



Installation and Operation Manual



GECO™·Lean Burn Gas Engine Controller

**Air/Fuel Ratio Controller
for Emissions-controlled, Stationary Gas Engines**

Manual 03616B



WARNING

Read this entire manual and all other publications pertaining to the work to be performed before installing, operating, or servicing this equipment. Practice all plant and safety instructions and precautions. Failure to follow instructions can cause personal injury and/or property damage.

The engine, turbine, or other type of prime mover should be equipped with an overspeed shutdown device to protect against runaway or damage to the prime mover with possible personal injury, loss of life, or property damage.

The overspeed shutdown device must be totally independent of the prime mover control system. An overtemperature or overpressure shutdown device may also be needed for safety, as appropriate.



CAUTION

To prevent damage to a control system that uses an alternator or battery-charging device, make sure the charging device is turned off before disconnecting the battery from the system.

Electronic controls contain static-sensitive parts. Observe the following precautions to prevent damage to these parts.

- Discharge body static before handling the control (with power to the control turned off, contact a grounded surface and maintain contact while handling the control).
- Avoid all plastic, vinyl, and Styrofoam (except antistatic versions) around printed circuit boards.
- Do not touch the components or conductors on a printed circuit board with your hands or with conductive devices.



IMPORTANT DEFINITIONS

WARNING—indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury.



CAUTION—indicates a potentially hazardous situation which, if not avoided, could result in damage to equipment.



NOTE—provides other helpful information that does not fall under the warning or caution categories.

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Regulatory Compliance Notes and Warnings

GECO™ controls are available which are suitable for use in Class I, Division 2, Groups A, B, C, and D per UL for Canada and U.S. or non-hazardous locations only.

Wiring must be in accordance with North American Class I, Division 2 wiring methods as applicable, and in accordance with the authority having jurisdiction.

**WARNING**

Explosion Hazard—Do not disconnect equipment unless power has been switched off or the area is known to be non-hazardous.

Explosion Hazard—Substitution of components may impair suitability for Class I, Division 2.

**AVERTISSEMENT**

Risque d'explosion—Ne pas débrancher l'équipement tant que le courant soit éteint, ou en cas l'ambiance est décidément non dangereuse.

Risque d'explosion—La substitution de composants peut rendre ce matériel inacceptable pour les emplacements de Classe I, Division 2.

Chapter 1.

General Information

Welcome!

This manual describes the Woodward GECO™·Lean Burn control. The GECO·Lean Burn control provides precise air/fuel ratio control for engines designed to use a lean mixture of air and fuel to maintain low exhaust emissions. It can be implemented in open loop mode; closed loop mode with wide-range exhaust gas oxygen measurement; or in generator set applications, it can operate in closed loop mode with engine efficiency feedback, using a kW transducer. It also has sophisticated strategies for quick response, failsafe operation, and system diagnostics.

GECO·Lean Burn System Features

- Microprocessor-based, air/fuel ratio control system; 9–30 Vdc operation
- Closed loop, air/fuel mixture control using exhaust oxygen feedback on mechanical drive engine systems
- Closed loop, air/fuel mixture control using generator power feedback on generator drive engine systems
- Continuous recalibration of open loop control mode during closed loop operation
- Capable of driving up to 2 fuel metering valves for “V” engine configurations
- RS-485 networking/communications support
- Comprehensive diagnostics
- 1 closed loop enable switch
- 1 alarm relay
- 1 shutdown relay
- LED Driver for power indication, alarm and shutdown
- Plug-in terminal strip connectors for ease of installation
- UL/cUL listed for Class I, Division 2, Groups A, B, C, and D hazardous locations



WARNING

The GECO·Lean Burn control does not detect cylinder detonation (knock) or misfire. Either of these conditions can cause the control to make erroneous adjustments to the air/fuel ratio and further aggravate the engine condition, possibly causing shutdown and/or damage. Woodward recommends that you do not install this control on an engine without detonation and misfire detection.

Definitions of Terms and Abbreviations

°C	Degree Celsius	MAP	Intake Manifold Absolute Pressure—an indicator of engine load
Closed Loop (CL)	Control using feedback signals from the controlled parameter	MAT	Intake Manifold Absolute Temperature—used to determine mixture density
Duty Cycle	Percent of on time per total on/off cycle time	Mdot	Mass flow rate
EBP	Exhaust Back Pressure	MPU	Magnetic Pickup speed sensor
EGT Sensor	Exhaust Gas Temperature sensor (K-type thermocouple)	N·m	Newton-meter (torque)
Equivalence Ratio	Normalized air/fuel ratio used to compare different fuels relative to stoichiometry $\text{phi } (\phi) = (A/F)_{\text{stoich}} / (A/F)_{\text{actual}}$ $\text{lambda } (\lambda) = 1/\text{phi}$	NGP	Natural Gas Pressure
Flo-Tech™ Valve	Fuel flow control valve that takes a PWM command signal from the GECO·Lean Burn control and increases or decreases the fuel flow to the mixer	Open Loop	Control without feedback from any controlled parameters
°F	Degree Fahrenheit	PC	Personal Computer
G-lead	Ignition pulse output signal (high voltage) used for engine speed measurement	phi (φ)	See equivalence ratio
kPa	kilopascal (pressure)	psi	Pounds per square inch (pressure)
kW	kilowatt (power)	psia	psi absolute pressure
kW Transducer	A transducer that measures the output power of the electrical generator and converts that measurement to a proportional 4–20 mA signal	psig	psi gauge pressure (over ambient)
lambda (λ)	See equivalence ratio	RPM	Revolutions Per Minute (rotational speed)
lb-ft	Pound-feet (torque)	RTV	Room Temperature Vulcanizing (silicone sealers)
lbm/hr/l	Pounds per hour per liter (mass flow rate per liter of engine displacement)	Stereo	Two separate fuel systems for each bank of cylinders including intake manifolds, throttles, and carburetors
LCD	Liquid Crystal Display	stoichiometric	Chemically balanced mixtures (all reactants mutually consumed)—in the case of engine air/fuel mixtures, just enough air to theoretically burn all the fuel
LED	Light Emitting Diode	TC	Thermocouple (see EGT)
		UEGO sensor	Universal Exhaust Gas Oxygen sensor
		W	Watt (power)

GECO·Lean Burn Control Specifications

Power Supply Operating Voltage:	9–30 Vdc (12 Vdc or 24 Vdc nominal)
Power Supply Rated Voltage:	8–32 Vdc
Power Consumption:	70 W maximum (application specific)
Inputs/Outputs:	2 Universal Exhaust Gas Oxygen Sensor (UEGO) 1 Watt Transducer, 4–20 mA 1 Magnetic Pickup speed input (100 V p-p) 2 Intake Manifold Absolute Pressure (MAP), 3 bar, 0–5 Vdc 1 Intake Manifold Absolute Temperature (MAT), 25 °C=2778 Ω nominal 2 Fuel Metering Valves 1 Alarm Relay 1 Shutdown Relay
Diagnostics:	Power Circuits Valve Current/Short Circuit Protection Closed loop Functions Adaptive Functions
Communications:	Configurable Open loop Default RS-232 Hand Held Terminal 6-pin RJ-12 RS-232 PC Interface DB9 RS-485 with Modbus [®] * protocol *—Modbus is a trademark of Modicon, Inc.

GECO·Lean Burn Control Environmental Specifications

Ambient Operating Temperature:	–40 to +70 °C (–40 to +158 °F)
Storage Temperature:	–55 to +105 °C (–67 to +221 °F)
Enclosure:	305 x 254 x 127 mm (12 x 10 x 5 inch), NEMA 12/13 with Quick-Release Latches
Regulatory Compliance:	
North American Compliance:	
UL:	UL Listed for Class I, Division 2, Groups A, B, C, and D; for use in Canada and the United States; UL File E120143

Flo-Tech™ Valve Specifications

Power Supply Voltage:	9–32 Vdc (12 Vdc or 24 Vdc nominal)
Power Consumption:	Must be able to supply 50 W for 0.25 second in transient conditions and 25 W continuous for steady state conditions
Inputs/Outputs:	Position Command—PWM 10–90% Nominal Actuator Range—0–70 degrees

Flo-Tech Valve Environmental Specifications

Operating Temperature:	−40 to +105 °C (−40 to +221 °F) housing temperature
Storage Temperature:	−55 to +105 °C (−67 to +221 °F)
Vibration:	Sine Sweep—US MIL-STD 810C, M514.2 Curve J (Mod) Random—US MIL-STD 202F, Method 214A, Cond. G
Temperature and Humidity:	SAE J1455

Chapter 2.

Electrostatic Discharge Awareness

All electronic equipment is static-sensitive, some components more than others. To protect these components from static damage, you must take special precautions to minimize or eliminate electrostatic discharges.

Follow these precautions when working with or near the control.

1. Before doing maintenance on the electronic control, discharge the static electricity on your body to ground by touching and holding a grounded metal object (pipes, cabinets, equipment, etc.).
2. 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.
3. 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.
4. Do not remove the printed circuit board (PCB) from the control cabinet unless absolutely necessary. If you must remove the PCB from the control cabinet, follow these precautions:
 - Do not touch any part of the 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 PCB, keep the new PCB in the plastic antistatic protective bag it comes in until you are ready to install it. Immediately after removing the old PCB from the control cabinet, place it in the antistatic protective bag.



CAUTION

To prevent damage to electronic components caused by improper handling, read and observe the precautions in Woodward manual 82715, *Guide for Handling and Protection of Electronic Controls, Printed Circuit Boards, and Modules*.

Chapter 3.

System Description and Application

GECO™·Lean Burn Air/Fuel Ratio Control

The Woodward GECO™·Lean Burn gas engine control is a microprocessor-based air/fuel ratio controller for carbureted, four-stroke cycle, lean-burn, gaseous-fueled engines. It is a closed-loop fuel control system that works in conjunction with the mechanical carburetor or mixer to precisely monitor and control the air/fuel ratio mixture over the full operating load and speed range of the engine.

The control can be used to precisely maintain the engine manufacturer's specified exhaust emission levels over the full operating load and speed range without operator intervention. Since lean-burn engines can be more susceptible to air/fuel ratio related wear or damage, the control can also be used to reduce or eliminate the resulting maintenance by preventing air/fuel ratio excursions.

The carburetor remains in place on the engine. A throttle valve (Woodward Flo-Tech™ valve) is located in the fuel line upstream of the carburetor/mixer. This valve will be used to control the fuel pressure delivered to the carburetor/mixer. A manifold absolute pressure sensor (MAP) and a manifold absolute temperature sensor (MAT) are used to measure intake manifold mixture pressure and temperature. A magnetic pickup (MPU) is mounted on the engine at a convenient location near the ring gear or other auxiliary drive gear that will provide an engine speed measurement.

Two sensor options are available for closed loop control feedback. Option one is a wide-range or universal exhaust gas oxygen sensor (UEGO) mounted in the engine exhaust flow to provide measurement of excess combustion oxygen that indicates precise air/fuel ratio. Or option two, for engines driving generators, a kilowatt transducer measuring generator output that allows the control to calculate engine efficiency which also indicates air/fuel ratio.

Alarm and shutdown outputs are also provided to allow integration into an engine or system control panel. The sensor and valve signals are monitored by the control; any detection of sensor or control malfunction can be indicated with these outputs. There is an alarm and shutdown LED output as well as an alarm and shutdown relay. These alarms are configured in the software.

The GECO·Lean Burn is applicable on engines that are designed to meet exhaust emission regulations by operating in the lean combustion region. The air/fuel ratio value which provides the lowest emissions in a lean burn engine varies depending on many parameters, including fuel composition, engine speed, load, and environmental factors, etc. Good control performance requires distinguishing small differences in a large amount of excess air. Exhaust oxygen measurement provides the most precise measure of excess air.

This type of exhaust oxygen measurement requires a universal exhaust gas oxygen (UEGO) sensor. This sensor provides a signal voltage vs air/fuel ratio for precise air/fuel mixture feedback. Unlike the stoichiometric exhaust oxygen sensors, the UEGO sensor signal is proportional to exhaust oxygen (and therefore equivalence ratio) over a wide range from a phi (ϕ) value of 0.50 to 1.10.



Figure 3-1. System Components with UEGO Sensor

Since the optimum ϕ (phi) value varies with load and speed, the intake manifold pressure (MAP) and engine speed (MPU) are measured to compensate for these variations. Additionally, with these measurements along with intake manifold temperature (MAT), an open loop calculation of air/fuel ratio can be made, giving the control an open loop control capability.

During “closed loop - adaptive” control operation, the system continuously learns the optimum control valve target position for various engine operating conditions. This continuously provides the best possible open loop and transient control performance when closed loop operation is unavailable or too slow.

Option 1—UEGO Closed Loop Control Mode

The universal exhaust gas oxygen (UEGO) sensor provides a measurement of the amount of excess air during combustion. This indicates the leanness of the air/fuel mixture. Since excess air in combustion reduces NO_x formation, controlling the amount of excess air will control NO_x emissions.

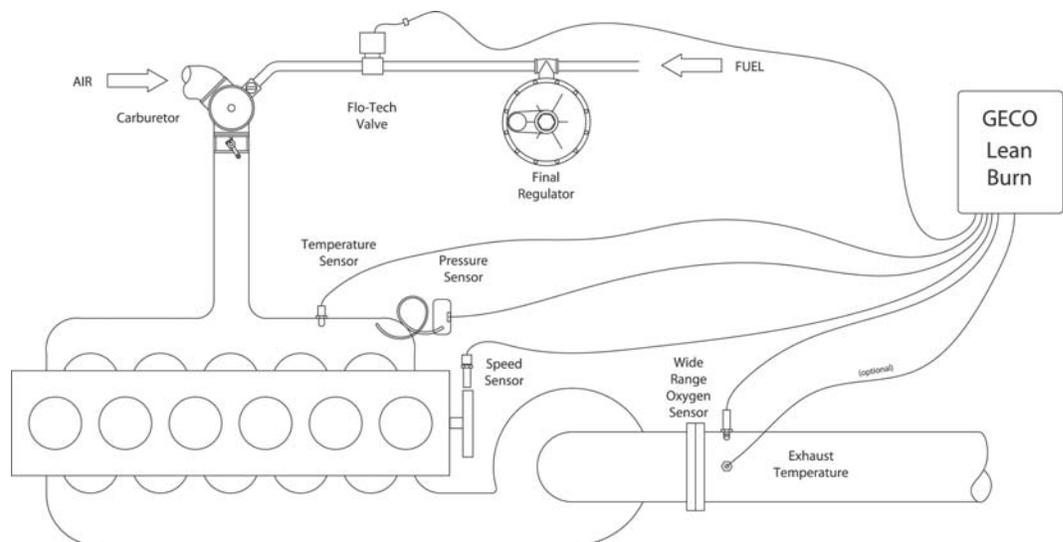


Figure 3-2. Option 1—UEGO Closed Loop Control

The UEGO sensor senses exhaust oxygen percent. The GECO·Lean Burn control converts the sensor signal into a value called phi (ϕ), or the equivalence ratio. The phi value indicates how lean the air/fuel ratio is from the reference value called the stoichiometric ratio. (The stoichiometric ratio is the ratio of air-to-fuel that will consume all of the fuel with no oxygen left over.) It typically ranges between 0.50 and 1.00. A value of 1.00 means the stoichiometric air/fuel ratio and the actual air/fuel ratio are equal, or there is no excess air. A value of 0.50 means the stoichiometric air/fuel ratio is half of the actual air/fuel ratio, or there is twice as much air as is needed for combustion.

The control compares the measured phi value to the target phi value. The target phi value comes from the phi table. The phi table allows you to set different phi target values at different loads and speeds of the engine operating range. Some engine manufacturers specify a single phi value (or exhaust oxygen value) under all operating conditions. Other manufacturers specify different phi values over the load and/or speed range. The phi table makes this easy. The speed signal from the MPU and the pressure signal from the MAP sensor establish the speed and load position on the table.

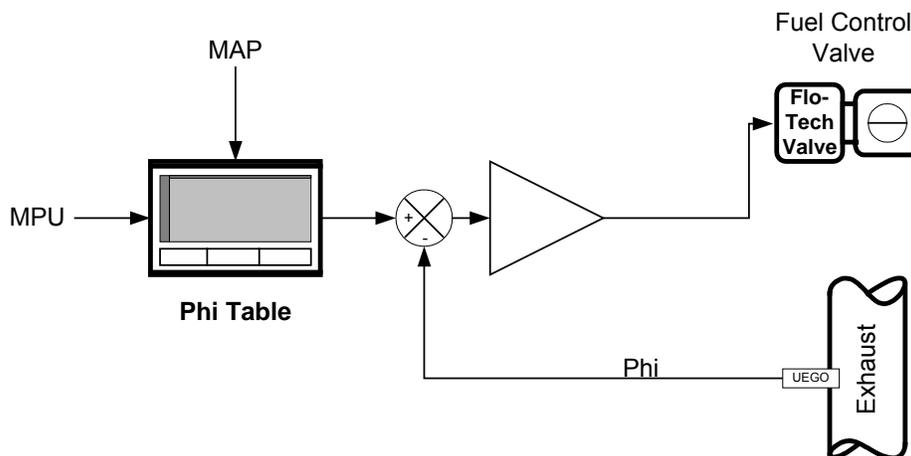


Figure 3-3. Basic Control Logic for UEGO Closed Loop Control

Once the phi values are compared, the control adjusts the fuel pressure to the carburetor to bring the measured phi value in line with the target. It is the fuel control valve that makes the fuel pressure adjustment.

The controller contains an engine model specific map of air/fuel equivalence ratio against intake manifold pressure (MAP) and engine speed. The equivalence ratio output of this map is compared to the equivalence ratio represented by the voltage of the universal exhaust gas oxygen (UEGO) sensor. The difference is the error used for the closed loop control function.

Option 2—KW Sensor Closed Loop Control Mode

This control mode utilizes the effect of air/fuel ratio on engine efficiency for an indirect measurement of air/fuel ratio. The MAP, MAT, and MPU signals are used to estimate the engine output power. This power calculation assumes the correct air/fuel ratio is present. The resulting power is compared to the actual electrical generator output power measured by a kilowatt transducer.

If the measured power differs from the estimated power, the control adjusts the fuel pressure to the carburetor to bring the measured power value in line with the estimated power. This will not affect the actual power output because the load/speed control will compensate with the throttle position. The result will be a constant power output at the air/fuel ratio originally assumed by the power estimation calculations.

Similarly to the UEGO closed loop control mode, the air/fuel ratio used in the estimated power calculations is a phi value taken from a table that allows for different values at different speeds and loads.

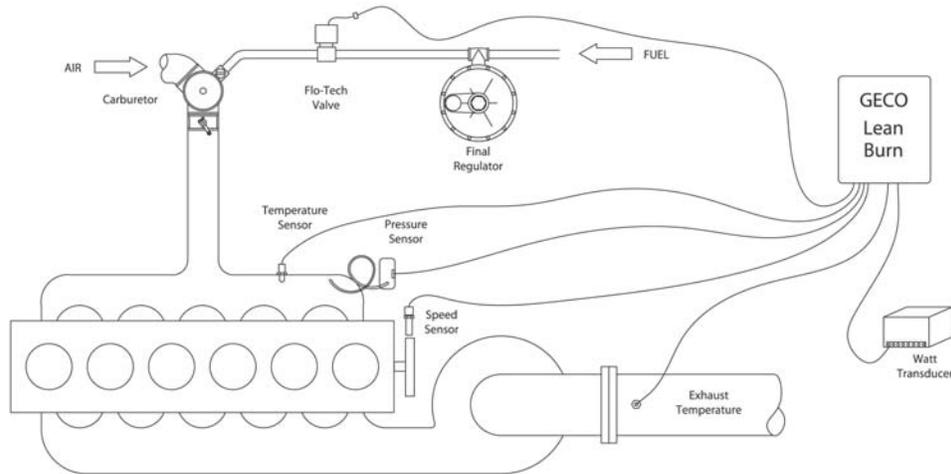


Figure 3-4. Option 2—KW Sensor Closed Loop Control

From the open loop control mixture flow calculations, the desired equivalence ratio, and the expected engine/generator efficiency, an expected output power from the generator is calculated. Comparing this with a measured electrical power output of the generator, the engine/generator total efficiency can be controlled to the extent that it is determined by air/fuel ratio. This is very effective in generator applications that have difficulties with UEGO sensors.

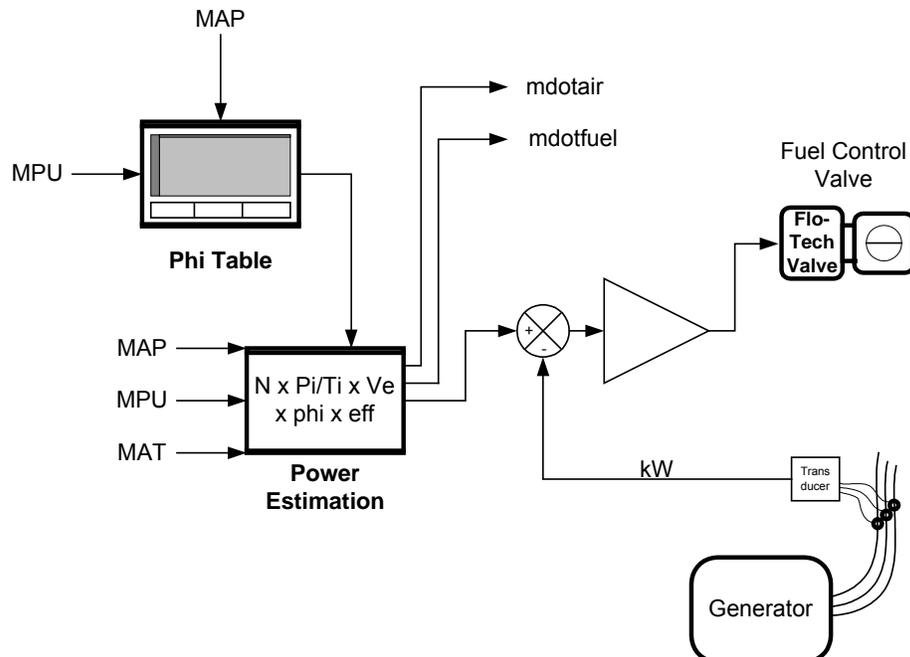


Figure 3-5. Basic Logic of KW Sensor Closed Loop Control

Open Loop Control Mode

The open loop control mode will control the air/fuel ratio of the engine without the closed loop UEGO or kW measurement. This mode is less accurate than either of the closed loop options, but it is more accurate than the carburetor alone. This mode positions the fuel control valve to predetermined values based on the load of the engine. The Valve Learn table is the look-up table in the control software used to set these values. The table has eight load points. Values in between load points are interpolated.

The open loop control mode can be used as the primary control mode, but it mainly serves as a backup to either of the closed loop modes. If the kW sensor fails or the UEGO sensor fails, the control automatically defaults to the open loop mode. The values in this table are normally entered manually during the initial control calibration. In some situations they can be entered automatically. This is called the Valve-Learn function, it is not initially active. It must be activated in the control if this feature is required.

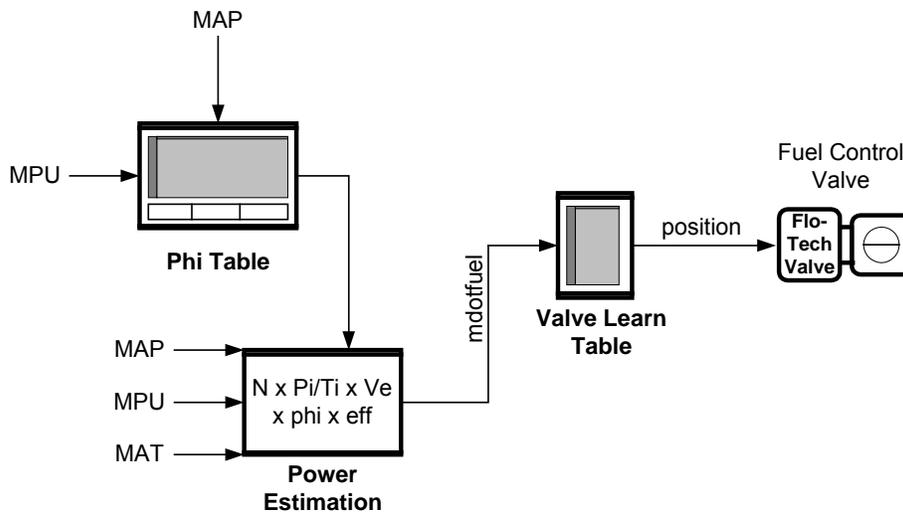


Figure 3-6. Open Loop Control Logic

The intake manifold pressure and temperature, along with engine speed, are used to calculate mixture flow into the engine. This mixture flow calculation requires a calibrated table of engine volumetric efficiency over the load and speed range of the engine. The calculated mixture flow and the desired equivalence ratio are then used to create a table of the fuel control valve position.

Valve-Learn Function

During open loop operation, the valve position is selected from the Valve-Learn table. Initially, this table is based on the optimum valve position of best control at the time of control calibration. Over time, if fuel BTU content changes or environment conditions change, these valve positions will no longer be optimum. The Valve-Learn function allows the control to learn new optimum valve positions from the closed loop operation. These new values are automatically entered into the Valve-Learn table whenever conditions are stable and closed loop accuracy is maintained.

Monitoring and Communications

For system reliability, the GECO·Lean Burn control monitors sensor inputs and control outputs for high and low failure conditions, and performs extensive self-diagnostics for system functionality. User-configurable alarm or shutdown control outputs are available for component failure or emissions compliance requirements.

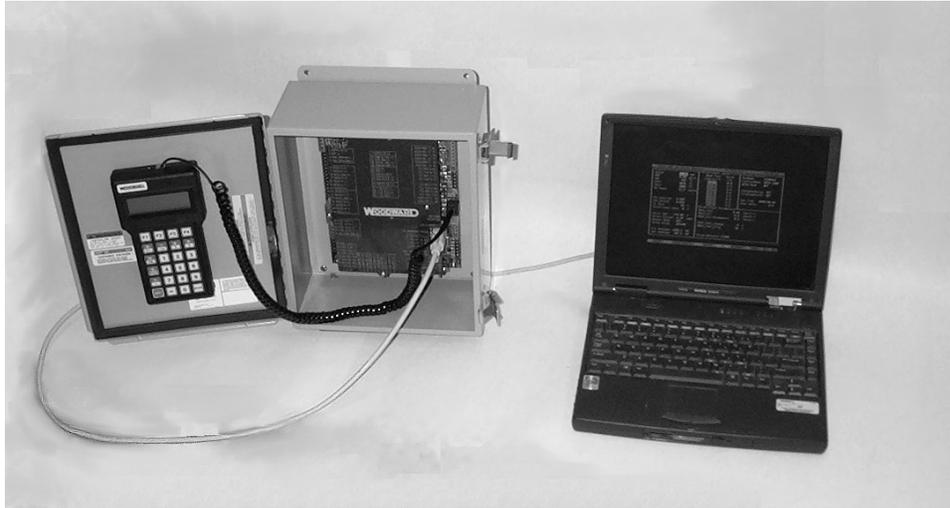


Figure 3-7. PC Communications

Engine		Status/Control	
Speed	1100 rpm	RunMode	RUNNING
MAP1	25.76 psia	Control1 Mode	CLOSED LOOP
MAP2	16.00 psia	Control2 Mode	OPEN LOOP
MAT	167 °F	UEGO1 Mode	OK
EGT1	77 °F	UEGO2 Mode	OFF
EGT2	77 °F	ShutdownRelay	OFF
DC Power	23.7 volts	ClsdLoopSwch	ON
Phi Desired	0.608	Valve1 Cmd	+57.00 %
Phi_Actual1	0.620	Valve2 Cmd	+57.00 %
Phi_Actual2	0.000	Manual Mode	OFF
CL Gain	10 %	Valve State	ACTIVE
Est Power	742 bhp	Valve1 Current	0.75 amps
Est Torque	4119 ft-lbs	Valve2 Current	0.09 amps
Run Time	0000:01:15		
Hour Meter	22.2		

ESC exit ENTER clear-fault SPACE pause PGUP-PGDN screens F2 save Tag Plot

Communication with the system is via a computer (PC) interface or by the hand-held terminal. Control setup and tuning can only be done through the PC interface screens (see left).

The PC software also includes many helpful features for system troubleshooting, including status indicators and data monitoring, and real-time plotting and logging.

Modbus Communication

The GECO·Lean Burn control is capable of sending information to a supervisory or SCADA system. The communication protocol is Modbus ASCII or RTU. This function is for information distribution and is not intended or capable of remote configuration or tuning.

System Diagram Examples

The following are system configuration diagrams for various engine arrangements. Sometimes two Flo-Tech valves are required and sometimes one. Sometimes two UEGO sensors are required and sometimes one. It is important to determine which arrangement to use since the number and wiring of different components is affected.

