ALL Power Labs
personal scale power

Section 6
Engine

Table of Contents

1. Engine

The Power Pallet engine is a spark-ignition engine, similar to those found in most automobiles, with some minor differences: a special-purpose mixing system provides the appropriate fuel/air mixture, and spark timing is advanced significantly to compensate for the slow flame propagation of producer gas. On stand-alone systems, the *Process Control Unit* (PCU) monitors and controls the engine. On grid-tie systems, the DeepSea control unit performs all engine control functions.

1.1 Power Pallet Engines

Power Pallet model	Engine Type
PP20, PP25	GM Vortec 3.0L 4cyl gasoline engine

1.2 Engine Specifications

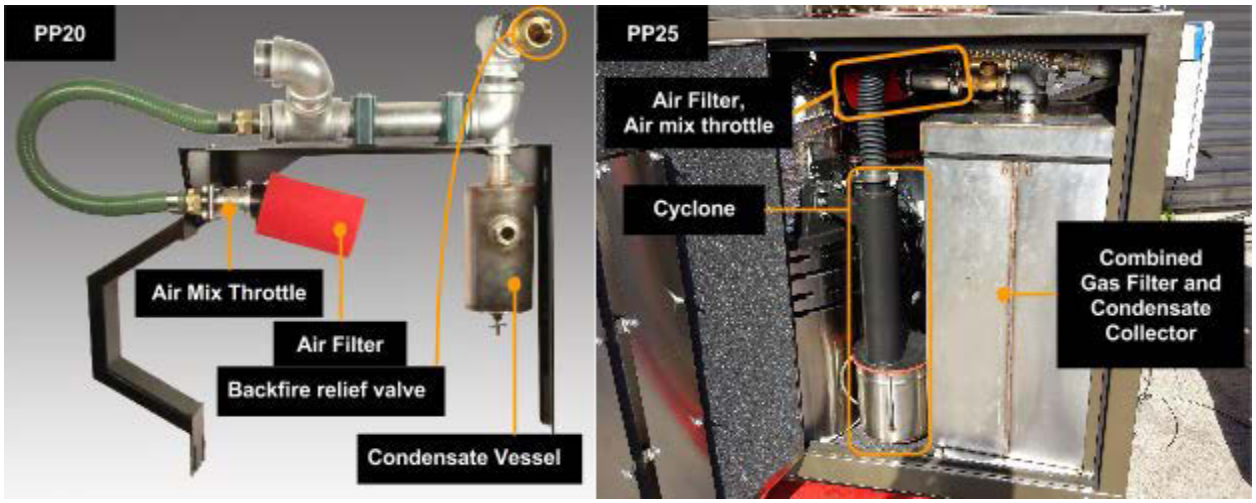
	PP20, PP25 @ 50Hz	PP20, PP25 @ 60Hz
RPM	1500	1800
Spark Advance	38° before top-dead-center	42° before top-dead-center

2. Mixing System

2.1 Overview

The system immediately preceding the engine is the mixing system, which mixes producer gas with air to the correct ratio. The intake of air is regulated by an air servo controlled by a PID (proportional integral derivative) loop run from the PCU based on input from the oxygen sensor reading the oxygen concentration in the exhaust. This method of regulation dynamically adjusts the air/fuel ratio to a target that is optimal for producer gas. Following the mixing of air and producer gas, condensation that forms in the gas is collected in the condensation vessel. The major components of this system are the condensate vessel, the oxygen sensor, and the air servo, each of which will be covered in detail in the following sections.

The lambda meter and air mixing sub-assembly are shown in the next figure. The air mixer intakes air at the red foam filter, introduces the air stream into the stream of producer gas. The introduction of air causes additional condensation to precipitate out of the gas; in the PP20 Power Pallet, the condensation is collected at the condensation vessel, whereas in the PP25, the condensation drops into the gas filter. A backfire pressure relief valve protects the gas circuit in the occasion of a backfire. The air and fuel mixture then proceeds to the engine.



2.2 Condensate Vessel (PP20 only)

The producer gas, when exiting the filter, is still quite warm and nearly saturated with water vapor. The condensate vessel is a stainless steel jar that collects water that condenses out of the producer gas after it cools from being mixed with air. Excessive condensate may damage the engine if too much of it enters the engine. The condensate vessel captures this liquid, and permits the user to easily drain it.

The condensate vessel has a sight glass that indicates when the condensate should be drained. The condensation vessel should be drained regularly, before there is enough liquid in the vessel to be visible through the sight glass. You should not wait until the sight glass is submerged to drain the vessel; this puts it at risk of being overfilled.

Warning: *Drain the condensate vessel only when the engine is off.*

To drain the vessel, screw the draincock upwards; this opens the internal valve that permits condensate to drain out. Condensate will flow out of the brass tap. Be sure to screw the tap back down when done. It is recommend that a plastic tube be mounted to the brass tap to assist in draining the condensate. (The tube is not included.) See Section 2 for condensate disposal.

