used as a catalyst high temperature shutdown device, but is not required for the operation of the system. The thermocouple has a 12” (standard) probe length. Type “K” thermocouple wire must be used when connecting this device to the controller.

MAT Sensor



The Manifold Air Temperature sensor is designed to monitor the intake manifold temperature within a wide temperature range. The MAT (Manifold Air Temperature) sensor is a thermistor design (thermal resistor) and is used in conjunction with other inputs to determine the mass airflow rate to the engine, which also determines the mass fuel flow rate and engine load.

MAT Sensor Cable Assembly



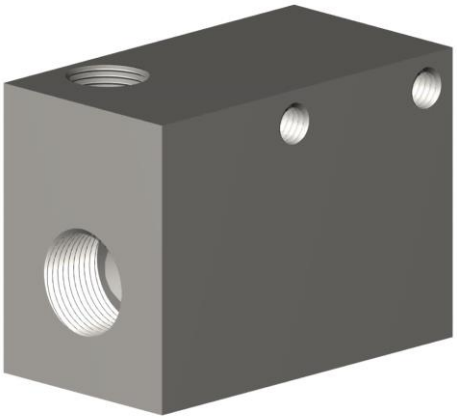
The MAT sensor cable assembly is an 18 gauge, two (2) conductor, shielded cable, with a standard length of 50 feet, terminated on one end with a modular connector for the MAT sensor. On applications requiring longer lengths, the MAT sensor cable is also available in 75 feet and 100 feet options. The maximum recommended length of this cable is 100 feet. Harness sheath color is Gray.

O2 NUT

18mm coupling for installation of the UEGO Sensor into the exhaust piping 304 SS female

The O2 Nut is constructed of 304 stainless steel, machined to 18mm x 1.5P threads for the sensor. The face of this coupling has a 125 RMS finish allowing for a proper gasket seal. This fitting can be welded to the exhaust pipe, over a ¾" hole which will allow the UEGO sensor thimble to be exposed to the exhaust flow at an optimum depth. This nut cannot be welded to cast iron with standard welding procedures.

UEGO SENSOR BLOCK – (Optional)



Used when the UEGO sensor is remotely mounted – 18mm x ¼" NPT x ½" NPT (1/4" NPT inlet; 1/2" NPT outlet). The UEGO Block is built of carbon steel to allow easy removal of the UEGO sensor during hot operations. It is equipped with 4 – 1/4" NC bolt holes (2 on each side) for mounting and increased stability.

Installation

Installation Checklist

1. Before installing the AFR-64L, make sure the engine is in good mechanical condition and the ignition and fuel systems are in good shape. By this, all cylinders have good compression, the valves are adjusted to factory specifications, the spark plugs are in good condition, properly gapped and torqued, and have good gaskets, the ignition timing is set at factory specifications, the carburetor/mixer is in good working order and the fuel pressures are set to factory specifications.

2. Inspect kit for installation parts. Ensure the parts, controllers, and harnesses are in the kit for the given application. Use the Parts List for the kit as a check list. Make sure enough conduit, conduit fittings, tubing, tubing fittings, and wire are on hand. AWG 16 shielded, twisted wire should be used for any connection not done by a harness piece. Thermocouple wiring can be AWG 20, shielded, twisted (recommended), thermocouple grade extension wire for Type K.

3. If the AFR-64L enclosure is to be used, remove the Engine Control Module (ECM) and Terminal Connector Board (TCB) from the enclosure before mounting or modifying the enclosure for conduit holes. Conduit entries at the top of the enclosure are not recommended, and especially should not be used with enclosures placed outside in the elements.

4. Run conduit and pull wire or harnesses for the UEGO Sensors, MAP Sensor, Fuel Control Valve(s), Magnetic Pick-Up, optional Pre- and Post- Catalyst/Thermocouples1 & 2, DC Power, and Auxiliary, Alarm And Shutdown Relays. Do not terminate any wiring at the Terminal Connecter Board (TCB) until all end devices have been connected or terminated.

5. Determine if the UEGO Sensors should be remote mounted. This would be done if the ambient temperature exceeds 250° F at the sensor location, if the exhaust temperature exceeds 1350°F at the UEGO SENSOR tip, or if there is a possibility of cross flow from opposite banks at the sensor installation location. The maximum tubing run length is 24” for all tubing.

6. Install the UEGO SENSORS (1-2). Determine single or dual bank operation. Determine mounting, using existing 18 x 1.5 mm connections, using O2 Sensor Couplings, or using UEGO Sensor Blocks.

7. Install the Manifold Absolute Pressure (MAP) Sensor. Locate a suitable pressure tap in the intake manifold and identify the mounting location for the sensor.

8. Install the Manifold Air Temperature (MAT) Senor in a suitable location in the intake manifold that will be a relative reading of the actual air temperature in the manifold.

9. Butterfly Full Authority (FA). Locate piping where the valve will be installed. This should be a place downstream of the engine fuel shutdown valve and the final cut regulator. It should be as close as possible to the carburetor / mixer, and a minimum of 3 pipe diameters downstream of the final cut regulator.

10. Decide whether the speed signal will be shared with other devices (never share with an ignition system or a speed control device), or whether the Magnetic Pick-Up (MPU) provided with the kit will be used.

11. Decide whether the optional Pre-Catalyst/Thermocouple1 and Post-Catalyst/Thermocouple2 will be used, and if used, where they will be installed. They are recommended for catalyst protection and should be installed as close as possible to the catalyst element(s).

12. After all sheet metal work is finished on the enclosure and the enclosure is mounted, put the ECM and TCB back in. Make sure all metal shavings and cuttings have been removed and the enclosure is clean and free from debris.

13. Terminate the connections from the wiring on the appropriate terminal block points. The battery's positive (+) connection should be the final connection made.

Safeguarding Electronics

All electronic equipment is sensitive to static electricity and magnetic fields, some components more than others. To protect these components from damage, you must take special precautions to minimize or eliminate electrostatic discharges and electromagnetic pulses (EMP).

Follow these precautions when working with or near the control.

1. **Before welding on engine skid**, the AFR-64L Control Module and the Terminal Connector Board (TCB) should be removed from the enclosure and placed in an antistatic protective bag.

2. Before touching electronics, discharge the static electricity on your body to ground by touching and holding a grounded metal object (pipes, cabinets, equipment, etc.).

3. Avoid the build-up of static electricity on your body by not wearing clothing made of synthetic materials. Wear cotton or cotton-blend materials as much as possible because these do not store static electric charges as much as synthetics.

4. Keep plastic, vinyl, and Styrofoam materials (such as plastic or Styrofoam cups, cup holders, cigarette packages, cellophane wrappers, vinyl books or folders, plastic bottles, and plastic ash trays) away from the control, the modules, and the work area as much as possible.

5. Avoid unnecessary removal of the Terminal Connector Board (TCB). If you must remove the TCB from the control cabinet, follow these precautions:

    - Do not touch any part of the printed circuit board (PCB) except the edges.

    - Do not touch the electrical conductors, the connectors, or the components with conductive devices or with your hands.

    - When replacing a TCB, keep the new TCB in the plastic antistatic protective bag it comes in until you are ready to install it. Immediately after removing the old TCB from the control cabinet, place it in the antistatic protective bag.

    - If shipping the AFR-64L Control Module (ECM) and/or Terminal Connector Board, the Module (ECM) and Terminal Connector Board should be placed in an antistatic protective bag and packed with static free Styrofoam material.

Matching the Kit to the Application and Parts Verification

Often the individual who has ordered this product and the individual faced with installing it are not one and the same. To save the installer potential time and grief, it will prove beneficial to verify the decisions made by the purchaser. Consequently, the installer should take a moment to consider the application and its general requirements.

The vast majority of application requirements will be straightforward. For example, mounting the air/fuel controller on a dual bank engine will *usually* call for two fuel control valves and 2 oxygen sensors. However, here is a list of deviations:

- Dual Bank Engine, 2 Carburetors, BUT Common Exhaust Manifold: Requires 2 fuel valves but ONE oxygen sensor mounted pre catalyst. Both fuel valves are wired in parallel to the left bank output of the controller only. The pre catalyst sensor is connected to the left bank pre catalyst UEGO input. The controller should be setup for a single bank engine.

- Dual Bank Engine, BUT 1 Carburetor (Exhaust manifold may be separate or common. It does not matter): Requires 1 fuel valve and 1 pre catalyst oxygen sensor. The fuel valve is connected to the left bank valve input. The pre catalyst sensor is wired to the left bank pre catalyst UEGO input. The controller should be setup for a single bank engine.

- Dual Bank Engine, 2 Carburetors, BUT no room for 2 pre catalyst sensors in exhaust: Requires 2 fuel valves and 1 pre catalyst sensor. The fuel valves are wired in parallel to the left bank input of the controller only. The controller should be setup for a single bank engine.

The Appendix contains diagrams of the many dual and single bank applications. Each drawing lists the kit number appropriate for the given application. Locate the diagram that represents your engine configuration and mark the page for future reference.

Verify Package Contents

Having verified the choice of kits purchased for the application, check the kits contents using the kit part listings in 'Parts and Supplies'.

Installation Guidelines for Components

General Guidelines for Mounting the Full Authority (FA) Valve Mounting

Required tools and hardware:

- Necessary tools for the removal of piping and associated supports (pipe wrenches; hand tools)
- Required pipe nipples and fittings to modify fuel piping
- Necessary pipe cutting and threading equipment
- Pipe thread sealant
- OEM gaskets and/or o-rings for engine's fuel system
- Support bracket (if required) for Full Authority fuel control valve

- **WARNING: Fuel flow into the engine when not running or during shutdown by using the ignition system (thereby allowing the engine to pull fuel though the engine as it spins down) can result in fuel filling the intake manifold where it could be ignited by a backfire or flowing to the exhaust system and catalytic converter (if present). There it could be ignited by the high temperatures sometimes present. It may also escape to atmosphere either through the air intake or through the exhaust thereby creating a hazardous atmosphere in the area.**

- **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/semi-automatic fuel shut-off valve(s) are mandated by National Fire Protection Association's "NFPA 37 – Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines."**

- **To prevent catalyst and/or engine damage, most engine manufactures recommend a specific engine shutdown procedure. Consult your engine manufacture for these procedures. If the procedures are not available, a general rule to follow would be to 1st turn off the engine's fuel system and then turn off the ignition system 5 to 10 seconds later. This would allow any remaining air fuel mixture to be combusted in the cylinders rather than in the exhaust system.**

The Full Authority valve must be installed downstream of the engine's final cut fuel pressure regulator and downstream of the engine fuel shut-off valve. It is a requirement that the spacing between the final cut regulator and the fuel control valve be at least three (3) pipe diameters. This spacing is necessary to prevent surging of the regulator pressure during the valve operation. Ideally, the fuel control valve should be mounted as close as possible to the engine's carburetor.

Here are two examples of Full Authority Valve mounting. Illustration 3 is not an ideal installation due to the spacing of the valve to the fuel pressure regulator. Illustration 4 is a better example because of the increased spacing between the fuel control valve and the fuel pressure regulator. The Full Authority Valve needs to be as close to the carburetor as possible. There is an arrow on the Full Authority Valve body to indicate flow direction.

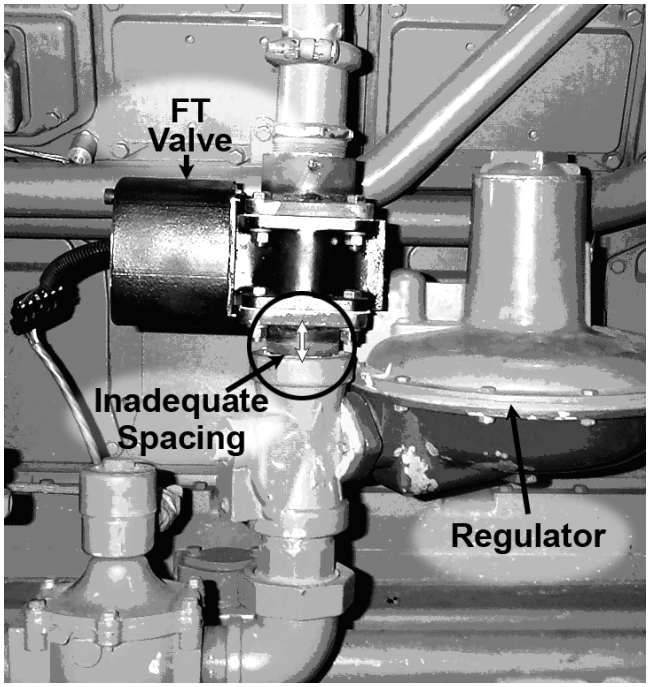


Illustration 3 – Improper Installation

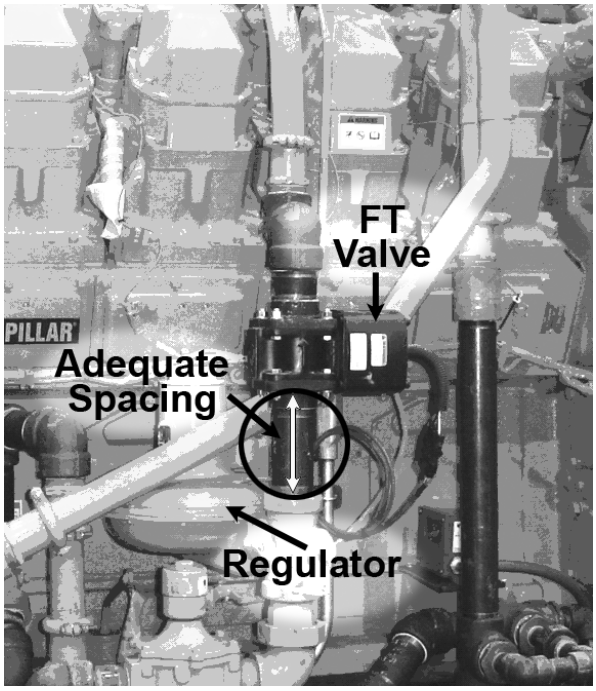


Illustration 4 – Proper Installation

The table below matches a given valve to its flange adapter size. Some applications will require bushings to match the fuel line size to the given flange adapter.

Butterfly Valve Size	Flange Size (NPT)
FL 25	1”
FT 33	2"
FL 50	2”
FT 60	2"
FT 68	2"
FT 75	3"

Armored hose for petroleum gas service could be used with the Full Authority Valve mounted by its body. Illustration 5 indicates the basic mounting bracket dimensions for the FT series valves. The bolts used are M8 x 10 mm long. Longer bolts will be needed to compensate for the thickness of the mounting plate. A slot in the bracket needs to be made for the cable as shown by the 1 inch diameter hole shown. Make a 1” slot from the bottom of the bracket to allow the hole as shown.

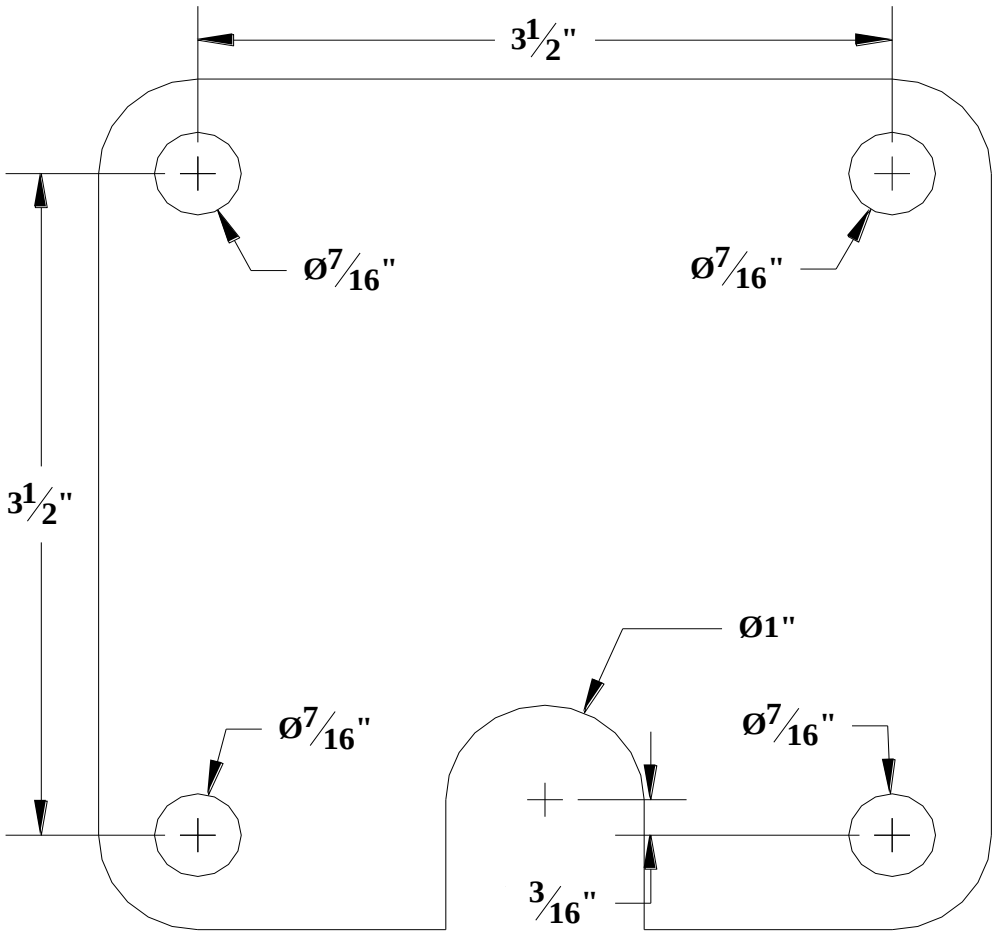


Illustration 5 - Dimensions for Making FT Full Authority Valve Mounting Bracket

UEGO Sensor Installation General Guidelines

UEGO Sensor

- See 'Installation Suggestion on Various Engine Types'.
- The UEGO sensor(s) should be mounted as close as practical to the engine exhaust manifold(s), after any turbo charger system.
- On any engine installation where there is a common intake or exhaust manifold, only one pre catalyst UEGO sensor will be needed.
- On applications where only one (1) UEGO sensor is used, the wiring should be connected to the Left Bank connectors only.
- On engine applications with dual carburetors and dual exhaust manifolds, one UEGO sensor will be used for each control bank.
- The maximum allowable shell temperature (melt down point) on the sensors is 500 °F (260°C). The sensors should never be installed in areas where the ambient air is stagnant and/or where the ambient air conditions exceed 250°F (121°C). The maximum thimble temperature is 1300°F.
- When the exhaust piping is insulated, the insulation should be removed from around the sensors to prevent overheating, a minimum of 3" diameter or 3 times the thickness of the insulation, whichever is greatest.
- When the exhaust pipe is installed horizontally, sensors should only be mounted between the 1:00 and 5:00 positions or the 7:00 to 11:00 positions. If the sensor is mounted vertically at the 12:00 & 6:00 positions, premature sensor failure will occur due to excessive shell temperatures and condensation build up in the exhaust pipe after shutdown. When the exhaust pipe is mounted vertically, orientation of the sensor should be to give the sensor the best chance for the lowest ambient air temperatures.
- Sensors should be installed with a light coat of anti-seize thread lubricant and torque to 30 lb-ft (40 Nm). Care should be taken that no excess anti-seize lubricant will come in contact with the sensor thimble.

UEGO Sensor Mounting

For an ambient temperatures less than 250°F.

Illustration 5 indicates the installation procedure used when the O2 Coupling that is optional with the kit is used. The mounting location of the pre catalyst sensor should be as close as practical to engine but should never be mounted pre turbocharger.

> **NOTE:** The O2 Coupling is constructed of 304 stainless steel and cannot be welded to cast iron by normal welding procedures.

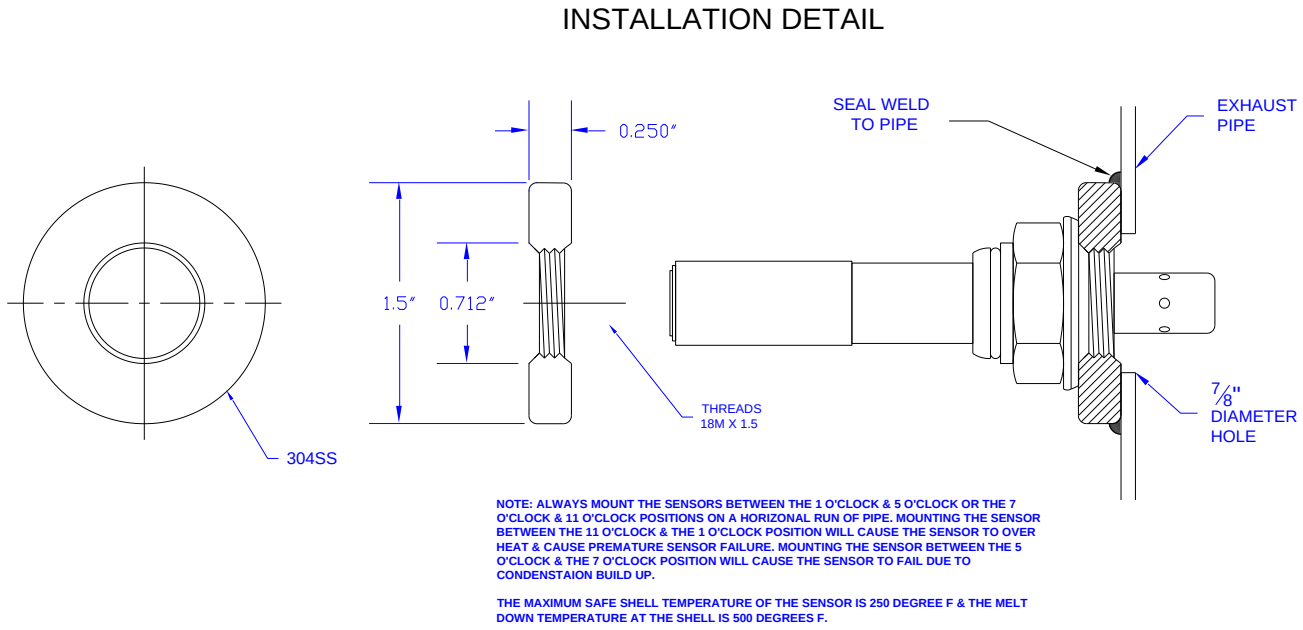


Illustration 5 - UEGO Sensor and O2 NUT

> **NOTE:** The holes in the sensor must be in the exhaust gas flow. On a horizontal pipe, the UEGO Sensor should be mounted between the clock positions of 1 and 5, or 7 and 11. Never mount the sensor between the clock positions of 11 and 1 (too hot), or 5 and 7 (condensation problems). The UEGO Sensor should be torqued to 30-35 foot-pounds. Illustration 6 indicates the horizontal pipe mounting rules.

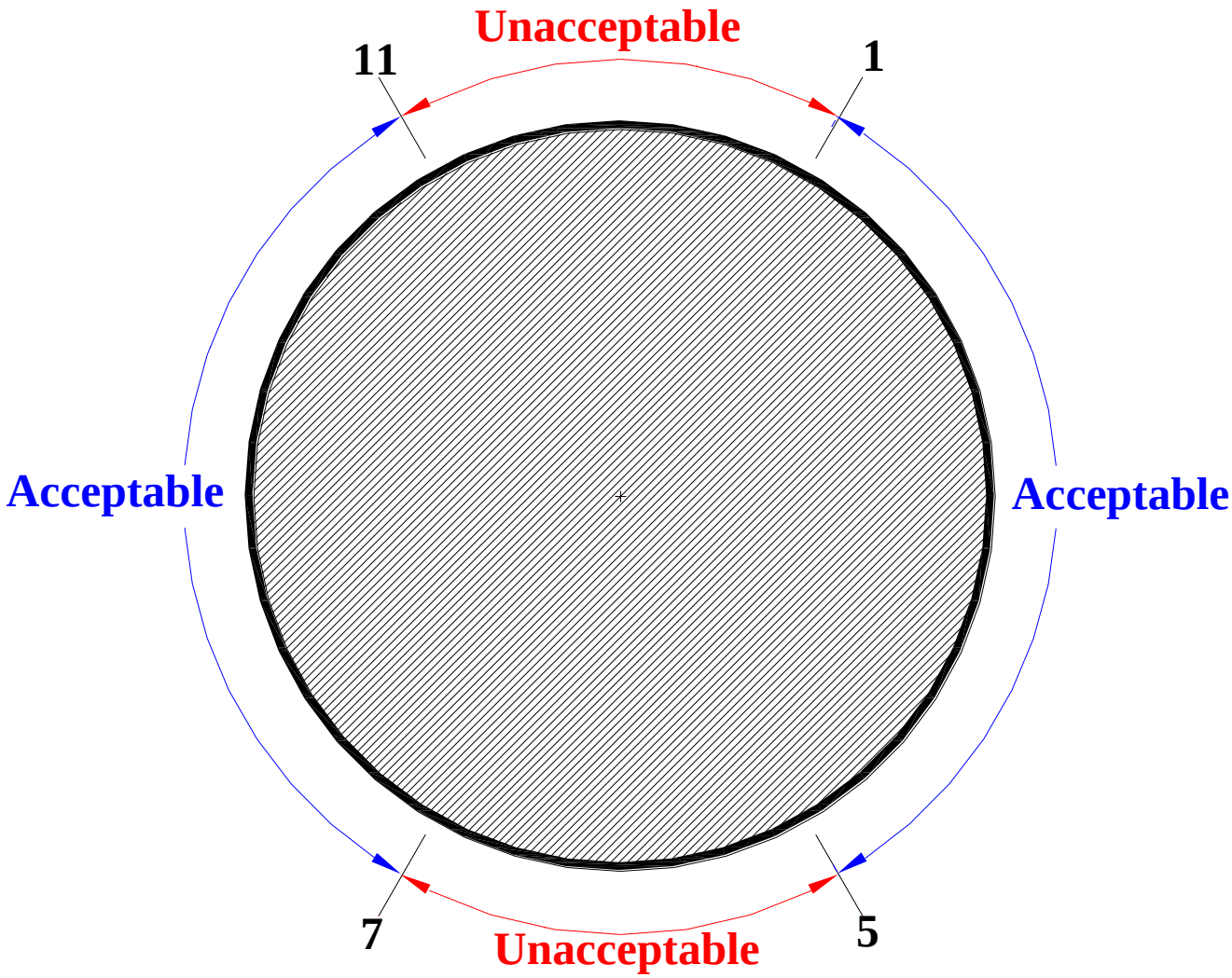


Illustration 6 - Allowed mounting orientations for UEGO Sensor on a horizontal pipe run

UEGO Sensor Mounting Using UEGO Sensor Block

For a sensor ambient temperatures greater than 250°F.

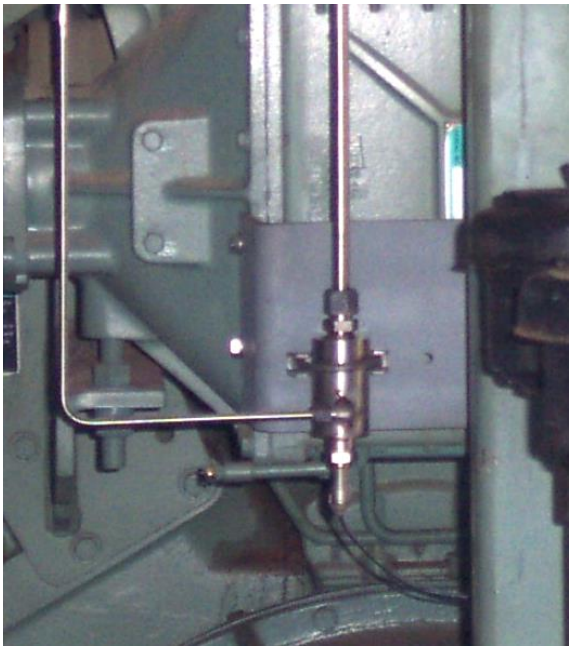
When the ambient temperature at the mounting point for the UEGO Sensor is greater than 250°F, or the exhaust back pressure is greater than 18" water column, the UEGO Sensor Block is used.

It is usually mounted by 1-3/4" U-Bolts, as it is 1-5/8" in diameter. It has a ½" NPT female outlet and a ¼" NPT female inlet. Below are pictures showing the stainless steel tubing, fittings, and brackets that may be used.

The UEGO block must not be exposed to a high pressure differential between its inlet and outlet. The inlet must be upstream of the turbocharger. The inlet should come from a location lower than the outlet.

All tubing should run up from the connection to the UEGO Sensor Block, and then down again from the UEGO Sensor block to the exhaust. Make sure there are no traps for moisture to collect when the engine is not running. Also, make sure the wires are routed so they will not get hot.

> **NOTE:** It is crucial for proper operation of the UEGO Block that the inlet connection not exceed ¼" tubing or pipe and that the outlet connection be no less than ½" tubing or pipe.



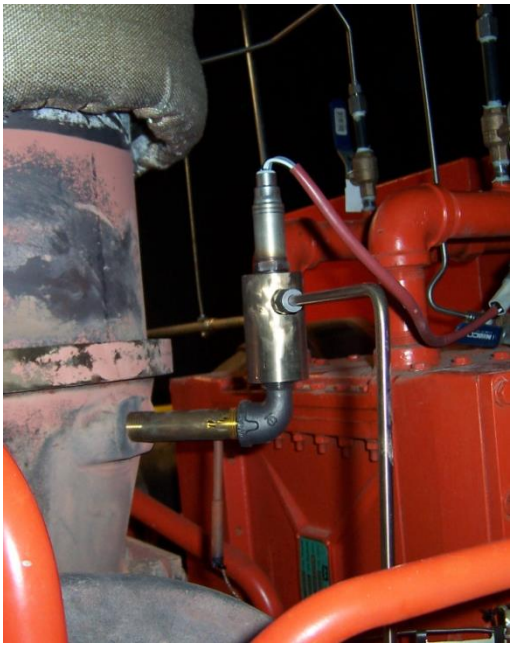


Illustration 7 – Incorrect installation - UEGO is mounted in the 6:00 o'clock position

Illustration 8 – Correct installation - UEGO Sensor is mounted in the 12:00 o'clock position

In Illustration 7, this is an example of an incorrect installation due to the orientation of the sensor. The sensor should never be mounted below the horizontal plane. Illustration 8 is an example of a properly installed UEGO Block.

Illustration 9 is an example of the desired inlet and outlet port locations on a turbocharged engine.

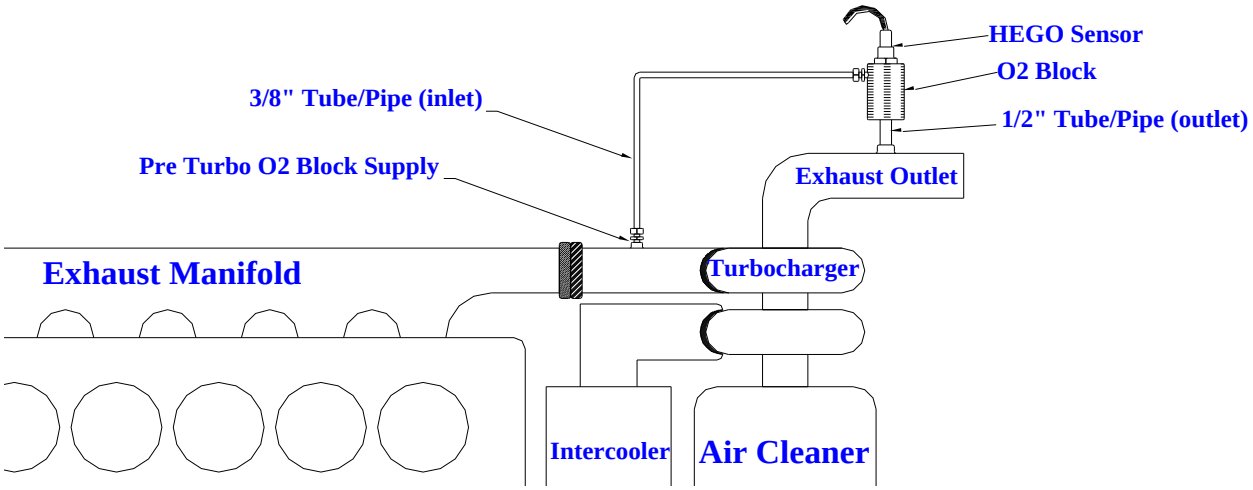


Illustration 9 - Proper UEGO Sensor Block Mounting for UEGO Sensor on a Turbocharged Engine

In the diagram above, looking at the top of a turbocharged engine, the UEGO Sensor Block Inlet is ¼" tubing tapped in before the turbocharger. The outlet from the UEGO Sensor Block is 1/2" tubing going into the exhaust pipe, downstream of the inlet connection. The orientation of the UEGO Sensor is in either the 12 o'clock position (OK for use with the UEGO Sensor Block), or the 3 or 9 o'clock positions.

