WOODWARD

Product Manual 91372
(Revision NEW, 2/2006)
Original Instructions

2300G Gas Engine Control

8280-3005 (Ordinary Locations)
8280-1070 (Hazardous Locations)

Application Manual

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

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Warnings and Notices

Important Definitions

This is the safety alert symbol. It is used to alert you to potential personal injury hazards. Obey all safety messages that follow this symbol to avoid possible injury or death.

- **DANGER**—Indicates a hazardous situation which, if not avoided, will result in death or serious injury.
- **WARNING**—Indicates a hazardous situation which, if not avoided, could result in death or serious injury.
- **CAUTION**—Indicates a hazardous situation which, if not avoided, could result in minor or moderate injury.
- **NOTICE**—Indicates a hazard that could result in property damage only (including damage to the control).
- **IMPORTANT**—Designates an operating tip or maintenance suggestion.

WARNING

Overspeed / Overtemperature / Overpressure

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

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

WARNING

Personal Protective Equipment

The products described in this publication may present risks that could lead to personal injury, loss of life, or property damage. Always wear the appropriate personal protective equipment (PPE) for the job at hand. Equipment that should be considered includes but is not limited to:

- **Eye Protection**
- **Hearing Protection**
- **Hard Hat**
- **Gloves**
- **Safety Boots**
- **Respirator**

Always read the proper Material Safety Data Sheet (MSDS) for any working fluid(s) and comply with recommended safety equipment.

WARNING

Start-up

Be prepared to make an emergency shutdown when starting the engine, turbine, or other type of prime mover, to protect against runaway or overspeed with possible personal injury, loss of life, or property damage.

WARNING

Automotive Applications

On- and off-highway Mobile Applications: Unless Woodward's control functions as the supervisory control, customer should install a system totally independent of the prime mover control system that monitors for supervisory control of engine (and takes appropriate action if supervisory control is lost) to protect against loss of engine control with possible personal injury, loss of life, or property damage.

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

Electrostatic Discharge Awareness

NOTICE **Electrostatic Precautions**	**Electronic controls contain static-sensitive parts. Observe the following precautions to prevent damage to these parts:** • **Discharge body static before handling the control (with power to the control turned off, contact a grounded surface and maintain contact while handling the control).** • **Avoid all plastic, vinyl, and Styrofoam (except antistatic versions) around printed circuit boards.** • **Do not touch the components or conductors on a printed circuit board with your hands or with conductive devices.** **To prevent damage to electronic components caused by improper handling, read and observe the precautions in Woodward manual *82715*, *Guide for Handling and Protection of Electronic Controls, Printed Circuit Boards, and Modules*.**

Follow these precautions when working with or near the control.

1. Avoid the build-up of static electricity on your body by not wearing clothing made of synthetic materials. Wear cotton or cotton-blend materials as much as possible because these do not store static electric charges as much as synthetics.
2. Do not remove the printed circuit board (PCB) from the control cabinet unless absolutely necessary. If you must remove the PCB from the control cabinet, follow these precautions:
   - Do not touch any part of the PCB except the edges.
   - Do not touch the electrical conductors, the connectors, or the components with conductive devices or with your hands.
   - When replacing a PCB, keep the new PCB in the plastic antistatic protective bag it comes in until you are ready to install it. Immediately after removing the old PCB from the control cabinet, place it in the antistatic protective bag.

Chapter 1.
General Information

Introduction

WARNING **The use of this control requires a separate anti knock device to monitor and shut down the engine when knocking appears.**

The Woodward part numbers belonging to the 2300G are the following:

- Hardware: 2300G:
  - Ordinary Locations 8280-3005
  - Hazardous Locations 8280-1070
- Application software: 2300G: 5418-2383
- HMI software 2300G: 5418-2385

The following drawings belong to the system:

- Functional block diagram: 3081-1397
- Control Wiring diagram: 9971-1167

The Woodward 2300G Gas Engine Control has the following functionality:

- Speed and/or Load control
- Load sharing
- Lean burn “Air Fuel Ratio” Control (based on the EGS-01 control)
- kWe measurements

The 2300G is a microprocessor-based digital control designed to include the functions of, and be compatible with, 2301A and 2301D load sharing controls. The increased flexibility of software allows the 2300G to include control functions that required additional equipment in previous versions of 2301A control systems. The 2300G therefore is suitable for upgrading existing control systems or increased functionality in new installations.

The control is housed in a sheet-metal chassis and consists of a single printed circuit board. The 2300G is set up and configured using an external computer connected at the 9-pin connector on the front of the control. The configuration software is supplied with each control.

The 2300G provide control in either isochronous, droop, or base load. The 2300G will allow for soft load transfer when being added to or removed from a bus.

The isochronous mode is used for constant prime mover speed with:

- Single prime mover operation or
- Two or more prime movers controlled by Woodward load sharing control systems on an isolated bus (loadsharing lines)

The droop mode is used for speed control as a function of load with:

- Single prime mover operation on an infinite bus or
- Parallel operation of two or more prime movers

The base load mode provides constant load level operation against a fixed grid (fixed frequency) with the load controlled by the 2300G.

- The load setting is set by a fixed reference (only accessible by the Interponent HMI)
- Raise/lower contact control of the reference.

The 2300D Control Hardware includes:

- 1 Load Sensor
- 1 Actuator Driver for Mixture Control
- 1 MPU Speed Sensor
- 1 Actuator Driver for Gas Flow Control
- 2 Configurable Analog Inputs for MAP and a MAT measuring
- 8 Discrete (Switch) Inputs
- 4 Configurable Discrete (Relay Driver) Outputs

WARNING

Use of this equipment by untrained or unqualified personnel could result in damage to the control or the installation's equipment and possible loss of life or personal injury. Make sure personnel using or working on this equipment are correctly trained.

This manual covers only equipment which is manufactured by Woodward and does not include operating instructions for the prime mover, or the driven devices or processes. For information about other Woodward units used on the prime mover please refer to the specific Woodward documentation supplied with each unit.

For specific operating information such as start-up, shutdown, and the prime mover's response to signals from the Woodward control, refer to the prime mover manufacturer's manual.

Associated Publications

The following publications contain additional product or installation information on Load Sharing and Speed Controls, and related components. These can be ordered from any Woodward office. Manuals can be downloaded with the following link: **www.woodward.com/pubs/pubpage.cfm**.

Manual	Title
25070	*Electronic Governor Installation Guide*
26260	*Governing Fundamentals and Power Management*
82384	*SPM-A Synchronizer*
37215	*SPM-D10 Synchronizer*
82510	*Magnetic Pickups and Proximity Switches for Electronic Controls*
82715	*Guide for Handling and Protection of Electronic Controls, Printed Circuit Boards, and Modules*
26237	*L-Series Position Control*
04141	*Flo-Tech™*
26168	*ProAct™ Digital Plus ITB*

Product Specification	Title
03202	*Woodward Watch Window Software*
82383	*SPM-A Synchronizer*
37297	*SPM-D10 Synchronizer*
82516	*EG-3P/6P/10P Actuator*
82575	*EGB-1P/2P Governor/Actuator*

System Compliance

This system complies with the relevant industry specifications and regulations.

General Safety Precautions

Obey the following safety precautions when you install the unit:

- Obey all cautions or warnings given in the procedures.
- Never bypass or override machine safety devices.

Identification Plate

The identification contains the following numbers:

- Part Number
- Serial Number
- Manufacturing Date

Always give the model number and serial number in any correspondence with Woodward.

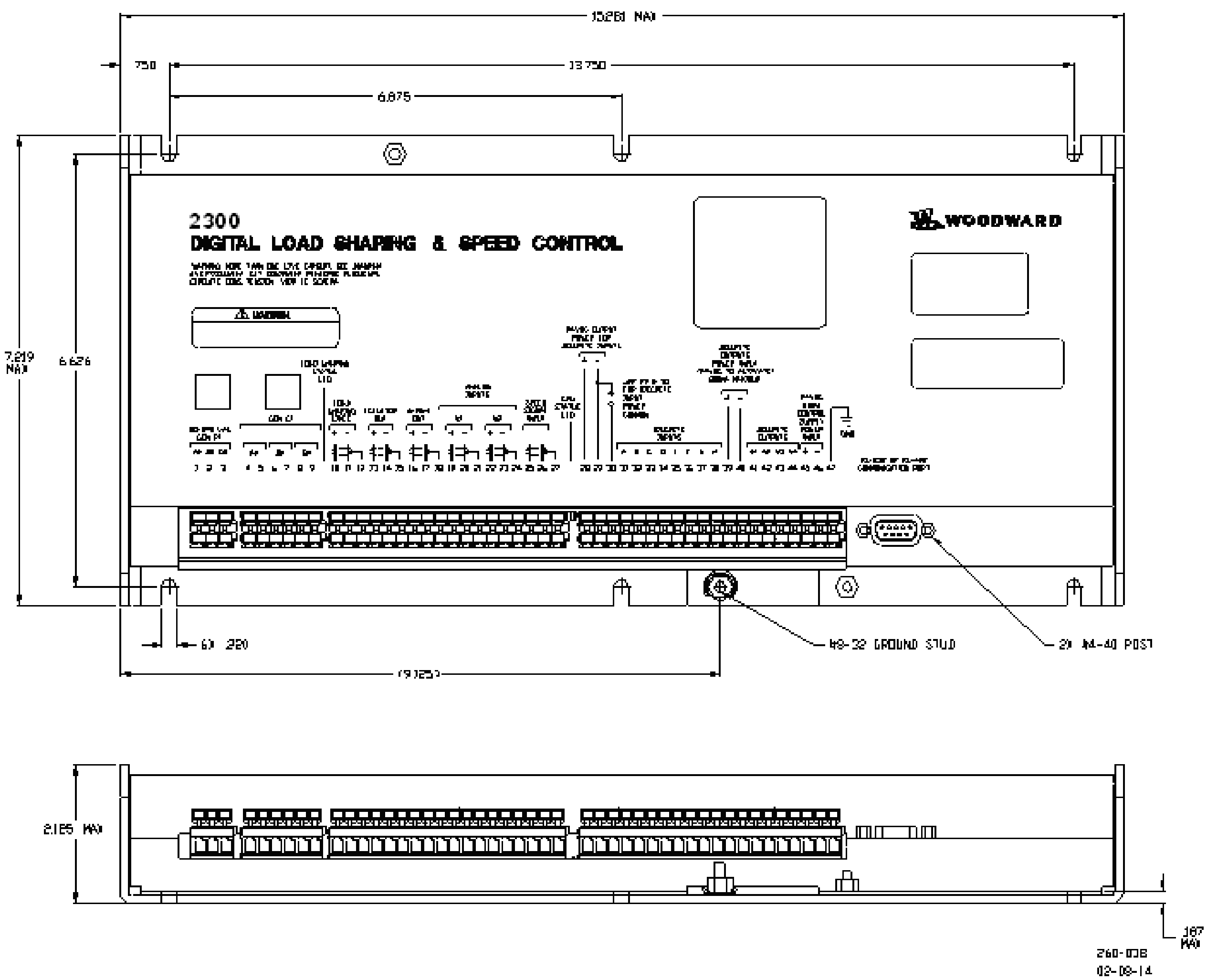


Figure 1-1. Outline Drawing

Chapter 2.
Installation

Introduction

This chapter contains general installation instructions for the 2300G control. Power requirements, environmental precautions, and location considerations are included to determine the best location for the control. Additional information includes unpacking instructions, electrical connections, and an installation checkout procedure.

Power Requirements

The 2300G control requires a voltage source of 18 to 40 Vdc, with a current capacity of at least 900 mA for operating power. If a battery is used for operating power, an alternator or other battery-charging device is necessary to maintain a stable supply voltage.

NOTICE **To prevent damage to the control, make sure that the alternator or other battery-charging device is turned off or disconnected before disconnecting the battery from the control.**

Location Considerations

This product is intended for installation in a “closed electrical operating area” or in an enclosed industrial control cabinet. Consider these requirements when selecting the mounting location:

- Adequate ventilation for cooling
- Space for servicing and repair
- Protection from direct exposure to water or to a condensation-prone environment
- Protection from high-voltage or high-current devices, or devices which produce electromagnetic interference
- Avoidance of vibration
- Selection of a location that will provide an operating temperature range of –40 to +70 °C (–40 to +158 °F)
- The control must NOT be mounted on the engine

Electrical Connections

All inputs and outputs are made through screwless spring-actuated terminal blocks. For EMI reasons, it is recommend that all low-current wires be separated from all high-current wire.

Using a standard 2.5 mm or 3/32 inch flat bladed screwdriver can actuate the spring clamp. The terminal blocks accept wires from 0.08–4 mm² (27–12 AWG). Two 18 AWG or three 20 AWG wires can be easily installed in each terminal. Wires for the fixed mounted power terminals should be stripped 5–6 mm (0.22 inch) long.

IMPORTANT	**Do not tin (solder) the wires that terminate at the terminal blocks. The spring-loaded terminal blocks are designed to flatten stranded wire, and if those strands are tinned together, the connection loses surface area and is degraded.**

Shields and Grounding

An individual shield termination is provided at the terminal block for each of the signals requiring shielding. All of these inputs should be wired using shielded, twisted-pair wiring. The exposed wire length beyond the shield should be limited to one 25 mm (1 inch). Relay outputs, contact inputs, and power supply wiring do not normally require shielding, but can be shielded if desired.

The 2300G is designed for shield termination to earth ground at the control. If intervening terminal blocks are used in routing a signal, the shield should be continued through the terminal block. If shield grounding is desired at the terminal block, it should be AC coupled to earth. All other shield terminations except at the control should be AC coupled to earth through a capacitor. A 1000 pF, 500 V capacitor is sufficient. The intent is to provide a low impedance path to earth for the shield at frequencies of 150 kHz and up. Multiple direct connections of a shield to earth risk high levels of current to flow within the shield (exception, see note below on cabinet installations).

Shields can be grounded at both ends (2300G and load) if the cable length is sufficiently short (i.e. within a cabinet) to prevent ground loop current in the shield.

IMPORTANT	**Cabinet Installations: If the 2300G is installed in a cabinet, shielded I/O can be terminated directly to the cabinet (earth ground) at the entry to the cabinet, as well as at the control.** **For EMC reasons, it is recommend that all low-current wires be separated from all high-current wires. Input Power ground terminal should also be wired to earth ground.**

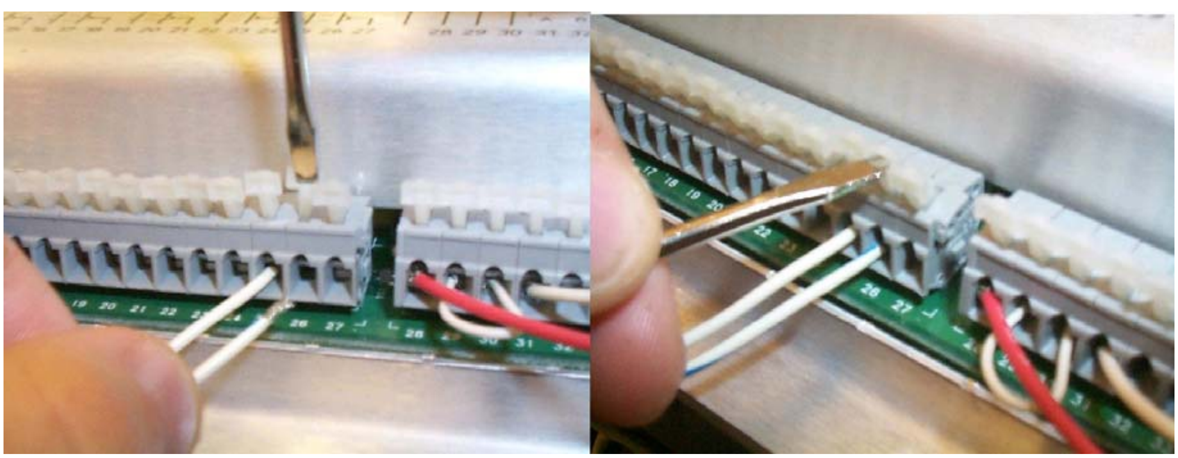


Figure 2-1. Installation of Wiring into Terminal

Setting Speed Range

The Microprocessor inside the 2300G calculates the speed range to be used by entering the engine/generator synchronous speed and number of gear teeth. This configured speed sets the hardware-to-software scaling.

⚠WARNING

The number of gear teeth is used by the control to convert pulses from the speed-sensing device to engine rpm. To prevent possible serious injury from an overspeeding engine, make sure the control is properly programmed to convert the gear-tooth count into engine rpm. Improper conversion could cause engine overspeed.

Potential Transformer Connections

Connect the potential transformer secondary leads to the following terminals:

- Phase A to terminal 1
- Phase B to terminal 2
- Phase C to terminal 3

The potential transformer secondary line-to-line voltage must produce 90 to 120 Vac or 200 to 240 Vac. Refer to the control wiring diagram, Figure 7-1.

Current Transformer Connections

The standard method of connecting the current transformers is shown in the control wiring diagram, Figure 7-1. An alternate method is the open delta connection shown in the insert in the plant wiring diagram.

Load Sharing Lines

The Load Sharing Lines provide an analog communication path between compatible controls. The 2300G provide an internal relay for connecting the Load Sharing Signal to the internal circuitry at the appropriate times. When the internal relay is closed, a green LED will illuminate between terminals 9 and 10. Because the load-sharing-line relay is contained in the control, no relay is required between the control and the load-sharing-line bus. Use shielded cable and connect the load-sharing lines directly to terminals 10(+) and 11(–). Connect the shield to terminal 12. When all controls in the system are of the 2300 or 2301A types, the shields may be connected continuously between controls. When load sharing with different controls, do not connect the shields at the point where connections are made to the load-sharing-line bus.

When running a single unit on an infinite bus with an external load control device, terminals 31 (Run), 33 (Gen. Breaker closed) and 37 (Load engine) must be connected to terminal 28 and terminal 38 (not in KW control) open, to connect the Load Matching Circuit (K4) to the load-sharing lines. The load-sharing lines must be wired to the external load control device. The circuit-breaker auxiliary contact will then be connected to this device and not to the 2300G.

Power Supply

Run the power leads directly from the power source to the control, connecting the negative lead to terminal 46, and the positive lead to terminal 45.

When power is applied, the 2300G begins performing internal memory tests to 'boot-up' the processor, which takes approximately 30 seconds to complete. The CPU Status LED between terminals 27 and 28 remains on during this boot-up. The control will remain in I/O lock and will not control the prime mover until the boot-up is complete. For systems requiring fast start functions, it will be necessary to continuously power the 2300G.

⚠WARNING **DO NOT attempt to start the prime mover while the CPU Status LED is ON.**

⚠WARNING **DO NOT apply power to the control at this time. Applying power before a control is completely connected may damage the control.**

IMPORTANT **The 18–40 Vdc input power must be supplied from a power supply/battery charger certified to IEC standard with SELV (Safety Extra Low Voltage) classified output. The installer should properly size wiring and fusing for the input power and PT/CT circuits.**

Discrete Inputs (Terminals 28–38)

Discrete inputs are the switch input commands to the 2300G control. They interact in such a way as to allow engine control and power management under a variety of conditions. Positive Voltage is supplied to the discrete input terminal when an input switch or relay contact closes. This will cause the input state for that discrete input to be "TRUE". The input terminal will be open circuited when the input switch or relay contact opens. This will cause the input state for that discrete input to be "FALSE". When the input switch or relay contact is closed, the voltage supplying the discrete inputs should be present from the appropriate discrete input (terminal 31, 32, 33, 34, 35, 36, 37, or 38) to terminal 30 (common). Terminal 30 is the common return path for all of the discrete input channels. A lower voltage indicates that the switch contacts have too high a resistance when closed and should be replaced. These terminals must be isolated from ground.

In systems that provide an external low voltage source to power the 2300G control, the discrete inputs may be powered by this external low voltage. The voltage source used must be capable of supplying 100 mA at a voltage level of 18 to 40 Vdc. Connect the external low voltage source negative to terminal 30(–). Connect the external low voltage source positive to the appropriate input switch or relay contact and connect the mated switch or relay contact to the corresponding discrete input terminal on the 2300G control.

In systems where the external low voltage dc power is not appropriate, the discrete inputs may be powered by the internal 24 Vdc Discrete Input Power source at terminal 28 and 29. This source is capable of supplying 100 mA at a voltage level of 24 Vdc. Connect the internal 24 Vdc voltage source positive from terminal 28 to the appropriate input switch or relay contact, and connect the mated switch or relay contact to the corresponding discrete input terminal on the 2300G control. Assure that a connection exists between terminal 29 and terminal 30 when using the internal Discrete Input Power. Do not power other devices with the internal discrete input power source, and assure that the switch or relay contacts used are isolated from any other circuit or system.

IMPORTANT

Discrete inputs with cable lengths greater than 30 meters that are used for critical functions, such as emergency stop, should not be floated in either an on or off state. These inputs should be switched to +24 Vdc or ground.

Close to Run (Terminal 31)

The external contact used to activate the Close to Run command connects to terminal 31. When the switch or relay contacts are closed, the control is allowed to control the fuel in an attempt to control the speed/load of the prime mover. When the switch or relay contacts are open, the mixture actuator is closed.

When the Run contact is closed the operator has 10 seconds (tunable) to start the engine and see speed on the MPU. Otherwise the control will detect a failed speed pick-up. In these 10 seconds there will be an override on the failure detection.

Reset (Terminal 32)

The reset can be used to reset Alarms or shutdowns. The reset is the same as the “software reset”. The OVERSPEED shutdown can only be given a reset when the engine speed is zero!

Generator Breaker (Terminal 33)

This contact initiates isochronous mode of the control when the generator is connected to an infinite bus. It also selects the second set of dynamics.

Base Load / Open Loop (Terminal 34)

This contact has two optional functions. Default it is used as Base Load activation contact. When the contact is closed the Base Load mode is selected (also KW-Control input and Breaker input need to be active TRUE) and the Load Reference will move to the, in the HMI adjusted setpoint. Raise and Lower contacts cannot be used in this mode to change the load setpoint. When opening the contact the load reference will remain at the same point. Raise and Lower can be used then to change the setpoint again. The setpoint cannot be changed when running in Baseload mode. First Baseload must de deselected and then the new setpoint adjusted. Then the Baseload mode can be selected again with the discrete input. The setpoint will move to the new adjusted setpoint then.

On the HMI a selection can be made to use this input as a “force to open loop” function. When closing this input disable the Gas Quality Close Loop (GQCL) functionality when high, this function is used when the gas engine has a second back-up fuel.

Raise (Terminal 35)

The input switch or relay contact used to activate the Raise Speed/Load command connects to terminal 35 (Discrete Input E). This discrete input changes the control operation by increasing the speed reference ramp when the Gen. Breaker contact input at terminal 33 is open, and by increasing the Load reference when in load control mode. The speed reference ramp can increase only to a software adjustable RAISE SPEED limit. The Load reference ramp can increase only to a software adjustable MAXIMUM LOAD limit. Both ramps increase at software adjustable rates.

With the contact open (discrete input in the “FALSE” state), the control will stop raising the speed or base load reference.

Lower (Terminal 36)

The input switch or relay contact used to activate the Lower Speed/Load command connects to terminal 36 (Discrete Input F). This discrete input changes the control operation by decreasing the speed reference ramp when the Gen. Breaker contact input at terminal 33 is open, and by decreasing the load reference when in load control mode. The speed reference ramp can decrease only to a software adjustable LOWER SPEED limit. The load reference ramp can decrease only to a software adjustable MINIMUM LOAD limit. Both ramps decrease at a software adjustable rate.

With the contact open (discrete input in the “FALSE” state), the control will stop lowering the speed or base load reference.

Load/Unload (Terminal 37)

The input switch or relay contact used to activate the Load Generator command connects to terminal 37. This discrete input will cause the Load Control Function to ramp to a distinct mode of operation. If the state of the input is “TRUE”, the Load Control Function will increase or decrease in order to achieve either Isochronous Load Sharing or Base Load operation. If the state of the input is “FALSE” (input switch or relay contact open), the Load Control Function will increase or decrease in order to achieve the Unload trip level. The Gen. Breaker/Droop Contact discrete input must be “TRUE” for the Generator input to affect the control.

KW control (Terminal 38)

The input switch or relay contact used to activate the Load Control command, connects to terminal 38. This discrete input will cause the Load Control Function to operate under raise and lower inputs. In this mode of operation the governor will control only the load on the generator, no speed control is performed. The utility (main) bus or an isochronous generator set must control the bus frequency while in Load Control operation. With the state of this input “TRUE”, isochronous load sharing with other units is disabled. With the state of this contact “FALSE”, isochronous load sharing with other units can occur. The Gen. Breaker/Droop Contact discrete input must be “TRUE” for the Base Load input to affect the control.

When going to Base Load control also the KW control input needs to be active (TRUE).

Analog Input #1 (Terminals 19-20)

This input is a MAP (Manifold Pressure) input. The MAP sensor is always installed downstream of any mixture throttle and mounted as close as possible to the inlet valve. The type of MAP signal can be software configured for 0–5 V, 1–5 V, 4–20 mA, or –2.5/+2.5 V.