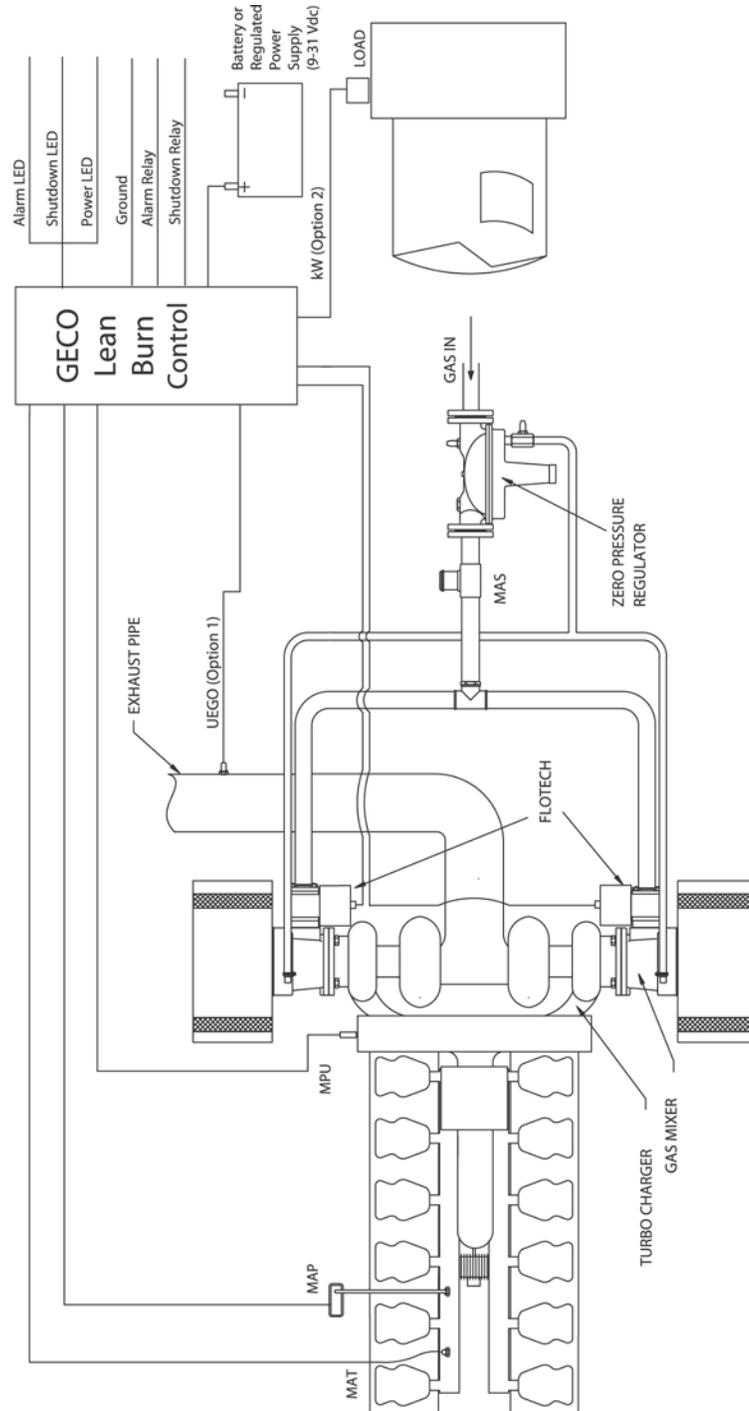


Figure 3-8. GECO System on Caterpillar 3500 with Low Pressure Deltec Carburetion

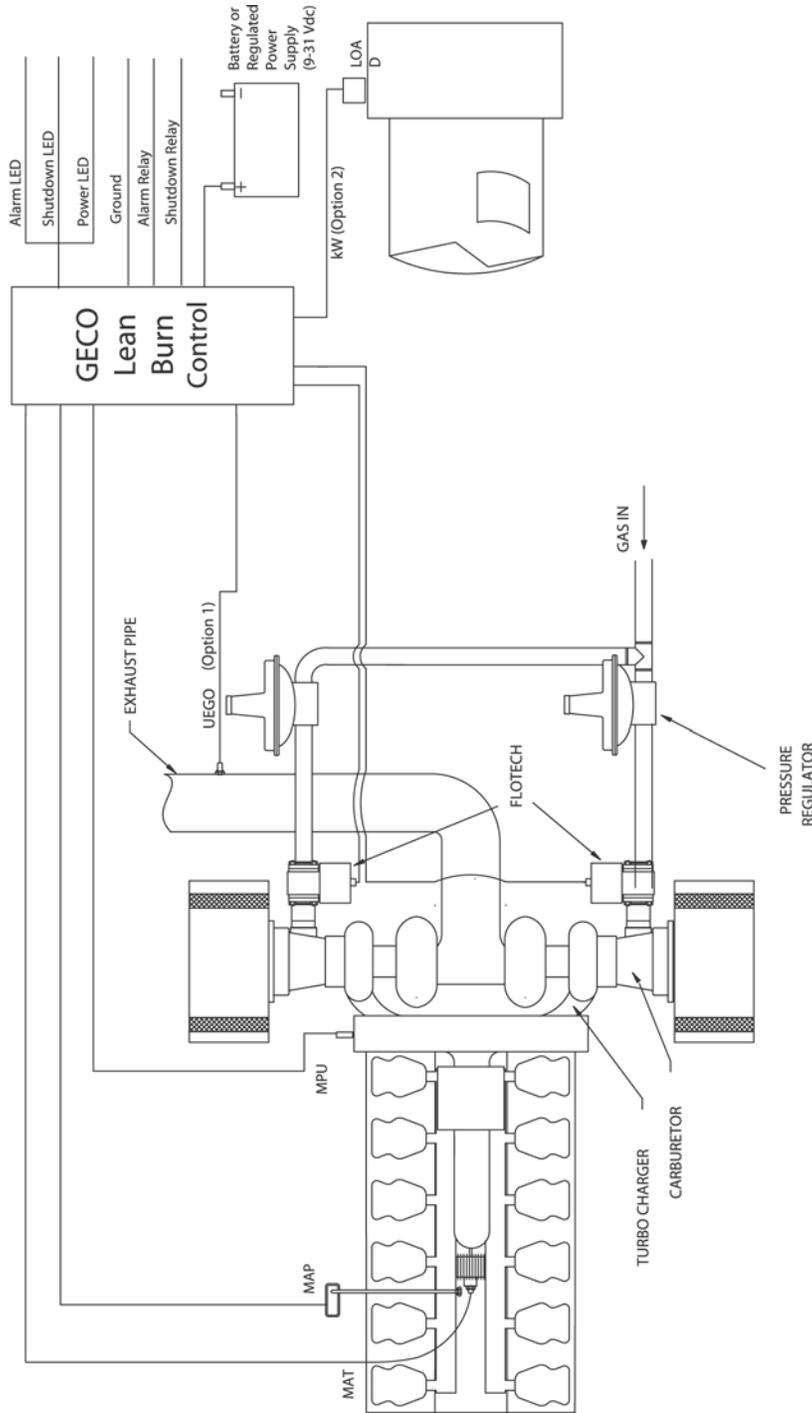


Figure 3-9. GECO System on Caterpillar 3500 with Low Pressure Impco Carburetion

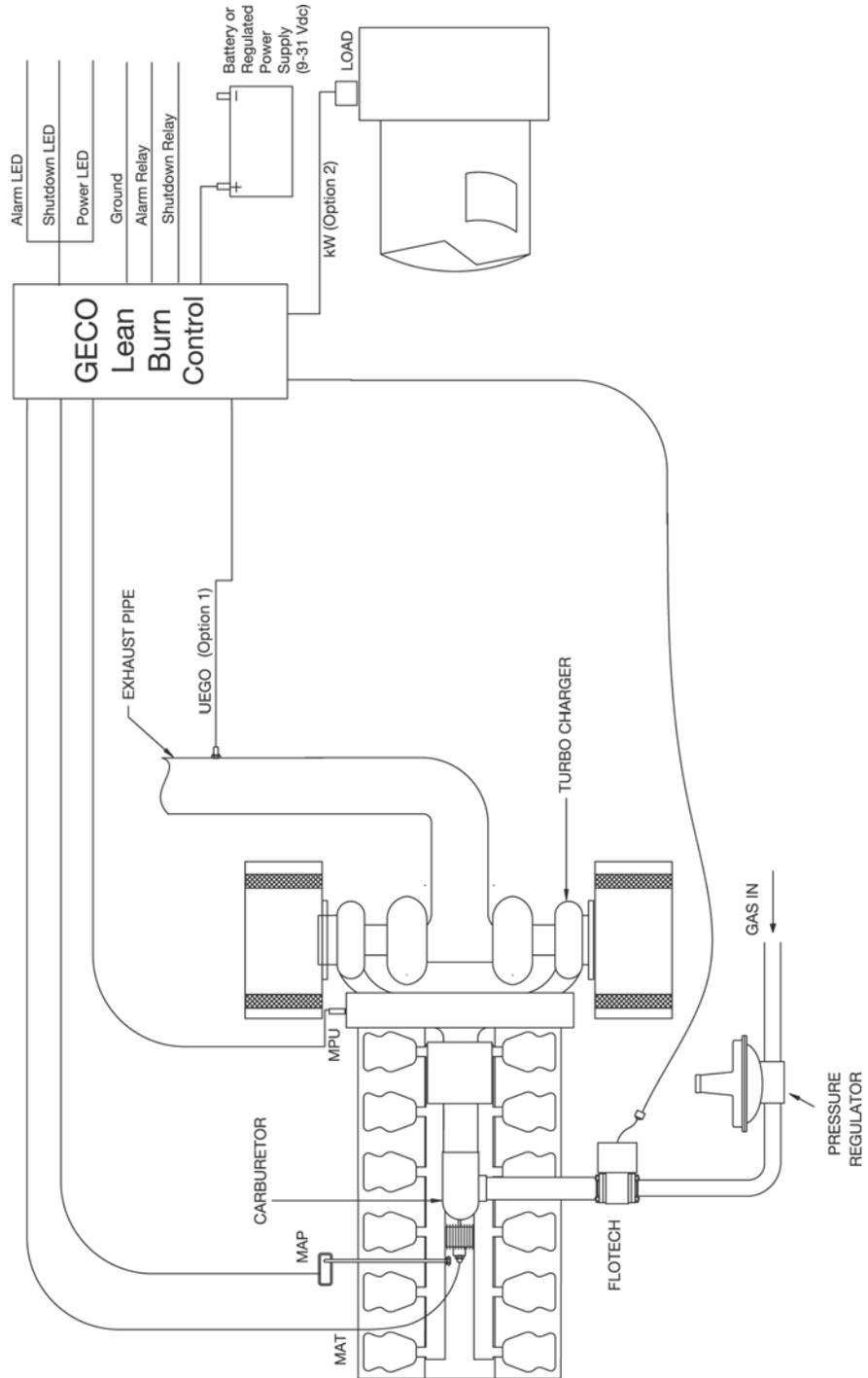


Figure 3-10. GECO System on Caterpillar 3500 with High Pressure Impco Carburetion

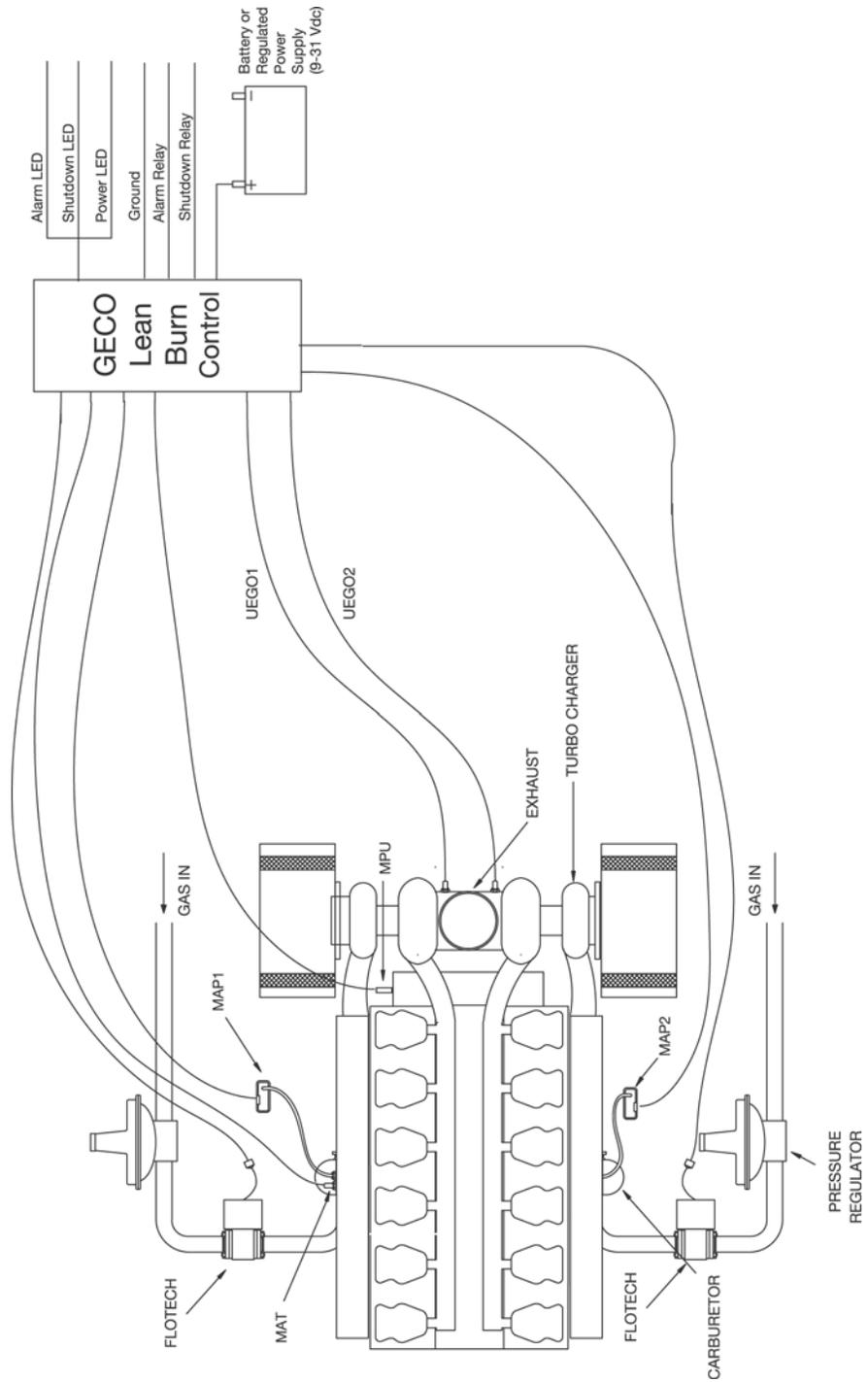


Figure 3-11. GECO System with UEGO Closed Loop Control on Waukesha 7042 with High Pressure Impco Carburetion

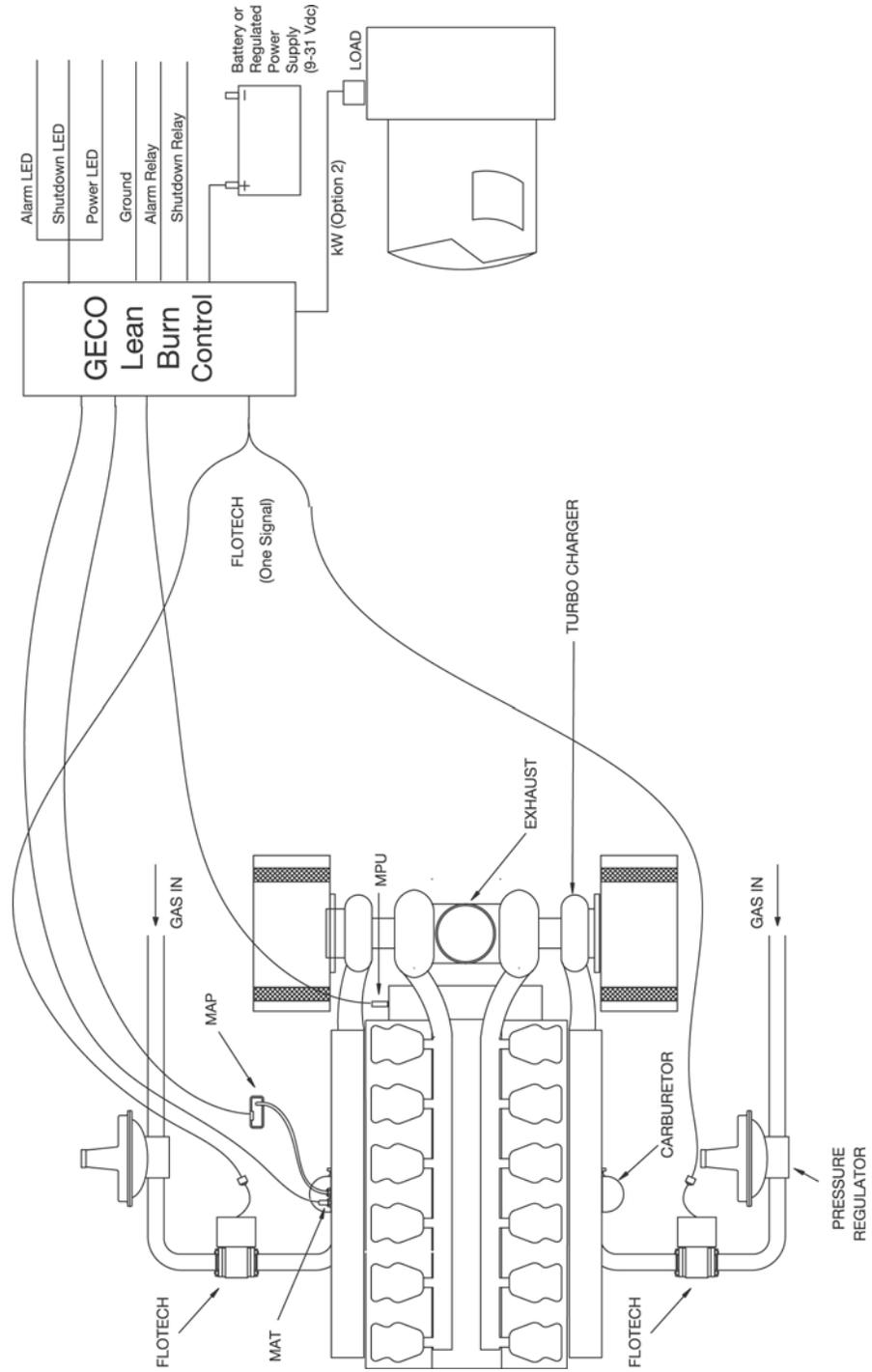


Figure 3-12. GECO System with KW Sensor Closed Loop Control on Waukesha 7042 with High Pressure Impco Carburetion

Chapter 4. System Components

Circuit Board Panel Assembly



[P/N 9907-866] The circuit board includes the microprocessor controller and all associated electronics for power regulation, signal inputs and filtering, controlled outputs, and communications. All system connections are made directly to the board through plug-in terminal strips and connectors. The board also includes a status indicator light, control mode switch, and a fuse.

Mounting

There are eight mounting holes in the circuit board. One 6.4 mm (0.250") hole is located at each corner and four 4.1 mm (0.160") holes are located at approximately the middle of each side. The lower left corner hole (the "power on" LED is at the "top" of the circuit board) also serves as a ground connection.

Connectors

The terminal strips around the edge of the circuit board are the connections for the analog and discrete I/O. There are 84 terminals total, but less than half will be used for a typical lean burn application.

The RJ-12 modular "telephone jack" connects the hand held terminal to the circuit board. See the section below in this chapter titled "Hand Held Terminal."



The 6-pin Molex connector next to the RJ12 connector provides a connection to a panel or remotely mounted LED display of power, alarm, and shutdown status. See the section below in this chapter titled "LED Status Indicators".

The "DB9" Subminiature 9-pin D connector is the RS232C connector for communications with the PC Service Tool software running on a laptop or desktop computer. A DB9 male-to-DB9 female RS232C cable is required to link the control to the computer. See the section below in this chapter titled "PC Service Tool Software". A null modem adapter is NOT required.

Power Indicator LED

The LED at the top of the circuit board indicates that power is currently applied to the circuit. Terminals 33 and 34 are the connection locations where 9–30 Vdc power is applied.

Toggle Switch

The toggle switch at the lower right corner of the circuit board provides a means to manually switch between Open Loop and Closed Loop control modes. When the switch handle is to the right, it is in Closed Loop mode.





Hand Held Terminal

[P/N 8928-395] A weather-resistant hand held terminal is stored inside the enclosure for monitoring of the GECO™·Lean Burn control. Data monitoring and fault checking and clearing can all be performed with this tool. Note that this hand held terminal is not interchangeable or compatible with other Woodward hand held programmers. See Chapter 5 for instructions on how to use the terminal.

The terminal features a 4 line, 20 character LCD display and a 24-key sealed membrane keypad. Communication with the control is through an RS-232, 6-pin RJ-12 connector (6-wire modular telephone jack). The specifications for this data

terminal are as follows:



WARNING

The GECO enclosure should not be opened when a hazardous atmosphere is present. Wiring connections which could cause sparks are available inside the cabinet.

EXPLOSION HAZARD—Do not disconnect while circuit is live unless area is known to be non-hazardous.

The GECO Control shall not be operated with the hand held terminal connected to the control when a hazardous atmosphere is present.

Operating Voltage:	4.8–5.3 Vdc (supplied by control)
Power Consumption:	150 mW, 470 mW with backlight
Communications:	RS-232 6-pin modular RJ-12 connector
Temperature Ratings:	
Ambient Operating Temperature:	0 to 50 °C (32 to 122 °F)
Storage Temperature:	–40 to +85 °C (–40 to +185 °F)



Enclosure

[P/N 1627-101] The circuit board and hand held terminal are enclosed in a rugged, powder-coated steel box. The enclosure is 305 x 254 x 127 mm (12 x 10 x 5 inches) with quick-release latches for easy access.

The environmental rating on this enclosure meets NEMA 12, NEMA 13, UL 50, IEC 60529, IP65, and JIC Standard EGP-1-1967. This means that the enclosure is designed to provide protection from dust, dirt, oil, and water.

There are no knockouts or pre-cut conduit openings in the enclosure. All four sides of the box are free of obstruction and available for conduit entry. We recommend locating knockouts in the bottom of the box. The entire circuit board assembly can be removed from the box by removing the four slotted screws in the mounting plate at the back of the box. This is recommended when conduit openings are added.

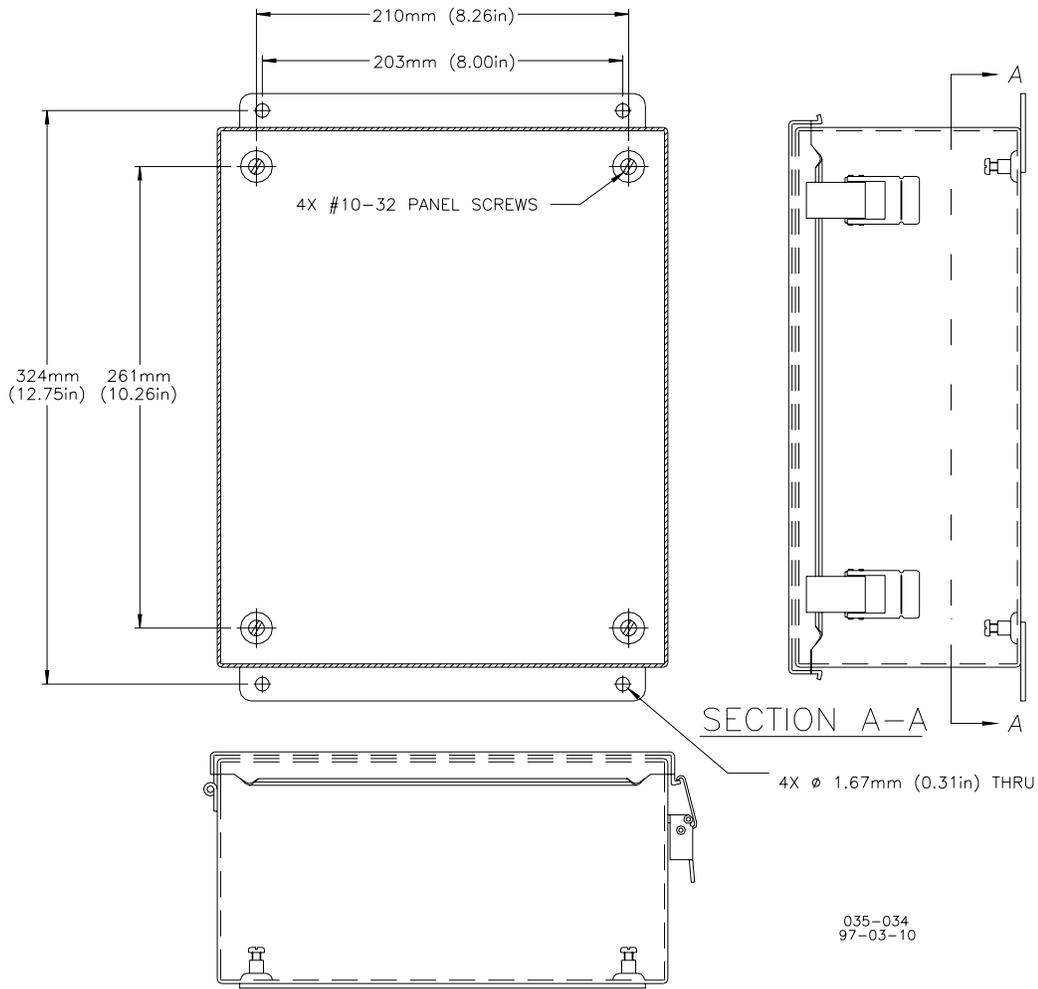


Figure 4-1. Mounting Dimensions

Flo-Tech™ Fuel Control Valve



[P/N 8235-142, 8235-160 or 8235-154] The Flo-Tech™ electrically-actuated valve controls fuel pressure to the air/fuel mixer. It is a butterfly-type valve available in 33, 48, 60, 68, and 75 mm bore sizes for various applications. The valve position responds proportionally to the position command signal.

Connector

The connector is a 6-pin automotive style. The Flo-Tech connector is the male or shroud. The mating connector is the female or tower, which is made up of one housing, five terminals, five wire seals, and one cavity plug.

This is available as a kit from your Woodward distributor (p/n 8923-371).

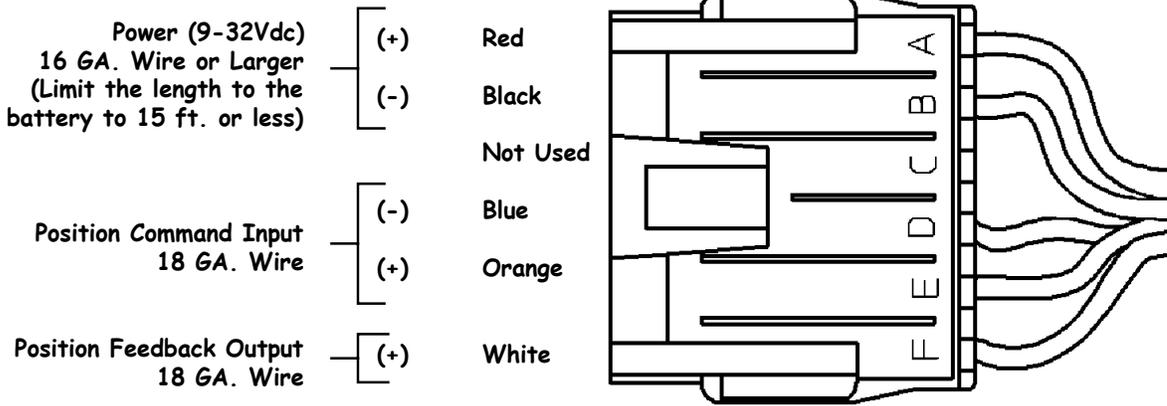


Figure 4-3. Connector Wiring Diagram

Command

The position command from the GECO·Lean Burn control is a 333 Hz, 0-20 V, pulse width modulated signal (PWM).

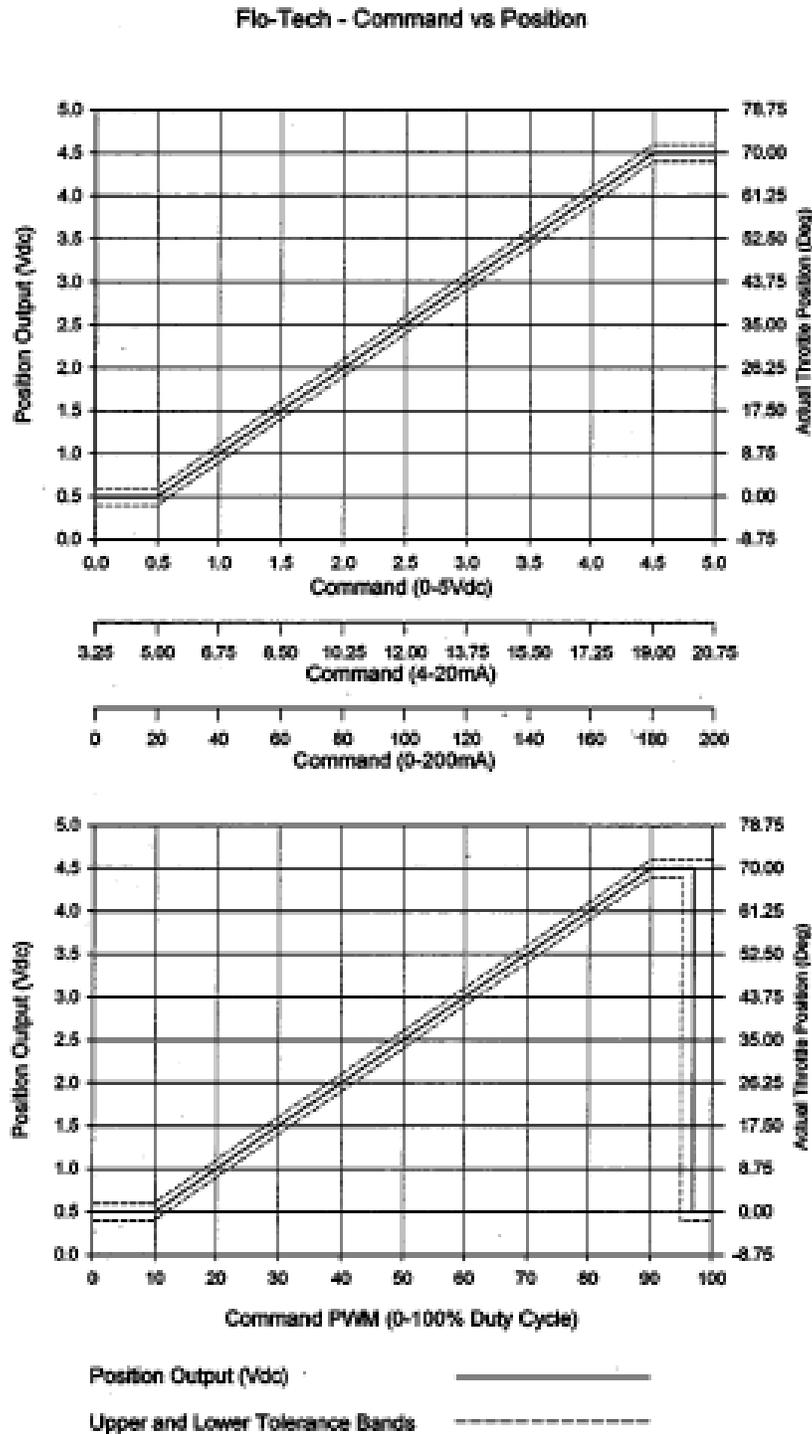


Figure 4-4. Command versus Position Feedback/Valve Position

Mounting Flanges

Each of the two mounting flanges on the valve housing has four 10 mm through-holes in a square 74 mm pattern. Note that the flange dimensions of the Flo-Tech 75 are different from the other Flo-Tech valves.

The base of the Flo-Tech actuator housing has an optional bolt pattern that can be used for mounting or support. It uses four M8x0.125 bolts in an 88.9 mm square pattern.

