



Installation and Operation Manual



EGS-01 Digital Engine Gas Metering System

Manual 36139 (Revision B)

IMPORTANT



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.

DEFINITIONS

- **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

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.



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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Any unauthorized modifications to or use of this equipment outside its specified mechanical, electrical, or other operating limits may cause personal injury and/or property damage, including damage to the equipment. Any such unauthorized modifications: (i) constitute "misuse" and/or "negligence" within the meaning of the product warranty thereby excluding warranty coverage for any resulting damage, and (ii) invalidate product certifications or listings.

NOTICE

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.

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*.

Revisions—Text changes are indicated by a black line alongside the text.

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Electrostatic Discharge Awareness

All electronic equipment is static-sensitive, some components more than others. To protect these components from static damage, you must take special precautions to minimize or eliminate electrostatic discharges.

Follow these precautions when working with or near the control.

1. Before doing maintenance on the electronic control, discharge the static electricity on your body to ground by touching and holding a grounded metal object (pipes, cabinets, equipment, etc.).
2. 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.
3. Keep plastic, vinyl, and Styrofoam materials (such as plastic or Styrofoam cups, cup holders, cigarette packages, cellophane wrappers, vinyl books or folders, plastic bottles, and plastic ash trays) away from the control, the modules, and the work area as much as possible.
4. 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.

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*.

Chapter 1.

General Information

Introduction

This manual describes how to install, monitor and commission your EGS-01 (Engine Gas-metering System). The manual is applicable for both types of EGS:

- EGS with speed and load control
- EGS without speed and load control

The parts of the manual applicable for EGS with speed and load control are clearly indicated.

Application

The EGS-01 is a gas-engine control module that can be used to control the gas flow in relation to airflow, at any engine load and speed condition. It can be applied to in-line and V-engines of any power output, naturally aspirated or turbo-charged.

The control is easily programmable by PC and it covers the wide range of gas qualities from landfill gas through to propane. Even a significant change in gas quality during normal operation of the engine is compensated by the control.

Explanation of names often used in a gas quality closed loop application

Mono system	One gas flow calculation per engine
Stereo system	Two gas flow calculations; one for each separate bank of a V-engine
Single TecJet system	One TecJet per gas flow calculation
Dual TecJet system	Two TecJets per gas flow calculation
Dual Fuel system	A system that uses two different gas types, e.g. biogas and natural gas, simultaneously.

Gas Flow Actuator

The EGS-01 forms an ideal combination with the TecJet™ (as developed by Woodward). The TecJet is an intelligent gas-metering actuator that converts the mass flow of gas, calculated by the EGS-01 control, into an actual gas flow to the engine.

From the EGS-01 the TecJet receives a gas-flow demand signal and the density of the gas, and the TecJet transmits data, such as gas temperature and pressure, differential pressure over the valve and the valve position, to the EGS-01.

Gas Quality Closed Loop

To keep the NOx emissions low, the engine should run at the correct Air to Fuel Ratio, over the entire speed and load range of the engine. In this manual the Air to Fuel Ratio is expressed by the symbol λ ($=1/\phi$). For maintaining λ over a longer period of time, even with a changing gas composition, Woodward does not rely on the feedback signal of an oxygen sensor that can be located in the exhaust pipe of the gas engine.

A patented control algorithm (Eur. Patent no. 0727574) in the EGS-01 control compensates automatically for a changing gas composition.

Using the programmed lower heat value of the gas, the calculated gas flow through the TecJet and the programmed efficiency of the generator set, the control calculates the power of the set. The ratio between the calculated power and the measured power is used for correction of the actual gas flow to the engine.

Generator Power Output

The Gas Quality Closed Loop option has been designed to be applied on generator sets, where a kW-signal is normally available. However a torque-signal also can be applied. A torque sensor is required when a gas-engine driven compressor is controlled by the system in Gas Quality Closed Loop mode.

Trim System versus Full Authority Systems

The number of gas engines that are equipped with Deltec Fuel Systems carburetors is about 50 000. These engines are operated with a simple and reliable fixed venturi type carburetor, an adjustable lean/rich gas valve and a zero-pressure regulator. The engine can be controlled with these three components. A λ -control can be used for small corrections of the gas flow, however the basic air/fuel ratio is determined by Bernoulli's Law and the engine even can run with a disconnected λ -control. Such a λ -control only has a trim function.

The EGS-01 is a full-authority system. This means that the total gas flow is calculated by the control, based on parameters such as load, speed and gas data. The engine cannot be operated without this control.

The biggest advantage of a full-authority system is the flexibility and the improved engine performance like starting, stability, transient and emissions. Control software, sensors and the control module will always be the same, only the size of the actuator is related to the engine output.

Gas Flow Calculation

To calculate the required fuel flow to an engine the airflow must be measured. Two methods are generally used. For smaller engines air mass-flow sensors based on hot wire or thin-film technology are used, mainly in the automotive industry.

In the EGS-01 control the so-called Speed/Density principle has been used. This principle calculates the mixture flow to the engine based on engine speed, cylinder displacement, manifold pressure and temperature, and volumetric efficiency of the engine.

This method is usually applied on larger bore engines for reliability and flexibility reasons.

Accessories

MAP sensor	To measure Manifold Air Pressure (MAP)
MAT sensor	To measure Manifold Air Temperature (MAT)
MPU	Magnetic Pick Up (MPU) to measure engine speed
Universal Exhaust Gas Oxygen (UEGO) sensor	To measure the A/F Ratio of the gas engine (only during commissioning)
Generator Load Sensor	For load sharing, droop-parallel or power closed loop mode at generator applications

Contents Included in this Package

Make sure that you have the items as listed below in the package:

- EGS-01 control
- EGS monitoring software diskette
- EGS manual (36139, this manual) (check our website for the latest issue, www.woodward.com)

After unpacking, check the EGS-01 control for signs of damage such as bent or dented panels, scratches, and broken parts. Contact Woodward if the control is damaged.

Chapter 2. Installation

Introduction

This chapter describes how to install your EGS-01 control and sensors. Installation procedures also cover power requirements and location considerations.

Location Considerations for the EGS-01 Control

Consider the following requirements when you select a mounting location for your EGS-01 control:

- When the EGS-01 control is located inside the engine room, then the unit should be mounted inside a separate cabinet to protect the unit from dirt, dust and heat radiation of the exhaust pipe.
- When the unit is located outside the engine room, then the cabinet of the generator set generally is used if there is sufficient space in this cabinet.
- The unit can be mounted in both a horizontal or/or a vertical orientation.
- Do not mount the EGS control on the engine or engine frame.

IMPORTANT

For user-friendly installation and operation of the unit, it is recommended that the unit is installed not lower than one meter and not higher than two meters from the floor.

- Please take into account that the cover of the control, or the entire control, must be removable for servicing.
- Prevent the unit control from direct exposure to water or condensation situations that exceed the limits set by IP56.
- Operating temperature between -20 and $+105$ °C.
- Install the EGS-01 control on a metal ground plate to ground the whole system.

For dimensions see the outline drawing, Figure 2-2.

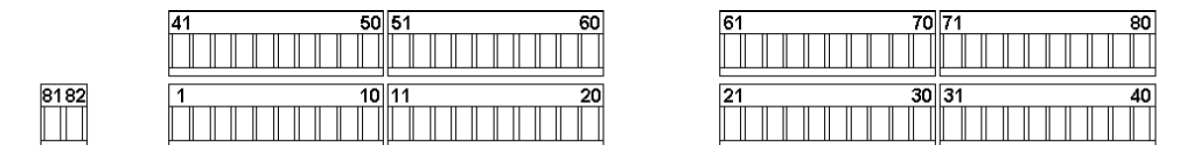


Figure 2-1. Terminal Numbers on the EGS-01

Handling

The EGS-01 has Phoenix connectors on the Printed Circuit Board (PCB). The counter part with the wire terminals is Woodward part number DL26600106. The upper deck connectors (terminal 41-80) must be removed to connect wires to the lower deck terminals (terminal 1-40).

With this type of connector it is possible to replace the control without disconnecting the bulk of the wiring from the wire terminals. Only the two power supply wires need to be disconnected from terminals 81 and 82 (using a small screwdriver).

IMPORTANT

Use a small screwdriver to separate the wire terminal part of the connector from the PCB part. Place the screwdriver between the two parts and turn the screwdriver, first on one side of the connector, then on the other. Do not force the connector apart.

Shielded Wiring

Connect all shielded wires to the stud on the EGS-01 control; see Figure 2-2.

Install the EGS-01 Control

Install the EGS-01 control with four screws as shown in Figure 2-2.

IMPORTANT

For installation of the TecJet gas control valve, see Woodward Manual 36102.

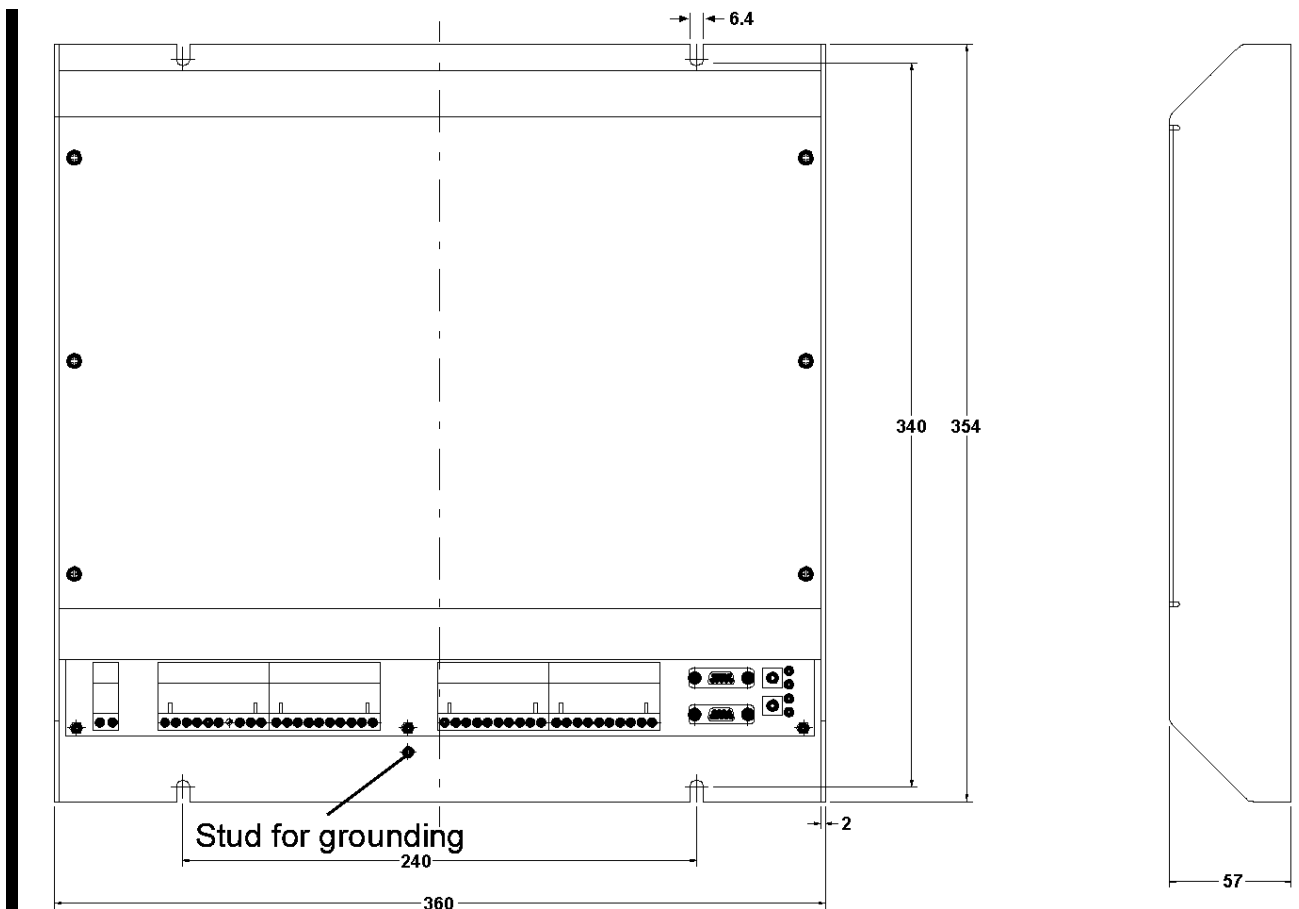


Figure 2-2. Outline Drawing of EGS-01 Control

Install the MPU

IMPORTANT

The speed of the engine is measured to calculate the mixture flow to the engine. The speed will also be used in many 3-dimensional tables for tuning the engine.

1. Install the Magnetic Pick Up (MPU) on the outside diameter of the flywheel gear, either through a housing or a bracket. Usually the MPU will be located in the flywheel housing of the engine.
2. Look for one of the threaded holes in the flywheel housing that the engine manufacturer usually prepares for MPU installation.
3. Set the gap between the MPU and the flywheel gear to between 0.25 and 1.25 mm.
4. Connect the MPU wires to the EGS-01 control (see the wiring diagram in Figure 2-8). The MPU wiring of the should always be shielded.