Analog Input #2 (Terminals 22-23)

This input is MAT input. The MAT (Manifold Temperature) sensor must be installed as closed to the inlet valves and on the cold side of the intercooler (as used on the engines). The input signal can be can be software configured for 0–5 V, 1–5 V, –2.5/+2.5 V or 4–20 mA.

Mixture Control Actuator output (Terminals 13-14)

The Mixture control Actuator is connected to terminals 13(+) and 14(–). The type of actuator output can be configured in software for a 0–200 mA, 0–20 mA or 4–20 mA.

The software configuration also allows for selection of Forward or Reverse acting actuator. Use shielded wires with the shield connected to terminal 15. Do not connect the shield to the actuator or any other point. The shield must have continuity the entire distance to the actuator, and must be insulated from all other conducting surfaces. Refer to the manuals listed in the “References” table for additional information on actuator installation.

Analog Output #1 (Terminals 16-17)

Analog output#1 is MAS valve (trim-valve) output. The output current is 4 to 20 mA. This current signal is supplied to terminals 16(+) and 17(–). Note that these terminals must be isolated from ground.

When a L-series Position Controller is used, the Analog Output #1 must be configured for 0–5 V. This can be done by parallel mounting a 250Ω resistor to terminals 16 (+) and 17 (–) The maximum output of the valve needs to be configured to approx.117%. This to avoid the output to exceed the 4.5 V. The L-series actuator handles input voltages between 0.5 and 4.5 volt. When the input on the valve exceeds the 4.5 V, it will shutdown the valve.

After installing check the full travel of the MAS valve (trim-valve) with the MAS valve (trim-valve) in manual mode.

Relay Driver Outputs (Terminals 41–44)

The 2300G contain four discrete output driver channels. The discrete outputs are low-side drivers with a maximum output current of 200 mA. The discrete output drivers are not isolated from each other, and are powered by an external +12 Vdc or +24 Vdc source connected at terminals 39(+) and 40(–). They are isolated from the internal power supplies of the 2300G control.

Relay Output #1

This relay indicates that the engine is running outside the limits set. The control uses the actual measured load to determine the MAP that belongs to this load under the calibrated conditions (for the adjusted and required NOx). This is compared to the actual MAP (compensated for MAT). When the difference between these two values is more then the adjusted limit value an alarm is set and the relay output activated. In this case the measured load (converted to RefMAP) is lower then the actual measured MAP - limit (lean running engine).

Relay Output #2

This relay indicates that the engine is running outside the limits set. The control uses the actual measured load to determine the MAP that belongs to this load under the calibrated conditions (for the adjusted and required NOx). This is compared to the actual MAP (compensated for MAT). When the difference between these two values is more then the adjusted limit value an alarm is set and the relay output activated. In this case the measured load (converted to RefMAP) is higher then the actual measured MAP + limit (rich running engine).

Relay Output #3

This is the alarm relay:

- AI#1 MAP input flt (depending on configuration this can also be a SD)
- AI#2 MAT input flt (depending on configuration this can also be a SD)
- Loadsensor flt
- Loadsharing lines flt
- RefMAP > band
- RefMAP < band

Relay Output #4

This is the shutdown relay:
- AI#1 MAP input flt (When configured as a SD this will also issue an ALM)
- AI#2 MAT input flt (When configured as a SD this will also issue an ALM)
- MPU failure
- Engine Overspeed
- Actuator in Testmode

RS-232 Communication Port

The Communication Port is the DB9 female connector at the end of the front terminal strip. This port is used to monitor control inputs, outputs, and operating parameters. Control configuration changes and adjustments can also be made. The 2300G port is connected to a computer serial port, and the external computer software is used to display control parameters. The standard software used to communicate with the 2300G is Woodward Watch Window. This software can read all control parameters, and values.

Woodward Watch Window can be downloaded at **www.woodward.com/software**. Under "-- Select a Product –" choose "Watch Window".

Also an HMI program can be used. This is described in Chapter 5.

IMPORTANT	**The communication port must be connected with an approved jacketed serial communication cable. The connector must be secured to the 2300G to prevent contact with other circuits.**

Installation Check-out Procedure

With the installation completed as described in this section, perform the following checkout procedure before beginning the start-up adjustments in Commissioning Chapter.

Visual Inspection

1. Check the linkage between the actuator and the prime mover for looseness or binding (if linkage is used). Refer to the appropriate actuator manual and to Woodward manual 25070, *Electronic Governor Installation Guide*, for additional information on linkages.

⚠WARNING	**The actuator lever should be near but not at the minimum position when the fuel or steam rack is at the minimum position. If the actuator lever gets to its minimum position before completely shutting off fuel or steam, the control may not be able to shut down the prime mover, causing damage to equipment or injury or death.**

2. Check for correct wiring in accordance with the control wiring diagram, Figure 7-1. Check for broken terminals and loose terminal screws.

3. Check the speed sensor for visible damage. Check the clearance of the magnetic pickup between the gear and the sensor, and adjust if necessary. Clearance should be between 0.25 and 1.0 mm (0.010 and 0.040 inch) at the closest point. Make sure the gear has less than 0.5 mm (0.020 inch) diametric runout. Refer to Woodward manual 82510, *Magnetic Pickups and Proximity Switches for Electronic Governors*, for more information.
4. Check the installation of the Trimvalve.
5. Check the installation of the zero-pressure regulator (compensation line, pre-adjustment).

Chapter 3.
Description of Operation

Introduction

This chapter provides an overview of the features and operation of the 2300 Gas Engine Control.

The 2300 Gas Engine Control uses a 32 bit microprocessor for all control functions. All control adjustments are made with an external computer that communicates with the control via a serial port. The external computer can be disconnected from the control during normal operation to provide security against tampering.

The control consists of 3 main parts:
- Speed control
- Load control
- Air/Fuel ratio control

Speed and Load Control Sections

Load Control

The load control section manages the prime mover load based on the load control mode:
- During parallel operation of two or more generators, the load sharing section senses the load carried by its generator and causes the loads of all generators in the system to be shared proportionally.
- During parallel operation of two or more generator or a generator paralleled against an infinite bus the control may be operated in kW-control mode.
- During parallel operation of two or more generator or a generator paralleled against an infinite bus the control may be operated in Droop mode.

Speed Control

The Speed Control system consists of:
- A speed sensing device (MPU) (1) to sense the speed of the prime mover
- A frequency sensor to software converter (2)
- A speed reference [software] (3) to which the prime mover speed can be compared
- A speed summer/amplifier [software] (4) with an output [software to hardware] proportional to the amount of fuel or steam required to maintain the desired speed at any given load
- An actuator (5) to control the Mixture flow of the prime mover

A speed-sensing device, such as a magnetic pickup, senses the speed of the prime mover, and converts it to an AC signal with a frequency proportional to prime mover speed. The frequency-to-software converter receives the AC signal from the speed sensor and changes it to a digital number representing prime mover rpm.

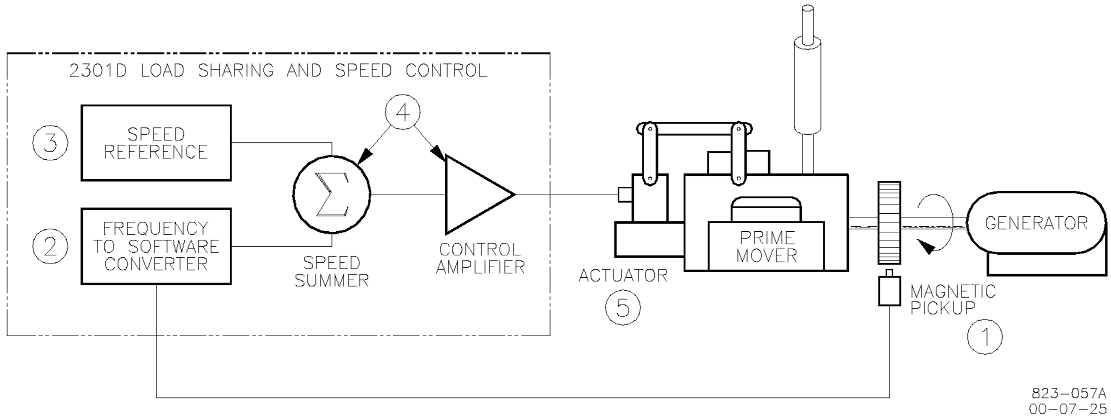


Figure 3-1. Speed Control System

A failed speed signal circuit monitors the speed signal input. When no signal is detected, it calls for minimum fuel. However, due to linkage adjustment or other restrictions in the external system, minimum actuator position may not permit prime mover shutdown.

PID control (Speed and Load control)
The PID controller compares the actual value with the setpoint. When the actual value is higher then the setpoint the PID output will decrease, when the actual value is lower then the setpoint the PID output will increase. There are 3 different control settings that determine the dynamic behavior of the PID:

- Proportional Gain
- Reset
- Derivative

The mixture actuator responds to the signal from the control by repositioning the mixture throttle, changing the speed of the prime mover until the speed signal and the reference are equal.

For controls with actuator current of 20 to 160 mA, minimum fuel is defined as:

- Actuator current less than 10 mA for forward-acting controls
- Actuator current greater than 180 mA for reverse-acting controls

The above mentioned PID settings can be attributed to different time domains. The Proportional action reacts on the present situation, the Integral action reacts on the past and the Derivative action predicts what will happen and reacts on that.

The output of a PID controller will change in response to a change in measurement or set-point. Tuned PID - Combinations of Proportional, Integral, and Derivative will provide the best type of process control required.

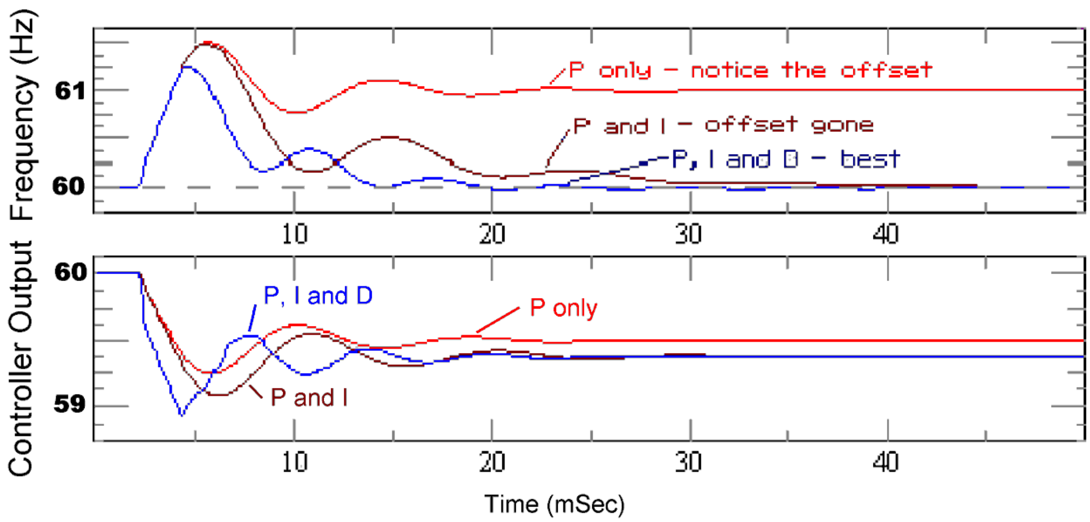


Figure 3-2. PID Response

Proportional Gain

The proportional response of the PID, is proportional to the process change. This process change can be a change in the setpoint or a change in the actual process value. The PID responds on a difference between the two inputs (input error). The higher the Proportional Gain, the higher the output change on the same input error.

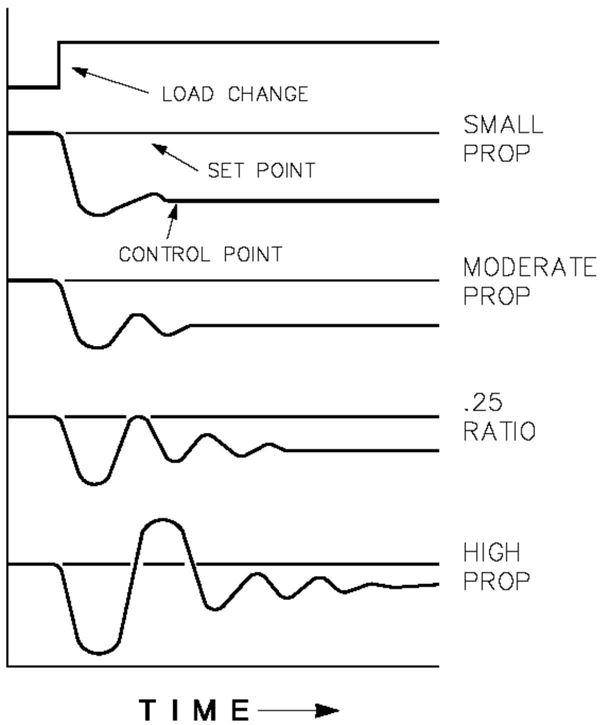


Figure 3-3. Effect of Proportional Gain Settings on Control

In the above graphs the result in the process on a load change is shown. The process is controlled by a proportional system only. The result on the process, of a control with a low P-gain is stable, but has a slow response and a large offset. A high P-gain will result in a faster response that gives a smaller offset but less stability. An optimum needs to be found in a fast enough response and a minimum of instability or ringing. The offset needs to be removed with the Integral action (reset rate).

In case of a speed control on a gas engine, the proportional response will result in a new position of the throttle. In the following graphs, the relationship between an increasing setting of the Proportional Gain and the PID response is shown. The response of the control on a Proportional Gain setting is:

Output = Prop. Gain x (Setpoint – Process)

The graphs are shown with a constant Reset and Derivative action.

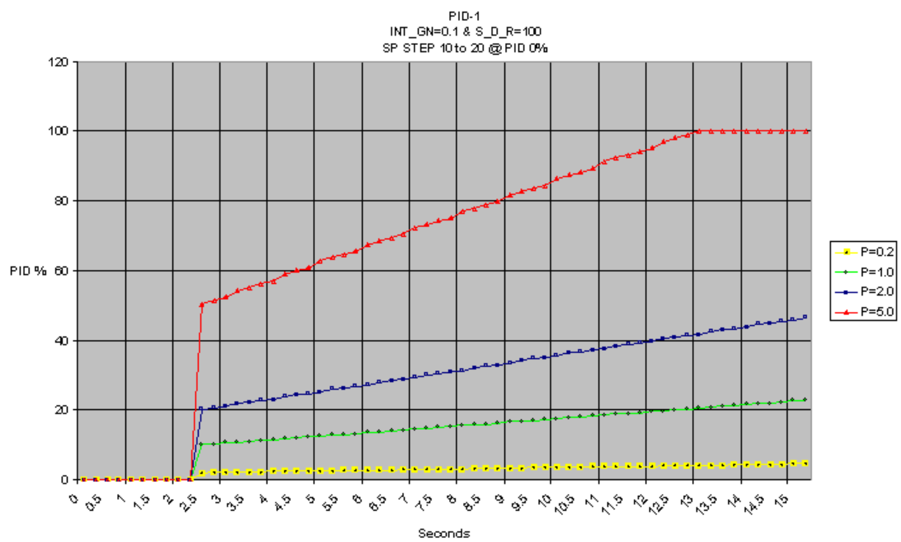


Figure 3-4. Proportional Gain with Fixed Integral and Derivative

Integral action (Reset)
Reset - The reset is the integral term in the PID controller. With integral action, the controls output is proportional to the amount of time the speed error is present. It prevents slow hunting at steady state and controls the time rate at which the speed error returns to zero after a speed or load disturbance.

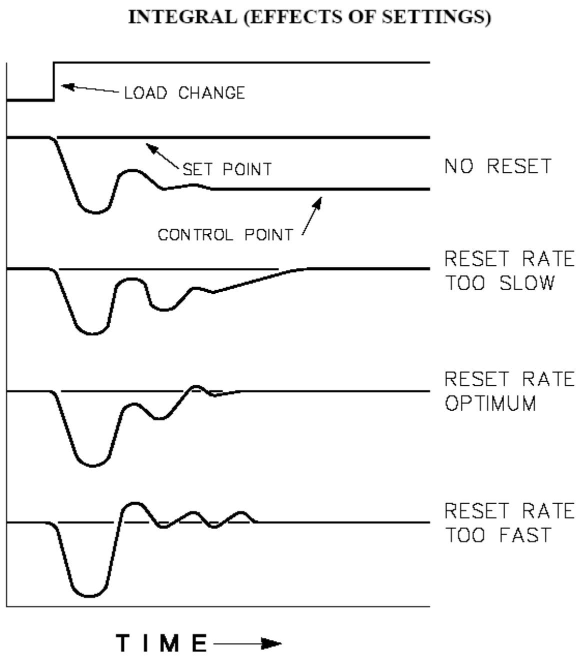


Figure 3-5. Effect of Integral Action on Control

The response of the process on a load change without Integral action is shown in the second graph. There will be an offset that stays. As soon as an Integral action is performed in the PID, the offset will be removed from the process. The higher the Integral action, or faster the Reset rate, the faster the control will remove the offset between the process value and the setpoint. When the integration is too fast, there will be an overcompensation and an oscillation will occur.

$$\text{Output} = \text{P-gain} \times \left[\frac{\text{I-gain}}{s} + 1 \right] \times (\text{setpoint} - \text{proces value})$$

$$\text{I-gain} = \frac{1}{Ti}$$

$$\text{Output} = \text{P-gain} \times \left[\frac{1}{Ti\,.\,s} + 1 \right] \times (\text{setpoint} - \text{proces value})$$

The Integral is a function of the magnitude and duration of the input error. It also depends on the adjustment of the Integral action in the PID control. In the graphs below, it is illustrated what effect the different settings of the Integral mean in the PID control. The higher the setting of the Integral, the faster it will change the output signal to integrate the input error to zero.

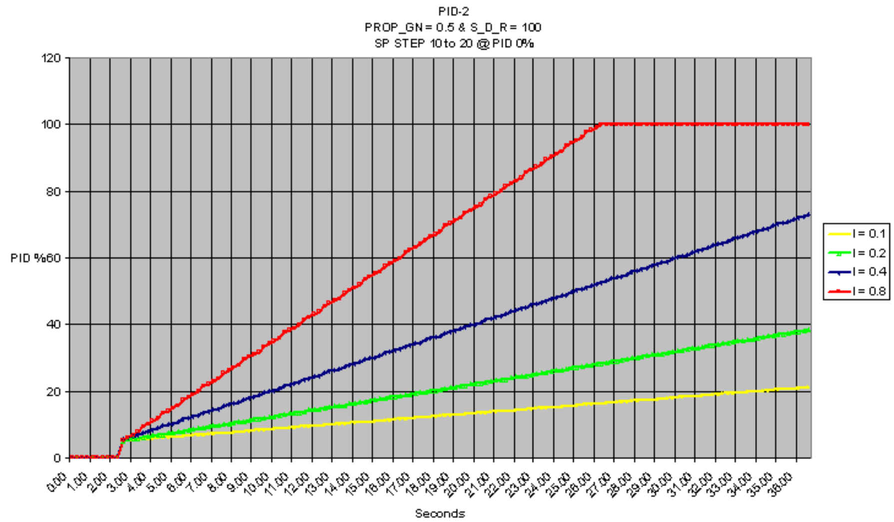


Figure 3-6. Integral Action when Using a Fixed P-gain and no Derivative

When using the above mentioned calculation the above graph can be explained. For example an I-gain of 0.4 (second graph from the top), this means a Ti = 2.5 seconds. A P-gain of 0.5 is used.

$$Ti = \frac{1}{\text{I-gain}} = \frac{1}{0.4} = 2.5$$

$$\text{Output} = 0.5 \times \left[\frac{1}{2.5s} + 1 \right] \times (10)$$

$$\text{Output} = \frac{2}{s} + 5$$

The output at i.e. 20 sec. is 20-2.5 sec. = 17.5 sec. since the step on the input, Output = (2 x 17.5) + 5 = 40

Derivative action (SDR or compensation)

Compensation - The compensation is the derivative term in the PID controller. With Derivative action, the controls output is proportional to the rate of change of the measurement or error.

The controls output is calculated by the rate of change of the measurement with time. Compensation is used to avoid overshoot.

Input Dominant is much jumpier and more responsive. Typically used in Line drives where the quickest response possible is needed. It can be a little unstable—almost jittery.

Input Dominant is 0.01 < D < 1.00

Feedback Dominant is 1.00< D < 100

In the EGS-02 default settings are Feedback dominant Compensation values.

The Derivative acts on the rate of change of the control error. Consequently, it is a *fast mode* which ultimately disappears in the presence of constant errors. It is sometimes referred to as a *predictive mode*, because of its dependence on the error trend. The main limitation of the derivative mode, viewed in isolation, is its tendency to yield large control signals in response to high-frequency control errors, such as errors induced by set-point changes or measurement noise.

DERIVATIVE (EFFECTS OF SETTINGS)

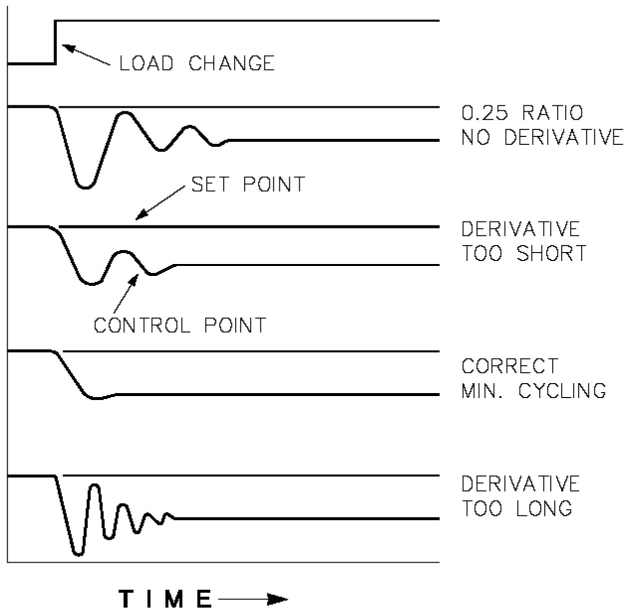


Figure 3-7. Effect of Derivative Action on Control

The net result of Derivative action is to oppose any process change and combined with Proportional action to reduce stabilization time in returning the process to the setpoint after an upset. The derivative will not remove offset.

The Woodward implementation of the Derivative action is split into two working domains, Input Dominant and Feedback Dominant.

- Input Dominant uses the output of the summing point to calculate the D component of the PID.
- Feedback Dominant uses the Present Feedback signal to calculate the next D component of the PID.

The allowed values for the Compensation range from 0 – 100. The common derivative is Feedback dominant, it is automatically selected with an Compensation from 1 to 100. The less common Compensation is Input dominant and is selected with Compensation values between 0 and 1.

Feedback dominant applies the derivative action to the integrator feedback term of the PID equation and is more stable than Input dominant derivative. This will not take corrective action as early and will be less noise sensitive. When tuning the derivative the Compensation will be established in the 1 to 100 range because it is easier to tune and more forgiving of excessive values.

Input dominant derivative applies the Compensation term before the integrator term of the PID equation. When the Compensation is less than 1, the derivative is Input dominant and reacts very quickly to process upsets. It is very sensitive, so it should only be used in applications without high frequency noise.

The reciprocal setting of the Compensation in one domain will appear identical in the other domain. As an example, the setting of an Compensation of 5.0 will appear the same as and Compensation of 0.2. The difference in response being the dominance features.

$$\text{Output} = \text{P-gain} \times \left[\frac{\text{I-gain}}{s} + 1\right] \times \left[\frac{s}{\text{SDR} \times \text{I-gain}} + 1\right] \times (\text{Setpoint} - \text{Process value})$$

Above gives the Feedback dominant transfer function of the Woodward PID implementation.

$$\text{Output} = \text{P-gain} \times \left[\frac{\text{I-gain}}{s} + 1\right] \times \left[\frac{\text{SDR} \times s}{\text{I-gain}} + 1\right] \times (\text{Setpoint} - \text{Process value})$$

Above gives the Input dominant transfer function of the Woodward PID implementation.

In the graphs below the PID response on a step is illustrated while using a fixed P-gain and Integral action (in the feedback dominant domain). It shows that an Compensation setting of 1 gives the highest reaction on an input change. A setting of 50 in the Compensation gives almost no effect on the output on a change in input.