For Naturally Aspirated engines, pitot tube type mounting is required. Illustration 11 shows a recommended design for the pitot tube type design. Several considerations need to be kept in mind when designing the pitot tube:

- The UEGO block and the pitot tubes should be orientated to avoid low spots where moisture could accumulate.

- The inlet tube/pipe must be 3/8” diameter and must be orientated so as the opening of the tube /pipe is facing into the exhaust flow.

- The outlet tube/pipe must be 1/2” diameter and must be orientated so as the opening of the tube/pipe is facing away from the exhaust flow.

This design will allow the exhaust gas to be forced into the UEGO Block via the 3/8” tube/pipe and sucked out of the UEGO Block via the 1/2” tube/pipe.

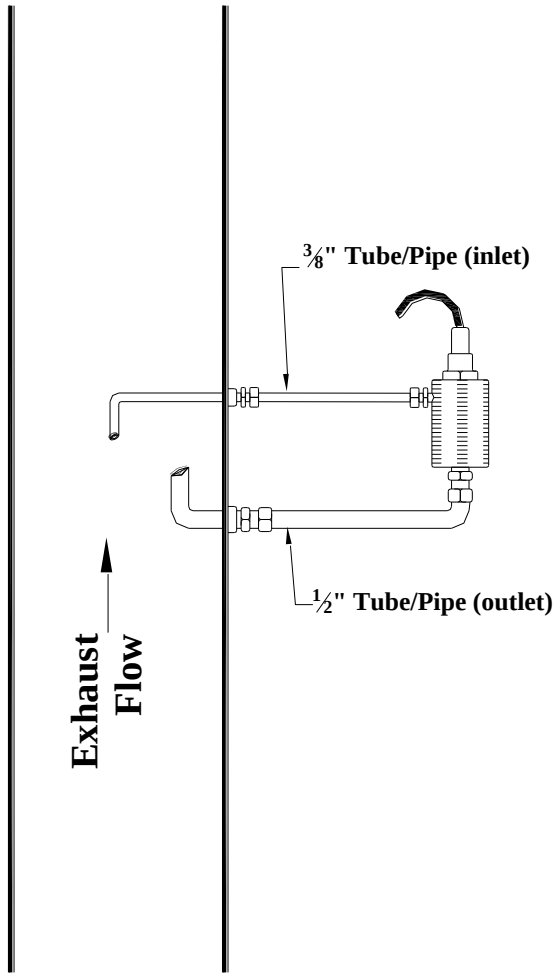
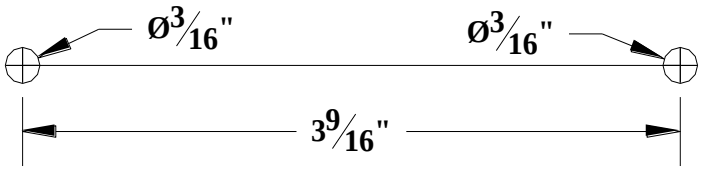


Illustration 10 - UEGO Sensor Block Mounting using Pitot Tube Installation on a Naturally Asperated Engine

MAP Sensor Installation

The MAP Sensor has a barbed nipple for 3/16” ID flexible automotive type petroleum fuel resistive tubing, or hose. It can be secured on that barbed nipple with an automotive style hose clamp. The following illustration shows the MAP Sensor mounting foot print.



MAP Sensor Foot Print

A bracket has been fabricated to mount the MAP sensor between the cylinders on a CAT G3516TA. The pressure connection is from a metal tubing tee in the Manifold Pressure tubing line already in place.

MAP Mounting on Intake Manifold

On engines like the Waukesha L7042G, where there are two Intake Manifolds, only one manifold pressure is monitored. The MAP Sensor must not see ambient temperatures higher than 200°F.

MAP Tap on Waukesha

MAT Sensor installation

The Manifold Air Temperature (MAT) sensor can be mounted anywhere in the intake manifold. The sensor requires a 3/8" NPT port in the intake manifold for mounting. It is designed to be weather resistant.

- See the Appendix for installation suggestion on various engine types
- The sensor must be installed were as not to be exposed to temperatures in excess of 250°F.

- Caution should be taken not to mount the sensor in an area that might be exposed to high-pressure water.
- Maximum design pressure of the sensor is 45 psia (3 bar absolute).
- The installation point on the intake manifold should be at a point where the mean intake manifold temperature can be read.

Left -- a typical installation on a Caterpillar G3500 series engine.
Right -- a typical installation on a Waukesha VHP series engine.

Mounting Thermocouples

The controller solely uses the optional thermocouples for catalyst over temperature protection. Thermocouples are not required for controller operation; however, jumpers should be installed across the thermocouple contacts on the Terminal Connection Board (TCB) if not used to prevent alarms. (See wiring section).

The controller is meant to interface with Type K, ungrounded thermocouples. The user will need to supply type K thermocouple wire at installation.

One thermocouple should be installed before the catalyst (if present) and the other post catalyst. Both should be located as close as possible to the catalyst itself. The thermocouple probes should extend well into the center of the pipe.

Mounting Magnetic Pickup

The controller requires a speed input. This can be from a G-Lead connection on the ignition or from the optionally supplied Magnetic Pickup. In some situations, the speed signal can be from a Magnetic Pick-Up used for a tachometer or controller. **Never share the MPU signal used by an electronic governor or ignition system with the controller!** Different components have different electrical characteristics and the consequences of failure are severe.

The illustration shows typical installation of the optional magnetic pickup (MPU) with the supplied harness. The MPU requires a 5/8-18 threaded hole. It has to be centered on the ring gear, and adjusted close to the teeth. The signal strength of the MPU is proportional to the gap from the tips of the flywheel teeth.

Screw the MPU in until the ring gear is touched. Then back it out 5/8 to 3/4 turn to get a 0.030" to 0.040" gap. Tighten the lock nut to 25 to 30 foot-pounds.

The signal strength is measured with an AC Volt Meter. The voltage must be above 3 VAC, and is preferred to be less than 10 VAC when connected to the controller. When not connected to the controller, the signal will be a higher voltage.

Enclosure Mounting and Conduit Entries

Before any enclosure modifications are made for conduit entries and anything else to be mounted on the enclosure, the ECM and TCB must be removed. They should not be put back in until all enclosure modifications are complete and all metal shavings have been removed.

Conduit entries should typically be from the bottom, but the sides can be used. However, the top should only be used in an indoors application.

With the ECM (black module) and TCB out of the enclosure, the TCB can be separated or installed using the violet colored cam latch of the TCB assembly. The ECM and the TCB should be separated as little as possible. It is almost impossible to operate the cam latch for the plug connector with the assembly mounted inside the enclosure. Removing the ECM and TCB and then separating them is a good way of protecting the ECM if any welding is to be done on the equipment.

The enclosure is mounted by 4 ¼" bolts, nuts, flat washers and lock washers. Care should be taken to separate wiring for different purposes using multiple conduit entries. The details of this are shown on the following diagram. One inch conduit is shown with the appropriate hole size. For other sizes use the below as a guide:

Conduit Size	Hole Size
1/2	7/8
3/4	1 1/8

1	1 3/8
1 1/4	1 3/4
1 1/2	2

Conduit Considerations

Conduit size and the choice of flex conduit versus rigid conduit must be made like any other installation. The choice of conduit pull boxes and junction boxes may be affected by the size of the plugs on the harnesses.

Always pull a harness using the free wire end from the location where the plug will be.

Gland fittings, strain reliefs or cord grips will be used in several places at the end of the conduit run.

Minimizing free wire runs, providing mechanical strength by the appropriate use of conduit and fittings, and strain relief of the wiring are the goals.

Make sure to run noise sensitive signals separately from noise creating wire.

Also separate non-incendive and intrinsically safe wiring from any other wiring.

Wire Termination

Refer to the table at the end of this section when making wiring connections to the Terminal Connection Board (TCB). For single bank engine applications all connections should be made to the Left Bank. The rare dual bank applications using only one pre catalyst oxygen sensor (UEGO) should have that sensor connected to the left bank pre catalyst UEGO input and **both** fuel valves wired to the left bank as well. (That is to say the valves should be wired in parallel to the left bank.) The controller is then configured for a single bank engine (one oxygen sensor).

General wiring considerations:

- Always use good cable and wire stripping tools, and crimping tools in good condition.
- Wherever possible, use stranded tinned copper (do not solder). Raw copper wiring will corrode easily. Make any splices inside a weather-proof conduit fitting.
- Always provide extra lengths of wiring at termination points so if there is a need to redo a connection, there will be plenty of wire to work with. It is much better to have a service loop of extra wire than to be short.
- The battery's positive (+) should be the final connection made to the board.

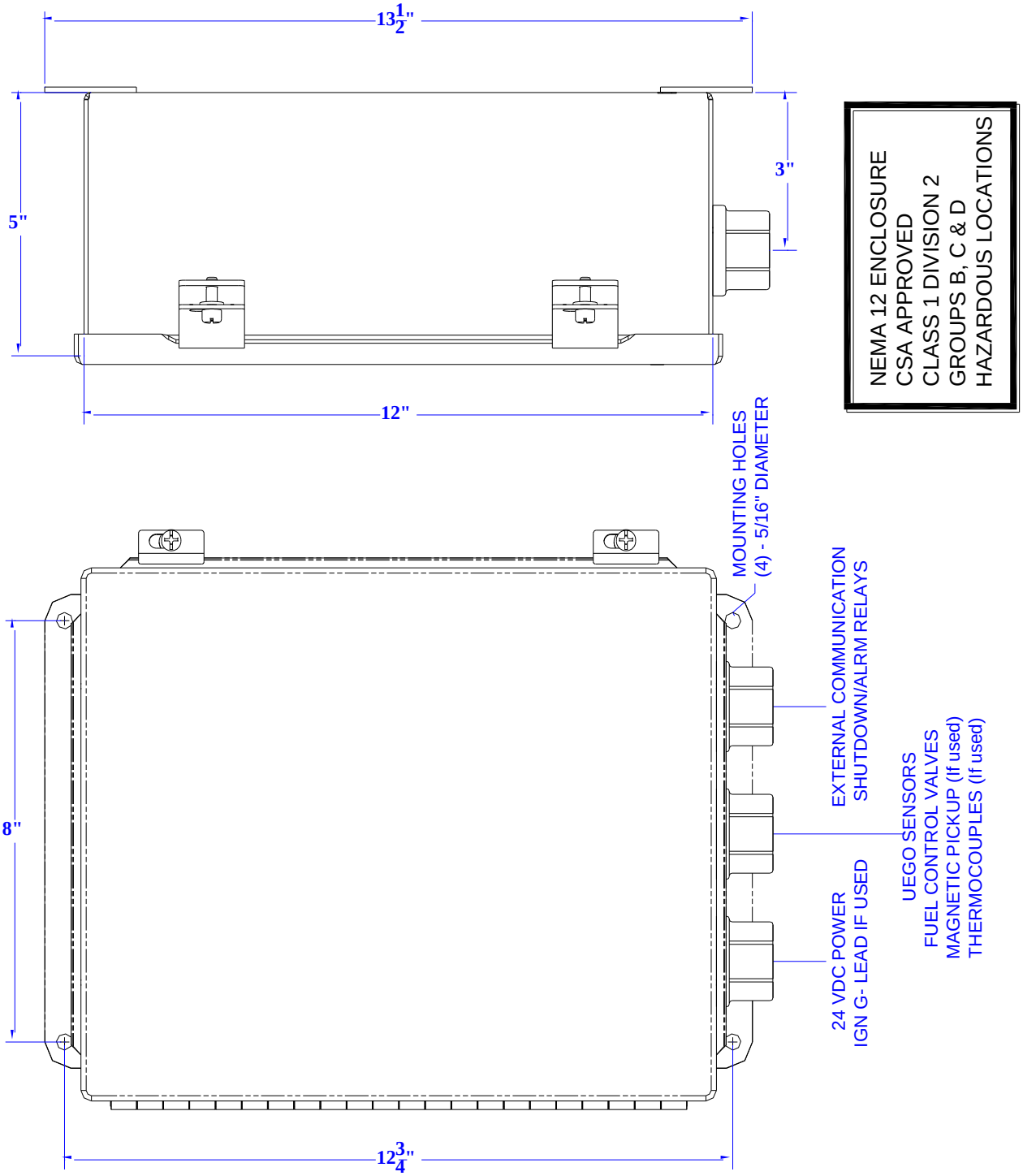


Illustration 11 - Enclosure Mounting Dimensions, Recommended Conduit Locations, and Wire Separation

Wiring Connections

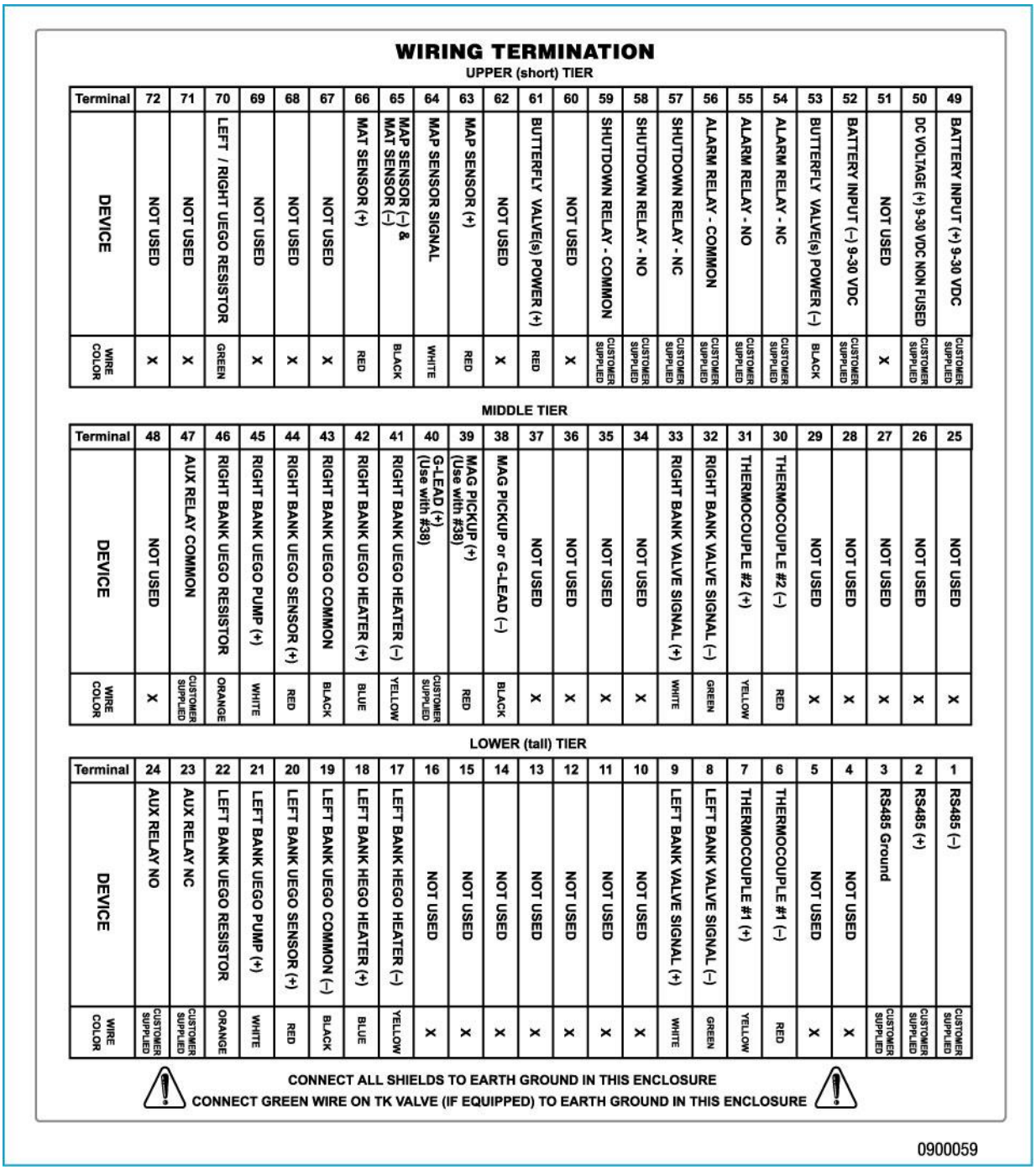
Wherever possible, use stranded tinned copper (do not solder). Raw copper wiring will corrode easily. Make any splices inside a weather-proof conduit fitting. Always provide extra lengths of wiring at termination points so if there is a need to redo a connection, there will be plenty of wire to work with. It is much better to have a service loop of extra wire than to be short. Always use good cable and wire stripping tools, and crimping tools in good condition.

Engine Mounting Requiring Disassembly of Engine

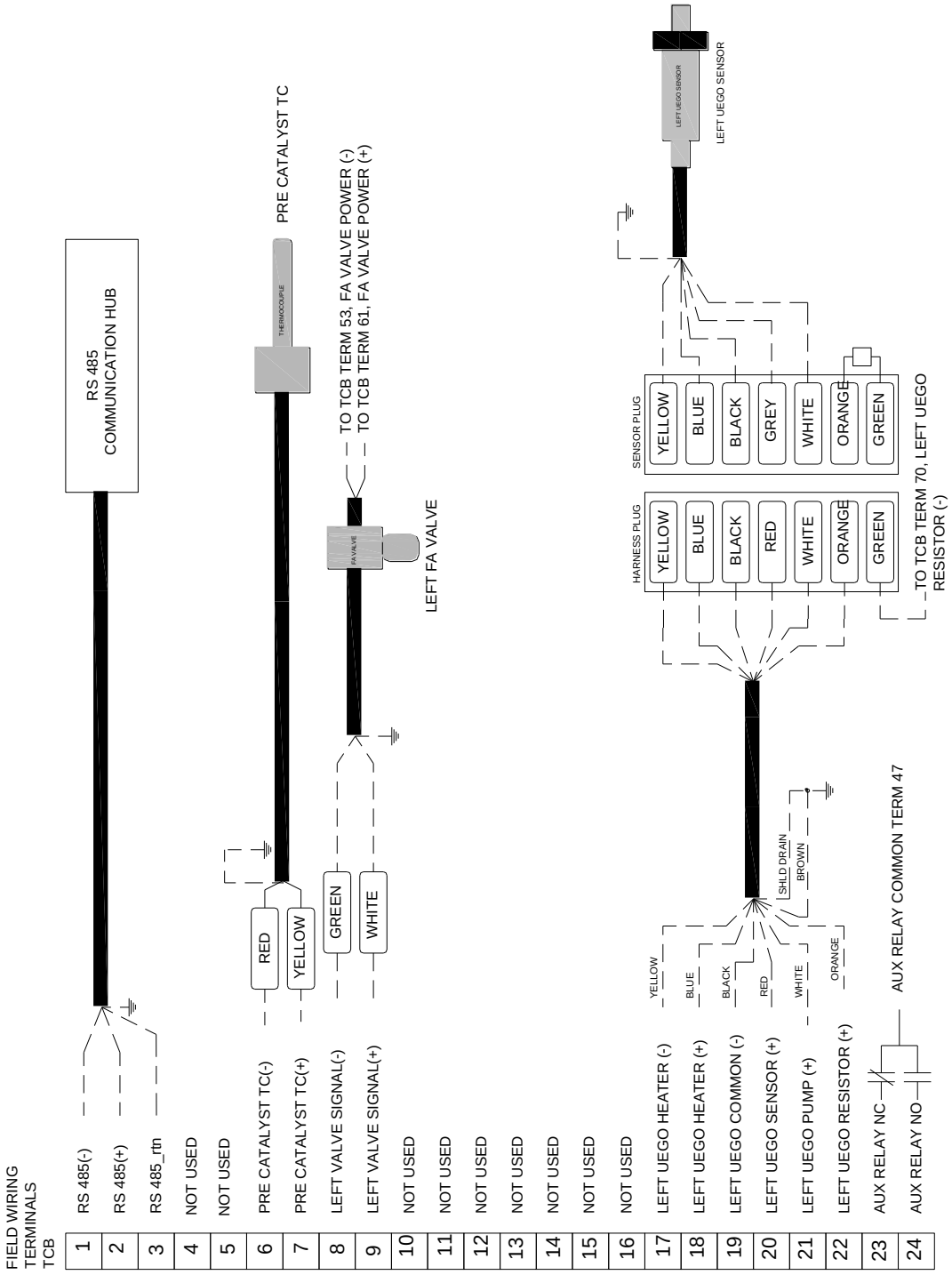
If there are no provisions or available connections to tap, or use for fuel pressure, intake manifold air pressure, UEGO mounting, manifold pressure or temperature, or exhaust temperature, then provisions must be made to have the tools and parts available to disassemble the part of the engine which must be modified by drilling and tapping. If the Intake Manifold has to be drilled and tapped, it should be removed from the engine so any filings can be properly removed prior to reassembly. The gaskets should be replaced when this is done. The same goes for any pipe or casting on the engine.

AFR-64L Wiring Schematic

General Wiring Termination – All Valves

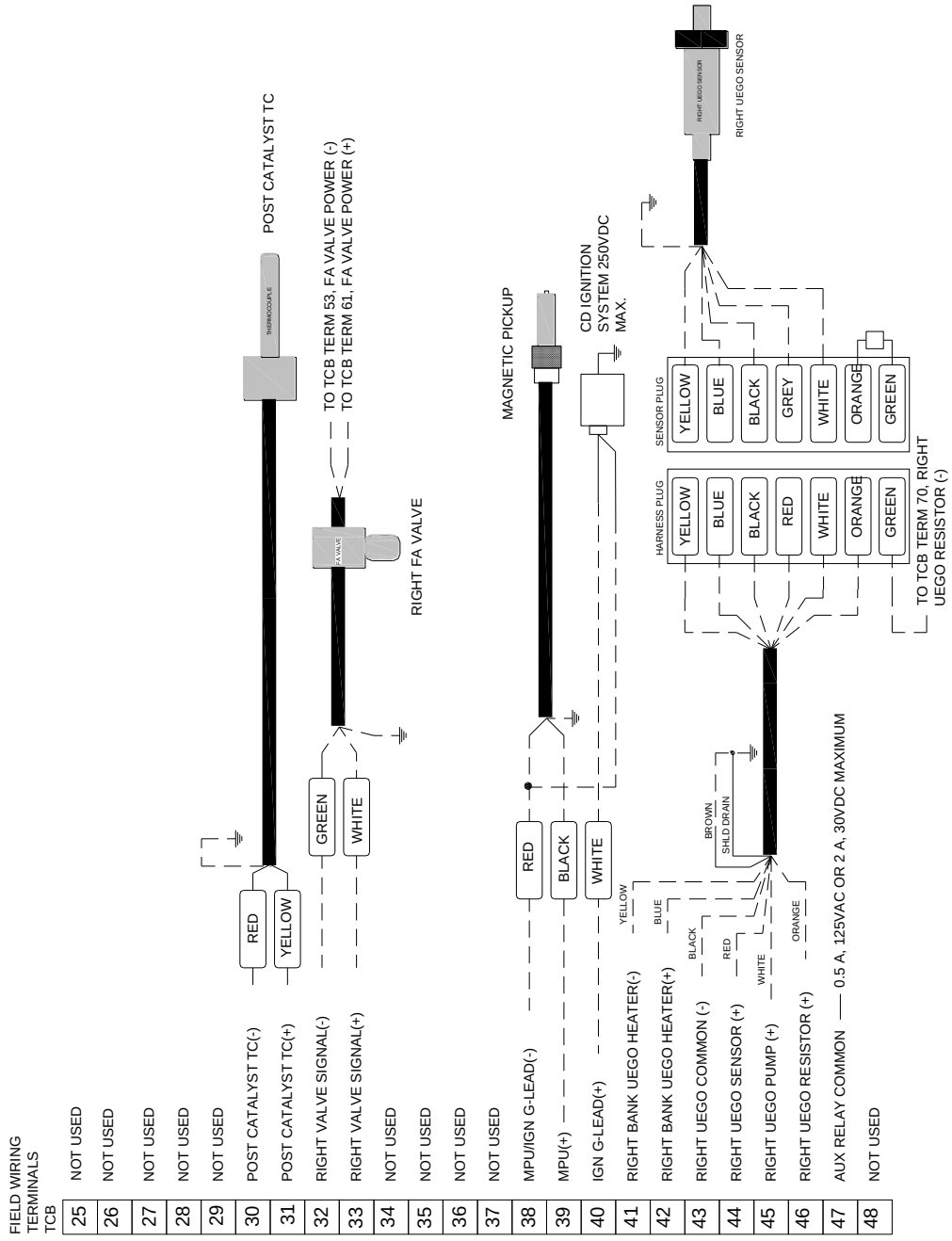


Butterfly Full Authority (FA) Valve Field Wiring Schematic – Lower Tier (tall)



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

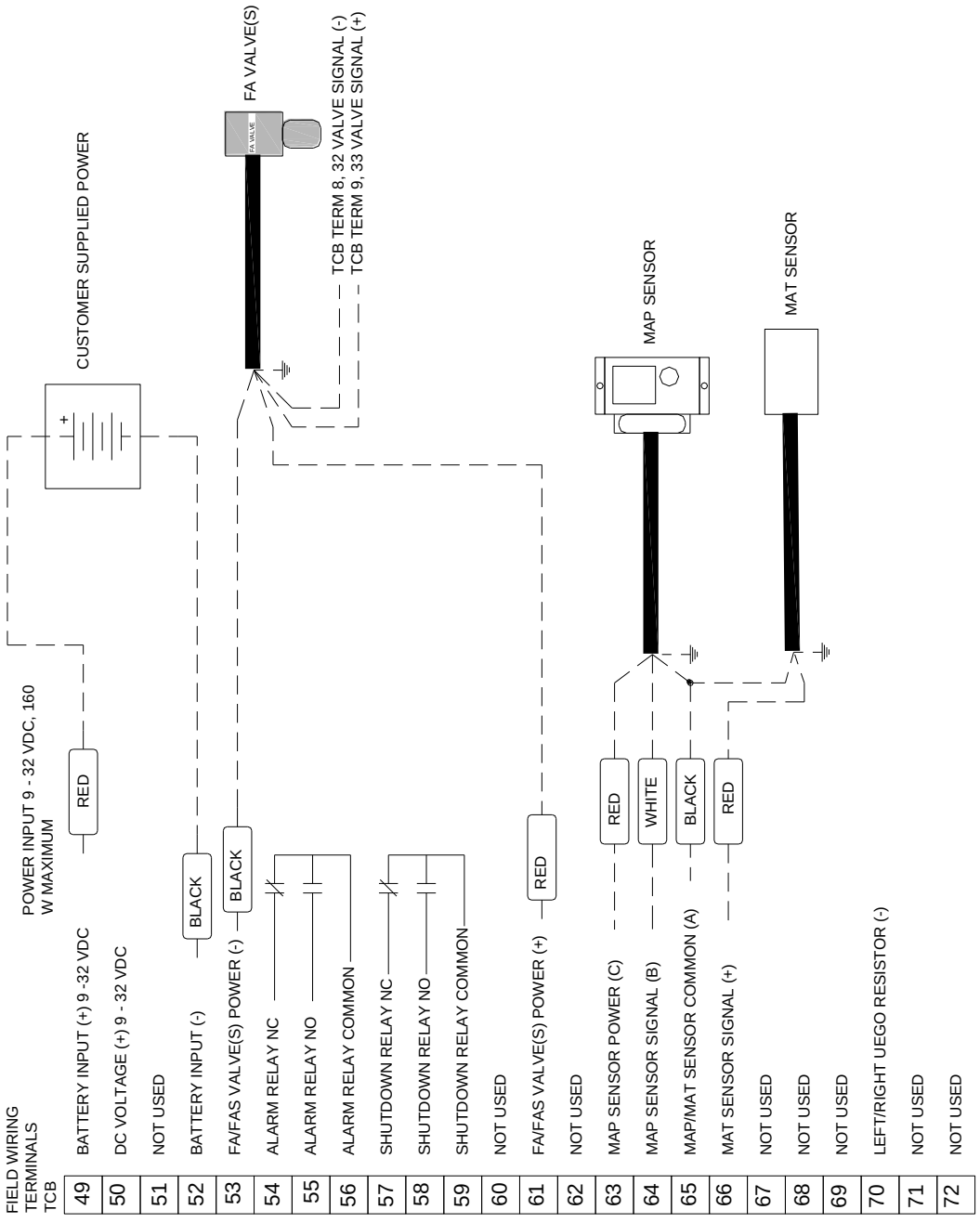
Butterfly Full Authority (FA) Valve Field Wiring Schematic – Middle Tier



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

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

Butterfly Full Authority (FA) Valve Field Wiring Schematic – Upper Tier (short)



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

Start-Up and Commissioning

1. Having installed the controller and all end devices, prepare for the commissioning by having:

    a. A laptop computer with the Compliance Controls software installed, and a good battery or power adapter. No other software should be running while the software is running. An open serial COM port (com 1 through 8) must be available to the controller software. (Sometimes other software on a computer will claim a COM port making it unavailable for other programs.) If RSLOGIX / RSVIEW, or any other PLC, HMI, or software that uses the serial port is installed, it may have to be uninstalled or temporarily disabled to free up a COM port.

    b. A null modem cable (pins 2 and 3 swapped from end to end, both ends DB9 female). This null modem cable (female x female x 10') is supplied with each controller.

    c. The password for full access control. See the password file in the program file menu *(Start > Programs > Compliance Controls> Passwords)*

    d. A multimeter capable of reading DC voltages up to 35 volts.

    e. An emissions analyzer capable of reading NO_x, CO and O_2.

    f. One 36" water manometer or similar type digital electronic manometer with isolation valves, to measure differential fuel pressure in inches water column (in. WC).

    g. Pressure Gauge capable of measuring the fuel line pressure upstream of the final cut regulator.

2. Plan to do the dirty work, like making provisions for the manometer connections, or mounting pressure gauge first, so your hands can be clean while operating the PC.

3. 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.

    If the Butterfly Full Authority (FA) Valve is used, the fuel pressure will be measured between the final cut regulator and the valve. The fuel pressure will always be measured between the fuel pressure 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, refer to illustration 12. 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. If a naturally aspirated engine is using a balanced regulator, refer to illustration 13 for the recommended measuring method. For non balanced regulators, refer to illustration 13 for the recommended measuring method.