Install the MAT Sensor

The Manifold Air Temperature (MAT) sensor is used for the mixture flow calculation and for the lambda-correction versus the inlet temperature. ("Manifold Mixture Temperature sensor" would be a better name for this sensor). An inlet temperature model will calculate the so-called "Inlet Temp" from the measured MAT.

For accurate sensing follow these guidelines (see Figure 2-3):

- It is important that the sensing element in the nose of the sensor measures the temperature that represents a good average of the flow. When the nose of the sensor is too close to the wall, the influence of the temperature of engine components affects the measurement.
 - The MAT sensor can be placed close after the throttle, since a model will calculate the Inlet Temp from the measured MAT. This software feature compensates for the mixture temperature during the flow from manifold to cylinder port (see Chapter 6).
1. Install the MAT sensor (PT100-type) in the inlet manifold of the engine.
 2. Connect the two wires of the sensor which are directly connected to the PT100 element, see the wiring diagram in Figure 2-6. The other wires are not required for the EGS-01 control.

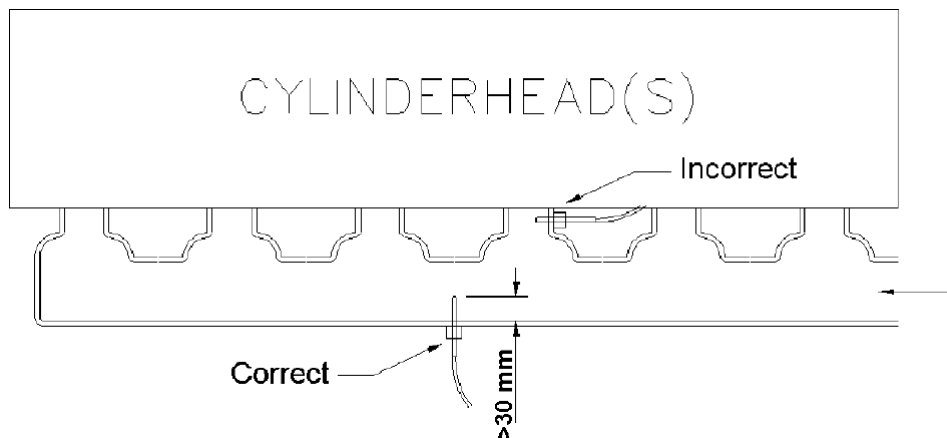


Figure 2-3. MAT Sensor Location

Install the MAP Sensor

The Manifold Absolute Pressure (MAP) Sensor is used for the calculation of the gas flow to the engine. For reliability reasons you are advised to use two MAP sensors per engine. For accurate sensing follow these guidelines (refer to Figure 2-4):

- Mount the MAP sensor at a position where only minor ambient temperature changes during normal operation can be expected. Use suitable tubing or hoses. It is not advisable to mount the MAP Sensor directly in or on the manifold as vibration over long periods of time can seriously affect or destroy the MAP Sensor. Ambient temperature changes within the manifold are not insignificant, and therefore can significantly lower the overall performance of the system.
 - Make the pressure connection of the MAP sensor downstream of the throttle valve, on the top surface of the manifold to avoid oil, water or dirt entering the sensor or hose.
 - Do not mount the pressure connection close to an intake port, direct after the throttle or at the dead end of the manifold to avoid erratic readings due to pulsation or strong turbulences.
 - It is recommended that each MAP sensor has its own hose. Do not use a single hose with a T-piece or it will be difficult to locate a broken hose. The hoses must be mounted in the manifold as close as possible to each other.
 - Position the MAP sensor higher than the sample point.
 - Mount the tube or hose continuously rising to avoid trapped oil, water or dirt in the hose or tube.
1. Install the MAP sensor.
 2. Connect the wires of the MAP sensor to the EGS-01 control according to Figure 2-6.

IMPORTANT

For the allowable temperature specifications, see the sensor specifications.

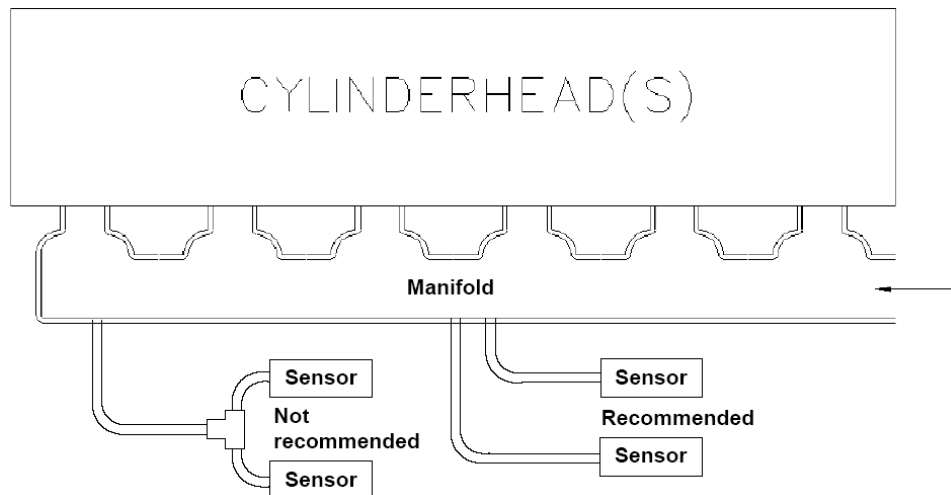


Figure 2-4. MAP Sensor Location

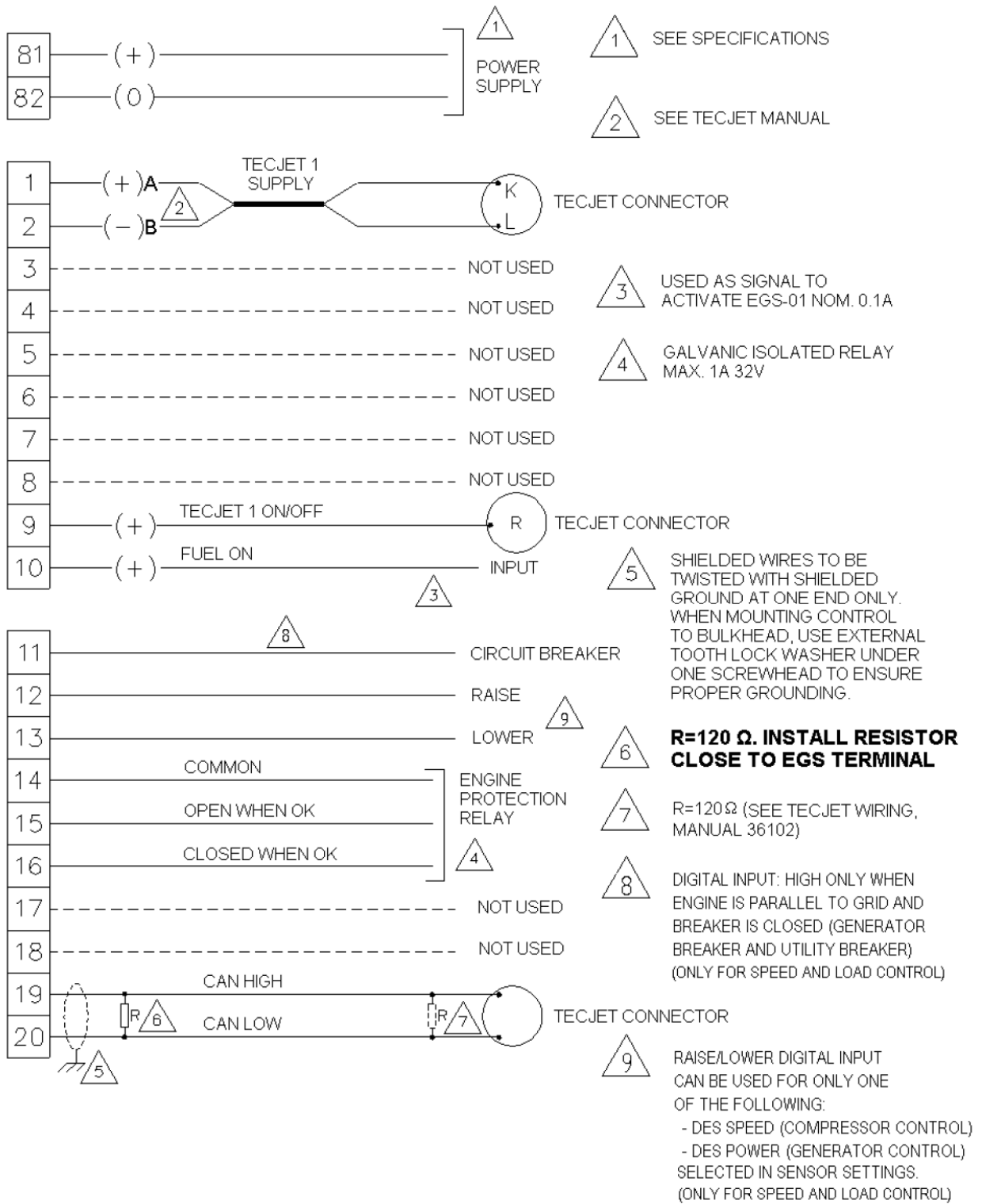
Electrical Connections

Refer to the following Figures for the electrical connections of your EGS-01 control:

- Figure 2-6, EGS Wiring Diagram (Terminals 21–40)
- Figure 2-8, EGS Wiring Diagram (Terminals 41–60)
- Figure 2-9, EGS Wiring Diagram (Terminals 61–80)
- Figure 2-10, Examples of Open and Grounded 0–20 mA Inputs
- Figure 2-11, EGS to TecJet Connection

The following input signals can also be transmitted to the EGS-01 through the "plant communication":

MAT_1	des._power	speed bias
MAT_2	meas._power	breaker closed
Ch4%	des. speed offset	des. ign. timing



NOTICE When the bit rate is set to 250 kbit/s, the maximum length of the TecJet to EGS cable is 25 meters. Do NOT increase the length of the cable.

Figure 2-5. EGS Wiring Diagram (Terminals 1–20 and 81–82)

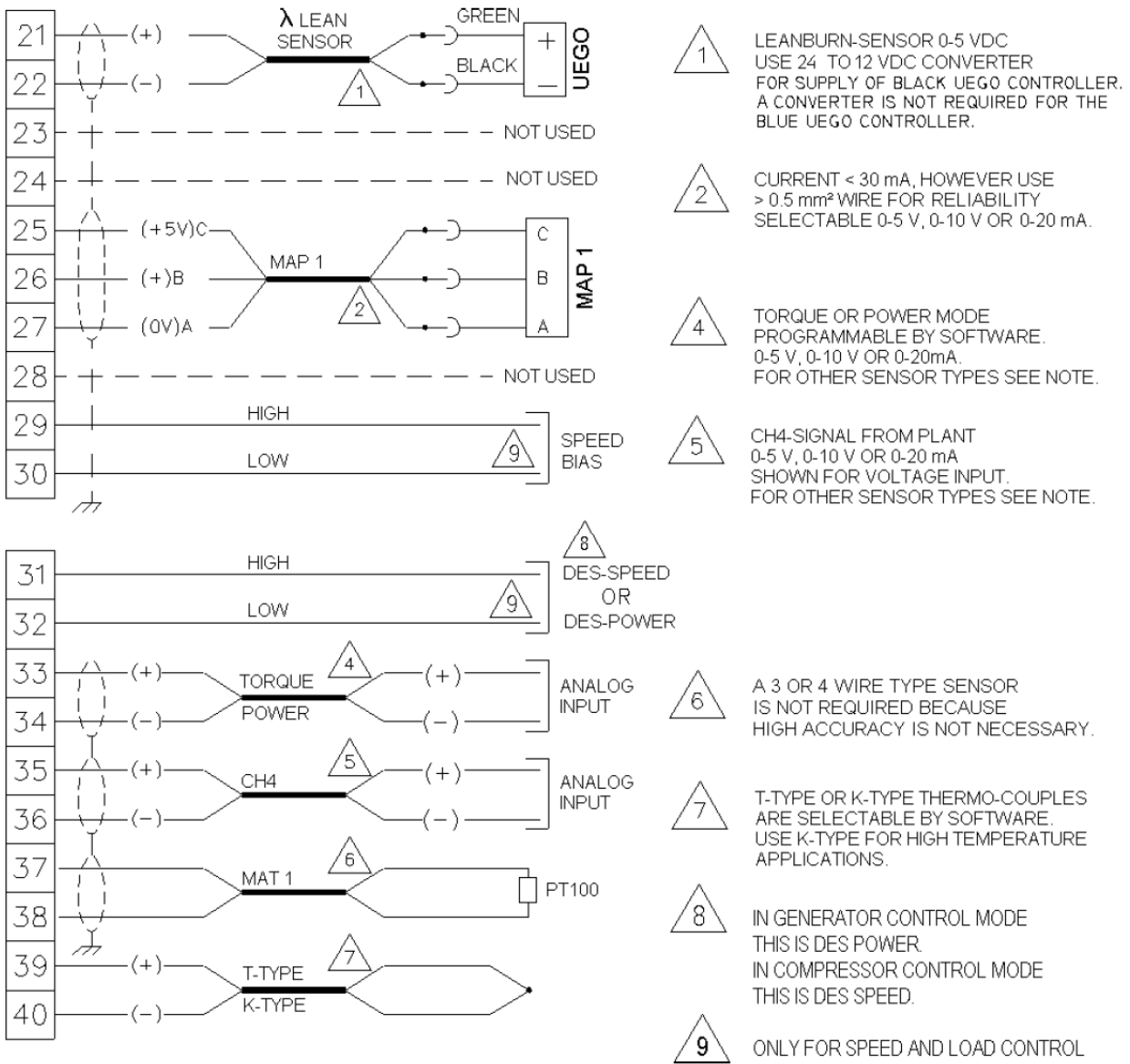


Figure 2-6. EGS Wiring Diagram (Terminals 21–40)

