

Waukesha[®] **ESM[®]**

VHP[®] Series Four[®], 7042GL/GSI Engine System Manager Operation & Maintenance

Fourth Edition

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Waukesha

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How To Use This Manual

CHAPTER 1 – SAFETY AND GENERAL

Section 1.00 – Safety

Safety Introduction	1.00-1
Safety Tags And Decals	1.00-1
Equipment Repair And Service	1.00-1
Acids	1.00-2
Batteries	1.00-2
Body Protection	1.00-2
Chemicals	1.00-2
General	1.00-2
Cleaning Solvents	1.00-2
Liquid Nitrogen/Dry Ice	1.00-2
Components	1.00-2
Heated Or Frozen	1.00-2
Interference Fit	1.00-2
Cooling System	1.00-3
Electrical	1.00-3
General	1.00-3
Ignition	1.00-3
Exhaust	1.00-3
Fire Protection	1.00-3
Fuels	1.00-3
General	1.00-3
Gaseous	1.00-3
Liquid	1.00-4
Intoxicants And Narcotics	1.00-4
Pressurized Fluids/Gas/Air	1.00-4
Protective Guards	1.00-4
Springs	1.00-4
Tools	1.00-4
Electrical	1.00-4
Hydraulic	1.00-4
Pneumatic	1.00-5
Weight	1.00-5
Welding	1.00-5
General	1.00-5
On Engine	1.00-5

Section 1.05 – General Information

English/Metric Conversions	1.05-1
Torque Values	1.05-2
Wiring Requirements	1.05-5

Section 1.10 – Description of Operation

Introduction	1.10-1
ESM System Components	1.10-4
Engine Control Unit (ECU)	1.10-4
Description Of ECU	1.10-4
ECU Status LEDs	1.10-4
ESM Electronic Service Program (ESP)	1.10-5
Description Of ESP	1.10-5
E-Help	1.10-5
User Interface Panels	1.10-5
ESM System Diagnostics	1.10-6
Safety Shutdowns	1.10-7
Start-Stop Control	1.10-7
Ignition System	1.10-8
Description Of Ignition System	1.10-8

Ignition Theory	1.10-8
Ignition Diagnostics	1.10-9
Detonation Detection	1.10-9
Description Of Detonation Detection	1.10-9
Detonation Theory	1.10-11
Method Of Detonation Detection and Timing Control	1.10-11
ESM System Speed Governing	1.10-12
Description Of Speed Governing	1.10-12
Governing Theory	1.10-12
Speed Governing Modes	1.10-13
<i>Speed Control</i>	1.10-13
<i>Load Control</i>	1.10-13
Governor Inputs And Calibrations	1.10-13
<i>Feedforward Control</i> <i>(Load Coming Control)</i>	1.10-13
<i>Synchronizer Control</i> <i>(Alternate Dynamics)</i>	1.10-13
AFR Control Description	1.10-14
Stoichiometric Oxygen Sensor	1.10-15
Lambda	1.10-15
Stepper	1.10-16
Theory Of Operation	1.10-16
<i>Control Routine</i>	1.10-16
<i>Setup for Catalyst Control</i>	1.10-17
<i>Dithering</i>	1.10-17
Definitions	1.10-18

CHAPTER 2 – PACKAGER'S GUIDE

Section 2.00 – Power Requirements

Power Requirements	2.00-1
Battery Requirements	2.00-2
Non Extender Series Engines –	
Power Supply with Air Start and Alternator	2.00-3
Power Supply by Customer	2.00-4
Power Supply with Electric Start and Alternator	2.00-5
Extender Series Engines –	
Power Supply with Air Start and Alternator	2.00-6
Power Supply by Customer	2.00-7
Power Supply with Electric Start and Alternator	2.00-8

Section 2.05 – Power Distribution Junction Box

Theory of Operation	2.05-1
Power Distribution Junction Box	2.05-1
24 VDC Power	2.05-1
<i>Making Power Connection Inside</i> <i>Power Distribution Junction Box</i>	2.05-1
Power Distribution Junction Box Connection (Non Extender Series Engines)	2.05-3
Power Distribution Junction Box Connection (Extender Series Engines)	2.05-3
Engine Shutdown Information	2.05-4
External Power Distribution Junction Box	
Local Control Options Harness	2.05-4
+24VFOR U and GND FOR U	2.05-4
ESTOP SW	2.05-4

CONTENTS

<i>G LEAD (Non Extender Series)</i>	2.05-4
<i>GOVSD+24V and GOV SD+</i>	2.05-5
Maintenance	2.05-5
Troubleshooting	2.05-5

Section 2.10 – System Wiring Overview

Wiring Diagram	2.10-1
Customer Interface Harness	2.10-1
Required Connections	2.10-4
Optional Connections	2.10-6
Local Control Option Harness	2.10-6
Governor Connections	2.10-6

Section 2.15 – Start-Stop Control

Start-Stop Control	2.15-1
Prelubing the Engine Without Starting	2.15-2
Cranking the Engine Over Without Starting and Without Fuel	2.15-2
Air-Start Valve	2.15-2
Air Prelube Valve	2.15-3

Section 2.20 – Governing

Governor/Speed Control	2.20-1
Speed Control Mode	2.20-1
<i>Fixed Speed</i>	2.20-1
<i>Variable Speed</i>	2.20-1
Load Control Mode	2.20-3
Rotating Moment of Inertia / Adjusting Gain	2.20-4
Feedforward Control (Load Coming)	2.20-4
Actuator Automatic Calibration	2.20-4

Section 2.25 – Fuel Valve

Fuel Valve	2.25-1
WKI	2.25-2

Section 2.30 – Safeties Overview

Individual Safety Shutdowns	2.30-1
Engine Overspeed	2.30-1
Low Oil Pressure	2.30-1
Oil Over-Temperature	2.30-1
Coolant Over-Temperature	2.30-1
Intake Manifold Over-Temperature	2.30-1
Engine Emergency Stop Buttons	2.30-2
Uncontrollable Engine Knock	2.30-2
Engine Overload	2.30-2
Customer-Initiated Emergency Shutdown	2.30-2
Overcrank	2.30-2
Engine Stall	2.30-2
Magnetic Pickup Problems	2.30-2
ECU Internal Faults	2.30-2
Security Violation	2.30-2
Alarms	2.30-2

Section 2.35 – ESM System Communications

MODBUS® (RS-485) Communications	2.35-1
Wiring	2.35-1
Protocol	2.35-2
How Do I Get MODBUS® for My PLC?	2.35-2
Personal Computers	2.35-2
Functionality	2.35-2

Fault Code Behavior	2.35-2
Data Tables	2.35-3
MODBUS® Exception Responses	2.35-3
Additional Information on MODBUS® Addresses 30038 – 30041	2.35-10
Local Control Panel	2.35-10
Local Displays Such as a Tachometer	2.35-10
User Digital Inputs	2.35-11

CHAPTER 3 – ESP OPERATION

Section 3.00 – Introduction to ESP

Electronic Service Program (ESP)	3.00-1
Description of ESP	3.00-1
Minimum Recommended Computer Equipment for ESM ESP Operation	3.00-2
Conventions Used with ESM ESP Programming	3.00-2
Information on Saving ESM System Calibrations	3.00-2
User Interface Panels	3.00-3
Fault Log	3.00-5
E-Help	3.00-6

Section 3.05 – ESP Panel Descriptions

Introduction	3.05-1
[F2] Engine Panel Description	3.05-2
[F3] Start-Stop Panel Description	3.05-4
[F4] Governor Panel Description	3.05-8
[F5] Ignition Panel Description	3.05-14
[F6] AFR Primary Fuel Panel Description	3.05-20
[F8] AFR Setup Panel Description	3.05-26
[F10] Status Panel Description	3.05-30
[F11] Advanced Panel Description	3.05-36
Fault Log Description	3.05-38

Section 3.10 – ESP Programming

Introduction to ESP Programming	3.10-1
Outline of Section 3.10	3.10-1
Initial Engine Startup	3.10-2
Downloading ESP to Hard Drive	3.10-3
Installing ESP CD to Hard Drive	3.10-4
Connecting PC to ECU	3.10-4
Starting ESP	3.10-5
Basic Programming in ESP	3.10-5
Saving to Permanent Memory	3.10-7
Programming WKI Value	3.10-8
Programming Load Inertia	3.10-9
Programming Air/Fuel Ratio	3.10-11
Programming NOx Level – LT Engine Applications Only	3.10-13
Programming Alarm And Shutdown Setpoints	3.10-14
Actuator Calibration	3.10-16
Programming Automatic Calibration	3.10-16
Performing Manual Calibration	3.10-17
Governor Programming	3.10-18
Variable Speed Applications	3.10-18
Fixed Speed Applications	3.10-19
Feedforward Control (Load Coming)	3.10-19
Synchronizer Control (Alternate Dynamics)	3.10-20
IPM-D Programming	3.10-20

Monitoring Ignition Energy Field	3.10-21
Monitoring Spark Reference Number	3.10-21
High Voltage Adjustment	3.10-21
Low Voltage Adjustment	3.10-22
No Spark Adjustment.....	3.10-22
Changing Units – U.S. or Metric	3.10-23
Reset Status LEDs on ECU	3.10-23
Copying Fault Log Information to the Clipboard ..	3.10-23
Taking Screen Captures of ESP Panels	3.10-24
Logging System Parameters.....	3.10-24
Create Text File	3.10-25
Creating .TSV File	3.10-27
Programming Baud Rate	
(MODBUS® Applications)	3.10-28
Programming ECU	
MODBUS® Slave ID	3.10-29
Programming Remote ECU for	
Off-Site Personnel.....	3.10-29
Introduction	3.10-29
Modem Setup	3.10-30
Using a Modem.....	3.10-32
Setting Up Modem to ECU for	
Proper Connection.....	3.10-32
Starting ESP for Modem Access	3.10-34
Connecting Modem To ECU And PC	3.10-35

CHAPTER 4 – TROUBLESHOOTING AND MAINTENANCE

Section 4.00 – Troubleshooting

Important.....	4.00-1
Additional Assistance.....	4.00-1
Introduction	4.00-1
Where to Begin	4.00-1
Determining Fault Code by	
Reading ECU Status LEDs.....	4.00-2
Determining Fault Code by	
Using ESP Fault Log	4.00-2
Using Fault Code for Troubleshooting	4.00-3
E-Help	4.00-3
Using E-Help.....	4.00-3
E-Help Window Description	4.00-4
<i>Using the Command Bar</i>	4.00-4
<i>Using the Navigation Pane</i>	4.00-5
<i>Using the Document Pane</i>	4.00-6
ESM System Fault Codes.....	4.00-7
Non-Code ESM System Troubleshooting	4.00-10

Section 4.05 – ESM System Maintenance

Maintenance Chart.....	4.05-1
ESP Total Fault History.....	4.05-2
Throttle Actuator Linkage.....	4.05-2
Adjusting Linkage	4.05-2
Inspection and Maintenance of	
Throttle Actuator Linkage.....	4.05-6
Alternator Belts	4.05-7
Inspection of Alternator Belts.....	4.05-7
Alternator Belt Tension	4.05-7
Knock Sensors.....	4.05-9
Installing Knock Sensors	4.05-9

<i>Verifying Knock Sensor Is</i>	
<i>Seated Flat</i>	4.05-10
Oxygen Sensor Replacement	4.05-10
Stepper Maintenance	4.05-11
ESM System Wiring	4.05-13
Battery Maintenance	4.05-13
External Inspection.....	4.05-13
Battery Indicated State of Charge	4.05-13

APPENDIX A - INDEX

Appendix A - Index	A-1
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WARRANTY INFORMATION

Express Limited Warranty Covering Products	
used in Continuous Duty Applications	W-1
Express Limited Warranty For Genuine	
Waukesha Service Parts and Waukesha	
Factory Remanufactured Service Parts	W-2
Express Limited Warranty For Products	
Operated in Excess of Continuous Duty Ratings	W-3

Your purchase of the Waukesha Engine System Manager (ESM) system was a wise investment. In the industrial engine field, the name Waukesha Engine stands for quality and durability. With normal care and maintenance this equipment will provide many years of reliable service.

Before placing the ESM system in service, read Chapter 1 very carefully. This chapter covers Safety and General Information.

Section 1.00 – “Safety” – Provides a list of warnings and cautions to make you aware of the dangers present during operation and maintenance of the engine. **READ THEM CAREFULLY AND FOLLOW THEM COMPLETELY.**

Section 1.05 – “General Information” – Provides conversion tables, torque values of metric and standard capscrews, and wiring information.

Section 1.10 – “Description of Operation” – Provides basic data on the ESM system such as system description, theory of operation, and definitions.

ALWAYS BE ALERT FOR THE SPECIAL WARNINGS WITHIN THE MANUAL TEXT. THESE WARNINGS PRECEDE INFORMATION THAT IS CRUCIAL TO YOUR SAFETY AS WELL AS TO THE SAFETY OF OTHER PERSONNEL WORKING ON OR NEAR THE ENGINE. CAUTIONS OR NOTES IN THE MANUAL CONTAIN INFORMATION THAT RELATES TO POSSIBLE DAMAGE TO THE PRODUCT OR ITS COMPONENTS DURING ENGINE OPERATION OR MAINTENANCE PROCEDURES.

This manual contains packager, operation, and maintenance instructions for the ESM system. There are four chapters within the manual, and each chapter contains one or more sections. The title of each chapter or section appears at the top of each page. To locate information on a specific topic, refer to the Table of Contents at the front of the manual or the Index at the back of the manual.

Recommendations and data contained in the manual are the latest information available at the time of this printing and are subject to change without notice. Since engine accessories may vary due to customer specifications, consult your local Waukesha Distributor or Waukesha Engine Service Operations Department for any information on subjects beyond the scope of this manual.

CONTENTS

SECTION 1.00 – SAFETY

SECTION 1.05 – GENERAL INFORMATION

SECTION 1.10 – DESCRIPTION OF OPERATION

SECTION 1.00

SAFETY

SAFETY INTRODUCTION

The following safety precautions are published for your information. Waukesha Engine, Dresser, Inc., does not, by the publication of these precautions, imply or in any way represent that they are the sum of all dangers present near industrial engines or fuel rating test units. If you are installing, operating, or servicing a Waukesha product, it is your responsibility to ensure full compliance with all applicable safety codes and requirements. All requirements of the Federal Occupational Safety and Health Act must be met when Waukesha products are operated in areas that are under the jurisdiction of the United States of America. Waukesha products operated in other countries must be installed, operated, and serviced in compliance with any and all applicable safety requirements of that country.

For details on safety rules and regulations in the United States, contact your local office of the Occupational Safety and Health Administration (OSHA).

The words “danger,” “warning,” “caution,” and “note” are used throughout this manual to highlight important information. Be certain that the meanings of these alerts are known to all who work on or near the equipment.



DANGER

This symbol identifies information about immediate hazards. Disregarding this information will result in SEVERE PERSONAL INJURY OR DEATH.



WARNING

This symbol identifies information about hazards or unsafe practices. Disregarding this information could result in SEVERE PERSONAL INJURY OR DEATH.



CAUTION

This symbol identifies information about hazards or unsafe practices. Disregarding this information *could* result in PRODUCT DAMAGE AND/OR PERSONAL INJURY.

NOTE: *This symbol identifies information that is NECESSARY TO THE PROPER OPERATION, MAINTENANCE, OR REPAIR OF THE EQUIPMENT.*

SAFETY TAGS AND DECALS



WARNING

To avoid severe personal injury or death, all warning tags and decals must be visible and legible to the operator while the equipment is operating.

EQUIPMENT REPAIR AND SERVICE

Proper maintenance, service, and repair are important to the safe, reliable operation of the unit and related equipment. Do not use any procedure not recommended in the Waukesha Engine manuals for this equipment.



WARNING

To prevent severe personal injury or death, always stop the unit before cleaning, servicing, or repairing the unit or any driven equipment.

Place all controls in the OFF position and disconnect or lock out starters to prevent accidental restarting. If possible, lock all controls in the OFF position and take the key. Put a sign on the control panel warning that the unit is being serviced.

Close all manual control valves, disconnect and lock out all energy sources to the unit, including all fuel, electric, hydraulic, and pneumatic connections.

Disconnect or lock out driven equipment to prevent the possibility of the driven equipment rotating the disabled engine.

SAFETY

WARNING

To avoid severe personal injury or death, ensure that all tools and other objects are removed from the unit and any driven equipment before restarting the unit.

WARNING

Allow the engine to cool to room temperature before cleaning, servicing, or repairing the unit. Hot components or fluids can cause severe personal injury or death.

Some engine components and fluids are extremely hot even after the engine has been shut down. Allow sufficient time for all engine components and fluids to cool to room temperature before attempting any service procedure.

ACIDS

WARNING

Comply with the acid manufacturer's recommendations for proper use and handling of acids. Improper handling or misuse could result in severe personal injury or death.

BATTERIES

WARNING

Comply with the battery manufacturer's recommendations for procedures concerning proper battery use and maintenance. Improper maintenance or misuse could result in severe personal injury or death.

BODY PROTECTION

WARNING

Always wear OSHA approved body, sight, hearing, and respiratory system protection. Never wear loose clothing, jewelry, or long hair around an engine. The use of improper attire or failure to use protective equipment may result in severe personal injury or death.

CHEMICALS

GENERAL

WARNING

Always read and comply with safety labels on all containers. Do not remove or deface the container labels. Improper handling or misuse could result in severe personal injury or death.

CLEANING SOLVENTS

WARNING

Comply with the solvent manufacturer's recommendations for proper use and handling of solvents. Improper handling or misuse could result in severe personal injury or death. Do not use gasoline, paint thinners, or other highly volatile fluids for cleaning.

LIQUID NITROGEN/DRY ICE

WARNING

Comply with the liquid nitrogen/Dry Ice manufacturer's recommendations for proper use and handling of liquid nitrogen/Dry Ice. Improper handling or use could result in severe personal injury or death.

COMPONENTS

HEATED OR FROZEN

WARNING

Always wear protective equipment when installing or removing heated or frozen components. Some components are heated or cooled to extreme temperatures for proper installation or removal. Direct contact with these parts could cause severe personal injury or death.

INTERFERENCE FIT

WARNING

Always wear protective equipment when installing or removing components with an interference fit. Installation or removal of interference components may cause flying debris. Failure to use protective equipment may result in severe personal injury or death.

COOLING SYSTEM

WARNING

Always wear protective clothing when venting, flushing, or blowing down the cooling system. Operational coolant temperatures can range from 180° – 250° F (82° – 121° C). Contact with hot coolant or coolant vapor can cause severe personal injury or death.

WARNING

Do not service the cooling system while the engine is operating or when the coolant is hot. Operational coolant temperatures can range from 180° – 250° F (82° – 121° C). Contact with hot coolant or vapor can cause severe personal injury or death.

ELECTRICAL

GENERAL

WARNING

Explosion Hazard – Do not disconnect equipment unless power has been switched off or the area is known to be non-hazardous. Improper maintenance or misuse could result in severe personal injury or death.

WARNING

Do not install, set up, maintain, or operate any electrical components unless you are a technically qualified individual who is familiar with the electrical elements involved. Electrical shock can cause severe personal injury or death.

WARNING

Disconnect all electrical power supplies before making any connections or servicing any part of the electrical system. Electrical shock can cause severe personal injury or death.

IGNITION

WARNING

Avoid contact with ignition units and wiring. Ignition system components can store electrical energy and if contacted can cause electrical shocks. Electrical shock can cause severe personal injury or death.

WARNING

Properly discharge any electrical component that has the capability to store electrical energy before connecting or servicing that component. Electrical shock can cause severe personal injury or death.

EXHAUST

WARNING

Do not inhale engine exhaust gases. Exhaust gases are highly toxic and could cause severe personal injury or death.

Ensure exhaust systems are leak free and that all exhaust gases are properly vented.

WARNING

Do not touch or service any heated exhaust components. Allow sufficient time for exhaust components to cool to room temperature before attempting any service procedure. Contact with hot exhaust system components can cause severe personal injury or death.

FIRE PROTECTION

WARNING

Refer to local and federal fire regulations for guidelines for proper site fire protection. Fires can cause severe personal injury or death.

FUELS

GENERAL

WARNING

Ensure that there are no leaks in the fuel supply. Engine fuels are highly combustible and can ignite or explode causing severe personal injury or death.

GASEOUS

WARNING

Do not inhale gaseous fuels. Some components of fuel gas are odorless, tasteless, and highly toxic. Inhalation of gaseous fuels can cause severe personal injury or death.

SAFETY



WARNING

Shut off the fuel supply if a gaseous engine has been cranked excessively without starting. Crank the engine to purge the cylinders and exhaust system of accumulated unburned fuel. Failure to purge accumulated unburned fuel in the engine and exhaust system can result in an explosion resulting in severe personal injury or death.

LIQUID



WARNING

Do not ingest liquid fuels or breathe in their vapors. Liquid fuels may be highly toxic and can result in severe personal injury or death.



WARNING

Use protective equipment when working with liquid fuels and related components. Liquid fuel can be absorbed into the body resulting in severe personal injury or death.

INTOXICANTS AND NARCOTICS



WARNING

Do not allow anyone under the influence of intoxicants and/or narcotics to work on or around industrial engines. Workers under the influence of intoxicants and/or narcotics are a hazard to both themselves and other employees and can cause severe personal injury or death to themselves or others.

PRESSURIZED FLUIDS/GAS/AIR



WARNING

Never use pressurized fluids/gas/air to clean clothing or body parts. Never use body parts to check for leaks or flow rates. Pressurized fluids/gas/air injected into the body can cause severe personal injury or death.

Observe all applicable local and federal regulations relating to pressurized fluid/gas/air.

PROTECTIVE GUARDS



WARNING

Provide guarding to protect persons or structures from rotating or heated parts. Contact with rotating or heated parts can result in severe personal injury or death.

It is the responsibility of the engine owner to specify and provide guarding. Refer to OSHA standards on “machine guarding” for details on safety rules and regulations concerning guarding techniques.

SPRINGS



WARNING

Use appropriate equipment and protective gear when servicing or using products that contain springs. Springs, under tension or compression, can eject if improper equipment or procedures are used. Failure to take adequate precautions can result in serious personal injury or death.

TOOLS

ELECTRICAL



WARNING

Do not install, set up, maintain, or operate any electrical tools unless you are a technically qualified individual who is familiar with them. Electrical tools use electricity and if used improperly could cause severe personal injury or death.

HYDRAULIC



WARNING

Do not install, set up, maintain, or operate any hydraulic tools unless you are a technically qualified individual who is familiar with them. Hydraulic tools use extremely high hydraulic pressure and if used improperly could cause severe personal injury or death.



CAUTION

Always follow recommended procedures when using hydraulic tensioning devices. Improper use of hydraulic tensioning tools could result in product damage and/or personal injury.

PNEUMATIC

 WARNING

Do not install, set up, maintain, or operate any pneumatic tools unless you are a technically qualified individual who is familiar with them. Pneumatic tools use pressurized air and if used improperly could cause severe personal injury or death.

WEIGHT

 WARNING

Always consider the weight of the item being lifted and use only properly rated lifting equipment and approved lifting methods. Failure to take adequate precautions can result in serious personal injury or death.

 WARNING

Never walk or stand under an engine or component while it is suspended. Failure to adhere to this could result in severe personal injury or death.

WELDING

GENERAL

 WARNING

Comply with the welder manufacturer's recommendations for procedures concerning proper use of the welder. Improper welder use can result in severe personal injury or death.

ON ENGINE

 CAUTION

Disconnect all engine harnesses and electronically controlled devices before welding on or near an engine. Failure to comply will void warranty. Failure to disconnect the harnesses and electronically controlled devices could result in product damage and/or personal injury.

SECTION 1.05

GENERAL INFORMATION

ENGLISH/METRIC CONVERSIONS

Table 1.05-1 English to Metric Formula Conversion

CONVERSION	FORMULA	EXAMPLE
Inches to Millimeters	Inches and any fraction in decimal equivalent multiplied by 25.4 equals millimeters.	2-5/8 in. = $2.625 \times 25.4 = 66.7$ mm
Cubic Inches to Litres	Cubic inches multiplied by 0.01639 equals litres.	9388 cu. in. = $9388 \times 0.01639 = 153.9$ L
Ounces to Grams	Ounces multiplied by 28.35 equals grams.	21 oz. = $21 \times 28.35 = 595$ g
Pounds to Kilograms	Pounds multiplied by 0.4536 equals kilograms.	22,550 lb. = $22,550 \times 0.4536 = 10,229$ kg
Inch Pounds to Newton-meters	Inch pounds multiplied by 0.113 equals Newton-meters.	360 in-lb = $360 \times 0.113 = 40.7$ N-m
Foot Pounds to Newton-meters	Foot pounds multiplied by 1.3558 equals Newton-meters.	145 ft-lb = $145 \times 1.3558 = 197$ N-m
Pounds per Square Inch to Bars	Pounds per square inch multiplied by 0.0690 equals bars.	9933 psi = $9933 \times 0.0690 = 685$ bar
Pounds per Square Inch to Kilograms per Square Centimeter	Pounds per square inch multiplied by 0.0703 equals kilograms per square centimeter.	45 psi = $45 \times 0.0703 = 3.2$ kg/cm ²
Pounds per Square Inch to Kilopascals	Pounds per square inch multiplied by 6.8947 equals kilopascals.	45 psi = $45 \times 6.8947 = 310$ kPa
Rotating Moment of Inertia (Force)	Pounds force x inches x squared seconds multiplied by 0.112985 equals kilograms x squared meters.	$123.9 \text{ lbf} \times \text{in.} \times \text{sec}^2 = 123.9 \times 0.112985 = 14 \text{ kg} \times \text{m}^2$
Rotating Moment of Inertia (Mass)	Pounds mass x squared feet multiplied by 0.04215 equals kilograms x squared meters.	$332.2 \text{ lbm} \times \text{ft}^2 = 332.2 \times 0.04215 = 14 \text{ kg} \times \text{m}^2$
Fluid Ounces to Cubic Centimeters	Fluid ounces multiplied by 29.57 equals cubic centimeters.	8 oz. = $8 \times 29.57 = 237$ cc
US Gallons to Litres	US Gallons multiplied by 3.7853 equals litres.	148 gal. = $148 \times 3.7853 = 560$ L
Degrees Fahrenheit to Degrees Centigrade	Degrees Fahrenheit minus 32 divided by 1.8 equals degrees Centigrade.	$212^\circ \text{ F} - 32 \div 1.8 = 100^\circ \text{ C}$

Table 1.05-2 Metric to English Formula Conversion (Part 1 of 2)

CONVERSION	FORMULA	EXAMPLE
Millimeters to Inches	Millimeters multiplied by 0.03937 equals inches.	67 mm = $67 \times 0.03937 = 2.6$ in.
Litres to Cubic Inches	Litres multiplied by 61.02 equals cubic inches.	153.8 L = $153.8 \times 61.02 = 9385$ cu. in.
Grams to Ounces	Grams multiplied by 0.03527 equals ounces.	595 g = $595 \times 0.03527 = 21.0$ oz.
Kilograms to Pounds	Kilograms multiplied by 2.205 equals pounds.	10,228 kg = $10,228 \times 2.205 = 22,553$ lb.
Newton-meters to Inch Pounds	Newton-meters multiplied by 8.85 equals inch pounds.	40.7 N-m = $40.7 \times 8.85 = 360$ in-lb
Newton-meters to Foot Pounds	Newton-meters multiplied by 0.7375 equals foot pounds.	197 N-m = $197 \times 0.7375 = 145$ ft-lb
Bars to Pounds per Square Inch	Bars multiplied by 14.5 equals pounds per square inch.	685 bar = $685 \times 14.5 = 9933$ psi

GENERAL INFORMATION

Table 1.05-2 Metric to English Formula Conversion (Continued), (Part 2 of 2)

CONVERSION	FORMULA	EXAMPLE
Kilograms per Square Centimeter to Pounds per Square Inch (psi)	Kilograms per square centimeter multiplied by 14.22 equals pounds per square inch.	$3.2 \text{ kg/cm}^2 = 3.2 \times 14.22 = 46 \text{ psi}$
Kilopascals to Pounds per Square Inch (psi)	Kilopascals multiplied by 0.145 equals pounds per square inch.	$310 \text{ kPa} = 310 \times 0.145 = 45.0 \text{ psi}$
Rotating Moment of Inertia (Force)	Kilograms x squared meters multiplied by 8.85075 equals pounds force x inches x squared seconds.	$14 \text{ kg} \times \text{m}^2 = 14 \times 8.85075 = 123.9 \text{ lbf} \times \text{in.} \times \text{sec}^2$
Rotating Moment of Inertia (Mass)	Kilograms x squared meters multiplied by 23.725 equals pounds mass x squared feet.	$14 \text{ kg} \times \text{m}^2 = 14 \times 23.725 = 332.2 \text{ lbm} \times \text{ft}^2$
Cubic Centimeters to Fluid Ounces	Cubic centimeters multiplied by 0.0338 equals fluid ounces.	$236 \text{ cc} = 236 \times 0.0338 = 7.98 \text{ oz.}$
Litres to US Gallons	Litres multiplied by 0.264 equals US gallons.	$560 \text{ L} = 560 \times 0.264 = 148 \text{ gal.}$
Degrees Centigrade to Degrees Fahrenheit	Degrees Centigrade multiplied by 1.8 plus 32 equals degrees Fahrenheit.	$100^\circ \text{ C} = 100 \times 1.8 + 32 = 212^\circ \text{ F}$

TORQUE VALUES

Table 1.05-3 U.S. Standard Capscrew Torque Values

SAE GRADE NUMBER	 GRADE 1 OR 2			 GRADE 5			 GRADE 8		
	TORQUE in-lb (N·m)			TORQUE in-lb (N·m)			TORQUE in-lb (N·m)		
THREADS	DRY	OILED	PLATED	DRY	OILED	PLATED	DRY	OILED	PLATED
1/4-20	62 (7)	53 (6)	44 (5)	97 (11)	80 (9)	159 (18)	142 (16)	133 (15)	124 (14)
1/4-28	71 (8)	62 (7)	53 (6)	124 (14)	106 (12)	97 (11)	168 (19)	159 (18)	133 (15)
5/16-18	133 (15)	124 (14)	106 (12)	203 (23)	177 (20)	168 (19)	292 (33)	265 (30)	230 (26)
5/16-24	159 (18)	142 (16)	124 (14)	230 (26)	203 (23)	177 (20)	327 (37)	292 (33)	265 (30)
3/8-16	212 (24)	195 (22)	168 (19)	372 (42)	336 (38)	301 (34)	531 (60)	478 (54)	416 (47)
	ft-lb (N·m)			ft-lb (N·m)			ft-lb (N·m)		
3/8-24	20 (27)	18 (24)	16 (22)	35 (47)	32 (43)	28 (38)	49 (66)	44 (60)	39 (53)
7/16-14	28 (38)	25 (34)	22 (30)	49 (56)	44 (60)	39 (53)	70 (95)	63 (85)	56 (76)
7/16-20	30 (41)	27 (37)	24 (33)	55 (75)	50 (68)	44 (60)	78 (106)	70 (95)	62 (84)
1/2-13	39 (53)	35 (47)	31 (42)	75 (102)	68 (92)	60 (81)	105 (142)	95 (129)	84 (114)
1/2-20	41 (56)	37 (50)	33 (45)	85 (115)	77 (104)	68 (92)	120 (163)	108 (146)	96 (130)
9/16-12	51 (69)	46 (62)	41 (56)	110 (149)	99 (134)	88 (119)	155 (210)	140 (190)	124 (168)
9/16-18	55 (75)	50 (68)	44 (60)	120 (163)	108 (146)	96 (130)	170 (230)	153 (207)	136 (184)
5/8-11	83 (113)	75 (102)	66 (89)	150 (203)	135 (183)	120 (163)	210 (285)	189 (256)	168 (228)
5/8-18	95 (129)	86 (117)	76 (103)	170 (230)	153 (207)	136 (184)	240 (325)	216 (293)	192 (260)
3/4-10	105 (142)	95 (130)	84 (114)	270 (366)	243 (329)	216 (293)	375 (508)	338 (458)	300 (407)
3/4-16	115 (156)	104 (141)	92 (125)	295 (400)	266 (361)	236 (320)	420 (569)	378 (513)	336 (456)
7/8-9	160 (217)	144 (195)	128 (174)	395 (535)	356 (483)	316 (428)	605 (820)	545 (739)	484 (656)
7/8-14	175 (237)	158 (214)	140 (190)	435 (590)	392 (531)	348 (472)	675 (915)	608 (824)	540 (732)
1.0-8	235 (319)	212 (287)	188 (255)	590 (800)	531 (720)	472 (640)	910 (1234)	819 (1110)	728 (987)
1.0-14	250 (339)	225 (305)	200 (271)	660 (895)	594 (805)	528 (716)	990 (1342)	891 (1208)	792 (1074)

NOTE: Dry torque values are based on the use of clean, dry threads.

Oiled torque values have been reduced by 10% when engine oil is used as a lubricant.

Plated torque values have been reduced by 20% for new plated capscrews.

Capscrews that are threaded into aluminum may require a torque reduction of 30% or more.

The conversion factor from ft-lb to in-lb is ft-lb x 12 equals in-lb.

Oiled torque values should be reduced by 10% from dry when nickel-based anti-seize compound is used as a lubricant.

Oiled torque values should be reduced by 16% from dry when copper-based anti-seize compound is used as a lubricant.

Table 1.05-4 Metric Standard Capscrew Torque Values (Untreated Black Finish)

COARSE THREAD CAPSCREWS (UNTREATED BLACK FINISH)								
ISO PROPERTY CLASS								
SIZE	TORQUE		TORQUE		TORQUE		TORQUE	
	N·m	in-lb	N·m	in-lb	N·m	in-lb	N·m	in-lb
M3	0.6	5	1.37	12	1.92	17	2.3	20
M4	1.37	12	3.1	27	4.4	39	10.4	92
M5	2.7	24	10.5	93	15	133	18	159
M6	4.6	41	10.5	93	15	133	10.4	92
M7	7.6	67	17.5	155	25	221	29	257
M8	11	97	26	230	36	319	43	380
M10	22	195	51	451	72	637	87	770
	N·m	ft-lb	N·m	ft-lb	N·m	ft-lb	N·m	ft-lb
M12	39	28	89	65	125	92	150	110
M14	62	45	141	103	198	146	240	177
M16	95	70	215	158	305	224	365	269
M18	130	95	295	217	420	309	500	368
M20	184	135	420	309	590	435	710	523
M22	250	184	570	420	800	590	960	708
M24	315	232	725	534	1020	752	1220	899
M27	470	346	1070	789	1519	1113	1810	1334
M30	635	468	1450	1069	2050	1511	2450	1806
M33	865	637	1970	1452	2770	2042	3330	2455
M36	1111	819	2530	1865	3560	2625	4280	3156
M39	1440	1062	3290	2426	4620	3407	5550	4093
FINE THREAD CAPSCREWS (UNTREATED BLACK FINISH)								
ISO PROPERTY CLASS								
SIZE	TORQUE		TORQUE		TORQUE			
	N·m	ft-lb	N·m	ft-lb	N·m	ft-lb		
M8 x 1	27	19	38	28	45	33		
M10 x 1.25	52	38	73	53	88	64		
M12 x 1.25	95	70	135	99	160	118		
M14 x 1.5	150	110	210	154	250	184		
M16 x 1.5	225	165	315	232	380	280		
M18 x 1.5	325	239	460	339	550	405		
M20 x 1.5	460	339	640	472	770	567		
M22 x 1.5	610	449	860	634	1050	774		
M24 x 2	780	575	1100	811	1300	958		

NOTE: The conversion factors used in these tables are as follows: One N·m equals 0.7375 ft-lb and one ft-lb equals 1.355818 N·m.

GENERAL INFORMATION

Table 1.05-5 Metric Standard Capscrew Torque Values (Electrically Zinc Plated)

COARSE THREAD CAPSCREWS (ELECTRICALLY ZINC PLATED)								
ISO PROPERTY CLASS								
SIZE	TORQUE		TORQUE		TORQUE		TORQUE	
	N·m	in-lb	N·m	in-lb	N·m	in-lb	N·m	in-lb
M3	0.56	5	1.28	11	1.8	16	2.15	19
M4	1.28	11	2.9	26	4.1	36	4.95	44
M5	2.5	22	5.75	51	8.1	72	9.7	86
M6	4.3	38	9.9	88	14	124	16.5	146
M7	7.1	63	16.5	146	23	203	27	239
M8	10.5	93	24	212	34	301	40	354
M10	21	186	48	425	67	593	81	717
	N·m	ft-lb	N·m	ft-lb	N·m	ft-lb	N·m	ft-lb
M12	36	26	83	61	117	86	140	103
M14	58	42	132	97	185	136	220	162
M16	88	64	200	147	285	210	340	250
M18	121	89	275	202	390	287	470	346
M20	171	126	390	287	550	405	660	486
M22	230	169	530	390	745	549	890	656
M24	295	217	675	497	960	708	1140	840
M27	435	320	995	733	1400	1032	1680	1239
M30	590	435	1350	995	1900	1401	2280	1681
M33	800	590	1830	1349	2580	1902	3090	2278
M36	1030	759	2360	1740	3310	2441	3980	2935
M39	1340	988	3050	2249	4290	3163	5150	3798
FINE THREAD CAPSCREWS (ELECTRICALLY ZINC PLATED)								
ISO PROPERTY CLASS								
SIZE	TORQUE		TORQUE		TORQUE			
	N·m	ft-lb	N·m	ft-lb	N·m	ft-lb		
M8 x 1	25	18	35	25	42	30		
M10 x 1.25	49	36	68	50	82	60		
M12 x 1.25	88	64	125	92	150	110		
M14 x 1.5	140	103	195	143	235	173		
M16 x 1.5	210	154	295	217	350	258		
M18 x 1.5	305	224	425	313	510	376		
M20 x 1.5	425	313	600	442	720	531		
M22 x 1.5	570	420	800	590	960	708		
M24 x 2	720	531	1000	737	1200	885		

NOTE: The conversion factors used in these tables are as follows: One N·m equals 0.7375 ft-lb, and one ft-lb, equals 1.355818 N·m.

WIRING REQUIREMENTS

All electrical equipment and wiring shall comply with applicable local codes. This Waukesha Engine standard defines additional requirements for Waukesha engines.



WARNING

Do not install, set up, maintain, or operate any electrical components unless you are a technically qualified individual who is familiar with the electrical elements involved. Electrical shock can cause severe personal injury or death.



WARNING

Disconnect all electrical power supplies before making any connections or servicing any part of the electrical system. Electrical shock can cause severe personal injury or death.

1. Whenever two or more wires run together, they should be fastened together at no more than 4 – 6 in. (10 – 15 cm) intervals, closer where necessary, with tie wraps or tape.

2. All wires should be mounted off hot areas of the engine with insulated clips, at intervals of no more than 12 in. (30 cm), closer where necessary. Wires must never be run closer than 6 in. (15 cm) to exhaust manifolds, turbochargers, or exhaust pipes.

3. In cases where wires do not run over the engine, they should be fastened to rigid, non-moving bodies with insulated clips when possible or tie wraps. Fasteners should be spaced at no more than 12 in. (30 cm) intervals.

4. When wires run through holes, rubber grommets should be installed in holes to protect the wires. Wires should never be run over rough surfaces or sharp edges without protection (see Item 11).



CAUTION

Do not use non-electrical grade RTV. Non-electrical RTVs can emit corrosive gases that can damage electrical connectors. Disregarding this information could result in product damage and/or personal injury.

5. An electrical grade RTV should be applied around the wires entering all electrical devices such as Murphy Junction Boxes and gas valves, Syncro Start speed switches, microswitch boxes used in conjunction with safety equipment, solenoids, etc. An electrical grade RTV is to be applied immediately after wire installation.

6. A small “drip loop” should be formed in all wires before entering the electrical devices. This drip loop will reduce the amount of moisture entering an electrical device via the wires if an electrical grade RTV does not seal completely.

7. The following procedures should be followed for wires entering engine junction boxes:

- Bottom entrance best and side entrance second best.
- Insert grommet in opening to protect wires.
- Wires to contain “drip loop” before entering box, except where using bottom entrance.
- When installing flexible conduit, use straight connector for side entrance. If top entrance is required, use elbow connector.

8. If wire harness has a covering, clamp harness so openings of covering are downward.

9. The routing of wires should be determined for reliability and appearance and not by shortest distance.

10. Installation connection wire must be coiled and secured to provide protection during shipment.

11. Each end of flexible metal conduit *must* have an insulating sleeve to protect wires from chafing.



WARNING

Always label “HIGH VOLTAGE” on engine-mounted equipment over 24 volts nominal. Failure to adhere to this warning could result in severe personal injury or death.

12. All engine-mounted electrical equipment over 24 volts nominal shall have “HIGH VOLTAGE” warning decal. Decal is to be attached to all the equipment and junction boxes on visible surface (vertical surface whenever possible).

13. Wiring that is routed in rigid or flexible conduit shall have all wire splices made only in junction boxes, outlet boxes, or equipment boxes. Wire splices shall not be located in the run of any conduit.

SECTION 1.10

DESCRIPTION OF OPERATION



INTRODUCTION

The Waukesha Engine System Manager (ESM) is a total engine management system designed to optimize engine performance and maximize uptime (see Figure 1.10-1). The ESM system integrates spark timing control, speed governing, detonation detection, start-stop control, air/fuel control (AFR equipped), diagnostic tools, fault logging, and engine safeties. ESM system automation and monitoring provides:

- Better engine performance
- Extensive system diagnostics
- Rapid troubleshooting of engines
- Local and remote monitoring capability used to trend engine performance
- Easy integration into an extensive data acquisition system

In addition, the ESM system has safety shutdowns such as low oil pressure, engine overspeed, high intake manifold air temperature, high coolant outlet temperature, and uncontrolled detonation.

User interface to the ESM system can be as simple as switches, potentiometers, and light bulbs, or as sophisticated as a PLC with a touch screen and remote data acquisition controlled by a satellite link.

See Figure 1.10-1 for a block diagram of the complete ESM system.

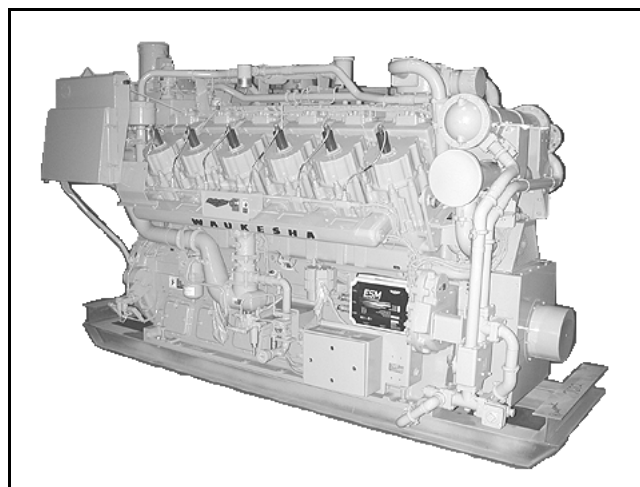


Figure 1.10-1 Engine System Manager (ESM) Installed on VHP Series Four 12-Cylinder Engine

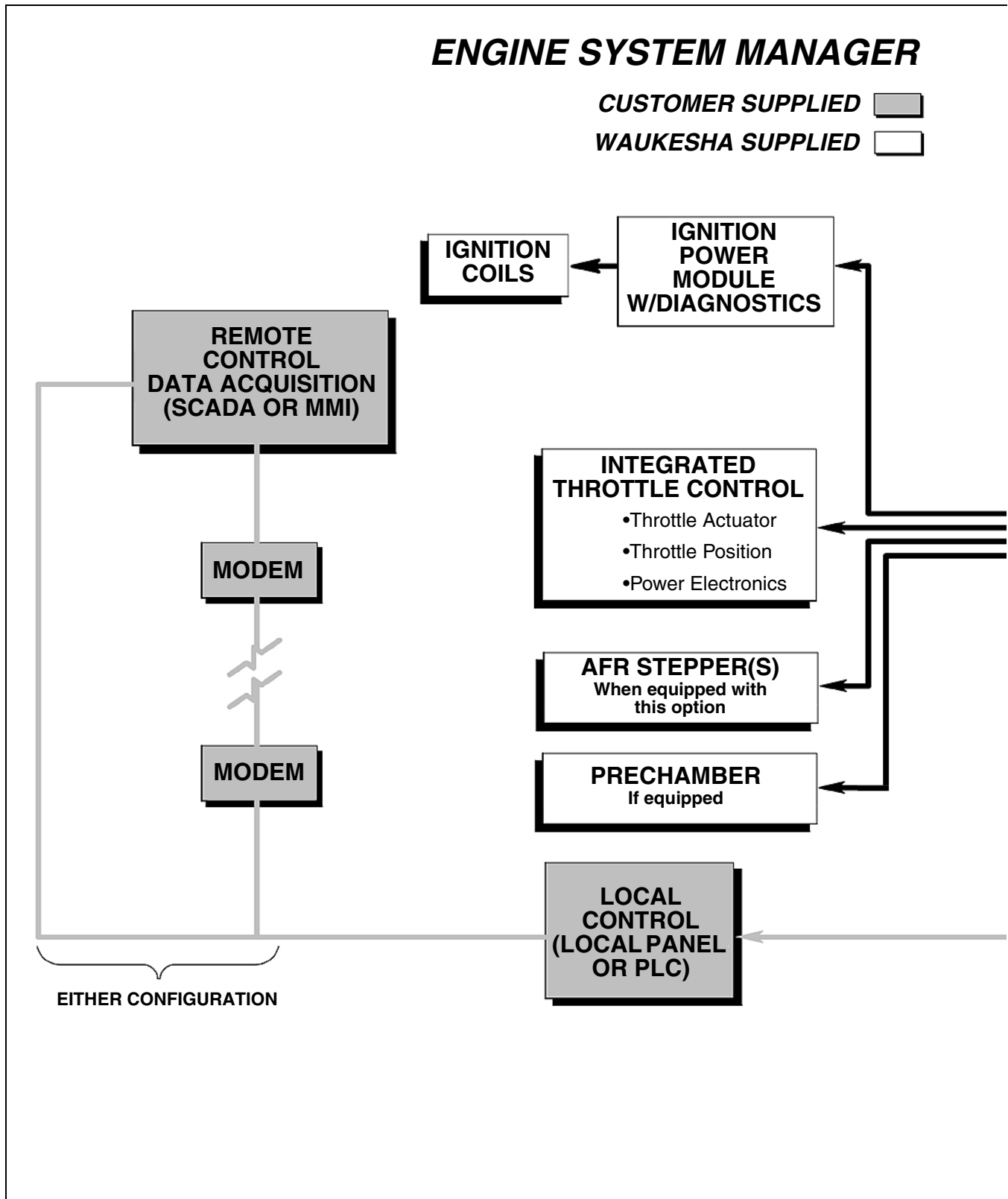
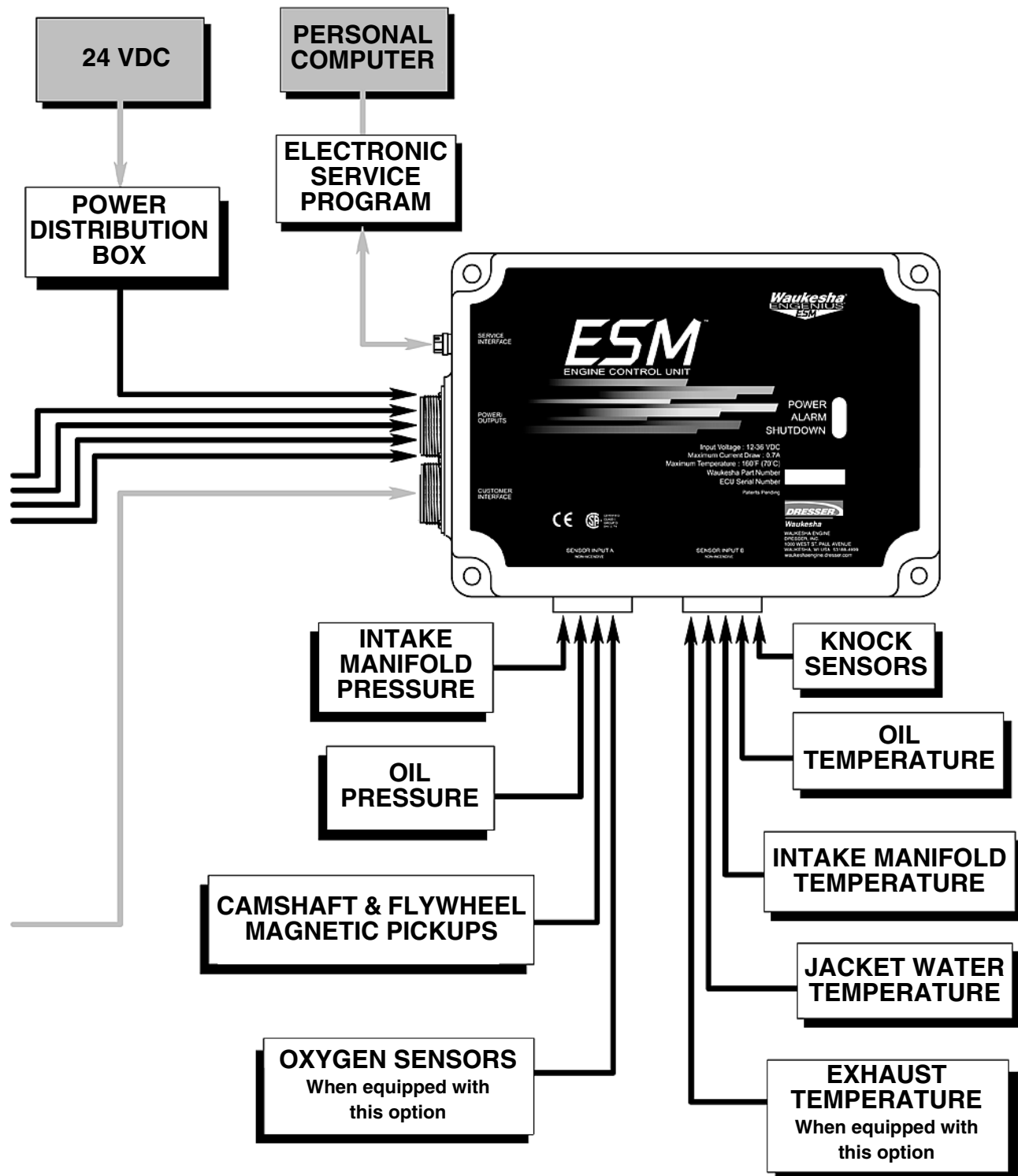


Figure 1.10-1 ESM System Block Diagram



DESCRIPTION OF OPERATION

ESM SYSTEM COMPONENTS

The ESM system including the modules and cables meets Canadian Standards Association (CSA) Class I, Division 2, Groups A, B, C, and D hazardous location requirements.

The ESM system includes the following equipment:

- Engine Control Unit (ECU)
- Ignition Power Module with Diagnostics (IPM-D)
- PC-based Electronic Service Program (ESP)
- Electric throttle actuation
- Prechamber control valve (VHP7042GL)
- Stepper(s) for the gas regulator (one per engine bank) (AFR equipped)

The ESM system includes the following engine mounted and wired sensors:

- Oil pressure sensor (1)
- Oil temperature sensor (1)
- Intake manifold pressure sensor(s)
- Intake manifold temperature sensor (1)
- Jacket water temperature sensor (1)
- Magnetic pickups (2)
- Knock sensors
- Oxygen sensor(s) (AFR equipped)
- Exhaust temperature sensor(s) (AFR equipped)

ENGINE CONTROL UNIT (ECU)

DESCRIPTION OF ECU

The Engine Control Unit (ECU) is the central module or “hub” of the ESM system (see Figure 1.10-2). The ECU is the single entry point of system control for easy interface and usability. The entire ESM system interfaces with the ECU. Based on system inputs, the ECU logic and circuitry drive all the individual subsystems.

The ECU is a sealed module with five connection points. The ECU configuration allows for simple electrical connections and simple setup. The ECU is CSA approved for Class I, Division 2, Groups A, B, C, and D (T4 temperature rating), hazardous location requirements.

All ESM system components, the customer-supplied PC with Electronic Service Program software, and customer-supplied data acquisition devices connect to the ECU. Communication is available through:

- Status LEDs (light emitting diodes) that flash alarm/shutdown codes on the front of the ECU

- Analog and digital signals in/out to local panel or customer PLC
- RS-485 (MODBUS® slave) communication to local panel or customer PLC (MODBUS® master)
- PC-based ESM Electronic Service Program via an RS-232 connection

ECU STATUS LEDs

The ECU has three Status LEDs on the cover: green (power), yellow (alarm), and red (shutdown). The green LED is on whenever power is applied to the ECU, the yellow LED flashes alarm codes, and the red LED flashes shutdown codes. The yellow and red LEDs flash codes that allow you to obtain information on the status of the system when an alarm or shutdown occurs. All codes have three digits, and each digit can be a number from 1 to 5. The codes display in the order that they occur (with the oldest code displayed first and the most recent code displayed last).

At the start of the code sequence, both the red and yellow LEDs will flash three times simultaneously. If there are any shutdown faults, the red LED will flash a three-digit code for each shutdown fault that occurred. If there are any alarm faults, the yellow LED will flash a three-digit code for each alarm that occurred. Between each three-digit code, both yellow and red LEDs will flash once at the same time to indicate that a new code is starting.

Once the fault is corrected, the Status LEDs on the ECU will remain flashing until one of two things happens: (1) the LEDs are cleared using the ESM Electronic Service Program or (2) the engine is restarted.



Figure 1.10-2 ESM Engine Control Unit (ECU)

The ECU Status LEDs are not considered to be the primary means of obtaining information on the status of the system, but rather a way of alerting the site technician that there is a problem and what that problem is (even if a PC with the Electronic Service Program is unavailable). See “ESM Electronic Service Program (ESP)” for more information.

ESM ELECTRONIC SERVICE PROGRAM (ESP)

DESCRIPTION OF ESP

The PC-based ESM Electronic Service Program (ESP) is the primary means of obtaining information on system status. ESP provides a user-friendly, graphical interface in a Microsoft® Windows® XP operating system environment (see Figure 1.10-4). If the user needs help, system information, or troubleshooting information while using the ESP software, an electronic help file is included. See “E-Help” on page 1.10-5 for more information. E-Help is accessed by pressing the [F1] function key on the keyboard.

ESP is a diagnostic tool and is the means by which the information recorded to the ECU fault logs can be read. Minimal site-specific programming is required.



This is the ESP icon that appears on your desktop after loading the software on your PC. To open the ESP software, double-click on the icon.

E-HELP

ESP contains an electronic help file named E-Help (see Figure 1.10-3 for a sample screen). E-Help provides general system and troubleshooting information in an instant as long as the user is using the PC with the ESP software. The user can quickly and easily move around in E-Help through electronic links (or hypertext links) from subject to subject. E-Help is automatically installed when the ESP software is installed. To access the help file any time while using the ESP software, press the [F1] function key on the keyboard or select **Help Contents...** from the **Help** menu in ESP.

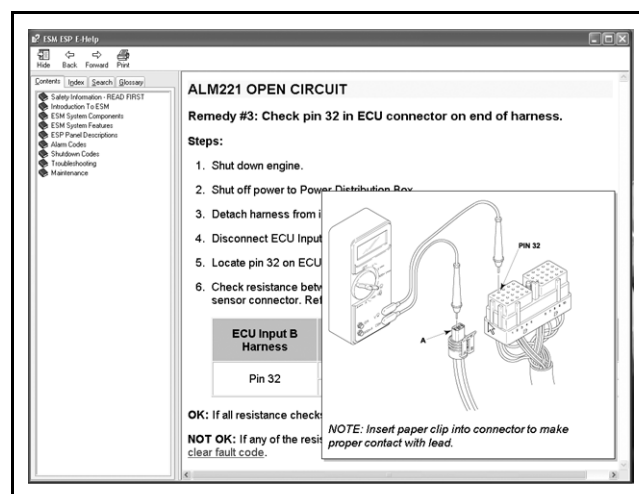


Figure 1.10-3 Sample E-Help Screen

USER INTERFACE PANELS

The ESM ESP software displays engine status and information on eight panels:

[F2] Engine Panel [F6] AFR Primary Fuel Panel*

[F3] Start-Stop Panel [F8] AFR Setup Panel*

[F4] Governor Panel [F10] Status Panel

[F5] Ignition Panel [F11] Advanced Panel

**The [F6] and [F8] panels are viewable on AFR equipped engines.*

These panels display system and component status, current pressure and temperature readings, alarms, ignition status, governor status, air/fuel control status (AFR equipped), and programmable adjustments.

Each of the panels is viewed by clicking the corresponding tab or by pressing the corresponding function key ([F#]) on the keyboard.

Refer to Section 3.05 *ESP Panel Descriptions* for a complete description of each panel.

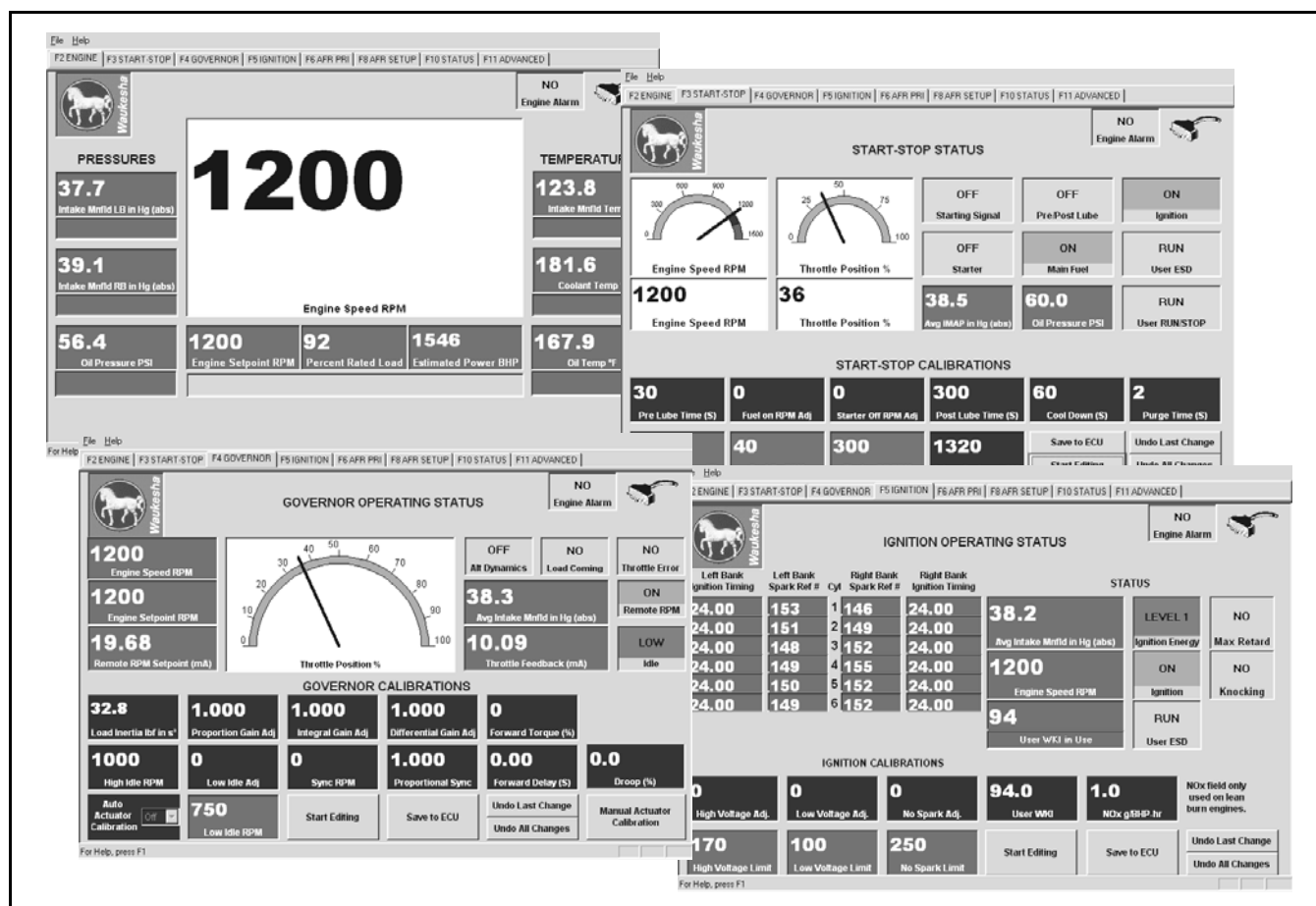


Figure 1.10-4 Electronic Service Program's (ESP's) Graphical User Interface

ESM SYSTEM DIAGNOSTICS

The ESM system performs self-diagnostics using the input and output values from the ECU, the sensors, and engine performance. The ECU detects faulty sensors and wires by:

- Checking for sensor readings that are out of programmed limits
- Cross-checking sensor readings with other sensor readings for correct and stable operation
- Completing checks that determine whether or not a sensor is operating out of the normal operating range

When a fault occurs, several actions may take place as a result. A fault can have both internal actions and external visible effects. Each fault detected will cause one or more of the following actions to occur:

- Alarm is logged by the ECU and appears in the ESP software's Fault Log. See Section 3.05 *ESP Panel Descriptions* for more information.
- Yellow and/or red Status LEDs on the front of the ECU light and begin to flash a fault code.

- Sensors and actuator switch into a "default state" where the actuator/sensors operate at expected normal values or at values that place the engine in a safe state. When the default state takes control, an alarm is signaled and the fault is logged but the engine keeps running (unless as a result of the fault a shutdown fault occurs).
- Shutdown occurs and the red Status LED on the front of the ECU lights and flashes a code.
- Alarm or shutdown signal is transmitted over the customer interface (RS-485 MODBUS® and digital output).

SAFETY SHUTDOWNS

The ESM system provides numerous engine safety shutdowns to protect the engine. These engine safety shutdowns include:

- Low oil pressure
- Engine overspeed
 - 10% overspeed instantaneous
 - Waukesha-calibrated to run no more than rated speed
 - User-calibrated driven equipment overspeed
- Engine overload (based on percentage of engine torque)
- Uncontrollable knock
- High intake manifold air temperature
- High jacket water coolant temperature
- Internal ECU faults
- Failure of magnetic pickup

When a safety shutdown occurs, several internal actions and external visible effects take place. Each safety shutdown will cause the following actions to occur:

- Ignition spark stops instantaneously.
- Gas shutoff valve is closed.
- The digital output from the ECU to the customer is changed to indicate to the customer's driven equipment or PLC that the ESM system has shut down the engine and something is not operating as expected.
- Red Status LED on the front of the ECU flashes the shutdown fault code.
- Shutdown signal is transmitted over the customer interface (RS-485 MODBUS® and digital output).
- An entry is added to the fault log and can be read using the ESM ESP software. See Section 3.05 *ESP Panel Descriptions* for more information.

START-STOP CONTROL

The ESM system manages the start, stop, and emergency stop sequences of the engine including pre- and postlube. Logic to start and stop the engine is built into the ECU, but the customer supplies the user interface (control panel buttons, switches, touch screen) to the ESM system.

The ESM system's start-stop process is controlled by three mandatory digital inputs: a start signal that is used to indicate to the ECU that the engine should be started and two shutdown signals (normal and emergency) that are used to give "permission" to run the engine. The three signals are: Start, Run/Stop, and Emergency Stop.

For the engine to start, the start signal must be configured as a momentary event such that it goes "high" (8.6 – 36 volts) for at least 1/2 second (not to exceed 1 minute). In addition, to start the engine the shutdown signals must both be "high" (8.6 – 36 volts). Although the start signal must go "low" (< 3.3 volts) after starting, the shutdown signals must remain high for the engine to run. If either shutdown signal goes low, even for a fraction of a second, the engine will stop.

During the "start" sequence, the ESM system performs the following steps:

- 1) Prelubes engine (programmable from 0 – 10,800 seconds using ESP software)
- 2) Engages starter motor (programmable rpm range using ESP software)
- 3) Turns fuel on (programmable above a certain rpm and after a user-calibrated purge time using ESP software)
- 4) Turns ignition on (after a user-calibrated purge time using ESP software)

During the normal "stop" sequence, the ESM system performs the following steps:

- 1) Begins cooldown period (programmable using ESP software)
- 2) Shuts off fuel
- 3) Stops ignition when engine stops rotating
- 4) Postlubes engine (programmable from 0 – 10,800 seconds using ESP software)
- 5) Actuator auto calibration (if desired, programmable using ESP software)

During the "emergency stop" sequence, the ESM system performs the following step:

- 1) Simultaneously shuts off fuel and ignition

NOTE: *If the engine is being used in a "standby" electric power generation application and the engine must not prelude on startup, the customer is responsible for controlling the prelude motor to automatically prelude the engine. Refer to Section 3 of Chapter 5 "Lubrication System" in the Installation of Waukesha Engines & Enginator® Systems Manual (Form 1091) for lubrication requirements in standby applications.*

DESCRIPTION OF OPERATION

IGNITION SYSTEM

DESCRIPTION OF IGNITION SYSTEM

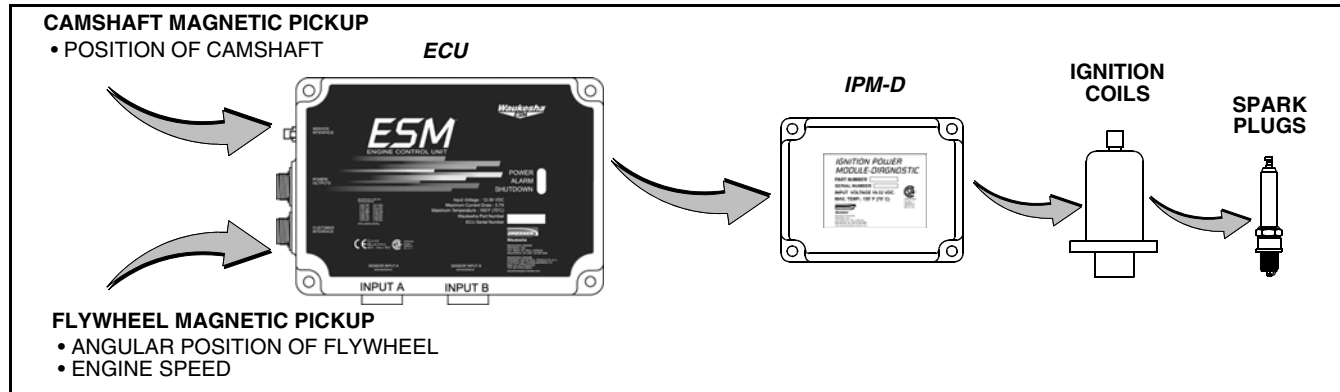


Figure 1.10-5 ESM Ignition System Diagram

The ESM system controls spark plug timing with a digital capacitive discharge ignition system. The ignition system uses the capacitor discharge principle that provides a high variable energy, precision-timed spark for maximum engine performance. The ESM ignition system provides accurate and reliable ignition timing, resulting in optimum engine operation.

The ESM ignition system uses the ECU as its central processor or “brain.” Two magnetic pickups are used to input information to the ECU. One pickup reads a magnet on the camshaft, and the other senses reference holes in the flywheel. See Figure 1.10-5 for the ESM ignition system diagram.

A separate module, the Ignition Power Module with Diagnostic capability (IPM-D), is needed to fire the spark plug at the required voltage (see Figure 1.10-6). The IPM-D is CSA approved for Class I, Division 2, Group D (T4 temperature rating), hazardous location requirements.

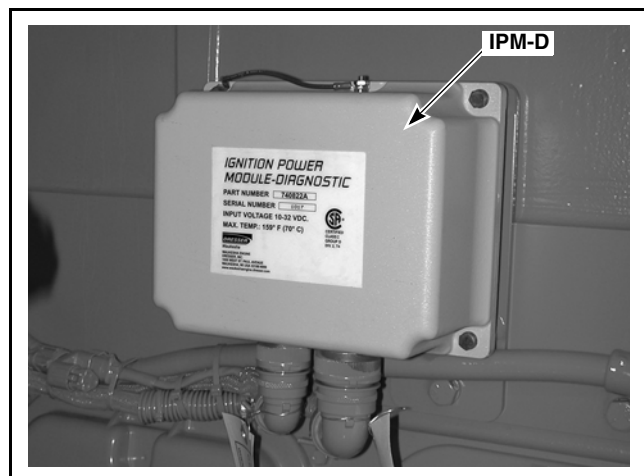


Figure 1.10-6 Ignition Power Module with Diagnostics (IPM-D)

IGNITION THEORY

The ECU is the “brain” of the ignition system. The ECU controls spark timing with information preprogrammed at the factory. The spark timing is determined by calibration and can vary with engine speed, intake manifold pressure, the WKI value, and several other variables that optimize engine performance.

The ECU also controls spark timing with the information from the engine-mounted knock sensors. When a knock signal exceeds the detonation threshold, the ECU retards timing incrementally on an individual cylinder basis to keep the engine out of detonation. See “Detonation Detection” on page 1.10-9 for more information.

Based on the preprogrammed information and readings, the ECU sends an electronic signal to the IPM-D that energizes the ignition coils to “fire” the spark plug. The IPM-D provides automatically controlled dual voltage levels. During normal engine operation, the IPM-D fires at a Level 1 (normal) ignition energy. The IPM-D fires at a Level 2 (high) ignition energy on engine startup or as a result of spark plug wear. See “Ignition Diagnostics” on page 1.10-9 for more information.

The IPM-D is a high energy, capacitor discharge solid-state ignition module. The power supply voltage is used to charge the energy storage capacitor. This voltage is then stepped up by the ignition coils. A signal from the ECU triggers the IPM-D to release the energy stored in the capacitor. When the IPM-D receives the signal, the energy in the ignition coil is used to fire the spark plug.

ESM engines have an index disc mounted on the camshaft gear and a magnetic pickup mounted on the gear cover of the engine (see Figure 1.10-7). The index disc is always fixed at the same angular location for every engine with the ESM system. The index disc has one magnet: the index magnet. The camshaft magnetic pickup determines which part of the four-stroke cycle the engine is in. Since the camshaft disc rotates at half the engine speed, the crankshaft must rotate twice for the cycle to end.

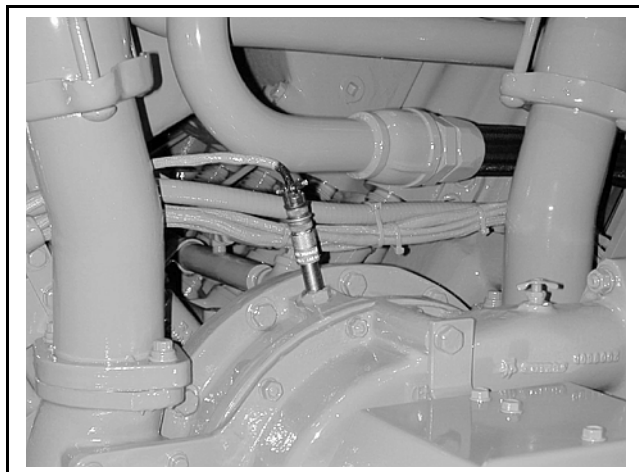


Figure 1.10-7 Magnetic Pickup – Gear Cover

Another magnetic pickup is used to sense 36 reference holes in the flywheel (see Figure 1.10-8). This magnetic pickup signals to the ECU: (1) the angular position of the crankshaft and (2) engine speed (rpm).

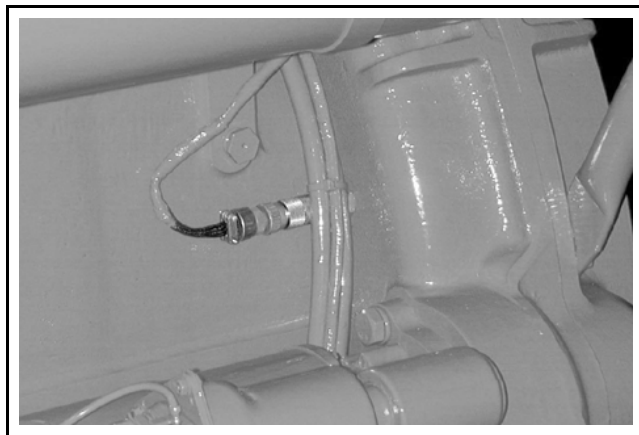


Figure 1.10-8 Magnetic Pickup – Flywheel Housing

IGNITION DIAGNOSTICS

IPM-D provides diagnostic information for both the primary and secondary sides of the ignition coil. The IPM-D detects shorted spark plugs and ignition leads, as well as spark plugs that require a boosted energy level to fire or do not fire at all. The diagnostic information is provided through a Controller Area Network (CAN) link between the ECU and IPM-D, and then to the customer's local control panel via MODBUS®.

Predictive diagnostics based on a spark reference number for each cylinder is used to monitor each spark plug's life. The spark reference number is an arbitrary number based on relative voltage demand. The spark reference number is displayed for each cylinder on the [F5] Ignition Panel in ESP. Spark reference numbers can be used to represent spark plug electrode wear (gap) and can be monitored (for example, with MODBUS®) and trended to predict the time of spark plug failure.

If sufficient spark plug wear is identified, IPM-D raises the power level of the ignition coil. As a result, the IPM-D's automatically controlled dual voltage levels maximize spark plug life. During normal engine operation, the IPM-D fires at a Level 1 (normal) ignition energy. The IPM-D fires at a Level 2 (high) ignition energy on engine startup or as a result of spark plug wear. If the ignition energy is raised to Level 2 (except on startup), an alarm is triggered to alert the operator that the plugs are wearing.

The ignition system has four levels of alarm: primary, low voltage, high voltage, and no spark. A primary alarm indicates a failed ignition coil or faulty ignition wiring. A low voltage alarm indicates a failed spark plug or shorted ignition coil secondary wire. A high voltage alarm indicates that a spark plug is getting worn and will need to be replaced soon. A no spark alarm indicates that a spark plug is worn and *must* be replaced. Each of these alarms can be remedied using the troubleshooting information in E-Help.

NOTE: Using the [F5] Ignition Panel in ESP, the user can adjust the faults' alarm and shutdown points to compensate for site conditions.

DETONATION DETECTION

DESCRIPTION OF DETONATION DETECTION

The ESM system includes detonation detection and protects Waukesha Engine spark ignited gas engines from damage due to detonation.

Detonation is the autoignition of the unconsumed end gas after the spark plug has fired during a normal flame-front reaction in an engine's combustion chamber. When this happens, pressure waves, created by multiple flame-fronts, slam together creating a high pressure pulse that causes engine components to vibrate. This vibration results in an audible "ping" or "knock" known as detonation. Avoiding detonation conditions is critical since detonation is typically destructive to engine components.

DESCRIPTION OF OPERATION

Detonation is caused by site conditions and/or engine misadjustment, not the engine. The conditions that promote detonation are extremely complex. See “Detonation Theory” for a definition of detonation and examples of detonation promoters and reducers.

The ESM system detects detonation by monitoring vibrations at each cylinder with engine-mounted knock sensors (see Figure 1.10-9 through Figure 1.10-11). When a signal exceeds a detonation threshold, the ESM system retards timing incrementally on an individual cylinder basis to keep the engine and each cylinder out of detonation or from “knocking.”



Figure 1.10-9 Knock Sensor (P/N A740110B)

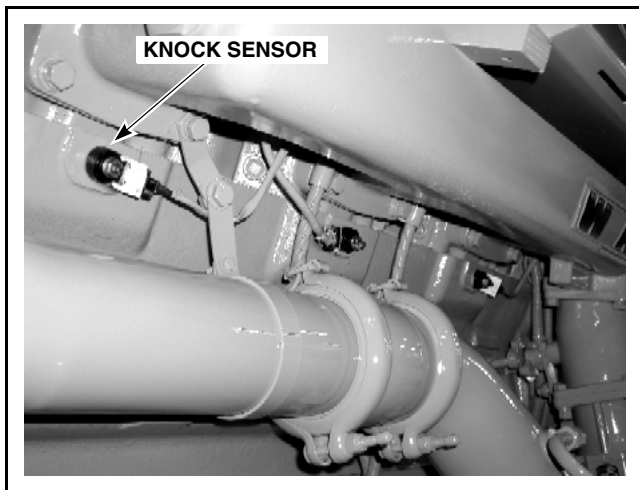


Figure 1.10-10 Knock Sensor (P/N A740110C)

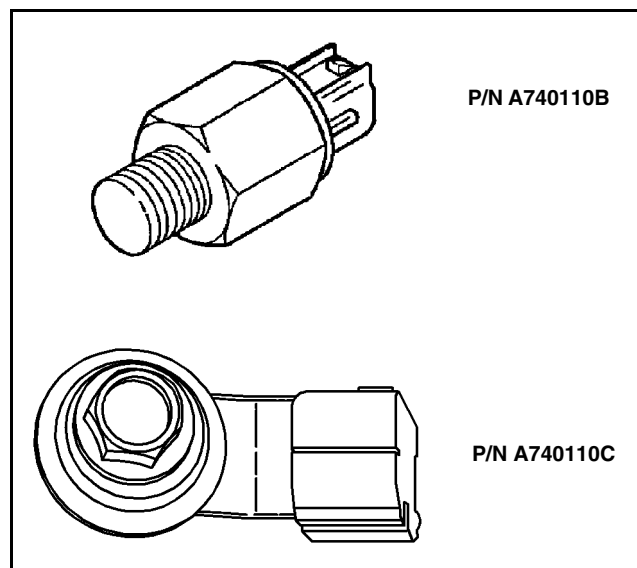


Figure 1.10-11 Knock Sensor

The following are the main features of the ESM system's detonation detection:

- The ESM system monitors for knock during every combustion event.
- A per-event measure of the knock level is compared to a reference level to determine if knock is present.
- Action taken by the ESM system when knock is detected is proportional to the knock intensity identified.
- To prevent misleading vibration signals that may exist at light loads from being incorrectly construed as knock, the ESM system will shut down on severe knock at loads less than 50% of manufacturer's rated load. This prevention also avoids unnecessary shutdowns while the engine is warming up or running at low loads.
- The ESM system requires no calibration of the detonation detection system by on-site personnel. The ESM system's detonation detection system is **self-calibrating**.
- If detonation is detected and the engine is shut down, the ECU records in the fault log that detonation occurred even if a PC was not connected.
- When a PC is connected to the ECU and the ESP software is active, the ESP software displays when detonation is occurring. If the engine is shut down due to detonation, the shutdown and number of detonating cylinders are recorded in the fault log. ESP provides a simple user interface for viewing engine status and troubleshooting information during engine detonation.

DETONATION THEORY

Detonation has been a known adversary of engine operation for many years. Avoiding detonation conditions is critical since detonation is typically destructive to engine components. Severe detonation often damages pistons, cylinder heads, valves, and piston rings. Damage from detonation will eventually lead to complete failure of the affected part. Detonation can be prevented; however, the conditions that promote detonation are extremely complex and many variables can promote detonation at any one time. This section defines detonation and gives examples of detonation promoters and reducers.

During *normal* combustion, the forward boundary of the burning fuel is called the “flame-front.” Research has shown that combustion in a gaseous air/fuel homogeneous mixture ignited by a spark is characterized by the more or less rapid development of a flame that starts from the ignition point and spreads continually outward in the manner of a grass fire.

When this spread continues to the end of the chamber without abrupt change in its speed or shape, combustion is called “normal.” When analyzing detonation, however, combustion is never normal.

The end gas is that part of the air/fuel charge that has not yet been consumed in the normal flame-front reaction. Detonation is due to the autoignition of the end gas after spark ignition has occurred. When detonation occurs, it is because compression of the end gas by expansion of the burned part of the charge raises its temperature and pressure to the point where the end gas autoignites. If the reaction of autoignition is sufficiently rapid and a sufficient amount of end gas is involved, the multiple flame-fronts will collide with sufficient force to be heard. This sound is referred to as audible “ping” or “knock.”

The tendency to detonate will depend on the humidity of intake air and the temperature and pressure of the end gas in the combustion chamber. Any change in engine operating characteristics that affects end gas temperature will determine whether combustion will result with or without detonation. The greater the end gas pressure and temperature and the time to which the end gas is exposed to this severe stress, the greater will be the tendency for the fuel to detonate.

Detonation is an extremely complex subject when dealing with internal combustion engines. The number of unpredictable variables in actual field running engines can be enormous. Table 1.10-1 lists the promoters and reducers of detonation.

Table 1.10-1 Detonation Promoters and Reducers

PROMOTERS	REDUCERS
Higher Cylinder Temperature	Lower Cylinder Temperatures
Lower WKI Fuels	Higher WKI Fuels
More Advanced Spark Timing	Less Advanced Spark Timing
Higher Compression Ratios	Lower Compression Ratios
Higher Inlet Pressure	Lower Inlet Pressure
Higher Coolant Temperatures	Lower Coolant Temperatures
Higher Intake Manifold Air Temperatures	Lower Intake Manifold Air Temperatures
Lower Engine Speeds	Higher Engine Speeds
Lower Atmospheric Humidity	Higher Atmospheric Humidity
Higher Engine Load	Lower Engine Load
Stoichiometric Air/Fuel Ratio (Rich Burn Engine)	Lean or Rich Air/Fuel Ratios (Without Engine Overload)
Rich Air/Fuel Ratio (Lean Burn Engine)	Lean Air/Fuel Ratios
Cylinder Misfire on Neighboring Cylinders	

METHOD OF DETONATION DETECTION AND TIMING CONTROL

The ESM system senses detonation with a technique called “windowing.” This technique allows the ESM system to look for detonation only during the combustion time when detonation could be present.

The “window” opens shortly after the spark plug fires to eliminate the effects of ignition noise. This noise is caused from the firing of the spark plug and subsequent “ring-out” of coils. This “sample” window is closed near the end of the combustion event at a predetermined angle after top dead center (ATDC) in crankshaft degrees (see Figure 1.10-12).

During detonation a unique vibration called “knock” frequency is produced. Knock frequency is just one of many frequencies created in a cylinder during engine operation. The knock sensors mounted at each cylinder convert engine vibrations to electrical signals that are routed to the ECU. The ECU removes the electrical signals that are not associated with detonation using a built-in filter.

When the filtered signal exceeds a predetermined limit (detonation threshold), the ESM system retards the ignition timing for the cylinder associated with that sensor by communicating internally with the ignition circuitry that controls the IPM-D. The amount the timing is retarded is directly proportional to the knock intensity. So when the intensity (loudness) is high, the ignition timing is retarded more than when the knock intensity is low.

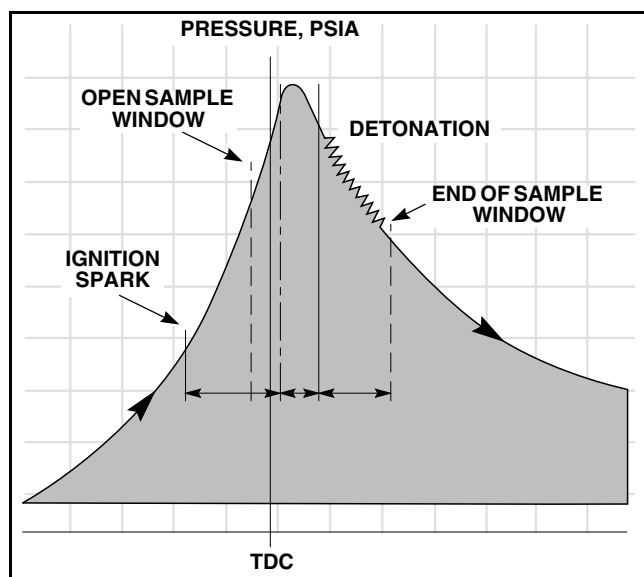


Figure 1.10-12 Windowing Chart

The ESM system controls timing between two predetermined limits: the maximum advanced timing and the most retarded timing. The maximum advanced timing is variable and depends on rpm, load, and the WKI value. The most retarded timing is a predetermined limit.

The maximum advanced timing value is used in two different ways. First, under normal loads the maximum advanced timing is the timing limit. Second, when the engine is under light load and cannot be knocking, it is used as the timing for all cylinders.

In the event the ESM system senses detonation that exceeds the detonation threshold, the ignition timing will be retarded at an amount proportional to the intensity of detonation sensed. Ignition timing will then be retarded until either the signal from the knock sensor falls below the detonation threshold or the most retarded timing position is reached. As soon as conditions permit, the ESM system will advance spark timing to the maximum setpoint at a predetermined rate. However, if after a predetermined time conditions do not permit timing to be advanced from the most retarded timing position, a fault is logged indicating the detonating cylinder(s), the red Status LED will blink the uncontrollable knock fault code on the ECU, and the engine will shut down after a short predetermined time.

If the customer directs the analog/digital outputs from the ECU to the local panel or PLC, steps can be taken to bring the engine out of detonation *before* engine shutdown. Using the digital or analog outputs from the ECU, a signal can be sent to a local panel or PLC indicating that detonation is occurring. This signal can be used to reduce the load on the engine to help bring the engine out of detonation. Should detonation continue, shutdown will occur.

ESM SYSTEM SPEED GOVERNING

DESCRIPTION OF SPEED GOVERNING

A governor controls engine speed (rpm) by controlling the amount of air/fuel mixture supplied to the engine. The ESM ECU contains the governor electronics and software that control the actuator. The ESM speed governing system allows the customer to make all control adjustments in one place and at one panel.

Integral ESM speed governing provides the following benefits:

- Ability to respond to larger load transients
- Better engine stability
- Easier setup
- Integrated operation diagnostics

GOVERNING THEORY

When governing, two values are needed: 1) the desired engine speed and 2) the current speed of the engine.

The ESM speed governing system is responsible for modifying the engine torque to produce the desired engine speed. The desired speed can be set by means of calibrations and/or external inputs. The difference between the current speed and the desired speed (or the speed error) is used to modify the torque to maintain the desired speed.

To determine current engine speed, the ESM system uses a magnetic pickup that senses 36 reference holes in the flywheel. As the holes pass the end of the magnetic sensor, a signal wave is generated. The frequency of the signal is proportional to engine speed. Based on the electrical signal from the magnetic pickup, the governor compares current engine speed with desired engine speed and responds by adjusting the throttle position of the engine. An electric actuator is used to convert the electrical signal from the ECU into motion to change the amount of air and fuel delivered to the engine through the throttle (see Figure 1.10-13).

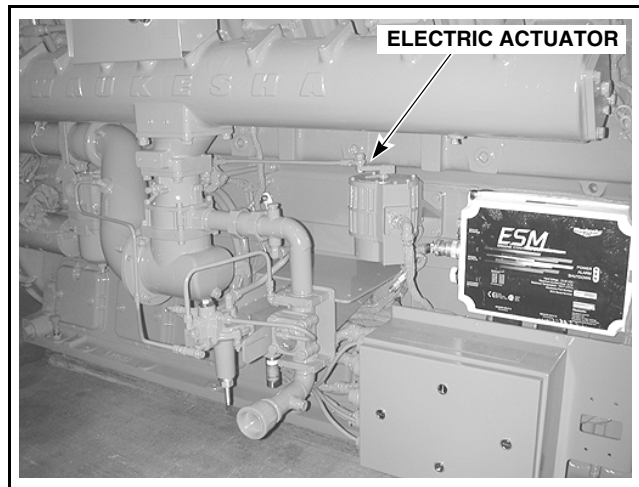


Figure 1.10-13 Electric Actuator and Throttle

SPEED GOVERNING MODES

Using inputs from the user's panel or PLC, the ESM system is set to run in one of two modes: speed control or load control.

Speed Control

Speed control mode allows the engine operator to choose a setpoint speed, and the governor will run at that speed. The control can be either isochronous or droop.

Isochronous control means that the governor will maintain a constant engine rpm regardless of load (within the capacity of the engine).

The governor can also operate in a droop mode, which means that the governor will allow the engine to slow down slightly under load. Droop is used to simulate the situation with mechanical governors where the engine will run at a slightly higher rpm than the setpoint when no load is placed on the engine. This feature can be used to synchronize the output of multiple generator sets driving an isolated electrical grid.

Load Control

Load control mode is used when a generator set is synchronized to a grid. In this case the grid controls speed, and the ESM speed governing system controls the engine load using signals from an external device.

GOVERNOR INPUTS AND CALIBRATIONS

Figure 1.10-14 illustrates the types of inputs to the ESM system for speed governing control. The actual inputs required to the ECU depend on the governing control desired.

Required external inputs are programmed to the ECU from a customer's local control panel or PLC. These inputs include remote speed/load setting, remote speed setting enable, rated speed/idle speed, and an auxiliary rpm input for load control. Using these customer inputs,

the ESM speed governing system is set to run in either speed control mode or load control mode.

Governing control is further customized for location requirements through user-selectable parameters describing the driven load. Custom control adjustments to the ESM speed governing system are made with ESP.

The rotating moment of inertia of the driven equipment must be programmed in ESP. Further gain calibrations may be made through ESP. The correct governor gain depends on the rotating moment of inertia of the engine and driven equipment. By inputting the rotating moment of inertia of the driven equipment, the gain is preset correctly aiding rapid startup of the engine. The rotating moment of inertia of the engine and the driven equipment are used in predicting throttle position.

The ESM speed governing system also allows the customer to calibrate the system to use other governing control features, including feedforward control (or load coming control) and synchronizer control (or alternate dynamics).

Feedforward Control (Load Coming Control)

Feedforward control (or load coming) is a proactive rather than a reactive feature that allows the engine to accept larger load additions than would normally be allowed without this feature.

Feedforward works by immediately opening the throttle by a user-calibrated amount when a digital input goes high (8.6 – 36 volts). One example of where this feature will help the performance of the engine is when starting a large electric motor that is operating in island electric power generation mode. Either at the moment the electric motor is started or a second or two before, the feedforward digital input is raised high, and the ESM system opens the throttle to produce more power. Unlike standard governing, the ESM system does not have to wait for the engine speed to drop before opening the throttle.

Synchronizer Control (Alternate Dynamics)

Alternate dynamics or synchronizer mode is used to rapidly synchronize an engine to the electric power grid by using cylinder timing to maintain constant engine speed. During the time the alternate dynamics input is high, the field is green and signals the user it is ON. During the time the alternate dynamics input is low, the field is gray and signals the user it is OFF. The lower gain values can be used to minimize actuator movement when the engine is synchronized to the grid and fully loaded to maximize actuator life.

Raising a high digital input (8.6 – 36 volts) to the ECU puts the ESM speed governing system in synchronizer control. The user can program a small speed offset to aid in synchronization.

DESCRIPTION OF OPERATION

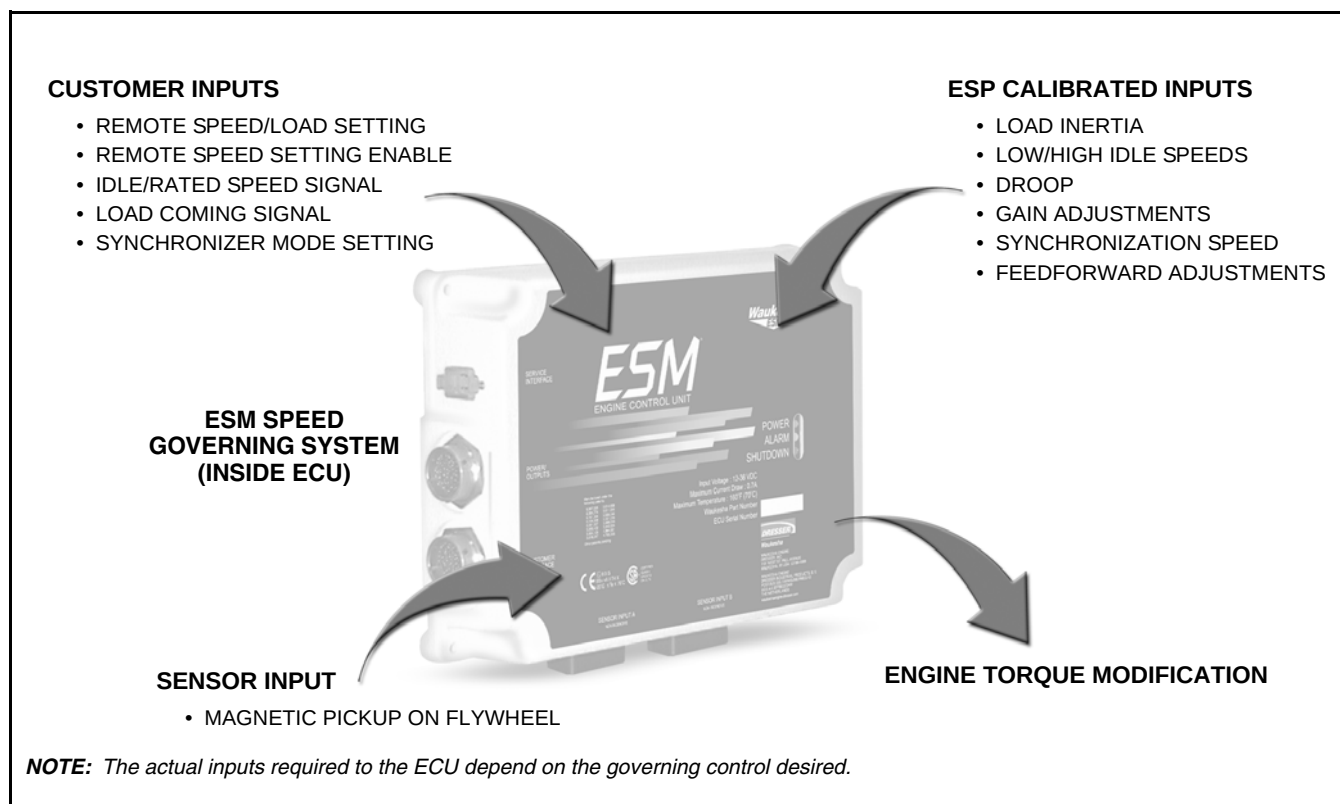


Figure 1.10-14 ESM Speed Governing System Inputs

AFR CONTROL DESCRIPTION

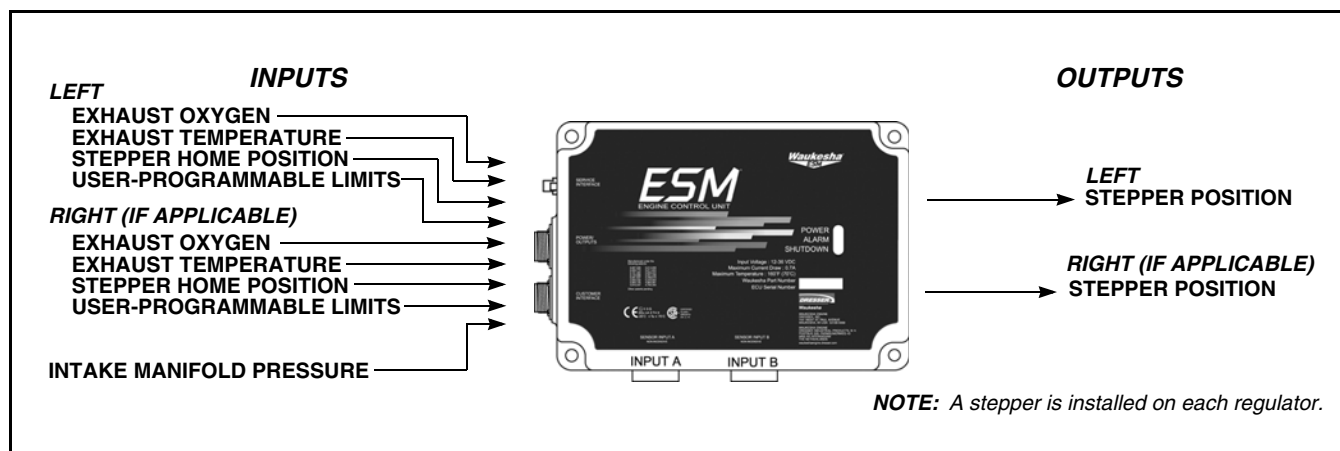


Figure 1.10-15 Rich Burn AFR Control Inputs and Outputs

The engine's Air/Fuel Ratio (AFR) is controlled by the ESM. An engine's air/fuel ratio is the amount of air measured by mass in relation to the mass of fuel supplied to an engine for combustion. By controlling an engine's air/fuel ratio with ESM AFR control, exhaust emissions are minimized while maintaining peak engine performance. The AFR control regulates the engine's air/fuel ratio even with changes in engine load, fuel pressure, fuel quality, and environmental conditions.

