



## ALL-ENCOMPASSING ENGINE & EMISSIONS CONTROL

# WOODWARD E<sup>3</sup> SERIES

## Control Systems for Rich and Lean Burn Gas Engines



Woodward's E<sup>3</sup> system is a fully integrated engine control solution that can be used as a stand-alone air/fuel ratio controller or as a complete gas engine emissions and engine control. The control systems comprise the E<sup>3</sup> product line of all-encompassing engine and emissions controls designed to meet the performance and reliability needs of gas engine manufacturers, owners, and operators.

The E<sup>3</sup> system is scalable to virtually any gas engine regardless of size or power output and is available for multiple applications including:

- Rich Burn or Stoichiometric engines using catalytic converters
- Lean Burn engines running exclusively on natural gas
- Lean Burn engines running exclusively on low BTU fuels such as landfill, digester, or biogas
- Lean Burn engines running on a blend of natural gas and low BTU fuel

### E<sup>3</sup> Controller

The E<sup>3</sup> controller is packaged in a NEMA-4 enclosure complete with an internal service port, and is pre-wired to a terminal strip for simple interface to the field wiring. Some versions of the system are available with an enclosure door mounted HMI for display of engine and system parameters such as speed, load, coolant temperature, manifold pressure and temperature, fuel valve and throttle position, along with full alarm annunciation.

### Fuel Valves

The control system is paired with Woodward's world-class line of valves with integrated digital electric actuators. These butterfly-style valves are used to control the fuel supply to the engine as well as the speed governing. Woodward's E<sup>3</sup> is set apart due to its integrated speed control algorithms that can be used to remove existing speed controllers in order to consolidate control functionalities into one integrated system.

### Ignition Controls

The E<sup>3</sup> system includes integrated ignition control for smaller engines in the appropriate BMEP range.



The ignition control is built into the E<sup>3</sup> controller which fires Woodward's heavy-duty Smart Coils for each cylinder. This integrates engine governing, air-fuel ratio, and ignition control into one single controller -- eliminating the need for a separate ignition control box on or near the engine.

### Engine Sensors

All necessary sensors are listed as a kit and are available for specific engine types. Depending on the application, a kit will typically consist of sensors for engine speed, manifold air pressure and temperature, engine coolant temperature, applicable oxygen sensors, and all required mating connectors.

Accessories are also available such as communication adapters for the controls and actuators, mating connectors, and pre-fabricated wiring harnesses.

The E<sup>3</sup> family of controls is approved by the CSA for use in areas requiring Class I, Division 2, Group A, B, C, & D certification.



# E<sup>3</sup> Control for Lean Burn Engines

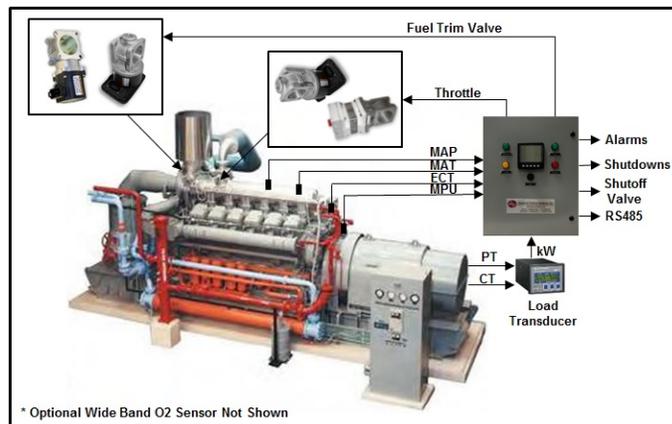
## Lean Burn Trim System



The E<sup>3</sup> Lean Burn Trim controller is primarily designed for use on lean burn, carbureted, natural gas-fueled engines. This system can also be used in some applications where low BTU fueled engines are operated such as landfills and digesters.

This version of the system utilizes a butterfly valve placed in the fuel inlet to the engine just before the carburetor. For engines with dual carburetors, such as the Caterpillar G3500 series, two valves are used.

The system is referred to as a trim system since the carburetor is setting the base air/fuel ratio and the butterfly valve is trimming or fine-tuning the fuel to the engine as commanded by the E<sup>3</sup> control.