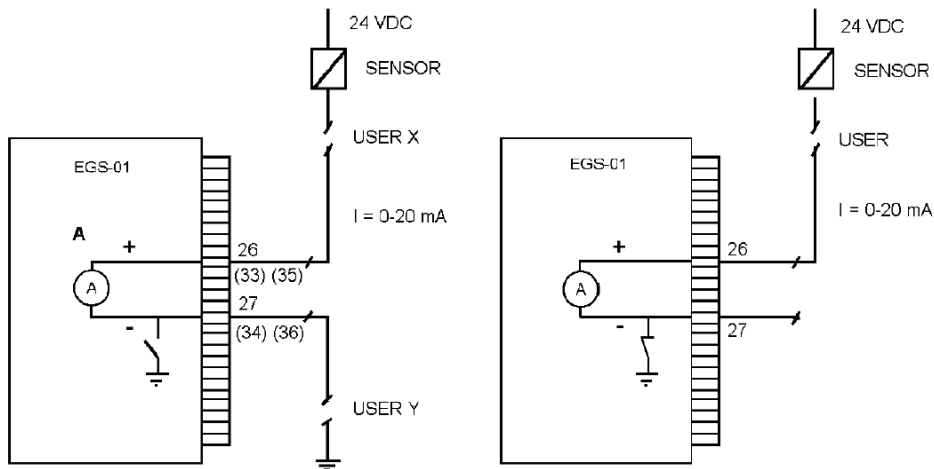


Figure 2-7. Examples of Open and Grounded 0–20 mA Inputs

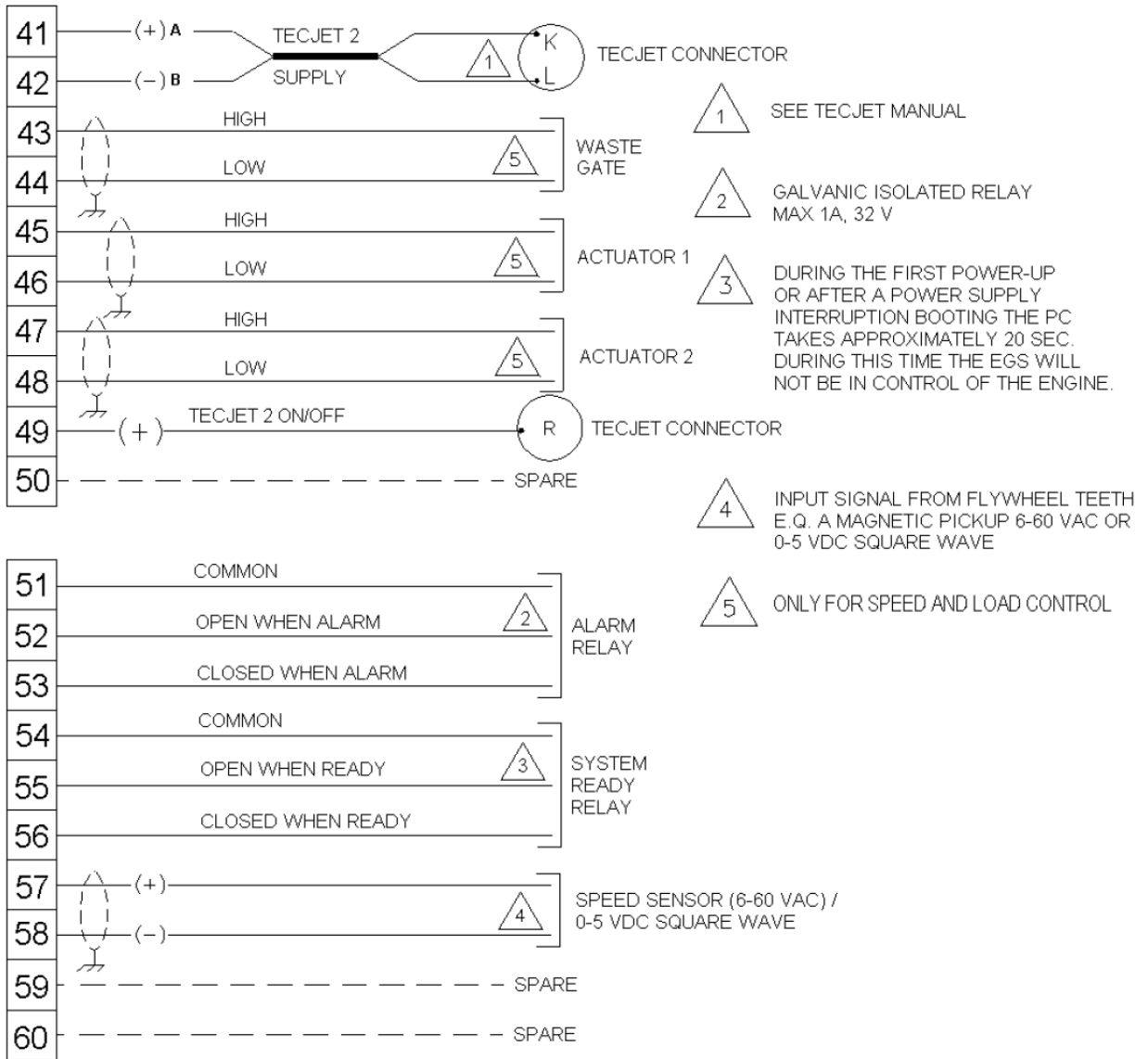


Figure 2-8. EGS Wiring Diagram (Terminals 41-60)

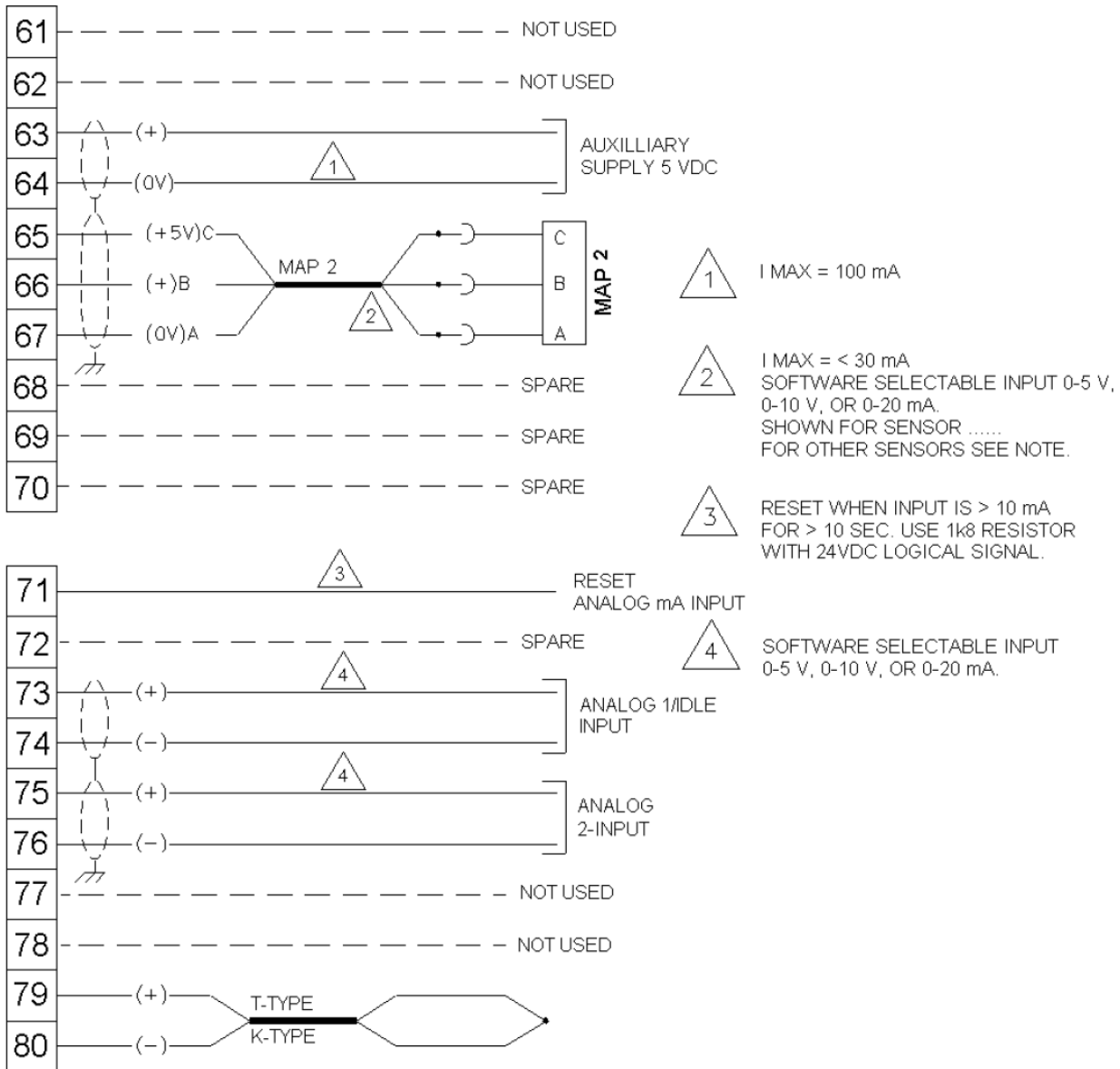


Figure 2-9. EGS Wiring Diagram (Terminals 61–80)