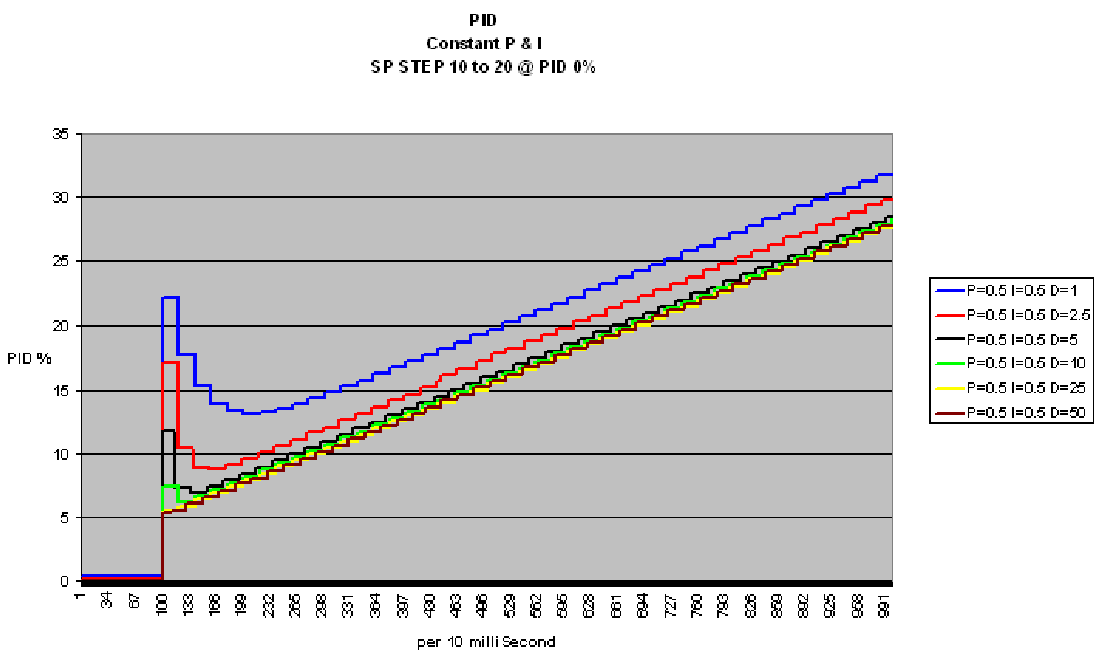


Figure 3-8. Derivative with Fixed Proportional Gain and Integral Action

Control Dynamics

The 2300 Gas Engine Control has two sets of dynamics.

Speed dynamics are active when the control is in Island mode. In this mode the control will keep bus frequency at the desired level. Single or Multiple Gain is selectable. When Multiple gain is selected, speed dynamics consist of 5-point curves where P-gain, I-gain and SDR are a function of generator load. This enables adequate dynamic response over the full load range of the generator.

Also, Fast Gain dynamics are implemented. When the error between actual speed and speed setpoint exceeds a tuned value (Gain Window), the actual P-gain will be multiplied by a tunable factor (Gain Ratio). This feature improves response during load transients.

Load dynamics are active as soon as the generator is connected to the utility**.** Single or Multiple Gain is selectable. When Multiple gain is selected, load dynamics consist of 5-point curves where P-gain, I-gain and SDR are a function of generator load. This enables adequate dynamic response over the full load range of the generator.

In load dynamics the same multiplier is active when the speed of the engine differs from the grid frequency. When the grid has a steady frequency, this function will not become active, because it will not be possible for the engine to have a speed other then the grid frequency (when the breaker is closed).

Start Limit Function

The Start Limit Function provides a limit to the actuator that controls the Mixture throttle, which prevents overfuel conditions during starting of the engine. As soon as the run command is high the start fuel limiter is armed. As soon as the PID is in control, the start limiter is released.

This Start Limit (%) value can be set in the Tuning – Speed page as a percentage of maximum actuator travel. The effect on a trimmed gas engine system is limited because the start performance depends greatly on the adjustment of the zero pressure regulator.

If no start limiter is required a setting of 100% will disable the start limiter.

Speed Reference and Ramps

This section describes the operation of the speed reference and ramp functions and their relationship to each other. Read this section carefully to make sure your sequencing provides the proper operating modes.

The control provides idle and rated speed setpoints, raise and lower rates for local operation and acceleration and deceleration ramp rates. Maximum speed setpoint is calculated by the control to be 110% of rated speed.

Accel ramp rate determines the rpm/s required for the engine to ramp from start to idle speed and from idle to rated speed.

Decel ramp rate determines the rpm/s required for the engine to ramp from rated speed to idle speed.

Raise and **lower** rates determine how fast speed is increased or decreased by raise and lower discrete input commands.

The idle speed setpoint is provided for start up. Idle speed may be set equal to or less than the rated speed setpoint. Idle is independent of the lower limit setpoint and may be set at a lower speed.

The idle speed setpoint is selected when the engine is started. As soon as idle speed is reached the control automatically ramps to rated speed with the acceleration ramp rate.

Closing either the raise (#35) or lower (#36) contacts while ramping from idle to rated results in immediate cancellation of the idle-to-rated ramp, and the ramp will stop at that point. After acceleration to rated speed is completed, the raise and lower commands increase and decrease engine speed based on the raise and lower rate settings. The raise and lower commands will not increase the speed reference above the raise limit (110% of rated speed) or below the lower limit (idle speed). The raise and lower commands can be used as speed trim inputs for manual synchronization.

If the system uses droop operation for paralleling, the raise and lower inputs will be load-setting inputs.

Droop Function

Load control operations do not function while in droop. The speed reference must be changed to increase or decrease the generator load while in droop. The base load and the load discrete inputs have no effect while operating in droop. The Gen.Breaker (#33) contact switches between load control and droop operation.

The droop function supplies a feedback path to bias the speed reference. The function of droop is to decrease the speed reference as the load increases. This is done by negatively biasing the output of the speed reference with the droop function. The Generator Breaker discrete input contact is used to switch the droop function on and off. The droop function can be permanently enabled by leaving the Generator Breaker contact discrete input (#33) false.

Load Reference and Ramp Functions

This section describes the operation of the load reference and ramp functions and their relation to each other. Droop operating mode has no ramp functions and is not included here. Isochronous load sharing descriptions apply to two or more units paralleled on a common isolated bus or by accessory device with the utility. Baseload descriptions apply to a unit paralleled with the utility or with one or more units on an isolated bus. Read this section carefully to be sure your sequencing provides the proper operating modes.

The control provides a minimum load (unload trip level) setpoint, maximum load setpoint, baseload setpoint, loading rate, unloading rate, and fast rate. Loading rate determines the kW per second increase when the load input is closed. Unloading rate determines the kW per second decrease when the load input is opened (unload).

In the isochronous mode (Generator breaker input #33 closed), closing the load contact #37 ramps the load setpoint from no-load to the load sharing setting. Opening the load contact #37 (unload) ramps the load to the unload trip level setting.

Closing the kW control #38 contact keeps the load setpoint at the loadsharing line level. Loadsetpoint can be changed with raise and lower inputs. Opening the kW-control contact #38 ramps the load to the load sharing setting.

When in kW-control operation, the load reference determines the load on the generator without regard to other units connected to the same load.

When the generator is carrying less load than the base load reference, the load bias is positive and the closed loop path increases the fuel to the engine. When the generator is carrying more load than the base load reference, the load bias is negative and the closed loop path will decrease the fuel to the engine. As the fuel to the engine is changed, the load and/or speed will change until the engine speed exactly matches the biased speed reference. At this steady state base load condition, the load bias is virtually zero and the biased speed reference, rated speed reference, and engine speed are virtually equal.

Opening the kW-control input contact #38 ramps the generator load from Load Control back into isochronous load sharing. However, opening the load input contact (unload) #37 instead, ramps the generator load from the Load Control setting to the unload trip level.

Closing the Baseload contact (when configured as baseload control) when in Isochronous loadsharing mode will not change modes. The control will remain in Isochronous loadsharing mode. When in KW-Control mode (#38 is also closed) then the control will ramp to the Base load setting. No raise an lower inputs can be used in baseload mode. When opening the Baseload contact when KW-control input is closed the load reference will remain at the same point. Raise and lower can then be used again to change load. When opening also the KW-Control input, the load reference will ramp to the loadsharing level and start isochronous loadsharing.

IMPORTANT **In isolated bus applications, a brief speed transient may occur when the load sharing relay closes following transfer from baseload back into isochronous load sharing.**

It is possible for the control to be in base load control while supplying power to a load, which is isolated from the infinite bus. The capability of the engine generator must be considered when operating this way. As an example consider two generators, one capable of providing 1200 kW and one capable of providing 600 kW. If the combined load demand to these generators is 750 kW while the 1200 kW generator is in steady state isochronous load sharing and the 600 kW generator is in steady state base load with a setpoint of 250 kW, the 1200 kW generator will again be carrying 500 kW and the 600 kW generator will again be carrying 250 kW. However, now as the total load demand increases only the 1200 kW generator will respond to the increase. At a combined load demand of 1450 kW, the 1200 kW generator will carry 1200 kW while the 600 kW generator in base load will still be carrying 250 kW. If the load demand exceeds 1450 kW, the steady state frequency of the bus will decrease and the load supplied by each individual generator will increase.

Soft Loading

The load command discrete input contact controls soft loading. If the load command discrete input is closed when the breaker (#33) input contact closes, the generator will soft load to the reference level of the mode selected (load sharing or base load). If the load command discrete input is open (unload) when the breaker (#33) closes, the generator will immediately unload to the Unload Trip Level set in the KW Setting menu. When the load command discrete input is closed, the generator will soft load to the reference level of the mode selected (load sharing or base load). The ramp rate is adjustable.

Soft Unloading

If the load command discrete input contact is opened (unload) while the breaker (#33) input contact is closed, the generator will soft unload from the present load level to the unload trip level. The load command discrete input must be maintained OPEN to complete the unload sequence.

> **IMPORTANT** **The Load Command discrete input must be maintained logic to operate the Soft Loading/Unloading sequence. The input must be OPEN to complete the Unload. The input must be CLOSED to complete the Load sequence and operate the generator in Isochronous Load Sharing or Base Load operating mode.**

Table 3-1. Description of Discrete Inputs while in Load Control

Gen brkr (33)	Base Load (34)	KW-control (38)	Load Gen (37)	Lower Spd/Ld (36)	Raise Spd/Ld (35)	Operation of Load Control
						Droop (speed control)
				X		Droop lower load (speed control)
					X	Droop raise load (speed control)
X			C			Load will ramp to isochronous load sharing
X			X			Isochronous load sharing as soon as generator load = system load
X			O			Load will ramp from isochronous load sharing to unload trip level
X						No effect
X		X	C			Load reference will ramp to internal minimum load reference
X		X	X			Load reference
X		X	X	X		Load reference will be lowered
X		X	X		X	Load reference will be raised
X		X	O			Load reference will ramp toward the unload trip level
X	X	X	X			Load reference will ramp to base load setting
X	X	X	X		X	Load reference will not change
X	X	X	X	X		Load reference will not change
X	X	X	O			Load control ramp to the unload trip level
X	X	X				Load control at the unload trip level

X = selected, C = closing, O = opening

Air/Fuel Ratio Control

A description of the A/F ratio control is given in the Functional block diagrams at the end of the manual. The A/F ratio control functions as a trim control on the main gas admission system (zero pressure regulator) as can be seen in the system overview below.

The main gas admission system consists of the carburetor and the zero pressure regulator. The trim valve between the carburetor and the zero pressure regulator works as a restrictor to change the air/fuel ratio in different operating conditions.

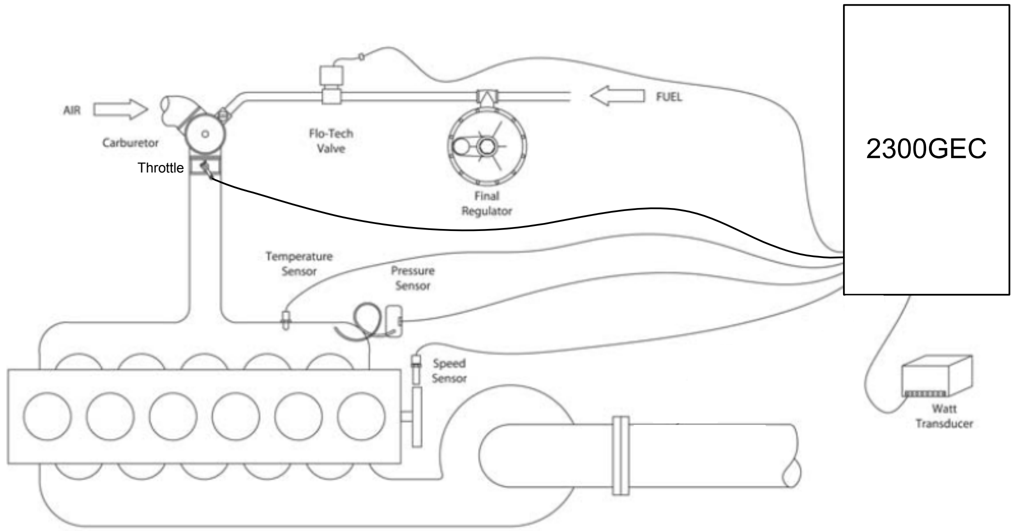


Figure 3-9. System Layout

The control of the trim valve is based on comparing the actual generated load by the engine to the theoretical amount of load that should be generated by the amount of gas burnt in the engine. To be able to do this, the theoretical amount of gas needs to be calculated (as it is not measured) and with this the theoretical load can be calculated.

The theoretical gas flow is calculated with the following parameters. The Manifold pressure MAP, the Manifold temperature MAT, the engine speed and some derived parameters, Ve and T_inlet.

The Volumetric efficiency (Ve) is determined from the MAP. The inlet temperature is calculated from the MAT. The engine speed and MAP are used directly in the Speed density model together with the Ve and the T_inlet. In the Speed density model the Qmn (normal mixture flow) is calculated. This is the theoretical amount of mixture (gas + air) going through the engine.

To calculate the amount of gas needed for this theoretical mixture the Reference Lambda (required Lambda) and the stoichiometric Lambda (m3 amount of air needed to burn 1 m3 of gas). With these values the Qmn (mixture flow) is converted to a Qgas (gas flow). This gas flow is then converted to the theoretical calculated load (Pcalc), the engine should deliver with that gas flow. To calculate the Pcalc, the generator efficiency the Total efficiency and the Lower Heating value are needed.

The Pcalc is then compared to the actual load on the generator. The Pcalc is used as setpoint and the actual load as process value. When the actual load is below the Pcalc the amount of gas to the carburetor is increased. When the actual load is above the Pcalc (theoretical desired load) the trim valve is further closed and the amount of gas to the carburetor reduced.

The above described system gives a closed loop system based on load to keep the lambda (air/fuel ratio) constant or within limits. The engine can also be run in open loop system (as can be seen in the functional block diagrams). This means that the position of the trim valve is only based on the MAP or the measured load. This open loop system is also used to calibrate the closed loop system as described in the Commissioning chapter.

Chapter 4.
HMI (Human Machine Interface) Communication

Introduction

The required hardware and software for the communication between the 2300G and the PC to be able to run the required HMI. This HMI is needed to make the necessary adjustments and calibrations to run the engine.

Requirements for Communication with the 2300G

To communicate successfully with the 2300G Gas Engine Control, the following hardware is needed:
- A Windows (95 or later) PC
- An RS-232 communication cable wired according to Figure 4-1

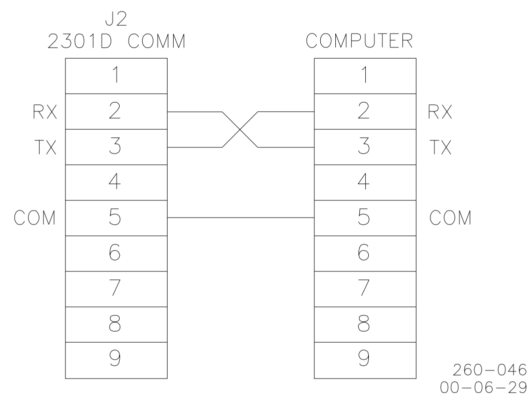


Figure 4-1. RS-232 Communication Cable

The following software and files can be downloaded and must be installed on the PC:
- Woodward Servlink Server & Watch Window
- Gas Engine Control HMI with p/n 5418-2385
  - Interponent application (HMI)
  - **2300G.reg** (for Windows 2000/XP) register-file to enable trending while using the Interponent Gas Engine Control HMI
  - **2300G_w9x_nt4.reg** (for Windows 95/98/NT4) register-file to enable trending while using the Interponent Gas Engine Control HMI.

First the Servlink and Watch Window applications need to be installed on the PC. After installation of these programs, the .reg files can be added to the Windows registry. This can be done by double clicking on one of the .reg files (depending on the current operating system of the HMI PC). Before running the .reg files be aware that your computers' registry is updated with an additional registry-file. This will not have any effect on the normal operating system and is used to activate the trending tool of the HMI.

If you are not familiar with the computers' registry, please contact your system operator for assistance.

Before being able to run the HMI, first a ***2300gec.net*** file needs to be created and installed in a directory:

C:\program files\Woodward\hmi\2300gasengine control

This is the network definition file.

Also the HMI application file (G2300) can be installed in this directory. A shortcut can be installed under Start → Programs → Woodward. See picture below.

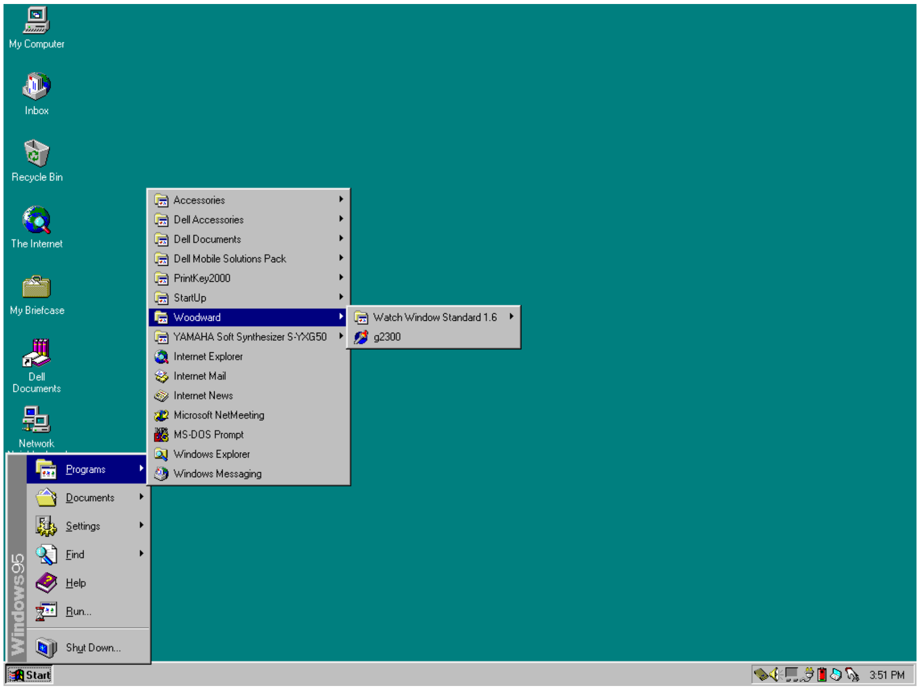


Figure 4-2. Installing a Shortcut

Before starting the HMI application G2300 file *for the first time* you must open Servlink Server to create the network definition file, ***2300gec.net.*** This file needs to be saved in the following directory:

C:\program files\Woodward\hmi\2300gasengine control

Start the Servlink Server as shown in the picture below:

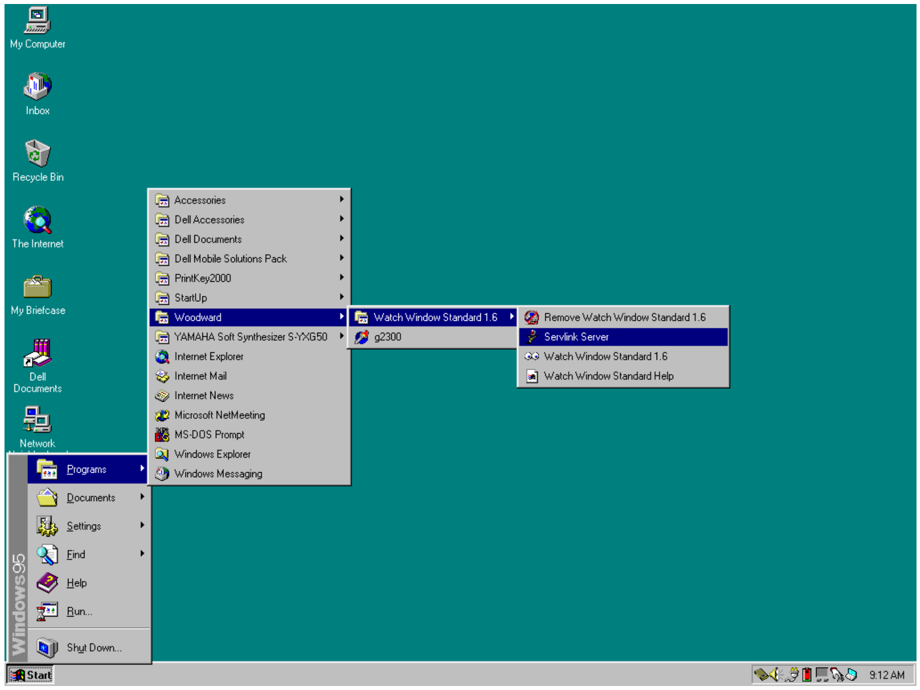


Figure 4-3. Starting Servlink

The next window will appear and select New under File to start a new network.

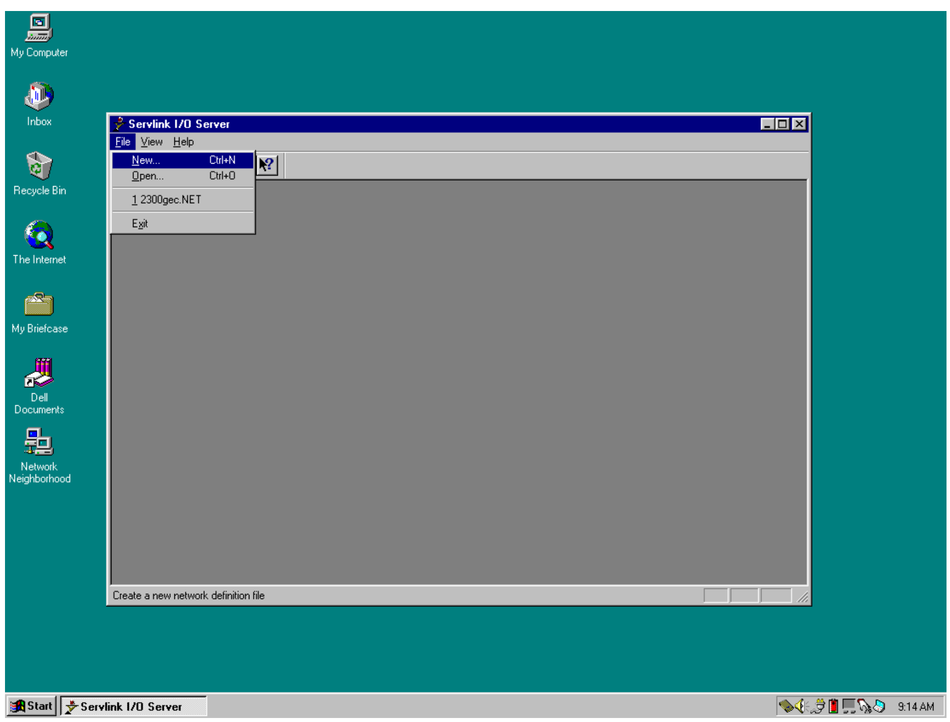


Figure 4-4. Create a New Network File

A Network Options window appears in where you can configure the communication. See picture below.

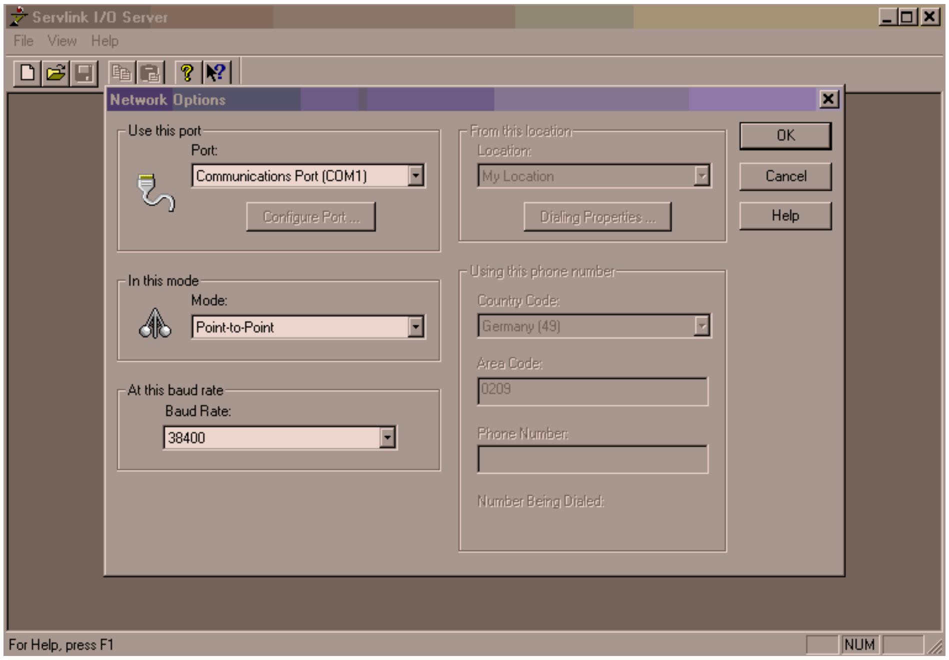


Figure 4-5. Configure Communications

Select the serial communication port from your pc. Mostly COM1.
The mode should be Point-to-Point.
Baud Rate must be 38400.
Press “OK” button to close this window.