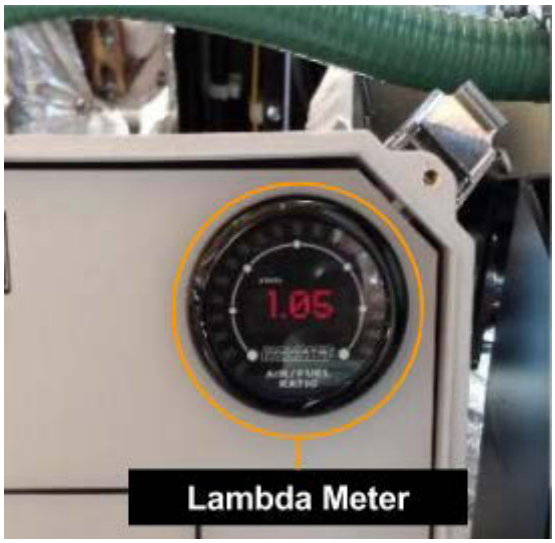
2.3 Oxygen Sensor and Lambda Meter

The Power Pallet uses a wideband oxygen sensor (model MTX-L) and digital lambda meter manufactured by Innovate Motorsports to monitor the oxygen content of the exhaust. The oxygen sensor is located in the engine exhaust stream and detects the amount of free oxygen (O_2) in the exhaust to determine if the fuel mixture is lean (proportion of oxygen exceeds the stoichiometric ratio) or rich (proportion of combustibles exceed the stoichiometric ratio). The sensor is monitored by the lambda meter and an analog output signal is sent to the Process Control Unit (PCU). This signal is used in a feedback control loop to maintain proper air/fuel ratio for desired combustion qualities in the engine. The air/fuel ratio is regulated by targeting a specific *lambda* (λ) value. Lambda is determined by the following equation:

Lambda indicates how the detected air/fuel ratio compares to the stoichiometric ratio; λ=1 indicates an exact match, λ<1 indicates a rich mixture, and λ>1 indicates a lean mixture. The target lambda value set point is 1.05, and is programmed into the code of the PCU board. This value is slightly lean in comparison to a perfectly stoichiometric mixture. This is done intentionally to produce cleaner exhaust emissions.

The software control loop is a proportional-integral-derivative (PID) type. The PID control values are stored in the internal memory of the PCU. If new firmware is to be flashed onto the PCU, be sure to save the PID values, as tuning them can be difficult and is not normally recommended without training. Default PID values may be set in the configurations menu. See Section 5 (Software) for more details on PID configurations.

When the automation system is first powered on, the lambda meter goes into a standby mode while the oxygen sensor begins preheating to reach operating temperature. Once the sensor has reached operating temperature, the lambda value is shown on the meter on the upper right corner of the automation front panel.



The lambda meter receives power from the ATX power supply located on the relay board to prevent signal dropout from larger current loads (e.g. engine start) on the 12 VDC battery. The PCU considers voltages below 0.25V to indicate an error or no signal condition from the lambda meter.