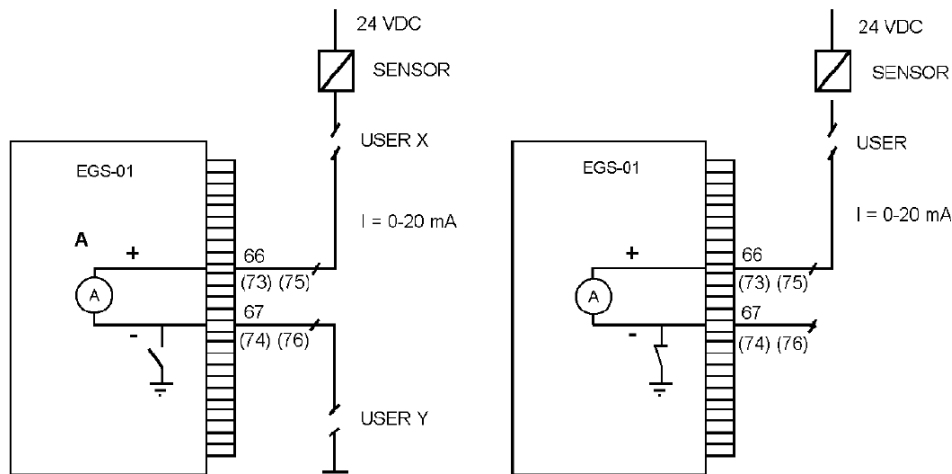


Figure 2-10. Examples of Open and Grounded 0–20 mA Inputs

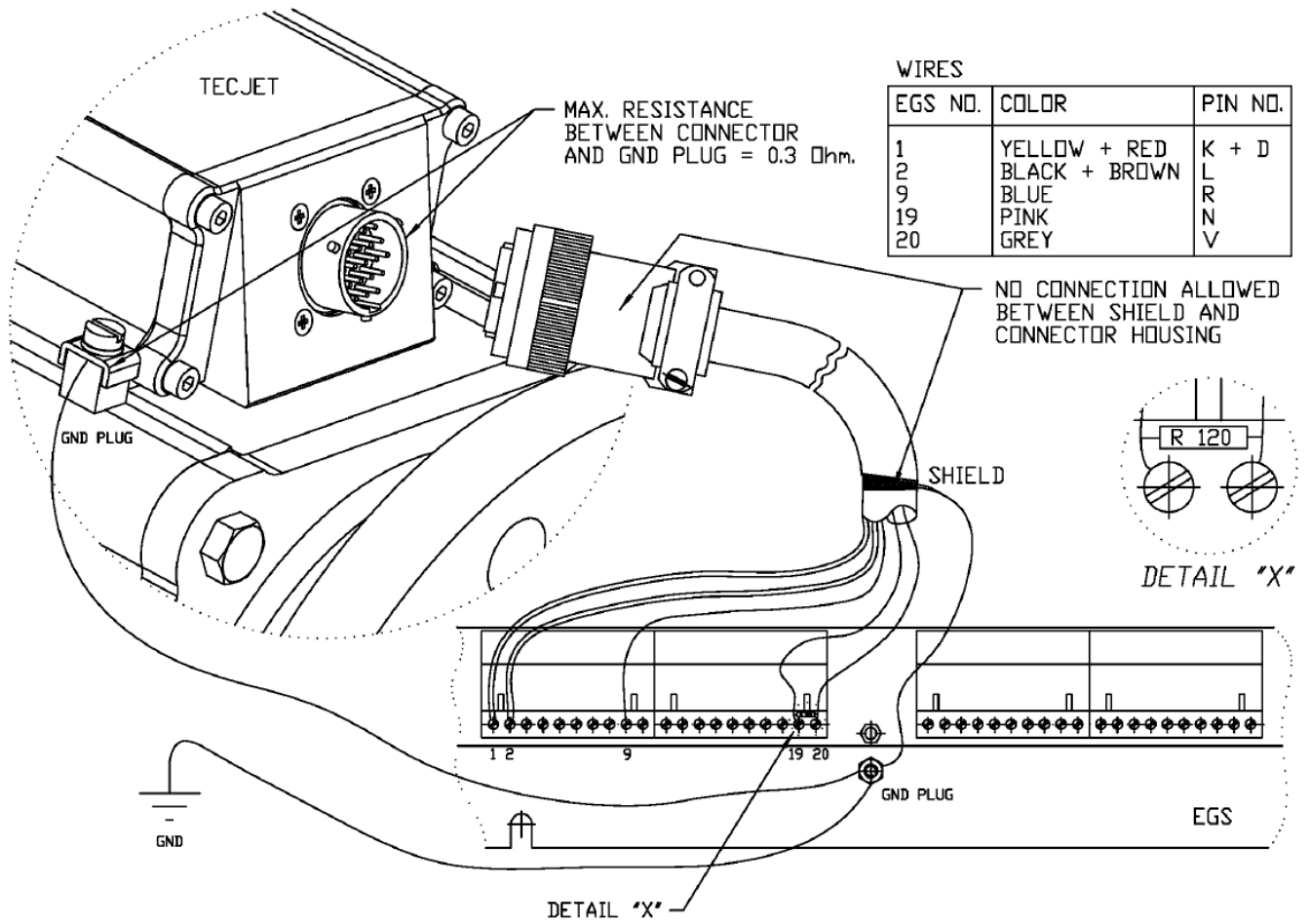


Figure 2-11. EGS to TecJet Connection (single TecJet only)

Chapter 3. Monitoring

Introduction

This chapter covers information on control settings, adjustments, installing the EGS monitor software on your PC and explanation of the monitor program.

IMPORTANT

Please be aware that the EGS monitor program should be run in MS-DOS mode, and not in DOS under Windows.

System Requirements

For EGS monitoring, your system has to meet the following system requirements:

- A PC, Pentium or faster
- A straight or 1:1 cable with 9-pin sub-D female plugs on both ends (see Figure 3-2)
- A free DOS communication port
- DOS 6.0 and Windows 95/98.

Install the EGS Monitor Software

Switch your PC on and start to install the EGS monitor software according to the following steps:

1. Ask your system operator to install a mouse start up command in the autoexec.bat file of your PC in order to activate the mouse driver in the MS-DOS mode. In many computers the mouse is only active under Windows. When you operate the EGS system without a mouse the menu can be opened using one of the key functions mentioned in the Key Functions section below.
2. Insert the "EGS monitor software" diskette into your drive A.
3. Start the Window Explorer and go to drive A.
4. Run the EGS.exe file from drive A to unzip and install the EGS monitor software on the drive C.
5. On the drive C an EGS directory will be made as shown in the example.

```
C:\EGS\EGS_xx1\EGSMON.EXE  
C:\EGS\EGS_xx2\EGSMON.EXE
```

↑
Version number

Run the EGS Monitor Software

1. Restart your PC in the MS-DOS mode, by clicking the button in the “Start”->”Shutdown” field.
2. After the MS-DOS prompt, type C:\EGS\, C:\EGS\EGS_XXX and click the Enter button.
3. Type “EGSMON” and click the Enter button, to run the EGS monitor software program. The screen will show the EGS authorization display as shown in Figure 3-1.

IMPORTANT

Another possibility to start in the MS-DOS mode is pressing the F8 button in the booting period before Windows starts.

It is also possible to make a shortcut to batch file on your PC which forces your PC to reboot in MS-DOS before running the EGS monitor program. If you make this shortcut, then you don't have to perform steps 1 and 2 as listed below.

1. Press F8.
2. Select “6” and press enter, so that the MS-DOS prompt appears.
3. After the MS-DOS prompt, type cd EGS\EGS_XXX (name of the file where the EGS software is located).
4. Type EGSMON to run the EGS monitor program.
5. Use the key functions as mentioned in the Key Functions section below.



Figure 3-1. EGS Authorization Display

Key Functions

When you use the EGS monitoring program without a mouse you have to use the following key functions to open the menus and change parameters.

Key	Function
Alt – S	Opens the system menu.
Alt – F	Opens the File menu.
Alt – V	Opens the View menu.
Alt – L	Opens the Logging menu.
Alt – P	Opens the Parameter menu.
Alt – R	Opens the Protection menu.
Alt – D	Opens the Diagnosis menu.
Tab key	To jump to the next field in any window.
Shift and Tab key	To jump to the previous field in any window.
Space bar	To enable / disable the options you require.
Alt-F4	To leave the EGS monitoring program.
“←” key	To scroll left through all menus.
“→” key	To scroll right through all menus.
“↑” key	To scroll up through all menus.
“↓” key	To scroll up through all menus. Pressing the “i” key or the “Ø” key can also have the function to change the option if you are in one of the windows.
Enter key	To confirm the settings or changes.

For quick editing of the tables (edit tables and axes tables), all tables have features to change the entire table, a row or a column with the following Alt-key combinations:

Key	Function
Alt – A	To add a value to all values in the table.
Alt – F	To fill the entire table with a value.
Alt – M	To multiply all values with a factor.
Alt – X	To fill a row with a new value.
Alt – Y	To fill a column with a new value.
Alt – D	To activate the dashboard

Authorization

The first authorization should be done by a supervisor who is responsible for the EGS system in your organization. The supervisor can assign other users and determine their level of access to the system.

The first time the supervisor opens the EGS monitoring program, “SUPERVISOR” must be used as the user name. Press the OK button to open the monitor software. The EGS system answers with “Do you wish to work with the EGS now ? “. Press the “ NO “ button, if you are not connected to an EGS system.

To protect the EGS system against unauthorized changes a password is used. The supervisor has to click the “System” menu and select the “Change Password” window. In the “Change Password” window, the supervisor has to enter the new password twice.

New users can be appointed by the supervisor by clicking the “System” menu and selecting the “Browse Users” window. Click “Add” then add a user name, enter a password twice and press “OK”.

There are three levels of operation in the EGS:

- **Supervisor:** The supervisor can change settings, parameters, start and stop the logging, assign users, monitor the system, etc.
- **Level 1:** The same as under Supervisor with the exception of assigning users
- **Level 2:** These users can only monitor the system and use the Datalog functions.
- **No password (View Mode):** These users can only monitor the system.

Cable Connection

1. Connect a cable between your PC and EGS-01 control. Use a cable with a 9-pin sub-D female plug on both ends. If the cable has a male and a female plug, use an adapter with a 9-pin female connector on both ends.

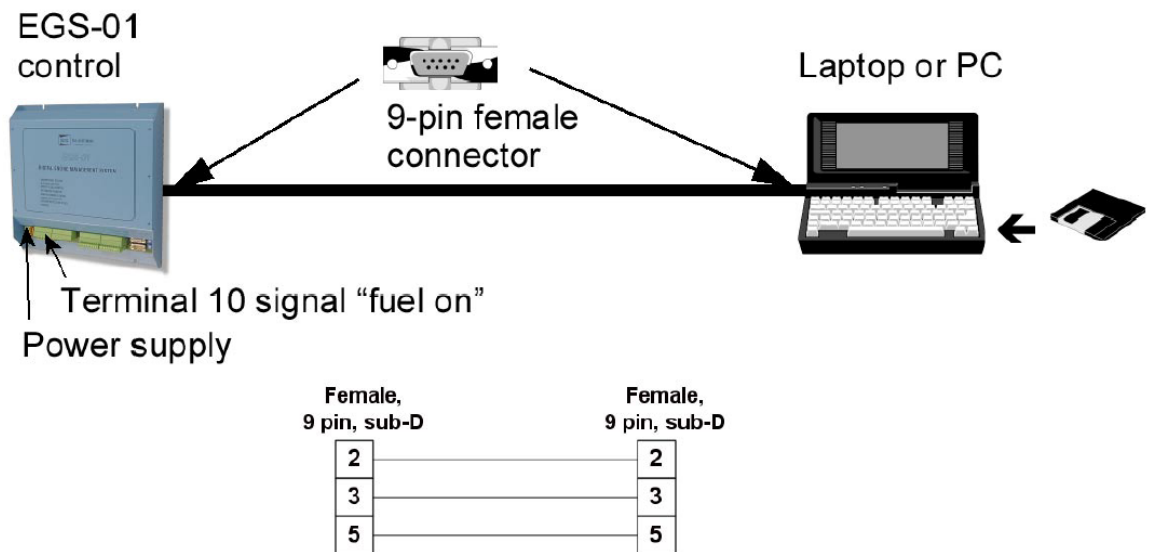


Figure 3-2. Cable Connection

IMPORTANT

The EGS-01 control only communicates with your PC when the supply-voltage and the signal "Fuel On" on terminal 10 are connected. You can check this using the three green LED's on the right side of the PCB. The "Power" and "FUEL ON" LED's should be on for minimum 15 seconds after the signal "Fuel On" is given.

2. Type user name and password to start the EGS monitoring program. The EGS-01 control displays the following question: "Do you wish to work on line with the EGS now?" Click the "YES" button to receive the current parameters from the EGS. If the parameters transmission from the EGS to your PC is successful the "Information" window appears on the screen.
3. Press the OK button to open the actual engine parameters, settings and to start the logging function.

IMPORTANT

When there is no communication between the PC and the EGS-01 control, the system shows the message: "Failed to connect. Retry?" or "Failed to repair the connection. Retry?" When there is still no communication after a few retries, check the COM port setting of the PC by setting port 1,2,3 or 4 to get the correct communication. Generally most PC's use COM port 1 as the default COM port.

On-line / Off-line**IMPORTANT**

When you are on-line the engine parameters in the EGS monitor program are always identical to the parameters in the EGS control.

If you are going to work on-line you have to decide whether you want to overwrite the PC parameters (1) or the EGS parameters (2).

1. On-line: parameters EGS → PC (the PC parameters will be overwritten by the parameter settings of the EGS-01 control).
2. On-line: parameters PC → EGS (the EGS-01 parameters will be overwritten by the parameter settings of the PC).

During normal EGS monitoring the parameters in the PC (EGS → PC) will almost always be overwritten. Sending parameters to the EGS-01 control is normally only done during initial set-up (PC → EGS).

NOTICE

If you send new parameters to the EGS control, the old parameters are overwritten.

IMPORTANT

The PC and EGS-01 control must have the same software version. A fault box appears if you load a different software version. The fault box will tell you which software version is valid.

Working off-line is used to prepare the EGS-01 control, such as setting the default parameters, before you commission the EGS-01 control. By working off-line you can also load a calibration (parameters from disk) into the EGS monitor program with the command "File, Open". This can be used to look at other (stored) engine calibrations.

IMPORTANT

"Dashboards" in the EGS monitoring program will only work when you are on-line.

Menus

On top of the EGS monitor screen is the main menu with the following sub-menus: System, File, View, Logging, Parameters, Protection and Diagnosis. Depending on user/level and/or system type, some sub-menus are not accessible and appear gray. On the bottom of the EGS monitor screen the monitor version (3.00), engine status: stopped/cranking/running, logging status: empty/logging/full, and on-line/off-line status are shown.

System Menu

The "System" menu contains version information of the EGS monitoring system, installation of new EGS software, and authorization of the EGS system and a communication window to select the correct COM-port to communicate with your EGS. The option "Change EGS Password" (see the Authorization section above) is only accessible on-line, and the option "Install EGS Software" only off line.