The communication between your pc and the 2300G control is performed and showed to you by the following window.

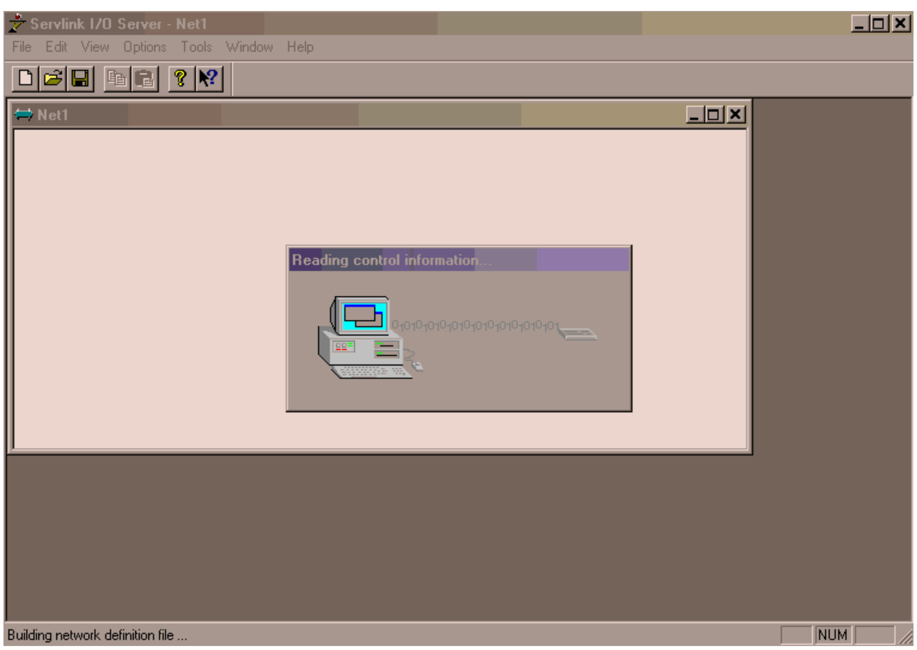


Figure 4-6. Uploading a New .net File

The connection has been established after you see the next window.

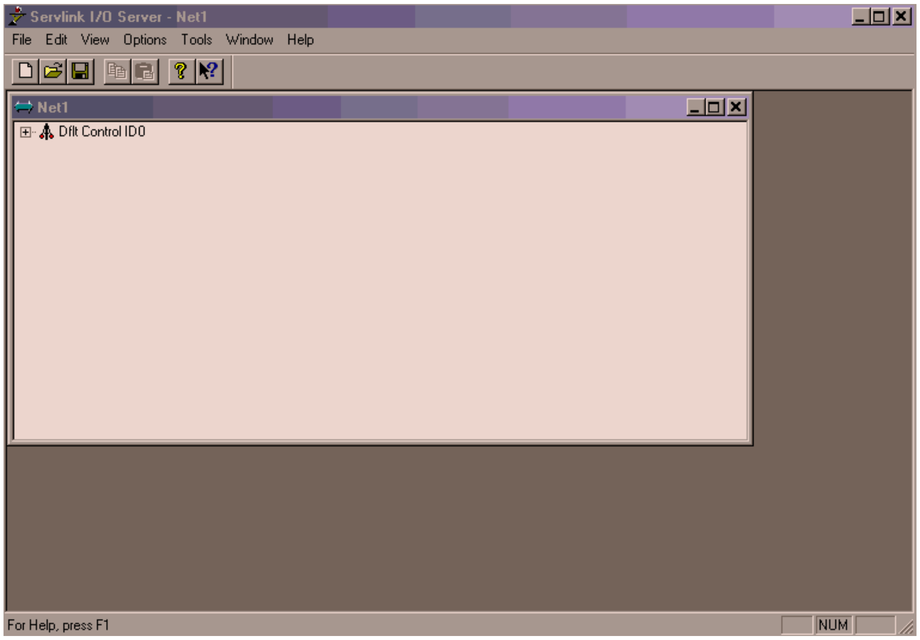


Figure 4-7. New .net File has been Created

Now you have to save this network in a different name so that the HMI recognizes the network file.
This should be done as follows. Go to File and select Save As…

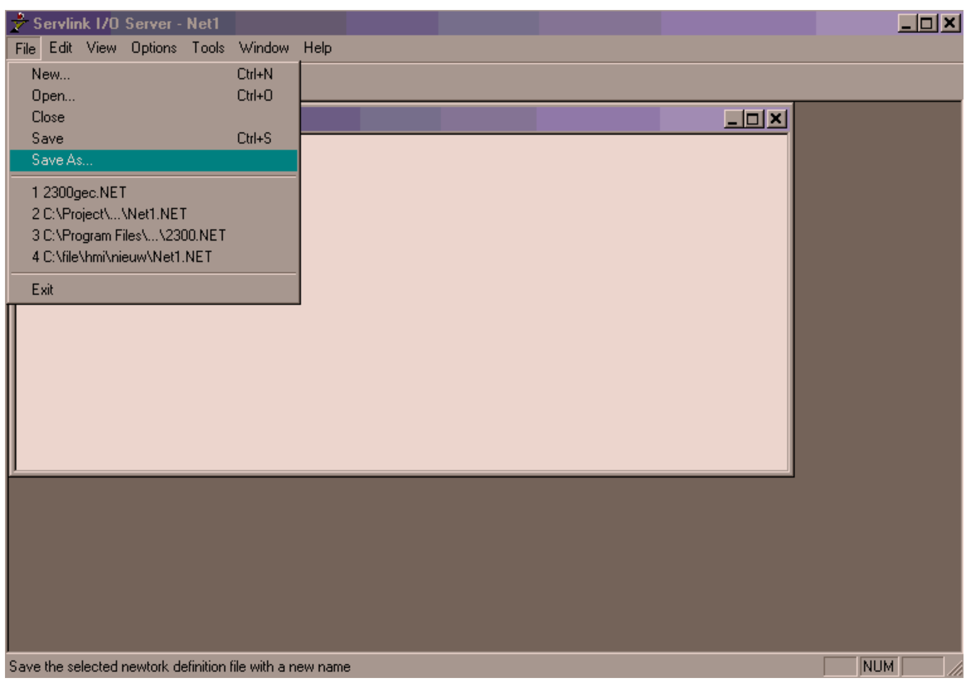


Figure 4-8. Saving the .net File

Find the following directory:
C:\program files\Woodward\hmi\2300 gas engine control
In this directory you see a file with the name:
2300gec.net
Save the file with exactly the same name.

You will be asked if you want to replace the existing file (if one exists already).
See picture below.

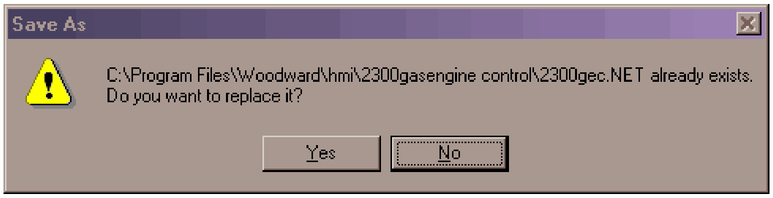


Figure 4-9. Overwriting the Old .net File

Push the “Yes” button.
Now you can close the complete Serving program by clicking on the cross on the top right corner.

The HMI software now can be started.

Chapter 5.
HMI (Human Machine Interface) Pages

Introduction

This chapter contains information on control calibration. Because of the variety of installations, plus system and component tolerances, the 2300G control must be tuned and configured for each system to obtain optimum performance.

This chapter contains information on how to enter control setpoints through the control's menu system using the software. Refer to Chapter 6, Commissioning the 2300G, for prestart-up and start-up settings and adjustments.

⚠WARNING	**An improperly calibrated control could cause an overspeed or other damage to the prime mover. To prevent possible serious injury from an overspeeding prime mover, read this entire procedure before starting the prime mover.**

NOTICE	**To prevent serious engine damage by engine knocking, use an external knock device.**

General

On top of each page three buttons can be toggled. Re-boot Control, Save Values and Configure Mode. Further the software ID app p/n is displayed.

To toggle the Re-boot button, the control must be in I/O lock. To get in I/O lock the Configure Mode button must be toggled. The following window will appear when toggling the Configure Mode button:

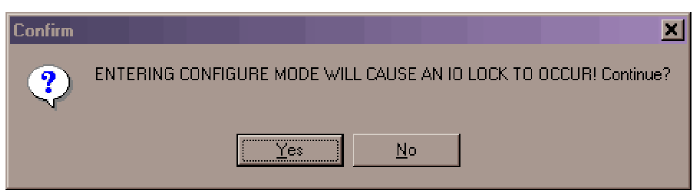


Figure 5-1. Going in I/O Lock

Before going into I/O lock, be sure the engine is not running. I/O lock will disable all input and output signals.

After pressing “Yes” the control is in I/O lock.

Now the Re-boot button can be toggled. The control now will automatically re-boot and the control is active again.

The Save Values button must be toggled each time a setting has been changed. Now the settings are burned on the EEPROM in the control. In case this is forgotten and the control is re-boot, the changed settings will be lost.

Monitor Page

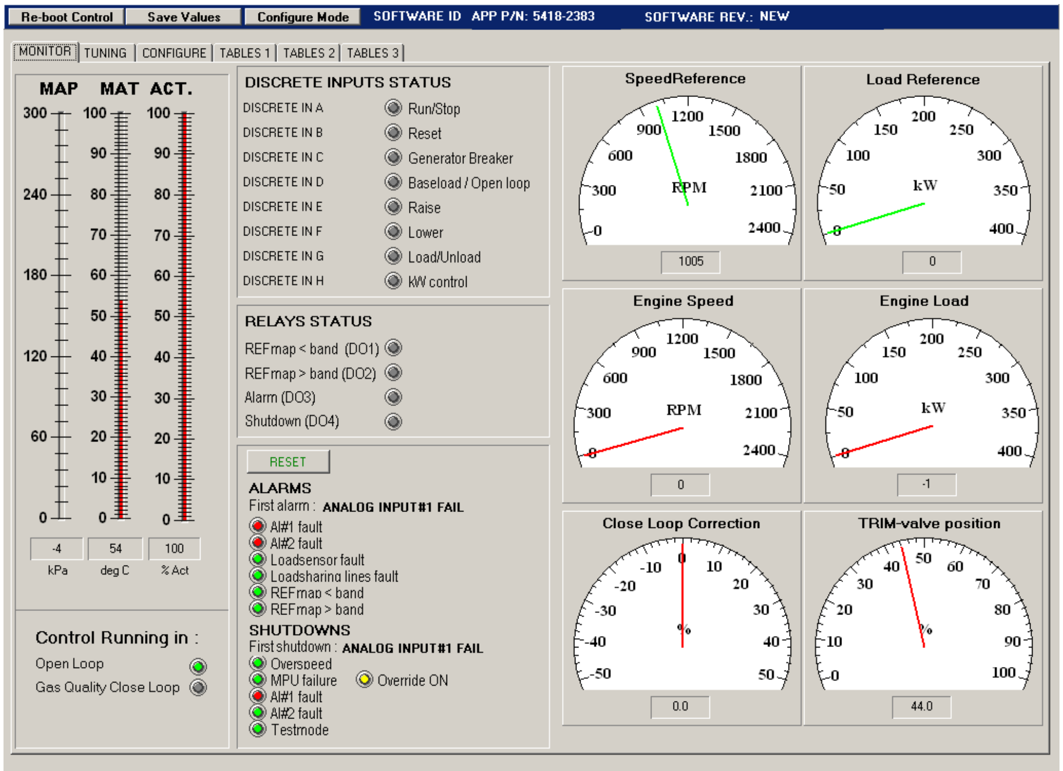


Figure 5-2. Monitor Page

The monitor screen is a display group for general monitoring of the engine/generator.

The **MAP** bar graph displays actual Manifold Absolute Pressure (kPa).

The **MAT** bar graph displays actual Manifold Air Temperature (deg. C).

The **Actuator** bar graph displays actual actuator position in percentage of full travel.

Control Running In

Displays the status of the control. When the control is running in open loop the LED will illuminate green. In this status the Gas Quality Close Loop LED will be gray.

The Gas Quality Close Loop LED will illuminate green when the control is running in Gas Quality Close Loop. In this status the Open Loop LED will be gray.

Discrete Inputs

LEDs display the status of the discrete inputs. When the input is inactive the LED will be gray. Activated the LED will illuminate yellow.

Relays

LEDs display the status of the relay outputs. When the input is inactive the LED will be gray. Activated the LED will illuminate yellow.

Alarms

First alarm displays the alarm that was the first to set the alarm latch.

LEDs display the alarm status of the analog inputs:

- When no alarm is present the LED will illuminate green
- When an input fails, the corresponding LED will illuminate red

Shutdowns

First shutdown displays the shutdown that was the first to set the shutdown latch.

LEDs display the shutdown status:

- When no shutdown is present the LED will illuminate green
- When a shutdown is set, the corresponding LED will illuminate red

Gauges

The gauges show the actual values of engine speed, speed reference, engine load, load reference, gas quality close loop correction and MAS valve (trim-valve) position.

Tuning Pages

This is a selection of pages where the adjustments of the speed and load control as well as the air fuel ratio control are done. Seven different tabs are available under this page that perform the different functions.

There is also a trending section where different signals are trended in time. This is done with an external program integrated in the HMI, described below. It is common for all the tuning pages.

Trendtool

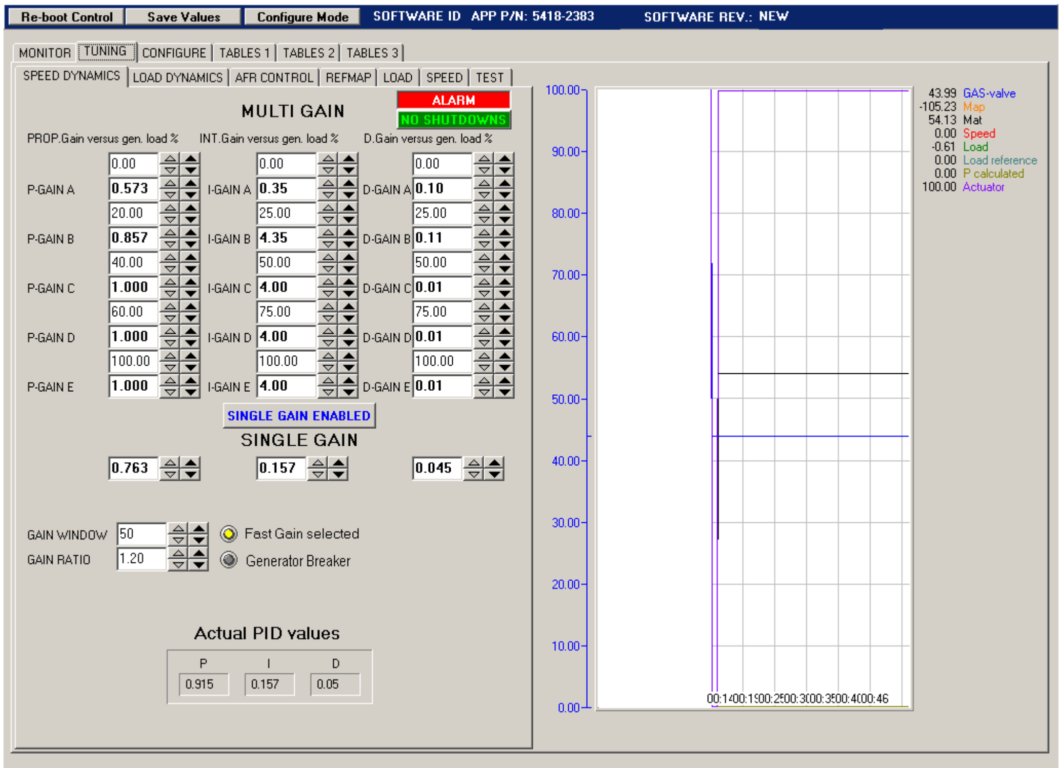


Figure 5-3. Trendtool

All Tabs under header “Tuning” show on the right side of the page a real-time trender that enables you to monitor and log engine performance. The trender program that is used is Woodward trendtool.

The values to be trended are GAS-valve position, MAP, MAT, Speed, Load, Load reference, P calculated and the actuator position.
To set up “Trendtool” right-mouse-click the trendtool area on the page to display the following pop-up:

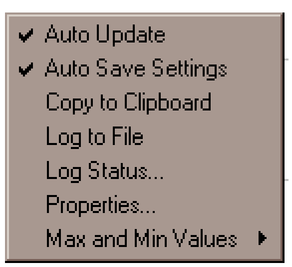


Figure 5-4. Trendtool Activation

Select Properties to display the following configuration screen.

Trend Configuration Screen

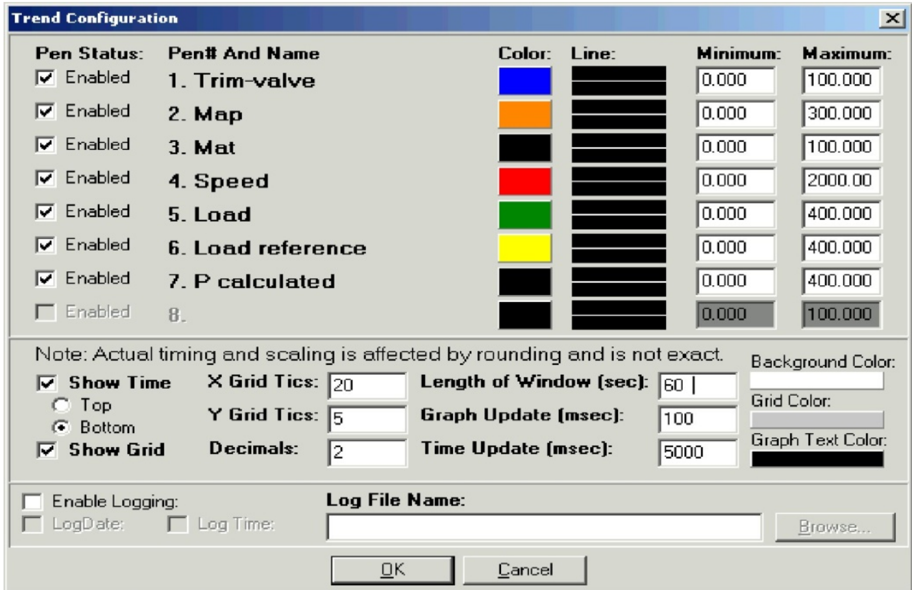


Figure 5-5. Trend Configuration

In the check boxes below the “**Pen Status**” header the corresponding pens can be switched on and off.

In the fields below “**Minimum**” and “**Maximum**” the range of the corresponding values can be adjusted.

With the **Show time** check box you can select whether a timestamp will be printed below the trend or not. In this case the timestamp will be printed at the bottom of the trend because the **Bottom** checkbox is selected.

With the **X Grid Tics** field the number of vertical lines in the window are defined. In this screen, the **Length of Window** is 60 seconds, so with 20 **X Grid tics** every 3 seconds a vertical line will be displayed

In the **Y Grid Tics** field the number of horizontal lines in the window are defined.

The **decimals** field controls the number of decimals that are displayed in the graph.

The **Graph update** field controls the time interval at which the graph is updated.

The **Time update** field controls the time interval at which the timestamp is Placed.

The **Enable Logging** checkbox controls whether data will be logged to file or not. When **Enable Logging** is selected, a filename and path MUST be defined in **Log File Name.** Click the OK button to activate Trend configuration.

To activate logging, right-mouse-click on the Trendtool area, the following pop-up menu will appear:

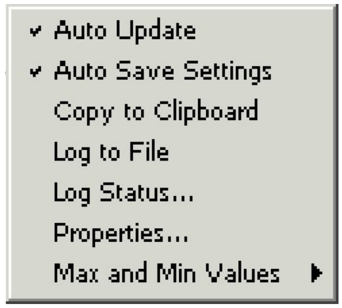


Figure 5-6. Logging Activation

Left-mouse-click **Log to File** to activate logging to file.

To stop logging right-mouse-click on the Trendtool area, and left mouse-click **Log to File** again.

Speed Dynamics Tab

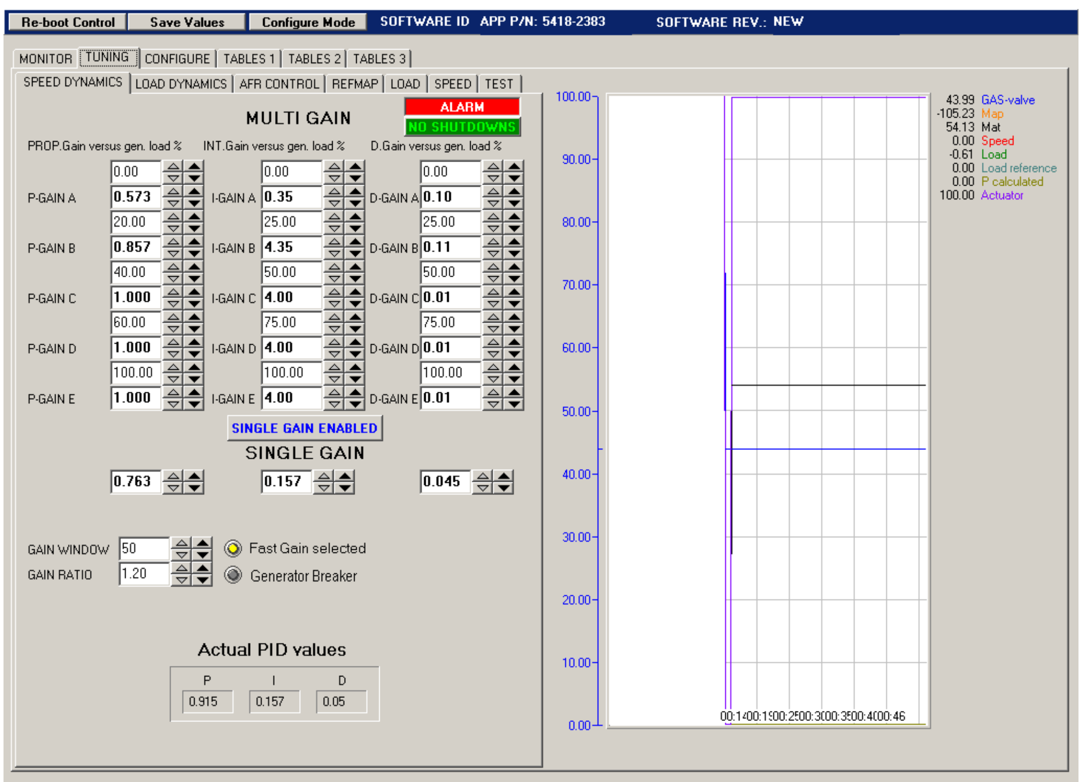


Figure 5-7. Speed Dynamics

Dynamic adjustments affect the stability and transient performance of the engine.

Two sets of dynamics are provided:

- Speed Dynamics (Speed control mode)
- Load Dynamics (Load control mode)

The control mode is selected automatically depending on the generator breaker feedback signal and the KW-Control input status

ALARM and SHUTDOWN indicators
These indicators are green when no alarm or shutdown is present. As soon as an alarm or a shutdown occurs, the corresponding indicator changes color to red.

PROP. GAIN versus generator load %
This 5-point curve determines the proportional gain as a function of generator load. Both load point and P-gain values can be adjusted. This 5-point curve is active when Multi Gain is Enabled.

INT. GAIN versus generator load %
This 5-point curve determines the integral gain as a function of generator load. Both load point and I-gain values can be adjusted. This 5-point curve is active when Multi Gain is Enabled.

D-GAIN versus generator load %
This 5-point curve determines the derivative gain as a function of generator load. Both load point and D-gain values can be adjusted. This 5-point curve is active when Multi Gain is Enabled.

MULTI or SINGLE GAIN ENABLED
With this toggle switch, Single Gain or Multi Gain mode can be selected.

SINGLE GAIN
With these spin edits P, I and D can be set for the full load range, typically this feature is not preferred on a gas-engine.

GAIN WINDOW, GAIN RATIO
When the speed error is greater than the GAIN WINDOW setting, the actual P-gain from multi gain or single gain is multiplied with GAIN RATIO. This is indicated with the yellow LED next to the GAIN WINDOW setting.

Actual PID values
These are the actual P, I and D values as they are used by the PID-controller.