The ESM AFR control is completely integrated into the ESM system, with all sensor inputs, control routines, and output actions handled by the ECU (see Figure 1.10-15).

STOICHIOMETRIC OXYGEN SENSOR

CAUTION Operation of an air/fuel ratio control system with a contaminated, failing, or faulty oxygen sensor may result in the engine system not meeting emissions reduction performance goals. Disregarding this information could result in product damage and/or personal injury.

CAUTION Always purchase ESM AFR oxygen sensors (P/N A740106D or later) from Waukesha Engine. Performance goals of the system cannot be met without Waukesha's oxygen sensor specifications. Disregarding this information could result in product damage and/or personal injury.

Service life of the stoichiometric oxygen sensor is typically 2000 hours. Since the sensor has no wearing parts, theoretical life is indefinite. However, oil additives, fuel contaminants, compounds released from certain RTV gasket materials, incorrectly applied thread anti-seize, and over-temperature can result in shortened sensor life.

Sensor applications for catalyst control are based on the output characteristics of the stoichiometric oxygen sensor. Figure 1.10-16 illustrates the sectional view of an oxygen sensor.

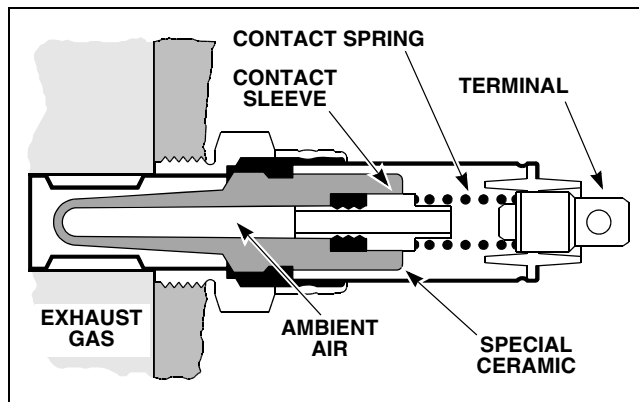


Figure 1.10-16 Sectional View of the Stoichiometric Oxygen Sensor

NOTE: The ESM system has a warm sensor check feature that means the oxygen sensor must reach a certain temperature to "light off" or become functional. A minimum exhaust temperature of 750° F (398° C) must be achieved before the AFR control becomes active.

The particular sensitivity of the stoichiometric sensor in the range around stoichiometry permits the sensor output signal to be fed as an actual value to the ECU. Any mixture deviation from the preset value is sensed by the stoichiometric sensor from the residual oxygen content of the exhaust gas and is transmitted to the ECU in the form of an electrical signal.

LAMBDA

Lambda is defined as the excess air/fuel ratio and is calculated as:

$$\text{Lambda} = \text{actual AFR} / \text{stoichiometric AFR}$$

The stoichiometric air/fuel ratio is the ideal ratio of air to fuel for complete combustion to take place with no unburned hydrocarbons or free oxygen products.

In an ideal case, the only products of this combustion would be water (H₂O) and carbon dioxide (CO₂). However, because engine combustion is not perfect, typical emission by-products include O₂, HC, NO_x, and CO. The catalyst then converts most of these to H₂O, CO₂, and nitrogen (N₂).

Using the above equation, an engine operating at exact stoichiometry would be at Lambda = 1. An engine optimized for exhaust emissions out for three-way catalyst control would more likely require a Lambda of 0.995, slightly rich of stoichiometry.

Under "rated" conditions, the stoichiometric air/fuel ratio for an engine running "typical" natural gas is 16.1:1; however, as fuel composition changes, the stoichiometric air/fuel ratio will also change (see Figure 1.10-17).

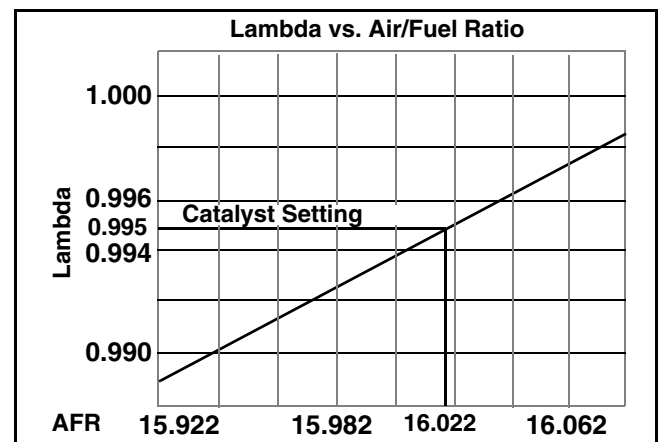


Figure 1.10-17 Lambda Graph

DESCRIPTION OF OPERATION

STEPPER

A stepper motor is used to adjust the gas/air at the direction of the ESM (see Figure 1.10-18 and Figure 1.10-19). The top cover has electronics built in to communicate with ESM. The stepper is mounted on the gas regulator.

The stepper is controlled using signals transmitted over the ESM CAN (Controller Area Network) communication bus, minimizing control wiring while maintaining a communication scheme. Stepper diagnostic information is relayed back to the ECU over the CAN bus.



Figure 1.10-18 AFR Stepper (Fisher Regulator)

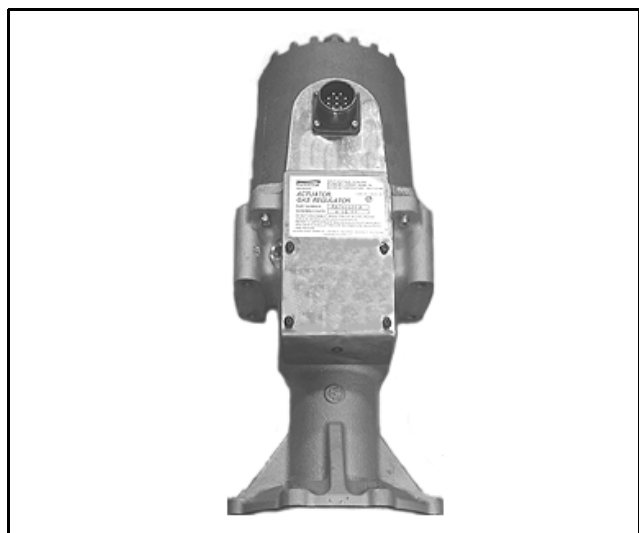


Figure 1.10-19 AFR Stepper (Mooney Regulator)

THEORY OF OPERATION

Control Routine

The ESM AFR routine controls engine air/fuel ratio by regulating the quantity of oxygen present in the exhaust stream. It actually maintains a constant Lambda over various speed, load, fuel, and environmental conditions.

Lambda is defined as the excess air/fuel ratio and is calculated as:

$$\text{Lambda} = \text{actual AFR} / \text{stoichiometric AFR}$$

The stoichiometric air/fuel ratio is the ideal ratio of air to fuel for complete combustion to take place with no unburned hydrocarbons or free oxygen products. Under "rated" conditions, the stoichiometric air/fuel ratio for an engine running "typical" natural gas is 16.1:1; however, as fuel composition changes, the stoichiometric air/fuel ratio will also change.

Using the above equation, an engine operating at exact stoichiometry would be at $\text{Lambda} = 1$. An engine optimized for exhaust emissions out for three-way catalyst control would more likely require a Lambda of 0.995, slightly rich of stoichiometry.

Using the output of the oxygen sensor, along with exhaust temperature, intake manifold pressure, and other information, the system is a closed-loop process that looks at engine sensor outputs and adjusts system inputs within preprogrammed settings to achieve the correct exhaust oxygen content resulting in the desired Lambda. By controlling to Lambda, instead of voltage, consistent performance is maintained regardless of engine operating conditions, environmental conditions, or fuel composition.

If the actual Lambda is different than the Lambda setpoint, the ESM AFR routine directs the stepper to adjust the gas/air pressure of the fuel regulator. The stepper adjusts the fuel regulator setting, within programmed limits, by increasing or decreasing the spring pressure acting on the regulator diaphragm. The design gives very accurate positioning capability. The regulator adjustment richens or leans out the air/fuel ratio depending on the current Lambda setpoint.

An exhaust temperature sensor is used to ensure that temperatures are high enough for correct operation of the oxygen sensor. A programmed minimum temperature must be achieved before "closed-loop" control is enabled.

Setup for Catalyst Control

The target setting is chosen to optimize engine out emissions for a three-way catalyst input. Three-way catalysts are used to oxidize carbon monoxide (CO) and hydrocarbons (HC), and to reduce oxides of nitrogen (NOx) on rich burn applications. These processes require high temperature and precise air/fuel ratio control. Best performance for emissions reduction is achieved when operating slightly rich of the stoichiometric air/fuel ratio.

As previously stated, the stoichiometric air/fuel ratio is the theoretical balance where exactly the required amount of air (O_2) is present to completely burn all of the fuel with no excess air. In an ideal case, the only products of this combustion would be water (H_2O) and carbon dioxide (CO_2). However, because engine combustion is not perfect, typical emission by-products include O_2 , HC, NOx, and CO. The catalyst then converts most of these to H_2O , CO_2 , and nitrogen (N_2).

The stoichiometric oxygen sensor in the exhaust stream provides feedback to the ECU module (Figure 1.10-16). The signal provides a means of controlling air/fuel ratio slightly rich of stoichiometry.

This is the range required to obtain best catalyst efficiencies for methane-based fuels.

The base value for the target setting is predetermined from the factory, and the user may set an offset to achieve the proper emissions output. The target Lambda should be determined with the use of an exhaust analyzer to locate the operating point of lowest stack emissions.

Note that the target offset may be set individually for different load levels as represented by intake manifold pressure to allow even tighter control under changing load conditions.

Dithering

The emissions control is fine-tuned by programming dither steps on the [F8] AFR Setup Panel. Dither steps allow the AFR system to oscillate around the stepper's normal movements plus or minus a user-programmed number of steps. This method widens the Lambda range that can be used in order to maintain required emissions.

As an example, the graph shown in Figure 1.10-21 represents the CO and NOx post catalyst emissions. Dithering (represented by the solid lines) produces lower emissions at each Lambda setpoint when compared to non-dithered applications (dotted lines). Dithering provides a wider range of Lambda setpoints while still maintaining reduced emissions.

While stepper movement is controlled by the ESM AFR routine, user-programmable limits must be programmed on the [F8] AFR Setup Panel in ESP (see Figure 1.10-22). This limits the stepper's travel range and triggers alarms if the system attempts to work outside of the range.

Another user setting required is that of the start position. This position is determined by an adjustment procedure for correct air/fuel ratio during engine start, and then is used to automatically set the stepper whenever the engine is being started. The stepper position will remain within the programmable limits after startup while the AFR control is in automatic mode (see Figure 1.10-20). If a limit is reached, an alarm will be raised. When in manual mode, the user can adjust the stepper position outside the programmable limits. Dithering, start position left, and start position right are programmed using the [F8] AFR Setup Panel in ESP. Refer to Section 3.05 *ESP Panel Descriptions* for complete information.

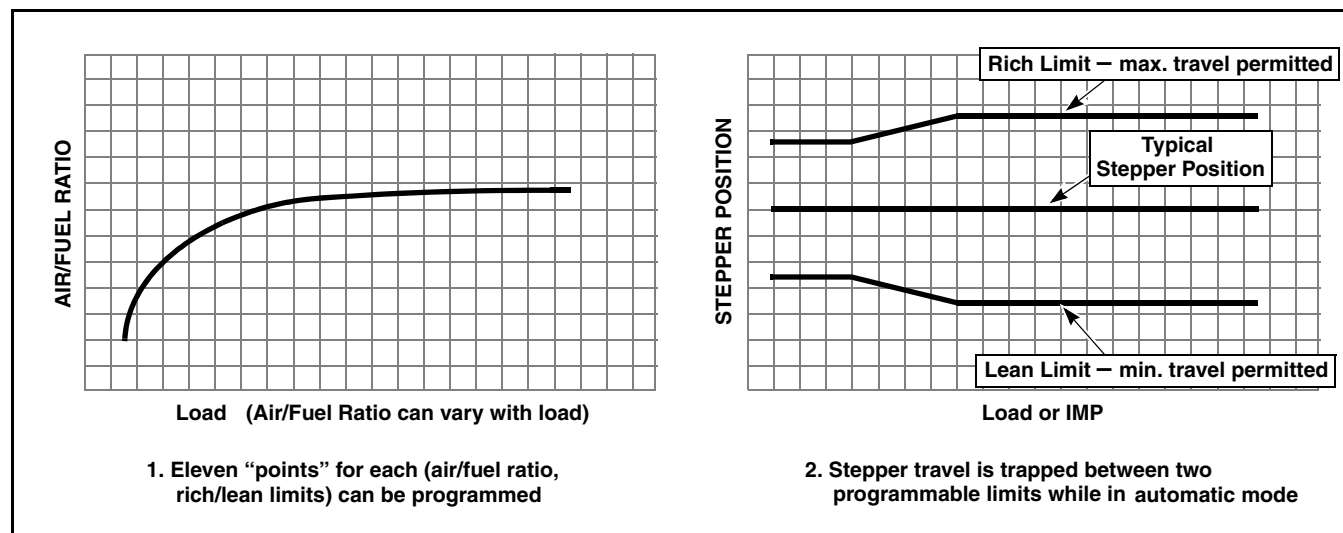


Figure 1.10-20 Air/Fuel Ratio and Stepper Limits vs. Load

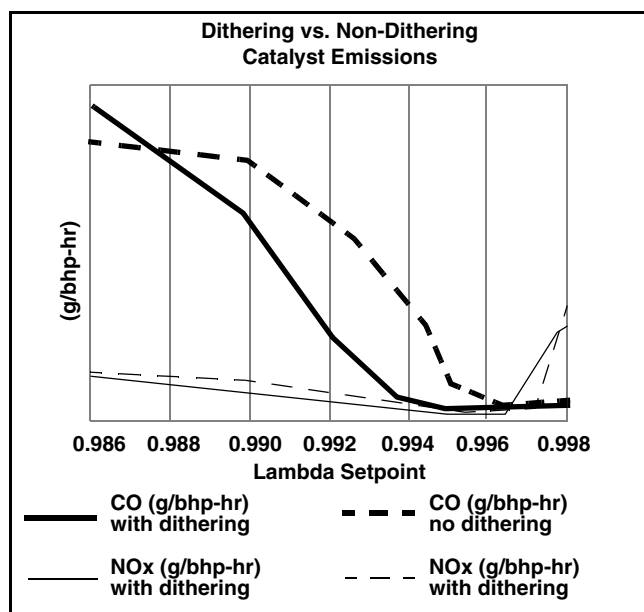


Figure 1.10-21 CO and NOx Post Catalyst Emissions – Dithering vs. No Dithering

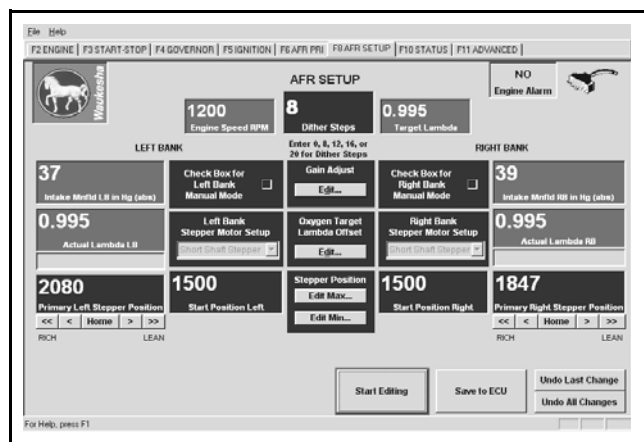


Figure 1.10-22 AFR Setup Panel

DEFINITIONS

NOTE: The terms defined in this manual are defined as they apply to Waukesha's ESM system ONLY. Definitions are not general definitions applicable to all situations.

Air/Fuel Ratio: Air/Fuel Ratio (AFR) is a term used to define the amount of air (in either weight or mass) in relation to a single amount of fuel.

Alternate Dynamics: See definition for "Synchronizer Control."

Analog Signals: A voltage or current signal proportional to a physical quantity.

Baud Rate: The baud rate is the number of signaling elements that occur each second. The baud indicates the number of bits per second (bps) that are transmitted. In ESP, baud rate can be programmed to 1200, 2400, 9600, or 19,200 bps.

Bus: A collection of wires through which data is transmitted from one part of a computerized system to another. A bus is a common pathway, or channel, between multiple devices.

Calibration: Since the ESM system is designed to work with various Waukesha engine families and configurations, an ECU is factory-calibrated to work with a specific engine model. For example, an ECU used on a VHP 7044 engine could not be used on a VHP 5794 engine without being recalibrated. The ECU contains thousands of calibrations such as the number of cylinders, timing, sensor default values, high/low limitations, and necessary filters (used to eliminate engine noise). An ECU calibration cannot be edited by the user.

CAN: Controller Area Network. A serial bus network of microcontrollers that connects devices, sensors, and actuator in a system for real-time control applications like the ESM system. Since messages in a CAN are sent through the network with unique identifiers (no addressing scheme is used), it allows for uninterrupted transmission if one signal error is detected. For example, if a stepper signal error is detected, the system will continue to control the other steppers and sensors.

CD-ROM: Compact Disk-Read Only Memory. A compact disk format used to hold text, graphics, and hi-fi stereo sound. It is like an audio CD but uses a different format for recording data. The ESM ESP software (including E-Help) is available in CD-ROM format.

DB Connector: A family of plugs and sockets widely used in communications and computer devices. DB connectors come in 9, 15, 25, 37, and 50-pin sizes. The DB connector defines the physical structure of the connector, not the purpose of each line.

Detonation: Detonation is the autoignition of the unconsumed end gas after the spark plug has fired during a normal flame-front reaction in an engine's combustion chamber. When this happens, pressure waves, created by multiple flame-fronts, slam together creating a high pressure pulse that causes engine components to vibrate. This vibration results in an audible "ping" or "knock" known as detonation. A good comparison is a grass fire. Normal combustion is similar to a grass fire. It begins at one end of a field, and the flame-front progresses in an orderly manner through the field. When all of the grass is burned, the combustion stops. During "grass-detonation," the grass would begin burning normally, but before the flames could sweep through the length of the field, some portion of the unburned grass would burst into flames.

Detonation Threshold: The detonation threshold is a self-calibrating limit to determine if a cylinder is detonating. Once a cylinder exceeds the detonation threshold, the ESM system retards ignition timing for the cylinder in detonation.

Digital Signals: Signals representing data in binary form that a computer can understand. The signal is a 0 or a 1 (off or on).

Dithering: Allows the user to fine-tune AFR emissions control. Dither steps allow the AFR system to oscillate around the stepper's normal movements plus or minus a user-programmed number of steps. In ESP, dither steps are programmed on the [F8] AFR Setup Panel. Program "0" to disable dithering.

Droop: When a governor operates in droop mode, it means that the governor will allow the engine to slow down slightly under load. Droop is used to simulate the situation with mechanical governors where the engine will run at a slightly higher rpm than the setpoint when no load is placed on the engine.

E-Help: ESP-Help. E-Help is the name of the electronic help file included with the ESM ESP software. E-Help provides general system and troubleshooting information.

Electronic Service Program (ESP): ESP is the PC-based service program (software) that is the primary means of obtaining information on ESM system status. ESP provides a graphical (visual) interface in a Microsoft® Windows® XP operating system environment. ESP is the means by which the information that the ECU logs can be read. The PC used to run the ESP software connects to the ECU via an RS-232 serial cable.

Engine Control Unit (ECU): The Engine Control Unit (ECU) is the central module, or "hub," of the ESM system. The entire ESM system interfaces with the ECU. All ESM system components, the PC with Electronic Service Program software, and customer-supplied data acquisition devices, connect to the ECU.

Fault: A fault is any condition that can be detected by the ESM system is considered to be out-of-range, unusual, or outside normal operating conditions. Included are the following:

- **Scale High:** A scale high fault indicates the value of the sensor is higher than its normal operating range.
- **Scale Low:** A scale low fault indicates the value of the sensor is lower than its normal operating range.
- **Short or Open Circuit:** A short or open circuit indicates sensor value is outside valid operating range and is most likely due to a damaged sensor or wiring.

Fault Log: The ECU records faults as they occur into the fault log. The fault log is viewed using the ESM ESP software.

Feedforward Control: Feedforward control (also called "Load Coming") is a governing feature that allows the engine to accept larger load additions than would normally be possible. Feedforward works by immediately opening the throttle by a user-calibrated amount when a digital input goes high.

Freewheeling Diode: A freewheeling diode is added across the coils of a relay or solenoid to suppress the high induced voltages that may occur when equipment is turned off.

Function Keys: A set of special keys on a computer keyboard that are numbered F1 – F12 which perform special functions depending on the application program in use.

Graphical User Interface (GUI): An interface that is considered user-friendly because pictures (or icons) accompany the words on the screen. The use of icons, pull-down menus, and the mouse make software with a graphical user interface easier to work with and learn.

Hard Drive: The primary computer storage medium normally internally sealed inside a PC. Typically, software programs and files are installed on a PC's hard drive for storage. Also referred to as the hard disk.

High Signal: A digital signal sent to the ECU that is between 8.6 and 36 volts.

Home Position: Home position is where the adjusting nut in the stepper is in its fully retracted position. When the home button on the [F6] or [F8] panel is clicked, ESM AFR control moves the stepper to the home position and then back to the start position. The stepper motor can be reset to the home position only while the engine is shut down.

Icon: A small picture on a PC screen that represents files and programs. Files and programs open when the user double-clicks the icon.

Ignition Power Module with Diagnostic Capability (IPM-D): The IPM-D is an electronic, digital-circuit ignition module that uses the high-energy, capacitor discharge principle. The ECU through its digital logic directs the IPM-D when to fire each spark plug.

Isochronous: When the governor control is isochronous, it means that the governor will control at a constant engine speed regardless of load (steady state).

Knock: See definition for "Detonation."

Knock Frequency: The unique vibration or frequency that an engine exhibits while in detonation.

DESCRIPTION OF OPERATION

Knock Sensor: Converts engine vibration to an electrical signal to be used by the ECU to isolate the “knock” frequency.

Lambda: Lambda is defined as the excess air/fuel ratio and is calculated as: $\text{Lambda} = \text{actual AFR} / \text{stoichiometric AFR}$. The ESM AFR routine controls engine air/fuel ratio by maintaining a constant Lambda over various speed, load, fuel, and environmental conditions.

Lean Limit: The most “retracted” stepper position or lowest gas/air that is user-programmed at which the engine can be safely operated in automatic mode. A more retracted stepper position allows less fuel to pass to the engine. Stepper operation is permitted only between the rich and lean limits (except during startup or manual mode). The minimum stepper position is programmed on the [F8] AFR Setup Panel.

LED: Light Emitting Diode. A semiconductor that emits light (not a light bulb) and is used as power, alarm, and shutdown indicators located on the front of the ECU.

Load Coming: See definition for “Feedforward Control.”

Load Control: The ESM load control mode is used when an engine is synchronized to a grid and/or other units. In this case the grid controls speed.

Load Inertia: Programming the load inertia or rotating mass moment of inertia of the driven equipment sets the governor gain correctly, aiding rapid setup of the engine. If this field is programmed correctly, there should be no need to program any of the gain adjustment fields. The rotating mass moment of inertia must be known for each piece of driven equipment and then added together.

Log File Processor: The “Start Logging All” and “Stop Logging All” buttons on the F11 panel are used to log all active system parameters during a user-determined period of time. The file that is saved is a binary file (extension .ACLOG) that must be extracted into a usable file format. Using the Log File Processor program installed with ESP, the binary file is converted into a Microsoft® Excel-readable file (.TSV) or a text file (.TXT). Once the data is readable as a .TSV or .TXT file, the user can review, chart, and/or trend the data logged as desired.

Low Signal: A digital signal sent to the ECU that is less than 3.3 volts.

Magnetic Pickup: A two-wire electrical device that produces a voltage and current flow as steel teeth or holes move by the face of the pickup.

Master-Slave Communications: Communications in which one side, called the “master,” initiates and controls the session. The “slave” is the other side that responds to the master’s commands.

MODBUS®: MODBUS® is a protocol or a set of rules governing the format of messages that are exchanged between computers which is widely used to establish communication between devices. MODBUS® defines the message structure that the ESM system and customer controllers will recognize and use, regardless of the type of networks over which they communicate. The protocol describes the process a controller uses to request access to another device, how it will respond to requests from the other devices, and how errors will be detected and reported. MODBUS® establishes a common format for the layout and content of messages.

Modem: Modulator Demodulator. A device that converts data from digital computer signals to analog signals that can be sent over a telephone line. This is called modulation. The analog signals are then converted back into digital data by the receiving modem. This is called demodulation.

NVRAM: Non-Volatile Random Access Memory. This is a type of RAM memory that retains its contents when power is turned off. When new values are saved in ESP, they are permanently saved to NVRAM within the ECU. When values are saved to NVRAM, the information is not lost when power to the ECU is removed. The user can save unlimited times to ECU NVRAM (permanent memory).

Open Circuit: An open circuit indicates that the signal being received by the ECU is outside the valid operating range and is most likely due to a damaged sensor or wiring.

Panel: ESP displays engine status and information on six panels (eight panels if AFR equipped): Engine, Start-Stop, Governor, Ignition, AFR Primary Fuel, AFR Setup, Status, and Advanced. These panels display system and component status, current pressure and temperature readings, alarms, ignition status, governor status, air/fuel control status (AFR only), and programmable adjustments.

Parasitic Load Adjust: Used on kW sensing engines, allows user to adjust for parasitic loads (alternator, engine-driven pumps, etc....) on the engine.

PC: Personal Computer. Refers to the IBM-compatible PC used for monitoring and troubleshooting the engine with the ESM ESP software. The PC used to run the ESP software connects to the ECU via an RS-232 serial cable.

PLC: Programmable Logic Controller. A microprocessor used in process control applications. PLC microprocessors are designed for high-speed, real-time, and rugged industrial environments.

RAM: Random Access Memory. RAM, temporary ECU memory, is used to evaluate programmed values before storing them to the ECU's permanent memory. When a programmable value is edited in ESP, the edited (but unsaved) value is stored in RAM. The contents of RAM are lost whenever power to the ECU is removed; however, the contents remain in ECU RAM even if the PC loses power or is disconnected from the ECU.

Rich Limit: The most "advanced" stepper position or highest gas/air that is user-programmed at which the engine can be safely operated in automatic mode. Since a more extended stepper position results in more fuel being delivered to the engine, this is the maximum stepper position or "rich limit." Stepper operation is permitted only between the rich and lean limits (except during startup or manual mode). The maximum stepper position is programmed on the [F8] AFR Setup Panel.

RS-232: Recommended Standard-232. One of a set of standards from the Electronics Industries Association for hardware devices and their interfaces. RS-232 is a well-known standard for transmitting serial data between computers and peripheral devices (modem, mouse, etc.). In the case of the ESM system, an RS-232 cable transmits data from the ECU to the PC and vice versa.

RS-485: Recommended Standard-485. One of a set of standards from the Electronics Industries Association for hardware devices and their interfaces. RS-485 is used for multi-point communications lines and is a specialized interface. The typical use for RS-485 is a single PC connected to several addressable devices that share the same cable. Think of RS-485 as a "party-line" communications system.

Sample Window: A predetermined start and end time in which each cylinder will be looked at for detonation. The window is used so that detonation is only looked for during the combustion event.

Scale High: A scale high fault indicates the value of the sensor is higher than its normal operating range.

Scale Low: A scale low fault indicates the value of the sensor is lower than its normal operating range.

Short Circuit: A short circuit indicates that the value of the sensor is outside the valid operating range and is most likely due to a damaged sensor or wiring.

Slave Communications: A computer or peripheral device controlled by another computer. For example, since the ESM system has MODBUS® slaves communications capability, one "master" computer or PLC could communicate with multiple ESM MODBUS® slaves over the two-wire RS-485 network.

Speed Control: The ESM speed control mode allows the engine operator to choose a setpoint speed, and the governor will control the engine at that speed. The control can be either isochronous or droop.

Start Position: Start position is a programmable stepper position used to set gas/air at a value that is favorable for engine starting. This is the stepper position ESM AFR control will move the stepper to before engine startup or after the stepper is sent to the home position. Although the preprogrammed value should be reasonable, some modification to the start position may be required to facilitate engine starting. Start position is programmed on the [F8] AFR Setup Panel.

Step: One "step" of the stepper motor equals 1/400 of 1 revolution of the stepper motor. This small change in position results in 0.00025 inch of linear travel of the adjusting nut within the stepper. This increases or decreases the fuel regulator spring pressure and correspondingly changes the gas/air pressure to the carburetor.

Stepper: A stepper is installed onto each regulator to adjust the fuel flow to the engine. The stepper adjusts the regulator setting by increasing or decreasing the spring pressure acting on the regulator diaphragm.

Stepper Motor: This specially designed electric motor that resides in the assembly produces a precise "step-wise" rotation of the motor shaft instead of the "traditional" continuous rotation of most electric motors.

Synchronizer Control: Synchronizer control (also known as "Alternate Dynamics") is governor dynamics used to rapidly synchronize an engine generator to the electric power grid.

Training Tool: A software program, separate from ESP, that is loaded on a PC during ESP installation and is for training use only. An ECU cannot be programmed using the Training Tool but allows the user to open ESP without an ECU connected.

User Interface: The means by which a user interacts with a computer. The interface includes input devices such as a keyboard or mouse, the computer screen and what appears on it, and program/file icons.

VGA: Video Graphics Array. A video display standard for color monitors. VGA monitors display 16 colors at a resolution of 640 x 480 pixels, the minimum standard display.

Windowing: A technique that allows the ESM system to look for detonation only during the combustion time when detonation could be present.

DESCRIPTION OF OPERATION

WKI: Waukesha Knock Index. An analytical tool, developed by Waukesha Engine, as a method for calculating the knock resistance of gaseous fuels. It is a calculated numeric value used to determine the optimum engine settings based on a specific site's fuel gas composition.

Workspace: The file containing ESP panels is called the workspace. The workspace file is saved to the hard drive upon installation of the software. When ESP is opened, the correct workspace for the engine is automatically opened.

Acronyms

AC: Alternating Current

AFR: Air/Fuel Ratio

ATDC: After Top Dead Center

bps: bits per second

CAN: Controller Area Network

CD-ROM: Compact Disk - Read Only Memory

CSA: Canadian Standards Association

CSV: Comma Separated Value

E-Help: ESP-Help

ECU: Engine Control Unit

ESM: Engine System Manager

ESP: Electronic Service Program

GUI: Graphical User Interface

HSD: High Side Driver

IMAT: Intake Manifold Air Temperature

IPM-D: Ignition Power Module with Diagnostic capability

LED: Light Emitting Diode

MB: Megabyte

MHz: Megahertz

NVRAM: Non-Volatile Random Access Memory

OC: Open Circuit

PC: Personal Computer

PLC: Programmable Logic Controller

RAM: Random Access Memory

rpm: revolutions per minute

RS: Recommended Standard

SC: Short Circuit

SH: Scale High

SL: Scale Low

VGA: Video Graphics Array

WKI: Waukesha Knock Index

CONTENTS

SECTION 2.00 – POWER REQUIREMENTS

SECTION 2.05 – POWER DISTRIBUTION JUNCTION BOX

SECTION 2.10 – SYSTEM WIRING OVERVIEW

SECTION 2.15 – START-STOP CONTROL

SECTION 2.20 – GOVERNING

SECTION 2.25 – FUEL VALVE

SECTION 2.30 – SAFETIES OVERVIEW

SECTION 2.35 – ESM SYSTEM COMMUNICATIONS

SECTION 2.00

POWER REQUIREMENTS

POWER REQUIREMENTS



WARNING

Do not install, set up, maintain, or operate any electrical components unless you are a technically qualified individual who is familiar with the electrical elements involved. Electrical shock can cause severe personal injury or death.



WARNING

Disconnect all electrical power supplies before making any connections or servicing any part of the electrical system. Electrical shock can cause severe personal injury or death.



CAUTION

Disconnect all engine harnesses and electronically controlled devices before welding on or near an engine. Failure to comply will void product warranty. Failure to disconnect the harnesses and electronically controlled devices could result in product damage and/or personal injury.

The ESM system requires 18 – 32 VDC. The peak-to-peak voltage ripple must be less than 2 volts. The maximum, or high end, battery voltage is 32 volts.

NOTE: The label on the ECU lists a voltage requirement of 12 – 36 VDC. That range is the power requirement for the ECU only. For proper operation of the ESM system, it requires 18 – 32 VDC.

The ESM system will run on 18 – 32 VDC, but if the voltage drops below 21 VDC, the ESM system will trigger an alarm (ALM454). ALM454 is triggered when the battery voltage is soon to be or is out of specification. ALM454 is a warning to the operator that some action must be taken to prevent possible future power loss below 18 VDC and engine shutdown. When ALM454 is active, the engine continues to operate as long as the supply voltage continues to power components on the engine.

For example, fuel valves typically require 18 VDC to open, so if the voltage falls below this level, the engine will stop. This ESM system alarm feature is similar to the “Low Fuel” light in cars. Although a car will operate for 25 – 50 miles (40 – 80 km) after the “Low Fuel” light turns on, the operator is warned that additional fuel is needed soon or the car will run out of gas.

NOTE: The 21 VDC ALM454 trip point was chosen because a lead-acid battery is at approximately 10% state of charge at 21 VDC.

Batteries are the preferred method of supplying the ESM system with clean, stable power. In addition, batteries have the advantage of continued engine operation should there be a disruption in the source of electric power. The batteries should be wired directly to the Power Distribution Box using the largest cable that is practical (00 AWG is the largest size that the Power Distribution Box can accommodate).

The alternator is not to be connected directly to the Power Distribution Box. The optional Waukesha alternator is connected to the alternator junction box. The battery cables are connected to the positive and negative studs in the alternator junction box and then to the batteries. The batteries filter the ripple output of the alternator.

Power can also be supplied to the ESM system by connecting a DC power supply directly to the Power Distribution Box. The disadvantage of the DC power supply is that if the AC power is lost, the engine shuts down immediately. In addition, there is no noise filtering done by a battery, so a more expensive power supply may be needed.

See Figure 2.00-1 – Figure 2.00-6, and Table 2.00-1 for wiring diagrams.

NOTE: The wiring diagrams in this manual are to be used as a reference only.

Refer to Section 2.05 *Power Distribution Junction Box “24 VDC Power”* for information on connecting power inside the Power Distribution Box.

POWER REQUIREMENTS

BATTERY REQUIREMENTS

Always keep the engine batteries in good operating condition and at full charge. Failure to do so may affect the performance of the ESM and other electronic controls.

Sulfation of batteries starts when specific gravity falls below 1.225 or voltage measures less than 12.4 V. Sulfation hardens the battery plates, reducing and eventually destroying the ability of the battery to generate power or to dampen ripples (noise) caused by battery charging or loads with switching power supplies. Failure of the battery to adequately dampen ripples may lead to malfunction of battery powered devices. See Section 4.05 *ESM System Maintenance* "Battery Maintenance".



WARNING

Comply with the battery manufacturer's recommendations for procedures concerning proper battery use and maintenance. Improper maintenance or misuse can cause severe personal injury or death.



WARNING

Batteries contain sulfuric acid and generate explosive mixtures of hydrogen and oxygen gases. Keep any device that may cause sparks or flames away from the battery to prevent explosion. Batteries can explode causing severe personal injury or death.



WARNING

Always wear protective glasses or goggles and protective clothing when working with batteries. You must follow the battery manufacturer's instructions on safety, maintenance and installation procedures. Failure to follow the battery manufacturer's instructions can cause severe personal injury or death.

NON EXTENDER SERIES ENGINES – POWER SUPPLY WITH AIR START AND ALTERNATOR

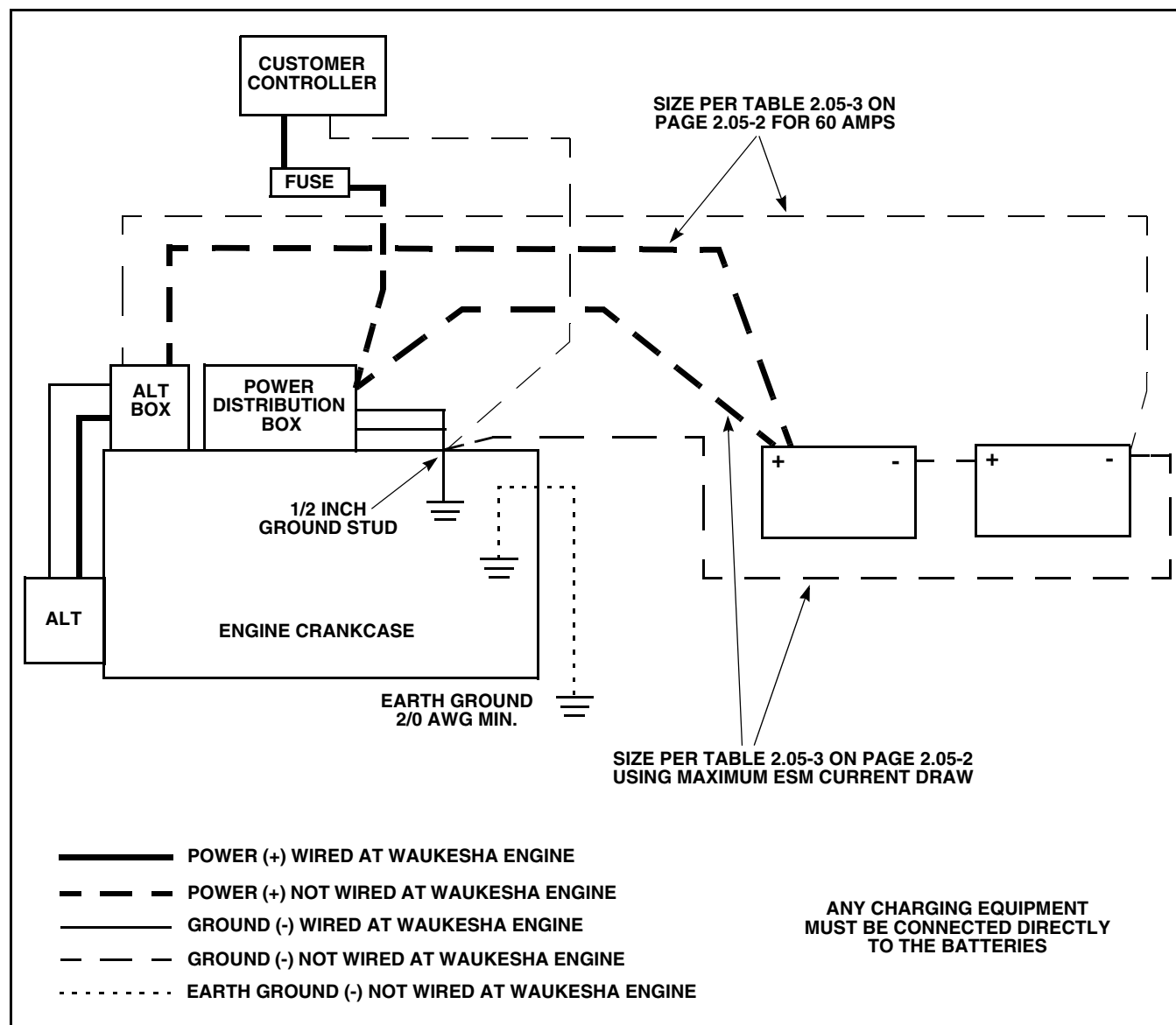


Figure 2.00-1 Power Supply with Air Start and Alternator (Non Extender Series Engines)

CAUTION Always turn the battery charger off first, before disconnecting the batteries. Then disconnect the battery negative (-) cable before beginning any repair work. Failure to disconnect the battery charger first could result in product damage and/or personal injury and voids product warranty.

POWER REQUIREMENTS

NON EXTENDER SERIES ENGINES – POWER SUPPLY BY CUSTOMER

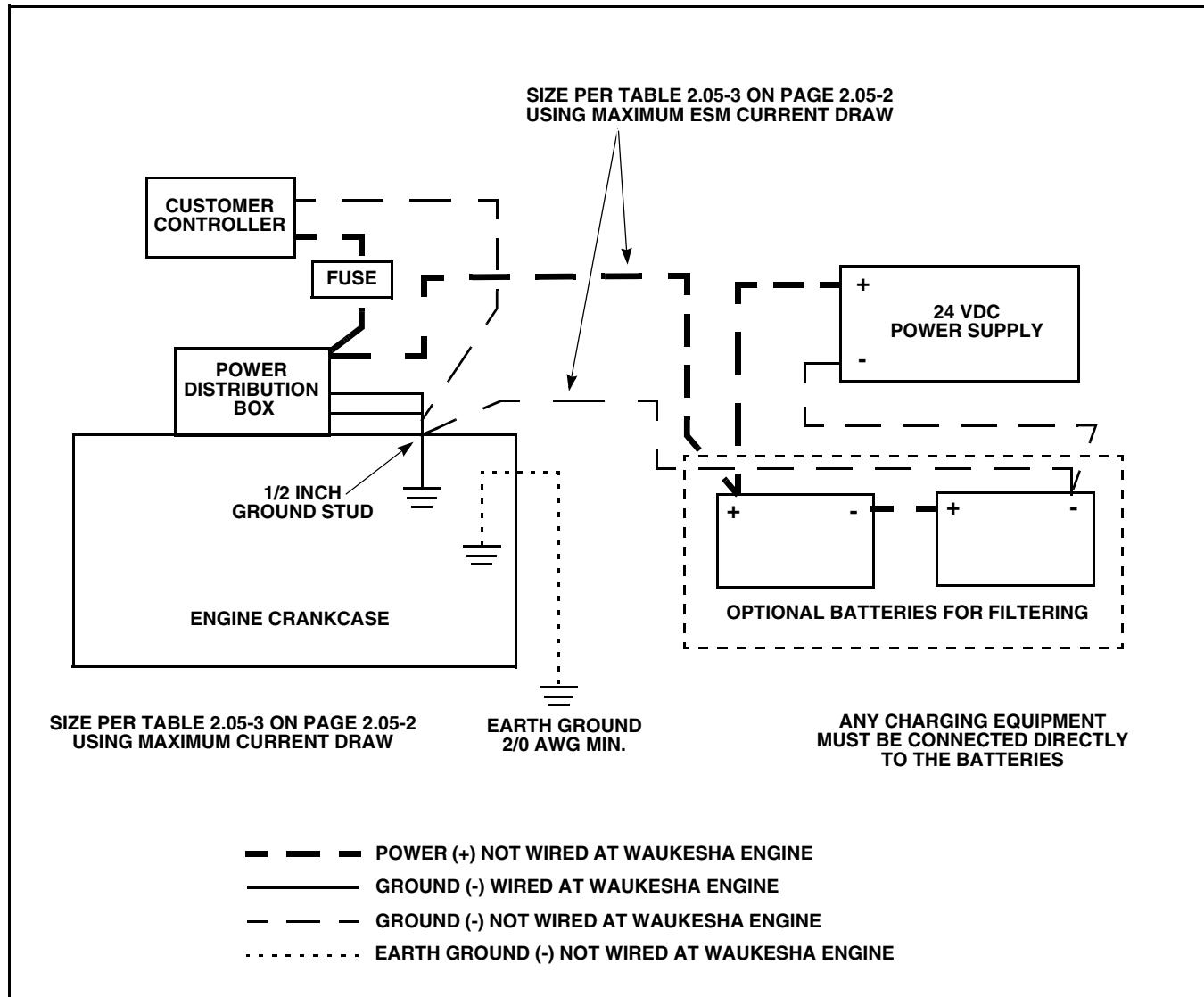


Figure 2.00-2 Power Supply by Customer (Non Extender Series Engines)

CAUTION Always turn the battery charger off first, before disconnecting the batteries. Then disconnect the battery negative (-) cable before beginning any repair work. Failure to disconnect the battery charger first could result in product damage and/or personal injury and voids product warranty.

NON EXTENDER SERIES ENGINES – POWER SUPPLY WITH ELECTRIC START AND ALTERNATOR

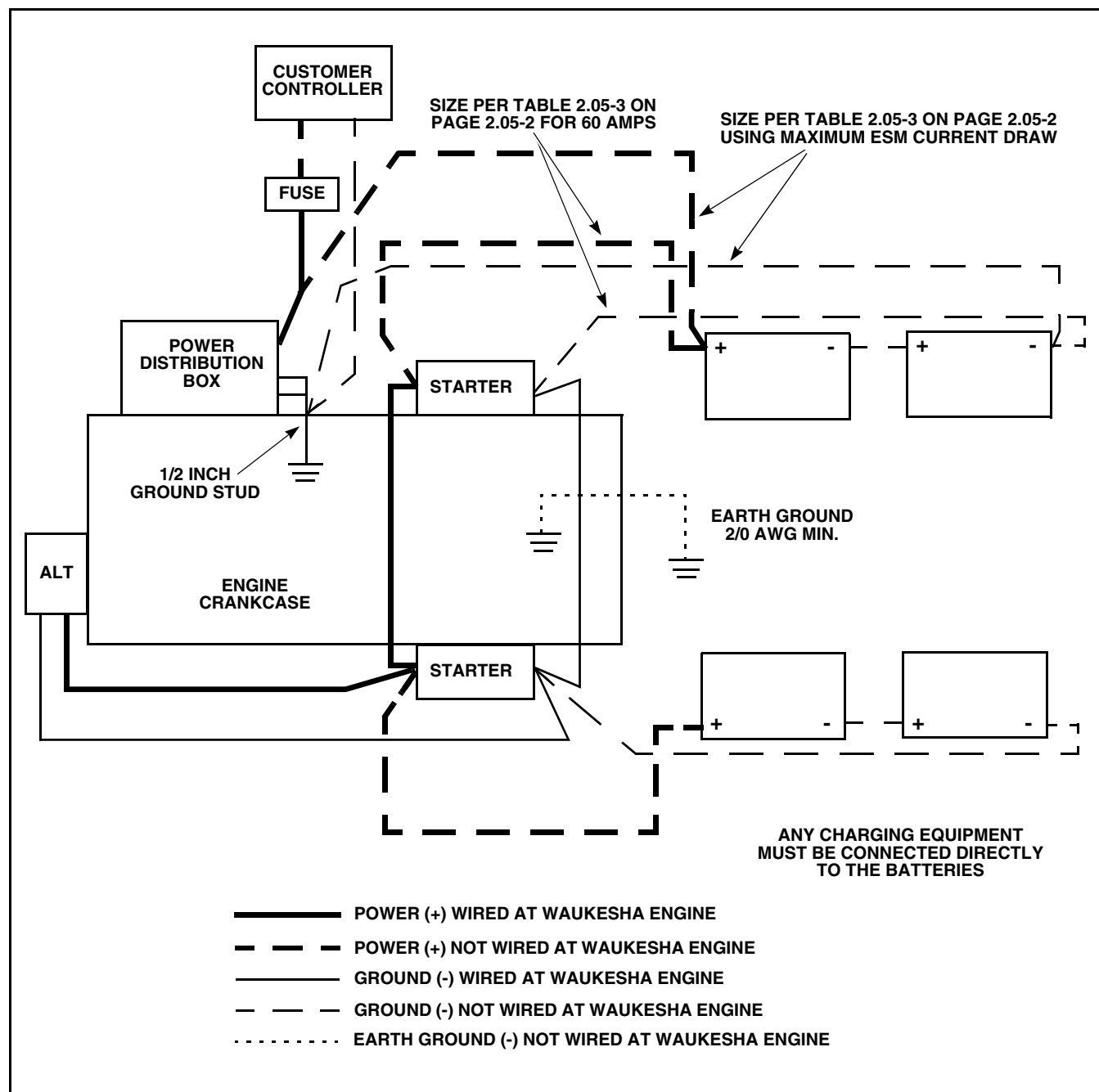


Figure 2.00-3 Power Supply with Electric Start and Alternator (Non Extender Series Engines)

CAUTION Always turn the battery charger off first, before disconnecting the batteries. Then disconnect the battery negative (-) cable before beginning any repair work. Failure to disconnect the battery charger first could result in product damage and/or personal injury and voids product warranty.

POWER REQUIREMENTS

EXTENDER SERIES ENGINES – POWER SUPPLY WITH AIR START AND ALTERNATOR

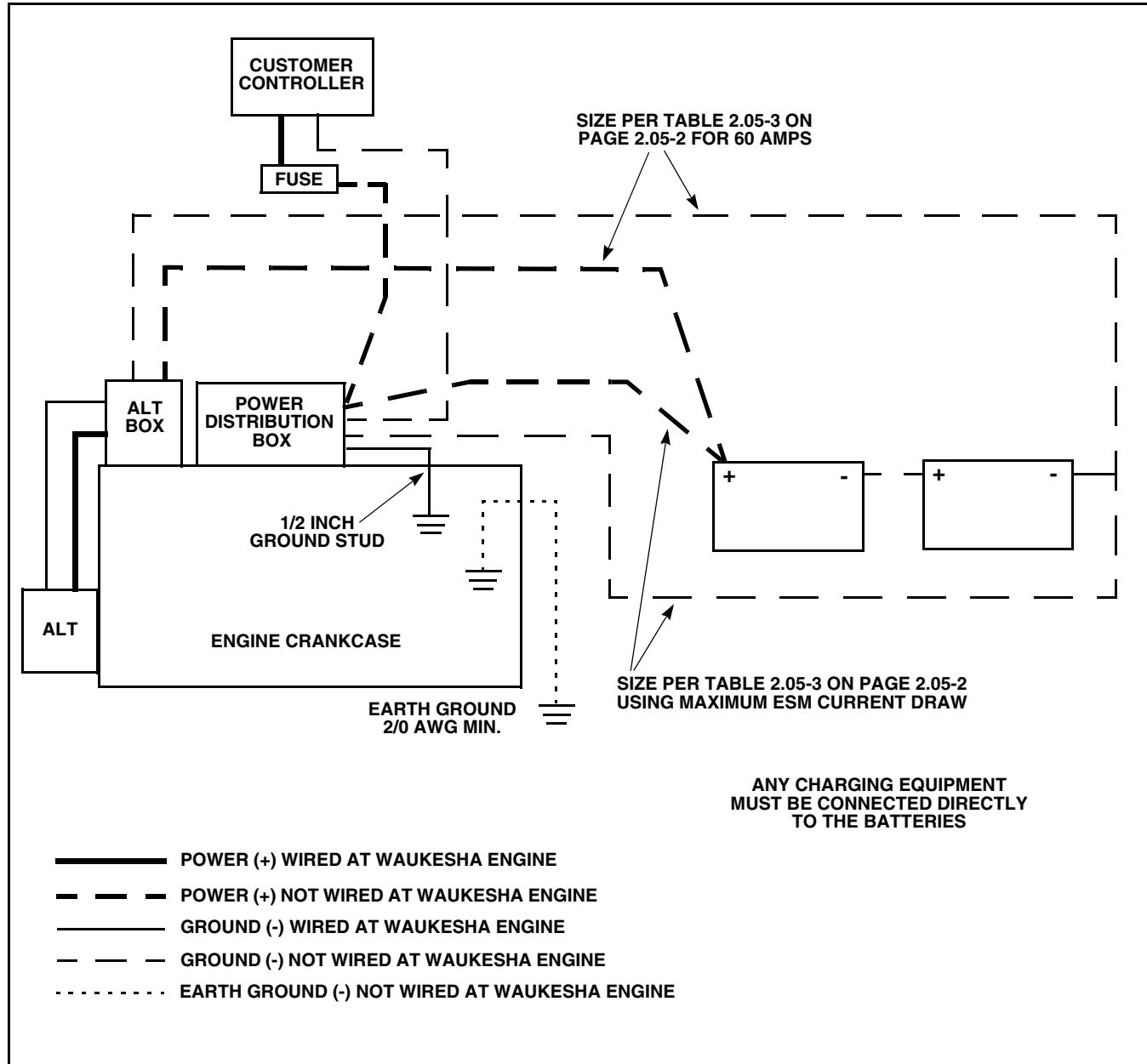


Figure 2.00-4 Power Supply with Air Start and Alternator (Extender Series Engines)

CAUTION Always turn the battery charger off first, before disconnecting the batteries. Then disconnect the battery negative (-) cable before beginning any repair work. Failure to disconnect the battery charger first could result in product damage and/or personal injury and voids product warranty.

EXTENDER SERIES ENGINES – POWER SUPPLY BY CUSTOMER

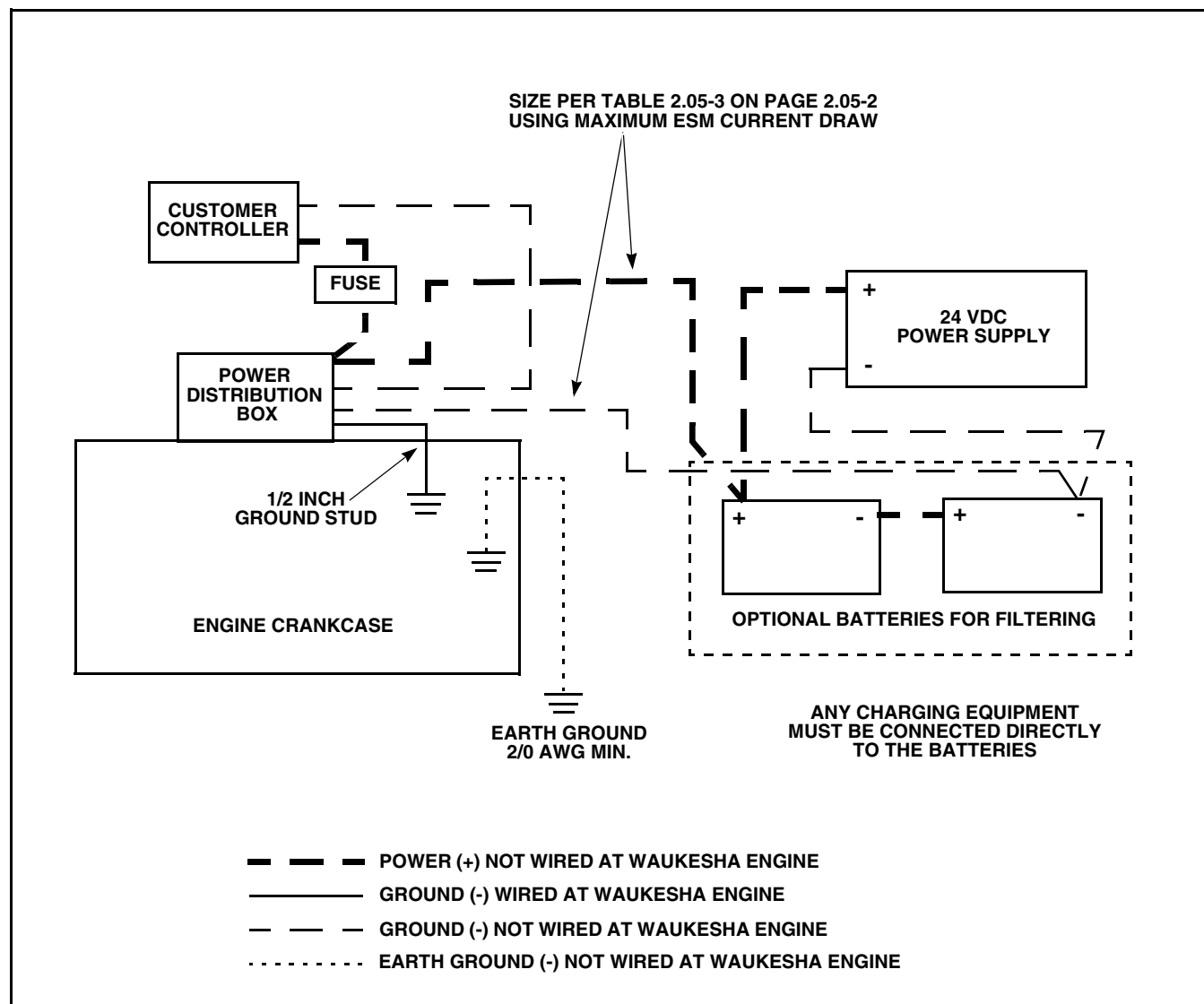


Figure 2.00-5 Power Supply by Customer (Extender Series Engines)

CAUTION Always turn the battery charger off first, before disconnecting the batteries. Then disconnect the battery negative (-) cable before beginning any repair work. Failure to disconnect the battery charger first could result in product damage and/or personal injury and voids product warranty.

POWER REQUIREMENTS

EXTENDER SERIES ENGINES – POWER SUPPLY WITH ELECTRIC START AND ALTERNATOR

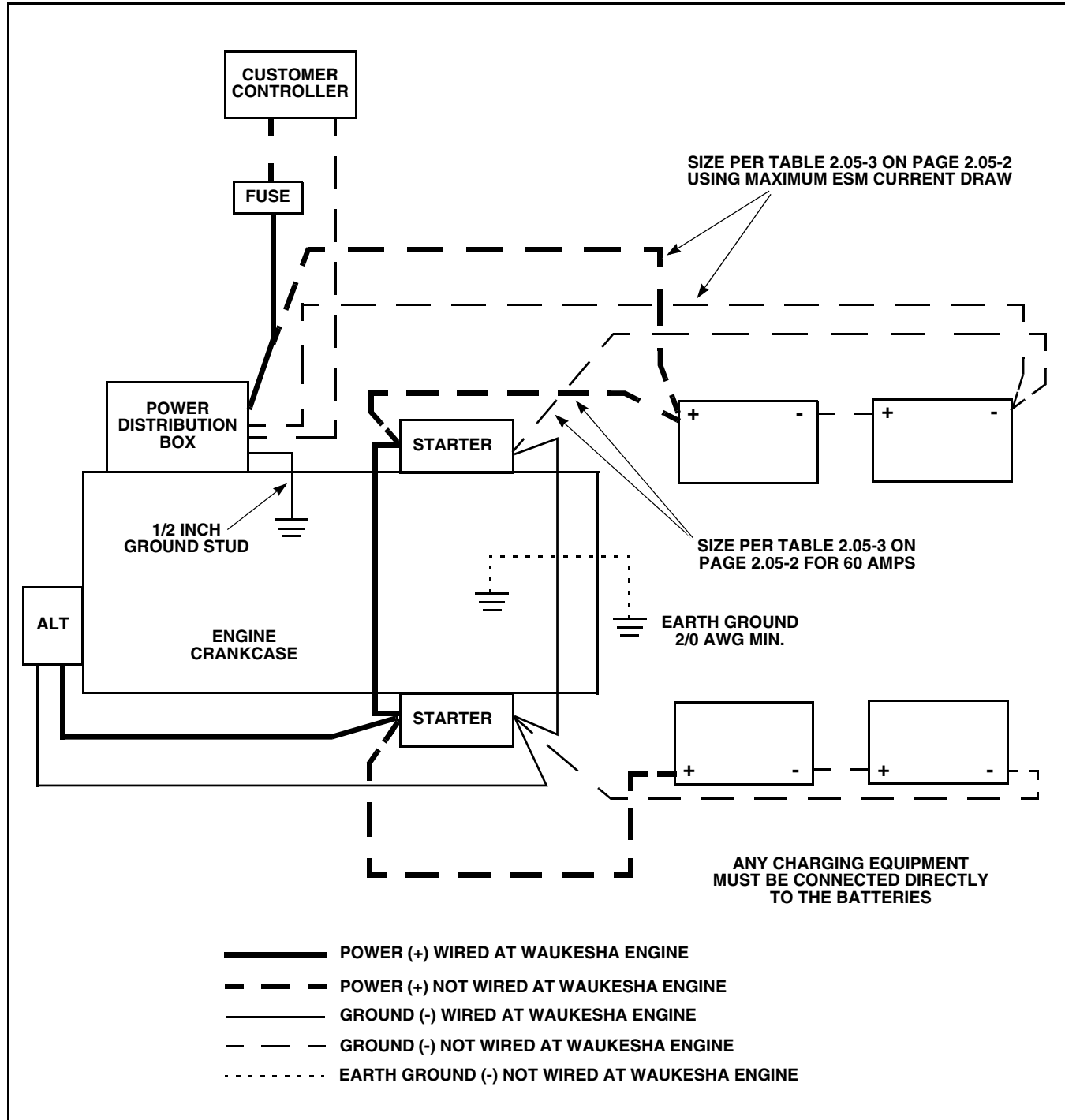
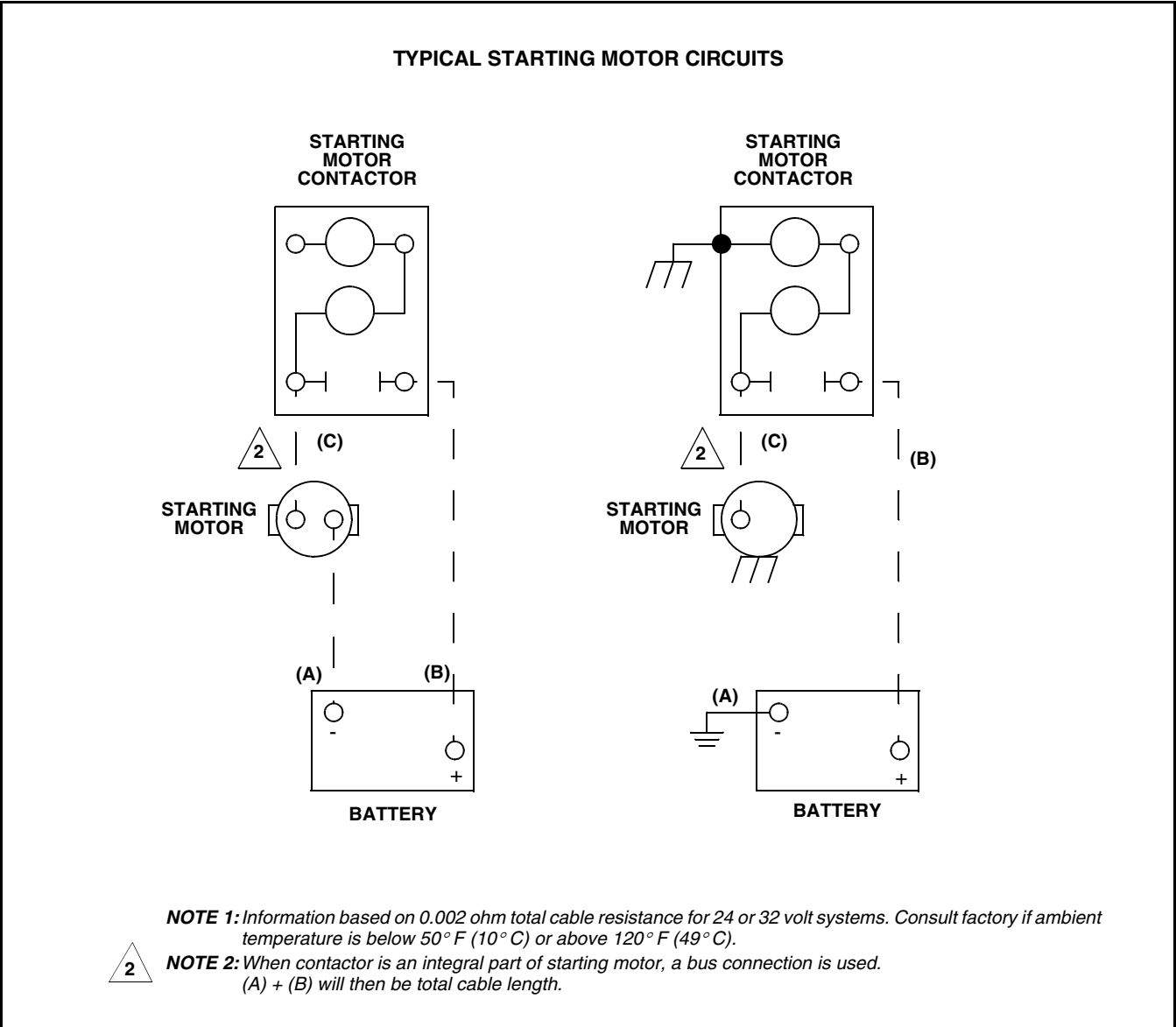


Figure 2.00-6 Power Supply with Electric Start and Alternator (Extender Series Engines)

CAUTION Always turn the battery charger off first, before disconnecting the batteries. Then disconnect the battery negative (-) cable before beginning any repair work. Failure to disconnect the battery charger first could result in product damage and/or personal injury and voids product warranty.

Table 2.00-1 Battery Cable Lengths for 24 or 32 Volt DC Starting Motor Circuits



SELECT SIZE OF CABLE FROM LISTING BELOW USING FIGURE POINTS A, B, AND C ABOVE:	
TOTAL CABLE LENGTH (A + B + C)	USE SIZE OF CABLE
Less than 16 ft. (4.9 m)	#0
16 – 20 ft. (4.9 – 6.1 m)	#00
20 – 25 ft. (6.1 – 7.6 m)	#000
25 – 32 ft. (7.6 – 9.8 m)	#0000 or (2) #0
32 – 39 ft. (9.8 – 11.9 m)	(2) #00
39 – 50 ft. (11.9 – 15.2 m)	(2) #000
50 – 64 ft. (15.2 – 19.5 m)	(2) #0000

POWER REQUIREMENTS

SECTION 2.05

POWER DISTRIBUTION JUNCTION BOX

THEORY OF OPERATION

The VHP utilizes either a integrated circuit version of the Power Distribution Junction Box (VHP Extender Series only, P/N 309204B) or a non-integrated circuit version Power Distribution Junction Box (VHP non Extender Series, P/N 214080G, P/N 214080E, and P/N 214080F) to distribute 24 VDC power to all the components on the engine that require power, such as the ECU, ignition and actuator so no other power connections are necessary.

It also triggers controlled devices such as the prelube motor and fuel valve. The VHP Extender Series Power Distribution Junction Box contains internal circuitry such that it will clamp input voltage spikes to a safe level before distribution, disable individual output circuits from high current events such as a wire short and have visual indicator LED's inside the box to aid in troubleshooting of the individual output circuits.

POWER DISTRIBUTION JUNCTION BOX



WARNING

Do not install, set up, maintain, or operate any electrical components unless you are a technically qualified individual who is familiar with the electrical elements involved. Electrical shock can cause severe personal injury or death.

This section describes the connections the packager must make to the ESM system's Power Distribution Junction Box.

24 VDC POWER

The packager needs to supply 24 VDC power to the Power Distribution Junction Box. The 24 VDC power is distributed from the Power Distribution Junction Box to all other components on the engine that require power, such as the IPM-D and ECU, so no other power connections are necessary.

See Table 2.05-1 for the ESM system's current draw information.

See Section 2.00 *Power Requirements* for information on the ESM system's power specifications.

Table 2.05-1 ESM System Current Draw

ENGINE MODEL	AVERAGE CURRENT DRAW (AMPS)	MAXIMUM CURRENT DRAW (AMPS)
VHP L7044GSI	4.2	12
VHP L7042GSI	4.2	12
VHP L7042GL	4.2	12
VHP L5774LT	4.2	12
VHP L5794GSI	4.2	12
VHP L5794LT	4.2	12
VHP F3524GSI	4.2	12
VHP F3514GSI	4.2	12
Engine off, ESM powered up for all engines – 1 AMP		
These values do not include USER POWER 24V for U (5 Amps max)		

Making Power Connection Inside Power Distribution Junction Box

Depending on the distance from either the batteries or power supply, choose appropriate cable diameters for ground and power using Table 2.05-3.

POWER DISTRIBUTION JUNCTION BOX

Table 2.05-2 Conversion Between AWG, mm², and Circular mils

AWG	mm ²	CIRCULAR MILS
0000	107.2	211592
000	85.0	167800
00	67.5	133072
0	53.4	105531
1	42.4	83690
2	33.6	66369
3	26.7	52633
4	21.2	41740
6	13.3	26251
8	8.35	16509
10	5.27	10383
12	3.31	6529.8
14	2.08	4106.6
16	1.31	2582.7

Table 2.05-3 Recommended Wire Sizes (AWG) vs. Round Trip Length Between Battery and Power Distribution Junction Box

ROUND TRIP LENGTH OF CONDUCTOR		MAXIMUM CURRENT (AMPS)												
FT	M	5	10	15	20	25	30	40	50	60	70	80	90	100
10	3.0	18	18	16	14	12	12	10	10	10	8	8	8	6
15	4.6	18	16	14	12	12	10	10	8	8	6	6	6	6
20	6.1	18	14	12	10	10	10	8	6	6	6	6	4	4
25	7.6	16	12	12	10	10	8	6	6	6	4	4	4	4
30	9.1	16	12	10	10	8	8	6	6	4	4	4	2	2
40	12.2	14	10	10	8	6	6	6	4	4	2	2	2	2
50	15.2	12	10	8	6	6	6	4	4	2	2	2	1	1
60	18.3	12	10	8	6	6	4	4	2	2	1	1	0	0
70	21.3	12	8	6	6	4	4	2	2	1	1	0	0	2/0
80	24.4	10	8	6	6	4	4	2	2	1	0	0	2/0	2/0
90	27.4	10	8	6	4	4	2	2	1	0	0	2/0	2/0	3/0
100	30.5	10	6	6	4	4	2	2	1	0	2/0	2/0	3/0	3/0
110	33.5	10	6	6	4	2	2	1	0	0	2/0	3/0	3/0	4/0
120	36.6	10	6	4	4	2	2	1	0	2/0	3/0	3/0	4/0	4/0
130	39.6	8	6	4	2	2	2	1	0	2/0	3/0	3/0	4/0	4/0
140	42.7	8	6	4	2	2	1	0	2/0	3/0	3/0	4/0	4/0	—
150	45.7	8	6	4	2	2	1	0	2/0	3/0	3/0	4/0	4/0	—
160	48.8	8	6	4	2	2	1	0	2/0	3/0	4/0	4/0	4/0	—

To make the ground and power connections:

WARNING

Disconnect all electrical power supplies and batteries before making any connections or servicing any part of the electrical system. Electrical shock can cause severe personal injury or death.

1. Locate the 1/2 inch ground stud on the right bank side of the crankcase. The ground stud is adjacent to the #4 cylinder's oil pan access door. The ground stud will have two ground cables attached to it from the Power Distribution Junction Box.
2. Remove the outer nut from the stud. Do not loosen or remove the factory-installed ground cables.
3. Attach ground cable to the ground stud using hardware as required.
4. Replace outer nut to the ground stud.
5. Apply corrosion protection material such as Krylon® 1307 or K1308 Battery Protector (or equivalent) to the ground connection.

Power Distribution Junction Box Connection (Non Extender Series Engines)

1. Locate packaged sealing glands inside Power Distribution Junction Box.
2. Choose an appropriately sized sealing gland for the +24 VDC power cable.
3. Feed the power cable through the POWER cord grip.
4. Install an appropriately sized ring terminal on the power cable.
5. Attach the power ring terminal to the positive 3/8 inch stud located under the red cover in the Power Distribution Junction Box (see Figure 2.05-1).

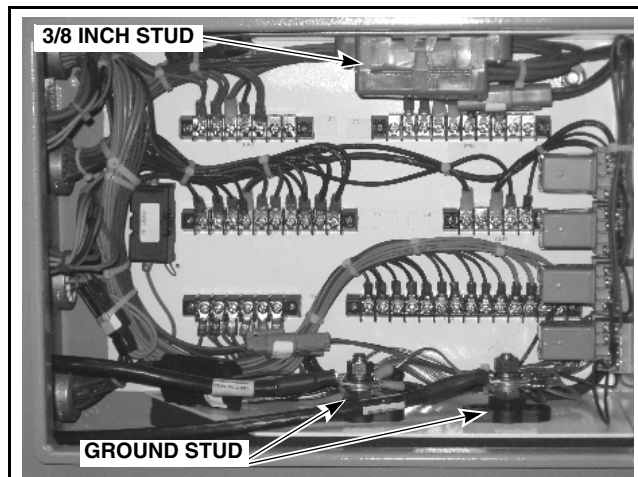


Figure 2.05-1 Power Distribution Junction Box (Non Extender Series Engines)

Power Distribution Junction Box Connection (Extender Series Engines)

1. Choose an appropriately sized sealing gland for the +24 VDC power cable.
2. Feed the power cable through the POWER cord grip.
3. Install an appropriately sized ring terminal on the power cable.
4. Attach the power ring terminal to the positive 3/8 inch stud located in the Power Distribution Junction Box (see Figure 2.05-2).
5. Attach prelube motor solenoid contracts to correctly labeled terminals (if customer supplied).
6. Attach fuel valve solenoid contact to correctly labeled terminals.

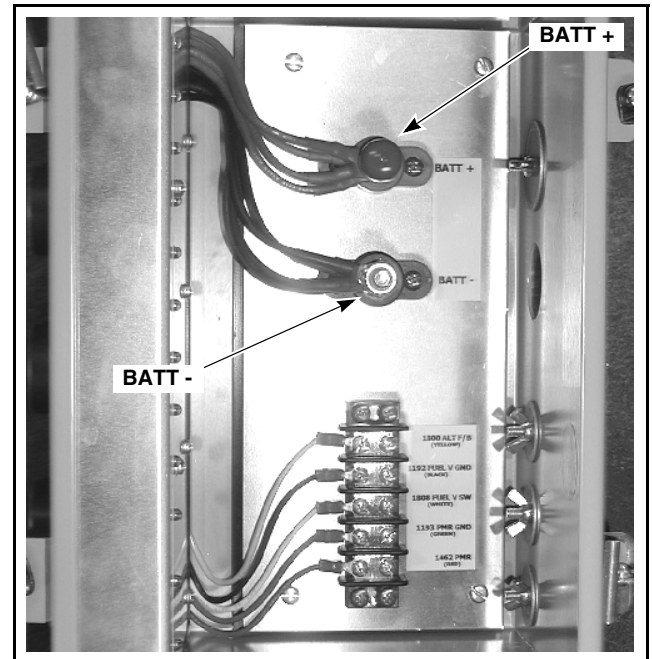


Figure 2.05-2 Power Distribution Junction Box (Extender Series Engines)

POWER DISTRIBUTION JUNCTION BOX

ENGINE SHUTDOWN INFORMATION

 WARNING

The Customer Emergency Shutdown must never be used for a normal engine shutdown. Doing so may result in unburned fuel in the exhaust manifold. It will also abort the actuator autocal and stop the postlube process that is beneficial to engine components. Failure to comply increases the risk of an exhaust explosion, which can result in severe personal injury or death.

NOTE: After a Customer Emergency Shutdown ESD222 CUST ESD is initiated (ESD pin 15 low), the Emergency Shutdown input ESD pin 15 should then be raised “high”. Raising ESD pin 15 high allows the ECU to go through a reboot. A subsequent start attempt may fail if it is initiated less than 60 seconds after raising ESD pin 15 high because the ECU is rebooting.

On engine shutdown, leave the ECU powered for at least one minute after completion of engine postlube. The ESM system does shutdown “post-processing” that needs to be completed before +24 VDC power is removed.

NOTE: See Section 2.15 *Start-Stop Control* for additional information.

EXTERNAL POWER DISTRIBUTION JUNCTION BOX LOCAL CONTROL OPTIONS HARNESS

A shipped loose, Local Control Option Harness has been included with your engine [standard harness length = 25 ft. (8 m); optional harness length = 50 ft. (15 m)]. The terminated end of the harness connects to the Power Distribution Box. Customer optional connections are made with the unterminated wires in the harness.

Table 2.05-4 lists and briefly describes the wires available for use on the Local Control Option Harness. For complete harness description, see Table 2.10-4 in Section 2.10.

Table 2.05-4 Local Control Option Harness

WIRE LABEL	DESCRIPTION
+24VFOR U	User +24 VDC Power (Output) (5 amps maximum)
GND FOR U	User Ground (Output)
ESTOP SW	Emergency Stop, Normally Open (Output)
ESTOP SW	Emergency Stop, Normally Open (Output)
G LEAD	“G-Lead” from ignition if jumpered in box
GOVSD+24V	Actuator Shutdown Switch Power
GOV SD+	Switch, Governor Actuator, G

+24VFOR U and GND FOR U

 CAUTION

Never attempt to power the engine using the +24VFOR U wire in the Local Control Option Harness. The +24VFOR U wire is for customer use to provide 24 VDC power to other equipment. Incorrectly powering the engine using the +24VFOR U wire could result in product damage and/or personal injury.

Power (24 VDC, 5 amps maximum) is available for items such as a local control panel and panel meters. The 24 VDC wires are labeled +24VFOR U and GND FOR U. **DO NOT POWER THE ENGINE THROUGH THIS CONNECTOR!**

ESTOP SW

The wires labeled ESTOP SW can be used to complete a circuit to turn on a light or horn if either of the red emergency stop buttons on the sides of the engine is pushed in. Pushing either of the red emergency stop buttons on the sides of the engine completes a circuit between the ESTOP SW wires.

The contact ratings for ESTOP SW are:

24 – 28 VDC = 2.5 A

28 – 600 VDC = 69 VA

G LEAD (NON EXTENDER SERIES)

The wire labeled G LEAD provides the G-lead from the IPM-D if a jumper is installed in the Power Distribution Junction Box. Waukesha *strongly discourages* connecting anything other than temporary test equipment to the IPM-D G-lead since accidental grounding of the G-lead will prevent the ignition from firing, shutting down the engine. If a local tachometer is desired, Waukesha recommends you use the 4 – 20 mA PROG OP 1 signal in the Customer Interface Harness to drive a 4 – 20 mA panel meter calibrated to show rpm. Refer to Section 2.35 *ESM System Communications* “Local Displays Such as a Tachometer” for additional information.

GOVSD+24V and GOV SD+

CAUTION Never connect the GOVSD+24V and the GOV SD+ wires with a 10 kΩ resistor while the engine is operating. Doing this will shut down the engine immediately and the throttle valve will close and will remain closed for approximately 20 seconds. After the 20 second lapse, the actuator may operate and adjust unsuitably to user requirements. Disregarding this information could result in product damage and/or personal injury.

This feature can be used by the customer to reduce current draw of the ESM system's actuator while the engine is shut down and in standby mode. Connecting GOVSD+24V and GOV SD+ with a 10 kΩ resistor will put the actuator in a low current draw standby mode. **NEVER connect GOVSD+24V and GOV SD+ with a 10 kΩ resistor while the engine is operating.**

MAINTENANCE

There is minimal maintenance that is associated with the Power Distribution Junction Box. Once a year inspect and check the following.

- Inspect connectors and connections to the Power Distribution Junction Box and verify they are secure.
- Remove cover to Power Distribution Junction Box and verify all terminals are tight, secure and corrosion free.
- Verify the bolts securing the Junction Box to the bracket and engine are tight.

TROUBLESHOOTING

Table 2.05-1 Troubleshooting (Extender Series)

If	Then
Power Distribution Junction Box has no LED lights on when the cover is removed.	Check input power to the Positive and Negative terminals to ensure there is a nominal 24 VDC
Status LED's inside Power Distribution Junction Box are very dim or flashing on and off.	Check input power to ensure there is a nominal 24 VDC
One of the Power Distribution outputs is turned off.	Recycle power to the Power Distribution Junction Box
One or more LED's turn off frequently which turn off the associated power distribution output.	Disconnect power to Power Distribution Junction Box and inspect wiring and terminations for wire degradation and/or shorts.
Power Distribution Junction Box will not turn on, distribute power or turn on status LED's even with 24 VDC applied.	Replace Power Distribution Junction Box

SECTION 2.10

SYSTEM WIRING OVERVIEW

WIRING DIAGRAM



WARNING

Explosion Hazard – Do not disconnect equipment unless power has been switched off or the area is known to be non-hazardous. Improper maintenance or misuse could result in severe personal injury or death.



WARNING

Do not install, set up, maintain, or operate any electrical components unless you are a technically qualified individual who is familiar with the electrical elements involved. Electrical shock can cause severe personal injury or death.



CAUTION

Disconnect all engine harnesses and electronically controlled devices before welding on or near an engine. Failure to comply will void product warranty. Failure to disconnect the harnesses and electronically controlled devices could result in product damage and/or personal injury.



CAUTION

The electrical interference from solenoids and other electrical switches will not be cyclic and can be as high as several hundred volts. This could cause faults within the ESM system that may or may not be indicated with diagnostics. Waukesha Engine requires a “freewheeling” diode be added across the coils of relays and solenoids to suppress high induced voltages that may occur when equipment is turned off. Failure to comply will void product warranty. Disregarding this information could result in product damage and/or personal injury.

Refer to the 2-page schematics at the end of this section.

NOTE: *The wiring diagrams in this manual are to be used as a reference only.*

CUSTOMER INTERFACE HARNESS

NOTE: *The Customer Interface Harness must be properly grounded to maintain CE compliance.*

Customer electrical connections to the ECU are made through a shipped loose harness called the Customer Interface Harness [standard harness length = 25 ft. (8 m); optional harness length = 50 ft. (15 m)]. The terminated end of the harness connects to a bulkhead connector behind the Power Distribution Box on the Power Distribution Box bracket. The unterminated end of the harness connects to customer connections. Table 2.10-1 (pages 2.10-2, 2.10-3, and 2.10-4) provides information on each of the unterminated wires in the Customer Interface Harness.

Some connections of the Customer Interface Harness are required for ESM system operation. See “Required Connection Descriptions – Customer Interface Harness” on page 2.10-5 for more information. See “Optional Connections” on page 2.10-6 for more information on optional connections.

Setting up user-adjustable parameters is through PC-based ESP and is done via a serial cable (RS-232) supplied by Waukesha Engine. This serial cable has a standard 9-pin RS-232 connection that plugs into the PC and an 8-pin plastic Deutsch® connector that plugs into the ECU.

SYSTEM WIRING OVERVIEW

Table 2.10-1 Customer Interface Harness Loose Wire Identification (Part 1 of 3)

WIRE LABEL	DESCRIPTION	SIGNAL NAME	SIGNAL TYPE	WIRE COLOR	FROM PIN	WIRE SIZE	SOCKET SIZE See Note 1	Wire #
ENG ALM	A digital output from the ECU that indicates that the ECU is in either alarm or shutdown mode.	Engine Alarm	Digital HSD O/P	WHT	14	18	20	1604
KNK ALM	A digital output from the ECU that indicates the engine is knocking and will shut down immediately unless some action is taken to bring the engine out of knock.	Engine Knocking	Digital HSD O/P	WHT	47	18	20	1617
ENG ESD	A digital output from the ECU that indicates that the ECU is in shutdown mode. Output is NOT latched.	Emergency Shutdown	Digital HSD O/P	WHT	42	18	20	1607
ESD	A digital input to the ECU from the local control that must be high for the engine to run. If ESD goes low, the engine performs an emergency shutdown.	Emergency Engine Shutdown	Digital I/P	YEL	15	18	20	1606
RUN/STOP	A digital input to the ECU from the local control that must be high for the engine to run. If RUN/STOP goes low, the engine performs a normal shutdown.	High = OK to Run Low = Normal Shutdown	Digital I/P	YEL	25	18	20	1611
GOV 40	Used for remote speed voltage input setting. Fit "jumper" between GOV 40 and GOV 41 to use 4 – 20 mA remote speed input.	Remote Speed Setting Mode Select	0.875 – 4.0 V I/P+ Fit "jumper" between 40 and 41 for 4 – 20 mA operation	TAN	40	18	20	1618
GOV 41	Used for remote speed voltage input setting. Fit "jumper" between GOV 40 and GOV 41 to use 4 – 20 mA remote speed input.	Remote Speed Setting Mode Select	0.875 – 4.0 V I/P- Fit "jumper" between 40 and 41 for 4 – 20 mA operation	TAN	41	18	20	1619
GOVREMSP+	Input to the ECU that is used for remote speed setting using 4 – 20 mA signal.	Remote Speed Setting 4 20 mA Signal +	4 – 20 mA I/P+ Open circuit for 0.875 – 4.0 V operation	LT GRN	39	18	20	1614
GOVREMSP-	Input to the ECU that is used for remote speed setting using 4 – 20 mA signal.	Remote Speed Setting 4 20 mA Signal -	4 – 20 mA I/P- Open circuit for 0.875 – 4.0 V operation	LT BLU	27	18	20	1613
GOVAUXSIG	Used for compatible load sharing input. Used for power generation applications only.	Aux. Input Signal	±2.5 V I/P	RED	28	18	20	1615
GOVAUXGND	Used for compatible load sharing input. Used for power generation applications only.	Aux. Input Ground	Ground	BLK	29	18	20	1110
GOVAUXSHD	Used as shield for compatible load sharing input.	Harness Shield	Shield	SLVR	46	18	20	1137
GOVALTSYN	Alternate governor dynamics. Used for power generation applications only to obtain a smooth idle for fast paralleling to the grid.	Alternate Governor Dynamics	Digital I/P	YEL	10	18	20	1620
GOVHL IDL	Digital input to the ECU that changes the operating rpm of the engine. Used for power generation applications only. When using GOVREMSEL, the input status of GOVHL IDL must be checked. See information on setting this input to a "safe mode" in Table 2.10-2.	Rated Speed/Idle Speed select	Digital I/P	YEL	37	18	20	1616

Table 2.10-1 Customer Interface Harness Loose Wire Identification (Continued), (Part 2 of 3)

WIRE LABEL	DESCRIPTION	SIGNAL NAME	SIGNAL TYPE	WIRE COLOR	FROM PIN	WIRE SIZE	SOCKET SIZE See Note 1	Wire #
GOVREMSEL	Digital input to the ECU that switches between either remote speed setting input or high/low idle input. Must be used to enable remote speed input. Not typically used for power generation.	Remote Speed select	Digital I/P	YEL	22	18	20	1608
LRG LOAD	Digital input to the ECU that "kicks" the governor to help the engine accept large load additions. Mainly useful for stand-alone power generation applications.	Load Coming	Digital I/P	YEL	20	18	20	1631
START	Momentary digital input to the ECU that is used to begin the engine start cycle.	Start Engine	Digital I/P	YEL	24	18	20	1609
LOGIC GND	Used as the negative connection point for 4 – 20 mA signals.	Customer Reference Ground	Ground via internal resettable fuse (See Note 2)	BLK	4	16	16	1111
WKI+	A 4 – 20 mA analog input to the ECU that represents the real time WKI rating of the fuel. Use not necessary for most applications. See Section 2.25 for scaling information.	Fuel Quality (WKI) Signal +	4 – 20 mA I/P+	LT GRN	30	18	20	1623
WKI-	A 4 – 20 mA analog input to the ECU that represents the real-time WKI rating of the fuel. Use not necessary for most applications. See Section 2.25 for scaling information.	Fuel Quality (WKI) Signal -	4 – 20 mA I/P-	LT BLU	31	18	20	1622
PROG OP 1	A 4 – 20 mA output from the ECU that represents an engine operating parameter. See Table 2.35-8 on page 2.35-11 for scaling and other information.	Average rpm	4 – 20 mA O/P+ (See Note 2)	DK GRN	9	18	20	1600
PROG OP 2	A 4 – 20 mA output from the ECU that represents an engine operating parameter. See Table 2.35-8 on page 2.35-11 for scaling and other information.	Oil Pressure	4 – 20 mA O/P+ (See Note 2)	DK GRN	21	18	20	1601
PROG OP 3	A 4 – 20 mA output from the ECU that represents an engine operating parameter. See Table 2.35-8 on page 2.35-11 for scaling and other information.	Coolant Temperature	4 – 20 mA O/P+ (See Note 2)	DK GRN	3	18	20	1602
PROG OP 4	A 4 – 20 mA output from the ECU that represents an engine operating parameter. See Table 2.35-8 on page 2.35-11 for scaling and other information.	Intake Manifold Absolute Pressure	4 – 20 mA O/P+ (See Note 2)	DK GRN	11	18	20	1603
RS 485A-	RS485 MODBUS®, see Section 2.35 for additional information.	RS485 A-	Comms	GRY	2	18	20	1305
RS 485B+	RS485 MODBUS®, see Section 2.35 for additional information.	RS485 B+	Comms	GRY	23	18	20	1306
ACT LOAD%	A 4 – 20 mA output from the ECU that represents the actual percentage of rated torque the engine is currently producing. See Table 2.35-8 on page 2.35-11 for scaling information.	Engine Load +	4 – 20 mA O/P+ (See Note 2)	DK GRN	32	18	20	1624
PIN 7	Reserved For Future Use	Future Use	4 – 20 mA I/P+	TAN	7	18	20	
PIN 8	Reserved For Future Use	Future Use	4 – 20 mA I/P-	TAN	8	18	20	
PIN 12	Reserved For Future Use	Future Use	Digital HSD O/P	TAN	12	18	20	
PIN 26	Reserved For Future Use	Future Use	Digital I/P	TAN	26	18	20	

SYSTEM WIRING OVERVIEW

Table 2.10-1 Customer Interface Harness Loose Wire Identification (Continued), (Part 3 of 3)

WIRE LABEL	DESCRIPTION	SIGNAL NAME	SIGNAL TYPE	WIRE COLOR	FROM PIN	WIRE SIZE	SOCKET SIZE See Note 1	Wire #
AVL LOAD%	A 4 – 20 mA output from the ECU that represents the available percentage of rated torque the engine is capable of producing. See Table 2.35-8 on page 2.35-11 for scaling information.	Available Load +	4 – 20 mA O/P+	DK GRN	33	18	20	1621
PIN 35	Reserved For Future Use	Future Use	Digital I/P	TAN	35	18	20	
PIN 36	Reserved For Future Use	Future Use	Digital I/P	TAN	36	18	20	
PIN 38	Reserved For Future Use	Future Use	Digital I/P	TAN	38	18	20	
USER DIP 1	A digital input to the ECU that can be used to indicate a customer alarm. See Section 2.35 for additional information.	User Defined Digital Input 1	Digital I/P	YEL	16	18	20	1627
USER DIP 2	A digital input to the ECU that can be used to indicate a customer alarm. See Section 2.35 for additional information.	User Defined Digital Input 2	Digital I/P	YEL	17	18	20	1628
USER DIP 3	A digital input to the ECU that can be used to indicate a customer alarm. See Section 2.35 for additional information.	User Defined Digital Input 3	Digital I/P	YEL	18	18	20	1629
USER DIP 4	A digital input to the ECU that can be used to indicate a customer alarm. See Section 2.35 for additional information.	User Defined Digital Input 4	Digital I/P	YEL	19	18	20	1630
–	–	No Connection	–	–	1	16	16	16
–	–	No Connection	–	–	5	16	16	16
–	–	No Connection	–	–	6	16	16	16
–	–	No Connection	–	–	34	16	16	16
–	–	No Connection	–	–	43	18	16	16
–	–	No Connection	–	–	44	18	16	16
RS 485SHD	Customer shield ground for RS485 twisted shielded pair wire	RS-485 Shield	–	SIL	13	18	16	1145
–	–	No Connection	–	–	45	18	16	16

NOTE 1: The connector for all the Customer Interface Harness wires is ECU-CC.

NOTE 2: Use LOGIC GND “Customer Reference Ground” as the negative connection point for these 4 – 20 mA signals. Self regulating solid state logic can become high impedance during an overcurrent event. The overcurrent logic is rated for 1.1 A.

REQUIRED CONNECTIONS

Table 2.10-2 lists **required** connections of the unterminated wires of the Customer Interface Harness that are necessary for the ESM system to enable the ignition and fuel. All digital inputs and outputs are referenced to battery negative. Digital High Side Driver (HSD) outputs can drive a maximum of 1 amp. All 4 – 20 milliamp inputs to the ECU are across an internal 200 Ω resistance. The input source common must be connected to Customer Reference Ground for proper operation (see Figure 2.10-1). This also applies when a 0.875 – 4.0 volt input is used. All 4 – 20 milliamp outputs from the ECU are internally powered with a maximum drive voltage of 8 volts.

NOTE: A high signal is a digital signal sent to the ECU that is between 8.6 and 36 volts. A low signal is a digital signal sent to the ECU that is less than 3.3 volts.

All the 4 – 20 milliamp inputs have the ability to disable under fault conditions. If the input current exceeds 22 milliamps (or the output voltage exceeds 4.4 volts), the input is disabled to protect the ECU. When a current source becomes an open circuit, it typically outputs a high voltage to try to keep the current flowing. This can lead to the situation where the ECU protection circuit remains disabled because it is sensing a high voltage (greater than 4.4 volts). In practice, this should only occur when a genuine fault develops, in which case the solution is to cycle the ECU power after repairing the fault.

The input is also disabled when the ECU is not powered. Therefore, if the current source is powered before the ECU, it will initially output a high voltage to try to make the current flow. The 4 – 20 milliamp inputs are all enabled briefly when the ECU is powered.

If the input source continues to supply a high voltage (greater than 4.4 volts) for longer than 500 microseconds, the ECU input will be disabled again. The fault can be cleared by removing power to both the ECU and the current source, then powering the ECU before the current source.

NOTE: It is recommended that the ECU remain powered at all times if possible. If not, always restore power to the ECU before powering the current source. A Zener diode is required to prevent the ECU from becoming disabled when a current source is powered before the ECU.