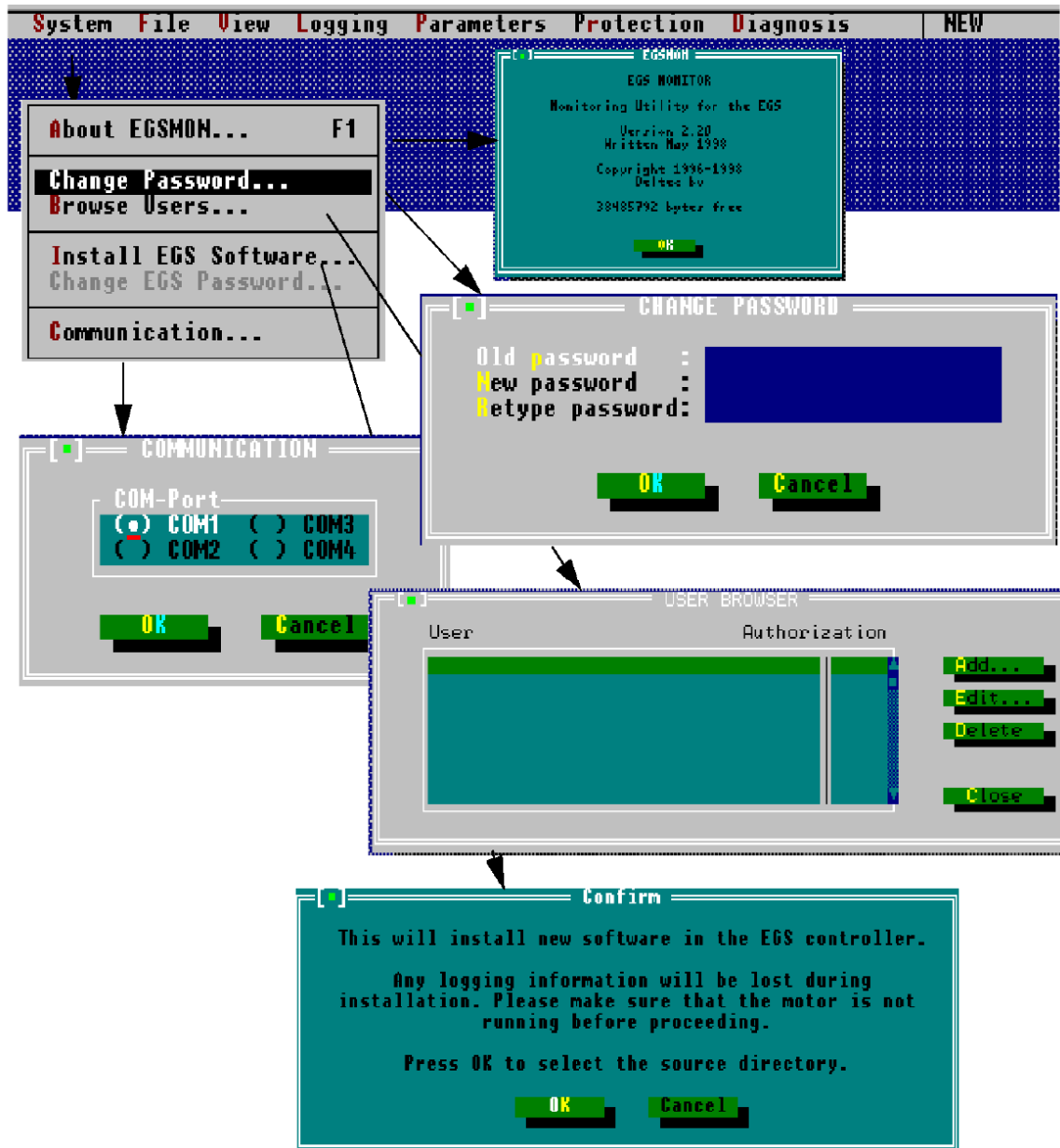


Figure 3-3. System Menu

File Menu

The “File” menu contains the following windows:

- Four options (new, open, save and save as) to manipulate the parameter settings used by the program.
- Three options (Dial, Hang Up, Reset Modem) to control the modem connection.
- Two options (Work Online, Work Offline) to control working on-line and off-line.
- A Change System Type window. Select here the type of EGS system configuration you are going to use for your engine. If you are working on-line you cannot change the “Change System Type” window. It is only possible when working off-line.
- An Options window to select another default directory for saving the EGS settings files.
- A DOS Shell window to go to DOS.
- An Exit field to quit the EGS monitoring program.

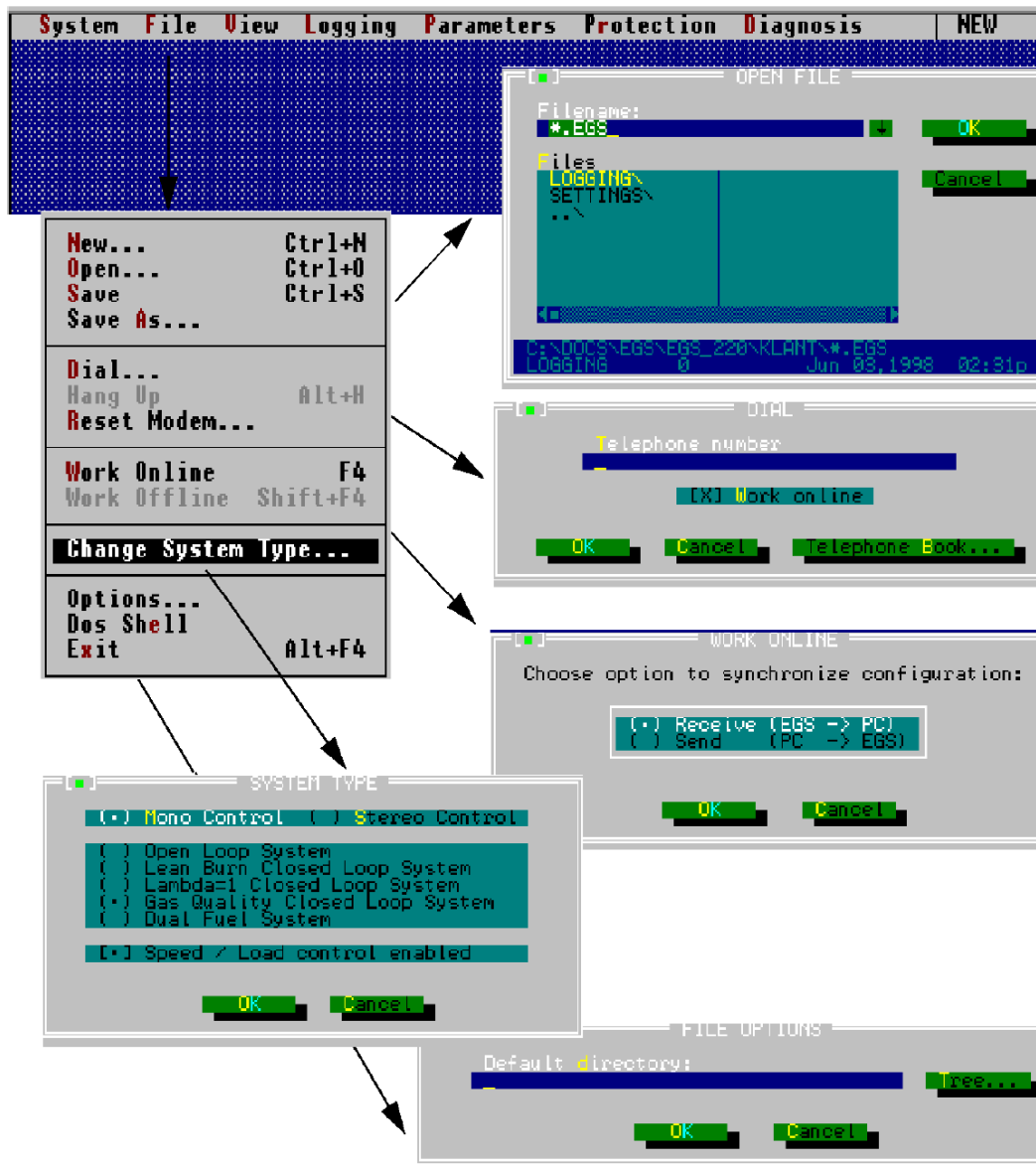


Figure 3-4. File Menu

View Menu

The “View” menu has the means to view all parameters. The “View“ menu contains the following windows:

- The Overall Status window which gives you an overview of the status the EGS control is functioning.
- The Mono Control window which gives you an overview of the measured and calculated engine and lambda parameters when your EGS system works in mono control.
- The TecJet Bank 1 window which gives an overview of the output parameters of TecJet 1.
- The TecJet Bank 2 window which gives an overview of the output parameters of TecJet 2. TecJet Bank 2 is only active when you are in stereo control.
- The Diagnosis Alarm Status window which gives you an overview of alarms that appear during EGS system failures. See also the Diagnosis Menu.
- The Engine Alarm Status window which gives you an overview of alarms that appear during engine alarms. See also the Protection Menu.
- The Speed and Load Control Window where all inputs, outputs and calculations related to speed and load can be found.
- The Ignition Timing window has three fields: basic timing, retarding and actual timing. The basic timing is the normal ignition timing of the engine received from the Parameters Engine / Engine window. The Basic timing field changes into desired timing when the timing is through plant communication. The Timing retarding is the timing from the FireFly to stop detonation. The Actual timing is the basic timing minus the timing retarding.
- The System Type window gives the system which is selected.
- The Version Info window gives information on which EGS version you are using at the moment.
- The Measured Values window gives you an overview of all values which the system measures at the input connections of the EGS system.

For more detailed information about the measured, calculated and output parameters in some of these windows, see the Explanation of Various Parameters in the View Menu section below. Speed and Load Control is “grayed” out if speed control software is not used.

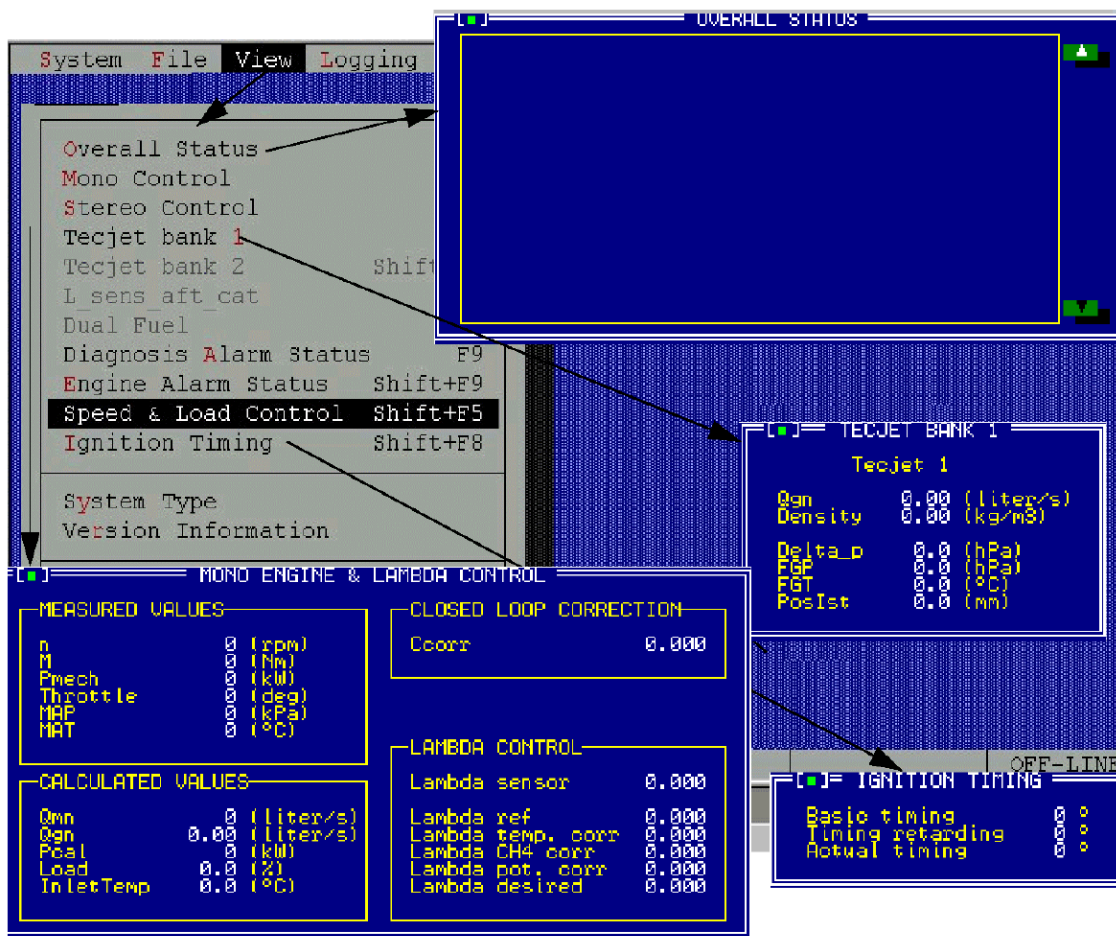


Figure 3-5. View Menu, Part 1

DIAGNOSIS ALARM STATUS

Code	Status	Cnt	Description
Diagnosis alarm state: Reset			

SPEED & LOAD CONTROL

- Engine speed actual: 0 (rpm)
- Engine speed setpoint: 0 (rpm)
- Speed bias: 0 (rpm)
- Load: 0 (%)
- P_mech: 0 (kW)
- P_desired: 0 (kW)
- Power reduction: 0 (kW)
- Speed_PID: 0.0 (%)
- kW_PID: 0.0 (%)
- Throttle 1 position: 0 (°)
- Throttle 2 position: 0 (°)
- Throttle 3 position: 0 (°)
- Breaker contact: Raise / Lower

SYSTEM TYPE

VERSION INFORMATION

```

EGS-01 : 3.00
EGS-02 :
EGS-03 :
Speed/load control :
    
```


MEASURED VALUES

Des_SP/Power:	0.000	U/MA	U Heater 1	0.000	U	Breaker	0
Reset	0.000	MA	U Heater 2	0.000	U	Raise	0
Mes_Power	0.000	MA	U Heater 3	0.000	U	Lower	0
CH4	0.000	U/MA	I Heater 1	0.000	MA	Fuel On	0
Analog 1	0.000	U/MA	I Heater 2	0.000	MA		
Analog 2	0.000	U/MA	I Heater 3	0.000	MA		
MAP 1	0.000	U/MA	Lpot 1	0.000	U		
MAP 2	0.000	U/MA	Lpot 2	0.000	U		
Speed bias	0.000	MA	T_koud	0.000	U		
MAT 1 Ref	0.000	U/MA	Up 24U in	0.000	U		
MAT 1 PT100	0.000	U/MA	Tcouple1 pos:	0.000	MA		
MAT 2 Ref	0.000	U/MA	Tcouple1 neg:	0.000	MA		
MAT 2 PT100	0.000	U/MA	Tcouple2 pos:	0.000	MA		
Lambda	0.000	U/MA	Tcouple2 neg:	0.000	MA		
Lambda	0.000	U/MA	NTC temp:	0.000	U		
Lambda	0.000	U/MA	Thermo1 temp:	0.000	U		
Lambda	0.000	U/MA	Thermo2 Temp:	0.000	U		

Figure 3-6. View Menu, Part 2

Logging Menu

The “Logging” menu contains the following windows:

- The Logging menu has the options to start, stop, clear, or to receive the logging of parameters when the EGS system is working on-line.
- The Parameters window gives you the possibility to log data (20 parameters) with the EGS. In the remote logging mode (this is fast, up to 200 Hz) data will be stored first in the RAM of the EGS and then transferred to the remote monitor PC. With internal logging (1s up to 999s) data is stored on the SSD of the EGS, so there will not be a loss of data if the power supply is switched off.
- The Option window gives you the possibility to make your own logging default directory.

