CONTROL TECHNOLOGIES FOR THE WORLD'S BEST ENGINES

CONTROL SOLUTIONS FOR LARGE ENGINES

Always Innovating for a Better Future

WOODWARD

RELIABLE SYSTEMS
FOR THE WORLD'S MOST DEMANDING APPLICATIONS

OUR TECHNOLOGY FOCUS

Emissions
Efficiency
Reliability
Safety
Global Support
Connectivity
Fuel Choice

ALWAYS INNOVATING FOR A BETTER FUTURE

Every day, we commit our resources, knowledge, and skills to help you tackle any challenge presented – from addressing efficiency initiatives, to innovating new control solutions for your future engine systems, to providing critical insight into your customers' environments. We take pride in knowing that you count on us for our technical knowledge, problem-solving capabilities, and collaborative nature. But most importantly, we value the confidence you place in us by selecting Woodward to play an essential role in your success.

Woodward's combination of combustion control, motion control, and electronic controls technologies enables more responsible energy use by reducing emissions, improving fuel utilization, and enabling power system integration. Our energy control technologies allow marine, power generation, rail, and mobile equipment engines to operate cleaner, more efficiently, and more reliably, while providing customers a choice in fuels.

MARKETS

Electrical Power Generation (Land Based & Marine)
Transportation (Ships, Locomotives, Trucks)
Pipeline (Pumps, Compressors)

VALUE THROUGH SYSTEMS

Woodward is committed to delivering high quality, reliable control systems that meet your needs and perform to your expectations. Our components and energy control systems are used in many diverse large reciprocating engine applications. We collaborate closely with our OEMs to provide the competitive advantages to develop innovative systems that enhance profitability and meet the increasing demand for engine control applications

SYSTEM-LEVEL TECHNOLOGIES

Our integrated systems are based on a foundation of key technologies – electronic controls and software, fuel and air delivery, and combustion control. With Woodward's fully integrated control system architectures, costs are significantly reduced while performance and external communications are enhanced.

Woodward's system experience includes full control of high pressure common rail, dual-fuel, natural gas, and bio-fueled engines across all size ranges and applications. Our rapid control system development tools allow easy customization by Woodward or your team.

COMBUSTION CONTROL

Ignition Management
Engine Control Units
Coils and Spark Plugs

AIR, FUEL AND EXHAUST CONTROL

High Pressure Diesel Fuel Injection
Hydro-Mechanical Governors
Control Valves
Actuators
Integrated Throttle Bodies

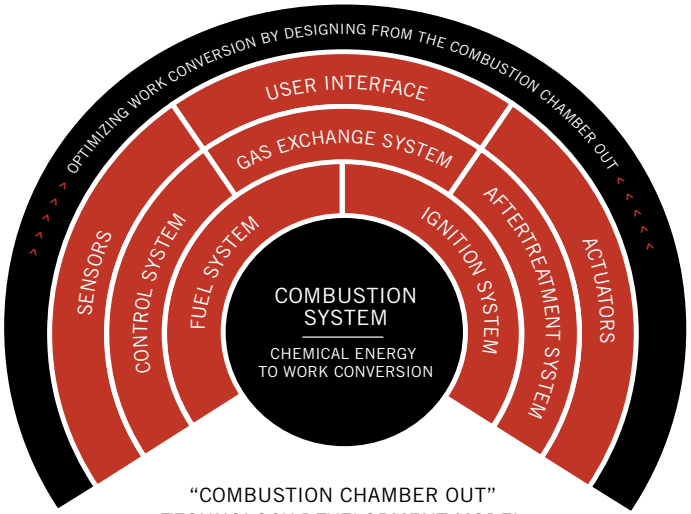
ELECTRONIC CONTROLS AND SOFTWARE

Engine Speed
Power
Emissions
Advanced Diagnostic and Prognostic Tools
Service Tools

IGNITION & COMBUSTION

HIGH EFFICIENCY COMBUSTION

To optimize the efficiency of our engine systems, we approach the design and development from the "combustion chamber out". Our combustion control solutions are proven to improve the in-cylinder emissions and efficiency of diesel and spark-ignited engines. For spark-ignited engines, Woodward ignition systems provide the high-energy spark needed to reliably ignite ultra-lean air-fuel mixtures. For large diesel engines, our mechanical, electronic unit injection, and high-pressure common-rail fuel injection systems help engine manufacturers improve engine efficiency and lower emissions.