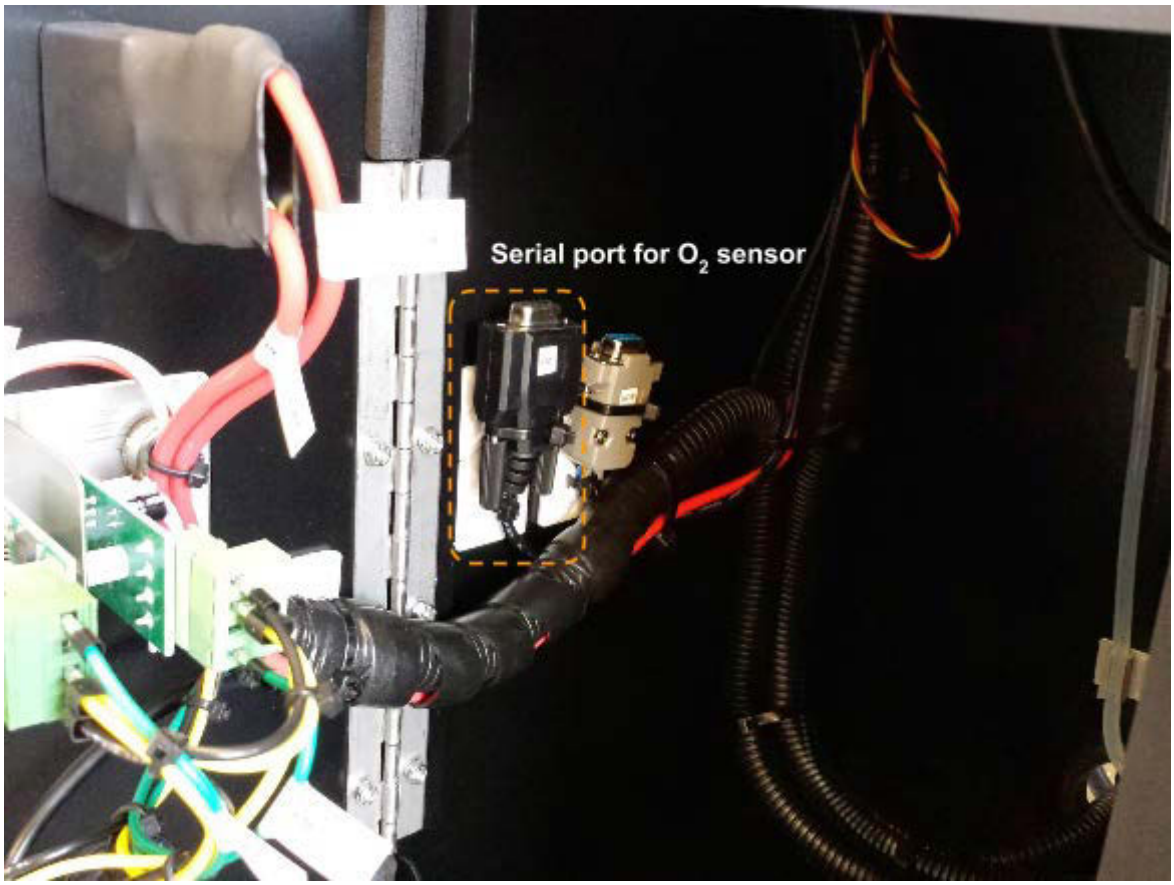
The MTX oxygen sensor comes with Logworks software, a program for updating the firmware, data logging signal values, and for changing the output characteristics of the analog outputs and the display values. The RS232 connector is located behind the automation front panel. It is not typically recommended to make changes to the oxygen sensor values as the control values have been tuned with the sensors stock signal characteristics.

2.4 Programming the Lambda Meter

Note: this section requires the use of the *Bosch Oxygen Sensor LogWorks Program*, or *LM Programmer*, found on the USB drive that comes with the user kit

Every lambda meter must be programmed before the first use. ALL Power Labs performs this programming on every Power Pallet before shipping. The following directions outline this process of re-programming the lambda meter in the field.

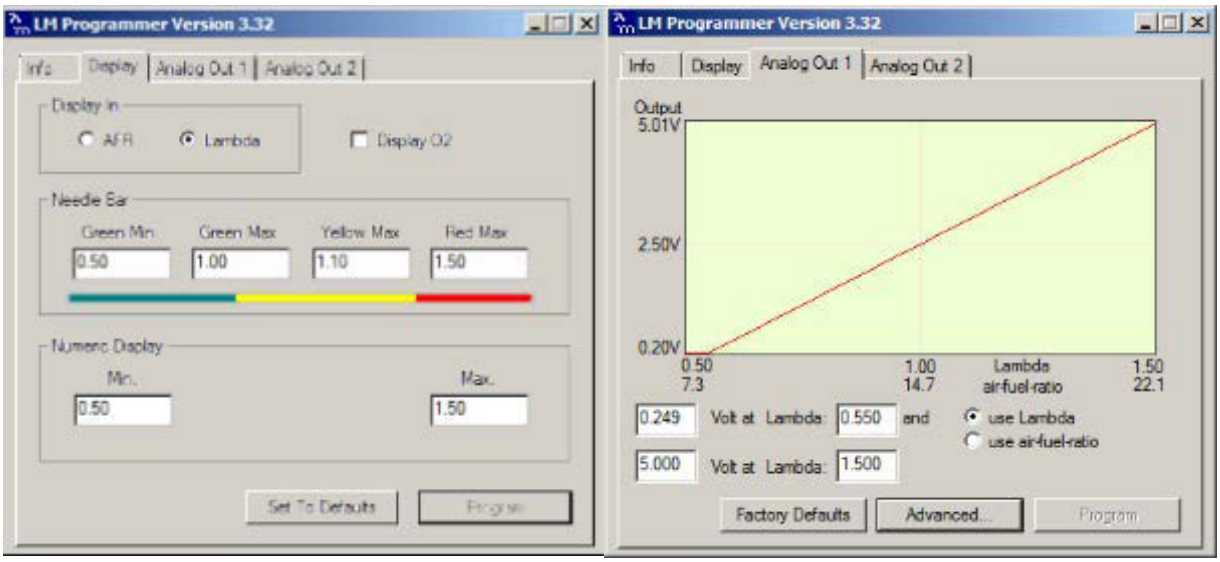
1. Make sure Power Pallet is turned on.
2. Use a serial programming cable to connect your computer to the lambda meter’s black serial cable on the left wall inside the podium.



Lambda Meter serial cable, inside the podium on the left wall.