For more detailed information, see Chapter 6.

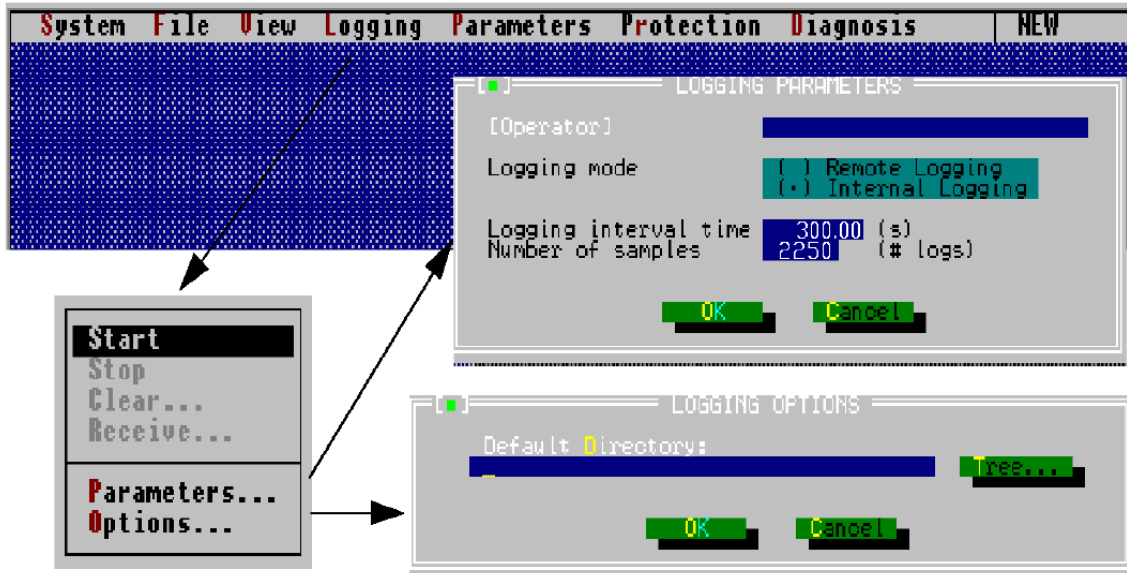


Figure 3-7. Logging Menu

Parameters Menu

The “Parameters” menu offers you a number of windows in which you can enter and modify the various parameters, such as engine parameters, air/fuel ratio parameters, etc. The “Parameters” menu contains the following windows, explained in this section:

- “Engine” window
- “Fuel System” window
- “Fuel Parameters” window
- “Air/Fuel Ratio” window
- “Speed & Load Control” window (only for EGS with Speed/Load Control)
- “Sensor” window
- “Transient” window
- “Closed Loop” window
- “CAN Interface” window
- “Plant Communication” window
- “Speed and Load Control” window (see Chapter 4) (only for EGS with Speed/Load Control).

IMPORTANT Variables between square brackets [...] are only used for information and are not used in calculations.

Parameters Menu / Engine

The Engine window has four separate windows: Engine, Volumetric Efficiency, Total Efficiency and Speed Density.

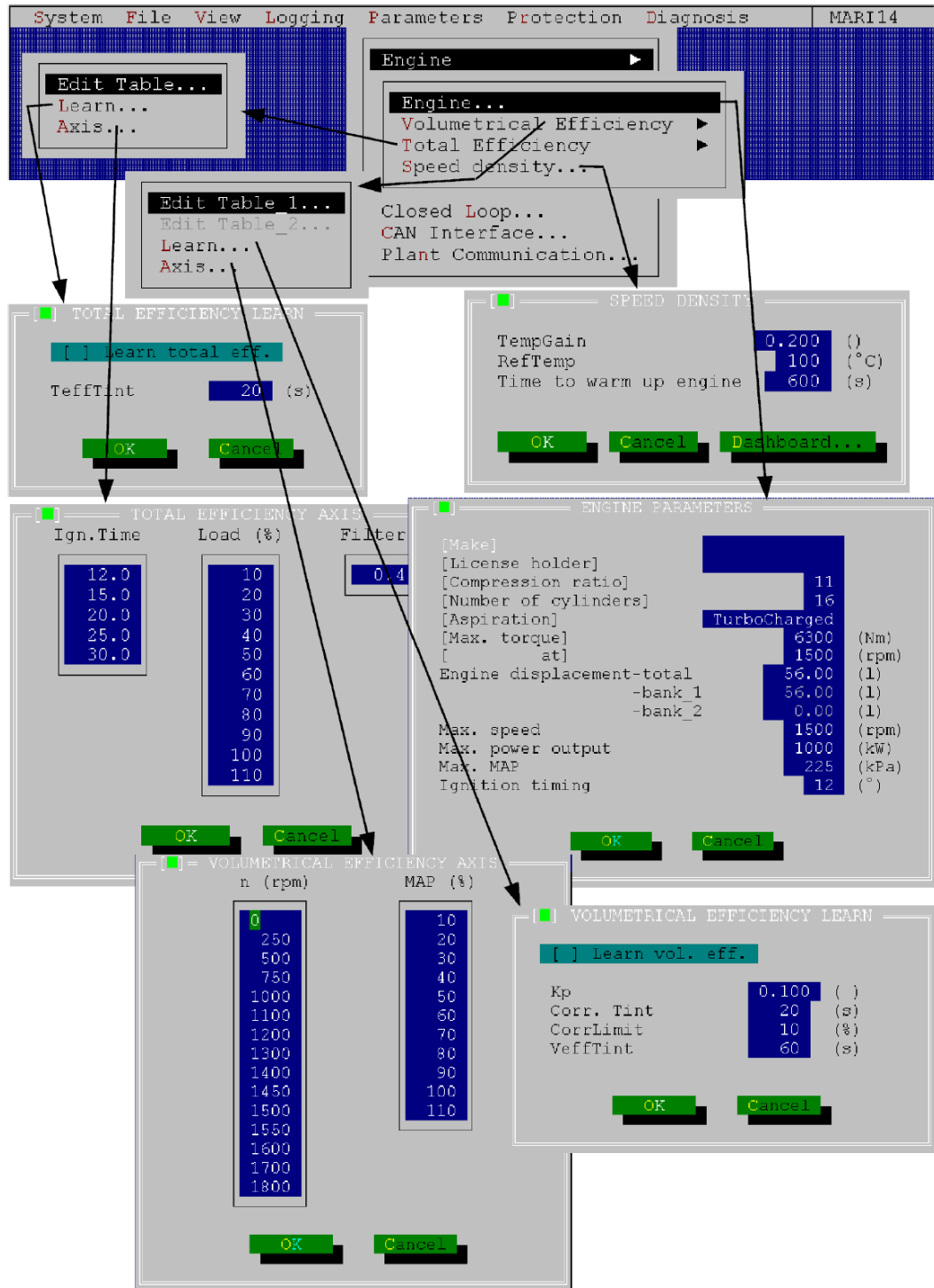


Figure 3-8. Parameters Menu / Engine, Part 1

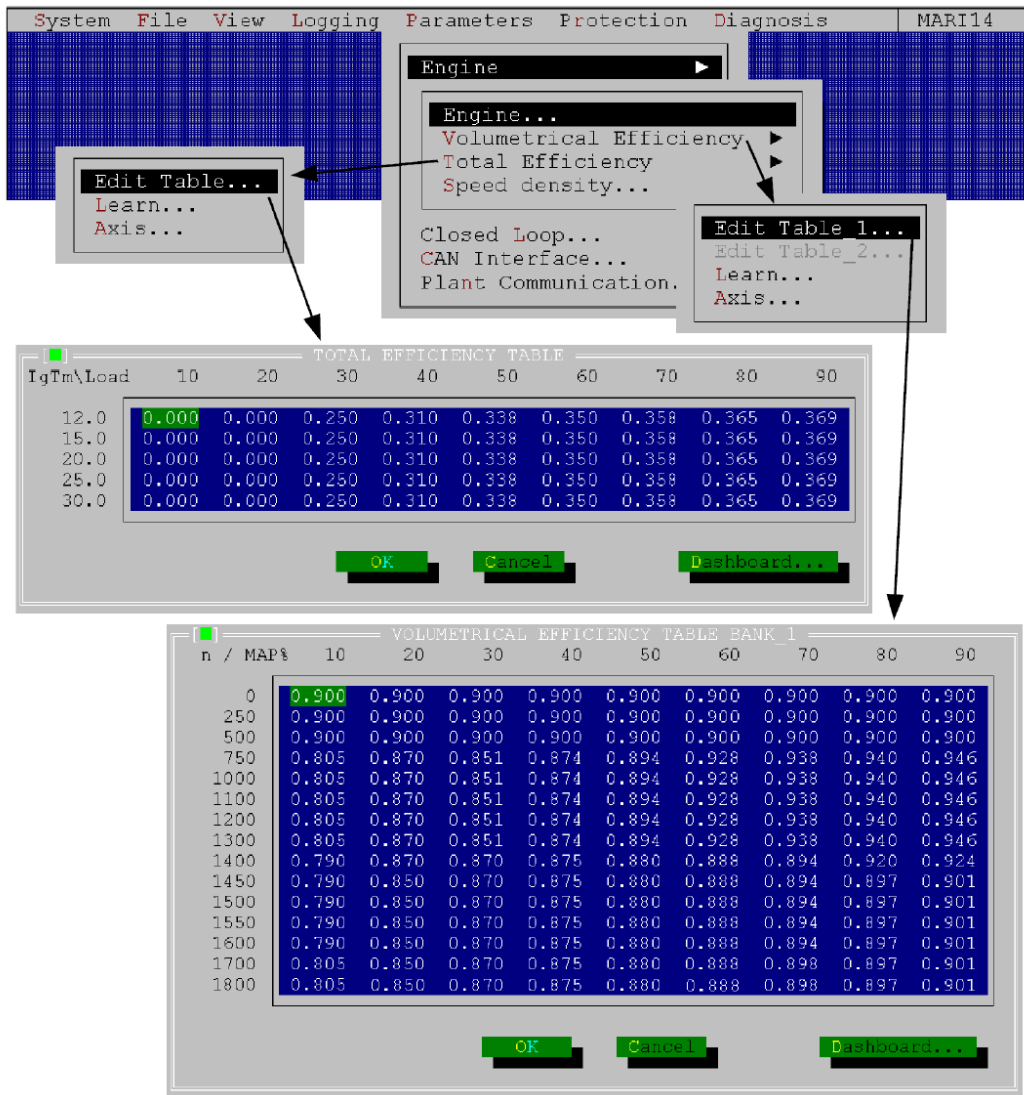


Figure 3-9. Parameters Menu / Engine, Part 2

Parameters Menu / Fuel System

In the Fuel System window you can enter data about the mixing unit and the TecJet. If two TecJets are being used on one "speed density calculation" where each TecJet should deliver half the calculated gas flow, the "Dual TecJet" check box should be enabled.