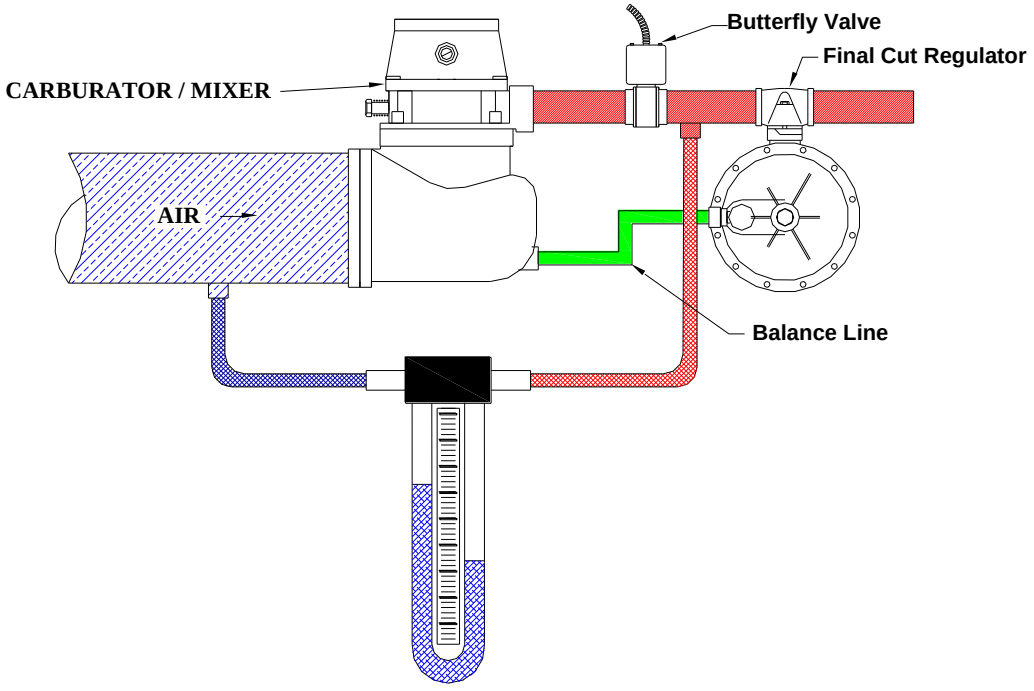


Illustration 12 – Fuel/Air Measurement – Butterfly Valve – Turbo Charged Engine & Naturally Aspirated Engine - Balanced Regulator

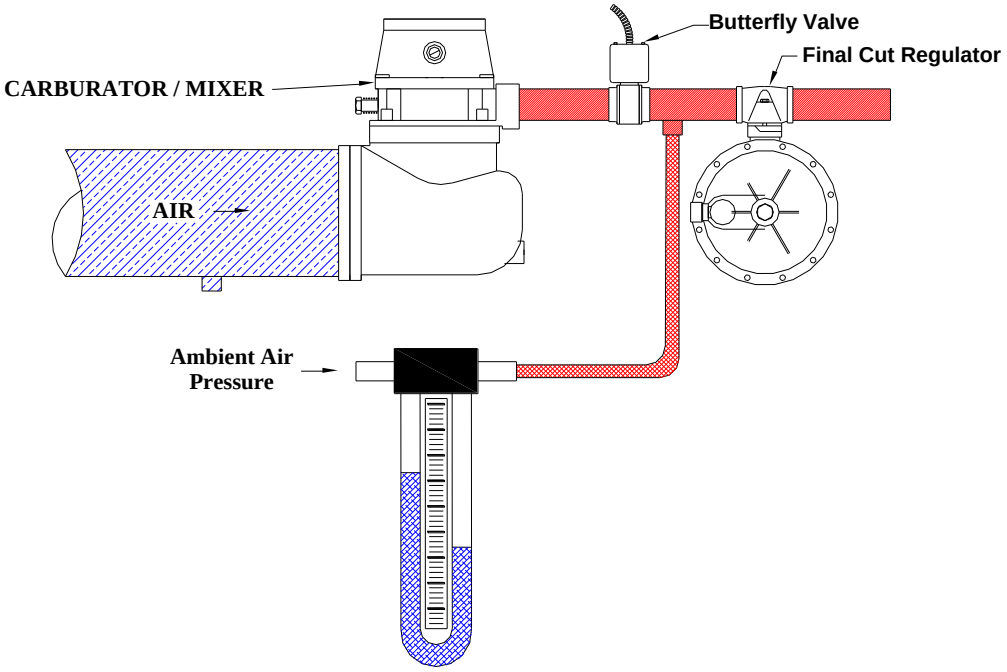
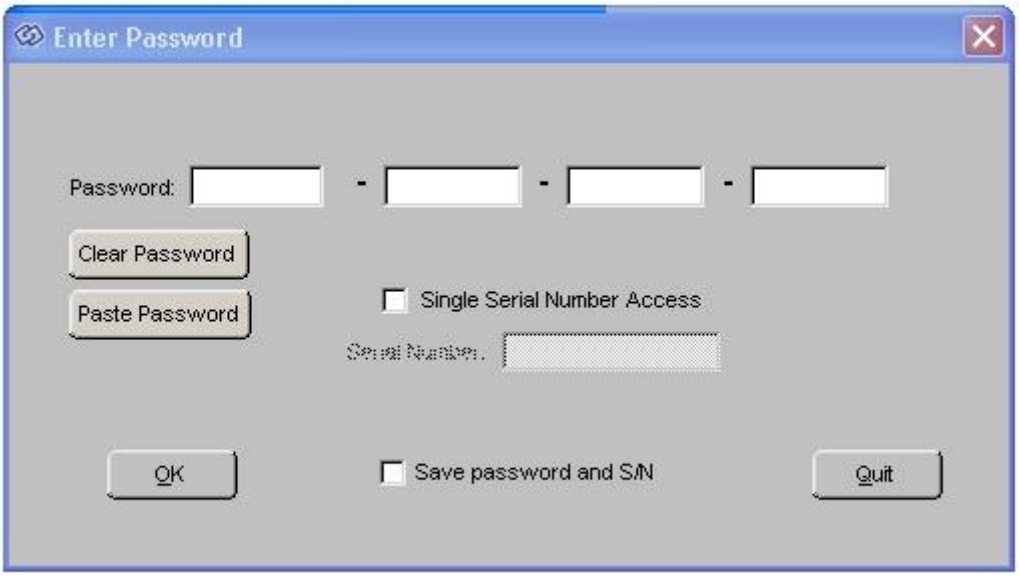


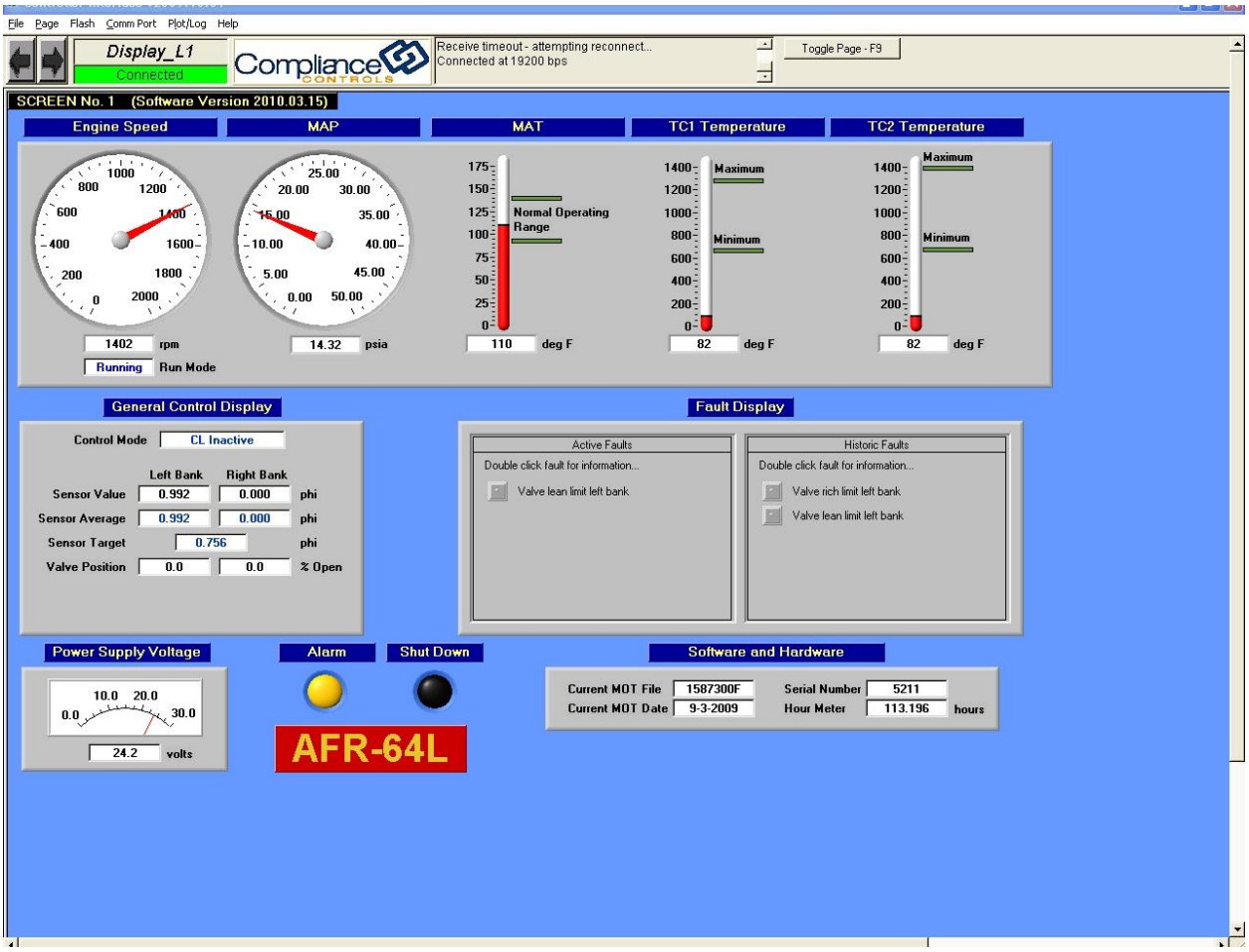
Illustration 13 – Fuel/Air Measurement – Butterfly Valve – Naturally Aspirated Engine - Non Balanced Regulator

4. Apply power to the controller. You can verify the controller is powered-up by the Power LED on the TCB located below the fuses. Turn on the PC and connect the null modem cable after booting-up from the com port on the PC to the com port on the controller. After the PC has booted-up, run the Compliance Controls software. You may have a desktop icon you can double click. If not, the executable file can be located in the "Start" menu (Start > Programs > Compliance Controls > Compliance Controls) or it can be located in the main operating drive, typically "C" in the program C:\Program Files\Compliance Controls\Controller Interface.exe. Once started, the password screen will come up first. It looks like this:



Enter the password and click OK. It is possible to accidentally login to the Rich Burn software for the AFR-64R controller. Make sure you use the AFR-64L password. The password can also be copied and pasted from the Windows Excel ® spread sheet or a basic text file that can be found in the Compliance Controls folder on the PC's hard drive. The password can be saved once it is entered into the password cells by clicking on the "Save password and S/N" check box. Once the password is saved, each time the software is started, the password is automatically entered.

5. On the PC screen, you will see something like this, depending on your screen size and resolution (the image shown if from a resolution of 1280 x 1024).



Note the green box under Display_L1 that says “Connected”, and the box to the right of the Compliance Controls logo that says “Connected at 19,200 bps. This lets you know you are communicating properly between the PC and the controller. If you do not see those, you will see the box below Display_L1 the same color as the box above it, and it will say “Not Connected”. The box to the right of the Compliance Controls logo will alternate between saying:

“Error opening com port 2 in HandleConnect Link error - attempting reconnect...”

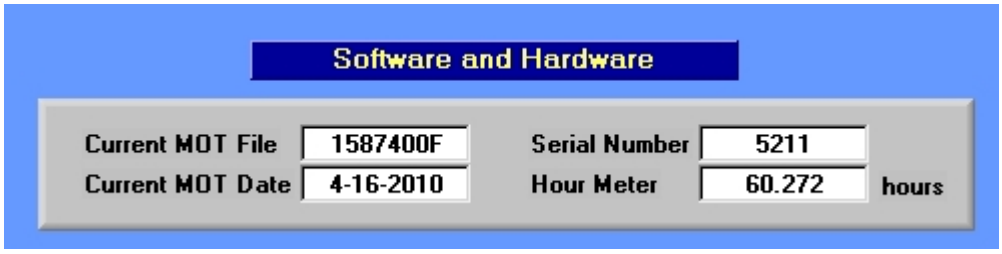
and

“Error opening com port 8 in HandleConnect Link error - attempting reconnect...”

If that happens, go to the troubleshooting section of this Manual.

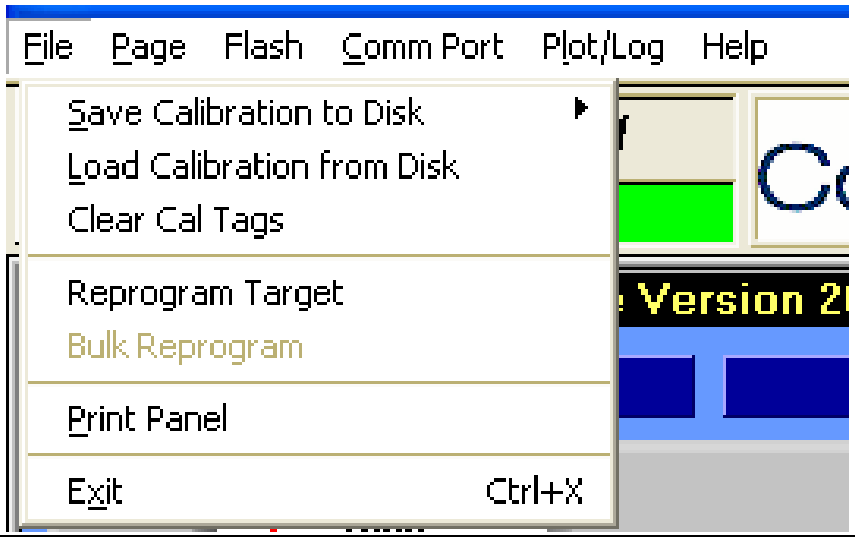
NOTE: Depending on your screen resolution, you may have to use the slider bars for up and down, or side to side to see various parts of each page, or screen.

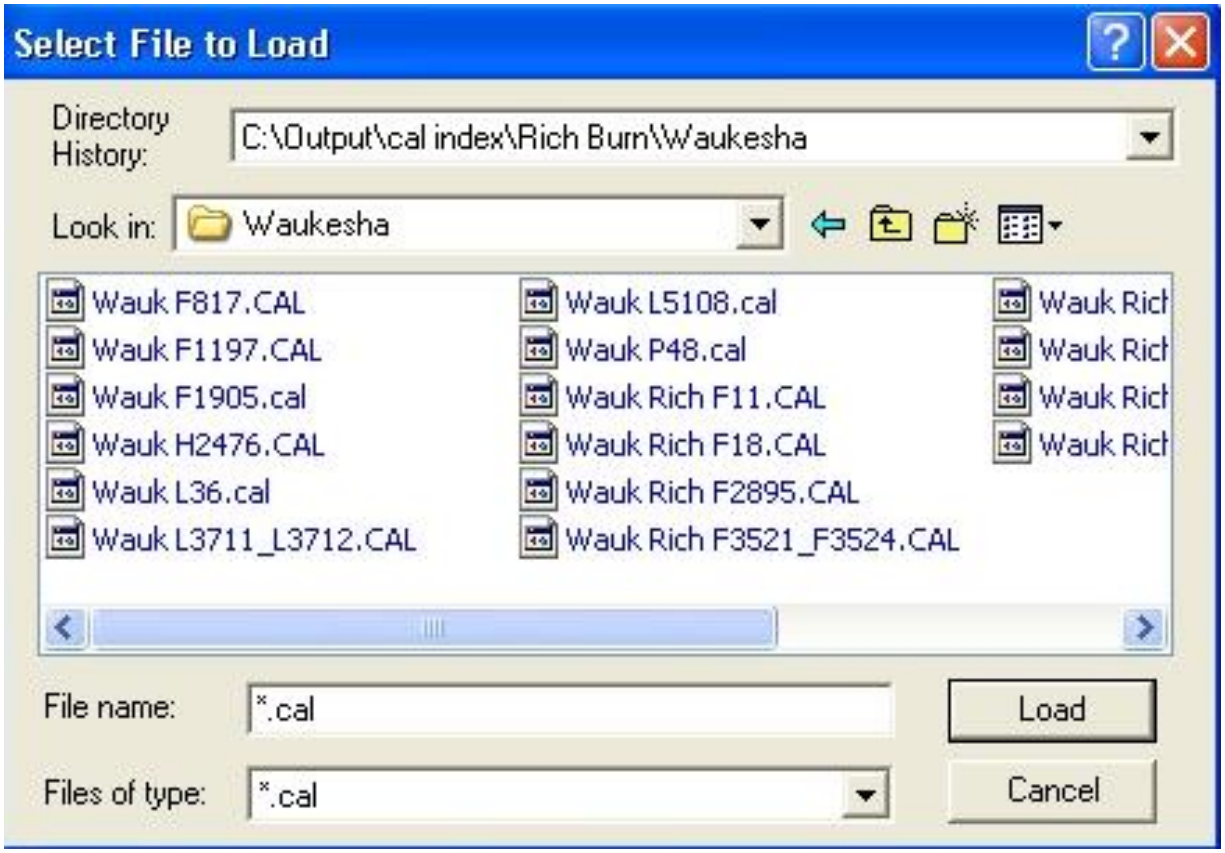
6. Look down and to the right of this screen.



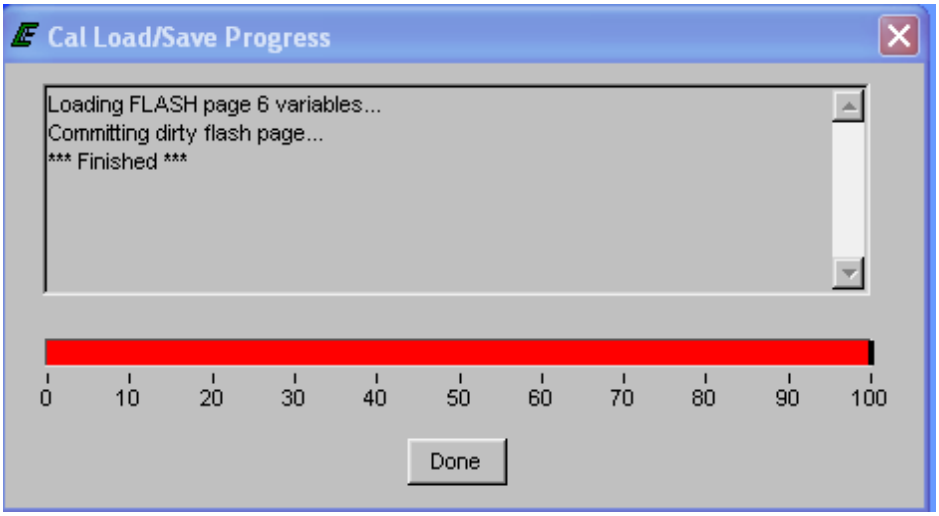
In the cell marked "Current MOT File". This file number should read "F" at the end of the file name. This means you have the current version of firmware. If you have an earlier revision, you will want to go to the instructions for loading the newer version. These instructions are in the Troubleshooting section.

7. The next step would be to choose a calibration (CAL) file for your particular engine. These CAL files are located in the "Output" folder on the "C" drive of your PC in a sub-folder named "CAL Index. Loading the CAL file is done by clicking on "*File"* (top left of screen), then "*Load Calibration from Disk*". You will get the window below. Choose the CAL file, and click Load. If a "CAL" file is not available for your engine, all parameters will need to be entered manually.



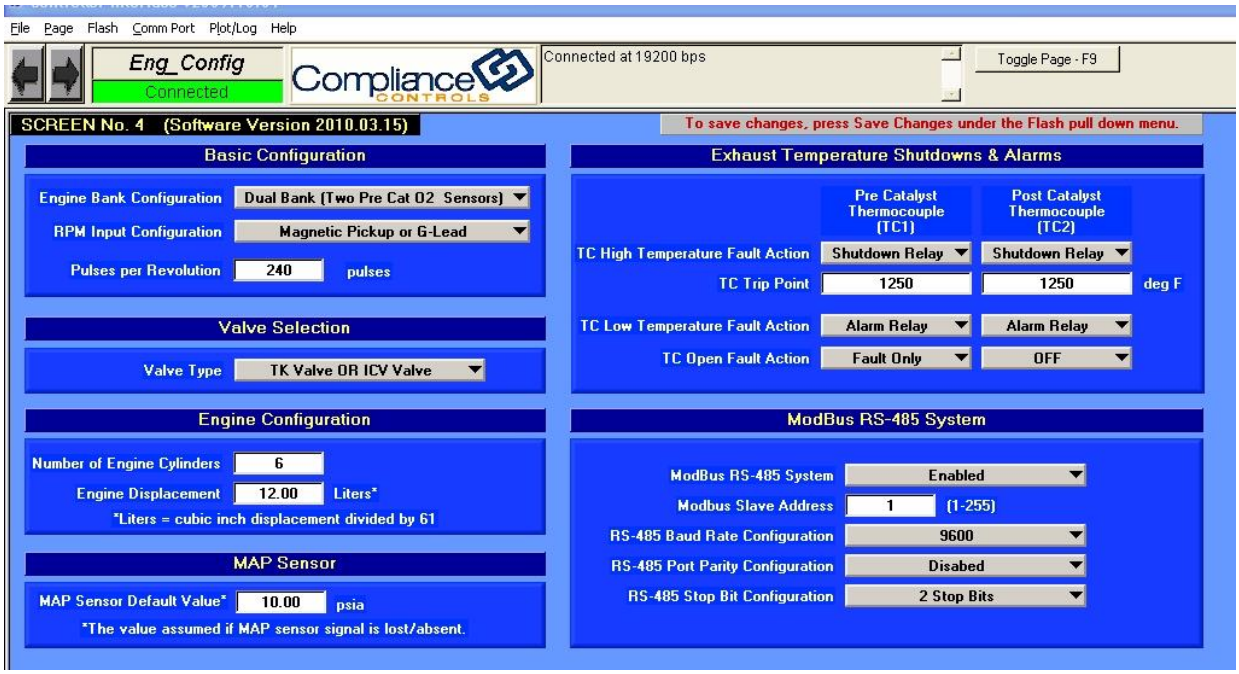


When the file has been loaded, you will get this window:



Click “Done” after you see “*** Finished ***”.

8. Next press the Page Up or Page Down key, or click the left or right arrow keys to go to Screen No. 4, the Eng_Config screen.



9. Here you will go to the thermocouple setup, labeled in the top right box as “Exhaust Temperature Shutdowns and Alarms”, as shown below.

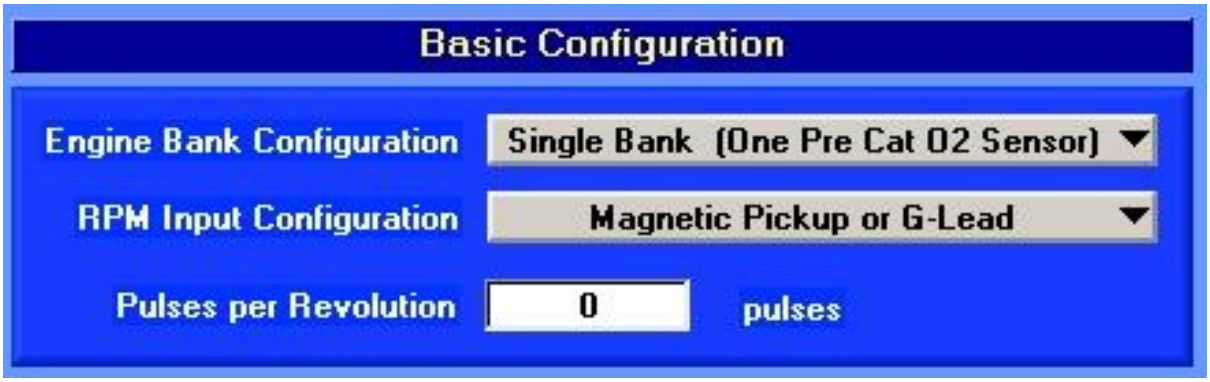
If you are not using thermocouples, you will want to set all 6 choices for “Off”. Each of the boxes with the Down Arrow at the right has these choices:

Off **Fault Only** **Alarm Relay** **Shutdown Relay**

Shutdowns can be cleared by cycling the power, or by clicking on the Red Shutdown lamp on the Display, Screen (Screen No. 1). Alarms can also be cleared by the PC by double clicking on the historical alarm. If you are using the high set point for the thermocouples, set that value at this time. It is recommended that the high catalyst trip points be set at 150°F above the normal operating temperature of the exhaust system or 1250°F, whichever is lowest. You must save these settings prior to making changes to any other part of the controller. To save the changes, click on Flash, then Save Changes. You will get a warning box like shown on the next page.

If you are done with the thermocouple set-up, click “Yes”. All changes are now saved to the onboard memory of the controller.

10. Even if you used a CAL file, you should review all the parameters to make sure they are in agreement with the engine and the air/fuel controller kit equipment. Start with the box “Basic Configuration” shown below.



For the Engine Bank Configuration, you will choose one of the following:

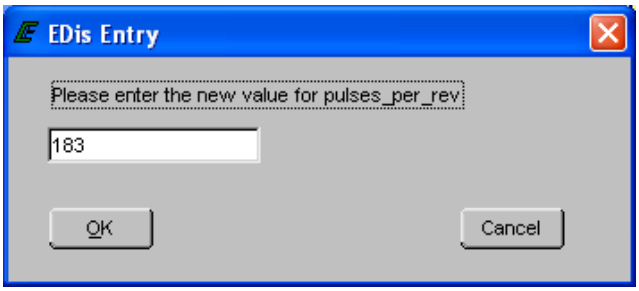
- Single Bank (One Pre Cat O2 Sensor) – *Uses only the Left Bank signals*
- Dual Bank (Two Pre Cat O2 Sensor) – *Uses both the Left and Right Bank signals*

.

RPM Input Configuration gives choices of:

- Disconnected
- Magnetic Pick Up or G-Lead *(factory default setting)*
- Not Used
- Nor Used
- Discrete - Ground=Running
- Discrete – Open=Running
- Discrete - +V=Running

You will always choose Magnetic Pick Up or G-Lead. Magnetic Pick-Ups are highly recommended because they offer greater resolution of speed signal and very much less electrical noise. Next choose the Pulses Per Revolution (If you do not know, there is a list of common engines in the back of the manual). Click on the number. You can then double click, or press Enter to get the edit window shown below.



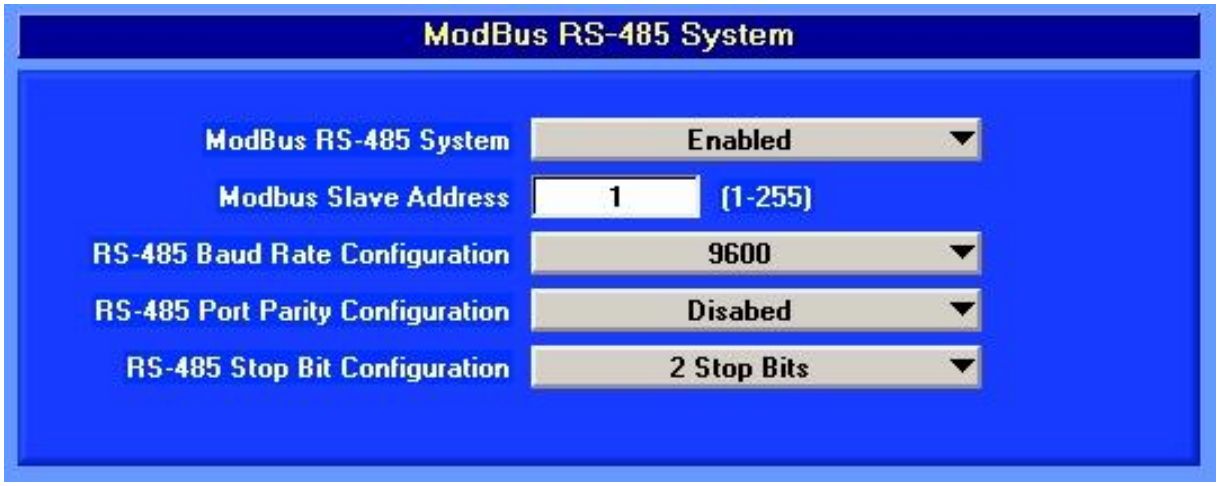
Type the number you want, then click OK, or press Enter. Next, go to the Valve Selection window shown on below.

For the Valve Type, choose the setting “Butterfly Valve.” Next go to the box for Engine Configuration shown below.

Choose the correct number of cylinders and liters displacement using the number editing window explained before. (If you are not sure of the Engine Displacement, there is a table in the back of the manual showing a list of common engines.) Engine Displacement is typically known as CID (Cubic Inches Displacement), which must be converted into Liters by dividing CID by 61.

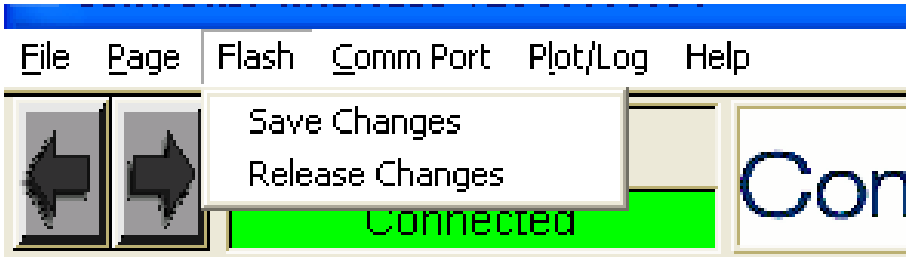
You have the option at this time to choose a “Default MAP Setting”. This setting is a manifold absolute pressure reading will go to if the MAP Sensor should fail. Set this default at your typical manifold absolute pressure during normal operation.

11. Also, while on this page, if Modbus communications is desired, for the UniOP, or remote monitoring, go to this part of the screen.

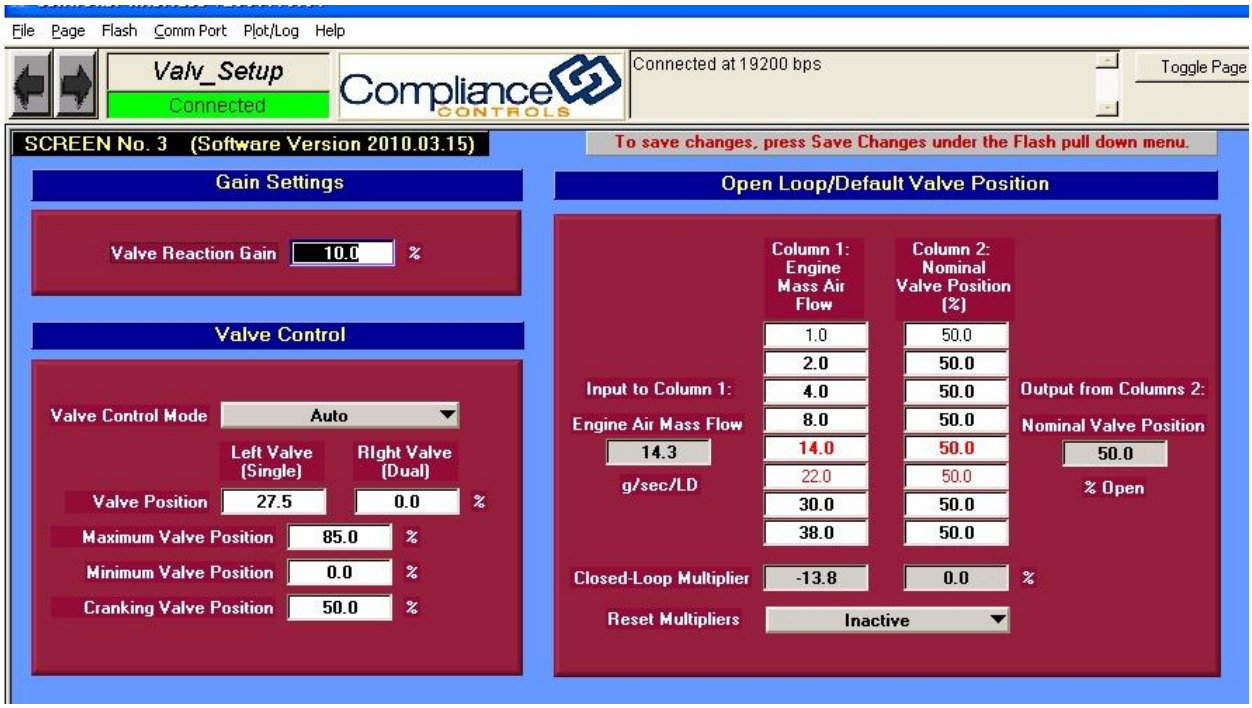


Default setting for the ModBus communications from the controller is as seen above. These settings are appropriate for use with the optional UniOP display but may need to be modified if another device is used to monitor the controller's operation. Contact your communication department for settings for other devices.

12. Click on Flash and Save Changes to save these settings as described before.



13. Next, press Page Up, or click the left arrow to go to Screen No. 3, Valv_Setup as shown below.



14. Prior to cranking the engine, a safe starting point for the "Valve Cranking Position" is 50%. While cranking the engine, if it seems the engine is starving for fuel and the Butterfly (FA) Valve is being used, raise the Cranking Valve Position 5.0 % at a time until it seems it is not starving for fuel. If the engine seems it is being flooded, lower the Cranking Valve Position 5.0 % at a time until it seems it is not being flooded.

15. Once the engine starts, let it warm-up. Put the "Valve Control Mode" into "Manual" to choose a valve position that allows the engine to warm-up.