3. Launch **LM Programmer**
4. Select the “Display” tab and set the values below.

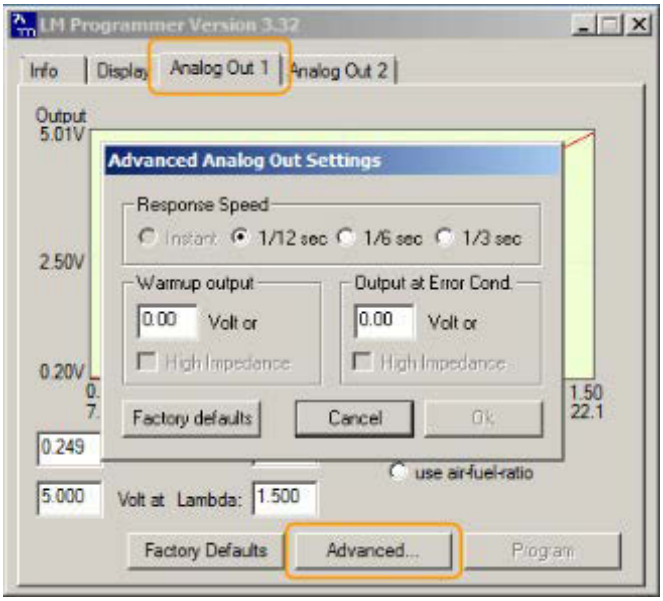
Setting	Value	Setting	Value
Green Min	0.5	Red Max	1.5
Green Max	1	Numeric Min	0.5
Yellow Max	1.1	Numeric Max	1.5
Display in	Lambda		



5. Set the same options for the "Analog Out 1" tab using table below:

Volts	Lambda
0.25	0.55
5	1.5

6. Enter the “Advanced” dialog box on the “Analog Out 1” tab and make sure that the response speed is set to $^{1}/_{12}$ sec and that both the Warmup Output and Error Outputs are set to 0.00V:



7. Repeat steps 5 and 6 for “Analog Out 2.”
8. Click “Program” to set these parameters.

2.5 Air Servo

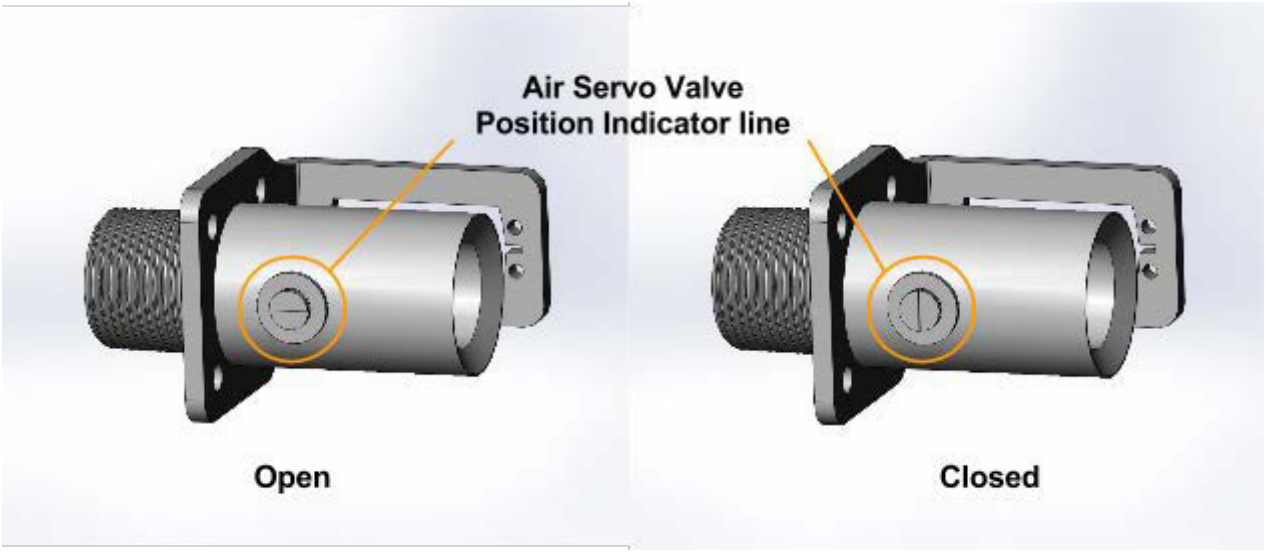
The air mixture servo valve has a small indicator line on the end of the shaft so one can visually see the valve positioning. Attached to the inlet of the air mixture servo valve is an oiled air filter.

2.5.1 Calibration

The air mixture servo is calibrated to the valve at assembly time, but in a few rare cases, it may be necessary for the user to adjust the stored values of the minimum and maximum positions.