Load Dynamics Tab

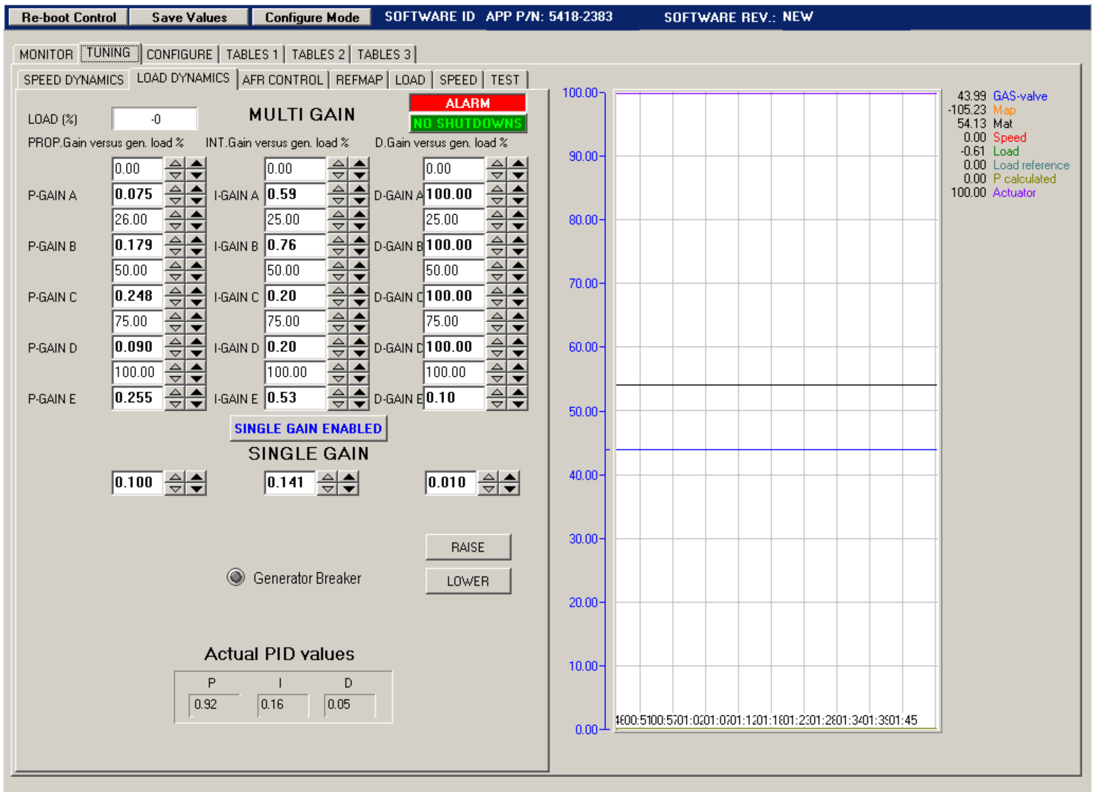


Figure 5-8. Load Dynamics

In the load control mode the PID controller keeps generator load equal to the load reference regardless of engine speed. This also means there is no frequency control and this needs to be done by a grid or a different engine if running in an island. To be in Load control mode, the generator breaker contact needs to be TRUE.

Raise load button
With this push button the load reference can be increased manually.

Lower load button
With this pushbutton the load reference can be decreased manually.

AFR Control Tab

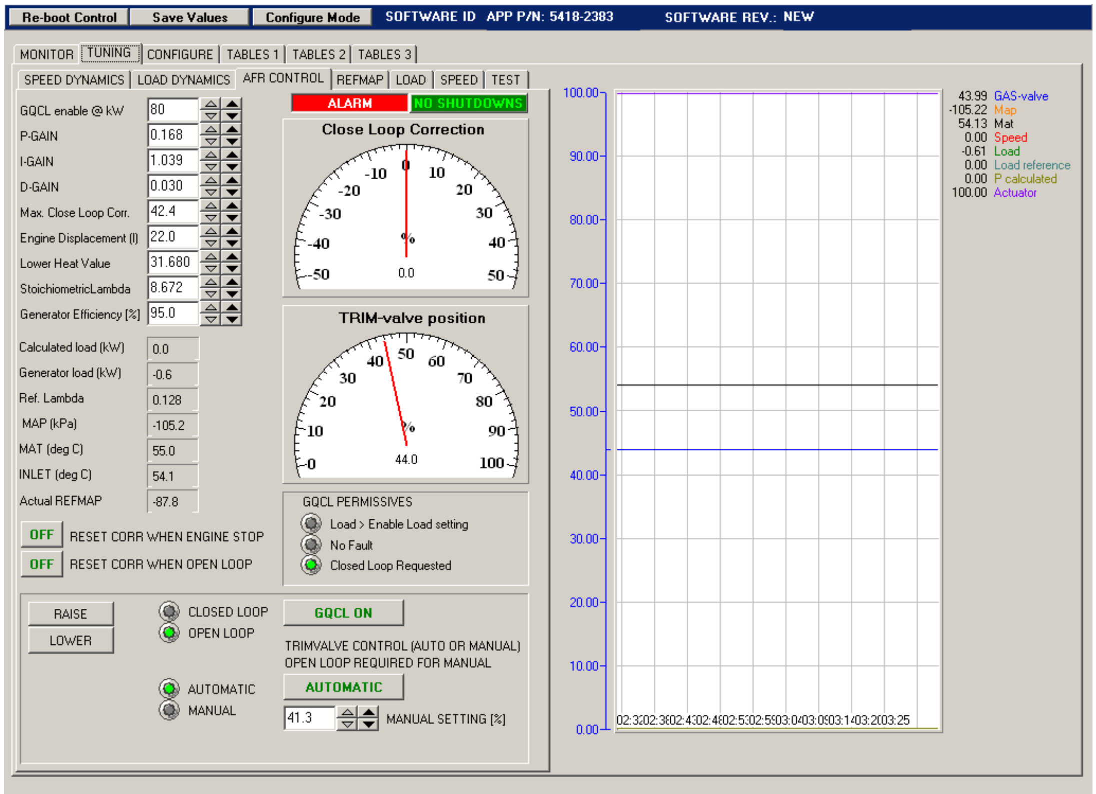


Figure 5-9. AFR Control Tab

GQCL enable @ kW
This is the kW-setpoint at which the GQCL mode will become active.

P, I and D-gain
These are the dynamic settings of the GQCL PID. These settings normally do not have to be changed.

Maximum Close Loop Correction (%)
These settings limit the positive and negative correction in percentage that the GQCL PID can make on the trim valve-position.

Engine Displacement (Liter)
The engine displacement in liters. It is used to calculate the airflow through the engine.
Fill out this value before calibrating the tables on the Table pages.

Lower Heating Value (MJ/m³)
The lower heating value (LHV) of the gas that is used at the time that the engine is being calibrated. It is used for the GQCL calculation. Fill out this value before calibrating the tables on the Table pages.

Stoichiometric Lambda (m³ air/m³ gas)
The stoichiometric air to fuel ratio of the gas that is used during calibration of the engine.

Fill out this value before calibrating the tables on the Table pages.

Gas Type	Symbol	HHV	LHV	Needed dry air for stoichiometric combustion	Needed wet air for stoichiometric combustion	Caloric value mixture
		MJ/m³	MJ/m³	m³/m³	m³/m³	MJ/m³
Methane	CH_4	39.82	35.88	9.565	9.671	3.362
Ethane	C_2H_6	70.31	64.35	16.869	17.056	3.564
Propane	C_3H_8	101.23	93.21	24.381	24.652	3.634
n-Butane	C_4H_{10}	133.69	123.47	32.298	32.657	3.668
Carbon monoxide	CO	12.63	12.63	2.387	2.413	3.701
Hydrogen	H_2	12.74	10.78	2.383	2.41	3.161
Gronings Natural gas		35.1	31.68	8.434	8.527	3.325
Ekofisk gas		44	39.82	10.519	10.646	3.419
Bio gas		23.89	21.53	5.739	5.803	3.165
LPG		114.21	105.31	27.548	27.854	3.65
n-Octane	C_8H_{18}	268.86	249.5	65.203	65.928	3.728

Calculated Load (kW)
This field displays the power as calculated by the control.

Generator Load (kW)
This field displays actual generator power measured by the control.

Reference Lambda (–)
This field displays the actual reference Lambda output of the table.

MAP (kPa)
This field displays the actual Manifold Absolute Pressure.

MAT (deg C)
This field displays the actual Manifold Air Temperature

INLET (deg C)
This field displays the Inlet Temperature of the engine. This means the MAT temperature compensated for the heating in the manifold. This calibration done in the TABLES 3 page (see below).

Actual REFMAP
This field displays the MAP compensated for MAT. It should be constant for the different load points when running with the same air fuel ratio. It is used to check with a deadband if the engine is still running within the limits of the alarm levels. It is also used as a backup of the load sensor in the droop system.

Reset of Correction Factor
The actual correction factor needed by the control to maintain the correct air/fuel ratio can be reset in different ways selected on the AFR CONTROL Tab.

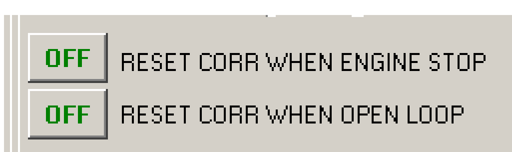


Figure 5-10. Reset Correction Factor

RESET CORR. WHEN ENGINE STOP:

OFF: The correction factor that is active when reaching zero speed is not set to 0, but left at its actual value.

ON: The correction factor is reset to 0 when reaching an engine stop condition.

RESET CORR. WHEN OPEN LOOP:

OFF: The correction factor that is active when reaching the minimum load for GQCL is not reset, but sampled and used again when going into GQCL the next time.

ON: The correction is reset to 0 when the GQCL is disabled.

The above functions are connected through an OR function. This means that either of these can reset the correction.

Close Loop Correction (%)
The gauge shows the actual Closed-loop correction that is calculated by the control in Closed-loop mode. This signal biases the actual open-loop setpoint of the MAS valve (trim-valve).

MAS valve (trim-valve) position (%)
The gauge shows the actual position of the MAS valve (trim-valve).

RAISE/LOWER button
With these buttons the load can be changed during the calibration process.

LED indicators CLOSED LOOP and OPEN LOOP
These LEDs indicate if the system is running in open loop, so without closed loop correction or in GQCL mode.

LED indicators GQCL permissives
These LEDs indicate if the system is in GQCL. When all the permissives are met, the system runs in GQCL.

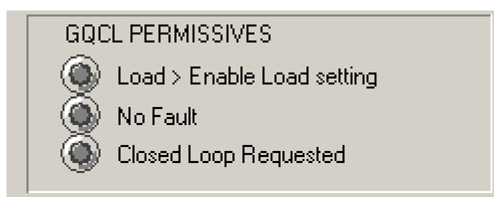


Figure 5-11. GQCL Permissives

- The load needs to be above the minimum required setting
- There should be no fault. This means:
  - The load sensing circuit needs to be OK
  - The MAP sensor should be OK (ANIN#1)
  - When Discrete input 34 is used as Open Loop selector, this input should not be active.
- Closed Loop needs to be selected with the button below.

Button OPEN LOOP / GQCL ON mode
With this button you can manual change the close-loop mode from Closed-loop into Open-loop (manual mode). However, to go into GQCL the permissives for this mode need to be met. The LED indicators in the area above the button show if the permissives are met.

Button MANUAL / AUTOMATIC
With this button you can change the operation of the MAS valve (trim-valve) from manual to automatic. Before the valve can be operated in Manual, the system should be in Open Loop.

REFMAP Tab

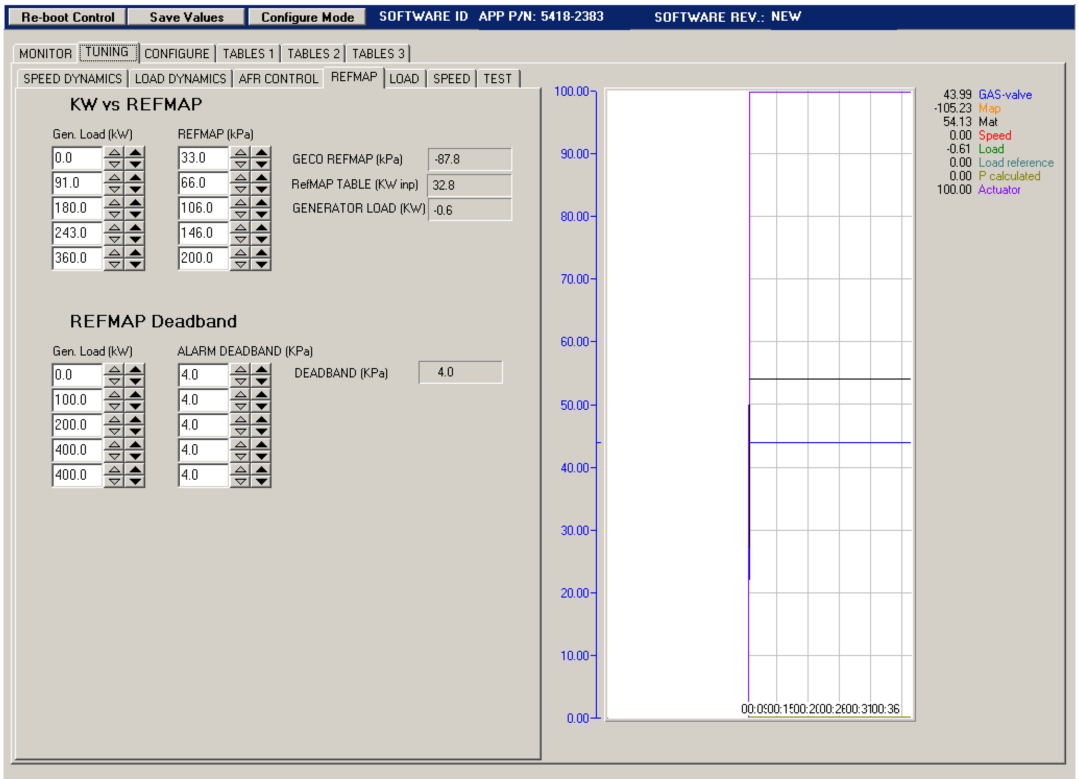


Figure 5-12. REFMAP

KW vs REFMAP table
With this table the RefMAP value is calculated. The input of the table is the measured generator load, the output is the MAP the engine needs to generate a certain load.

This value is compared to the actual MAP the engine is running on. This difference is compared to an alarm deadband value.

REFMAP Deadband
This table determines the alarm deadband for a certain load range. The alarm deadband value is compared to the absolute difference between the actual MAP (compensated for MAT) and the calculated REFMAP. When this difference is more than the deadband alarm value, an alarm will be given.

Load Tab

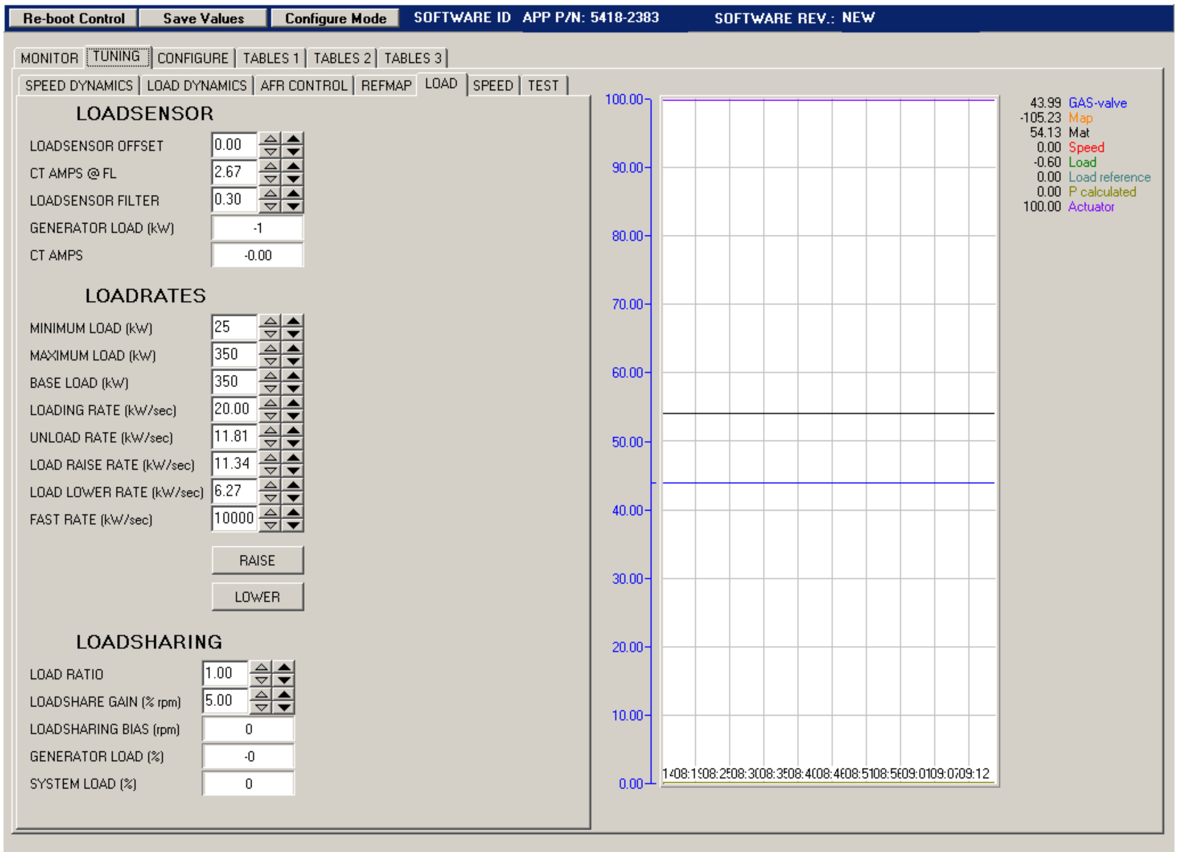


Figure 5-13. Load Tab

On the **LOAD** Tab, the load control parameters can be tuned.

LOAD SENSOR section
The 2300 Gas Engine Control calculates the real power from the PT and CT inputs. Since current transformers can have several different ratios, the load sensor can be tuned to match the actual installed CT.

LOAD SENSOR OFFSET
With this parameter the offset of the load sensor can be adjusted.

CT AMPS @ FL
With this parameter the maximum current of the CT's is adjusted. Maximum current at full load of the engine needs to be measured or calculated and entered here.

LOAD SENSOR FILTER
This parameter sets the time constant of the load sensor filter.

GENERATOR LOAD (kWe)
This field displays the actual calculated generator load (kWe).

CT AMPS
This field displays the actual CT amps. It can be used to determine the CT amps @ full load.

LOADRATES section

MINIMUM LOAD (kW)
This set point is the minimum load that the load reference can be set to.

MAXIMUM LOAD (kW)
This set point is the maximum load that the load reference can be set to.

BASE LOAD (kW)
This set point is the base load that the load reference can be set to.
The base load must be set between the minimum and maximum load.

LOADING RATE (kW/sec)
This rate is the rate in kW/sec at which the load reference will ramp up when the generator is in kW-mode and the discrete LOAD/UNLOAD- input is activated.

UNLOAD RATE (kW/sec)
This rate is the rate in kW/sec at which the load reference will ramp down when the generator is in kW-mode and the discrete LOAD/UNLOAD- input is de-activated.

LOAD RAISE RATE (kW/sec)
This rate is the rate in kW/sec at which the load reference will ramp up when the RAISE input, or the RAISE button on this screen is activated.

LOAD LOWER RATE (kW/sec)
This rate is the rate in kW/sec at which the load reference will ramp down when the LOWER input, or the LOWER button on this screen is activated.

FAST RATE (kW/sec)
This rate is the rate in kW/sec at which the load reference will ramp when an emergency shutdown or breaker open contact is given.

RAISE
This momentary button is used to raise the load reference.

LOWER
This momentary button is used to lower the load reference.

LOADSHARING section

LOAD RATIO
This parameter sets what proportion of load the engine will take when in load sharing mode. Normally this value should be 1, when for some reason load sharing should be asymmetric, this parameter can be tuned between 0 and 1

LOADSHARE GAIN
This parameter sets the dynamic response of the load sharing control. This value should normally not be tuned.

LOADSHARE BIAS
This field displays the actual speed bias in rpm that the load-sharing algorithm adds to the speed reference.

GENERATOR LOAD %
This field displays actual generator load in percent.

SYSTEM LOAD %
This field displays system load (load sharing lines signal) in percent

Speed Tab

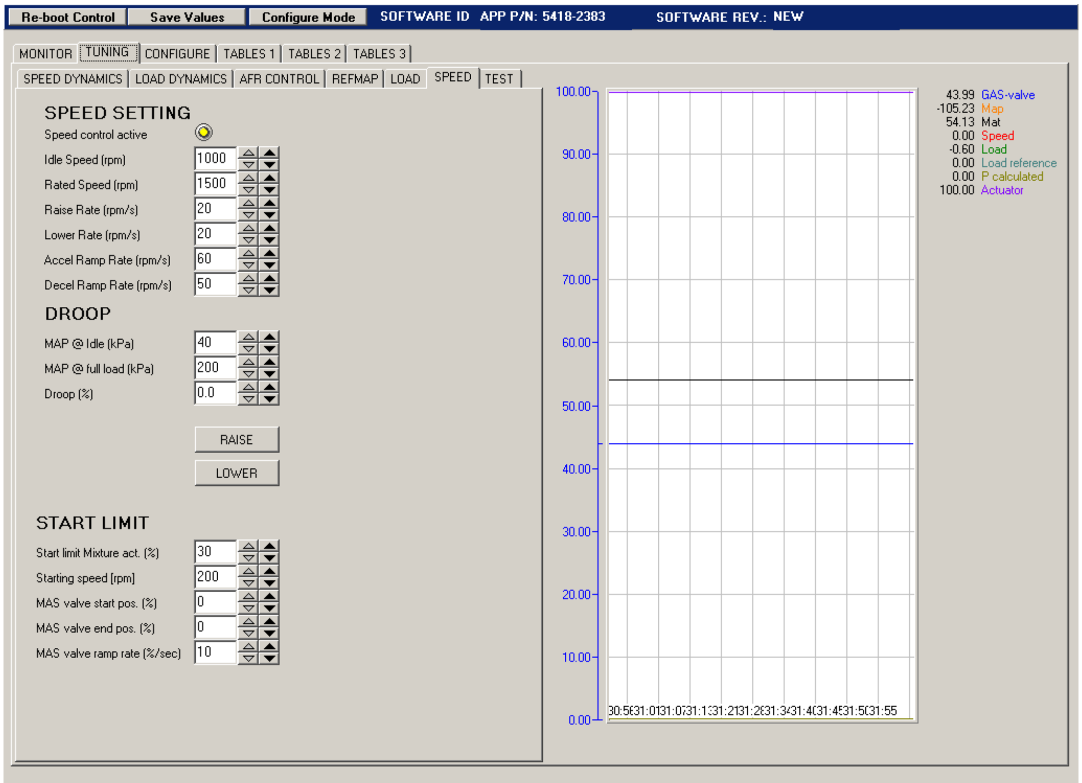


Figure 5-14. Speed Tab

On the **SPEED** Tab the different speed setting parameters can be set.

SPEED SETTING section
Speed control active
This indicator illuminates yellow when speed control is active. In load control the indicator will be gray.

IDLE SPEED (rpm)
This setting sets the minimum speed of the engine.

RATED SPEED (rpm)
This setting sets the nominal speed of the engine.

Raise Rate (rpm/sec)
This setting sets the rate in rpm/sec. at which the speed reference will raise when the RAISE input is activated.

Lower Rate (rpm/sec)
This setting sets the rate in rpm/sec. at which the speed reference will lower when the LOWER input is activated.

Accel Ramp Rate (rpm/sec)
This setting sets the rate in rpm/sec. at which the speed reference will raise when rated speed is selected.

Decel Ramp Rate (rpm/sec)
This setting sets the rate in rpm/sec at which the speed reference will lower when idle speed is selected.

DROOP section
MAP @ Idle (kPa)
Record the MAP @idle and fill in this value
This value will be used for droop calculation in case the load sensing fails then droop will be a function of MAP.

MAP @ Full Load (kPa)
Record the MAP @ full load and fill in this value
This value will be used for droop calculation in case the load sensing fails then droop will be a function of MAP.

DROOP %
This setting sets the droop % as a function of generator load.
When the load sensing fails droop will be a function of MAP.

Raise
This momentary button is used to raise the speed reference.

Lower
This momentary button is used to lower the speed reference.

START limit section
Start limit Mixture act. (%)
This setting is the maximum throttle position during engine start. As soon as the PID is in control, the limiter is de-activated.