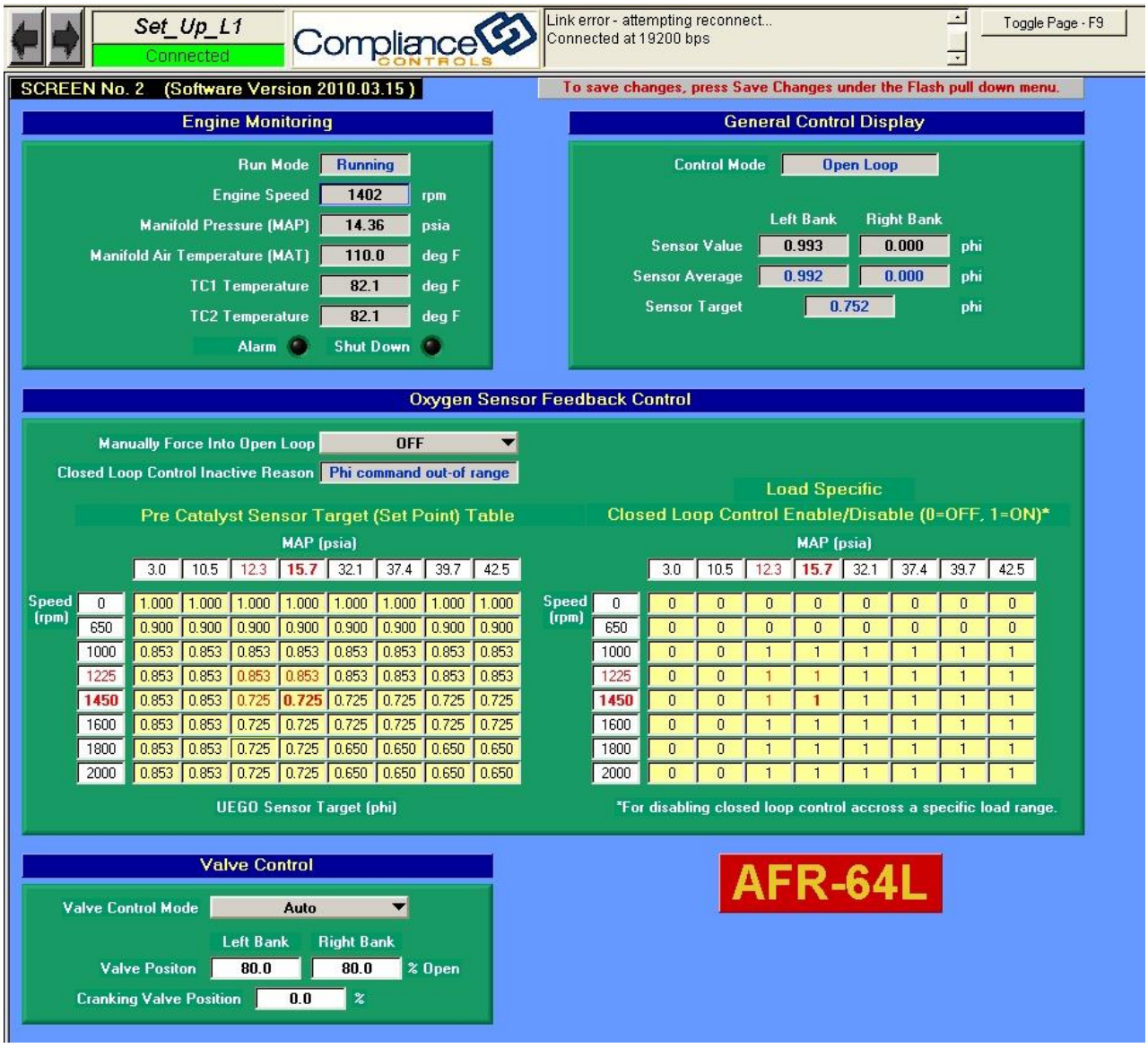
Load the engine as much as possible. Make a good determination of the percentage load the engine is running at, taking into account the Intake Manifold Pressure and where it is related to the maximum manifold pressure, Engine Speed and its relationship to the maximum engine speed, and the Altitude. Another way to estimate the load is if you can get the unit running at the conditions of a performance run from a compressor sizing program. On a generator, you could read the kW generated and compare that to the maximum rating of the generator. Set the Valve Position to a position from the table below based on the load the engine is running at.

Percent Engine Load	Percent Valve Position
100	70
80	65
60	60
40	55

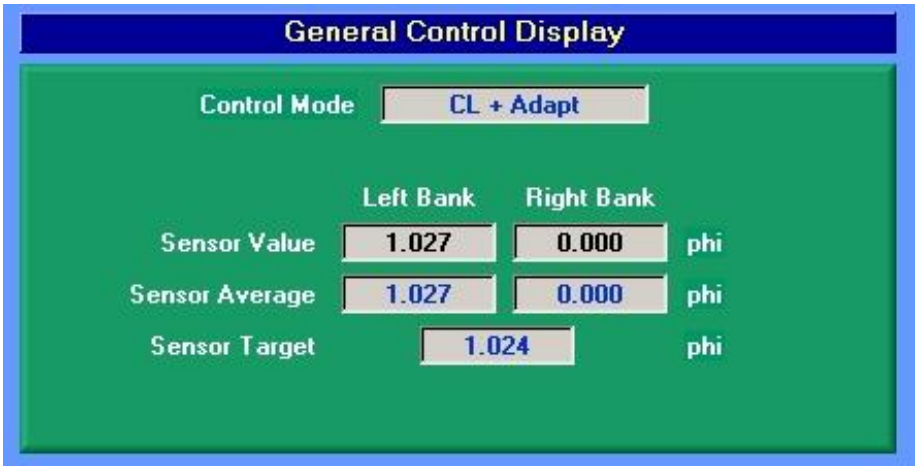
If there are two valves, do the same for the second valve. You may have to manually set the valve position in order to get the engine to full load.

16. Put an Exhaust Gas Analyzer in the exhaust. Adjust the load screw(s) on the carburetor(s) until the desired emissions levels are achieved. No more adjustment to the load screws should be done after this.

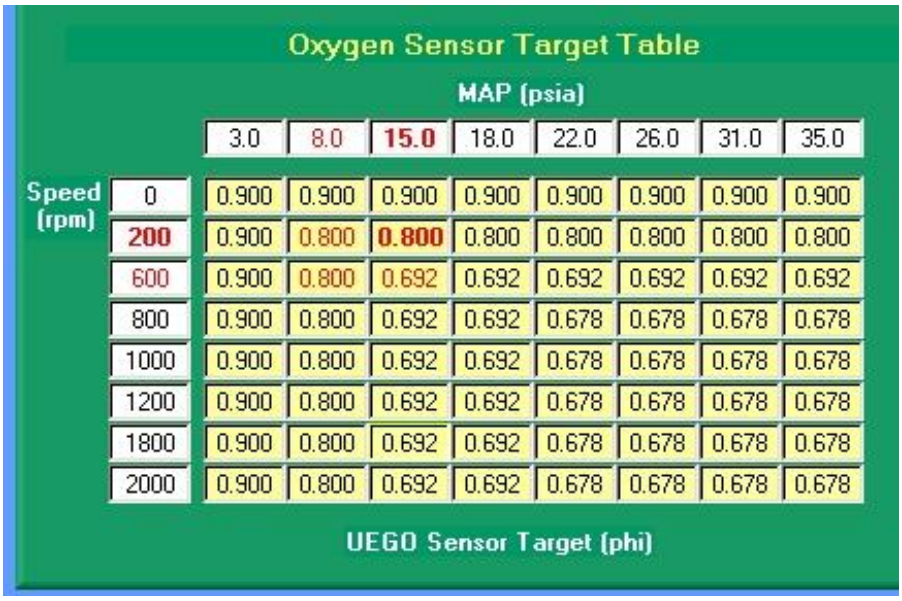
17. Now go to the Set_Up_L1 (Screen No. 2).


Set_Up_L1
Connected
Compliance CONTROLS
Link error - attempting reconnect...
Connected at 19200 bps
Toggle Page - F9
SCREEN No. 2 (Software Version 2010.03.15)
To save changes, press Save Changes under the Flash pull down menu.
Engine Monitoring
Run Mode Running
Engine Speed 1402 rpm
Manifold Pressure (MAP) 14.36 psia
Manifold Air Temperature (MAT) 110.0 deg F
TC1 Temperature 82.1 deg F
TC2 Temperature 82.1 deg F
Alarm
Shut Down
General Control Display
Control Mode Open Loop
Left Bank Right Bank
Sensor Value 0.993 0.000 phi
Sensor Average 0.992 0.000 phi
Sensor Target 0.752 phi
Oxygen Sensor Feedback Control
Manually Force Into Open Loop OFF
Closed Loop Control Inactive Reason Phi command out-of range
Pre Catalyst Sensor Target (Set Point) Table
MAP (psia)
3.0 10.5 12.3 15.7 32.1 37.4 39.7 42.5
Speed (rpm)
0 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000
650 0.900 0.900 0.900 0.900 0.900 0.900 0.900 0.900
1000 0.853 0.853 0.853 0.853 0.853 0.853 0.853 0.853
1225 0.853 0.853 0.853 0.853 0.853 0.853 0.853 0.853
1450 0.853 0.853 0.725 0.725 0.725 0.725 0.725 0.725
1600 0.853 0.853 0.725 0.725 0.725 0.725 0.725 0.725
1800 0.853 0.853 0.725 0.725 0.650 0.650 0.650 0.650
2000 0.853 0.853 0.725 0.725 0.650 0.650 0.650 0.650
UEGO Sensor Target (phi)
Load Specific
Closed Loop Control Enable/Disable (0=OFF, 1=ON)*
MAP (psia)
3.0 10.5 12.3 15.7 32.1 37.4 39.7 42.5
Speed (rpm)
0 0 0 0 0 0 0 0 0
650 0 0 0 0 0 0 0 0
1000 0 0 1 1 1 1 1 1
1225 0 0 1 1 1 1 1 1
1450 0 0 1 1 1 1 1 1
1600 0 0 1 1 1 1 1 1
1800 0 0 1 1 1 1 1 1
2000 0 0 1 1 1 1 1 1
*For disabling closed loop control accross a specific load range.
Valve Control
Valve Control Mode Auto
Left Bank Right Bank
Valve Positon 80.0 80.0 % Open
Cranking Valve Position 0.0 %
AFR-64L

18. Note the Sensor Values as seen in the General Control Display window as shown below. The Sensor Value in Phi should ideally read in a range from 0.700 to 0.450 depending on the required exhaust oxygen concentration. The higher the Phi value, the lower the exhaust oxygen concentration will be.



19. In the window below, Oxygen Sensor Target Table, first scale the RPM to the useful range for the engine, then scale the MAP in psia to reasonable values for normal engine operation where compliance to emissions regulations are desired. **NOTE** – The Speed and MAP Tables require a minimum operating point. The minimum **RPM point must be set to 0** and the minimum operating point for the **MAP setting should be 3 psia**. Any values above these points will cause the controller to malfunction at operating points below these minimum settings.

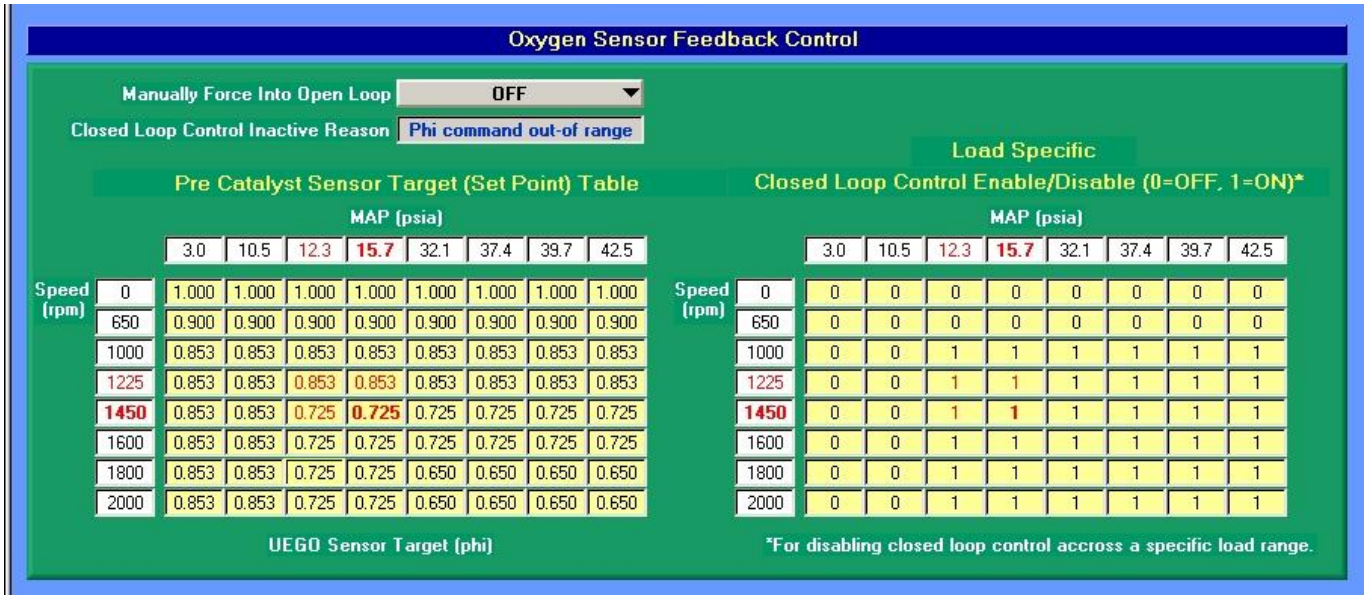


For example, what is shown starts at 3.0 psia, and has increments up to 35 psia. For the engine being controlled, make reasonable assumptions about the reasonable range of MAP. The increments do not have to be even. It is important that the maximum engine RPM and MAP setting in these tables be set above the highest possible operating ranges of the engine. If the engine MAP or RPM exceed the operating range of the table, the controller will no longer control properly.

As another example, if you have an engine that will not idle at less than 600 RPM, and has a maximum speed of 1200 RPM, and a maximum boost pressure of 15 psig, and really does not ever run in a vacuum, then your table increments might be more like this shown below. The first speed data point has to be 0 RPM, and the first pressure data point has to be 3.0 psia.

Original value	**New Value**	**Original Value**	**New Value**
RPM	*RPM*	*MAP psia*	*MAP psia*
0	0	3	3
200	600	8	15
600	700	15	17
800	800	18	20
1000	900	22	23
1200	1000	26	26
1800	1100	31	28
2000	1250	35	32

The values entered will be automatically updated on both tables -- the Oxygen Sensor Target Table and the Load Specific Control Table.



Oxygen Sensor Feedback Control

Manually Force Into Open Loop: OFF

Closed Loop Control Inactive Reason: Phi command out-of range

Pre Catalyst Sensor Target (Set Point) Table

MAP (psia)

Speed (rpm)	3.0	10.5	12.3	15.7	32.1	37.4	39.7	42.5
0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
650	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900
1000	0.853	0.853	0.853	0.853	0.853	0.853	0.853	0.853
1225	0.853	0.853	0.853	0.853	0.853	0.853	0.853	0.853
1450	0.853	0.853	0.725	0.725	0.725	0.725	0.725	0.725
1600	0.853	0.853	0.725	0.725	0.725	0.725	0.725	0.725
1800	0.853	0.853	0.725	0.725	0.650	0.650	0.650	0.650
2000	0.853	0.853	0.725	0.725	0.650	0.650	0.650	0.650

UEGO Sensor Target (phi)

Load Specific

Closed Loop Control Enable/Disable (0=OFF, 1=ON)*

MAP (psia)

Speed (rpm)	3.0	10.5	12.3	15.7	32.1	37.4	39.7	42.5
0	0	0	0	0	0	0	0	0
650	0	0	0	0	0	0	0	0
1000	0	0	1	1	1	1	1	1
1225	0	0	1	1	1	1	1	1
1450	0	0	1	1	1	1	1	1
1600	0	0	1	1	1	1	1	1
1800	0	0	1	1	1	1	1	1
2000	0	0	1	1	1	1	1	1

*For disabling closed loop control accross a specific load range.

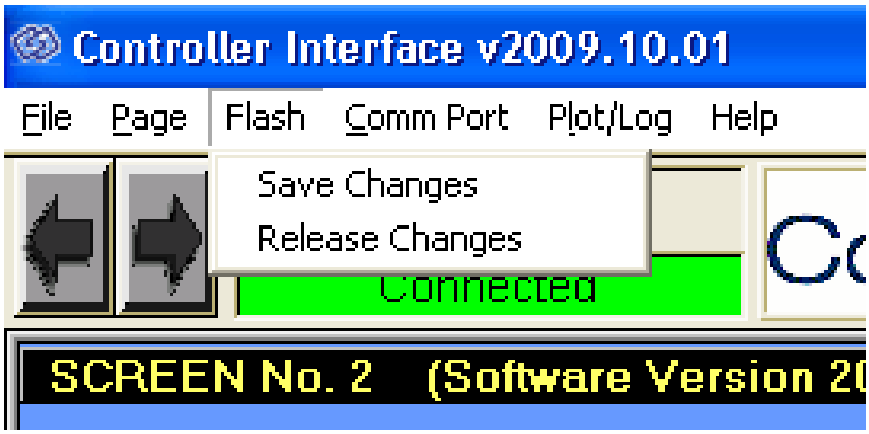
Next, enter the Sensor Value reading from the General Control Display into the red highlighted cells in the Oxygen Sensor Target Table.

While entering the desired values in the working cell, the values can be entered one cell at a time or multiple cells can be tagged for change. To tag more than one cell, click on one cell, hold down the “Shift” key on the PC key board, move the tag from cell to cell with the key board’s “Arrow” keys. Type in any number and hit the “Enter” key. All tagged cell will be changed.

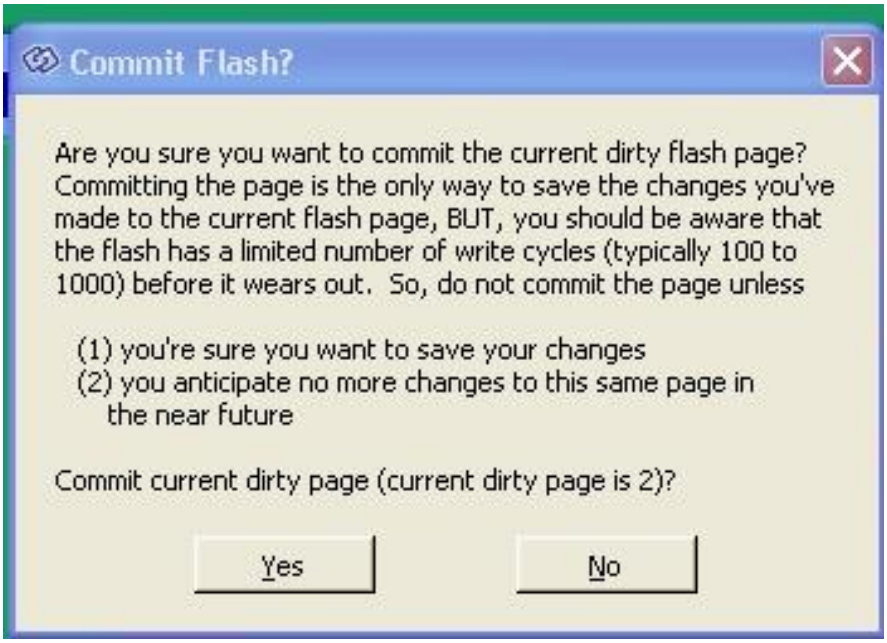
At this point, the valve control should be returned to automatic operation. No further changes should be made to the load screw setting or the final cut regulator fuel pressure. The load screw position and engine’s fuel pressure should be recorded at this time for future reference.

20. If possible, vary the load and/or speed while analyzing the emissions to fill in as many cell ranges as possible. These tables are used by interpolating between 4 points. Try to be as close to an RPM value and as close to a MAP pressure value as possible when entering other points in the table. It might be best to make the RPM or MAP values at the top and left edge of the table into your stable data points when doing this. The only rules for the values for the RPM and the MAP are that they start at 0 RPM and 3.0 PSIA, and the RPM increases from top to the bottom, and the MAP increases from the left to the right. Another way is to enter the average values in all cells highlighted in red, and all cells touching those cells.

21. Next, you will want to save all the settings by having it "Flashed" in the controller. Without doing that, the data will be lost if power is interrupted. Click on Flash and then *"Save Changes"*.



22. Once you choose to save the changes you will get the *"Commit Flash"* message window that cautions about flashing the memory hundreds of times. Click Yes.



23. It is recommended to save your work by saving the cal file. Click on File, then Save Calibration to Disk > will give the following choices:

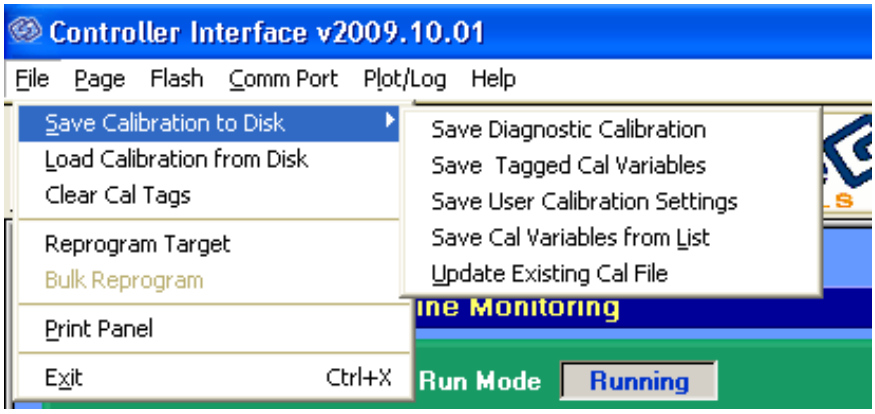
Save Diagnostic Calibration

Save Tagged Cal Variables

Save User Calibration Settings

Save Cal Variables from List

Update Existing Cal File



Choose "Save User Calibration Settings". You will get the following window.

Make sure you have the path and folder location you want, and give the file a name. A suggestion for "File name" would be to use the unit number, engine type, and the date. File name cannot exceed 64 characters.

24. You can now remove the Emissions Analyzer, the manometer, shut down the PC software, and unplug your PC. The Start-Up and Commissioning is complete.

Initial Setup and Commissioning Outline

1. Tools and equipment required prior to engine startup and commissioning

    a. PC with the latest Compliance Controls display software, currently version 2010.03.15. PC must have 1 open com port

    b. Female x Female null modem communications cable (provided with kit)

    c. Password for full access control

    d. Calibration (CAL) file for the engine

    e. A multimeter capable of reading DC voltages up to 35 volts

    f. An emissions analyzer capable of reading NOx, CO and O_2

    g. One 36" Manometer or similar type digital electronic manometer with isolation valves to measure fuel pressure in inches water column (in. WC).

    h. Pressure Gauge capable of measuring the fuel line pressure upstream of the final cut regulator

2. Setup manometer and/or pressure gauge on fuel system as described in *"Start-Up and Commissioning"* section of this manual.

3. Insure the controller has been powered up.

4. Connect the null modem communication cable to the male DB9 connector on the TCB and to the open serial port on the PC.

5. Start PC Display software and enter password if it has not been previously saved.

6. On "Screen 1 – Display_L1" verify that the latest MOT file software is loaded onto the ECM. At the release of this manual (April 2010) the current MOT file version letter is F and the date is 04-16-2010. This version is considered "Revision F".

7. If the MOT file revision is different that Revision F, refer to the *"Troubleshooting Section"* for procedures on updating the MOT file.

8. Install a calibration file, if available, for the engine application. Refer to the "Start-Up and Commissioning" section of this manual for CAL file installation instructions. Otherwise setup the parameters manually as detailed below.

9. Change to "Screen 4 – Eng_Config" to adjust the following areas:

a. Exhaust Temperature Alarm and Shutdown

    i. TC High Temperature Fault Action

    ii. TC Trip Point

    iii. TC Low Temperature Fault Action

    iv. TC Open Fault Action

b. After the Exhaust Temperature parameters have been set, the changes must be "Flashed" to the EEPROM prior to continuing the setup of the controller. See *"Start-Up and Commissioning"* section of this manual for details on this action.

c. If a CAL file was not available for the engine application, set the following parameters; if a CAL file was available for the engine application, verify the following parameters:

    i. Engine Bank Configuration – Single Bank or Dual Bank

    ii. RPM Input Configuration - This setting should always be set to "Magnetic Pickup or G-Lead"

    iii. Pulses per Revolution

    iv. Valve Type – "Butterfly Valve".

    v. Number of Engine Cylinders

    vi. Engine Displacement in Liters – CID divided 61

    vii. If the ModBus RS-485 system is not being used, skip to Bullet 11

    viii. ModBus RS-485 System

    ix. ModBus Slave Address

    x. RS-485 Port Parity Configuration

    xi. RS-485 Stop Bit Configuration

    xii. Flash changes made to this point

10. Change to "Screen 3 – Valv_Setup" and adjust the following area:

    a. If an Engine CAL file was used, verify the settings:

    b. Gain Settings –

        i. Valve Reaction Gain – Set between 10 and 25%

    c. Valve Control –

i. Minimum Valve Position – Set at 0%

ii. Maximum Valve Position – FT/FL Valve = 85%

iii. Cranking Valve Position – FT/FL Valve = application specific, typically 50%

11. Change to “Screen 2 – Set_Up_L1”
12. Start the engine.
13. Once the engine has started and the Engine RPM has stabilized, set the valve control to “Manual”
14. Enter a desired valve position for the control banks used. If controller is set up as a “Single Bank” application, only the Left Bank will be used. Use these Parameters for determining the desired valve position:
    a. 100 to 81% engine load = 70% valve
    b. 80 to 61% engine load = 65% valve
    c. 60 to 41% engine load – 60% valve
    d. 40 t0 21% engine load = 55% valve
    e. 20% and lower = 50% valve
15. Load the engine to the desired operating point.
16. Sample the exhaust emissions levels.
17. Adjust the carburetor load screw(s) until the desired emissions levels are achieved. NOTE – When working with a Dual Bank configuration, insure that both carburetors are adjusted evenly. This is done by monitoring the Sensor Voltages for the Left and Right Banks.
18. Enter the Oxygen Sensor Average reading into the red highlighted cells in the Oxygen Sensor Target Table.
19. Change the Valve Control to Auto
20. Monitor the emissions levels to insure that the desired emissions levels are maintained. If the desired emissions are not achieved, change the pre catalyst target values until the desired emissions are achieved
    a. An increase in the target value = Richer
    b. A decrease in the target value = Leaner
21. NOTE – No further adjustments should be made to the carburetor’s load screw or the engine’s fuel pressure after this point.
22. Change the engine’s load and/or speed to the next desired operating range
23. Adjust the Oxygen Sensor Target values to achieve the desired emissions levels at this load.

a. An increase in the target value = Richer

b. A decrease in the target value = Leaner

24. Repeat steps 23 and 24 as many times as possible to cover as much of the table's operating range as possible.

25. Return the engine to a standard, stable load.

26. At the top left hand side of any screen, click on the Flash pull down menu and click on "Save Changes".

27. Again at the top left hand corner of any screen, click on the File pull down menu and choose "Save Calibration to Disk". In this pull down menu, choose "Save all calibration parameters which you have write access"

28. Choose a file name and save the CAL file to a location of your choice.

29. Setup and commissioning of the system is now complete. Monitor the operation of the system. Changes can be made to the system at any time if emissions requirements change. Remember to "Flash" any further changes to the EEPROM.

Troubleshooting, Maintenance and Replacement

Product Support

The following troubleshooting guidelines are provided for you to use when corrective action is needed. However, if you need technical assistance please contact your distributor.

To find an FW MURPHY distributor in your area, please visit our web site at

www.FWMurphy.com

FW MURPHY™
PRODUCTION CONTROLS

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Visual Troubleshooting and Meter Checking

The TCB (Terminal Connector Board) connected to the ECM has indicator LED's (Light Emitting Diodes, or lights). They are Power, Alarm, Shutdown, and Auxiliary. The Alarm, Shutdown, and Auxiliary LED's are connected to relays, which have Form "C" contacts (COM (common), NO (Normally Open), and NC (Normally Closed)). The relays are energized when their associated LED's are lit. The Power LED is lit when power is connected and the fuses are good. There are two 5 Amp fuses. They are:

Buss C520 5 Amps 250 V

Below is a sketch of the TCB as it is mounted in the enclosure so you can see the locations of the terminal blocks, relays, LED's and fuses. The Phillips head screws shown should never be removed.

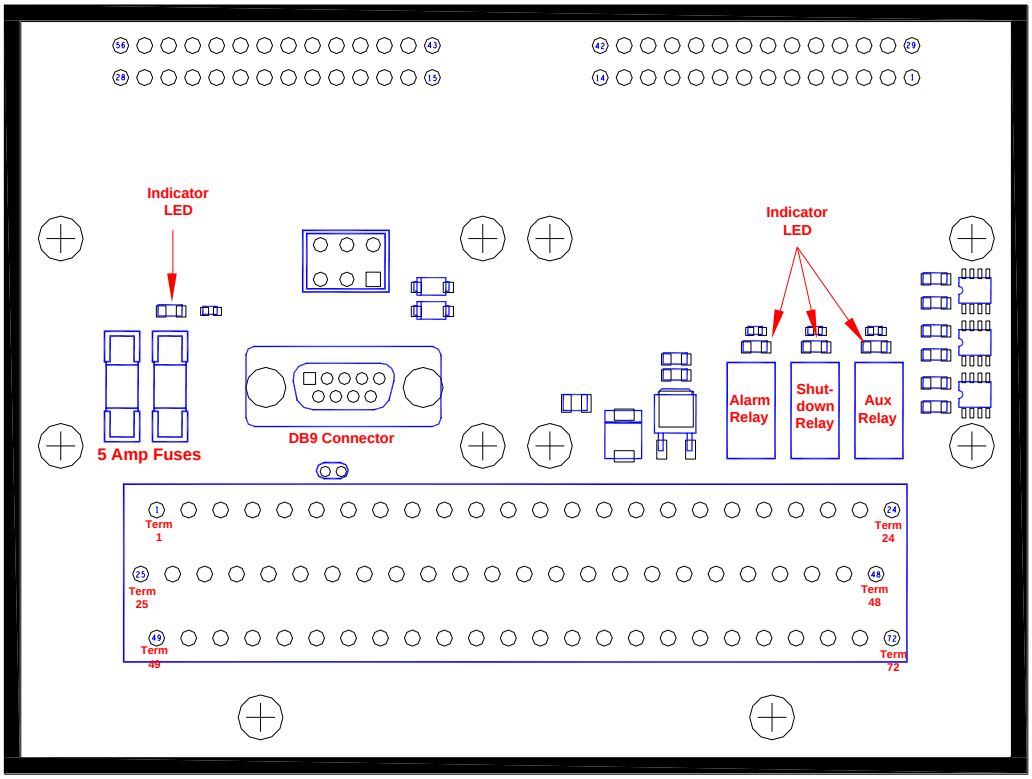


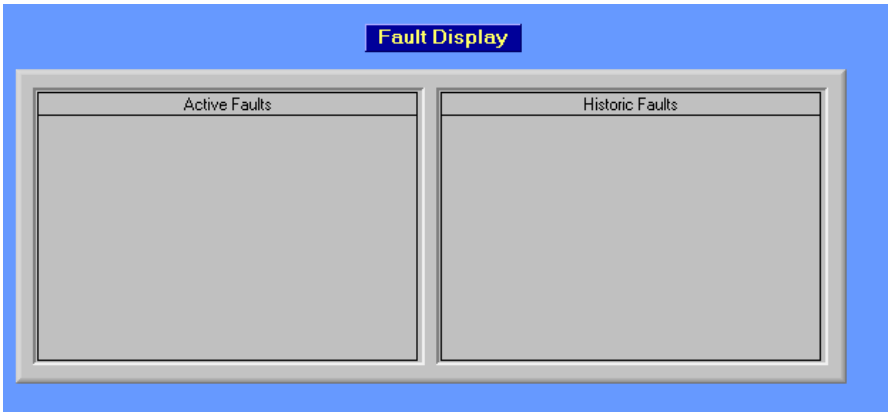
Illustration 18 – TCB Layout

If the Power LED is not lit, and DC power is measured with a meter at terminals 49 (Battery Input +) and 52 (Battery Input -), then check the fuses. Both fuses are used are connected parallel. Try measuring with the red probe of the volt meter at the bottom end of the fuses, the end away from the terminal blocks and the black probe of the meter at terminal 52 or 53.

If the fuses are blown, turn off the power, remove the fuses, remove any wires from terminal 52, and use your meter measuring Ohms between the bottom end of the fuse clips and terminal 52 or 53. You should measure 20 k to 30 k Ohms. If the reading is much lower (less than 10 Ohms), then remove any wires from terminals 18, 42, and 61. If the reading goes up to the 20 k to 30 k region, then check each of the wires that were disconnected from terminals 18, 42, and 61 versus earth ground. The wires that were connected to terminals 18 (Left Bank UEGO Heater +) and 42 (Right Bank UEGO Heater +) should read in the neighborhood of 100 k Ohms when reading back to terminal 52 or 53. The wire connected to terminal 61 (FT Valve Power) should read in the neighborhood of 30 M Ohms when reading back to terminal 52 or 53. If any of these wires reads low, like the reading from the fuses, then that wire, harness, or device is suspect. With those wires disconnected, again measure from the bottom of the fuses to terminal 52. If the reading is in the neighborhood of 20 k to 30 k Ohms, then the problem has been found and replacing the fuses will cure the problem after the wire, harness, or end device has been replaced.

If the low ohms reading are still present, then the ECM and TCB should be returned for repair, and a new ECM and TCB installed.

If the Power LED is lit, and the Shutdown LED is lit, then there are several steps to go through if a PC is not available to connect to read the problem from the Fault Display as shown below from Screen No. 1 below.



With the unit powered, and running, the following list of voltage ranges are normal for the terminals listed:

(NOTE: All Voltages have a tolerance of measurement. These values are given as a guideline, and are not expected to be exact. These are ball park values unless specified otherwise. 0 VDC means Power Supply minus (-). The values were measured with the black probe of the meter on terminal 52.)