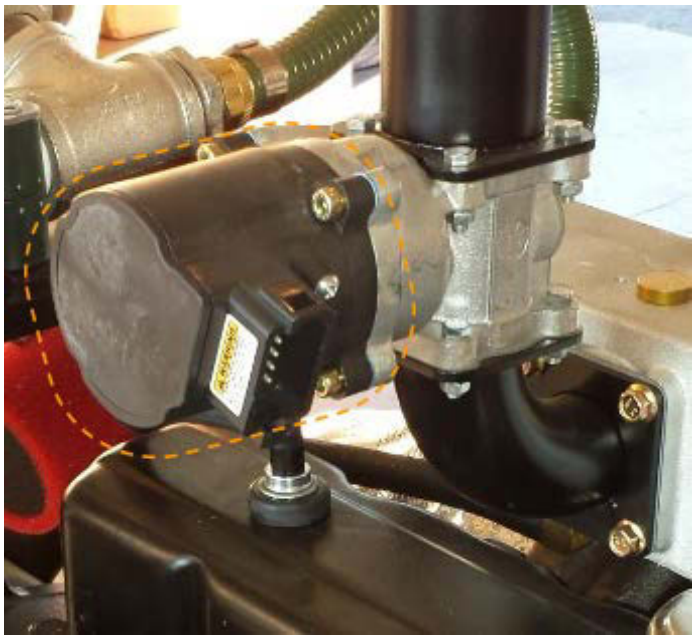
Use the leftmost PCU button to advance to air servo calibration menu. Cursor position indicates the value being adjusted. For “Min” this is for the closed position.

1. Use + and - to adjust valve so that it is closed completely in the vertical position.
2. Press "ADV". Use + and - to adjust valve for the open position to be horizontal.



Observe that the indicator line on the end of the valve shaft. This indicates the valve position.

3. Engine Governor



Note: this section requires the use of the Woodward Governor *L Series Configuration Tool*, found on the USB drive that comes with the user kit

The Woodward L-series 36mm ITB throttle assembly is an engine governor; it maintains a steady engine speed by monitoring the frequency of the electronic signal produced by the MPU (Magnetic Pick-Up), which indicates the flywheel speed, and adjusts the throttle butterfly valve to counteract any acceleration or deceleration of the flywheel. The engine speed must remain steady for the Power Pallet to produce a stable AC electrical output frequency. The governor's operating parameters are programmed using a computer with special software from the manufacturer. Within this program, the settings and control dynamics can be changed. (Default configurations are available.) It is not recommended to change these values outside of the available configurations unless the operator is fully knowledgeable about the system.

Before the governor can be used for the first time it must be programmed and calibrated. The engine governors are calibrated by ALL Power Labs prior to commissioning. In the rare condition that the governor must be entirely reprogrammed and calibrated, the following instructions outline these procedures.

3.1 Programming the Electronic Governor

The governor must be powered on before it can be programmed. The governor power is on the same circuit as the engine ignition. Depending on the Power Pallet model and build date the exact method required for powering on the governor may differ.

3.1.1 Standalone Systems

These instructions are for Power Pallets with a relay board running v1.11 software.

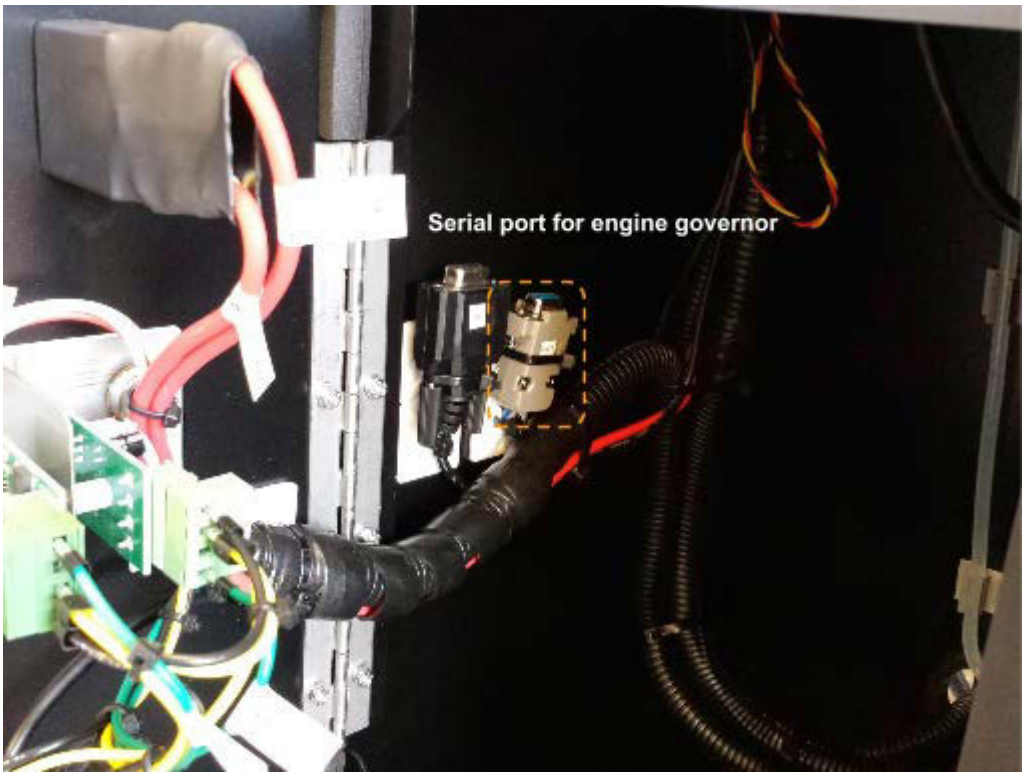
Turn on the Power Pallet. The PCU will boot and show the system status screen. Press the left-most button under the display until the **Testing** screen appears. Press the button labeled **TEST** until the **ENGINE** test mode is activated. The governor should now be powered on, and should emit a soft electronic humming noise.