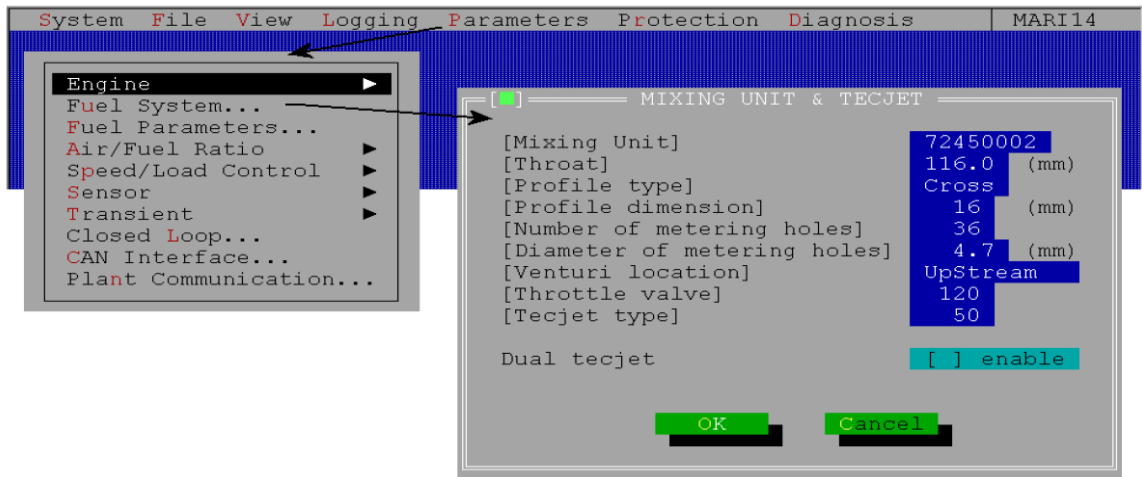


Figure 3-10. Parameters Menu/ Fuel System

Parameters Menu/Fuel Parameters

The Fuel Parameters window gives you the possibility to enter values for the LHV, density and lambda_stoich. of the gas that will be used. If the check box "measure CH4%" is enabled, the gas parameters will be calculated depending on the CH4% signal of an external CH4% analyzer. Only the highlighted parameters are in use.

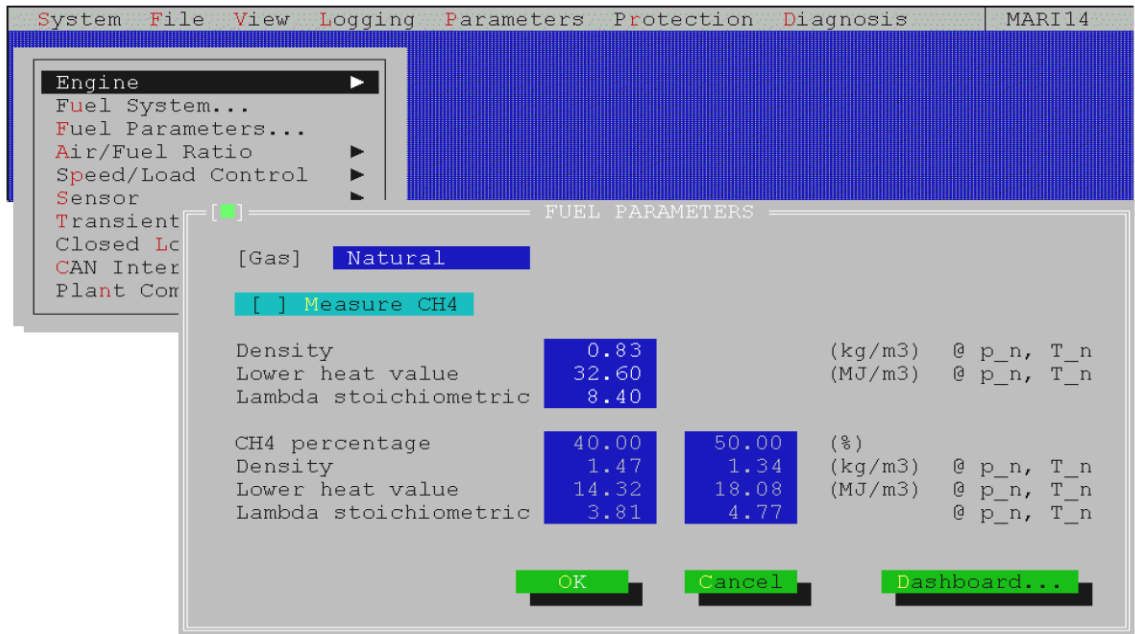


Figure 3-11. Parameters Menu / Fuel Parameters

Parameters Menu / Air Fuel Ratio

The Air/Fuel Ratio window has four separate windows: Ref, Inlet Temp, CH4 and Potmeter.

In the Ref window you can set the Lambda Ref Axes and edit the Lambda Ref Table.

In the Inlet Temp window you can set the Lambda Inlet Temp Correction.

In the Potmeter window you can limit the range of the lambda potmeters to prevent the user adjusting them out of range. The lambda potmeters are located next to the EGS connections.

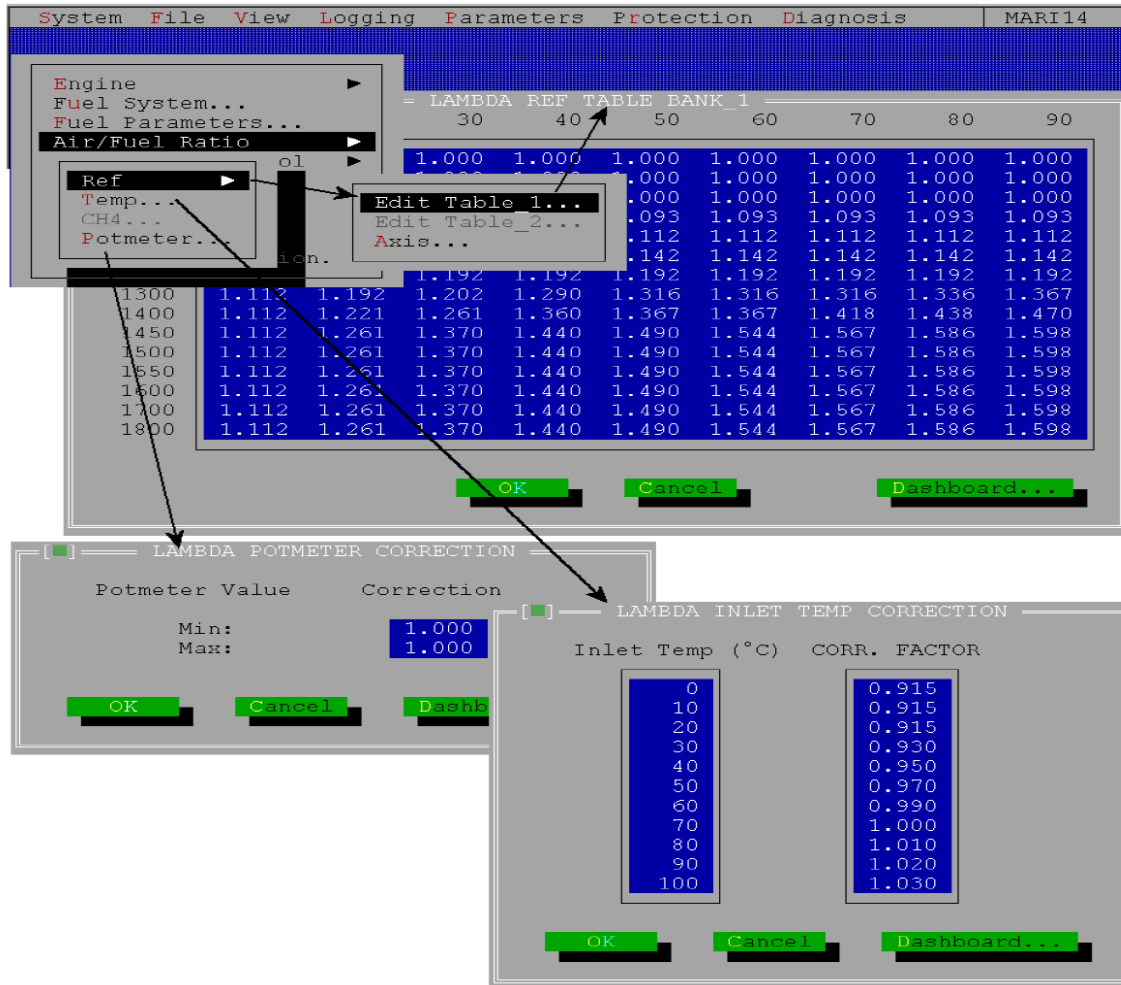


Figure 3-12. Parameters Menu / Air Fuel Ratio

Parameters Menu / Speed/Load Control (only for Speed/Load Control)

The Speed/Load Control menu accesses the following windows:

- The Control Mode window lets you set the type of applications that the EGS-01 will control (see the Control Modes section in Chapter 4)
- The Speed Setpoints window enables start, idle and rated speed setpoints and durations to be set and used (see the Start, Idle, and Rate Speeds Setpoints and Actuator Output section in Chapter 4)
- The Load Setpoints window is used to set the maximum engine torque (see the Compressor Mode, Torque Limiter/Load Setpoints section in Chapter 4)

- The Throttle Setpoints window is used to define the relation between the output of the speed or power control and the throttle angle (see the Throttle Linearization and Calibration section in Chapter 4)
- The Duty-Cycle Setpoints window lets you calibrate the relationship between desired throttle angle and the PWM output signal (see the Throttle Linearization and Calibration section in Chapter 4)
- The Speed Dynamics window is used to set the "gain", "stability" and (actuator) "compensation" (see the Speed Control Dynamics section in Chapter 4)
- The Power Dynamics window is used to enter the "gain versus power" setting for engines running parallel to the grid in "kW-PID" (see the Power Control Dynamics section in Chapter 4)
- The Test Mode window