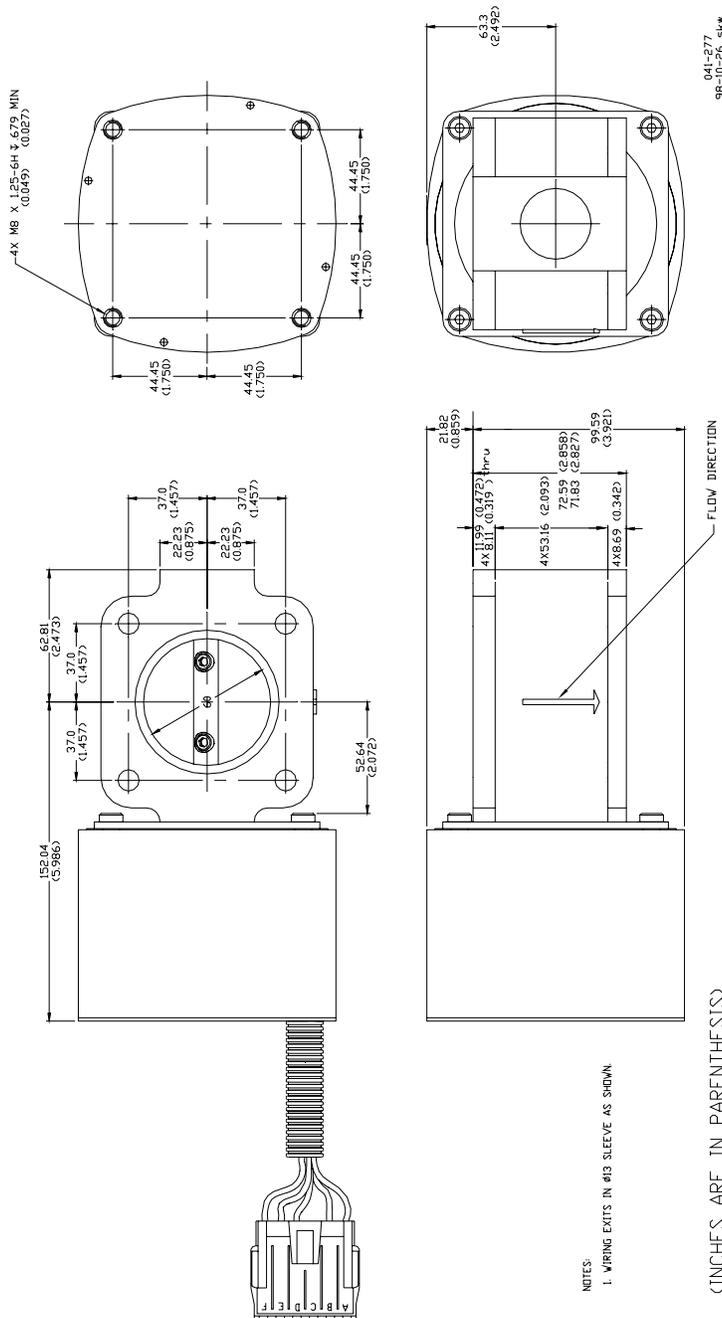
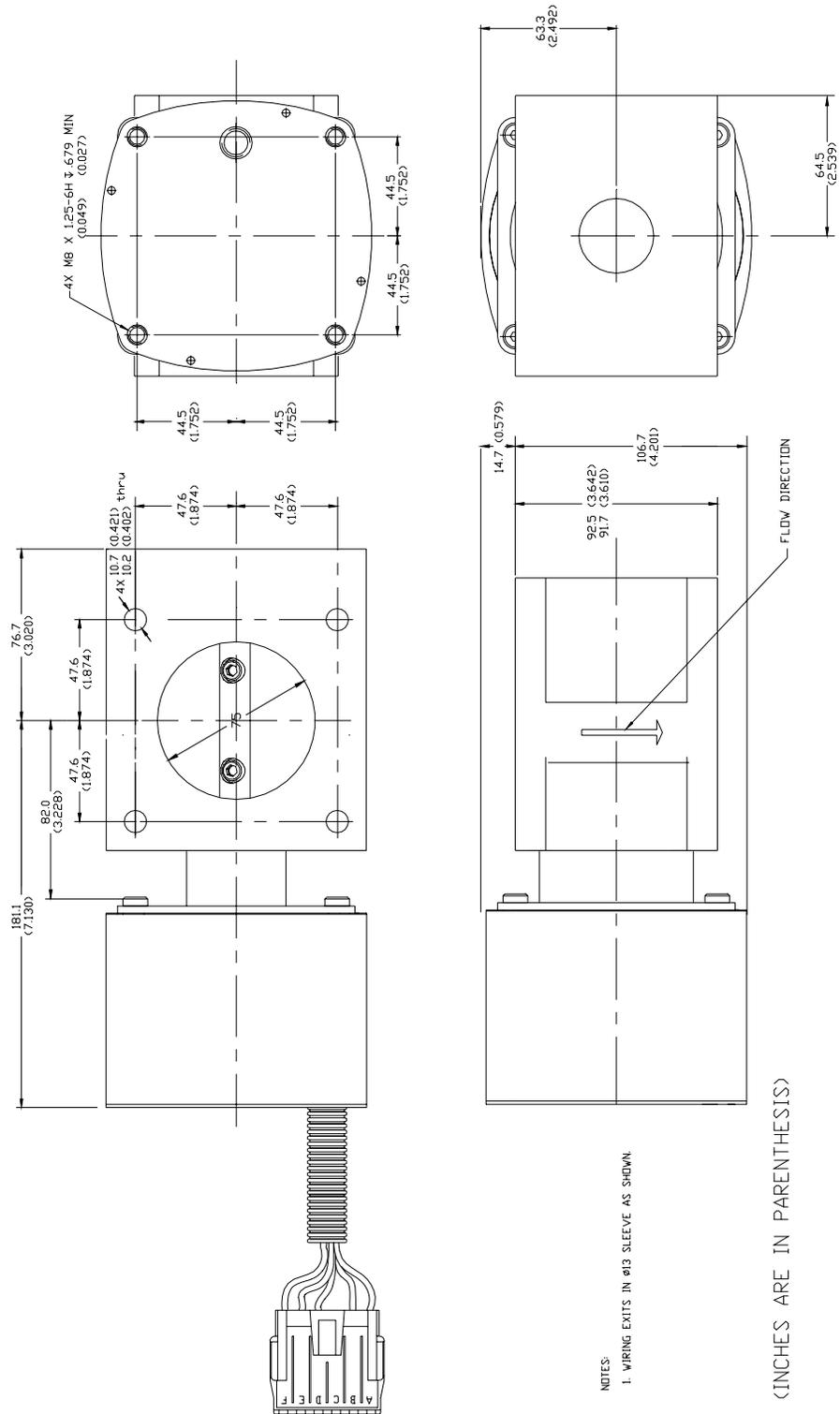


Figure 4-5. Flo-Tech Outline Drawing (33/48/60/68 mm bores)



041-278
98-10-28 skw

Figure 4-6. Flo-Tech Outline Drawing (75 mm bore)

UEGO Sensor



The Universal Exhaust Gas Oxygen sensor (UEGO) is used by the controller to measure the amount of oxygen in the exhaust gas. It is a wide-range oxygen sensor developed for the automotive industry. It is required when using the UEGO Closed Loop Control Mode (see Chapter 3).

This sensor is sometimes called the “5-wire sensor”. There are five wires between the sensor and the connector. However, between the connector and the control, there are seven wires.

The extra two wires provide the control with the correct sensor calibration, which is contained in a calibration resistor imbedded in the connector.

Connector wiring:

Terminal	Wire color	Function	GECO Terminal
1	–	unused	–
2	red	sensor cell	6
3	white	pumping cell	7
4	black	ground	8
5	orange	heater, 12V	12
6	yellow	heater, ground	11
7	–	calibration resistor	10
8	–	calibration resistor	9

The sensor connector is an automotive-style connector. This connector should not be removed because it contains the calibration resistor.

The sensor mounts in the exhaust with an M18x1.5 thread. Any gas leakage through the threaded fitting will cause erroneous measurements. These threads should be torqued to 41 ±5 N·m (30 ±4 lb-ft).

MAP Sensor



The Manifold Absolute Pressure sensor (MAP) is used by the controller to measure the intake manifold pressure. It is an absolute pressure sensor with a 300 kPa (43.5 psi) range and a 0–5 Vdc output signal. Like the UEGO sensor, it was developed for the automotive industry.

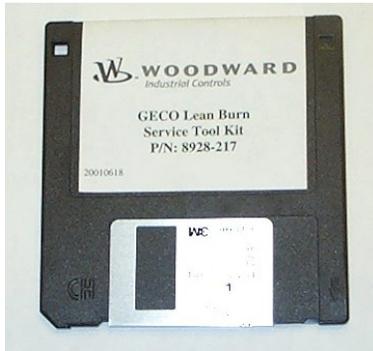
The intake manifold pressure signal comes to the MAP sensor via a 1/4" (6.4 mm) hose.

The mating connector is available from Woodward as a kit, p/n 8928-397. A crimping tool such as Packard Electric p/n 12014254 or similar is needed for the best connections.

Connector Wiring:

Terminal	Function	GECO Terminal
A	Ground	5
B	Signal	1
C	Power, 5 Vdc	4

PC Service Tool Software



[P/N 9927-236] The PC service tool software is executed on a Microsoft DOS compatible PC. When the COM1 or COM2 ports of the PC are connected to the RS232C port of the GECO·Lean Burn control (DB9 connector), the service tool software will provide monitoring and display of the set-up and tuning parameters of the GECO·Lean Burn control application software.

The RS 232C connection is made with a straight-through (no null modem adapter) cable,

9-pin “DB9” male to 9-pin “DB9” female.

Minimum PC requirements are:

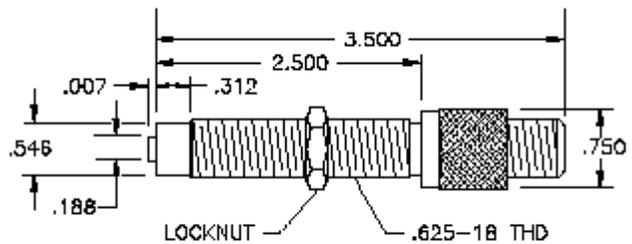
- Intel 486 processor
- 1 MB of RAM memory
- DOS 6.22, RS232C serial port
- [This software will NOT run on Windows NT®.]

RS 485

Terminals 63 and 64 on the edge of the circuit board are the RS 485 connection.

Speed Sensor

[P/N 202-816, 1680-622, or 1680-631] The speed sensor can be either a Magnetic Pick Up (MPU) or a signal from the ignition system “G-lead”. The control software must be configured for the speed signal source. Terminal 47 is for the “G-lead” input; terminals 49 and 50 are the MPU inputs.



1680-622 STANDARD LONG MAGNETIC PICKUP

MAT Sensor

The Manifold Air Temperature sensor (MAT) is used by the controller to measure the intake manifold temperature. Like the UEGO and the MAP sensors, it was developed for the automotive industry. The mating connector is available from Woodward, p/n 8928-398.



Connector wiring:

Terminal	Function	GECO Terminal
B or A	Ground	60
A or B	Signal	56

The MAT sensor mounts in the intake manifold with a 3/8" (9.5 mm) NPT pipe thread.

Watt Transducer



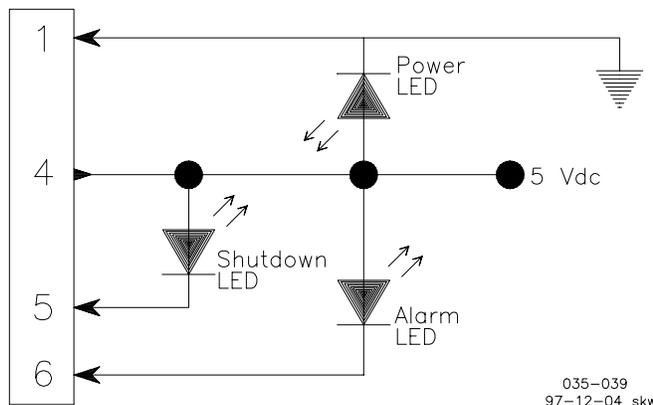
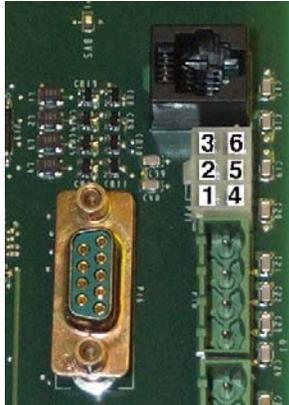
When the kW sensor closed loop control option is implemented with the GECO·Lean Burn control, the generator output power signal is required at terminals 55 and 60. This is a 4–20 mA signal scaled appropriately for the generator size. There are many watt transducers that can be used.

A transducer with a response time of approximately 250 ms for 0 to 90-percent is satisfactory. A signal from a digital device such as a PLC must be updated every 5–20 ms—updates over 50 ms will definitely result in unsatisfactory control performance.

Status Indicator LEDs

If the operator wishes to install LED lights for GECO·Lean Burn control power, alarm, and shutdown (with or without the alarm and shutdown relay outputs), the circuit board also includes a 6-pin connector specifically for indicator LEDs.

LED Wiring Diagram



The LEDs can be connected as in the wiring diagram above. Also, you can check with your GECO·Lean Burn distributor for availability of pre-wired, panel-mounted LED modules that include a DB9 connector for a PC, or an RS12 connector for the hand held terminal.

Chapter 5. Control Operation

Closed Loop Strategy

Although the GECO™·Lean Burn control has many features, its core function is lean burn air/fuel ratio control. The carburetor or mixer continues to be the primary air/fuel ratio controller and the GECO·Lean Burn control fine-tunes and trims the carburetor by adjusting the carburetor fuel supply pressure.

The Impco and Deltec carburetors have an air/fuel ratio adjustment called a “power screw”, “power valve”, or “main adjustment screw”. This adjustment is a manually operated valve that restricts the fuel flow to the air/fuel mixer. The fuel control valve of the GECO·Lean Burn control system (the Flo-Tech™ valve) is mounted in the fuel supply line to the carburetor and becomes an automatically variable air/fuel ratio adjustment for the carburetor, replacing the function of the “power valve”. The GECO·Lean Burn control continuously adjusts the air/fuel ratio setting of the carburetor to match the target value stored in the control software.

The control software stores the target air/fuel ratio value in the form of the equivalence ratio or phi value:

$$\text{Equivalence Ratio (phi)} = \frac{\text{Stoichiometric air/fuel ratio}}{\text{Actual air/fuel ratio}}$$

The stoichiometric air/fuel ratio (by volume) for pure methane fuel is 9.57:1. If 50-percent excess air is required for lean combustion, $1.50 \times 9.57 = 14.36$. The phi value is $9.57/14.36 = 0.67$.

An equivalence ratio of 1.0 is the same as a stoichiometric air/fuel ratio. An equivalence ratio of 0.50 means there is twice as much air as stoichiometric. Most lean burn engines will operate between 0.50 and 0.75. The control stores a target phi value for many points over the whole speed and load range of the engine. These stored values are in the form of a table. The columns of the table are engine load levels as measured by absolute intake manifold pressure. The rows of the table are engine speed values. Using the manifold pressure sensor (MAP) and the speed sensor (MPU or G-lead), the correct target phi value is selected from the table. An abbreviated example of the table is shown below:

RPM	MAP (psia)					
	0.00	8.00	16.0	24.0	32.0	40.0
0	1.000	1.000	1.000	0.800	0.750	0.750
200	1.000	1.000	0.850	0.750	0.700	0.700
400	1.000	0.920	0.770	0.680	0.650	0.650
600	1.000	0.850	0.700	0.650	0.620	0.620
800	1.000	0.780	0.680	0.620	0.600	0.600
1000	1.000	0.750	0.650	0.590	0.570	0.570
1200	1.000	0.720	0.630	0.550	0.540	0.540
1400	1.000	0.720	0.630	0.550	0.540	0.540

Equivalence Ratio

Option 1, the UEGO Sensor Closed Loop Control Mode, uses an exhaust oxygen measurement for actual air/fuel ratio feedback. This type of exhaust oxygen measurement requires a universal exhaust gas oxygen (UEGO) sensor. This sensor has a “pump” signal, a “sense” signal, a calibration resistor signal, and a sensor heater. The control uses all of these signals to measure the correct equivalence ratio. This measured value is compared to the target equivalence ratio in the control microprocessor. The control output is sent to the Flo-Tech valve in the form of a pulse-width modulated (PWM) signal.

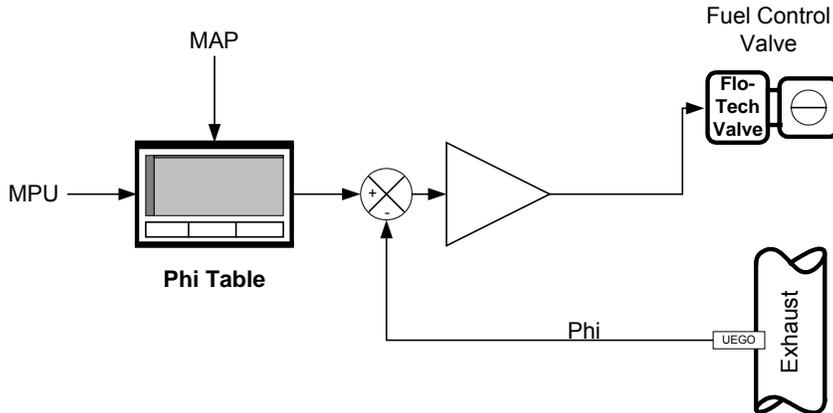


Figure 5-1. UEGO Closed Loop Control Mode Diagram

Option 2, the kW Sensor Closed Loop Control Mode, uses the selected target air/fuel ratio along with an engine efficiency calculation to estimate the engine power output. This estimated power is compared to the measured electrical power output of the generator. If the estimated power does not match the measured power, it is because the actual air/fuel ratio does not match the target air/fuel ratio and the control signal adjusts the Flo-Tech valve to correct.

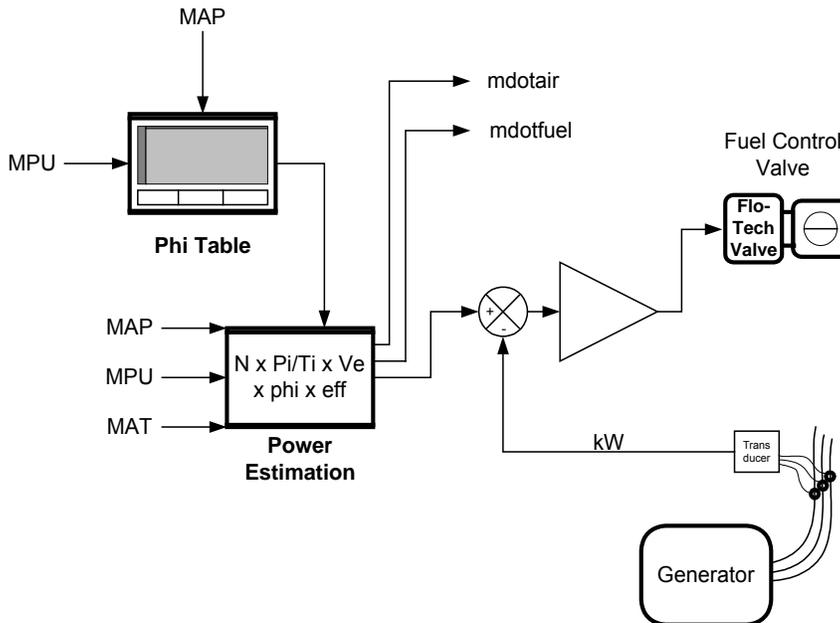


Figure 5-2. kW Sensor Closed Loop Control Mode Diagram

Open Loop Strategy

Open loop means that the closed loop feedback signal is not used or is not available. In the case of option 1, the closed loop feedback signal is the UEGO signal. In the case of option 2, the closed loop signal is the kW transducer measuring the generator output. If this signal is lost or unavailable, the control will automatically revert to open loop operation.

In open loop operation, the control commands the fuel control valve (Flo-Tech valve) to take a predetermined position stored in the control software. This position comes from what is called the Valve-Learn Table. The table contains eight “load” levels, and each level can have a different valve position command. Valve positions between the table values are interpolated. The “load” levels are not based on manifold pressure alone, but on a calculated and normalized fuel flow called “Mdot Fuel” in the software. “Mdot Fuel” is an intermediate value from the engine power calculation. It is approximately equal to the pounds per hour of fuel flow per liter of engine displacement. It requires the MAP and MPU sensor values for its calculation.

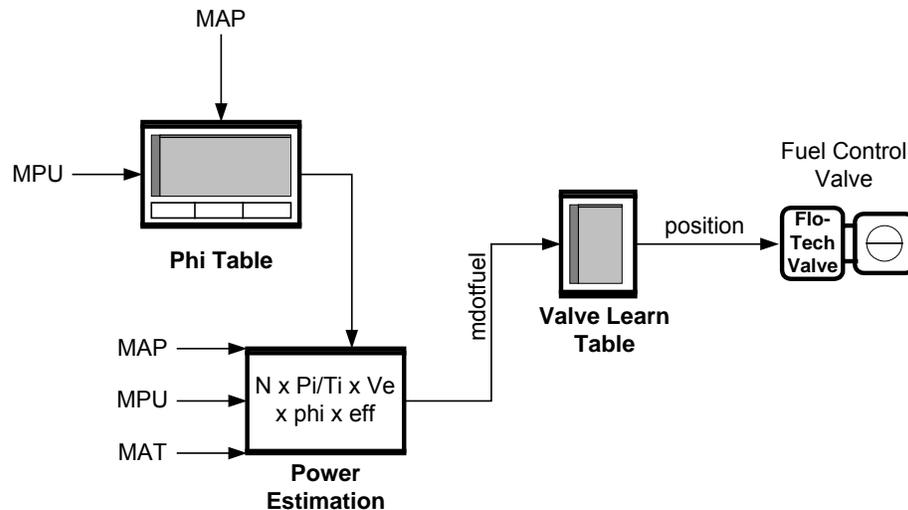


Figure 5-3. Open Loop Control Mode Diagram

These predetermined valve positions in the table are normally entered manually at the time of installation and setup. They can also be learned through an internal “Valve-Learn” function during normal closed loop operation. While the engine and control are operating in one of the closed loop modes, the control “reads” the correct valve position at the current load and enters it into the table for possible future use. This “Valve-Learn” function is disabled by entering a “0” in the “Valve-Learn Gain”. If the engine normally operates over a narrow load range and only learns a few values, it will not necessarily function properly when called upon. It is suggested that the Valve-Learn function only be used when an approximately correct Valve-Learn Table has already been entered manually.

The control can be switched into open loop operation at any time by switching the open-loop/closed-loop toggle switch (the CLE switch) located on the bottom right corner of the circuit board.

Start-up Strategy

During engine start-up, the sensors do not provide useful information for engine air/fuel ratio control operation. The GECO·Lean Burn control ignores most of these sensor readings and positions the Flo-Tech fuel control valve as a function of engine speed and air-flow. When the engine reaches “run” speed, it enables open loop operation. When sufficient load has been added to increase air-flow into the engine to the minimum value (Mdot_air Breakpoint), it enables closed loop operation.

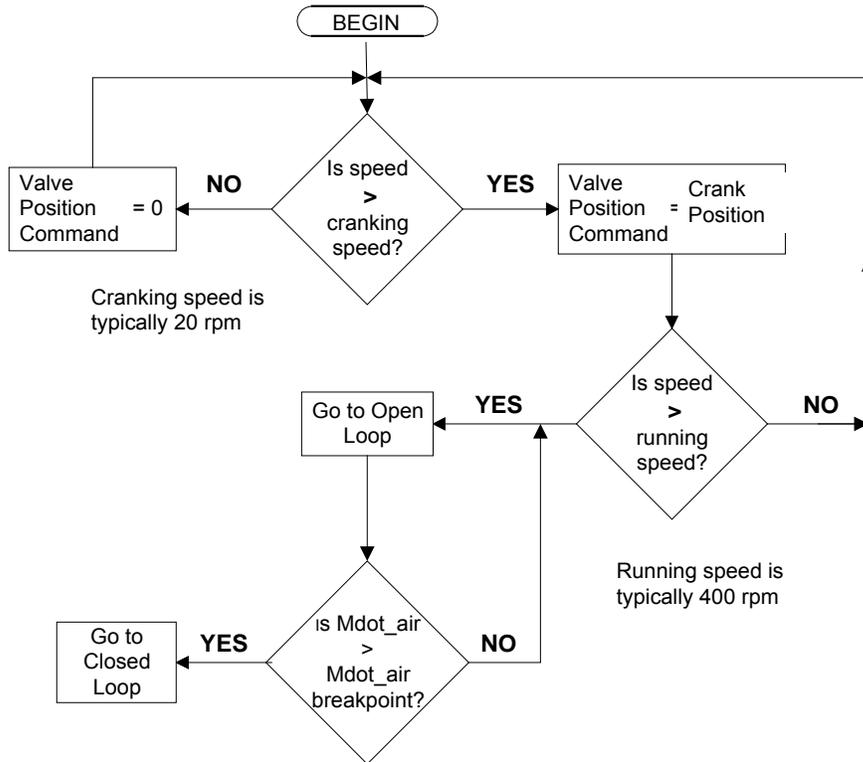


Figure 5-4. Start Sequence Flowchart

In more detail, when the engine is shut down, the MPU sensor reads 0 speed. At this time, the Flo-Tech valves are closed down to 0, effectively cutting off fuel flow to the engine. At cranking, the control looks for an engine speed of at least 100 rpm before opening the Flo-Tech valves to the “Crank Default” position. The valves remain at this position until the engine accelerates to approximately 450 rpm. At 450, the valve position control passes to the Valve-Learn Table. The valve position is taken from this table until the “Mdot_air breakpoint” is reached. Just as with the “Mdot Fuel” value, the power estimation calculation has a byproduct of “Mdot_air.” It is an approximate value of the pounds per hour of air-flow into the engine per liter of displacement. This value will, of course, rise as the engine speeds up and loads up. The “Mdot_air breakpoint” is the value of “Mdot_air” at which the closed loop control is activated. This value can be set at any level, but would typically be the value that represents approximately 50-percent load. At this time the control will move into closed loop operation.

Modbus Communication

The GECO·Lean Burn control serves as a Modbus “slave” unit and will respond to requests for information from a properly programmed “master”.

The table below gives some examples of the parameters available. A complete list is available in the Appendix . The register addresses in the proper Modbus format will provide the numerical or Boolean values. These values must then be scaled properly for meaningful information.

It is not necessary to read all of the information available. Modbus protocol allows you to read only the registers of interest.

This function is for information distribution and is not intended or capable of remote configuration or tuning.

Example of Modbus Register List

Address	Analog Description	Address	Boolean Description
1	Engine speed	1	MAP1 voltage high alarm
2	Intake manifold pressure - bank 1	2	MAT voltage high alarm
3	Intake manifold pressure - bank 2	6	MAP2 voltage high alarm
4	Average intake manifold pressure	7	Battery voltage high alarm
5	Exhaust back pressure - bank 1	9	MAP1 voltage low alarm
6	Exhaust back pressure - bank 2	10	MAT voltage low alarm
9	Intake manifold temperature	14	MAP2 voltage low alarm
12	Cold junction (controller) temperature	15	Battery voltage low alarm
13	Target maximum boost pressure	18	UEGOH1 voltage high alarm
30	Closed loop control value - bank 1	20	UEGOR1 voltage high alarm
31	Closed loop control value - bank 2	22	UEGOS1 voltage high alarm
34	Fuel valve command - bank 1	24	UEGOP1 voltage high alarm
35	Fuel valve command - bank 2	26	UEGOH1 voltage low alarm
36	Target equivalence ratio	28	UEGOR1 voltage low alarm
37	UEGO1 equivalence ratio - bank 1	30	UEGOS1 voltage low alarm
38	UEGO2 equivalence ratio - bank 2	32	UEGOP1 voltage low alarm
39	Controller supply voltage	35	TC2 lower than expected alarm
41	Measured generator output power	36	TC1 lower than expected alarm
42	Estimated generator output power	39	TC2 open (high) alarm
43	Estimated engine power	40	TC1 open (high) alarm
44	Estimated engine torque	58	MAT higher than expected alarm
45	Thermocouple 1 temperature	61	CL on bank 2 hit positive limit alarm
46	Thermocouple 2 temperature	62	CL on bank 2 hit negative limit alarm
		63	CL on bank 1 hit positive limit alarm
		64	CL on bank 1 hit negative limit alarm

Chapter 6.

Hand Held Terminal Operation

Hand Held Terminal Operation



The hand held terminal is designed to accommodate the day-to-day monitoring functions for operation of the GECO™·Lean Burn controller. The main uses are to review current operating conditions and check for any previous faults. When a fault condition is corrected, the terminal can be used to clear the fault indication and restore normal operation (some faults will deactivate closed loop control, activate the alarm relay, or activate both alarm and shutdown relays). More extensive control and fault configuration ability is available with an access code through the PC interface software. Contact your GECO·Lean Burn distributor for more information.

A hand held set-up mode is activated by holding down any key when power is applied. Although it should never be necessary to change this configuration, it can be initiated accidentally during power-up or when the unit is disconnected from the GECO·Lean Burn ECU board. The first screen displays “Contrast”. The 1 key will increase the LCD display contrast, and the 2 key will decrease it. The 3 key accepts the current value. The next screen displays “Baud: 9600”. This value must be at 9600 Baud for proper operation—the GECO·Lean Burn controller communicates only at this speed. The last set-up screen displays “DF: 8n1”. The data format must be 8n1 for proper operation.



WARNING

The GECO enclosure should not be opened when a hazardous atmosphere is present. Wiring connections, which could cause sparks, are located inside the cabinet.

EXPLOSION HAZARD—Do not disconnect while circuit is live unless area is known to be non-hazardous.

The GECO control shall not be operated with the hand held terminal connected to the control when a hazardous atmosphere is present.

The active keys and functions are described below. The control screens are described in the following section.