Starting speed [rpm]
This setting is the speed at which the MAS (trim-valve) offset becomes active and is set to its start position. (This feature is meant to troubleshoot engine start problems and should be left at default value under normal conditions)

MAS valve start pos. [%]
This setting is the offset added to the normal position the MAS valve has during start-up of the engine. This value can be positive or negative and is set immediately when the Starting speed is reached. (This feature is meant to troubleshoot engine start problems and should be left at default value (=0) under normal conditions)

MAS valve end pos. [%]
This setting is the offset added to the normal position the MAS valve has during start-up of the engine. The control ramps to this offset value with a tunable ramp rate from the start position (entered above) after reaching starting speed. When this value is not 0, there will remain an offset in the position of the MAS value under normal running conditions. (This feature is meant to troubleshoot engine start problems and should be left at default value (=0) under normal conditions)

MAS valve ramp rate [%/sec]
This setting determines the rate the offset is reduced from the starting position to the end position during the start-up of the engine. (This feature is meant to troubleshoot engine start problems and should be left at default value under normal conditions)

TEST Tab

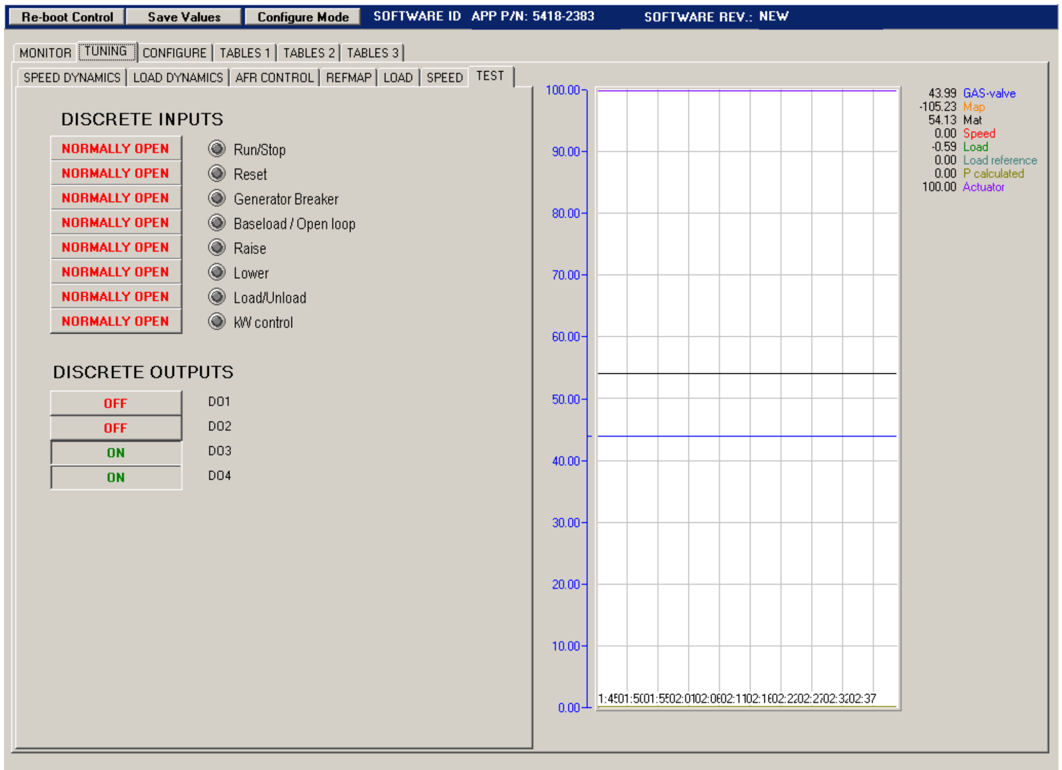


Figure 5-15. Test Tab

The testing of inputs and outputs should be done with care. It has an immediate effect on the control as this happens in real time.

DISCRETE INPUTS

On the **Test** Tab all digital input channels can be toggled from normally open into normally close.

Changing the channel from normally open into normally close will change the status of the LED. In normally close status the LED will illuminate yellow, otherwise it will be gray.

DISCRETE OUTPUTS

On the **Test** Tab all digital output channels can be toggled from normally open into normally close.

Configure Page

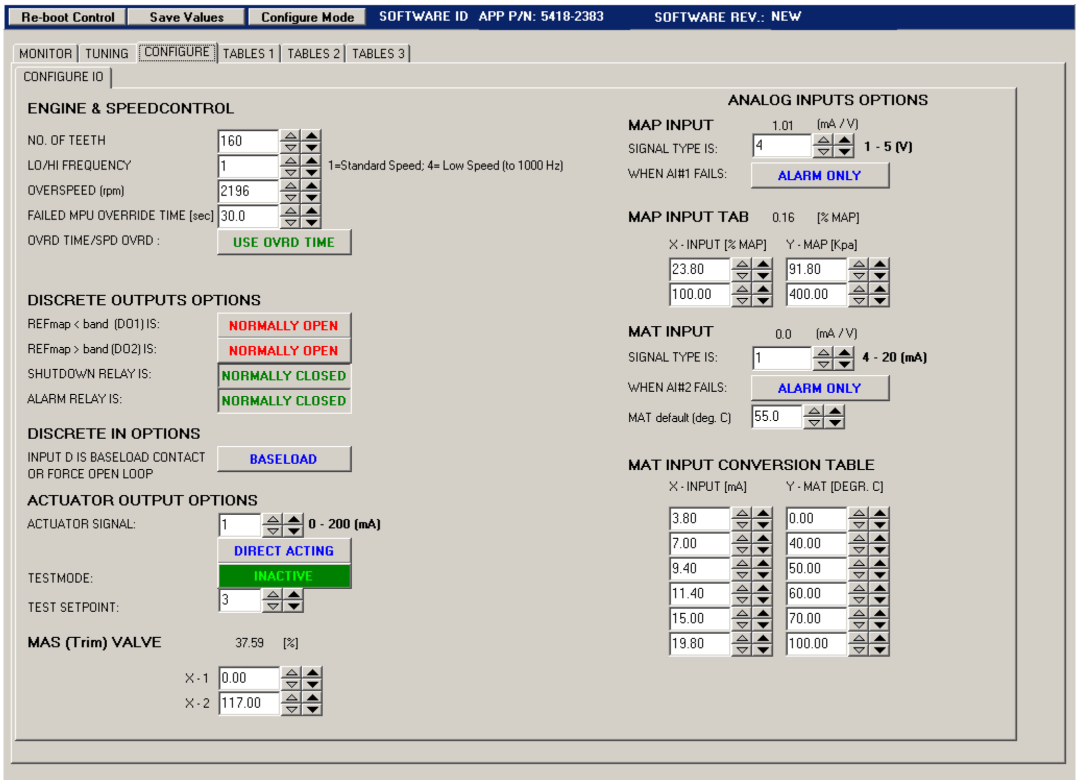


Figure 5-16. Configure Page

Engine & Speed Control Section

NUMBER OF TEETH
This is the number of teeth or holes of the gear or flywheel.

NOTICE	Make sure the Rated Speed and Number of Teeth are set correctly for your application as described earlier in this chapter.

LO/HI FREQUENCY
Speed function 1 is used for standard speed sensing for MPU sensors. The speed is sensed once every 1/16th of a full engine revolution.

Speed functions 2 and 3 are not used.

Speed function 4 is specifically designed to give readings at low speeds. Speed is calculated by using only two inter-tooth time intervals. This function measures the time between each tooth and stores the two most recent measurements. This block samples and averages these two measurements each time the block executes and uses the average to calculate speed. This speed function is only usable for frequencies under 1000 Hz!

OVERSPEED (rpm)
When the engine runs above this speed the control gives a shutdown command to the mixture throttle/Actuator and also the Shutdown relay will be activated.

WARNING

The engine must be equipped with an overspeed shutdown device, operating fully independently from the prime mover control, to protect against runaway or damage to the engine, possible personal injury or loss of life should the electric control or the actuator fail.

Discrete Outputs Options

REFmap < band (DO1)
This relay will be activated when the REFmap value exceeds the alarm deadband value. The RefMAP value is calculated with a table. The input of the table is the measured generator load, the output is the MAP the engine needs to generate a certain load.
This value is compared to the actual MAP the engine is running on. This difference is compared to an alarm deadband value. The relay can be configured to be normally closed or normally open.

REFmap > band (DO2)
This relay will be activated when the REFmap value exceeds the alarm deadband value. The RefMAP value is calculated with a table. The input of the table is the measured generator load, the output is the MAP the engine needs to generate a certain load.
This value is compared to the actual MAP the engine is running on. This difference is compared to an alarm deadband value. The relay can be configured to be normally closed or normally open.

SHUT DOWN RELAY
This relay will be activated when a shutdown is present. The relay can be configured to be normally closed or normally open.

ALARM RELAY
This relay will be activated when an alarm is present. The relay can be configured to be normally closed or normally open.

Discrete Input Options

Input D (34)
This input is configurable for either Base Load operation or Force to Open Loop. When configured as Base Load, the input status determines if the baseload setpoint on the HMI is used (also the breaker contact and the KW-control input should be TRUE) or the control remains in normal KW control (Load control). When the contact is closed, the load reference will move to the selected Base Load reference (this is only tunable at the HMI, there is no analog input for this setpoint). The raise and lower inputs are not functional when in baseload control.

When configured as Force to Open Loop, the input will switch off the GQCL when made active TRUE. When switched off it will return to GQCL.

Actuator Output Options

ACTUATOR SIGNAL:
- 1 = 0–200 mA
- 2 = 4–20 mA
- 3 = 0–20 mA

With the toggle button direct or reverse acting can be selected.

The toggle button for Test Mode activates the actuator to be in test mode. Only do this when the gas supply valve is fully closed. When the test mode is activated a shutdown is also activated.

Enter a desired value in Test Setpoint to have the actuator move to this value. After testing, toggle the Test Mode button again to make it inactive.

MAS (Trim) VALVE

Calibration of the MAS valve can be done here. When the valve is put in manual mode and can be moved (see Tuning page; AFR Control tab), the output signal to the trim valve can be checked. It should not exceed the minimum and maximum allowed values. In case of an L-series actuator these values are 0.5 to 4.5 volts when using a voltage input model.

Analog Input Options

MAP INPUT
The value displayed here shows input signal in mA or Volts, depending on the signal type.

SIGNALTYPE
Here the input signal type can be configured:
- 1 = 4–20 mA
- 2 = 0–5 V
- 3 = ±2.5 V
- 4 = 1–5 V

WHEN AI#1 (MAP) FAILS
This toggle button will configure alarm or shutdown when the MAP input fails. This is default calibrated at 12.5% of the range (2 mA and 22 mA).

If **ALARM ONLY** is selected and the MAP sensor fails, the control will automatically switch to Open Loop and the alarm will be activated. AI#1 Fault under header Alarms on the Monitor page then illuminates red.

If **SHUTDOWN** is selected and the MAP sensor fails, the control will automatically generates a shutdown and. AI#1 Fault under header Shutdowns on the Monitor page then illuminates red.

MAP INPUT TAB

Input calibration is performed with the table. The X-input in % MAP can be defined and the Y-output in kPa is tuned.

The MAP value displayed is the input to the curve in % MAP.

MAT INPUT
The value displayed here shows input signal in mA or Volts, depending on the signal type.

SIGNALTYPE
Here the input signal type can be configured:

- 1 = 4–20 mA
- 2 = 0–5 V
- 3 = ±2.5 V
- 4 = 1–5 V

WHEN AI#2 FAILS
This toggle button will configure alarm or shutdown when the MAT input fails. This is default calibrated at 12.5% of the range (2 mA and 22 mA).

If **ALARM ONLY** is selected and the MAT sensor fails, the control will automatically uses the default MAT-value.
AI#2 Fault under header Alarms on the Monitor page then illuminates red.

If **SHUTDOWN** is selected and the MAT sensor fails, the control will automatically generates a shutdown.
AI#2 Fault under header Shutdowns on the Monitor page then illuminates red.

MAT INPUT CONVERSION TABLE

Because MAT-sensors can have different characteristics, this input can be calibrated using a 6-point curve.

The x-values represent the input values, the y-values are the temperatures in degrees Celsius.

Tables Pages

TABLES 1 Page

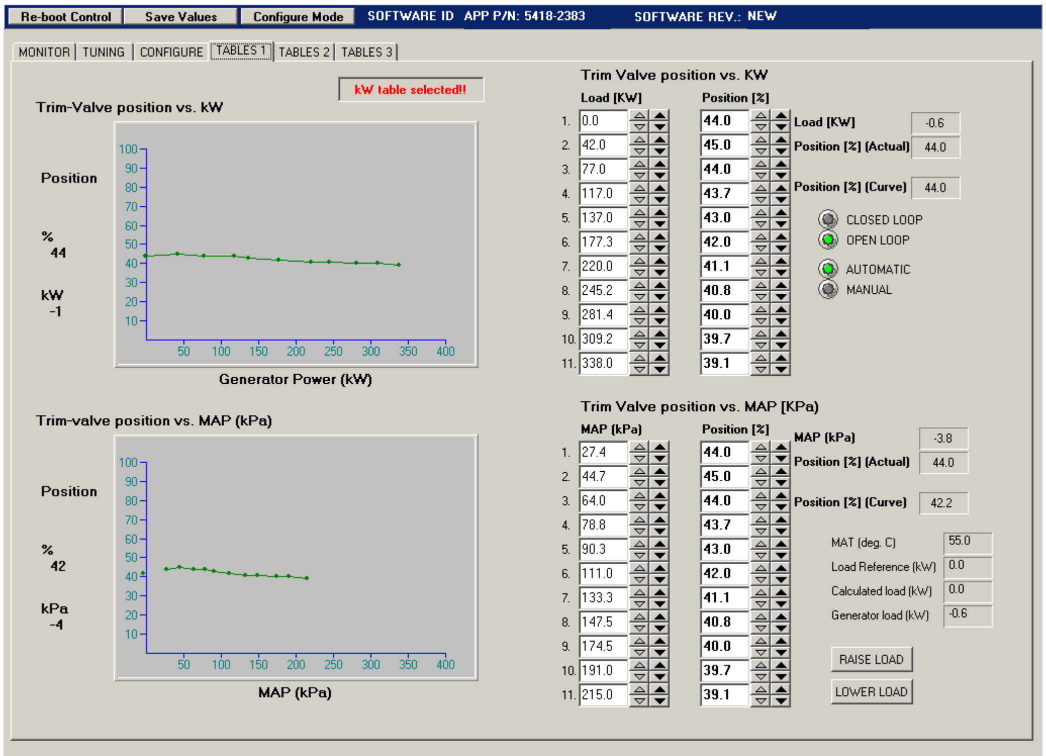


Figure 5-17. TABLES 1 Page

The button on the top of the page determines which of the two curves is selected. The top one based on KW load or the bottom one based on MAP.

MAS (trim-valve) position (%) vs Generator Power (kW)
In this table the "open loop" position of the MAS valve (trim-valve) will be set against generator output.

The MAS valve (trim-valve) position is in % of the full travel. The Generator power output (kW) is measured by the integrated kW sensor.

The tuning of the curve can be done in two ways. Directly in the table on the right side of the page. It can also be done in the curve itself. You need to go with the mouse to the point in the curve you want to change and click the right mouse button. The tag Properties will appear.

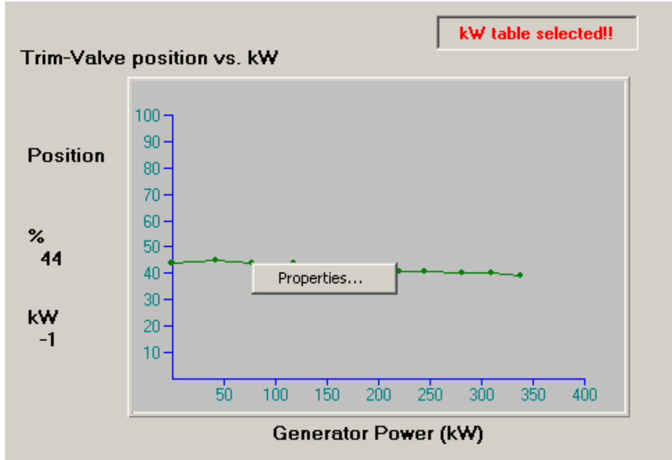


Figure 5-18. Point Selection

After clicking on the properties a window will pop up where the values can be changed.

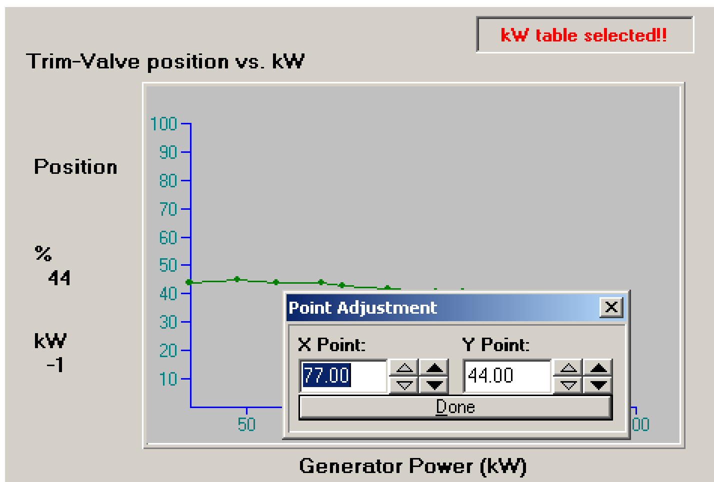


Figure 5-19. Changing Values in the Curve

MAS valve (trim-valve) position (%) vs MAP (kPa)
In this table the “open loop” position of the MAS valve (trim-valve) will be set against Manifold Pressure.

The MAS valve (trim-valve) position is in % of the full travel.

The Manifold pressure (kPa) is measured by the Manifold Absolute Pressure sensor.

TABLES 2 Page

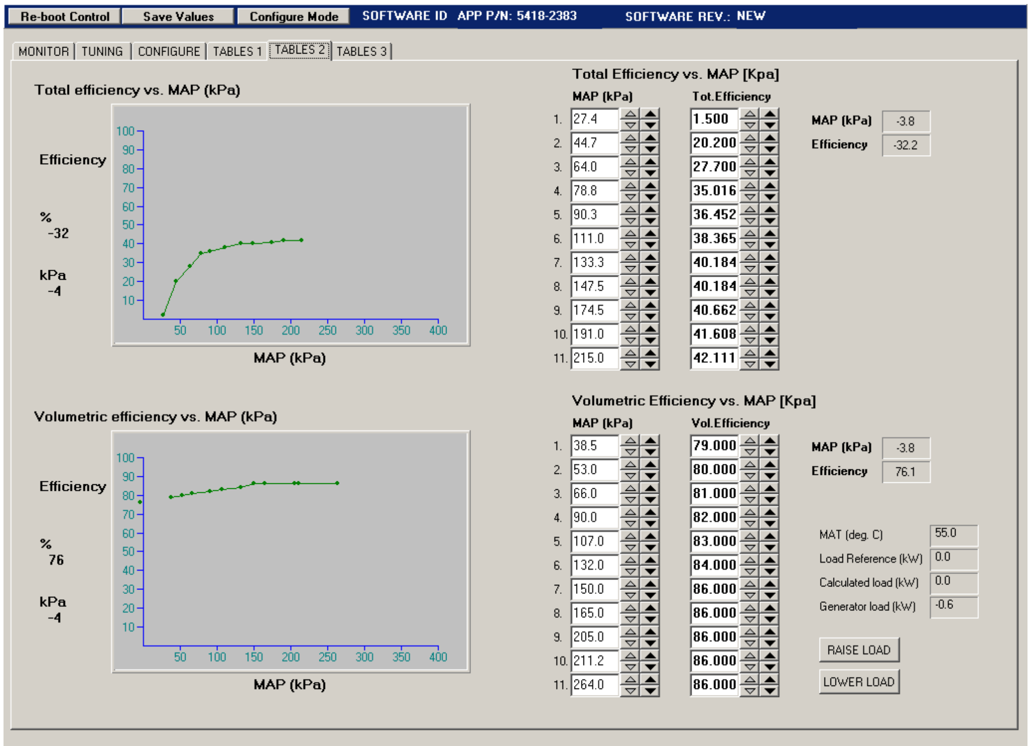


Figure 5-20. TABLES 2 Page

Total Efficiency (%) vs MAP (kPa)
In this table the genset Total efficiency (%) is mapped again the MAP (kPa).

Volumetric Efficiency (%) vs MAP (kPa)
In this table the genset Volumetric efficiency (%) can be mapped again the MAP (kPa). However, under normal condition this table/curve does not need to be changed. All changes can be done in the Total efficiency table.

TABLES 3 Page

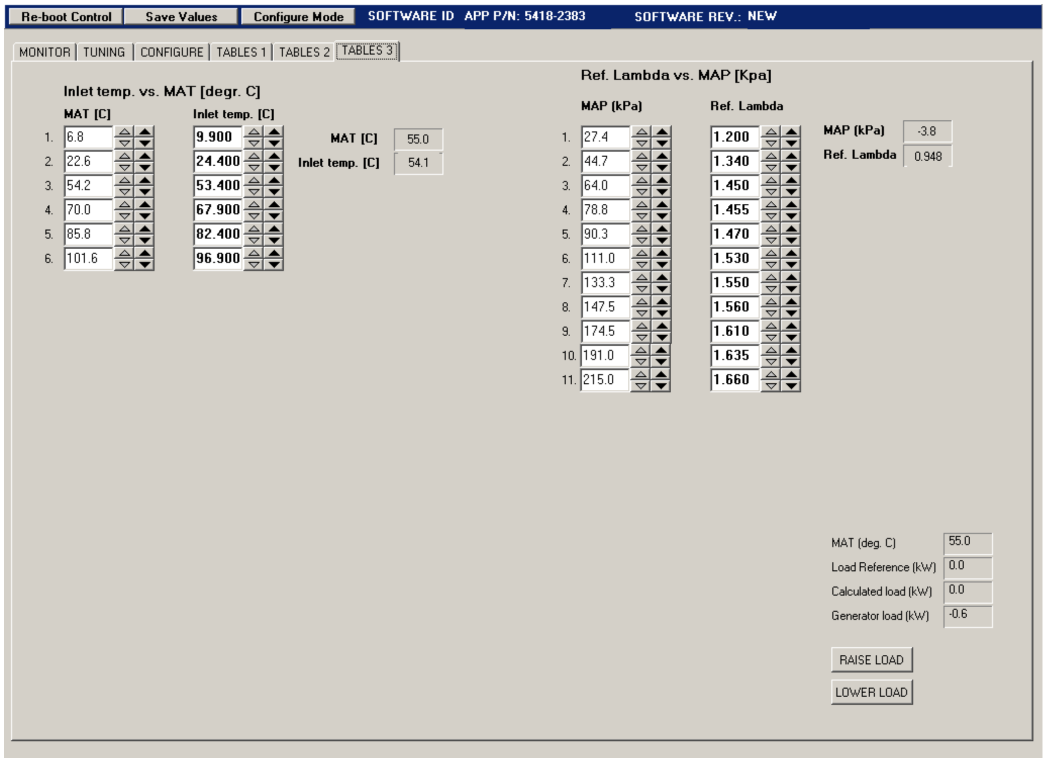


Figure 5-21. TABLES 3 Page

Inlet temp. vs. MAT [degr.C]

This table as mentioned earlier in the manual determines the difference in the air temperature when entering the inlet manifold and when entering the cylinder. The heating that takes place in the movement of the air through the manifold is taken into account in this table. To be able to calibrate this curve, the MAT temperature needs to be changed under further constant conditions. This means the MAT temperature is changed by changing the intercooler temperature. The resulting change in air fuel ratio needs can then be compensated by changing the Inlet temperature setting in the table. This value needs to be tuned until the air fuel ratio is back at its original value. In this way changes in MAT/Inlet temperature will change the calculated fuel flow and thus the required correction to maintain a constant air fuel ratio.

Ref. Lambda vs MAP (kPa)

In this table the Ref. Lambda (–) values are mapped against the MAP (kPa). This is the desired or reference Lambda table. For the different load conditions a Lambda can be calibrated. This lambda is than the reference for the correction when running in GQCL control.

Chapter 6.
Commissioning the 2300G

Checks Before Engine Start

Before starting the engine, take the following actions:

- Verify that the Emergency Stop and Gas shut-off valves are working properly.
- Verify that wiring is connected according the wiring diagram (refer to Chapter 7, Control Wiring Diagram).
- Check that shielding is connected to ground on 2300 side only.
- Verify that all gas-supply lines are gas tight and properly mounted.
- Connect the PC to the control and start the HMI.
- Check that all inputs are functioning properly.

Speed Signal Check

Make sure that the gas supply to the engine is shut-off.

Crank the engine and measure the speed signal. The voltage should be more than 1.0 V_{RMS} during cranking. If necessary, adjust the distance between MPU and flywheel or gear to obtain a proper speed signal.

On the HMI the cranking speed should now be visible.

Actuator Check

When an all-electric actuator is installed, an actuator check can be performed when the engine is stopped (no Run contact is active).

On the **Actuator output options** section push the **TESTMODE INACTIVE** button to force the actuator into test mode.