The Zener diode should be a 6.2 Volt, 1.0 Watt Zener diode from (+) to (-) across all 4-20 mA input signals (see Figure 2.10-1). This diode may be applied at the signal source, such as an output card of a PLC, or at an intermediate junction box commonly used where the Customer Interface Harness terminates (see Figure 2.10-1).

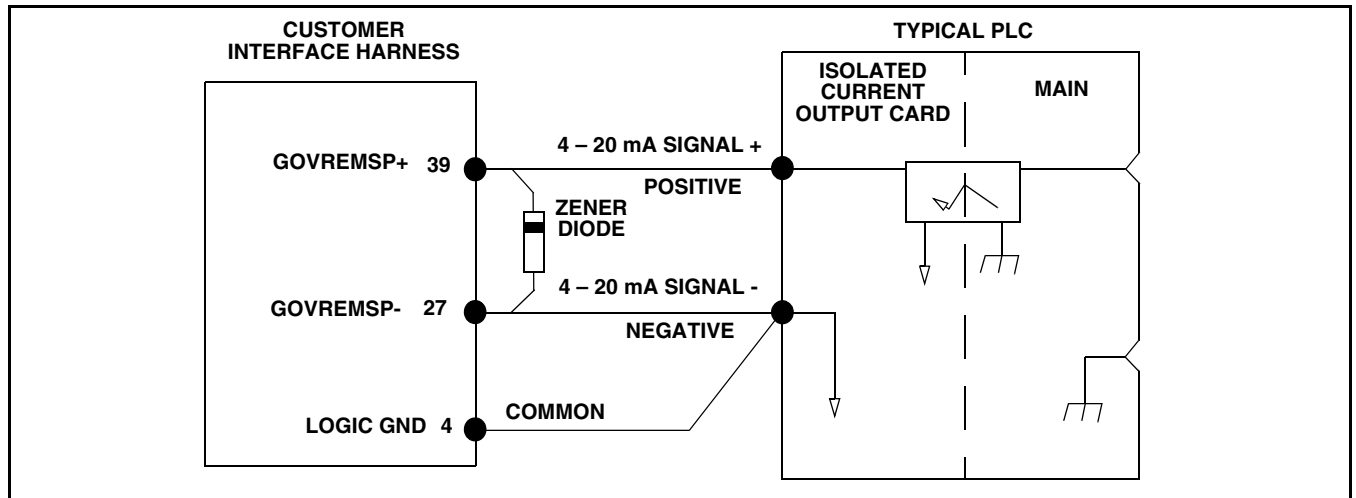


Figure 2.10-1 Example Connecting User 4 – 20 mA Analog Inputs To A PLC

Table 2.10-2 Required Connection Descriptions – Customer Interface Harness

DESCRIPTION	TYPE OF SIGNAL	PHYSICAL CONNECTION
Start Engine	Input	Momentary (>1/2 second and <60 seconds) digital signal input to ECU to begin the starting process, must momentarily be connected to +24 VDC nominal (8.6 – 36 volts) for the ECU to start the engine. START
Normal Shutdown (Run / Stop)	Input	A digital signal input to the ECU that must be connected to +24 VDC nominal (8.6 – 36 volts) for the engine to run. If RUN/STOP goes open circuit, the engine performs a normal shutdown.
Emergency Shutdown	Input	A digital signal input to the ECU that must be connected to +24 VDC nominal (8.6 – 36 volts) for the engine to run. If ESD goes open circuit, the engine performs an emergency shutdown. NOTE: Do not use this input for routine stopping of the engine. After a emergency shutdown and rpm is zero, ESD input should be raised to high to reset the ESM. If ESD input remains low, ESM reset will be delayed and engine may not start for up to 1 minute.
Rated Speed / Idle Speed (Fixed Speed Application)	Input	Digital signal input to ECU, must be connected to +24 VDC nominal (8.6 – 36 volts) for rated speed, open circuit for idle speed and remote speed setting enable (GOVREMSEL) must be open circuit. When using the <i>Remote Speed/Load Setting</i> , GOVHL IDL should be set to a safe mode. "Safe mode" means that if the wire that enables remote rpm operation (GOVREMSEL) fails, the speed setpoint will default to the GOVHL IDL idle value. Consider all process/driven equipment requirements when programming idle requirements.
Remote Speed / Load Setting (Variable Speed Application)	Input	Either 4 – 20 milliamp or 0.875 – 4.0 volt input to ECU. Inputs below 2 milliamp (0.45 volts) and above 22 milliamps (4.3 volts) are invalid. Input type can be changed by fitting a jumper across pins 40 and 41 to enable the 4 – 20 milliamp option. GOVREMSP- and GOVREMSP+ are used for the 4 – 20 milliamp input. For voltage, input pin 40 is the + voltage input and pin 41 is the – voltage input. Refer to Figure 2.10-1 for an example showing the user 4-20 mA analog inputs.
Remote Speed Setting Enable (Variable Speed Application)	Input	Digital signal input to ECU must be connected to +24 VDC nominal (8.6 – 36 volts) to enable remote speed/load setting. GOVREMSEL NOTE: When programming Rated Speed/Idle Speed, GOVHL IDL must be set to safe mode.

NOTE: BOLD letters in table match wire label names.

SYSTEM WIRING OVERVIEW

OPTIONAL CONNECTIONS

Table 2.10-3 lists optional connection descriptions of the unterminated wires of the Customer Interface Harness.

Table 2.10-3 Optional Connection Descriptions – Customer Interface Harness

DESCRIPTION	PHYSICAL CONNECTION
Analog Outputs	4 – 20 milliamp analog outputs from the ECU that can be used to read engine parameters such as oil pressure, coolant outlet temperature, engine speed, and intake manifold pressure (see Table 2.35-8). PROG OP 1 through PROG OP 4
MODBUS®	The ECU is a MODBUS® RTU slave operating from 1200 to 19,200 baud on “two-wire” RS-485 hardware. Current operating values such as oil pressure and fault information are available. Baud rate and slave ID number are programmed with ESP. See Section 2.35 <i>ESM System Communications</i> “MODBUS® (RS-485) Communications” for variable addresses. RS 485A- and RS 485B+
Engine OK / Emergency Shutdown	Digital signal output from ECU goes from open circuit to +24 VDC nominal (battery voltage – 1 volt) when ECU performs an emergency shutdown. ENG ESD
Engine Alarm	Digital signal output from ECU goes from open circuit to +24 VDC nominal (battery voltage – 1 volt) when ECU detects engine problem. Output remains +24 VDC nominal while an alarm is active. As soon as alarm condition is resolved, digital signal returns to open circuit. ENG ALM
WKI Value	A 4 – 20 milliamp input to the ECU that allows the customer to change the input fuel quality (WKI) in real time. (4 mA = 20 WKI; 20 mA = 135 WKI) WKI+ and WKI-
Uncontrolled Knock	Digital signal output from ECU goes from open circuit to +24 VDC nominal (battery voltage – 1 volt) when ECU cannot control engine knock. Allows customer knock control strategy such as load reduction instead of the ECU shutting down the engine. KNK ALM
Current Operating Torque	A 4 – 20 milliamp output from the ECU that represents the current engine torque output on a 0 – 125% of rated engine torque scale. ACT LOAD%
Desired Operating Torque	A 4 – 20 milliamp output from the ECU that represents the desired operating torque of the engine. Always indicates 100% of rated engine torque unless there is an engine fault such as uncontrollable knock. AVL LOAD%
Aux Speed Input	A ± 2.5 volt input to the ECU used for compatibility to Woodward™ generator control products (or other comparable control products). GOVAUXSIG and GOVAUXGND
Synchronizer Mode/Alternate Governor Dynamics	Digital signal input to the ECU when +24 VDC nominal (8.6 – 36 volts) allows synchronizer mode/alternate governor dynamics. User can program a small speed offset to aid in synchronization. GOVALTSYN
Load Coming	Digital signal input to the ECU when +24 VDC nominal (8.6 – 36 volts) is applied, signals the ECU that a large load will be applied to the engine. This input can be used to aid in engine load acceptance. User can program delay time from receipt of digital signal to action by the ECU and amount of throttle movement action. LRG LOAD
Four Digital Inputs	Four digital signal inputs to the ECU when +24 VDC nominal (8.6 – 36 volts) is applied allows user to wire alarm and/or shutdown digital outputs of the local control into ESM. The purpose of these four digital inputs to the ECU is to aid in troubleshooting problems with the driven equipment. USER DIP 1 through USER DIP 4

NOTE: **BOLD** letters in table match wire label names.

LOCAL CONTROL OPTION HARNESS

A shipped loose, Local Control Option Harness has been included with your engine [standard harness length = 25 ft. (8 m); optional harness length = 50 ft. (15 m)]. The terminated end of the harness connects to the Power Distribution Box. Customer optional connections are made with the unterminated wires in the harness.

VHP Non Extender Series® Table 2.10-4 or *VHP Extender Series® Table 2.10-5* provide information on each of the wires in the unterminated end of the Local Control Option Harness.

GOVERNOR CONNECTIONS

The governor actuator is always drawing power so if you have battery-powered ignition, power is being drawn from the battery even with the engine shut down. To remedy this you can pull the battery or you could put the battery in reduced power mode, but power will still be drawn from the battery. The GOVSD+24V and GOV SD+ wires of the Local Control Option Harness can be used as a way to reduce power demand from the battery. See wiring schematic.

This feature can be used by the customer to reduce current draw of the ESM system's actuator while the engine is shut down and in standby mode. Connecting GOVSD+24V and GOV SD+ with a 10 k Ω resistor will put the actuator in a low current draw standby mode. **NEVER connect GOVSD+24V and GOV SD+ with a 10 k Ω resistor while the engine is operating.**

Table 2.10-4 Non Extender Series® Local Control Option Harness Loose Wire Identification

WIRE LABEL	SIGNAL NAME	SIGNAL TYPE	WIRE COLOR	FROM PIN	WIRE SIZE	SOCKET SIZE
+24VFOR U	User Power	+24 VDC nominal	RED	B	12	12
GND FOR U	User Ground	Ground	BLK	E	12	12
ESTOP SW	Emergency Stop Switch, Normally Open	Depends on hardware wired to switch	TAN	L	16	16
ESTOP SW	Emergency Stop Switch, Normally Open	Depends on hardware wired to switch	TAN	M	16	16
G LEAD	“G” Lead, Normally Open	Up to 180 V, ignition capacitor discharge	GRY	P	16	16
GOVSD+24V	Shutdown Switch Power	+24 VDC nominal	RED	D	14	12
GOV SD+	Switch, Governor Actuator, G	Shutdown input	PUR	G	16	12

Table 2.10-5 Extender Series® Local Control Option Harness Loose Wire Identification

WIRE LABEL	SIGNAL NAME	SIGNAL TYPE	WIRE COLOR	FROM PIN	WIRE SIZE	SOCKET SIZE
+24VFOR U	User Power	+24 VDC nominal	RED	W	18	16
GND FOR U	User Ground	Ground	BLK	N	18	16
ESTOP SW	Emergency Stop Switch, Normally Open	Depends on hardware wired to switch	TAN	E	18	16
ESTOP SW	Emergency Stop Switch, Normally Open	Depends on hardware wired to switch	TAN	F	18	16
GOVSD+24V	Shutdown Switch Power	+24 VDC nominal	RED	U	18	16
GOV SD+	Switch, Governor Actuator, G	Shutdown input	PUR	H	18	16
PREL CTRL	Customer Pre-Lube Control	+24 VDC digital I/P	BRN	X	18	16

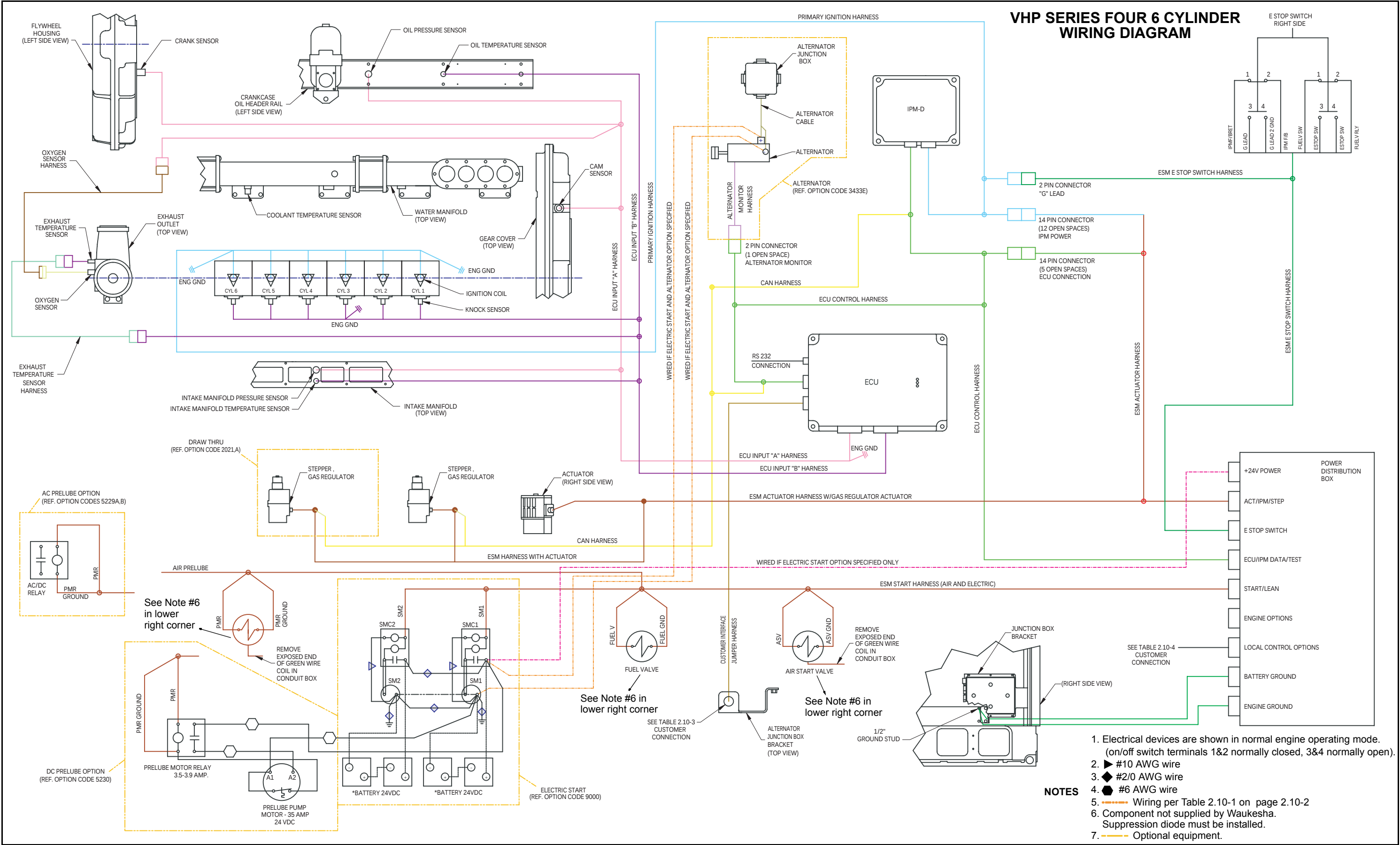


Figure 2.10-2 VHP Series Four 6 Cylinder Wiring Diagram

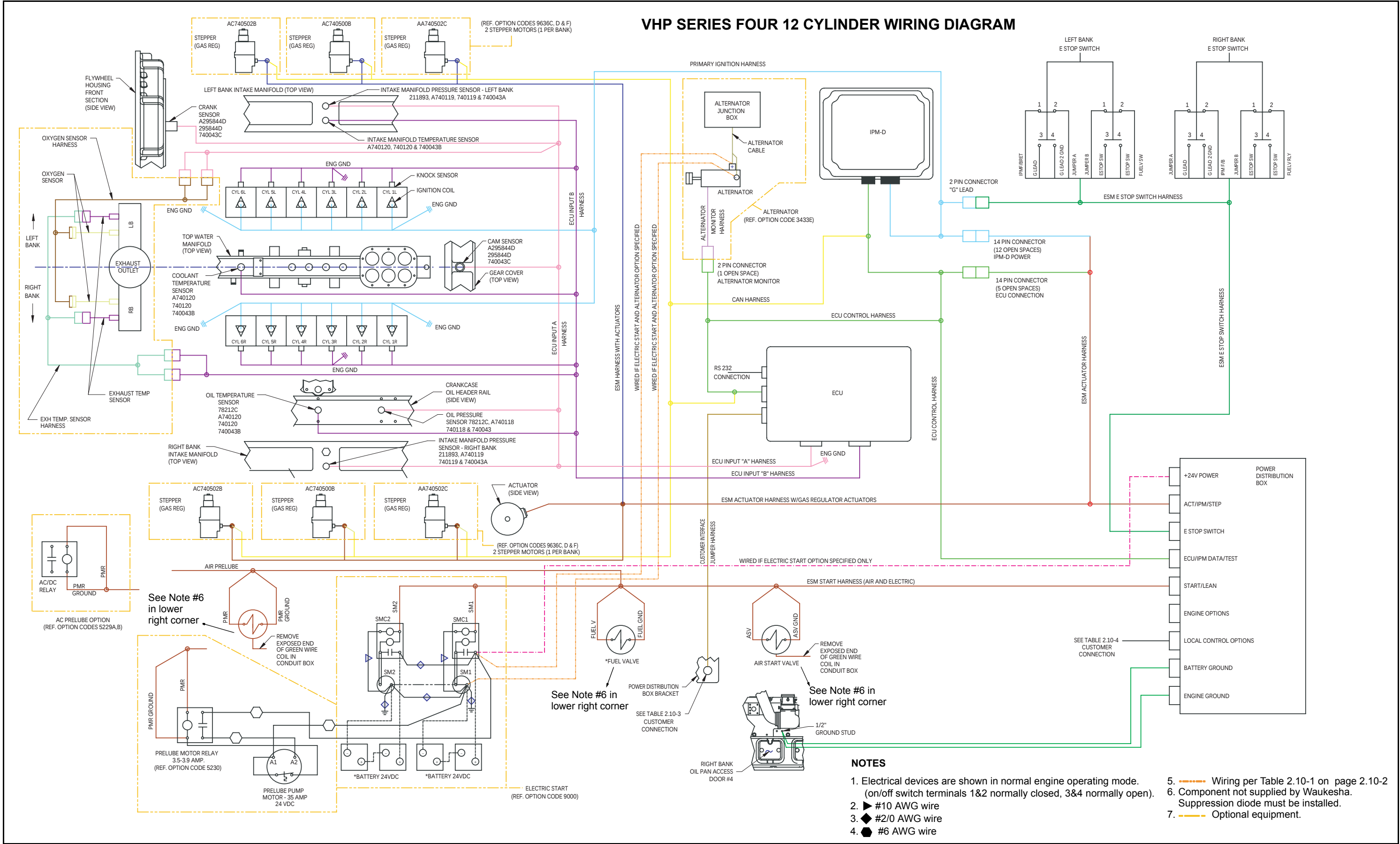


Figure 2.10-3 VHP Series Four 12 Cylinder Wiring Diagram

SECTION 2.15

START-STOP CONTROL

START-STOP CONTROL

NOTE: *If the engine is being used in a “standby” electric power generation application and the engine must not prelube on startup, the customer is responsible for controlling the prelube motor to automatically prelube the engine. Refer to Section 3 of Chapter 5 “Lubrication System” in the Installation of Waukesha Engines & Enginator® Systems Manual (Form 1091) for lubrication requirements in standby applications.*

The ESM system manages the start, normal stop, and emergency stop sequences of the engine including pre- and postlube. Logic to start and stop the engine is built into the ECU, but the user/customer supplies the interface (control panel buttons, switches, touch screen) to the ESM system.

The ESM system's start-stop process is controlled by three mandatory digital inputs: a start signal that is used to indicate to the ECU that the engine should be started and two shutdown signals (normal and emergency) that are used to give “permission” to run the engine. The three signals are Start, Run/Stop, and Emergency Stop.

For the engine to start, the start signal must be configured as a momentary event such that it goes “high” (8.6 – 36 volts) for at least 1/2 second (not to exceed 1 minute). In addition, to start the engine the shutdown signals must both be “high” (8.6 – 36 volts). Although the start signal must go “low” (< 3.3 volts) after starting, the shutdown signals must remain high for the engine to run. If either shutdown signal goes low, even for a fraction of a second, the engine will stop.

After receiving a start signal with the emergency stop and run/stop signals high, the ECU first prelubes the engine for a user-calibrated period of time.

Once the prelube is complete, the starter is activated. The ignition is energized after the engine has rotated through a minimum of two complete engine revolutions and a user-calibrated purge timer has expired.

When the engine speed reaches an rpm determined by Waukesha Engine factoring in a user offset rpm ($\pm$), the main fuel valve is energized. The engine then increases speed until it reaches its governed rpm.

Once the starter is activated, a timing circuit begins that causes a shutdown on overcrank if the engine does not reach a minimum speed within an amount of time calibrated by Waukesha Engine.

 **CAUTION** If an electric starter motor is used and a start attempt fails, wait at least two minutes (or a time period per the manufacturer's instructions) before attempting an engine restart. The starter motor must cool down before engine restart to prevent damage to the starter motor. Disregarding this information could result in product damage and/or personal injury.

The starter motor is de-energized at an rpm calibrated by Waukesha Engine factoring in a user offset rpm (+). If the run/stop digital input to the ECU goes low and after a user-calibrated cooldown period, the engine is stopped by first de-energizing the main fuel and then de-energizing the ignition as the engine speed drops to zero. If the engine fails to stop in a preprogrammed period of time (typically less than one minute) after the fuel valve has been de-energized, the ignition is de-energized, forcing a shutdown. If the emergency stop digital input to the ECU goes low, then the fuel and ignition are de-energized simultaneously. When the engine stops after a normal shutdown, it is postlubed for a user-calibrated period of time.

The engine should be stopped by causing the normal stop (or run/stop) input to go “low” (< 3.3 volts). This will turn off the fuel supply before ignition is halted, eliminating unburned fuel. It will also activate the actuator autocal and run the postlube supplying oil to vital engine components. The emergency shutdown input should remain “high” (8.6 – 36 volts) at all times unless an emergency situation occurs that requires the immediate shutdown of the engine.

WARNING

The Customer Emergency Shutdown must never be used for a normal engine shutdown. Doing so may result in unburned fuel in the exhaust manifold. It will also abort the actuator autocall and stop the postlube process that is beneficial to engine components. Failure to comply increases the risk of an exhaust explosion, which can result in severe personal injury or death.

If the ESM system detects a serious engine fault and shuts the engine down, it will energize a digital output from the ECU so that the user control knows the ESM system shut the engine down.

The ESM will immediately disable fuel and ignition. The postlube and actuator autocall will not run if the following critical ESD's occur:

- ESD222 CUST ESD
- ESD223 LOW OIL PRESS
- ESD313 LOCKOUT/IGNITION

All other ESD's will allow the postlube and actuator autocall to occur.

NOTE: *It is extremely important to not use ESD222 CUST ESD for normal shutdowns as the postlube will not occur.*

After a Customer Emergency Shutdown ESD222 CUST ESD is initiated (ESD pin 15 low), the Emergency Shutdown input ESD pin 15 should then be raised "high". Raising ESD pin 15 high allows the ECU to go through a reboot. A subsequent start attempt may fail if it is initiated less than 60 seconds after raising ESD pin 15 high because the ECU is rebooting.

If the ESM system detects a fault with the engine or the ESM system's components that is not serious enough to shut the engine down, a different digital output will be energized so that the user control knows of the alarm.

If the engine is being used for standby electric power generation and needs to be producing power within a short period of time after a start signal is received, then it is the packager's responsibility to control the prelube motor and to prelube the engine. In this situation the user pre- and postlube times must be set to zero.

Refer to Section 3 of Chapter 5 "Lubrication System" in the *Installation of Waukesha Engines & Engine Systems* manual (Form 1091-5) for lubrication requirements in standby applications.

See Figure 2.15-2 for Start Flow Diagram.

See Figure 2.15-3 for Stop Flow Diagram.

See Figure 2.15-4 for Emergency Stop Flow Diagram.

PRELUBING THE ENGINE WITHOUT STARTING

The following describes how to prelube the engine without starting the engine. Refer to Section 3.10 *ESP Programming* for programming instructions.

- Using ESP, program the "Pre Lube Time" field on the [F3] Start-Stop Panel to the maximum time of 10,800 seconds (180 minutes). Then begin the start sequence. After the engine prelubes for a sufficient time and before the end of 180 minutes, perform a normal shutdown sequence to cancel the start attempt. *Be sure to reprogram the prelube time to the previous value and save value to permanent memory.*

CRANKING THE ENGINE OVER WITHOUT STARTING AND WITHOUT FUEL

The following describes how to turn the engine over without starting the engine and without fuel. Refer to Section 3.10 *ESP Programming* for programming instructions.

- Using ESP, program the "Purge Time" field on the [F3] Start-Stop Panel to the maximum time of 1800 seconds (30 minutes). Then begin the start sequence. After a Waukesha-programmable crank time, the ESD231 Overcrank shutdown fault will trip and the engine will stop cranking. Repeat again if necessary. *Be sure to reprogram the purge time to the previous value and save to permanent memory.*

AIR-START VALVE

Once the ESM system receives an engine start signal from the user's panel, the ESM system controls the entire start process, including the sequence of events shown in Figure 2.15-2. Part of the start process includes engaging the starter. When the solenoid on the air-start valve receives the electronic voltage signal from the ECU to engage the starter, the air-start valve allows air to flow to the starter.

If the air starter option is ordered from Waukesha, only venting is required by the packager. If the packager is supplying the air starter, the packager needs to interface with the engine-mounted air-start valve. No electrical connections are required.

The air-start valve requires two vent connections: a 1/4 inch NPT vent for the air-start valve and a 1/8 inch NPT vent for the air-start valve solenoid. The packager is responsible for venting this system to meet applicable local codes. If the packager is supplying the air starter, the air-start valve supply connection is 1/4 inch NPT. Failure to interface through the air-start valve provided will result in ESM system fault codes.

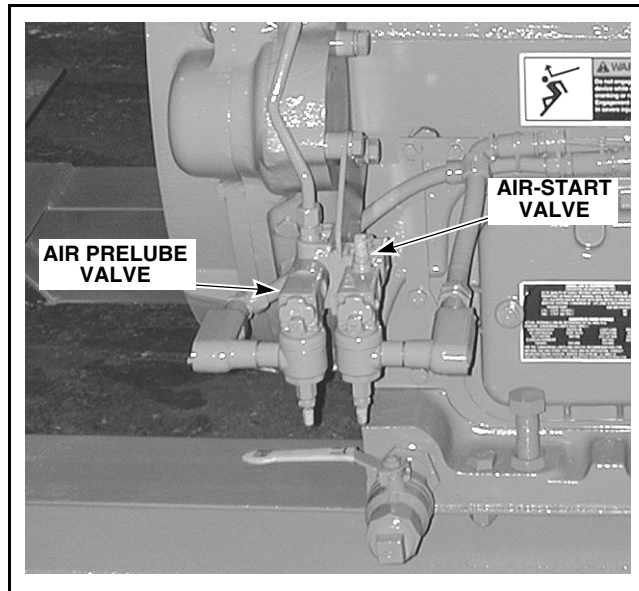


Figure 2.15-1 Air Valves

AIR PRELUBE VALVE

The air prelube valve requires user connections for the two vents: a 1/2 inch NPT vent for the air prelube valve and a 1/8 inch NPT vent for the air prelube valve solenoid. The packager is responsible for venting this system to meet applicable local codes.

START-STOP CONTROL

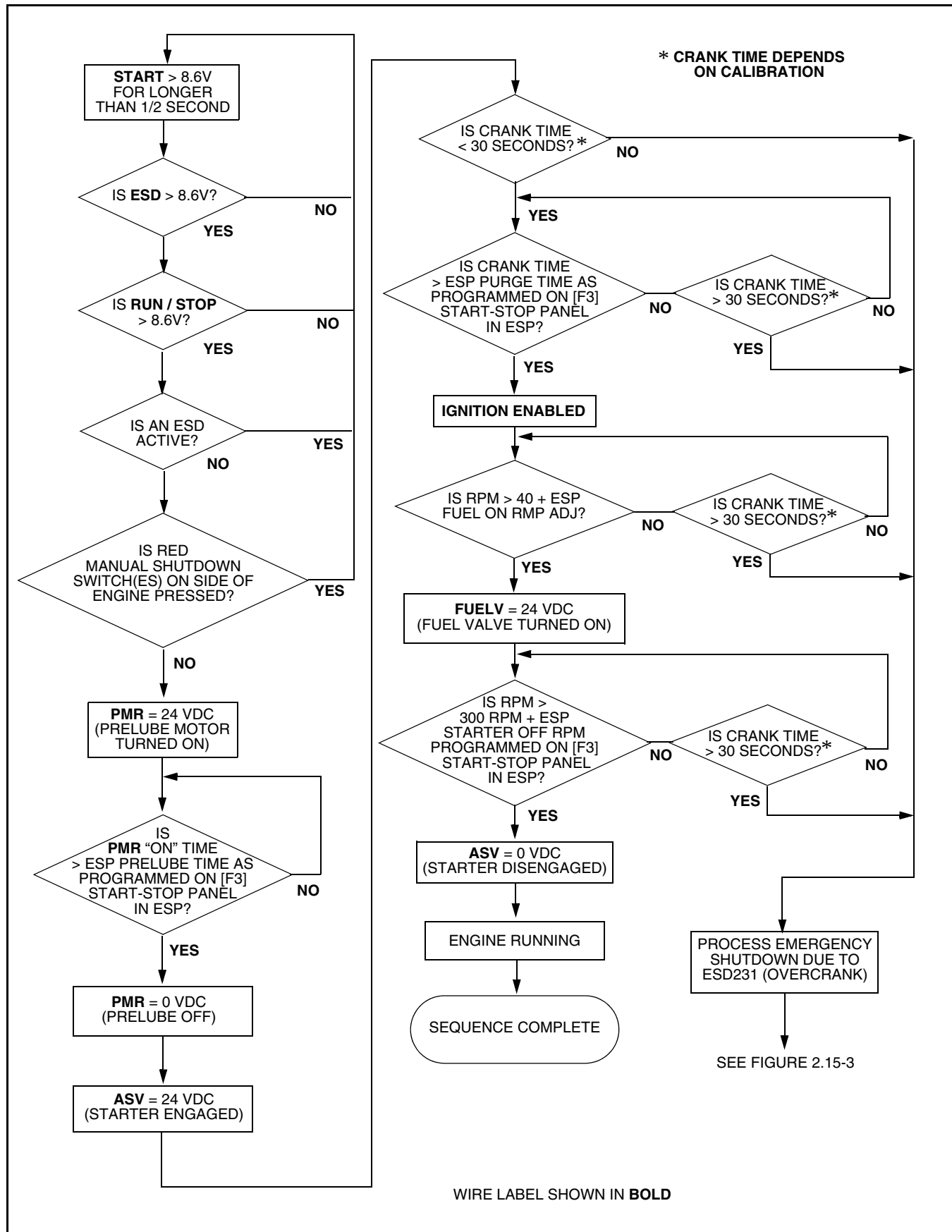


Figure 2.15-2 Start Flow Diagram

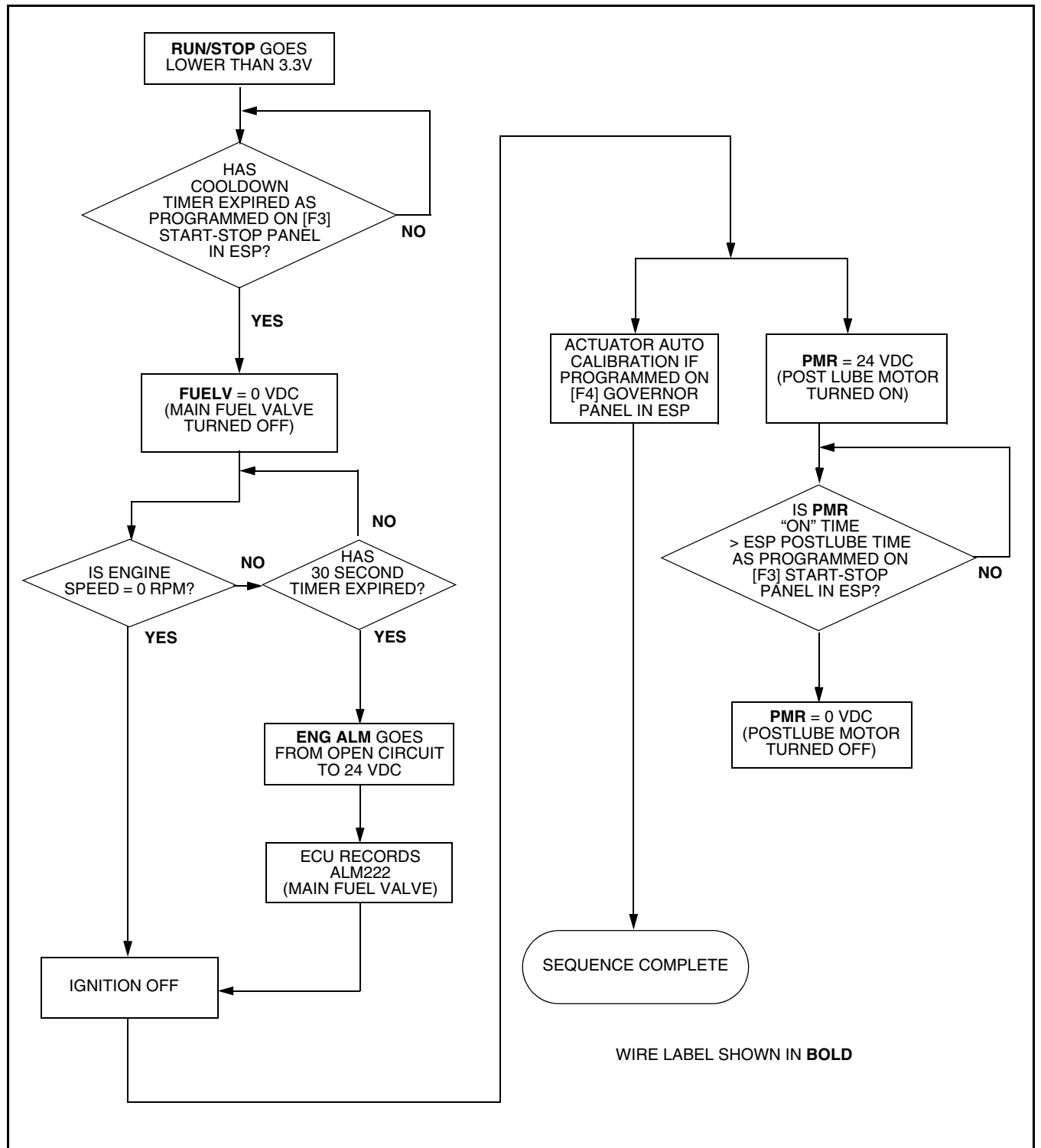


Figure 2.15-3 Stop Flow Diagram

START-STOP CONTROL

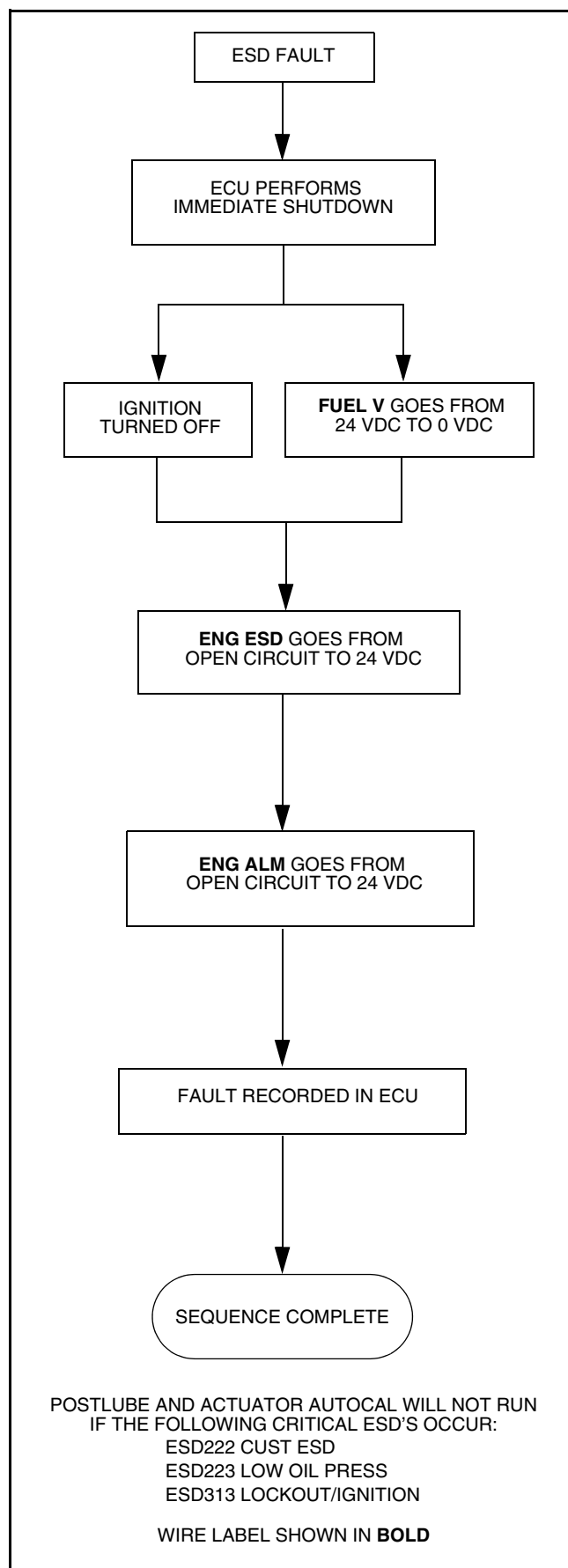


Figure 2.15-4 Emergency Stop Flow Diagram

SECTION 2.20

GOVERNING

GOVERNOR/SPEED CONTROL

This section discusses the ESM system's governing and speed control.

The ESM speed governing system provides speed and load control using information based on digital and analog inputs from the customer. The ESM system's governor has two different operating modes: speed control and load control. In speed control mode, the governor will control the engine speed by increasing or decreasing the engine power output. In load control mode, the speed is controlled by an exterior force such as the electrical grid and the load is varied by a generator control product.

SPEED CONTROL MODE

The engine speed setpoint can be controlled to a fixed value or can be varied in response to a process variable such as desired flow rate of gas if the engine is powering a gas compressor.

Fixed Speed



WARNING

Never set the high idle speed above the safe working limit of the driven equipment. If the GOVREMSP signal goes out of range or the GOVREMSEL signal is lost, then the engine will run at the speed determined by the status of GOVHL IDL and calibrated low or high idle speeds. Disregarding this information could result in severe personal injury or death.

There are two fixed speeds available: low idle and high idle. Low idle speed is the default, and high idle is obtained by connecting a digital input to the ECU of +24 VDC nominal. Low idle speed is preset for each engine family, but by using ESP the low idle speed can be offset lower or higher than the preset value. High idle speed is also adjustable directly using ESP but is constrained to be higher than low idle speed and no higher than the maximum rated speed of the engine. See Figure 2.20-1 for a logic diagram showing fixed speed.

The digital signal input to the ECU must be connected to +24 VDC nominal (8.6 – 36 volts) for rated speed, open circuit for idle speed, and remote speed setting enable (GOVREMSEL) must be an open circuit. When using the Remote Speed/Load Setting, GOVHL IDL should be set to a safe mode. "Safe mode" means that if the wire that enables remote rpm operation (GOVREMSEL) fails, the speed setpoint will default to the GOVHL IDL idle value. Consider all process/driven equipment requirements when programming idle requirements.

Variable Speed

Connecting the **GOVREMSEL** digital input to the ECU at +24 VDC nominal enables variable speed mode. The speed setpoint can then be varied with either a 4 – 20 mA or a 0.875 – 4.0 volt input (see Figure 2.20-2).

The ESM system checks for an out-of-range input that is less than 2 mA, greater than 22 mA, less than 0.45 volts, or greater than 4.3 volts. If an out-of-range speed setpoint is detected, the engine will then run at the speed indicated by the status of the high idle/low idle digital input. The engine speed setpoint range is already preadjusted to go from minimum to maximum engine speed using the 4 – 20 mA input (see Table 2.20-1). See Figure 2.20-3 for a logic diagram showing variable speed.

Table 2.20-1 Setpoint Speed Range

ENGINE MODEL	SPEED RANGE (4 – 20 mA RANGE)
F3514GSI/F3524GSI	750 – 1206 rpm
L7042GSI/L7044GSI	750 – 1206 rpm
L5774LT	750 – 1206 rpm
L5794GSI	750 – 1206 rpm
L5794LT	750 – 1206 rpm
L7042GL (Minimum idle speed of 800 rpm, if variable speed mode is selected, the minimum setpoint rpm is 800 rpm)	800 – 1206 rpm

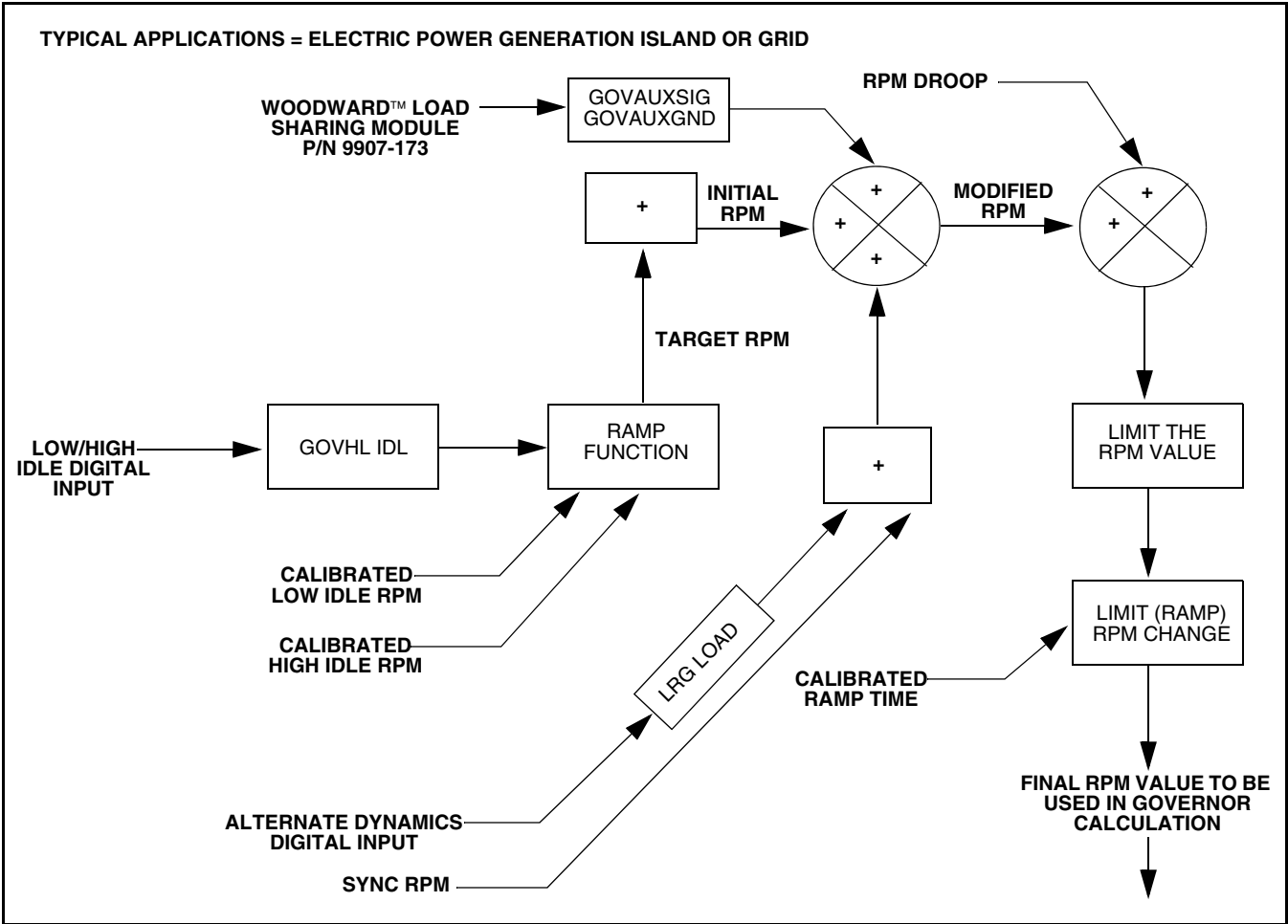


Figure 2.20-1 Logic Diagram Showing Fixed Speed

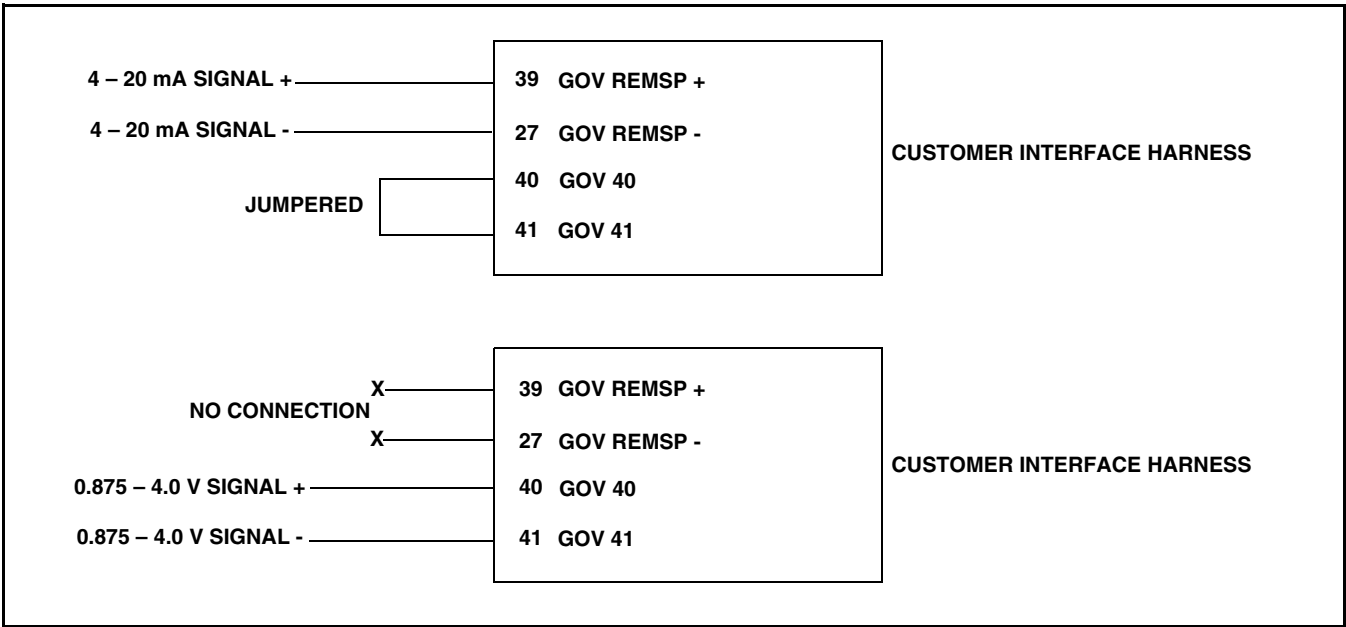


Figure 2.20-2 Connection Options for Variable Speed Setting Input

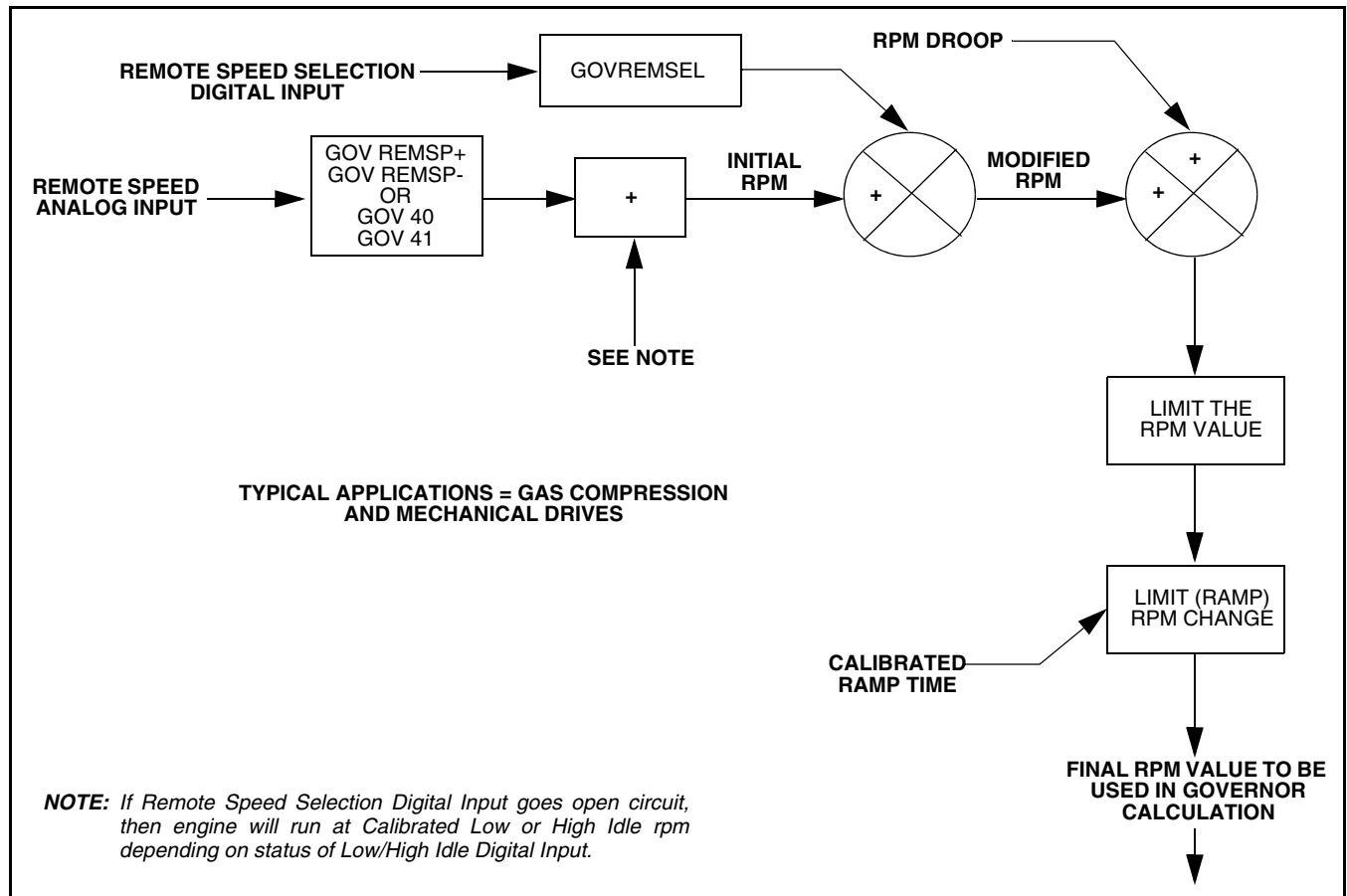


Figure 2.20-3 Logic Diagram Showing Variable Speed

LOAD CONTROL MODE

Load control mode is only applicable when the engine speed is already controlled by an external force such as an electric grid. To run in load control mode, the engine must be first synchronized to the electric grid. The ESM system has a unique feature for easier synchronization to the grid by better controlling idle speed by using the spark timing in addition to the throttle. Synchronizer or alternate dynamics mode can be enabled by bringing a digital input on the ECU to +24 VDC nominal. In addition to providing an excellent stable idle, synchronizer mode can also be used to offset the idle speed higher.

The SYNC RPM is adjusted so that the actual engine speed setpoint is approximately 0.2% higher than synchronous speed. For example, if the grid frequency is 60 Hz (1200 rpm), the high idle is adjusted so that the engine speed setpoint is 1.002 times 1200 rpm, which is 1202 rpm. This ensures that the electric phasing of the grid and the engine are different so that the phases will *slide* past each other.

When an external synchronizer determines that the voltage and phase of the generator match the grid, the breaker is closed. The load of the engine can now be controlled by an external load control such as the Woodward™ Load Sharing Module (Woodward™ P/N 9907-173) through the GOVAUXSIG and GOVAUXGND -2.5 to +2.5 volt input of the ESM system (see Figure 2.20-4).

The speed bias output of most load sharing devices can be configured to match the -2.5 to +2.5 volt input range of the ESM GOVAUXSIG and GOVAUXGND inputs. Refer to the load sharing device manual for information on how to configure the range and offset of the speed bias output of your load sharing device. Next start the engine and adjust the Proportional and Integral gains of the load sharing device to obtain stable operation of the engine power output. Refer to the load sharing device manual for more information on how to set the gains of the device.

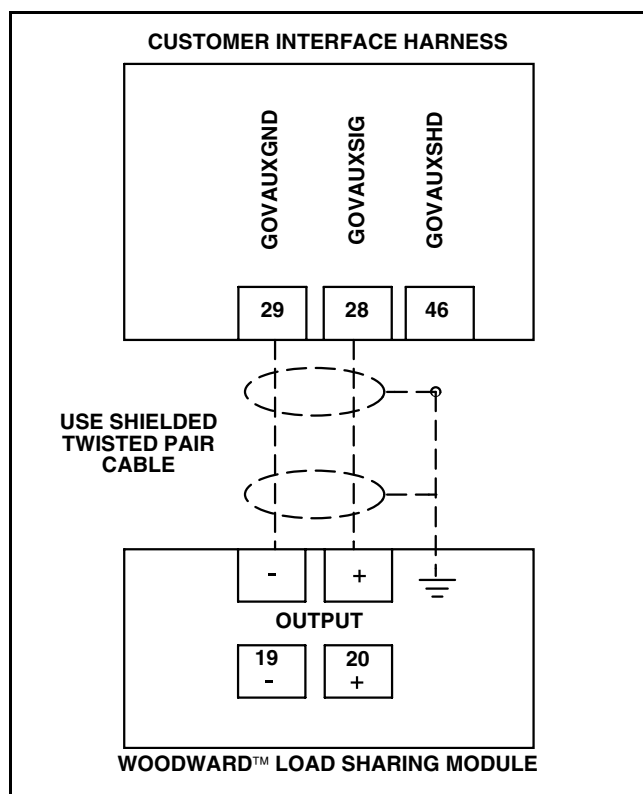


Figure 2.20-4 External Load Control – Woodward™ Load Sharing Module

ROTATING MOMENT OF INERTIA / ADJUSTING GAIN

The ESM system has the unique feature that correct gains for an engine model are preloaded to the ECU. Having the gains preloaded can greatly reduce startup time when compared to using aftermarket governors.

To make this work, the ECU needs only one piece of information from the customer: the rotating moment of inertia or load inertia of the driven equipment. Once this information is available, the ECU calculates the actual load changes on the engine based on speed changes. **Rotating moment of inertia is not the weight or mass of the driven equipment.** Rotating moment of inertia is needed for all driven equipment.

CAUTION Ensure that the correct rotating moment of inertia (load inertia) is programmed in ESP for the engine's driven equipment. Failure to program the moment of inertia for the driven equipment on the engine in ESP will lead to poor steady state and transient speed stability. Disregarding this information could result in product damage and/or personal injury.

Setting the rotating moment of inertia (or load inertia) with ESP is the first task when setting up an engine and **must** be done with the engine not rotating. The rotating moment of inertia value is programmed on the [F4] Governor Panel in ESP.

Refer to Section 3.10 *ESP Programming* "Programming Load Inertia" for programming steps.

FEEDFORWARD CONTROL (LOAD COMING)

The ESM system has a feature, Feedforward Control, that can be used to greatly improve engine response to large loads. One example of how this feature can be used would be in stand-alone electric power generation applications where the engine is supplying variable loads such as lights, miscellaneous small loads, and one large electric motor.

For example, the starter for a large electric motor could be routed to a PLC so that a request to start the electric motor would go through the PLC. When the PLC received the request to start the electric motor, it first would set the large load coming digital input on the ECU high for 0.5 seconds and then 1 second later actually start the electric motor. This would give the ESM system a 1 second head start to open the throttle even before the load was applied and the engine speed drops.

The behavior of the large load coming digital input can be customized through "trial and error" with ESP. The percent of rated load of the electric motor is set in the "Forward Torque" field on the [F4] Governor Panel. The Forward Delay is the lag time of the ESM system from receipt of the Load Coming signal until action is taken. As the **LRG LOAD** digital input goes high (8.6 – 36 volts), the engine speed should go above setpoint rpm for approximately 1 second before the load is applied. Typically the "Forward Torque" field is set to 125% and "Forward Delay" is programmed to optimize the system's behavior.

ACTUATOR AUTOMATIC CALIBRATION

To work correctly, the ESM system must know the fully closed and fully open end points of throttle actuator movement. Using ESP, the ESM system can be set up to automatically go through calibration each time the engine stops (except on Emergency Shutdown). Allow 30 seconds after the engine stops for the actuator calibration to finish. If the engine has been shut down by an Emergency Shutdown, then no actuator automatic calibration will occur. If a start signal is received while the actuator is calibrating, the calibration procedure will be aborted and the engine will initiate its start sequence.

Refer to Section 3.10 *ESP Programming* "Actuator Calibration" for more information.

SECTION 2.25

FUEL VALVE

FUEL VALVE

This section describes how the ESM system controls the main fuel valve and how to set up the ESM system for the customer's fuel quality.

 **CAUTION** Wire the customer-supplied fuel gas shut-off valve so it is controlled by the ESM system. If the fuel valve is controlled independently of the ESM system, fault codes will occur when the fuel valve is not actuated in sequence by the ESM system. Disregarding this information could result in product damage and/or personal injury.

 **CAUTION** The electrical interference from solenoids and other electrical switches will not be cyclic and can be as high as several hundred volts. This could cause faults within the ESM system that may or may not be indicated with diagnostics. Waukesha Engine requires a “freewheeling” diode be added across the coils of relays and solenoids to suppress high induced voltages that may occur when equipment is turned off. Failure to comply will void product warranty. Disregarding this information could result in product damage and/or personal injury.

The customer must supply a fuel gas shutoff valve that is to be installed and wired using the ESM system's Start Harness to the Power Distribution Box (see oversized fold-out at the end of Section 2.10 for wiring diagram). For VHP Extender Series engines, the valve is to be wired directly into the Power Distribution Box by the customer. The ESM system has software to correctly sequence the main and prechamber fuel valves on and off during starting and stopping. If the fuel valve is controlled independently of the ESM system, expect fault codes to occur when the fuel valve is not actuated in sequence by the ESM system.

The fuel valve should be a 24 VDC energized-to-open valve. Relay #3 in the Power Distribution Box supplies the fuel valve with battery voltage at a maximum of either 3 amps with the CSA approved Power Distribution Box, or 10 or 15 amps with the non-CSA approved Power Distribution Box. The VHP Extender Series Power Distribution Box supplies up to 15 amps to the valve using solid state circuitry with built-in short circuit protection.

NOTE: All inductive loads such as a fuel valve must have a suppression diode installed across the valve coil as close to the valve as is practical.

A fuel control harness is prewired to the Power Distribution Box through connector Start/Lean Burn on the side of the box. The other end of the harness is coiled and tie-wrapped to the engine.

The fuel valve harness is 10 ft. (3 m) long so the fuel valve can be located 10 ft. (3 m) from the center of the right side of the engine. Two wires are provided on the Start Harness from the Power Distribution Box. It is the packager's responsibility to connect the Start Harness wires to the fuel valve.

NOTE: Non Extender Series and 6-cylinder engines only – The harness provided by Waukesha Engine connects to the fuel valve and terminates in flexible conduit with a 1/2 inch NPT fitting.

For VHP Extender Series engines (including 7042GL/GSI engines), the valve is to be wired directly into the Power Distribution Box, with the wires terminated at the terminal block shown in Figure 2.05-2. The position FUEL V SW is the (+) connection, and FUEL V GND is the (-) connection. Rigid conduit, liquid-tight flexible conduit, or other industry standard should be used along with the correct fittings as appropriate to maintain resistance to liquid intrusion.

Refer to S-6656-23 (or current revision) “Natural Gas Pressure Limits to Engine-Mounted Regulator” in the *Waukesha Technical Data Manual (General Volume)* for minimum fuel pressure required for your application.

WKI

The Waukesha Knock Index (WKI) is an analytical tool, developed by Waukesha Engine, as a method for calculating the knock resistance of gaseous fuels. It is a calculated numeric value used to determine the optimum engine settings based on a specific site's fuel gas composition.

The WKI value can be determined using an application program for the Microsoft® Windows® XP operating system. The computer program will calculate the WKI value from a customer's gas analysis breakdown. The computer program has been distributed to Waukesha Technical Data Book holders and is also available by contacting a Distributor or Waukesha Engine Sales Engineering Department.

Once the WKI value is known, it can be entered into the ECU using the ESP software. This is important since spark timing and engine derate curves as a function of the WKI value are stored in the ECU.

See Section 3.10 *ESP Programming* "Programming WKI Value" for more information.

For applications with changing fuel conditions, such as a wastewater treatment plant with natural gas backup, the ESM system can be signaled about the fuel's changing WKI value in real-time using the two WKI analog input wires in the Customer Interface Harness. The calibration of the Customer Interface Wires, **WKI+** and **WKI-**, is shown in Table 2.25-1. An input less than 2 mA or greater than 22 mA indicates a wiring fault, and the default WKI value is used instead.

Table 2.25-1 Calibration of Remote WKI Input

ANALOG USER INPUT	4 mA	20 mA
WKI Fuel Quality Signal	20 WKI	135 WKI

SECTION 2.30

SAFETIES OVERVIEW

INDIVIDUAL SAFETY SHUTDOWNS

Individual safety shutdowns are discussed in this section. Should any of the safety shutdowns below be activated, a digital output from the ECU will go from open circuit to +24 VDC nominal. The cause of engine shutdown can be seen with the flashing LED code, with ESP, and through MODBUS®. Refer to Section 4.00 *Troubleshooting* “ESM System Fault Codes” for a list of ESM system alarm and shutdown codes.

The [F11] advanced screen is used to adjust alarm and shutdown setpoints for oil pressure, jacket water temperature, intake manifold temperature, and oil temperature. Alarm and shutdown setpoints can only be programmed in a safe direction and cannot exceed factory limits.

ENGINE OVERSPEED

The ESM system is calibrated by Waukesha Engine (not user-programmable) to perform an immediate emergency shutdown upon detection of engine speed greater than 110% of rated rpm. In addition, the ESM system will shut down an engine that is consistently run above rated rpm. For example, running a 1200 rpm VHP engine at 1250 rpm will cause a shutdown after a period of time calibrated by Waukesha Engine.

In addition to the engine overspeed calibrated by Waukesha Engine, the user has the option to program an engine overspeed shutdown to protect driven equipment for situations where the driven equipment is rated at a lower speed than the engine. Driven equipment overspeed is programmable from 0 to 2200 rpm on the [F3] Start-Stop Panel in ESP. If the programmed value of user overspeed for the driven equipment exceeds engine overspeed, the engine overspeed value takes precedence. For example, a VHP has a factory-programmed engine overspeed trip point of 1320 rpm. If the driven equipment overspeed is set to 1500 rpm, and the engine speed exceeds 1320 rpm, the engine will be shut down.

If the driven equipment overspeed is set to 1100 rpm and the engine speed exceeds 1100 rpm, but is less than 1320 rpm, the engine will be shut down.

LOW OIL PRESSURE

The ESM system is calibrated by Waukesha Engine to both alarm and shut down on low oil pressure. The alarm and shutdown points are listed in S-8382-2 (or latest revision) or Service Bulletin 1-2620E (or latest revision) for each engine family. The ESM system uses several techniques to avoid falsely tripping on low oil pressure when either starting or stopping the engine. The low oil pressure alarm and shutdown points are a function of engine speed. In addition, low oil pressure alarm and shutdowns are inhibited for a period of time calibrated by Waukesha Engine after engine start.

OIL OVER-TEMPERATURE

The ESM system is calibrated by Waukesha Engine to both alarm and shut down upon high oil temperature detection. High oil temperature alarm and shutdowns are inhibited for a period of time that is calibrated by Waukesha Engine after engine start.

COOLANT OVER-TEMPERATURE

The ESM system is calibrated by Waukesha Engine to both alarm and shut down upon high coolant temperature detection. The alarm and shutdown points are listed in S-8382-2 (or latest revision) or Service Bulletin 1-2620E (or latest revision) for each engine family. High coolant temperature alarm and shutdowns are inhibited for a period of time calibrated by Waukesha Engine after engine start or stop.

INTAKE MANIFOLD OVER-TEMPERATURE

The ESM system is calibrated by Waukesha Engine to both alarm and shut down upon high intake manifold temperature detection. The alarm and shutdown points are listed in S-8382-2 (or latest revision) or Service Bulletin 1-2620E (or latest revision) for each engine family. High intake manifold temperature alarm and shutdowns are inhibited for a period of time calibrated by Waukesha Engine after engine start or stop.

SAFETIES OVERVIEW

ENGINE EMERGENCY STOP BUTTONS

When either of the red emergency stop buttons mounted on the side of the engine is pressed, the engine will perform an emergency stop. In addition, if the IPM-D power fails, the engine will perform an emergency stop.

UNCONTROLLABLE ENGINE KNOCK

Uncontrollable engine knock will shut the engine down after a period of time calibrated by Waukesha Engine. A digital output from the ECU indicates that uncontrollable knock is occurring so that the customer can initiate some knock reduction strategy such as reducing engine load.

NOTE: *Uncontrollable knock is a safety shutdown on all ESM engines except those L5774LT engines built prior to January 2006.*

ENGINE OVERLOAD

If the engine is run at more than 10% over rated power (or percent specified by Waukesha Engine), it will be shut down after a period of time. The amount of time the engine is allowed to run at overload is determined by Waukesha Engine.

CUSTOMER-INITIATED EMERGENCY SHUTDOWN

If the customer emergency shutdown circuit opens either because of some driven equipment problem or failure of the wire, the engine will perform an emergency shutdown.

OVERCRANK

If the engine is cranked longer than the time calibrated by Waukesha Engine, the starting attempt is terminated, the ignition and fuel are stopped, and the starter motor is de-energized.

ENGINE STALL

If the engine stops rotating without the ECU receiving a shutdown signal from the customer's equipment, then the ESM system will perform an emergency shutdown. One reason for an engine stall would be failure of an upstream fuel valve starving the engine of fuel and causing a shutdown. The ESM system then shuts off the engine fuel shutoff valve and stops ignition so that should the upstream problem be fixed, the engine does not accidentally start again.

MAGNETIC PICKUP PROBLEMS

Failure of either camshaft or crankshaft magnetic pickups or wiring will trigger an emergency engine shutdown.

ECU INTERNAL FAULTS

Certain ECU internal faults will trigger an engine emergency shutdown.

SECURITY VIOLATION

The ECU is protected from unauthorized reprogramming. In addition, the calibrations programmed to the ECU are engine specific. If the user attempts to calibrate the ESM system with the wrong engine information, a security fault will occur.

ALARMS

The ESM system may also trigger a number of alarms, none of which will actively shut the engine down. If an alarm is tripped, a digital output on the ECU will go from open circuit to +24 VDC nominal. The cause of alarm can be seen with the flashing LED code, with ESP, and through MODBUS[®]. Refer to Section 4.00 *Troubleshooting* "ESM System Fault Codes" for list of ESM system alarm and shutdown codes.

If the customer wishes to shut down the engine on a sensor/wiring alarm of the oil pressure sensor (ALM211) or coolant temperature sensor (ALM333), use a 4 – 20 mA analog output or the values in MODBUS[®]. It is the customer's responsibility to supply a third party device (such as a PLC) to read either the oil pressure and/or coolant temperature 4 – 20 mA signal or MODBUS[®] outputs and generate a shutdown signal.

SECTION 2.35

ESM SYSTEM COMMUNICATIONS

MODBUS® (RS-485) COMMUNICATIONS

This section describes the MODBUS® slave RTU (Remote Terminal Unit) messages that the ECU is capable of transmitting. MODBUS® is an industrial communications network that uses the Master-Slave topology. MODBUS® was originally developed in 1978 by Modicon to allow PLC-to-sensor communications using RS-232 hardware. The standard has advanced to allow RS-485 (EIA/TIA-485 Standard) hardware and multidrop networking.

The RS-485 network hardware used in the ECU permits one master on the network with up to 32 devices. The ECU is capable of acting as a MODBUS® RTU slave at up to 19,200 baud over the RS-485 communications link of the ECU. The baud rate can be changed by using ESP to 1200, 2400, 9600, or 19,200 baud. The lower baud rates are to accommodate slower communications links such as radio or microwave modems.

In ESP the user can assign an identification number (1 of 247 unique addresses) to a particular ECU allowing other devices such as PLCs to share the network even if they use the same data fields.

The baud rate and the ECU identification number are user-programmable. No other programming is required in ESP for MODBUS®. Refer to Section 3.10 *ESP Programming* “Programming Baud Rate (MODBUS® Applications)” and “Programming ECU MODBUS® Slave ID” for more information.

Table 2.35-2 lists the function codes implemented in the ESM system.

NOTE: *The ECU will respond with exception responses wherever applicable and possible. See “MODBUS® Exception Responses” on page 2.35-3 for more information.*

All 16-bit quantities specified in this document are in Motorola format (most significant byte first). Similarly, when two 16-bit registers are joined to form a 32-bit double register, the most significant word comes first.

Example: The following is an example of the use of two 16-bit registers that are joined to form a 32-bit value:

Current engine hours use MODBUS® registers 40041 and 40042. If the value of register 40041 = 3 and register 40042 = 5474, then the total engine hours in seconds is:

$$3 \times 65536 + 5474 = 202082 \text{ seconds} \\ (\text{or } 56.13389 \text{ hours})$$

In order for communication to work between the master and slave units, the communication parameters must be adjusted to match (see Table 2.35-1). The ESM system is configured at the factory as 9600 baud, 8 data bits, none parity, and 1 stop bit.

Table 2.35-1 Communication Parameters

BAUD RATE	DATA BITS	PARITY	STOP BITS
1200	8	None	1
2400	8	None	1
9600	8	None	1
19,200	8	None	1

WIRING

The MODBUS® wiring consists of a two-wire, half-duplex RS-485 interface. RS-485 is ideal for networking multiple devices to one MODBUS® master (such as a PC or PLC). Since half duplex mode does not allow simultaneous transmission and reception, it is required that the master control direction of the data flow. The master controls all communication on the network while the ECU operates as a slave and simply responds to commands issued by the master. This Master-Slave topology makes it inexpensive to monitor multiple devices from either one PC or PLC.

NOTE: *It is possible to use a master with a full duplex RS-485 interface; however, it is necessary to connect the two positive and negative signals together. So Tx- and Rx- become “A” and Tx+ and Rx+ become “B.”*

Two MODBUS[®] wires are available at the end of the Customer Interface Harness (loose wires). The two wires are gray and labeled **RS 485A-** and **RS 485B+**. Refer to Table 2.10-1 for harness connection, and refer to Figure 2.10-3 for VHP Series Four 12-Cylinder Wiring Diagram.

RS-485 networking needs termination resistors if long wire runs are used. Termination resistors of 120 Ω are placed across the RS-485 A- and B+ wires at the devices at both ends of the network. For short distances of 32 ft. (10 m) or less and with slower baud rates, termination resistors are not needed.

NOTE: Typically, short distances of 32 ft. (10 m) would not require termination resistors; however, if you experience communication errors, first check the programmed baud rate on the [F11] Advanced Panel. The baud rate to be programmed is determined by the MODBUS[®] master. If communication errors persist, termination resistors may be necessary, even at short distances.

PROTOCOL

The MODBUS[®] protocol can be used in two different modes: RTU (Remote Terminal Unit) and ASCII (American Standard Code of Information Interchange). The ESM system works only in the RTU mode. In RTU mode every element is represented by 8 bits (except data that can consist of a variable number of successive bytes).

HOW DO I GET MODBUS[®] FOR MY PLC?

MODBUS[®] is typically a secondary protocol for many PLC manufacturers. Most PLC manufacturers use their own proprietary protocol and MODBUS[®] is either not supported or an option. However, third party suppliers have filled the gap and made MODBUS[®] available for a wide range of PLCs.

PERSONAL COMPUTERS

RS-485 cards for PCs are available from many sources; however, not all RS-485 cards are the same. Two-wire RS-485 cannot transmit and receive at the same time. Microsoft[®] Windows[®] does not turn off the transmitter without special software or additional hardware on the RS-485 card.

Before specifying PC software, make sure it has the ability to turn off the RS-485 transmitter or use a RS-485 card with special hardware to turn off the transmitter when not in use. National Instruments[™] makes one example of a RS-485 card with special hardware. To make the National Instruments[™] RS-485 card work with Lookout[™] software, the serial port should be set for **hardwired** with a receive gap of 30 bytes.

FUNCTIONALITY

The ECU is a MODBUS[®] slave and will provide data to a MODBUS[®] master device. The data that will be made available will include most filtered analog input values and some derived values. **No control is done through MODBUS[®].**

FAULT CODE BEHAVIOR

The MODBUS[®] fault codes behave exactly like the flashing LED codes. As soon as a fault is validated, it is latched and remains that way until either the engine is shut down and then restarted, or the fault codes are cleared using ESP.

NOTE: MODBUS[®] fault codes trigger when the LED codes cycle through the flashing code sequence. So when a new fault occurs, neither the MODBUS[®] nor the LEDs are updated until the current LED code flashing sequence is finished. Due to this behavior, you may notice up to a 30-second delay from when a fault occurs and when the fault is registered through MODBUS[®]. The length of delay will depend on the number of faults and the size of the digits in the fault code (for example, ALM211 will require less time to flash than ALM552).

The following scenario illustrates the fault code behavior.

The engine has been running without any alarm codes until a particularly hot day when the ECU detects a coolant over-temperature alarm. MODBUS[®] address 40008 goes from 0 to 333 and MODBUS[®] address 40007 goes from 0 to 1, alarm codes. MODBUS[®] addresses 40023 and 40024 contain the time the coolant over-temperature alarm was tripped in seconds. Finally, MODBUS[®] address 00006 changes from 0 to 1 indicating the alarm is currently active.

Later during the day, the ambient temperature cools and MODBUS[®] address 00006 changes back to 0 indicating the alarm is no longer active. All the other MODBUS[®] addresses remain the same.

The next day the battery voltage drops below 21 volts and ALM454 becomes active. MODBUS[®] address 40008 remains at 333 and MODBUS[®] address 40009 changes from 0 to 454. MODBUS[®] address 40007 changes from 1 to 2. MODBUS[®] addresses 40023 and 40024 contain the time in seconds that ALM333 became active. MODBUS[®] addresses 40025 and 40026 contain the time in seconds that ALM454 became active.

The communication network is susceptible to noise when no nodes are transmitting. Therefore, the network must be biased to ensure the receiver stays in a constant state when no data signal is present.

This can be done by connecting one pair of resistors on the RS-485 balanced pair: a pull-up resistor to a 5V voltage on the RS485A- circuit and a pull-down resistor to the common circuit on the RS485B+ circuit. The resistor must be between 450Ω and 650Ω. This must be implemented at one location for the whole serial bus. Alternatively, a Fail-Safe Bias Assembly is available (P/N P122048).

DATA TABLES

The MODBUS® function codes supported are codes 01 to 04. Table 2.35-2 lists the address IDs that are associated with each function code. The subsequent sections set out the message IDs in detail.

Function codes are located in Table 2.35-4 through Table 2.35-7.

Table 2.35-2 MODBUS® Function Codes

FUNCTION CODE	MODBUS® NAME	ADDRESS ID
01	Read Coil Status	0XXXX
02	Read Input Status	1XXXX
03	Read Holding Registers	4XXXX
04	Read Input Registers	3XXXX

NOTE: When performing the device addressing procedure, it is of great importance that there are not two devices with the same address. In such a case, the whole serial bus can behave in an abnormal way, with it being impossible for the master to communicate with all present slaves on the bus.

MODBUS® EXCEPTION RESPONSES

The ECU will respond with exception responses wherever applicable and possible.

When a master device sends a signal to a slave device, it expects a normal response. Four possible responses can occur from a master's signal:

- If the slave device receives the signal error-free and can handle the signal normally, a normal response is returned.
- If the slave device does not receive an error-free signal, no response is returned. The master program will eventually process a time-out condition for the signal.
- If the slave device receives the signal but detects an error, no response is returned. The master program will eventually process a time-out condition for the signal.
- If the slave device receives the signal error-free but cannot handle it, the slave will return an exception response informing the master of the nature of the error. See Table 2.35-3 for exception responses.

Table 2.35-3 MODBUS® Exception Responses

CODE	NAME	MEANING
01	ILLEGAL FUNCTION	The function code received in the signal is not an allowable action for the slave device.
02	ILLEGAL DATA ADDRESS	The data address received in the signal is not an allowable address for the slave device.

ESM SYSTEM COMMUNICATIONS

Table 2.35-4 Function Code 01 (0XXXX Messages)

MODBUS® ADDRESS	NAME	DESCRIPTION	ENGINEERING UNITS
00001	Main Fuel Valve	Status of the main fuel valve	1 = ON 0 = OFF
00002	Pre-Chamber Fuel Valve	Status of the prechamber fuel valve (if applicable)	1 = ON 0 = OFF
00003	Engine Running	Whether the engine is running or not running	1 = RUNNING 0 = OFF
00004	Starter Motor	Whether the starter motor is engaged or not	1 = ENGAGED 0 = OFF
00005	Pre/PostLube	Whether the pre/postlube pump is running	1 = RUNNING 0 = OFF
00006	Engine Alarm	Whether a validated alarm is active	1 = ON 0 = OFF
00007	Engine Shutdown	Whether the shutdown is active	1 = OK 0 = SHUTDOWN
00008	Engine Knocking	Whether the engine is in uncontrollable knock	1 = ON 0 = OFF
00009	No Spark	Whether the engine is experiencing a no-spark situation	1 = NO SPARK 0 = OK
00010	Ignition Power Level	Whether the ignition power level is high or low	1 = HIGH 0 = LOW
00011	Ignition Enabled	Whether the ignition is enabled or not	1 = ON 0 = OFF

Table 2.35-5 Function Code 02 (1XXXX Messages)

MODBUS® ADDRESS	NAME	DESCRIPTION	ENGINEERING UNITS
10001	Start Engine Signal	Whether the start engine signal is active	1 = Start Engine Signal High 0 = Start Engine Signal Low
10002	Normal Shutdown	Whether the normal shutdown signal is active	1 = Normal Shutdown 0 = OK To Run
10003	Emergency Shutdown	Whether the emergency shutdown signal is active	1 = Emergency Shutdown 0 = OK To Run
10004	Remote rpm Select	Whether the remote rpm analog input is active or inactive	1 = Remote rpm Select Active 0 = Remote rpm Select Inactive
10005	Run High Idle	Whether the run high-idle digital input is active	1 = Run Engine At High Idle 0 = Run Engine At Low Idle
10006	Load Coming	Whether the load-coming digital input is active	1 = Load Coming Digital Input Active 0 = Load Coming Digital Input Inactive
10007	Alternate Dynamics/ Synchronizer Mode	Whether the alternate governor dynamics is active	1 = Alternate Gov Dynamics Is Active 0 = Alternate Gov Dynamics Is Inactive
10008	Lockout Button/Ignition Module	Whether either the lockout button has been depressed or the IPM-D has failed, or is not powered	1 = Lockout Active 0 = Lockout Inactive
10009	User Digital Input 1	Whether user digital input 1 is high	1 = User DIP 1 High 0 = User DIP 1 Inactive
10010	User Digital Input 2	Whether user digital input 2 is high	1 = User DIP 2 High 0 = User DIP 2 Inactive
10011	User Digital Input 3	Whether user digital input 3 is high	1 = User DIP 3 High 0 = User DIP 3 Inactive
10012	User Digital Input 4	Whether user digital input 4 is high	1 = User DIP 4 High 0 = User DIP 4 Inactive
10013	Alternator	Whether the engine-driven alternator is operating correctly	1 = Alternator OK 0 = Alternator Not OK
10014	AFR Manual/Automatic Status (Left Bank)	Whether the air/fuel ratio control is in manual or automatic mode	1 = Automatic Mode 0 = Manual Mode
10015	AFR Manual/Automatic Status (Right Bank)	Whether the air/fuel ratio control is in manual or automatic mode	1 = Automatic Mode 0 = Manual Mode
10016	Reserved For Future Use		
10017	Reserved For Future Use		

Table 2.35-6 Function Code 03 (4XXXX Messages) (Part 1 of 2)

MODBUS® ADDRESS	NAME	ENGINEERING UNITS
40001	Number of ESD fault codes	16-bit unsigned integer that goes from 0 to 5
40002	First ESD fault code to occur*	16-bit unsigned integer that goes from 111 to 555, excluding any values that contain zeros (see Table 4.00-3 for ESD Fault Codes)
40003	Second ESD fault code to occur*	16-bit unsigned integer that goes from 111 to 555, excluding any values that contain zeros (see Table 4.00-3 for ESD Fault Codes)
40004	Third ESD fault code to occur*	16-bit unsigned integer that goes from 111 to 555, excluding any values that contain zeros (see Table 4.00-3 for ESD Fault Codes)
40005	Fourth ESD fault code to occur*	16-bit unsigned integer that goes from 111 to 555, excluding any values that contain zeros (see Table 4.00-3 for ESD Fault Codes)
40006	Fifth ESD fault code to occur*	16-bit unsigned integer that goes from 111 to 555, excluding any values that contain zeros (see Table 4.00-3 for ESD Fault Codes)
40007	Number of ALM fault codes	16-bit unsigned integer that goes from 0 to 5
40008	First ALM fault code to occur*	16-bit unsigned integer that goes from 111 to 555, excluding any values that contain zeros (see Table 4.00-2 for ALM Fault Codes)
40009	Second ALM fault code to occur*	16-bit unsigned integer that goes from 111 to 555, excluding any values that contain zeros (see Table 4.00-2 for ALM Fault Codes)
40010	Third ALM fault code to occur*	16-bit unsigned integer that goes from 111 to 555, excluding any values that contain zeros (see Table 4.00-2 for ALM Fault Codes)
40011	Fourth ALM fault code to occur*	16-bit unsigned integer that goes from 111 to 555, excluding any values that contain zeros (see Table 4.00-2 for ALM Fault Codes)
40012	Fifth ALM fault code to occur*	16-bit unsigned integer that goes from 111 to 555, excluding any values that contain zeros (see Table 4.00-2 for ALM Fault Codes)
40013 40014	Engine operating hours (in seconds) of most recent ESD fault code	32-bit unsigned integer – full range
40015 40016	Engine operating hours (in seconds) of second most recent ESD fault code	32-bit unsigned integer – full range
40017 40018	Engine operating hours (in seconds) of third most recent ESD fault code	32-bit unsigned integer – full range
40019 40020	Engine operating hours (in seconds) of fourth most recent ESD fault code	32-bit unsigned integer – full range
40021 40022	Engine operating hours (in seconds) of fifth most recent ESD fault code	32-bit unsigned integer – full range
40023 40024	Engine operating hours (in seconds) of most recent ALM fault code	32-bit unsigned integer – full range
40025 40026	Engine operating hours (in seconds) of second most recent ALM fault code	32-bit unsigned integer – full range
40027 40028	Engine operating hours (in seconds) of third most recent ALM fault code	32-bit unsigned integer – full range
40029 40030	Engine operating hours (in seconds) of fourth most recent ALM fault code	32-bit unsigned integer – full range
40031 40032	Engine operating hours (in seconds) of fifth most recent ALM fault code	32-bit unsigned integer – full range
40033	Desired engine load	16-bit unsigned integer that goes from 0 to 2304 (0 – 112%)
40034	Actual engine load	16-bit unsigned integer that goes from 0 to 2560 (0 – 125%)
40035	Position of stepper motor 1 – left bank	16-bit unsigned integer that goes from 0 to 20,000
40036	Position of stepper motor 2 – right bank	16-bit unsigned integer that goes from 0 to 20,000
40037	Reserved For Future Use	
40038	Reserved For Future Use	

ESM SYSTEM COMMUNICATIONS

Table 2.35-6 Function Code 03 (4XXXX Messages) (Continued), (Part 2 of 2)

MODBUS® ADDRESS	NAME	ENGINEERING UNITS
40039	Reserved For Future Use	
40040	Reserved For Future Use	
40041 40042	Current engine operating hours (in seconds)	32-bit unsigned integer – full range
40043	Rich stepper maximum motor limit of active fuel (left bank)	16-bit unsigned integer that goes from 0 to 20,000
40044	Lean stepper minimum motor limit of active fuel (left bank)	16-bit unsigned integer that goes from 0 to 20,000
40045	Rich stepper maximum motor limit of active fuel (right bank)	16-bit unsigned integer that goes from 0 to 20,000
40046	Lean stepper minimum motor limit of active fuel (right bank)	16-bit unsigned integer that goes from 0 to 20,000
40047	Reserved For Future Use	
40048	Reserved For Future Use	
40049	Reserved For Future Use	
40050	Reserved For Future Use	
40051	Countdown in seconds until engine starts once starter pressed	16-bit unsigned integer that goes from 0 to 20,000

NOTE: * For a description of the MODBUS® fault code behavior, see “Fault Code Behavior” on page 2.35-2.

Table 2.35-7 Function Code 04 (3XXXX Messages) (Part 1 of 4)

MODBUS® ADDRESS	NAME	SCALING	ENGINEERING UNITS
30001	Average rpm	Average engine rpm * 4	16-bit unsigned integer that goes from 0 to 8800 (0 – 2200 rpm)
30002	Oil pressure	Oil pressure * 2 in units of kPa gauge	16-bit unsigned integer that goes from 0 to 2204 (0 – 1102 kPa)
30003	Intake manifold absolute pressure	Intake manifold pressure * 4 in units of kPa absolute	16-bit unsigned integer that goes from 0 to 2304 (0 – 576 kPa)
30004	Reserved For Future Use		
30005	Throttle position	Throttle position in units of percent open * 20.48	16-bit unsigned integer that goes from 0 to 2048 (0 – 100%)
30006	Reserved For Future Use		
30007	Reserved For Future Use		
30008	Coolant outlet temperature	(Coolant outlet temperature in C + 40) * 8	16-bit unsigned integer that goes from 0 to 1520 (-40 – 150° C)
30009	Spark timing 1	(Spark timing + 15) * 16 of 1st cylinder in the firing order	16-bit unsigned integer that goes from 0 to 960 (-15 – 45° BTDC)
30010	Spark timing 2	(Spark timing + 15) * 16 of 2nd cylinder in the firing order	16-bit unsigned integer that goes from 0 to 960 (-15 – 45° BTDC)
30011	Spark timing 3	(Spark timing + 15) * 16 of 3rd cylinder in the firing order	16-bit unsigned integer that goes from 0 to 960 (-15 – 45° BTDC)
30012	Spark timing 4	(Spark timing + 15) * 16 of 4th cylinder in the firing order	16-bit unsigned integer that goes from 0 to 960 (-15 – 45° BTDC)
30013	Spark timing 5	(Spark timing + 15) * 16 of 5th cylinder in the firing order	16-bit unsigned integer that goes from 0 to 960 (-15 – 45° BTDC)
30014	Spark timing 6	(Spark timing + 15) * 16 of 6th cylinder in the firing order	16-bit unsigned integer that goes from 0 to 960 (-15 – 45° BTDC)
30015	Spark timing 7	(Spark timing + 15) * 16 of 7th cylinder in the firing order	16-bit unsigned integer that goes from 0 to 960 (-15 – 45° BTDC)
30016	Spark timing 8	(Spark timing + 15) * 16 of 8th cylinder in the firing order	16-bit unsigned integer that goes from 0 to 960 (-15 – 45° BTDC)
30017	Spark timing 9	(Spark timing + 15) * 16 of 9th cylinder in the firing order	16-bit unsigned integer that goes from 0 to 960 (-15 – 45° BTDC)
30018	Spark timing 10	(Spark timing + 15) * 16 of 10th cylinder in the firing order	16-bit unsigned integer that goes from 0 to 960 (-15 – 45° BTDC)
30019	Spark timing 11	(Spark timing + 15) * 16 of 11th cylinder in the firing order	16-bit unsigned integer that goes from 0 to 960 (-15 – 45° BTDC)

Table 2.35-7 Function Code 04 (3XXXX Messages) (Continued), (Part 2 of 4)

MODBUS® ADDRESS	NAME	SCALING	ENGINEERING UNITS
30020	Spark timing 12	(Spark timing + 15) * 16 of 12th cylinder in the firing order	16-bit unsigned integer that goes from 0 to 960 (-15 – 45° BTDC)
30021	Spark timing 13	(Spark timing + 15) * 16 of 13th cylinder in the firing order	16-bit unsigned integer that goes from 0 to 960 (-15 – 45° BTDC)
30022	Spark timing 14	(Spark timing + 15) * 16 of 14th cylinder in the firing order	16-bit unsigned integer that goes from 0 to 960 (-15 – 45° BTDC)
30023	Spark timing 15	(Spark timing + 15) * 16 of 15th cylinder in the firing order	16-bit unsigned integer that goes from 0 to 960 (-15 – 45° BTDC)
30024	Spark timing 16	(Spark timing + 15) * 16 of 16th cylinder in the firing order	16-bit unsigned integer that goes from 0 to 960 (-15 – 45° BTDC)
30025	Desired spark timing	(Spark timing + 15) * 16	16-bit unsigned integer that goes from 0 to 960 (-15 – 45° BTDC)
30026	Battery voltage	Battery voltage * 16	16-bit unsigned integer that goes from 0 to 640 (0 – 40 VDC)
30027	Intake manifold air temperature (left bank)	(Intake manifold air temperature in C + 40) * 8	16-bit unsigned integer that goes from 0 to 1520 (-40 – 150° C)
30028	Oil temperature	(Oil temperature in C + 40) * 8	16-bit unsigned integer that goes from 0 to 2048 (-40 – 216° C)
30029	First exhaust temperature	(1st exhaust temperature in C + 40) * 2 (left bank)	16-bit unsigned integer that goes from 0 to 1840 (-40 – 880° C)
30030	Second exhaust temperature	(2nd exhaust temperature in C + 40) * 2 (right bank)	16-bit unsigned integer that goes from 0 to 1840 (-40 – 880° C)
30031	Reserved For Future Use		
30032	Reserved For Future Use		
30033	Setpoint rpm	Setpoint rpm * 4 Example: If register 30033 = 4000, then 4000/4 = 1000 rpm	16-bit unsigned integer that goes from 0 to 8800 (0 – 2200 rpm)
30034	IMAP left bank/rear	Intake manifold pressure * 4 in units of kPa absolute	16-bit unsigned integer that goes from 0 to 2304 (0 – 576 kPa)
30035	IMAP right bank/front	Intake manifold pressure * 4 in units of kPa absolute	16-bit unsigned integer that goes from 0 to 2304 (0 – 576 kPa)
30036	Reserved For Future Use		
30037	Ambient temperature	(Ambient temp. in Centigrade + 40) * 8	16-bit unsigned integer that goes from 0 to 1120 (-40 – 100° C)
30038 30039	Digital input values	A 32-bit number representing the status of all of the 1XXXX messages NOTE: For more information on addresses 30038–30039, see “Additional Information on MODBUS® Addresses 30038 – 30041” on page 2.35-10.	32-bit unsigned integer – full range
30040 30041	Digital output values	A 32-bit number representing the status of all of the 0XXXX messages NOTE: For more information on addresses 30040–30041, see “Additional Information on MODBUS® Addresses 30038 – 30041” on page 2.35-10.	32-bit unsigned integer – full range
30042	Reserved For Future Use		
30043	Reserved For Future Use		
30044	Rich burn Lambda actual 1 (left bank)	Lambda * 4096	16-bit unsigned integer that goes from 0.9000 to 1.1000
30045	Rich burn Lambda actual 1 (right bank)	Lambda * 4096	16-bit unsigned integer that goes from 0.9000 to 1.1000
30046	Reserved For Future Use		
30047	Reserved For Future Use		
30048	WKI value	(WKI -16) *16	16-bit unsigned integer that goes from 0 to 2048 (16 – 144 WKI)
30049	Reserved For Future Use		
30050	Reserved For Future Use		
30051	Reserved For Future Use		

ESM SYSTEM COMMUNICATIONS

Table 2.35-7 Function Code 04 (3XXXX Messages) (Continued), (Part 3 of 4)

MODBUS® ADDRESS	NAME	SCALING	ENGINEERING UNITS
30052	Reserved For Future Use		
30053	Reserved For Future Use		
30054	Reserved For Future Use		
30055	Reserved For Future Use		
30056	Reserved For Future Use		
30057	Reserved For Future Use		
30058	The ECU temperature	(Temperature in Centigrade + 40) * 8	16-bit unsigned integer that goes from 0 to 1120 (-40 – 100° C)
30059	The voltage from the left bank rich burn oxygen sensor	Volts * 1024	16-bit unsigned integer that goes from 0 to 1536 (0 – 1.5 VDC)
30060	The voltage from the right bank rich burn oxygen sensor	Volts * 1024	16-bit unsigned integer that goes from 0 to 1536 (0 – 1.5 VDC)
30061	The rpm modification value from a Woodward™ Generator control	(rpm + 250) * 4	16-bit unsigned integer that goes from 0 to 2000 (-250 – 250 rpm)
30062	Engine torque	% * 20.48	16 bit unsigned integer that goes from 0 to 2560 (0 to 125%)
30063	Rated torque	% * 20.48	16 bit unsigned integer that goes from 0 to 2560 (0 to 125%)
30064	Spark reference number cyl. #1 in firing order	Value * 1	16-bit unsigned integer that goes from 0 to 255
30065	Spark reference number cyl. #2 in firing order	Value * 1	16-bit unsigned integer that goes from 0 to 255
30066	Spark reference number cyl. #3 in firing order	Value * 1	16-bit unsigned integer that goes from 0 to 255
30067	Spark reference number cyl. #4 in firing order	Value * 1	16-bit unsigned integer that goes from 0 to 255
30068	Spark reference number cyl. #5 in firing order	Value * 1	16-bit unsigned integer that goes from 0 to 255
30069	Spark reference number cyl. #6 in firing order	Value * 1	16-bit unsigned integer that goes from 0 to 255
30070	Spark reference number cyl. #7 in firing order	Value * 1	16-bit unsigned integer that goes from 0 to 255
30071	Spark reference number cyl. #8 in firing order	Value * 1	16-bit unsigned integer that goes from 0 to 255
30072	Spark reference number cyl. #9 in firing order	Value * 1	16-bit unsigned integer that goes from 0 to 255
30073	Spark reference number cyl. #10 in firing order	Value * 1	16-bit unsigned integer that goes from 0 to 255
30074	Spark reference number cyl. #11 in firing order	Value * 1	16-bit unsigned integer that goes from 0 to 255
30075	Spark reference number cyl. #12 in firing order	Value * 1	16-bit unsigned integer that goes from 0 to 255
30076	Spark reference number cyl. #13 in firing order	Value * 1	16-bit unsigned integer that goes from 0 to 255
30077	Spark reference number cyl. #14 in firing order	Value * 1	16-bit unsigned integer that goes from 0 to 255

Table 2.35-7 Function Code 04 (3XXXX Messages) (Continued), (Part 4 of 4)

MODBUS® ADDRESS	NAME	SCALING	ENGINEERING UNITS
30078	Spark reference number cyl. #15 in firing order	Value * 1	16-bit unsigned integer that goes from 0 to 255
30079	Spark reference number cyl. #16 in firing order	Value * 1	16-bit unsigned integer that goes from 0 to 255
30080	Rich burn setpoint Lambda	Lambda * 4096	16-bit unsigned integer that goes from 0.9000 to 1.1000
30081	Reserved For Future Use		
30082	Reserved For Future Use		
30083	Reserved For Future Use		
30084	Oil Temperature Alarm Limit	(Oil temperature in C + 40) * 8	16-bit unsigned integer that goes from 0 to 2048 (-40 to 216° C)
30085	Oil Temperature Shutdown Limit	(Oil temperature in C + 40) * 8	16-bit unsigned integer that goes from 0 to 2048 (-40 to 216° C)
30086	IMAT Alarm Limit	(Intake manifold air temperature in C + 40) * 8	16-bit unsigned integer that goes from 0 to 1520 (-40 to 150° C)
30087	IMAT Shutdown Limit	(Intake manifold air temperature in C + 40) * 8	16-bit unsigned integer that goes from 0 to 1520 (-40 to 150° C)
30088	Coolant Temperature Alarm Limit	(Coolant temperature in C + 40) * 8	16-bit unsigned integer that goes from 0 to 1520 (-40 to 150° C)
30089	Coolant Temperature Shutdown Limit	(Coolant temperature in C + 40) * 8	16-bit unsigned integer that goes from 0 to 1520 (-40 to 150° C)
30090	Gauge Oil Pressure Alarm Limit	Oil pressure * 2 in units of kPa gauge	16-bit unsigned integer that goes from 0 to 2204 (0 to 1102 kPa)
30091	Gauge Oil Pressure Shutdown Limit	Oil pressure * 2 in units of kPa gauge	16-bit unsigned integer that goes from 0 to 2204 (0 to 1102 kPa)

NOTE: Engine firing order is stamped on the engine nameplate. The VHP Series Four® 6-cylinder engine firing order is: 1, 5, 3, 6, 2, 4. The VHP Series Four® 12-cylinder engine firing order is: 1R, 6L, 5R, 2L, 3R, 4L, 6R, 1L, 2R, 5L, 4R, 3L.