Hand Held Navigation and Control Keys

F4	This key is used to turn on the LCD screen backlight for 60 seconds. The backlight will make the screen readable in low-light conditions.
>	This key is used to skip to the next screen. Use of the shift key is not necessary.
ESC	
<	This key is used to skip to the previous screen. Use of the shift key is not necessary.
SPACE	
+	This key is used to move the blinking cursor to the next field left.
←	
-	This key is used to move the blinking cursor to the next field right.
→	
#	This key is used to move the blinking cursor to the next field up.
↑	
*	This key is used to move the blinking cursor to the next field down.
↓	
ENTER	This key is used to select the current field in order to change values or control parameters. Once a new value has been typed, press the key again to enter. Control parameter options are toggled by repeatedly pressing the key. This key is also used to clear a fault or shutdown status. If the fault condition is still present, the fault indication will immediately return.

Hand Held Terminal Control Screens

GECO Lean-Burn
 Hi BTU Fuel
 w/ kW Sensor
 9927-234-A 08/18/99

GECO Lean-Burn
 Hi BTU Fuel
 w/ UEGO Feedback
 9927-235-A 08/18/99

GECO Lean-Burn
 Low BTU Fuel
 w/ kW Sensor
 9927-233-A 07/30/99

CLEAR ALL CODES
 (review codes first)
 SHUTDOWNS: CLR
 ALARMS: CLR

Modes	
RUN MODE:	RUN
CONTROL MODE:	ADPT
MANUAL MODE:	OFF

RPM XXX	DCPwr XX.X
MAT XXX	
MAP XXX	
UEGO (Phi) X.XXX	

1.) On system power-up, the red power indicator light on the GECO·Lean Burn circuit board will illuminate and the hand held terminal will boot up with the title screen. The model number for the control software, along with the revision and revision date, will be displayed.

2.) If fault codes need to be cleared quickly to resume normal operation, all alarm and shutdown codes can be cleared from this screen. However, for trending, maintenance, and documentation, the individual codes should be reviewed and recorded first. If the cause for any fault has not been fixed, the fault will reactivate immediately. Press the ENTER key when a CLR field is blinking to clear all faults. Individual faults can be cleared one at a time on other screens as well.

3.) This screen shows the status of the various operating modes. RUN MODE indicates the status of the start sequencing. The fuel control valve is positioned differently depending on whether the engine is stopped (STOP), cranking (CRNK), or running (RUN). CONTROL MODE indicates whether the controlling function is in open loop (OPEN), closed loop (CLOSE), or closed loop-adaptive (ADPT) mode. MANUAL MODE can only be ON or OFF.

4.) The input sensor values are included on this screen: the engine speed (RPM), manifold air temperature (MAT), manifold absolute pressure (MAP), fuel/air ratio (UEGO or Phi), and the power supply voltage (DCPwr).

PhiTarg:	X.XXX
PhiAct:	X.XXX
PhiMod:	+X.X
Valve %:	XX.X

5.) The fuel/air ratio (Phi) monitoring screen displays the target (PhiTarg) and the measured (PhiAct) fuel/air ratios. The tuned modifier value (PhiMod) is also displayed along with the fuel control valve position in percent (Valve %).

ESTIMATED OUTPUT		
Eng Est	XXX	bhp
Gen Est	XXX	kW
Gen Act	XXX	kW

6.) This screen is only visible on the kW Sensor version of the GECO·Lean Burn control software. It shows the output of the engine (Eng Est) and the generator (Gen Est) as estimated by the control and the measured output of the generator (Gen Act).

3001 Gains		
CL Gain:		XX
Valve Learn:	XX	
Vlv Learn Ena:		ON

7.) The GECO·Lean Burn control gain values are displayed here. The closed loop gain value (CL Gain) controls system response and stability. Higher numbers produce faster control response, but stability is reduced. The valve learn gain (Valve Learn) determines how rapidly the control learns new open loop valve positions during normal engine operation. The valve learn enable value (Vlv Learn Ena) indicates the status of the valve learn function.

mdot fuel:	X.XX
mdot air:	XX.X
mdot air brk:	XX.X
fuel valve %:	XX.XX

8.) Calculated fuel mass flow per liter of engine displacement (mdot fuel). Calculated air mass flow per liter of engine displacement (mdot air). The tuned air mass flow breakpoint (mdot air brk) above which the valve learn function is active when the Valve Learn function is enabled. The fuel control valve position (fuel valve %).

Faults	Hi	Lo
MAT	OK	OK
MAP	OK	OK
MAT Hi	Exp	OK

9.) This screen shows faults associated with the manifold temperature and pressure signals. If the manifold air temperature (MAT) or the manifold absolute pressure (MAP) signals are out of range high or low, a fault will be indicated here. In addition, if the MAT is within range but higher than expected (MAT Hi Exp), a fault will be indicated.

Faults	Hi	Lo
kW Signal	OK	OK
kW Hi	Exp	OK

10.) This screen shows faults associated with the kW transducer signal. It only appears when the kW Sensor control is operating. If the kilowatt signal (kW Signal) is out of range high or low, a fault will be indicated here. In addition, if the kW is within range of the sensor but higher than expected (kW Hi Exp), a fault will be indicated.

Faults	Hi	Lo
Valve Lim	OK	OK
Valve Cur	OK	OK
Pwr Volt	OK	OK

11.) Faults associated with the fuel control valves or power supply are on this screen. If the fuel control valve has reached its limit, either high or low, a fault will be indicated here. If the valve current or power supply voltage is out of range high or low, a fault will also be indicated.

UEGO Faults	Hi	Lo
UEGO Sense	OK	OK
UEGO Pump	OK	OK

12.) Faults associated with the exhaust gas oxygen sensor signal (UEGO) are shown on the next two screens. These two screens appear only on the exhaust oxygen closed loop control. The UEGO Sense, UEGO Pump, Resistor, and Heater are all important parts of the exhaust oxygen sensor function.

UEGO Faults	Hi	Lo
Resistor		OK
OK		
Heater	OK	OK

13.) The miscellaneous Faults on this screen are for internal control operation and problems with the engine speed signal (MPU Noise). The SHUTDOWNS indicates if the Controller has shutdown the engine due to input faults that have been configured for shutdown.

Faults		
ECM: OK	MPU Noise :	OK
SHUTDOWNS		
Controller: OK		

GECO Internal Timers	
Running	X.X hours
Total	X hours

14.) GECO·Lean Burn control timer totals are shown on this screen. Running is the time in hours since the last engine start. Total is the total engine operating hours since the control was installed.

Chapter 7.

Oxygen Sensor Closed Loop Control (PC Interface Software Operation)



The PC service tool software is executed on a Microsoft DOS compatible PC. When the COM1 or COM2 ports of the PC are connected to the RS-232C port of the GECO™·Lean Burn control (DB9 connector), the service tool software will provide monitoring and display of the set-up and tuning parameters of the GECO·Lean Burn control application software.

The RS-232C connection is made with a straight-through (no null modem adapter) cable, 9-pin “DB9” male to 9-pin “DB9” female.

The GECO·Lean Burn PC software includes the interface screens with separate “frames” for related data or functions. The following sections explain operator navigation and describe the individual screens, frame by frame. Like the Hand Held Terminal, many of the frames indicate fault status, and these faults can be cleared using the ENTER key. In addition, the PC interface allows configuration changes.

To start the PC interface software operation:

1. With a DB9 male to DB9 female RS-232 cable, connect the on-line control DB9 female RS-232 port to the PC DB9 serial port.
2. Insert the diskette into drive A of your PC.
3. Find the directory of drive A in Windows Explorer.
4. Double click on the file called 9927-236.exe.

The control will attempt communication on COM1 and COM2 before closing on a failed communication attempt. If COM3 or COM4 is needed, it must be entered in the command line, “9927-236.exe – com3.” If metric units are needed, a “-siunits” flag is used, the default units are US.

Screen Navigation

All interface screens show the following reminders along the bottom of the screen:

ESC exit **ENTER** modify **SPACE** pause **PGUP-PGDN** screen **F2** save Tag Plot

The PgUp and PgDn (page up and page down) keys are used to toggle through each individual screen. Screens 3, 4, and 5 require password access (contact your GECO·Lean Burn distributor for more information). The interface screens also show a reverse-color cursor highlighting the current configurable variable. This cursor is moved to other variable locations with the arrow keys on the PC keyboard. To change a variable, press Enter when the variable is selected with the cursor. A command line will appear near the bottom of the screen where new values may be entered. In the case of a variable which has modes (rather than a numerical value), such as fault disable/enable/enable+shutdown, the modes can be toggled with the arrow keys, then selected with the ENTER key. The current text information from any screen can be saved to a file with the F2 function key. The ESC (escape) key will exit from the GECO·Lean Burn interface program.

Oxygen Sensor Closed Loop Control

Screen 1: GECO·Lean Burn UEGO Feedback Monitor

Engine		Status/Control	
Speed	1100 rpm	RunMode	RUNNING
MAP1	25.76 psia	Control1 Mode	CLOSED LOOP
MAP2	16.00 psia	Control2 Mode	OPEN LOOP
MAT	167 °F	UEGO1 Mode	OK
EGT1	77 °F	UEGO2 Mode	OFF
EGT2	77 °F	ShutdownRelay	OFF
DC Power	23.7 volts	ClsdLoopSwch	ON
Phi_Desired	0.608	Valve1 Cmd	+57.00 %
Phi_Actual1	0.620	Valve2 Cmd	+57.00 %
Phi_Actual2	0.000	Manual Mode	OFF
CL Gain	10 %	Valve State	ACTIVE
Est Power	742 bhp	Valve1 Current	0.75 amps
Est Torque	4119 ft-lbs	Valve2 Current	0.09 amps
Run Time	0000:01:15		
Hour Meter	22.2		

ESC exit ENTER clear-fault SPACE pause PGUP-PGDN screens F2 save Tag Plot

Screen 2: GECO·Lean Burn Adaptive Air/fuel Calibration

Engine		Valve-Learn Table	
Speed	1100 rpm	Mdot Fuel (lbm/hr/l)	Valve-Learn %
MAP_average	25.76 psia		Bank1 Bank2
MAT	167 °F	0.00	19.9 19.9
EGT1	77 °F	0.35	85.2 85.2
EGT2	77 °F	1.50	85.2 85.2
Phi_Desired	0.608	2.25	73.8 73.8
Phi_Actual1	0.620	3.00	67.2 67.2
Phi_Actual2	0.000	4.00	62.1 62.1
CL Gain	10 %	5.00	59.0 59.0
Valve-Learn Gain	10 %	11.00	57.0 57.0
Valve1 Cmd	+57.00 %	Valve-Learn Parameters	
Valve2 Cmd	+57.00 %	Mdot_fuel	3.43 lbm/hr/l
Manual Mode	OFF	Mdot_air	94.1 lbm/hr/l
Valve State	ACTIVE	Mdot_air breakpoint	39.0 lbm/hr/l
Control1 Mode	CLOSED LOOP	Mdot_fuel_change	1 %
Control2 Mode	OPEN LOOP	Mdot_fuel_trig	30 %
		Valve Defaults FIXED	

ESC exit ENTER clear-fault SPACE pause PGUP-PGDN screens F2 save Tag Plot



NOTE

Access to screens 3, 4, and 5 requires entering a password for configuration protection. Contact your GECO·Lean Burn distributor for more information.

Screen 3: GECO·Lean Burn UEGO Feedback Diagnostic Codes

3 GECO 3001 UEGO Feedback Diagnostic Codes ID:9927-235-A 08/27/99

Faults			Shutdowns		
ClearAll	High	Low	ClearAll	High	
MAP1 Sensor	133:FAULT	134:OK	Exhaust Temp	2:OK	
MAP2 Sensor	233:OK	234:OK			
MAT Sensor	123:OK	125:OK	Controller	1:OK	
MAT Higher Exp	124:OK				
CJC Sensor	191:OK	192:OK	Faults (continued)		
EGT1 Sensor	193:OK	194:OK		High	Low
EGT2 Sensor	195:OK	196:OK	Valve1 Limit	144:OK	145:OK
DC Power	153:OK	152:OK	Valve2 Limit	244:OK	245:OK
UEGO1 Sense	113:OK		Valve1 Current	186:OK	187:OK
UEGO1 Heater	158:OK	159:OK	Valve2 Current	286:OK	287:OK
UEGO1 Pump	163:OK	162:OK			
UEGO1 Resistor	168:OK	169:OK			
UEGO2 Sense	213:OK				
UEGO2 Heater	258:OK	259:OK		Misc	
UEGO2 Pump	263:OK	262:OK	ECU Processor	153:OK	
UEGO2 Resistor	268:OK	269:OK	MPU Noise	142:OK	

ESC exit ENTER clear-fault SPACE pause PGUP-PGDN screens F2 save Tag Plot

Screen 4: GECO·Lean Burn Phi Calibration

4 GECO 3001 Phi Calibration ID:9927-235-A 08/27/99

	MAP (psia)												
	0.00	3.20	6.40	9.60	12.80	16.00	19.20	22.40	25.60	28.80	32.00	35.20	
0	1.000	1.000	1.000	1.000	1.000	1.000	0.902	0.841	0.800	0.770	0.748	0.731	
120	1.000	1.000	1.000	1.000	0.995	1.000	0.889	0.827	0.785	0.758	0.738	0.723	
240	1.000	1.000	1.000	0.919	0.799	0.740	0.708	0.691	0.680	0.673	0.668	0.664	
360	1.000	1.000	0.934	0.769	0.713	0.686	0.672	0.665	0.660	0.657	0.655	0.641	
480	1.000	1.000	0.811	0.714	0.682	0.668	0.660	0.656	0.649	0.641	0.632	0.623	
600	1.000	1.000	0.753	0.689	0.669	0.660	0.653	0.648	0.640	0.631	0.622	0.612	
720	1.000	0.957	0.724	0.677	0.662	0.651	0.644	0.639	0.631	0.622	0.612	0.602	
840	1.000	0.885	0.704	0.669	0.658	0.643	0.633	0.628	0.620	0.611	0.602	0.591	
960	1.000	0.835	0.691	0.664	0.649	0.635	0.620	0.614	0.607	0.598	0.590	0.582	
1080	1.000	0.799	0.682	0.660	0.644	0.625	0.608	0.591	0.586	0.581	0.577	0.572	
1150	1.000	0.775	0.677	0.658	0.640	0.617	0.579	0.570	0.565	0.561	0.560	0.560	
1200	1.000	0.775	0.677	0.658	0.640	0.617	0.579	0.570	0.565	0.561	0.560	0.560	
1250	1.000	0.775	0.677	0.658	0.640	0.617	0.579	0.570	0.565	0.561	0.560	0.560	
1400	1.000	0.775	0.677	0.658	0.640	0.617	0.579	0.570	0.565	0.561	0.560	0.560	

Equivalence Ratio (Phi)			
RPM	1208 rpm	Phi Target	0.617
MAP_avg	16.00 psia	Phi Actual1	0.545
MAT	167 °F	Phi Actual2	0.000
CL Gain	10 %	Phi Modifier	+0.0 %
		Valve1 Cmd	+90.00 %
		Valve2 Cmd	+0.00 %
		Manual Mode	OFF
		Valve State	ACTIVE

ESC exit ENTER modify SPACE pause PGUP-PGDN screen F2 save Tag Plot

Screen 5: GECO·Lean Burn UEGO Feedback Configuration

Inputs		Fault Enables		Shutdown—Enable—Limit	
UEGO1	ON	MAT low	ENABLED	EGT1	DISABLED 1200 °F
UEGO2	OFF	MAT high	ENABLED	EGT2	DISABLED 1400 °F
MAT	ON	MAT high expect	ENABLED	Engine	
EGT1	OFF	EGT open	DISABLED	Cylinders	16
EGT2	OFF	EGT low expect	DISABLED	Displacement	69.0 L
MAP1	ON	NGP low	DISABLED	Rated Power	1088 bhp
MAP2	OFF	NGP high	DISABLED	Rated MAP	32.00 psia
NGP	OFF	NGP low expect	DISABLED	Rated RPM	1200 rpm
		NGP high expect	DISABLED	RPM Pulse/Rev	183
		Valve1 cur min	DISABLED	RPM Source	MAG-PU
Fuel Valves		Valve1 cur max	DISABLED	RPM Auto Mode	DISABLED
Valve 1	ON	Valve2 cur min	DISABLED	ModBus Configuration	
Valve 2	OFF	Valve2 cur max	DISABLED	Mode	OFF
Run Default	+57.0 %	MAP low	ENABLED	Parity	NONE
Crk Default	+85.0 %	MAP high	ENABLED	Baud	9600
		MAP high press	40.00 psia	Address	99
MAP Calibration		Miscellaneous		Access	USER
Unscaled	2.84 V	Barometer	14.50 psia	Activity	OFF
Scaled	25.76 psia			Mem Module	OK
Offset	+0.039 V				
Span	8.939 psi/V				

ESC exit ENTER modify SPACE pause PGUP-PGDN screen F2 save Tag Plot

The following is an explanation of the individual screen frames:

Screen 1: Engine

Engine	
Speed	943 rpm
MAP1	25.76 psia
MAP2	16.00 psia
MAT	167 °F
EGT1	77 °F
EGT2	77 °F
DC Power	23.7 volts
Phi_Desired	0.608
Phi_Actual1	0.620
Phi_Actual2	0.000
CL Gain	10 %
Est Power	742 bhp
Est Torque	4119 ft-lbs
Run Time	0000:01:15
Hour Meter	22.2

Speed—Engine rpm from magnetic pickup (MPU) or “G-lead”.

MAP1—Intake manifold absolute pressure in pounds per square inch.

MAP2—Second bank intake manifold absolute pressure in pounds per square inch.

MAT—Intake manifold air temperature in degrees Fahrenheit.

EGT1—Optional thermocouple input in degrees F.

EGT2—Optional thermocouple input in degrees F.

DC Power—Power supply voltage to the circuit board.

Phi_Desired—Air/fuel equivalence ratio set point target.

Phi_Actual1—Measured air/fuel equivalence ratio.

Phi_Actual2—Measured air/fuel

equivalence ratio for second bank.

CL Gain—Proportional gain of closed loop air/fuel ratio control, the range is 0 to 100%.

Est Power—Estimated engine power based on control inputs, in units of brake horsepower.

Est Torque—Estimated engine torque based on control inputs, in units of pound-feet (abbreviated here as ft-lbs).

Run Time—The time, in hours, since the last engine start.

Hour Meter—The total engine run time since the control was installed.

Screen 1: Status/Control

Status/Control			
RunMode		RUNNING	
Control1 Mode		CLOSED LOOP	
Control2 Mode		OPEN LOOP	
UEGO1 Mode		FAULT	
UEGO2 Mode		OFF	
ShutdownRelay		OFF	
ClsdLoopSwtch		ON	
Valve1 Cmd	+57.00	%	
Valve2 Cmd	+57.00	%	
Manual Mode		OFF	
Valve State		ACTIVE	
Valve1 Current	0.75	amps	
Valve2 Current	0.09	amps	

RunMode—STOPPED, CRANKING, RUNNING. These are the start sequence modes. Once the engine reaches idle speed, it should be in the RUNNING mode.

Control1 Mode—OPEN LOOP, CLOSED LOOP, ADAPTIVE. These are the air/fuel ratio control modes.

Control2 Mode—(same)
UEGO1 Mode—FAULT, OFF, ON, INIT-1, INIT-2. The status of the UEGO sensor circuit. INIT-1 and INIT-2 are phases of the start sequence.

UEGO2 Mode—(same)
ShutdownRelay—OFF, ON. The state of the shutdown output.
ClsdLoopSwtch—OFF, ON. The position of the closed loop switch on the circuit board.

Valve1 Cmd—Fuel control valve

PWM position command in units of duty cycle percentage.

Valve2 Cmd—Second bank fuel control valve PWM position command in units of duty cycle percentage.

Manual Mode—OFF, ON. This mode can be activated only while in the OPEN LOOP control mode. It allows for manual positioning of the control valves.

Valve State—ACTIVE or HOLDING. This indicates the fuel control valve status as to whether it is holding a fixed value or actively adjusting to maintain a set point.

Valve1 Current—Fuel control valve command signal current in amperes.

Valve2 Current—Second bank fuel control valve command signal current in amperes.

Screen 2: Engine

Engine			
Speed	948	rpm	
MAP_average	25.76	psia	
MAT	167	°F	
EGT1	77	°F	
EGT2	77	°F	
Phi_Desired	0.608		
Phi_Actual1	0.620		
Phi_Actual2	0.000		
CL Gain	10	%	
Valve-Learn Gain	0	%	
Valve1 Cmd	+57.00	%	
Valve2 Cmd	+57.00	%	
Manual Mode	OFF		
Valve State	ACTIVE		
Control1 Mode	CLOSED LOOP		
Control2 Mode	OPEN LOOP		

Speed—Engine rpm from magnetic pickup (MPU) input.

MAP_average—Manifold absolute pressure in pounds per square inch. If the second bank pressure sensor is used, this is the average of the two MAP values.

MAT—Manifold air temperature in degrees Fahrenheit.

EGT1—Optional thermocouple input in degrees F.

EGT2—Optional thermocouple input in degrees F.

Phi_Desired—Air/fuel equivalence ratio set point target.

Phi_Actual1—Actual measured air/fuel equivalence ratio.

Phi_Actual2—Actual measured air/fuel equivalence ratio of a independent second bank.

CL Gain—Proportional gain of closed loop air/fuel ratio control, the range is 0 to 100%.

Valve-Learn Gain—The rate at which the ADAPTIVE control learns new Open Loop fuel valve positions. The control is shipped with the Valve-Learn Gain set to 0%. The control will not learn any new valve positions until this gain value is raised. This should be done only after the engine and control have been set up and calibrated to prevent learning of erroneous valve positions.

Valve1 Cmd—Fuel control valve PWM position command in units of duty cycle percentage.

Valve2 Cmd—Second bank fuel control valve PWM position command in units of duty cycle percentage.

Manual Mode—OFF, ON. This mode can be activated only when in the OPEN LOOP control mode. It allows for manual positioning of the control valves.

Valve State—HOLDING

Control1 Mode—OPEN LOOP, CLOSED LOOP, ADAPTIVE. These are the air/fuel ratio control modes.

Control2 Mode—OPEN LOOP, CLOSED LOOP, ADAPTIVE. These are the second bank air/fuel ratio control modes.

Screen 2: Valve Learn Table

Valve-Learn Table		
Mdot Fuel (lbm/hr/l)	Valve-Learn %	
	Bank1	Bank2
0.00	19.9	19.9
0.35	85.2	85.2
1.50	85.2	85.2
2.25	73.8	73.8
3.00	67.2	67.2
4.00	62.1	62.1
5.00	59.0	59.0
11.00	57.0	57.0

Mdot Fuel—These values represent the operating range of the engine in terms of fuel mass flow per liter of engine displacement. These eight values should be evenly distributed from idle to full power. The highlighted values are the two values between which the control is interpolating an open loop valve position command.

Valve-Learn %—The learned fuel valve position commands that the control will use in the event that OPEN LOOP mode is activated for any reason. A position is learned for each load point represented by the Mdot Fuel values above. New values are learned only when the engine is operating in a steady state. When utilized, actual fuel valve position command values are interpolated from the two closest values from the table.

Screen 2: Valve Learn Parameters

Valve-Learn Parameters		
Mdot_fuel	3.43	lbm/hr/l
Mdot_air	94.1	lbm/hr/l
Mdot_air breakpoint	39.0	lbm/hr/l
Mdot_fuel_change	1	%
Mdot_fuel_trig	30	%
Valve Defaults	Variable	

Mdot_fuel—The current calculated fuel mass flow value in units of pounds per hour per liter of engine displacement.

Mdot_air—The current calculated air mass flow value in pounds per hour per liter of engine displacement.

Mdot_air breakpoint—The value of air mass flow above which the closed loop function is enabled. Also, it divides “high loads” from “low loads” for purposes of blocking the Valve-Learn function.

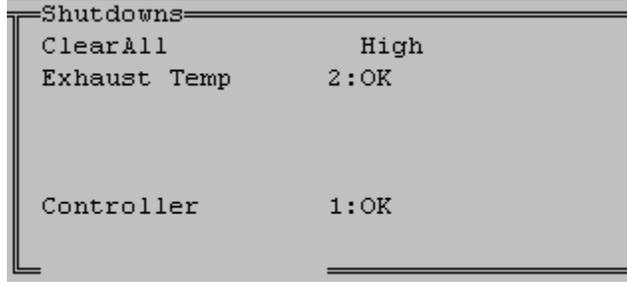
Mdot_fuel_change—The current fuel flow derivative or rate of change in units of percent per second. This is a measure of the magnitude of engine transient response to a load change.

Mdot_fuel_trig—The trigger point at which the control temporarily switches to OPEN LOOP mode and utilizes the Valve-Learn table for better transient response by the controller.

Valve Defaults—FIXED, VARIABLE (ALL LOADS), VARIABLE (LOW LOADS), VARIABLE (HIGH LOADS). This, in conjunction with Mdot air breakpoint, determines what portion of the Valve-Learn table is available to the Valve-Learn function. It should remain on VARIABLE (ALL LOADS) unless consultation with your authorized GECO·Lean Burn distributor confirms that a change is needed.

MPU Noise—The control is measuring an unreasonably high speed. Noise on the MPU signal would cause this.

Screen 3: Shutdowns



ClearAll—Clears all alarm faults.

Exhaust Temperature—If exhaust temperature thermocouples are used, they can be configured to shut the engine down when the alarm is tripped. This indicates if that is the cause of a shutdown.

Controller—This will indicate if the controller has triggered a shutdown command.

Screen 4: Equivalence Ratio (Phi) Table

4		GECO 3001 Phi Calibration										ID:9927-235-A	08/27/99		
		MAP (psia)													
		0.00	3.20	6.40	9.60	12.80	16.00	19.20	22.40	25.60	28.80	32.00	35.20		
	0	1.000	1.000	1.000	1.000	1.000	1.000	0.902	0.841	0.800	0.770	0.748	0.731		
	120	1.000	1.000	1.000	1.000	0.995	1.000	0.889	0.827	0.785	0.758	0.738	0.723		
	240	1.000	1.000	1.000	0.919	0.799	0.740	0.708	0.691	0.680	0.673	0.668	0.664		
	360	1.000	1.000	0.934	0.769	0.713	0.686	0.672	0.665	0.660	0.657	0.655	0.641		
R	480	1.000	1.000	0.811	0.714	0.682	0.668	0.660	0.656	0.649	0.641	0.632	0.623		
P	600	1.000	1.000	0.753	0.689	0.669	0.660	0.653	0.648	0.640	0.631	0.622	0.612		
M	720	1.000	0.957	0.724	0.677	0.662	0.651	0.644	0.639	0.631	0.622	0.612	0.602		
	840	1.000	0.885	0.704	0.669	0.658	0.643	0.633	0.628	0.620	0.611	0.602	0.591		
	960	1.000	0.835	0.691	0.664	0.649	0.635	0.620	0.614	0.607	0.598	0.590	0.582		
	1080	1.000	0.799	0.682	0.660	0.644	0.625	0.608	0.591	0.586	0.581	0.577	0.572		
	1150	1.000	0.775	0.677	0.658	0.640	0.617	0.579	0.570	0.565	0.561	0.560	0.560		
	1200	1.000	0.775	0.677	0.658	0.640	0.617	0.579	0.570	0.565	0.561	0.560	0.560		
	1250	1.000	0.775	0.677	0.658	0.640	0.617	0.579	0.570	0.565	0.561	0.560	0.560		
	1400	1.000	0.775	0.677	0.658	0.640	0.617	0.579	0.570	0.565	0.561	0.560	0.560		

Equivalence Ratio (Phi)						
RPM	1208	rpm	Phi Target	0.617	Valve1 Cmd	+90.00 %
MAP_avg	16.00	psia	Phi Actual1	0.545	Valve2 Cmd	+0.00 %
MAT	167	°F	Phi Actual2	0.000	Manual Mode	OFF
CL Gain	10	%	Phi Modifier	+0.0 %	Valve State	ACTIVE

ESC exit ENTER modify SPACE pause PGUP-PGDN screen F2 save Tag Plot

Table Column Headings: MAP, psia—Intake manifold ABSOLUTE pressure.

Table Row Headings: RPM—Engine speed.

Table Values: Equivalence Ratio (Phi)—Air/fuel equivalence ratio (the inverse of lambda, λ) for the respective engine operating parameters.

RPM—Engine speed in revolutions per minute.

MAP_avg—Average of the two intake manifold pressures if two are used.

MAT—Intake manifold air temperature in degrees Fahrenheit.

CL Gain—Proportional gain of the exhaust oxygen air/fuel control loop.

Phi Target—Air/fuel equivalence ratio set point target from the appropriate point on the table.

Phi Actual1—Air/fuel equivalence ratio feedback from the oxygen sensor.

Phi Actual2—Second bank air/fuel equivalence ratio feedback.

Phi Modifier—Value of the equivalence ratio calibration table modifier.

Valve1 Cmd—Fuel valve command signal duty cycle in percent.

Valve2 Cmd—Second bank fuel valve command signal duty cycle in percent.

Manual Mode—OFF, ON. This mode can be activated only when in the OPEN LOOP control mode. It allows for manual positioning of the control valves.

Valve State—HOLDING or ACTIVE. The fuel control valve is holding a position, as it would in OPEN LOOP mode or MANUAL MODE, or it is actively moving to hold the set point.

Screen 5: Inputs

Inputs	
UEGO1	ON
UEGO2	OFF
MAT	ON
EGT1	OFF
EGT2	OFF
MAP1	ON
MAP2	OFF
NGP	OFF

UEGO1—Oxygen sensor input is ON or OFF, terminals 6-12. During the software configuration phase of the installation. The inputs that will be utilized by the control for the specific application should be turned on here.

UEGO2—Second bank oxygen sensor input is ON or OFF, terminals 13-19.

MAT—The manifold air temperature sensor input is ON or OFF, terminals 56 & 60. If it is OFF, a default value for MAT will be used by the control.

EGT1—Optional thermocouple sensor input is ON or OFF, terminals 71 & 72.

EGT2—Optional thermocouple sensor input is ON or OFF, terminals 73 & 74.

MAP1—The intake manifold absolute pressure sensor input is ON or OFF, terminals 1, 4 & 5.

MAP2—The second bank intake manifold absolute pressure sensor input is ON or OFF, terminals 54, 59 & 60.

NGP—An optional 5 Vdc input is ON or OFF, terminals 3 & 5.

Screen 5: Fuel Valves

Fuel Valves	
Valve 1	ON
Valve 2	OFF
Run Default	+57.0 %
Crk Default	+85.0 %

Valve 1—The fuel control valve output channel is ON or OFF, terminals 20 & 21.

Valve 2—The second bank fuel control valve output channel is ON or OFF, terminals 22 & 23.

Run Default—This is the fuel control valve position command that is used if the CLOSED LOOP and OPEN LOOP control functions are both disabled.