1. RS-485 – 0 VDC not connected, 2 to 3 VDC and jumping when connected (polling device dependent)

2. RS-485 + 4 VDC not connected, 2 to 3 VDC and jumping when connected (polling device dependent)

3. 0 VDC

6. 0 VDC

7. < 40 mVDC for less than 1800 F, see chart for mV vs. deg. F voltage created by TC – Pre Cat

8. 0 VDC

9. 0.15 VDC when below 25 RPM – LB, FT Valve Signal

   6 VAC, 2 VDC, 312.5 Hz at 0%, running

   7.6 VAC, 23 VDC, 312.5 Hz at 85 % running

17. Pulse Width Modulated 100 Hz, DC reading will vary from Power Supply Plus to near Power Supply Minus depending on duty cycle (90 % will give close to minus, and 10% will give close to plus) this is the transistor output for the PWM for the UEGO heater. When it turns off, it is Power Supply (+). When it turns on, it is close to Power Supply (-).

18. Power Supply + (9-32 VDC) -- LB UEGO Heater

23. AUX RELAY NC – when relay not energized COM volts, when relay energized, connected device not connected voltage

24. AUX RELAY NO – when relay not energized, connected device not connected voltage, when relay energized, COM volts

30. 0 VDC

31. < 40 mVDC for less than 1800 F, see chart for mV vs. deg. F voltage created by TC – #2

32. 0 VDC

33. 0.15 VDC when below 25 RPM – RB, FT Valve Signal

   6 VAC, 2 VDC, 312.5 Hz at 0%, running

   7.6 VAC, 23 VDC, 312.5 Hz at 85 % running

38. 0 VDC

39. Mag Pick-Up +, 0.2 1- 100 VAC rms, 8 – 10,000 Hz (10 kHz)

40. 0 – 250 VDC pulsing, G Lead for Ignition Speed Signal

41. Pulse Width Modulated 100 Hz, DC reading will vary from Power Supply Plus to near Power Supply Minus depending on duty cycle (90 % will give close to minus, and 10% will give close to plus) this is the transistor output for the PWM for the UEGO heater. When it turns off, it is Power Supply (+). When it turns on, it is close to Power Supply (-).

42. Power Supply + (9-32 VDC) -- RB UEGO Heater

47. AUX RELAY COM – Power Supply +, Power Supply -, connected device common, connected device voltage

49. Power Supply + 9 – 32 VDC Customer Power Supply Connect

50. Power Supply + 9 – 32 VDC

52. 0 VDC Customer Power Supply Connect

53. 0 VDC -- FT Valve Power

54. ALARM RELAY NC – when relay not energized COM volts, when relay energized, connected device not connected voltage

55. ALARM RELAY NO – when relay not energized, connected device not connected voltage, when relay energized, COM volts

56. ALARM RELAY COM – Power Supply +, Power Supply -, connected device common, connected device voltage

57. SHUTDOWN RELAY NC – when relay not energized COM volts, when relay energized, connected device not connected voltage

58. SHUTDOWN RELAY NO – when relay not energized, connected device not connected voltage, when relay energized, COM volts

59. SHUTDOWN RELAY COM – Power Supply +, Power Supply -, connected device common, connected device voltage

61. Power Supply + FT Valve Power

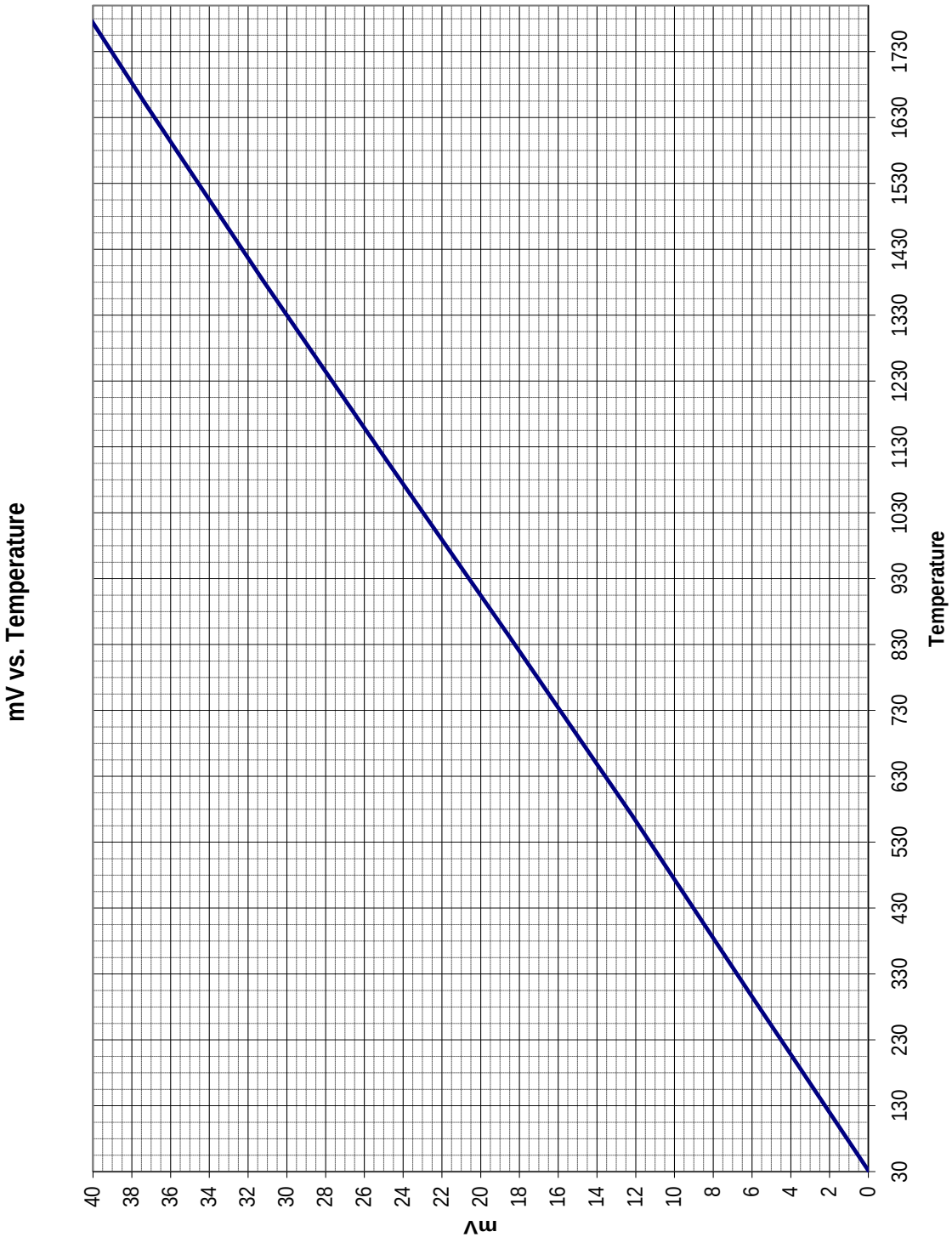
63. 5 VDC

64. MAP signal 0 -5 DVC, see chart with Volts vs. PSIA for the MAP sensor

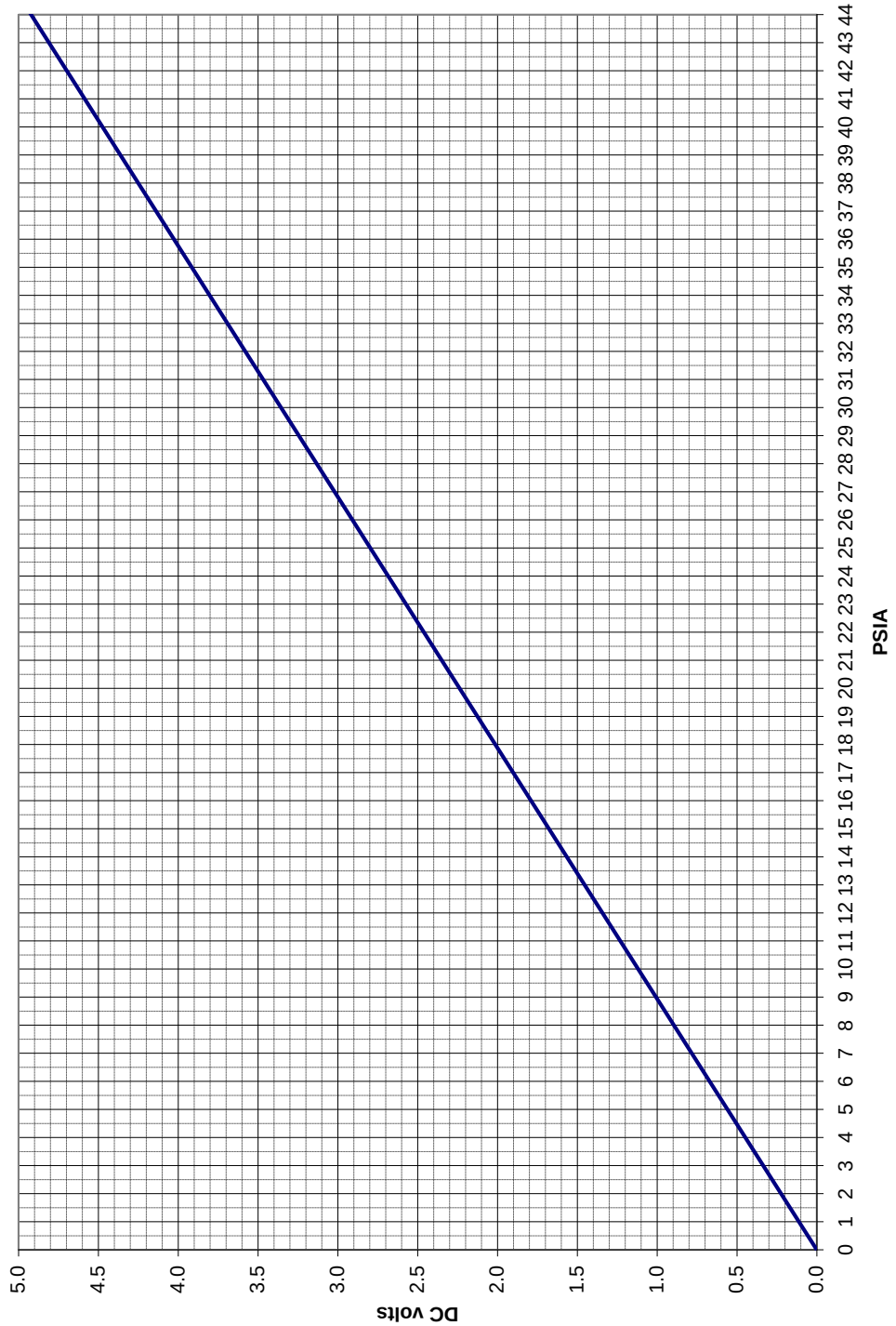
65. 0 VDC

See Charts for mV vs. deg. F for Type K thermocouples, VDC vs. PSIA for the MAP Sensor.

Thermocouple mV vs. Temperature



MAP Sensor VDC vs. PSIA



FT Valve Position Testing

At the plug connector for the FT valve, on the FT Valve side, voltage can be read to see what the valve position feedback signal is. See the diagram below to see how to connect the Multi-meter to read Volts DC. The readings will be in the range of 0 – 5 VDC. Undo the latch at either side of the plug and remove the rubber plugs from the locations indicated. Place the meter probes in the holes indicated after the rubber sealing plugs have been removed. Three charts are included to show the Feedback Voltage versus the Percentage Driven. There will be some variation between valves.

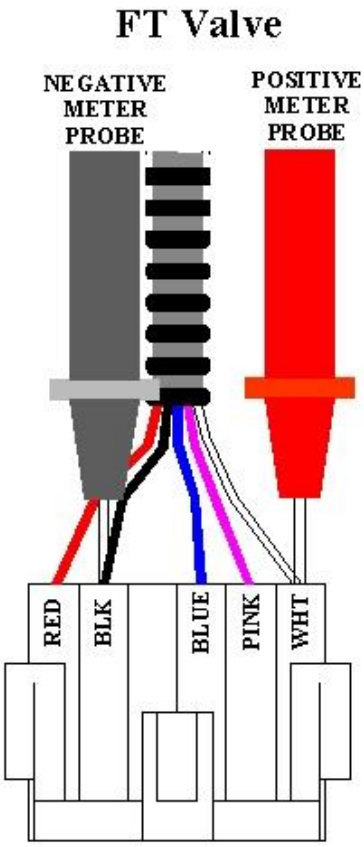
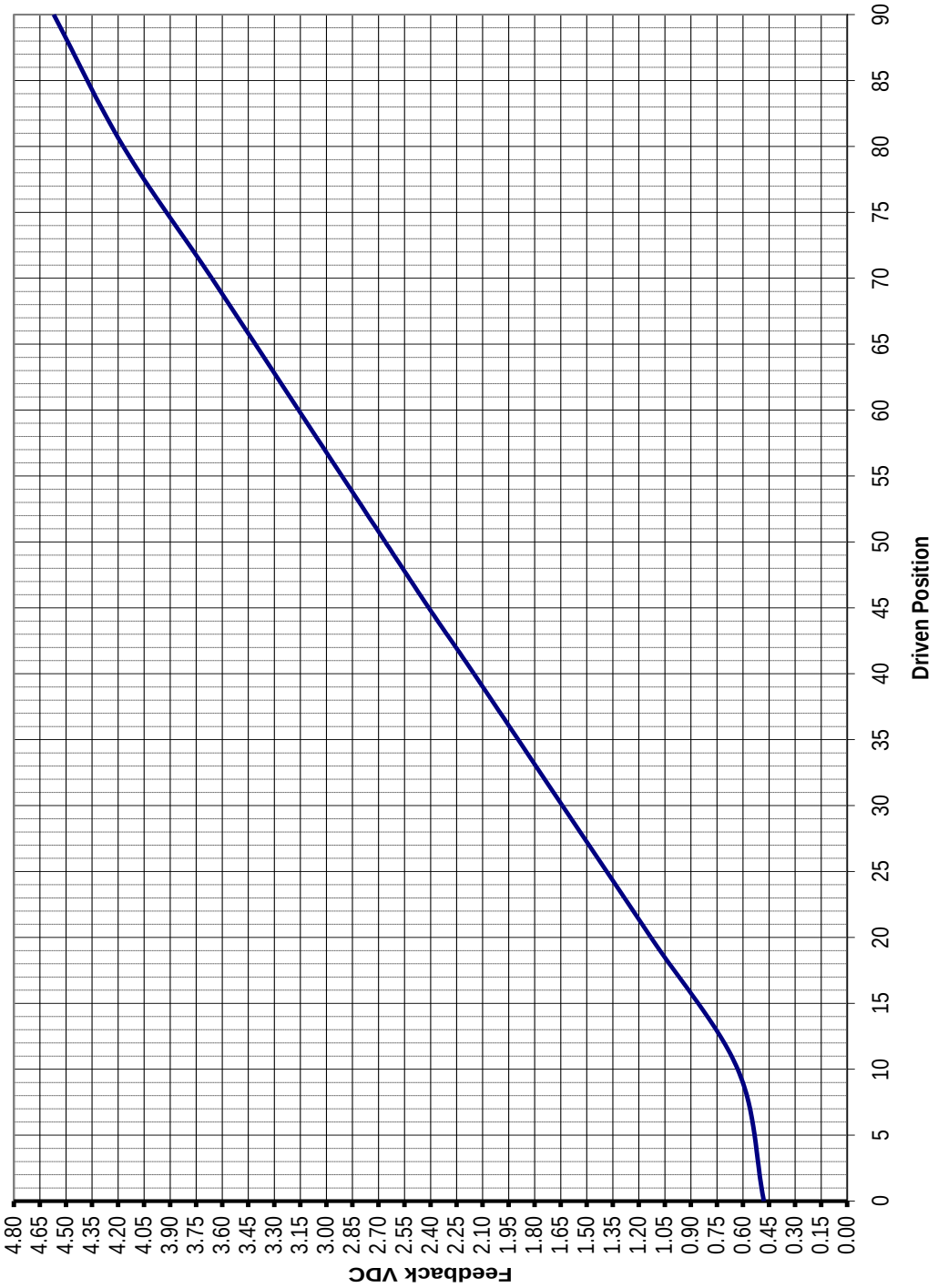


Illustration 19 – FT Valve Position Testing Probe Placement

Push the meter probes in until DC voltage is read. It will be in the range of 0 – 5 VDC. There is some variance from valve to valve. The chart represents those variances.

FT Valve Position Feedback vs. Driven Position



Troubleshooting Action Steps

When values are read at the terminal block different than what was listed, follow these steps:

1. Disconnect the wiring at the TCB for the trouble points.
2. Disconnect the device at the other end of the wires.
3. Measure Ohms between the disconnected wires at the controller end and ground. There should never be any reading except Open Lead, or open circuit. If there are any readings showing Ohms, then that wiring, harness, or cable is shorted to ground and needs to be replaced.
4. Measure Ohms between individual wires of wiring, a harness, or a cable. The readings should always be Open Lead, or open circuit. If there are any readings of Ohms, then that wiring, harness, or cable has shorts between the wires and needs to be replaced.

If the wiring harnesses or cables pass the tests above, then the devices that were connected to the wiring harness, or cable should be checked with a meter. At this point, the device is the most likely suspect. But there are a few things that can be checked.

1. Thermocouples – Check the thermocouple wire versus the metal of the sheath, or skid ground for Ohms. Ungrounded (the only kind recommended) thermocouples must show open circuit

   Use an independent device to read the thermocouple to get temperature readings from it to check the accuracy of the Thermocouple.

   Use a thermocouple simulator to put a calibrated signal into the unit.

   MilliVolts can be read from the thermocouple, but the reading is subject to Cold Junction Compensation, and can have large errors as compared to a thermocouple table, or the chart already shown.

2. UEGO checking

The Ohms between Heater + and Heater – should be approximately 7.

3. Magnetic Pick-up 1000 Ohms

4. MAP Sensor with the plug connector at the top, and the red meter probe always on the left,

Left to Center	5.46 k Ohms
Center to Right	9.59 k Ohms
Left to Right	4.14 k Ohms

5. FT Valve

   Red probe to Red wire on far end Black probe on Black wire 35 M Ohms

   Red Probe to Blue wire (harness green) Black probe to Pink wire (harness white) 157-158 k Ohms

   Red Probe to White wire, Black probe to Black wire 0.97 m Ohms

Troubleshooting Communications with the PC

If the PC will not communicate with the controller, there are several things to check.

1. Check the Com Port settings in the software. The choices are:

   Automatic, COM1, COM2, COM3, COM4, COM5, COM6, COM7, or COM8

   Usually Automatic will work fine. But it may be necessary to force the selection. In the Control Panel for the PC, depending on your OS (Windows whatever) choose the Classic View, then choose System, then in the Hardware tab, choose Device Manager, then expand "Ports (COM & LPT)". Double click on the COM port you are trying to use. You will get a Window titled "Communications Port (COM1) Properties. That window has tabs for General, Port Settings, Driver and Resources. Again depending on your operating system the choices may be different. The main thing is that Windows thinks the port is working, it is enabled, the settings are for a Baud Rate greater than 19,200, 8 Data Bits, Parity – None, Stop bits – 1, Flow Control – None. In the Advanced button, you may want to uncheck the box for the FIFO buffers.

2. Try another device, or a PC to PC connection using Hyperterminal and a null modem cable.

3. Check the null modem cable for continuity end to end. The end to end pin out should be:

   Pin 1 Pin 4

   Pin 2 Pin 3

   Pin 3 Pin 2

   Pin 4 Pin 1

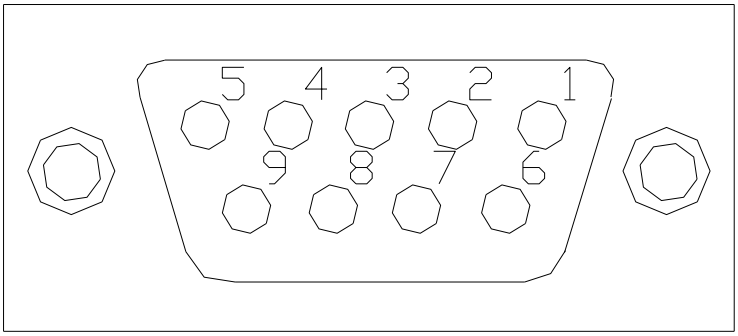
   Pin 5 Pin 5

   Pin 6 not used either end

   Pin 7 pin 8

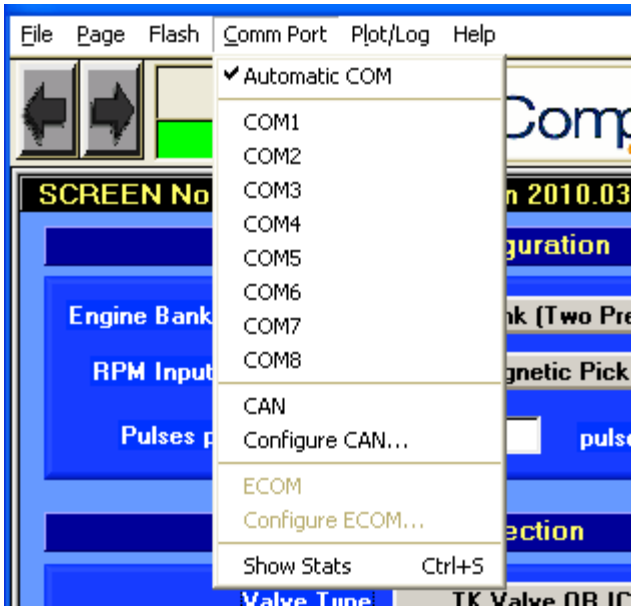
   Pin 8 Pin 7

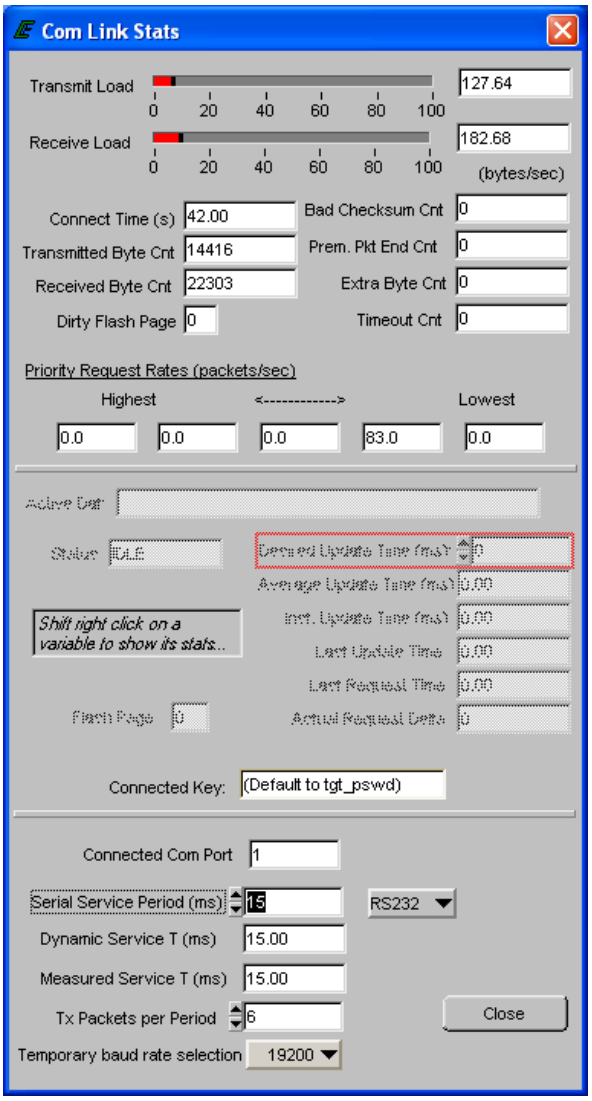
Pin 9 Pin 9



4. Make sure no other software “owns” the COM port. You may have to disable or uninstall the conflicting software.

5. If you click on “COM Port”, then *“Show Stats”*, you will get this window shown below.





Loading a MOT file

To reload the controller's operating software (MOT file), follow these steps:

1) Insure that the engine is shutdown and controller is powered up.
2) Start the "Display Software" on your PC.
3) Click on the "File" pull down menu at the top left hand side of the screen (on any screen)
4) Click on the "Reprogram Target" button.
5) Choose the operating file (MOT file) for the controller in use. At the time of this publication the current operating file (MOT file) is AFR-64L_rev_F. Contact your local Compliance Control's distributor if the operating software that you have is not the most current. Or, if you have already obtained a user name and password for the Extranet part of the Compliance Controls web site, you can check there for the latest release there.

Plotting Techniques and Diagnostics

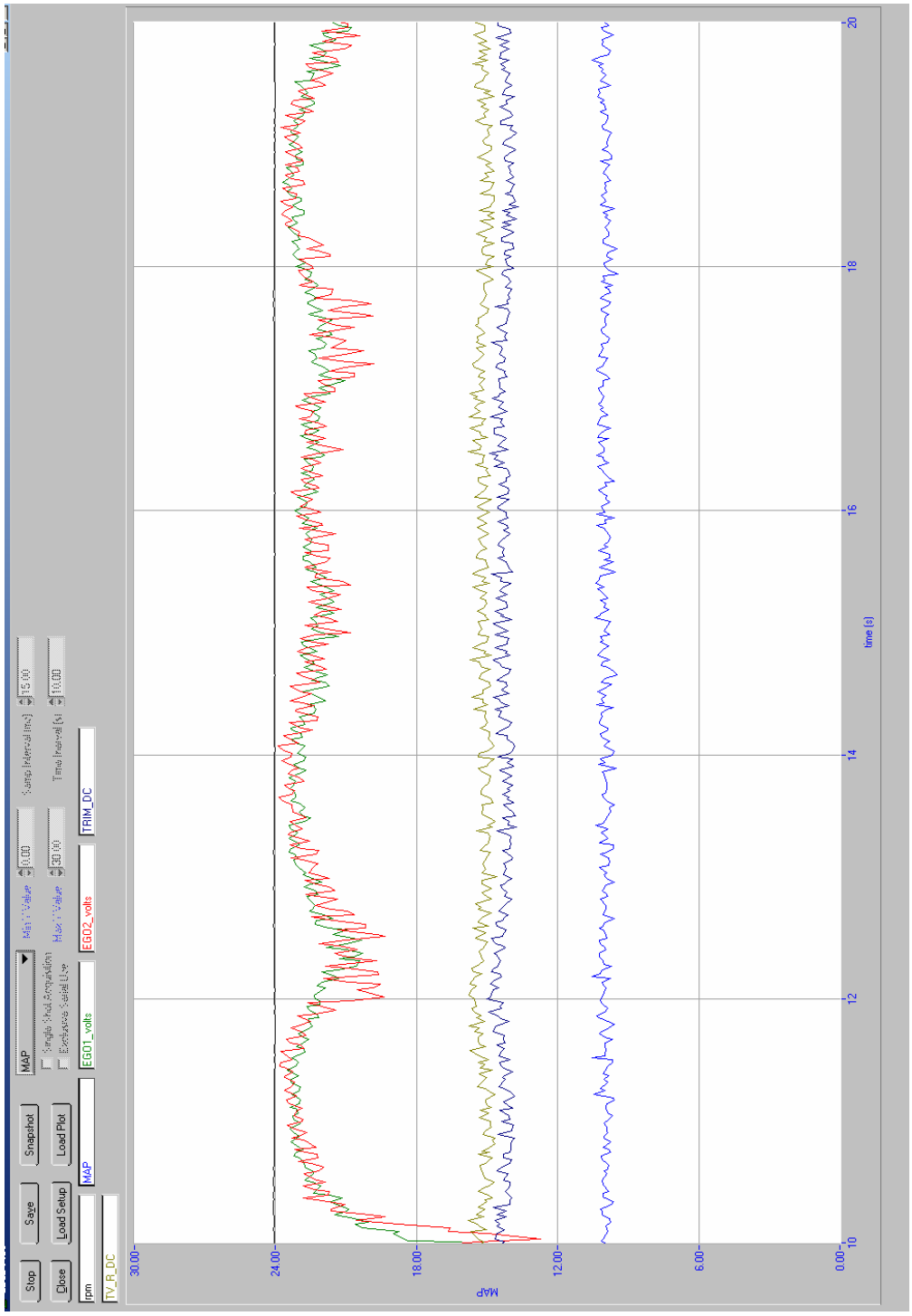
The plotting command is a very useful tool in setting up and monitoring the controller. The "oscilloscope" style plotting allows variables to be plotted for a graphical representation. The following steps are how to plot the data.

1) When looking at a screen, move the mouse cursor to the variable to be plotted.
2) Right click on the variable.
3) The variable cell color will be changed from gray or white to green.
4) A maximum of ten (10) variables may be tagged for a single plot
5) Once all variables are tagged, press the 'p' key to plot.
6) The plotting will be started with a default time of 10 seconds.
7) All variables of the plotting can be changed while in plotting mode.

When saving plots, only the data displayed on the screen at the time when the “Save” button is pressed will be saved. To save the plot, follow these steps:

1) Press the “SAVE” button
2) Choose a file name and a file location.
3) Press the save button at the bottom right hand side of the screen.

Plot Example:


Stop
Save
Snapshot
Close
Load Setup
Load Plot
rpm
MAP
EGO1_volts
EGO2_volts
TRIM_DC
TV_R_DC
MAP
30.00
24.00
18.00
12.00
6.00
0.00
10
12
14
16
18
20
time (s)

Maintenance

The air/fuel controller and system components were designed to be very reliable in operation. Very few of the components require maintenance; however the heated exhaust gas oxygen sensors (UEGO), intake manifold pressure (MAP) sensor and the thermocouple sensors have a limited life and will require regular replacement. A regular program for engine maintenance should continue after the air/fuel system is installed. To provide emissions compliance, the original engine systems need to be in proper working order. Please review the warning statements, and any warnings associated with the exhaust system components. The use of certain gasket sealers (RTV), thread sealers and high temperature thread lubricants can cause poisoning of the oxygen sensors. Contact your FW MURPHY distributor for a list of possible sensor poisons. The frequent replacement required for the oxygen sensor can cause these contaminants to build up relatively quickly. Excessive engine oil consumption can also cause these effects over longer periods of time. The AFR-64L system will relieve the operator of constant carburetor tuning for emissions compliance, but consistent engine maintenance is still required.

Replacement Information

The replacement of sensors will depend mainly on engine operating hours. Below is an estimated life expectancy of the controller end devices:

- UEGO Sensors – The UEGO sensor's operation is monitored by the controller. The controller will inform the user of a failure of any of the sensor components during normal operation. The sensor should only be changed upon a failure. If the engine is not run for a period greater than 18 months the sensor should be replaced due to the possibility of moisture saturation.
- MAP Sensor – 16,000 hours of engine operation or 36 months installed, whichever occurs first.
- MAT Sensor – 16,000 hours of engine operation or 36 months installed, whichever occurs first.
- Thermocouple – 36,000 hours of engine operation or 48 months installed, whichever occurs first.