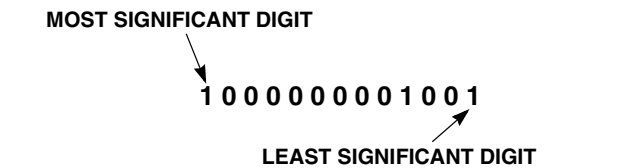
ADDITIONAL INFORMATION ON MODBUS®
ADDRESSES 30038 – 30041

To save programming time, one MODBUS® address can be read that provides information on up to 16 additional addresses. MODBUS® address 30039 (30038 is not currently used) provides values for 1XXXX MODBUS® messages. MODBUS® address 30041 (30040 is not currently used) provides values for 0XXXX MODBUS® messages. These additional addresses can be read by converting the 30039 and 30041 values to binary numbers.

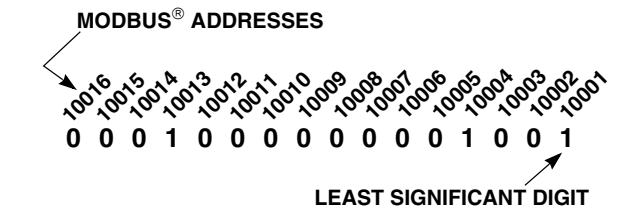
For addresses 10001 – 10016, convert register 30039 to a binary number (see Example 1). For addresses 00001 – 00016, convert register 30041 to a binary number (see Example 2). Then use the binary number to determine the status of the 1XXXX or 0XXXX messages using Table 2.35-5.

Example 1:

In this example, one 16-bit number is used to represent the status of the first 16 1XXXX messages. First the value of register 30039 must be converted from decimal to binary code. If the value of register 30039 = 4105, then that value, 4105, must be converted to a binary number. In binary code, 4105 = 1000000001001.



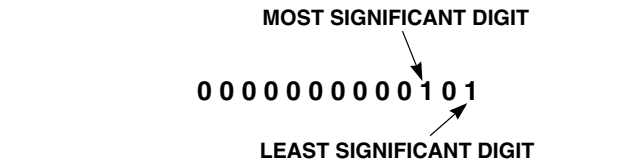
Each 0 or 1 represents a 1XXXX MODBUS® address starting with the least significant digit.



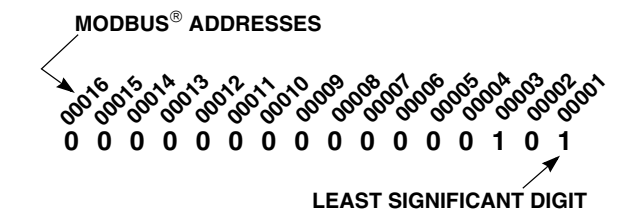
“ON” corresponds to a 1, and “OFF” corresponds to a 0 (zero). So addresses 10001, 10004, and 10013 are “ON.” This means that referring to Table 2.35-5 on page 2.35-4 in this section, the Start Engine Signal is active, the Remote rpm Select is active, and the Alternator is OK. All other 1XXXX MODBUS® messages are off or inactive.

Example 2:

In this example, one 16-bit number is used to represent the status of the first 16 0XXXX messages. First the value of register 30041 must be converted from decimal to binary code. If the value of register 30041 = 5, then that value, 5, must be converted to a binary number. In binary code, 5 = 101.



Each 0 or 1 represents a 0XXXX MODBUS® address starting with the least significant digit.



“ON” corresponds to a 1, and “OFF” corresponds to a 0 (zero). So addresses 00001 and 00003 are “ON.” This means that referring to Table 2.35-4 on page 2.35-4 in this section, the Main Fuel Valve is on and the engine is running. All other 0XXXX MODBUS® messages are off or inactive.

LOCAL CONTROL PANEL

This section describes how the ESM system interacts with a local customer-supplied control panel. With the ESM system, the packager may choose any compatible control panel providing the packager flexibility.

LOCAL DISPLAYS SUCH AS A TACHOMETER

The ESM system has a number of 4 – 20 mA analog outputs that can be either read into a PLC or read with a local display such as those made by Newport Electronics, Simpson, or Omega (see Table 2.35-8). The displays can be used for locally mounted tachometer, oil pressure, coolant temperature, or intake manifold pressure displays. Displays are available in 24 VDC, AC, or loop powered, the latter requiring no external power source.

NOTE: Non Extender Series® Engines – Ignition powered tachometers using the G-lead of the IPM-D are strongly discouraged because an accidental short of the G-lead to ground will stop the ignition from firing, preventing the engine from running.

Table 2.35-8 Calibration of Analog Outputs

ANALOG OUTPUT	WIRE NAME	4 mA	20 mA
Average rpm	PROG OP1	0 rpm	2016 rpm
Oil pressure	PROG OP2	0 psig (0 kPa)	100 psig (690 kPa)
Coolant temperature	PROG OP3	32° F (0° C)	320° F (160° C)
Intake manifold absolute pressure	PROG OP4	0 in-hg Abs. (0 kPa Abs.)	149 in-hg Abs. (504 kPa Abs.)
Percentage of rated torque the engine is producing (not applicable for 7042GL/GSI engines)	ACT LOAD%	0%	125%

USER DIGITAL INPUTS

There are four digital inputs labeled USER DIP 1, USER DIP 2, USER DIP 3, and USER DIP 4 in the Customer Interface Harness. When a +24 VDC signal is applied to one of these inputs, ALM541 is activated by the ESM system. The alarm is recorded in the ESP Fault Log and the yellow Status LED on the front of the ECU flashes the alarm code.

The purpose of these four digital inputs is to provide system diagnostic capability for customer-supplied equipment. Since non-volatile memory is not always available with the local control package, the USER DIP makes it possible to wire external signals into the ESM system so that a service technician can more quickly find the source of customer equipment problems. **Note that only an alarm signal is activated – no other control action is taken by the ESM when one of the USER DIPs goes high!**

The following examples explain how the USER DIP inputs can be used in the field.

Example 1

An example using one of these USER DIP inputs would be to wire an oil level alarm into the ESM system. This level sensor is of the Normally Open type, where the contacts are open when the oil is at proper level, and the contacts close to complete a signal path when the oil level falls too low (see Figure 2.35-1).

When the oil level is low, the contacts complete a +24 VDC signal into the USER DIP and ALM541 for USER DIP 1 is activated. Also, the yellow Status LED on the ECU flashes the alarm code.

NOTE: The negative side of the 24 VDC supply must be connected to the customer reference ground wire labeled LOGIC GND.

Example 2

If a solid state level sensor is used, of the type that completes a path to ground (called an open collector), when the oil falls below a certain level, the logic must be inverted. Remember that the USER DIP needs +24 VDC to activate an alarm condition. A Normally Open relay contact is used to generate the correct signal. This example is shown in Figure 2.35-2.

When the oil level is high, the sensor does not activate, so it holds the base of the relay coil at supply voltage. The relay contacts remain open, and the USER DIP is low. When the oil level becomes low, the sensor completes the circuit to ground by sinking current, and the relay coil energizes. This causes the contacts to close and +24 VDC is applied to the USER DIP and ALM541 is activated. Also, the yellow Status LED on the ECU flashes the alarm code.

Example 3

The oil level sensor can also be used to trigger an engine shutdown. Since the ESD digital input must remain at +24 VDC for the engine to run, and opening the circuit will cause a shutdown, inverted logic can be used with a Normally Closed relay contact to properly manipulate the signal. This example is shown in Figure 2.35-3.

When the oil level becomes low, the relay is energized as in the previous example, and the ESD input is opened, resulting in an engine shutdown and shutdown code ESD222. Also, the red Status LED on the ECU flashes the shutdown code.

NOTE: The engine cannot be restarted until the fault condition, in this example the low oil level, is corrected.

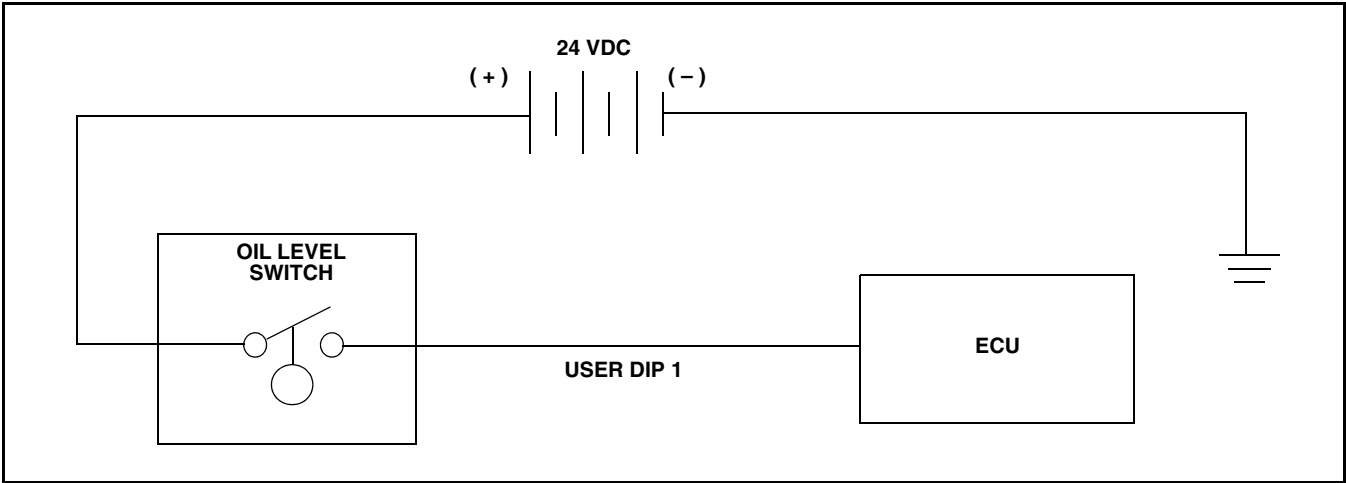


Figure 2.35-1 Example: User Digital Input Used with Oil Level Switch (Normally Open Type)

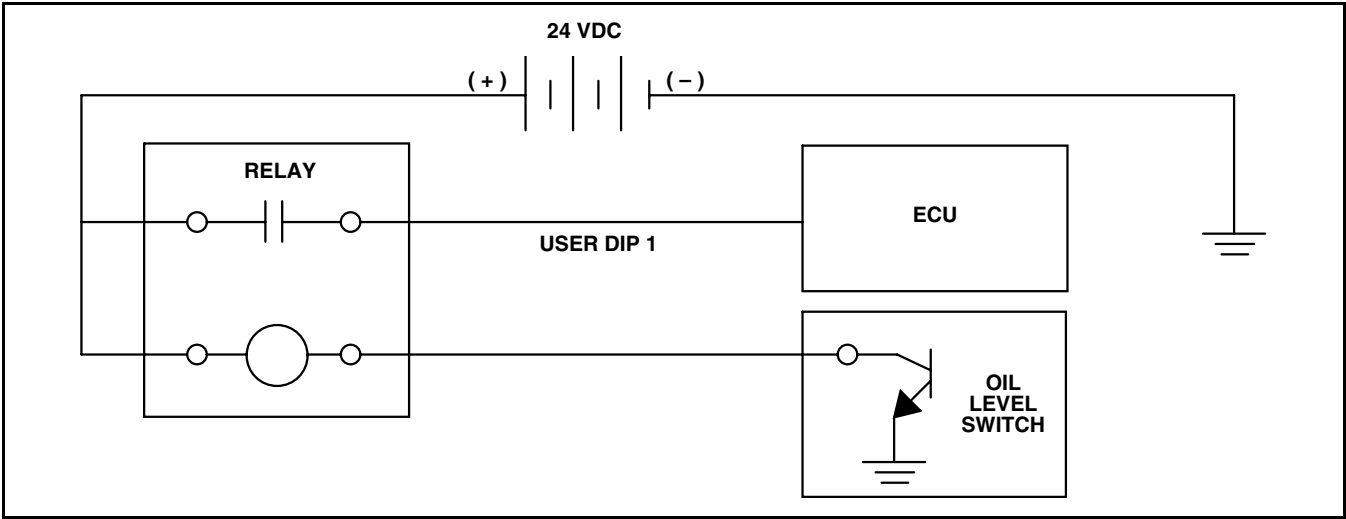


Figure 2.35-2 Example: User Digital Input Used with Solid State Level Sensor (Open Collector)

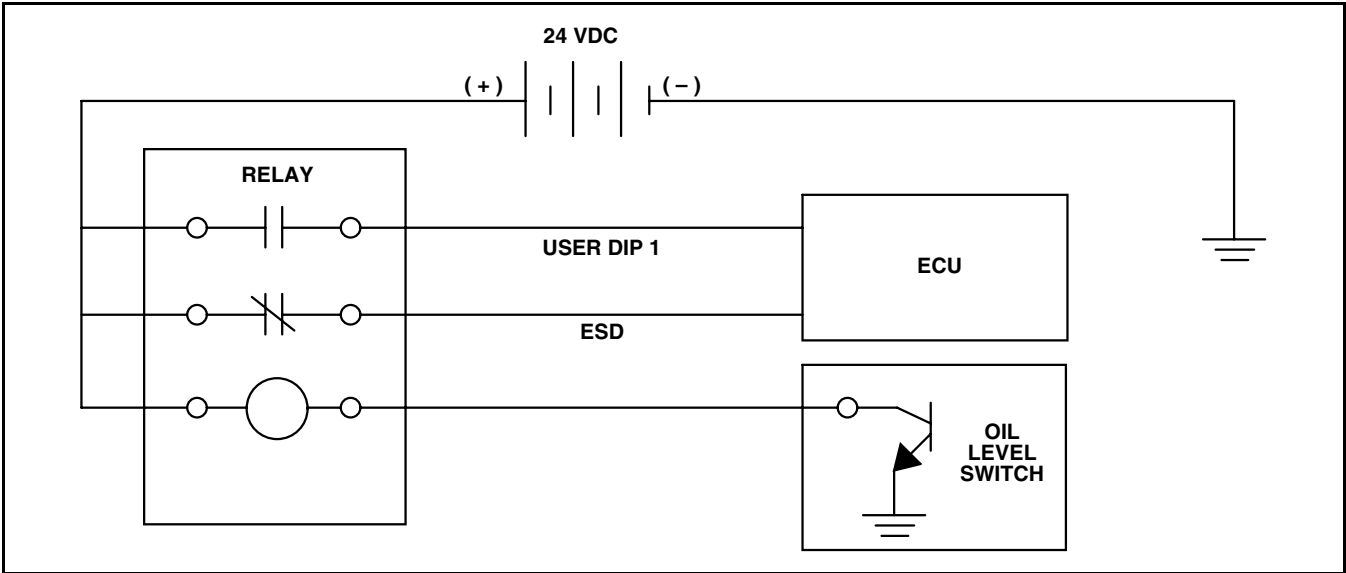


Figure 2.35-3 Example: User Digital Input Used to Trigger an Engine Shutdown

CONTENTS

SECTION 3.00 – INTRODUCTION TO ESP

SECTION 3.05 – ESP PANEL DESCRIPTIONS

SECTION 3.10 – ESP PROGRAMMING

SECTION 3.00

INTRODUCTION TO ESP

ELECTRONIC SERVICE PROGRAM (ESP)

DESCRIPTION OF ESP



WARNING

Explosion Hazard – Do not disconnect equipment unless power has been switched off or the area is known to be non-hazardous. Improper maintenance or misuse could result in severe personal injury or death.

The PC-based ESM Electronic Service Program (ESP) is the primary means of obtaining information on system status. ESP provides a user-friendly, graphical interface in a Microsoft® Windows® XP operating system environment. (see Figure 3.00-1). If the user needs help, system information, or troubleshooting information while using the ESP software, an electronic help file is included.

ESP is a diagnostic tool and is the means by which the information recorded to the ECU fault logs can be read. Minimal site-specific programming is required.

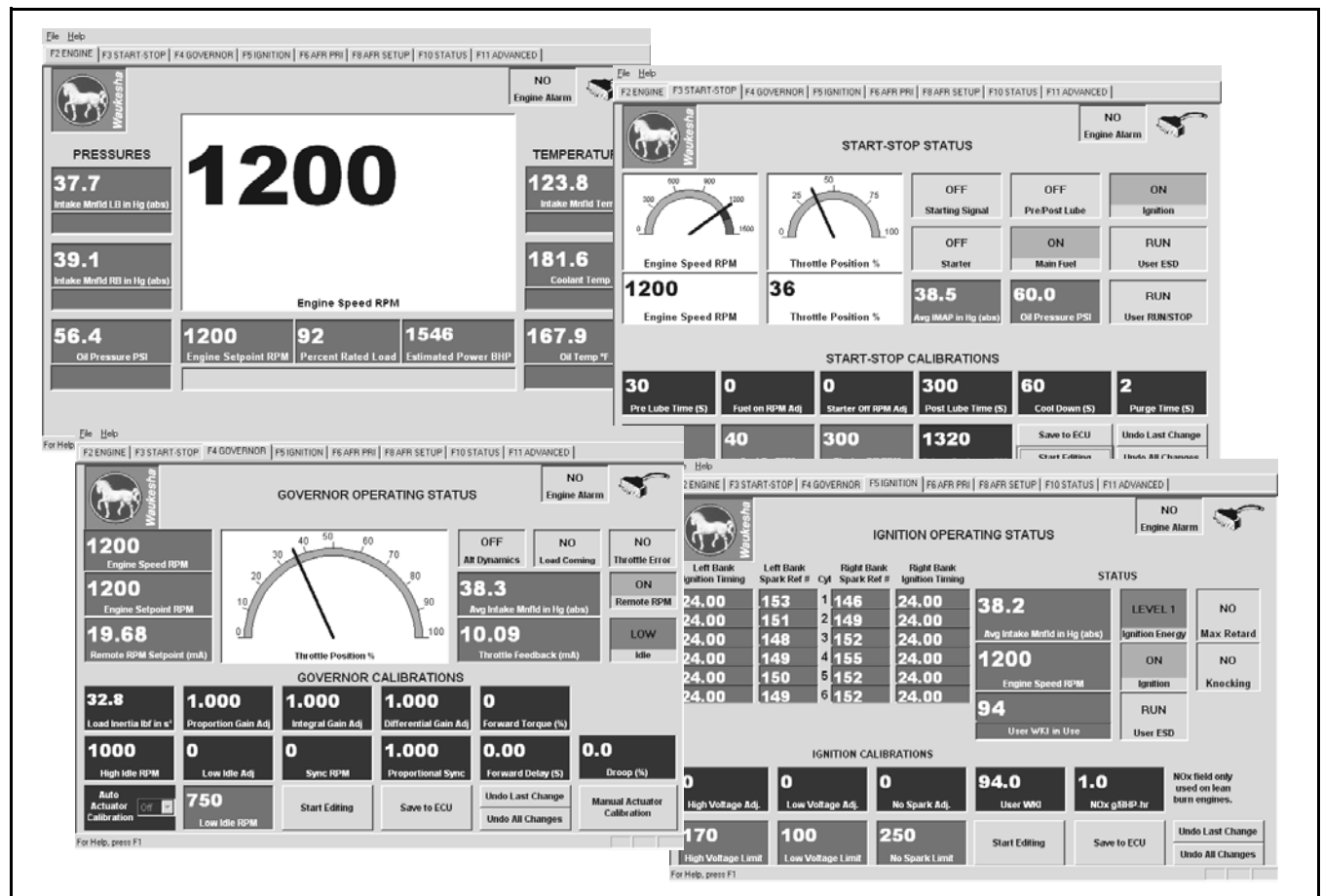


Figure 3.00-1 ESP's Graphical User Interface

INTRODUCTION TO ESP

MINIMUM RECOMMENDED COMPUTER EQUIPMENT FOR ESM ESP OPERATION

The PC used to run the ESP software connects to the ECU via a serial cable (RS-232) supplied by Waukesha Engine. This serial cable has a standard 9-pin RS-232 connection that plugs into the PC and an 8-pin plastic Deutsch® connector that plugs into the ECU.

A CD-ROM contains the ESP software and E-Help that is to be installed on the PC's hard drive.

The minimum PC requirements are:

- 700 MHz processor
- 128 MB RAM
- 200 MB free hard disk space
- Microsoft® Windows® XP operating system
- Microsoft® Internet Explorer 5.0
- 800 x 600 Color VGA Display
- RS-232 Serial Port
- CD-ROM Drive
- Mouse or other pointing device recommended but not required

CONVENTIONS USED WITH ESM ESP PROGRAMMING

The following is a list of conventions used in the ESP software and documentation:

- All commands enclosed in brackets, [], are found on the PC keyboard.
- Menu names and menu options are in **bold** type.
- Panel names and dialog box names begin with Uppercase Letters.
- Field and button names begin with Uppercase Letters and are enclosed in quotes (" ").
- ESP panels can be accessed by pressing the corresponding function key ([F2], [F3], etc.), or by clicking on the tab of the panel with the mouse.
- E-Help can be accessed by pressing [F1].
- The [Return] key is the same as the [Enter] key (on some keyboards [Return] is used instead of [Enter]).
- The fields on the ESP user interface screens are color-coded to provide an easy-to-understand graphical interface. See Table 3.00-1 for color key.

Table 3.00-1 Color Key For ESP User Interface Panels

COLOR	MEANING
Gray	Off (No Alarm)
Teal (Blue-Green)	Readings and Settings (General operating information such as temperature and pressure readings)
White	Dials and Gauges
Green	On or Normal System Operation
Pink	Low, Warmup, or Idle Signal
Yellow	Alarm or Sensor/Wiring Check
Red	Warning or Shutdown
Dark Blue	User-Programmable (Very little programming is required for ESM system operation – see Section 3.10 for programming information)

INFORMATION ON SAVING ESM SYSTEM CALIBRATIONS

The ESM system is designed to be used with various Waukesha engine families and configurations. Consequently, it must be tailored to work with site-specific information. This is achieved by calibrating (programming) an ECU with information that is appropriate for the engine and the site-specific application.

The ECU is programmed for the engine, using the ESP software on a PC at the engine site. Although ESP is saved on a PC, all programmed information is saved to, and resides in, the ECU. **You do not need to have a PC connected with ESP running to operate an engine with the ESM system.** ESP is only the software used to monitor engine operation, troubleshoot faults, log data, and load new calibrations to the ECU.

The ECU contains both volatile (non-permanent) random access memory (RAM) and non-volatile (permanent) random access memory (NVRAM).

Once an engine is programmed in ESP, the values are saved in RAM in the ECU and become the active values. RAM is used to evaluate programmed values before storing them to the ECU's permanent memory. The contents of RAM are lost whenever power to the ECU is removed. However, the contents remain in ECU RAM even if the PC loses power or is disconnected from the ECU.

To permanently save programmed values, the user must complete the steps in ESP necessary to save to the ECU. The new values are then saved permanently to NVRAM. When values are saved to NVRAM, the information is not lost when power to the ECU is removed. Once the values are saved to permanent memory, the previous save to permanent memory cannot be retrieved. The user can save unlimited times to ECU NVRAM (permanent memory).

USER INTERFACE PANELS

NOTE: Complete ESP user interface panel descriptions are provided in Section 3.05 ESP Panel Descriptions. The descriptions provided in this section provide only a general overview of each panel.

The ESM ESP software displays engine status and information:

[F2] Engine Panel [F6] AFR Primary Fuel Panel*

[F3] Start-Stop Panel [F8] AFR Setup Panel*

[F4] Governor Panel [F10] Status Panel

[F5] Ignition Panel [F11] Advanced Panel

*The [F6] and [F8] panels are viewable with AFR equipped engines.

These panels display system and component status, current pressure and temperature readings, alarms, ignition status, governor status, air/fuel control status, and programmable adjustments.

Each of the panels is viewed by clicking the corresponding tab or by pressing the corresponding function key ([F#]) on the keyboard. The following paragraphs briefly describe each of these panels.

NOTE: The [F1] function key displays ESP's electronic help file called "E-Help." E-Help provides general system and troubleshooting information. See "E-Help" on page 3.00-6 for more information. [F1] is not located on the PC screen as a panel; it is only a function key on the keyboard.

[F2] ENGINE: The Engine Panel displays current system readings of engine speed, left and right bank intake manifold pressures, oil pressure, intake manifold temperature, coolant temperature, and oil temperature (see Figure 3.00-2). Displayed under the engine speed is the engine setpoint RPM, percent of rated load, and estimated power.

If a sensor or wiring failure is detected, the status bar, under the affected sensor, will change from teal (blue-green) to yellow, and a message will appear in the status bar telling the user to check sensor and wiring for proper operation.

Also, the "Engine Alarm" field in the upper right corner will change from gray (deactivated/no engine alarm) to yellow (alarm). In case of a shutdown, the deactivated (gray) status bar under the "Engine Setpoint RPM" field turns red and a message signals the user of the emergency shutdown.

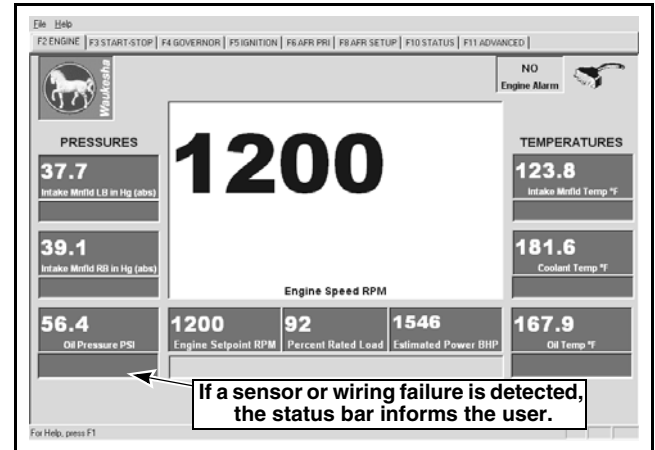


Figure 3.00-2 Engine Panel

[F3] START-STOP: The typical engine Start-Stop Panel displays engine speed, throttle position, average intake manifold pressure (IMAP), and oil pressure (see Figure 3.00-3). The display also has signals for pre/post lube state, starting, ignition enabled, starter engagement, main fuel and if there is an emergency or normal shutdown. This panel also allows the user to make Start-Stop adjustments by calibrating pre/post lube time, purge time, Cool Down, fuel on RPM, starter off RPM, and driven equipment ESD speed.

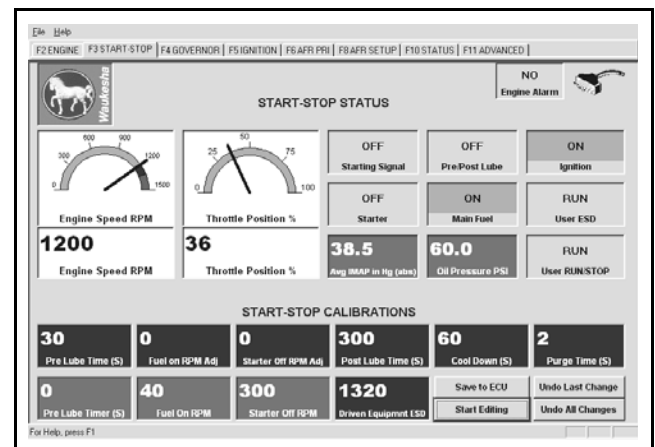


Figure 3.00-3 Start-Stop Panel

The Start-Stop Panel on 7042GL/GSI engines also displays prechamber fuel valve engagement information and fields for calibration (see Figure 3.00-4).

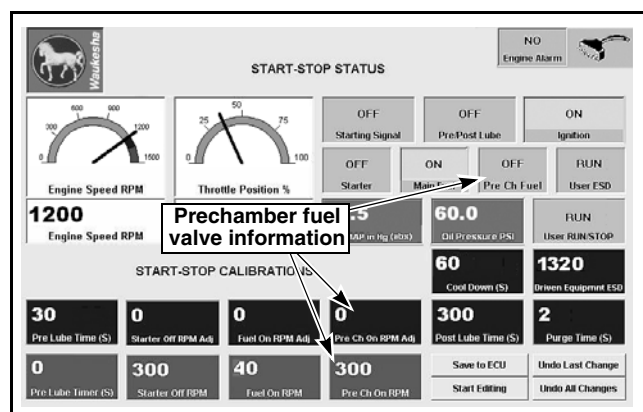


Figure 3.00-4 Start-Stop Panel – 7042GL/GSI Engine

[F4] GOVERNOR: The Governor Panel displays engine speed, throttle feedback, throttle position percentage, engine and remote RPM setpoints, and average intake manifold pressure (see Figure 3.00-5). In addition, this display shows the current state of the alternate governing dynamics, load coming input, throttle alarm, remote RPM, and idle RPM activity. This panel also allows the user to make governor adjustments by calibrating gain, droop, load inertia, idle and other ESM system governing control features such as synchronization speed, feedforward adjustments, and auto actuator calibration.

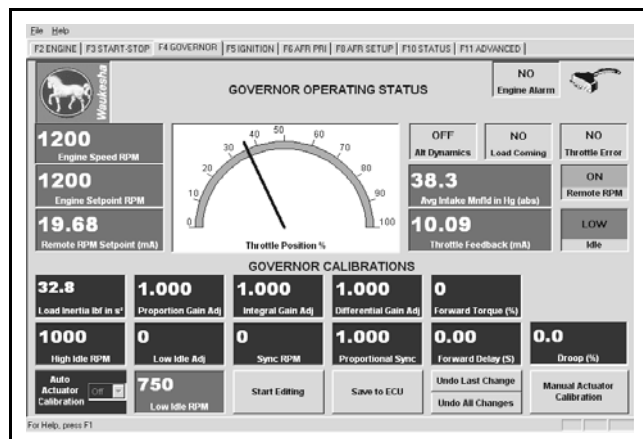


Figure 3.00-5 Governor Panel

[F5] IGNITION: The Ignition Panel displays engine speed, intake manifold pressure, ignition timing for each cylinder, ignition enabled, ignition level, maximum retard, WKI value used, and knock detection (see Figure 3.00-6). This panel also allows the user to make IPM-D adjustments by calibrating high voltage, low voltage, and no spark limits. In addition, the WKI value and NOx emission levels (for use on LT engines only) are calibrated on the Ignition Panel.

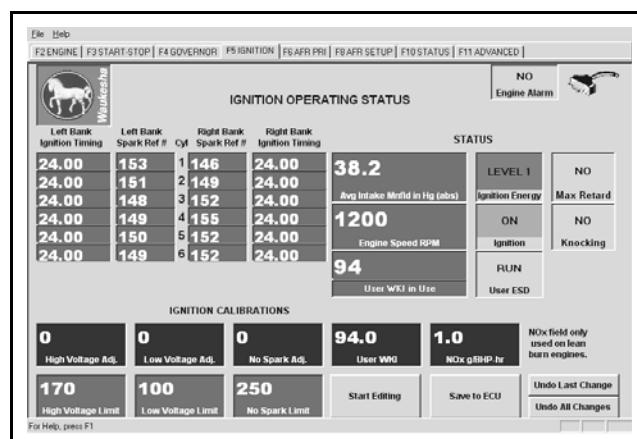


Figure 3.00-6 Ignition Panel

[F6] AFR PRI: The AFR Primary Fuel Panel is used to monitor AFR system performance (see Figure 3.00-7). This panel displays engine speed and target Lambda. Also, displayed for both left and right banks, is the actual Lambda, primary stepper position, minimum and maximum stepper setpoints, stepper operating mode, intake manifold pressure, oxygen and exhaust sensor status, and AFR operating mode (automatic or manual). This panel also allows the user to change either bank from automatic to manual mode and adjust stepper position using the arrow buttons.

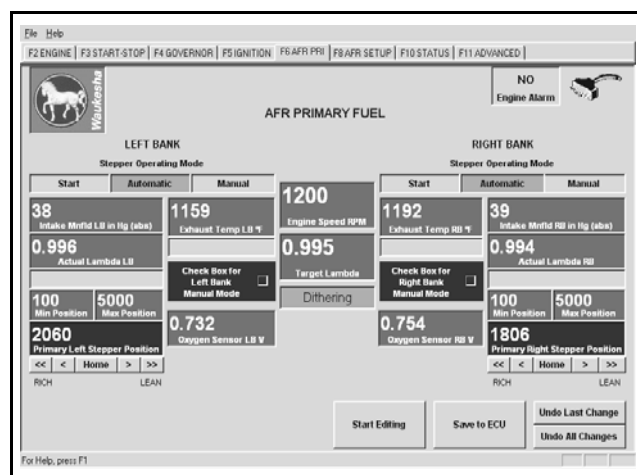


Figure 3.00-7 AFR Primary Fuel Panel

[F8] AFR SETUP: The AFR Setup Panel is used to program and fine-tune the AFR system (see Figure 3.00-8). This panel will only be displayed on an engine equipped with Waukesha factory-installed air/fuel ratio control. This panel displays engine speed, target Lambda and displayed for both left and right banks are the intake manifold pressure, actual Lambda, and primary stepper position. This panel also allows the user to calibrate the dither steps, gain, oxygen target Lambda offset, and the minimum/maximum stepper positions. The user can set either left or right banks start (or home) position, stepper position using the arrow buttons, length of stepper motor shaft used, and change from automatic to manual mode.

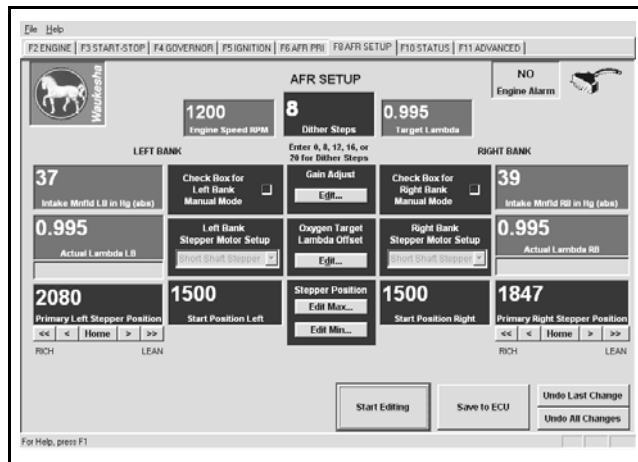


Figure 3.00-8 AFR Setup Panel

[F10] STATUS: The Status Panel displays the number of faults occurring in the system, if any type of shutdown is in process, if there is an engine alarm, and the engine start readiness (see Figure 3.00-9). The ignition system status displays if the IPM-D is enabled, ignition energy level, maximum retard, and if there is engine knocking. The ECU status displays ECU temperature, battery voltage, ECU hours, and if calibrations, faults, and statistics are loaded. The engine status displays engine speed, engine setpoint, if remote RPM is enabled, low or high idle, state of the alternate governor dynamics, and if the main fuel valve is engaged.

In addition, the Status Panel on 7042GL engines displays prechamber fuel valve status in the lower right corner.

The Status Panel also makes it possible for the user to view a log of all the current and historical faults (see “Fault Log” in this section for more information), reset status LED’s, manually calibrate the throttle actuator, change all ESP panels from U.S. to metric units, and to view version details.

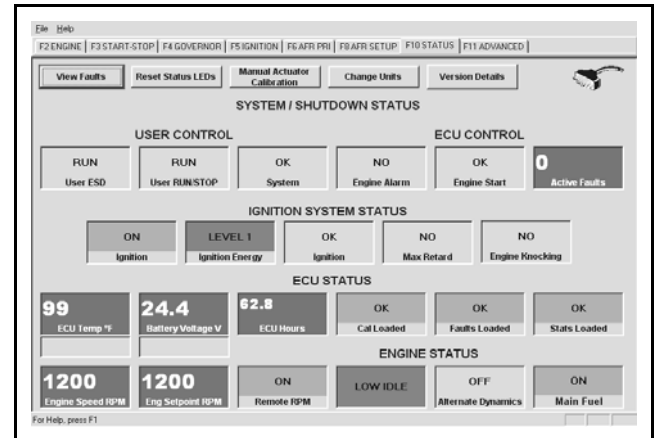


Figure 3.00-9 Status Panel

[F11] ADVANCED: The Advanced Panel is used to program MODBUS[®] settings and to adjust alarm and shutdown setpoints for oil pressure, jacket water temperature, intake manifold temperature, and oil temperature. Alarm and shutdown setpoints can only be programmed in a safe direction and cannot exceed factory limits.

In addition, all active system parameters can be logged into readable text. This allows the user to review, chart, and/or trend the data logged as desired.

Users can also send updated calibration information to the ECU, and to signify if a Waukesha alternator is installed (see Figure 3.00-10).

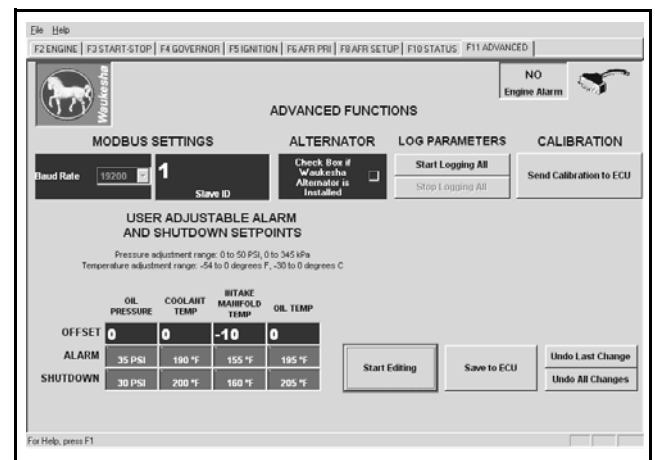


Figure 3.00-10 Advanced Panel

FAULT LOG

The ESM system features extensive engine diagnostics capability. The ECU records system faults as they occur. A “fault” is any condition that can be detected by the ESM system that is considered to be out-of-range, unusual, or outside normal operating conditions. One method of obtaining diagnostic information is by viewing the Fault Log using the ESM ESP software (see Figure 3.00-11). ESP displays the data provided by the ECU.

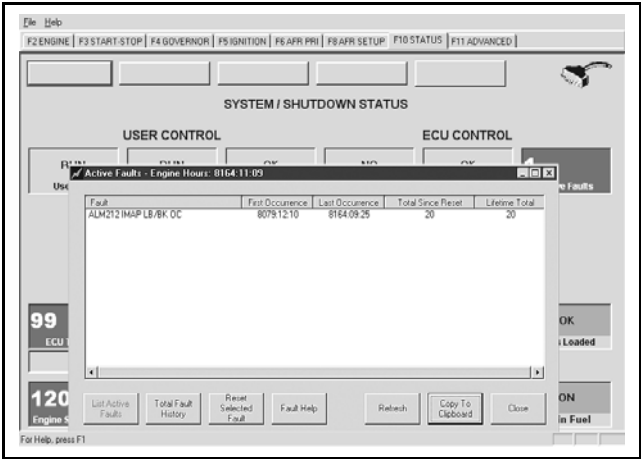


Figure 3.00-11 Fault Log

The Fault Log can be viewed by selecting the “View Faults” button on the [F10] Status Panel using the ESP software. The Fault Log displays the name of the fault, the first time the fault occurred since the fault was reset (in ECU hours:minutes:seconds), the last time the fault occurred since reset, the number of times the fault occurred since reset, and the total number of times the fault occurred in the lifetime of the ECU. All the fault information is resettable except for the total number of times the fault occurred during the lifetime of the ECU.

E-HELP

ESP contains an electronic help file named E-Help (see Figure 3.00-12 for a sample screen). E-Help provides general system and troubleshooting information in an instant as long as the user is using the PC with the ESP software. The user can quickly and easily move around in E-Help through electronic links (or hypertext links) from subject to subject. E-Help is automatically installed when the ESP software is installed.

To access the help file any time while using the ESP software, press the [F1] function key on the keyboard or select **Help Contents...** from the **Help** menu in ESP. As an additional aid in troubleshooting, double-clicking a fault listed in the Fault Log will open E-Help directly to the troubleshooting information for that fault. See “E-Help” for more information.

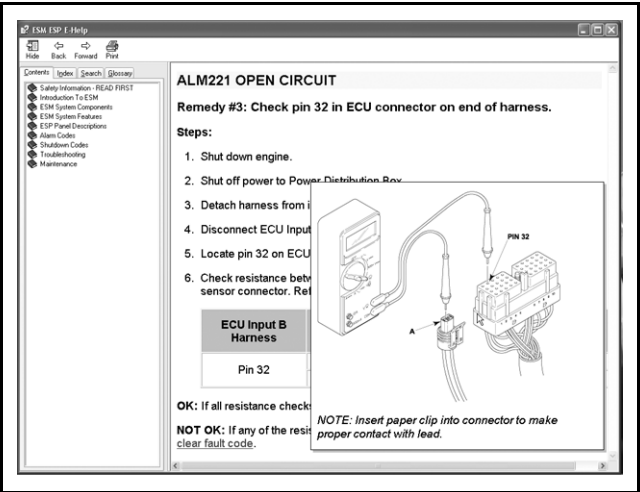


Figure 3.00-12 Sample E-Help Screen

SECTION 3.05

ESP PANEL DESCRIPTIONS

INTRODUCTION

This section provides a description of each ESP panel and the fields and buttons found on each panel. Figure 3.05-1 identifies and describes the common features found on the ESP panels.

[F2] Engine Panel Description.....	Page 3.05-2
[F3] Start-Stop Panel Description	Page 3.05-4
[F4] Governor Panel Description	Page 3.05-8
[F5] Ignition Panel Description	Page 3.05-14

[F6] AFR Primary Fuel Panel Description	Page 3.05-20
[F8] AFR Setup Panel Description	Page 3.05-26
[F10] Status Panel Description	Page 3.05-30
[F11] Advanced Panel Description	Page 3.05-36
Fault Log Description	Page 3.05-38

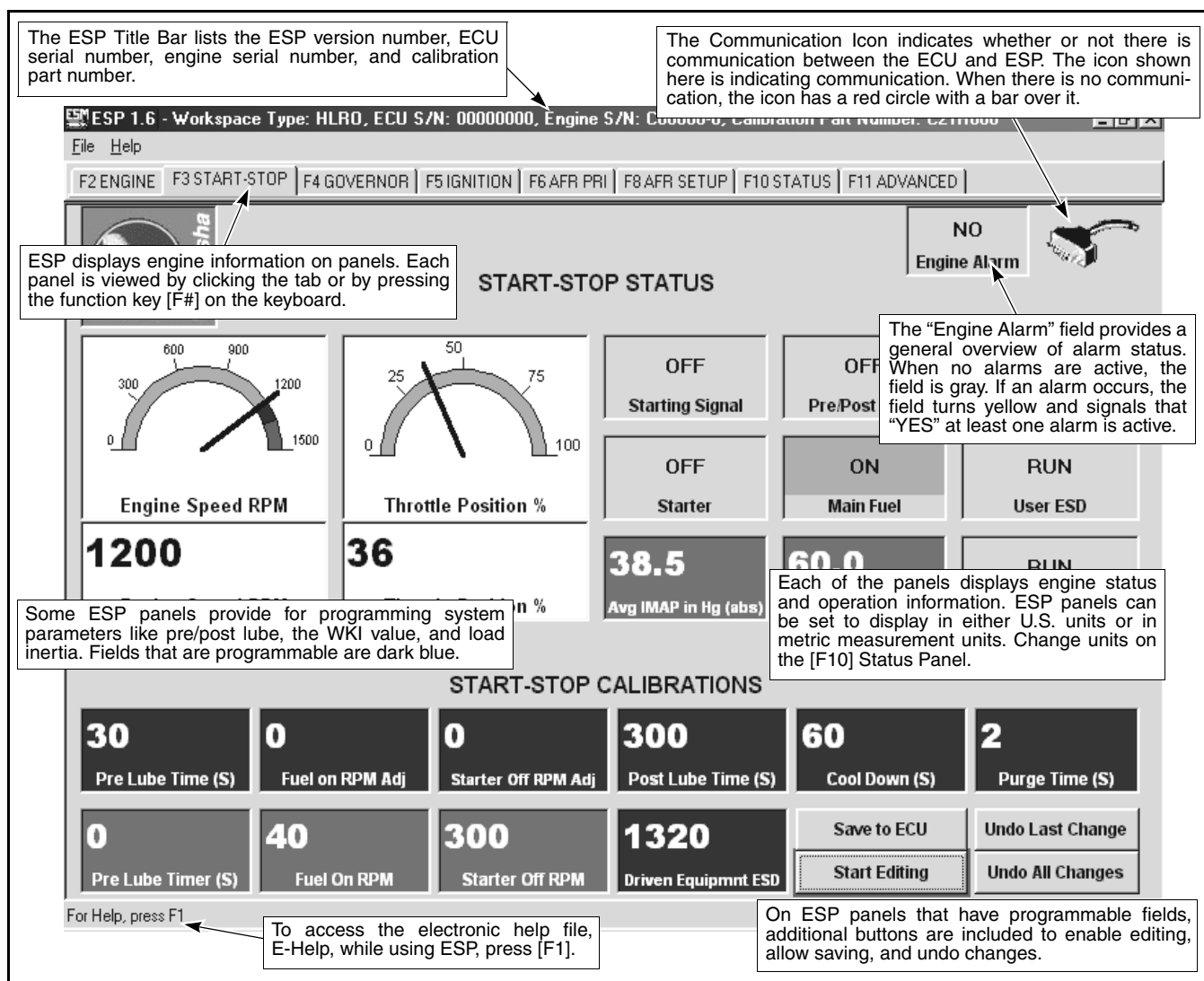


Figure 3.05-1 Description of Common Features Found on ESP Panels

[F2] ENGINE PANEL DESCRIPTION

The Engine Panel displays current system readings of engine speed, left and right bank intake manifold pressures, oil pressure, intake manifold temperature, coolant temperature, and oil temperature. Displayed under the engine speed is the engine setpoint RPM, percent of rated load, and estimated power. If a sensor or wiring failure is detected, the status bar, under the affected sensor, will change from teal (blue-green) to yellow, and a message will appear in the status bar telling the user to check sensor and wiring for proper operation. Also, the “Engine Alarm” field in the upper right corner will change from gray (deactivated/no engine alarm) to yellow (alarm). In case of a shutdown, the deactivated (gray) status bar under the “Engine Setpoint RPM” field turns red and a message signals the user of the emergency shutdown.

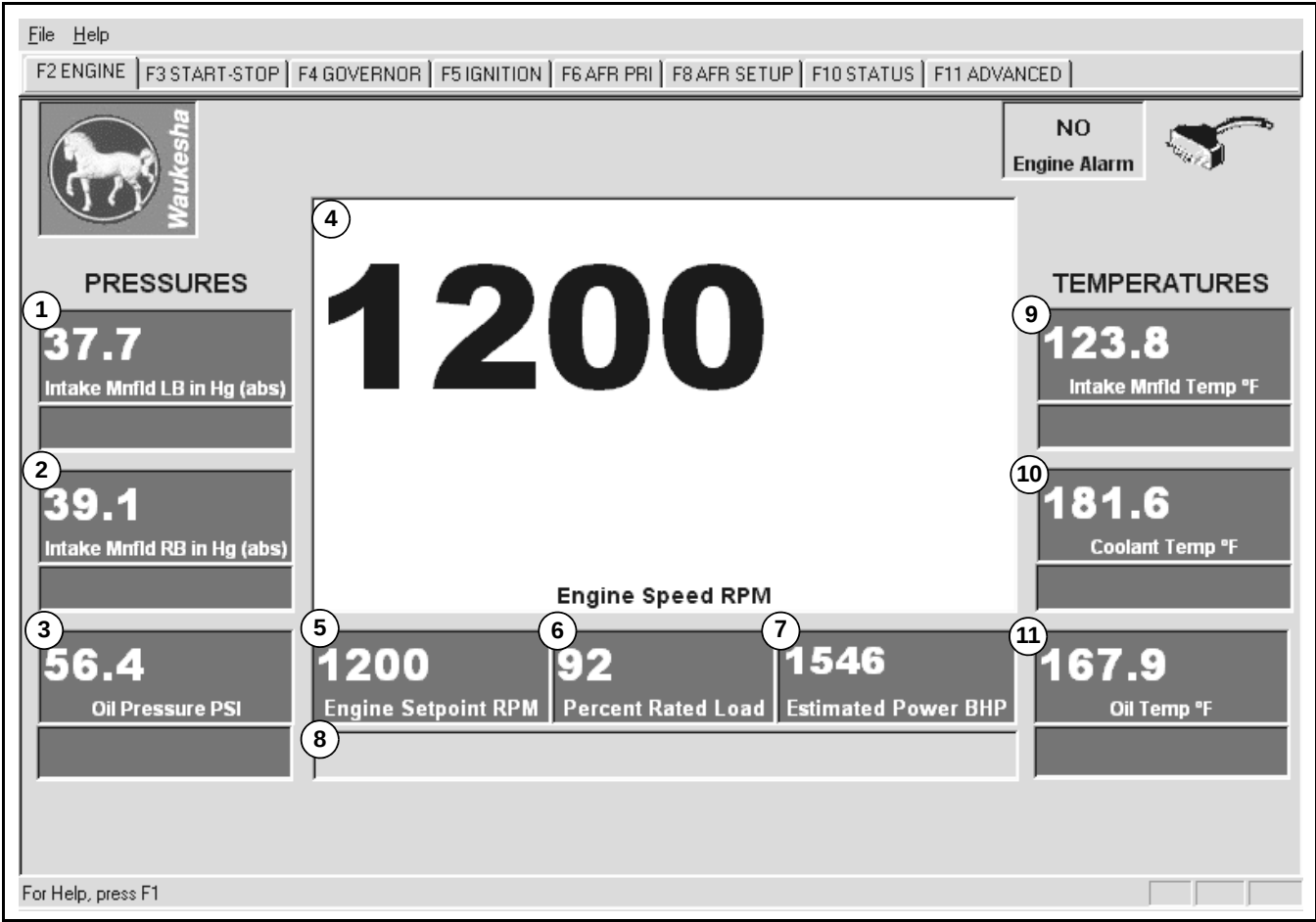


Figure 3.05-2 Engine Panel in ESP – Fields 1 through 11

[F2] ENGINE PANEL DESCRIPTION – REFER TO FIGURE 3.05-2

- ① **“Intake Mnfld LB”** This field displays the engine’s left bank intake manifold pressure. Units are in-Hg absolute (kPa absolute). If an intake manifold pressure sensor or wiring fault occurs, the status bar beneath this field signals an alarm (turns yellow) and provides the user a message to fix the sensor or wiring. *NOTE: When a sensor or wiring fault is detected, the field displays a default value, not the actual value.*
- ② **“Intake Mnfld RB”** This field displays the engine’s right bank intake manifold pressure. Units are in-Hg absolute (kPa absolute). If an intake manifold pressure sensor or wiring fault occurs, the status bar beneath this field signals an alarm (turns yellow) and provides a message to fix the sensor or wiring. *NOTE: When a sensor or wiring fault is detected, the field displays a default value, not the actual value.*
- ③ **“Oil Pressure”** This field displays the engine’s gauge oil pressure in the main oil header. Units are psi (kPa gauge). If an oil pressure sensor or wiring fault occurs, the status bar beneath this field signals an alarm (turns yellow) and provides a message to fix the sensor or wiring. *NOTE: When a sensor or wiring fault is detected, the field displays a default value, not the actual value.*
- ④ **“Engine Speed”** This field displays current engine speed (rpm).
- ⑤ **“Engine Setpoint”** This field displays the engine speed (rpm) setpoint. The engine speed setpoint is determined by a user input, not internal calibrations.
- ⑥ **“Percent Rated Load”** This field displays an approximation of percent rated torque (load). The approximation is based on ECU inputs and engine operating factors. Not applicable for 7042GSI/GL engines.
- ⑦ **“Estimated Power”** This field displays an approximation ($\pm 5\%$) of actual engine power in BHP (kW). The approximation is based on ECU inputs and assumes correct engine operation. Not applicable for 7042GSI/GL engines.
- ⑧ **“ESD/No ESD”** This field signals the user that an emergency shutdown is in process. When the engine is operating or off, the field remains deactivated (gray). If the engine shuts down due to an emergency, the field signals the emergency shutdown (turns red) and provides the user a message indicating an emergency shutdown is in process. When the shutdown is complete, the field deactivates (turns gray) and the shutdown is recorded in the fault log history. However, the field remains active (in shutdown mode) if the lockout or E-Stop (emergency stop) button(s) on the engine is depressed.
- ⑨ **“Intake Mnfld Temp”** This field displays the engine’s left bank intake manifold temperature. Units are °F (°C). If an intake manifold temperature sensor or wiring fault occurs, the status bar beneath this field signals an alarm (turns yellow) and provides the user a message to fix the sensor or wiring. *NOTE: When a sensor or wiring fault is detected, the field displays a default value, not the actual value.*
- ⑩ **“Coolant Temp”** This field displays the engine’s coolant temperature at the outlet of the engine. Units are °F (°C). If a coolant temperature sensor or wiring fault occurs, the status bar beneath this field signals an alarm (turns yellow) and provides the user a message to fix the sensor or wiring. *NOTE: When a sensor or wiring fault is detected, the field displays a default value, not the actual value.*
- ⑪ **“Oil Temp”** This field displays the engine’s oil temperature in the main oil header. Units are °F (°C). If an oil temperature sensor or wiring fault occurs, the status bar beneath this field signals an alarm (turns yellow) and provides the user a message to fix the sensor or wiring. *NOTE: When a sensor or wiring fault is detected, the field displays a default value, not the actual value.*

ESP PANEL DESCRIPTIONS

[F3] START-STOP PANEL DESCRIPTION

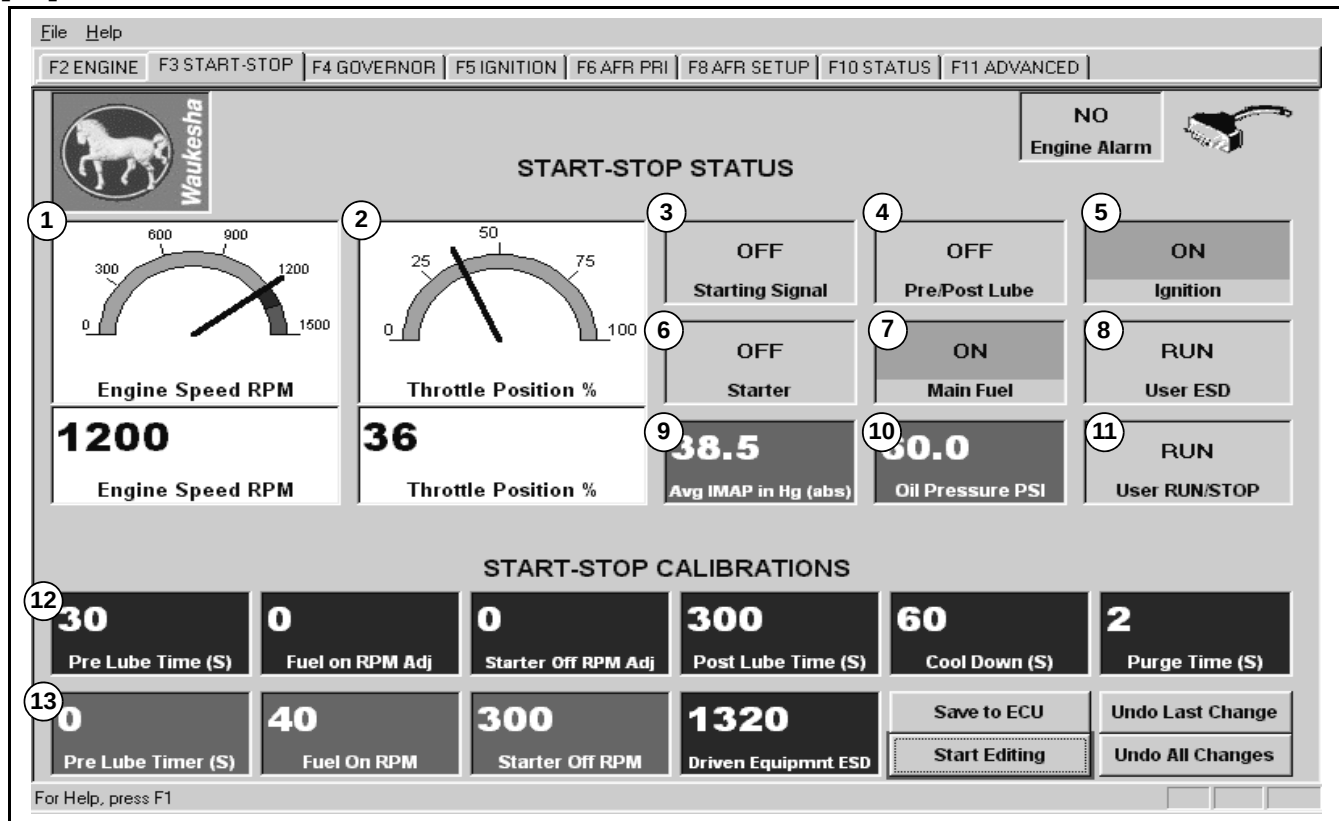


Figure 3.05-3 Start-Stop Panel in ESP – Fields 1 through 13

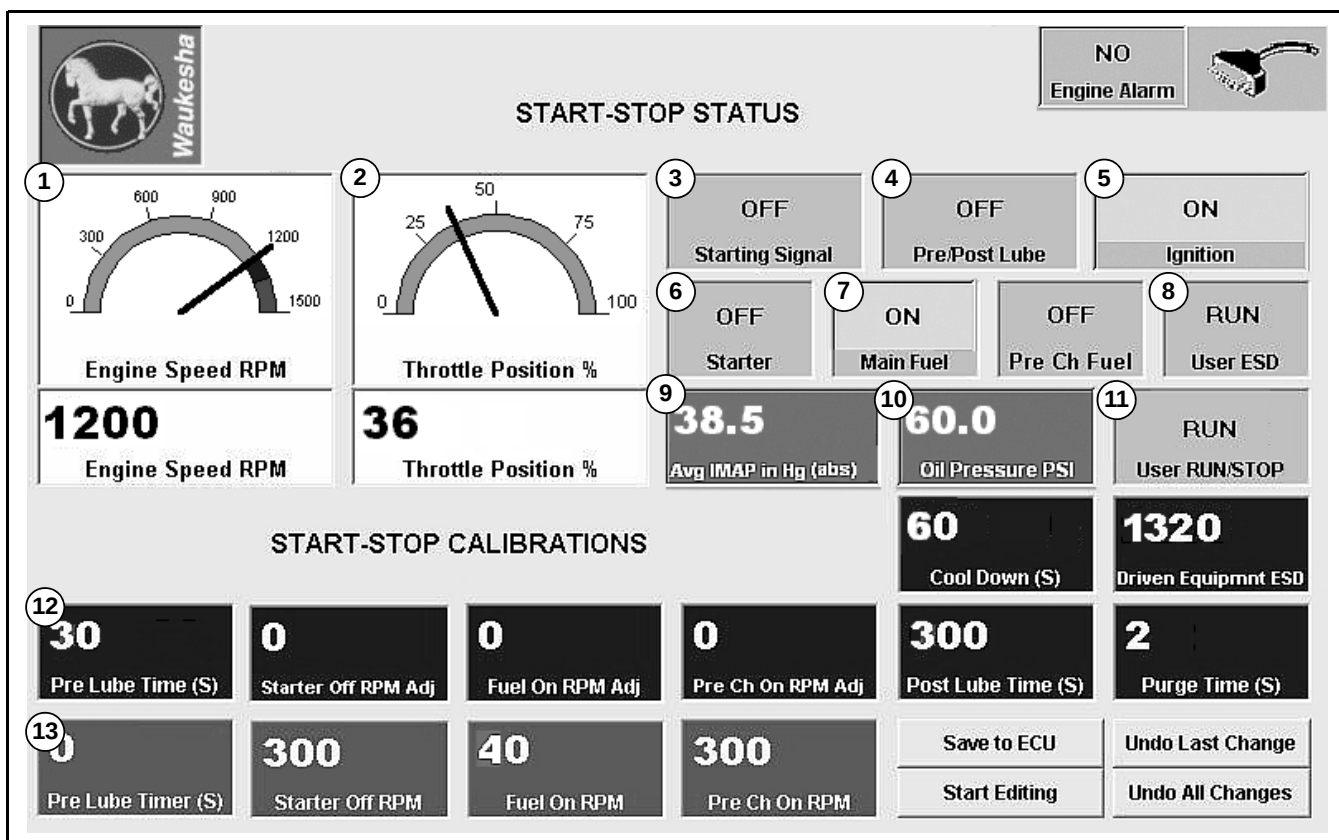


Figure 3.05-4 Start-Stop Panel in ESP – Fields 1 through 13 (7042GL Engine)

[F3] START-STOP PANEL DESCRIPTION – REFER TO FIGURE 3.05-3 AND FIGURE 3.05-4

The engine Start-Stop Panel displays engine speed, throttle position, average intake manifold pressure (IMAP), and oil pressure (see Figure 3.05-3). The display also has signals for pre/post lube state, starting, ignition enabled, starter engagement, main fuel, and if there is an emergency or normal shutdown. This panel also allows the user to make Start-Stop adjustments by calibrating pre/post lube time, purge time, cool down, fuel on RPM, starter off RPM, and driven equipment ESD speed.

The Start-Stop Panel on 7042GL/GSI engines also displays prechamber fuel valve engagement information and fields for calibration (see Figure 3.05-4).

- ① **“Engine Speed”** This field displays current engine speed (rpm).
- ② **“Throttle Position”** This field displays throttle position in terms of the percentage the throttle valve is open.
- ③ **“Starting Signal”** This field signals when the digital start signal, a digital input to the ECU, is high (8.6 – 36 volts) or low (< 3.3 volts). During the time the digital start signal is high, the field is green and signals the user it is ON. During the time the digital start signal is low, the field is gray and signals the user it is OFF.
- ④ **“Pre/Post Lube”** This field signals when the oil pump is engaged and is either in pre- or postlube. During the time the prelube oil pump is engaged, the field is green and signals the user it is ON. During the time the prelube oil pump is disengaged, the field is gray and signals the user it is OFF.
- ⑤ **“Ignition”** This field signals when the IPM-D is enabled and is ready to receive a signal from the ECU to fire each spark plug. During the time the IPM-D is enabled, the field is green and signals the user it is ON. During the time the ignition is disabled, the field is gray and signals the user it is OFF.
- ⑥ **“Starter”** This field signals when the starter motor is engaged. The starter motor is engaged based on “Starter Off RPM” and “Purge Time” settings. During the time the starter motor is engaged, the field is green and signals the user it is ON. During the time the starter motor is disengaged, the field is gray and signals the user it is OFF.
- ⑦ **“Main Fuel”** This field signals when the main fuel valve is engaged by the ECU. During the time the main fuel valve is engaged, the field is green and signals the user it is ON. During the time the main fuel valve is disengaged, the field is gray and signals the user it is OFF.
- ⑧ **“User ESD”** This field signals that an emergency shutdown is in process based on a customer input. During an emergency shutdown, the field is red and signals the user that an E-STOP (emergency stop) is active. When E-STOP is displayed, the engine cannot be restarted. When the engine is not in an emergency shutdown mode, the field is gray and signals the user that the engine is ready to RUN.
- ⑨ **“Avg IMAP”** This field displays the average intake manifold pressure. Units are in-Hg absolute (kPa absolute). On a vee engine, the left and right intake manifold pressure readings are averaged together and displayed in this field. If one of the intake manifold pressure sensors fails, the field displays only the reading from the working sensor. If both sensors fail, the field is unable to display the actual value and a default value is displayed instead.
- ⑩ **“Oil Pressure”** This field displays the engine’s gauge oil pressure in the main oil header. Units are psi (kPa gauge). If an oil pressure sensor or wiring fault occurs, the status bar beneath this field signals an alarm (turns yellow) and provides the user a message to fix the sensor or wiring. When a sensor or wiring fault is detected, the field displays a default value, not the actual value.
- ⑪ **“User RUN/STOP”** This field signals that a normal shutdown is in process based on a customer input. During a normal shutdown, the field is red and signals the user that the engine will STOP. When STOP is displayed, the engine cannot be restarted. When the engine is not in a shutdown mode, the field is gray and signals the user that the engine is ready to RUN.
- ⑫ **“Pre Lube Time”** This field allows the user to program engine prelube timing. Units are in seconds. Prelube timing can be programmed from 0 – 10,800 seconds (0 – 180 minutes).
- ⑬ **“Pre Lube Timer”** This field allows the user to see the remaining time left for prelube. For example, if 300 seconds has been entered in the “Pre Lube Time” field, the “Pre Lube Timer” field will display zero until a start is requested. After the start request, the pre lube timer will start counting down (from 300 seconds).

Field descriptions continued on next page...

ESP PANEL DESCRIPTIONS

[F3] START-STOP PANEL DESCRIPTION

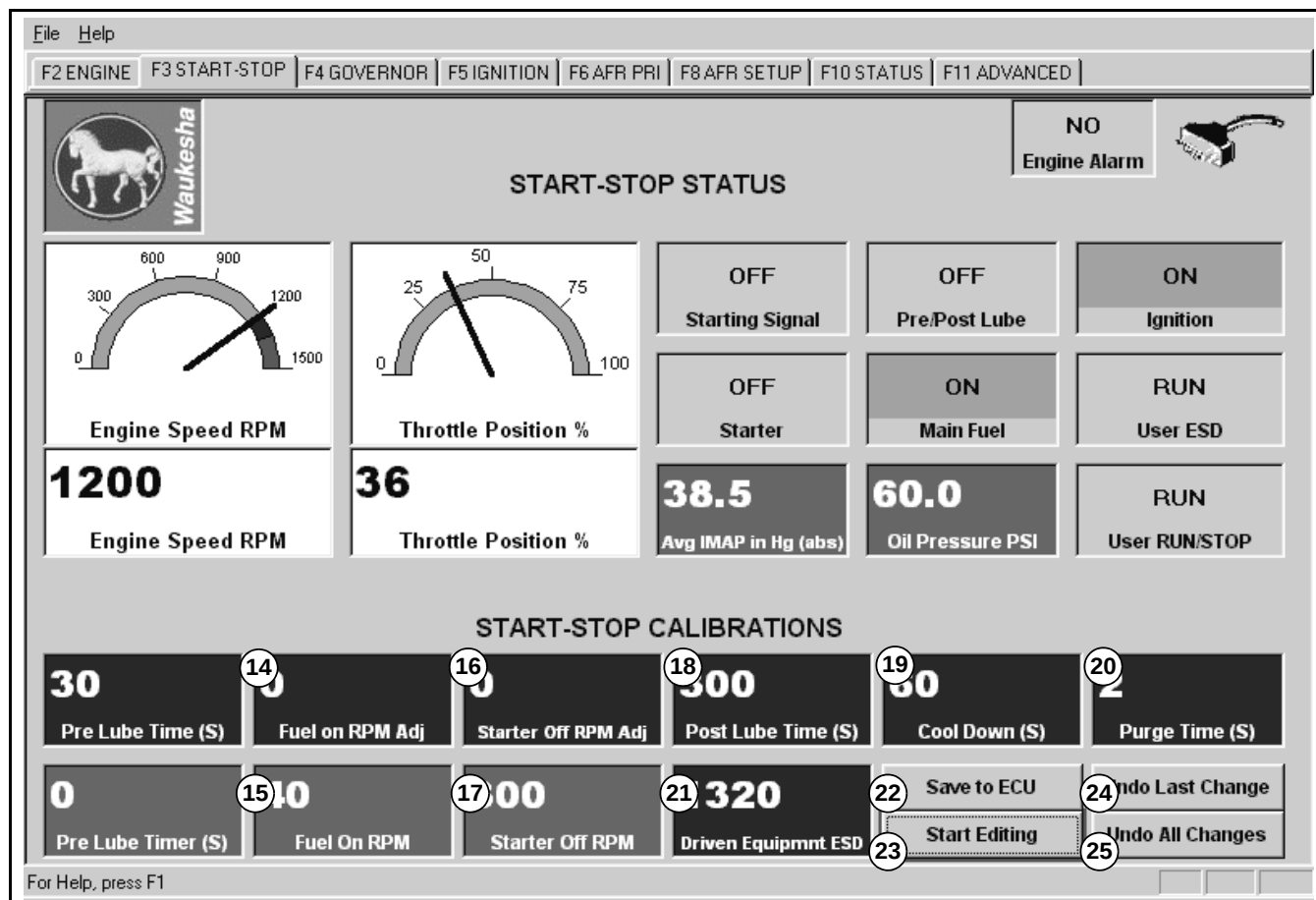


Figure 3.05-5 Start-Stop Panel in ESP – Fields 14 through 25 (VHP Series Four Engine)

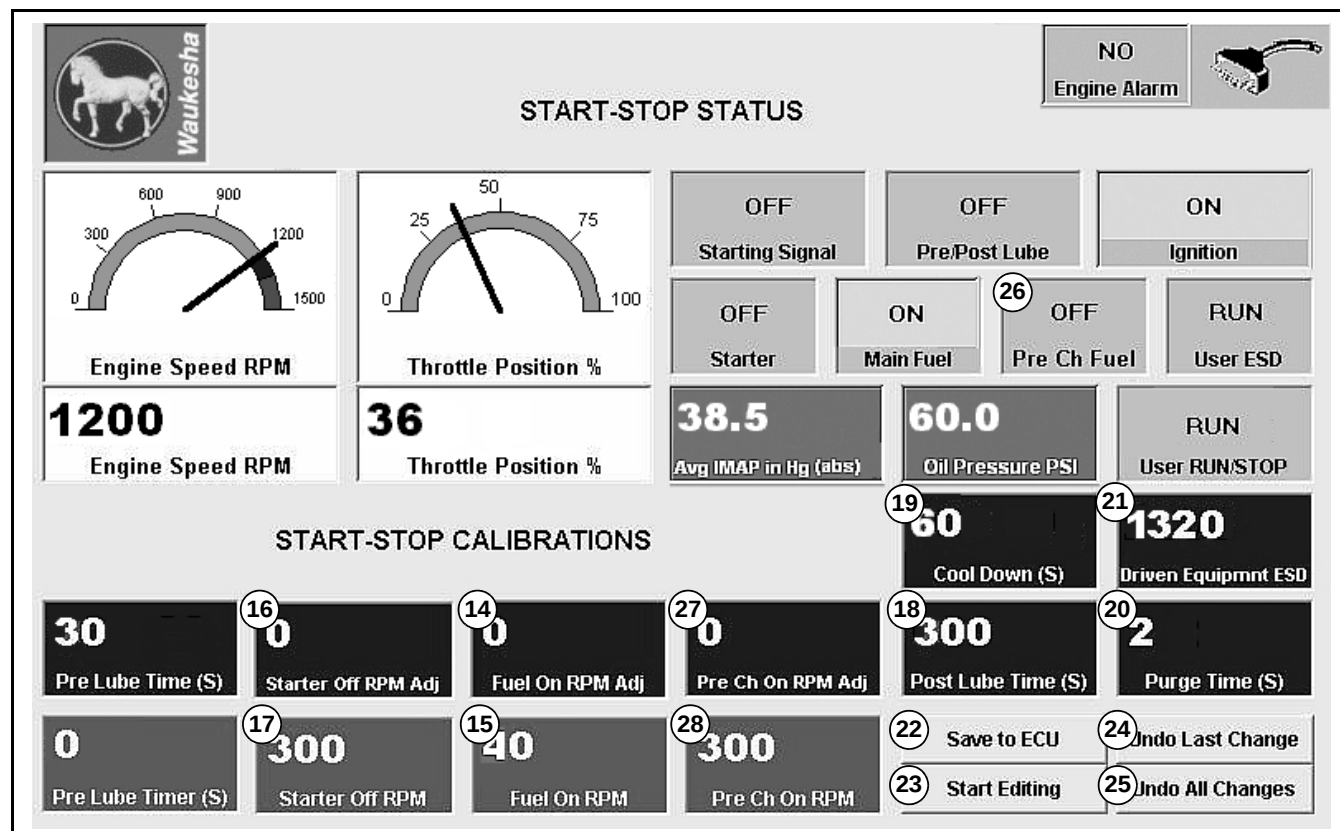


Figure 3.05-6 Start-Stop Panel in ESP – Fields 14 through 28 (7042GL Engine)

[F3] START-STOP PANEL DESCRIPTION – REFER TO FIGURE 3.05-5 AND FIGURE 3.05-6

- 14 15 “Fuel On RPM Adj” and “Fuel On RPM”** These fields allow the user to view and program the rpm at which the fuel valve is turned on. The teal (blue-green) “Fuel On RPM” field displays the actual programmed rpm setting. The dark blue “Fuel On RPM Adj” field allows the user to adjust the actual setting by entering a value from -50 to +100 rpm. When an adjustment is entered, the actual “Fuel On RPM” is updated to reflect the adjustment.
- 16 17 “Starter Off RPM Adj” and “Starter Off RPM”** These fields allow the user to view and program the rpm at which the starter motor is turned off. The teal (blue-green) “Starter Off RPM” field displays the actual programmed rpm setting. The dark blue “Starter Off RPM Adj” field allows the user to adjust the actual setting by entering a value from 0 to +100 rpm. When an adjustment is entered, the actual “Starter Off RPM” is updated to reflect the adjustment.
- 18 “Post Lube Time”** This field allows the user to program engine postlube timing. Units are in seconds. Postlube timing can be programmed from 0 to 10,800 seconds (0 to 180 minutes).
- 19 “Cool Down”** This field allows the user to program engine cooldown. Units are in seconds. Cooldown is the amount of time that the engine will continue to run after a normal shutdown is activated. Cooldown can be programmed from 0 to 10,800 seconds (0 to 180 minutes).
- 20 “Purge Time”** This field allows the user to program a purge time. Units are in seconds. Purge time is the amount of time after first engine rotation that must expire before the fuel valve and ignition are turned on. *NOTE: Although purge time can be programmed from 0 to 1800 seconds (30 minutes), a purge time greater than 30 seconds will prevent the engine from starting.*
- 21 “Driven Equipment ESD”** This field allows the user to program an overspeed shutdown to protect driven equipment. Driven equipment overspeed can be programmed from 0 to 2200 rpm. If programmed driven equipment overspeed exceeds engine overspeed, the engine overspeed value takes precedence. For example, a VHP has a factory-programmed engine overspeed trip point of 1320 rpm. If the driven equipment overspeed is set to 1500 rpm, and the engine speed exceeds 1320 rpm, the engine will be shut down. If the driven equipment overspeed is set to 1100 rpm and the engine speed exceeds 1100 rpm, but is less than 1320 rpm, the engine will be shut down.
- 22 “Save to ECU”** This button is used to save programmed values to NVRAM (permanent memory) in the ECU. Changes saved to permanent memory will not be lost if power to the ECU is removed. See Section 3.10 *ESP Programming* “Saving to Permanent Memory” for more information. *NOTE: Programmed values not saved to permanent memory are stored in RAM (temporary memory). When values are in RAM, ESP can be closed and the PC disconnected from the ECU while keeping all changes; however, changes will be lost if power to the ECU is removed or when the engine is shut down.*
- 23 “Start Editing”** This button must be clicked prior to editing programmable (dark blue) fields in ESP. Clicking this button puts ESP in “editing mode.” The user will not be able to enter new values if ESP is not in editing mode. While in editing mode, the button will read, “Stop Editing – Currently Editing.” When the editing mode is off, the button will read “Start Editing.” See Section 3.10 *ESP Programming* “Basic Programming in ESP” for more information.
- 24 “Undo Last Change”** This button allows the user to reset the last change made while in editing mode back to the programmed value that was last saved to permanent memory (NVRAM) in the ECU.
- 25 “Undo All Changes”** This button allows the user to reset all the programmable fields back to the programmed parameters that were last saved to permanent memory (NVRAM) in the ECU.
- 26 “Pre Ch Fuel”** This field signals when the pre-chamber fuel valve is turned on. During the time the prechamber fuel valve is engaged, the field is green and signals the user it is ON. During the time the prechamber fuel valve is disengaged, the field is gray and signals the user it is OFF.
- 27 28 “Pre Ch On RPM Adj” and “Pre Ch On RPM”** These fields allow the user to view and program the rpm at which the prechamber fuel valve is turned on. The teal (blue-green) “Pre Ch On RPM” field displays the actual programmed rpm setting. The dark blue “Pre Ch On RPM Adj” field allows the user to adjust the actual setting by entering a value from -50 to +300 rpm. When an adjustment is entered, the actual “Pre Ch On RPM” is updated to reflect the adjustment.

ESP PANEL DESCRIPTIONS

[F4] GOVERNOR PANEL DESCRIPTION

The Governor Panel displays engine speed, throttle feedback, throttle position percentage, engine and remote RPM setpoints, and average intake manifold pressure. In addition, this display shows the current state of the alternate governing dynamics, load coming input, throttle alarm, remote RPM, and idle rpm activity. This panel also allows the user to make governor adjustments by calibrating gain, droop, load inertia, idle, and other ESM system governing control features such as synchronization speed, feedforward adjustments, and auto actuator calibration.

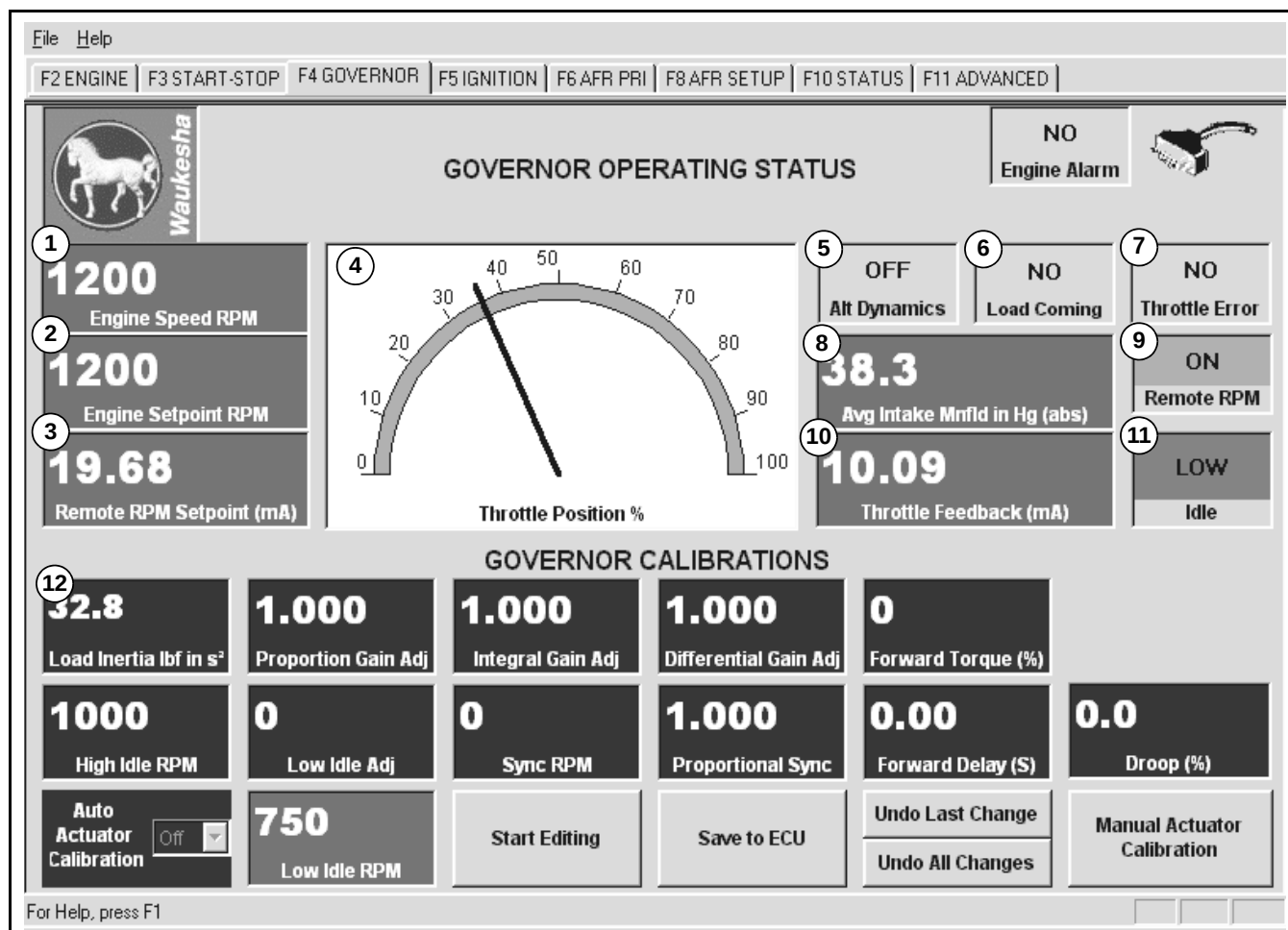


Figure 3.05-7 Governor Panel in ESP – Fields 1 through 12

[F4] GOVERNOR PANEL DESCRIPTION – REFER TO FIGURE 3.05-7

- ① **“Engine Speed”** This field displays current engine speed (rpm).
- ② **“Engine Setpoint RPM”** This field displays the engine speed (rpm) setpoint. The engine speed setpoint is determined by a user input, not internal calibrations.
- ③ **“Remote RPM Setpoint”** This field displays the remote rpm setpoint if the remote rpm input 4 – 20 mA (0.875 – 4.0 V) is active. The setpoint is only displayed in mA.
- ④ **“Throttle Position”** This field displays throttle position in terms of the percentage the throttle valve is open.
- ⑤ **“Alt Dynamics”** This field signals when the Alternate Governor Dynamics digital input is high (8.6 – 36 volts) or low (< 3.3 volts). Alternate dynamics or synchronizer mode is used to rapidly synchronize an engine to the electric power grid by using cylinder timing to maintain constant engine speed. During the time the alternate dynamics input is high, the field is green and signals the user it is ON. During the time the alternate dynamics input is low, the field is gray and signals the user it is OFF. The lower gain values can be used to minimize actuator movement when the engine is synchronized to the grid and fully loaded to maximize actuator life.
- ⑥ **“Load Coming”** This field signals when the load coming digital input is high (8.6 – 36 volts) or low (< 3.3 volts). Load coming or feedforward control is used to allow the engine to accept large load additions. During the time the load coming input is high, the field is green and signals the user that YES, the load coming feature is being used. During the time the load coming input is low, the field is gray and signals the user that NO, the load coming feature is not being used.
- ⑦ **“Throttle Error”** This field signals when the throttle actuator sends a digital input to the ECU indicating the actuator is in an alarm state. During the time when the throttle actuator is in an alarm state, the field is yellow and signals the user that YES, a throttle actuator fault exists (ALM441). During the time when the throttle actuator is not in an alarm state, the field is gray and signals the user that NO throttle actuator fault exists.
- ⑧ **“Avg Intake Mnfld”** This field displays the average intake manifold pressure. Units are in-Hg absolute (kPa absolute). On a vee engine, the left and right intake manifold pressure readings are averaged together and displayed in this field. If one of the intake manifold pressure sensors fails, the field displays only the reading from the working sensor. If both sensors fail, the field is unable to display the actual value and a default value is displayed instead.
- ⑨ **“Remote RPM”** This field signals when the remote rpm is ON or OFF. Remote rpm is determined by a customer digital input. When the input is high (8.6 – 36 volts), remote rpm is active. During the time the remote rpm input is high, the field is green and signals the user it is ON. During the time the remote rpm input is low (< 3.3 volts), the field is gray and signals the user it is OFF. When remote rpm is OFF, engine speed is based on “Idle” (Field 11) and “High Idle RPM” (Field 13) or “Low Idle RPM” (Field 17).
- ⑩ **“Throttle Feedback”** This field displays the throttle actuator’s position in mA. 4 mA = 0%; 20 mA = 100%.
- ⑪ **“Idle”** This field indicates whether low idle rpm or high idle rpm is active. Low or high idle rpm is determined by a customer digital input. When the input is low (< 3.3 volts), LOW is displayed in the pink field. When the input is high (8.6 – 36 volts), HIGH is displayed in the pink field. See “High Idle RPM” (Field 13) and “Low Idle RPM” (Field 17) for values of high and low idle.
- ⑫ **“Load Inertia”** This field **must** be programmed by the user for proper engine operation. By programming the load inertia or rotating mass moment of inertia of the driven equipment, the governor gain is preset correctly, aiding rapid startup of the engine. If this field is programmed correctly, there should be no need to program gain adjustments [“Proportional Gain Adj” (Field 15), “Integral Gain Adj” (Field 18), and “Differential Gain Adj” (Field 20)]. The rotating mass moment of inertia must be known for each piece of driven equipment and then added together. See Section 3.10 *ESP Programming* “Programming Load Inertia” for more information. *NOTE: Rotating moment of inertia is not the weight or mass of the driven equipment. It is an inherent property of the driven equipment and does not change with engine speed or load. Contact the coupling or driven equipment manufacturer for the moment of inertia value.*

Field descriptions continued on next page...

[F4] GOVERNOR PANEL DESCRIPTION

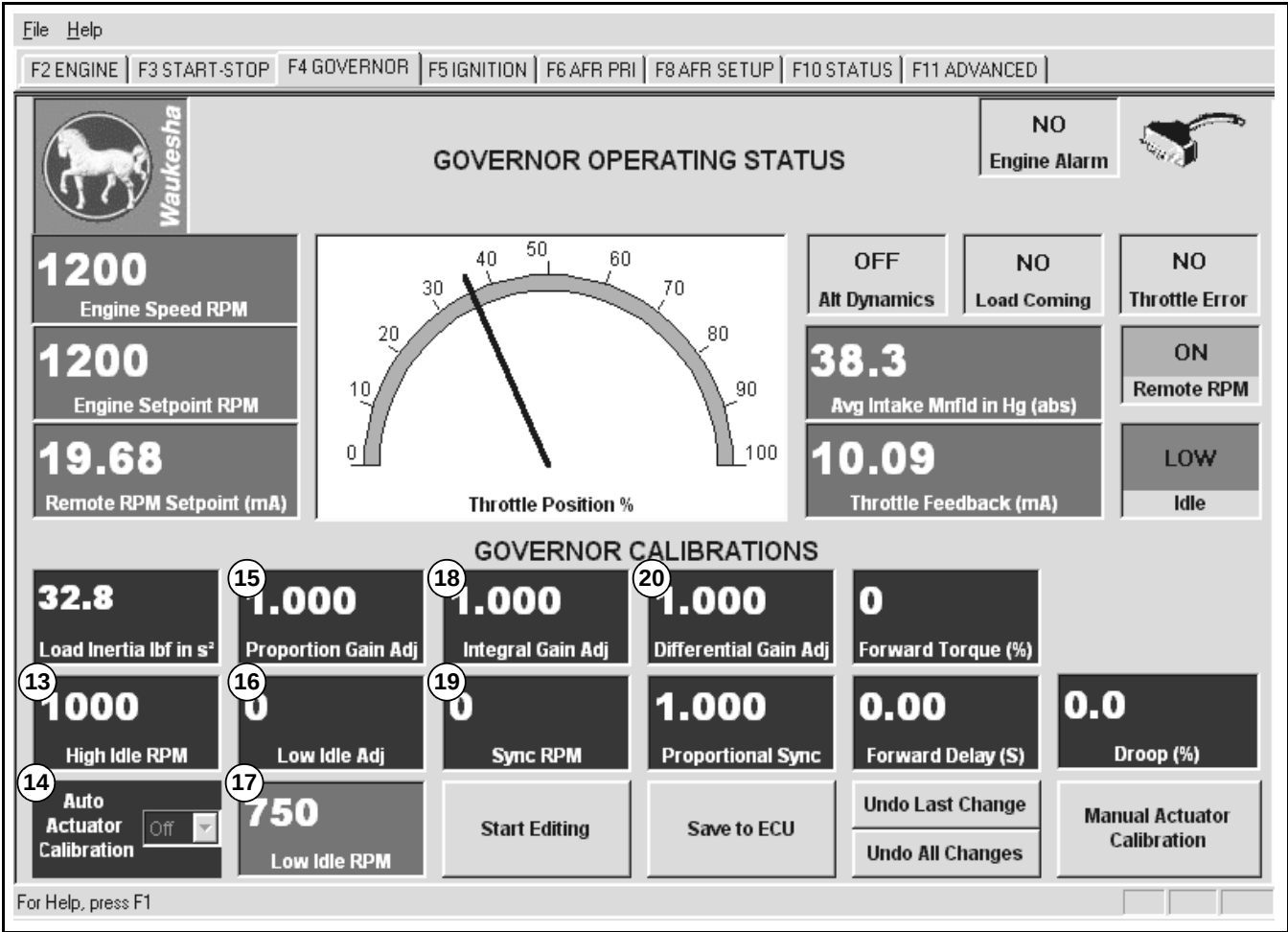


Figure 3.05-8 Governor Panel in ESP – Fields 13 through 20

[F4] GOVERNOR PANEL DESCRIPTION – REFER TO FIGURE 3.05-8

⑬ **“High Idle RPM”** This field allows the user to program the high idle rpm. The high idle setting is used when the rated speed/idle speed digital input is high (8.6 – 36 volts) and “Remote RPM” (Field 9) is OFF. The high idle rpm can be programmed from 800 to 2200 rpm (not to exceed a preprogrammed maximum speed). Internal calibrations prevent the engine from running faster than rated speed +10%.

⑭ **“Auto Actuator Calibration”** This field allows the user to program the ESM system to automatically calibrate the throttle actuator during every normal shutdown. The benefits to calibrating the actuator automatically are (1) performing the calibration when the actuator is hot (normal operating condition), and (2) if any actuator problems are detected, they are found on engine shutdown and not startup. See Section 3.10 *ESP Programming* “Actuator Calibration” for more information.

⑮ **“Proportion Gain Adj”** This field allows the user to adjust proportional gain by a multiplier of 0.500 – 1.050. Proportional gain is a correction function to speed error that is proportional to the amount of error. When an error exists between actual engine speed and engine speed setpoint, a proportional gain calibrated by Waukesha Engine is multiplied to the speed error. This is done to increase or decrease throttle response to correct speed error. Although the user can program the proportional gain multiplier with this field to “fine-tune” throttle response, it is typically not adjusted. “Integral Gain Adj” (Field 18) and “Differential Gain Adj” (Field 20) are also used to correct speed error:

Correction =

$$(\text{speed error} \times \text{proportional gain} \times \text{proportional gain adjust}) +$$

$$\left(\int_0^x \text{speed error dt} \times \text{integral gain} \times \text{integral gain adjust} \right) +$$

$$\left(\frac{d \text{ speed error}}{dt} \times \text{differential gain} \times \text{differential gain adjust} \right)$$

⑮ ⑰ **“Low Idle Adj”** and **“Low Idle RPM”** These fields allow the user to view and program the low idle rpm setting. The low idle setting is used when the rated speed/idle speed digital input is low (< 3.3 volts) and “Remote RPM” (Field 9) is OFF. The teal (blue-green) “Low Idle RPM” field displays the

actual programmed low idle rpm setting. The dark blue “Low Idle Adj” field allows the user to adjust the actual setting by entering a value from -50 to +100 rpm. When an adjustment is entered, the actual “Low Idle RPM” is updated to reflect the adjustment. *NOTE: The low idle rpm cannot be set above the high idle rpm.*

⑱ **“Integral Gain Adj”** This field allows the user to adjust integral gain by a multiplier of 0.502 – 1.102 and 0.000. Integral gain is a correction function to speed error that is based on the amount of time the error is present. When an error exists between actual engine speed and engine speed setpoint, an integral gain calibrated by Waukesha Engine is multiplied to the integral of the speed error. This is done to increase or decrease throttle response to correct or reduce speed error. Although the user can program the integral gain multiplier with this field to “fine-tune” throttle response, it is typically not adjusted. “Proportional Gain Adj” (Field 15) and “Differential Gain Adj” (Field 20) are also used to correct speed error. See speed error correction equation under the description for Field 15.