3.1.2 Grid-Tie Systems

Grid-tie capable systems manage the engine and generator with a dedicated genset controller. On these systems the governor power is connected to the system power and is always on when the system is on.

3.1.3 Connecting To The Governor

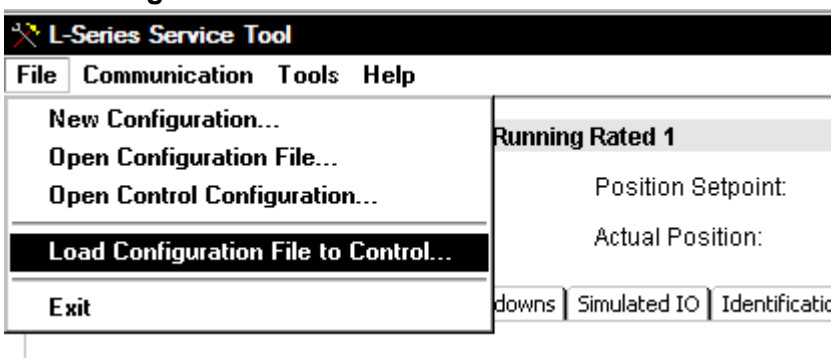
1. Connect computer serial cable to the "**GOV**" RS-232 connector on the left wall inside the automation cabinet.



2. Open the Woodward **L-Series Configuration Tool**, select the appropriate serial port. (The exact port name may vary.) Once connected the configuration diagram will pop up. If screen is blank or lines turn grey, the signal with the governor was lost and will need to be reconnected.