"COMBUSTION CHAMBER OUT" TECHNOLOGY DEVELOPMENT MODEL

SPARK PLUGS

Woodward's spark plug program is focused on large industrial gas engines and offers engine manufacturers a longer-life spark plug, optimized and tailored for their specific engine design and conditions, while improving combustion efficiencies and reducing emissions.

IGNITION SYSTEMS

Woodward's ignition systems offer a solution for all types of modern gas engines. They meet today's requirements for modern gas engines, ranging from smart inductive coils to high-energy AC ignition systems.

HIGH-PRESSURE COMMON RAIL INJECTORS

Common rail systems injectors help OEMs achieve the primary objectives of their existing and future engine designs – higher injection pressures, improved engine performance and durability, and meeting mandated emissions targets.

AIR, FUEL & EXHAUST DELIVERY

Woodward offers a complete line of precise and durable fuel and air management components. Our approach to designing and building fast acting, accurate, durable fuel metering devices with high precision and durability make Woodward technologies the obvious choice for any industrial diesel or gaseous fuel application. Woodward's vast experience allows us to engineer solutions that optimize engine emissions and efficiency through precise control of air flow, fuel flow, combustion processes, exhaust flow, and aftertreatment with an integrated systems approach.

SOLUTIONS OVERVIEW

- Wide range of sizes from 33 mm to 180 mm
- Temperature operation from ambient to 750 ° C, with optional water cooling
- Capable of operating in high-pressure and low-pressure applications
- Integrated throttle bodies that contain an actuator and throttle valve in one assembly
- Engine throttle bodies precisely control the flow of gaseous fuel to the engine with a single point valve
- Throttled valves for bypass, wastegate, EGR, and similar applications

> **WASTEGATE VALVE**
High Temperature Bypass Valve

GAS ADMISSION VALVES

Gas admission valves provide precision multi-point fuel admission for large gas engines, optimizing engine performance, emissions, and load response.

HIGH-TEMPERATURE WASTEGATE VALVES

Wastegate (or turbo bypass) is an effective method to improve efficiency on lean-burn gas, stoichiometric gas, and diesel engines.

THROTTLE AND MIXER SYSTEMS

The integration of throttle and actuator results in excellent transient response and stability, and requires no hydraulics, pneumatics, or gear train. The ITB (Integrated Throttle Body) offers an efficient, long-lasting, and easily installed throttle option.

MASS FLOW CONTROL VALVES

Full-authority valve technologies control fuel mass flow using onboard electronics and pressure/temperature transducers, and are often used with biogas or other fuels having varying heat content.

HYDRAULIC-MECHANICAL ENGINE GOVERNORS AND ACTUATORS

Available in work output ratings from 10.8 inch-pounds up to 500 foot-pounds, Woodward governors and actuators are used in power generation, marine, pump, compression, and vehicle applications.

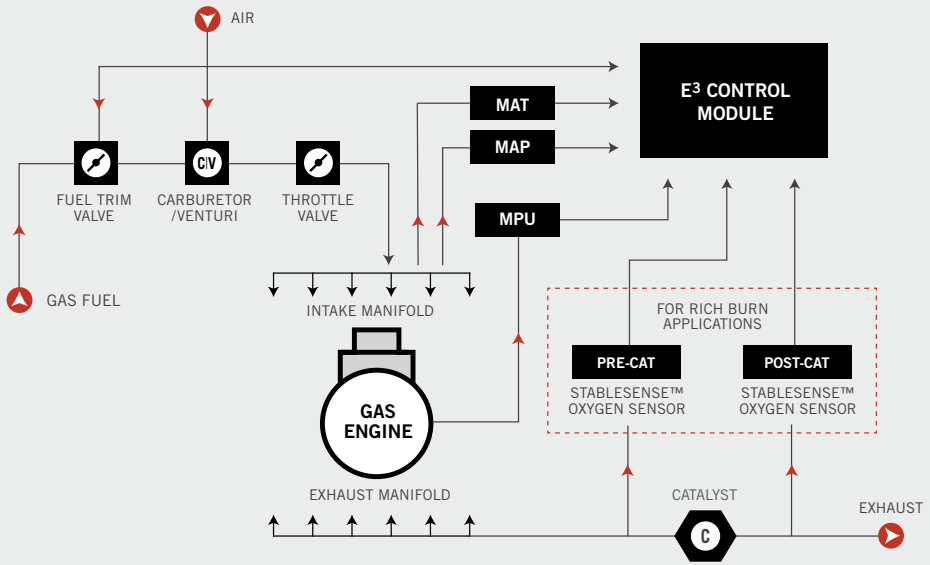
HIGH-PRESSURE COMMON-RAIL PUMPS AND INJECTORS

Our common rail systems are designed for industrial (non-automotive) engines, including pumps, injectors, and controls, with key considerations related to extended lifetimes and times between services.