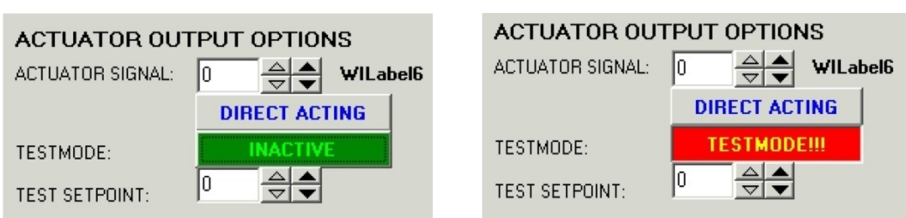


Figure 6-1. Actuator Output Options

Now the actuator can be set to any position by adjusting the “test setpoint” with the spin-edit. Check that the linkage between actuator and throttle valve is connected properly and that it does not bind during travel.

Verify that the actuator moves as expected. If necessary, the actuator can be set to operate reverse-acting by toggling the **DIRECT ACTING** button.

When ready, toggle the **TEST MODE** button to change it to **INACTIVE** again.

MAS valve (trim-valve) Check

The trim valve can be set in any position by toggling the **GQCL ENABLE** button, which will change to **MANUAL**.

Using the **MANUAL SETTING** spin-edit, the trim valve position can be adjusted between 0 and 100%. Manual setting becomes active as soon as the manual setting is within 1% of the actual trim valve position. Verify that the MAS valve (trim-valve) moves as expected.

Toggle the **MANUAL** button to change back into **GQCL ENABLE**.

Calibrate Inputs and Adjust Required Settings

Make the required adjustments on the following pages:

- Configure page
- Tuning page
  - Speed Dynamics
  - Speed
  - Test

All settings need to be saved by using the Save button on top of the HMI to store the new values in the EEPROMs.

Starting the Engine

Before starting the engine the Zero-pressure regulator needs to be pre-set to an average setting. Then the engine can be cranked to measure the dP over the regulator. This setting depends on the engine, but should be several cm of water dP.

The control needs to be configured for open loop control. See for this the AFR CONTROL page in the HMI. The buttons on the bottom of the page need to be set for Open Loop (click the button when it is on GQCL ON) and to Manual (click the button when it is on Automatic). To get the Trim valve in manual control move the setpoint of the Manual Setting to the value of the MAS valve (trim-valve) position. The manual control will then take over command and will follow the manual setting.

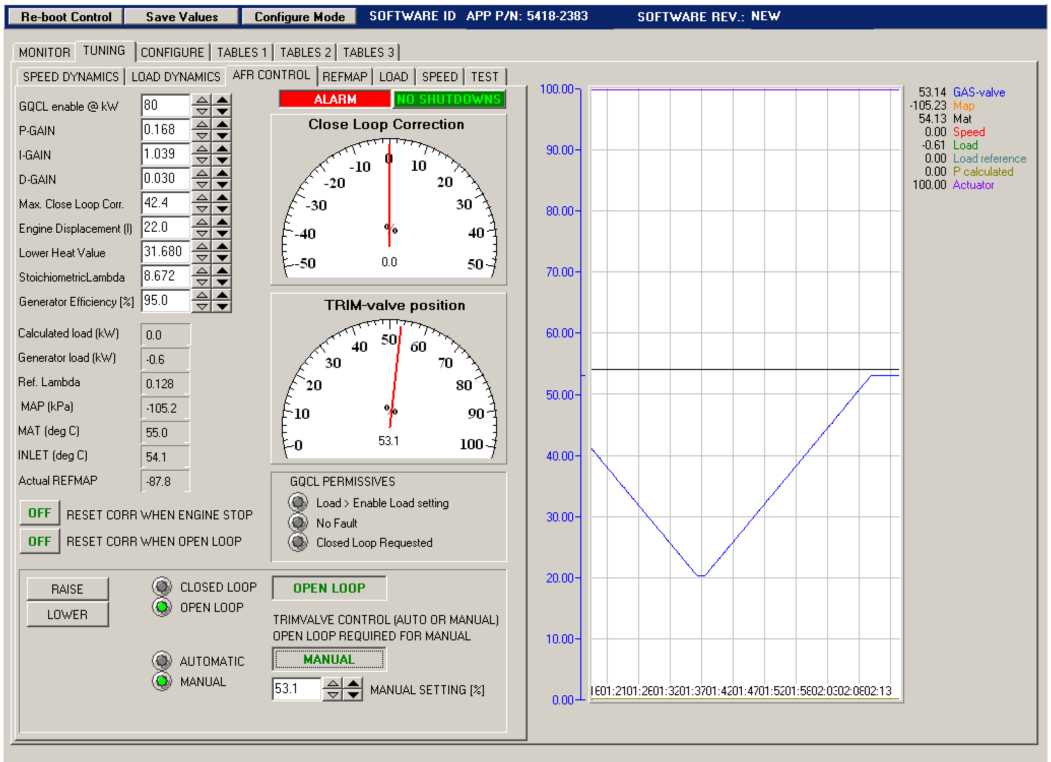


Figure 6-2. AFR Control Tuning

Adjust the Trim valve to a position of about 50%. In that way it will not form a restriction during start-up of the engine when running on the zero-pressure regulator.

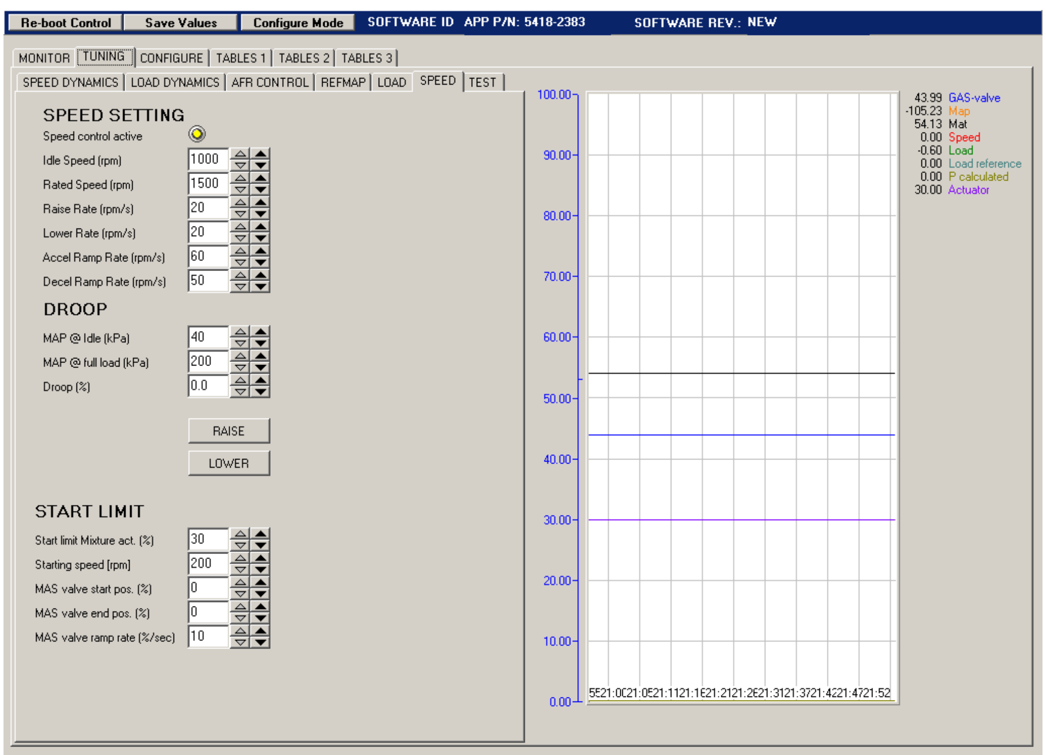


Figure 6-3. Speed Setting Adjustments

The start performance of the engine is mainly depending on the adjustment of the zero-pressure regulator. However also different settings in the control can be done to improve the performance. The position of the mixture actuator during start-up can be set. It should be fairly open because the gas admission is determined by the zero pressure regulator and the MAS valve (trim-valve) during start-up. The position of the MAS valve (trim-valve) can be determined in open loop and manual valve control as described above. This value will be entered in the open loop tables later.

It is possible to enter an offset to the MAS valve (trim-valve) during start-up in the above shown HMI page. The Starting speed determines the speed where the MAS valve start pos. offset will become active. This value is added to the position the valve receives from the tables. This offset value can be positive or negative. The offset will be removed with the MAS valve ramp rate (%/sec), and return to the normal table setting for the valve setpoint. Under normal conditions with a correct working zero pressure regulator this feature should not be needed and left at the default setting of 0% offset.

Check that the Run/Stop command functions properly.

Open the gas supply valve to the engine, and start the engine.

Tuning Dynamics and AFR Settings

The dynamic response of a gas engine is highly dependant on the Air Fuel Ratio that the engine has to run on. Therefore the AFR first has to be set to obtain the desired exhaust gas emissions, and at the same moment dynamics should be set to give acceptable performance.

After AFR has been set for the full load range of the engine, the Dynamics settings can be optimized.

Tuning Dynamics and AFR Settings in Speed Control Mode

To tune the 2300G in speed control mode, the following hardware is needed:

- A load bank that can absorb full engine load
- A calibrated exhaust gas analyzer.

On HMI Figure 6-2 (AFR Control Tuning) verify that **Lower Heat value** and **Stoichiometric Lambda** and **DISPLACEMENT** are set to the correct values.

On the HMI Speed Dynamics Page, tune the PID settings to give acceptable speed control.

Select the TABLES 1 page on the HMI. Push the **Push To Select kW table** button on the top of the page. It will then show **kW table selected!**

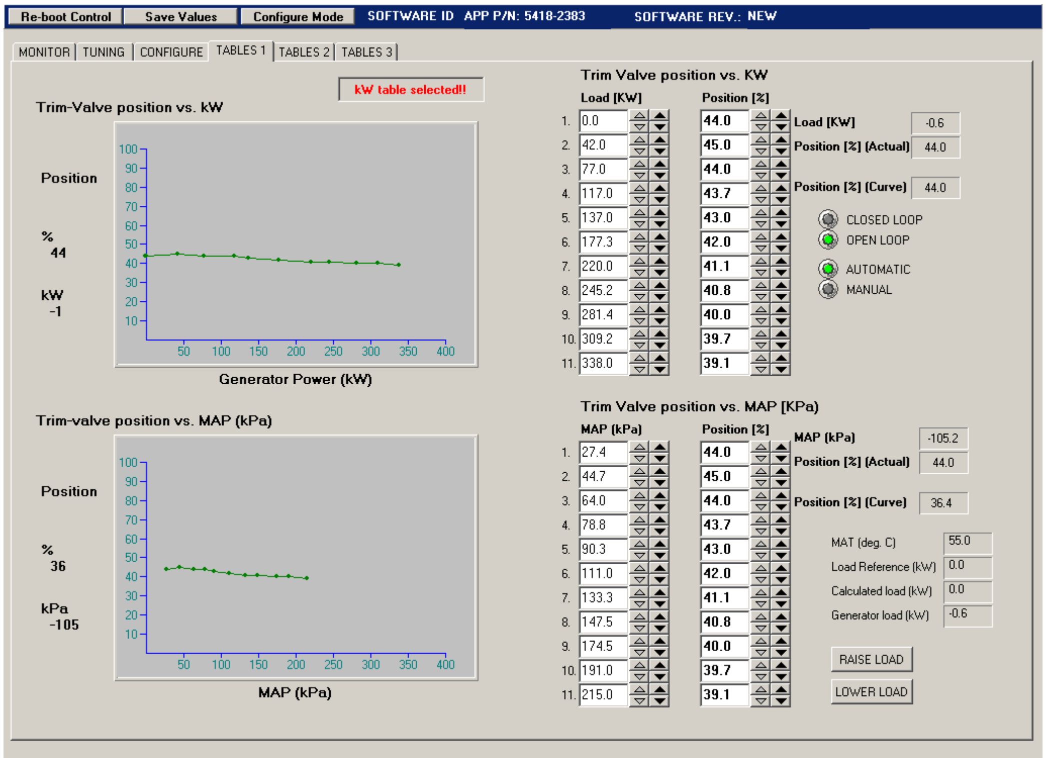


Figure 6-4. Configuring Tables

This will select the top half of the page and will use the open loop table based on measured generator load. Check the position of the MAS valve (trim-valve) and copy the setting to the first point in the table (no load). Switch the **MAS valve** then to **Automatic** on the same AFR page. Leave the valve in Open Loop mode. The gas trim valve will now take position according to the "MAS valve position vs kW" table.

This table has 11 setpoints that enables a valve position setting for every 10% load interval. Use the following table to record the different values:

Gen Load KW	Gen Load %	MAP [kPa]	Valve pos. [%]	ref Lambda	NOx	o2	Tot. Efficiency (make Pcalc=Pgen) [%]	Vol. Efficiency [%]
35	10	41.7	82	1.3	77	4.8	20	80
70	20	55.2	82	1.32	122	5.05	31.6	81
105	30	69.8	79.3	1.33	204	5.22	34.38	82
140	40	85.7	77.7	1.36	269	5.5	38.25	83
175	50	101.7	75.6	1.35	427	5.46	39.49	84
215	60	123	71.5	1.38	452	5.8	40.69	86
250	70	143.3	67.6	1.42	426	6.18	40.9	86
285	80	162.3	65.5	1.44	418	6.36	41.8	86
320	90	185.2	62	1.46	392	6.64	41.5	86
350	100	202	62	1.47	433	6.69	42.2	86
0	0	35.8	69.6	1.4	43	6		

The values in the table are examples.

1. Run the engine at x% generator load (start with no load)
2. Record the actual generator load and enter in the table above.
3. Set the “MAS valve position” spin-edit in the “MAS valve position vs kW table” to the correct position to obtain the desired emissions.
4. Record the MAP value at the actual generator load and enter in the table above.
5. Record the MAS valve position value and enter in the table above.
6. Record the NOx and O2 values from the analyzer.
7. Fill in this MAP value in the MAP spin-edits in the following tables:
   - MAS valve position vs MAP
   - Ref.Lambda vs MAP
   - Total efficiency vs MAP
   - Volumetric Efficiency vs MAP
8. Copy the “MAS valve position” found in step 3 to the “MAS valve pos. vs MAP” table.
9. Set “Ref. Lambda” spin-edit in the “Ref.Lambda vs MAP” table to the same value as the lambda reading of the exhaust gas analyzer.
10. Set “Total Efficiency” spin-edit in the “Total efficiency vs MAP” table so that generator power is equal to calculated power.
11. Check the emissions again.
12. Repeat steps 1 to 10 for all 10% load intervals, applying load using the load bank.
13. Optimize SPEED DYNAMICS settings to give optimum dynamic performance over the full load range.
14. Push the kW table selected!! Button to change it back into Push To Select kW table. The gas trim valve position is now a function of MAP.
15. Check the emissions again over the full load range of the engine. When the “MAS valve position vs MAP” table was set correctly in the previous steps, the emissions will be the same.

Tuning Dynamics and AFR Settings in Load Control Mode

For this procedure the engine must be parallel to the grid. Also a calibrated exhaust analyzer is needed.
On all HMI tuning pages, the **Raise Load** and **Lower Load** buttons are used to adjust generator load.

On HMI Figure 6-2 (AFR Control Tuning), verify that **Lower Heatvalue** and **Stoichiometric Lambda** and **DISPLACEMENT** are set to the correct values. Leave the MAS valve in Open Loop control and Automatic mode (AFR CONTROL page).

Start the engine and tune on the HMI Speed Dynamics Page the PID settings to give acceptable speed control. After synchronizing and closing generator breaker, the load control will become active by closing digital input #38. Now automatically the Load Dynamics become active.

The procedure to tune Dynamics and AFR settings in load control mode is the same as for speed control mode, but LOAD DYNAMICS should now be tuned.

Tuning the GQCL Algorithm

To tune the GQCL algorithm, select the HMI Figure 6-2 (AFR Control Tuning).

Set GQCL enable @kW on Figure 6-2 (AFR Control Tuning) at the correct level to enable the GQCL algorithm. The GQCL algorithm is reliable above reference Lambda 1.3. Switch the MAS valve control on the AFR page to **GQCL ON** to switch to closed loop control. As soon as the load is above the enable setting the control will go in closed loop control and based on the theoretical loop compared to the actual load, compensate the fuel flow to maintain an actual lambda that is close to the reference lambda.

The GQCL-PID normally should not be tuned because the default values provide responsive and stable AFR control. If GQCL control is unstable, first check that the engine is in good condition (e.g. emissions, spark plugs, gas pressure) before trying to tune the PID.

Maximum Correction

The **MAX CORRECTION** setting scales the GQCL-PID. It is the maximum positive or negative correction in % position that can be made on the trim valve position.

Reset of Correction Factor

The actual correction factor needed by the control to maintain the correct air/fuel ratio can be reset in different ways selected on the AFR CONTROL Tab.

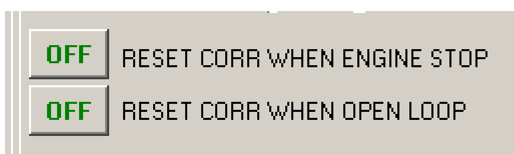


Figure 6-5. Reset Correction Factor

RESET CORR. WHEN ENGINE STOP:

OFF: The correction factor that is active when reaching zero speed is not set to 0, but left at its actual value.

ON: The correction factor is reset to 0 when reaching an engine stop condition.

RESET CORR. WHEN OPEN LOOP:

OFF: The correction factor that is active when reaching the minimum load for GQCL is not reset, but sampled and used again when going into GQCL the next time.

ON: The correction is reset to 0 when the GQCL is disabled.

The above functions are connected through an OR function. This means that either of these can reset the correction.

KW vs REFMAP and REFMAP Deadband Calibration

The KW vs REFMAP table can be filled with the values recorded during the AFR calibration session above.

The **MAP alarm Deadband** setting is the error in % MAP for a given load that the engine can still safely run on. This alarm detects whether the engine reaches misfire or detonation limits.

To properly use this function, the table below the REFMAP alarm deadband must be set.

MAT AFR Correction by Inlet Temperature Correction

MAT AFR correction adjusts AFR as a function of MAT. The MAT is converted with a table into the Inlet temperature of the engine. The tuning of this table is done by changing the intercooler temperature to get a different inlet temperature. The change in lambda needs to be compensated with a change in the inlet tuning for that MAT point in the table.

- If MAT increases relative to the nominal MAT, AFR will be corrected in the lean direction.
- When MAT decreases, AFR will be corrected in the rich direction.

When the 2300G is in GQCL mode, part of the error will be corrected automatically therefore only a small additional correction has to be made.

Chapter 7.
Control Wiring Diagram

This chapter contains Control Wiring Diagram 9971-1167.

1. SHIELDED WIRES TO BE TWISTED PAIRS , WITH SHIELD GROUNDED AT CONTROL END ONLY

2. POINT OF GROUNDING , IF REQUIRED BY WIRING CODE

3. INTERNAL CURRENT TRANSFORMER BURDEN MUST BE CONNECTED ACROSS POWER SOURCE CURRENT TRANSFORMER AT ALL TIMES TO PREVENT LETHAL HIGH VOLTAGES

4. POWER SOURCE CURRENT TRANSFORMERS SHOULD BE SIZED TO PRODUCE 5A SECONDARY CURRENT AT MAXIMUM GENERATOR CURRENT. CURRENT TRANSFORMER BURDEN IS LESS THAN 0.1 VA PER PHASE.

5. WITH ABALANCED THREE PHASE LOAD AND UNITY POWER FACTOR , THE CURRENT TRANSFORMERS SHOULD BE WIRED IN THE CORRECT POTENTIAL LEG AND MUST BE PHASED AS FOLLOWS :

   PHASE A : POTENTIAL TERMINAL1 WITH RESPECT TO NEUTRAL , IN PHASE WITH TERMINALS 4 TO 5

   PHASE B : POTENTIAL TERMINAL1 WITH RESPECT TO NEUTRAL , IN PHASE WITH TERMINALS 6 TO 7

   PHASE C : POTENTIAL TERMINAL1 WITH RESPECT TO NEUTRAL , IN PHASE WITH TERMINALS 8 TO 9

6. FOR OPTIONAL CURRENT TRANSFORMER CONNECTION SEE DETAIL “**A”**

7. WARNING:

   DO NOT USE FOR EMERGENCY SHUTDOWN , THE PRIME MOVER SHOULD BE EQUIPPED WITH A SEPARATE OVERSPEED, OVERTEMPERATURE OR OVERPRESSURE SHUTDOWN DEVICE(S) TO PROTECT AGAINST RUNAWAY OR DAMAGE TO THE PRIME MOVER WITH POSSIBLE PERSONAL INJURY OR LOSS OF LIFE.

8. IF METERS ARE NOT CONNECTED , JUMPERS MUST BE INSTALLED IN PLACE OF METERS SHOWN

9. INDICATES RELAY COIL OR LAMP , 200 Ma MAXIMUM PER CHANNEL

10. OPTIONAL , SEE BILL OF MATERIAL

11. DISCRETE INPUTS THAT ARE USED FOR CRITICAL FUNCTIONS , WITH CABLE LENGTHS GREATER THAN 30 METERS , SHOULD NOT BE FLOATED IN EITHER “ON” OR “OFF” STATE. THESE INPUTS SHOULD BE SWITCHED TO +24Vdc OR GROUND.

WOODWARD Industrial Controls	Engr: G.J.de Wit	2300 GASENGINE CONTROL WIRING DIAGRAM		
		SYSTEM NR. 8280-3005	9971-1167	REV. NEW
	Date: 9-2-2006			sheet 1 of 3

Figure 7-1a. Control Wiring Diagram 9971-1167

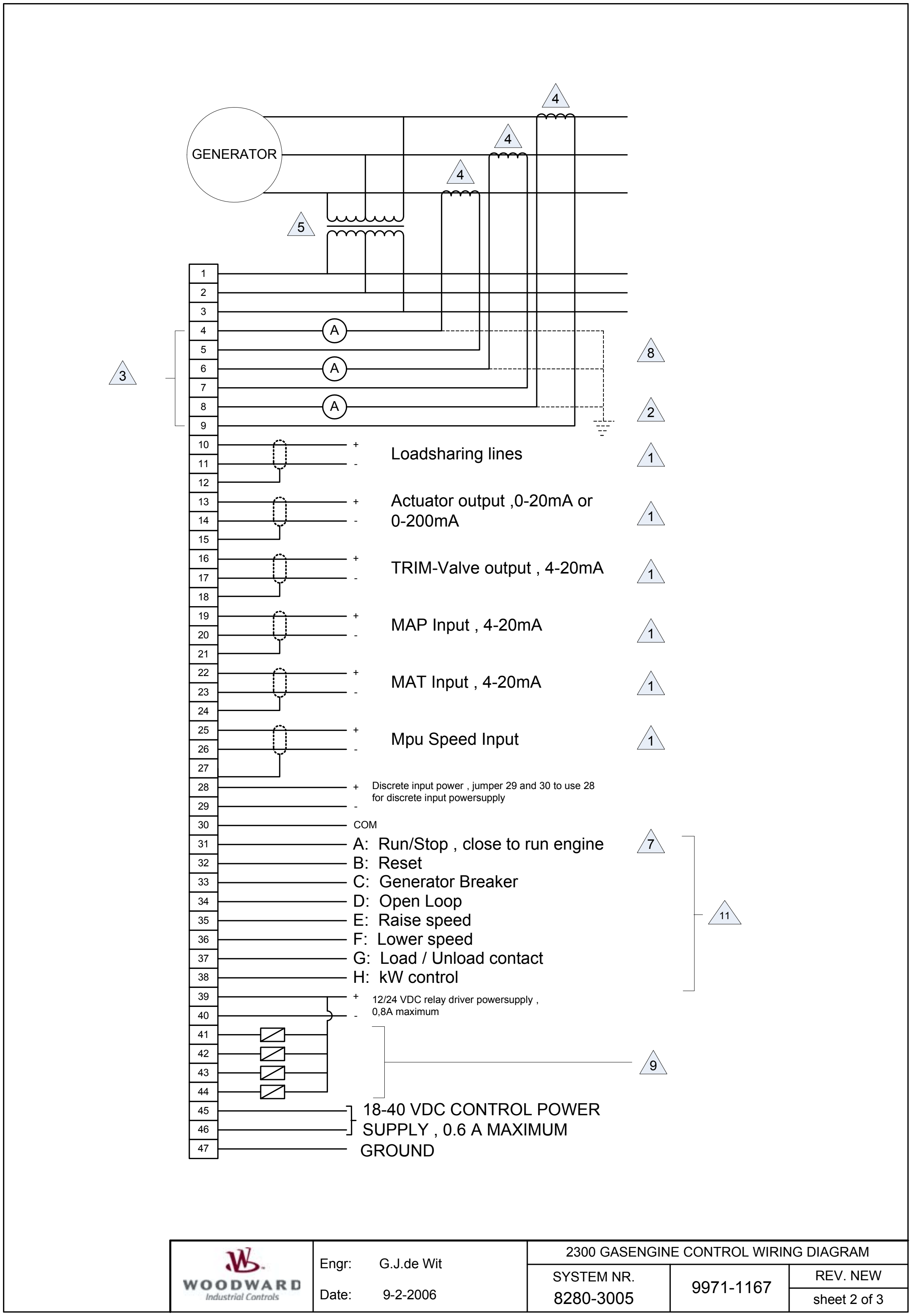
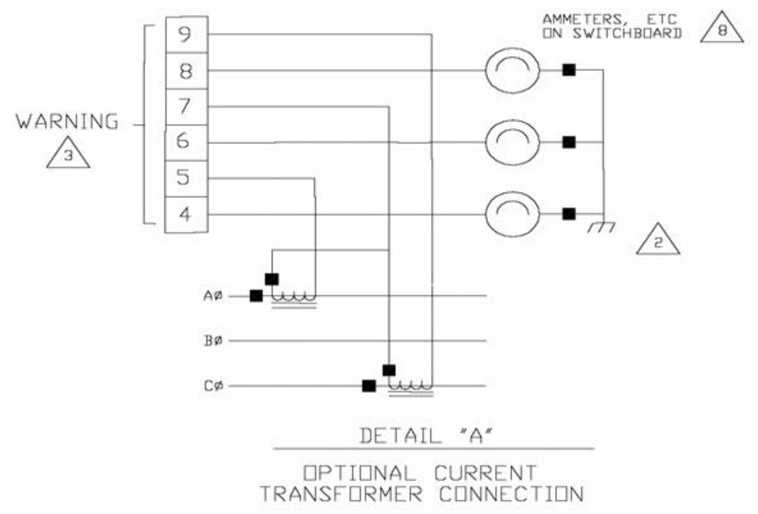


Figure 7-1b. Control Wiring Diagram 9971-1167



WOODWARD Industrial Controls	Engr: G.J.de Wit	2300 GASENGINE CONTROL WIRING DIAGRAM		
		SYSTEM NR. 8280-3005	9971-1167	REV. NEW
	Date: 9-2-2006			sheet 3 of 3

Figure 7-1c. Control Wiring Diagram 9971-1167

Chapter 8. Functional Block Diagram

This chapter contains Functional Block Diagram 3081-1397.