Crank Default—This is the fuel control valve position command that is used during the start sequence when the control detects that the engine is in a “cranking” mode. When the control measures an engine speed between 20 and 400 rpm, it assumes that an engine start is underway and opens the fuel control valves to this position. This default value should be chosen to facilitate engine startup.

Screen 5: MAP Calibration

MAP Calibration		
Unscaled	2.84	V
Scaled	25.76	psia
Offset	+0.039	V
Span	8.939	psi/V

This frame is for calibrating the MAP sensor input channels. Adjust the offset and span to achieve the proper scaling. Both MAP1 and MAP2 must have the same scaling.

Unscaled—This is the voltage reading from the MAP sensor.

Scaled—This is the MAP sensor reading converted to engineering units, normally psia.

Offset—This is the offset value used by the control to convert the unscaled MAP voltage to the scaled engineering units.

Span—This is the span value used by the control to convert the unscaled MAP voltage to the scaled engineering units.

Screen 5: Fault Enables

Fault Enables	
MAT low	ENABLED
MAT high	ENABLED
MAT high expect	ENABLED
EGT open	DISABLED
EGT low expect	DISABLED
NGP low	DISABLED
NGP high	DISABLED
NGP low expect	DISABLED
NGP high expect	DISABLED
Valve1 cur min	DISABLED
Valve1 cur max	DISABLED
Valve2 cur min	DISABLED
Valve2 cur max	DISABLED
MAP low	ENABLED
MAP high	ENABLED
MAP high press	40.00 psia

This frame is for enabling the fault detection software for each of the input channels.

MAT low—ENABLED, ENABLED+SD, or DISABLED.

MAT high—ENABLED, ENABLED+SD, or DISABLED.

MAT high expect—ENABLED, ENABLED+SD, or DISABLED.

EGT open—ENABLED, ENABLED+SD, or DISABLED.

EGT low expect—ENABLED, ENABLED+SD, or DISABLED.

NGP low—ENABLED, ENABLED+SD, or DISABLED.

NGP high—ENABLED, ENABLED+SD, or DISABLED.

NGP low expect—ENABLED, ENABLED+SD, or DISABLED.

NGP high expect—ENABLED, ENABLED+SD, or DISABLED.

Valve 1 cur min—ENABLED, ENABLED+SD, or DISABLED.

Valve 1 cur max—ENABLED, ENABLED+SD, or DISABLED.

Valve 2 cur min—ENABLED, ENABLED+SD, or DISABLED.

Valve 2 cur max—ENABLED, ENABLED+SD, or DISABLED.

MAP low—ENABLED, ENABLED+SD, or DISABLED.

MAP high—ENABLED, ENABLED+SD, or DISABLED.

MAP high press—This is the pressure value above which the MAP sensor is considered to have failed.

Screen 5: Miscellaneous

Miscellaneous	
Barometer	14.50 psia

Barometer—Set the average atmospheric pressure at the engine site to adjust the control for altitude.

Screen 5: Shutdown Enables

Shutdown	Enable	Limit
EGT1	DISABLED	1200 °F
EGT2	DISABLED	1400 °F

EGT1—ENABLED or DISABLED.

EGT2—ENABLED or DISABLED.

Screen 5: Engine Configuration

Engine	
Cylinders	16
Displacement	69.0 L
Rated Power	1088 bhp
Rated MAP	32.00 psia
Rated RPM	1200 rpm
RPM Pulse/Rev	183
RPM Source	MAG-PU
RPM Auto Mode	DISABLED

Cylinders—Number of engine power cylinders.

Displacement—Engine nominal displacement in liters.

Rated Power—Engine rated brake horsepower.

Rated MAP—Intake manifold absolute pressure at rated power.

Rated RPM—Engine rated speed.

RPM Pulse/Rev—The number of gear teeth per revolution seen by the magnetic pickup.

RPM Source—Magnetic pickup or G-lead. This identifies the source of the speed signal.

RPM Auto Mode—ENABLED or DISABLED. When DISABLED, the start sequence switches from CRANKING to RUNNING at 450 rpm. When ENABLED, this switch takes place at a speed calculated from the Rated RPM. This allows the control to be used on engines that run at less than 450 rpm. A 300 rpm engine will switch at 250 rpm.

Screen 5: Modbus Configuration

ModBus Configuration	
Mode	OFF
Parity	NONE
Baud	9600
Address	99
Access	USER
Activity	OFF
Mem Module	OK

Mode—MODBUS ASCII, MODBUS RTU, or OFF

Parity—EVEN, ODD, or NONE

Baud—Choice of possible communication baud rates.

Address—Two-digit numerical slave address.

Access—USER or OPERATOR

Activity—YES or NO, this indicates if the control is recognizing communication activity on the RS485 port.

Mem Module—OK indicates that the Modbus circuitry is functioning properly.

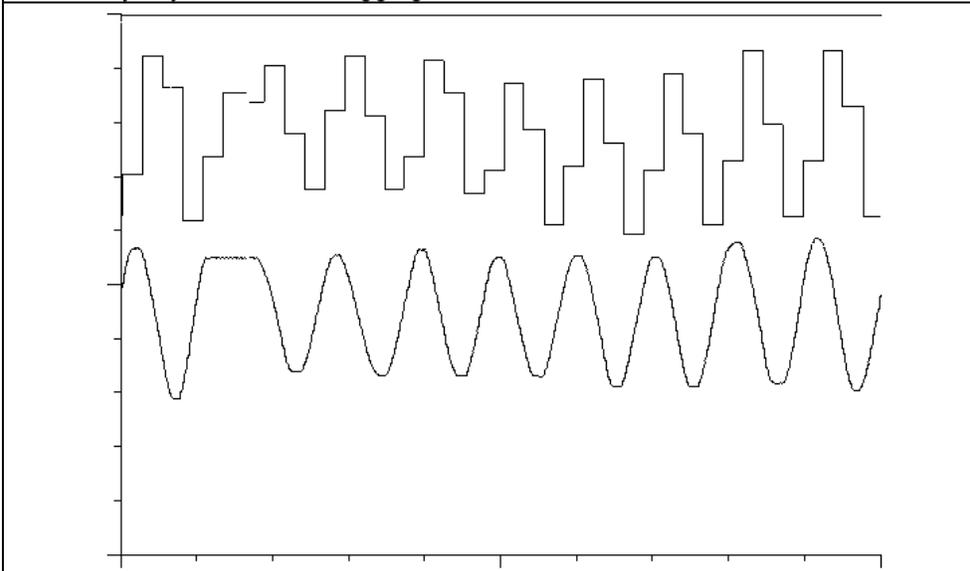
Plotting and Data Logging

```

Enter the full scale time in seconds (10.000000): 10.0
Do you want to data log the variables to disk? (y/n)? (N): y
Enter the data logging sampling interval in seconds (0.05000): 0.05
Enter the data logging output file name (datalog.dat): datalog.dat

Data logging initialized to record FIRST 10.0000 seconds of data to the file
DATALOG.DAT

Press any key to start data logging.
    
```



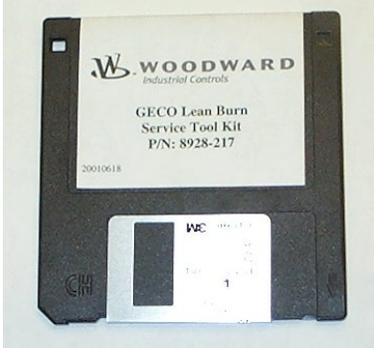
A very useful feature for troubleshooting is the plotting and data logging capability of the GECO·Lean Burn interface software. Up to six variables may be selected with the cursor and the T (Tag) key. The selected data is then displayed in a scanning, scope-type format with the P (Plot) key.

Display time scale and data logging information will be requested by the software, but the defaults (10 second scan, no logging) can be accepted by simply pressing the ENTER key at these input lines to quickly display the data. The space bar key will freeze (pause) the display for review. To return to the interface screens, press the ESC (escape) key.

If data logging is desired, the program will request information about the data time intervals and file names as shown on the plot information screen. The first full-scale time scan will be saved to the file with data for every sampling interval step. The normal plotting function will continue thereafter. These data files can then be reviewed and used to generate reports or graphs in other software applications.

Chapter 8.

KW Sensor Closed Loop Control (PC Interface Software Operation)



The PC service tool software is executed on a Microsoft DOS compatible PC. When the COM1 or COM2 ports of the PC are connected to the RS-232C port of the GECO™·Lean Burn control (DB9 connector), the service tool software will provide monitoring and display of the set-up and tuning parameters of the GECO·Lean Burn control application software.

The RS-232C connection is made with a straight-through (no null modem adapter) cable, 9-pin “DB9” male to 9-pin “DB9” female.

The GECO·Lean Burn PC software includes the interface screens with separate “frames” for related data or functions. The following sections explain operator navigation and describe the individual screens, frame by frame. Like the Hand Held Terminal, many of the frames indicate fault status, and these faults can be cleared using the ENTER key. In addition, the PC interface allows configuration changes.

To start the PC interface software operation:

1. With a DB9 male to DB9 female RS232 cable, connect the on-line control DB9 female RS-232 port to the PC DB9 serial port.
2. Insert the diskette into drive A of your PC.
3. Find the directory of drive A in Windows Explorer.
4. Double click on the file called 927-236.exe.

If none of the optional “-“ flags are used, the control will attempt communication on COM1 and COM2 before closing on a failed communication attempt. If COM3 or COM4 is needed, it must be entered in the command line, “9927-236.exe – com3.” If metric units are needed, a “-siunits” flag is used, the default units are US.

Screen Navigation

All interface screens show the following reminders along the bottom of the screen:

ESC exit **ENTER** modify **SPACE** pause **PGUP-PGDN** screen **F2** save Tag Plot

The PgUp and PgDn (page up and page down) keys are used to toggle through each individual screen. Screens 3, 4, and 5 require password access (contact your GECO·Lean Burn distributor for more information). The interface screens also show a reverse-color cursor highlighting the current configurable variable. This cursor is moved to other variable locations with the arrow keys on the PC keyboard. To change a variable, press Enter when the variable is selected with the cursor. A command line will appear near the bottom of the screen where new values may be entered. In the case of a variable which has modes (rather than a numerical value), such as fault disable/enable/enable+shutdown, the modes can be toggled with the arrow keys, then selected with the ENTER key. The current text information from any screen can be saved to a file with the F2 function key. The ESC (escape) key will exit from the GECO·Lean Burn interface program.

KW Sensor Closed Loop Control

Screen 1: GECO·Lean Burn KW Sensor Monitor

```

1  GECO 3001 KW Sensor Monitor          ID:9927-234-A          08/18/99
-----Engine-----Valve-Learn Table-----Status/Control-----
Speed          943 rpm
MAP            25.76 psia
MAT            167 °F
EGT1           77 °F
EGT2           77 °F
DC Power       23.7 volts

Phi_Desired    0.608
Phi_Actual     0.623
CL Gain        10 %
Valve-Learn Gain 0 %

Valve Cmd      +56.99 %
Valve Current  0.75 amps
Manual Mode    OFF
Valve State    ACTIVE

Est GenPower   525.0 KW
Act GenPower   525.0 KW

Mdot Fuel      (lbm/hr/l)
Valve          (%)
0.00           19.9
0.35           85.2
1.50           85.2
2.25           73.8
3.00           67.2
4.00           62.1
5.00           59.0
11.00          57.0

RunMode        RUNNING
ControlMode    CLOSED LOOP
UEGO Mode      ON

ShutdownRelay  OFF
ClsdLoopSwch  ON

Run Time       0000:00:21
Hour Meter     4.557

-----Valve-Learn Parameters-----
Mdot_fuel      3.46 lbm/hr/l
Mdot_air       95.2 lbm/hr/l
Mdot_air breakpoint 39.0 lbm/hr/l

Mdot_fuel_change 0 %
Mdot_fuel_trig  30 %

Valve Defaults FIXED
    
```

ESC exit ENTER clear-fault SPACE pause PGUP-PGDN screens F2 save Tag Plot

Screen 2: GECO·Lean Burn KW Sensor Diagnostic Codes

```

2  GECO 3001 KW Sensor Diagnostic Codes ID:9927-234-A          08/18/99
-----Faults-----Shutdowns-----
ClearAll      High      Low
MAP Sensor    133:OK      134:OK
Overboost     173:OK
MAT Sensor    123:FAULT   125:OK
MAT Higher Exp 124:OK
CJC Sensor    191:OK      192:OK
EGT1 Sensor   193:OK      194:OK
EGT2 Sensor   195:OK      196:OK
DC Power      153:OK      152:OK

ClearAll      High
Exhaust Temp  2:OK

Controller    1:OK

-----Faults (continued)-----

Valve Limit   144:OK      145:OK
Valve Current 186:OK      187:OK

UEGO Sense    113:OK
UEGO Heater   158:OK      159:OK
UEGO Pump     163:OK      162:OK
UEGO Resistor 168:OK      169:OK

KW Feedback   115:OK      114:FAULT
KW Higher Exp 117:OK

ECU Processor 153:OK
MPU Noise     142:OK

Misc
    
```

ESC exit ENTER clear-fault SPACE pause PGUP-PGDN screens F2 save Tag Plot

Screen 3: GECO·Lean Burn Volumetric Efficiency Screen

3		GECO 3001 Volumetric Efficiency Screen											ID:9927-233-A	08/27/99	
		MAP (psia)													
		0.00	3.20	6.40	9.60	12.80	16.00	19.20	22.40	25.60	28.80	32.00	35.20		
R	0	55.0	55.0	59.0	65.0	68.0	71.0	74.0	75.0	76.0	76.0	76.0	76.0		
P	120	55.0	55.0	59.0	65.0	68.0	71.0	74.0	75.0	76.0	76.0	76.0	76.0		
M	240	59.0	59.0	64.0	69.0	72.0	75.0	78.0	79.0	80.0	80.0	80.0	80.0		
	360	62.0	62.0	67.0	72.0	75.0	78.0	81.0	82.0	83.0	83.0	83.0	83.0		
	480	64.0	64.0	69.0	74.0	77.0	80.0	83.0	84.0	85.0	85.0	85.0	85.0		
	600	65.0	65.0	70.0	75.0	78.0	81.0	84.0	85.0	86.0	86.0	86.0	86.0		
	720	64.0	64.0	69.0	74.0	77.0	80.0	83.0	84.0	85.0	85.0	85.0	85.0		
	840	64.0	64.0	69.0	74.0	77.0	80.0	83.0	84.0	85.0	85.0	85.0	85.0		
	960	64.0	64.0	69.0	74.0	77.0	80.0	83.0	84.0	85.0	85.0	85.0	85.0		
	1080	64.0	64.0	69.0	74.0	77.0	80.0	83.0	84.0	85.0	85.0	85.0	85.0		
	1150	63.2	63.2	66.7	70.6	75.0	79.6	82.2	83.6	84.2	84.5	84.7	84.7		
	1200	63.2	63.2	66.7	70.6	75.0	79.6	82.2	83.6	84.2	84.5	84.7	84.7		
	1250	63.2	63.2	66.7	70.6	75.0	79.6	82.2	83.6	84.2	84.5	84.7	84.7		
	1400	55.0	55.0	60.0	64.0	69.0	74.0	77.0	80.0	83.0	83.0	83.0	83.0		

		Volumetric Efficiency (%)			
RPM	901 rpm	Est GenPower	110.4 KW	Valve Cmd	+85.16 %
MAP	10.00 psia	Act GenPower	0.0 KW	Valve State	HOLDING
MAT	167 °F	Gen Efficiency	94.9 %	CL Gain	10 %
Phi Target	0.710	Phi Actual	0.545	Phi Modifier	+0.0 %

ESC exit ENTER modify SPACE pause PGUP-PGDN screen F2 save Tag Plot



NOTE

Access to screens 3, 4, and 5 requires entering a password for configuration protection. Contact your GECO·Lean Burn distributor for more information.

Screen 4: GECO·Lean Burn Phi Calibration

4		GECO 3001 Phi Calibration											ID:9927-233-A	08/27/99	
		MAP (psia)													
		0.00	3.20	6.40	9.60	12.80	16.00	19.20	22.40	25.60	28.80	32.00	35.20		
R	0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000		
P	120	1.000	1.000	1.000	1.000	1.000	1.000	0.902	0.848	0.812	0.788	0.771	0.759		
M	240	1.000	1.000	1.000	0.929	0.824	0.773	0.746	0.732	0.722	0.717	0.712	0.709		
	360	1.000	1.000	0.941	0.798	0.750	0.728	0.716	0.710	0.706	0.703	0.695	0.693		
	480	1.000	1.000	0.834	0.752	0.725	0.712	0.706	0.695	0.693	0.692	0.675	0.674		
	600	1.000	1.000	0.784	0.730	0.713	0.706	0.694	0.676	0.675	0.674	0.664	0.663		
	720	1.000	0.962	0.760	0.720	0.708	0.695	0.676	0.665	0.664	0.663	0.652	0.652		
	840	1.000	0.898	0.743	0.713	0.704	0.693	0.674	0.664	0.653	0.652	0.652	0.651		
	960	1.000	0.855	0.732	0.709	0.695	0.675	0.664	0.653	0.652	0.651	0.651	0.651		
	1080	1.000	0.824	0.724	0.706	0.693	0.674	0.663	0.652	0.651	0.651	0.651	0.650		
	1150	1.000	0.803	0.720	0.705	0.692	0.673	0.663	0.652	0.651	0.651	0.650	0.649		
	1200	1.000	0.803	0.720	0.705	0.692	0.673	0.663	0.652	0.651	0.651	0.650	0.649		
	1250	1.000	0.803	0.720	0.705	0.692	0.673	0.663	0.652	0.651	0.651	0.650	0.649		
	1400	1.000	0.813	0.721	0.705	0.692	0.673	0.663	0.651	0.651	0.650	0.650	0.649		

		Equivalence Ratio (Phi)			
RPM	896 rpm	Phi Target	0.710	Valve Cmd	+85.16 %
MAP	10.00 psia	Phi Actual	0.545	CL Gain	10 %
MAT	167 °F	Phi Modifier	+0.0 %	Valve State	HOLDING
Gen Eff	94.9 %	Est GenPower	110.4 KW	Act GenPower	0.0 KW

ESC exit ENTER modify SPACE pause PGUP-PGDN screen F2 save Tag Plot

Screen 5: GECO·Lean Burn KW Sensor Configuration

Inputs		Fault Enables		Shutdown=Enable=Limit	
UEGO	ON	MAT low	ENABLED	EGT1	DISABLED 1200 °F
MAT	ON	MAT high	ENABLED	EGT2	DISABLED 1400 °F
EGT1	OFF	MAT high expect	ENABLED	Engine	
EGT2	OFF	EGT open	DISABLED	Cylinders	16
MAP	ON	EGT low expect	DISABLED	Displacement	69.0 L
NGP	OFF	NGP low	DISABLED	Rated Power	1088 bhp
Fuel Valve		NGP high	DISABLED	Rated MAP	32.00 psia
Valve	ON	NGP low expect	DISABLED	Rated RPM	1200 rpm
Run Default	+57.0 %	NGP high expect	DISABLED	Gen Efficiency	94.9 %
Crk Default	+85.0 %	Valve cur min	DISABLED	RPM Pulse/Rev	183
KW Calibration		Valve cur max	DISABLED	RPM Source	MAG-PU
Unscaled	0.00 V	KW low	ENABLED	RPM Auto Mode	DISABLED
Scaled	525.7 KW	KW high	ENABLED	ModBus Configuration	
Offset	-0.882 V	KW high expect	ENABLED	Mode	OFF
Span	415.08 KW/V	MAP low	ENABLED	Parity	NONE
MAP Calibration		MAP high	ENABLED	Baud	9600
Unscaled	2.84 V	MAP high press	40.00 psia	Address	99
Scaled	25.76 psia	Miscellaneous		Access	USER
Offset	+0.039 V	Barometer	14.50 psia	Activity	OFF
Span	8.939 psi/V				

ESC exit ENTER modify SPACE pause PGUP-PGDN screen F2 save Tag Plot

The following is an explanation of the individual screen frames:

Screen 1: Engine

Engine		
Speed	943	rpm
MAP	25.76	psia
MAT	167	°F
EGT1	77	°F
EGT2	77	°F
DC Power	23.7	volts
Phi_Desired	0.608	
Phi_Actual	0.623	
CL Gain	10	%
Valve-Learn Gain	10	%
Valve Cmd	+56.99	%
Valve Current	0.75	amps
Manual Mode	OFF	
Valve State	ACTIVE	
Est GenPower	525.0	KW
Act GenPower	525.0	KW

- Speed**—Engine rpm from magnetic pickup (MPU) or “G-lead”.
- MAP**—Intake manifold absolute pressure in pounds per square inch.
- MAT**—Intake manifold air temperature in degrees Fahrenheit.
- EGT1**—Optional thermocouple input in degrees F.
- EGT2**—Optional thermocouple input in degrees F.
- DC Power**—Power supply voltage to the circuit board.
- Phi_Desired**—Air/fuel equivalence ratio set point target.
- Phi_Actual**—Measured air/fuel equivalence ratio.
- CL Gain**—Proportional gain of closed loop air/fuel ratio control, the range is 0 to 100%.
- Valve-Learn Gain**—The rate at which the ADAPTIVE control learns new Open Loop fuel valve positions.
- Valve Cmd**—Fuel control valve PWM position command in units of duty cycle

percentage.

Valve Current—Fuel control valve command signal current in amperes.
Manual Mode—OFF, ON. This mode can be activated only when in the OPEN LOOP control mode. It allows for manual positioning of the control valves.

Valve State—HOLDING or ACTIVE. The fuel control valve is holding a position, as it would in OPEN LOOP mode or MANUAL MODE, or it is actively moving to hold the phi target.

Est GenPower—Estimated generator output power based on control inputs, in units of kilowatts.

Act GenPower—Measured generator output power based on the watt transducer input, in units of kilowatts.

Screen 1: Valve Learn Table

Valve-Learn Table	
Mdot Fuel (lbm/hr/l)	Valve (%)
0.00	19.9
0.35	85.2
1.50	85.2
2.25	73.8
3.00	67.2
4.00	62.1
5.00	59.0
11.00	57.0

Mdot Fuel—These values represent the operating range of the engine in terms of fuel mass flow per liter of engine displacement. The highlighted values are the two values between which the control is interpolating an open loop valve position.

Valve-Learn %—The learned fuel valve position command that the control will use in the event that OPEN LOOP mode is activated for any reason. A position is learned for each load point represented by the Mdot Fuel values above. New values are learned only when the engine is

operating in a steady state. When utilized, actual fuel valve position command values are interpolated from the two closest values from the table. The highlighted value is the value that will be re-learned when the opportunity arises.

Screen 1: Valve Learn Parameters

Valve-Learn Parameters		
Mdot_fuel	3.43	lbm/hr/l
Mdot_air	94.1	lbm/hr/l
Mdot_air breakpoint	39.0	lbm/hr/l
Mdot_fuel_change	1	%
Mdot_fuel_trig	30	%
Valve Defaults	Variable	

Mdot_fuel—The current calculated fuel mass flow value units of pounds per hour per liter of engine displacement.

Mdot_air—The current calculated air mass flow value in pounds per hour per liter of engine displacement.

Mdot_air breakpoint—The value of air mass flow above

which the closed loop function is enabled. Also, it divides “high loads” from “low loads” for purposes of blocking the Valve-Learn function.

Mdot_fuel_change—The current fuel flow derivative or rate of change in units of percent per second. This is a measure of the magnitude of engine transient response to a load change.

Mdot_fuel_trig—The trigger point at which the control temporarily switches to OPEN LOOP mode and utilizes the Valve-Learn table for better transient response by the controller.

Valve Defaults—FIXED, VARIABLE (ALL LOADS), VARIABLE (LOW LOADS), VARIABLE (HIGH LOADS). This, in conjunction with Mdot air breakpoint, determines what portion of the Valve-Learn table is available to the Valve-Learn function. It should remain on VARIABLE (ALL LOADS) unless consultation with your authorized GECO·Lean Burn distributor confirms that a change is needed.

Screen 1: Status/Control

Status/Control	
RunMode	RUNNING
ControlMode	CLOSED LOOP
UEGO Mode	ON
ShutdownRelay	OFF
ClsdLoopSwch	ON
Run Time	0000:00:21
Hour Meter	4.557

RunMode—STOPPED, CRANKING, RUNNING. These are the start sequence modes. Once the engine reaches idle speed, it should be in the RUNNING mode.

ControlMode—OPEN LOOP, CLOSED LOOP, ADAPTIVE. These are the air/fuel ratio control modes.

UEGO Mode—FAULT, OFF, ON, INIT-1, INIT-2

ShutdownRelay—OFF, ON. The state of the shutdown output.

ClsdLoopSwch—OFF, ON. The position

of the closed loop switch on the circuit board.

Run Time—The time, in hours, since the last engine start.

Hour Meter—The total engine run time since the control was installed.

Screen 2: Faults

Faults			
ClearAll	High	Low	
MAP Sensor	133:OK	134:OK	
Overboost	173:OK		
MAT Sensor	123:FAULT	125:OK	
MAT Higher Exp	124:OK		
CJC Sensor	191:OK	192:OK	
EGT1 Sensor	193:OK	194:OK	
EGT2 Sensor	195:OK	196:OK	
DC Power	153:OK	152:OK	
Valve Limit	144:OK	145:OK	
Valve Current	186:OK	187:OK	
UEGO Sense	113:OK		
UEGO Heater	158:OK	159:OK	
UEGO Pump	163:OK	162:OK	
UEGO Resistor	168:OK	169:OK	
KW Feedback	115:OK	114:FAULT	
KW Higher Exp	117:OK		

Faults (continued)

Misc	
ECU Processor	153:OK
MPU Noise	142:OK

This frame shows the status of the input fault detection function:

ClearAll—Clears all alarm faults.

MAP Sensor—Intake manifold pressure voltage is out of range, i.e. above 4.5 Vdc, below 0.5 Vdc, or higher than “MAP high press” (see Screen 5).

MAT Sensor—Intake mixture temperature sensor resistance is out of range.

MAT Higher Exp—Intake mixture temperature is in range but higher than expected.

CJC—The thermocouple cold junction sensor that is mounted on the circuit board has a fault.

EGT1 Sensor—This is an optional thermocouple sensor indication.

EGT2 Sensor—This is an optional thermocouple sensor indication

DC Power—Power supply is above 30 Vdc or below 9 Vdc.

Valve Limit—The fuel control valve has reached its stroke limit and is therefore not in control.

Valve Current—The fuel control valve command signal current is out of range.

UEGO Sense—There is an out of range fault in the sense circuit of the wide range oxygen sensor.

UEGO Heater—There is an out of range fault in the heater circuit of the wide range oxygen sensor.

UEGO Pump—There is an out of range fault in the pump circuit of the wide range oxygen sensor.

UEGO Resistor—There is an out of range fault in the resistor circuit of the wide range oxygen sensor.

ECU Processor—A problem has been detected by the electronic control unit processor.

MPU Noise—The control is measuring an unreasonably high speed. Noise on the MPU signal could cause this.

Screen 2: Shutdowns

Shutdowns	
ClearAll	High
Exhaust Temp	2:OK
Controller	1:OK

ClearAll—Clears all alarm faults.

Exhaust Temperature—If exhaust temperature thermocouples are used, they can be configured to shut the engine down when the alarm is tripped. This indicates if

that is the cause of a shutdown.

Controller—This will indicate if the controller has triggered a shutdown command.

Screen 3: Engine Volumetric Efficiency Table

GECO 3001 Volumetric Efficiency Screen ID:9927-233-A 08/27/99												
MAP (psia)												
	0.00	3.20	6.40	9.60	12.80	16.00	19.20	22.40	25.60	28.80	32.00	35.20
0	55.0	55.0	59.0	65.0	68.0	71.0	74.0	75.0	76.0	76.0	76.0	76.0
120	55.0	55.0	59.0	65.0	68.0	71.0	74.0	75.0	76.0	76.0	76.0	76.0
240	59.0	59.0	64.0	69.0	72.0	75.0	78.0	79.0	80.0	80.0	80.0	80.0
360	62.0	62.0	67.0	72.0	75.0	78.0	81.0	82.0	83.0	83.0	83.0	83.0
480	64.0	64.0	69.0	74.0	77.0	80.0	83.0	84.0	85.0	85.0	85.0	85.0
600	65.0	65.0	70.0	75.0	78.0	81.0	84.0	85.0	86.0	86.0	86.0	86.0
720	64.0	64.0	69.0	74.0	77.0	80.0	83.0	84.0	85.0	85.0	85.0	85.0
840	64.0	64.0	69.0	74.0	77.0	80.0	83.0	84.0	85.0	85.0	85.0	85.0
960	64.0	64.0	69.0	74.0	77.0	80.0	83.0	84.0	85.0	85.0	85.0	85.0
1080	64.0	64.0	69.0	74.0	77.0	80.0	83.0	84.0	85.0	85.0	85.0	85.0
1150	63.2	63.2	66.7	70.6	75.0	79.6	82.2	83.6	84.2	84.5	84.7	84.7
1200	63.2	63.2	66.7	70.6	75.0	79.6	82.2	83.6	84.2	84.5	84.7	84.7
1250	63.2	63.2	66.7	70.6	75.0	79.6	82.2	83.6	84.2	84.5	84.7	84.7
1400	55.0	55.0	60.0	64.0	69.0	74.0	77.0	80.0	83.0	83.0	83.0	83.0

Volumetric Efficiency (%)			
RPM	901 rpm	Est GenPower	110.4 KW
MAP	10.00 psia	Act GenPower	0.0 KW
MAT	167 °F	Gen Efficiency	94.9 %
Phi Target	0.710	Phi Actual	0.545
		Valve Cmd	+85.16 %
		Valve State	HOLDING
		CL Gain	10 %
		Phi Modifier	+0.0 %

ESC exit ENTER modify SPACE pause PGUP-PGDN screen F2 save Tag Plot

Volumetric Efficiency—Values in units of percent for the respective engine operating parameters.

RPM—Engine speed in revolutions per minute.

MAP—Intake manifold pressure in pounds per square inch.

MAT—Intake manifold air temperature in degrees Fahrenheit.

Phi Target—Air/fuel equivalence ratio set point target from the appropriate point on the table.

Est GenPower—Estimated generator output power based on control inputs, in units of kilowatts.

Act GenPower—Measured generator output power based on the watt transducer input, in units of kilowatts.

Gen Efficiency—The generator efficiency without the engine. This value is entered by the operator.

Phi Actual—Air/fuel equivalence ratio feedback from the oxygen sensor.