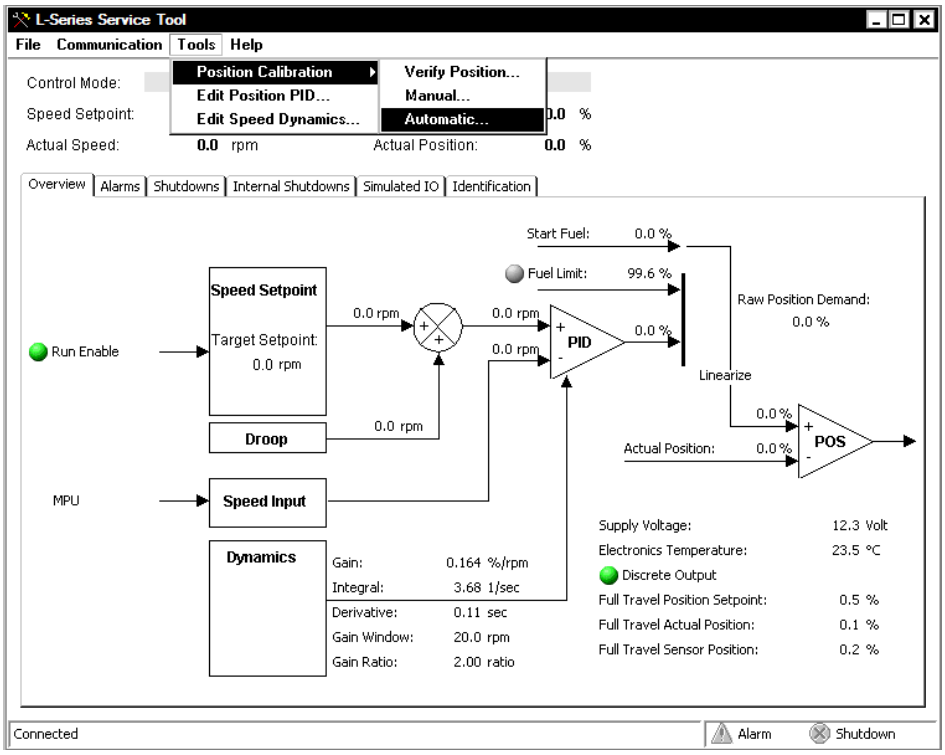
3.1.4 Loading a Configuration File

1. In the L-series Tool select:
   File → Load Configuration File to Control...

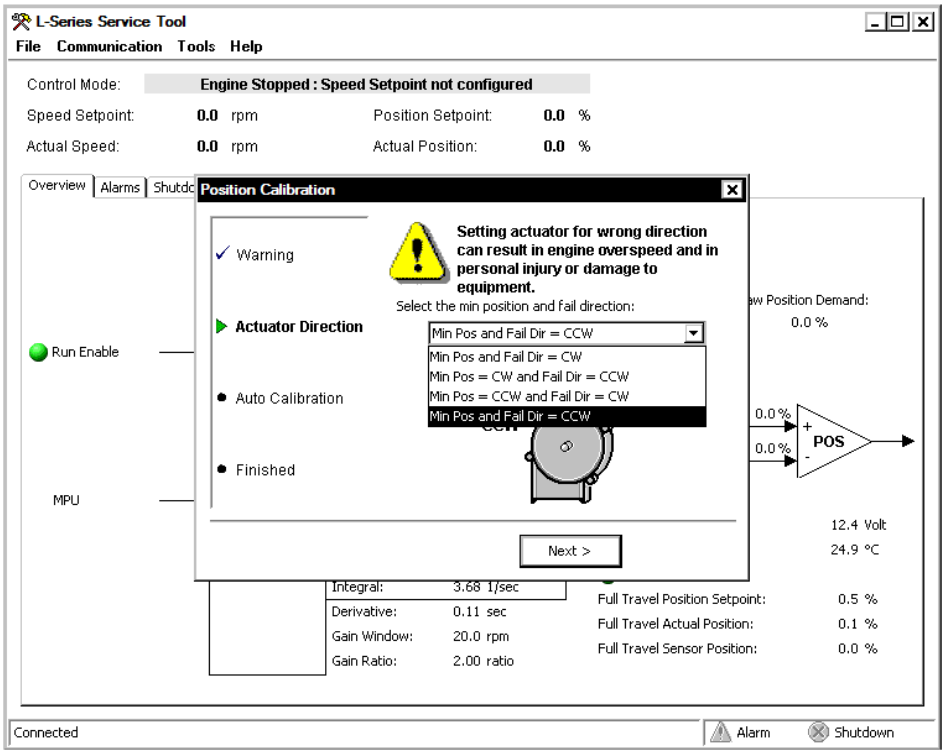


Select the configuration file that corresponds with the specification of the Power Pallet.

3.1.5 Calibrating the Electronic Governor

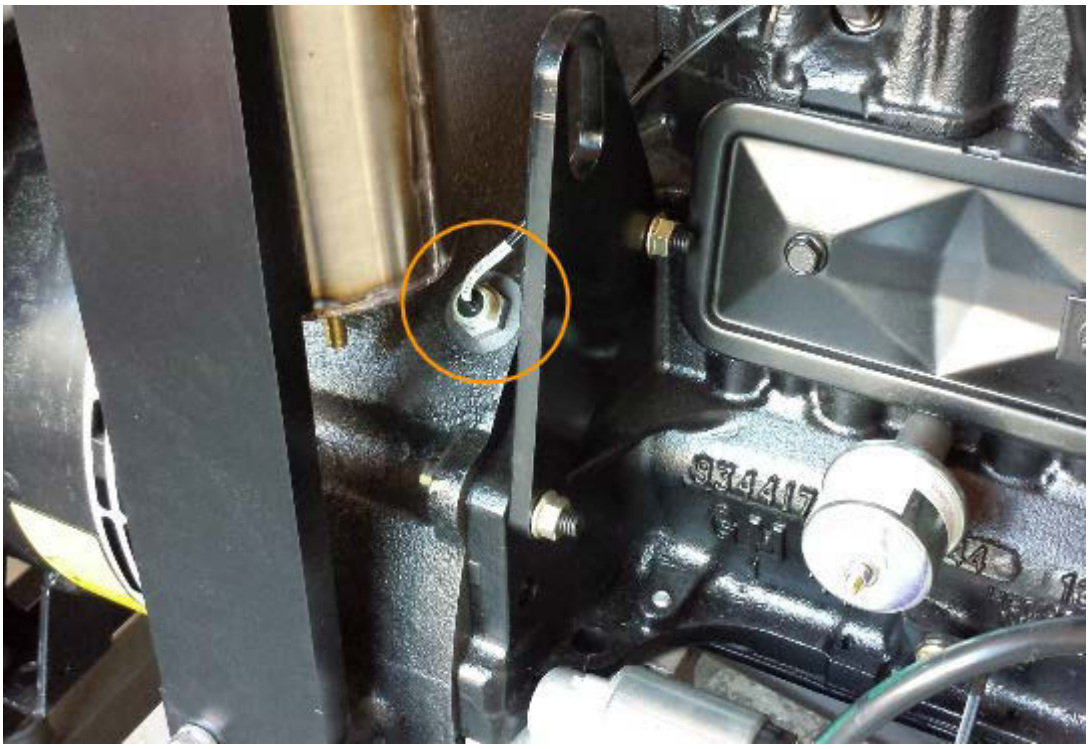


1. To calibrate the governor position use the menu: **Tools →Position Calibration → Automatic**
2. Click the box for “The preceding has been followed” to continue.
3. Follow the on-screen instructions. All settings can be left at their defaults. **Note:** In the “Actuator Direction Screen” make sure counter clockwise (CCW) is selected.
4. Click “Finished”.
5. Power off the Power Pallet