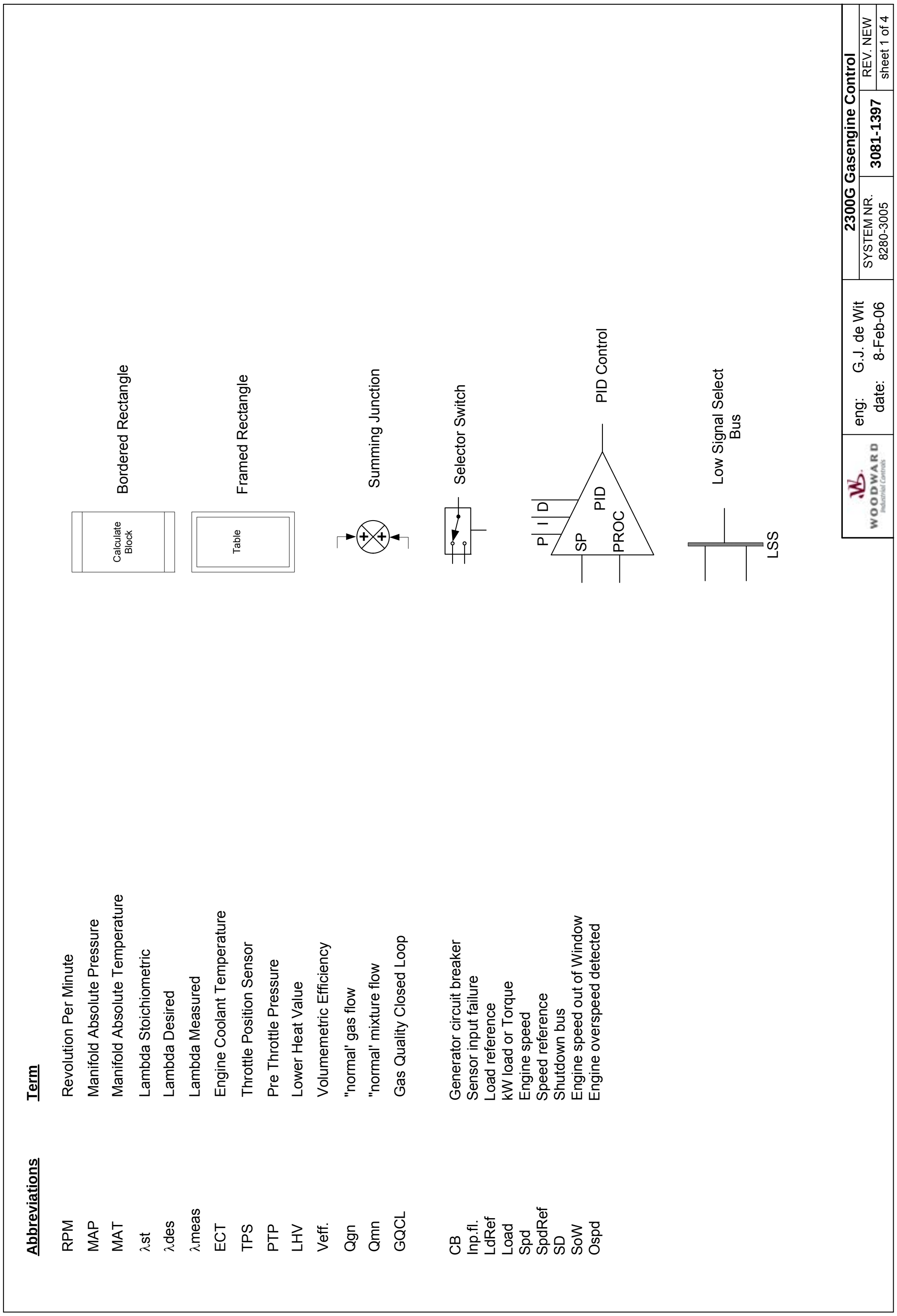


Figure 8-1a. Functional Block Diagram 3081-1397

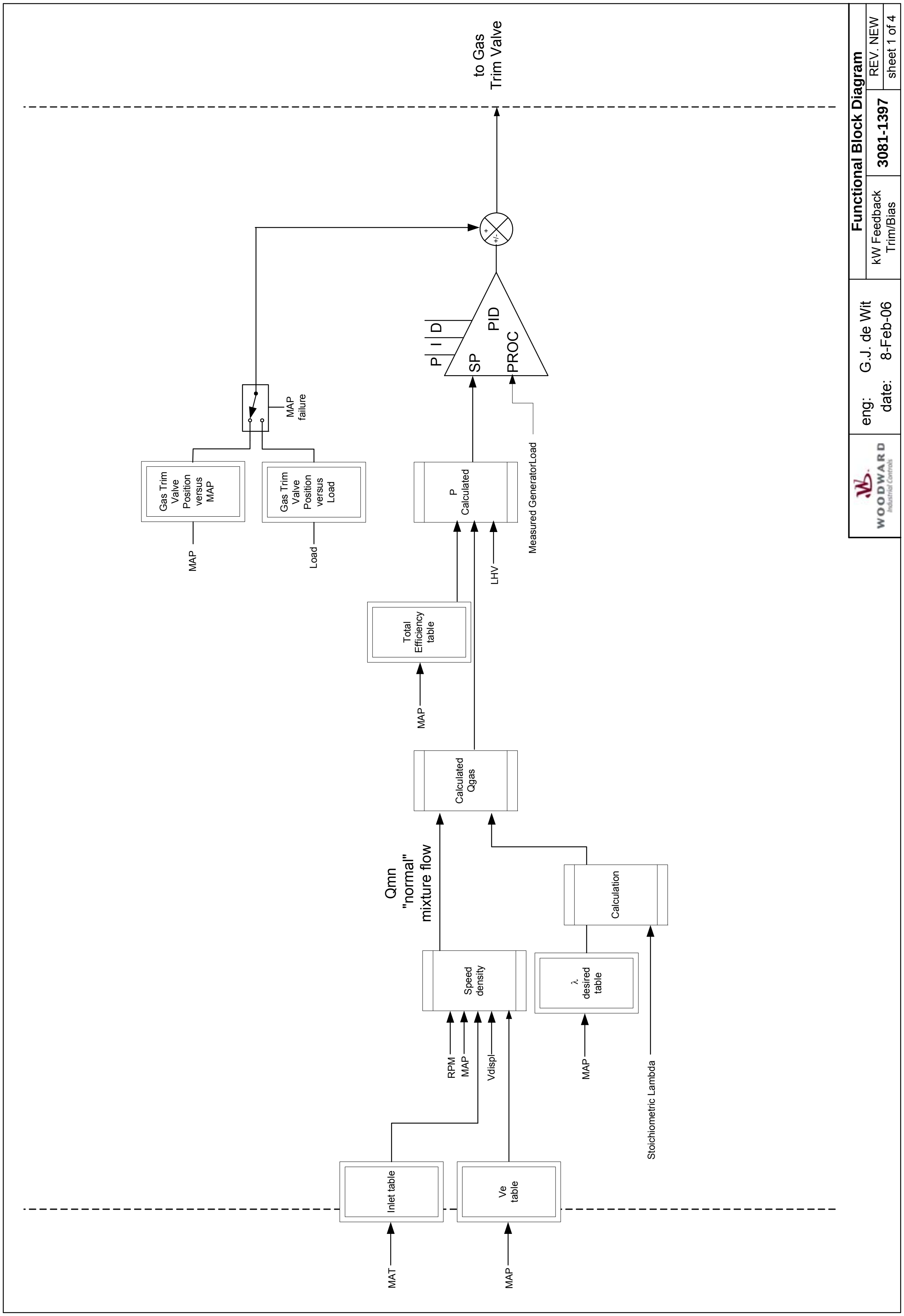


Figure 8-1b. Functional Block Diagram 3081-1397

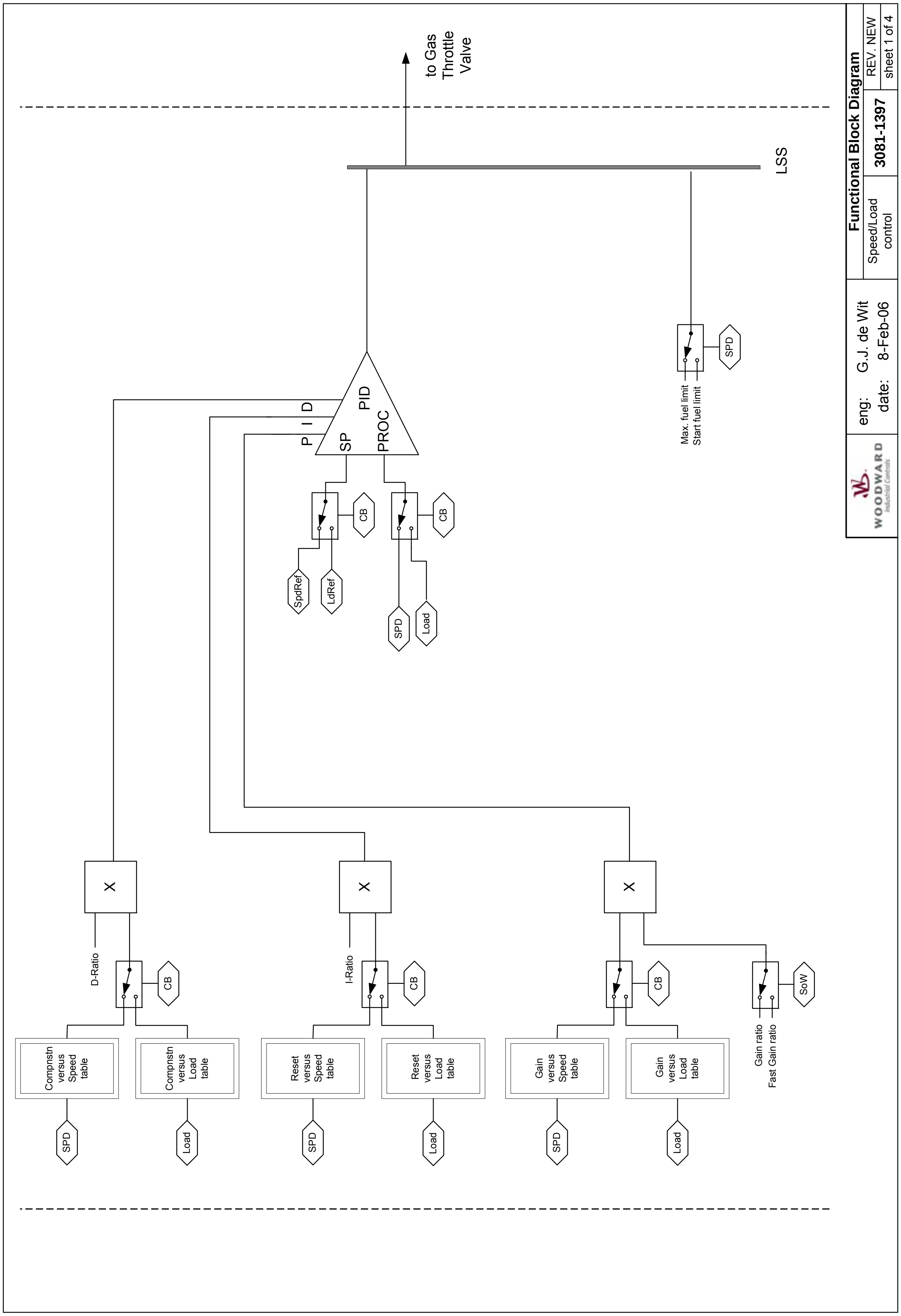


Figure 8-1c. Functional Block Diagram 3081-1397

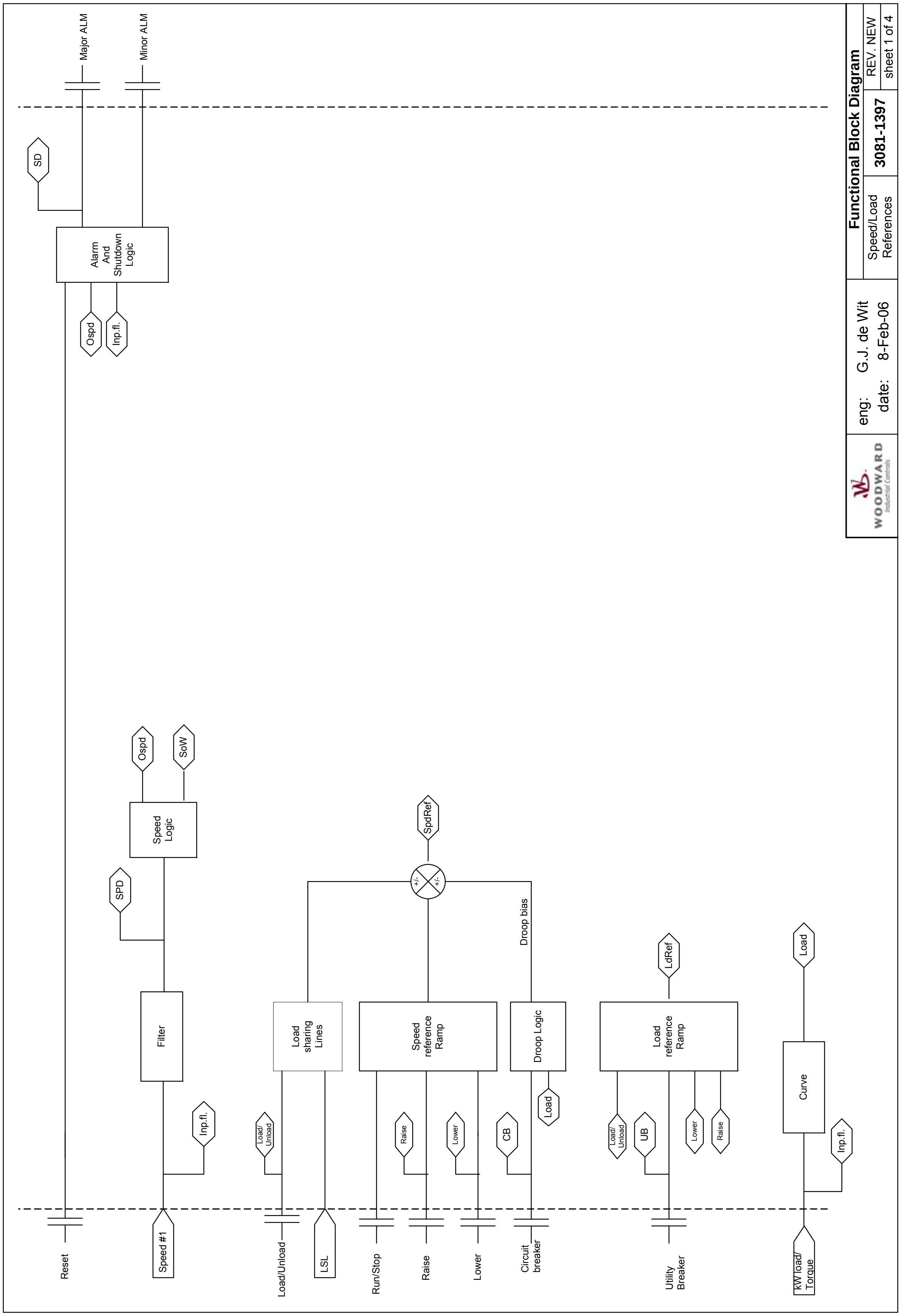


Figure 8-1d. Functional Block Diagram 3081-1397

Chapter 9.
Product Support and Service Options

Product Support Options

If you are experiencing problems with the installation, or unsatisfactory performance of a Woodward product, the following options are available:

1. Consult the troubleshooting guide in the manual.
2. Contact the **OE Manufacturer or Packager** of your system.
3. Contact the **Woodward Business Partner** serving your area.
4. Contact Woodward technical assistance via email (**EngineHelpDesk@Woodward.com**) with detailed information on the product, application, and symptoms. Your email will be forwarded to an appropriate expert on the product and application to respond by telephone or return email.
5. If the issue cannot be resolved, you can select a further course of action to pursue based on the available services listed in this chapter.

OEM or Packager Support: Many Woodward controls and control devices are installed into the equipment system and programmed by an Original Equipment Manufacturer (OEM) or Equipment Packager at their factory. In some cases, the programming is password-protected by the OEM or packager, and they are the best source for product service and support. Warranty service for Woodward products shipped with an equipment system should also be handled through the OEM or Packager. Please review your equipment system documentation for details.

Woodward Business Partner Support: Woodward works with and supports a global network of independent business partners whose mission is to serve the users of Woodward controls, as described here:

- A **Full-Service Distributor** has the primary responsibility for sales, service, system integration solutions, technical desk support, and aftermarket marketing of standard Woodward products within a specific geographic area and market segment.
- An **Authorized Independent Service Facility (AISF)** provides authorized service that includes repairs, repair parts, and warranty service on Woodward's behalf. Service (not new unit sales) is an AISF's primary mission.
- A **Recognized Engine Retrofitter (RER)** is an independent company that does retrofits and upgrades on reciprocating gas engines and dual-fuel conversions, and can provide the full line of Woodward systems and components for the retrofits and overhauls, emission compliance upgrades, long term service contracts, emergency repairs, etc.

A current list of Woodward Business Partners is available at **www.woodward.com/directory**.

Product Service Options

Depending on the type of product, the following options for servicing Woodward products may be available through your local Full-Service Distributor or the OEM or Packager of the equipment system.

- Replacement/Exchange (24-hour service)
- Flat Rate Repair
- Flat Rate Remanufacture

Replacement/Exchange: Replacement/Exchange is a premium program designed for the user who is in need of immediate service. It allows you to request and receive a like-new replacement unit in minimum time (usually within 24 hours of the request), providing a suitable unit is available at the time of the request, thereby minimizing costly downtime.

This option allows you to call your Full-Service Distributor in the event of an unexpected outage, or in advance of a scheduled outage, to request a replacement control unit. If the unit is available at the time of the call, it can usually be shipped out within 24 hours. You replace your field control unit with the like-new replacement and return the field unit to the Full-Service Distributor.

Flat Rate Repair: Flat Rate Repair is available for many of the standard mechanical products and some of the electronic products in the field. This program offers you repair service for your products with the advantage of knowing in advance what the cost will be.

Flat Rate Remanufacture: Flat Rate Remanufacture is very similar to the Flat Rate Repair option, with the exception that the unit will be returned to you in “like-new” condition. This option is applicable to mechanical products only.

Returning Equipment for Repair

If a control (or any part of an electronic control) is to be returned for repair, please contact your Full-Service Distributor in advance to obtain Return Authorization and shipping instructions.

When shipping the item(s), attach a tag with the following information:
- return number;
- name and location where the control is installed;
- name and phone number of contact person;
- complete Woodward part number(s) and serial number(s);
- description of the problem;
- instructions describing the desired type of repair.

Packing a Control

Use the following materials when returning a complete control:
- protective caps on any connectors;
- antistatic protective bags on all electronic modules;
- packing materials that will not damage the surface of the unit;
- at least 100 mm (4 inches) of tightly packed, industry-approved packing material;
- a packing carton with double walls;
- a strong tape around the outside of the carton for increased strength.

NOTICE

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

Replacement Parts

When ordering replacement parts for controls, include the following information:
- the part number(s) (XXXX-XXXX) that is on the enclosure nameplate;
- the unit serial number, which is also on the nameplate.

Engineering Services

Woodward's Full-Service Distributors offer various Engineering Services for our products. For these services, you can contact the Distributor by telephone or by email.

- Technical Support
- Product Training
- Field Service

Technical Support is available from your equipment system supplier, your local Full-Service Distributor, or from many of Woodward's worldwide locations, depending upon the product and application. This service can assist you with technical questions or problem solving during the normal business hours of the Woodward location you contact.

Product Training is available as standard classes at many Distributor locations. Customized classes are also available, which can be tailored to your needs and held at one of our Distributor locations or at your site. This training, conducted by experienced personnel, will assure that you will be able to maintain system reliability and availability.

Field Service engineering on-site support is available, depending on the product and location, from one of our Full-Service Distributors. The field engineers are experienced both on Woodward products as well as on much of the non-Woodward equipment with which our products interface.

For information on these services, please contact one of the Full-Service Distributors listed at **www.woodward.com/directory**.

Contacting Woodward's Support Organization

For the name of your nearest Woodward Full-Service Distributor or service facility, please consult our worldwide directory published at **www.woodward.com/directory**.

You can also contact the Woodward Customer Service Department at one of the following Woodward facilities to obtain the address and phone number of the nearest facility at which you can obtain information and service.

Products Used In Electrical Power Systems

Facility	Phone Number
Brazil	+55 (19) 3708 4800
China	+86 (512) 6762 6727
Germany:	
Kempen	+49 (0) 21 52 14 51
Stuttgart	+49 (711) 78954-510
India	+91 (129) 4097100
Japan	+81 (43) 213-2191
Korea	+82 (51) 636-7080
Poland	+48 12 295 13 00
United States	+1 (970) 482-5811

Products Used In Engine Systems

Facility	Phone Number
Brazil	+55 (19) 3708 4800
China	+86 (512) 6762 6727
Germany	+49 (711) 78954-510
India	+91 (129) 4097100
Japan	+81 (43) 213-2191
Korea	+82 (51) 636-7080
The Netherlands	+31 (23) 5661111
United States	+1 (970) 482-5811

Products Used In Industrial Turbomachinery Systems

Facility	Phone Number
Brazil	+55 (19) 3708 4800
China	+86 (512) 6762 6727
India	+91 (129) 4097100
Japan	+81 (43) 213-2191
Korea	+82 (51) 636-7080
The Netherlands	+31 (23) 5661111
Poland	+48 12 295 13 00
United States	+1 (970) 482-5811

For the most current product support and contact information, please visit our website directory at **www.woodward.com/directory**.

Technical Assistance

If you need to contact technical assistance, you will need to provide the following information. Please write it down here before contacting the Engine OEM, the Packager, a Woodward Business Partner, or the Woodward factory:

General

Your Name ______________________

Site Location ______________________

Phone Number ______________________

Fax Number ______________________

Prime Mover Information

Manufacturer ______________________

Engine Model Number ______________________

Number of Cylinders ______________________

Type of Fuel (gas, gaseous, diesel, dual-fuel, etc.) ______________________

Power Output Rating ______________________

Application (power generation, marine, etc.) ______________________

Control/Governor Information

Control/Governor #1

Woodward Part Number & Rev. Letter ______________________

Control Description or Governor Type ______________________

Serial Number ______________________

Control/Governor #2

Woodward Part Number & Rev. Letter ______________________

Control Description or Governor Type ______________________

Serial Number ______________________

Control/Governor #3

Woodward Part Number & Rev. Letter ______________________

Control Description or Governor Type ______________________

Serial Number ______________________

Symptoms

Description ______________________

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If you have an electronic or programmable control, please have the adjustment setting positions or the menu settings written down and with you at the time of the call.

We appreciate your comments about the content of our publications.

Send comments to: icinfo@woodward.com

Please reference publication 91372.

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Woodward has company-owned plants, subsidiaries, and branches, as well as authorized distributors and other authorized service and sales facilities throughout the world.

Complete address / phone / fax / email information for all locations is available on our website.