Troubleshooting Guide

Problem/Fault	Trigger Point	Possible Cause	Correction
MAP High Pressure	MAP Pressure greater than 42 psia - Disables Adaptive Learn	Faulty MAP sensor	Replace MAP sensor
		Wiring harness shorted	Replace harness
		MAP sensor connected to port other than intake manifold	Move connection to intake manifold
		Shorted connection on TCB	Replace TCB
		Faulty ECM control module	Replace ECM module
		MOT file corrupted	Reload most recent MEC-R MOT file
MAP Low Pressure	MAP voltage less than 0.050 volts DC - Disables Adaptive Learn	Faulty MAP sensor	Replace MAP sensor
		Wiring harness open	Replace harness
		Open connection on TCB	Replace TCB
		Faulty ECM control module	Replace ECM module
		MOT file corrupted	Reload most recent MEC-R MOT file
Thermocouple 1 or 2 Open	Exhaust temperature exceeds 1800 degrees F for more than 1 second	Open or broken thermocouple wiring	Replace or repair wiring
		Open or broken thermocouple probe	Replace themocouple probe
		Open connection on TCB	Replace TCB
		Faulty ECM control module	Replace ECM module
		MOT file corrupted	Reload most recent MEC-R MOT file
Thermocouple 1 or 2 High Temp	Exhaust temperature exceeds user defined set point for greater than 5 seconds	Cylinder misfire	Check ignition system
			Change spark plugs
			Check cylinder compression
		Thermocouple bad	Replace themocouple probe
		Faulty ECM control module	Replace ECM module
		MOT file corrupted	Reload most recent MEC-R MOT file
Thermocouple 1 or 2 Low Temp	Exhaust temperature less than 500 degrees F for greater than 300 seconds	Faulty thermocouple	Replace thermocouple
		Shorted thermocouple wire	Replace thermocouple wire
		Incorrect wire type	Replace wire with type “K” compatible wire
		Shorted TCB connection	Replace TCB
		Faulty ECM control module	Replace controller
		MOT file corrupted	Reload most recent MEC-R MOT file
CJC High Voltage	CJC voltage greater than 4.95 volts DC	Faulty ECM control module	Replace ECM module
		MOT file corrupted	Reload most recent MEC-R MOT file
CJC Low Voltage	CJC voltage less than 0.050 volts DC	Faulty ECM control module	Replace ECM module
		MOT file corrupted	Reload most recent MEC-R MOT file
MAT High Voltage	MAT voltage greater than 4.950 volts DC - Disables Adaptive Learn	Incorrect MEC-R MOT file loaded	Reload most recent MEC-R MOT file
		MOT file corrupted	Reload most recent MEC-R MOT file

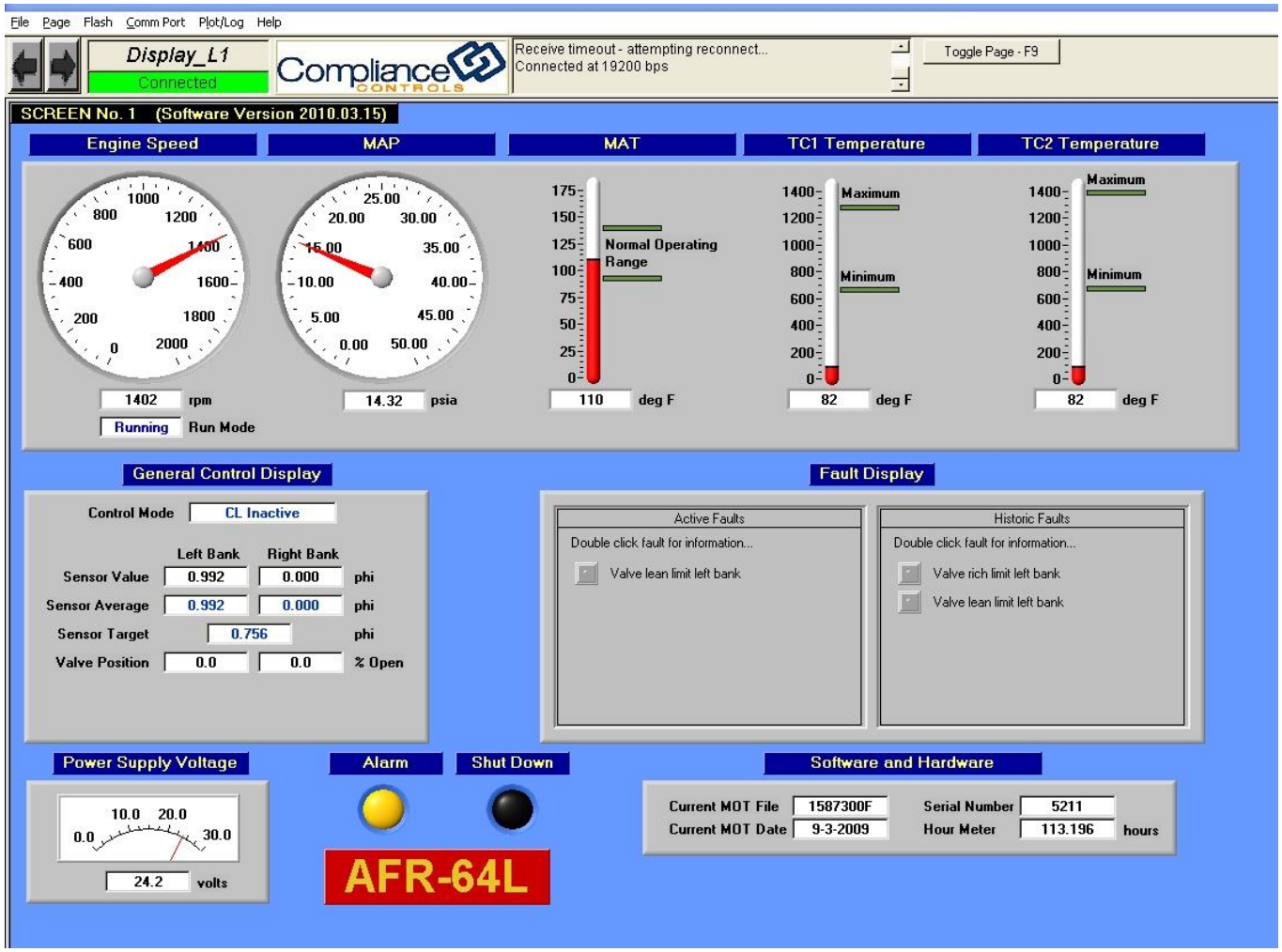
Problem/Fault	Trigger Point	Possible Cause	Correction
MAT Low Voltage	MAT voltage less than 0.050 volts DC - Disables Adaptive Learn	Incorrect MEC-R MOT file loaded	Reload most recent MEC-R MOT file
		MOT file corrupted	Reload most recent MEC-R MOT file
MAT High Temp Pre-Alarm	MAT Temperature exceeds 150 degrees F - Disables Adaptive Learn	Incorrect MEC-R MOT file loaded	Reload most recent MEC-R MOT file
		MOT file corrupted	Reload most recent MEC-R MOT file
MAT High Temp Alarm	MAT Temperature exceeds 160 degrees F - Disables Adaptive Learn	Incorrect MEC-R MOT file loaded	Reload most recent MEC-R MOT file
		Faulty TCB	Replace TCB
		Faulty ECM control module	Replace controller
		MOT file corrupted	Reload most recent MEC-R MOT file
BP High Pressure	Barometric Pressure greater than 16.0 psia	Faulty ECM control module	Replace controller
		MOT file corrupted	Reload most recent MEC-R MOT file
BP Low Pressure	Barometric Pressure less than 8.30 psia	Faulty ECM control module	Replace controller
		MOT file corrupted	Reload most recent MEC-R MOT file
Voltage High	Supply voltage greater than 32.0 volts DC - Disables Adaptive Learn - Cycle power to reset	Power supply	Replace power supply
		Cross connection	Check for cross connection with other power supply
		Faulty ECM control module	Replace controller
		MOT file corrupted	Reload most recent MEC-R MOT file
Voltage Low	Supply voltage less than 9.5 volts DC - Disables Adaptive Learn - Cycle power to reset	Power supply faulty	Replace power supply
		Poor connection	Improve connection
		Faulty TCB	Replace TCB
		Faulty ECM control module	Replace controller
		MOT file corrupted	Reload most recent MEC-R MOT file
Max Govern Speed Override	Observed engine speed greater than 4500 RPM	Pulses per revolution set incorrectly	Adjust pulses per revolution
		Dirty magnetic pickup	Clean magnetic pickup
		Faulty magnetic pickup	Replace Magnetic pickup
		MOT file corrupted	Reload most recent MEC-R MOT file
		Faulty ECM controller	Replace ECM controller
5VE High Voltage	5 volt extermal voltage supply greater than 5.4 volts DC - Disables Adaptive Learn	Faulty ECM control module	Replace controller
		MOT file corrupted	Reload most recent MEC-R MOT file

Problem/Fault	Trigger Point	Possible Cause	Correction
5VE Low Voltage	5 volt extermal voltage supply less than 4.6 volts DC - Disables Adaptive Learn	Faulty ECM control module	Replace controller
		MOT file corrupted	Reload most recent MEC-R MOT file
Fuel Rev Limit	Observed engine speed greater than 4800 RPM	Pulses per revolution set incorrectly	Adjust pulses per revolution
		Dirty magnetic pickup	Clean magnetic pickup
		Faulty magnetic pickup	Replace Magnetic pickup
		MOT file corrupted	Reload most recent MEC-R MOT file
		Faulty ECM controller	Replace ECM controller
Spark Rev Limit	Observed engine speed greater than 4900 RPM	Pulses per revolution set incorrectly	Adjust pulses per revolution
		Dirty magnetic pickup	Clean magnetic pickup
		Faulty magnetic pickup	Replace Magnetic pickup
		MOT file corrupted	Reload most recent MEC-R MOT file
		Faulty ECM controller	Replace ECM controller
AL High Left or Right Bank	Adaptive Learn - Actual fuel control valve position greater than "Nominal" valve position by +30% of range	Carburetor set too lean	Adjust carburetor load screw – rich
		Fuel pressure too low	Increase fuel pressure at final cut regulator
		HEGO sensor failure	Replace faulty HEGO sensor
		Fuel control valve not responding	Check valve wiring; Replace fuel control valve
AL Low Left or Right Bank	Adaptive Learn - Actual fuel control valve position less than "Nominal" valve position by -30% of range	Carburetor set too rich	Adjust carburetor load screw – lean
		Fuel pressure too high	decrease fuel pressure at final cut regulator
		HEGO sensor failure	Replace faulty HEGO sensor
		Fuel control valve not responding	Check valve wiring; Replace fuel control valve
CL High Left or Right Bank	Closed Loop - Adapted Pre Catalyst target valve greater than Pre Catalyst target by +30% of range	Pre-Catalyst Phi values set too lean	Adjust Phi values richer
		HEGO sensor failure	Replace faulty HEGO sensor
		Fuel control valve not responding	Check valve wiring; Replace fuel control valve
CL Low Left or Right Bank	Closed Loop - Adapted Pre Catalyst target valve less than Pre Catalyst target by -30% of range	Pre-Catalyst Phi values set too rich	Adjust Phi values leaner
		HEGO sensor failure	Replace faulty HEGO sensor
		Fuel control valve not responding	Check valve wiring; Replace fuel control valve
EGO Fault Left, Right or Post Catalyst	HEGO sensor cold or non responsive for greater than 60 seconds - Disables Adaptive Learn	HEGO sensor failure	Replace faulty HEGO sensor
		MOT file corrupted	Reload most recent MEC-R MOT file
		Faulty TCB	Replace TCB
		Faulty ECM controller	Replace ECM controller
COP Failure	Processor failure	Faulty ECM controller	Replace ECM controller
Invalid interrupt	Processor failure	Faulty ECM controller	Replace ECM controller

Problem/Fault	Trigger Point	Possible Cause	Correction
UEGO Heater Supply High Voltage	HEGO sensor heater supply heater voltage persistanty high	HEGO sensor failure	Replace faulty HEGO sensor
		MOT file corrupted	Reload most recent MEC-R MOT file
		Faulty TCB	Replace TCB
		Faulty ECM controller	Replace ECM controller
UEGO Heater Supply Low Voltage	HEGO sensor heater supply heater voltage persistanty low	HEGO sensor failure	Replace faulty HEGO sensor
		MOT file corrupted	Reload most recent MEC-R MOT file
		Faulty TCB	Replace TCB
		Faulty ECM controller	Replace ECM controller
A/D loss	Processor failure	Faulty ECM controller	Replace ECM controller
RT1 Loss	Processor failure	Faulty ECM controller	Replace ECM controller
RT2 Loss	Processor failure	Faulty ECM controller	Replace ECM controller
RT3 Loss	Processor failure	Faulty ECM controller	Replace ECM controller
Flash Checksum Invalid	Processor failure	Faulty ECM controller	Replace ECM controller
RAM Failure	Processor failure	Faulty ECM controller	Replace ECM controller
High HEGO Sensor Voltage	Not a coded fault - General troubleshooting only	Engine running too rich	Adjust carburetor leaner
		Fuel control valve failure	Replace fuel control valve
		Faulty oxygen sensor wiring harness - open	Replace wiring harness
		Faulty oxygen sensor	Replace oxygen sensor
		Oxygen sensor overheating	Cool or relocate oxygen sensor
		Exhaust leak / oxygen intrusion	Correct exhaust leak
		Faulty TCB	Replace TCB
		Faulty ECM controller	Replace ECM controller
		MOT file corrupted	Reload most recent MEC-R MOT file
HEGO Sensor Voltage Low	Not a coded fault - General troubleshooting only	Engine running too lean	Adjust carburetor richer
		Fuel control valve failure	Replace fuel control valve
		Faulty oxygen sensor wiring harness - shorted	Replace wiring harness
		Faulty oxygen sensor	Replace oxygen sensor
		Oxygen sensor overheating	Cool or relocate oxygen sensor
		Exhaust leak / oxygen intrusion	Correct exhaust leak
		Faulty TCB	Replace TCB
		Faulty ECM controller	Replace ECM controller
		MOT file corrupted	Reload most recent MEC-R MOT file

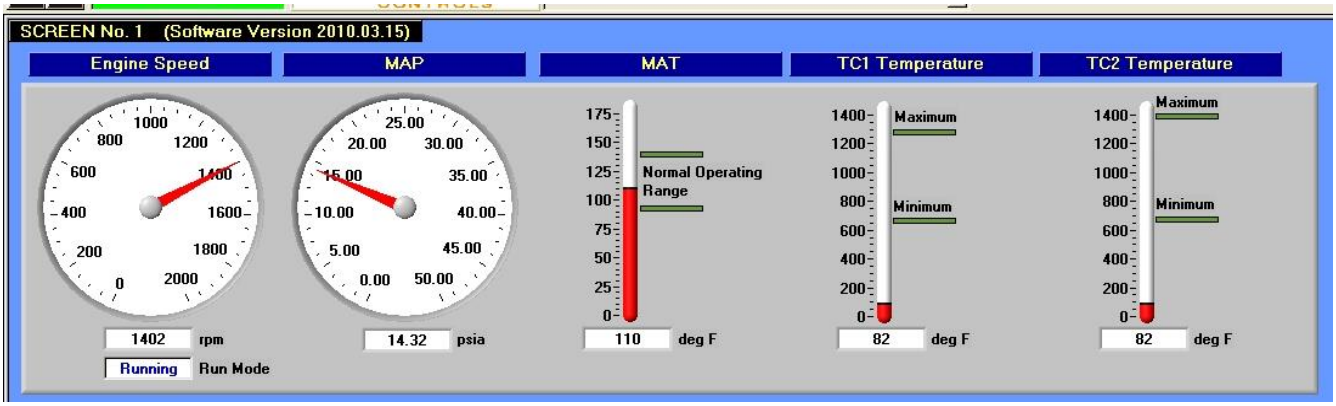
PC Display Screen Description

Display Screen (Screen No. 1)



On the "Display Screen (Screen No. 1)", all engine operating parameters monitored by the controller and all of the controller's operational parameters can be seen.

Engine Operating Parameters Group



Engine Speed – Actual engine speed. Expressed in Revolutions Per Minute (RPM).

MAP – Intake Manifold Absolute Pressure. Expressed in Pounds per Square Inch Absolute (PSIA).

MAT – Intake Manifold Air Temperature. Expressed in degrees Fahrenheit

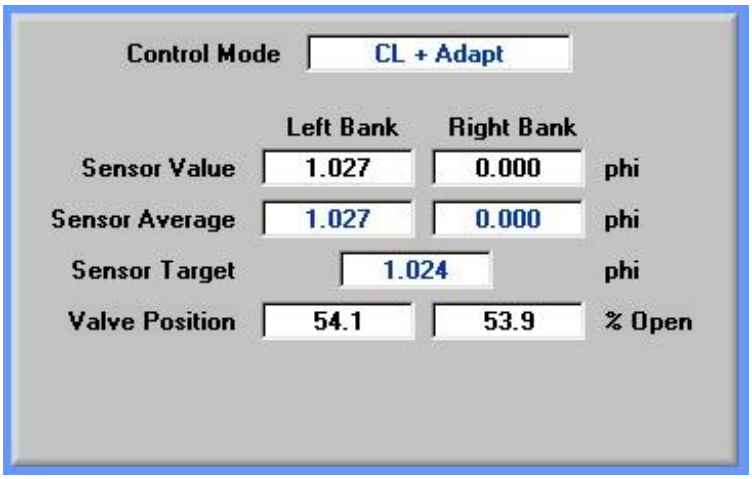
Run Mode - Indicates the mode of operation of the engine as determined by the engine speed input. Three operating modes are seen though out the operation of the controller from engine start to engine shutdown:

- STOP – any engine speed below 2 RPM;
- CRANKING – engine speeds greater than 2 RPM and less than 450 RPM;
- RUNNING – any engine speed greater than 450 RPM.

TC1 Temperature – The actual exhaust gas temperature entering the catalytic converter housing. Expressed as Degrees Fahrenheit (°F).

TC2 Temperature – The actual TC2 exhaust gas temperature . Expressed as Degrees Fahrenheit (°F).

General Control Display Group



Control Mode – Indicates the operating mode of the controller.

- **Open Loop** – The control system has not yet met all of the requirements to go into Closed Loop. In this mode no input from the UEGO sensors are required for operation. The controller only operates at predetermined valve positions.
- **CL Inactive** – Closed Loop Inactive. In this mode the controller has met all necessary parameters to go into Closed Loop operation but is locked out of Closed Loop by the Sensor Control Table (see the "Setup" screen). The controller operates the same as it would in Open Loop.
- **CL Active** – Closed Loop Active. In this mode the controller has met all necessary parameters for operation and has been cleared to control by the Closed Loop Enable Table. The controller operates on the feed back signal from the Left and/or Right Bank UEGO sensors only.
- **CL + Adapt** – Same as CL Active

Sensor Value – These are real time Phi values that the controller calculates when it reads the actual UEGO sensor voltage. These values are used by the controller to calculate a Sensor Average.

Sensor Average – These values are calculated rolling averages of the Sensor Values and are used by the controller drive the engine to the appropriate air/fuel ratio.

Sensor Target – These are the Phi values used by the controller to drive the engine air/fuel ratio to a desired point.

Valve Position – These are the actual fuel valve position expressed as a percent open: 0% being fully closed and 85% being fully open.

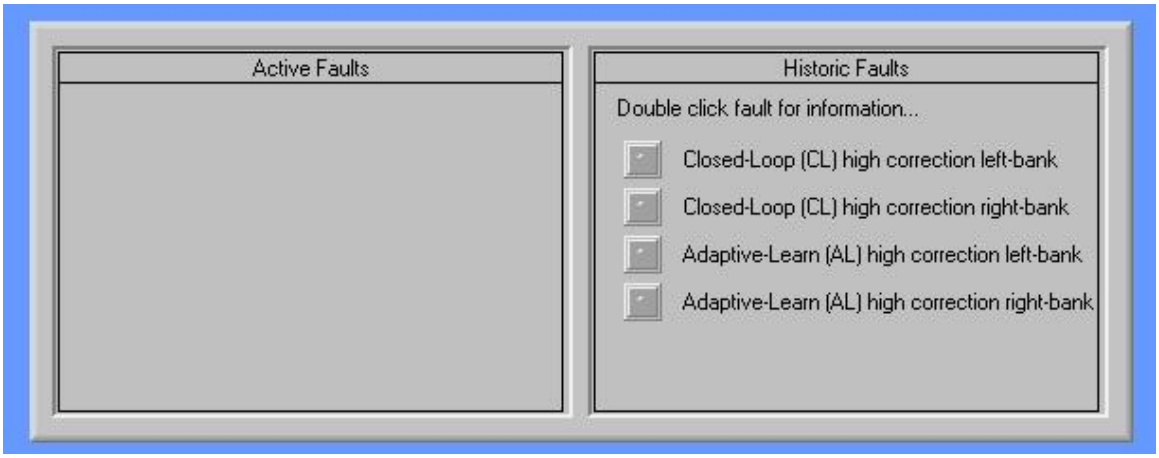
Sensor Average – These values are calculated rolling averages of the Sensor Values and are used by the controller drive the engine to the appropriate air/fuel ratio.

Sensor Target – These are the Phi values used by the controller to drive the engine air/fuel ratio to a desired point.

Valve Position – This is the PWM command to the fuel control valve with 0% being fully closed and 85% being fully open for the FT/FL valves (Full Authority valves).

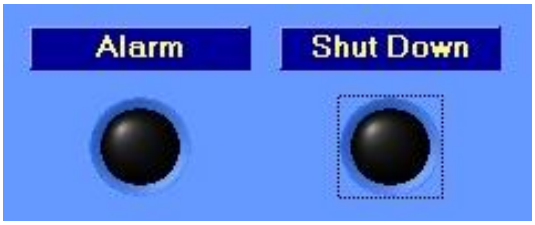
Power Supply Voltage – The actual DC supply voltage to the controller.

Fault Display Group



Active Fault Box – (Left) In this box all current faults are displayed. Once the fault clears itself, the fault is removed from this box. Only Current or Active faults are displayed. A list of Faults and possible causes can be found in Chapter 11 – "Troubleshooting and Maintenance". When a fault is logged into this box, the Fault Relay is energized and the contacts switch state. The Fault Relay can only be cleared once all of the faults in the Active Fault Box have been cleared.

Historic Fault Box – (Right) In this box all current faults and previously cleared faults are stored. Once an Active Fault clears itself, the fault is stored in the Historic Fault Box. These faults can only be cleared manually by double clicking the red box next to the fault, choosing the fault to clear and acknowledging the fault.



Alarm Indicator Lamp – This amber lamp is illuminated anytime a fault is logged into the Active Fault Box. This is an indication that the Fault Relay has been energized. This lamp will stay illuminated until all active faults have been cleared.

Shutdown Indicator Lamp – This red lamp is illuminated anytime the controller has recognized a shutdown indication. At this time only the Exhaust Temperature faults will illuminate this lamp and energize the Shutdown Relay. This lamp will stay illuminated until all shutdown faults have been cleared and acknowledged. Once the shutdown has been cleared, a single click on the Red Lamp will reset the shutdown relay.

Software and Hardware Group

In this group all information about the controller hardware and the installed software appear.

Current MOT File – Indicates which software (MOT file) is currently loaded onto controller. At this time all, AFR-64L controllers are shipped with a MOT file number 1587400 followed by a revision letter such as “F” and dated, 4-16-2010. This file is located in the <C:\Output> folder on your hard drive and is named AFR64L_revF for ease of identification.

Current MOT Date – Indicates the date in which the current software (MOT file) was created.

Serial Number – Indicates the serial number of the ECM.

Hour Meter – Indicates the life timer for (factory purposes) of the controller’s ECM. This internal clock only operates when a run signal is present. This clock cannot be zeroed.

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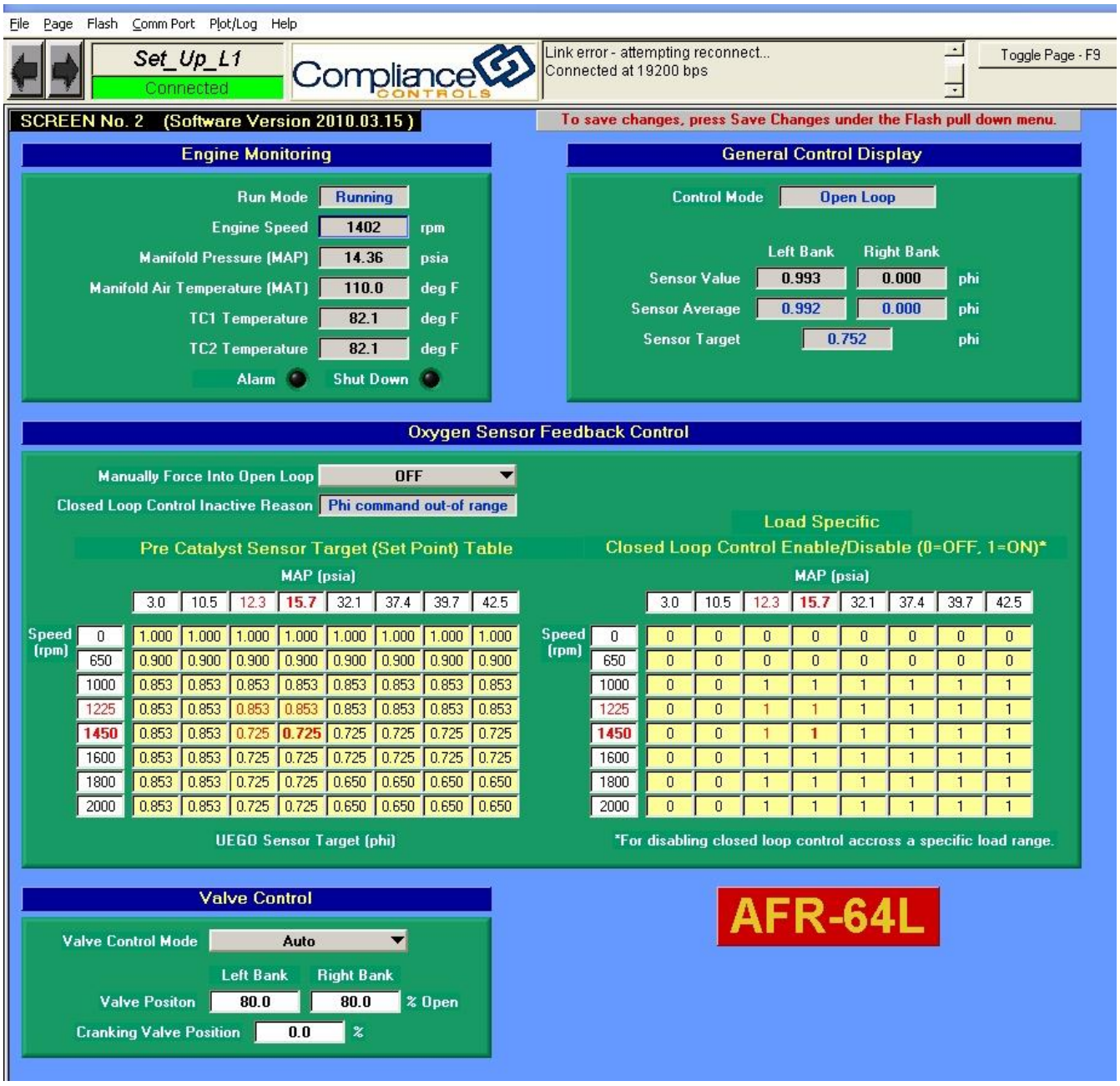
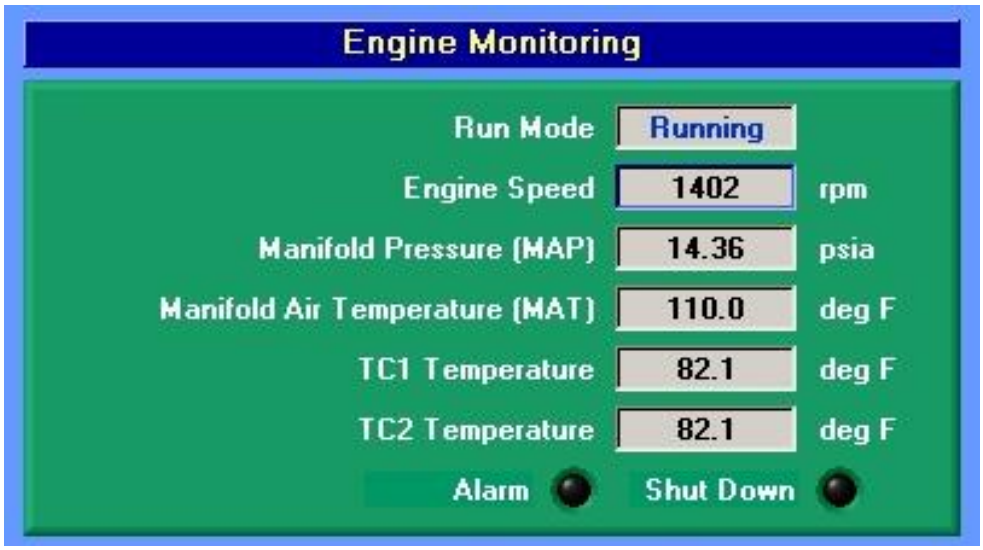
SET-UP SCREEN (Screen No. 2)



From the “SETUP” Screen (Screen No. 2), all of the controller’s targeting parameters can be set, as well as monitoring of the engine’s real time operating parameters. This screen’s main purpose is for the setup and fine adjustment of the controller.

This screen is divided into four main groups: Engine Monitoring, General Control Display, Oxygen Sensor Feedback Control and Valve Control.

Engine Monitoring Group



Run Mode – Indicates the mode of operation of the engine as determined by the engine speed input. Three operating modes are seen though out the operation of the controller from engine start to engine shutdown:

- **STOP** – any engine speed below 25 RPM;
- **CRANKING** – engine speeds greater than 25 RPM and below 450 RPM;
- **RUNNING** – any engine speed greater than 450 RPM.

Engine Speed – Actual engine speed, expressed in Revolutions Per Minute (RPM).

Manifold Pressure – Intake Manifold Absolute Pressure (MAP). Expressed in Pounds per Square Inch Absolute (PSIA).

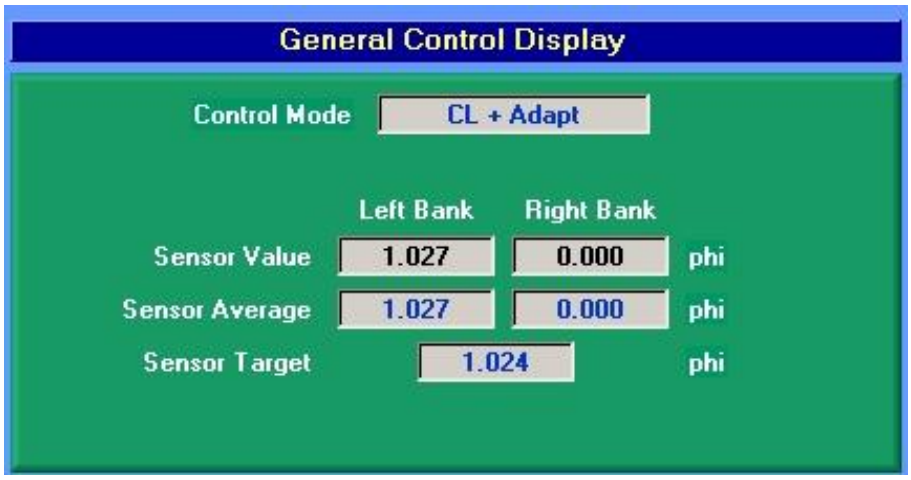
Manifold Air Temperature – Intake Manifold Air Temperature (MAT) – Expressed in degrees Fahrenheit (°F)

TC1 Temperature – The actual exhaust gas temperature. Expressed as Degrees Fahrenheit (°F).

TC2 Temperature – The actual exhaust gas temperature. Expressed as Degrees Fahrenheit (°F).

Alarm and Shut Down Indicator Lamps – These lamps, amber for Alarm and red for Shut Down, indicate whether a fault has been detected and recorded. Refer to the "Fault Group" on the Display screen as to what the related fault is. These faults and/or Alarms cannot be cleared from this screen.

General Controls Display Group



Control Mode – Indicates the operating mode of the controller. In this cell there are four (4) possible operating modes:

- Open Loop – The control system has not yet met all of the requirements to go into Closed Loop. In this mode no input from the UEGO sensors are required for operation. In this mode the controller only operates at predetermined valve positions.
- CL Inactive – Closed Loop Inactive. In this mode the controller has met all necessary parameters to go into Closed Loop operation but is locked out of Closed Loop by the Sensor Control Table. In this mode, the controller operates the same as it would in Open Loop.
- CL Active – Closed Loop Active. In this mode the controller has met all necessary parameters for operation and has been cleared to control by the Closed Loop Enable Table. The controller operates on the feedback signal from the Left Bank and/or Right Bank UEGO sensors only.
- CL + Adapt – Closed Loop + Adaptive, the controller operates with the feedback signal from the UEGO sensor.

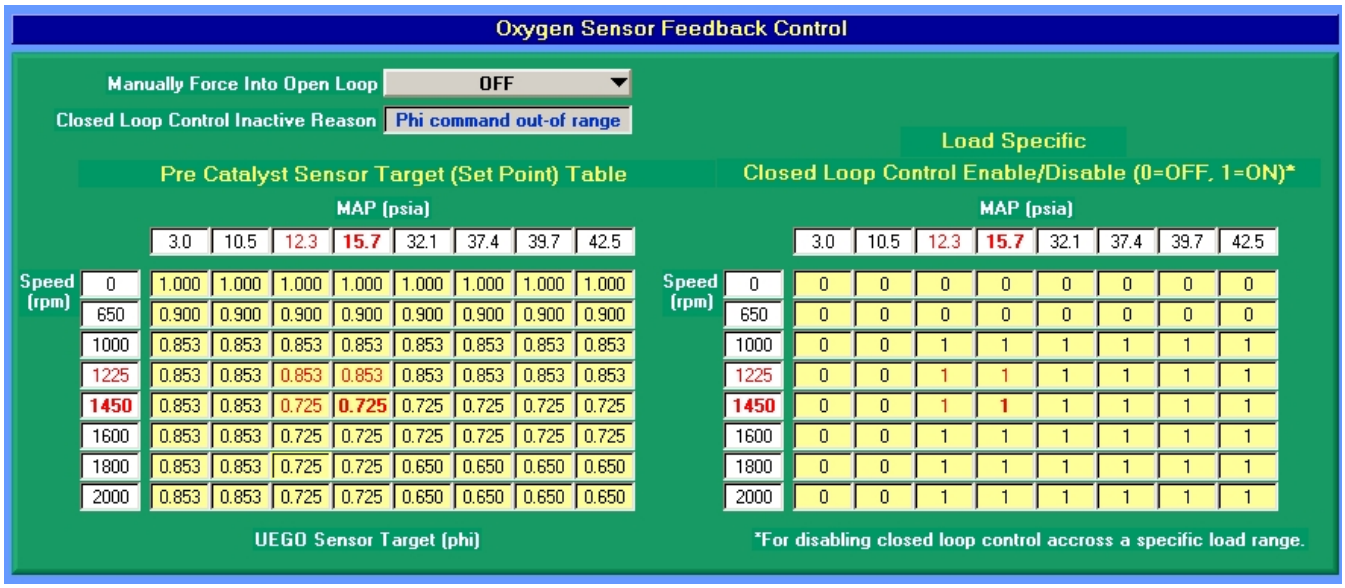
Sensor Value – These are real time Phi values that the controller calculates when it reads the actual UEGO sensor voltage. These values are used by the controller to calculate a Sensor Average.