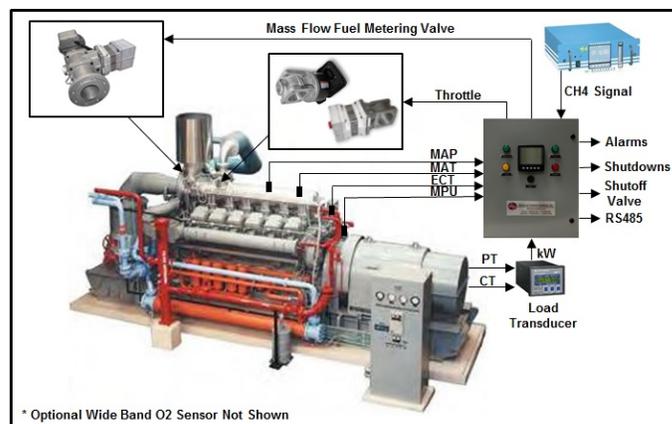
**System Overview – Lean Burn Trim Application**

## Full Authority System

While the Lean Burn Trim system can be utilized in some select applications running low BTU fueled engines, the E<sup>3</sup> Full Authority controller is designed specifically for this purpose. These applications include landfill, digester, or bio-fuel. The Full Authority system enables the engine to be much more responsive to variations in fuel quality. This is accomplished by replacing the simple butterfly valve used in the trim system with a true mass-flow metering valve with on-board fuel temperature and pressure sensors. This valve allows the control to deliver precisely the right amount of fuel to the engine at any given time, which is extremely important during engine start-up and when running under a certain load threshold.

The control is able to compensate for changes in gas quality up to  $\pm 10\%$  CH<sub>4</sub>. With the addition of a CH<sub>4</sub> signal input to the E<sup>3</sup> from an external gas quality

analyzer, the control can compensate for changes between 20-100% CH<sub>4</sub>.



**System Overview – Full Authority Application**

## Patented Closed-Loop Operation for Generator Applications

In a generator application, the E<sup>3</sup> control System can be operated in two different closed-loop modes: UEGO Closed Loop or Gas Quality Closed Loop (GQCL).

UEGO Closed Loop utilizes an oxygen sensor in full-time operation and is part of the base system. This mode of operation is comparable to what is used in air/fuel ratio controllers from other manufacturers on the market. The drawback to this is the requirement for an oxygen sensor installed in the engine exhaust to be used in the system at all times. Since standard oxygen sensors on the market are designed for automotive-style gasoline engines, not natural gas engines, the lifetime of standard sensors in operation on industrial gas engines is typically an issue. Gas Quality Closed Loop (GQCL) control

(patents: US5657732 / EP0727574B1) uses engine efficiency and generator load measurement to eliminate the oxygen sensors. The E<sup>3</sup> control calculates the amount of fuel required for a given emissions output and then commands the fuel control valve to deliver the optimum amount of fuel to the engine. In this manner, only the precise amount of fuel is delivered in order to achieve the highest fuel economy without putting the engine into detonation or misfiring conditions. GQCL operation is based on algorithms that are exclusive to Woodward, resulting in a system that is set apart from the competition offering increased performance for a comparable price. The only addition required is a kW load feedback signal into the E<sup>3</sup> control. This can come from an existing load transducer or one can be added.

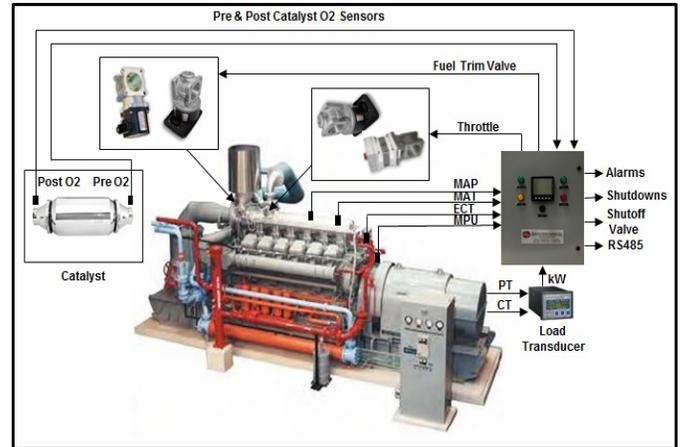


# E<sup>3</sup> Control for Rich Burn Engines



The E<sup>3</sup> Rich Burn control system is designed for use on stoichiometric, natural gas-fueled engines. The control system provides highly stable, closed-loop control of air/fuel ratio on engines using three-way catalysts and features Woodward's exclusive StableSense™ technology.