4. MPU

The MPU (magnetic pick-up) is a sensor installed in the engine flywheel housing which outputs a 3V pulsed signal as the teeth on the flywheel pass near it. The frequency of these pulses are used by the engine governor to determine the rotation speed of the engine.



The MPU is circled above. In the rare case where you must make adjustments, you may need to detach the condensate vessel for ease of tool access to the MPU.

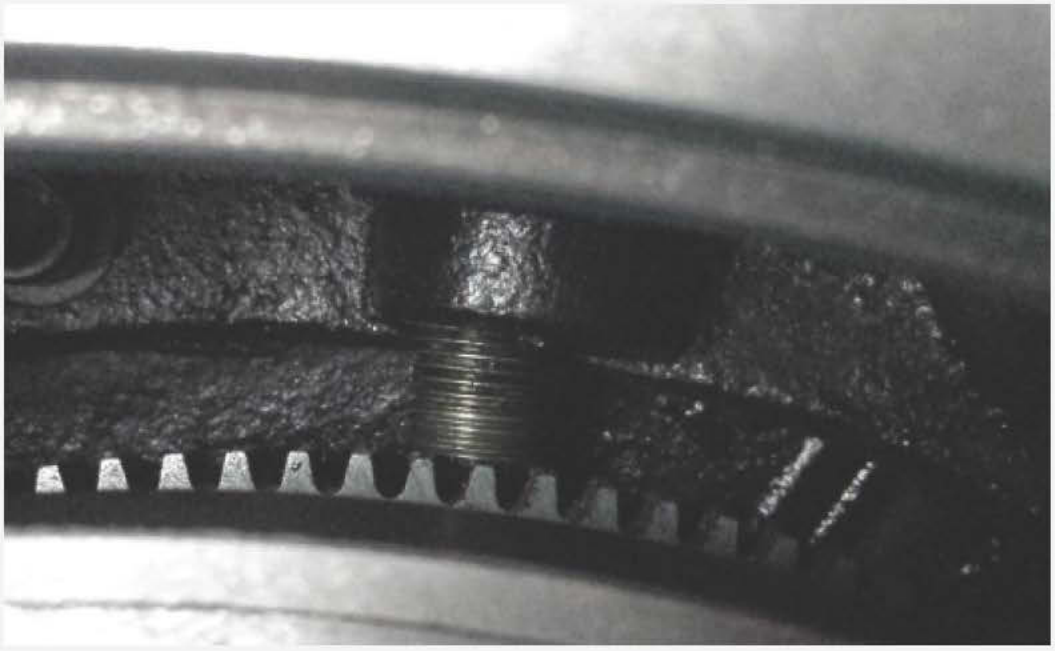
Installation and tuning of the MPU is performed at the factory and should not normally require adjustment. In the case that the MPU is disturbed, fails to produce a strong enough signal or requires replacement, it must be re-adjusted.

4.1 Adjusting the MPU

Warning: MPU adjustment risks

Extreme care must be taken when adjusting the MPU to avoid contact with the flywheel teeth. Contact with the flywheel teeth can result in destruction of the MPU.

This MPU was destroyed by contact with the flywheel teeth while the engine was running.



Internal view of the MPU. It is only separated a few thousandths of an inch from the flywheel.

The MPU is essentially as close as possible without actually touching the teeth; the separation is only a few thousandths of an inch. This close positioning enables the MPU to produce a 3V signal for the governor by induction from the teeth of the flywheel.

To adjust the MPU:

1. Make sure the engine is off.
2. Loosen the lock nut until the sensor can turn freely.
3. Thread the MPU in until it just contacts the teeth of the flywheel. Do this by hand if possible; if using a tool, be careful to stop turning just as the MPU contacts the flywheel.
4. Turn the MPU back ¼ a turn.
5. Use a wrench to hold the MPU steady and lock the MPU's position in place with the lock nut.
6. Turn the engine with the starter while measuring the voltage on the sensor terminals using a meter in the AC mode. Adjust the sensor until the voltage reads in the range of 2-3V. If you must make adjustments, do so only with the engine off. Each adjustment should be about ⅛ of a turn or less; be very careful not to have the sensor touch the flywheel to avoid a collision. If contact is made, back the sensor out by a ¼ turn, and try again.
7. When the voltage is around 3V, hold the sensor steady and lock its position with the lock nut.