Sensor Average – These values are calculated rolling averages of the Sensor Values and are used by the controller drive the engine to the appropriate air/fuel ratio.

Sensor Target – These are the Phi values used by the controller to drive the engine air/fuel ratio to a desired point.

Valve Position – These are the actual fuel valve position expressed as a percent open: 0% being fully closed and 85% being fully open.

Oxygen Sensor Feedback Control Group



Manually Force Into Open Loop – In this pull down menu there are two choices for operation.

- **On** – This setting forces the controller into Open Loop operation regardless of load point (effectively disabling oxygen sensor closed loop feedback).
- **Off** – This is the normal setting for the controller when oxygen sensor closed loop feedback is desired.

CL Inactive Cause – Closed Loop Inactive Cause. In this cell, the controller indicates what the cause is for the closed loop operation being inactive. There are four (4) causes:

- **Manual Force Inactive** – This indicates that the oxygen feedback control has been forced inactive.
- **CL Ena Map = 0** – This indicates that the engine speed and/or load has not reached a point where the Closed Loop Enable Table will allow the controller to go active.
- **Phi Command out of Range** – The operation of the engine has exceeded the operation range of the sensor. This condition causes the controller to default into Open Loop operation.

- **None** – Indicates that there is no cause for the Closed Loop to be inactive. At this point the controller is in automatic operation.

Oxygen Sensor Target Table – In this group, the user defines the control target for the Left and Right Banks. While the controller is in closed loop, the controller looks at this lookup table to determine a valid target as define by the engine speed and manifold pressure. This table is user defined in all 3 cell groups; MAP Cells, Speed Cells and the Target Cells.

- **MAP Cells** –Located in the upper row. This field comes from the factory with pre set pressure ranges. These cells may have to be adjusted according to the engine application. These cells can range from 3 psia to 45 psia. The adjustments to these cells must be in ascending order and should plot out in a smooth line. Changing values in this table will automatically change the range in the Sensor Control Table (see below). All parameters in this field are user definable **BUT the lowest low point of these cells must be set at 3 psia. Any setting higher than this low point will cause the controller to operate erratically.**

- **Speed Cells** – Located in the left hand column. These cells come from the factory with preset speed ranges. These cells will need to be reset according to the systems application. Changing values in this table will automatically change the range in the Sensor Control Table (see below). **The low setting for the SPEED cell must be set at 0 rpm. Any setting higher than this low point will cause the controller to operate erratically.**

- **Target Cells** – The remaining cells to the right of the Speed Cells and below the MAP Cells are the Target Cells. These cell ranges will need to be defined by the user during the system setup according to the desired emissions level at varying loads and speeds. All values in these cells are expressed as Phi.

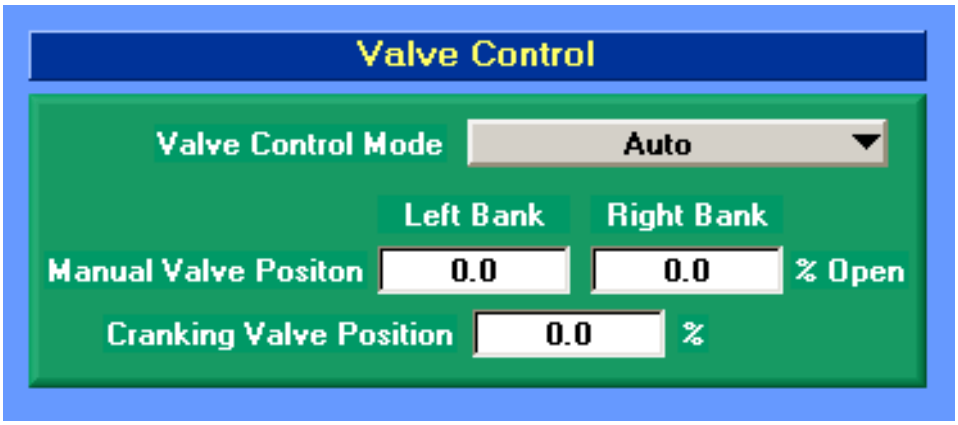
Oxygen Sensor Control Table – In this table, the user defines when the controller should go into automatic operation and when it should remain operating from the Open Loop Table. This table is user defined in all 3 cell groups; MAP Cells, Speed Cells and the Open Loop Cells. Entering a 1 for closed loop and entering a 0 for open loop define an open loop cell.

- **MAP Cells** – share same values as other table. See above.

- **Speed Cells** – share same values as other table. See above.

Closed Loop Cells – The remaining cells to the right of the Speed Cells and below the MAP Cells are the Open Loop Cells. These cell ranges will need to be defined by the user during the system setup according to the desired open loop position at varying loads and speeds.

Valve Control Group



Valve Control Mode – In this pull down menu there are two (2) modes of valve operation:

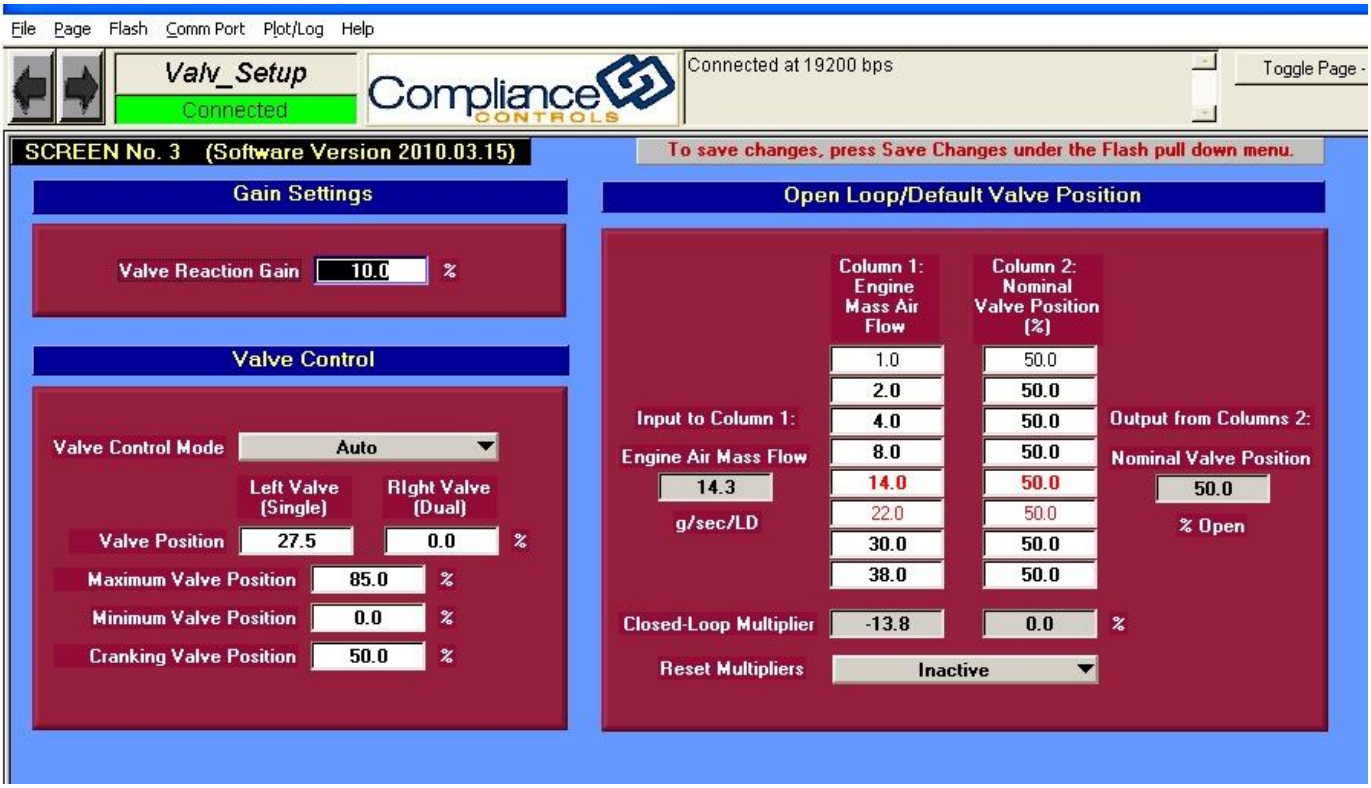
- **Auto** – In this mode the controller is in control of the operation of the valves and determines their positions according to the desired UEGO sensor target.
- **Manual** – In this mode, the user can determine a valve position for the valves. When this mode is chosen, a desired valve position can be entered into the valve position cell.

Manual Valve Positions – While in Manual Mode, desired valve positions can be entered into these cells and the valves would be forced into the position. While in Auto Mode the actual valve positions are indicated here.

Cranking Valve Position – In this cell, the starting position for the control valves are entered. This is the position of the fuel control valves at speeds greater than 2 RPM and less than 450

RPM. This value is typically between 10 to 85%, depending on the amount of fuel needed to start the engine.

Valve Set-Up (Screen No. 3)

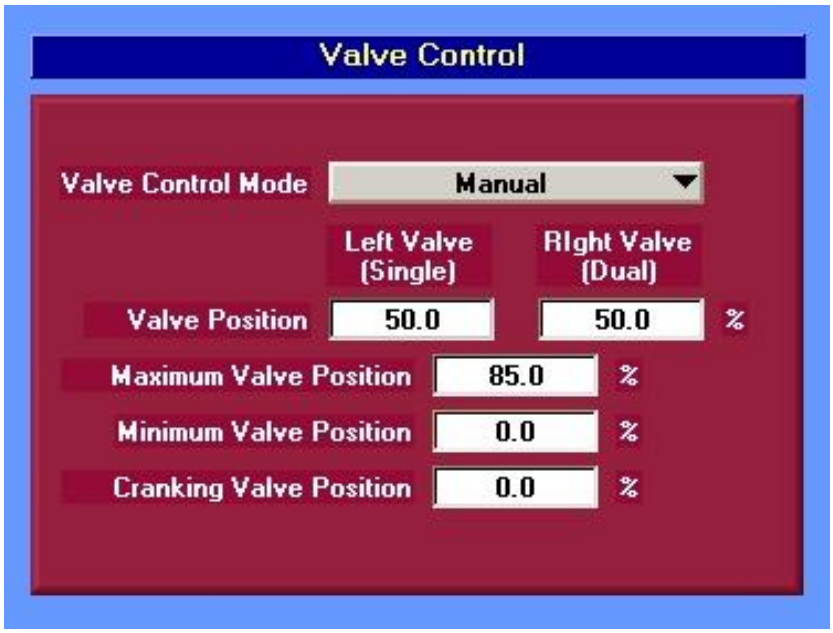


From the “VALVE SET-UP” screen (screen no. 3), the controller gains are adjusted and the fuel control valves are matched to the engine.

Gain Setting Group

Valve Reaction Gain – This gain setting adjusts the time that the valve(s) reacts to the error between the sensor reading and the sensor targets. The **factory default is sufficient for most applications.** Setting this value lower slows down the response rate of the controller (and setting higher speeds it up). If this gain setting is adjusted too high, the controller may tend to over compensate for errors or potentially oscillate. If adjustment is needed, use the lowest gain setting that is sufficient.

Valve Control



Valve Control Mode – In this pull down menu there are two (2) modes of valve operation:

- **Auto** – In this mode the controller is in control of the operation of the valves and determines their positions according to the desired UEGO sensor target.
- **Manual** – In this mode, the user can determine a valve position for the valves. When this mode is chosen, a desired valve position can be entered into the valve position cell

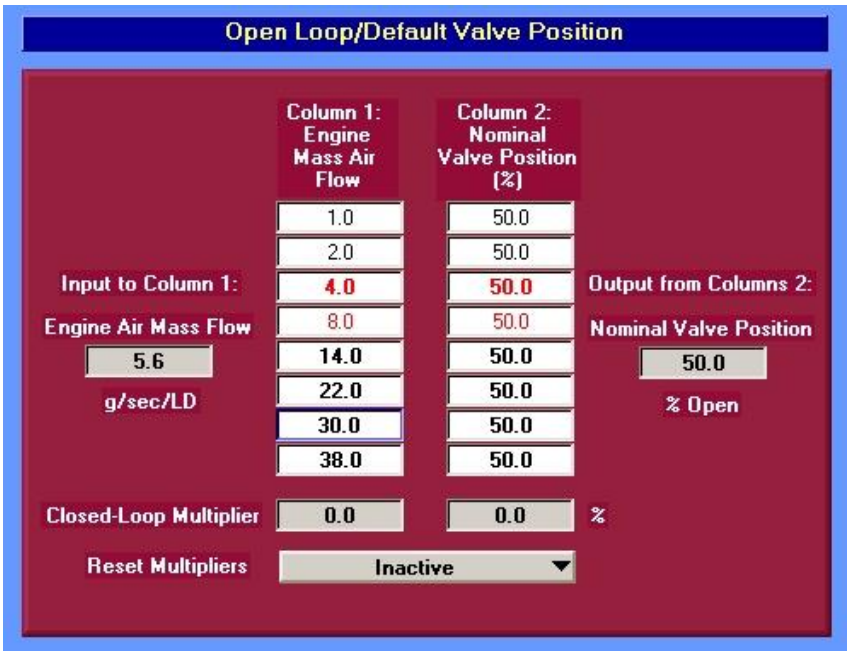
Valve Position – In these cells, the actual valve position is indicated during normal operation. During the setup, the valve positions can be manually entered while in *"MANUAL"* valve mode.

Maximum Valve Position - This is a user defined field. In this cell, the maximum allowed valve command is defined. When using the full authority valves, the maximum opening cannot exceed 85%.

Minimum Valve Position - This is a user defined field. In this cell, the minimum closing position of the valve is defined. With all valve types, it is recommended to set this position at 0% to allow the controller have the widest possible control range.

Cranking Position – This is a user defined field. In this cell, the valve position during engine cranking is defined (between 25 RPM and 450 RPM). This value is typically between 10 to 85%, depending on the amount of fuel needed to start the engine.

Open Loop/Default Valve Position Group



Open Loop/Default Valve Position Table – This section is divided into two (2) columns: Column 1 - Engine Mass Air Flow and Column 2 - Nominal Valve Position (%).

- **Engine Mass Air Flow** – These cells are used as a reference as to the particular load that the engine is currently operating at. These cells are not typically defined by the user, but can be adjusted as needed to fit a particular application. This field is expressed in grams per second per liter displacement (g/sec/LD).

- **Nominal Valve Position** - These cells are used as a reference as to the calculated nominal valve position of the controller during normal operation. This is the valve position that the system would default to in the event of a UEGO sensor failure. During normal operation, this position should be as close as possible to the actual valve position.

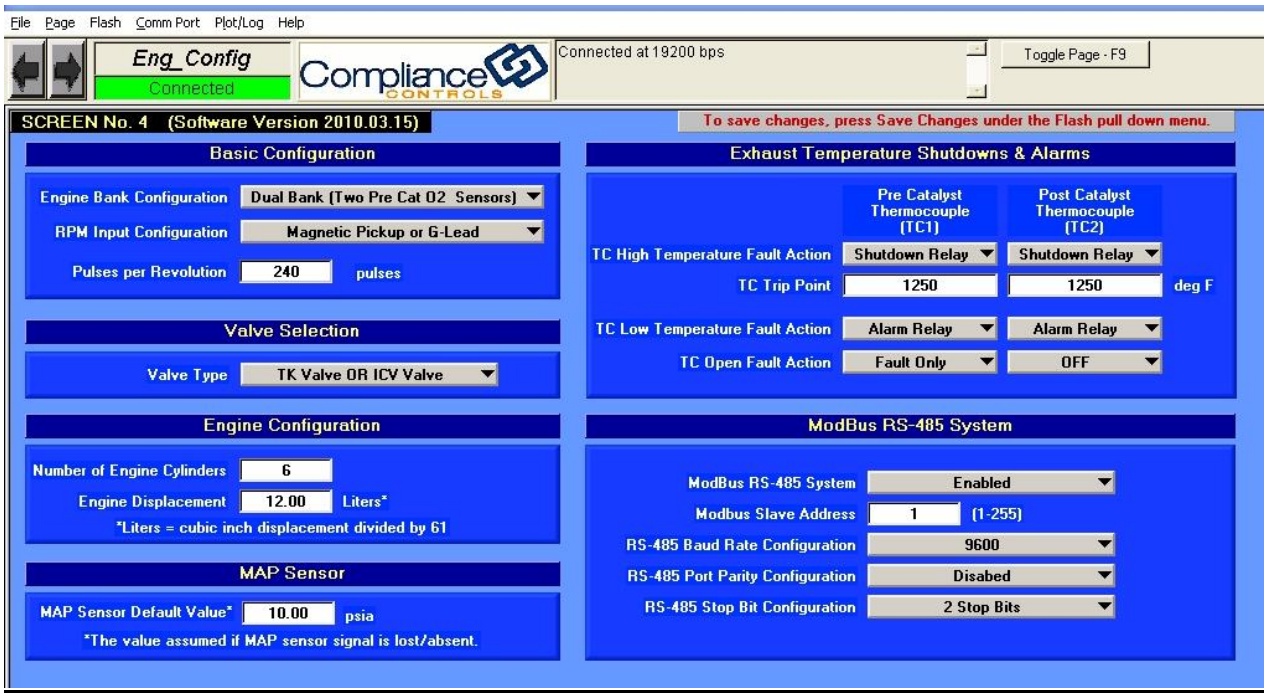
Engine Mass Air Flow – In this cell, the calculated mass air flow rate to the engine is displayed. The controller calculates this value from the user defined engine parameters as well as the engine speed, and intake manifold pressure. This value is used by the controller as a point of reference as to the load of the engine and is expressed in grams per second per liter.

Nominal Valve Position – In this cell, the calculated nominal valve position is displayed.

Closed Loop Multiplier – These two cells indicate the amount of offset applied to the Left Bank and Right Bank Phi targets. These values are expressed as a percentage.

Reset Multipliers - This pull down menu allows the user to reset all the multipliers back to zero (0). Care should be taken here because this will clear the accumulated closed loop feedback offsets and cause the valve(s) to swing to positions approximate to those entered into the Open Loop Table. If this would be a significant change in valve position, it is suggested the controller be first placed into Manual Mode, the valve(s) gradually stepped down to the approximate Open Loop Table value, the controller returned back to Auto Mode, and then the closed loop multipliers cleared.

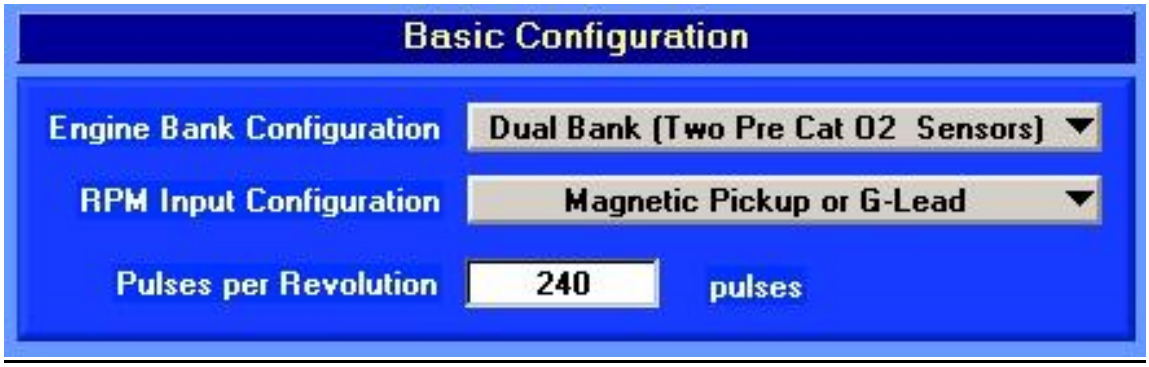
Engine Configuration (Screen No. 4)



From the “ENGINE CONFIGURATION” screen (screen 4), the controller is configured for the particular engine that it has been installed on as well as the exhaust temperature shutdown and alarm functions. This screen’s main purpose is for the matching of the controller to the engine.

This screen is divided into six (6) main groups: Basic Configuration, Exhaust Temperature Shutdown and Alarms, Valve Selection, Engine Configuration, MAP Sensor and ModBus RS-485 System.

Basic Configuration Group



Engine Bank Configuration – In this pull down menu, the number of valves and UEGO sensors needed are determined

- **Single Bank (One Pre Cat O2 Sensor)** – Designed for inline engines or "V" Bank design engines using a common exhaust manifold or a common intake manifold. This mode allow for the use of one (1) pre catalyst UEGO sensor and one (1) fuel control valve output. In this operation mode, only the Left Bank oxygen sensor and control valve is used and operational.
- **Dual Bank (Two Pre Cat Sensors)** – Designed for "V" Bank engines using two (2) intake manifolds and two (2) exhaust manifolds. This mode allows for the operation of dual UEGO sensors and Dual control valves. In this operation mode, both of the oxygen sensors and control valves are operational.

NOTE:

When the controller is setup as a single bank system, only the Left Bank oxygen sensor and control valve is used.

RPM Input Configuration – In this pull down menu, the type of speed input device is determined.

- **Disconnected** – No input device is used. The controller will never see a speed signal. This input mode will not allow the controller to go into operation and is never recommended.

- **Magnetic Pickup or G-Lead** – In this input mode, two types of configuration can be used to determine pulses per revolution and engine speed:

    - **Magnetic Pickup** – A magnetic pickup is the preferred method of pulse measurement due to the low occurrence of RF noise generated. The Magnetic Pickup is typically installed over the flywheel ring gear and counts the pulses generated as the flywheel teeth pass over the magnet in the magnetic pickup.

    - **G-Lead** – The G-Lead is a sensing lead from the ignition system that reads all voltages from all cylinders. Each time a cylinder fires, the G-Lead reads the pulse generated by the firing of that cylinder. The controller senses this firing and determines the engine speed by how many cylinders are fired each crankshaft rotation. Due to the high occurrences of RF noise generated by ignition systems, we do not recommend the use of the G-Lead input.

- **Not Used –** These options are just as they are stated “Not Used”. These may be used in future application expansion of the controller.

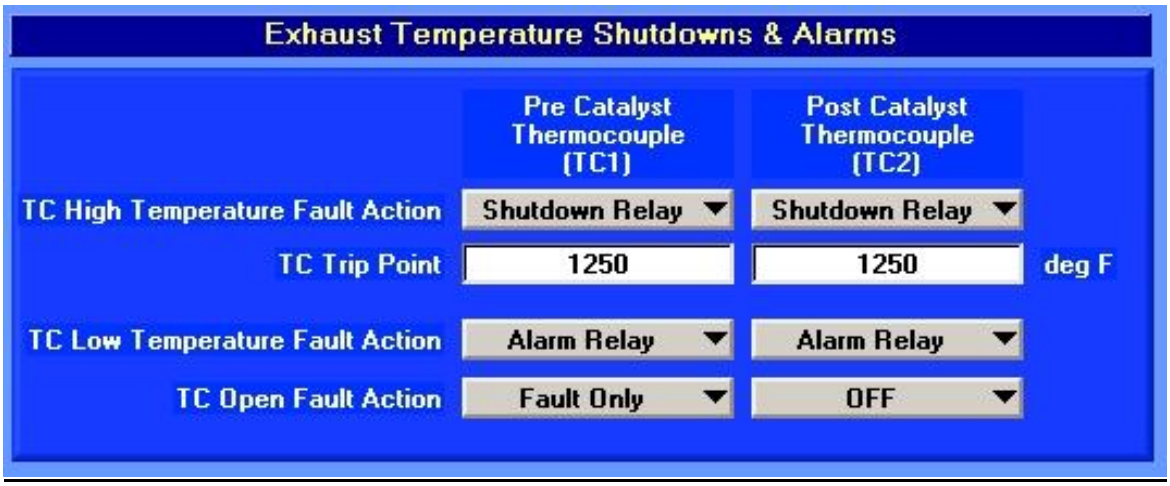
- **Discrete – Ground = Running** – This feature is designed for troubleshooting of the controller only. By grounding the (+) terminal of the Magnetic Pickup input on the TCB and choosing this option, the controller will generate a false speed signal of 1000 RPM. This option is not recommended for normal operation of the controller. This will cause the controller to stay active at all times. This option should only be used when advised by a FW Murphy service technician.

- **Discrete – Open = Running** – This feature is designed for troubleshooting of the controller only. By not connecting any wires to (+) terminal of the Magnetic Pickup input on the TCB and choosing this option, the controller will generate a false speed signal of 1000 RPM. This option is not recommended for normal operation of the controller. This will cause the controller to stay active at all times. This option should only be used when advised by a FW Murphy service technician.

- **Discrete – +V = Running** – Not currently activated. This feature is designated for future application expansion of the controller.

Pulses Per Revolution – In this cell the number of pulses per revolution are entered. If a Magnetic Pickup is used, this is the number of teeth on the flywheel ring gear. If a G-Lead is used this number is typically ½ of the total number of cylinders of the engine. See the Appendix – "Engine Data" for a list of the most common engine types and the number of flywheel teeth for these engines.

Exhaust Temperature Shutdown & Alarm Group



In this group, the controller can be configured to set an alarm or a shutdown during engine operation according to the exhaust temperature condition. All items are divided into two (2) columns: Pre-Catalyst Thermocouple (TC1) and Post- Catalyst Thermocouple (TC2).

TC high temperature fault action –This feature is used primarily as a catalyst protection device. This field has a pull down menu with four (4) options:

- **Off** – The controller ignores all temperature readings. No alarms/faults or shutdowns will be used.
- **Fault Only** – Only a fault code is generated in the active and historic fault boxes during a high temperature condition. No relays are activated.

- **Alarm Relay** – The controller sets an alarm on the fault screens and the Alarm/Fault relay is activated.
- **Shutdown Relay** - The controller sets an alarm on the fault screens and activates the Shutdown relay.

TC Trip Point - "When the Thermocouple Temperature is greater than" – In these cells the thermocouple high temperature trip points are set. For most catalyst applications, this value should be set to 150°F above the normal operating point of the exhaust system. This value should never exceed 1350°F

TC low temperature fault action – This feature is primarily used as a thermocouple assurance device. If a temperature of less than 500° F is seen for greater than 6 minutes after an engine run signal has been received, the controller will flag this fault and assume that the thermocouple is bad. This field has a pull down menu with four (4) options:

- **Off** – The controller ignores all temperature readings. No alarms/faults or shutdowns will be used.
- **Fault Only** – Only a fault code is generated in the active and historic fault boxes during a low temperature condition. No relays are activated.
- **Alarm Relay** – The controller sets an alarm on the fault screens and the Alarm/Fault relay is activated.
- **Shutdown Relay** - The controller sets an alarm on the fault screens and activates the Shutdown relay.

TC open fault action - This feature is primarily used as a thermocouple assurance device. If a sudden elevation in temperature (greater than 1800° F) is seen in less than 1 second, the controller will flag this fault and assume that the thermocouple device is bad. This field has a pull down menu with four (4) options:

- **Off** – The controller ignores all temperature readings. No alarms/faults or shutdowns will be used.

- **Fault Only** – Only a fault code is generated in the active and historic fault boxes during an open condition. No relays are activated.
- **Alarm Relay** – The controller sets an alarm on the fault screens and the Alarm/Fault relay is activated.
- **Shutdown Relay** - The controller sets an alarm on the fault screens and activates the Shutdown relay.

Any changes to this group must be committed (flashed) to the EPROM before continuing.

Valve Selection Group

Valve Type – The AFR-64L controller uses the Butterfly Valve type and should be set accordingly:

- **TK Valve or ICV Valve –** not used with the AFR-64L
- **Butterfly Valve –** This is the valve used for the AFR-64L controller and therefore the correct setting. It is a full authority type control valve and thus enables the controller to manipulate all of the fuel to the engine. These valves have a PWM input range of 0% to 85%.

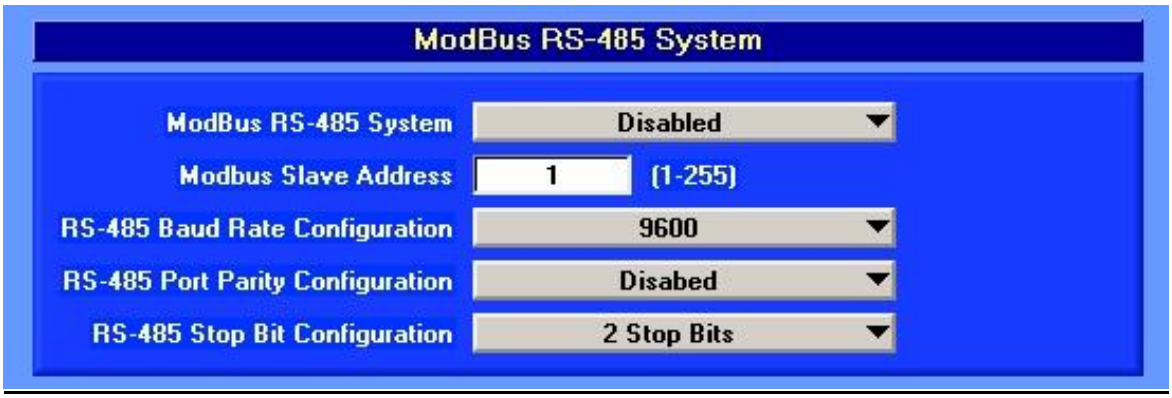
Engine Configuration Group

In this group, the controller is matched to the engine. This information is vital to the proper operation of the controller. This data is used by the controller to calculate load points during its operation and should be as accurate as possible.

Number of cylinders – This is the total number of cylinders of the engine.

Engine Displacement – The total engine displacement is entered here. The displacement is expressed in Liters. If the cubic inch displacement is known, divide this number by 61 to convert it to liters displacement.

ModBus RS-485 System Configuration Group



This group is divided into 5 basic sections and is used to define the communication type and control to an outside communication device.

On this screen the communication capabilities of the controller are enabled, disabled and monitored.

Appendix

Terms and Definitions

ATM	Atmospheric (pressure), 14.7 psia at sea level (29.92 inches mercury, 1.01 bar)
°C	Degrees Celsius/Centigrade
Closed Loop (CL)	Control using feedback signals from the controlled parameters
COM Port	A DB9 (RS232) communication port, mounted on the "Interface Module", used for communication and controller setup via a PC computer.
Duty Cycle	Percent of "on" time per total PWM signal on/off cycle time. For a PWM valve, this will determine how open the valve will be.
ECM	Engine Control Module
EMI	Electro Magnetic Interference
EPR	Electronic Pressure Regulator
Equivalence ratio	Normalized air/fuel ratio used to compare different fuels relative to stoichiometry phi (ϕ) = (A/F)stoich / (A/F)actual

°F	Degrees Fahrenheit
Fault	Indicates a system malfunction. Also known as Alarm. Faults will not shutdown the engine, unless configured to do so.
Gain	A percentage of a predetermined time frame in which the controller sees a change until the time it reacts to the change
G-Lead	Ignition pulse output signal (high voltage) used to measure engine speed
UEGO Sensor	Universal Exhaust Gas Oxygen sensor
kW	Kilowatt (power)
Lambda (λ)	A measurement of excess air in the exhaust stream. A normalized air/fuel ratio used to compare different fuels related to stoichiometry (1(λ) = stoichiometry). Also Know as equivalence ratio. Lambda is the inverse of Phi
LCD	Liquid Crystal Display
LED	Light Emitting Diode
MAP	Manifold Absolute Pressure sensor – Used to monitor the intake manifold absolute pressure. Has a range of 0 – 43 psia (0-3 bar absolute). Used as an indicator of engine load.

MAT	Manifold Absolute Temperature sensor. Used to monitor the intake manifold temperature over a wide temperature range.
MPU	Magnetic Pickup – speed sensor
Open Loop	Control without feedback from any controlled parameters
PC	Personal Computer
PCB	Printed Circuit Board
Phi (ϕ)	A measurement of excess fuel in the exhaust stream. Phi is the inverse of Lambda (1/lambda). Also known as equivalence ratio.
Plotting	A diagnostic tool used to troubleshoot the engine and controller. Any numerical input or output can be tagged and plotted on a graph at time periods from 1 second to 10,000 seconds
psia	Pounds per square inch absolute, pressure
psig	Pounds per square inch gauge, pressure (over ambient)
PWM	Pulse Width Modulated
RF	Radio Frequency noise. An electrical noise that occurs at radio frequency
RPM	Revolutions Per Minute (rotation speed)

Status Module A user interface module that only incorporates 3 status lights (power, alarm & shutdown)

Stereo Separate fuel systems for each bank of cylinders including intake manifolds, throttles, and carburetors on a multi-bank engine.