Valve Cmd—Fuel valve command signal duty cycle in percent.

Valve State—HOLDING or ACTIVE. The fuel control valve is holding a position, as it would in OPEN LOOP mode or MANUAL MODE, or it is actively moving to hold the efficiency target.

CL Gain—Proportional gain of the engine efficiency control loop.
Phi Modifier—Value of the equivalence ratio calibration table modifier.

Screen 4: GECO·Lean Burn Phi Calibration

GECO 3001 Phi Calibration													ID:9927-233-A	08/27/99
MAP (psia)														
	0.00	3.20	6.40	9.60	12.80	16.00	19.20	22.40	25.60	28.80	32.00	35.20		
0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000		
120	1.000	1.000	1.000	1.000	1.000	1.000	0.902	0.848	0.812	0.788	0.771	0.759		
240	1.000	1.000	1.000	0.929	0.824	0.773	0.746	0.732	0.722	0.717	0.712	0.709		
360	1.000	1.000	0.941	0.798	0.750	0.728	0.716	0.710	0.706	0.703	0.695	0.693		
R 480	1.000	1.000	0.834	0.752	0.725	0.712	0.706	0.695	0.693	0.692	0.675	0.674		
P 600	1.000	1.000	0.784	0.730	0.713	0.706	0.694	0.676	0.675	0.674	0.664	0.663		
M 720	1.000	0.962	0.760	0.720	0.708	0.695	0.676	0.665	0.664	0.663	0.652	0.652		
840	1.000	0.898	0.743	0.713	0.704	0.693	0.674	0.664	0.653	0.652	0.652	0.651		
960	1.000	0.855	0.732	0.709	0.695	0.675	0.664	0.653	0.652	0.651	0.651	0.651		
1080	1.000	0.824	0.724	0.706	0.693	0.674	0.663	0.652	0.651	0.651	0.651	0.650		
1150	1.000	0.803	0.720	0.705	0.692	0.673	0.663	0.652	0.651	0.651	0.650	0.649		
1200	1.000	0.803	0.720	0.705	0.692	0.673	0.663	0.652	0.651	0.651	0.650	0.649		
1250	1.000	0.803	0.720	0.705	0.692	0.673	0.663	0.652	0.651	0.651	0.650	0.649		
1400	1.000	0.813	0.721	0.705	0.692	0.673	0.663	0.651	0.651	0.650	0.650	0.649		

Equivalence Ratio (Phi)					
RPM	896 rpm	Phi Target	0.710	Valve Cmd	+85.16 %
MAP	10.00 psia	Phi Actual	0.545	CL Gain	10 %
MAT	167 °F	Phi Modifier	+0.0 %	Valve State	HOLDING
Gen Eff	94.9 %	Est GenPower	110.4 KW	Act GenPower	0.0 KW

ESC exit ENTER modify SPACE pause PGUP-PGDN screen F2 save Tag Plot

Equivalence Ratio (Phi)—Air/fuel equivalence ratio (the inverse of lambda, λ) for the respective engine operating parameters.

RPM—Engine speed in revolutions per minute.

MAP—Intake manifold pressures in pounds per square inch.

MAT—Intake manifold air temperature in degrees Fahrenheit.

Gen Eff—Generator efficiency in percent of input energy without the engine. If the default value is not correct, set a new value that the control will use to calculate the engine shaft output to engine fuel input.

Phi Target—Air/fuel equivalence ratio set point target from the appropriate point on the table.

Phi Actual—Air/fuel equivalence ratio feedback from the oxygen sensor.

Phi Modifier—Value of the equivalence ratio calibration table modifier.

Est GenPower—Estimated generator output power based on control inputs, in units of kilowatts.

Valve Cmd—Fuel valve command signal duty cycle in percent.

CL Gain—Proportional gain of the engine efficiency control loop.

Valve State—HOLDING or ACTIVE. The fuel control valve is holding a position, as it would in OPEN LOOP mode or MANUAL MODE, or it is actively moving to hold the phi target.

Act GenPower—Measured generator output power based on the watt transducer input, in units of kilowatts.

Screen 5: Inputs

Inputs	
UEGO	ON
MAT	ON
EGT1	OFF
EGT2	OFF
MAP	ON
NGP	OFF

UEGO1—Oxygen sensor input is ON or OFF, terminals 6-12. During the software configuration phase of the installation, the inputs that will be utilized by the control for the specific application should be turned on here.

UEGO2—Second bank oxygen sensor input is ON or OFF, terminals 13-19.

MAT—The manifold air temperature sensor input is ON or OFF, terminals 56 & 60. If it is OFF, a default value for MAT will be used by the control.

EGT1—Optional thermocouple sensor input is ON or OFF, terminals 71 & 72.

EGT2—Optional thermocouple sensor input is ON or OFF, terminals 73 & 74.

MAP1—The intake manifold absolute pressure sensor input is ON or OFF, terminals 1, 4 & 5.

MAP2—The second bank intake manifold absolute pressure sensor input is ON or OFF, terminals 54, 59 & 60.

NGP—An optional 0-5 Vdc input is ON or OFF, terminals 3 & 5.

Screen 5: Fuel Valve

Fuel Valve			
Valve	ON		
Run Default	+57.0	%	
Crk Default	+85.0	%	

Valve—The fuel control valve output channel is ON or OFF, terminals 20 & 21.

Run Default—This is the fuel control valve position command that is used if the CLOSED LOOP and OPEN LOOP Valve learn table functions are both disabled.

Crk Default—This is the fuel control valve

position command that is used during the start sequence when the control detects that the engine is in a “cranking” mode. When the control measures an engine speed between 20 and 400 rpm, it assumes that an engine start is underway and opens the fuel control valves to this position. This default valve position should be chosen to facilitate engine startup.

Screen 5: kW Transducer Calibration

KW Calibration			
Unscaled	0.00	V	
Scaled	525.7	KW	
Offset	-0.882	V	
Span	415.08	KW/V	

This frame is for calibrating the kW transducer input channel. Adjust the offset and span to achieve the proper scaling.

Unscaled—This is the voltage reading across a 221 Ω resistor of the 4-20 mA signal from the kW transducer.

Scaled—This is the kW transducer reading converted to kilowatts.

Offset—This is the offset value used by the control to convert the unscaled kW transducer voltage to kilowatts.

Span—This is the span value used by the control to convert the unscaled kW transducer voltage to kilowatts.

Screen 5: MAP Calibration

MAP Calibration			
Unscaled	2.84	V	
Scaled	25.76	psia	
Offset	+0.039	V	
Span	8.939	psi/V	

This frame is for calibrating the MAP sensor input channels. Adjust the offset and span to achieve the proper scaling.

Unscaled—This is the voltage reading from the MAP sensor.

Scaled—This is the MAP sensor reading converted to pounds per square inch.

Offset—This is the offset value used by the control to convert the unscaled MAP voltage to pounds per square inch.

Span—This is the span value used by the control to convert the unscaled MAP voltage to pounds per square inch.

Screen 5: Fault Enables

Fault Enables	
MAT low	ENABLED
MAT high	ENABLED
MAT high expect	ENABLED
EGT open	DISABLED
EGT low expect	DISABLED
NGP low	DISABLED
NGP high	DISABLED
NGP low expect	DISABLED
NGP high expect	DISABLED
Valve cur min	DISABLED
Valve cur max	DISABLED
KW low	ENABLED
KW high	ENABLED
KW high expect	ENABLED
MAP low	ENABLED
MAP high	ENABLED
MAP high press	40.00 psia

This frame is for enabling the fault detection software for each of the input channels.

- MAT low**—ENABLED, ENABLED+SD, or DISABLED.
- MAT high**—ENABLED, ENABLED+SD, or DISABLED.
- MAT high expect**—ENABLED, ENABLED+SD, or DISABLED.
- EGT open**—ENABLED, ENABLED+SD, or DISABLED.
- EGT low expect**—ENABLED, ENABLED+SD, or DISABLED.
- NGP low**—ENABLED, ENABLED+SD, or DISABLED.
- NGP high**—ENABLED, ENABLED+SD, or DISABLED.
- NGP low expect**—ENABLED, ENABLED+SD, or DISABLED.
- NGP high expect**—ENABLED, ENABLED+SD, or DISABLED.

- ENABLED+SD, or DISABLED.
- Valve cur min**—ENABLED, ENABLED+SD, or DISABLED.
- Valve cur max**—ENABLED, ENABLED+SD, or DISABLED.
- KW low**—ENABLED, ENABLED+SD, or DISABLED.
- KW high**—ENABLED, ENABLED+SD, or DISABLED.
- KW high expect**—ENABLED, ENABLED+SD, or DISABLED.
- MAP low**—ENABLED, ENABLED+SD, or DISABLED.
- MAP high**—ENABLED, ENABLED+SD, or DISABLED.
- MAP high press**—This is the pressure value above which the MAP sensor is considered to have failed.

Screen 5: Miscellaneous

Miscellaneous	
Barometer	14.50 psia

Barometer—Set the average atmospheric pressure at the engine site to adjust the control for altitude.

Screen 5: Shutdown Enables

Shutdown	Enable	Limit
EGT1	DISABLED	1200 °F
EGT2	DISABLED	1400 °F

- EGT1**—ENABLED or DISABLED.
- EGT2**—ENABLED or DISABLED.

Screen 5: Engine Configuration

Engine	
Cylinders	16
Displacement	69.0 L
Rated Power	1088 bhp
Rated MAP	32.00 psia
Rated RPM	1200 rpm
Gen Efficiency	94.9 %
RPM Pulse/Rev	183
RPM Source	MAG-PU
RPM Auto Mode	DISABLED

- Cylinders**—Number of engine power cylinders.
- Displacement**—Engine nominal displacement in liters.
- Rated Power**—Engine rated brake horsepower.
- Rated MAP**—Intake manifold absolute pressure at rated power.
- Rated RPM**—Engine rated speed.
- Gen Efficiency**—Enter a value here for the generator rated efficiency.
- RPM Pulse/Rev**—The number of gear teeth per revolution seen by the magnetic pickup.

RPM Source—MAG-PU or G-LEAD. This identifies the source of the speed signal.

RPM Auto Mode—ENABLED or DISABLED. When DISABLED, the start sequence switches from CRANKING to RUNNING at 450 rpm. When ENABLED, this switch takes place at a speed calculated from the Rated RPM. This allows the control to be used on engines that run at less than 450 rpm. A 300 rpm engine will switch at 250 rpm.

Screen 5: Modbus Configuration

ModBus Configuration	
Mode	OFF
Parity	NONE
Baud	9600
Address	99
Access	USER
Activity	OFF
Mem Module	OK

Mode—MODBUS ASCII, MODBUS RTU, or OFF

Parity—EVEN, ODD, or NONE

Baud—Choice of possible communication baud rates.

Address—Two digit numerical slave address.

Access—USER, or OPERATOR

Activity—YES or NO, this indicates if the control is recognizing communication

activity on the RS485 port.

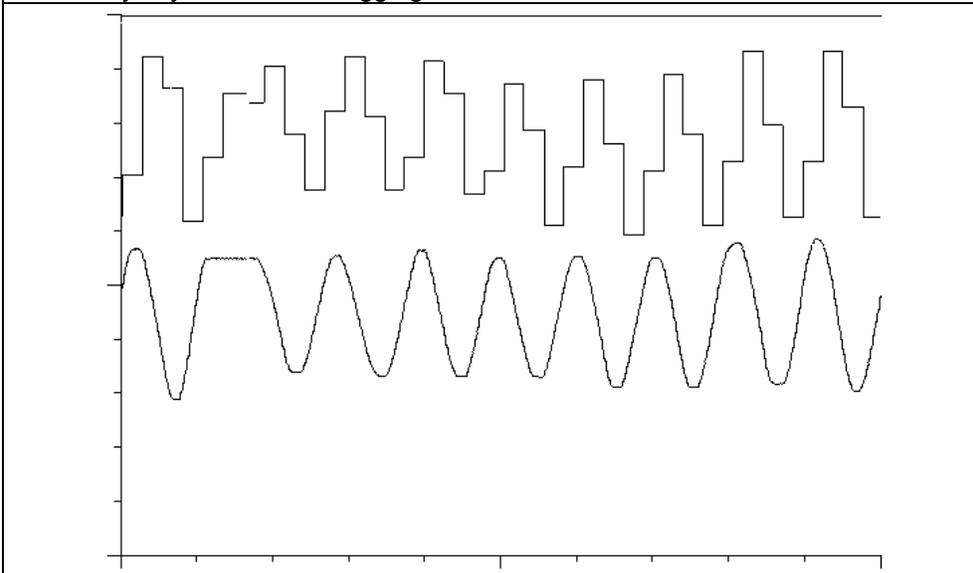
Mem Module—OK indicates that the Modbus circuitry is functioning properly.

Plotting and Data Logging

Enter the full scale time in seconds (10.000000): 10.0
 Do you want to data log the variables to disk? (y/n)? (N): y
 Enter the data logging sampling interval in seconds (0.05000): 0.05
 Enter the data logging output file name (datalog.dat): datalog.dat

Data logging initialized to record FIRST 10.0000 seconds of data to the file DATALOG.DAT

Press any key to start data logging ...



A very useful feature for troubleshooting is the plotting and data logging capability of the GECO·Lean Burn interface software. Up to six variables may be selected with the cursor and the T (Tag) key. The selected data is then displayed in a scanning, scope-type format with the P (Plot) key.

Display time scale and data logging information will be requested by the software, but the defaults (10 second scan, no logging) can be accepted by simply pressing the ENTER key at these input lines to quickly display the data. The space bar key will freeze (pause) the display for review. To return to the interface screens, press the ESC (escape) key.

If data logging is desired, the program will request information about the data time intervals and file names as shown on the plot information screen. The first full-scale time scan will be saved to the file with data for every sampling interval step. The normal plotting function will continue thereafter. These data files can then be reviewed and used to generate reports or graphs in other software applications.

Chapter 9. Installation/Setup

The GECO™·Lean Burn system installer should be able to perform the following tasks with a high level of quality and workmanship, with consideration given to any applicable laws and regulations for the specific location.

Installation Tasks

- Provide a suitable controller mounting location.
- Install weather-tight conduit and wiring, including grommet-end junction boxes and automotive-style electrical connectors.
- Provide the controller with a magnetic pickup speed signal (100 V p-p).
- Drill and tap (or weld) the oxygen sensor port into the engine exhaust system.
- Drill and tap (or weld) the MAP and MAT sensor ports into the intake system.
- Cut and weld tubing and flanges. Fabricate strong, stiff mounting brackets with consideration for vibration and fatigue.
- Provide a power source for the controller (9–30 Vdc). A 5 Amp slow blow fuse should be installed in-line with the power supply input.
- Analyze exhaust emissions for calibration.
- Operate a laptop computer or the hand held programmer to calibrate the GECO·Lean Burn control.

**NOTE**

If the installer is unfamiliar or unable to complete any of the installation requirements listed above, contact your GECO·Lean Burn distributor for information on qualified installers.

Included GECO·Lean Burn Components

- GECO·Lean Burn controller and Hand Held Terminal
- GECO·Lean Burn controller manual
- Flo-Tech™ fuel control valve(s)

Required Engine Components

- Engine must have detonation detection/protection
- Engine must have misfire detection/protection

**CAUTION**

To prevent serious damage to the engine, it must be equipped with detonation and misfire protection.

Required Installer-Provided Components

- 9–30 Vdc power supply, 70 W for the control, 50 W for each Flo-Tech™ valve
- Electrical conduit
- Wiring as shown in the plant wiring diagrams
- Magnetic pickup speed signal (100 V p-p max) or “G-lead” wiring
- Oxygen sensor port (18 mm x 1.5 internally threaded, gasket spot face or weld bung)
- UEGO sensor (5-wire)
- Intake manifold pressure sensor (0–5 Vdc; 0–300 kPa absolute pressure)
- Intake manifold temperature sensor (25 °C nominal)
- Fittings for fuel metering valve

Optional Installer-Supplied Components

- Indicator lights/annunciator panel
- Alarm relay circuit
- Shutdown relay circuit

Unpacking

Before handling the control, read Electrostatic Discharge Awareness in Chapter 2. Be careful when unpacking the electronic control. Check the control for signs of damage such as bent panels, scratches, and loose or broken parts. If any damage is found, immediately notify the shipper.

Power Requirements

The GECO·Lean Burn control requires a voltage source of 9 to 30 Vdc. The controller draws a maximum of 70 W. Each Flo-Tech valve draws up to 50 W. A 5 Amp slow blow fuse should be installed in-line with the power supply input.



NOTE

If a battery is used for operating power, an alternator or other battery-charging device is necessary to maintain a stable supply voltage.

All tunable values that have been changed in the programming mode will stay in memory on power supply failure. For proper operation, the GECO·Lean Burn control requires an engine speed signal from a magnetic pickup speed sensor or ignition system “G-lead”.



CAUTION

To prevent damage to the control, do not exceed the input voltage range. Make sure that the alternator or other battery-charging device is turned off or disconnected before disconnecting the battery.

Controller Location Considerations



- Access to and clearance for front cover
- Access for conduit on bottom or sides of unit
- Ventilation
- Space for servicing and repair
- Protection from direct exposure to water or to a condensation-prone environment
- Protection from high-voltage or high-current devices, or devices which produce electromagnetic interference
- Avoidance of vibration; if the control is mounted to an engine skid, shock isolators are required; contact your GECO·Lean Burn distributor for

more information

- Selection of a location that will provide an operating temperature range of –40 to +70 °C (–40 to +158 °F) internal box temperature
- Access to earth ground for grounding the enclosure



NOTE

To avoid damage to the circuit board or hand held terminal, these items should be removed from the enclosure before mounting or punching conduit holes. The circuit board is attached to a mounting plate for easy removal and re-installation.

See the Enclosure Outline Diagram below for mounting hole locations.

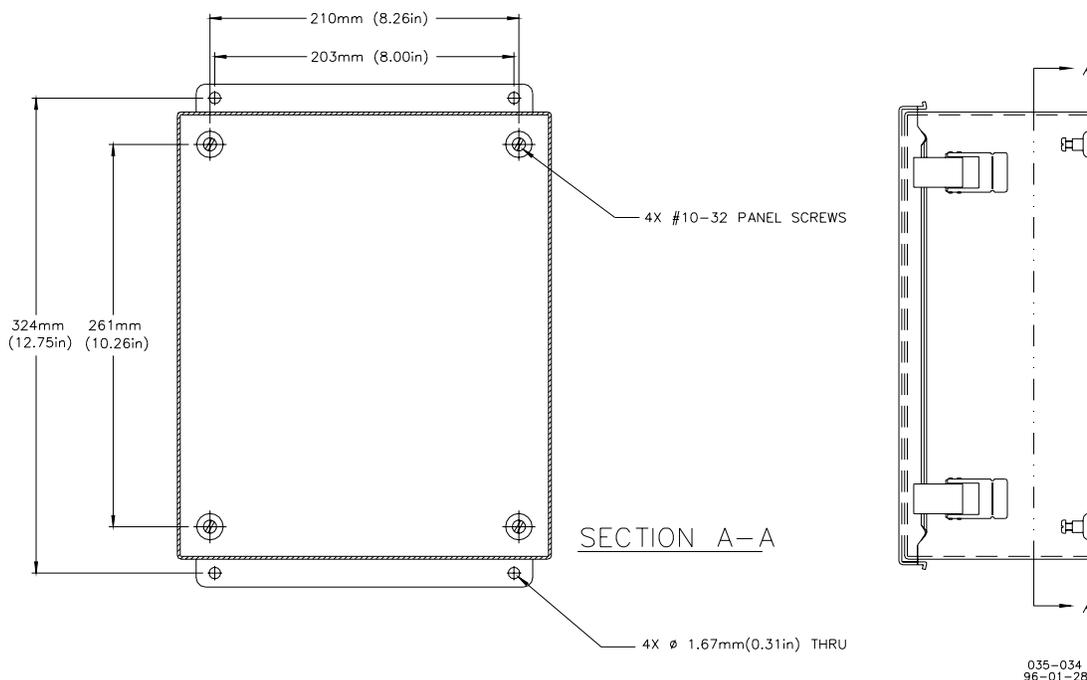


Figure 9-1. Enclosure Outline Drawing

Class I, Division 2, Groups A, B, C, D Hazardous Locations

This electronic control in its enclosure is suitable for use in Class I, Division 2, Groups A, B, C, and D, or non-hazardous locations only.



WARNING

Explosion Hazard—Substitution of components may impair suitability for Class I, Division 2.

Explosion Hazard—Do not connect or disconnect equipment unless power has been switched off or the area is known to be non-hazardous.



NOTE

Installation wiring must be in accordance with Class I, Division 2 wiring methods in Article 501-4(b) of the NEC, and in accordance with the authority having jurisdiction.

Wiring Installation

All wiring must be in accordance with North American Class I, Division 2 hazardous location installation requirements and in accordance with the authority having jurisdiction. This wiring should not run in the same conduit as wiring carrying alternating current or high voltage wiring signal wire. Any new alarm and shutdown wiring for the operator control panel such as switches, lights, horn, or gages should also be installed at this time. The GECO enclosure should be properly connected to earth ground.

Making Electrical Connections

External wiring connections and shielding requirements for control installation are shown in the Plant Wiring Diagram. Shielded cable with spiral wrapped foil and a separate twisted shield wire or braided shield cable is recommended for all sensor input, control output, and communications wiring.

Shielded Wiring

All shielded cable must be twisted-conductor pairs. Do not attempt to tie the twisted shield wire. All signal lines should be shielded to prevent picking up stray signals from adjacent equipment. Connect the shields to the indicated terminals on the Plant Wiring Diagram. Wire exposed beyond the shields should be as short as possible. The sensor end of the shields must be left open and insulated from any other conductor. DO NOT run shielded signal wires along side or in the same conduit with other wires carrying large currents.

Where shielded cable is required, cut the cable to the desired length and prepare the cable as instructed below:

- Strip outer insulation from BOTH ENDS, exposing shield and wire. DO NOT CUT THE SHIELD WIRE.
- Carefully remove the excess foil shield, leaving enough shield wire to reach the proper GECO·Lean Burn control terminal.
- Separate the inner conductor(s) from the shield. If the shield is the braided type, twist it to prevent fraying.
- Remove 6 mm (1/4 inch) of insulation from the inner conductors for GECO·Lean Burn plug-in terminals.

Wiring Considerations

- Wiring must meet local codes.
- GECO enclosure should be tied to earth ground.
- High voltage or high current wires should run in separate conduit from GECO·Lean Burn sensors and valves.
- Avoid conduit or wire proximity to hot surfaces—especially exhaust components.
- Grommets must be installed in holes, conduit ends, or boxes to protect wire insulation.
- Where wiring exits from grommet-end boxes, electrical RTV should be used for water-tight seal; the cable should be long enough to tie into a “drip loop” before entering conduit.
- Where conduit connects to junction boxes, the side or bottom is best; use an elbow when top connection is necessary.
- Flexible metal conduit must have sleeve inserts at junctions for insulation protection.
- If sensor wires have a protective covering, the cover should be tied with ends pointing down to drain liquids.
- Shields must be grounded to circuit board terminals only.
- Shields must be carried continuously through terminal blocks, splices, or connectors and must not be tied to any other shields unless sharing circuit board terminal location.
- All conduit wiring breaks or splices must be in junction, outlet, or equipment boxes only.

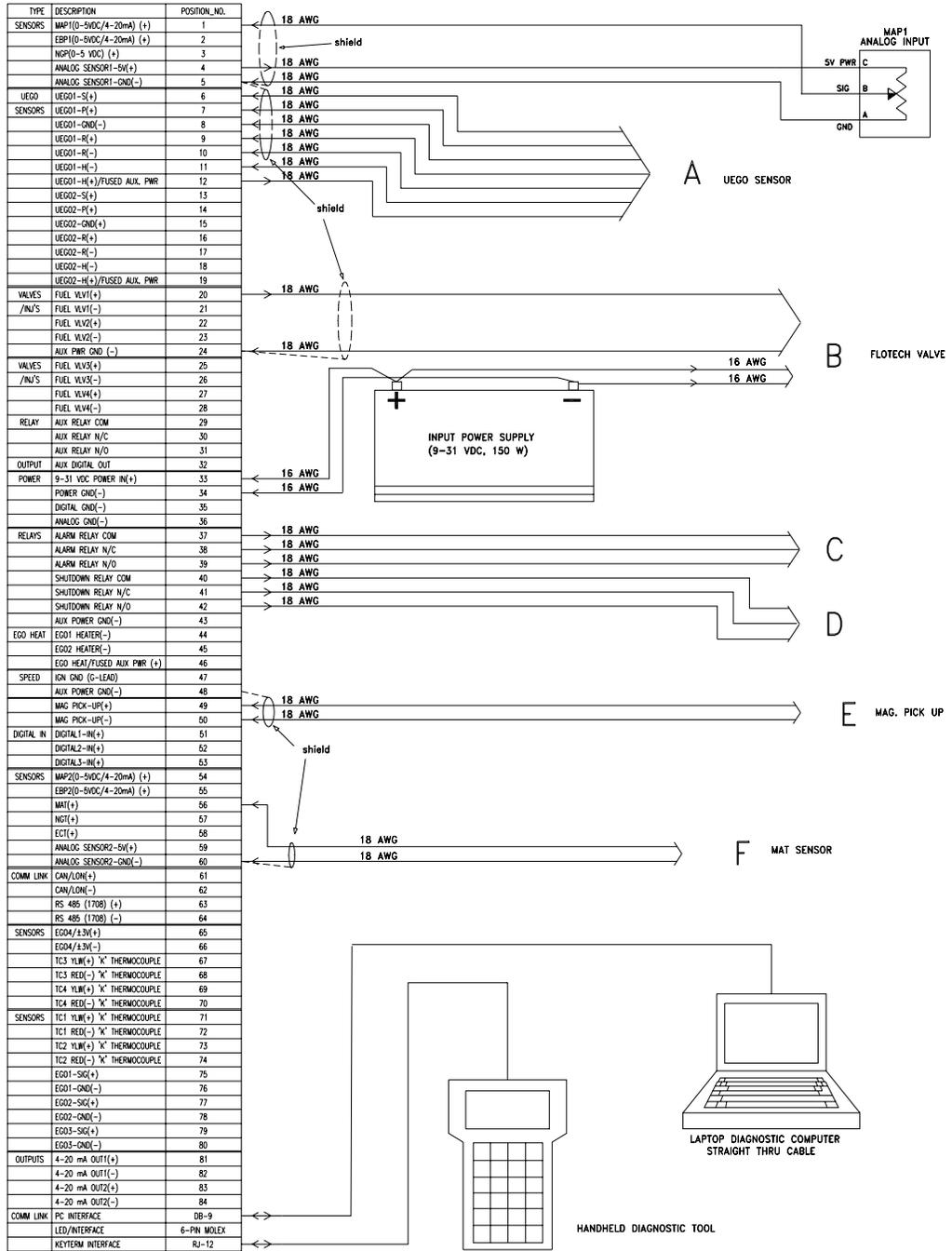


Figure 9-2a. Wiring for Single Bank or “V” Engine with Common Intake Manifold and UEGO (such as Caterpillar 3500)

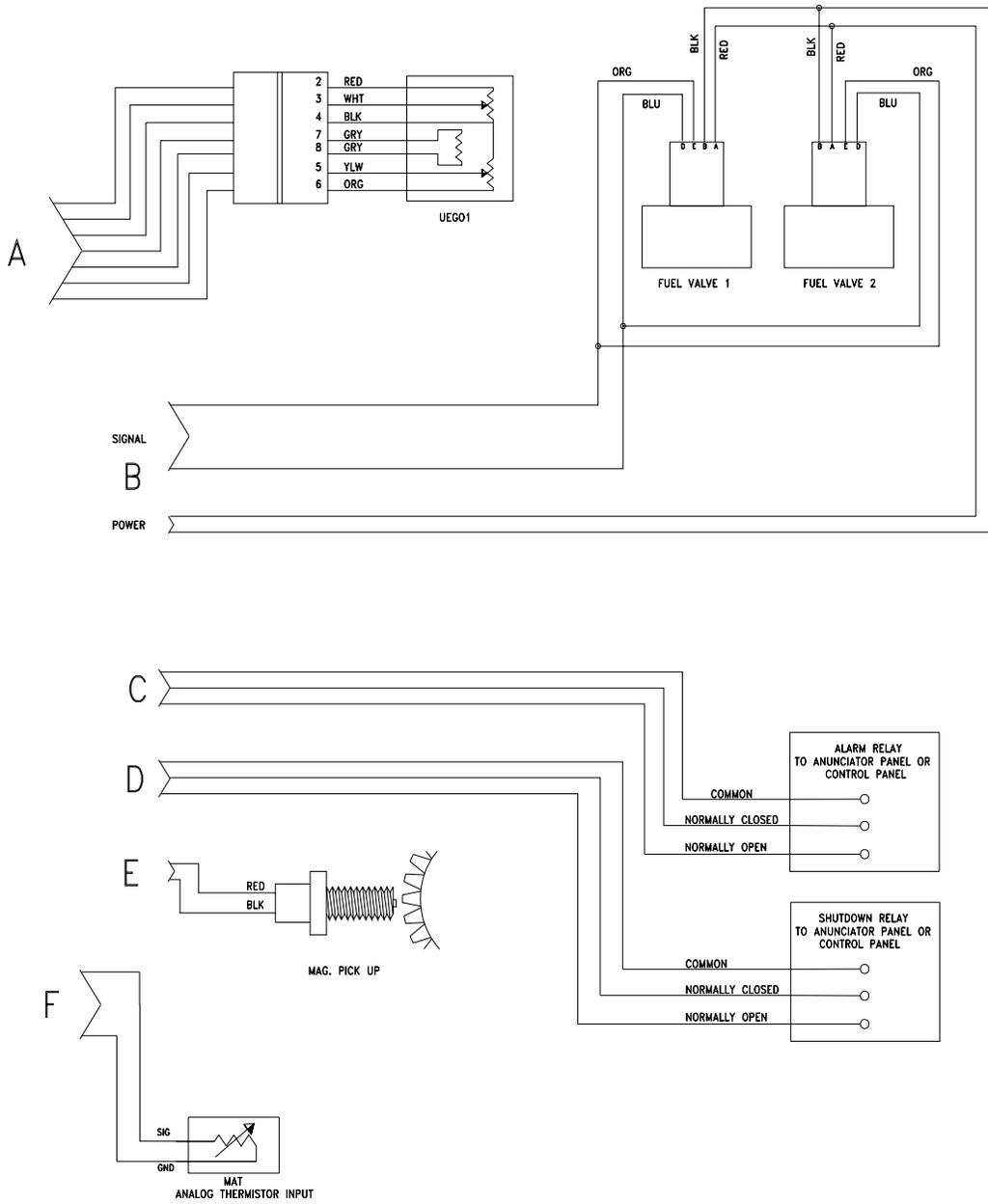


Figure 9-2b. Wiring for Single Bank or "V" Engine with Common Intake Manifold and UEGO (such as Caterpillar 3500)