The system is configurable for use on inline or V-engines with either a single fuel supply or a dual fuel supply with a separate manifold for each bank. For engines with a single fuel supply, a pre-catalyst and post-catalyst oxygen sensor is used. For engines with an independent fuel supply for each bank, an additional pre-catalyst oxygen sensor is added to the second bank and the control utilizes automatic bank balancing for improved engine performance. In addition, the system can be expanded by adding pre and post catalyst temperature and pressure sensors for active catalyst monitoring.



**System Overview – Rich Burn Application**

## Exclusive StableSense™ Technology

The E<sup>3</sup> Rich Burn system features StableSense™ technology utilizing Woodward's patented oxygen sensors. While other systems in the marketplace utilize standard automotive oxygen sensors that were designed for gasoline engines, Woodward has developed and patented an oxygen sensor specifically for industrial gas engines.

These sensors are more rugged and, since they are purpose-built for gas engines, not gasoline engines, they offer an operating life that is unparalleled by standard automotive sensors in industrial applications as they are unaffected by engine exhaust methane and hydrogen. The E<sup>3</sup> StableSense™ control algorithms paired with the sensors are able to provide automatic control over the engine's air/fuel ratio and optimize the amount of time the engine remains in compliance.



## Integrated Speed Control & Governing



All versions of the E<sup>3</sup> control system offer an important feature that differentiates it from the competition. The system includes an integrated digital speed controller that can replace an existing mechanical governor or older analog electronic speed control. This option allows the speed control to be integrated with the air/fuel ratio control in the same unit which improves emissions control and engine stability since these two fundamental functions are designed to work together.



Choosing the speed control option also brings the benefits of digital speed control including ease of setup and tuning with real-time graphical trending, more configuration options including multiple dynamics for different operational conditions, and improved control response.

Adding speed control to the E<sup>3</sup> system requires only the addition of an electric actuator to the engine. This also allows for replacing any existing throttle linkage. One available option is utilizing a stand-alone actuator with an engine mounting and linkage kit that includes the mounting bracket, short linkage, and required hardware. A second option is the use of an integrated throttle body and actuator which eliminates the throttle linkage altogether. Standard kits are available for Caterpillar G3500 series engines.



# Ordering Information\*



## Control Cabinets

Lean Burn Trim System, with HMI	2935-0002
Rich Burn Trim System, with HMI	2935-0003
Full Authority System, Low BTU Fuel Applications, no HMI	2935-0004

## Engine Sensor Kits

Caterpillar G3400 and G3500 Series, Lean Burn Engines	5959-0004
Waukesha 7042 Series, Lean Burn Engines	5959-0005
Caterpillar G3400 and G3500 Series, Rich Burn Engines	5959-0006
Waukesha 7042 Series, Rich Burn Engines	5959-0007
Caterpillar G3400 and G3500 Series, Low BTU Fuel	5959-0008

## Fuel Valve Options

L-Series Valve, Lean and Rich Burn Engines, 25mm Bore	8404-2056
L-Series Valve, Lean and Rich Burn Engines, 36mm Bore	8404-2057
F-Series Valve, Lean and Rich Burn Engines, 48mm Bore	8235-668
L-Series Valve, Lean and Rich Burn Engines, 50mm Bore <sup>1</sup>	8404-2058
F-Series Valve, Lean and Rich Burn Engines, 60mm Bore <sup>2</sup>	8235-669
F-Series Valve, Lean and Rich Burn Engines, 68mm Bore	8235-622
TecJet Valve, Low BTU Fuel Applications, Small Bore	8407-527
TecJet Valve, Low BTU Fuel Applications, Large Bore <sup>2</sup>	8407-523