⑲ **“Sync RPM”** This field allows the user to program a synchronous rpm to allow easier synchronization to the electric grid. The additional rpm programmed in this field is added to the engine setpoint rpm if the “Alt Dynamics” field is ON. The synchronous rpm can be programmed from 0 to 64 rpm.

⑳ **“Differential Gain Adj”** This field allows the user to adjust differential gain by a multiplier of 0.502 – 1.102 and 0.000. Differential gain is a correction function to speed error that is based on direction and rate of change. When an error exists between actual engine speed and engine speed setpoint, a differential gain calibrated by Waukesha Engine is multiplied to the derivative of the speed error. This is done to increase or decrease throttle response to correct or reduce speed error. Although the user can program the differential gain multiplier with this field to “fine-tune” throttle response, it is typically not adjusted. “Proportional Gain Adj” (Field 15) and “Integral Gain Adj” (Field 18) are also used to correct speed error. See speed error correction equation under the description for Field 15.

Field descriptions continued on next page...

[F4] GOVERNOR PANEL DESCRIPTION

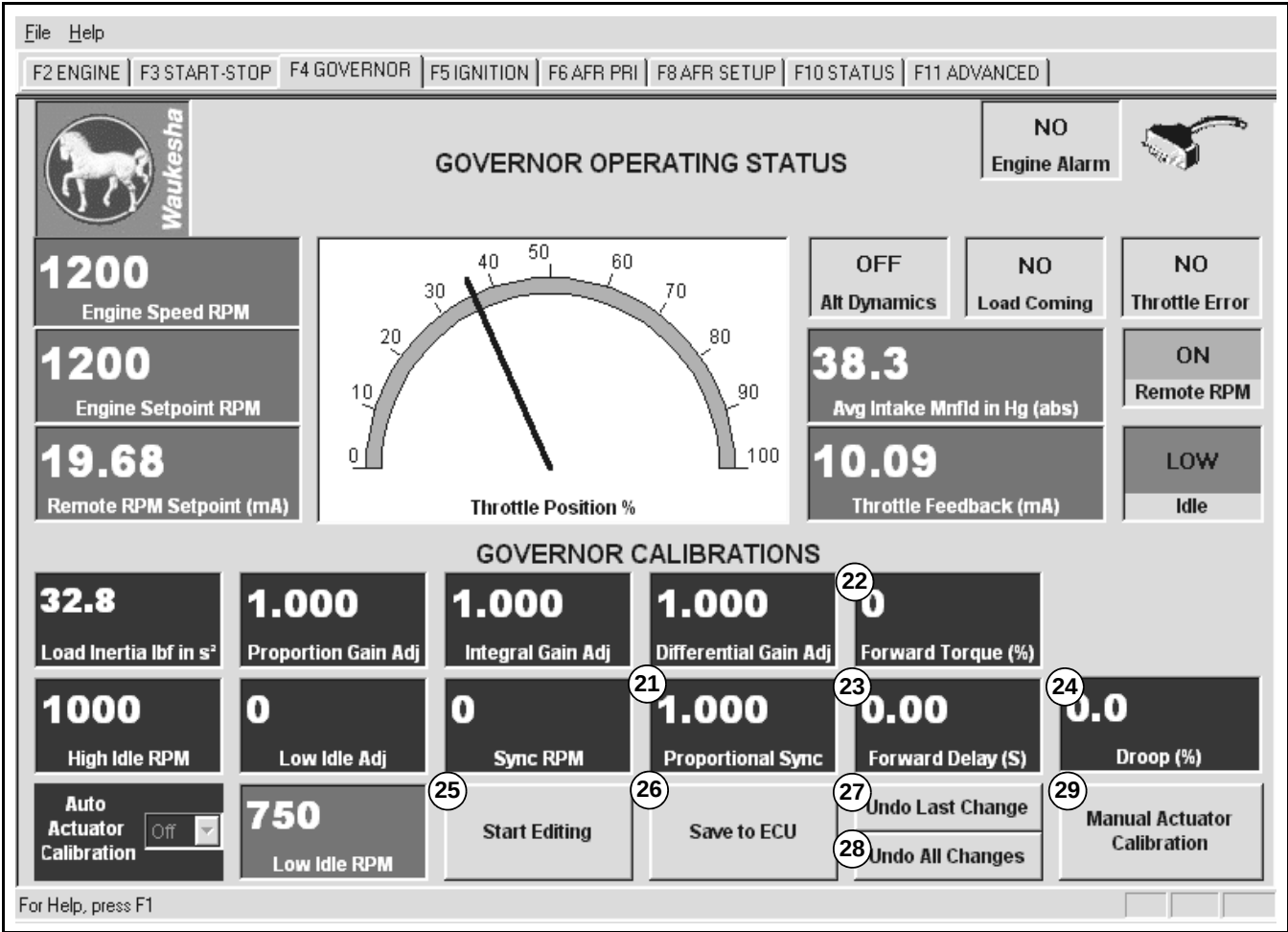


Figure 3.05-9 Governor Panel in ESP – Fields 21 through 29

[F4] GOVERNOR PANEL DESCRIPTION – REFER TO FIGURE 3.05-9

- 21 **“Proportional Sync”** This field allows the user to adjust proportional synchronous gain by a multiplier of 0.500 – 1.050. Proportional synchronous gain is a correction function to speed error that is proportional to the amount of error when operating in Alternate Dynamics mode only. Proportional synchronous gain is a lower multiplier than proportional gain because of the need to synchronize to the electric grid. When an error exists between actual engine speed and engine speed setpoint, a Waukesha-calibrated proportional synchronous gain is multiplied to the speed error. This is done to increase or decrease throttle response to correct speed error. Although the user can program the proportional synchronous gain multiplier with this field to “fine-tune” throttle response, it is typically not adjusted. “Integral Gain Adj” (Field 18) and “Differential Gain Adj” (Field 20) are also used to correct speed error. See speed error correction equation on page 3.05-11 under the description for Field 15.
- 22 **“Forward Torque”** This field allows the user to program the forward torque amount of load coming. When the load coming signal goes high, and after the forward delay timer has expired, the throttle opens by the programmed torque percent. The forward torque can be programmed from 0 to 125%.
- 23 **“Forward Delay”** This field allows the user to program the forward delay timer of load coming. When the load coming signal goes high, the forward delay must expire before the throttle opens to the programmed torque percent. Units are in seconds. The forward delay can be programmed from 0 to 60 seconds.
- 24 **“Droop”** This field allows the user to adjust the percent of droop. Droop allows steady-state speed to drop as load is applied. Droop is expressed as a percentage of normal average speed. Droop can be programmed from 0 to 5%.
- 25 **“Start Editing”** This button must be clicked prior to editing programmable (dark blue) fields in ESP. Clicking this button puts ESP in “editing mode.” The user will not be able to enter new values if ESP is not in editing mode. While in editing mode, the button will read “Stop Editing – Currently Editing.” When the editing mode is off, the button will read “Start Editing.” See Section 3.10 *ESP Programming* “Basic Programming in ESP” for more information.
- 26 **“Save to ECU”** This button is used to save programmed values to NVRAM (permanent memory) in the ECU. Changes saved to permanent memory will not be lost if power to the ECU is removed. See Section 3.10 *ESP Programming* “Saving to Permanent Memory” for more information. *NOTE: Programmed values not saved to permanent memory are stored in RAM (temporary memory). When values are in RAM, ESP can be closed and the PC disconnected from the ECU while keeping all changes; however, changes will be lost if power to the ECU is removed or when the engine is shut down.*
- 27 **“Undo Last Change”** This button allows the user to reset the last change made while in editing mode back to the programmed parameter that was last saved to permanent memory (NVRAM) in the ECU.
- 28 **“Undo All Changes”** This button allows the user to reset all the programmable fields back to the programmed parameters that were last saved to permanent memory (NVRAM) in the ECU.
- 29 **“Manual Actuator Calibration”** This button allows the user to manually calibrate the throttle actuator. To work correctly, the ESM system must know the fully closed and fully open end points of throttle actuator movement. To establish the fully closed and fully open end points, the throttle actuator must be calibrated. A manual calibration can be performed when the engine is not rotating and after postlube and the ESM system’s post-processing is complete. If an emergency shutdown is active, a manual calibration cannot be completed. See Section 3.10 *ESP Programming* “Actuator Calibration” for more information.

ESP PANEL DESCRIPTIONS

[F5] IGNITION PANEL DESCRIPTION

The Ignition Panel displays engine speed, intake manifold pressure, ignition timing for each cylinder, ignition enabled, ignition level, maximum retard, WKI value used, and knock detection. This panel also allows the user to make IPM-D adjustments by calibrating high voltage, low voltage, and no spark limits. In addition, the WKI value and NOx emission levels (for use on LT engines only) are calibrated on the Ignition Panel.

File Help

F2 ENGINE | F3 START-STOP | F4 GOVERNOR | F5 IGNITION | F6 AFR PRI | F8 AFR SETUP | F10 STATUS | F11 ADVANCED

Waukesha

IGNITION OPERATING STATUS

NO Engine Alarm

Left Bank Ignition Timing	Left Bank Spark Ref #	Right Bank Spark Ref #	Right Bank Ignition Timing	STATUS
24.00	153	1	24.00	LEVEL 1
24.00	151	2	24.00	Ignition Energy
24.00	148	3	24.00	ON
24.00	149	4	24.00	Ignition
24.00	150	5	24.00	RUN
24.00	149	6	24.00	User ESD

38.2
Avg Intake Mnfld in Hg (abs)

1200
Engine Speed RPM

94
User WKI in Use

NO
Max Retard

NO
Knocking

IGNITION CALIBRATIONS

0 High Voltage Adj.	0 Low Voltage Adj.	0 No Spark Adj.	94.0 User WKI	1.0 NOx g/BHP-hr
170 High Voltage Limit	100 Low Voltage Limit	250 No Spark Limit	Start Editing	Save to ECU

NOx field only used on lean burn engines.

Undo Last Change

Undo All Changes

For Help, press F1

Figure 3.05-10 Ignition Panel in ESP – Fields 1 through 12

[F5] IGNITION PANEL DESCRIPTION – REFER TO FIGURE 3.05-10

- ① **“Left Bank Ignition Timing”** This field displays individual cylinder timing in degrees before top dead center (° BTDC).
- ② ③ **“Left Bank Spark Ref #” and “Right Bank Spark Ref #”** These fields display the spark reference number for each cylinder. The spark reference numbers can be used to represent spark plug electrode wear (gap) and can be monitored (for example, with MODBUS®) and trended to predict the time of spark plug failure. The spark reference number is an arbitrary number based on relative voltage demand and is a feature of the IPM-D’s predictive diagnostics capability. A gradual increase in the spark reference number is expected over time as the spark plug wears. The closer to end of spark plug life, the faster the number will increase. If sufficient spark plug wear is monitored, IPM-D raises the power level of the ignition coil to Level 2 (see description for “Ignition Energy” field below). Once Level 2 energy is applied, the spark reference number will decrease initially but the Fault Log will indicate the cylinder number of the spark plug that is wearing out. *NOTE: When using MODBUS® the cylinder number is in firing order. For example, if #5 cylinder triggers an alarm for having a worn-out spark plug, the user should check the spark plug of the 5th cylinder in the firing order.*
- ④ **“Right Bank Ignition Timing”** This field displays individual cylinder timing in degrees before top dead center (° BTDC).
- ⑤ **“Avg Intake Mnfld”** This field displays the average intake manifold pressure. Units are in-Hg absolute (kPa absolute). On a vee engine, the left and right intake manifold pressure readings are averaged together and displayed in this field. If one of the intake manifold pressure sensors fails, the field displays only the reading from the working sensor. If both sensors fail, the field is unable to display the actual value and a default value is displayed instead.
- ⑥ **“Ignition Energy”** This field indicates at what level of energy the IPM-D is firing the spark plugs: Level 1 (low/normal) or Level 2 (high). During normal engine operation, the IPM-D fires at a Level 1 ignition energy. The IPM-D fires at a Level 2 ignition energy on engine startup or as a result of spark plug wear. If the ignition energy is raised to Level 2 (except on startup), an alarm is triggered to alert the operator. The pink field will signal the user whether the ignition level is LEVEL 1 or LEVEL 2.
- ⑦ **“Max Retard”** This field alerts the user when any cylinder’s timing has reached the maximum retard in timing allowed. If any cylinder’s timing is at maximum retard, the field is yellow and signals the user that YES, a cylinder is at maximum retard. The user can determine which cylinder(s) are at maximum retard by looking for the lowest individual cylinder timing displayed on the left of the screen. When none of the cylinders are at maximum retard, the field is gray and signals the user that NO cylinders are at maximum retard.
- ⑧ **“Engine Speed”** This field displays current engine speed (rpm).
- ⑨ **“Ignition”** This field signals when the IPM-D is enabled and is ready to receive a signal from the ECU to fire each spark plug. During the time the IPM-D is enabled, the field is green and signals the user it is ON. During the time the ignition is disabled, the field is gray and signals the user it is OFF.
- ⑩ **“Knocking”** This field alerts the user that knock is present when the cylinder timing is at maximum retard. When knock is sensed with at least one cylinder, the field is yellow and signals the user that YES, knock is present. The user can determine which cylinder(s) is knocking by looking at the individual cylinder timings displayed on the left of the screen.
- ⑪ **“User WKI in Use”** This field indicates whether the WKI (Waukesha Knock Index) value used by the ESM system is based on the user-defined value programmed in “User WKI” (Field 19) or is remotely inputted to the ECU using a 4 – 20 mA optional user input. When the WKI value is programmed in ESP, the field indicates “User WKI in Use.” When the WKI value is being inputted in real time through the optional analog user input, the field indicates “Remote WKI in Use.”
- ⑫ **“User ESD”** This field signals that an emergency shutdown is in process based on a customer input. During an emergency shutdown, the field is red and signals the user that an E-STOP (emergency stop) is active. When E-STOP is displayed, the engine cannot be restarted. When the engine is not in an emergency shutdown mode, the field is gray and signals the user that the engine is ready to RUN.

Field descriptions continued on next page...

[F5] IGNITION PANEL DESCRIPTION

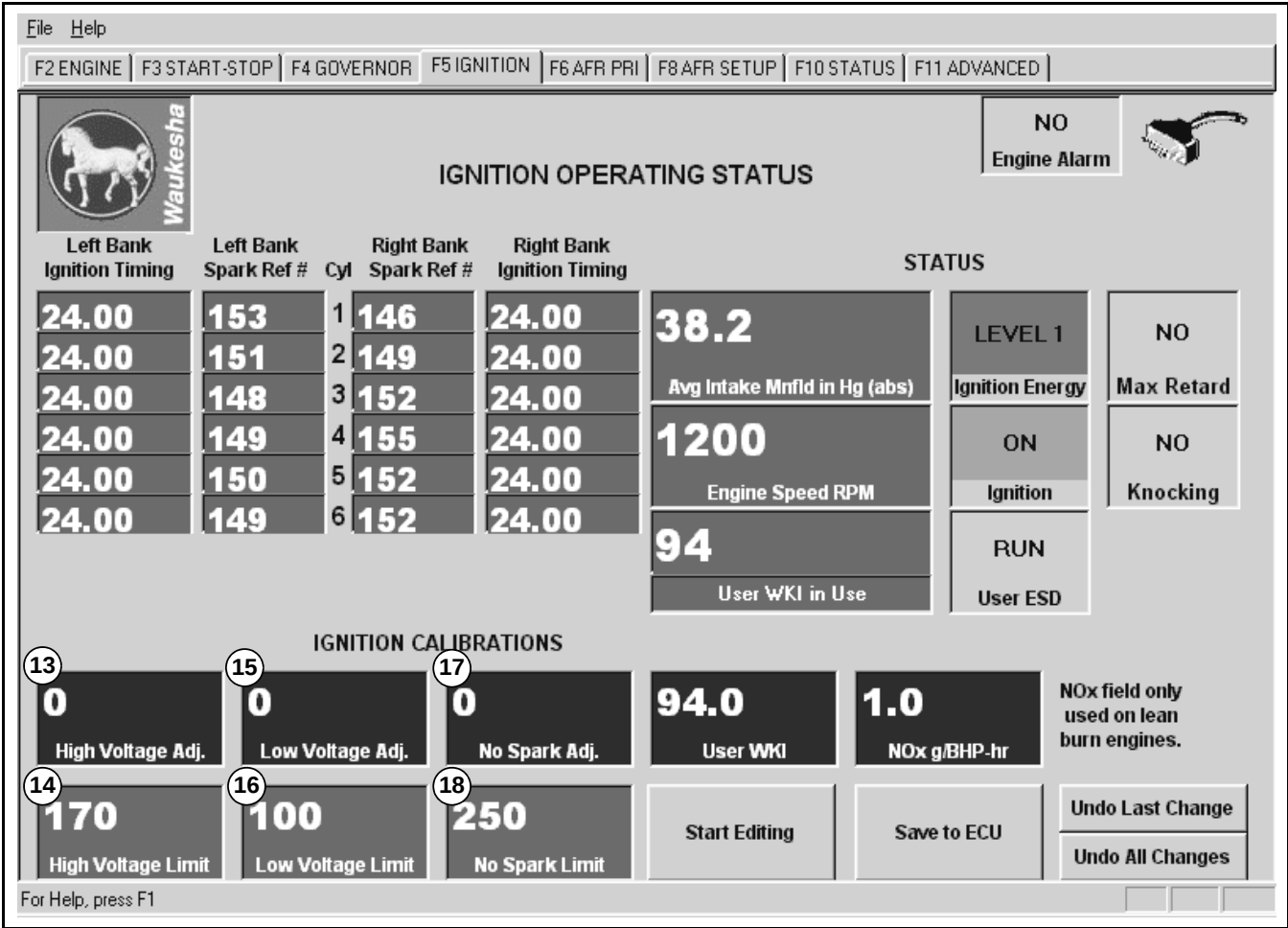


Figure 3.05-11 Ignition Panel in ESP – Fields 13 through 18

[F5] IGNITION PANEL DESCRIPTION – REFER TO FIGURE 3.05-11

13 14 “High Voltage Adj.” and “High Voltage Limit” These fields allow the user to view and adjust the high voltage alarm limit setting. The high voltage limit is based on the spark reference number. When a cylinder’s spark reference number exceeds the high voltage limit, the ignition energy is raised to a Level 2 (high) ignition energy and an alarm is triggered. Based on a thorough trend analysis of the spark reference numbers, the user may want to adjust the high voltage limit to fit the specific needs of the engine. Improper use of this adjustment may limit the effectiveness of IPM-D diagnostics. Programming the “High Voltage Adj.” to a positive number will delay triggering the high voltage limit alarm until the spark plugs are more worn. Likewise, reducing the “High Voltage Adj.” will advance triggering the high voltage limit alarm, allowing more time between when an alarm is triggered and spark plug failure. The teal (blue-green) “High Voltage Limit” field displays the actual programmed high voltage limit setting. The dark blue “High Voltage Adj.” field allows the user to adjust the actual setting by entering a value from -30 to +30. When an adjustment is entered, the actual “High Voltage Limit” is updated to reflect the adjustment. See Section 3.10 *ESP Programming “IPM-D Programming”* for more information. *NOTE: The “High Voltage Limit” field has a defined range (min./max.) that can be programmed. If the user programs a positive or negative adjustment that exceeds this defined range, the “High Voltage Limit” field will display the actual high voltage setting, even though the adjustment entered may calculate to be different. For example, if the default high voltage limit is 170 but cannot exceed 190 for the engine (a factory setting), the “High Voltage Limit” field will display the actual high voltage setting. So if the user programs an adjustment of +30 (which exceeds 190), “30” will appear in the “High Voltage Adj.” field and “190” will appear in the “High Voltage Limit” field. The same holds true for negative adjustments.*

15 16 “Low Voltage Adj.” and “Low Voltage Limit” These fields allow the user to view and adjust the low voltage alarm limit setting. The low voltage limit is based on the spark reference number. When a cylinder’s spark reference number goes below the low voltage limit, an alarm is triggered, identifying a low voltage demand condition that may have resulted from a shorted coil or secondary lead, deposit buildup or a failed spark plug (failure related to “balling” or shorting). Based on a thorough trend analysis of the spark reference numbers, the user may want to adjust the low voltage limit to fit the specific needs of the engine. Improper use of this adjustment may limit the effectiveness of IPM-D diagnostics. Typically this limit is not adjusted. The teal (blue-green) “Low Voltage Limit” field displays

the actual programmed low voltage limit setting. The dark blue “Low Voltage Adj.” field allows the user to adjust the actual setting by entering a value from -30 to +30. When an adjustment is entered, the actual “Low Voltage Limit” is updated to reflect the adjustment. See Section 3.10 *ESP Programming “IPM-D Programming”* for more information. *NOTE: The “Low Voltage Limit” field has a defined range (min./max.) that can be programmed. If the user programs a positive or negative adjustment that exceeds this defined range, the “Low Voltage Limit” field will display the actual low voltage setting, even though the adjustment entered may calculate to be different. For example, if the default low voltage limit is 100 but cannot exceed 120 for the engine (a factory setting), the “Low Voltage Limit” field will display the actual low voltage setting. So if the user programs an adjustment of +30 (which exceeds 120), “30” will appear in the “Low Voltage Adj.” field and “120” will appear in the “Low Voltage Limit” field. The same holds true for negative adjustments.*

17 18 “No Spark Adj.” and “No Spark Limit” The “No Spark Adj.” and “No Spark Limit” fields allow the user to view and adjust the no spark alarm limit setting. The no spark limit is based on the spark reference number. When a cylinder’s spark reference number exceeds the no spark limit, an alarm is triggered, indicating that a spark plug is worn and must be replaced. Based on a thorough trend analysis of the spark reference numbers, the user may want to adjust the no spark limit to fit the specific needs of the engine. Improper use of this adjustment may limit the effectiveness of IPM-D diagnostics. Typically this limit is not adjusted. The teal (blue-green) “No Spark Limit” field displays the actual programmed no spark limit setting. The dark blue “No Spark Adj.” field allows the user to adjust the actual setting by entering a value from -25 to +25. When an adjustment is entered, the actual “No Spark Limit” is updated to reflect the adjustment. See Section 3.10 *ESP Programming “IPM-D Programming”* for more information. *NOTE: The “No Spark Limit” field has a defined range (min./max.) that can be programmed. If the user programs a positive or negative adjustment that exceeds this defined range, the “No Spark Limit” field will display the actual no spark setting even though the adjustment entered may calculate to be different. For example, if the default no spark limit is 200 but cannot exceed 215 for the engine (a factory setting), the “No Spark Limit” field will display the actual no spark setting. So if the user programs an adjustment of +25 (which exceeds 215), “25” will appear in the “No Spark Adj.” field and “215” will appear in the “No Spark Limit” field. The same holds true for negative adjustments.*

Field descriptions continued on next page...

ESP PANEL DESCRIPTIONS

[F5] IGNITION PANEL DESCRIPTION

File
Help

F2 ENGINE
F3 START-STOP
F4 GOVERNOR
F5 IGNITION
F6 AFR PRI
F8 AFR SETUP
F10 STATUS
F11 ADVANCED



NO
Engine Alarm



IGNITION OPERATING STATUS

Left Bank Ignition Timing	Left Bank Spark Ref #	Cyl	Right Bank Spark Ref #	Right Bank Ignition Timing	38.2 Avg Intake Mnfld in Hg (abs) 1200 Engine Speed RPM 94 User WKI in Use LEVEL 1 Ignition Energy ON Ignition RUN User ESD NO Max Retard NO Knocking
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IGNITION CALIBRATIONS

0	0	0	19	20	NOx field only used on lean burn engines.
High Voltage Adj.	Low Voltage Adj.	No Spark Adj.	User WKI	NOx g/BHP-hr	
170	100	250	21	22	23
High Voltage Limit	Low Voltage Limit	No Spark Limit	Start Editing	Save to ECU	Undo Last Change
					24 Undo All Changes

For Help, press F1

Figure 3.05-12 Ignition Panel in ESP – Fields 19 through 24

[F5] IGNITION PANEL DESCRIPTION – REFER TO FIGURE 3.05-12

- ①9 **“User WKI”** This field **MUST** be programmed by the user for proper engine operation. The user must enter the WKI (Waukesha Knock Index) value of the fuel. The WKI value can be determined using an application program for the Microsoft® Windows® XP operating system. The computer program will calculate the WKI value from a customer’s gas analysis breakdown. The WKI value application program designed by Waukesha Engine uses an index for calculating knock resistance of gaseous fuels. The WKI value must be based on the composition of a fuel sample taken from the engine site and analyzed using the application program or as dictated on a Special Application Approval (SAA). Contact your local Distributor for more information.
- ②0 **“NOx”** (For use on LT engines only.) This field allows the user to set the desired NOx emissions level (engine out at the exhaust stack) at which the engine will run. The field displays the programmed NOx level, not the actual level. Based on the programmed NOx level, the ESM system will adjust ignition timing in an attempt to meet the programmed NOx level. However, the actual NOx output of the engine will not always match the programmed NOx level for several reasons. First, the ESM system calculates NOx based on a combination of sensor readings logged by the ECU and Waukesha-calibrated values. Two examples of Waukesha-calibrated values are humidity and exhaust oxygen since the ESM system does not measure these variables. Also, the ESM system includes a preprogrammed correction factor to allow for statistical variations with the engine. As a result, the engine in most cases will emit less NOx than the actual programmed NOx level. Units are in g/BHP-hr or mg/m³ (n) @ 0° C, 101.25 kPa, 5% O₂. The range that NOx can be programmed varies with the engine (L5794LT range is 1.5 – 5.0 g/BHP-hr). *NOTE: To correct for differences in the actual engine-out NOx emissions and that of the programmed NOx level, the user input should be adjusted in the appropriate direction until the actual engine-out emissions meet the user’s desired level (e.g., the NOx field may require a value of 2.5 g/BHP-hr to achieve 2.0 g/BHP-hr NOx emissions at the exhaust stack).*
- ②1 **“Start Editing”** This button must be clicked prior to editing programmable (dark blue) fields in ESP. Clicking this button puts ESP in “editing mode.” The user will not be able to enter new values if ESP is not in editing mode. While in editing mode, the button will read “Stop Editing – Currently Editing.” When the editing mode is off, the button will read “Start Editing.” See Section 3.10 *ESP Programming* “Basic Programming in ESP” for more information.
- ②2 **“Save to ECU”** This button is used to save programmed values to NVRAM (permanent memory) in the ECU. Changes saved to permanent memory will not be lost if power to the ECU is removed. See Section 3.10 *ESP Programming* “Saving to Permanent Memory” for more information. *NOTE: Programmed values not saved to permanent memory are stored in RAM (temporary memory). When values are in RAM, ESP can be closed and the PC disconnected from the ECU while keeping all changes; however, changes will be lost if power to the ECU is removed or when the engine is shut down.*
- ②3 **“Undo Last Change”** This button allows the user to reset the last change made while in editing mode back to the programmed parameter that was last saved to permanent memory (NVRAM) in the ECU.
- ②4 **“Undo All Changes”** This button allows the user to reset all the programmable fields back to the programmed parameters that were last saved to permanent memory (NVRAM) in the ECU.

[F6] AFR PRIMARY FUEL PANEL DESCRIPTION

The AFR Primary Fuel Panel is used to monitor AFR system performance. This panel displays engine speed and target Lambda. Also, displayed for both left and right banks are the actual Lambda, primary stepper position, minimum and maximum stepper setpoints, stepper operating mode, intake manifold pressure, oxygen and exhaust sensor status, and AFR operating mode (automatic or manual). This panel also allows the user to change either bank from automatic to manual mode and adjust stepper position using the arrow buttons.

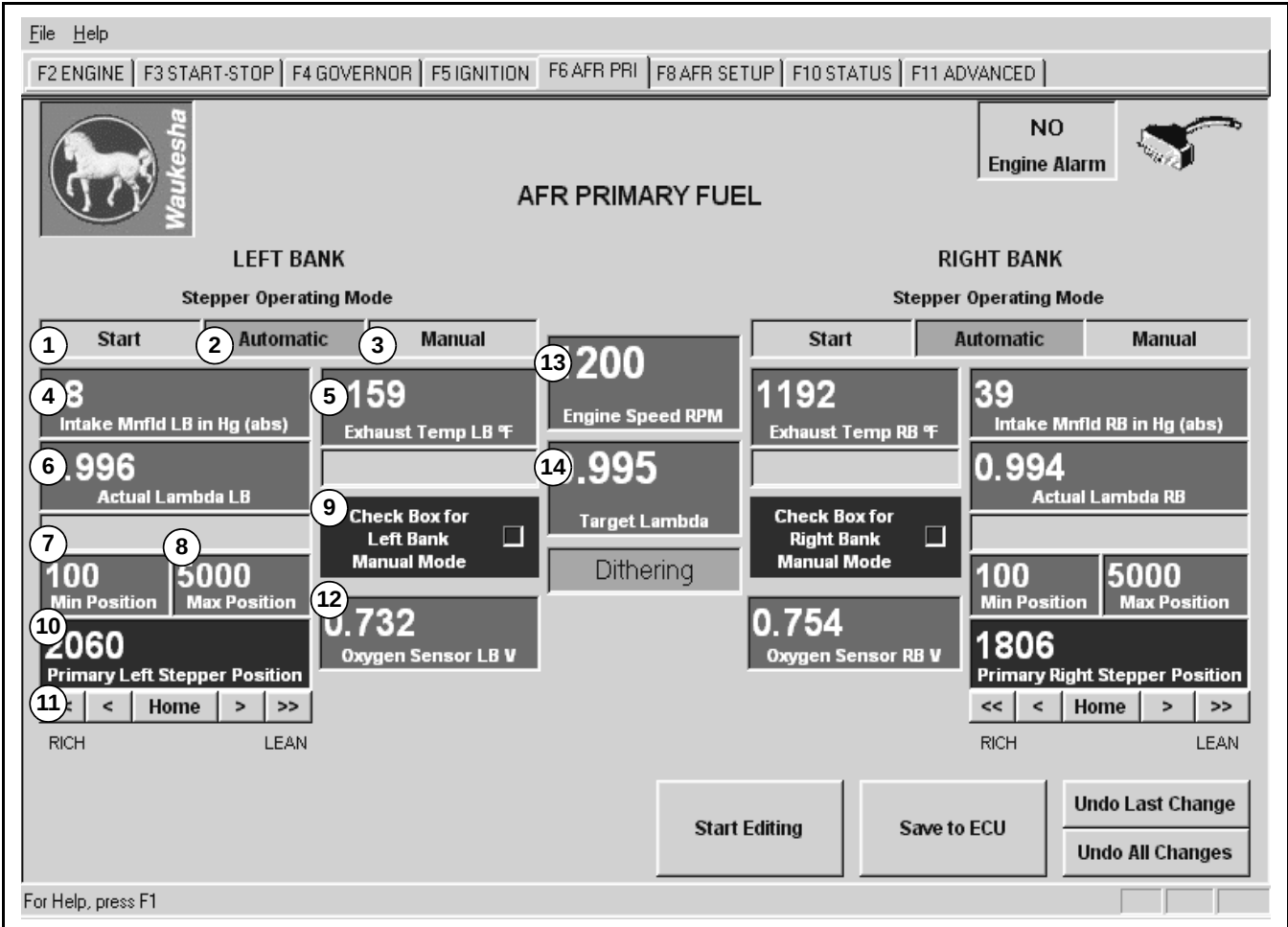


Figure 3.05-13 AFR Primary Fuel Panel in ESP – Fields 1 through 14

[F6] AFR PRIMARY FUEL PANEL DESCRIPTION – REFER TO FIGURE 3.05-13

- ① **“Start”** This field signals when the engine is in its starting mode and the left bank stepper motor is held at a user-defined start position programmed on the [F8] AFR Setup Panel. When the engine is not in start mode, the field is gray.
- ② **“Automatic”** This field signals that the ESM AFR system is automatically controlling stepper movement. When the AFR system is not in automatic control, the field is gray.
- ③ **“Manual”** This field signals that the user has selected to be in manual mode. Manual mode allows the user to adjust stepper position using the arrow buttons (<< < > >>). When in manual mode, the AFR system does not perform any automatic stepper adjustments; it will only move stepper position with user adjustment. When the AFR system is not in manual mode, the field is gray.
- ④ **“Intake Mnfld”** This field displays the engine's left bank intake manifold pressure. Units are in-Hg absolute (kPa absolute). If an intake manifold pressure sensor or wiring fault occurs, the status bar beneath this field signals an alarm (turns yellow) and provides a message to fix the sensor or wiring. *NOTE: When a sensor or wiring fault is detected, the field displays a default value, not the actual value.*
- ⑤ **“Exhaust Temp”** This field displays the post-turbine, left bank, exhaust temperature. Units are °F (°C). If an exhaust sensor or wiring fault occurs, the status bar beneath this field signals an alarm (turns yellow) and provides a message to fix the sensor or wiring. *NOTE: When a sensor or wiring fault is detected, the field displays a default value, not the actual value.*
- ⑥ **“Actual Lambda”** This field displays actual Lambda. Lambda is equal to the amount of air present relative to that of a stoichiometric mixture. For example, a Lambda of 1.0000 is equal to an air/fuel ratio of approximately 16:1. Slightly rich of stoichiometry, or a Lambda of 0.995, is the typical setpoint of catalyst engines.
- ⑦ **“Min Position”** This field displays the minimum left bank stepper position that is programmed on the [F8] AFR Setup Panel. The value displayed is the minimum stepper motor position at the engine's current intake manifold pressure level.
- ⑧ **“Max Position”** This field displays the maximum left bank stepper position that is programmed on the [F8] AFR Setup Panel. The value displayed is the maximum stepper motor position at the engine's current intake manifold pressure level.
- ⑨ **“Check Box for Left Bank Manual Mode”** This field allows the user to change the AFR system mode of operation on the engine's left bank from automatic to manual mode. Normally the AFR system operates in automatic mode; however, the user can click the check box changing the system to manual mode. Manual mode allows the user to adjust stepper position using the arrow buttons on the panel. When changed into manual mode, the AFR system does not perform any automatic stepper adjustments; it will only move stepper position with user adjustment. Check mark is ON; no check mark is OFF.
- ⑩ **“Primary Left Stepper Position”** This field displays the current position of the left bank stepper motor.
- ⑪ **“Arrow Buttons”** and **“Home”** The AFR system must be in manual mode for the user to use the left bank arrow buttons. The double arrow buttons (<< >>) move the stepper motor up or down in 400-step increments. The single arrow buttons (< >) move the stepper motor up or down in 25-step increments. The home button moves the stepper motor to the home position and then back to the start position only when the engine is not running. If the user clicks on the home button while the engine is running, an error message appears.
- ⑫ **“Oxygen Sensor”** This field displays the voltage of the left bank oxygen sensor. If an oxygen sensor or wiring fault occurs, the status bar beneath this field signals an alarm (turns yellow) and provides a message to fix the sensor or wiring. *NOTE: When a sensor or wiring fault is detected, the field displays a default value, not the actual value.*
- ⑬ **“Engine Speed”** This field displays current engine speed (rpm).
- ⑭ **“Target Lambda”** This field displays the target Lambda setpoint the AFR system is adjusting the stepper position to maintain. The target Lambda is based on a Waukesha-calibrated value and a user off-set programmed on the [F8] AFR Setup Panel.

Field descriptions continued on next page...

[F6] AFR PRIMARY FUEL PANEL DESCRIPTION

FileHelp

F2 ENGINEF3 START-STOPF4 GOVERNORF5 IGNITIONF6 AFR PRIF8 AFR SETUPF10 STATUSF11 ADVANCED



AFR PRIMARY FUEL

NO Engine Alarm

LEFT BANK

RIGHT BANK

Stepper Operating Mode

StartAutomaticManual

38 Intake Mnfld LB in Hg (abs)

0.996 Actual Lambda LB

100 Min Position5000 Max Position

2060 Primary Left Stepper Position

<<<<Home>>>>

RICHLEAN

Stepper Operating Mode

StartAutomaticManual

1200 Engine Speed RPM

0.995 Target Lambda

Dithering

1518192 Exhaust Temp RB °F

1939 Intake Mnfld RB in Hg (abs)

200.994 Actual Lambda RB

21 Check Box for Right Bank Manual Mode

22

23100 Min Position5000 Max Position

24.754 Oxygen Sensor RB V

251806 Primary Right Stepper Position

26<<<<Home>>>>

RICHLEAN

Start Editing

Save to ECU

Undo Last Change

Undo All Changes

For Help, press F1

Figure 3.05-14 AFR Primary Fuel Panel in ESP – Fields 15 through 26

[F6] AFR PRIMARY FUEL PANEL DESCRIPTION – REFER TO FIGURE 3.05-14

- ①5 **“Start”** This field signals when the engine is in its starting mode and the right bank stepper motor is held at a user-defined start position programmed on the [F8] AFR Setup Panel. When the engine is not in start mode, the field is gray.
- ①6 **“Automatic”** This field signals that the ESM AFR system is automatically controlling stepper movement. When the AFR system is not in automatic control, the field is gray.
- ①7 **“Manual”** This field signals that the user has selected to be in manual mode. Manual mode allows the user to adjust stepper position using the arrow buttons (<< < > >>). When in manual mode, the AFR system does not perform any automatic stepper adjustments; it will only move stepper position with user adjustment. When the AFR system is not in manual mode, the field is gray.
- ①8 **“Exhaust Temp”** This field displays the post-turbine, right bank, exhaust temperature. Units are °F (°C). If an exhaust sensor or wiring fault occurs, the status bar beneath this field signals an alarm (turns yellow) and provides the user a message to fix the sensor or wiring. *NOTE: When a sensor or wiring fault is detected, the field displays a default value, not the actual value.*
- ①9 **“Intake Mnflnd”** This field displays the engine’s right bank intake manifold pressure. Units are in-Hg absolute (kPa absolute). If an intake manifold pressure sensor or wiring fault occurs, the status bar beneath this field signals an alarm (turns yellow) and provides the user a message to fix the sensor or wiring. *NOTE: When a sensor or wiring fault is detected, the field displays a default value, not the actual value.*
- ②0 **“Actual Lambda”** This field displays actual Lambda. Lambda is equal to the amount of air present relative to that of a stoichiometric mixture. For example, a Lambda of 1.0000 is equal to an air/fuel ratio of approximately 16:1. Slightly rich of stoichiometry, or a Lambda of 0.995, is the typical setpoint of catalyst engines.
- ②1 **“Check Box For Right Bank Manual Mode”** This field allows the user to change the AFR system mode of operation on the engine’s right bank from automatic to manual mode. Normally the AFR system operates in automatic mode; however, the user can click the check box changing the system to manual mode. Manual mode allows the user to adjust stepper position using the arrow buttons on the panel. When changed into manual mode, the AFR system does not perform any automatic stepper adjustments; it will only move stepper position with user adjustment. Check mark is ON; no check mark is OFF.
- ②2 **“Min Position”** This field displays the minimum right bank stepper position that is programmed on the [F8] AFR Setup Panel. The value displayed is the minimum stepper motor position at the engine’s current intake manifold pressure level.
- ②3 **“Max Position”** This field displays the maximum right bank stepper position that is programmed on the [F8] AFR Setup Panel. The value displayed is the maximum stepper motor position at the engine’s current intake manifold pressure level.
- ②4 **“Oxygen Sensor”** This field displays the voltage of the right bank oxygen sensor. If an oxygen sensor or wiring fault occurs, the status bar beneath this field signals an alarm (turns yellow) and provides the user a message to fix the sensor or wiring. *NOTE: When a sensor or wiring fault is detected, the field displays a default value, not the actual value.*
- ②5 **“Primary Right Stepper Position”** This field displays the current position of the right bank stepper motor.
- ②6 **“Arrow Buttons”** and **“Home”** The AFR system must be in manual mode for the user to use the right bank arrow buttons. The double arrow buttons (<< >>) move the stepper motor up or down in 400-step increments. The single arrow buttons (< >) move the stepper motor up or down in 25-step increments. The home button moves the stepper motor to the home position and then back to the start position only when the engine is not running. If the user clicks on the home button while the engine is running, an error message appears.

Field descriptions continued on next page...

[F6] AFR PRIMARY FUEL PANEL DESCRIPTION

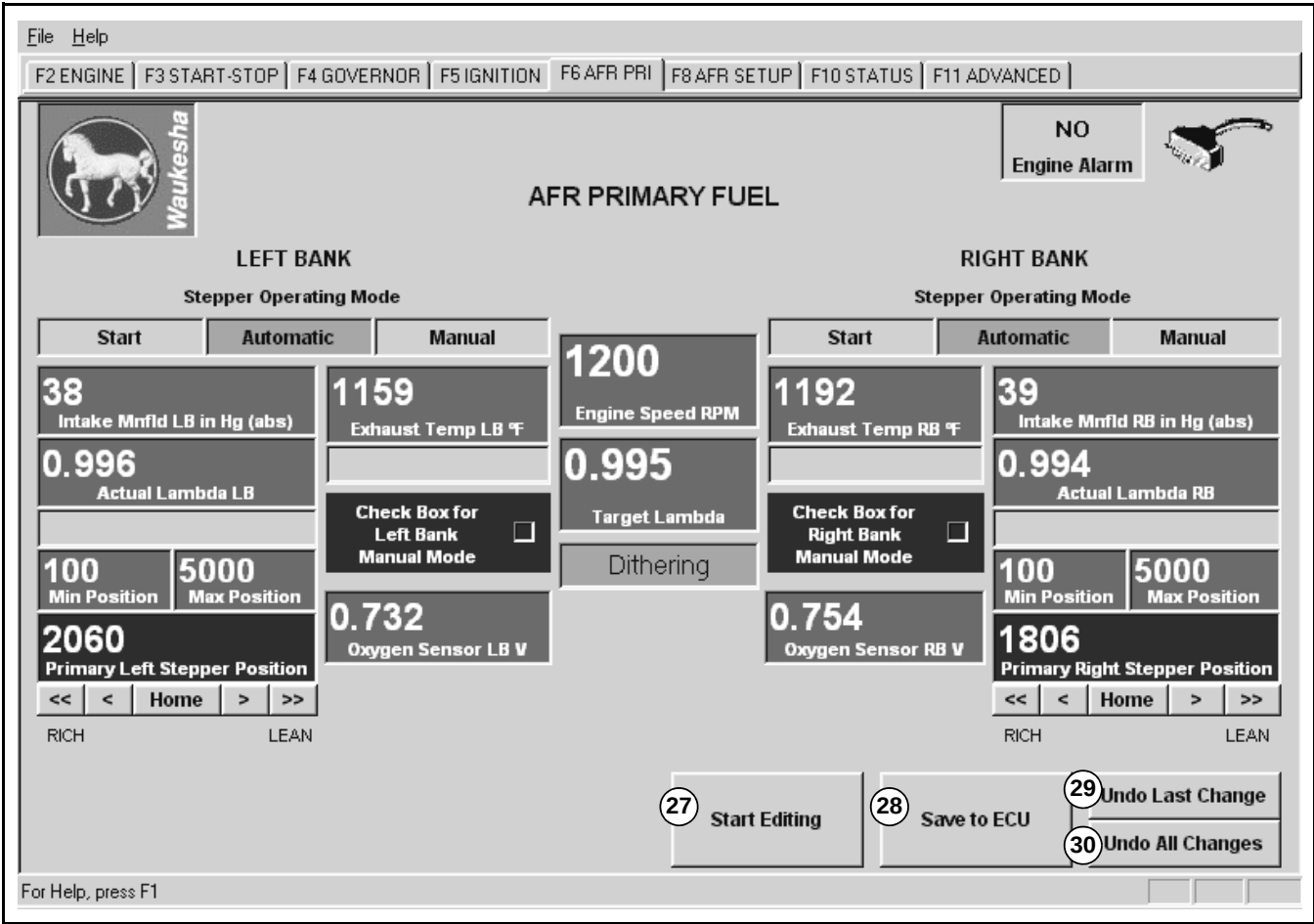


Figure 3.05-15 AFR Primary Fuel Panel in ESP – Fields 27 through 30

[F6] AFR PRIMARY FUEL PANEL DESCRIPTION – REFER TO FIGURE 3.05-15

②7 **“Stop Editing – Currently Editing”** This button must be clicked prior to editing programmable (dark blue) fields in ESP. Clicking this button puts ESP in “editing mode.” The user will not be able to enter new values if ESP is not in editing mode. While in editing mode, the button will read “Stop Editing – Currently Editing.” When the editing mode is off, the button will read “Start Editing.” See Section 3.10 *ESP Programming* “Basic Programming in ESP” for more information.

②8 **“Save to ECU”** This button is used to save programmed values to NVRAM (permanent memory) in the ECU. Changes saved to permanent memory will not be lost if power to the ECU is removed. See Section 3.10 *ESP Programming* “Saving to Permanent Memory” for more information. *NOTE: Programmed values not saved to permanent memory are stored in RAM (temporary memory). When values are in RAM, ESP can be closed and the PC disconnected from the ECU while keeping all changes; however, changes will be lost if power to the ECU is removed or when the engine is shut down.*

②9 **“Undo Last Change”** This button allows the user to reset the last change made while in editing mode back to the programmed parameter that was last saved to permanent memory (NVRAM) in the ECU.

③0 **“Undo All Changes”** This button allows the user to reset all the programmable fields back to the programmed parameters that were last saved to permanent memory (NVRAM) in the ECU.

[F8] AFR SETUP PANEL DESCRIPTION

The AFR Setup Panel is used to program and fine-tune the AFR system. This panel will only be displayed on an engine equipped with Waukesha factory installed air/fuel ratio control. This panel displays engine speed, target Lambda and displayed for both left and right banks are the intake manifold pressure, actual Lambda, and primary stepper position. This panel also allows the user to calibrate the dither steps, gain, oxygen target Lambda offset, and the minimum/maximum stepper positions. The user can set either left or right banks start (or home) position, stepper position using the arrow buttons, length of stepper motor shaft used, and change from automatic to manual mode.

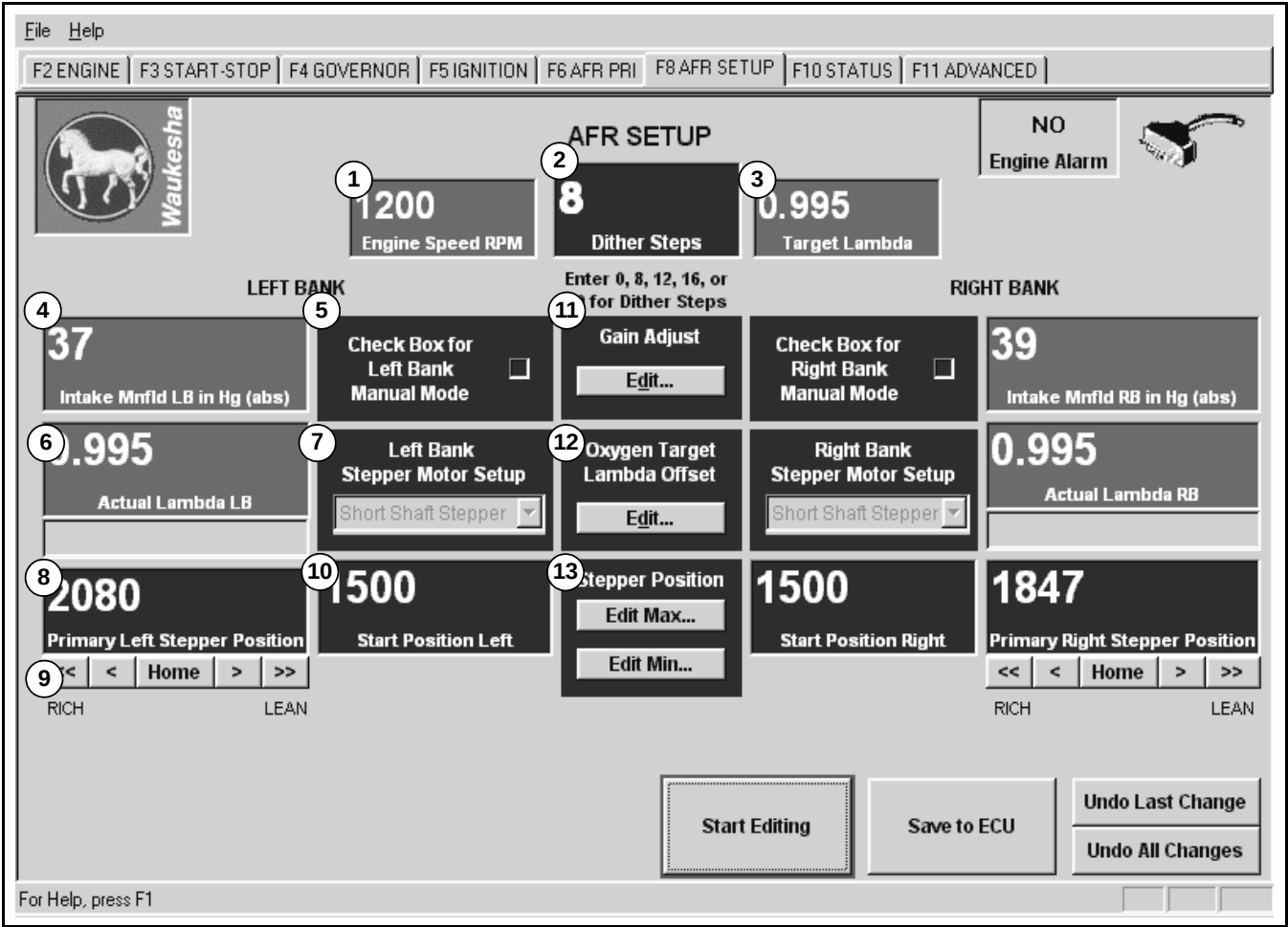


Figure 3.05-16 AFR Setup Panel in ESP – Fields 1 through 13

[F8] AFR SETUP PANEL DESCRIPTION REFER TO FIGURE 3.05-16

- ① **“Engine Speed”** This field displays current engine speed (rpm).
- ② **“Dither Steps”** This field allows the user to program dither steps that allow the AFR system to oscillate around the stepper’s normal movements plus or minus a user-programmed number of steps (0 = OFF; 8 = ± 8 steps; 12 = ± 12 steps; 16 = ± 16 steps; 20 = ± 20 steps).
- ③ **“Target Lambda”** This field displays the target Lambda setpoint the AFR system is adjusting stepper position to maintain. The target Lambda is based on a Waukesha-calibrated value and a user offset programmed in Field 12.
- ④ **“Intake Mnfld LB”** This field displays the engine’s intake manifold pressure. Units are in-Hg absolute (kPa absolute). If an intake manifold pressure sensor or wiring fault occurs, the status bar beneath this field signals an alarm (turns yellow) and provides a message to fix the sensor or wiring. *NOTE: When a sensor or wiring fault is detected, the field displays a default value, not the actual value.*
- ⑤ **“Check Box for Left Bank Manual Mode”** This field allows the user to change the AFR system mode of operation of the engine’s left bank from automatic to manual mode. Normally the AFR system operates in automatic mode; however, the user can click the check box, changing the system to manual mode. Manual mode allows the user to adjust stepper position using the arrow buttons (<< < > >>). When changed into manual mode, the AFR system will not make automatic stepper adjustments; it will only move stepper position with user adjustment. Check mark is ON; no check mark is OFF.
- ⑥ **“Actual Lambda”** This field displays actual Lambda. Lambda is equal to the amount of air present relative to that of a stoichiometric mixture. For example, a Lambda of 1.0000 is equal to an air/fuel ratio of approximately 16:1. Slightly rich of stoichiometry, or a Lambda of 0.995, is the typical setpoint of catalyst engines.
- ⑦ **“Left Bank Stepper Motor Setup”** This field allows the user to program the correct left bank stepper motor for their engine. The length of the stepper motor shaft must be programmed so the AFR system knows the stepper motor range. The number of steps is dependent on engine configuration and fuel regulator model. The short shaft stepper has 5,800 steps (GSI engines); the long shaft stepper has 20,000 steps (GSID engines). This field will be set at the factory but can be reprogrammed by the user.
- ⑧ **“Primary Left Stepper Position”** This field displays the current position of the left bank stepper motor.
- ⑨ **“Arrow Buttons”** and **“Home”** The AFR system must be in manual mode for the user to use the left bank arrow buttons. The double arrow buttons (<< >>) move the stepper motor up or down in 400-step increments. The single arrow buttons (< >) move the stepper motor up or down in 25-step increments. The home button moves the stepper motor to the home position and then back to the start position only when the engine is not running. If the user clicks on the home button while the engine is running, an error message appears.
- ⑩ **“Start Position Left”** This field displays the start position of the left bank stepper motor.
- ⑪ **“Gain Adjust”** This field allows the user to program the speed that the stepper motor reaches its setpoint. The range of adjustment is listed at the bottom of the programming table. The user can program the gain with this field to fine-tune both steady-state and transient AFR performance.
- ⑫ **“Oxygen Target Lambda Offset”** This field allows the user to program an offset to the Waukesha-calibrated target Lambda. By clicking on the “Edit...” button, a programming table is opened. The user programs an offset based on intake manifold pressure by subtracting or adding a slight Lambda amount. The range of adjustment is listed at the bottom of the programming table. The user can program an offset with this field to fine-tune AFR performance.
- ⑬ **“Stepper Position Edit Min/Max”** This field allows the user to program minimum and maximum stepper positions at various levels of intake manifold pressure. By clicking on the “Max...” or “Min...” button, a programming table is opened. The AFR system adjusts the stepper motor between two programmable limits to maintain the oxygen sensor voltage. The minimum and maximum positions, which define the stepper motor adjustment range, are determined by establishing an air/fuel ratio curve. By defining the stepper motor adjustment range, the user can maintain stable engine operation and set limits for troubleshooting or indication of sensor wear.

Field descriptions continued on next page...

[F8] AFR SETUP PANEL DESCRIPTION

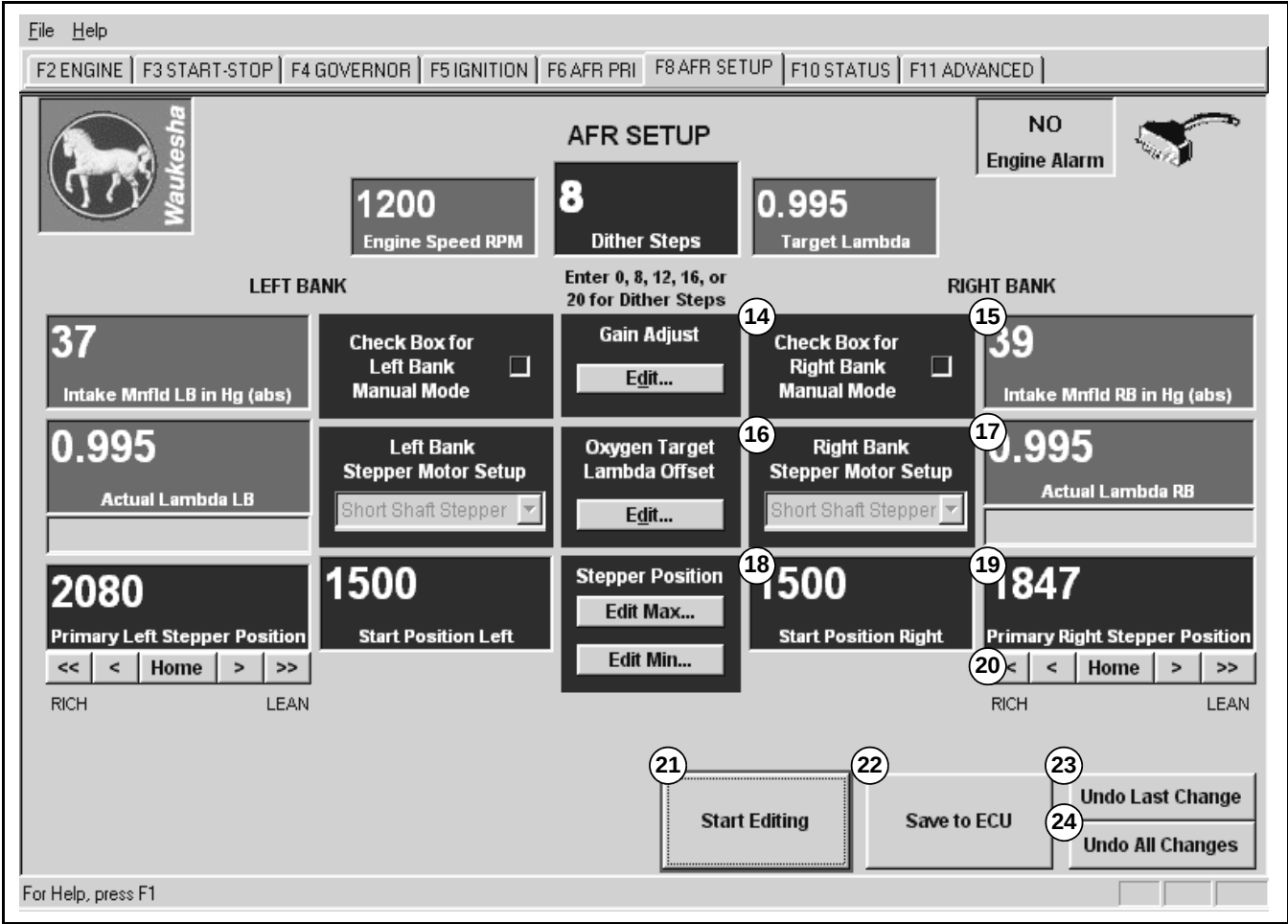


Figure 3.05-17 AFR Setup Panel in ESP – Fields 14 through 24

[F8] AFR SETUP PANEL DESCRIPTION – REFER TO FIGURE 3.05-17

- 14 “Check Box for Right Bank Manual Mode”** This field allows the user to change the AFR system mode of operation of the engine’s right bank from automatic to manual mode. Normally the AFR system operates in automatic mode; however, the user can click the check box, changing the system to manual mode. Manual mode allows the user to adjust stepper position using the arrow buttons (<< >> >>). When changed into manual mode, the AFR system will not make automatic stepper adjustments; it will only move stepper position with user adjustment. Check mark is ON; no check mark is OFF.
- 15 “Intake Mnfld RB”** This field displays the engine’s intake manifold pressure. Units are in-Hg absolute (kPa absolute). If an intake manifold pressure sensor or wiring fault occurs, the status bar beneath this field signals an alarm (turns yellow) and provides a message to fix the sensor or wiring. *NOTE: When a sensor or wiring fault is detected, the field displays a default value, not the actual value.*
- 16 “Right Bank Stepper Motor Setup”** This field allows the user to program the correct right bank stepper motor for the engine. The length of the stepper motor shaft must be programmed so the AFR system knows the stepper motor range. The number of steps is dependent on engine configuration and fuel regulator model. The short shaft stepper has 5,800 steps (GSI engines); the long shaft stepper has 20,000 steps (GSID engines). This field will be set at the factory but can be reprogrammed by the user.
- 17 “Actual Lambda”** This field displays actual Lambda. Lambda is equal to the amount of air present relative to that of a stoichiometric mixture. For example, a Lambda of 1.0000 is equal to an air/fuel ratio of approximately 16:1. Slightly rich of stoichiometry, or a Lambda of 0.995, is the typical setpoint of catalyst engines.
- 18 “Start Position Right”** This field displays the start position of the right bank stepper motor.
- 19 “Primary Right Stepper Position”** This field displays the current position of the right bank stepper motor.
- 20 “Arrow Buttons” and “Home”** The AFR system must be in manual mode for the user to use the right bank arrow buttons. The double arrow buttons (<< >>) move the stepper motor up or down in 400-step increments. The single arrow buttons (< >) move the stepper motor up or down in 25-step increments. The home button moves the stepper motor to the home position and then back to the start position only when the engine is not running. If the user clicks on the home button while the engine is running, an error message appears.
- 21 “Stop Editing – Currently Editing”** This button must be clicked prior to editing programmable (dark blue) fields in ESP. Clicking this button puts ESP in “editing mode.” The user will not be able to enter new values if ESP is not in editing mode. While in editing mode, the button will read “Stop Editing – Currently Editing.” When the editing mode is off, the button will read “Start Editing.” See Section 3.10 *ESP Programming* “Basic Programming in ESP” for more information.
- 22 “Save to ECU”** This button is used to save programmed values to NVRAM (permanent memory) in the ECU. Changes saved to permanent memory will not be lost if power to the ECU is removed. See Section 3.10 *ESP Programming* “Saving to Permanent Memory” for more information. *NOTE: Programmed values not saved to permanent memory are stored in RAM (temporary memory). When values are in RAM, ESP can be closed and the PC disconnected from the ECU while keeping all changes; however, changes will be lost if power to the ECU is removed or when the engine is shut down.*
- 23 “Undo Last Change”** This button allows the user to reset the last change made while in editing mode back to the programmed parameter that was last saved to permanent memory (NVRAM) in the ECU.
- 24 “Undo All Changes”** This button allows the user to reset all the programmable fields back to the programmed parameters that were last saved to permanent memory (NVRAM) in the ECU.

[F10] STATUS PANEL DESCRIPTION

The Status Panel displays the number of faults occurring in the system, if any type of shutdown is in process, if there is an engine alarm, and the engine start readiness. The ignition system status displays if the I-PMD is enabled, ignition energy level, maximum retard, and if there is engine knocking. The ECU status displays ECU temperature, battery voltage, ECU hours, and if calibrations, faults, and statistics are loaded. The engine status displays engine speed, engine setpoint, if remote RPM is enabled, low or high idle, state of the alternate governor dynamics, and if the main fuel valve is engaged.

NOTE: In addition, the Status Panel on 7042GL/GSI engines displays prechamber fuel valve engagement in the lower right corner (see Figure 3.05-21).

The Status Panel also makes it possible for the user to view a log of all the current and historical faults (see “Fault Log Description” in this section for more information), reset status LEDs, manually calibrate the throttle actuator, change all ESP panels from U.S. to metric units, and to view version details.

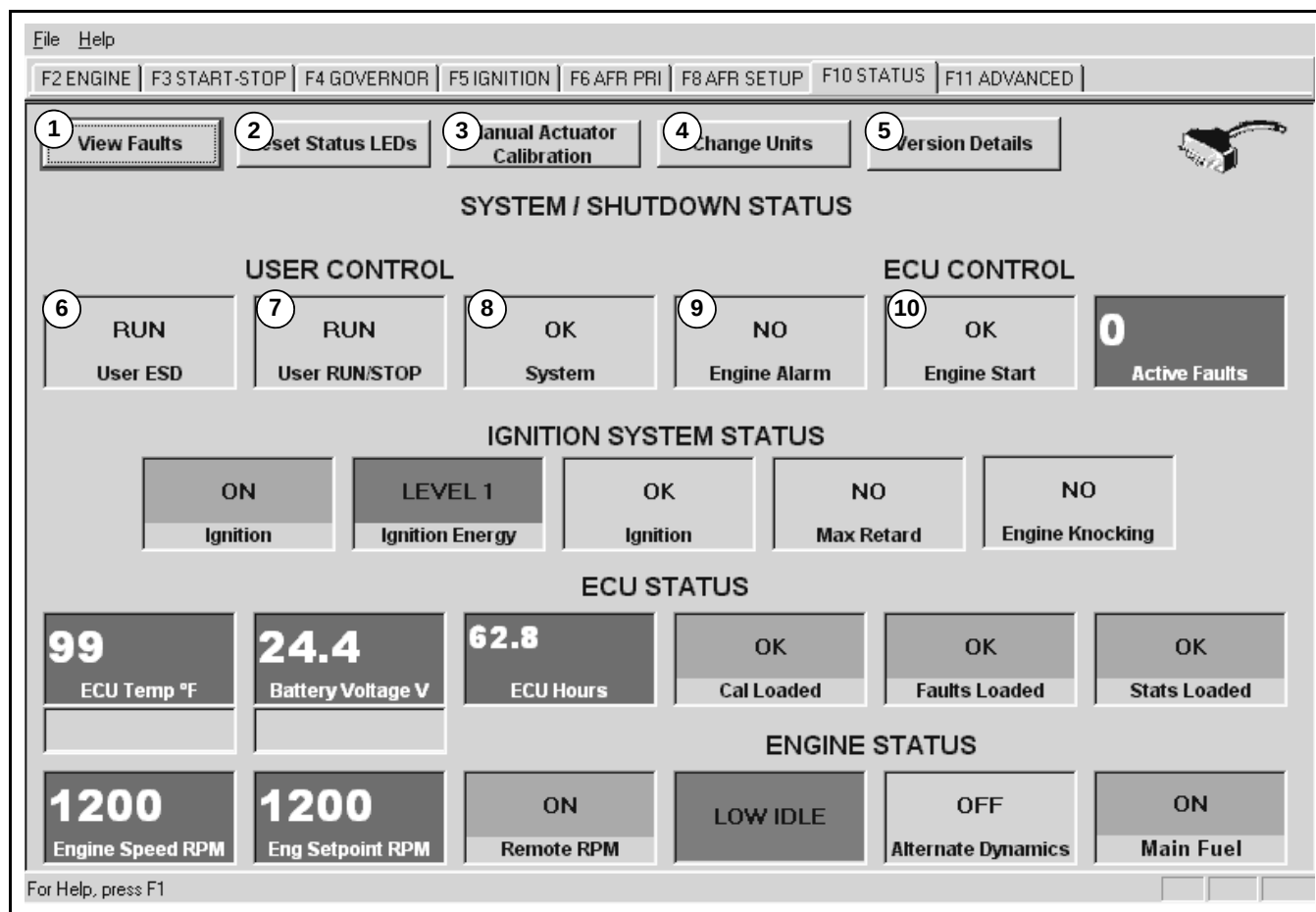


Figure 3.05-18 Status Panel in ESP – Fields 1 through 10

[F10] STATUS PANEL DESCRIPTION – REFER TO FIGURE 3.05-18

- ① **“View Faults”** This button allows the user to view the Fault Log. See “Fault Log Description” on page 3.05-38 for more information.
- ② **“Reset Status LEDs”** This button allows the user to reset the status LEDs on the ECU. When an ESM system fault is corrected, the fault disappears from the ESM ESP active fault log and the ESP screens will no longer indicate an alarm; however, the yellow and/or red Status LED(s) on the ECU will remain flashing the fault code(s) even after the fault(s) is cleared. The code will continue to flash on the ECU until one of two things happens: (1) the LED(s) is reset using ESP or (2) the engine is restarted. See Section 3.10 *ESP Programming* “Reset Status LEDs on ECU” for more information.
- ③ **“Manual Actuator Calibration”** This button allows the user to manually calibrate the throttle actuator. To work correctly, the ESM system must know the fully closed and fully open end points of throttle actuator movement. To establish the fully closed and fully open end points, the throttle actuator must be calibrated. A manual calibration can be performed when the engine is not rotating and after postlube and the ESM system’s post-processing is complete. If an emergency shutdown is active, no programming can be completed. See Section 3.10 *ESP Programming* “Actuator Calibration” for more information.
- ④ **“Change Units”** This button allows the user to change all the ESP panel fields to display in either U.S. units or in metric measurement units. See Section 3.10 *ESP Programming* “Changing Units – U.S. or Metric” for more information.
- ⑤ **“Version Details”** This button allows the user to view the serial number(s) and calibration number of the ECU and engine. This information is provided to verify that the ECU is calibrated correctly for the engine on which it is installed.
- ⑥ **“User ESD”** This field signals that an emergency shutdown is in process based on a customer input. During an emergency shutdown, the field is red and signals the user that an E-STOP (emergency stop) is active. When E-STOP is displayed, the engine cannot be restarted. When the engine is not in an emergency shutdown mode, the field is gray and signals the user that the engine is ready to RUN.
- ⑦ **“User RUN/STOP”** This field signals that a normal shutdown is in process based on customer input. During a normal shutdown, the field is red and signals the user that the engine will STOP. When STOP is displayed, the engine cannot be restarted. When the engine is not in a shutdown mode, the field is gray and signals the user that the engine is ready to RUN.
- ⑧ **“System”** This field alerts the user when the ESM system activates a shutdown. During an ESM system shutdown, the field is red and signals the user that an E-SHUTDOWN is active. When this field indicates E-SHUTDOWN, a 24 VDC signal to the customer (through the Customer Interface Harness) is provided. When the engine is not in an emergency shutdown mode, the field is gray and signals the user that the engine is OK.
- ⑨ **“Engine Alarm”** This field signals that an ESM system engine alarm is active. During an active alarm, the field is yellow and signals the user that an ALARM is active. When this field indicates an alarm, a 24 VDC signal to the customer (through the Customer Interface Harness) is provided. During the time when no alarms are present, the field is gray and signals the user that the system is OK.
- ⑩ **“Engine Start”** This field indicates system readiness to start. If there is no ESM system-related reason not to start the engine, the field is gray and signals the user that the engine is OK to start. If there is anything preventing the engine from starting, the field is red and signals the user NO START is possible.

Field descriptions continued on next page...

[F10] STATUS PANEL DESCRIPTION

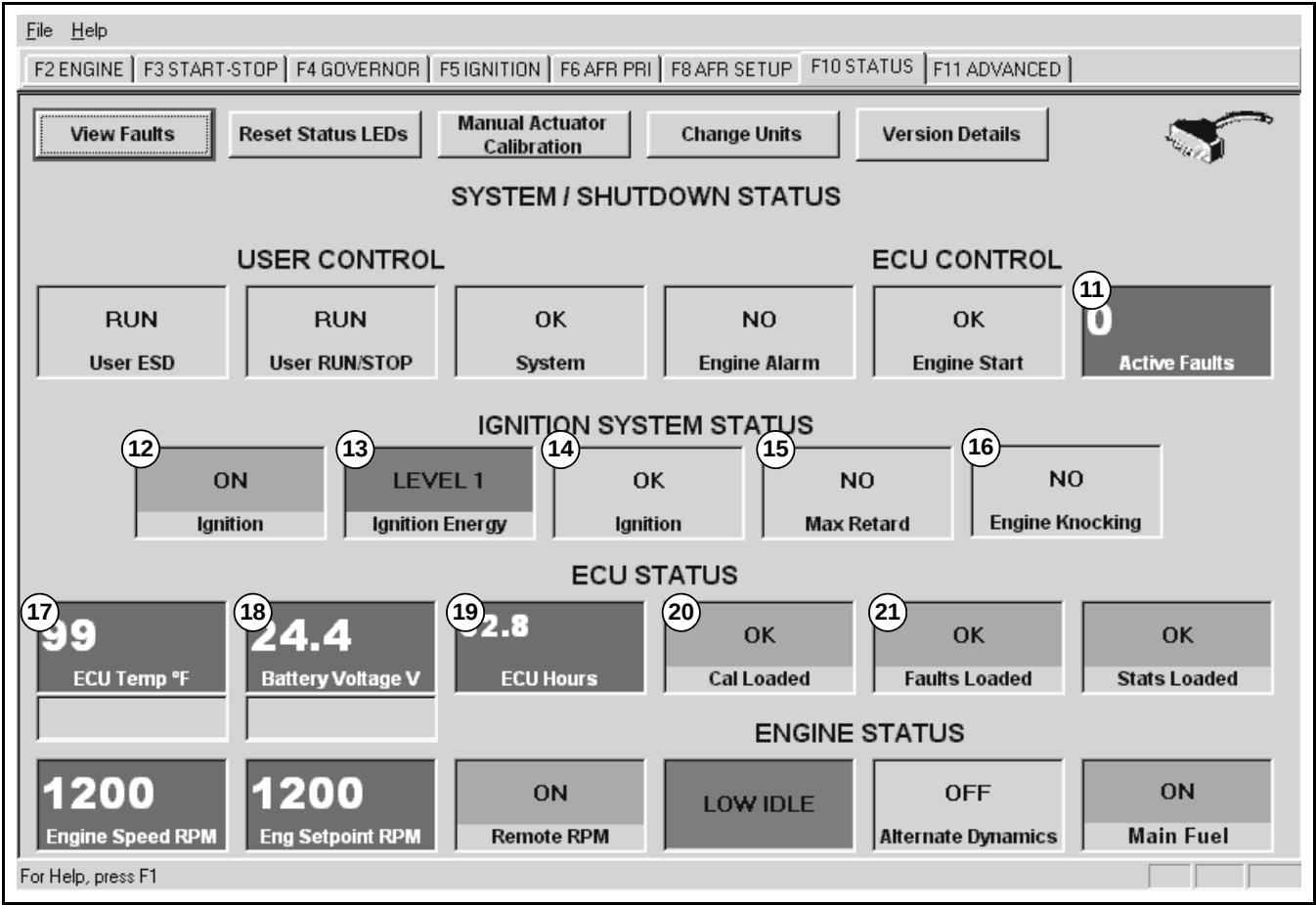


Figure 3.05-19 Status Panel in ESP – Fields 11 through 21

[F10] STATUS PANEL DESCRIPTION – REFER TO FIGURE 3.05-23

- ⑪ **“Active Faults”** This field indicates the total number of active faults as determined by the ESM system. View the fault log for detailed listing of active faults. See “Fault Log Description” on page 3.05-38 for more information.
- ⑫ **“Ignition”** This field signals when the IPM-D is enabled and is ready to receive a signal from the ECU to fire each spark plug. During the time the IPM-D is enabled, the field is green and signals the user that the IPM-D is ON. During the time the ignition is disabled, the field is gray and signals the user that the IPM-D is OFF.
- ⑬ **“Ignition Energy”** This field indicates at what level of energy the IPM-D is firing the spark plugs: Level 1 (low/normal) or Level 2 (high). During normal engine operation, the IPM-D fires at a Level 1 ignition energy. The IPM-D fires at a Level 2 ignition energy on engine startup or as a result of spark plug wear. If the ignition energy is raised to Level 2 (except on startup), an alarm is triggered to alert the operator. The pink field will signal the user whether the ignition level is LEVEL 1 or LEVEL 2.
- ⑭ **“Ignition”** This field alerts the user when the IPM-D is sending a signal to the ECU that indicates that one or both of the E-Stop (emergency stop) buttons on the side of the engine are depressed, or it indicates the IPM-D is not receiving 24 volts, or it indicates the IPM-D is not working correctly. When one of these conditions exists, the field is yellow and signals the user that an ignition ALARM exists. If the IPM-D signal to the ECU is good, the field is gray and signals the user that it is OK.
- ⑮ **“Max Retard”** This field alerts the user when any cylinder’s timing has reached the maximum retard in timing allowed. If any cylinder is at maximum retard, the field is yellow and signals the user that YES, at least one cylinder has reached the maximum retard in timing allowed. The user can determine which cylinder(s) is at maximum retard by looking for the lowest individual cylinder timing displayed on the [F5] Ignition Panel. When none of the cylinders are at maximum retard, the field is gray and signals the user that NO cylinders are at maximum retard.
- ⑯ **“Engine Knocking”** This field alerts the user when knock is present in a cylinder. When knock is sensed with at least one cylinder, the field is yellow and signals the user that YES, knock is present. The user can determine which cylinder(s) is knocking by looking at the individual cylinder timings displayed on the [F5] Ignition Panel. If no knock is present, the field is gray and signals the user that NO knock is present.
- ⑰ **“ECU Temp”** This field displays the internal temperature of the ECU. Units are °F (°C). If the ECU temperature is too high, the status bar beneath the field is yellow and signals the user that the ECU temperature is HIGH. ALM455 becomes active if the ECU temperature increases beyond the maximum recommended operating temperature.
- ⑱ **“Battery Voltage”** This field displays the current battery voltage. If the battery voltage goes below 21 VDC, the status bar beneath the field is yellow and signals the user that the voltage is TOO LOW. Some action must be taken to prevent possible further power loss below 18 VDC or the engine will shut down. ALM454 becomes active if the battery voltage remains below 21 VDC for longer than 30 seconds. ESP does not display the actual voltage if it falls outside the acceptable range (acceptable range: 21 – 32 volts). For example, if actual voltage is 19.4 volts, ESP displays 21 volts on the Status Panel.
- ⑲ **“ECU Hours”** This field displays the number of hours the engine has been running with the current ECU installed.
- ⑳ **“Cal Loaded”** This field should always be green and signal OK. If the field is red and signals NO calibration loaded, contact your local Waukesha Distributor for technical support.
- ㉑ **“Faults Loaded”** This field should always be green and signal the user it is OK. If the field is red and signals the user that NO faults are loaded, contact your local Waukesha Distributor for technical support.

Field descriptions continued on next page...

[F10] STATUS PANEL DESCRIPTION

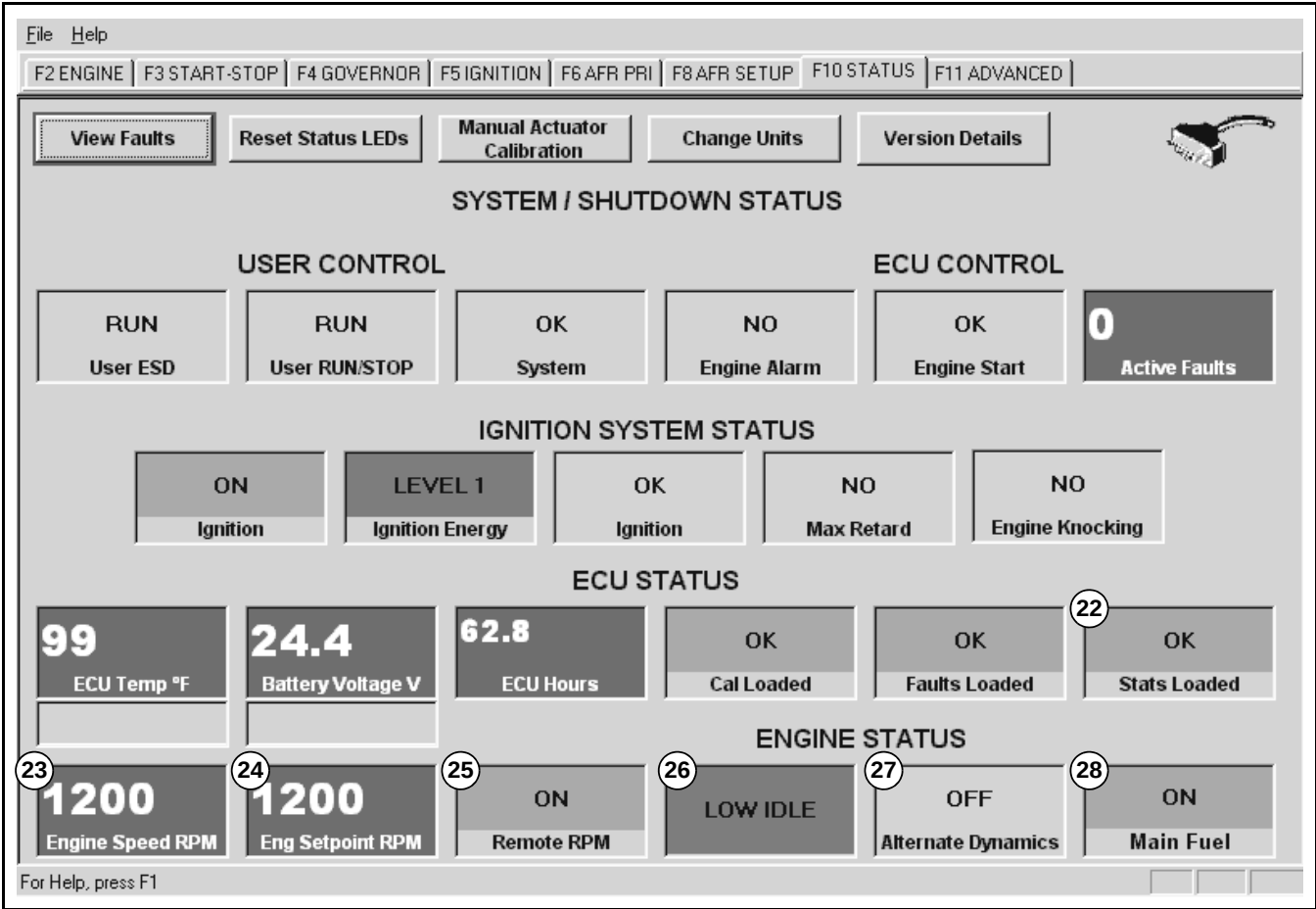


Figure 3.05-20 Status Panel in ESP – Fields 22 through 28

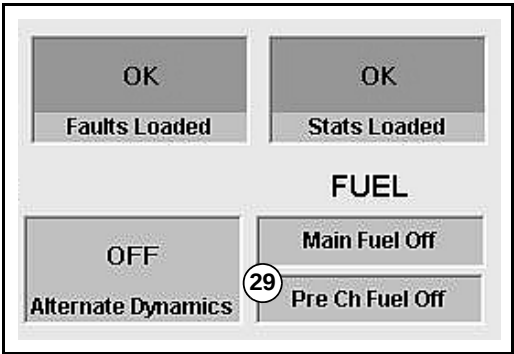


Figure 3.05-21 Status Panel in ESP – Field 29 (7042GL Prechamber Fuel)

[F10] STATUS PANEL DESCRIPTION – REFER TO FIGURE 3.05-20 and FIGURE 3.05-21

- ②② **“Stats Loaded”** This field should always be green and signal the user it is OK. If the field is red and signals the user that NO statistics are loaded, contact your local Waukesha Distributor for technical support.
- ②③ **“Engine Speed”** This field displays current engine speed (rpm).
- ②④ **“Eng Setpoint”** This field displays the engine speed (rpm) setpoint. The engine speed setpoint is determined by a customer input, not internal calibrations.
- ②⑤ **“Remote RPM”** This field signals when the remote rpm is ON or OFF. Remote rpm is determined by a customer digital input. When the input is high (8.6 – 36 volts), remote rpm is active. During the time the remote rpm input is high, the field is green and signals the user it is ON. During the time the remote rpm input is low (< 3.3 volts), the field is gray and signals the user it is OFF.
- ②⑥ **“Idle”** This field indicates whether low idle rpm or high idle rpm is active. Low or high idle rpm is determined by a customer digital input. When the input is low (< 3.3 volts), LOW IDLE is displayed in the pink field. When the input is high (8.6 – 36 volts), HIGH IDLE is displayed.
- ②⑦ **“Alternate Dynamics”** This field signals when the Alternate Governor Dynamics digital input is high (8.6 – 36 volts) or low (< 3.3 volts). Alternate dynamics or synchronizer mode is used to rapidly synchronize an engine to the electric power grid by using cylinder timing to maintain constant engine speed. During the time the alternate dynamics input is high, the field is green and signals the user it is ON. During the time the alternate dynamics input is low, the field is gray and signals the user it is OFF.
- ②⑧ **“Main Fuel”** This field signals when the main fuel valve is engaged by the ECU. During the time the main fuel valve is engaged, the field is green and signals the user it is ON. During the time the main fuel valve is disengaged, the field is gray and signals the user it is OFF.
- ②⑨ **“Pre Ch Fuel”** This field signals when the pre-chamber fuel valve is engaged by the ECU. During the time the prechamber fuel valve is engaged, the field is green and signals the user it is ON. During the time the prechamber fuel valve is disengaged, the field is gray and signals the user it is OFF.

[F11] ADVANCED PANEL DESCRIPTION

The Advanced Panel is used to program MODBUS® settings, and to set alarm and shutdown setpoints for oil pressure, jacket water, intake manifold, and oil temperature. Users can also send updated calibration information to the ECU, and to signify if a Waukesha alternator is installed. In addition, all active system parameters can be logged into readable text. This allows the user to review, chart, and/or trend the data logged as desired.

FileHelp

F2 ENGINEF3 START-STOPF4 GOVERNORF5 IGNITIONF6 AFR PRIF8 AFR SETUPF10 STATUSF11 ADVANCED



NO Engine Alarm

ADVANCED FUNCTIONS

MODBUS SETTINGS

ALTERNATOR

LOG PARAMETERS

CALIBRATION

1 Baud Rate 19200

2 Slave ID

3 Check Box if Waukesha Alternator is Installed

4 Start Logging All

5 Stop Logging All

6 Send Calibration to ECU

USER ADJUSTABLE ALARM AND SHUTDOWN SETPOINTS

Pressure adjustment range: 0 to 50 PSI, 0 to 345 kPa
Temperature adjustment range: -54 to 0 degrees F, -30 to 0 degrees C

	OIL PRESSURE	COOLANT TEMP	INTAKE MANIFOLD TEMP	OIL TEMP
OFFSET	7 0	8 0	9 -10	10 0
ALARM	35 PSI	190 °F	155 °F	195 °F
SHUTDOWN	30 PSI	200 °F	160 °F	205 °F

11 Start Editing

12 Save to ECU

13 Undo Last Change

14 Undo All Changes

For Help, press F1

Figure 3.05-22 Advanced Panel in ESP – Fields 1 through 14

[F11] ADVANCED PANEL DESCRIPTION – REFER TO FIGURE 3.05-22

- ① **“Baud Rate”** This field allows the user to program MODBUS® baud rate to 1200, 2400, 9600, or 19,200 bps (bits per second). See Section 3.10 *ESP Programming* “Programming Baud Rate (MODBUS® Applications)” for more information.
- ② **“Slave ID”** This field allows the user to program a unique identification number for each ECU (up to 32) on a multi-ECU networked site. The identification number that can be programmed can range from 1 to 247. By programming an identification number, the user can communicate to a specific ECU through MODBUS® using a single MODBUS® master when multiple ECUs are networked together. See Section 3.10 *ESP Programming* “Programming ECU MODBUS® Slave ID” for more information.
- ③ **“Check Box if Waukesha Alternator is Installed”** This check box must be checked if a Waukesha Engine alternator with the Alternator Monitor Harness is installed on the engine to properly diagnose and signal an alarm if an alternator problem occurs. If the check box is not checked and a Waukesha alternator is installed, no alarm will be triggered when an alternator problem occurs. If the box is checked and the engine does not have a Waukesha alternator, an alarm will be generated all the time.
- ④ ⑤ **“Start Logging All” and “Stop Logging All”** These buttons are used to log all active system parameters during a user-determined period of time. The file that is saved is a binary file (extension .ACLOG) that must be extracted into a usable file format. Using the Log File Processor program installed with ESP, the binary file is converted into a Microsoft® Excel-readable file (.TSV) or a text file (.TXT). Once the data is readable as a .TSV or .TXT file, the user can review, chart, and/or trend the data logged as desired. See Section 3.10 *ESP Programming* “Logging System Parameters” for more information.
- ⑥ **“Send Calibration to ECU”** This button is used to send a calibration file to the ECU.
- ⑦ ⑧ ⑨ ⑩ **“Offset”** These fields allow the user to adjust the alarm and shutdown fields. This enables the user to fine tune alarm and shutdown settings or test safeties. Setpoints are only adjustable in the safe direction from the factory settings. The alarm and shutdown fields display the setting for the alarm and shutdown.
- ⑪ **“Start Editing”** This button must be clicked prior to editing programmable (dark blue) fields in ESP. Clicking this button puts ESP in “editing mode.” The user will not be able to enter new values if ESP is not in editing mode. While in editing mode, the button will read “Stop Editing – Currently Editing.” When the editing mode is off, the button will read “Start Editing.” See Section 3.10 *ESP Programming* “Basic Programming in ESP” for more information.
- ⑫ **“Save to ECU”** This button is used to save programmed values to NVRAM (permanent memory) in the ECU. Changes saved to permanent memory will not be lost if power to the ECU is removed. See Section 3.10 *ESP Programming* “Saving to Permanent Memory” for more information. *NOTE: Programmed values not saved to permanent memory are stored in RAM (temporary memory). When values are in RAM, ESP can be closed and the PC disconnected from the ECU while keeping all changes; however, changes will be lost if power to the ECU is removed or when the engine is shut down.*
- ⑬ **“Undo Last Change”** This button allows the user to reset the last change made while in editing mode back to the programmed parameter that was last saved to permanent memory (NVRAM) in the ECU.
- ⑭ **“Undo All Changes”** This button allows the user to reset all the programmable fields back to the programmed parameters that were last saved to permanent memory (NVRAM) in the ECU.

FAULT LOG DESCRIPTION

One method of obtaining diagnostic information is by viewing the Fault Log in ESP. ESP displays the data provided by the ECU. The Fault Log can be displayed either to list only the active faults or to list the history of all the faults that occurred in the lifetime of the ECU.

The Fault Log displays the name of the fault, the first time the fault occurred since the fault was reset (in ECU hours:minutes:seconds), the last time the fault occurred since reset, the number of times the fault occurred since reset, and the total number of times the fault occurred in the lifetime of the ECU. All the fault

information is resettable except for the total number of times the fault occurred during the lifetime of the ECU.

The faults listed in the Fault Log can be sorted by clicking on a column name. For example, clicking on “Fault” will sort alarms/shutdowns in numerical order based on the fault code. Clicking on “First Occurrence” will sort alarms/shutdowns in order of occurrence.

As an additional aid in troubleshooting, double-clicking a fault listed in the Fault Log will open E-Help directly to the troubleshooting information for that fault.

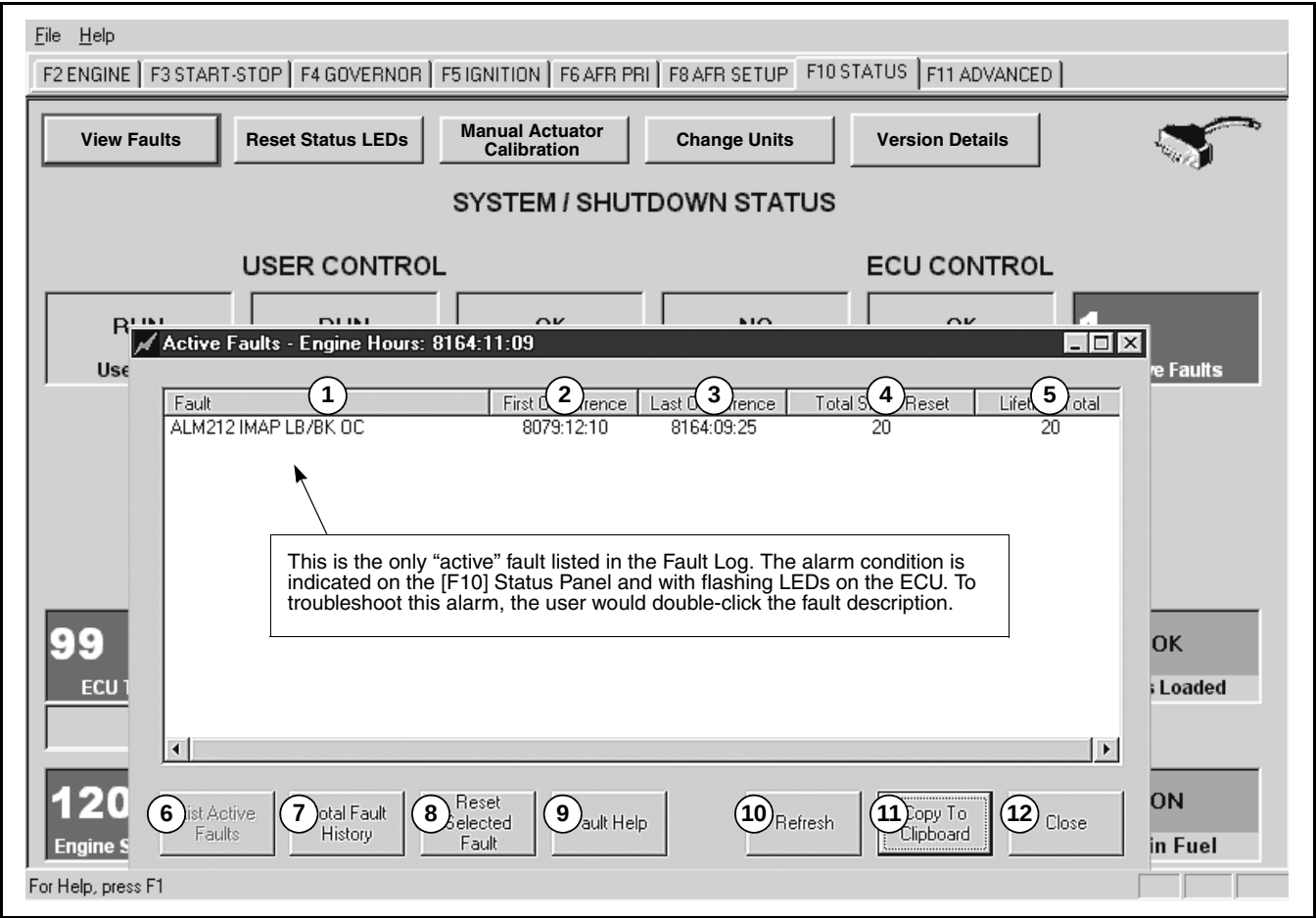


Figure 3.05-23 Fault Log in ESP – Fields 1 through 12

FAULT LOG DESCRIPTION – REFER TO FIGURE 3.05-23

- ① **“Fault”** This field displays the fault code and description for the alarm or shutdown condition that exists. Alarm codes in ESP are identified with the letters “ALM” preceding the alarm code. Emergency shutdown codes are identified with the letters “ESD” preceding the shutdown code. Double-clicking a fault listed in the Fault Log will open E-Help directly to the troubleshooting information for that fault.
- ② **“First Occurrence”** This field displays the first time the fault listed occurred since the fault was reset (in ECU hours:minutes:seconds). This field is resettable.
- ③ **“Last Occurrence”** This field displays the last time the fault listed occurred since the fault was reset (in ECU hours:minutes:seconds). This field is resettable.
- ④ **“Total Since Reset”** This field displays the number of times the fault occurred since the fault was reset. This field is resettable.
- ⑤ **“Lifetime Total”** This field displays the total number of times the fault occurred in the lifetime of the ECU. This field is not resettable.
- ⑥ ⑦ **“List Active Faults” and “Total Fault History”** These buttons allow the user to view either the active fault listing or the total fault history. The Active Fault Log only lists active faults indicated by flashing Status LEDs and alarm fields on the ESP panels. The Total Fault History lists all the faults that occurred in the lifetime of the ECU.
- ⑧ **“Reset Selected Fault”** This button allows the user to reset Fields 2, 3, and 4 back to zero of the selected (or highlighted) fault listed in the log.
- ⑨ **“Fault Help”** This button allows the user to open E-Help.
- ⑩ **“Refresh”** This button allows the user to update or refresh the Fault Log. When the Fault Log is open, the information is not automatically refreshed. For example, if the Fault Log is displayed on screen, and a fault is corrected, the Fault Log will not refresh itself to reflect the change in active faults. The user must refresh the Fault Log to view the updated information.
- ⑪ **“Copy To Clipboard”** This button allows the user to copy to the PC's clipboard the Fault Log information. The information can then be pasted as text in Microsoft® Word or another word processing program. See Section 3.10 *ESP Programming* “Copying Fault Log Information to the Clipboard” for more information.
- ⑫ **“Close”** This button closes the Fault Log.