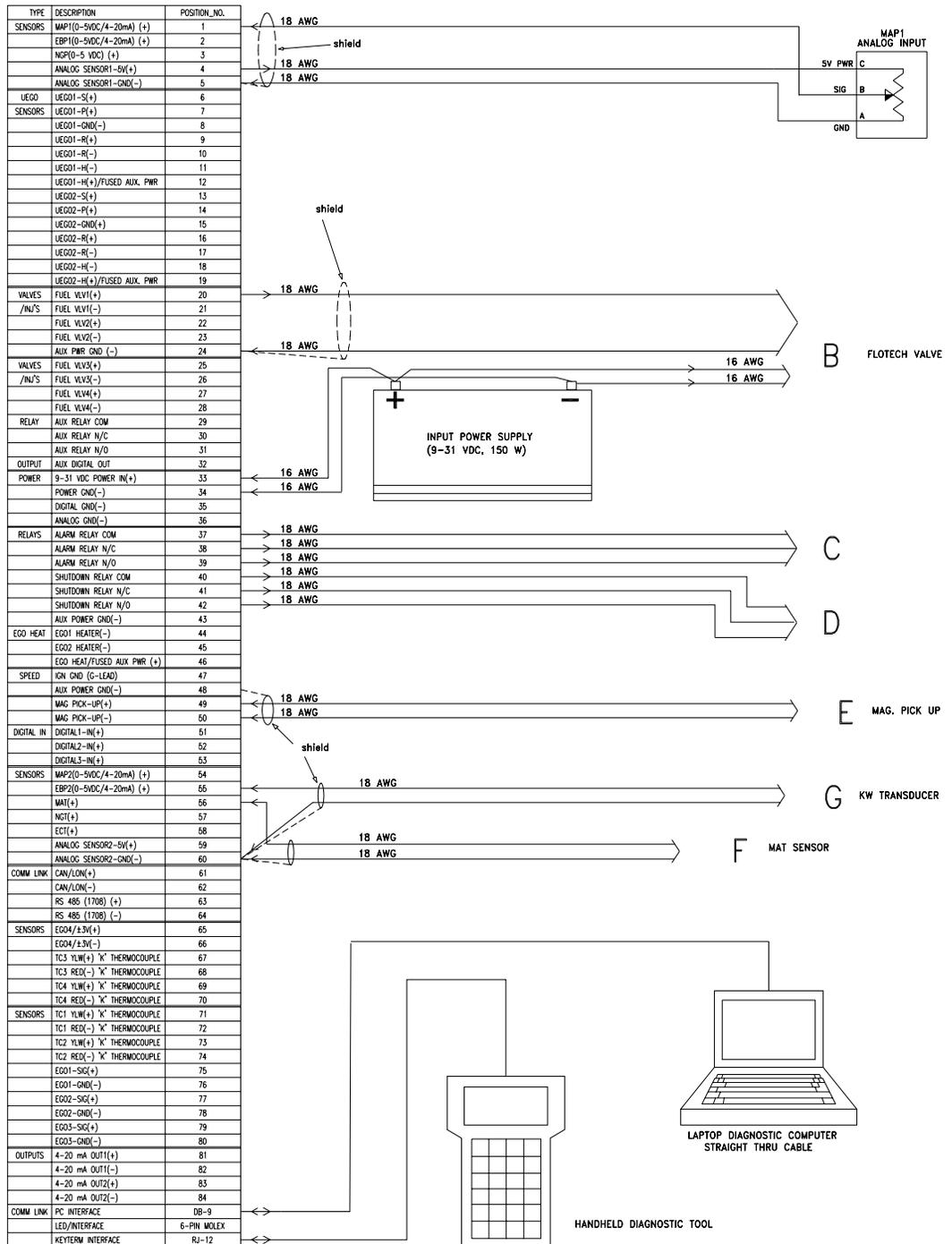


Figure 9-3a. Wiring for Single Bank or “V” Engine with Common Intake Manifold and KW Sensor (such as Caterpillar 3500)

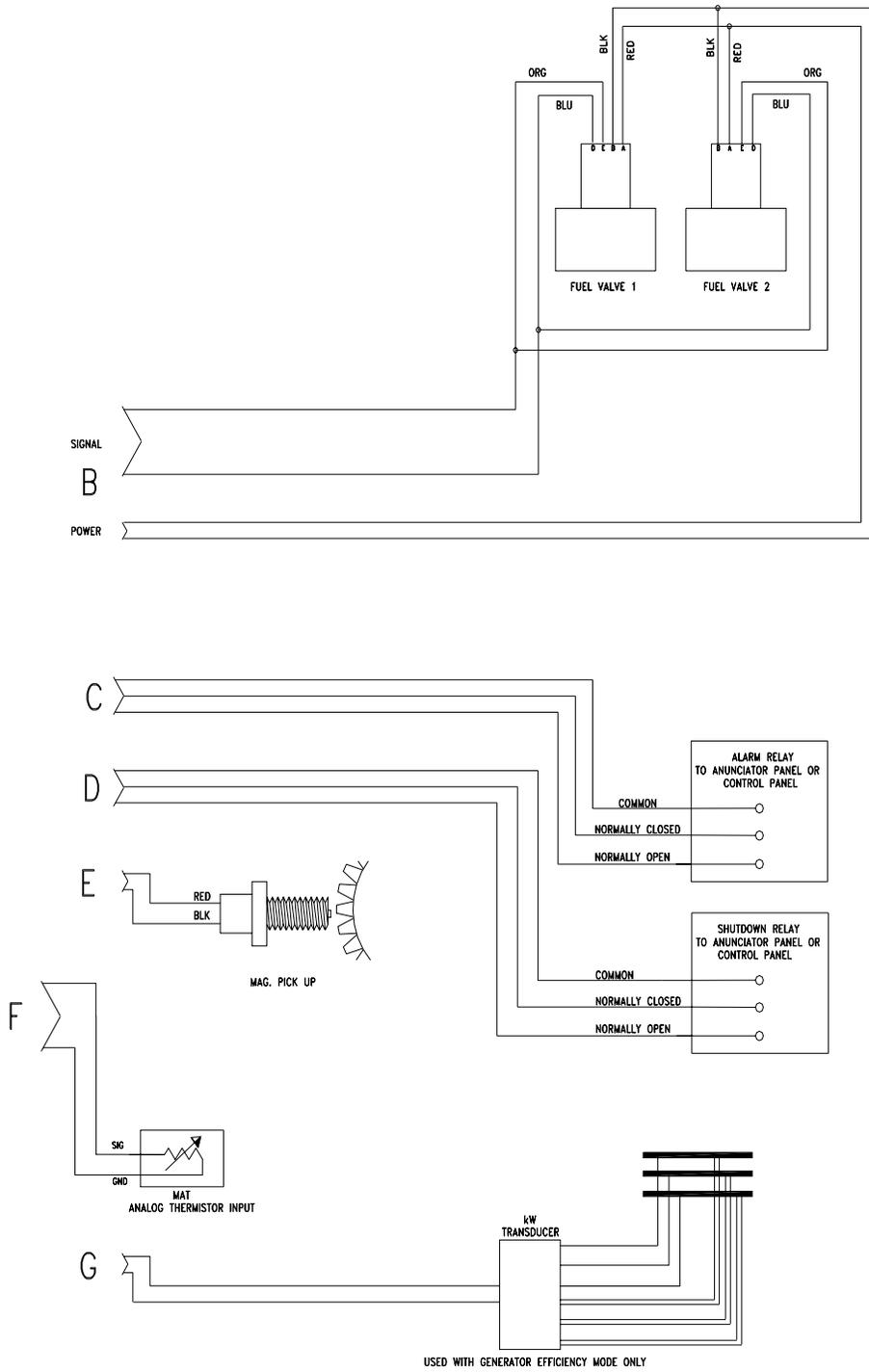


Figure 9-3b. Wiring for Single Bank or "V" Engine with Common Intake Manifold and KW Sensor (such as Caterpillar 3500)

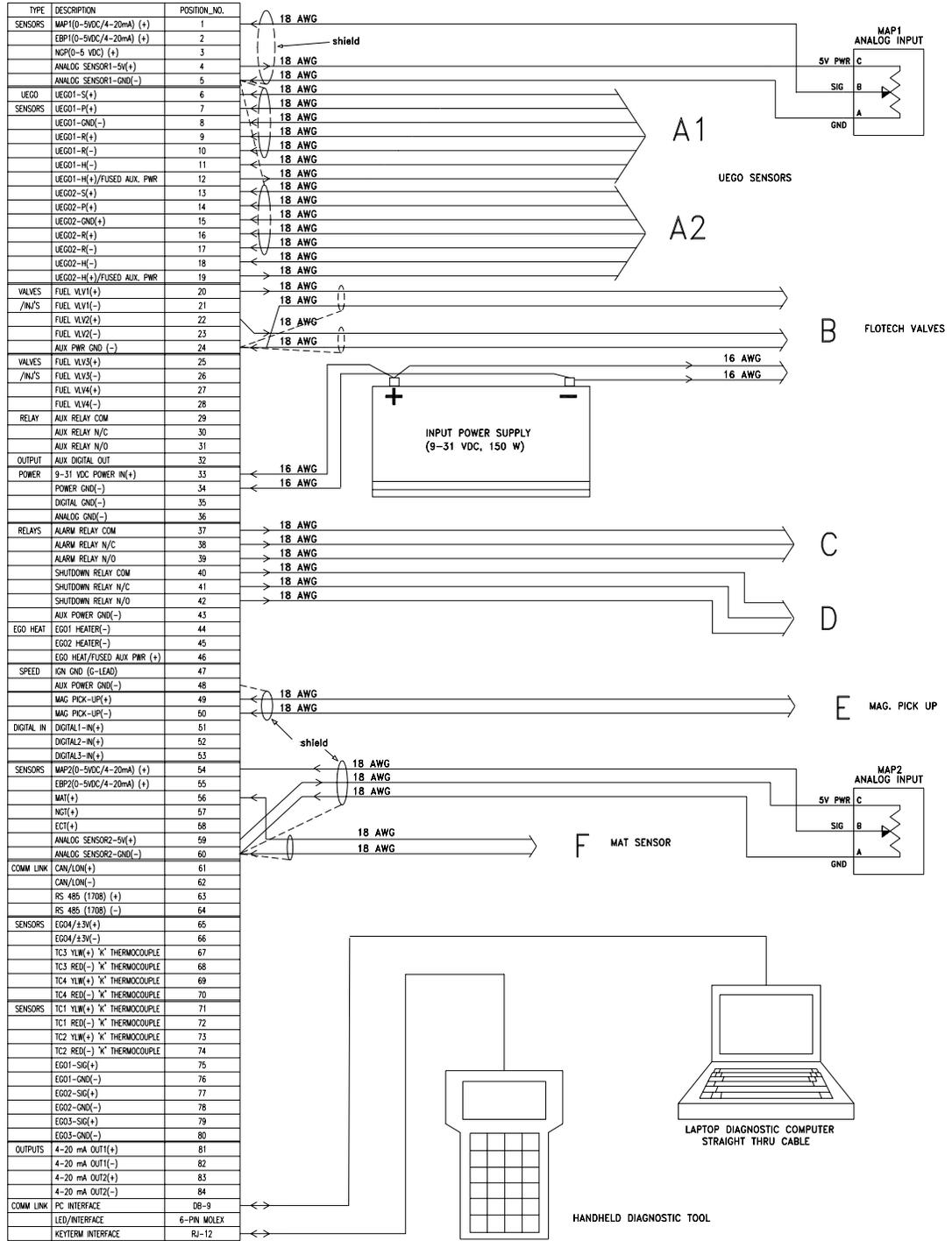


Figure 9-4a. Wiring for “V” Engine with Separate Intake Manifolds (such as Waukesha 7042)

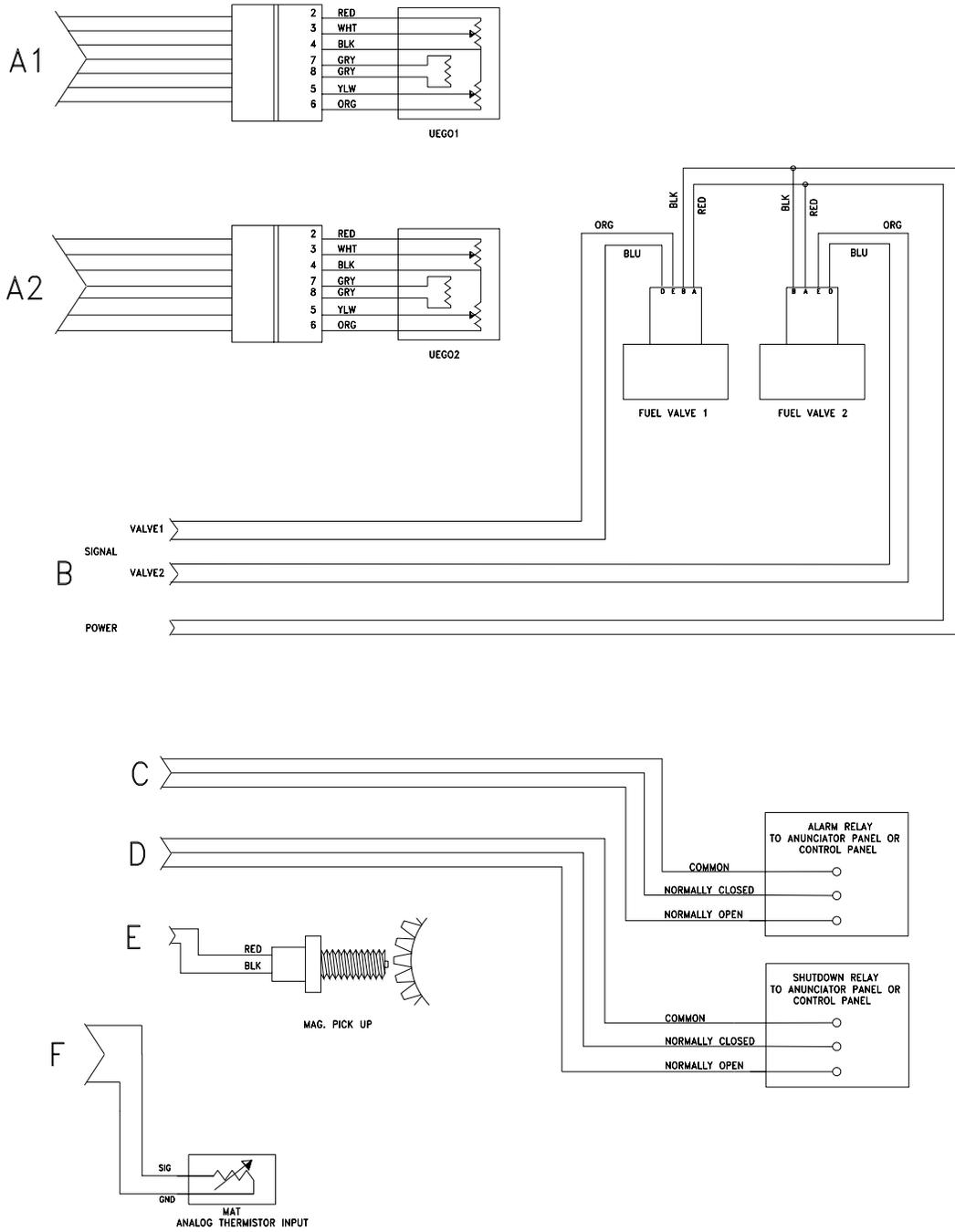


Figure 9-4b. Wiring for "V" Engine with Separate Intake Manifolds (such as Waukesha 7042)

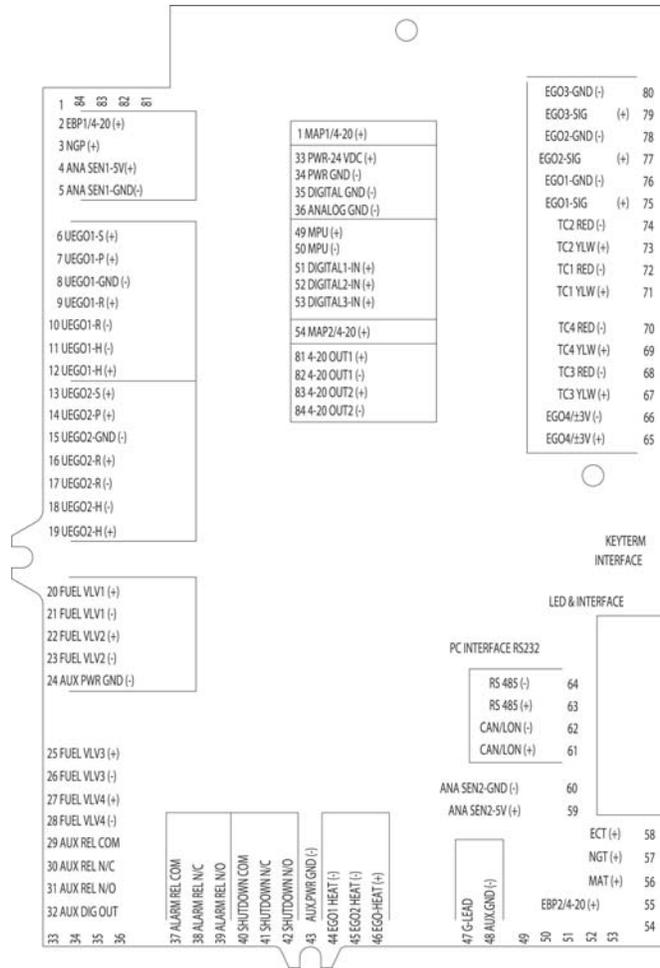


Figure 9-5. Legend Plate

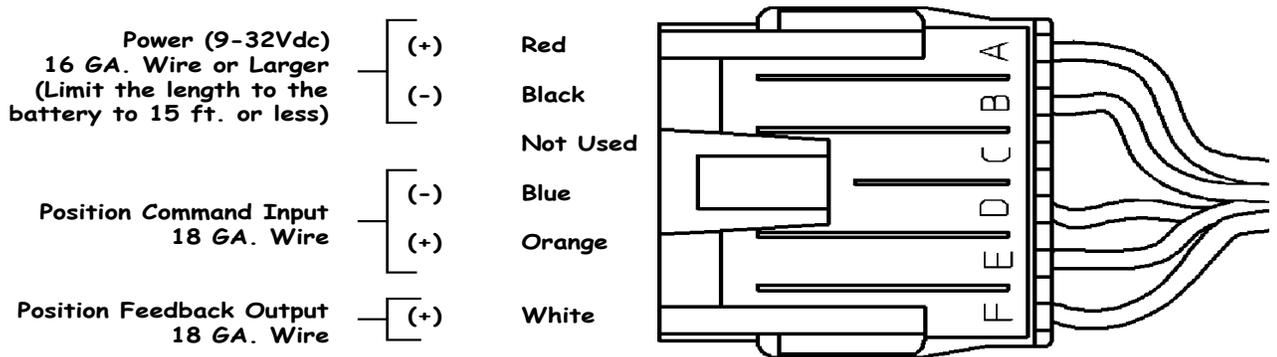
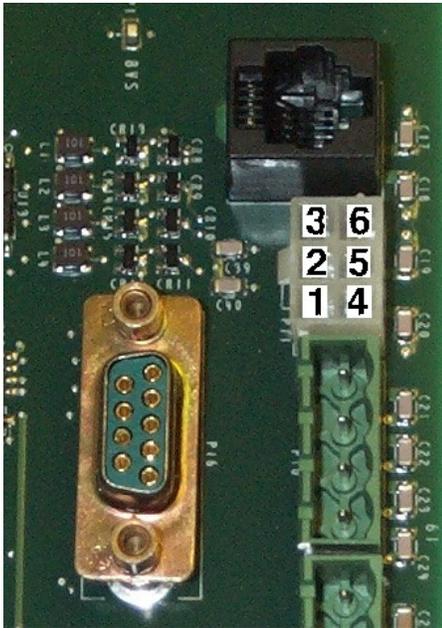
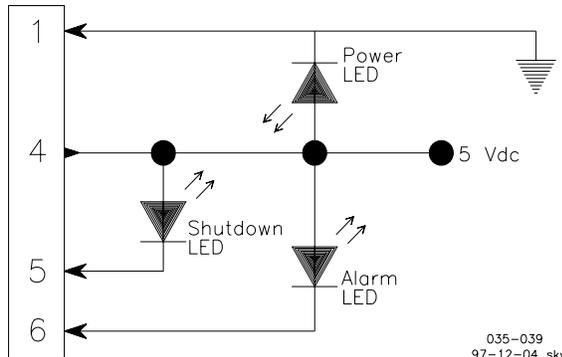


Figure 9-6. Flo-Tech™ (Packard) Connector Wiring Diagram

Status Indicator LEDs



If the operator wishes to install lights for GECO·Lean Burn control power, alarm, and shutdown (with or without the alarm and shutdown relay outputs), the CIRCUIT BOARD also includes a 6-pin connector specifically for indicator LEDs. The LEDs should be connected with a module available from your GECO·Lean Burn distributor.



Software Installation

The GECO·Lean Burn control includes software for two separate functions. The user interface software is the program used to configure the system and perform all the data streaming and diagnostic work as described in the Operation section. This software will be updated periodically, but the program name can always be recognized by the extension .EXE. The other software is the programming for the microprocessor, which may also be updated to add features and new functions to the GECO·Lean Burn system (this program has the extension .S19). These two programs work together when changes are made to the configuration or calibration of the system parameters. Changes made on the user interface screens will communicate with the CIRCUIT BOARD microprocessor and update the on-board programming as well. The .S19 files are application specific calibration files. A different file is needed for the engine model (e.g. Caterpillar G3500LE), fuel composition (e.g. high or low BTUs), or control mode (e.g. UEGO or kW sensor).

	Description	Part Number
	KW Sensor Closed Loop Control for Low BTU Fuel (<600 Btu/scf)	9927-233
	KW Sensor Closed Loop Control for High BTU Fuel (>600 Btu/scf)	9927-234
	UEGO Sensor Closed Loop Control	9927-235
	Shipment software	9927-194



CAUTION

An unsafe condition could occur with improper use of these software tools. Only trained personnel should have access to these tools.

The interface software can be run directly off the 3.5 inch floppy disk drive, but it is recommended that a backup copy of the disk be used, with the original disk safely stored. It may be more convenient to copy and run the software on the internal hard drive of the PC, again with the original disk safely stored. In addition to the .EXE and .S19 files described above, the user interface requires the GRAPH.FON support file on the same disk, in the same directory or folder as the other software.

Updating Application Programming (.S19 file)

An .S19 file can be downloaded to the circuit board with the user interface software as follows:

- Shut engine down.
- From any screen, type Alt-D (hold the Alt key and press D at the same time).
- An input message at the bottom of the screen will request the password included with the update software. Contact your GECO·Lean Burn distributor for more information.
- Another message will request the pathname of the new .S19 file (example: c:\geco\9927235.S19).
- The new program will then be downloaded to the flash memory.

Flo-Tech Installation Diagrams

The Flo-Tech actuator/valve may be mounted in any position. Each of the two mounting flanges on the valve housing has four 10 mm through-mounting holes in a square 74 mm pattern. The base of the Flo-Tech actuator housing has an optional bolt pattern that can be used for mounting or support. It uses four M8x0.125 bolts in an 88.9 mm square pattern.

Configuration and Calibration

These instructions assume that the engine is in good operating condition and the ***mechanical carburetor has been properly installed and calibrated.***

Carburetor Tuning:

1. The software that is in the control when it is shipped is designed to drive the Flo-Tech valves to wide open during engine start when power is applied to the control and to the valves. This allows the calibration and tuning of the carburetor to be completed before calibration and tuning of the GECO·Lean Burn control.

Control Configuration Before Engine Start:

2. Based on closed loop control mode, engine model, and fuel composition, select the appropriate *.S19 file from the software diskette.

Download the selected *.S19 file into the control by following the Software Installation instructions earlier in this chapter.

3. Enter the password to get full access to the configuration and calibration screens on the PC. Go to the Configuration screen on page 5. Enter the engine specific parameters:
 - cylinders
 - displacement
 - rated power
 - rated MAP
 - rated rpm
 - gen. efficiency
 - rpm pulse/rev.
 - rpm source

Enable the desired alarm and shutdown functions. Enable the appropriate sensors. Enter the calibration values for the kW transducer and MAP sensor, if needed. Check that the Crank Default valve position is set at 85%.

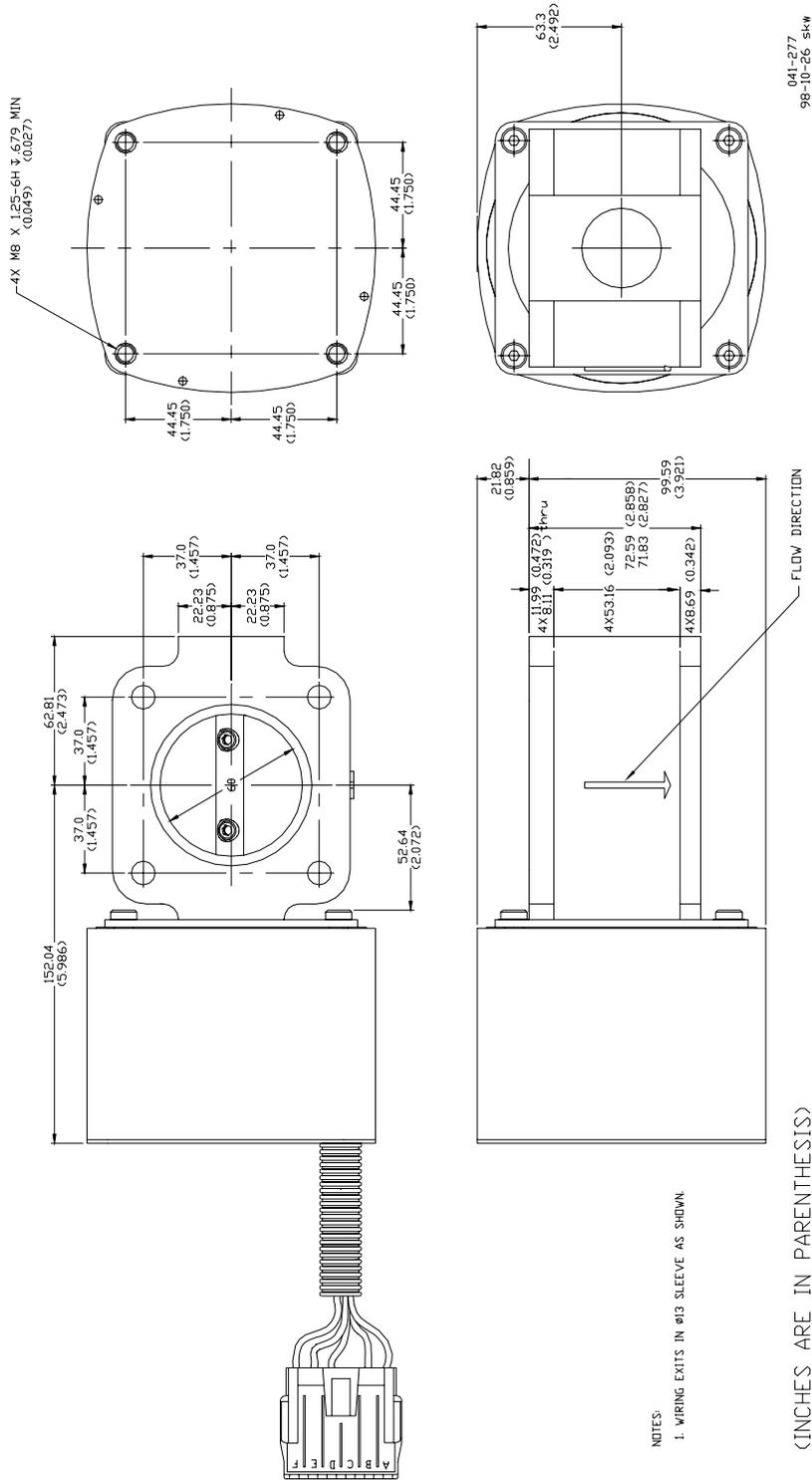
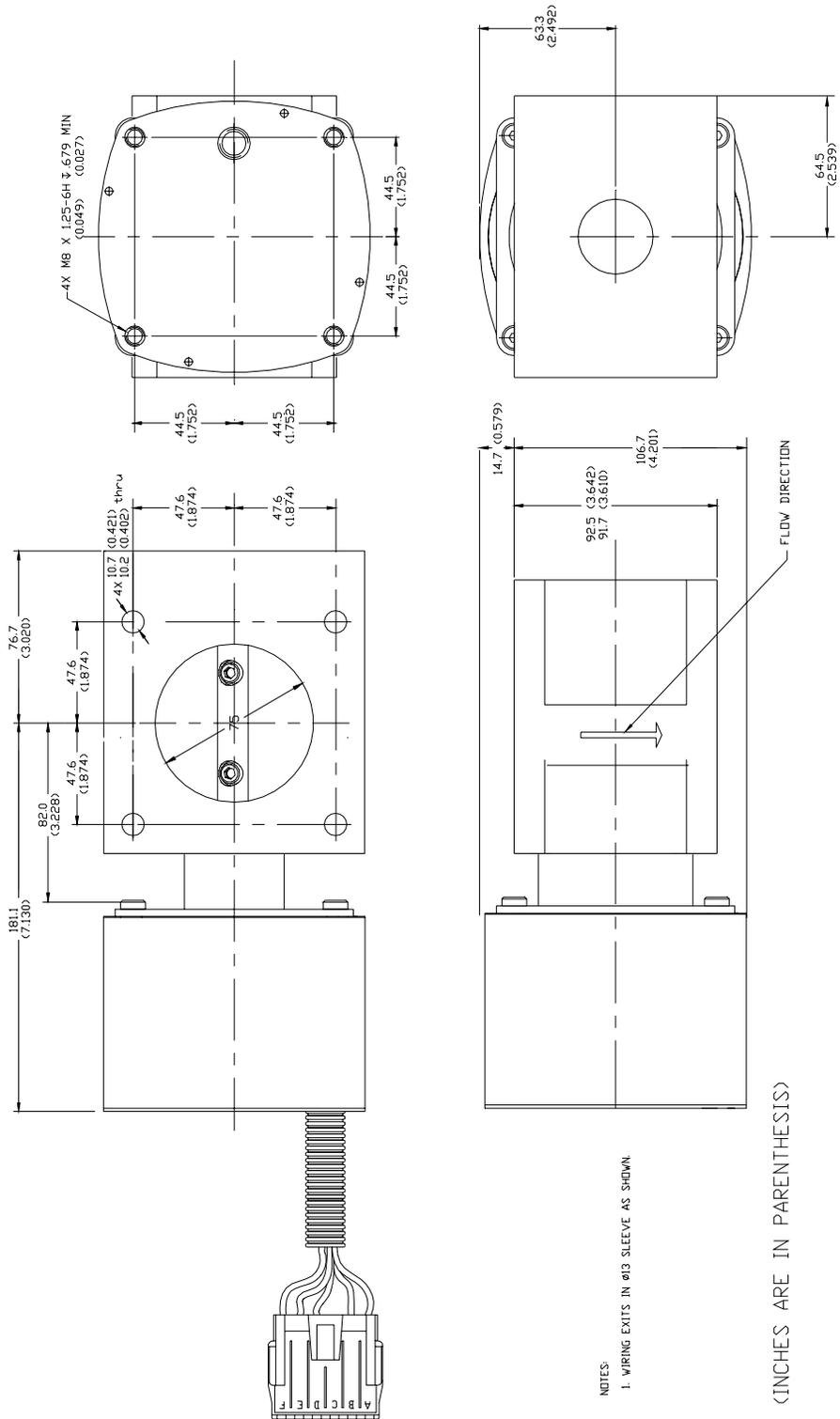


Figure 9-7. Flo-Tech Outline Drawing (33/48/60/68 mm bores)



041-278
98-10-28 skw

Figure 9-8. Flo-Tech Outline Drawing (75 mm bore)

4. Move to the Diagnostic screen on page 3 (UEGO control) or page 2 (kW control). Check that the cursor is highlighting the ClearAll label and press the Enter key. Check to see that all faults are cleared and remain clear.
5. Set the circuit board toggle switch to Open Loop. Go to the Valve-Learn table on page 2 (UEGO) or page 1 (kW). Check that the default valve settings are between 85 and 90% (wide open). The default valve settings will hold the Flo-Tech valve open so that at initial startup the engine will run on the mechanical carburetor only.
6. Verify that the MAP signal is reading atmospheric pressure.