<sup>1</sup> Commonly used on Caterpillar G3412 engines

<sup>2</sup> Commonly used on Caterpillar G3516A engines

## OPTIONAL

### Speed Control

F-Series Butterfly Valve, 48mm Throttle Bore	8235-602
F-Series Butterfly Valve, 60mm Throttle Bore	8235-606
F-Series Butterfly Valve, 68mm Throttle Bore <sup>1</sup>	8235-610
ProAct ISC Butterfly Valve, 85mm Throttle Bore	8235-339
ProAct ISC Butterfly Valve, 95mm Throttle Bore	8235-337
ProAct ISC Butterfly Valve, 105mm Throttle Bore <sup>2</sup>	8235-198
ProAct ISC Butterfly Valve, 120mm Throttle Bore <sup>3</sup>	8235-305
ProAct ISC Butterfly Valve, 135mm Throttle Bore	8235-360
Caterpillar G3500 Series, ProAct ISC Actuator to Replace EG3P <sup>4</sup>	8404-204
Caterpillar G3500 Series, ProAct ISC Actuator Mounting & Linkage Kit <sup>4</sup>	5340-7415

<sup>1</sup> Commonly used on Caterpillar G3406 engines

<sup>2</sup> Commonly used on Caterpillar G3412 engines

<sup>3</sup> Commonly used on Caterpillar G3516A engines

<sup>4</sup> Replaces EG3P actuator and factory linkage

### Accessories

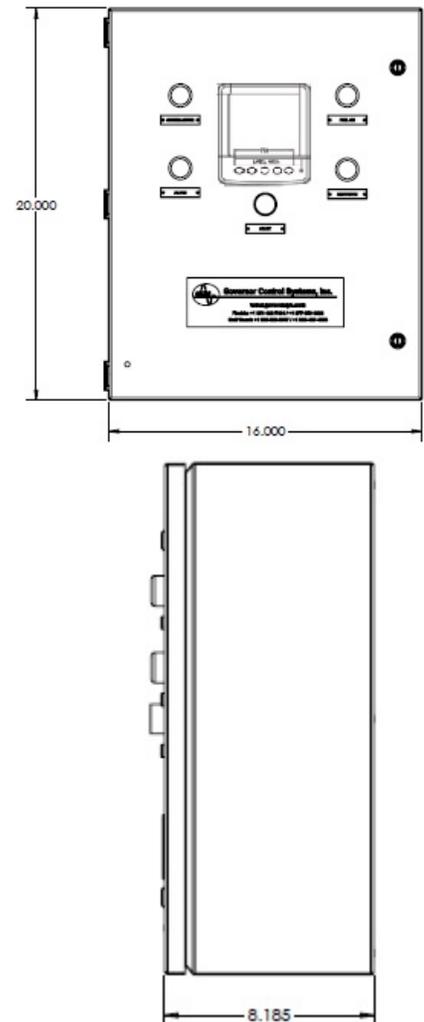
Load Transducer for Generator Applications	5959-0009
Load Transducer, DIN Rail Mounting Kit	8923-1023
Communication Adapter for E <sup>3</sup> Controller	6130-0010
Communication Adapter for L-Series Valve	8923-1061
Communication Adapter for F-Series Valve	8923-1255
Mating Connector Kit for L-Series Valves	8928-396
Mating Connector Kit for F-Series Valves	5995-0033
Mating Connector Kit for ProAct ISC and TecJet Valve	6995-1021
Wiring Harness, ProAct ISC and TecJet Valve, 90° Connector, 4 ft.	2845-0007
Wiring Harness, ProAct ISC and TecJet Valve, Str Connector, 4 ft.	2845-0008
Wiring Harness, ProAct ISC and TecJet Valve, 90° Connector, 6 ft.	2845-0018
Wiring Harness, ProAct ISC and TecJet Valve, 90° Connector, 8 ft.	2845-0026
Wiring Harness, ProAct ISC and TecJet Valve, 90° Connector, 30 ft.	2845-0025

\* A basic E<sup>3</sup> system for air-fuel ratio control consists of:

- control cabinet
- sensor kit
- fuel valve

To add integral engine governing to the package, select a speed control option. For engines requiring ignition control or other application-specific information, contact GCS.

## Control Cabinet Dimensions



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