SECTION 3.10

ESP PROGRAMMING

INTRODUCTION TO ESP PROGRAMMING

This section provides the steps necessary to program the ESM system using ESP. Very little programming is required. To operate an engine with the ESM system installed, WKI value and Load Inertia must be programmed. Other programmable fields, however, may be programmed to set user preferences and to fine-tune engine operation.

Six ESP panels have user-programmable (dark blue) fields: [F3] Start-Stop Panel, [F4] Governor Panel, [F5] Ignition Panel, [F6] AFR Primary Fuel Panel, [F8] AFR Setup Panel, and [F11] Advanced Panel. The other panels provide system readings (temperature/pressure) and operating status.

If this is the initial startup of the ESM system on your engine, complete ALL the procedures provided in this section. If the engine has been operating with the ESM system, it may be necessary to complete only applicable subsections of the provided programming instructions.

OUTLINE OF SECTION 3.10

An outline with a description of the subsections included in Section 3.10 is provided below.

Initial Engine Startup.....page 3.10-2
Provides the steps necessary to start the ESP program on the PC.

Downloading ESP to Hard Drive.....page 3.10-3
Provides the steps necessary to download the ESP software from the internet to the user's hard drive.

Installing ESP CD to Hard Drivepage 3.10-4
Provides the steps necessary to install the ESP software from a CD to the user's hard drive.

Connecting PC to ECUpage 3.10-4
Provides the steps necessary to connect the PC to the ECU using an RS-232 serial cable supplied by Waukesha Engine.

Starting ESPpage 3.10-5
Provides the steps necessary to start the ESP program on the PC.

Basic Programming in ESP.....page 3.10-5
Provides general instructions on how to edit any programmable (dark blue) field in ESP.

Saving to Permanent Memorypage 3.10-7
Provides the steps necessary for saving edited values to permanent memory (NVRAM) in the ECU.

Programming WKI Valuepage 3.10-8
Provides the steps necessary to program the WKI value. The WKI value must be programmed correctly for proper engine operation.

Programming Load Inertiapage 3.10-9
Provides the steps necessary to program the rotating moment of inertia (load inertia). Load inertia must be programmed correctly for proper engine operation.

Programming Air/Fuel Ratiopage 3.10-11
Provides the steps necessary to program the basic air/fuel ratio setup. The air/fuel ratio must be programmed correctly for proper engine operation.

Programming NOx Level – LT Engine Applications Only.....page 3.10-13
Provides the steps necessary to program the desired NOx emissions level (engine out at the exhaust stack) at which the engine will run.

Programming Alarm And Shutdown Setpointspage 3.10-14
Provides the steps necessary to program alarm and shutdown setpoints. Setpoints are only adjustable in a safe direction; factory settings cannot be exceeded.

Actuator Calibrationpage 3.10-16
Provides the steps necessary to calibrate the throttle actuator either automatically or manually.

Governor Programming page 3.10-18

Provides information on the ESM speed governing system for fixed speed applications, variable speed applications, feedforward control, and synchronizer control.

IPM-D Programming page 3.10-20

Provides information on fine-tuning ESM IPM-D predictive diagnostics.

Changing Units – U.S. or Metric page 3.10-23

Provides the steps necessary to change all the ESP panel fields to display in either U.S. or metric measurement units.

Reset Status LEDs on ECU page 3.10-23

Provides the steps necessary to reset the Status LEDs on the ECU.

Copying Fault Log Information to the Clipboard

..... page 3.10-23

Provides the steps necessary to copy to the PC's clipboard information from the Fault Log that can be pasted in Microsoft® Word or another word processing program.

Taking Screen Captures of ESP Panels

..... page 3.10-24

Provides the steps necessary to take a screen capture of an ESP panel that can be saved and printed in Microsoft® Word or another word processing program.

Logging System Parameters page 3.10-24

Provides the steps necessary to log system parameters that can be read in Microsoft® Word or Excel.

Programming Baud Rate (MODBUS® Applications)

..... page 3.10-28

Provides the steps necessary to program the baud rate when using MODBUS®.

Programming ECU MODBUS® Slave ID

..... page 3.10-29

Provides the steps necessary to program an identification number to an ECU when using MODBUS®.

Programming Remote ECU for Off-Site Personnel

..... page 3.10-29

Provides the steps necessary to program an identification number to a remote ECU for off-site personnel.

Using a Modem page 3.10-32

Provides the steps necessary to (1) connect the PC to the ECU via a modem and (2) start ESP using the modem access option.

INITIAL ENGINE STARTUP

Below is a general overview of the steps needed to be completed on initial engine startup.

NOTE: Review the following:

Section 3.00 Introduction to ESP for PC requirements, ESP program description, and saving information.

Section 3.05 ESP Panel Descriptions for a detailed explanation of each of the panels in ESP.



Do not install, set up, maintain, or operate any electrical components unless you are a technically qualified individual who is familiar with the electrical elements involved. Electrical shock can cause severe personal injury or death.

1. Visually inspect the ESM system installation to be sure that all wiring conforms to the requirements of this manual, local codes, and regulatory bodies. Refer to Section 2.00, Section 2.05, and Section 2.10 for wiring and power specifications.

2. Apply power to the ESM system.

3. Using a digital voltmeter, measure the voltage between the power terminals in the Power Distribution Box. Verify that the power supply voltage is within the specification provided in Section 2.00 *Power Requirements*.

NOTE: To download ESP or install ESP from the CD, see “Downloading ESP to Hard Drive” on page 3.10-3 or “Installing ESP CD to Hard Drive” on page 3.10-4.

4. Install ESP and related workspace files to the hard drive.

5. Connect your PC to the ECU and start ESP.

6. Go through each ESP panel. Determine what fields need to be programmed based on user preference and engine performance (such as pre/post lube, high/low idle).

7. Be sure to program the following fields (these fields **must** be programmed):

- “Load Inertia” field on the [F4] Governor Panel
- “User WKI” field on the [F5] Ignition Panel
- Rich and lean limits on the [F8] AFR Setup Panel (AFR equipped engines)

8. Save values to permanent memory.

9. Perform a manual calibration of the throttle actuator.

10. Start engine.

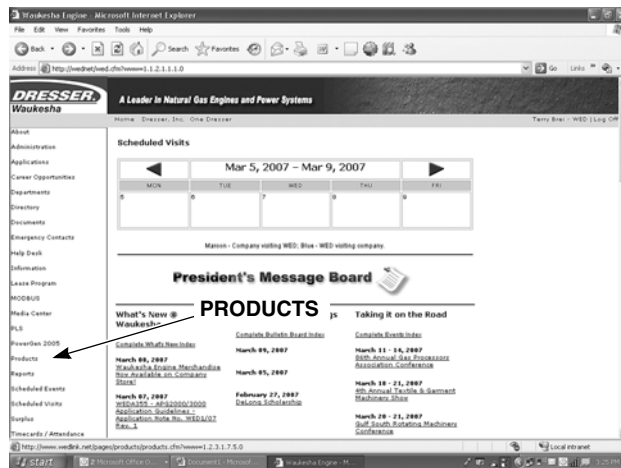
11. Observe engine performance. Make changes as necessary.

12. Save all changes to permanent memory.

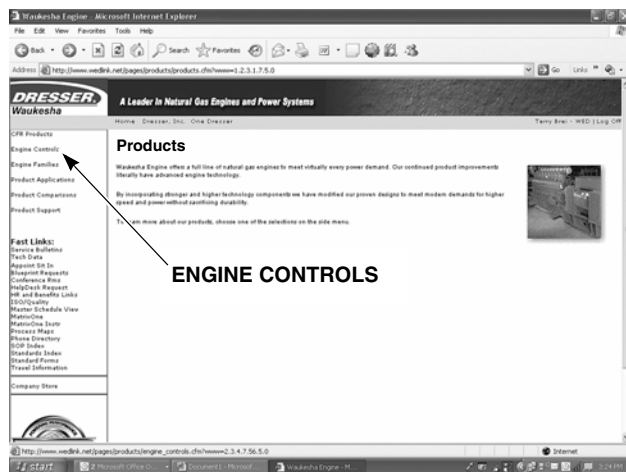
DOWNLOADING ESP TO HARD DRIVE

NOTE: Before downloading the ESP program from wedlink.net, verify you have administration rights on your computer or have the IT department download and install the program. The file will be saved as a .zip file and will need to be extracted. Your computer will need pkzip or winzip to extract the files.

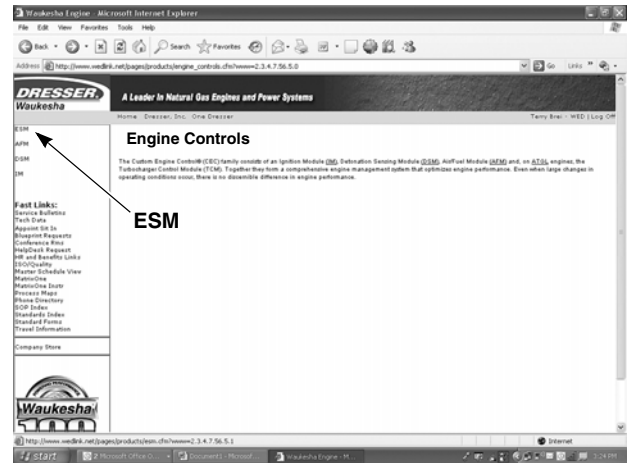
1. Log on to www.wedlink.net and select “Products” located on left side of screen.



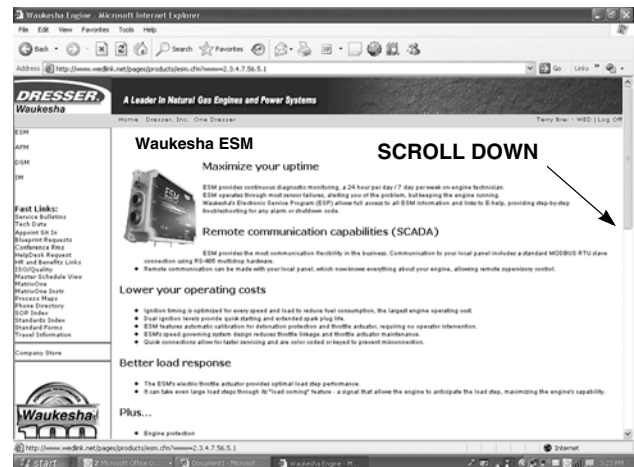
2. Select “Engine Controls” located on left side of screen.



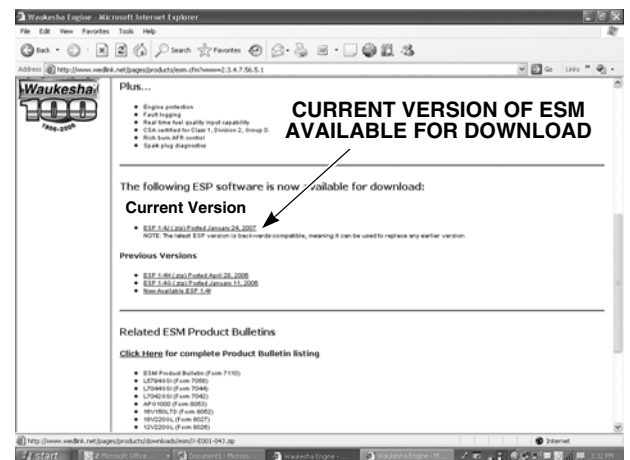
3. Select “ESM” located on left side of screen.



4. The ESM screen contains the ESP program download.



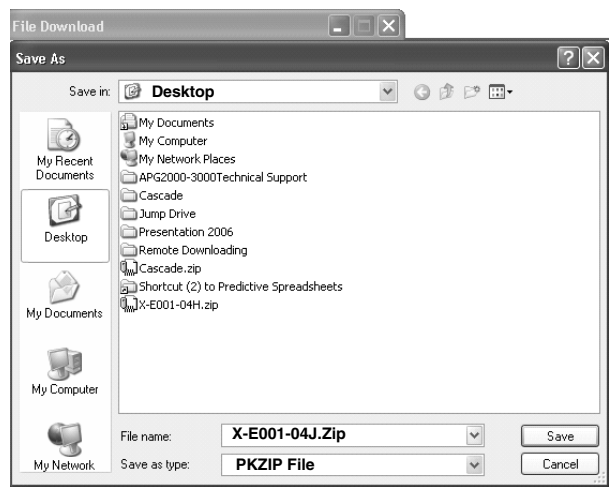
5. Scroll down until the “Current Version” of ESP available for download is located.



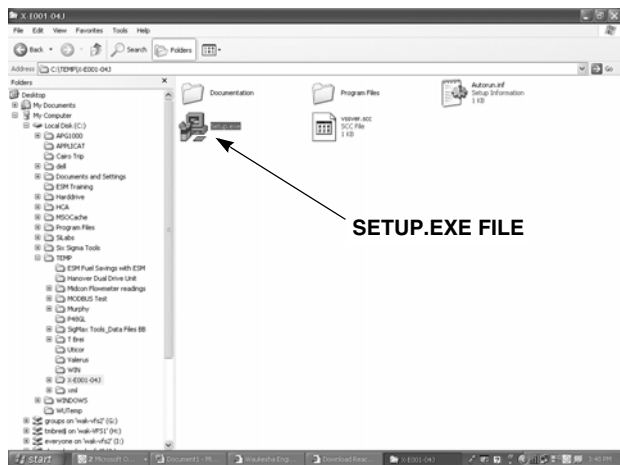
6. Right-click on the link and choose “Save As.”

ESP PROGRAMMING

7. Save program to a folder that allows easy access. A recommendation would be under your desktop as shown below:



8. Save the file to your computer (download time may be extensive depending on Internet speed).
9. Open the .zip file with pkzip or a similar extraction program.
10. After file is unzipped, open the folder that was unzipped and run the setup.exe file and follow the installation wizard to install the program.



INSTALLING ESP CD TO HARD DRIVE

The ESM ESP CD contains an installation program to automatically load ESP on the hard drive of your PC. Complete the steps that follow to load the ESP software using the installation program.

1. Make sure your PC meets the system requirements listed in Section 3.00 *Introduction to ESP* “Minimum Recommended Computer Equipment for ESM ESP Operation”.
2. Start Microsoft® Windows® XP operating system on your PC.

3. Close any other applications that may be open on your PC’s desktop.
 4. Insert the ESP CD into the CD drive of your PC.
 - If Autorun is enabled on your PC system, installation starts automatically approximately 30 seconds after the CD is inserted. Continue with Step 7.
 - If the Autorun is disabled on your PC system, continue with Step 5.
 5. From the **Start** menu, select **Run...**
 6. Type **d:\setup.exe** and click “OK” (if “D” is not the letter of your CD drive, type in the appropriate letter).
 7. Follow the instructions that appear on the screen until installation is complete.
- NOTE:** By default, the ESP software is installed in C:\Program Files\ESM.
8. When installation is complete, four ESP-related icons will appear on your desktop.

DESCRIPTION	ICON
ESM ESP Icon: Double-clicking this icon opens the standard ESP program.	
ESM Training Tool Icon: Double-clicking this icon opens a version of ESP that is used for training only. This program runs even without an ECU connected.	
ESP Modem Access Icon: Double-clicking this icon opens a version of ESP that allows use of ESP with a modem and requires modem cables for use (See “Using a Modem” on page 3.10-32).	
Log File Processor Icon: Double-clicking this icon opens a program that converts ESP log files into a file format read by Microsoft® Excel (See “Logging System Parameters” on page 3.10-24).	

CONNECTING PC TO ECU

An RS-232 serial cable (P/N 740269) supplied by Waukesha Engine is used to connect the PC to the ECU. This cable has a 9-pin RS-232 connection that plugs into the PC and an 8-pin Deutsch® connector that plugs into the ECU.

NOTE: The PC can be connected to the ECU via a modem connection. See “Using a Modem” on page 3.10-32 for more information on modem connections and ESP startup information.

NOTE: If the ESP software and associated workspace files are not saved to your PC’s hard drive, complete the steps under the section See “Installing ESP CD to Hard Drive” on page 3.10-4.

1. Locate the RS-232 serial cable supplied by Waukesha Engine.

2. Connect the 9-pin end of the RS-232 serial cable to the PC's communication port. Typically, this is port 1 (also referred to as COM 1, serial a, or serial 1) (see Figure 3.10-1).
3. Connect the 8-pin Deutsch® connector of the serial cable to the "Service Interface" connection on the side of the ECU (see Figure 3.10-1).
4. Make sure all connections are secure.

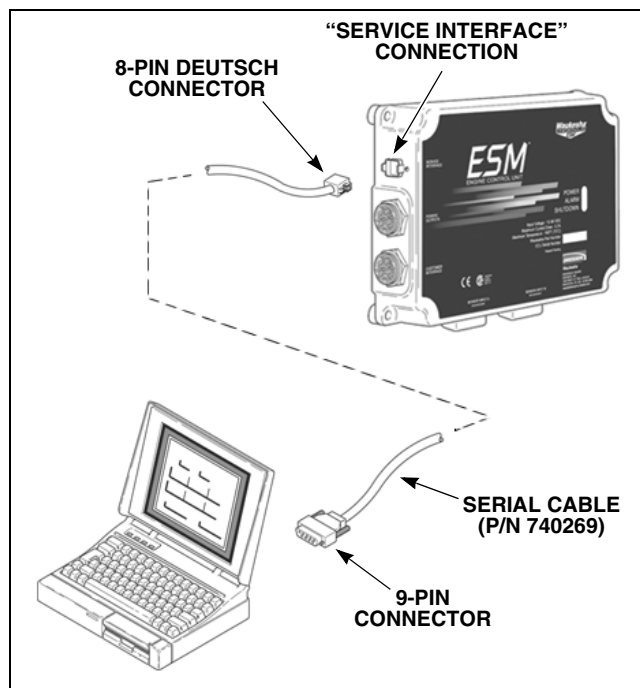


Figure 3.10-1 Serial Cable Connection between PC and ECU

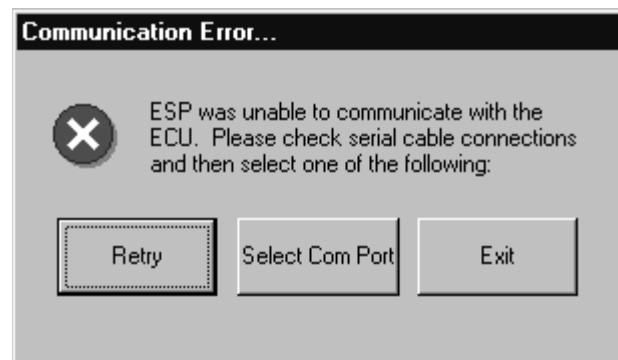
STARTING ESP

Once the PC is connected to the ECU, ESP can be started on the PC.

1. Apply power to the ECU.
2. Start ESP by one of the following methods:
 - Double-click the ESM ESP icon on your desktop.



- From the Windows® taskbar (lower-left corner of your desktop), click **Start** → **All Programs** → **Waukesha Engine Controls** → **Engine System Manager (ESM)** → **ESP**.
3. If on ESP startup an error occurs, check serial cable connections to the PC and ECU. Click "Retry."



4. If after checking serial cable and retrying connection an error still occurs, click "Select Com Port."
5. From the Com Port dialog box, select the communication port that you are using for communication to the ECU. Click "OK."
6. Once ESP is open, you can always verify you have a good connection between the ECU and PC by looking at the "connection" icon on the top right corner of the ESP screen (see Table 3.10-1).

Table 3.10-1 Verify Connection

DESCRIPTION	ICON
Connection: This icon indicates that there is a good connection between the ECU and ESP on your PC.	
No Connection: This icon indicates that there is not a connection between the ECU and ESP on your PC. See Note below.	

NOTE: If the icon displayed indicates no connection, either there is no power to the ECU, the serial cable is not connected properly to the ECU or PC, or the cable is defective.

BASIC PROGRAMMING IN ESP

This section explains how to edit the programmable (dark blue) fields in ESP. To edit the programmable fields, ESP must be in editing mode.

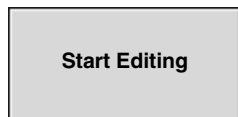
Two fields in ESP require programming: the WKI value and Load Inertia. To program the "WKI" field, See "Programming WKI Value" on page 3.10-8. To program the "Load Inertia" field, See "Programming Load Inertia" on page 3.10-9.

The other fields can be programmed to set user preferences and to fine-tune engine operation like pre-post lube and low/high idle. Go through each ESP panel. Determine what fields need to be programmed based on user preference and engine performance. Section 3.05 *ESP Panel Descriptions* provides a description of all the fields on each of the panels.

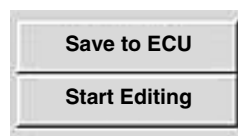
ESP PROGRAMMING

NOTE: For more information on governor programming, see “Governor Programming” on page 3.10-18.

1. Click on the “Start Editing” button. While in editing mode, the button will read “Stop Editing – Currently Editing.”



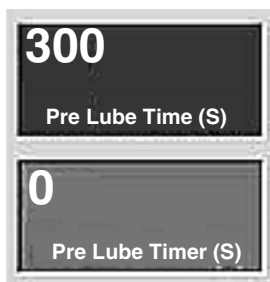
NOTE: The [F3] Start-Stop Panel “Start Editing” button differs slightly from the other screens (see depiction below).



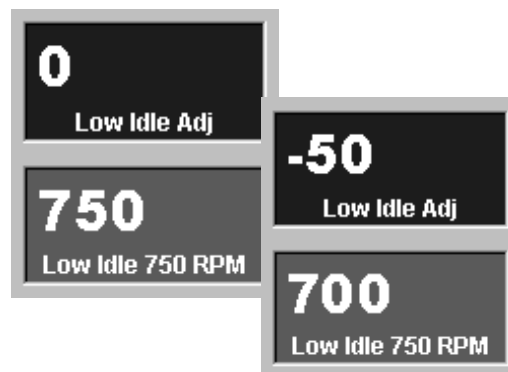
[F3] Start-Stop Panel “Start Editing” Button

2. Double-click the field or highlight the value to be edited.
3. Enter the new value. If the value entered exceeds the programmable limits, the field will default to the highest/lowest allowable value for that field. Note the following:
 - Most fields are programmed by entering the desired value within the highest/lowest allowable value for that field.

NOTE: If 300 seconds has been entered in the “Pre Lube Time” field, the “Pre Lube Timer” field will display zero until a start is requested. After the start request, the Pre Lube Timer will start counting down (from 300 seconds). Countdown will be aborted if a user stop or ESD occurs.



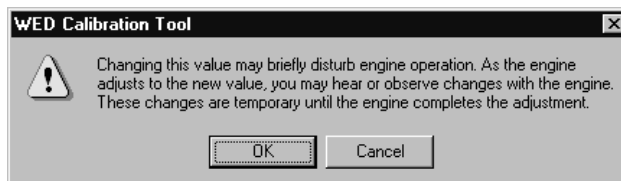
- Some fields are programmed by entering an adjustment value ($\pm$) to the default value. The teal (blue-green) bottom field displays the actual programmed value. The dark blue (top) field allows the operator to adjust the actual value by entering a $\pm$ offset. When an adjustment is entered, the default field updates to reflect the adjustment. If you want to return to the original default value, program the adjustment field to 0 (zero).



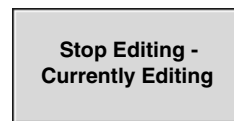
4. Once the new value is entered, press [Enter]. Once [Enter] is pressed, the new value becomes “active,” meaning the ECU is using the new value to operate the ESM system. The new value, however, is temporarily saved to RAM in the ECU.

NOTE: The contents of RAM (temporary memory) are lost whenever power to the ECU is removed or on engine shutdown.

5. Since an entered value is active as soon as [Enter] is pressed, it is possible that you will notice a brief engine disruption as the engine adjusts to the new value. If a new value could cause brief engine disruption, a dialog box will appear notifying you of the potential for a brief engine disruption. Click “OK” to continue.



6. Edit other fields as necessary.
7. When all values are entered, click the “Stop Editing” button. While the editing mode is OFF, the button will read “Start Editing.”



8. Observe engine performance. Make modifications as necessary.
9. Save changes to permanent memory if desired. See “Saving to Permanent Memory” for instructions.

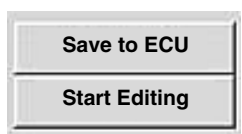
SAVING TO PERMANENT MEMORY

This section provides the programming steps necessary to save edited values to permanent memory (NVRAM).

1. Click the "Save to ECU" button on the [F3] Start-Stop Panel, [F4] Governor Panel, [F5] Ignition Panel, or [F11] Advanced Panel.

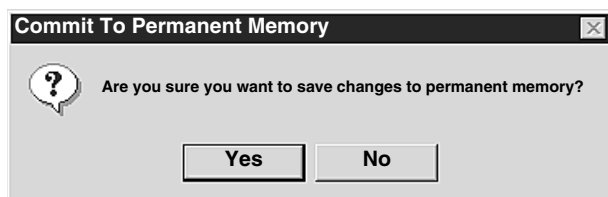


NOTE: The [F3] Start-Stop Panel "Save to ECU" button differs slightly from the other screens (see depiction below).

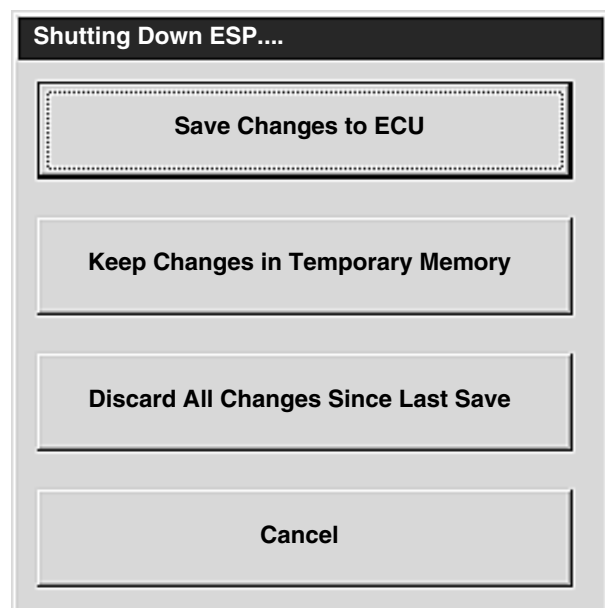


[F3] Start-Stop Panel "Save to ECU" Button

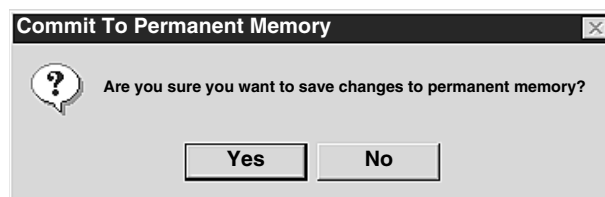
2. When asked are you sure you want to save to the ECU, click "Yes."



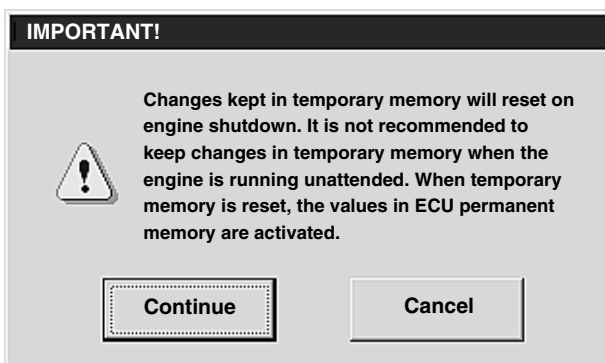
3. If you exit ESP without saving to the ECU, a dialog box appears with four options: "Save Changes to ECU," "Keep Changes in Temporary Memory," "Discard All Changes Since Last Save," and "Cancel."



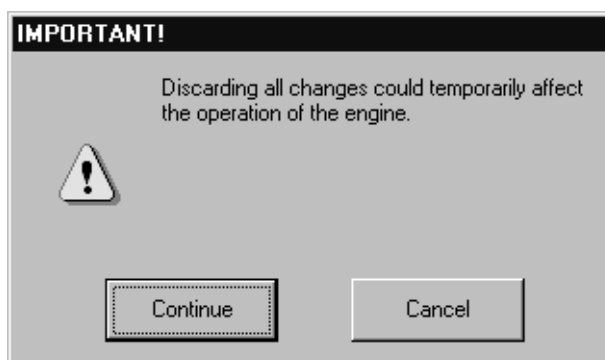
- **"Save Changes to ECU"** Click this button to save all changes to permanent memory in the ECU before exiting. When the dialog box asks you to confirm the save to permanent memory, click "Yes."



- **"Keep Changes in Temporary Memory"** Click this button to keep all changes in temporary memory in the ECU. You will be able to close ESP and disconnect the PC from the ECU while keeping all changes; however, changes will be lost if power to the ECU is removed or the engine is shut down. Read the information on the dialog box that appears. Click "Continue."



- **"Discard All Changes Since Last Save"** Click this button to reset the ECU to the programmed parameters that were last saved to permanent memory in the ECU. Since all the "active" values used by the ECU will be reset to those last saved, it is possible that you will notice a brief engine disruption as the engine adjusts to the new value. Click "Continue."



- **"Cancel"** Click this button to cancel exiting from ESP. Any values in temporary memory will remain in temporary memory.

PROGRAMMING WKI VALUE



CAUTION

Ensure that the correct WKI value is programmed in ESP. Failure to program the WKI value correctly could lead to poor engine performance and the potential for engine detonation. Detonation could result in product damage and/or personal injury.

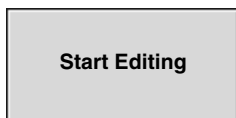
The “User WKI” (Waukesha Knock Index) field on the [F5] Ignition Panel in ESP **must** be programmed by the user for proper engine operation. The user must enter the WKI value of the fuel. The WKI value can be determined using an application program for the Microsoft® Windows® XP operating system. The computer program will calculate the WKI value from a customer’s gas analysis breakdown. The WKI value must be based on the composition of a fuel sample taken from the engine site and analyzed using the application program or as dictated on a Special Application Approval (SAA). Contact your local Distributor for additional information.

Complete the following steps to program the WKI value.

1. View the [F5] Ignition Panel in ESP.

The screenshot shows the 'IGNITION OPERATING STATUS' window. It includes a table for 'Left Bank Ignition Timing' and 'Right Bank Ignition Timing'. The 'User WKI' field is highlighted with a value of 94.0. Other fields include 'High Voltage Adj.', 'Low Voltage Adj.', 'No Spark Adj.', 'User WOI', and 'NOx g/BHP-hr'. Buttons for 'Start Editing', 'Save to ECU', and 'Undo Last Change' are visible at the bottom.

2. Click on the “Start Editing” button. While in editing mode, the button will read “Stop Editing – Currently Editing.”



3. Double-click the “User WKI” field or highlight the currently programmed WKI value.

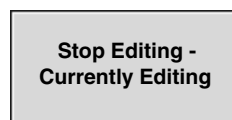


4. Enter the WKI value of the fuel. The WKI value must be based on the composition of a fuel sample taken from the engine site and analyzed using the application program or as dictated on a Special Application Approval (SAA). Contact your local Distributor for additional information.

5. Press [Enter]. Once [Enter] is pressed, the new value becomes “active,” meaning the ECU is using the new value to operate the ESM system. The changed value is temporarily saved to the ECU.

NOTE: The contents of RAM (temporary memory) are lost whenever power to the ECU is removed.

6. Click the “Stop Editing” button. While the editing mode is OFF, the button will read “Start Editing.”



7. Save value to permanent memory. Click the “Save to ECU” button.



8. When asked are you sure you want to save to the ECU, click “Yes.”

The dialog box asks: 'Are you sure you want to save changes to permanent memory?'. It has 'Yes' and 'No' buttons.

PROGRAMMING LOAD INERTIA

CAUTION Ensure that the correct rotating moment of inertia (load inertia) is programmed in ESP for the engine's driven equipment. Failure to program the moment of inertia for the driven equipment on the engine in ESP will lead to poor steady state and transient speed stability. Disregarding this information could result in product damage and/or personal injury.

The "Load Inertia" field on the [F4] Governor Panel in ESP **must** be programmed by the operator for proper engine operation.

By programming the load inertia or rotating moment of inertia of the driven equipment, the governor gain is preset correctly, aiding rapid startup of the engine.

The rotating moment of inertia must be known for each piece of driven equipment and then added together. Rotating moment of inertia is needed for all driven equipment. **Rotating moment of inertia is not the weight or mass of the driven equipment.**

NOTE: The rotating moment of inertia of driven equipment is an inherent property of the driven equipment and does not change with engine speed or load. Contact the coupling or driven equipment manufacturer for the moment of inertia value.

To determine the rotating moment of inertia for ALL driven equipment, you must determine the rotating moment of inertia for each piece of driven equipment (being consistent with U.S./English and metric units). Once you have the value for each piece of driven equipment, you sum all the values. The summed value is what is programmed on the [F4] Governor Panel in ESP.

Complete the steps on the following page to program the rotating moment of inertia.

NOTE: Setting the rotating moment of inertia (or load inertia) with ESP is part of setting up an engine with the ESM system and **must** be done with the engine not rotating.

Table 3.10-2 VHP Generator Set Moment of Inertia

GENERATOR MANUFACTURER	MODEL	RPM	ROTATING MOMENT OF INERTIA	
			lbf-in.-sec ²	kg * m ²
Kato	6P6-2350	1000	508	57
Kato	6P6-2500	1200	538	61
Kato	6P6-2850	1000	606	68
Kato	6P6-1900	1200	421	48
Magnetek	MTG846/B/C	1000/1200	770	87

Table 3.10-3 VHP Generator Set (with Bearings) Moment of Inertia

GENERATOR MANUFACTURER	MODEL	BEARINGS	RPM	ROTATING MOMENT OF INERTIA	
				lbf-in.-sec ²	kg * m ²
Leroy Somer North America	LS661-01	1	1000/1200	511	57.7
Leroy Somer North America	LS661-03	1	1000/1200	624	70.5
Leroy Somer North America	LS661-04	1	1000/1200	680	76.8
Leroy Somer North America	MTG636	1	1000/1200	283	32
Leroy Somer North America	LS661-04	2	1000/1200	656	74.1
Leroy Somer North America	LS661-05	2	1000/1200	712	80.4
Leroy Somer North America	LS661-06	2	1000/1200	795	89.8
Leroy Somer North America	LS661-07	2	1000/1200	874	98.8

Table 3.10-4 Compressor Moment of Inertia

COMPRESSOR MANUFACTURER	MODEL	RPM	ROTATING MOMENT OF INERTIA	
			lbf-in.-sec ²	kg * m ²
Ariel	JGK/4	1200	49	6
Ariel	JGD/2	1200	61	7
Ariel	JGD/4	1200	108	12
Dresser Rand	6HOS4	1000	61	7
Dresser Rand	5D-VIP4	1200	42	5
Dresser Rand	5C-VIP2	1200	14	2

Table 3.10-5 Coupling Moment of Inertia

COUPLING MANUFACTURER	MODEL	ROTATING MOMENT OF INERTIA	
		lbf-in.-sec ²	kg * m ²
Rexnord Thomas	600CMR*	69	7.8
Rexnord Thomas	700CMR*	90	10.2
Rexnord Thomas	750CMR*	104	11.8
Rexnord Thomas	800CMR*	169	19.1
Rexnord Thomas	850CMR*	190	21.5
Stromag	PVP 66651 G	110	12.4
Woods	80FSH	156	18
Woods	75FSH	113	13
Woods	70FSH	68	8
Renold Hi Tec	RB5.5	103	11.6324

NOTE: * For 28.875 inch diameter coupling

1. Shut down engine but do not remove power from the ECU.

2. Determine the rotating moment of inertia for each piece of driven equipment. Refer to the tables identified for typical generator, compressor, and coupling moment of inertia values:

- Table 3.10-2 lists typical rotating moments of inertia for generator sets.
- Table 3.10-3 lists typical rotating moments of inertia for generator sets with bearings.
- Table 3.10-4 lists typical rotating moments of inertia for compressors.
- Table 3.10-5 lists typical rotating moments of inertia for couplings.

NOTE: If your driven equipment is not listed in these tables, contact the coupling or driven equipment manufacturer for the moment of inertia value.

3. Add together all the moment of inertia values of the driven equipment to determine the moment of inertia value to be programmed in ESP. See Example Number 1 below.

4. For driven equipment including either a speed increaser or a speed reducer, you must square the ratio of the speed increase and multiply that by the rotating moment of inertia of the driven equipment that is not running at engine speed. See Example Number 2.

Example Number 1:

The following example shows how the moment of inertia for driven equipment is determined for an engine using the tables provided.

Engine Application: L7044GSI compressor application

Compressor: Ariel JGK/4

Coupling: Rexnord 750CMR

According to Table 3.10-4 and Table 3.10-5:

Compressor Moment of Inertia = 49 lbf-in.-sec²

Coupling Moment of Inertia = 104 lbf-in.-sec²

This means that the total rotating moment of inertia for the driven equipment is:

$$49 \text{ lbf-in.-sec}^2 + 104 \text{ lbf-in.-sec}^2 = 153 \text{ lbf-in.-sec}^2$$

The total load inertia, 153 lbf-in.-sec² is then programmed on the [F4] Governor Panel in ESP.

Example Number 2:

NOTE: If a speed increaser or reducer is used, the ratio of the speed increase must be squared, then multiplied by the rotating moment of inertia of the driven equipment that is not running at engine speed.

Engine Application: F3421GSI water pump application

Water Pump: Byron Jackson 16GM water pump (7-Stage pump including line shafting and HSG output shafting inertia totaling 7.79 lbf-in.-sec²).

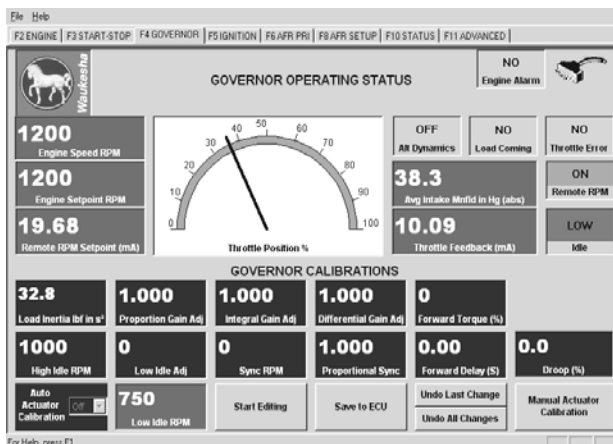
Coupling: U-Joint coupling and Amarillo gear Model SSH750A (speed increaser ratio of 1.5 with LSFG input shafting inertia totaling 12.29 lbf-in.-sec²).

This means that the driven load inertia (referred back to the engine speed) is:

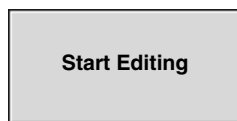
$$12.29 \text{ lbf-in.-sec}^2 + (7.79 \times 1.5^2) = 29.82 \text{ lbf-in.-sec}^2$$

The driven load inertia, 29.82 lbf-in.-sec² (3.37 kg-m²) is then programmed on [F4] Governor Panel in ESP.

5. View the [F4] Governor Panel in ESP.

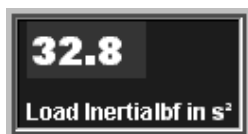


6. Click on the “Start Editing” button. While in editing mode, the button will read “Stop Editing – Currently Editing.”



7. Double-click the “Load Inertia” field or highlight the currently programmed load inertia value.

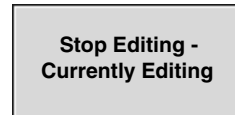
8. Enter the sum of the moment of inertia values of all driven equipment.



9. Press [Enter]. Once [Enter] is pressed, the new value becomes “active,” meaning the ECU is using the new value to operate the ESM system. The changed value is temporarily saved to the ECU.

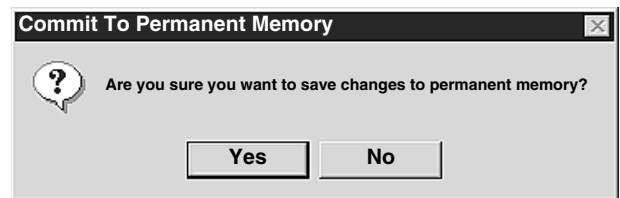
NOTE: The contents of RAM (temporary memory) are lost whenever power to the ECU is removed.

10. Click the “Stop Editing” button. While the editing mode is OFF, the button will read “Start Editing.”



11. Save value to permanent memory. Click the “Save to ECU” button.

12. When asked are you sure you want to save to the ECU, click “Yes.”



PROGRAMMING AIR/FUEL RATIO

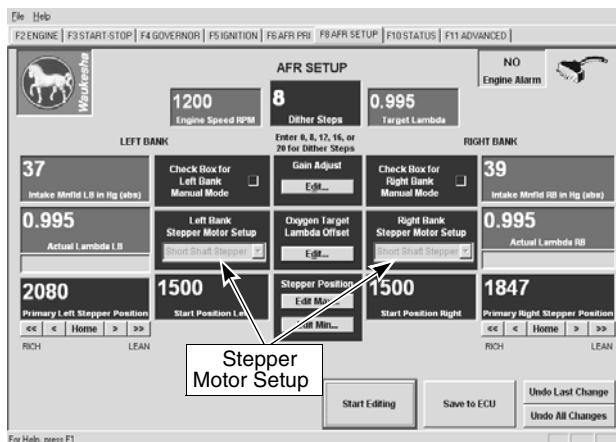
The ESM comes preprogrammed to maintain the proper Air/Fuel Ratio for catalyst control. If required, the ESM system can be programmed using the [F8] AFR Setup Panel to calibrate the left and right bank stepper limits after carburetor adjustments.

1. Set main fuel pressure to 30 – 60 psi (low fuel pressure system must be capable of supplying 6 inches of water column (H₂O) gas pressure to the carburetors).

2. Turn each carburetor screw all the way in, then turn out 4 – 5 turns. On vee engines, the same number of turns on both banks.

3. Using ESP, go to [F8] AFR Setup Panel and verify either short shaft or long shaft stepper motor has been selected.

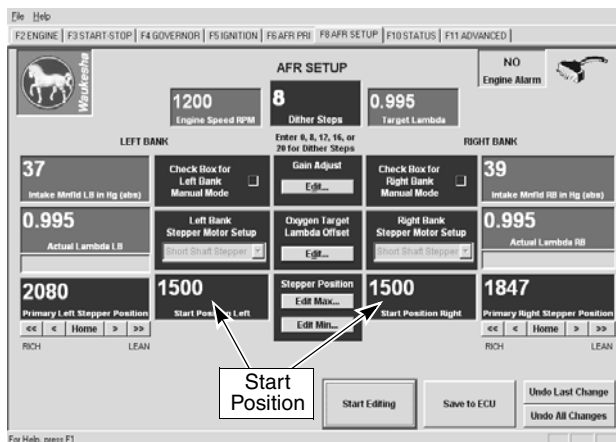
ESP PROGRAMMING



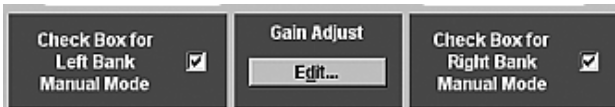
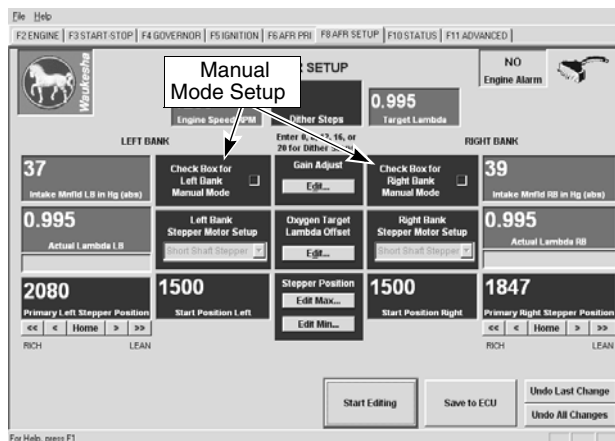
- Short shaft stepper (5800 steps) is selected for GSI blow-thru fuel system.
- Long shaft stepper (20,000 steps) is selected for GSI draw-thru low pressure fuel system.



- On [F8] AFR Setup Panel, verify AFR start position is set to 1500 steps. On draw-thru engines the start position should be set to 5000 steps.

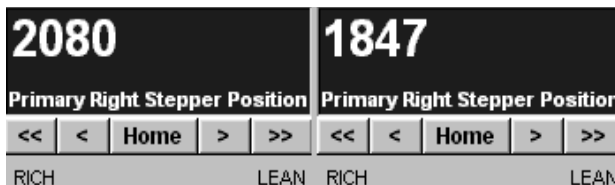
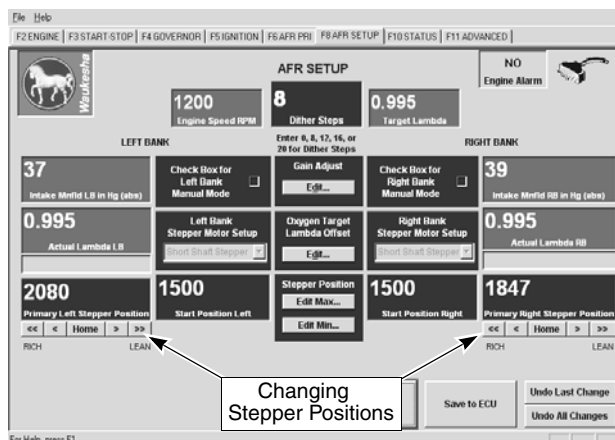


- Set steppers to manual mode by clicking the check box for each bank on the [F8] AFR Setup Panel.



- Start engine.

- At idle, (no load), set gas/air to $4\frac{1}{2} \pm \frac{1}{2}$ in. ($5\frac{1}{2} \pm \frac{1}{2}$ in. draw-thru) by manually changing stepper position. This is done by clicking on the double (large move) or single (small move) arrows under the actual stepper position on the [F8] AFR Setup Panel.

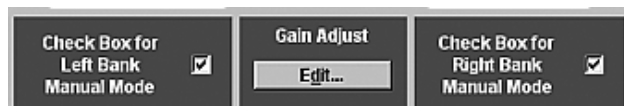


- If actual position is below 600 steps to achieve a gas/air reading of $4\frac{1}{2} \pm \frac{1}{2}$ in. (draw-thru – if actual position is below 3000 steps to achieve $5\frac{1}{2} \pm \frac{1}{2}$ in.), a shim may need to be installed between stepper and regulator (Fisher regulators only).

- B. If the actual position is above 3000 steps to achieve a gas/air reading of $4\frac{1}{2} \pm \frac{1}{2}$ in. (draw-thru – if the actual position is above 17000 steps to achieve $5\frac{1}{2} \pm \frac{1}{2}$ in.), check the regulator spring to verify the correct one has been installed.

8. On vee engines, the gas/air reading between the left and right banks should be within $\pm \frac{1}{2}$ in. of one another.

9. Uncheck manual mode box to run in automatic mode.



10. Verify there are no current alarms presents. If alarms are active, they may interfere with stepper control.

11. At rated speed/load in automatic, stepper should be running between 1000 and 3500 steps (3000 and 17000 steps if draw-thru). Adjust carburetors to achieve this and recheck gas/air. Gas/air reading should be between 4 – 8 inches.

- To lower stepper position, turn the carburetor screw counterclockwise (rich).
- To raise stepper position, turn the carburetor screw clockwise (lean).

12. If everything is set up properly, both banks should be within approximately 500 steps of each other (2000 steps for draw-thru). If not, recheck gas/air and read-just carburetors.

PROGRAMMING NOx LEVEL – LT ENGINE APPLICATIONS ONLY

Using ESP the user can program the desired NOx emissions level (engine out at the exhaust stack) at which the engine will run. The NOx field on the [F5] Ignition Panel in ESP displays the programmed NOx level, not the actual level.

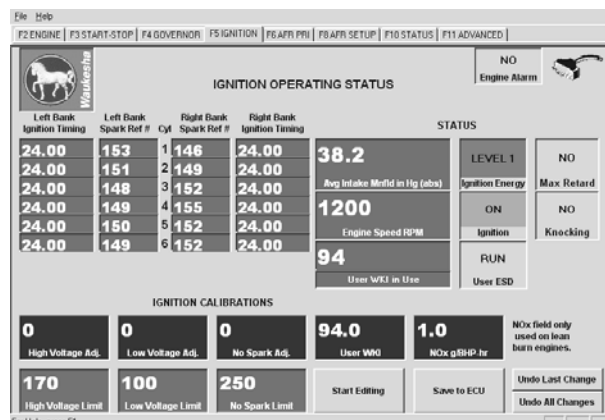
Based on the programmed NOx level, the ESM system will adjust ignition timing in an attempt to meet the programmed NOx level.

However, the actual NOx output of the engine will not always match the programmed NOx level for several reasons. First, the ESM system calculates NOx based on a combination of sensor readings logged by the ECU and Waukesha-calibrated values. Two examples of Waukesha-calibrated values are humidity and exhaust oxygen since the ESM system does not measure these variables. Also, the ESM system includes a preprogrammed correction factor to allow for statistical variations with the engine.

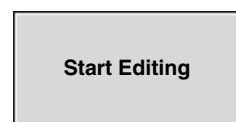
As a result, the engine in most cases will emit less NOx than the actual programmed NOx level.

Complete the following steps to program the NOx level.

1. View the [F5] Ignition Panel in ESP.



2. Click on the “Start Editing” button. While in editing mode, the button will read “Stop Editing – Currently Editing.”



3. Double-click the “NOx” field or highlight the currently programmed NOx level.



4. Enter the desired NOx emissions level (engine out at the exhaust stack) at which the engine will run. The NOx field displays the programmed NOx level, not the actual level. The range that NOx can be programmed varies with the engine (the L5794LT engine range is 1.5 – 5.0 g/BHP-hr).

5. The actual NOx output of the engine will not always match the programmed NOx level. To correct for differences in the actual engine out NOx emissions and that of the programmed NOx level, the NOx field should be adjusted in the appropriate direction until the actual engine out emissions meet the user's desired level. For example, the NOx field may require a value of 2.5 g/BHP-hr to achieve 2.0 g/BHP-hr NOx emissions at the exhaust stack.

ESP PROGRAMMING

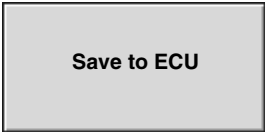
6. Press [Enter]. Once [Enter] is pressed, the new value becomes “active,” meaning the ECU is using the new value to operate the ESM system. The changed value is temporarily saved to the ECU.

NOTE: The contents of RAM (temporary memory) are lost whenever power to the ECU is removed.

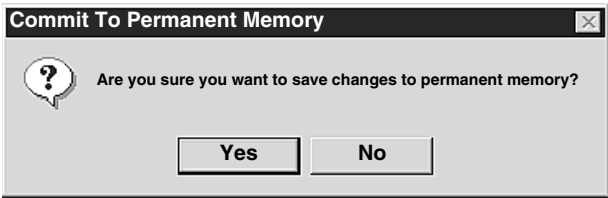
7. Click the “Stop Editing” button. While the editing mode is OFF, the button will read “Start Editing.”



8. Save value to permanent memory. Click the “Save to ECU” button.



9. When asked are you sure you want to save to the ECU, click “Yes.”



PROGRAMMING ALARM AND SHUTDOWN SETPOINTS

NOTE: These changes are standard on all engines built after January 1, 2006.

Complete the following steps to program the alarm and shutdown setpoints.

1. View the [F11] Advanced Functions Panel in ESP.

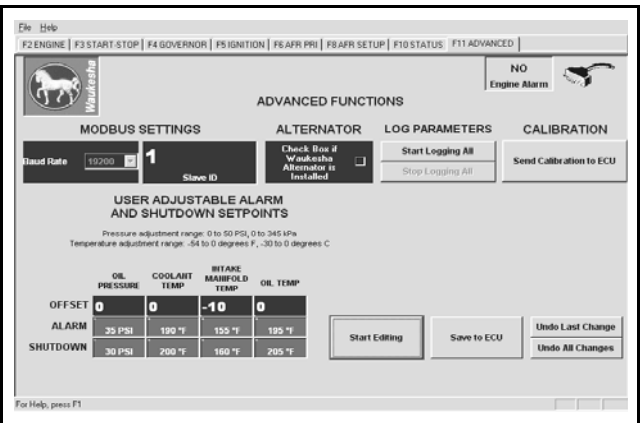


Figure 3.10-2 F11 Advanced Functions Panel in ESP

NOTE: When testing alarms or shutdowns, always run engine at no load.

1. Click on the “Start Editing” button. While in editing mode, the button will read “Stop Editing – Currently Editing.”



2. Double-click the field or highlight the value to be edited.

NOTE: The lowest temperature offset value allowed is -54° F (-30° C). The highest oil pressure offset value allowed is +50 psi (345 kPa).

3. Enter the value. If the value entered exceeds the programmable limits, the field will default to the highest/lowest allowable value for that field.

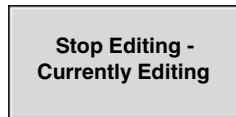
- Oil Pressure – an offset of 5 psi changes the alarm threshold to 40 psi (from 35 psi), and the shutdown threshold to 35 psi (from 30 psi). Oil pressure offsets are always positive. Oil pressure alarm/shutdown values can never be less than what was set at the factory.
- Jacket Water Temperature – an offset of -5° F changes the alarm threshold to 185° F (from 190° F), and the shutdown threshold to 195° F (from 200° F). Jacket water temperature offsets are always negative. Jacket water temperature alarm/shutdown values can never be greater than what was set at the factory.
- Intake Manifold Temperature – an offset of -10° F changes the alarm threshold to 155° F (from 165° F), and the shutdown threshold to 160° F (from 170° F). Intake manifold temperature offsets are always negative. Intake Manifold temperature alarm/shutdown values can never be greater than what was set at the factory.
- Oil Temperature – an offset of -5° F changes the alarm threshold to 190° F (from 195° F) and the shutdown threshold to 200° F (from 205° F). Oil temperature offsets are always negative. Oil temperature alarm values can never be greater than what was set at the factory.

	OIL PRESSURE	JACKET WATER TEMP	INTAKE MANIFOLD TEMP	OIL TEMP
OFFSET	5	-5	-10	-5
ALARM	40 PSI	185° F	155° F	190° F
SHUTDOWN	35 PSI	195° F	160° F	200° F

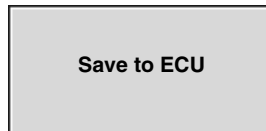
4. Once the new value is entered, press [Enter]. Once [Enter] is pressed, the new value becomes “active,” meaning the ECU is using the new value to operate the ESM system. The new value is temporarily saved to RAM in the ECU.

NOTE: The contents of RAM (temporary memory) are lost whenever power to the ECU is removed or on engine shutdown.

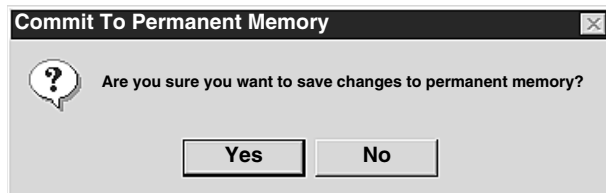
5. If necessary, edit other fields.
6. When all values are entered, click the “Stop Editing” button. While the editing mode is OFF, the button will read “Start Editing.”



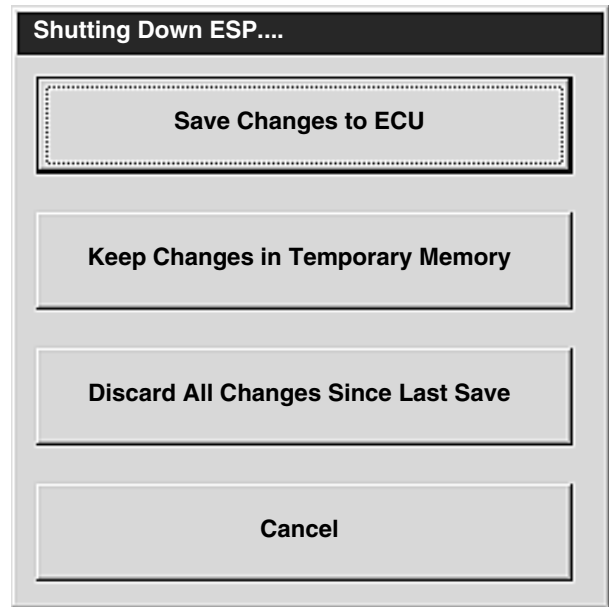
7. Observe engine performance. Make modifications as necessary.
8. Save changes to permanent memory if desired.



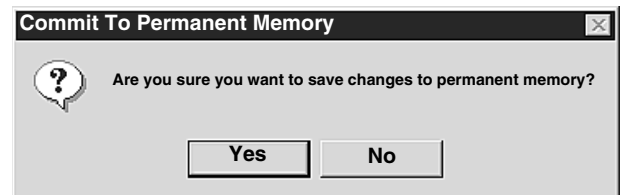
9. When asked are you sure you want to save to the ECU, click “Yes.”



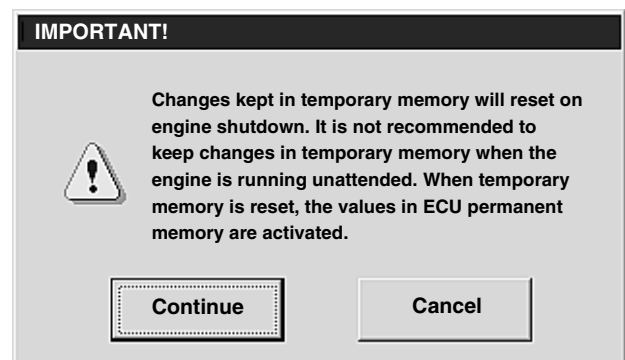
10. If you exit ESP without saving to the ECU, a dialog box appears with four options: “Save Changes to ECU,” “Keep Changes in Temporary Memory,” “Discard All Changes Since Last Save,” and “Cancel.”



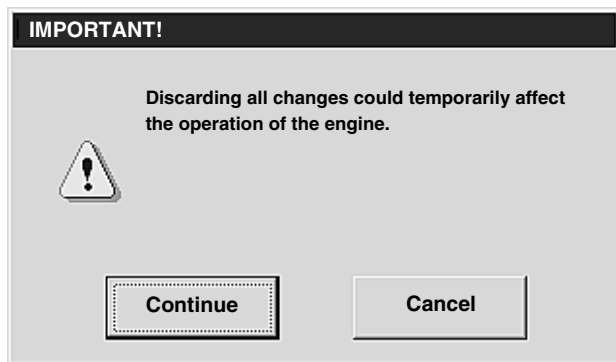
- **“Save Changes to ECU”** Click this button to save all changes to permanent memory in the ECU before exiting. When the dialog box asks you to confirm the save to permanent memory, click “Yes.”



- **“Keep Changes in Temporary Memory”** Click this button to keep all changes in temporary memory in the ECU. You will be able to close ESP and disconnect the PC from the ECU while keeping all changes; however, changes will be lost if power to the ECU is removed or the engine is shut down. Read the information on the dialog box that appears. Click “Continue.”



- **“Discard All Changes Since Last Save”** Click this button to reset the ECU to the programmed parameters that were last saved to permanent memory in the ECU. Click “Continue.”



- **“Cancel”** Click this button to cancel exiting from ESP. Any values in temporary memory will remain in temporary memory.

ACTUATOR CALIBRATION

To work correctly, the ESM system must know the fully closed and fully open end points of throttle actuator movement. To establish the fully closed and fully open end points, the throttle actuator must be calibrated.

The throttle actuator can be automatically calibrated on each engine shutdown (except on Emergency Shutdown) through ESP programming, or the actuator can be calibrated manually. Automatic calibration is strongly recommended. See “Programming Automatic Calibration” on page 3.10-16 or “Performing Manual Calibration” on page 3.10-17.

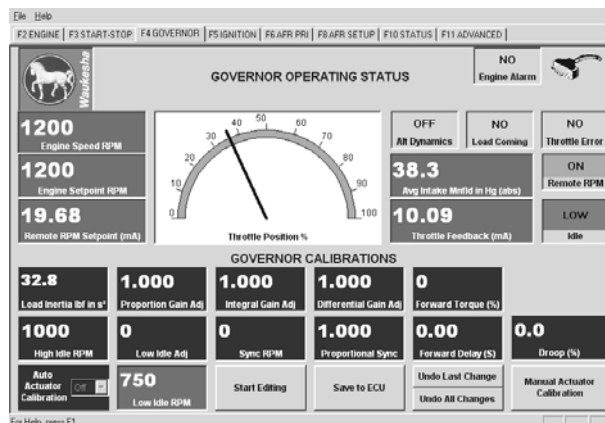
NOTE: On initial engine startup, perform a manual calibration of the actuator.

PROGRAMMING AUTOMATIC CALIBRATION

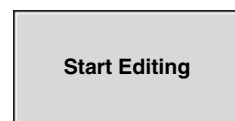
Using ESP, the ESM system can be programmed on the [F4] Governor Panel to automatically calibrate the throttle actuator each time the engine stops (except on Emergency Shutdown). During the automatic calibration, the ECU “learns” the fully closed and fully open end points of throttle actuator. The benefits to calibrating the actuator automatically are (1) performing the calibration when the actuator is hot, and (2) if any actuator problems are detected, they are found on engine shutdown and not startup.

Complete the following:

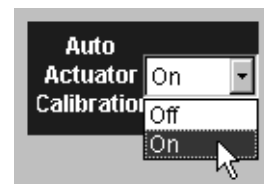
1. View the [F4] Governor Panel in ESP.



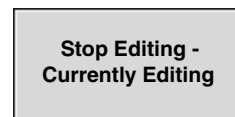
2. Click on the “Start Editing” button. While in editing mode, the button will read “Stop Editing – Currently Editing.”



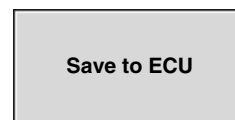
3. Click on the drop-down menu arrow in the “Auto Actuator Calibration” field.



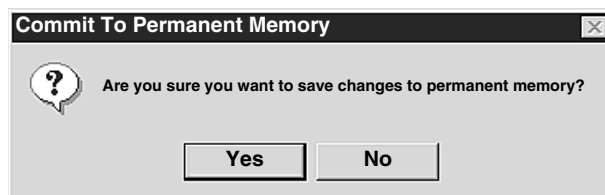
4. From the drop-down menu, select “On” or “Off.”
5. When selection is made, click the “Stop Editing” button. While the editing mode is OFF, the button will read “Start Editing.”



6. To save setting to permanent memory, click the “Save to ECU” button.



7. When asked are you sure you want to save to the ECU, click “Yes.”



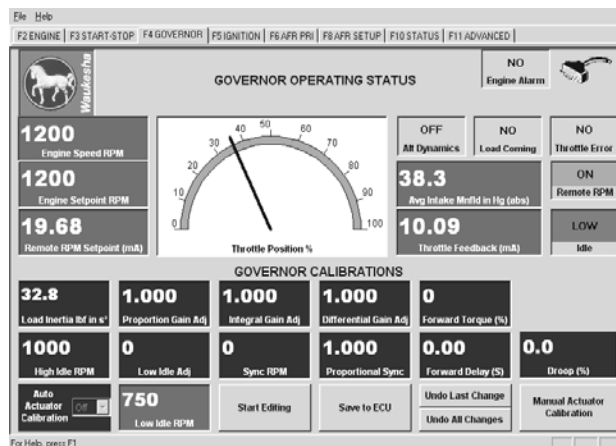
PERFORMING MANUAL CALIBRATION

To manually verify that the ECU knows the fully closed and fully open end points of throttle actuator movement, run an actuator calibration using ESP. A manual calibration can be performed when the engine is not rotating and after postlube and the ESM system's post-processing is complete. If an emergency shut-down is active, a manual calibration cannot be completed.

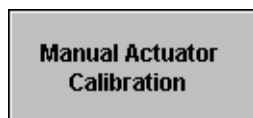
NOTE: On initial engine startup, perform a manual calibration of the actuator.

Complete the following:

1. Shut down engine, but do not remove power from the ECU.
2. View the [F10] Status Panel in ESP. If any E-Stop fields or shutdown fields are active (shown in red), you will not be able to perform a manual calibration until they are corrected. Refer to Section 4.00 *Troubleshooting* for information on how to troubleshoot the ESM system using the electronic help file, E-Help.
3. View the [F4] Governor Panel in ESP.



4. Click on the "Manual Actuator Calibration" button on the [F4] Governor Panel.



5. Click "Actuator AutoCal" from the dialog box.



NOTE: The "LBS AutoCal" feature is not used with this release of the ESM system.

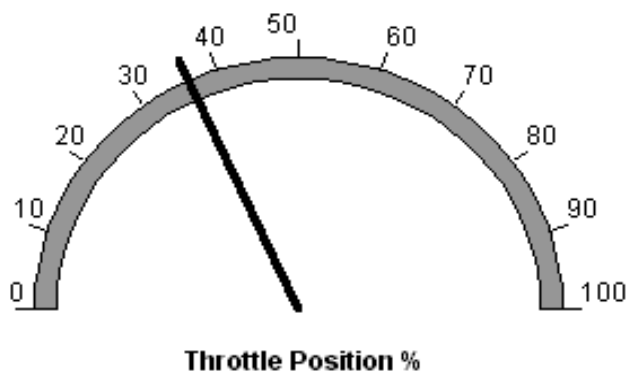
6. If the engine is stopped and has completed postlube and post-processing, a dialog box appears, verifying the ESM system is ready to perform the calibration. Click "OK."



NOTE: If the engine has not stopped or is not ready to perform a manual calibration, a dialog box appears, providing the reason for not doing the manual calibration. Click "OK." Wait a few minutes before attempting manual calibration.



7. During the calibration process, several messages appear, indicating that the actuator is being calibrated.
8. Observe the actuator lever and the throttle shaft as the "Throttle Position" field displays actuator movement.



What is observed on the engine and what is displayed in the field should match. You should observe the Throttle Position needle move from 0 to 100% in large steps.

Note the following:

- If the actuator movement does not follow the needle movement listed, troubleshoot the ESM system by following the remedies provided for ALM441 in E-Help (even if this is not an active fault). Refer to Section 4.00 *Troubleshooting* for information on how to troubleshoot the ESM system using the electronic help file, E-Help.
- If your observations show no movement with either the actuator or ESP, troubleshoot the ESM system by following the remedies provided for ALM441 in E-Help (even if this is not an active fault). Refer to Section 4.00 *Troubleshooting* for information on how to troubleshoot the ESM system using the electronic help file, E-Help.
- If the needle in the “Throttle Position” field does not move, but the throttle actuator on the engine does, ALM441 should be active. The “Throttle Error” field on the [F4] Governor Panel should be yellow, signaling the user that YES, a throttle error occurred. Refer to Section 4.00 *Troubleshooting* for information on how to troubleshoot the ESM system using the electronic help file, E-Help.
- If the needle in the “Throttle Position” field does move, but the throttle actuator on the engine does not, it could be an internal error in the ECU or a corrupt ESP. Contact your local Waukesha Distributor for technical support.

NOTE: If the ESM system detects a fault with the throttle actuator, the “Throttle Error” field on the [F4] Governor Panel turns yellow and signals the user that YES, a throttle error occurred. Refer to Section 4.00 *Troubleshooting* for information on how to troubleshoot the ESM system using the electronic help file, E-Help.

9. Confirmation appears when the calibration is complete. Click the “OK” button to continue.

NOTE: When confirmation appears, it simply means that the ESM system is done calibrating the actuator, but does not indicate whether or not the calibration was successful. You must observe actual actuator movement.



GOVERNOR PROGRAMMING

This section provides information on the ESM speed governing system for fixed speed applications, variable speed applications, feedforward control, and synchronizer control.

VARIABLE SPEED APPLICATIONS

When operating an engine for variable speed applications, user connections determine the rpm setpoint. When the Remote Speed Select input signal is high (8.6 – 36 volts), the “Remote RPM” field on the [F4] Governor Panel is green and signals the user that it is ON. The speed setpoint is varied with either a 4 – 20 mA or a 0.875 – 4.0 volt input (ESP displays this value in mA only).

If an out-of-range speed setpoint is detected or if the wire that enables remote rpm operation fails, the speed setpoint will default to the low/high idle values. The “Idle” field on the [F4] Governor Panel indicates whether the LOW or HIGH signal is active. The idle speeds must be set to a safe rpm.

The following fields on the [F4] Governor Panel should be reviewed to make sure they are correctly programmed for variable speed application:

- **“Load Inertia”:** This field **must** be programmed by the operator for proper engine operation. See “Programming Load Inertia” on page 3.10-9 for programming information.
- **“High Idle”:** This field allows the user to program the high idle rpm. Although customer connections determine the rpm setpoint in variable speed applications, the high idle setting must be programmed to a “safe” value in case an out-of-range speed setpoint is detected or if the wire that enables remote rpm operation fails. The high idle rpm can be programmed from 800 to 2200 rpm (not to exceed a preprogrammed maximum speed). Internal calibrations prevent the engine from running faster than rated speed +10%. See “Basic Programming in ESP” on page 3.10-5 if this field requires programming.

- **“Low Idle”** and **“Low Idle Adjust”**: These fields allow the user to view and program the low idle rpm setting. Although customer connections determine the rpm setpoint in variable speed applications, the low idle setting must be programmed to a “safe” value in case an out-of-range speed setpoint is detected or if the wire that enables remote rpm operation fails. The teal (blue-green) “Low Idle RPM” field displays the actual programmed low idle rpm setting. The dark blue “Low Idle Adj” field allows the user to adjust the actual setting by entering a value from -50 to +100 rpm. When an adjustment is entered, the actual “Low Idle RPM” is updated to reflect the adjustment. *(NOTE: The low idle rpm cannot be set higher than the high idle rpm.)* See “Basic Programming in ESP” on page 3.10-5 if low idle requires programming.
- **“Droop”**: This field allows the user to adjust the percent of droop. Droop allows steady state speed to drop as load is applied. Droop is expressed as a percentage of normal average speed. Droop can be programmed from 0 to 5%. See “Basic Programming in ESP” on page 3.10-5 if this field requires programming.
- **“Auto Actuator Calibration”**: It is recommended that ESP be programmed to perform an automatic throttle actuator calibration on normal shutdown. See “Actuator Calibration” on page 3.10-16 for programming information.
- **“High Idle”**: This field allows the user to program the high idle rpm. The high idle setting is used when the rated speed/idle speed digital input is high (8.6 – 36 volts) and the “Remote RPM” field is OFF. The high idle rpm can be programmed from 800 to 2200 rpm (not to exceed a preprogrammed maximum speed). Internal calibrations prevent the engine from running faster than rated speed +10%. See “Basic Programming in ESP” on page 3.10-5 if high idle requires programming.
- **“Low Idle”** and **“Low Idle Adjust”**: These fields allow the user to view and program the low idle rpm setting. The low idle setting is used when the rated speed/idle speed digital input is low (less than 3.3 volts) and the “Remote RPM” field is OFF. The teal (blue-green) “Low Idle RPM” field displays the actual programmed low idle rpm setting. The dark blue “Low Idle Adj” field allows the user to adjust the actual setting by entering a value from -50 to +100 rpm. When an adjustment is entered, the actual “Low Idle RPM” is updated to reflect the adjustment. *(NOTE: The low idle rpm cannot be set higher than the high idle rpm.)* See “Basic Programming in ESP” on page 3.10-5 if low idle requires programming.
- **“Droop”**: This field allows the user to adjust the percent of droop. Droop allows steady state speed to drop as load is applied. Droop is expressed as a percentage of normal average speed. Droop can be programmed from 0 to 5%. See “Basic Programming in ESP” on page 3.10-5 if this field requires programming.
- **“Auto Actuator Calibration”**: It is recommended that ESP be programmed to perform an automatic throttle actuator calibration on normal shutdown. See “Actuator Calibration” on page 3.10-16 for programming information.

FIXED SPEED APPLICATIONS

There are two fixed speeds available: low idle and high idle.

Low idle speed is the default and high idle is obtained by connecting a digital input on the ECU to +24 VDC nominal. When the voltage signal goes high (8.6 – 36 volts), high idle speed is active. Low idle speed is preset for each engine family, but by using ESP the low idle speed can be offset lower or higher than the preset value. High idle speed is also adjustable using ESP, but is constrained to be higher than low idle speed and no higher than the maximum rated speed of the engine.

The following fields on the [F4] Governor Panel should be reviewed to make sure they are correctly programmed for fixed speed application.

- **“Load Inertia”**: This field **must** be programmed by the operator for proper engine operation. See “Programming Load Inertia” on page 3.10-9 for programming information.

FEEDFORWARD CONTROL (LOAD COMING)

Feedforward control is used to greatly improve engine response to large loads. One example of how this feature can be used would be in stand-alone electric power generation applications where the engine is supplying variable loads such as lights, miscellaneous small loads, and one large electric motor.

For example, the contactor for a large load could be routed to a PLC so that a request to add the load would go through the PLC. When the PLC received the request to add the load, it first would set the large load coming digital input on the ECU high for 0.5 seconds and then 1 second later actually close the contactor to add the load. This would give the ESM system a 1 second head start to open the throttle, even before the load was applied and the engine speed dropped. *(Times used are examples only.)*

The behavior of the large load coming digital input can be customized through “trial and error” with ESP. The percent of rated load of the electric motor is set in the “Forward Torque” field on the [F4] Governor Panel. The Forward Delay is the lag time of the ESM system from receipt of the Load Coming signal until action is taken. As the **LRG LOAD** digital input goes high (8.6 – 36 volts), the engine speed should go above setpoint rpm for approximately 1 second before the load is applied. Typically the “Forward Torque” field is set to 125% and “Forward Delay” is programmed to optimize the system’s behavior.

The following fields on the [F4] Governor Panel should be reviewed to make sure they are correctly programmed for Feedforward Control.

- **“Forward Torque”:** This field allows the user to program the forward torque amount of load coming. When the load coming signal goes high, and after the forward delay timer has expired, the throttle opens by the programmed torque percent. The forward torque can be programmed from 0 to 125%. See “Basic Programming in ESP” on page 3.10-5 if this field requires programming.
- **“Forward Delay”:** This field allows the user to program the forward delay timer of load coming. When the load coming signal goes high, the forward delay must expire before the throttle opens to the programmed torque percent. Units are in seconds. The forward delay can be programmed from 0 to 60 seconds. See “Basic Programming in ESP” on page 3.10-5 if this field requires programming.

SYNCHRONIZER CONTROL (ALTERNATE DYNAMICS)

Synchronizer control or alternate dynamics are governor dynamics that can be used to rapidly synchronize an engine to the electric power grid. These lower gain values can also be used to minimize actuator movement when the engine is synchronized to the grid and fully loaded to maximize actuator life.

Raising a high digital input (8.6 – 36 volts) to the ECU puts the ESM system’s governor in synchronizer control. The user can program a small speed offset (“Sync RPM” field) to aid in synchronization.

The “Sync RPM” field must be adjusted so that the actual engine speed setpoint is approximately 0.2% higher than synchronous speed. The additional rpm programmed in this field is added to the setpoint rpm when the “Alternate Dynamics” field is green and signals it is ON. For example, if the grid frequency is 60 Hz (1200 rpm), the “High Idle” field is programmed so that the engine speed setpoint is 0.002 times 1200 rpm which is 1202 rpm.

This ensures that the electric phasing of the grid and the engine are different so that the phases will *slide* past each other. When an external synchronizer determines that the voltage and phase of the generator match the grid, the breaker is closed. The load of the engine can now be controlled by an external load control.

NOTE: When an error exists between the “Engine Speed” field and the “Engine Setpoint RPM” field, a proportional synchronous gain calibrated by Waukesha Engine is multiplied to the speed error. The gain is multiplied to increase or decrease throttle response to correct the speed error. The “Proportion Gain Adj” field allows fine-tuning for best throttle response but is typically not programmed.

The following field on the [F4] Governor Panel should be reviewed to make sure it is correctly programmed for Synchronizer Control.

- **“Sync RPM”:** This field allows the user to program a synchronous rpm to allow easier synchronization to the electric grid. The additional rpm programmed in this field is added to the engine setpoint rpm if the “Alt Dynamics” field is ON. The synchronous rpm can be programmed from 0 to 64 rpm. See “Basic Programming in ESP” on page 3.10-5 if this field requires programming.

IPM-D PROGRAMMING

This section provides information on fine-tuning ESM IPM-D predictive diagnostics. Although the IPM-D’s default values are appropriate for all applications, the user can fine-tune the default values to compensate for site conditions and minor variations between individual ignition coils.

IPM-D provides diagnostic information for both the primary and secondary sides of the ignition coil. The IPM-D detects shorted spark plugs and ignition leads, as well as spark plugs that require a boosted energy level to fire or do not fire at all. The diagnostic information is provided through a Controller Area Network (CAN) link between the ECU and IPM-D, and then to the customer’s local control panel via MODBUS®.

Four thresholds calibrated by Waukesha Engine have been programmed into the ECU to trigger four different levels of alarm:

- **Primary:** Indicates a failed ignition coil or faulty ignition wiring

NOTE: Another possible cause of a primary alarm would be the activation of the red lockout or E-stop (emergency stop) button on the side of the engine while the engine is running.

- **Low Voltage:** Indicates a failed spark plug or shorted ignition coil secondary wire

- **High Voltage:** Indicates that a spark plug is getting worn and will need to be replaced
- **No Spark:** Indicates that a spark plug is worn and *must* be replaced

When the spark reference number reaches one of the four programmed thresholds, an alarm is triggered. Three of these four thresholds (low voltage, high voltage, and no spark) were designed to be adjustable so the user can customize IPM-D predictive diagnostics to fit the specific needs of each engine. Using the [F5] Ignition Panel in ESP, the user can adjust the faults' alarm and shutdown points to compensate for site conditions and minor variations in spark reference numbers between individual coils.

NOTE: *The IPM-D default values are appropriate for all engine applications.*

NOTE: *Improper use of these adjustments may limit the effectiveness of IPM-D diagnostics.*

MONITORING IGNITION ENERGY FIELD

The "Ignition Energy" field on the [F5] Ignition Panel indicates at what level of energy the IPM-D is firing the spark plugs: Level 1 (low) or Level 2 (high). The pink "Ignition Energy" field will signal the user whether the ignition level is LEVEL 1 or LEVEL 2.

During normal engine operation, the IPM-D fires at a Level 1 (normal) ignition energy. The IPM-D fires at a Level 2 (high) ignition energy on engine startup or as a result of spark plug wear. When sufficient spark plug wear is monitored, IPM-D raises the power level of the ignition coil. If the ignition energy is raised to Level 2 (except on startup), an alarm is triggered to alert the operator.

Once Level 2 energy is applied, the spark reference number will decrease initially but the Fault Log will indicate the cylinder number of the spark plug that is wearing out.

NOTE: *When using MODBUS® the cylinder number is in firing order. For example, if #5 cylinder triggers an alarm for having a worn-out spark plug, the user should check the spark plug of the fifth cylinder in the firing order. Engine firing order is stamped on the engine nameplate. The VHP Series Four 6-cylinder engine firing order is: 1, 5, 3, 6, 2, 4. The VHP Series Four 12-cylinder engine firing order is: 1R, 6L, 5R, 2L, 3R, 4L, 6R, 1L, 2R, 5L, 4R, 3L.*

MONITORING SPARK REFERENCE NUMBER

The spark reference number is an arbitrary number based on relative voltage demand at the spark plug and is calculated each time the cylinder fires.

The usefulness of the spark reference number lies in how much a number changes over time as a spark plug erodes. Based on a thorough trend analysis of the spark reference numbers, the user may want to adjust the high, low, or no spark voltage limits. It will take some testing and adjustment to obtain thresholds that optimize the use of these features. For maximum benefit, the spark reference number for each cylinder should be recorded at normal operating load with new spark plugs installed and then monitored over a period of time for changes.

The "Left Bank Spark Reference #" and "Right Bank Spark Reference #" fields on the [F5] Ignition Panel display the spark reference number for each cylinder. As the voltage increases, the spark reference number also increases. A gradual increase in the spark reference number is expected over time as the spark plug wears. The closer to end of spark plug life, the faster the spark reference number will increase.

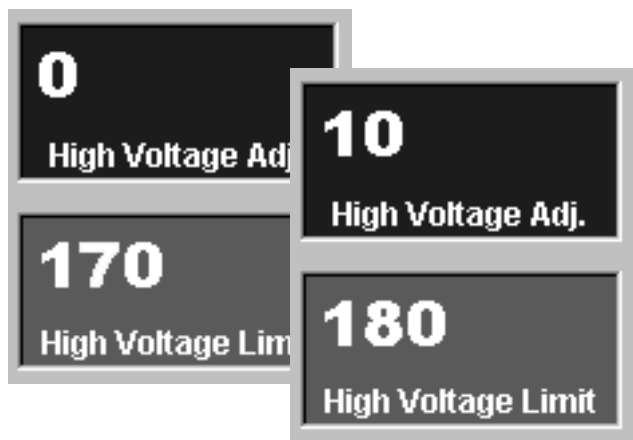
HIGH VOLTAGE ADJUSTMENT

NOTE: *Improper use of the High Voltage Adjustment may limit the effectiveness of IPM-D diagnostics.*

The "High Voltage Adj." and "High Voltage Limit" fields allow the user to view and adjust the high voltage alarm limit setting. The high voltage limit is based on the spark reference number. When a cylinder's spark reference number exceeds the high voltage limit, the ignition energy is raised to a Level 2 (high) ignition energy and an alarm is triggered. Based on a thorough trend analysis of the spark reference numbers, the user may want to adjust the high voltage limit to fit the specific needs of the engine. Improper use of this adjustment may limit the effectiveness of IPM-D diagnostics.

Programming the "High Voltage Adj." to a positive number will delay triggering the high voltage limit alarm until the spark plugs are more worn. Likewise, reducing the "High Voltage Adj." will advance triggering the high voltage limit alarm, allowing more time between when an alarm is triggered and spark plug failure.

- The teal (blue-green) "High Voltage Limit" field displays the actual programmed high voltage limit setting. The dark blue "High Voltage Adj." field allows the user to adjust the actual setting by entering a value from -30 to +30. When an adjustment is entered, the actual "High Voltage Limit" is updated to reflect the adjustment. See "Basic Programming in ESP" on page 3.10-5 if this field requires programming.



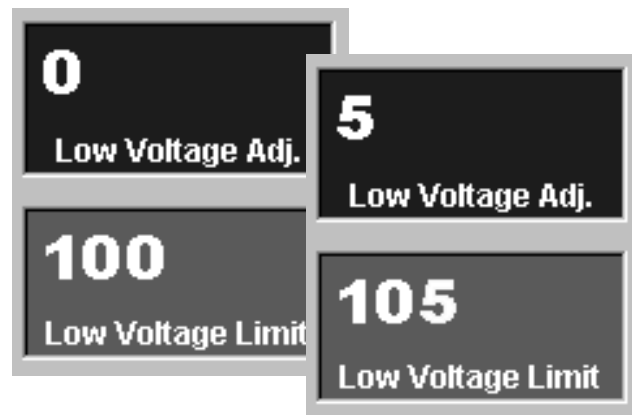
NOTE: The “High Voltage Limit” field has a defined range (min./max.) that can be programmed. If the user programs a positive or negative adjustment that exceeds this defined range, the “High Voltage Limit” field will display the actual high voltage setting even though the adjustment entered may calculate to be different. For example, if the default high voltage limit is 170 but cannot exceed 190 for the engine (a factory setting), the “High Voltage Limit” field will display the actual high voltage setting. So if the user programs an adjustment of +30 (which exceeds 190), “30” will appear in the “High Voltage Adj.” field and “190” will appear in the “High Voltage Limit” field. The same holds true for negative adjustments.

LOW VOLTAGE ADJUSTMENT

NOTE: Improper use of the Low Voltage Adjustment may limit the effectiveness of IPM-D diagnostics.

The “Low Voltage Adj.” and “Low Voltage Limit” fields allow the user to view and adjust the low voltage alarm limit setting. The low spark limit is based on the spark reference number. When a cylinder’s spark reference number goes below the low spark limit, an alarm is triggered, identifying a low voltage demand condition that may have resulted from a shorted coil or secondary lead, deposit buildup, or a failed spark plug (failure related to “balling” or shorting). Based on a thorough trend analysis of the spark reference numbers, the user may want to adjust the low voltage limit to fit the specific needs of the engine. Improper use of this adjustment may limit the effectiveness of IPM-D diagnostics. **Typically this limit is not adjusted.**

- The teal (blue-green) “Low Voltage Limit” field displays the actual programmed low voltage limit setting. The dark blue “Low Voltage Adj.” field allows the user to adjust the actual setting by entering a value from -30 to +30. When an adjustment is entered, the actual “Low Voltage Limit” is updated to reflect the adjustment. See “Basic Programming in ESP” on page 3.10-5 if this field requires programming.



NOTE: The “Low Voltage Limit” field has a defined range (min./max.) that can be programmed. If the user programs a positive or negative adjustment that exceeds this defined range, the “Low Voltage Limit” field will display the actual low voltage setting even though the adjustment entered may calculate to be different. For example, if the default low voltage limit is 100 but cannot exceed 120 for the engine (a factory setting), the “Low Voltage Limit” field will display the actual low voltage setting. So if the user programs an adjustment of +30 (which exceeds 120), “30” will appear in the “Low Voltage Adj.” field and “120” will appear in the “Low Voltage Limit” field. The same holds true for negative adjustments.

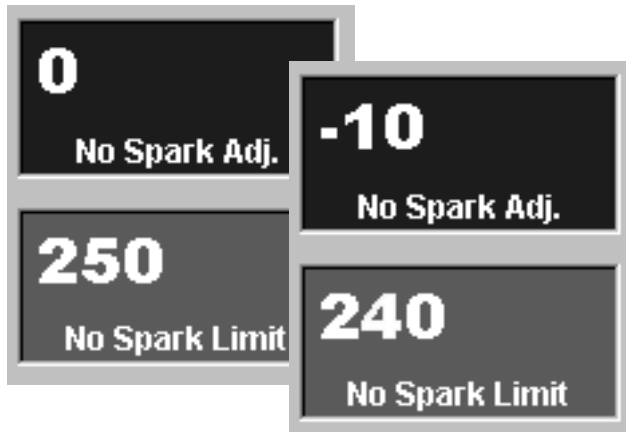
NO SPARK ADJUSTMENT

NOTE: Improper use of the No Spark Adjustment may limit the effectiveness of IPM-D diagnostics.

The “No Spark Adj.” and “No Spark Limit” fields allow the user to view and adjust the no spark alarm limit setting. The no spark limit is based on the spark reference number.

When a cylinder’s spark reference number exceeds the no spark limit, an alarm is triggered, indicating that a spark plug is worn and must be replaced. Based on a thorough trend analysis of the spark reference numbers, the user may want to adjust the no spark limit to fit the specific needs of the engine. Improper use of this adjustment may limit the effectiveness of IPM-D diagnostics. **Typically this limit is not adjusted.**

The teal (blue-green) “No Spark Limit” field displays the actual programmed no spark limit setting. The dark blue “No Spark Adj.” field allows the user to adjust the actual setting by entering a value from -25 to +25. When an adjustment is entered, the actual “No Spark Limit” is updated to reflect the adjustment. See “Basic Programming in ESP” on page 3.10-5 if this field requires programming.

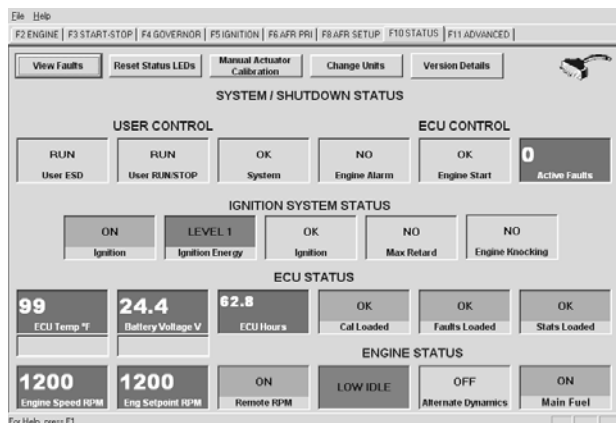


NOTE: The “No Spark Limit” field has a defined range (min./max.) that can be programmed. If the user programs a positive or negative adjustment that exceeds this defined range, the “No Spark Limit” field will display the actual no spark setting even though the adjustment entered may calculate to be different. For example, if the default no spark limit is 200 but cannot exceed 215 for the engine (a factory setting), the “No Spark Limit” field will display the actual no spark setting. So if the user programs an adjustment of +25 (which exceeds 215), “25” will appear in the “No Spark Adj.” field and “215” will appear in the “No Spark Limit” field. The same holds true for negative adjustments.

CHANGING UNITS – U.S. OR METRIC

Units in ESP can be viewed in either U.S. or metric measurement units. To change units displayed on ESP panels, complete the following:

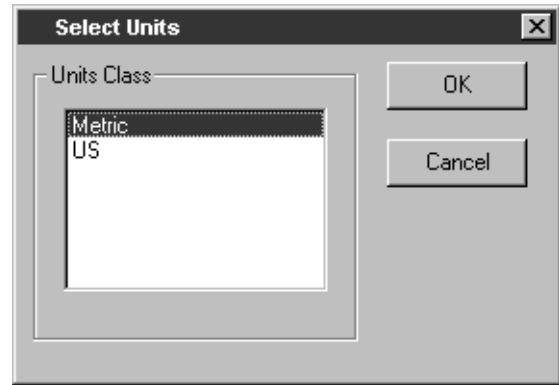
1. In ESP, click on the [F10] Status Panel.



2. Click on the “Change Units” button.



3. Select the unit type to be displayed in ESP: “Metric” or “US.”



4. Click “OK.” All the field values on each panel will be shown in the selected units.

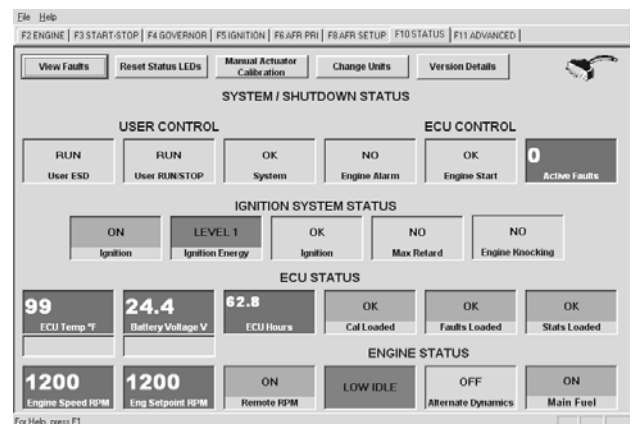
RESET STATUS LEDS ON ECU

When an ESM system’s fault is corrected, the fault disappears from the ESM ESP active fault log and the ESP screens will no longer indicate an alarm.

However, the yellow and/or red Status LED(s) on the ECU will remain flashing the fault code(s) even after the fault(s) is cleared. The code will continue to flash on the ECU until one of two things happens: (1) the LED(s) is reset using ESP or (2) the engine is restarted.

To clear the Status LED(s) using ESP, complete the following:

1. In ESP, click on the [F10] Status Panel.



2. Click the “Reset Status LEDs” button. The Status LEDs on the front of the ECU will clear.

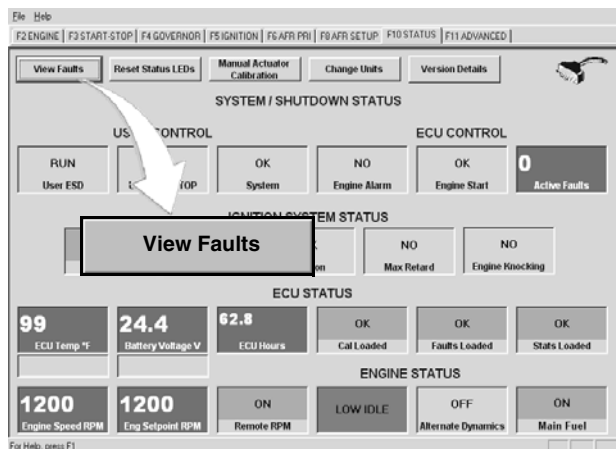
COPYING FAULT LOG INFORMATION TO THE CLIPBOARD

In ESP, the operator has an option to copy to the PC’s clipboard information on the Fault Log. The information can then be pasted as editable text in Microsoft® Word or another word processing program.

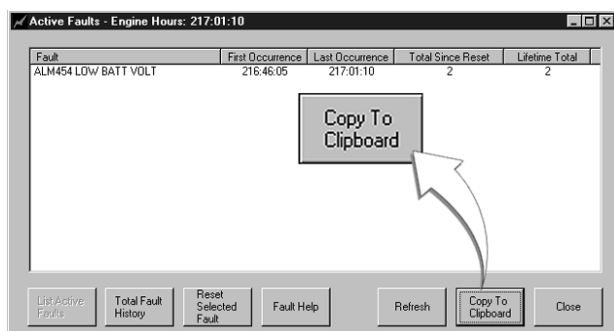
Complete the following steps to copy to the clipboard the fault log information.

ESP PROGRAMMING

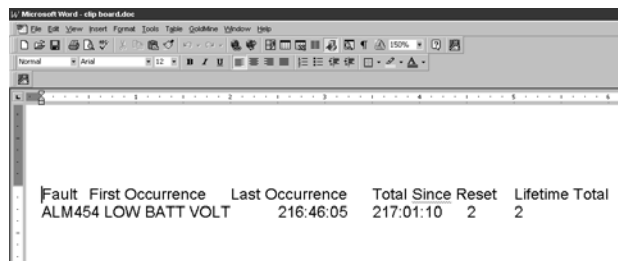
1. In ESP, click on the [F10] Status Panel.
2. View the Fault Log by clicking the “View Faults” button on the [F10] Status Panel.



3. Click the “Copy to Clipboard” button to copy the information listed in the Fault Log.



4. Open a Microsoft® Word file.
5. Paste the text information into the file by selecting **Edit** then **Paste** from the Microsoft® Word or Excel menu.



NOTE: You will need to format pasted text in Microsoft® Word or Excel to align columns and to display information as desired.

6. The Microsoft® Word or Excel file can then be saved and/or printed.

TAKING SCREEN CAPTURES OF ESP PANELS

A screen capture of the ESP panels can be made by using the screen capture feature of Microsoft® Windows® XP. A screen capture is the act of copying what is currently displayed on the screen. If the system is in graphics mode, the screen capture will result in a graphics file containing a bitmap of the image. Once the screen capture is taken, the screen capture can be pasted into a Microsoft® Word or Excel file (or another word processing program file), saved, and printed.

NOTE: It is recommended that you take a screen capture of all the ESP screens after ESM system programming is complete and save them for future reference.