Calibrate Open Loop Valve Table below 50% Load:

7. Start the engine.
8. Verify the GECO·Lean Burn control speed measurement to confirm the correct Pulse/rev.
9. After the engine has warmed up, record the current Mdot_fuel value and enter this value in the first point of the Valve-Learn table.
10. Increase speed to the maximum rated speed of the engine. Record the current Mdot_fuel value and enter this value in the second point of the Valve-Learn table.
11. Ramp the engine load up to approximately 50%. Record the current Mdot_fuel and the Mdot_air values. Enter the Mdot_fuel value in the third point of the Valve-Learn table. Enter the Mdot_air value into the Mdot_air breakpoint parameter.

Transfer Mixture Control from Power Valve to Flo-Tech Valve:

12. Ramp the engine load up to the most common operating conditions. Record the current Mdot_fuel value.
13. Measure the exhaust oxygen content for a reference point.
14. Set the control mode to Manual (on page 1 or 2). Enter a new Flo-Tech valve position command several percentage points lower than the initial value of 85%. This will cause the exhaust oxygen measurement to increase.
15. Open the carburetor “power valve” (or air/fuel ratio adjustment) to bring the exhaust oxygen content back to the original reference point.
16. Repeat steps 15 and 16 until the Flo-Tech valve position is between 50 and 55%.
17. Using an exhaust emissions analyzer, verify that the current air/fuel ratio is correct. If necessary, manually adjust the Flo-Tech valve position to tune in the correct value. Record this valve position and, if present, the UEGO sensor reading.
18. Enter this valve position command in all points of the Valve-Learn table.
19. Return control mode to Open Loop.

Phi Table Calibration (Option 1—UEGO sensor control):

20. Change to the Phi Calibration screen on page 4. Keep the engine load at its most common operating condition. Adjust the “Phi Modifier” to increase or decrease the Phi Target value to match the Phi Actual value. (If the Phi Modifier adjustment does not have enough range to bring the Phi Target into alignment with the Phi Actual value, go to the next step.)
21. If the Phi Target and Phi Actual values are within 0.05 of each other, set the onboard switch to Closed Loop. Note that the current operating point of the engine is highlighted on the Phi table. Adjust the Phi table value to meet the required emission level. Increasing Phi will richen the mixture and reducing Phi will lean the mixture. Record the Mdot_fuel value and the valve position command. If the most common operating point is full power, enter the Mdot_fuel value and the valve position command in the last point of the Valve-Learn table. If it is not full power, enter these values into the next-to-last point of the Valve-Learn table.
22. Adjust the engine to 100% load if it is not already there. Adjust the Phi values in the Phi table as before to meet required emission levels. Enter the Mdot_fuel value and valve position command value into the last point of the Valve-Learn table. Repeat this process over the operating range of the engine (that is, 50% to 100% load and minimum to maximum speed). At each of these points, verify that engine emissions or exhaust oxygen are at the expected values. If not, adjust the Phi values in the table to achieve the desired results. Remember that the control interpolates between points on the table so that changing two or even four values on the table may be necessary to get the desired Phi Target value. Also, record the final Mdot_fuel and valve position command values at each operating point.
23. Use these recorded values of Mdot_fuel and valve position command to fill in the last four points of the Valve-Learn table.
24. Adjust Phi values outside of the normal operating range so that unusual operating conditions do not lead to control mistakes.
25. For future reference, record the configuration, calibration, and tuning values entered into the control.

Phi Table Calibration (Option 2—kW sensor control):

26. Change to the Phi Calibration screen on page 4. Keep the engine load at its most common operating condition. Adjust the “Phi Modifier” to increase or decrease the Est GenPower value to match the Act GenPower value. If the Phi Modifier adjustment does not have enough range to bring the Est GenPower value into alignment with the Act GenPower value, reduce the generator efficiency, Gen Eff, one percent at a time until the Est GenPower matches the Act GenPower.
27. Set the onboard switch to Closed Loop. Note that the current operating point of the engine is highlighted on the Phi table. Check to see if the engine is meeting the required emission levels. If not, adjust the Phi table value to meet the required emission level. Increasing Phi will richen the mixture and reducing Phi will lean the mixture. Record the Mdot_fuel value and the valve position command. If the most common operating point is full power, enter the Mdot_fuel value and the valve position command in the last point of the Valve-Learn table. If it is not full power, enter these values into the next-to-last point of the Valve-Learn table.

28. Adjust the engine to 100% load if it is not already there. Adjust the Phi values in the Phi table as before to meet required emission levels. Enter the Mdot_fuel value and valve position command value into the last point of the Valve-Learn table. Repeat this process over the operating range of the engine (that is, 50% to 100% load and minimum to maximum speed). At each of these points, verify that engine emissions or exhaust oxygen are at the expected values. If not, adjust the Phi values in the table to achieve the desired results. Remember that the control interpolates between points on the table so that changing two or even four values on the table may be necessary to get the desired Phi Target value. Also, record the final Mdot_fuel and valve position command values at each operating point.
29. Use these recorded values of Mdot_fuel and valve position command to fill in the last four points of the Valve-Learn table.
30. Adjust Phi values outside of the normal operating range so that unusual operating conditions do not lead to control mistakes.
31. For future reference, record the configuration, calibration, and tuning values entered into the control.

Chapter 10.

Maintenance and Fault Indications

This chapter provides information for keeping the GECO™·Lean Burn Air/fuel Controller in proper working order. Contact your GECO·Lean Burn distributor for service options.



WARNING

The GECO·Lean Burn Air/fuel Ratio Controller is designed to supplement existing fuel controls in order to automatically provide the optimum fuel mixture for emissions compliance. As described in this manual, the system can be helpful for engine tuning and diagnosis; however, the GECO·Lean Burn control is not a fix for an existing malfunction. The original engine, including the mechanical components, air throttle(s), carburetor(s), governor, ignition system, and safety shutdowns must be in proper working order before the GECO·Lean Burn control is put into operation.

Maintenance

The GECO·Lean Burn controller and system components were designed to be very reliable in operation. None of the components require any maintenance, however the exhaust gas oxygen sensor's intake manifold pressure and temperature sensors have a limited life and will require regular replacement. A regular program for engine maintenance should continue after the GECO·Lean Burn system is installed. To provide emissions compliance, the original engine systems need to be in proper working order. Please review the warning statement above, and any warnings associated with the exhaust system components (UEGO sensor). The use of certain gasket and thread sealers or high temperature thread lubricants can cause poisoning of the oxygen sensor. 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 GECO·Lean Burn system will relieve the operator of constant carburetor tuning for emissions compliance, but consistent engine maintenance is still required.

Safety Checks

The GECO·Lean Burn controller alarm and shutdown relays should be included in a regular safety check to verify their functionality.

Replacement Information

The highest maintenance requirement is for the automotive oxygen sensor (UEGO). The typical life expectancy for these components is on the order of 2000 hours, or about three months of continuous service.

Troubleshooting

The diagnostic functions of the GECO·Lean Burn system are reported to the user either through the hand held interface or the PC interface software. Certain faults can also cause alarm or shutdown conditions, if these systems have been configured and integrated into the existing engine control panel. The table below describes all the faults and conditions that will cause an alarm or shutdown condition. In addition, the plotting and data logging features of the PC interface software (see Chapter 4, Operation) can be very valuable for troubleshooting an intermittent fault or difficult diagnosis.

Diagnostic Faults—Indication only	Fault Conditions
No Alarm or Shutdown	
Closed loop valve limit low	Valve Command \leq 5.0%
Closed loop valve limit high	Valve Command \geq 99.0%
DC Power supply voltage low	Voltage $<$ 9.5 V and RunMode = RUNNING
DC Power supply voltage high	Voltage $>$ 31.0 V and RunMode = RUNNING
ECU Processor	Internal microprocessor errors
Trigger	Noisy speed signal MPU
CJC Sensor open	$>$ 4.95 V ($>$ 300 °F)
CJC Sensor lower than expected	$<$ 0.05 V ($<$ 45 °F)
Alarm and Shutdown Configuration	
Disable/Enable/Enable+Shutdown	
UEGO max voltage	$>$ 1.1 Volts
MAP low	$<$ 0.25 Vdc
MAP high	$>$ MAP high pressure
kW feedback	Calculated from Rated Power and kW Sensor calibration
kW higher than expected	Calculated from Rated Power and kW Sensor calibration
Flo-Tech™ valve current low	$<$ 0.1 Amp and Valve Cmd $>$ 30%
Valve current high	$>$ 0.6 Amp and Valve Cmd $<$ 50% or short detected

Symptoms Without Indicated Faults

Flo-Tech valves remain closed preventing engine from starting:

- Verify speed signal to control is good.
- Verify 24 Vdc power to Flo-Tech valves.
- Check valve crank default position is open enough for engine to start.
- Verify 24 Vdc power to control.

At high power operating conditions, Flo-Tech valves close down too much for engine to carry full load:

- Verify that turbocharger can supply sufficient air for engine to run at desired air/fuel ratio.

No hand held display:

- Unplug and re-plug hand held cable [SEE WARNING BELOW].
- Check circuit board LED for power supply, check power fuse.
- Hand held cable.
- Hand held programmer.
- Circuit board.

Strange hand held display:

- Power-on setup mode (see Operation section, hand held programmer).
- Unplug and re-plug hand held cable [SEE WARNING BELOW].

**WARNING**

The GECO enclosure should not be opened when a hazardous atmosphere is present. Wiring connections, which could cause sparks, are located inside the cabinet.

EXPLOSION HAZARD—Do not disconnect while circuit is live unless area is known to be non-hazardous.

High emissions:

- Exhaust air leak—causes UEGO signal errors.
- Ignition timing.
- Ignition system components.
- UEGO target calibration—recalibrate Installation section guidelines.

RPM Signal Issues

The controller will follow several different control strategies depending on the engine speed signal. If the controller is not receiving proper speed signals, or if the “pulses/rev” setting is not correct, the GECO·Lean Burn control may default to an incorrect operating condition.

There are three main operating conditions based on engine speed:

- Stopped—below 20 rpm—fuel metering valves closed.
- Cranking—from 20 to 400 rpm—fuel metering valves default.
- Running—above 400 rpm—open loop or closed loop.

Chapter 11.

Service Options

The GECO™·Lean Burn control is sold and serviced by Woodward's authorized distributors in North America, Central America, and the Caribbean:

Western Canada

Alberta Governor Service

5977 103A Street

Edmonton, AB T6H 2J7, Canada

phone— +1 (780) 437-4673

fax— +1 (780) 434-2339

e-mail— todd@albertagovernor.com

website— www.albertagovernor.com

Eastern Canada

Croman Control Systems

548 Edgeley Boulevard

PO Box 5480

Concord, ON L4K 1B6, Canada

phone— +1 (416) 667-5952

toll-free— 1 (800) 268-9506 (North America)

fax— +1 (416) 667-5919

e-mail— rbryan@toromont.com (applications)

e-mail— controlsystems@toromont.com
(general inquiries)

website— www.cromancontrols.com

Mexico

AZO Engineered Systems SA de CV

Lago Chapala #61, Col. Anahuac

Mexico D.F., CP. 11320, Mexico

phone— +52 (55) 5341-3412 ext. 108

fax— +52 (55) 5341-5191

e-mail— woodward@azo-group.com

website— www.azo-group.com

Central America & Caribbean

Power Management & Control Systems NV (PMCS)

Curaçao Airport Economic Zone

Building F—Unit FI-3

PO Box 3905

Curaçao, Netherlands Antilles

phone— +599 (9) 833-9365

fax— +599 (9) 833-9366

e-mail— info@pmcsnv.com

website— www.pmcsnv.com

Rocky Mountain US

Winn-Marion Barber, LLP

355 Inverness Drive South, Unit B

Englewood, CO 80112, USA

phone— +1 (303) 778-0902

fax— +1 (303) 733-9836

e-mail— woodward@winn-marion.com

website— www.winn-marion.com

Southeast US**Governor Control Systems Inc. (GCS)**

3101 SW 3rd Avenue
Fort Lauderdale, FL 33315, USA
phone– +1 (954) 462-7404
toll-free– 1 (877) 659-6328 (North America)
fax– +1 (954) 761-8768
e-mail– woodward@govconsys.com
website– www.govconsys.com

South Central US**Fair Engineering Sales**

PO Box 8739
2022 Tamvest Court
Mandeville, LA 70448, USA
phone– +1 (985) 626-0077
toll-free– 1 (800) 375-0077 (North America)
fax– +1 (985) 626-5432
e-mail– fairengr@fairengineering.com
website– www.fairengineering.com

Northeast/North Central US**Peaker Services Inc. (PSI)**

8080 Kensington Court
Brighton, MI 48116, USA
phone– +1 (248) 437-4174
toll-free– 1 (800) 622-4224 (North America)
fax– +1 (248) 437-8280
e-mail– kstone@peaker.com
website– www.peaker.com

Southwest US**Drake Controls**

5227 Langfield Road
Houston, TX 77040, USA
phone– +1 (713) 996-0190
fax– +1 (713) 996-0195

Northwestern/Pacific US**Case Marine and Industrial Inc.**

1100 NW 51st Street
Seattle, WA 98107, USA
phone– +1 (206) 352-8000
after hrs– +1 (206) 719-6066
fax– +1 (206) 352-8060
e-mail– solutions@casemarine.com
website– www.casemarine.com

Appendix.

Modbus Register Addresses

Integer Input/Output Parameters

Integer Address	Parameter Name	Parameter Description	Internal Bytes	Internal Units	Multiply By	Then Add	To Obtain
1	RPM	Engine speed	2	[16.0] rpm	1	0	rpm
2	MAP1	Intake manifold pressure - bank 1	2	[8.8] psia	0.0039063	0	psia
3	MAP2	Intake manifold pressure - bank 2	2	[8.8] psia	0.0039063	0	psia
4	MAP	Average intake manifold pressure	2	[8.8] psia	0.0039063	0	psia
5	EBP1	Exhaust back pressure - bank 1	2	[8.8] psia	0.0039063	0	psia
6	EBP2	Exhaust back pressure - bank 2	2	[8.8] psia	0.0039063	0	psia
7	BP	Barometric pressure	2	[8.8] psia	0.0039063	0	psia
8	NGP	Natural gas pressure	2	[8.8] psia	0.0039063	0	psia
9	MAT	Intake manifold temperature	2	[10.6] deg R	0.015625	-460	deg F
12	CJC	Cold junction (controller) temperature	2	[13.3] deg F	0.125	0	deg F
30	CL1	Closed loop control value - bank 1	2	[S0.15]	0.0030518	0	%
31	CL2	Closed loop control value - bank 2	2	[S0.15]	0.0030518	0	%
34	VALVE1	Fuel valve command - bank 1	2	[S0.15]	0.0030518	0	%
35	VALVE2	Fuel valve command - bank 2	2	[S0.15]	0.0030518	0	%
36	PHI_TARG	Target equivalence ratio for lean-burn control	2	[1.15] phi	3.052E-05	0	phi
37	UEGO1_PHI	UEGO sensor indicated equivalence ratio - bank 1	2	[1.15] phi	3.052E-05	0	phi
38	UEGO2_PHI	UEGO sensor indicated equivalence ratio - bank 2	2	[1.15] phi	3.052E-05	0	phi
39	VOLTAGE	Controller supply voltage	1	[0.8] 32.45V	0.1272742	0	volts
41	GENERATOR_ACT	Measured generator output power	2	[16.0] bhp	0.7457	0	KW
42	GENERATOR_EST	Estimated generator output power	2	[16.0] bhp	0.7457	0	KW
43	POWER_EST	Estimated engine power	2	[16.0] bhp	1	0	bhp
44	TORQUE_EST	Estimated engine torque	2	[16.0] ft-lbs	1	0	ft-lbs
45	TC1	Thermocouple 1 temperature	2	[13.3] deg F	0.125	0	deg F
46	TC2	Thermocouple 2 temperature	2	[13.3] deg F	0.125	0	deg F
47	TC3	Thermocouple 3 temperature	2	[13.3] deg F	0.125	0	deg F
48	TC4	Thermocouple 4 temperature	2	[13.3] deg F	0.125	0	deg F
49	VALVE1_CUR	Valve driver 1 current	1	[0.8] 6.18A	0.0243273	0	amps
50	VALVE2_CUR	Valve driver 2 current	1	[0.8] 6.18A	0.0243273	0	amps
55	RUN_MODE	0=stopped, 1=cranking, 2=running	1	integer	1	0	0,1,2
56	CONTROL_MODE	0=open loop, 1=closed loop, 3=adaptive+CL for bank1	1	integer	1	0	0,1,3

57	CONTROL_MODE	0=open loop, 1=closed loop, 2 3=adaptive+CL for bank2	1	integer	1	0	0,1,3
62	INJ1_VOLTS	INJ1 raw (unfiltered and scaled) voltage	1	[0.8] 5V	0.0196078	0	volts
63	INJ2_VOLTS	INJ2 raw (unfiltered and scaled) voltage	1	[0.8] 5V	0.0196078	0	volts
66	TC1_VOLTS	TC1 raw (unfiltered and scaled) voltage	1	[0.8] 5V	0.0196078	0	volts
67	TC2_VOLTS	TC2 raw (unfiltered and scaled) voltage	1	[0.8] 5V	0.0196078	0	volts
68	TC3_VOLTS	TC3 raw (unfiltered and scaled) voltage	1	[0.8] 5V	0.0196078	0	volts
69	TC4_VOLTS	TC4 raw (unfiltered and scaled) voltage	1	[0.8] 5V	0.0196078	0	volts
70	V_VOLTS	V raw (unfiltered and scaled) voltage	1	[0.8] 5V	0.0196078	0	volts
72	MAT_VOLTS	MAT raw (unfiltered and scaled) voltage	1	[0.8] 5V	0.0196078	0	volts
73	NGT_VOLTS	NGT raw (unfiltered and scaled) voltage	1	[0.8] 5V	0.0196078	0	volts
74	UEGO1_VOLTS	UEGO1 raw (unfiltered and scaled) voltage	1	[0.8] 5V	0.0196078	0	volts
75	UEGOS1_VOLTS	UEGOS1 raw (unfiltered and scaled) voltage	1	[0.8] 5V	0.0196078	0	volts
76	UEGOP1_VOLTS	UEGOP1 raw (unfiltered and scaled) voltage	1	[0.8] 5V	0.0196078	0	volts
77	UEGOH1_VOLTS	UEGOH1 raw (unfiltered and scaled) voltage	1	[0.8] 5V	0.0196078	0	volts
78	UEGO2_VOLTS	UEGO2 raw (unfiltered and scaled) voltage	1	[0.8] 5V	0.0196078	0	volts
79	UEGOS2_VOLTS	UEGOS2 raw (unfiltered and scaled) voltage	1	[0.8] 5V	0.0196078	0	volts
80	UEGOP2_VOLTS	UEGOP2 raw (unfiltered and scaled) voltage	1	[0.8] 5V	0.0196078	0	volts
81	UEGOH2_VOLTS	UEGOH2 raw (unfiltered and scaled) voltage	1	[0.8] 5V	0.0196078	0	volts
82	MAP1_VOLTS	MAP1 raw (unfiltered and scaled) voltage	1	[0.8] 5V	0.0196078	0	volts
83	MAP2_VOLTS	MAP2 raw (unfiltered and scaled) voltage	1	[0.8] 5V	0.0196078	0	volts
84	NGP_VOLTS	NGP raw (unfiltered and scaled) voltage	1	[0.8] 5V	0.0196078	0	volts
85	CJC_VOLTS	CJC raw (unfiltered and scaled) voltage	1	[0.8] 5V	0.0196078	0	volts
86	EBP1_VOLTS	EBP1 raw (unfiltered and scaled) voltage	1	[0.8] 5V	0.0196078	0	volts
87	EBP2_VOLTS	EBP2 raw (unfiltered and scaled) voltage	1	[0.8] 5V	0.0196078	0	volts
88	UEGOR1_VOLTS	UEGOR1 raw (unfiltered and scaled) voltage	1	[0.8] 5V	0.0196078	0	volts
89	UEGOR2_VOLTS	UEGOR2 raw (unfiltered and scaled) voltage	1	[0.8] 5V	0.0196078	0	volts
90	PROM_ID1	Application code - first 4 digits	2	integer	1	0	4 digits
91	PROM_ID2	Application code - last 4 digits	2	integer	1	0	4 digits
92	PROM_ID3	Calibration date month	2	integer	1	0	2 digits
93	PROM_ID4	Calibration date day	2	integer	1	0	2 digits
94	PROM_ID5	Calibration date year (2-digit)	2	integer	1	0	2 digits
95	PROM_ID6	Engine maker code	2	integer	1	0	integer
96	PROM_ID7	Engine model year (4-digit)	2	integer	1	0	4 digits
97	PROM_ID8	Engine displacement	2	0.1 liters/bit	0.1	0	liters
98	PROM_ID9	Cylinders	2	integer	1	0	cyl.
99	PROM_ID10	Engine displacement	2	cu. in.	1	0	cu. in.
100	PROM_ID11	UNUSED	2	integer	1	0	integer

101	PROM_ID12	HCN - Hardware compatibility number	2	integer	1	0	integer
102	PROM_ID13	SCN - Software compatibility number	2	integer	1	0	integer
103	PROM_ID14	WGC SCN - Woodward software compatibility number	2	integer	1	0	integer
104	PROM_ID15	GECO Model number	2	integer	1	0	integer
105	PROM_ID16	Revision code	2	integer	1	0	2-byte ASCII

Boolean Input/Output Parameters

Boolean Address	Table Index	Bit	Parameter Name	Parameter Description	Clear	Set	Set	Clear
1	0	0	MAP1_HIGH_AL	MAP1 voltage high alarm	OK	FAULT	0	1
2	1	1	MAT_HIGH_AL	MAT voltage high alarm	OK	FAULT	0	1
3	2	2	NGP_HIGH_AL	NGP voltage high alarm	OK	FAULT	0	1
6	5	5	MAP2_HIGH_AL	MAP2 voltage high alarm	OK	FAULT	0	1
7	6	6	BAT_HIGH_AL	Battery voltage high alarm	OK	FAULT	0	1
9	1	0	MAP1_LOW_AL	MAP1 voltage low alarm	OK	FAULT	0	1
10	1	1	MAT_LOW_AL	MAT voltage low alarm	OK	FAULT	0	1
11	2	2	NGP_LOW_AL	NGP voltage low alarm	OK	FAULT	0	1
14	5	5	MAP2_LOW_AL	MAP2 voltage low alarm	OK	FAULT	0	1
15	6	6	BAT_LOW_AL	Battery voltage low alarm	OK	FAULT	0	1
17	2	0	UEGOH2_HIGH_AL	UEGOH2 voltage high alarm	OK	FAULT	0	1
18	1	1	UEGOH1_HIGH_AL	UEGOH1 voltage high alarm	OK	FAULT	0	1
19	2	2	UEGOR2_HIGH_AL	UEGOR2 voltage high alarm	OK	FAULT	0	1
20	3	3	UEGOR1_HIGH_AL	UEGOR1 voltage high alarm	OK	FAULT	0	1
21	4	4	UEGOS2_HIGH_AL	UEGOS2 voltage high alarm	OK	FAULT	0	1
22	5	5	UEGOS1_HIGH_AL	UEGOS1 voltage high alarm	OK	FAULT	0	1
23	6	6	UEGOP2_HIGH_AL	UEGOP2 voltage high alarm	OK	FAULT	0	1
24	7	7	UEGOP1_HIGH_AL	UEGOP1 voltage high alarm	OK	FAULT	0	1
25	3	0	UEGOH2_LOW_AL	UEGOH2 voltage low alarm	OK	FAULT	0	1
26	1	1	UEGOH1_LOW_AL	UEGOH1 voltage low alarm	OK	FAULT	0	1
27	2	2	UEGOR2_LOW_AL	UEGOR2 voltage low alarm	OK	FAULT	0	1
28	3	3	UEGOR1_LOW_AL	UEGOR1 voltage low alarm	OK	FAULT	0	1
29	4	4	UEGOS2_LOW_AL	UEGOS2 voltage low alarm	OK	FAULT	0	1
30	5	5	UEGOS1_LOW_AL	UEGOS1 voltage low alarm	OK	FAULT	0	1
31	6	6	UEGOP2_LOW_AL	UEGOP2 voltage low alarm	OK	FAULT	0	1
32	7	7	UEGOP1_LOW_AL	UEGOP1 voltage low alarm	OK	FAULT	0	1
35	4	2	TC2_LOW_EXP_AL	TC2 lower than expected alarm	OK	FAULT	0	1
36	3	3	TC1_LOW_EXP_AL	TC1 lower than expected alarm	OK	FAULT	0	1
39	6	6	TC2_HIGH_AL	TC2 open (high) alarm	OK	FAULT	0	1
40	7	7	TC1_HIGH_AL	TC1 open (high) alarm	OK	FAULT	0	1
42	5	1	MEM_AL	Bad memory byte alarm	OK	FAULT	0	1
43	2	2	COP_AL	COP fail detected alarm	OK	FAULT	0	1
44	3	3	EXEC_AL	Illegal instruction execution detected alarm	OK	FAULT	0	1
45	4	4	CLOCK_AL	Clocks stopped alarm	OK	FAULT	0	1

46	5	STACK_AL	Stack overflow alarm	OK	FAULT	0	1	
47	6	TIMING_AL	A/D conversions not completed alarm	OK	FAULT	0	1	
48	7	ISR_AL	Unscheduled or improper interrupt alarm	OK	FAULT	0	1	
55	6	6	NGP_LOW_EXP_A L	NGP lower than expected alarm	OK	FAULT	0	1
56	7	7	NGP_HIGH_EXP_ AL	NGP higher than expected alarm	OK	FAULT	0	1
58	7	1	MAT_HIGH_EXP_ AL	MAT higher than expected alarm	OK	FAULT	0	1
65	8	0	OVERSPEED_AL	OverSpeed detected alarm	OK	FAULT	0	1
72	7	EBP2_LOW_AL	EBP2 out of range low alarm	OK	FAULT	0	1	
73	9	0	EBP2_HIGH_AL	EBP2 out of range high alarm	OK	FAULT	0	1
76	3	EBP1_LOW_AL	EBP1 out of range low alarm	OK	FAULT	0	1	
77	4	EBP1_HIGH_AL	EBP1 out of range high alarm	OK	FAULT	0	1	
82	#	1	INJ2_LOW_AL	Injector driver 2 current low alarm	OK	FAULT	0	1
83		2	INJ1_LOW_AL	Injector driver 1 current low alarm	OK	FAULT	0	1
86	5	INJ2_HIGH_AL	Injector driver 2 current high alarm	OK	FAULT	0	1	
87	6	INJ1_HIGH_AL	Injector driver 1 current high alarm	OK	FAULT	0	1	
91	#	2	CJC_LOW_AL	Cold junction compensation temperature low alarm	OK	FAULT	0	1
95	6	CJC_HIGH_AL	Cold junction compensation temperature high alarm	OK	FAULT	0	1	
128	#	7	TC1_L_SD	TC1 low temperature shutdown	OK	SHUTDOWN	0	1
129	#	0	TC2_L_SD	TC2 low temperature shutdown	OK	SHUTDOWN	0	1
136		7	TC1_H_SD	TC1 high temperature shutdown	OK	SHUTDOWN	0	1
137	#	0	TC2_H_SD	TC2 high temperature shutdown	OK	SHUTDOWN	0	1
144		7	CTRL_FAULT_SD	Controller internal diagnostic shutdown	OK	SHUTDOWN	0	1
145	#	0	OVERSPEED_SD	Overspeed shutdown	OK	SHUTDOWN	0	1
157	#	4	SD_RELAY	Shutdown relay state	OFF	SHUTDOWN	0	1
160		7	AL_RELAY	Alarm relay state	OFF	ALARM	0	1
186	#	1	CL_SWITCH	Closed-loop enable toggle switch state	OL	CL_ENABLE	0	1
188	3	MAN_CTRL	Manual valve control selection	AUTO	MANUAL	0	1	
189	4	AL_CLEARALL	Alarm clear-all trigger	NORMA L	CLEARALL	1	0	
190	5	SD_CLEARALL	Shutdown clear-all trigger	NORMA L	CLEARALL	1	0	

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