E³: ALL-ENCOMPASSING ENGINE AND EMISSIONS CONTROL FOR GAS ENGINES

All E³ solutions provide a systems approach to complete engine and emissions control of lean burn, rich burn, on-board fuel blending, and dual-fuel engines. The E³ system is comprised of an E³ controller, inlet air throttle, fuel trim valve, and oxygen sensor for all-encompassing engine control over engine speed, load, air/fuel ratio, and ignition timing. This integrated approach eliminates clutter, wiring issues, multiple boxes, and multiple software protocols, while increasing performance, staying within emissions compliance, and lowering overall cost of ownership.

// For more information visit www.woodward.com/E3



CONTROLLERS & SOFTWARE

Woodward's engine control capabilities include primary engine control, rapid development software tools, engine system protection, and complete engine system solutions. Our expertise comes from decades of experience managing engines of virtually every size, type, and application – whether they operate under diesel engine fuel injection systems or run on natural gas, propane, bio-fuel, or dual-fuel.

PRIMARY ENGINE TO COMPLETE SYSTEM CONTROL

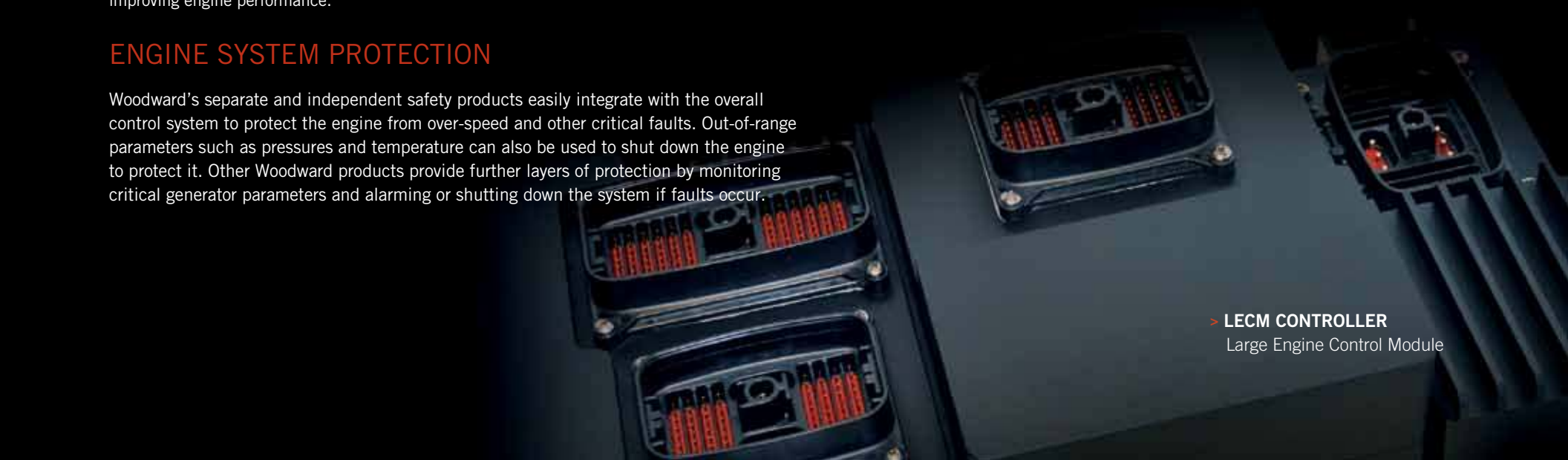
Our primary engine control solutions offer fast, accurate speed and load control, precise air-to-fuel ratio control, and precision injector driver control, providing a secure foundation on which all other system functionality can be built. Other engine and system parameters can be added to influence the engine's basic control functions. These additional parameters, which are often achieved through Woodward accessory equipment, include generator synchronization and load sharing, generator package control, marine propulsion system control, and compressor and pump systems. This easy system integration reduces system complexity and support while improving engine performance.