Stoichiometric A chemically balanced mixture (all reactants are mutually consumed) – in the case of an engine air/fuel ratio mixture, just enough air to theoretically burn all of the fuel

TC Thermocouple – Only type "K" is used in this application

TCB Terminal Connector Board

System Specification

System Power Specifications (dependent on number of end devices)

Device	Steady State @ 24V DC (amps)	Steady State @ 12V DC (amps)
UNIOP Display	0.25	0.50 (when used with optional 12 to 24V DC converter for 12 volt operation)
ECM	0.15	0.15
Oxygen Sensor (each)	1.00 (each)	1.00
FT Valve **NOTE FT Valve:** Peak current draw during transient conditions of .25 sec is 2.1 amps @ 24V DC and 4.2 amps @ 12V DC	1.10 (each)	2.20
FL Valve **NOTE FL Valve:** Peak current draw during transient conditions of .25 sec is 1.3 amps @ 24V DC and 2.6 amps @ 12V DC	1.00 (each)	2.00

Controller

Power Supply	24 volts DC – optional 12-24 volt DC to DC converter available for UniOP display
Enclosure	NEMA 12

Controller - Environmental

Operating Temperature	-40 to +185°F (-40 to +85°C)
Storage Temperature	-40 to +185°F (-40 to +85°C)

Full Authority FL Valve

Valve Sizes	Fuel Piping Sizes
25mm	Up to 1” NPT
50mm	Up to 2“ NPT

Supply Power	10 - 32 volts DC
Signal Power	0 - 32 volts DC (application specific)
Signal	Pulse Width Modulated (PWM)

Full Authority (FT) Valve

Valve Sizes	Fuel Piping Sizes
33mm	Up to 1 ¼” NPT
60mm	Up to 2 “ NPT
75mm	Up to 3” NPT
Housing Burst Pressure	200 psig
Max. Working Pressure	40 psig
Wire Size	18 AWG
Supply Power	9-32 volts DC
Signal Power	0 - 32 volts DC (application specific)
Signal	Pulse Width Modulated (PWM)

Valve – Environmental

Operating Temperature	-40 to +158°F (-40 to +70°C) housing temp.
Vibration	Sine Wave 10-2000 Hz at 10 g’s peak-peak

INPUTS

UEGO Sensor	(Heated Zirconia Oxygen Sensor)
Voltage	0.0 to 1.0 volts DC (sensor generated)
Ambient Temperature	500 °F (260°C) shell temperature maximum
Operating Temperature	660° to1350 °F (349F to 733°C) sensor tip
Heater Circuit	1 amp maximum

MAP Sensor

Input Power	0-5 volts DC
Pressure Range	0-3 bar absolute
	0-43.5 pounds per square inch absolute
Temperature Range	-40° to 250 °F (-40° to 121°C)

Magnetic Pickup	0.20-100 Vrms
	100 volts AC (peak to peak)
	8-10,000 Hz

G-Lead	+/- 250 volts DC

Alarm/Shutdown/Aux Relays

Dry Contact Relays	120 watt maximum (dual contact)

4 amps at 30 volts

UniOP Display

Power Supply	24 VDC with optional 12 to 24V DC converter for 12 volt operation
Power Consumption	0.25 amps maximum @ 24V (0.50 amps with 12 to 24V converter)
Text Display	4 Line x 20 Character per line

Environmental

Operating Temperature	-4° to 140°F (-20° to 60°C)

Notes, Warnings & Precautions

NOTES:

- **To avoid damage to the ECM module and circuit board, these items should be removed from the enclosure before mounting or installation of conduit entries. The ECM is attached to a mounting plate for easy removal and re-installation.**

- **If the installer is unfamiliar or unable to complete any of the installation requirements listed above, contact your FW MURPHY distributor for information on qualified installers. See Chapter 12 – Product Support for contact information.**

- **The engine should be shutdown prior to updating the software.**

- **The 304 stainless steel UEGO coupling cannot be welded to cast iron with standard welding procedures!**

WARNINGS & PRECAUTIONS

- **To avoid damage to the Full Authority valve, the butterfly plate should never be removed.**

- **To avoid damage to the ECM and circuit board, these items should be removed from the enclosure before any welding is performed on the engine skid or attached equipment. The ECM is attached to a mounting plate for easy removal and re-installation.**

- **The power supply and the G-lead must be run in separate dedicated conduit to isolate other signals from possible EMI and RF interference!**

- **Prior to the installation of any conduit entries, the ECM and Circuit board should be removed from the enclosure! See Chapter 6 – Safeguarding Electrical Circuit Boards prior to removal!**

- **The controller enclosure should not be opened when a hazardous atmosphere is present. Wiring connections that could cause sparks are present inside cabinet.**

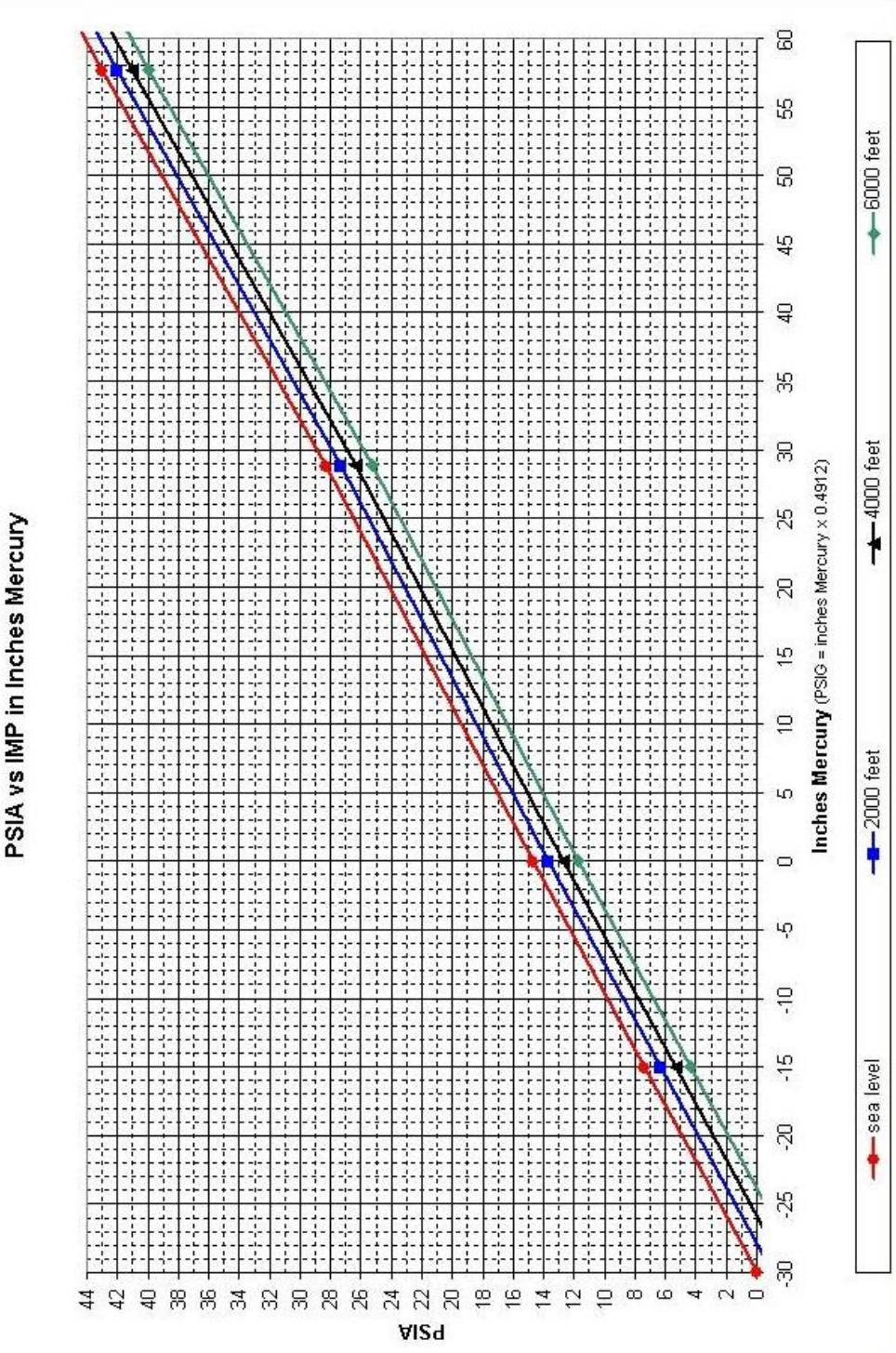
- **Never disconnect while circuits are live unless area is known to be non-hazardous.**

- **The controller's fuel control valves are not designed as a positive sealing valve. These fuel control valves should be installed downstream of a fuel shut off device to prevent fuel gas leaks while the engine is not running!**

- **The UEGO sensor maximum shell temperature (melt down point) is 500°F (260°C). These sensors should never be installed in areas where the ambient air is stagnant and/or where the ambient air conditions exceed 250°F (121°C).**

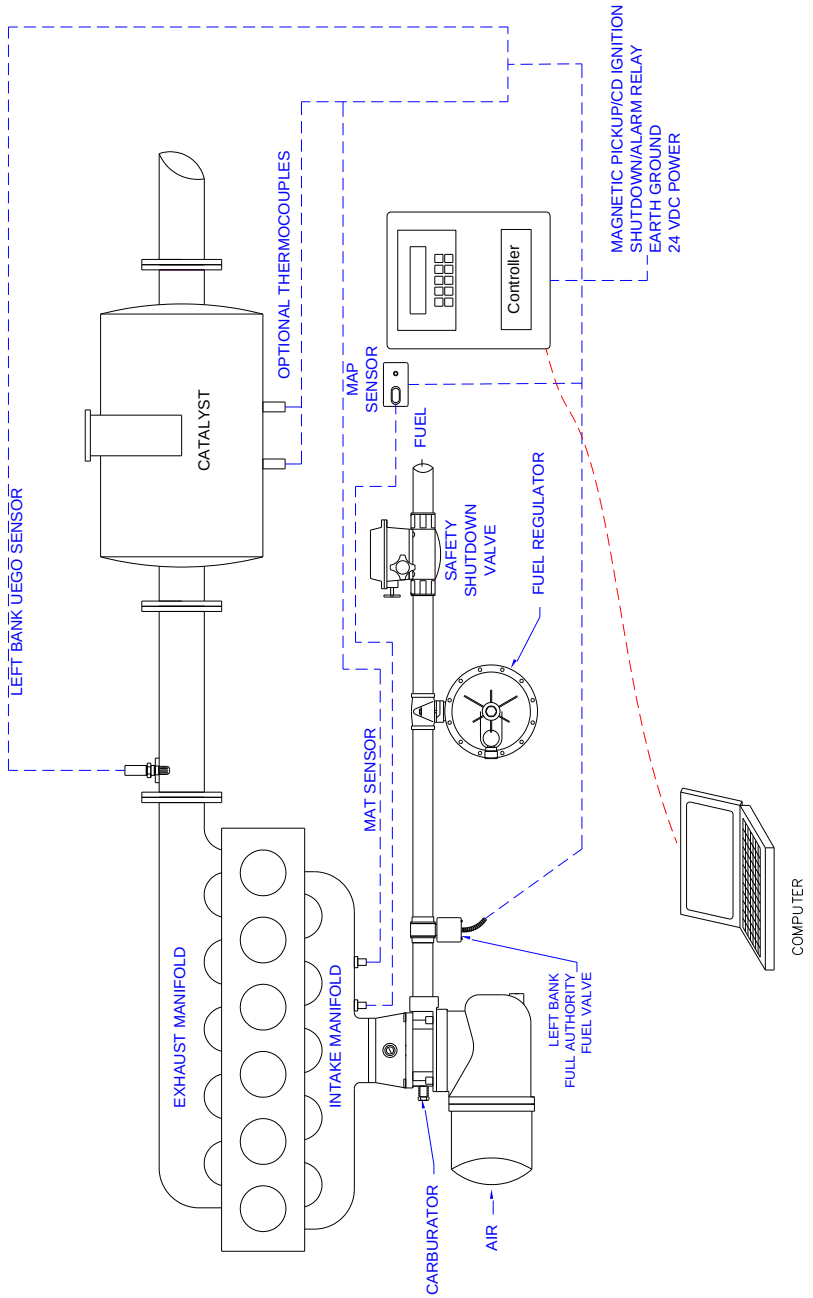
- **All electrical connections should be performed by qualified personnel and should meet all Federal, State, Local and End User electrical codes**

PSIA vs. Intake Manifold Pressure in Inches of Mercury

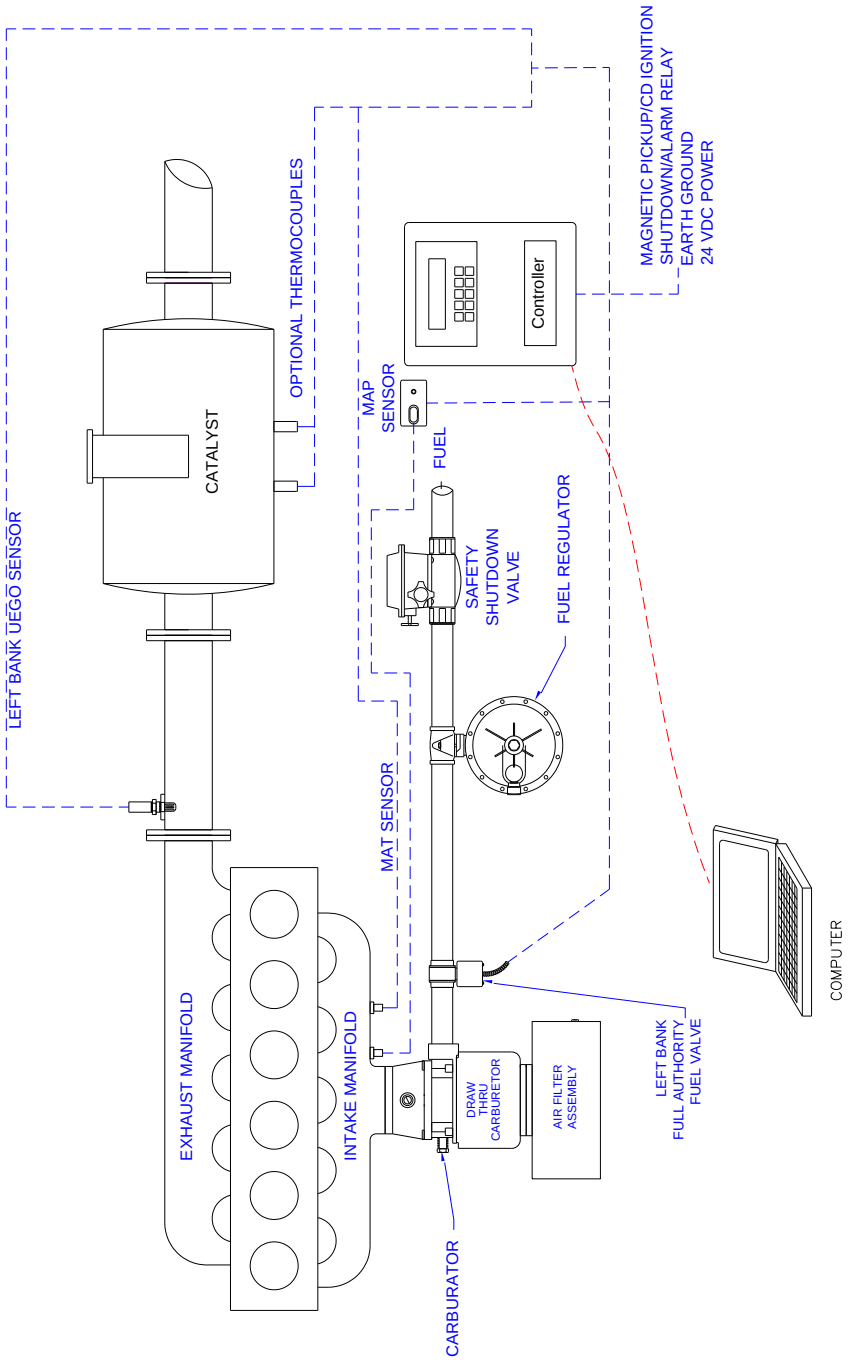


Installation Layouts Examples

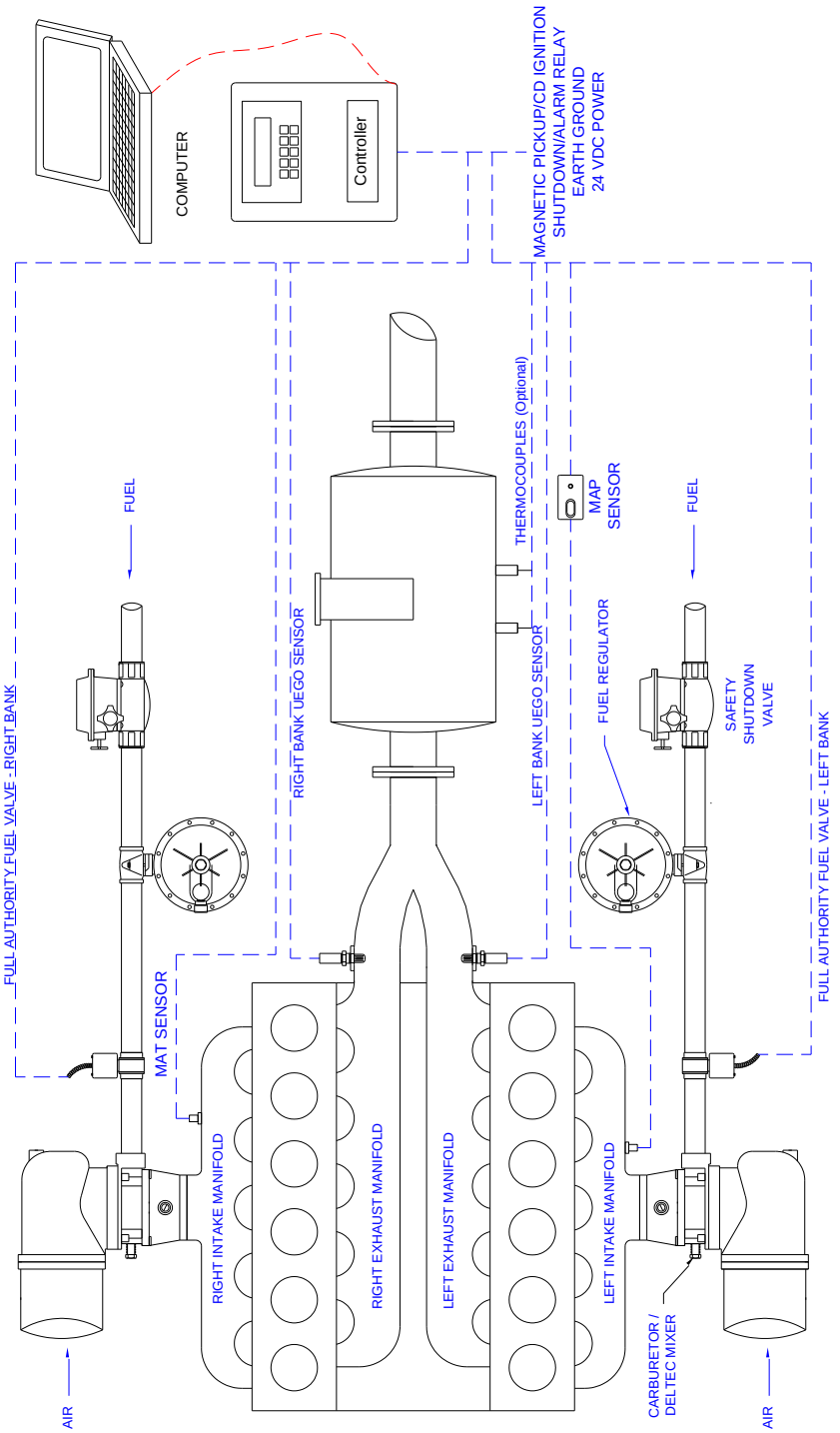
AFR-ND-L-64L-11-FA## *(Single Bank, High Pressure Carburetor, Full Authority Valve)*



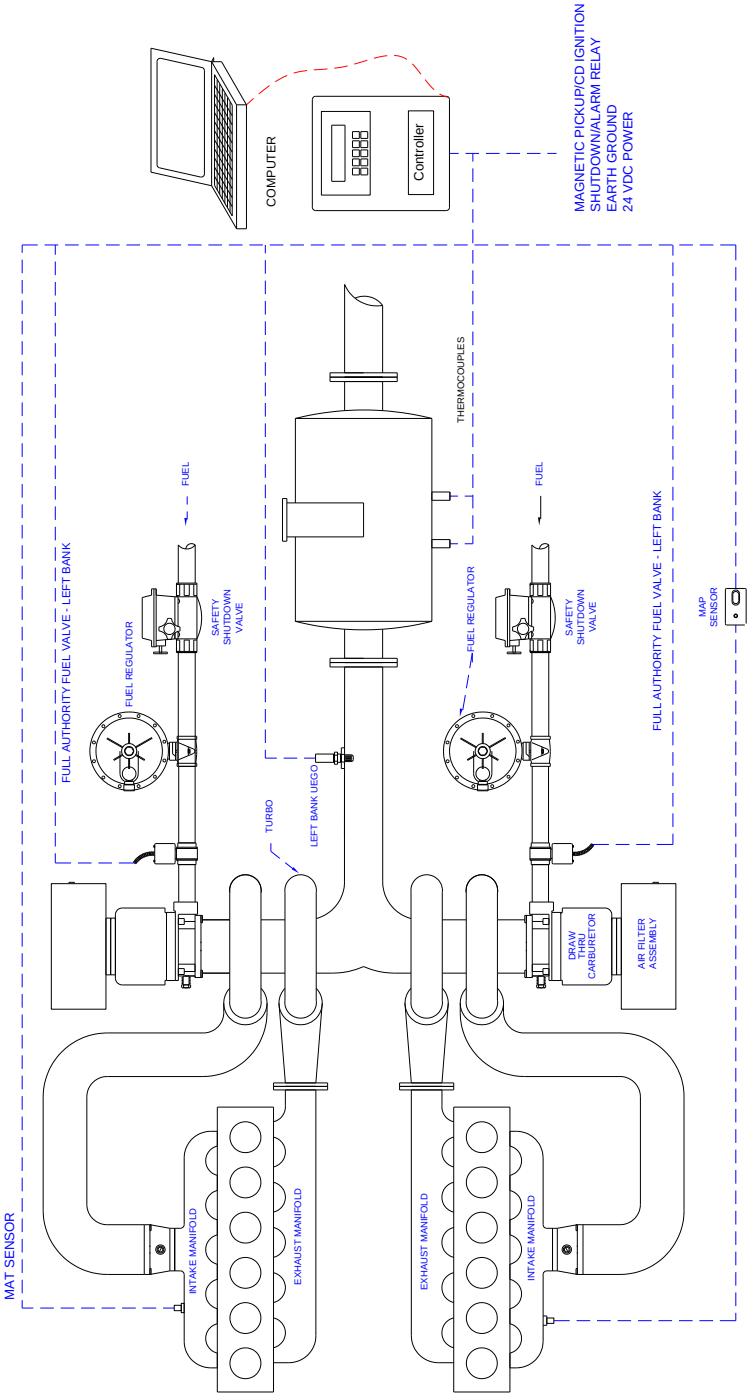
AFR-ND-L-64L-11-FA## *(Single Bank, High Pressure Carburetor, Full Authority Valve)*



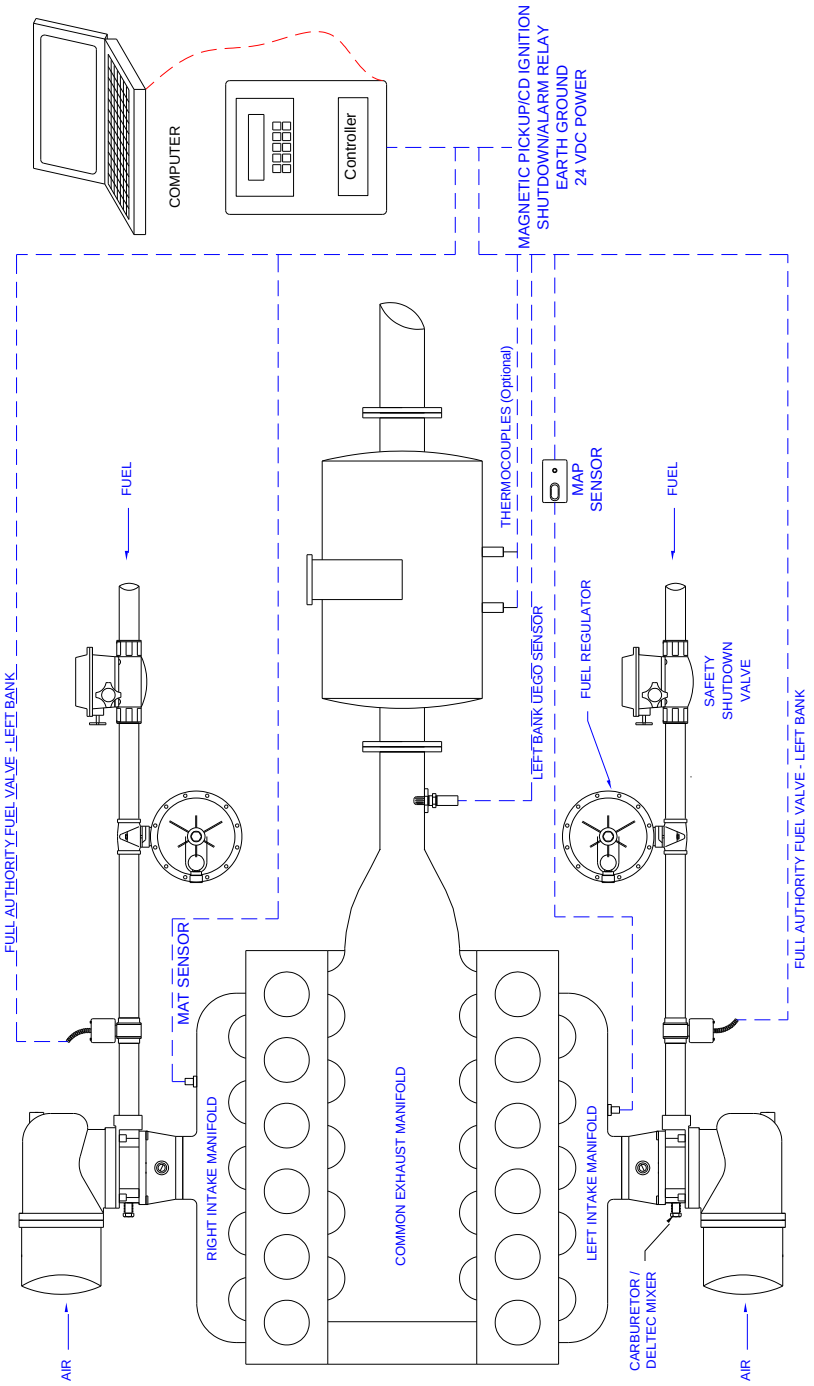
AFR-ND-L-64L-22-FA## *(Dual Bank, High Pressure Carburetor, Full Authority Valve)*



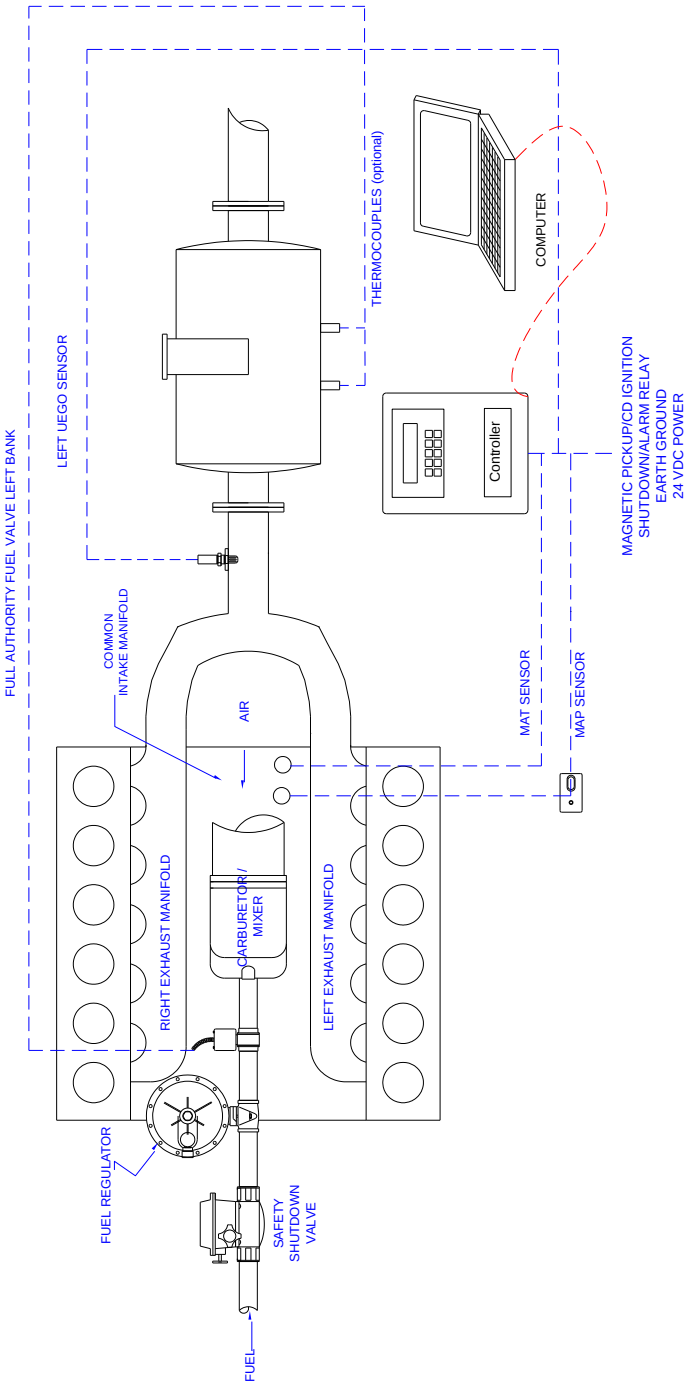
AFR-ND-L-64L-22-FA## *(Dual Bank, Low Pressure Carburetor, Full Authority Valve)*



AFR-ND-L-64L-22-FA## *(Dual Bank, High Pressure Carburetor, Common Exhaust Manifold Full Authority Valve)*



AFR-ND-L-64L-11-FA## *(Dual Bank, High Pressure Carburetor, Common Intake Manifold Full Authority Valve) (Cat 3500 series)*



Engine Data

Engine Manufacture	Engine Model	Number of Cylinders	Displacement Liters	Flywheel Tooth Count
Caterpillar	G3304	4	7.0	157
Caterpillar	G3306	6	10.5	157
Caterpillar	G3406	6	13.4	157
Caterpillar	`G3408	8	17.9	157
Caterpillar	G3412	12	26.9	157
Caterpillar	G3508	8	33.7	183
Caterpillar	G3512	12	50.5	183
Caterpillar	G3516	16	67.4	183
Caterpillar	G342	6	20.4	183
Caterpillar	G379	8	32.2	183
Caterpillar	G398	12	48.3	183
Caterpillar	G399	16	64.4	183
White	6G510	6	50.2	230
White	6G825	6	81.0	230
White	8G825	8	108.0	230
White	12G825	12	162.0	230
White	16G825	16	216.0	230
Arrow	VRG220	4	3.6	121
Arrow	VRG330	6	5.4	121

Waukesha	F817	6	13.4	138
Waukesha	F1197	6	19.6	144
Waukesha	F11	6	11.0	148
Waukesha	F18	6	18.0	150
Waukesha	H24	8	24.0	150
Waukesha	L36	12	36.0	165
Waukesha	P48	16	48.0	165
Waukesha	F1905	6	31.2	158
Waukesha	F2895	6	47.5	208
Waukesha	F3521	6	57.7	208
Waukesha	H2475	8	40.6	204
Waukesha	L3711	12	60.8	204
Waukesha	L5108	12	83.7	208
Waukesha	L5790	12	94.9	208
Waukesha	L7042	12	115.4	208
Waukesha	P9390	12	153.9	208
Waukesha	8L–AT27GL	8	142.5	267
Waukesha	12V-AT27GL	12	213.9	291
Waukesha	16V-AT27GL	16	285.0	291

Liters = Cubic Inch Displacement divided 61

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