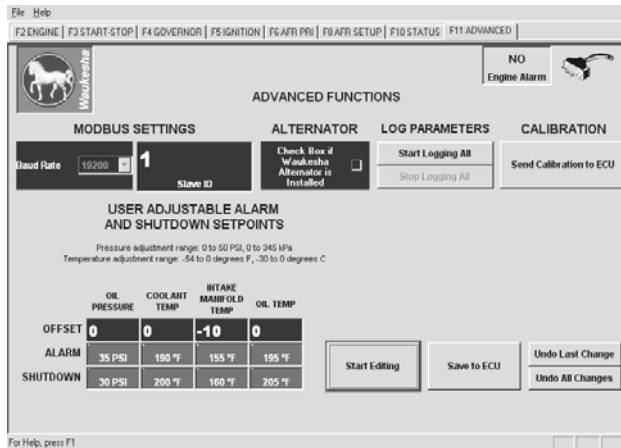
To take a screen capture, complete the following:

1. View the desired ESP panel.
2. Press [Alt] and then [Print Screen] on the keyboard to save the screen capture image to the PC's clipboard.
3. Open a Microsoft® Word file.
4. Paste the image into the file by selecting **Edit** then **Paste** from the Microsoft® Word menu.
5. The Microsoft® Word or Excel file can then be saved and/or printed.

LOGGING SYSTEM PARAMETERS

All active system parameters during a user-determined period of time can be logged using ESP. The file that is saved is a binary file (file extension .AClog) that must be converted or extracted into a usable file format. Using the Log File Processor program installed with ESP, the binary file is extracted into a Microsoft® Excel-readable file (.TSV) or a text file (.TXT). Once the data is readable as a .TSV or .TXT file, the user can review, chart, and/or trend the data logged as desired. Complete the following:

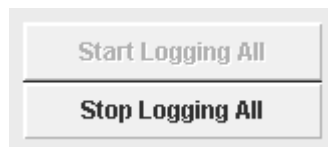
1. In ESP, click on the [F11] Advanced Panel.



2. Click the “Start Logging All” button.

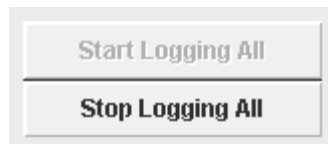


3. The “Start Logging All” button becomes inactive and the “Stop Logging All” button becomes active. At this point, data is being logged onto the PC’s hard drive.

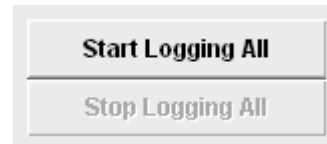


4. Allow the engine to run while the data is logged. It is recommended that 1 – 2 hours be the maximum amount of time that is allowed to log data. Microsoft® Excel has a maximum number of columns/rows and if too much engine data is logged, capacity will be exceeded.

5. When you want to stop logging data, click the “Stop Logging All” button.



6. The “Stop Logging All” button becomes inactive and the “Start Logging All” button becomes active.



7. Start the ESP Log File Processor program by one of the following methods.

- Double-click the Log File Processor icon on your desktop. If ESP is open, you will have to exit ESP to access the icon, or you will have to drag the ESP window by its title bar to one side of the screen to access the icon.



- From the Windows® taskbar (lower-left corner of your desktop), click **Start** → **All Programs** → **Waukesha Engine Controls** → **Engine System Manager (ESM)** → **Log File Processor**.

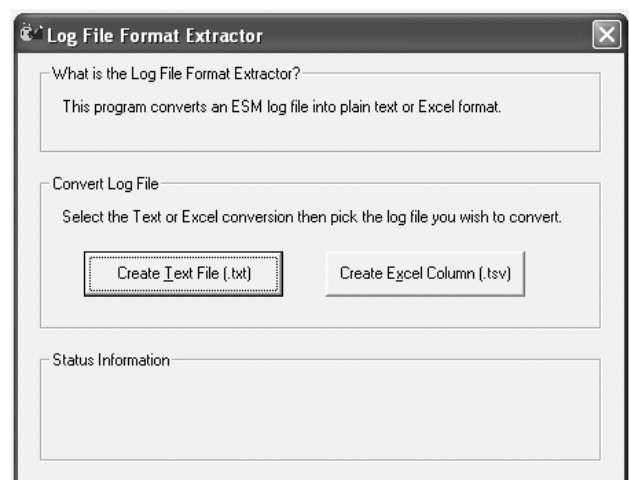
8. Determine whether you would like to extract the file into a .TXT file that can be opened in Microsoft® Word or another word processing program; or if you would like to extract the file into a .TSV file that can be opened and charted in Microsoft® Excel or another spreadsheet program.

- If you want to create a .TXT file, continue with “Create Text File.”
- If you want to create a .TSV file, continue with “Create .TSV File.”

CREATE TEXT FILE

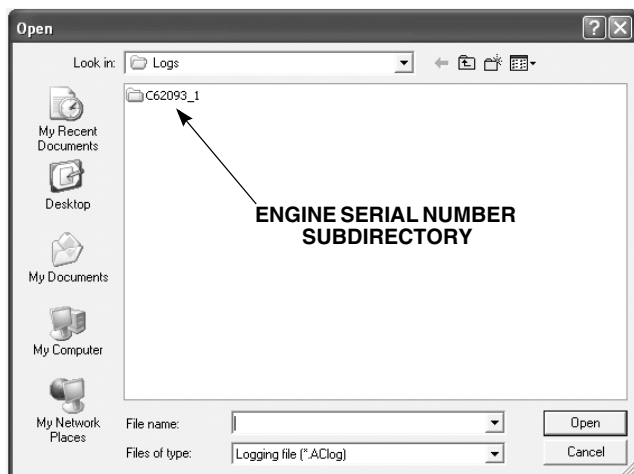
The following steps explain how to extract a logged file (a file with the extension .AClog) into a .TXT file that can be opened in Microsoft® Word or another word processing program.

1. Click the “Create Text File” button.

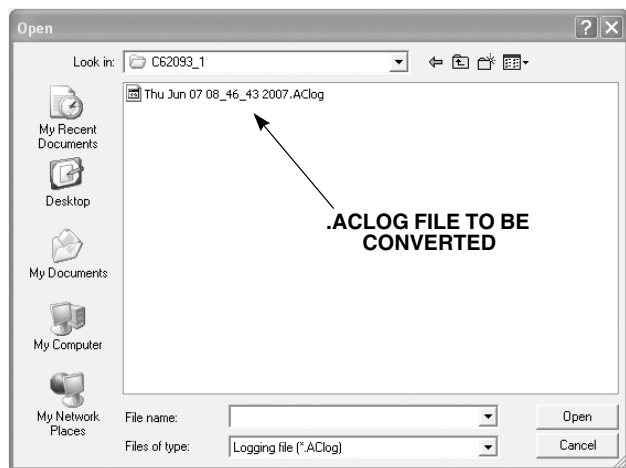


ESP PROGRAMMING

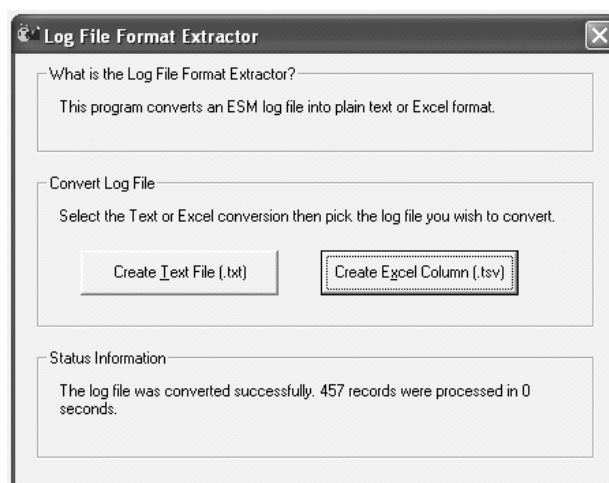
2. The Log File Processor needs you to locate the log file needing extraction. All log files are saved to C:\Program File\Esm\Logs. Within the directory “Logs” there is a subdirectory (or subdirectories) named with the engine serial number. The log file is saved in the subdirectory of the appropriate engine.



3. Select the desired .AClog file to be extracted. Click “Open.”



4. The Log File Processor program will extract the files. The “Log File Format Extractor” dialog box will indicate to you when the extraction is complete.

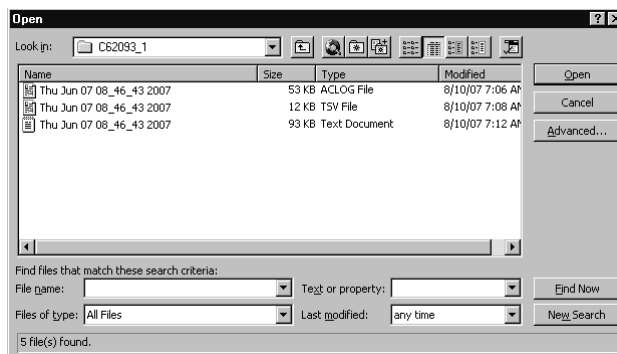


5. Close the “Log File Format Extractor” dialog box by clicking “X” in upper right corner. The Log File Processor program is now closed.

6. Open Microsoft® Word or another word processing program.

7. Locate the text file that was just created. The text file will be in the same subdirectory as the .AClog file. Click desired .TXT file to be opened. Click “Open.”

NOTE: To view .TXT files, change the “Files of type” to read “All Files.”



8. Review logged data.

```

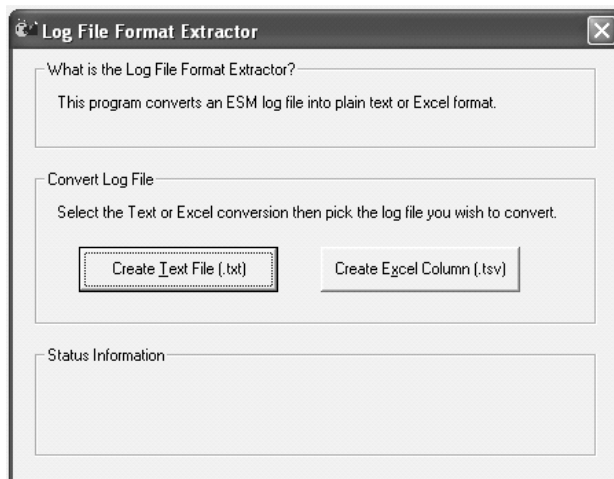
Thu Jun 07 08_46_43 2007 - Microsoft Word
File Edit View Insert Format Tools Table Window Help
100%
Logging started at :- Thu Jun 07 08:46:43 2007
17400 Main Fuel Supply 1
17400 Engine Hours - (hours) 830.453888888889
17400 Engine No Start 0
17400 Short Faults OK 1
17400 Faults Validated - (absolute) 2
17400 Stats OK 1
17400 Run Signal 0
17400 Lubrication Pump 0
17400 Starter 0
17400 Start RPM - (RPM) 300
17400 Engine Start Countdown - (s) 0
17400 Main Fuel On - (RPM) 40
17400 Channel 3 - (mA) 5.52503052503043
17400 Channel 4 - (mA) 6.19658119658109
17400 Throttle Error 0
17400 Load Coming 0
17400 Low Idle - (RPM) 750
17400 Pre Chamber Fuel On - (RPM) 300
17400 Pre Chamber Fuel Valve 1
17400 First Pre-turbine Exhaust Temperature - (°F) 32
17400 Second Pre-turbine Exhaust Temperature - (°F) 32
17400 First Rich Burn Exhaust Oxygen - (V) 0.8349609375
17400 Second Rich Burn Exhaust Oxygen - (V) 0.8408203125
17400 First Rich Burn Exhaust Oxygen 1
17400 Second Rich Burn Exhaust Oxygen 1
17400 Max Pos (load) PL - (steps) 3500
17400 Max Pos (load) PR - (steps) 3500
17400 Min Pos (load) PL - (steps) 750
17400 Min Pos (load) PR - (steps) 750
17400 Position PL - (steps) 3000
17400 Position PR - (steps) 3000
17400 Control Mode PL 5
17400 Control Mode PR 5
17400 Current Fuel 0
17440 Average RPM - (RPM) 815.25
17440 Percentage Engine Torque - (%) 13.623046875
17440 First Intake Manifold Air Pressure 1
17440 Second Intake Manifold Air Pressure 1
17440 Intake Air Manifold Temperature 1
17440 Oil Pressure 1
17440 Counter - (s) 436
17440 Coolant Outlet Temperature 1
17440 First Intake Manifold Air Pressure - (in Hg (abs)) 18.9666
17440 Second Intake Manifold Air Pressure - (in Hg (abs)) 19.8522

```

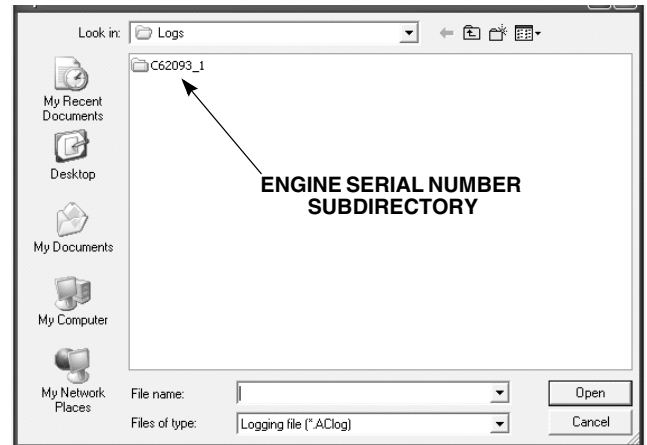
CREATING .TSV FILE

The following steps explain how to extract a logged file (a file with the extension .AClog) into a .TSV file that can be opened in Microsoft® Excel and charted.

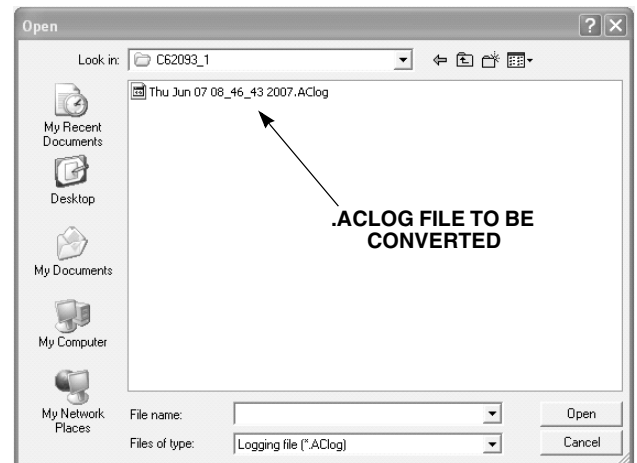
1. Click the “Create Excel Column” button.



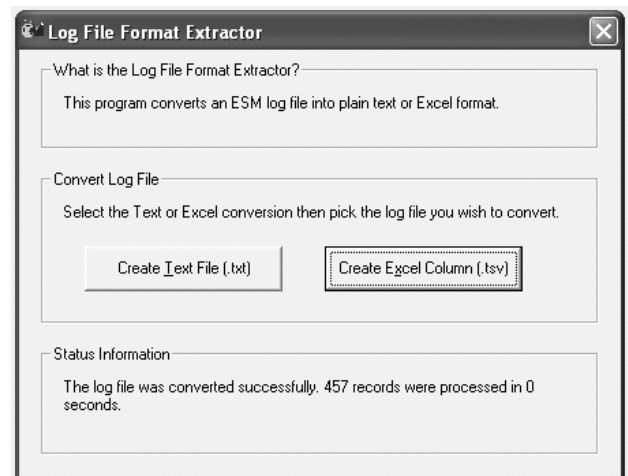
2. The Log File Processor needs you to locate the log file needing extraction. All log files are saved to C:\Program Files\Esm\Logs. Within the directory “Logs” there is a subdirectory (or subdirectories) named with the engine serial number. The log file is saved in the subdirectory of the appropriate engine.



3. Select the desired .AClog file to be extracted. Click “Open.”



4. The Log File Processor program will extract the files. The “Log File Format Extractor” dialog box will indicate to you when the extraction is complete.



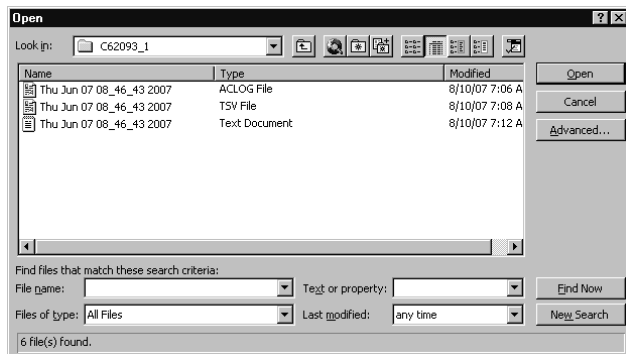
5. Close the “Log File Format Extractor” dialog box by clicking “X” in upper right corner. The Log File Processor program is now closed.

ESP PROGRAMMING

6. Open Microsoft® Excel or another spreadsheet software program.

7. Locate the .TSV file that was just created. The .TSV file will be in the same subdirectory as the .AClog file. Click desired .TSV to be opened. Click "Open."

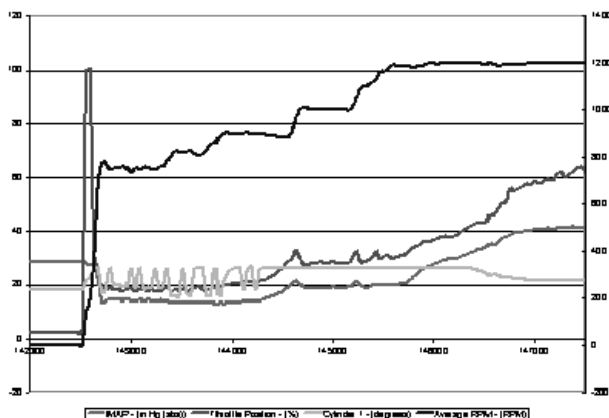
NOTE: To view .TSV files, change the “Files of type” to read “All Files.”



8. Open the file to view log.

[illegible]

9. Using Microsoft® Excel, you can then plot or chart the logged parameters.

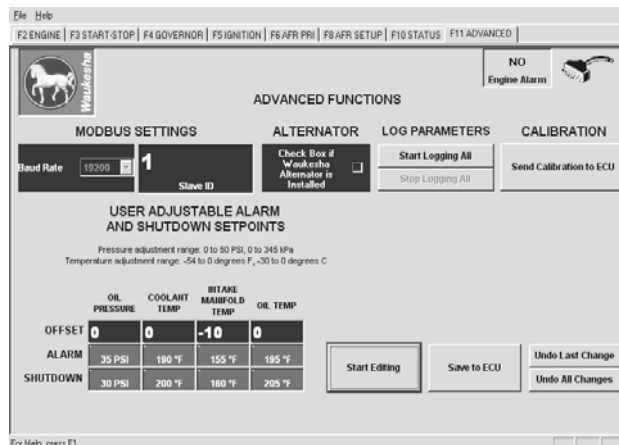


PROGRAMMING BAUD RATE (MODBUS® APPLICATIONS)

In MODBUS® applications it is necessary to program the baud rate setting in ESP. The MODBUS® baud rate can be programmed to 1200, 2400, 9600, or 19,200 bps (bits per second). The baud rate to be programmed is determined by the MODBUS® master.

Complete the following:

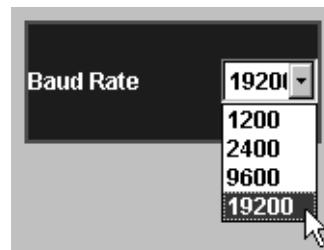
1. In ESP, click on the [F11] Advanced Panel.



2. Click on the “Start Editing” button. While in editing mode, the button will read, “Stop Editing – Currently Editing.”

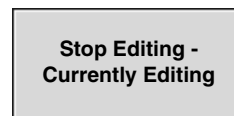


3. Click on the drop-down menu arrow in the “Baud Rate” field.

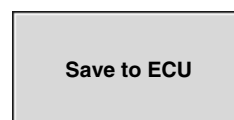


4. From the drop-down menu, select “1200,” “2400,” “9600,” or “19200.” The baud rate to be programmed is determined by the MODBUS® master.

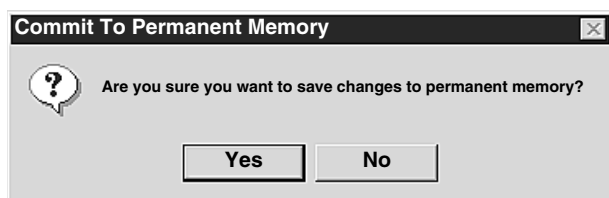
5. When the selection is made, click the “Stop Editing” button. While the editing mode is OFF, the button will read “Start Editing.”



6. To save setting to permanent memory, click the "Save to ECU" button.



- When asked are you sure you want to save to the ECU, click "Yes."

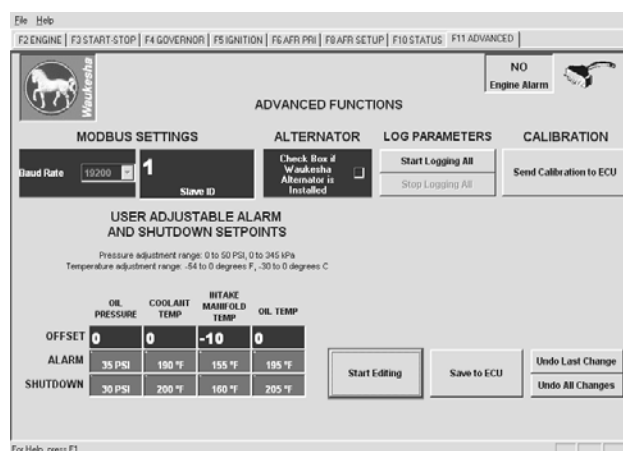


PROGRAMMING ECU MODBUS® SLAVE ID

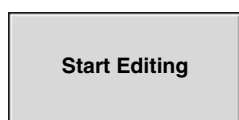
In MODBUS® applications you may program a unique slave identification for each ECU (up to 32) on a multi-ECU networked site. The MODBUS® slave identification that can be programmed can range from 1 to 247. By programming an slave identification, you can communicate to a specific ECU through MODBUS® using a single MODBUS® master when multiple ECUs are networked together.

Complete the following:

- In ESP, click on the [F11] Advanced Panel.



- Click on the "Start Editing" button. While in editing mode, the button will read "Stop Editing – Currently Editing."



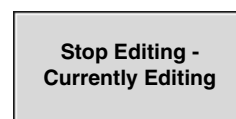
- Double-click the field or highlight the value in the "Slave ID" field.



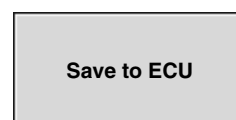
- Enter the slave identification to be assigned to the ECU. The slave identification that can be programmed can range from 1 to 247.



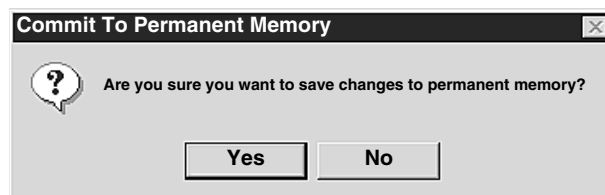
- Verify that the slave identification entered is the number the MODBUS® master is looking for.
- Click the "Stop Editing" button. While the editing mode is OFF, the button will read "Start Editing."



- To save slave identification to permanent memory, click the "Save to ECU" button.



- When asked are you sure you want to save to the ECU, click "Yes."



PROGRAMMING REMOTE ECU FOR OFF-SITE PERSONNEL

INTRODUCTION

This procedure explains how to connect a modem to an ECU for remote programming at your site. Waukesha Engine's Remote Programming Modem Tool Kit (P/N 489943) is required. The Waukesha ESM ECU (Engine Control Unit) is remotely programmed using two modems: one modem at the factory and one at your site. This procedure works for either a blank (non-programmed) ECU or a previously programmed ECU. Once your connections are complete, the Waukesha Parts Department will download the program to the ECU.

ESP PROGRAMMING

Table 3.10-6 ESM Remote Programming P/N 489943

QTY	DESCRIPTION	P/N
1	U.S. Robotics Modem Model 5686 with power cord and telephone cord (see Figure 3.10-5)	740299A
1	Modem Cable	740269A
1	ECU Power Cable	740299

Table 3.10-7 Equipment Not Provided in Kit

QTY	DESCRIPTION
1	ESM ECU that requires programming or re-programming
2	Phone lines: one analog line to connect modem for downloading and one to call Waukesha Engine when setup at your site is complete

MODEM SETUP

1. Remove modem from package.
2. Place modem in Auto Answer Mode by setting dip switches on back of modem as shown (see Figure 3.10-3). Dip switches must be set so switches 3 and 8 are ON (down) and all others are OFF (up).

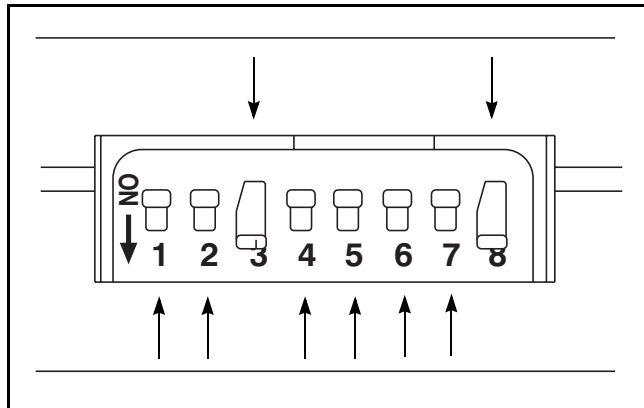


Figure 3.10-3 Setting Dip Switches on Modem

NOTE: Refer to Figure 3.10-4, Figure 3.10-5 and Figure 3.10-6 for the following Steps.

3. Plug the circular connection on the ECU Power Cable (P/N 740299) into the connection named "Power/Outputs" on the side of the ECU.
4. Plug the other end of the ECU Power Cable into an outlet. The ECU Power Cable can plug into a 100–240 V, 50/60 Hz power source; however, a plug adapter may be required.
5. Verify that the power LED on the front of the ECU is lit. If the LED on the ECU is not lit, make sure the ECU Power Cable is connected correctly to the "Power/Outputs" connection on the side of the ECU and make sure outlet has power.

6. Plug the 8-pin connector of the Modem Cable into the connection named "Service Interface" on the side of the ECU.
7. Plug the 25-pin connector of the Modem Cable into the back of the modem.
8. Plug the modem's power cord into the back of the modem. The modem's power cord can plug into a 60 Hz power source only. A converter and/or plug adapter will be required for 50 Hz power sources.

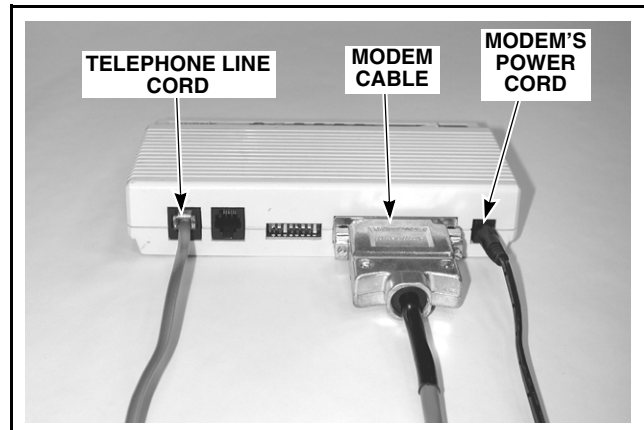


Figure 3.10-4 Connections to Back of Modem

9. Plug the modem's power cord into an outlet.
 10. Plug telephone cord into back of modem as shown in Figure 3.10-4. Be sure telephone line is connected to correct port (port on the far left).
 11. Plug the other end of the telephone cord into the phone jack on the wall.
- NOTE:** The phone jack must be an analog port. Digital lines will not function correctly.
12. Turn on modem.
 13. Verify that the AA ("Auto Answer"), CS ("Clear to Send"), and TR ("Terminal Ready") LEDs on the modem are lit (see Figure 3.10-5).

NOTE: If the correct LEDs on the modem are not lit, check all connections and LEDs. Connections must be correct. If LEDs still do not light, contact Waukesha Parts Department for assistance.

14. The connection is complete and you are ready for downloading. Contact your Customer Service Representative at Waukesha Engine to complete remote programming. Waukesha Engine will download the ECU Program from the factory to your site via a modem.

NOTE: After the Waukesha Engine representative establishes connection with your modem but before actual downloading begins, the CD ("Carrier Detect") and ARQ/FAX ("Fax Operations") LEDs will be lit.

15. During download, the RD ("Received Data"), SD ("Send Data"), and TR ("Terminal Ready") LEDs on the modem will be flashing. The download will take approximately 5 – 10 minutes. When finished, the Waukesha representative will verify download is complete and successful.

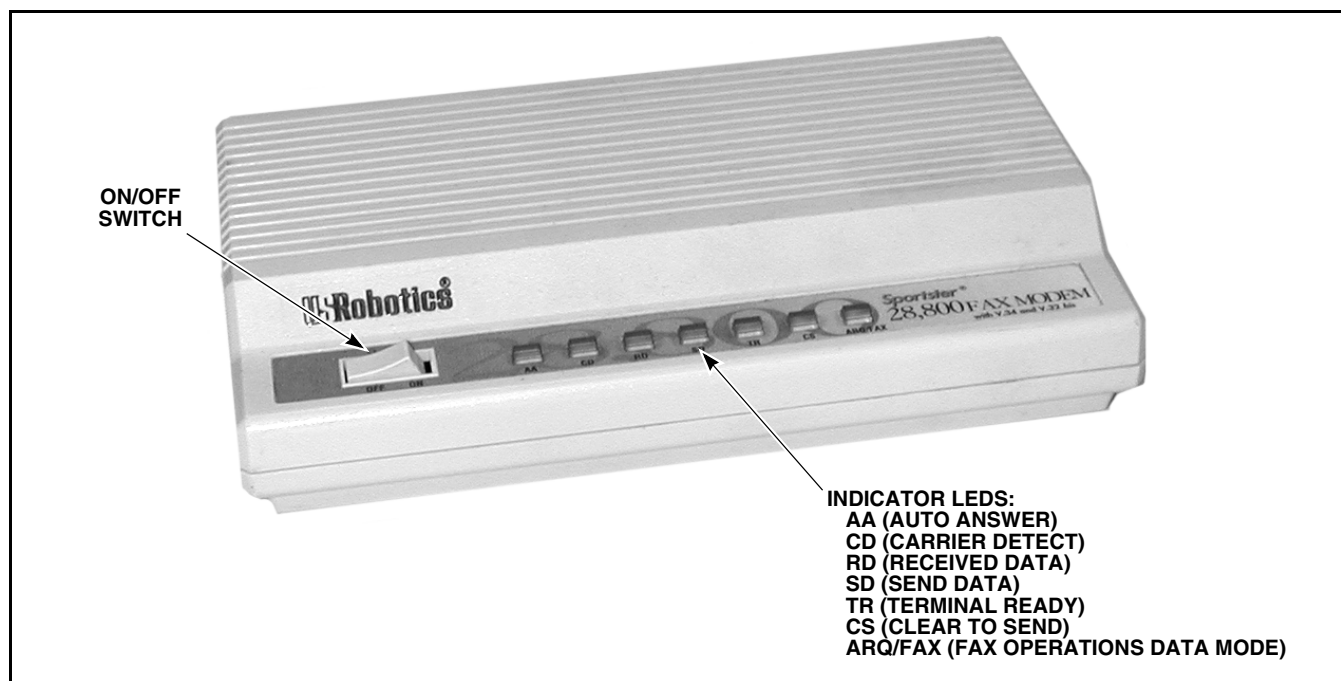


Figure 3.10-5 Front of Modem

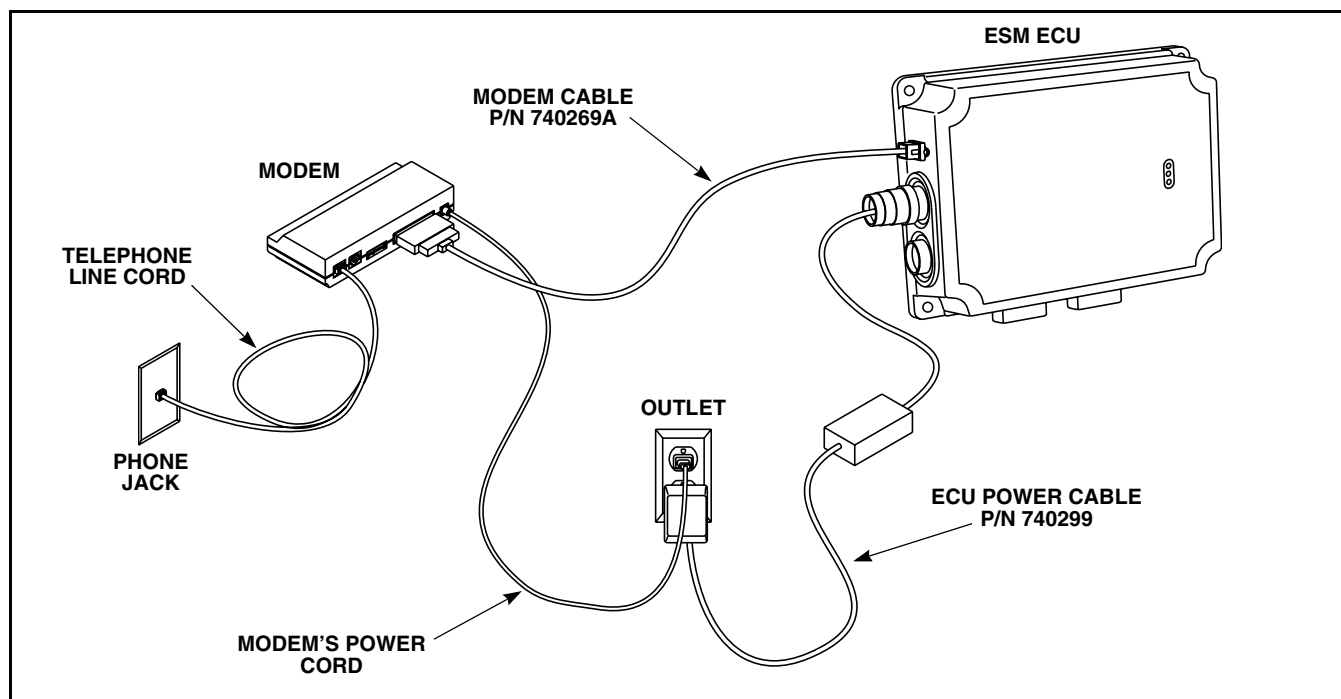


Figure 3.10-6 ECU Remote Programming Schematic

USING A MODEM

Temporary remote monitoring of an engine with the ESM system is possible through the use of a modem. A modem is a device that enables a computer to transmit data over telephone lines. Using ESP and a modem, you can “dialup” the ECU to monitor ESM system status and make programming changes remotely.

NOTE: High-speed cable and satellite modems will not work with the ESM system’s modem function.

IMPORTANT! This manual assumes that you are already familiar with modem devices, modem initialization strings, other modem concepts, and HyperTerminal. If you need more information on these topics, refer to the user’s manual provided with the modem or with the modem manufacturer.

To remotely monitor an engine through a modem, the following supplies are required:

- “Modem to ECU” Connection
 - RS-232 serial cable (P/N 740269A) available from Waukesha Engine
 - External Modem (see “Setting Up Modem to ECU for Proper Connection”)
- “PC to Modem” Connection
 - External/internal modem
 - RS-232 cable (if external modem is used, connects modem to PC)

NOTE: For best modem communications, use a “matched” pair (same brand) of modems.

SETTING UP MODEM TO ECU FOR PROPER CONNECTION

NOTE: The following steps in this section do not need to be performed if using the modem in Waukesha Engine’s Remote Programming Modem Tool Kit (P/N 489943), which comes preprogrammed from the factory.

The modem connected to the ECU requires special setup programming so it will work with the ECU. The modem (1) must be set in “auto answer” mode, a modem feature that accepts a telephone call and establishes the connection, and (2) must be set at 38,400 baud. Auto answer mode and baud rate are programmed using HyperTerminal. HyperTerminal is a terminal software program that enables the modem to connect properly to the ECU. HyperTerminal is included as part of Microsoft® Windows® XP operating system.

Complete the following steps:

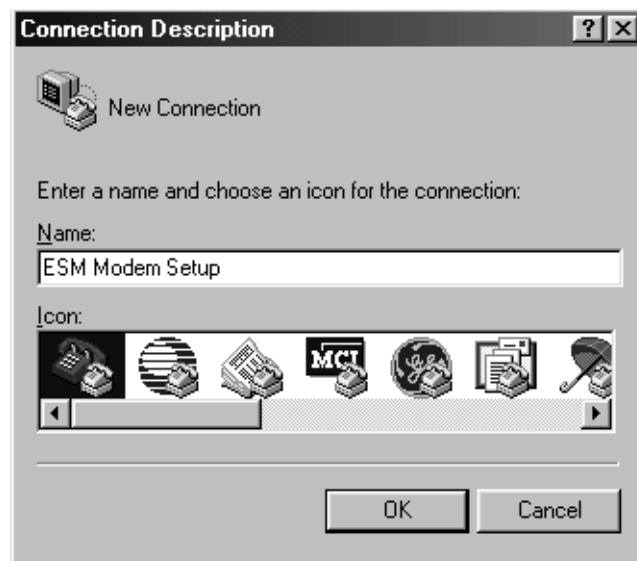
NOTE: Some modems may have dip switches (tiny toggle switches) that must be set to put the modem in auto answer mode. Refer to the user’s manual provided with the modem or contact the modem manufacturer. Set the dip switches as required and continue with Step 1.

1. Using a PC to external modem cable, temporarily connect a PC to the external modem that will be connected to the ECU.

2. Start HyperTerminal. From the Windows® taskbar, click **Start** → **Programs** → **Accessories** → **HyperTerminal**.

NOTE: HyperTerminal is a terminal program included with Microsoft® Windows® XP operating system. If HyperTerminal is not installed, install the program using the Add/Remove Programs icon in the Control Panel. You may need your original Microsoft® Windows® CD-ROM for installation.

3. Give the HyperTerminal session a name.



4. Select an icon.

5. Click “OK.”

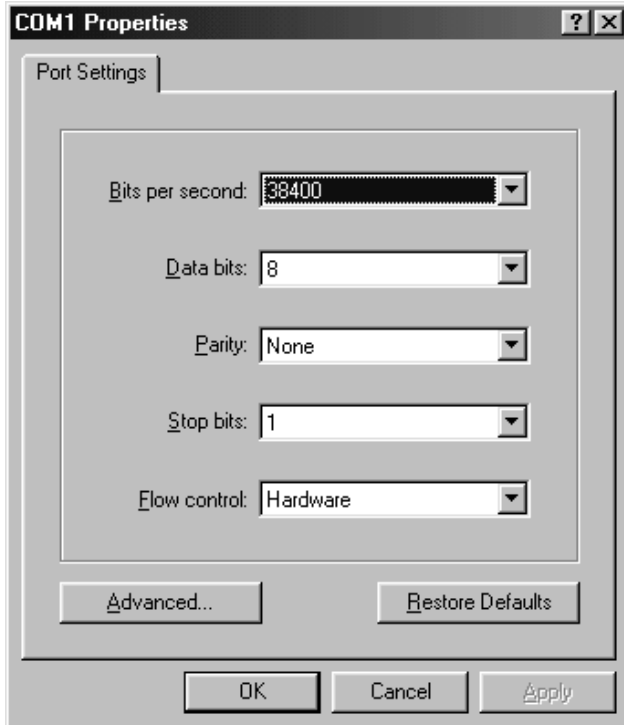
6. Click the selection arrow on the “Connect using” drop-down menu and select the COM port your modem is connected to (not the modem name).

7. When you select the COM port, the other fields on the dialog box are deactivated (grayed). Click “OK.”

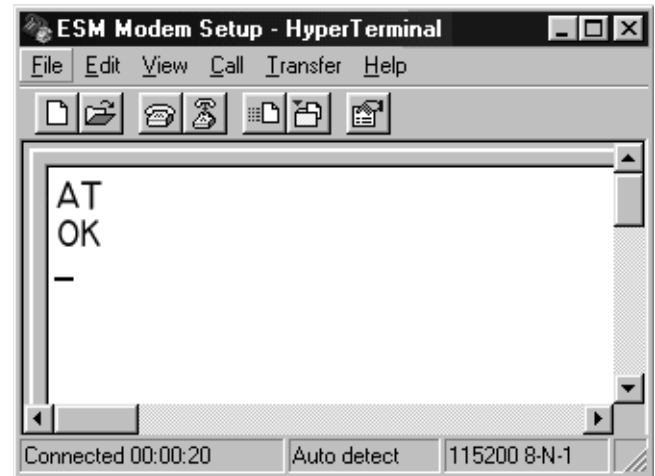


8. In the next dialog box, set the baud rate between the PC and the modem to 38,400 baud. Click "OK."

NOTE: To avoid resetting the baud rate, the modem being set up must be a "dedicated" modem and used only with the ECU. If the modem is used with another device, the baud rate setting may be overwritten.



9. The HyperTerminal window opens and you are able to control your modem with commands. Type "AT" and press [Enter]. The modem should reply with "OK."



NOTE: If no "AT" or "OK" appears, there is a basic communication problem between the PC and the modem. Most likely the COM port selected is incorrect. Check selected COM port and try again.

10. Turn auto answer mode on by typing "ATS0=1" (that is ATZero=1, not the letter O) and press [Enter].

11. Save the change to NVRAM by typing "AT&W0" (that is AT&Wzero, not the letter O) and press [Enter].

12. Turn the modem off and then on again.

13. Type "ATI4" (that is AT, capital letter i, 4).

14. The modem will respond with multiple lines that look similar to:

Current Settings.....

```

B0 E1 L4 M1 N5 Q0 V1 X5
&B1 &C1 &D2 &G0 &H3 &J0 &K4 &L0 &M0 &N0 &P0 &R1 &S0 &X &Y1
*B0 *C0 *D0 *E0 *F0 *G0 *I0 *L0 *M0 *P9 *Q2 *S0

```

S00=001 S01=000 S02=043 S03=01 S04=010

S05=008 S06=003 S07=060 S08=002 S09=006

S10=007 S11=070 S12=000 S13=000 S14=002

S15=002 S16=000 S17=018 S18=000 S19=000

S20=002 S21=178 S22=000 S23=105 S24=138

S25=000 S26=000 S27=156 S28=068 S29=000

S30=000 S31=017 S32=019 S33=255 S34=030

S35=032 S36=000 S37=000 S38=000 S39=032

S40=000 S41=000 S42=000 S43=008 S44=000

S45=100 S46=028 S47=064 S48=000 S49=134

S50=000 S51=000 S52=000 S53=000 S54=000

S55=000 S56=000 S57=000 S58=000 S59=000

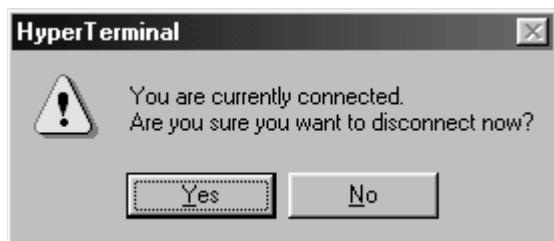
OK

ESP PROGRAMMING

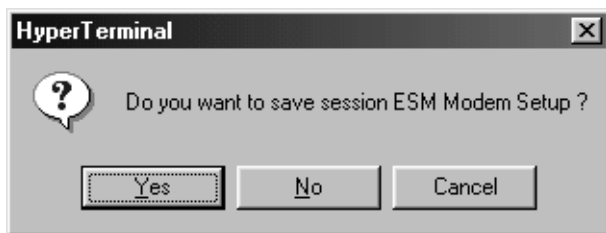
15. Although the lines in Step 14 may not be exactly what is shown on your PC, make sure that the parameter, `S00=001`, is listed. Parameter `S00=001` is the programming code to the modem that enables the auto answer mode.

16. Exit HyperTerminal.

17. Click “Yes” to disconnect.



18. Click “Yes” to save the HyperTerminal session.



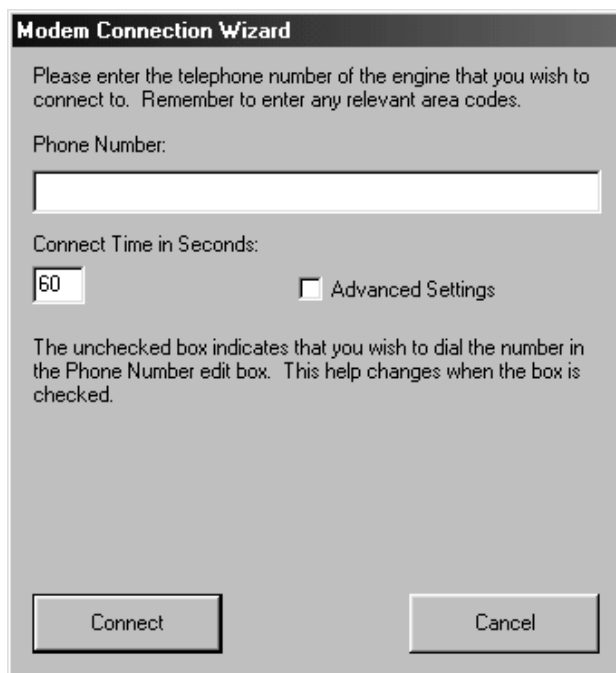
19. Continue with “Connecting Modem to ECU and PC.”

STARTING ESP FOR MODEM ACCESS

1. Apply power to the ECU.
2. Turn on power to PC.
3. Start ESP for modem use by one of the following methods:
 - Double-click the ESM ESP modem icon on your desktop.



- From the Windows® taskbar (lower-left corner of your desktop), click **Start** → **All Programs** → **Waukesha Engine Controls** → **Engine System Manager (ESM)** → **ESP (Modem Access)**.
4. On program startup, ESP will check for a modem. Once ESP finds the modem on the PC, a dialog box appears asking to attempt a connection. Click “Yes.”
 5. Enter the phone number to the engine modem you wish to connect in the “Modem Connection Wizard” dialog box. Enter phone number without spaces or dashes.



6. The ESP modem wizard will attempt to “dial up” the modem. Note the following:

- If connection is successful, ESP will run, displaying the six engine panels. Setup is complete. Monitor engine operation or program ESP as necessary.
- If connection is unsuccessful, click “Retry.” If connection is still unsuccessful, continue with Step 7.



7. Check the telephone number typed in the “Modem Connection Wizard” dialog box.

8. Retry connection. Click “Connect.”

9. ESP modem wizard will re-attempt to “dial up” the modem. Note the following:

- If connection is successful, ESP will run, displaying the six engine panels. Installation is complete. Monitor engine operation or program ESP as necessary.
- If connection is unsuccessful, click “Cancel.” Continue with Step 10.

10. If your modem dials but does not connect with the answering modem, or if you have problems getting or staying connected, you might need to adjust the modem initialization string. Click the “Advanced Settings” check box on the “Modem Connection Wizard” dialog box.

NOTE: Always use CAPITAL letters (upper case) for the modem initialization string in the Advanced Settings check box.

11. Enter the modem’s initialization string (command) in CAPITAL letters (upper case). Most connection problems are resolved with the proper modem initialization string. The initialization string gives the modem a set of instructions for how to operate during a call. Almost every modem brand and model has its own variation of “ATCommand Set” and “S-register” settings.

NOTE: Detailed discussion of modem initialization strings is beyond the scope of this manual. You can get an initialization string from the user’s manual provided with the modem, from the modem manufacturer, or from a variety of Internet web sites.

12. Click “Connect.”

13. The ESP modem wizard will attempt to “dial up” the modem. Note the following:

- If connection is successful, ESP will run, displaying the six engine panels. Installation is complete. Monitor engine operation or program ESP as necessary.
- If connection is unsuccessful, click “Retry.”

14. If connection continues to be unsuccessful, refer to the user’s manual provided with the modem or contact the modem manufacturer.

CONNECTING MODEM TO ECU AND PC

An RS-232 serial cable (P/N 740269A), available from Waukesha Engine, is used to connect a modem to the ECU. This cable has a 25-pin RS-232 connection that plugs into the modem and an 8-pin Deutsch® connector that plugs into the ECU.

Complete the following:

1. Obtain an RS-232 serial cable (P/N 740269A) from Waukesha Engine for modem use.
2. Connect the 25-pin end of the RS-232 serial cable to the external modem (see Figure 3.10-7). Connect to the “dedicated” modem you set up for use with the ECU following the steps in the section “Setting Up Modem to ECU for Proper Connection”.
3. Connect the 8-pin Deutsch® connector of the serial cable to the “Service Interface” connection on the side of the ECU.
4. Connect PC to modem (see Figure 3.10-7 for sample setup).
5. Make sure all connections are secure.

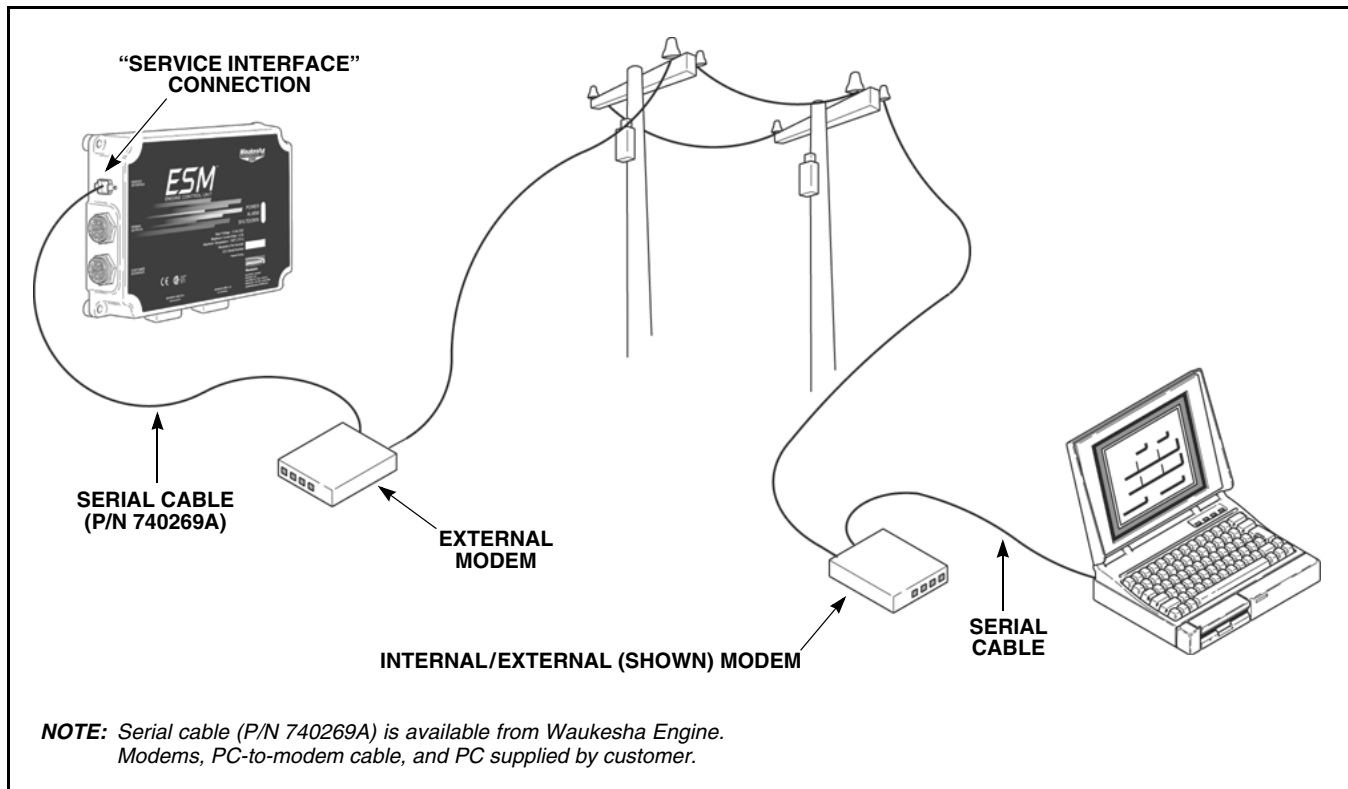


Figure 3.10-7 Modem Connections from ECU to PC

CONTENTS

SECTION 4.00 – TROUBLESHOOTING

SECTION 4.05 – ESM SYSTEM MAINTENANCE

SECTION 4.00

TROUBLESHOOTING

IMPORTANT

ADDITIONAL ASSISTANCE

Waukesha Engine's worldwide distribution network provides customers with parts, service and warranty support. Each distributor has a vast inventory of genuine Waukesha parts and factory trained service representatives. Waukesha distributors are on call 24 hours a day, with the parts and service personnel to provide quick and responsive solutions to customers' needs. Please contact your local Waukesha Engine Distributor for assistance.

Have the following information available:

1. Engine serial number.
2. ECU serial number.
3. ECU calibration part number (this is visible at the top of the ESP screen when connected to an ECU).
4. ECU faults list.
5. Detailed description of the problem.
6. List of what troubleshooting has been performed so far and the results of the troubleshooting.

INTRODUCTION

The ESM system provides extensive engine diagnostics that allow rapid troubleshooting and repair of engines. If an engine alarm or shutdown condition is detected by the ESM system, the operator is informed of the fault by a series of flashing LEDs on the ECU or by monitoring the ESM system with ESP.

- The operator is notified of an alarm or shutdown by three Status LEDs on the ECU.
- When a PC is connected to the ECU and ESP is running, the operator is notified of an alarm or shutdown on the ESP panels in addition to the Status LEDs.

The primary means of obtaining information on system status and diagnostic information is by using ESP, the PC-based service program. ESP displays six panels (eight panels with AFR option) of engine operation and status information. For example, the [F10] Status Panel provides the option to view an active fault listing, as well as a historical record of faults. ECU Status LEDs are not considered to be the primary means of obtaining information on the status of the system, but rather a way of alerting the site technician that there is a problem and what that problem is (even if a PC with ESP is unavailable).

WHERE TO BEGIN

To begin troubleshooting an engine due to an ESM system alarm or shutdown, you must first determine the alarm or shutdown code(s). A code can be determined from reading the Status LEDs on the ECU or by viewing the Fault Log accessed from the [F10] Status Panel in ESP.

All fault codes have three digits, and each digit can be a number from 1 to 5. There is a set of codes for alarms and a separate set of codes for emergency shutdowns. Alarm codes in ESP are identified with the letters "ALM" preceding the alarm code.

Emergency shutdown codes are identified with the letters "ESD" preceding the shutdown code. For example, the three-digit code "222" for an alarm is identified by ESP as ALM222. The three-digit code "231" for an emergency shutdown is identified by ESP as ESD231.

To determine the fault code, continue with the section "Determining Fault Code by Reading ECU Status LEDs" or "Determining Fault Code by Using ESP Fault Log".

DETERMINING FAULT CODE BY READING ECU STATUS LEDS

The ECU has three Status LEDs on the cover: green (power), yellow (alarm), and red (shutdown) (see Figure 4.00-1). The green LED is on whenever power is applied to the ECU. The yellow and red LEDs flash codes when an alarm or shutdown occurs. A fault code is determined by counting the sequence of flashes for each color.



Figure 4.00-1 ECU Status LEDs

At the start of the code sequence, both the red and yellow LEDs will flash three times simultaneously. If there are any emergency shutdown faults, the red LED will flash a three-digit code for each shutdown fault that occurred. Then if there are any alarm faults, the yellow LED will flash a three-digit code for each alarm that occurred.

Between each three-digit code, both yellow and red LEDs will flash once at the same time to indicate that a new code is starting. The fault codes display in the order that they occur (with the oldest displayed code first and the most recent code displayed last).

NOTE: Once the fault is corrected, the Status LEDs on the ECU will remain flashing until one of two things happens: (1) the LEDs are cleared using ESP or (2) the engine is restarted.

DETERMINING FAULT CODE BY USING ESP FAULT LOG

When using ESP, you are notified of an alarm or shut-down fault on the ESP panels. Several windows on the panels in ESP inform the operator of a fault. For a description of the fault, the fault log must be read.

To view the Fault Log, click the “View Faults” button on the [F10] Status Panel using ESP (see Figure 4.00-2).

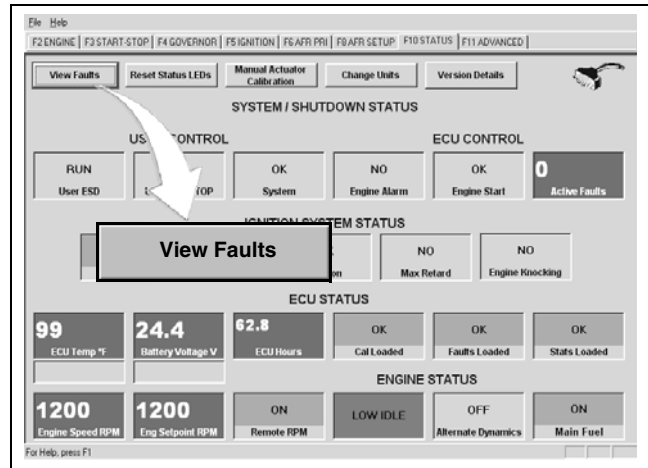


Figure 4.00-2 View Faults Button on [F10] Status Panel

The Fault Log displays the description of the fault, the first time the fault occurred since the fault was reset (in ECU hours:minutes:seconds), the last time the fault occurred since reset, the number of times the fault occurred since reset, and the total number of times the fault occurred in the lifetime of the ECU (see Figure 4.00-3).

The description of the fault briefly identifies the state of the fault that occurred. To define the fault as much as possible, the description may include acronyms (see Table 4.00-1), a number identifying the cylinder and/or component affected, and the words “Left” or “Right” to identify the engine bank affected. Below is an example of a fault and its description:

ALM343 OXYGEN LB SC

FAULT CODE OXYGEN SENSOR LEFT BANK SHORT CIRCUIT

Table 4.00-1 Acronyms in Fault Log Descriptions

ACRONYM	DEFINITION
BK	Back
FLT	Fault
FT	Front
IGN	Ignition
IMAP	Intake Manifold Air Pressure
LB	Left Bank
OC	Open Circuit
RB	Right Bank
SC	Short Circuit
SH	Scale High (sensor value higher than normal operating range)
SL	Scale Low (sensor value lower than normal operating range)

Also within the Fault Log dialog box, you can view a list of active faults or the total history of faults that occurred in the ECU's lifetime. For more information on the Fault Log, refer to Section 3.05 *ESP Panel Descriptions* "Fault Log Description".

NOTE: All the fault information is resettable except for the total number of times the fault occurred during the lifetime of the ECU.

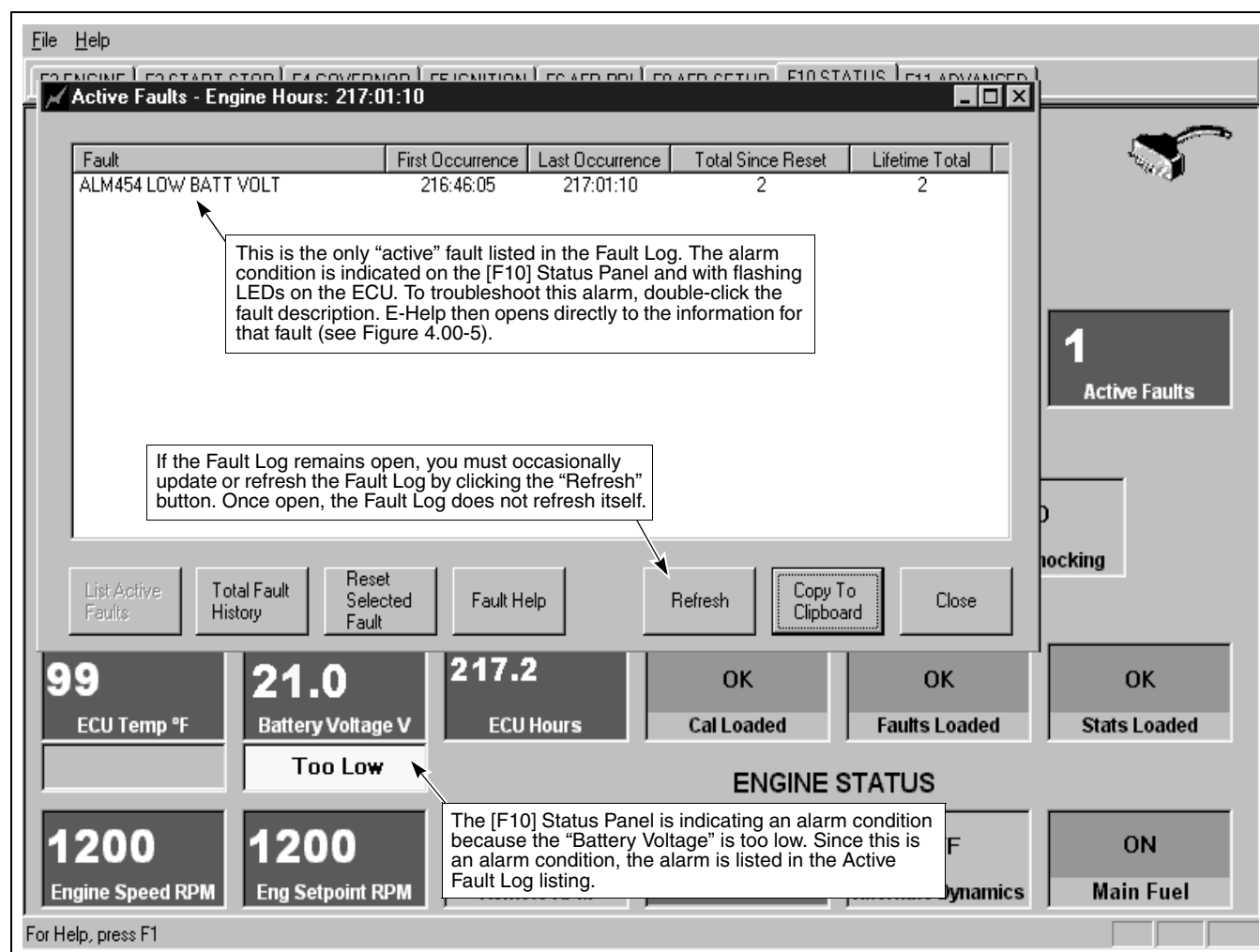


Figure 4.00-3 Fault Log in ESP

USING FAULT CODE FOR TROUBLESHOOTING

Once you have determined the fault code, you can begin ESM system troubleshooting. ESP features an electronic help file named E-Help. Detailed troubleshooting information is available in E-Help. However, if you do not have access to a PC, Table 4.00-2 and Table 4.00-3 provide information on the ESM system's alarm and shutdown codes.

E-HELP

ESP contains an electronic help file named E-Help. E-Help provides general system and troubleshooting information in an instant as long as you are using the PC with the ESP software. You can quickly and easily move around in E-Help through electronic links (or hypertext links) from subject to subject. E-Help is automatically installed when the ESP software is installed.

NOTE: Although E-Help is viewable through ESP, E-Help is its own program and opens in a new window, separate from ESP. To return to ESP and continue monitoring, you need to minimize or close the E-Help program/window.

USING E-HELP

To access E-Help while using ESP, press the [F1] function key on the keyboard or select "Help Contents..." from the Help menu. When you access E-Help by pressing [F1] or by selecting "Help Contents...", you will open the help file at the E-Help welcome screen (see Figure 4.00-4). Click the E-Help logo to enter the help file.

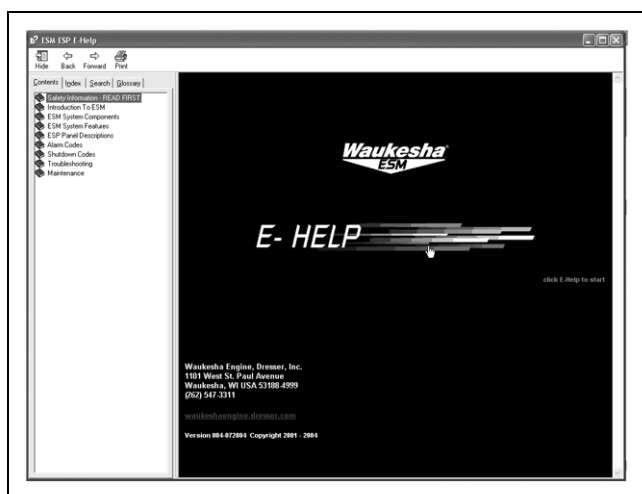


Figure 4.00-4 E-Help Welcome Screen

E-Help can also be accessed and opened to a specific alarm or shutdown code through the fault log on the [F10] Status Panel.

To open E-Help to a specific fault code, view the Fault Log by clicking the “View Faults” button on the [F10] Status Panel using ESP. Then double-click on the fault description. E-Help will open to the specific fault’s troubleshooting procedure.

NOTE: If the Fault Log remains open, you must occasionally update or refresh the log by clicking the “Refresh” button. Once open, the Fault Log does not refresh itself.

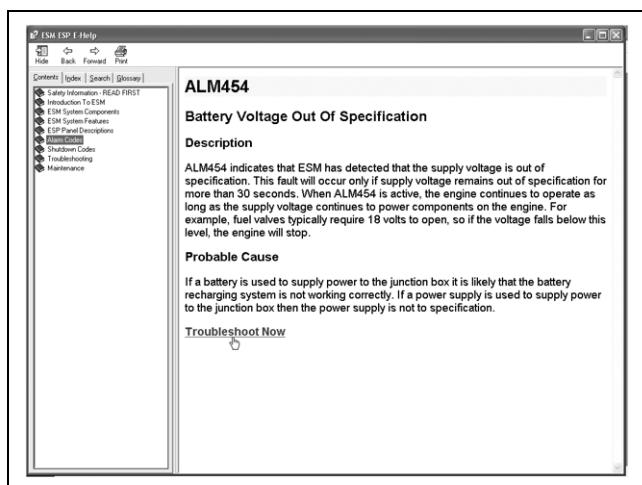


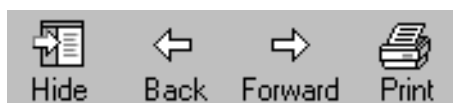
Figure 4.00-5 E-Help Troubleshooting Information For ALM454

E-HELP WINDOW DESCRIPTION

The E-Help window is divided into two panes. The left pane is the navigation pane; the right pane is the document pane (see Figure 4.00-6). Above the panes is the command bar.

Using the Command Bar

The command bar has four buttons: “Hide/Show” button, “Back” button, “Forward” button, and “Print” button.



- **“Hide/Show” button:** You can hide the navigation pane if desired. When the navigation pane is closed, the document pane can be maximized to the size of the full screen.
 - To hide the navigation pane, click the “Hide” button.
 - To view the navigation pane, click the “Show” button.
- **“Back” and “Forward” buttons:** E-Help includes “Back” and “Forward” buttons for navigating, just like Internet browsing software.
 - To return to the previously viewed topic, click the “Back” button.
 - To go to the window that was displayed prior to going back, click the “Forward” button.
- **“Print” button:** To print the information displayed in the document pane, click the “Print” button. You can chose to print the selected topic (as seen in the document pane), or you can print the selected heading and all subtopics.

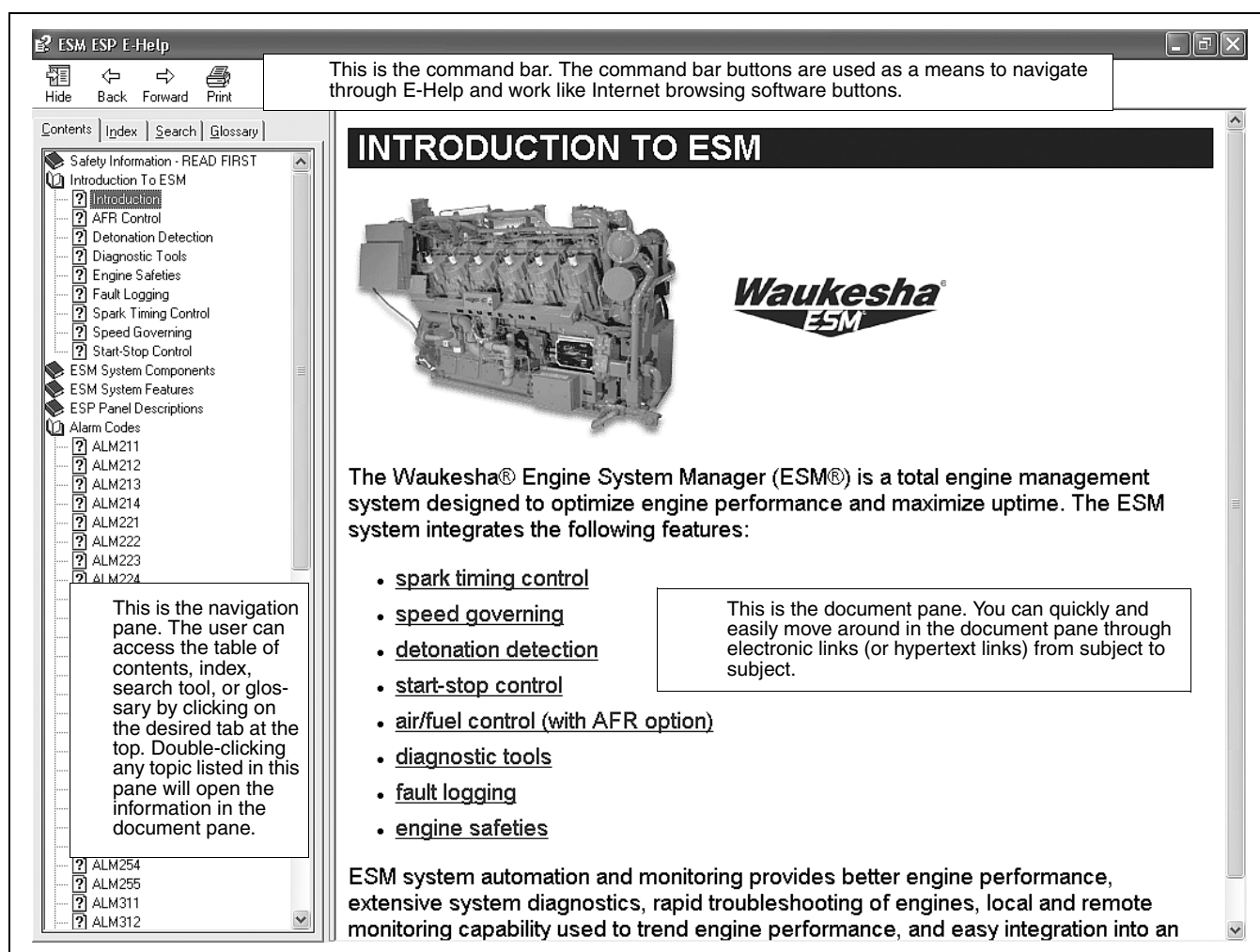
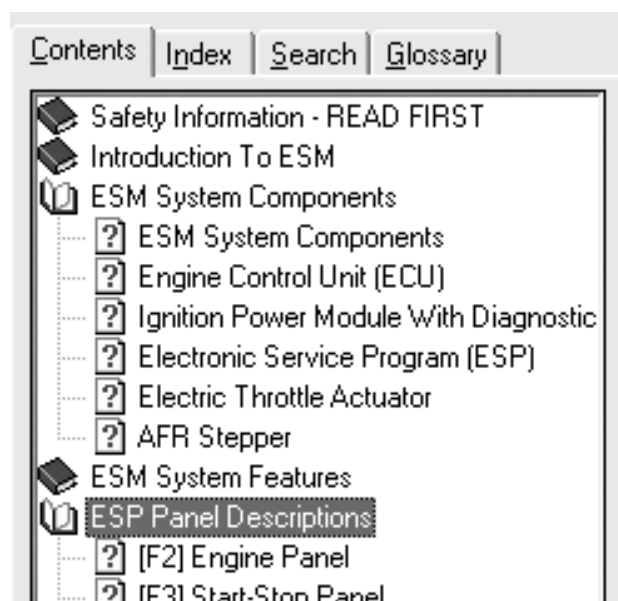


Figure 4.00-6 E-Help Command Bar, Navigation Pane, and Document Pane

Using the Navigation Pane

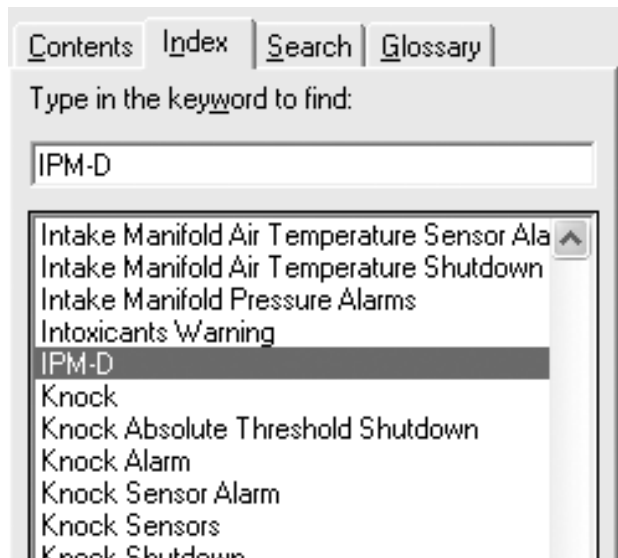
The navigation pane navigates the user through E-Help. At the top of the navigation pane are four tabs. Clicking these tabs allows you to see a table of contents for E-Help, an index tool, a search tool, and a glossary of ESM system-related terms.

- **“Contents” Tab:** Click the “Contents” tab to scroll through the table of contents for E-Help. Double-clicking the closed book icons in the Contents listing will reveal all relevant topics. Double-clicking on an open book icon will close the contents listing.

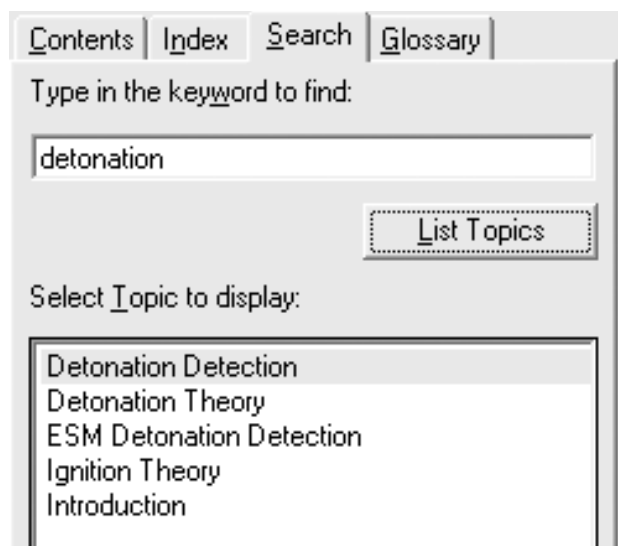


TROUBLESHOOTING

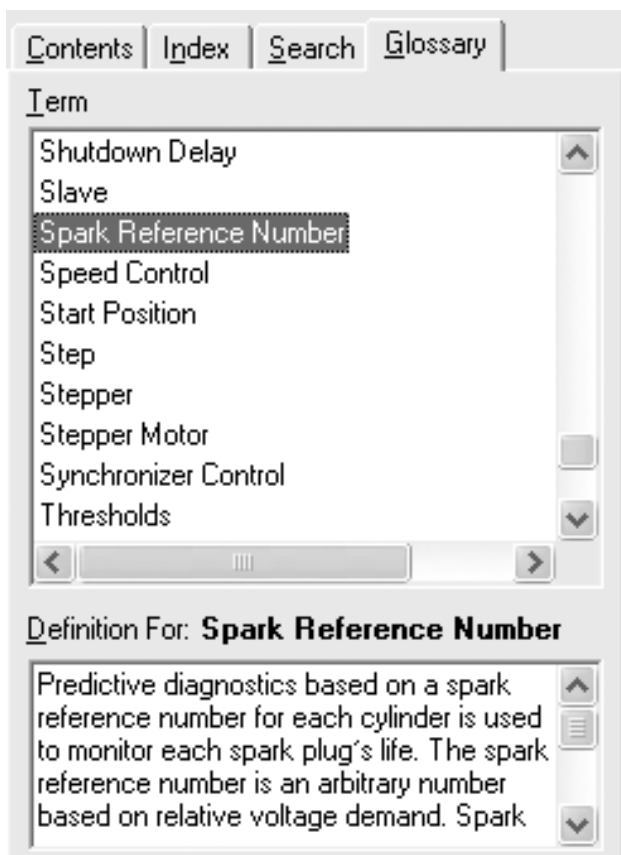
- **“Index” Tab:** Click the “Index” tab to search for topics by using an index of help subjects. The “Index” tab is similar to an index at the back of a book. Type in a key word to find a word listed in the index. Double-click an index entry to view that entry in the document pane.



- **“Search” Tab:** Click the “Search” tab to do a basic search on the word or phrase you want to find. Type in a word or phrase and press [Enter]. In the “Search” tab will be listed all the places in E-Help where that word or phrase is used exactly as it was typed. Double-click on a search finding to view that entry in the document pane.



- **“Glossary” Tab:** Click the “Glossary” tab to view a glossary of terms used in the ESM system’s documentation. Click on a term to view its definition.



Using the Document Pane

You can quickly and easily move around in E-Help through electronic links (or hypertext links) from subject to subject.

When you move the cursor over an electronic link, the cursor changes from an arrow into a hand. Electronic links are underlined. When clicked, a link will jump you from one topic or window to another topic or window. Some links cause a pop-up window to appear, displaying additional information or a figure (see Figure 4.00-7). Use the “Back” and “Forward” buttons in the command bar to navigate.

When you click a “Related Topics” button, a pop-up menu opens displaying a list of topics you can view. The topics listed are relevant to the information you are currently reading in the document pane.



ALM212 OPEN CIRCUIT

Remedy #3: Check pin 17 in ECU connector on end of harness.

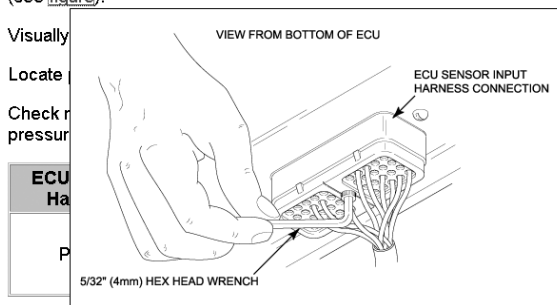
Steps:

1. Shut down engine.
2. Shut off power to Power Distribution Box.
3. Detach harness from intake manifold pressure sensor.
4. Disconnect ECU Input "A" Harness from Sensor Input "A" on ECU (see figure).

5. Visually

6. Locate

7. Check r
pressur



OK: If all resistance checks are OK, continue with Remedy #4

Figure 4.00-7 Sample of Figure Pop-Up

ESM SYSTEM FAULT CODES

Table 4.00-2, Table 4.00-3, and Table 4.00-4 and provide information on the ESM system's alarm and emergency shutdown codes.

Table 4.00-2 ESM System's Alarm Fault Codes (Part 1 of 2)

ALARM FAULT CODE	FAULT CONDITION	DESCRIPTION
ALM211	OIL PRESS	Oil pressure sensor/wiring fault
ALM212	IMAP LB/BK	Left bank intake manifold pressure sensor/wiring fault
ALM213	OIL TEMP	Oil temperature sensor/wiring fault
ALM214	IMAP RB/FT	Right bank intake manifold pressure sensor/wiring fault
ALM221	IMAT	Intake manifold air temperature sensor/wiring fault
ALM222	MAIN FUEL VALVE	Leaking fuel valve/engine failed to stop in a timely fashion
ALM223	LOW OIL PRESS	Low oil pressure
ALM225	KNOCK SENS	Knock sensor ## (where ## is the cylinder number) in the firing order is either open circuit or short circuit
ALM231	IGN 1ST CYL*	First cylinder in the firing order has a fault with its ignition system
ALM232	IGN 2ND CYL*	Second cylinder in the firing order has a fault with its ignition system
ALM233	IGN 3RD CYL*	Third cylinder in the firing order has a fault with its ignition system
ALM234	IGN 4TH CYL*	Fourth cylinder in the firing order has a fault with its ignition system
ALM235	IGN 5TH CYL*	Fifth cylinder in the firing order has a fault with its ignition system
ALM241	IGN 6TH CYL*	Sixth cylinder in the firing order has a fault with its ignition system
ALM242	IGN 7TH CYL*	Seventh cylinder in the firing order has a fault with its ignition system
ALM243	IGN 8TH CYL*	Eighth cylinder in the firing order has a fault with its ignition system
ALM244	IGN 9TH CYL*	Ninth cylinder in the firing order has a fault with its ignition system
ALM245	IGN 10TH CYL*	Tenth cylinder in the firing order has a fault with its ignition system
ALM251	IGN 11TH CYL*	Eleventh cylinder in the firing order has a fault with its ignition system
ALM252	IGN 12TH CYL*	Twelfth cylinder in the firing order has a fault with its ignition system
ALM253	IGN 13TH CYL*	Thirteenth cylinder in the firing order has a fault with its ignition system
ALM254	IGN 14TH CYL*	Fourteenth cylinder in the firing order has a fault with its ignition system
ALM255	IGN 15TH CYL*	Fifteenth cylinder in the firing order has a fault with its ignition system

TROUBLESHOOTING

Table 4.00-2 ESM System's Alarm Fault Codes (Continued), (Part 2 of 2)

ALARM FAULT CODE	FAULT CONDITION	DESCRIPTION
ALM311	IGN 16TH CYL*	Sixteenth cylinder in the firing order has a fault with its ignition system
ALM312	OVERLOAD	Engine is overloaded
ALM313	IGN FLT	Ignition system signal being received by ECU is out of normal range
ALM315	HIGH INTAKE TEMP	Intake manifold air temperature too high
ALM322	CALIBRATE ACT	Various causes: linkage and actuator
ALM323	STUCK THROT LINK	Throttle linkage binding
ALM332	IGN COM FAULT	A communications problem exists between the IPM-D and the ECU
ALM333	HIGH COOLANT TEMP	Engine coolant temperature too high
ALM334	WIDE OPEN THROTTLE	The throttle has been at WOT too long
ALM335	HIGH OIL TEMP	Engine oil temperature too high
ALM341	STEPPER	Left bank stepper home/not connected
ALM342	STEPPER	Right bank stepper home/not connected
ALM343	OXYGEN LB	Left bank oxygen sensor/wiring fault
ALM344	EXH TEMP LB	Left bank exhaust temperature sensor/wiring fault
ALM345	OXYGEN RB	Right bank oxygen sensor/wiring fault
ALM351	EXH TEMP RB	Right bank exhaust temperature sensor/wiring fault
ALM353	HIGH IGN PWR	Ignition energy level is at Level 2 (or highest level) – at least one spark plug on the engine is getting worn and should be replaced
ALM411	HIGH EXHAUST TEMP	Right bank/left bank exhaust temperature too high
ALM413	LEAN LIMIT	Left stepper has reached lean limit
ALM415	RICH LIMIT	Left stepper has reached rich limit
ALM422	COOLANT TEMP	Sensor/wiring fault
ALM423	LEAN LIMIT	Right stepper has reached lean limit
ALM425	RICH LIMIT	Right stepper has reached rich limit
ALM432	STEPPER COM FLT	Stepper communication fault
ALM441	THROTTLE ACTUATOR	Actuator/wiring fault
ALM451	REMOTE RPM	Remote rpm analog input is over the acceptable range; wiring fault
ALM454	BATT VOLT	Battery voltage out of specification
ALM455	HIGH ECU TEMP	ECU's temperature has increased beyond the maximum recommended operating temperature
ALM523	ALTERNATOR	Alternator/wiring fault
ALM541	USER DIP	User digital input changed state
ALM542	START ON WITH RPM>0	Start engine signal should be off when the engine is running; otherwise engine will immediately restart upon shutdown
ALM552	ENG BEING DRIVEN	Engine is being rotated by the driven equipment; sparks and fuel have been cut by the ECU
ALM555	INTERNAL FAULT	Internal error in ECU; call the factory

NOTE: * The ignition system alarms are in order of engine firing order. Engine firing order is stamped on the engine nameplate. The VHP Series Four® 6-cylinder engine firing order is: cyl. 1, 5, 3, 6, 2, 4. The VHP Series Four® 12-cylinder engine firing order is: 1R, 6L, 5R, 2L, 3R, 4L, 6R, 1L, 2R, 5L, 4R, 3L.

Table 4.00-3 ESM System's Shutdown Fault Codes

SHUTDOWN FAULT CODE	SHUTDOWN CONDITION	DESCRIPTION
ESD212	CRANK MAG PICKUP	ECU detects fewer crankshaft pulses between camshaft pulses than it was expecting
ESD214	CAM MAG PICKUP	Too many crankshaft pulses are identified between magnetic pickups (or no magnetic pickup pulses are detected)
ESD221	OVERSPEED ENGINE	Engine overspeed; engine was running faster than allowed
ESD222	CUST ESD	Shutdown has been triggered by an external action; by customer equipment
ESD223	LOW OIL PRESS	Pressure signal from the sensor is below a threshold setpoint and means that the oil pressure may have been below normal operating conditions
ESD224	KNOCK	Specific cylinder was at its maximum retarded timing due to knock and exceeded an absolute threshold
ESD231	OVERCRANK	Time the engine has been cranking has exceeded a maximum crank time
ESD232	ENGINE STALL	Engine stopped rotating independent of ECU which did not receive a signal to stop
ESD251	OVERSPEED DRIVE EQUIP	Customer set overspeed limit exceeded; check throttle actuator and linkage
ESD312	OVERLOAD	Engine was overloaded
ESD313	LOCKOUT/IGNITION	Lockout or E-Stop (emergency stop) button on the engine is "ON" or there is a power problem with the IPM-D module (either it is not powered up or the internal fuse is blown)
ESD315	HIGH IMAT	Intake manifold air temperature too high
ESD333	HIGH COOLANT TEMP	Engine coolant temperature too high
ESD335	KNOCK ABS THRESHOLD	A knock sensor output value exceeded an absolute threshold programmed to ECU
ESD424	HIGH OIL TEMP	Engine oil temperature is too high
ESD551	UPDATE ERROR/FAULT	Update error/fault
ESD553	SECURITY VIOLATION	Engine type that is permanently coded in the ECU does not match with the downloaded calibration
ESD555	INTERNAL FAULT	Serious internal error in ECU; call the factory; do not attempt to restart engine

TROUBLESHOOTING

NON-CODE ESM SYSTEM TROUBLESHOOTING

Table 4.00-4 provides non-code troubleshooting for the ESM system. Non-code troubleshooting includes any system faults that do not have ALM or ESD alarm codes that are logged in the Fault Log in ESP.

NOTE: *ESP is used as a tool in troubleshooting non-code faults.*

Table 4.00-4 Non-Code ESM System Troubleshooting (Part 1 of 2)

IF...	THEN
Engine does not rotate when start button is pressed	- View the [F10] Status Panel in ESP. Look at the six fields under the "System/Shutdown Status" heading on the [F10] Status Panel. Each field should be gray and indicate that the ESM system is OK or that there are NO shutdowns active. If there are any active shutdowns, correct the problem indicated in the Fault Log. - If the [F10] Status Panel in ESP indicates no shutdowns, view the [F3] Start-Stop Panel and verify that the "Starting Signal" field turns green when you press the start button. If the "Starting Signal" field does not turn green, check the wiring. - Verify that +24 VDC power is applied to the wires: ESD and RUN/STOP. Correct power supply if necessary. - After an emergency shutdown and rpm is zero, ESD input should be raised to high to reset the ESM. If ESD input remains low, ESM reset will be delayed and engine may not start for up to 1 minute.
Engine rotates but does not start	- Use a timing light to verify whether or not sparks are being generated. - If sparks are generated, check to see if the fuel valve is opening. To check if the fuel valve is opening, feel the solenoid section of the fuel valve as the start engine button is pressed. If you do not feel movement, check and correct the fuel valve to junction box relay wiring and check the junction box relay to ECU for 24 VDC when the start engine button is pressed. - View the [F3] Start-Stop Panel to verify purge time is programmed. •C13xxx, 15xxx, and 17xxx Calibration – Although purge time can be programmed from 0 to 1800 seconds (30 minutes), a purge time greater than 15 seconds will prevent the engine from starting, since an overcrank shutdown fault (ESD231) occurs at 15 seconds. If purge time is too high, reprogram between 0 and 14 seconds. •C21xxx Calibration – Although purge time can be programmed from 0 to 1800 seconds (30 minutes), a purge time greater than 30 seconds will prevent the engine from starting, since an overcrank shutdown fault (ESD231) occurs at 30 seconds. If purge time is too high, reprogram between 0 and 29 seconds.
Engine is not running at desired speed	- View the [F2] Engine Panel in ESP and verify that the "Engine Setpoint RPM" field and the "Engine Speed RPM" field are the same. Note the following: • If the "Engine Setpoint RPM" and "Engine Speed RPM" fields are the same, there is an electrical problem. Continue with "b. Electrical Problem" below. • If the "Engine Setpoint RPM" and "Engine Speed RPM" fields are not the same, there is an engine problem. Continue with "c. Engine Problem" below. - Electrical Problem <i>Fixed Speed Mode</i> - Verify the status of the high/low idle digital input. The GOVHL IDL must be at a nominal 24 VDC to be running at the high idle speed. Correct input as required. - Verify that the high idle speed on the [F4] Governor Panel is set correctly. Correct speed setting as required. <i>Variable Speed Mode</i> - Verify that the Remote Speed digital input of the ECU is at a nominal 24 VDC. See the [F4] Governor Panel to verify the status of the Remote Speed digital input. Correct input as required. - Verify the value of the Remote RPM Setpoint in mA on the [F4] Governor Panel. If you are using the Remote RPM speed input as either a voltage or milliamp input, the equivalent milliamp value is shown in ESP. Should the equivalent milliamp value fall below 2 mA or above 22 mA, the ESM system will assume there is a wiring problem and will run at either the high or low idle speed, depending on the status of the high/low idle digital input (GOVHL IDL). Check wiring. - If you are unable to reach the lowest speed the engine is allowed to run at, change the "Low Idle Adj" calibration on the [F4] Governor Panel to -50 rpm. - Engine Problem - If the engine speed is slower than the setpoint, there is an ignition, turbocharger, or fuel problem; or the engine is overloaded. Correct as required. - If the engine speed is higher than the setpoint, the throttle linkage is probably misadjusted and is not allowing the throttle to close all the way. Correct as required.

Table 4.00-4 Non-Code ESM System Troubleshooting (Continued), (Part 2 of 2)

IF...	THEN
Intake manifold air pressure readings vary by more than 0.5 in-Hg (1.69 kPa) on GSI engines or 1.0 in-Hg (3.39 kPa) on LT engines (VHP vee engines only)	a. View the [F2] Engine Panel in ESP and verify that the readings for intake manifold air pressure are outside the acceptable limits. The values of the left and right bank intake manifold air pressure readings should be within 0.5 in-Hg (1.69 kPa) absolute on GSI engines and 1.0 in-Hg (3.39 kPa) absolute on LT engines of each other. b. If the values do vary beyond acceptable limits, an engine problem exists, such as the throttle plates may not be synchronized, the turbochargers or wastegates may not be working correctly, or air/fuel ratio may not be balanced from bank-to-bank. For information on these engine systems, refer to the following: • For information on throttle actuator linkage, refer to "Throttle Actuator Linkage" on page 4.05-2 in this manual. • For information on fuel system adjustment and maintenance, refer to Section 4.05 of <i>Form 6287, Waukesha VHP Series Four Operation & Maintenance Manual</i>. • For information on turbocharger and wastegate maintenance, refer to Section 4.20 of <i>Form 6287, Waukesha VHP Series Four Operation & Maintenance Manual</i>. NOTE: For detailed repair and overhaul information on VHP Series Four 12-cylinder engines, refer to Form 6296, Waukesha VHP Series Four 12-Cylinder GSI/LT Repair & Overhaul Manual.

SECTION 4.05

ESM SYSTEM MAINTENANCE

MAINTENANCE CHART

This section describes the recommended maintenance procedures for ESM system components. Minimal maintenance is required for the ESM system. Table 4.05-1 provides a list of the recommended maintenance items and includes a description of the service required, the service interval, and the page number where specific maintenance information is found for that item in this manual.

IMPORTANT! Continue to perform standard engine maintenance as provided in the applicable engine's operation and maintenance manual.

Table 4.05-1 Maintenance Chart for ESM[®] System Components

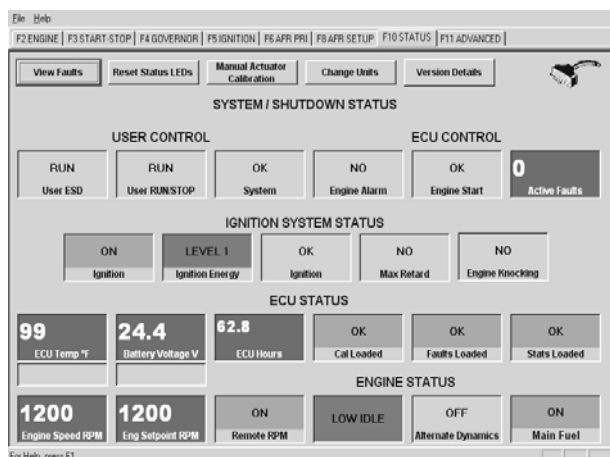
ITEM	SERVICE	INTERVAL	INFORMATION PROVIDED ON PAGE
ESP Total Fault History	Review	Every month	page 4.05-2
Throttle Actuator Linkage	Inspect, Lubricate, Test	Every year or as needed	page 4.05-2
Alternator Belts (if equipped)	Inspect	Every year	page 4.05-7
Knock Sensors	Inspect	Every year	page 4.05-9
Oxygen Sensors (with AFR option)	Replace	2000 hours	page 4.05-10
Stepper (with AFR option)	Inspect, Clean, Lubricate, Test	Every year	page 4.05-11
ESM System Wiring	Inspect Wiring/Harnesses, Secure Connections, Check Ground Connections, Verify Incoming Power Is Within Specification	Every year	page 4.05-13
Batteries	Inspect Water Level, Corrosion, Specific Gravity, Test	Semiannual	page 4.05-13

ESP TOTAL FAULT HISTORY

Every month review the Total Fault History accessed in ESP. Look for patterns of faults that may have occurred over the lifetime of the ECU. By reviewing the Total Fault History, you can see if fault patterns exist that require additional troubleshooting and/or inspection.

For more information on the Fault Log, refer to Section 3.05 *ESP Panel Descriptions* “Fault Log Description”.