ENGINE SYSTEM PROTECTION

Woodward's separate and independent safety products easily integrate with the overall control system to protect the engine from over-speed and other critical faults. Out-of-range parameters such as pressures and temperature can also be used to shut down the engine to protect it. Other Woodward products provide further layers of protection by monitoring critical generator parameters and alarming or shutting down the system if faults occur.

PRECISE CONTROL FOR ANY APPLICATION

Power Generation
Gas Compression
Alternative Fuel Vehicles
Locomotives
Marine Propulsion and Auxiliary Power
Mobile and Industrial Equipment



> **LECM CONTROLLER**
Large Engine Control Module

COMPLETE ENGINE CONTROL WITH INJECTION CONTROL

Engine mounted modules control all aspects of gas, diesel, and dual fuel reciprocating engines including: speed/load, air/fuel ratio, fuel injection, ignition timing, knock detection, engine sequencing, and diagnostics. Through expanded I/O on CAN networks, many additional engine monitoring and protection functions are available.

STANDARD HARDWARE ENGINE CONTROLLER

A range of standard sized control modules accommodate any size engine control application and deliver optimal flexibility for complex control strategies using Woodward application software. They lend themselves to rapid prototyping of typical control functions, such as speed and air/fuel ratio control, as well as other engine control functions that may be required.

LOAD SHARING SPEED CONTROL

Load sharing and speed controls monitor the power out of generators driven by diesel or gaseous fueled engines, enabling them to isochronously load share with the utility or other gensets. Changing the setting in the software allows the application to accommodate engine speed ranges, gear teeth, and forward or reverse acting actuation.

GENSET CONTROLLER

A wide range of genset control and protection products provide the flexibility and features needed to fit a wide variety of power generation applications, such as synchronizing, soft loading, and paralleling. Common applications include: emergency standby, cogeneration, marine ship/shore power, island prime power, or utility paralleling with peak shaving and import/export power control.

ENGINE SYSTEM PROTECTION

The Woodward HighPROTEC monitors the functions of a generator driven by the engine and protects both the generator and engine if malfunctions are detected. And, the Woodward ProTech SX provides an independent over-speed monitoring system and can monitor a variety of other engine and system functions that can be used to shut down the engine in case there are serious problems.

RAPID CONTROL SYSTEM DEVELOPMENT TOOLS

Software development tools such as MotoHawk® or GAP™ provide customers with the ability to program, calibrate, and service engine and turbine control systems. GAP and MotoHawk software tools allow original equipment manufacturers to rapidly develop and deploy powerful turbine and engine application control systems without writing software code.

Woodward's software control solutions offer fast development cycle times, high flexibility and customer ownership of intellectual properties. Using our suite of controller products, software tools, and application engineering expertise, you can build your production controls in a flash.

Woodward software solutions support a model-based design philosophy that enhances the ability to directly target the solution to production hardware. GAP and MotoHawk have the ability to create real-time simulation that enable complete testing of the application before commissioning.

BENEFITS

- Simpler, faster development and lower cost for fleet testing
- Better testing using real production hardware
- Develop, analyze, and enhance software features in Simulink
- Direct access to the production I/O from Simulink
- Readable documentation of system design
- Real-time simulation capabilities

CONTROL TECHNOLOGIES FOR THE WORLD'S BEST ENGINES

1. New Belgium Brewery
2. HHI Marine Engine
3. Gas Compression
4. Blue Fighter and Olympic Commander
5. Plains End Power Plant

GLOBAL SUPPORT

Woodward knows that its customers need to locate in growth areas, so we are right there with them – designing, manufacturing, and servicing our products. Careful consideration of environmental and cultural differences is the key to establishing Woodward as a concerned global citizen.

Our internal teams are comprised of employees from many locations as well – encouraging fresh ideas, offering a variety of views on how to meet new challenges, and providing our employees the opportunity to make a worldwide impact. Woodward's plants, offices, and service centers span the globe:

North and Central America, South America, Europe, Middle East and Africa, Russia, China, India, ASEAN and Oceania.

Our global presence allows us to respond quickly to the needs of our customers. Customers and the industry at large recognize our people as a competitive advantage through their diverse representation of the global community. Additionally, as a company and as employees, we respond to the needs of our local communities by donating our time, talent, and money.

For more information contact a representative or visit our website at: www.woodward.com

Technical and other after-sales support services for your Woodward on-engine control products.

Woodward's global network of independent Business Partners and our engine manufacturer and engine packager customers provide an extensive range of technical and other after-sales support services for your Woodward on-engine control products.

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