1. In ESP, click on the [F10] Status Panel.



2. To view the Fault Log, click the “View Faults” button on the [F10] Status Panel.



3. The Fault Log displays the fault code, a description of the fault, the first time the fault occurred since the fault was reset (in ECU hours:minutes:seconds), the last time the fault occurred since reset, the number of times the fault occurred since reset, and the total number of times the fault occurred in the lifetime of the ECU. Within the Fault Log dialog box, you can view a list of active faults or the total history of faults that occurred in the ECU's lifetime.

4. To view the Total Fault History, click the “Total Fault History” button on the Fault Log dialog box.

NOTE: If the Fault Log remains open, you must occasionally update or refresh the log by clicking the “Refresh” button. Once open, the Fault Log does not refresh itself.

THROTTLE ACTUATOR LINKAGE

ADJUSTING LINKAGE

The following steps describe the procedure for properly setting the governor linkage rod and levers on the actuator and the throttle shaft.

1. Install the governor lever (see Figure 4.05-1) on the governor terminal shaft to the angle shown in the appropriate figure (see Figure 4.05-2 and Figure 4.05-3). The terminal shaft must be in the NO FUEL position. Secure with hex head screw and nut.

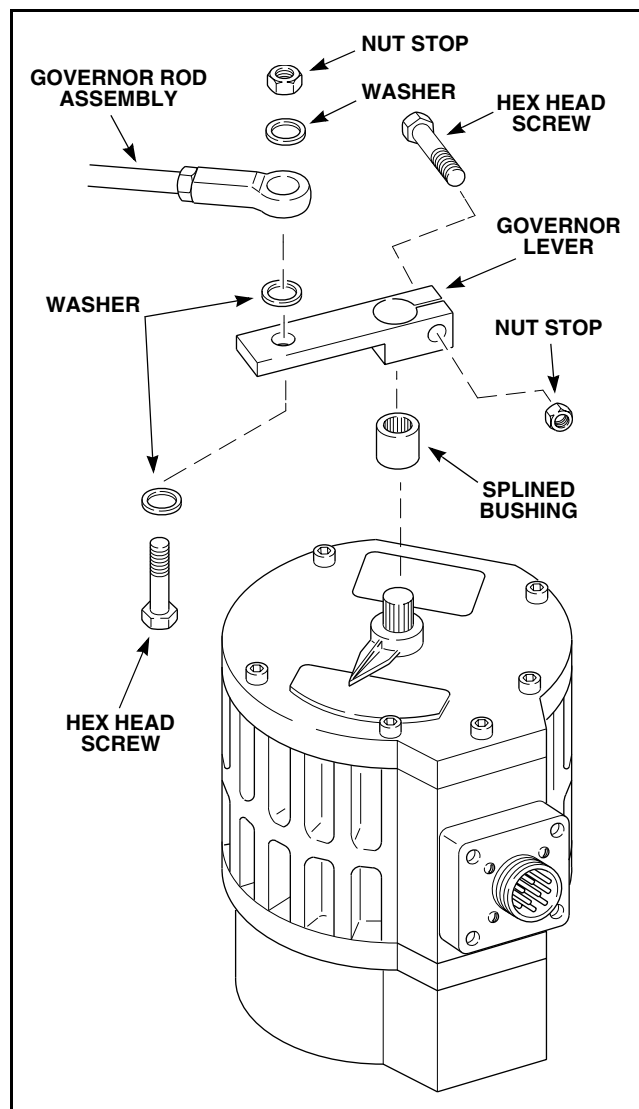


Figure 4.05-1 Governor Linkage

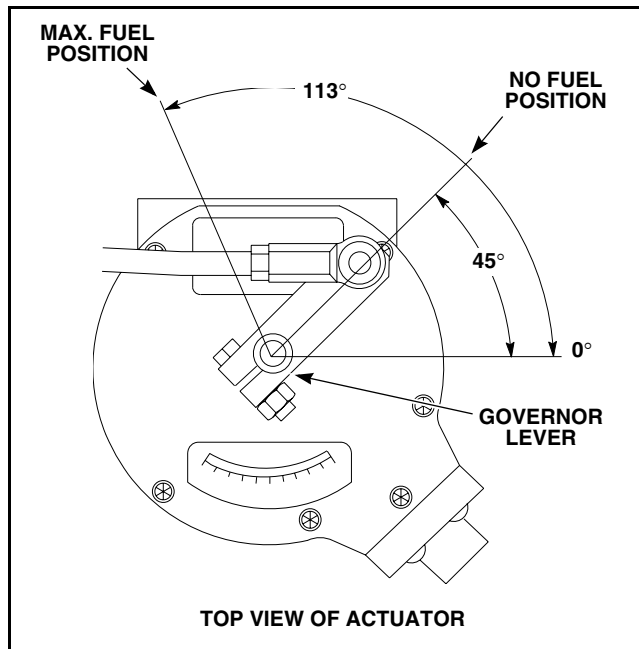


Figure 4.05-2 Governor Terminal Shaft Angles – 6-Cylinder GSI VHP Engines

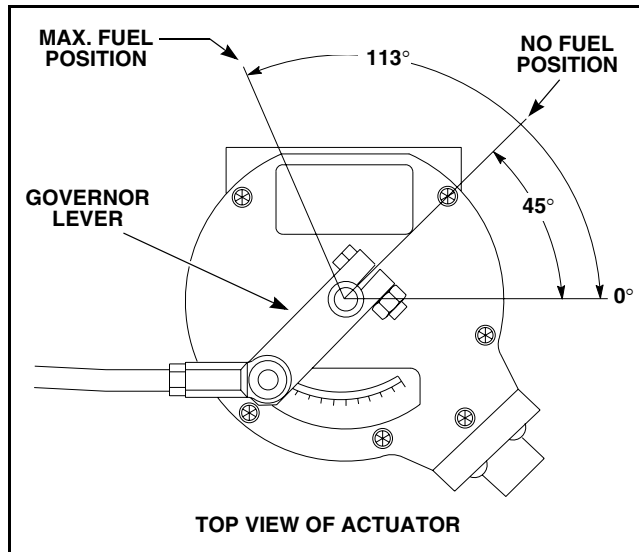


Figure 4.05-3 Governor Terminal Shaft Angles – 6-Cylinder Draw-Thru and 12-Cylinder VHP Engines

2. Install the throttle lever on the regulating cross-shaft to the angle shown for your engine type in Figure 4.05-4 or Figure 4.05-5. The butterfly valve must be in the CLOSED position. Secure with hex head screw, washers, and nut.
3. Attach left-hand side of governor rod assembly to the lever on the butterfly valve. Tighten nuts on governor rod assembly.
4. With the governor terminal shaft in the NO FUEL position and with the butterfly valve held CLOSED, adjust the governor rod for length so that the rod end and the hole in the governor lever align.
5. Attach right-hand side of governor rod assembly to the lever on the governor terminal shaft. Tighten nuts on governor rod assembly.
6. Check for throttle and governor travel to angles specified in Figure 4.05-2 or Figure 4.05-3 and Figure 4.05-4 or Figure 4.05-5.
7. Check to ensure that no binding occurs.
8. Check all fasteners on the rod and levers for tightness. Thread engagement on all rod ends must be a minimum of seven threads.
9. Verify proper operation of the throttle actuator by performing a manual calibration of the actuator using ESP. Refer to Section 3.10 *ESP Programming* "Performing Manual Calibration" for programming steps.

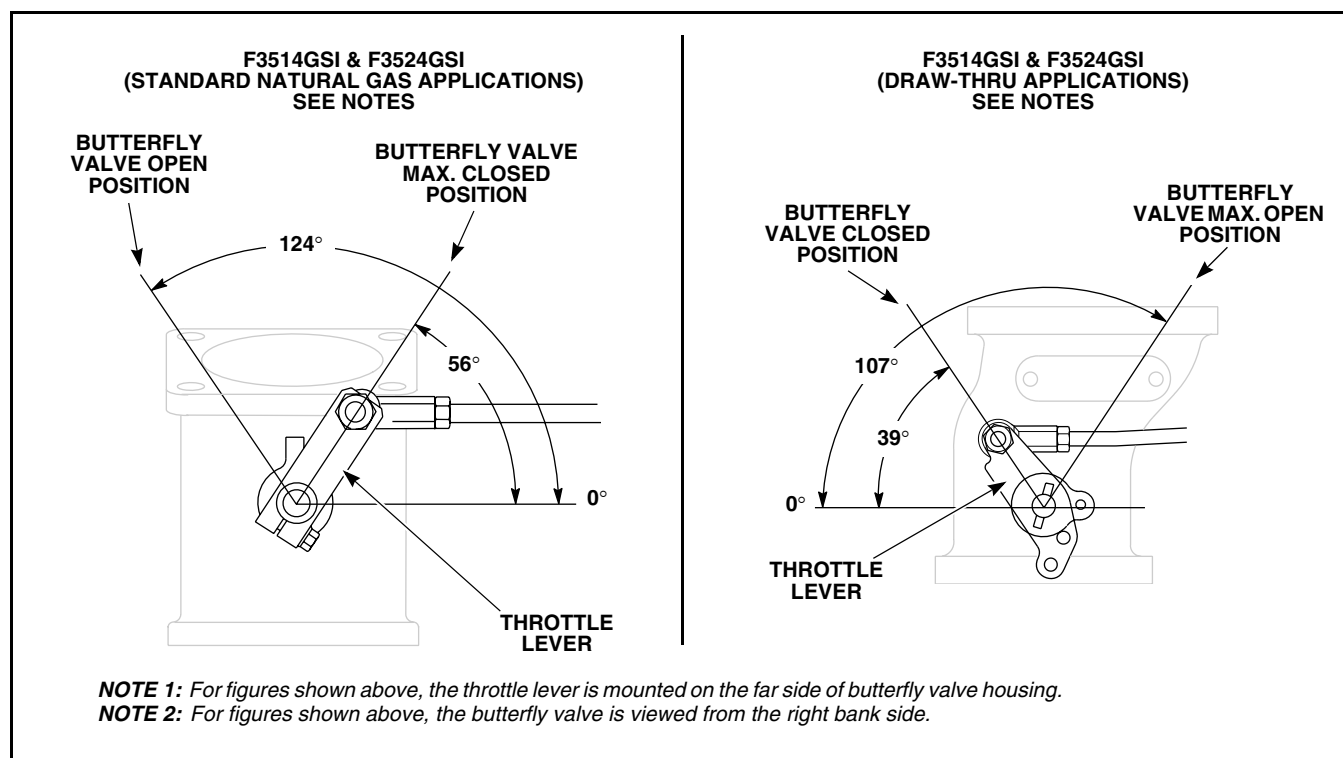


Figure 4.05-4 Butterfly Valve Cross Shaft Angles – 6-Cylinder Engines

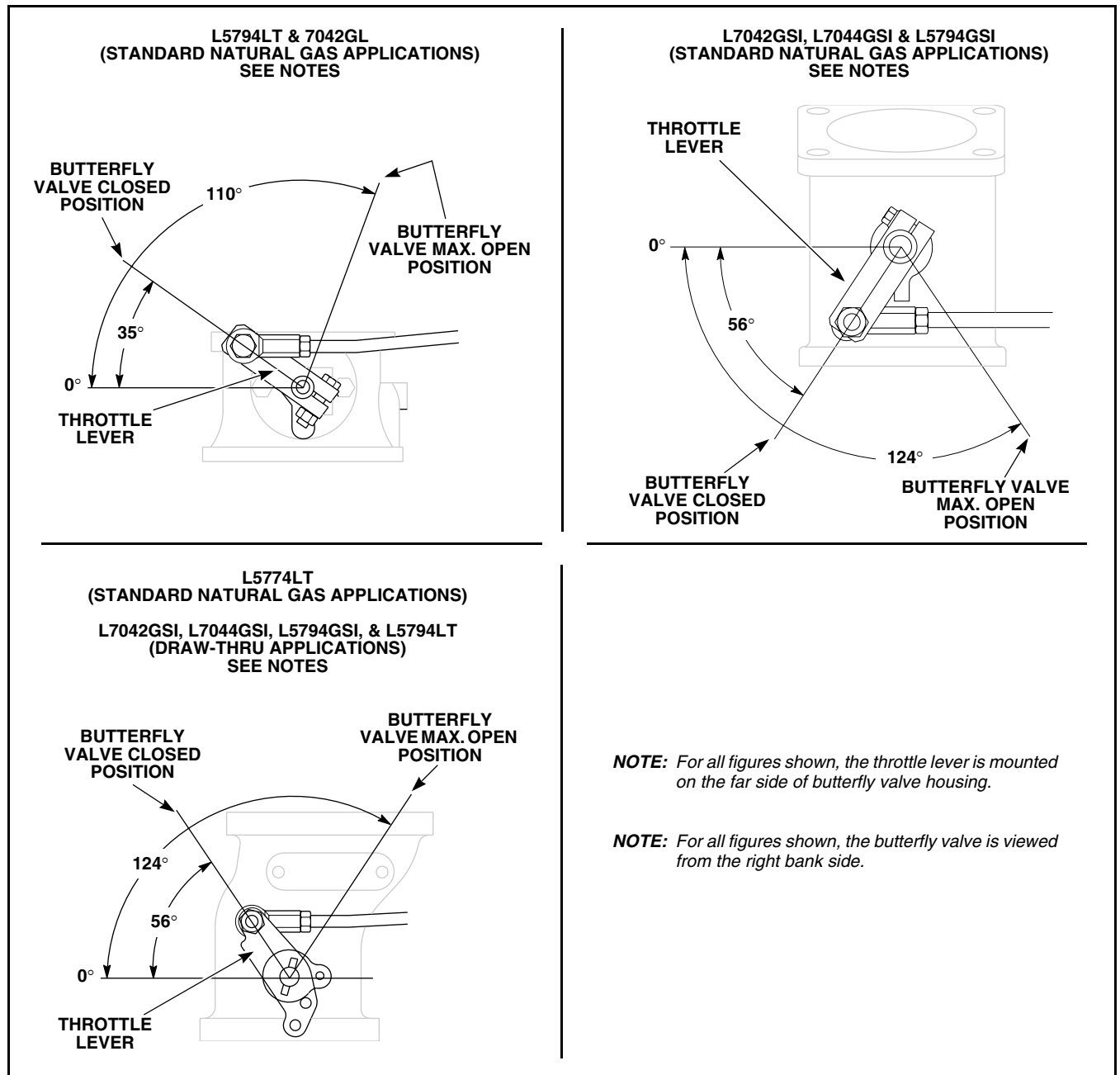


Figure 4.05-5 Butterfly Valve Cross Shaft Angles – 12-Cylinder Engines

ESM SYSTEM MAINTENANCE

INSPECTION AND MAINTENANCE OF THROTTLE ACTUATOR LINKAGE

Every year, or as needed, the throttle actuator linkage must be inspected and lubricated. To perform maintenance to the throttle actuator linkage, complete the following.



WARNING

To prevent severe personal injury or death, always stop the unit before cleaning, servicing, or repairing the unit or any driven equipment.

1. Shut down engine.
2. Inspect rod ends. If worn, replace.
3. Using a grease gun, lubricate the grease fittings on the throttle actuator linkage with CITGO Lithoplex® Grease NLGI2 (service temperature range 20 – 250° F [-7 – 121° C]) or equivalent (see Figure 4.05-6).
4. Verify proper operation of the throttle actuator by performing a manual calibration of the actuator using ESP. Refer to Section 3.10 *ESP Programming* “Performing Manual Calibration” for programming steps.

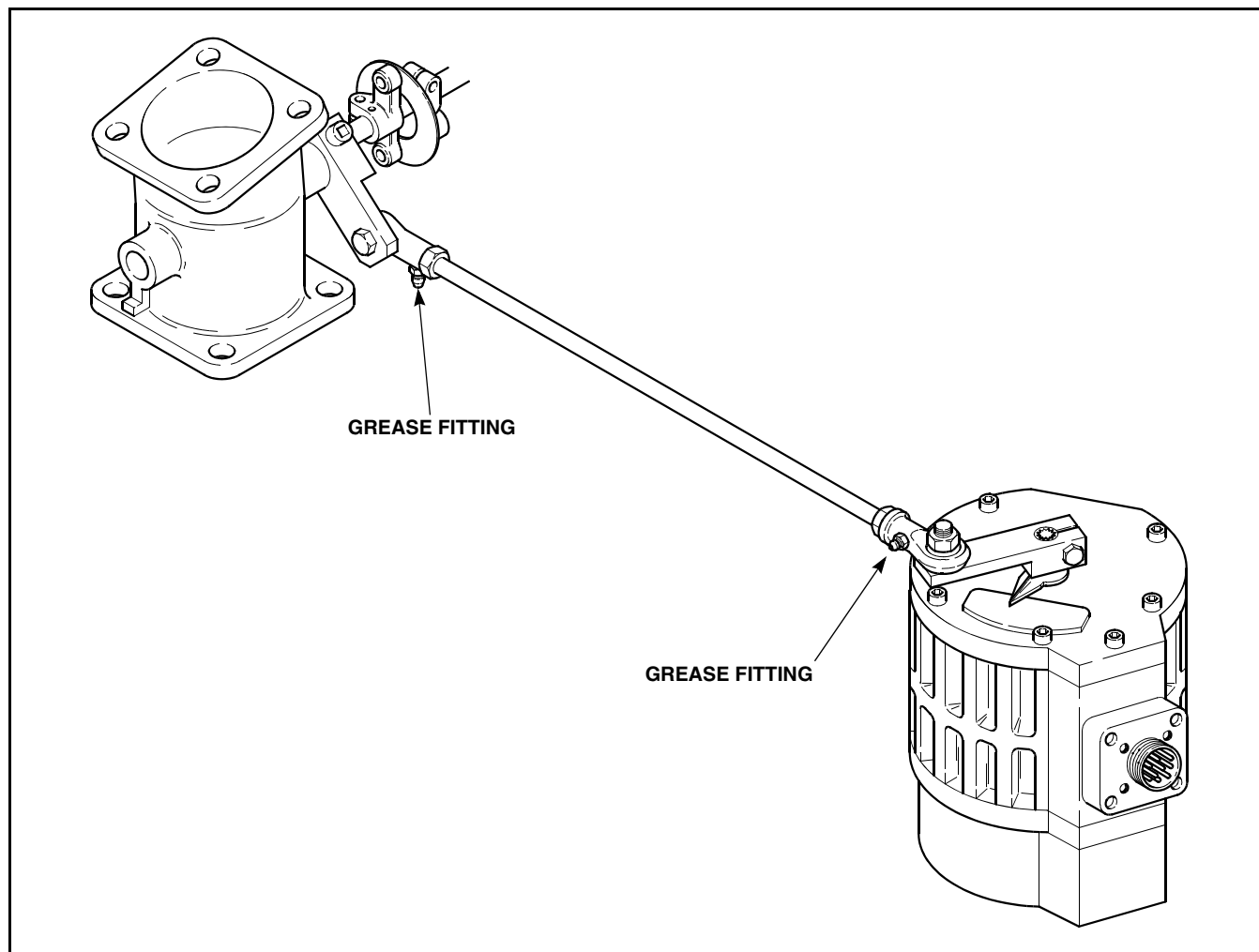


Figure 4.05-6 Grease Fittings on Throttle Actuator Linkage

ALTERNATOR BELTS

INSPECTION OF ALTERNATOR BELTS

Every year the alternator belts (see Figure 4.05-7) must be inspected; however, the frequency of inspection is determined largely by the type of operating conditions. High speed operation, high temperatures, and dust and dirt all increase wear.

NOTE: The alternator uses two drive belts to increase belt life and ensure reliability. These belts are a matched set and must be replaced as a pair to ensure proper operation.

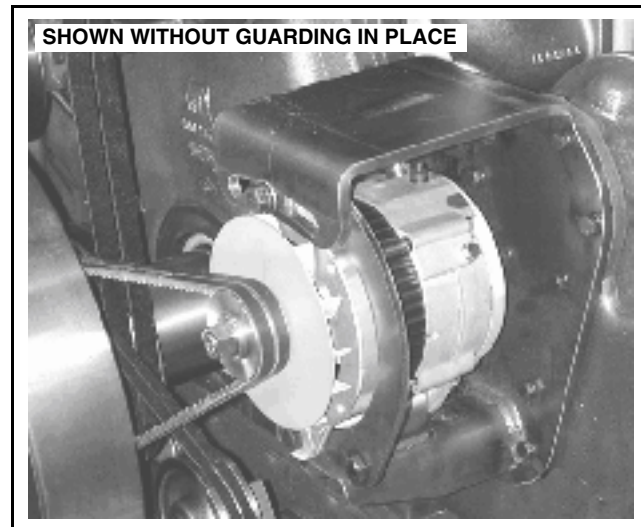


Figure 4.05-7 Alternator Belts

WARNING

To prevent severe personal injury or death, always stop the unit before cleaning, servicing, or repairing the unit or any driven equipment.

WARNING

Always install the safety guards after completing any service operation. Never operate the engine with the safety guards removed. Disregarding this information could result in severe personal injury or death.

1. Remove the guarding from the alternator.
2. Inspect the alternator belt for fraying, cracks, or wear.

 CAUTION Be sure that the belts are cool when the tension is checked or adjusted. The thermal expansion of warm belts will result in a false tension reading. Disregarding this information could result in product damage and/or personal injury.

3. Check belt tension. To check belt tension, depress the belt with your fingers. A tensioned belt will feel alive and springy. Belts that are too tight will not deflect; loose belts will feel dead.
4. Replace belts if necessary.
5. When replacing belts, always replace the entire set of belts, not just the one that looks worn. Always use new, matching belt sets to ensure proper belt operation.
6. To avoid belt damage, always loosen the pulley adjustment when installing belts. Never pry a belt over a pulley.
7. Keep belts at the proper tension. See "Alternator Belt Tension".
8. Reinstall the guarding over the alternator.

ALTERNATOR BELT TENSION

NOTE: Extender Series engines use an automatic tensioner, no manual adjustment is required.

New belts will stretch shortly after installation. Loose belts will slip, causing power loss and heat buildup. Belts that are too tight will deteriorate rapidly and wear out alternator shaft bearings. Complete the following steps to adjust belt tension.

WARNING

To prevent severe personal injury or death, always stop the unit before cleaning, servicing, or repairing the unit or any driven equipment.

WARNING

Always install the safety guards after completing any service operation. Never operate the engine with the safety guards removed. Disregarding this information could result in severe personal injury or death.

1. Remove the guarding from the alternator.
2. Loosen the pivot bolt on the alternator (see Figure 4.05-8).

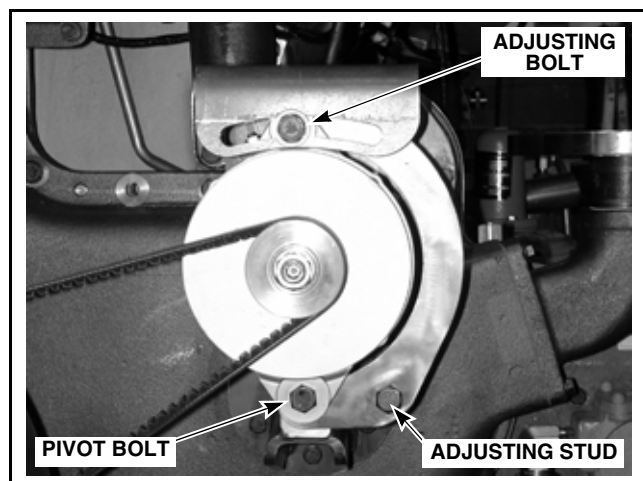


Figure 4.05-8 Alternator Belt Adjustment

3. Loosen the adjusting bolt on the alternator (see Figure 4.05-8). Make sure the alternator body rotates freely around the pivot bolt.

CAUTION Belts that are too tight result in excessive stretching and overheating. Too much tension may also damage alternator components, such as sheaves and shafts, and lead to premature failure. Disregarding this information could result in product damage and/or personal injury.

CAUTION Belts that are too loose result in belt slippage. Slippage causes burn spots, overheating, rapid wear and breakage. The vibration created by loose belts may also be sufficient to cause unnecessary wear of the pulley grooves. Disregarding this information could result in product damage and/or personal injury.

4. Tighten adjusting stud with torque wrench in Position 1 (recommended – see Figure 4.05-9) or in Position 2 (alternate – see Figure 4.05-10). Make sure torque wrench is held at angle shown in the applicable figure. Torque values are different for new and used belts.

5. While holding the appropriate torque value, tighten the adjusting bolt and pivot bolt.

6. Reinstall the guarding over the alternator.

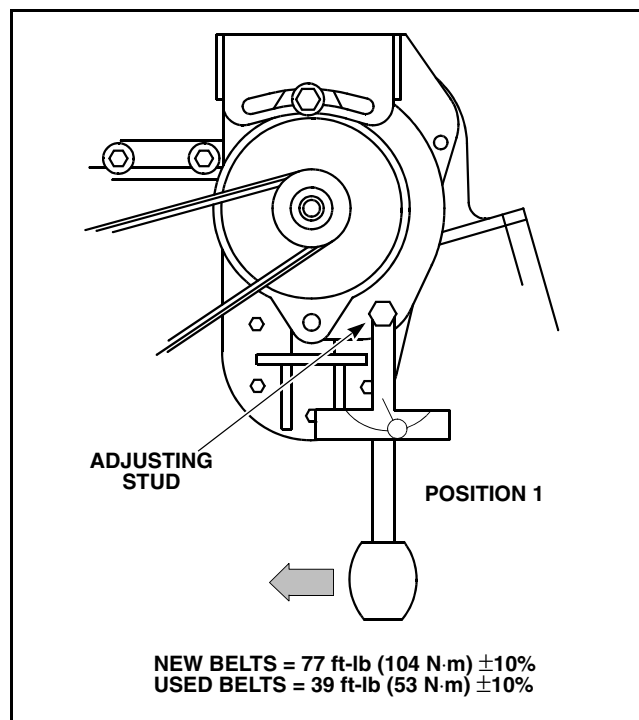


Figure 4.05-9 Torque Requirements Using Torque Wrench in Position 1 (Recommended)

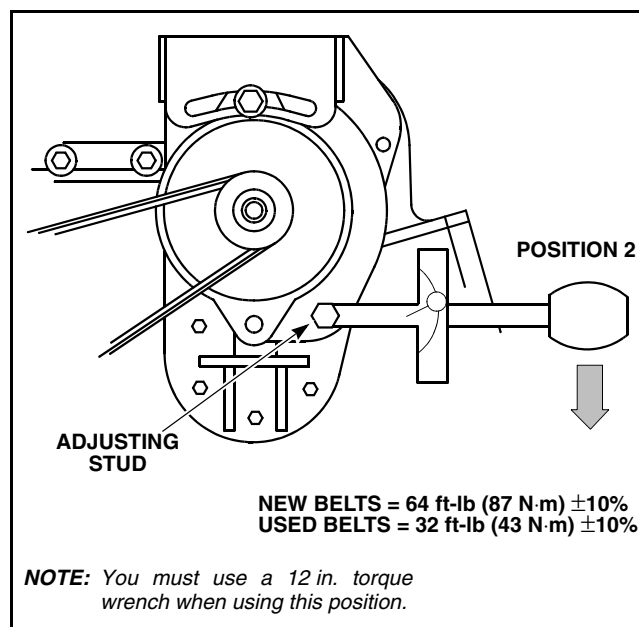


Figure 4.05-10 Torque Requirements Using Torque Wrench in Position 2 (Alternate)

KNOCK SENSORS

Every year each knock sensor must be inspected for an accumulation of dirt/grit, connector wear, and corrosion. If a knock sensor has an accumulation of dirt, carefully clean visible end of knock sensor and surrounding area. If a knock sensor connector looks worn or if corrosion is evident, remove the knock sensor to clean or replace as necessary.

To reinstall a knock sensor, complete the steps in "Installing Knock Sensors" below. The knock sensors must be properly tightened and seated flat against the mounting surface as the instructions explain.

There are two versions of knock sensors, P/N A740110B and P/N A740110C (see Figure 4.05-11).

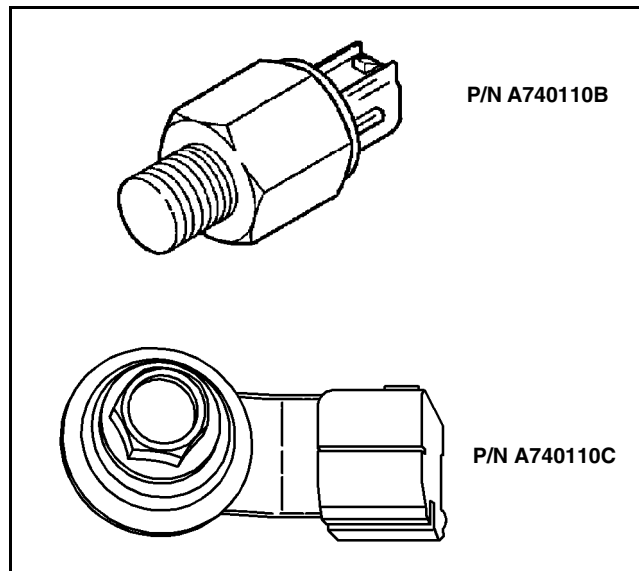


Figure 4.05-11 Knock Sensor

INSTALLING KNOCK SENSORS

NOTE: Knock sensor (P/N A740110B) with its connector will extend about 2 in. (51 mm) away from the surface of the crankcase. There should be at least 3 in. (76 mm) of clearance perpendicular to the knock sensor surface. Knock sensor (P/N A740110C) should have at least 3 in. (76 mm) of clearance parallel to the knock sensor surface.

1. Thoroughly clean knock sensor mounting hole and area around mounting hole. The knock sensors are installed just below the intake ports on the sides of the engine crankcase (see Figure 4.05-12 and Figure 4.05-13).

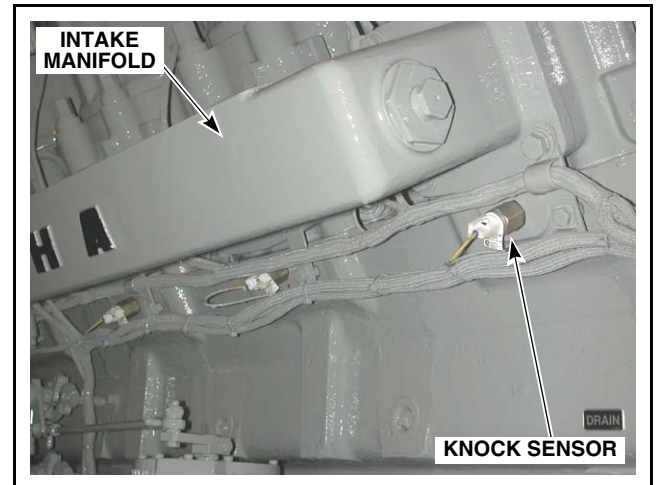


Figure 4.05-12 Knock Sensor (P/N A740110B)

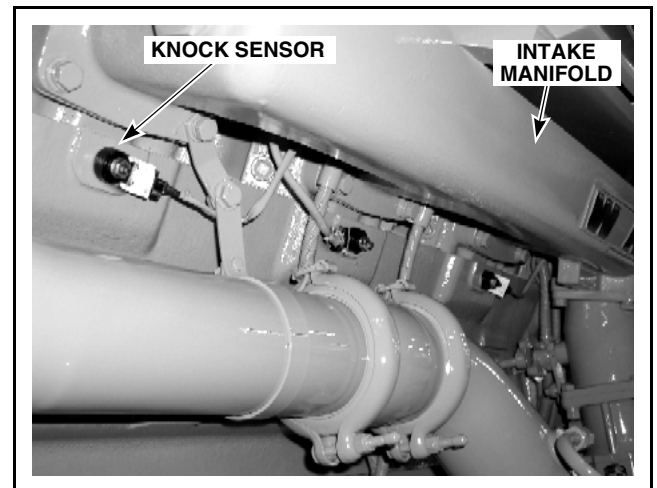


Figure 4.05-13 Knock Sensor (P/N A740110C)

CAUTION Drilled and tapped hole (knock sensor surface) must be flat, smooth (RMS 63), and be perpendicular to the drilled hole. Make sure knock sensor mounting surface is free of paint. If the knock sensor is not mounted flush with the mounting surface or if the surface is not within RMS63, the knock sensor WILL provide incorrect signals to the ESM system. Disregarding this information could result in product damage and/or personal injury.

2. Verify that the mounting surface is flat and smooth (RMS63) using a Profilometer. Although it is recommended to use a Profilometer, if one is not available, lightly run your finger over mounting surface. The surface should be free of any ripples and imperfections and should be polished smooth.

IMPORTANT! When completing Step 3 and Step 4, verify that the knock sensor is seated flat against the mounting surface. See next section, “Verifying Knock Sensor Is Seated Flat”, for necessary steps.

CAUTION Do not drop or mishandle knock sensor. If knock sensor is dropped or mishandled it must be replaced. Disregarding this information could result in product damage and/or personal injury.

3. Install knock sensor into the threaded mounting hole (see Figure 4.05-12).

CAUTION Do not overtighten knock sensor. Overtightening will cause damage to the knock sensor. Disregarding this information could result in product damage and/or personal injury.

4. Tighten knock sensor:

- P/N A740110B – Tighten knock sensor to **35 – 40 ft-lb (47 – 54 N-m) dry**.
- P/N A740110C – Tighten hex nut to **177 in-lb (20 N-m) dry**.

5. Repeat this mounting procedure for each knock sensor.

Verifying Knock Sensor Is Seated Flat

Use the method provided below to verify that the knock sensor is seated flat against the mounting hole surface.

1. Apply a very thin coat of a blueing paste, such as Permatex® Prussian Blue (or equivalent), to seating surface of knock sensor (see Figure 4.05-14).

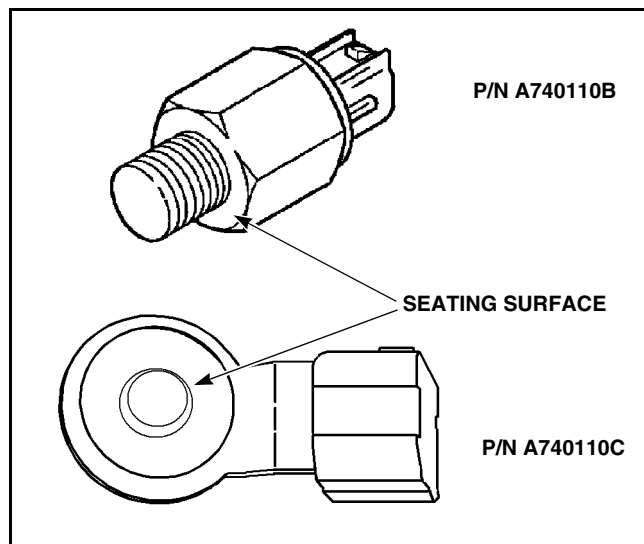


Figure 4.05-14 Knock Sensor Seating Surface

2. Install and remove knock sensor.

3. Examine imprint left by blueing agent on the crankcase and sensor seating surface.

- If the imprint on the crankcase and sensor seating surface is uniform, the sensor has full-face contact with mounting surface.
- If the imprint on the crankcase and sensor seating surface is NOT uniform, the sensor does not have full-face contact with mounting surface. The mounting hole will have to be plugged and re-tapped to make the hole perpendicular to the mounting surface.

4. Reinstall knock sensor by completing Step 3 and Step 4 of knock sensor installation.

OXYGEN SENSOR REPLACEMENT

Oxygen sensors (P/N A740106D) are maintenance items and replacement will be required. Service life of the stoichiometric oxygen sensor is typically 2000 hours. Since the sensor has no wearing parts, theoretical life is indefinite. However, oil additives, fuel contaminants, compounds released from certain RTV gasket materials, incorrectly applied thread anti-seize, and over-temperature can result in shortened sensor life. Replace the oxygen sensors every 2000 hours.

If the AFR stepper is reaching the stepper limits and you find yourself adjusting the Lambda value to compensate for this condition, it may indicate that the oxygen sensor is failing. Replacement of the oxygen sensor is recommended.

CAUTION Operation of an air/fuel ratio control system with a contaminated, failing, or faulty oxygen sensor may result in the engine system not meeting emissions reduction performance goals. Disregarding this information could result in product damage and/or personal injury.

CAUTION Always purchase ESM AFR oxygen sensors (P/N A740106D or later) from Waukesha Engine. Performance goals of the system cannot be met without Waukesha's oxygen sensor specifications. Disregarding this information could result in product damage and/or personal injury.

Replacement oxygen sensors (P/N 740106D or later) must be purchased from Waukesha Engine. Oxygen sensors purchased from other retailers may affect sensor life and will negatively affect AFM or AFR control. Performance goals of the AFR system cannot be met without Waukesha's oxygen sensor specifications.

To install a new oxygen sensor, complete the following:

WARNING

Allow sufficient time for oxygen sensor to cool to room temperature before attempting any service procedure. Contact with hot sensor could cause severe personal injury. Disregarding this information could result in severe personal injury or death.

1. Disconnect sensor harness from oxygen sensor.
2. Remove oxygen sensor from mounting hole.
3. Thoroughly clean hole and area around sensor mounting hole. Be careful not to drop debris through mounting hole.

 **CAUTION** Do not drop or mishandle oxygen sensor. The ceramic component inside the sensor is vulnerable to thermal and mechanical shock. Improper handling could damage the oxygen sensor, making the sensor unusable. Disregarding this information could result in product damage and/or personal injury.

 **CAUTION** Do not apply (or contact) anti-seize to the oxygen sensor's sensing element (louvered end) OR to the area above sensor threads. **APPLY ANTI-SEIZE ONLY TO THE THREADED AREA OF SENSOR.** Contact with anti-seize compound on the sensing element or area above sensor threads will result in incorrect sensor operation.

NOTE: New sensors are packaged with an anti-seize compound already applied to the sensor threads. There is no need to apply additional anti-seize unless reinstalling a used sensor. If required, very sparingly use a nickel-based anti-seize compound that will withstand temperatures of 1500° F (816° C). Apply compound **ONLY** to sensor threads.

NOTE: A special Waukesha socket (P/N 475039) is available to tighten the stoichiometric oxygen sensor. Contact your Waukesha Distributor for ordering information.

4. Thread the oxygen sensor into the mounting hole. Tighten oxygen sensor to 28 – 34 ft-lb (38 – 46 N·m).
5. Reconnect harness to oxygen sensor.

STEPPER MAINTENANCE

Every year the stepper(s) must be inspected, cleaned, and lubricated. To perform yearly maintenance to the stepper(s), refer to Figure 4.05-15 and Figure 4.05-16 and complete the following:

1. Remove power from ESM system.
2. Disconnect harness from stepper.
3. Remove stepper from fuel regulator.
4. Remove control (main) spring.
5. Inspect and clean interior of stepper.
6. Lubricate spring adjusting nut and stepper shaft with CITGO Lithoplex Grease NLGI 2 (service temperature range 20 – 250° F [-7 – 121° C]) or equivalent.
7. Verify proper operation of stepper:
 - A. Reconnect harness to stepper.
 - B. Insert control spring into stepper.
 - C. Apply power to ESM system.
 - D. Using ESP, view [F8] AFR Setup Panel.
 - E. Click box “On” in the “Check Box for Left/Right Bank Manual Mode” field located on the [F8] panel to put ESM AFR control in manual mode.
 - F. Click left or right “Home” button on [F8] panel.
 - G. Verify shaft inside stepper first moves counter-clockwise and control spring moves partially into stepper assembly until “home” position is reached. Then the stepper shaft must rotate clockwise and control spring must move out of the stepper assembly until it comes to rest in stepper's programmed start position.
 - H. Once stepper motor function has been verified, remove power from ESM system.
 - I. Disconnect harness from stepper.

NOTE: The Fisher 99 regulator uses a gasket and shim to make sure the stepper-to-regulator interface is well seated. The gasket and shim make electrical connection convenient and minimize mechanical stress on the connector.

8. Fisher 99 Regulator – verify gasket and shim on stepper are installed (see Figure 4.05-15).
9. Fisher 99 Regulator – apply anti-seize compound to threads of stepper.
10. Fisher 99 Regulator – place control spring in position and install stepper onto fuel regulator.

ESM SYSTEM MAINTENANCE

11. Mooney Regulator – apply Lubriplate No. 105™ or petroleum grease to spring washer. Washer prevents control spring from “binding” on diaphragm assembly when compressed (see Figure 4.05-16).

12. Mooney Regulator – install control spring and secure stepper into pilot body with capscrews.

13. Reconnect harness to stepper.

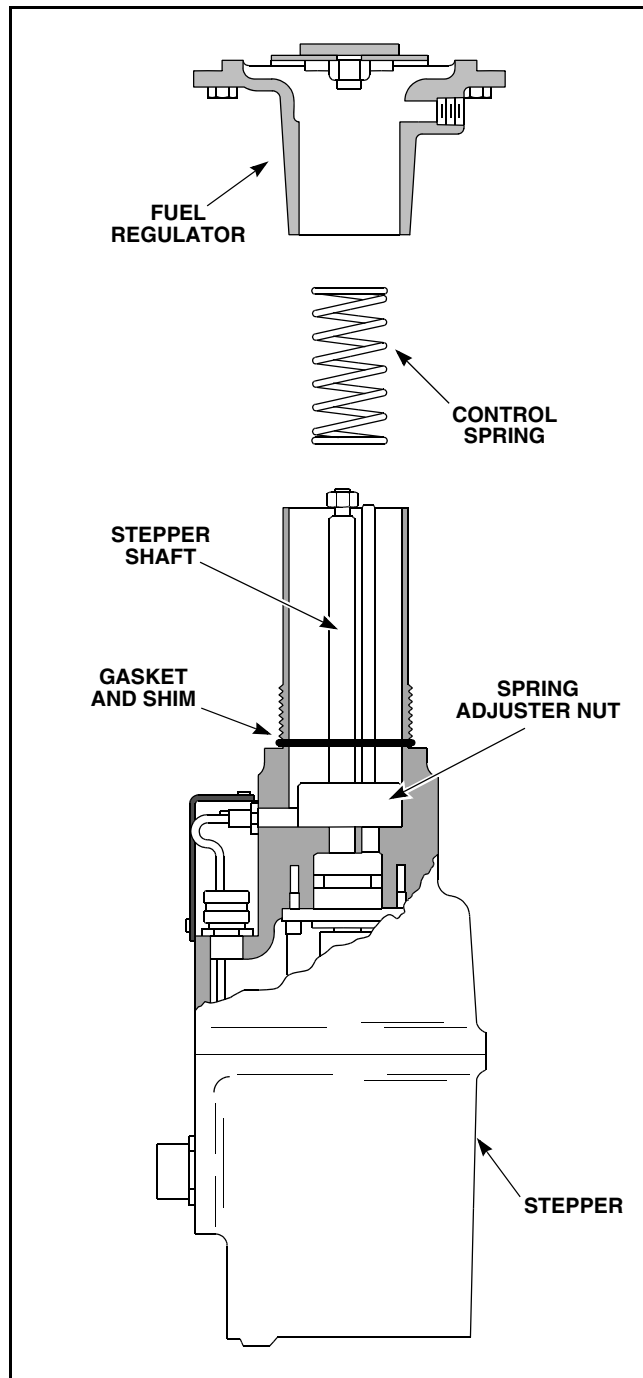


Figure 4.05-15 AFR Stepper (Fisher 99 Regulator)

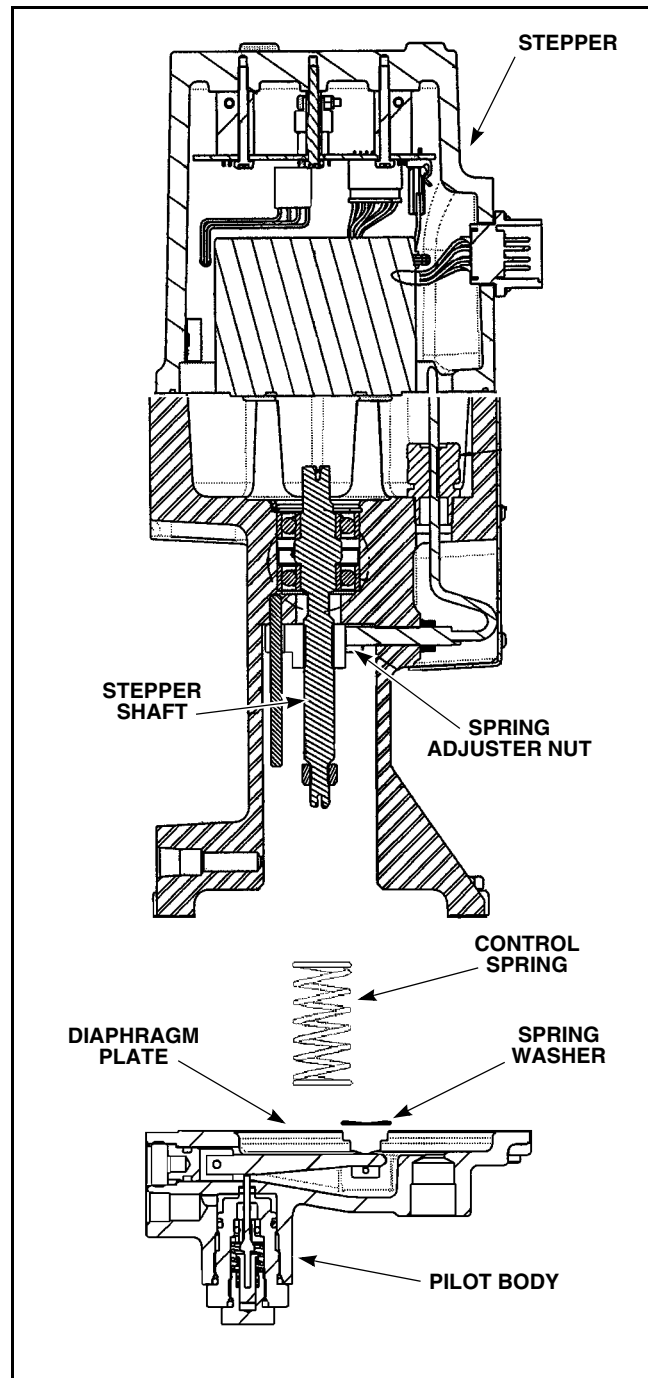


Figure 4.05-16 AFR Stepper (Mooney Regulator)

ESM SYSTEM WIRING

WARNING

Do not install, set up, maintain, or operate any electrical components unless you are a technically qualified individual who is familiar with the electrical elements involved. Electrical shock can cause severe personal injury or death.

WARNING

Disconnect all electrical power supplies before making any connections or servicing any part of the electrical system. Electrical shock can cause severe personal injury or death.

CAUTION

Disconnect all engine harnesses and electronically controlled devices before welding on or near an engine. Failure to comply will void product warranty. Failure to disconnect the harnesses and electronically controlled devices could result in product damage and/or personal injury.

Inspect all ESM system wiring harnesses and make sure all connections are secure. For information on ESM system wiring, harness connections, and power supply requirements, refer to Section 2.00 *Power Requirements*, Section 2.05 *Power Distribution Junction Box*, and Section 2.10 *System Wiring Overview* in this manual.

BATTERY MAINTENANCE

WARNING

Comply with the battery manufacturer's recommendations for procedures concerning proper battery use and maintenance. Improper maintenance or misuse can cause severe personal injury or death.

WARNING

Batteries contain sulfuric acid and generate explosive mixtures of hydrogen and oxygen gases. Keep any device that may cause sparks or flames away from the battery to prevent explosion. Batteries can explode causing severe personal injury or death.

WARNING

Always wear protective glasses or goggles and protective clothing when working with batteries. You must follow the battery manufacturer's instructions on safety, maintenance and installation procedures. Failure to follow the battery manufacturer's instructions can cause severe personal injury or death.

NOTE: Perform an external inspection of the battery before checking the indicated state of charge to verify that the battery is in good physical condition.

EXTERNAL INSPECTION

Periodically inspect batteries and determine their condition. The cost of replacing other components, if they have been damaged by electrolyte corrosion, could be alarmingly high and accidental injuries could ensue. Any batteries that have cracks or holes in the container, cover, or vents, through which electrolyte will leak, should be replaced. Batteries contaminated with electrolyte (caused by over-topping with water), which have corroded terminal posts or low electrolyte levels, have been neglected.

1. Examine the battery externally.
2. Verify electrolyte levels are correct.
3. See Table 4.05-4 troubleshooting chart.

BATTERY INDICATED STATE OF CHARGE

NOTE: The battery must be fully charged for several hours before testing. If batteries have been receiving a charge current within the previous few hours, the open-circuit voltage may read misleadingly high. The surface charge must be removed before testing. To remove surface charge, the battery must experience a load of 20 amps for 3-plus minutes.

1. Use a temperature compensated hydrometer to measure the electrolyte specific gravity readings in each cell. Record the readings.
2. Measure the open-circuit voltage across the terminals. Record the reading.
3. Using the recorded values, determine the state of charge (see Table 4.05-2).
4. See Table 4.05-4 troubleshooting chart.

The state of charge listed is an approximation. The relationship between state of charge and voltage varies by CCA rating and size. Voltage below 11.90 V may mean that the battery has a shorted cell or that the plates are sulfated and cannot accept a charge. See Table 4.05-2.

ESM SYSTEM MAINTENANCE

Table 4.05-2 Determining State of Charge

VOLTAGE	STATE OF CHARGE	SPECIFIC GRAVITY
12.70 & Above	100 %	.280
12.50	75 %	.240
12.30	50 %	.200
12.10	25 %	.170
11.90 & Below	Discharged	.140

Table 4.05-3 Cranking Amps – Commercial Batteries

	4D	8D
CCA @ 0° F (-18° C)	1000A	1300A
CA @ 32° F (0° C)	1200A	1560A
RC minutes @ 25 A	320 min.	435 min.
CCA = Cold Cranking Amps CA = Cranking Amps RC = Reserve Capacity		

Table 4.05-4 Battery Troubleshooting

IF		THEN
Battery Appearance	Has cracks or holes in the container or cover.	Replace battery.
	Has corroded terminals posts.	
	Has black deposits on underside of vent plugs.	Battery has been overcharged (see NOTE 4) Verify battery charger is operating correctly and settings are correct.
	Has black "tide-marks" on inside walls about one inch below the cover.	
Electrolyte Level	Is low.	Fill electrolyte to correct level.
	Is adjusted frequently.	Battery is receiving too much charging current. Verify battery charger is operating correctly and settings are correct.
State of Charge	Is 75% or greater.	Verify battery is good with a high rate load test (see NOTE 3).
	Is between 25% and 75%.	Recharge battery (see NOTE 2).
	Is less than 25%.	Replace battery.
	Measured open-circuit voltage is lower than value given in Table 4.05-2.	
Specific Gravity of Cells	Odd cells with specific gravity readings 0.050 lower than other cells.	Replace battery (internally short-circuited).
	Is uniformly low.	Verify battery charger is operating correctly and settings are correct, and recharge battery (see NOTE 1).

NOTE 1: Batteries with low but uniform specific gravities in each cell that clearly require an extended recharge may have become deeply discharged. This may be nothing more than a battery charger problem, but the system should be checked out before the battery is returned to service.

NOTE 2: Recharging – Batteries which are at less than 75% state of charge need recharging before proceeding with any further tests. Observe that the battery does accept a charging current, even though it may be small in amperes, when the charger is switched on. The battery must be fully charged for several hours before testing. If batteries have been receiving a charge current within the previous few hours, the open-circuit voltage may read misleadingly high. The surface charge must be removed before testing. To remove surface charge, the battery must experience a load of 20 amps for 3 plus minutes.

NOTE 3: High-Rate Load Test – If the state-of-charge is 75% or higher, the battery should be given a high-rate load test. Typically, the high-rate load tester will discharge a battery through an adjustable carbon-pile resistance and indicate the terminal voltage as the discharge proceeds. After 15 seconds, the battery voltage will not drop below a specified value (typically 9.6 V) if the battery is in good condition and if the current is set at about 50% of the Cold Cranking Amps (CCA) (see Table 4.05-3). The minimum acceptable voltage reading will vary as battery temperature decreases. Read and follow the manufacturer's instructions for the tester.

NOTE 4: Overcharging – Batteries that have suffered as a result of considerable overcharging may show extremely low electrolyte levels, black deposits on the underside of the vent plugs, or black "tide-marks" on the inside walls of the container from about one inch below the cover. If these signs are present, the battery charger setting must be checked and reset according to the manufacturer's instructions before a battery is returned to service. Batteries in which electrolyte levels have to be adjusted frequently are clearly receiving too much charging current.

A

Acronyms, *1.10-22*

Actuator

Automatic Calibration, *2.20-4*

Throttle Actuator, *1.10-12*

Advanced Panel, *3.05-36*

AFR Control

Description, *1.10-14*

Alarms

Description, *2.30-2*

List Of Fault Codes, *4.00-7*

Alternate Dynamics

Synchronizer Control, *1.10-13*

Alternator Belts

Maintenance, *4.05-7*

Tension, *4.05-7*

Analog

Outputs, *2.35-11*

Signals, *1.10-18*

B

Battery Maintenance, *4.05-13*

Baud Rate

Definition, *1.10-18*

C

Calibration, *1.10-18*

CD-ROM, *1.10-18*

Clipboard, *3.10-23*

Coolant, *2.30-1*

Customer Interface Harness

Description, *2.10-1*

Loose Wire Identification Table, *2.10-2*

D

DB Connector, *1.10-18*

Definitions

Alternate Dynamics, *1.10-18*

Analog Signals, *1.10-18*

Baud Rate, *1.10-18*

Bypass Control, *1.10-18*

Calibration, *1.10-18*

CD-ROM, *1.10-18*

DB Connector, *1.10-18*

Detonation, *1.10-18*

Detonation Threshold, *1.10-19*

Digital Signals, *1.10-19*

Droop, *1.10-19*

ECU, *1.10-19*

E-Help, *1.10-19*

ESP, *1.10-19*

Fault, *1.10-19*

Fault Log, *1.10-19*

Feedforward Control, *1.10-19*

Free Wheeling Diode, *1.10-19*

Fuel Control Valve, *1.10-19*

Function Keys, *1.10-19*

Graphical User Interface, *1.10-19*

Hard Drive, *1.10-19*

High Signal, *1.10-19*

Icon, *1.10-19*

IPM-D, *1.10-19*

Isochronous, *1.10-19*

Knock Frequency, *1.10-19*

Knock Sensor, *1.10-20*

LED, *1.10-20*

Load Coming, *1.10-20*

Load Control, *1.10-20*

Load Inertia, *1.10-20*

Log File Processor, *1.10-20*

Low Signal, *1.10-20*

Magnetic Pickup, *1.10-20*

Master-Slave Communications, *1.10-20*

MODBUS[®], *1.10-20*

Modem, *1.10-20*

NVRAM, *1.10-20*

Open Circuit, *1.10-20*

Panel, *1.10-20*

Parasitic Load Adjust, *1.10-20*

PC, *1.10-20*

Percent Oxygen Adjustment, *1.10-20*

RAM, *1.10-21*

Random Access Memory, *1.10-21*

RS-232, *1.10-21*

RS-485, *1.10-21*

Sample Window, *1.10-21*

Scale High, *1.10-21*

Scale Low, *1.10-21*

Short or Open Circuit, *1.10-21*

Slave, *1.10-21*

Speed Control, *1.10-21*

Start Position, *1.10-21*

Stepper, *1.10-21*

Stepper Motor, *1.10-21*

Synchronizer Control, *1.10-21*

Training Tool, *1.10-21*

User Interface, *1.10-21*

VGA, *1.10-21*

WKI, *1.10-22*

Detonation Detection

- Definition, *1.10-18*
- Description, *1.10-9*
- Knock Sensor, *1.10-10, 4.05-9*
- Promoters And Reducers, *1.10-11*
- Theory, *1.10-11*
- Threshold, *1.10-19*
- Timing Control, *1.10-11*
- Uncontrollable Knock Safety, *2.30-2*

Diagnostics, *1.10-6*

Digital

- Inputs, *2.35-11*
- Signals, *1.10-19*

Droop

- Definition, *1.10-19*

E

ECU

- Connecting To Modem, *3.10-35*
- Connecting To PC, *3.10-4*
- Definition, *1.10-19*
- Description, *1.10-4*
- Determining Fault Code, *4.00-2*
- Internal Faults, *2.30-2*
- Photo, *1.10-4*
- Resetting LEDs, *3.10-23*
- Status LEDs, *1.10-4*

E-Help

- Command Bar, *4.00-4*
- Definition, *1.10-19*
- Description, *1.10-5, 3.00-6, 4.00-3*
- Document Pane, *4.00-6*
- Navigation Pane, *4.00-5*
- Troubleshooting, *4.00-3*

Electronic Help

- E-Help, *1.10-5, 3.00-6*

Electronic Service Program

- ESP, *1.10-5*

Emergency Stop

- Buttons, *2.30-2*
- Description, *2.15-1*
- ESTOP SW Wire, *2.05-4*
- Sequence Diagram, *2.15-6*

Engine Control Unit

- ECU, *1.10-4*

Engine Panel, *3.05-2*

Engine Stall, *2.30-2*

Engine System Manager

- ESM, *1.10-1*

ESM

- Acronyms, *1.10-22*
- Additional Assistance Troubleshooting, *4.00-1*
- Alarms, *2.30-2*
- Battery Requirements, *2.00-2*
- Components, *1.10-4*
- Definitions, *1.10-18*
- Description, *1.10-1*
- Detonation Detection, *1.10-9*
- Diagnostics Overview, *1.10-6*
- E-Help, *1.10-5, 3.00-6*
- Electronic Service Program, *1.10-5*
- Engine Control Unit, *1.10-4*
- Fault Codes, *4.00-7*
- Fuel Valve, *2.25-1*
- Governing, *1.10-12, 2.20-1*
- Ignition Power Module With Diagnostics, *1.10-8*
- Ignition System, *1.10-8*
- Local Control Panel, *2.35-10*
- Maintenance, *4.05-1*
- MODBUS[®], *2.35-1*
- Power Distribution Box, *2.05-1*
- Power Requirements, *2.00-1*
- Programming, *3.10-1*
- Safety Shutdowns, *1.10-7, 2.30-1*
- Start-Stop Control, *1.10-7, 2.15-1*
- Theory of Operation, *2.05-1*
- Troubleshooting, *4.00-1*
- User Interface Panels, *1.10-5*

ESP

- Basic Programming, *3.10-5*
- Computer Requirements, *3.00-2*
- Conventions, *3.00-2*
- Definition, *1.10-19*
- Description, *1.10-5, 3.00-1*
- Determining Fault Code, *4.00-2*
- Icon, *1.10-5*
- Installation, *3.10-4*
- Logging System Parameters, *3.10-24*
- Maintenance, *4.05-2*
- Modem Access, *3.10-34*
- Panel Descriptions
 - [F10] Status Panel, *3.05-30*
 - [F11] Advanced Panel, *3.05-36*
 - [F2] Engine Panel, *3.05-2*
 - [F3] Start-Stop Panel, *3.05-4*
 - [F4] Governor Panel, *3.05-8*
 - [F5] Ignition Panel, *3.05-14*
 - [F6] AFR Primary Fuel, *3.05-20*
 - [F8] AFR Setup - Typical, *3.05-26*
- Fault Log, *3.05-38*
- Introduction, *3.05-1*
- Saving Information, *3.00-2*

Saving To Permanent Memory, *3.10-7*
 Starting Program, *3.10-5*
 Taking Screen Captures, *3.10-24*
 Training Tool, *1.10-21*
 Troubleshooting, *4.00-1*
 User Interface Panels, *1.10-5, 3.00-3*

F

Fault

Alarm Codes, *4.00-7*
 Definition, *1.10-19*
 History, *4.05-2*

Fault Log

Copying Information To Clipboard, *3.10-23*
 Definition, *1.10-19*
 Description, *3.00-5*
 Field Descriptions, *3.05-38*

Feedforward Control

Definition, *1.10-19*
 Description, *1.10-13*
 Governing, *2.20-4*

Fixed Speed

Description, *2.20-1*
 Logic Diagram, *2.20-2*
 Programming, *3.10-19*

Free Wheeling Diode, *1.10-19*

Fuel Valve

Description, *2.25-1*
 Wiring, *2.25-1*
 WKI, *2.25-2*

Function Keys, *1.10-19*

G

Gain Adjustments, *2.20-4*

Gas Shutoff Valve

Fuel Valve, *2.25-1*

Governing

Actuator And Throttle, *1.10-13*
 Adjusting Gain, *2.20-4*
 Calibrations, *1.10-13*
 Description, *1.10-12, 2.20-1*
 Droop, *1.10-19*
 Feedforward Control, *1.10-13, 2.20-4*
 Fixed Speed, *2.20-1*
 Inputs, *1.10-13*
 Load Control, *2.20-3*
 Programming In ESP, *3.10-18*
 Rotating Moment Of Inertia, *2.20-4*
 Speed Control Mode, *2.20-1*
 Speed Modes, *1.10-13*

Synchronizer Control, *1.10-13*
 Theory, *1.10-12*
 Variable Speed, *2.20-1*

Governor Panel, *3.05-8*

Graphical User Interface

Definition, *1.10-19*
 Picture, *1.10-6*

H

Harnesses

Customer Interface Harness, *2.10-1*
 Local Control Option Harness, *2.05-4*
 Start Harness, *2.25-1*
 Wiring Diagram, *2.10-1*

High Signal, *1.10-19*

How To Use This Manual, *1-v*

I

Icon

Definition, *1.10-19*

Ignition Panel, *3.05-14*

Ignition Power Module With Diagnostics

IPM-D, *1.10-8*

Ignition System

Description, *1.10-8*
 Theory, *1.10-8*

Intake Manifold, *2.30-1*

IPM-D

Definition, *1.10-19*
 Description, *1.10-8*
 Photo, *1.10-8*
 Programming, *3.10-20*

Isochronous, *1.10-19*

K

Knock

Detonation Detection, *1.10-19*

Knock Frequency, *1.10-19*

Knock Sensor

Definition, *1.10-20*
 Detonation Detection, *1.10-9*
 Installation, *4.05-9*
 Maintenance, *4.05-9*
 Photo, *1.10-10, 4.05-9*

L

LEDs

- Definition, *1.10-20*
- Description, *1.10-4*
- Determining Fault Code, *4.00-2*
- Resetting, *3.10-23*

Load Coming

- Feedforward Control, *1.10-13*

Load Control

- Definition, *1.10-20*
- Description, *1.10-13*
- Governing, *2.20-3*

Load Inertia

- Description, *2.20-4*
- Tables, *3.10-9*

Local Control Option Harness

- +24VFOR U, *2.05-4*
- Description, *2.05-4*
- ESTOP SW, *2.05-4*
- G LEAD, *2.05-4*
- GND FOR U, *2.05-4*
- GOV SD+, *2.05-5*
- GOVSD+24V, *2.05-5*
- Loose Wire Identification Table, *2.10-7*

Local Control Panel

- Description, *2.35-10*
- Local Displays, *2.35-10*
- MODBUS[®], *2.35-1*
- User Analog Outputs, *2.35-11*
- User Digital Inputs, *2.35-11*

Logging System Parameters, *3.10-24*

Low Signal, *1.10-20*

M

Magnetic Pickups

- Definition, *1.10-20*
- On Cam Gear Cover, *1.10-9*
- On Flywheel, *1.10-9*
- Photos, *1.10-9*
- Safeties, *2.30-2*

Maintenance

- Alternator Belts, *4.05-7*
- Chart, *4.05-1*
- ESP Total Fault History, *4.05-2*
- Knock Sensors, *4.05-9*
- Stepper, *4.05-11*
- Throttle Actuator Linkage, *4.05-2*
- Wiring, *4.05-13*

Master-Slave Communications, *1.10-20*

MODBUS[®]

- Baud Rate, *1.10-18, 1.10-19*
- Communication Parameters, *2.35-1*
- Data Tables, *2.35-3*
- Definition, *1.10-20*
- Description, *2.35-1*
- Fault Code Behavior, *2.35-2*
- Function Code 01 Table, *2.35-4*
- Function Code 02 Table, *2.35-4*
- Function Code 03 Table, *2.35-5*
- Local Control Panel, *2.35-10*
- Master-Slave Communications, *1.10-20*
- Protocol, *2.35-2*
- Slave, *1.10-21*
- Wiring, *2.35-1*

Modem

- Definition, *1.10-20*
- Programming, *3.10-32*

Most Retarded Timing, *1.10-21*

N

Non-Code Troubleshooting, *4.00-10*

NVRAM

- Definition, *1.10-20*
- ECU, *3.00-2*
- Saving In ESP, *3.10-7*

O

Oil Pressure, *2.30-1*

Overcrank, *2.30-2*

Overload, *2.30-2*

Overspeed, *2.30-1*

Oxygen Sensor Replacement, *4.05-10*

P

Panels

- User Interface Panels, *3.00-3*

PC

- Connecting To ECU, *3.10-4*
- Connecting To Modem, *3.10-35*
- Definition, *1.10-20*
- Requirements, *3.00-2*

Permanent Memory

- Description, *3.00-2*
- Saving To, *3.10-7*

Personal Computer

- PC, *1.10-20*

PLC

Definition, *1.10-20*
 Local Control Panel, *2.35-10*
Power Distribution Box
 Connecting 24 VDC Power, *2.05-1*
 Description, *2.05-1*
 Local Control Option Harness
 Description, *2.05-4*
 Loose Wire Identification Table, *2.10-7*
 Shutdown Information, *2.05-4*
 Wiring Diagram, *2.10-1*
Power Supply
 24 VDC Supply By Customer, *2.00-4, 2.00-7*
 Air Start And Alternator, *2.00-3, 2.00-6*
 Electric Start And Alternator, *2.00-5, 2.00-8*
 Power Distribution Box, *2.05-1*
 Shutdown Information, *2.05-4*
 Specifications, *2.00-1*
 Wiring Diagram, *2.10-1*
Programmable Logic Controller
 PLC, *1.10-20*
Programming
 Computer Requirements, *3.00-2*
 Connecting PC To ECU, *3.10-4*
 Conventions, *3.00-2*
 ECU MODBUS® Slave ID, *3.10-29*
 Governor
 Feedforward, *3.10-19*
 Fixed Speed, *3.10-19*
 Synchronizer, *3.10-20*
 Variable Speed, *3.10-18*
 Installing ESP, *3.10-4*
 Introduction, *3.10-1*
 IPM-D
 High Voltage Adjustment, *3.10-21*
 Low Voltage Adjustment, *3.10-22*
 No Spark Adjustment, *3.10-22*
 Panel Color Key, *3.00-2*
 Saving Information, *3.00-2*
 Starting ESP, *3.10-5*
 User Interface Panel Descriptions
 [F10] Status Panel, *3.05-30*
 [F11] Advanced Panel, *3.05-36*
 [F2] Engine Panel, *3.05-2*
 [F3] Start-Stop Panel, *3.05-4*
 [F4] Governor Panel, *3.05-8*
 [F5] Ignition Panel, *3.05-14*
 [F6] AFR Primary Fuel Panel, *3.05-20*
 [F8] AFR Setup Panel- Typical, *3.05-26*
 Fault Log, *3.05-38*
 Introduction, *3.05-1*

R

RAM
 Definition, *1.10-21*
 ECU, *3.00-2*
Random Access Memory
 RAM, *1.10-21*
Rotating Moment Of Inertia
 Load Inertia, *2.20-4*
RS-232, *1.10-21*
RS-485, *1.10-21*

S

Safeties - ESM System
 Alarms, *2.30-2*
 Coolant Over Temperature, *2.30-1*
 Customer Initiated Emergency Shutdown, *2.30-2*
 ECU Internal Faults, *2.30-2*
 Emergency Stop Buttons, *2.30-2*
 Engine Overload, *2.30-2*
 Engine Overspeed, *2.30-1*
 Engine Stall, *2.30-2*
 Intake Manifold Over Temperature, *2.30-1*
 Low Oil Pressure, *2.30-1*
 Magnetic Pickups, *2.30-2*
 Overcrank, *2.30-2*
 Security Violation, *2.30-2*
 Uncontrollable Engine Knock, *2.30-2*
Safety
 Acids, *1.00-2*
 Batteries, *1.00-2*
 Body Protection, *1.00-2*
 Chemicals, *1.00-2*
 Cleaning Solvents, *1.00-2*
 General, *1.00-2*
 Liquid Nitrogen/Dry Ice, *1.00-2*
 Components, *1.00-2*
 Heated Or Frozen, *1.00-2*
 Interference Fit, *1.00-2*
 Cooling System, *1.00-3*
 Electrical, *1.00-3*
 General, *1.00-3*
 Ignition, *1.00-3*
 Equipment Repair And Service, *1.00-1*
 Exhaust, *1.00-3*
 Fire Protection, *1.00-3*
 Fuels, *1.00-3*
 Gaseous, *1.00-3*
 General, *1.00-3*
 Liquid, *1.00-4*
 Intoxicants And Narcotics, *1.00-4*

- Pressurized Fluids/Gas/Air, 1.00-4
- Protective Guards, 1.00-4
- Safety Tags And Decals, 1.00-1
- Springs, 1.00-4
- Tools, 1.00-4
 - Electrical, 1.00-4
 - Hydraulic, 1.00-4
 - Pneumatic, 1.00-5
- Weight, 1.00-5
- Welding, 1.00-5
 - General, 1.00-5
 - On Engine, 1.00-5
- Safety Shutdowns
 - Shutdown, 1.10-7
- Sample Window, 1.10-21
- Screen Captures, 3.10-24
- Security Violations, 2.30-2
- Sensors
 - Engine Mounted, 1.10-4
- Shutdown
 - Emergency Stop Sequence Diagram, 2.15-6
 - Information, 2.05-4
 - Safeties, 1.10-7
 - Coolant Over-Temperature, 2.30-1
 - Customer-Initiated Emergency Shutdown, 2.30-2
 - ECU Internal Faults, 2.30-2
 - Emergency Stop Buttons, 2.30-2
 - Engine Overload, 2.30-2
 - Engine Overspeed, 2.30-1
 - Engine Stall, 2.30-2
 - Intake Manifold Overtemperature, 2.30-1
 - Low Oil Pressure, 2.30-1
 - Magnetic Pickups, 2.30-2
 - Oil Over-Temperature, 2.30-1
 - Overcrank, 2.30-2
 - Security Violation, 2.30-2
 - Uncontrollable Knock, 2.30-2
 - Start-Stop Control, 2.15-1
 - Stop Sequence Diagram, 2.15-5
- Slave, 1.10-21
- Speed Control
 - Definition, 1.10-21
 - Description, 1.10-13
 - Governing, 2.20-1
- Speed Governing
 - Governing, 1.10-12, 1.10-14
- Stall, 2.30-2
- Start-Stop Control
 - Description, 1.10-7, 2.15-1
 - Emergency Stop Sequence Diagram, 2.15-6
 - Start Sequence Diagram, 2.15-4
 - Stop Sequence Diagram, 2.15-5

- Start-Stop Panel, 3.05-4
- Startup
 - Initial Programming, 3.10-2
 - Start Sequence Diagram, 2.15-4
 - Start-Stop Control, 2.15-1
- Status LEDs
 - LEDs, 1.10-4
- Status Panel, 3.05-30
- Stepper Maintenance, 4.05-11
- Synchronizer Control
 - Definition, 1.10-21
 - Description, 1.10-13
 - Programming, 3.10-20
- System Requirements, 3.00-2

T

- Theory
 - Detonation, 1.10-11
 - Governing, 1.10-12
 - Ignition, 1.10-8
- Throttle Actuator
 - Calibration, 3.10-16
 - Description, 1.10-12
 - Linkage Adjustment, 4.05-2
 - Maintenance, 4.05-2
 - Photo, 1.10-13
 - Programming, 3.10-16
- Torque Values, 1.05-2
- Training Tool, 1.10-21
- Troubleshooting
 - Determining Fault Code, 4.00-2
 - E-Help, 4.00-3
 - Fault Codes, 4.00-7
 - Introduction, 4.00-1
 - Maintenance Chart, 4.05-1
 - Non-Code, 4.00-10
 - Non-Code Troubleshooting, 4.00-10

U

- Units – U.S./Metric, 3.10-23
- User Digital Inputs, 2.35-11
- User Interface Panels
 - [F10] Status, 3.00-5, 3.05-30
 - [F11] Advanced, 3.00-5, 3.05-36
 - [F2] Engine, 3.00-3, 3.05-2
 - [F3] Start-Stop, 3.00-3, 3.05-4
 - [F4] Governor, 3.00-4, 3.05-8
 - [F5] Ignition, 3.00-4, 3.05-14
 - [F6] AFR PRI, 3.00-4, 3.05-20

[F8] AFR Setup, *3.00-5, 3.05-26*
 Color Key, *3.00-2*
 Definition, *1.10-21*
 Description, *1.10-5*
 Fault Log, *3.00-5*

V

Variable Speed
 Description, *2.20-1*
 Logic Diagram, *2.20-3*
 Programming, *3.10-18*
 VGA, *1.10-21*

W

Waukesha Knock Index
 WKI, *1.10-22*
 Wiring
 Diagram, *2.10-1*
 Fuel Valve, *2.25-1*
 Maintenance, *4.05-13*
 MODBUS[®], *2.35-1*
 Power Distribution Box, *2.05-1*
 Power Specifications, *2.00-1*
 Power Supply
 Air Start And Alternator, *2.00-3, 2.00-6*
 Battery Cable Lengths, *2.00-9*
 Electric Start And Alternator, *2.00-5, 2.00-8*
 Supply By Customer, *2.00-4, 2.00-7*
 Requirements, *1.05-5*
 Shutdown Information, *2.05-4*
 WKI
 Definition, *1.10-22*
 Description, *2.25-2*
 Programming, *3.10-8*

**WAUKESHA ENGINE, DRESSER, INC. - EXPRESS LIMITED WARRANTY COVERING
PRODUCTS USED IN CONTINUOUS DUTY APPLICATIONS**

INTRODUCTION

CONTINUOUS DUTY DEFINITION: The highest load and speed which can be applied, subject to Waukesha's approved ratings in effect at time of sale.

I. TERMS OF EXPRESS LIMITED WARRANTY

- A. Waukesha Engine warrants that it will repair or replace, AT ITS ELECTION AND EXPENSE, any Genuine Waukesha Service Part installed on an engine, or Enginator®, or product (hereinafter referred to as "Products") manufactured by Waukesha, which proves to have had a defect in material or workmanship.
- B. Waukesha Engine further warrants that it will repair or replace, AT ITS ELECTION AND EXPENSE, any component of the Waukesha Product damaged as the direct result of a warrantable defect in a Product during the term of coverage.

II. TERM LIMITATIONS OF EXPRESS LIMITED WARRANTY

- A. This coverage shall commence upon initial new Products start-up date and shall expire upon the earlier of the following:
 - 1. 12 months after the initial new Products start-up date; or
 - 2. 24 months after the original shipment date of the covered Products by Waukesha Engine.
- B. Notwithstanding the foregoing, Waukesha further warrants that the cylinder block casting, cylinder head castings, connecting rod forgings, and crankshaft forging will be free from defects in material or workmanship. This additional warranty only covers failures of the specific items noted within this subparagraph.

This coverage shall expire upon the earlier of the following:

- 1. 60 months after the initial new Products start-up date; or
- 2. 25,000 hours of operation of the covered Products; or
- 3. 72 months after the original shipment date of the covered Products by Waukesha Engine.

NOTE: No damage from other sources, such as damage from the loss of a crankshaft bearing, shall be considered as a forging defect.

III. WAUKESHA'S RESPONSIBILITIES UNDER THE EXPRESS LIMITED WARRANTY

Waukesha shall be responsible for:

- A. The repair or replacement, at Waukesha's election, of covered defective parts and all reasonable labor required regarding a warranted failure during the express limited warranty term. All such labor shall be provided by Waukesha's authorized contractor or distributor.
- B. Reasonable and necessary travel and expenses incurred by Waukesha's authorized contractor or distributor.
- C. Replacement of lubricating oil, coolant, filter elements, or other normal maintenance items that are contaminated and/or damaged as a direct result of a warranted failure.

IV. OWNER'S RESPONSIBILITIES UNDER THE EXPRESS LIMITED WARRANTY

Owner shall be responsible for:

- A. The operation and maintenance of the Products within the guidelines established by Waukesha.
- B. Making the Products available to Waukesha or Waukesha's authorized contractors or distributors for any warranty repair, during normal business hours.
- C. All additional costs incurred for premium or overtime labor, should owner request that repairs be made on a premium or overtime schedule.
- D. All costs incurred as the result of removal or reinstallation of the Products as may be required to effect any warranted repair.
- E. All administrative costs and expenses resulting from a warranted failure.
- F. Any costs of transportation, towing, repair facilities, or associated costs.
- G. All labor, travel, mileage, and other related costs and expenses associated with a claim made pursuant to subparagraph II (B) above.
- H. Loss of revenue and loss of or damage to real and/or personal property.

V. LIMITATION OF WAUKESHA'S OBLIGATIONS

The obligations of Waukesha under this express limited warranty shall be waived and voided, and Waukesha shall not, thereafter, be responsible for:

- A. Any failure resulting from owner or operator abuse or neglect, including but not by way of limitation, any operation, installation, application, or maintenance practice not in accordance with guidelines or specifications established by Waukesha; or
- B. Any failure resulting from unauthorized modifications or repairs of the Products; or
- C. Any failure resulting from overload, overspeed, overheat, accident, improper storage; or
- D. Failure of owner to promptly provide notice of a claimed defect; or
- E. Failure of Products for which Waukesha did not receive properly completed start-up reports; or
- F. Repairs of a covered failure performed with non-genuine Waukesha parts; or
- G. Repairs of a covered failure performed by non-authorized contractors or distributors; or
- H. Failure to make Products available to Waukesha or its authorized representatives; or
- I. Failure to supply documents such as drawings and specifications relating to the specific application of the Products.

VI. APPLICABILITY AND EXPIRATION

The warranties set out above are extended to all owners in the original chain of distribution. The warranties and obligations of Waukesha shall expire and be of no further effect upon the dates of expiration of the applicable warranty periods.

THE FOREGOING SETS FORTH WAUKESHA'S ONLY OBLIGATIONS AND OWNERS' EXCLUSIVE REMEDY FOR BREACH OF WARRANTY, WHETHER SUCH CLAIMS ARE BASED ON BREACH OF CONTRACT, TORT (INCLUDING NEGLIGENCE AND STRICT LIABILITY), OR OTHER THEORIES, AND THE FOREGOING IS EXPRESSLY IN LIEU OF OTHER WARRANTIES WHATSOEVER EXPRESSED, IMPLIED, AND STATUTORY, INCLUDING WITHOUT LIMITATION, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE.

Notwithstanding the preceding, in no event shall Waukesha be liable for any direct, special, incidental, or consequential damages (whether denominated in contract, tort strict liability, negligence, or other theories) arising out of this Agreement or the use of any Products provided under this Agreement.

Any action arising hereunder or relating hereto, whether based on breach of contract, tort (including negligence and strict liability), or other theories must be commenced within two (2) years after the cause of action accrues or it shall be barred.

BINDING ARBITRATION

- (a) Buyer and Seller shall attempt, in good faith, to resolve any dispute arising out of or relating to this agreement, or the products and/or services provided hereunder, promptly by negotiation between executives. If the matter has not been resolved within sixty (60) days of a party's request for negotiation, either party may initiate arbitration as herein after provided.
- (b) Any dispute arising out of or related to this agreement or the products and/or services provided hereunder which has not been resolved by the negotiation procedure described above, shall be settled by binding arbitration administered by the American Arbitration Association in accordance with its Commercial Arbitration Rules and judgment on the award rendered by the arbitrator(s) may be entered in any court having jurisdiction thereof.
- (c) Unless Buyer and Seller otherwise agree in writing, the arbitration panel shall consist of three arbitrators. The arbitrator(s) shall have no authority to award punitive or other damages not measured by the prevailing party's actual damages and may not, in any event, make any ruling, finding or award that does not conform to the terms and condition of this agreement. The law of Texas shall govern.
- (d) The arbitration proceeding shall be conducted in English, in Dallas, Texas.

See form M464 for the most current warranty terms. Effective February 22, 2006

**WAUKESHA ENGINE, DRESSER, INC. - EXPRESS LIMITED WARRANTY FOR
GENUINE WAUKESHA SERVICE PARTS AND WAUKESHA FACTORY REMANUFACTURED SERVICE PARTS**

INTRODUCTION

This warranty only applies to Genuine Waukesha Service Parts and Waukesha Factory Remanufactured Service Parts (to include assemblies and short blocks) (hereinafter referred to as "Service Parts") sold by Waukesha Engine and used for repair, maintenance, or overhaul of Waukesha Products.

I. TERMS OF EXPRESS LIMITED WARRANTY

- A. Waukesha Engine warrants that it will repair or replace, AT ITS ELECTION AND EXPENSE, any Genuine Waukesha Service Part installed on an engine, or Enginator®, or product (hereinafter referred to as "Products") manufactured by Waukesha, which proves to have had a defect in material or workmanship.
- B. Waukesha Engine Division further warrants that it will repair or replace, AT ITS ELECTION AND EXPENSE, any component of the Waukesha Product damaged as the direct result of a warrantable defect in a Product during the term of coverage.

II. TERM LIMITATIONS OF EXPRESS LIMITED WARRANTY

This coverage shall commence upon the date the Service Part is installed and shall expire upon the earlier of the following:

- A. 12 months after the date the part is installed; or
- B. 24 months after the purchase date from an authorized Waukesha Distributor.

III. WAUKESHA'S RESPONSIBILITIES UNDER THE EXPRESS LIMITED WARRANTY

Waukesha shall be responsible for:

- A. The repair or replacement, at Waukesha's election, of covered defective Service Parts and progressive damage as explained in Paragraph 1B of this warranty.
- B. Labor time to repair or replace the defective part as established by the Waukesha Labor Guide Manual. All reimbursable labor costs shall be provided by Waukesha's authorized Distributor.
- C. The reimbursement of documented Distributor expenses covering Freight, Customs, Brokers Fees, and Import Duties to obtain the replacement Service Part from Waukesha.

IV. OWNER'S RESPONSIBILITIES UNDER THE EXPRESS LIMITED WARRANTY

Owner shall be responsible for:

- A. The operation and maintenance of the Products/Service Parts within the guidelines established by Waukesha.
- B. Making The Products/service Parts available to Waukesha or Waukesha's authorized Distributors for any warranty repair, during normal business hours.
- C. All additional costs incurred for premium or overtime labor, should owner request that repairs be made on a premium or overtime schedule.
- D. All costs incurred as the result of removal or reinstallation of the Products as may be required to effect any warranted repairs.
- E. All administrative costs and expenses resulting from a warranted failure.
- F. Any costs of transportation, towing, repair facilities, or associated costs.
- G. All travel, mileage, and other related Distributor costs and expenses associated with repair under the terms of this Service Parts Warranty.
- H. All additional labor time in excess of Waukesha's Labor Guide for the warrantable repair.
- I. Loss of revenue and loss of/or damage to real and/or personal property.

V. Limitation Of Waukesha's Obligations

The obligations of Waukesha under this express limited warranty shall be waived and voided, and Waukesha shall not, thereafter, be responsible for:

- A. Any failure resulting from owner or operator abuse or neglect, including but not by way of limitation, any operation, installation, application, maintenance, or assembly practice not in accordance with guidelines or specifications established by Waukesha; or
- B. Any failure resulting from unauthorized modifications or repairs of the Products or Service Parts; or
- C. Any failure resulting from overload, overspeed, overheat, accident; or
- D. Failure of owner to promptly provide notice of a claimed defect; or
- E. Failure of Service Parts for which Waukesha did not receive proper documentation concerning the Service Parts purchase date from an authorized Waukesha Engine Distributor; or
- F. Repairs of a covered failure performed with non-genuine Waukesha parts; or
- G. Repairs of a covered failure performed by non-authorized contractors or distributors; or
- H. Failure to make Products and Service Parts available to Waukesha or its authorized representative; or
- I. Failure to supply documents such as drawings and specifications relating to the specific application of the Products; or
- J. Any failure of Service Parts resulting from misapplication or improper repair procedures; or
- K. Any failure or damage resulting from the improper or extended storage of a Service Part; or
- L. Freight, Customs, Broker Fees, and Import Duties if appropriate documentation is not provided; or
- M. Normal wear items or consumable parts such as belts, spark plugs, lubricating oil filters, air filters, etc. are not considered defective if in need of routine replacement, rebuild, or maintenance during the term of the warranty.

VI. APPLICABILITY AND EXPIRATION

The warranty set out above is extended to the original purchaser of the Genuine Waukesha Service Parts. The warranty and obligations of Waukesha shall expire and be of no further effect upon the date of expiration of the applicable warranty period.

VII. WARRANTY ADMINISTRATION

This warranty is administered exclusively by an authorized Waukesha Distributor. The invoice for the failed Service Parts must be provided to the distributor to determine whether the warranty is applicable.

Contact the nearest authorized Waukesha Distributor for assistance with warranty matters or questions. The location of the nearest authorized Distributor is available by contacting Waukesha Engine at (262) 547-3311.

THE FOREGOING SETS FORTH WAUKESHA'S ONLY OBLIGATIONS AND OWNERS' EXCLUSIVE REMEDY FOR BREACH OF WARRANTY, WHETHER SUCH CLAIMS ARE BASED ON BREACH OF CONTRACT, TORT (INCLUDING NEGLIGENCE AND STRICT LIABILITY), OR OTHER THEORIES, AND THE FOREGOING IS EXPRESSLY IN LIEU OF OTHER WARRANTIES WHATSOEVER EXPRESSED, IMPLIED, AND STATUTORY, INCLUDING WITHOUT LIMITATION, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE.

Notwithstanding the preceding, in no event shall Waukesha be liable for any direct, special, incidental, or consequential damages (whether denominated in contract, tort strict liability, negligence, or other theories) arising out of this Agreement or the use of any products provided under this Agreement.

Any action arising hereunder or relating hereto, whether based on breach of contract, tort (including negligence and strict liability), or other theories must be commenced within two (2) years after the cause of action accrues or it shall be barred.

BINDING ARBITRATION

- (a) Buyer and Seller shall attempt, in good faith, to resolve any dispute arising out of or relating to this agreement, or the products and/or services provided hereunder, promptly by negotiation between executives. If the matter has not been resolved within sixty (60) days of a party's request for negotiation, either party may initiate arbitration as hereinafter provided.
- (b) Any dispute arising out of or related to this agreement or the products and/or services provided hereunder which has not been resolved by the negotiation procedure described above, shall be settled by binding arbitration administered by the American Arbitration Association in accordance with its Commercial Arbitration Rules and judgment on the award rendered by the arbitrator(s) may be entered in any court having jurisdiction thereof.
- (c) Unless Buyer and Seller otherwise agree in writing, the arbitration panel shall consist of three arbitrators. The arbitrator(s) shall have no authority to award punitive or other damages not measured by the prevailing party's actual damages and may not, in any event, make any ruling, finding or award that does not conform to the terms and conditions of this agreement. The law of Texas shall govern.
- (d) The arbitration proceeding shall be conducted in English, in Dallas, Texas.

See Form M-463 for the most current warranty terms; effective February 22, 2006.

**WAUKESHA ENGINE, DRESSER, INC. EXPRESS LIMITED WARRANTY
FOR PRODUCTS OPERATED IN EXCESS OF CONTINUOUS DUTY RATINGS**

INTRODUCTION

This warranty only applies to engines which Waukesha Engine has approved to operate in excess of the continuous duty rating.

APPLICATIONS COVERED BY THIS WARRANTY

Standby Service Applications: This rating applies to those systems used as a secondary or backup source of electrical power. This rating is the output the system will produce continuously (no overload), 24 hours per day for the duration of the prime power source outage.

Intermittent Service Applications: This rating is the highest load and speed that can be applied in variable speed mechanical system applications only (i.e., blowers, pumps, compressors, etc.). Operation at this rating is limited to a maximum of 3500 hours/year. For continuous operation for any length of time between the continuous and intermittent ratings, see the Peak Shaving Application rating procedure.

Peak Shaving Applications: The rating for a peak shaving application is based on the number of horsepower-hours available per year at site specific conditions. All applications using a peak shaving rating require a signed Special Application Approval (SAA) from Waukesha's Application Engineering Department.

I. TERMS OF EXPRESS LIMITED WARRANTY

- A. Waukesha Engine warrants that it will repair or replace, AT ITS ELECTION AND EXPENSE, any Genuine Waukesha Service Part installed on an engine, or Enginator®, or product (hereinafter referred to as "Products") manufactured by Waukesha, which proves to have had a defect in material or workmanship.
- B. Waukesha Engine Division further warrants that it will repair or replace, AT ITS ELECTION AND EXPENSE, any component of the Waukesha Product damaged as the direct result of a warrantable defect in a Product during the term of **coverage**.

II. TERM LIMITATIONS OF EXPRESS LIMITED WARRANTY

- A. This coverage shall commence upon initial new Products start-up date and shall expire upon the earlier of the following:
 - 1. 60 months or 3500 hours, whichever occurs first, after the initial new Products start-up date; or
 - 2. 72 months after the original shipment date of the covered Products by Waukesha Engine.
- B. Notwithstanding the foregoing, Waukesha further warrants that the cylinder block casting, cylinderhead castings, connecting rod forgings, and crankshaft forging will be free from defects in material or workmanship. This additional warranty only covers failure of the specific items noted within this subparagraph. This coverage shall expire upon the earlier of the following:
 - 1. 60 months after the initial new Products start-up date; or
 - 2. 25,000 hours of operation of the covered Products; or
 - 3. 2 months after the original shipment date of the covered Products by Waukesha Engine.

NOTE: No damage from other sources, such as damage from the loss of a crankshaft bearing, shall be

III. WAUKESHA'S RESPONSIBILITIES UNDER THE EXPRESS LIMITED WARRANTY

Waukesha shall be responsible for:

- A. The repair or replacement, at Waukesha's election, of covered defective parts and all reasonable labor required regarding a warranted failure during the express limited warranty term. All such labor shall be provided by Waukesha's authorized contractor or distributor.
- B. Reasonable and necessary travel and expenses incurred by Waukesha's authorized contractors or distributor.
- C. Replacement of lubricating oil, coolant, filter elements, or other normal maintenance items that are contaminated and/or damaged as a direct result of a warranted failure.

NOTWITHSTANDING THE FOREGOING, WAUKESHA SHALL NOT BE RESPONSIBLE FOR LABOR COSTS ASSOCIATED WITH WARRANTY CLAIMS BROUGHT PURSUANT TO SUBPARAGRAPH II (B).

IV. OWNER'S RESPONSIBILITIES UNDER THE EXPRESS LIMITED WARRANTY

Owner shall be responsible for:

- A. The operation of the product within the allowable HP-HR/YR rating granted by the specific Special Application Approval for the product.
- B. The operation and maintenance of the Products within the guidelines established by Waukesha.
- C. Making the Products available to Waukesha or Waukesha's authorized contractors or distributors for any warranty repair, during normal business hours.
- D. All additional costs incurred for premium or overtime labor, should owner request that repairs be made on a premium or overtime schedule.
- E. All costs incurred as the result of removal or reinstallation of the Products as may be required to effect any warranted repair.
- F. All administrative costs and expenses resulting from a warranted failure.
- G. Any costs of transportation, towing, repair facilities, or associated costs.
- H. All labor, travel, mileage, and other related costs and expenses associated with a claim made pursuant to subparagraph II (B) above.
- I. Loss of revenue and loss of or damage to real and/or personal property.

V. LIMITATION OF WAUKESHA'S OBLIGATIONS

The obligations of Waukesha under this express limited warranty shall be waived and voided, and Waukesha shall not, thereafter, be responsible for:

- A. Any failure resulting from owner or operator abuse or neglect, including but not by way of limitation, any operation, installation, application, or maintenance practice not in accordance with guidelines or specifications established by Waukesha; or
- B. Any failure resulting from unauthorized modifications or repairs of the Products; or
- C. Any failure resulting from overload, overspeed, overheat, accident, improper storage; or
- D. Failure of owner to promptly provide notice of a claimed defect; or
- E. Failure of Products for which Waukesha did not receive properly completed start-up reports; or
- F. Repairs of a covered failure performed with non-genuine Waukesha parts; or
- G. Repairs of a covered failure performed by non-authorized contractors or distributors; or
- H. Failure to make Products available to Waukesha or its authorized representatives; or
- I. Failure to supply documents such as drawings and specifications relating to the specific application of the Products.

VI. APPLICABILITY AND EXPIRATION

The warranties set out above are extended to all owners in the original chain of distribution. The warranties and obligations of Waukesha shall expire and be of no further effect upon the dates of expiration of the applicable warranty periods.

THE FOREGOING SETS FORTH WAUKESHA'S ONLY OBLIGATIONS AND OWNERS' EXCLUSIVE REMEDY FOR BREACH OF WARRANTY, WHETHER SUCH CLAIMS ARE BASED ON BREACH OF CONTRACT, TORT (INCLUDING NEGLIGENCE AND STRICT LIABILITY), OR OTHER THEORIES, AND THE FOREGOING IS EXPRESSLY IN LIEU OF OTHER WARRANTIES WHATSOEVER EXPRESSED, IMPLIED, AND STATUTORY, INCLUDING WITHOUT LIMITATION, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE.

Notwithstanding the preceding, in no event shall Waukesha be liable for any direct, special, incidental, or consequential damages (whether denominated in contract, tort strict liability, negligence, or other theories) arising out of this Agreement or the use of any Products provided under this Agreement.

Any action arising hereunder or relating hereto, whether based on breach of contract, tort including negligence and strict liability, or other theories must be commenced within two (2) years after the cause of action accrues or it shall be barred.

BINDING ARBITRATION

- (a) Buyer and Seller shall attempt, in good faith, to resolve any dispute arising out of or relating to this agreement, or the products and/or services provided hereunder, promptly by negotiation between executives. If the matter has not been resolved within sixty (60) days of a party's request for negotiation, either party may initiate arbitration as herein after provided.
- (b) Any dispute arising out of or related to this agreement or the products and/or services provided hereunder which has not been resolved by the negotiation procedure described above, shall be settled by binding arbitration administered by the American Arbitration Association in accordance with its Commercial Arbitration Rules and judgment on the award rendered by the arbitrator(s) may be entered in any court having jurisdiction thereof.
- (c) Unless Buyer and Seller otherwise agree in writing, the arbitration panel shall consist of three arbitrators. The arbitrator(s) shall have no authority to award punitive or other damages not measured by the prevailing party's actual damages and may not, in any event, make any ruling, finding or award that does not conform to the terms and condition of this agreement. The law of Texas shall govern.
- (d) The arbitration proceeding shall be conducted in English, in Dallas, Texas.

See Form 467 for the most current warranty terms. Effective February 22, 2006