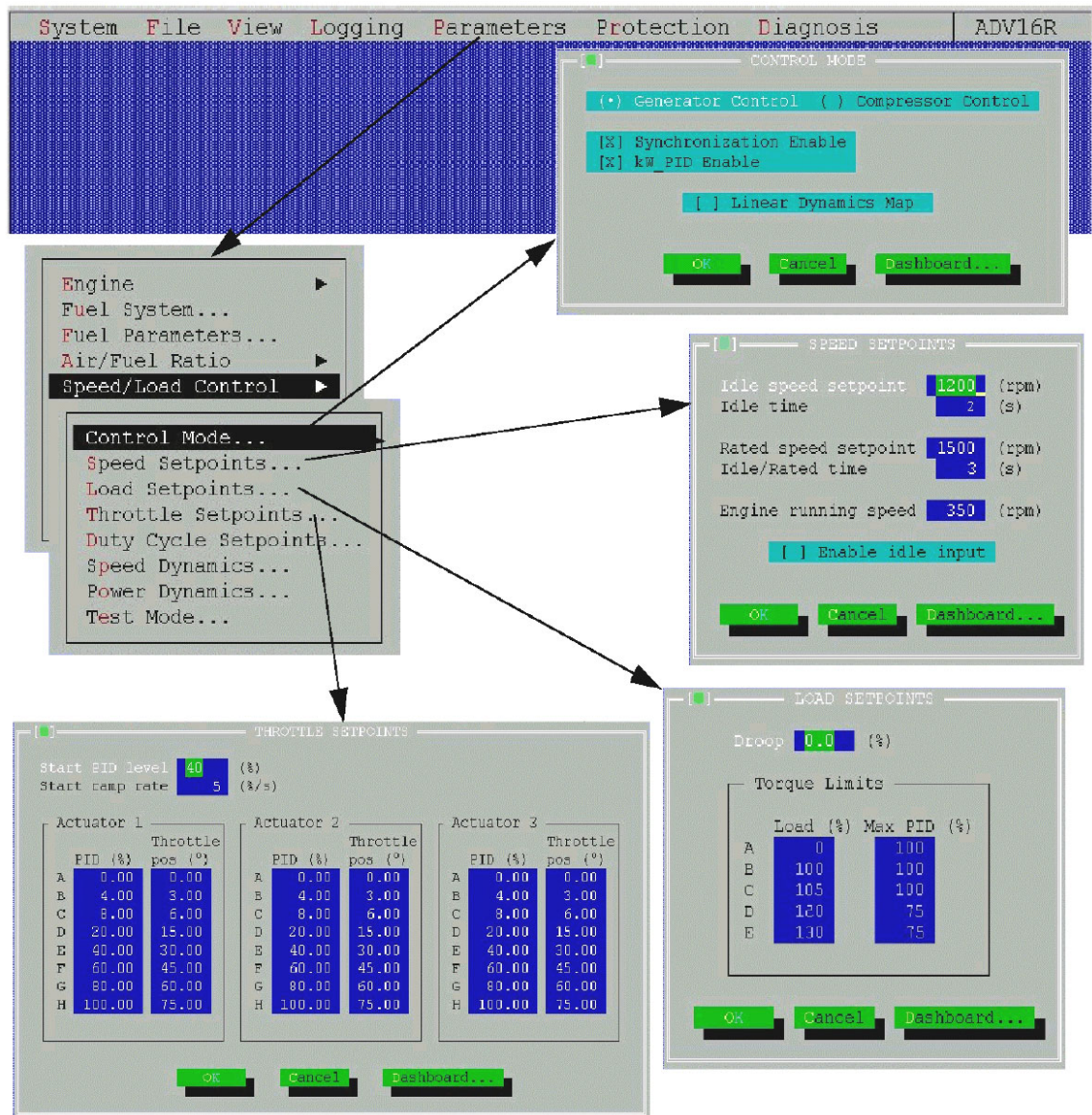


Figure 3-13. Parameters Menu / Speed/Load Control Part 1

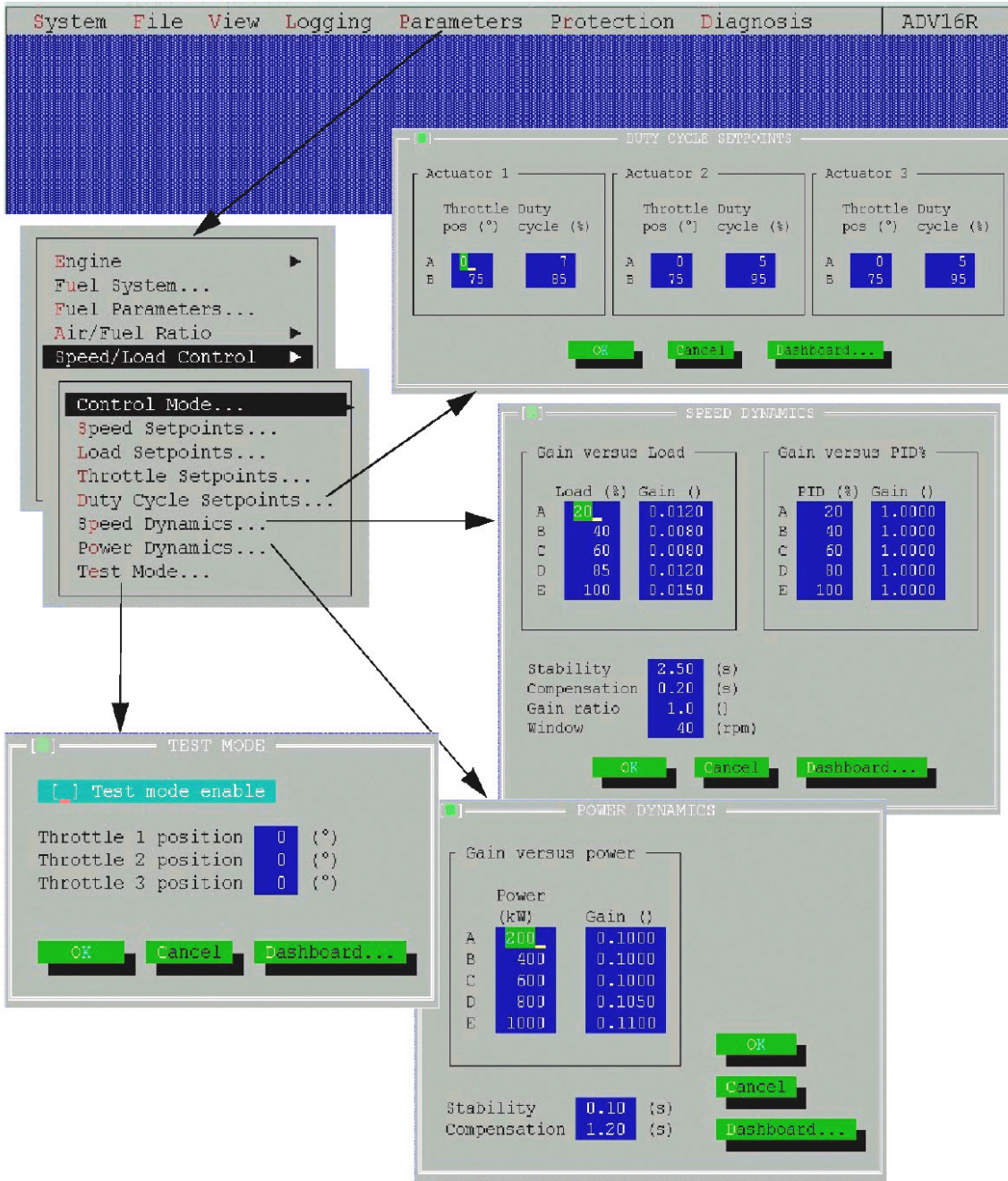


Figure 3-14. Parameters Menu / Speed/Load Control Part 2

Parameters Menu / Sensors

In the Sensor window you can enter or modify the settings, such as range, input, type, etc., of all mentioned sensors.

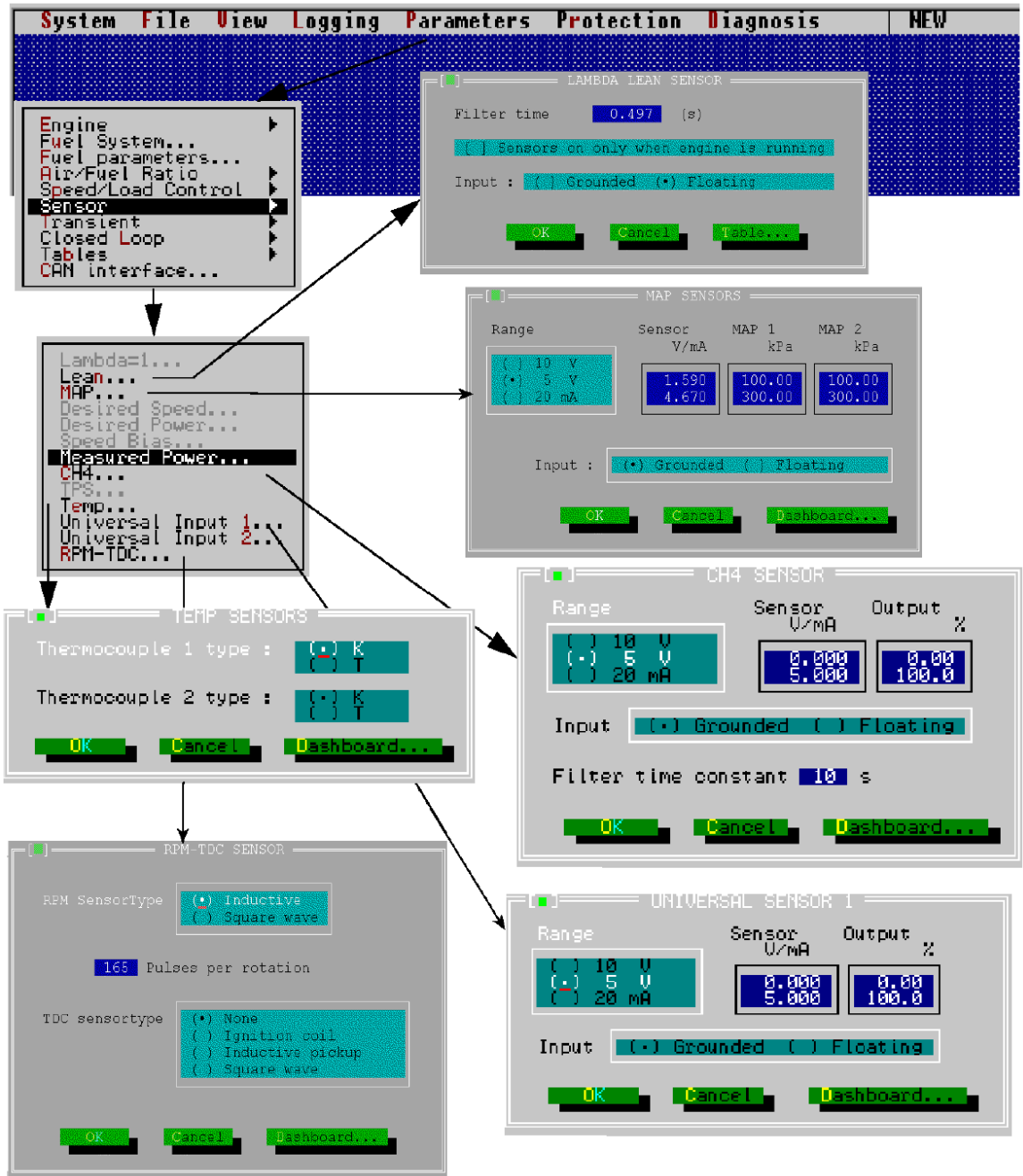


Figure 3-15. Parameters Menu / Sensors

Parameters Menu / Transient

In the Transient window you will find the manifold volume and the number of dMAP/dt samples which are the parameters to improve transient performance.

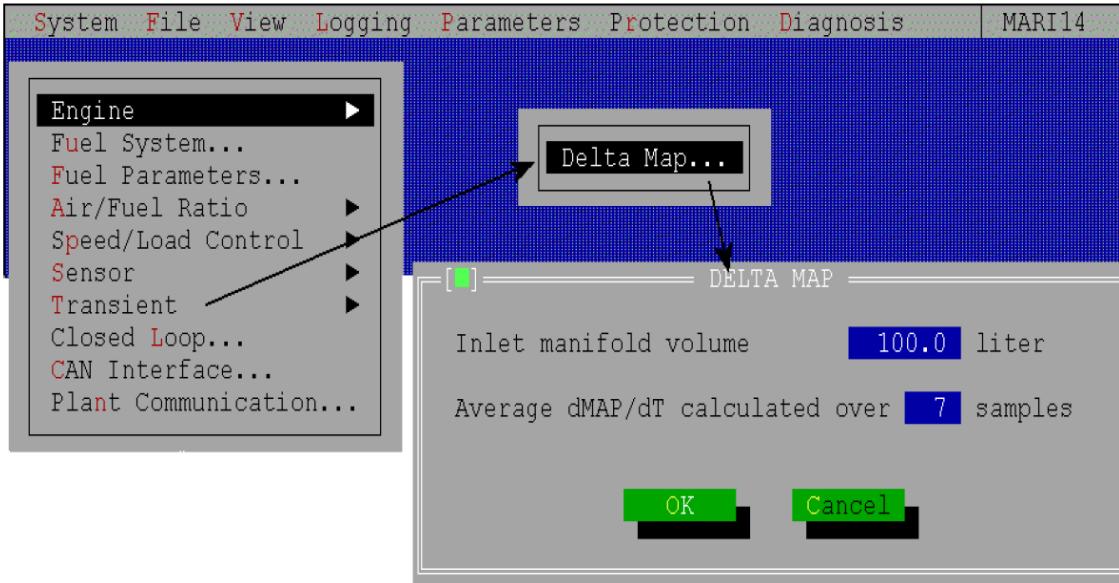


Figure 3-16. Parameters Menu / Transient

Parameters Menu / Closed Loop

In the Closed Loop windows you can enter or modify the parameters for the closed loop options.

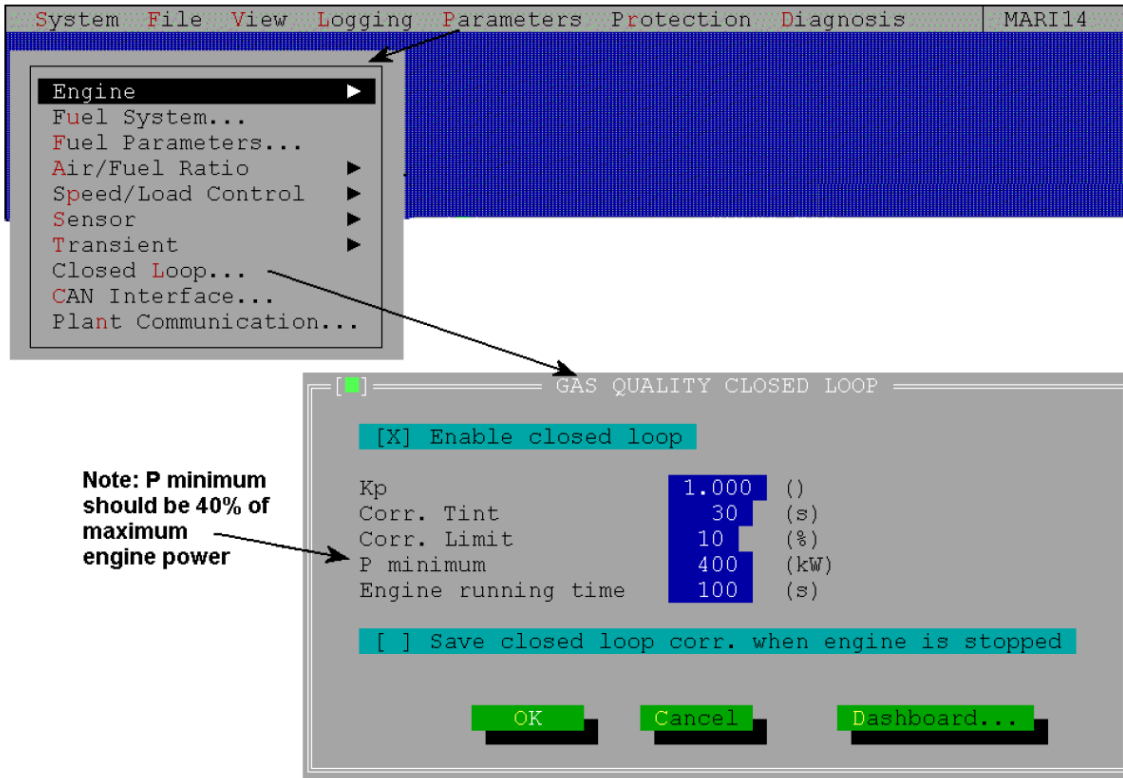


Figure 3-17. Parameters Menu / Closed Loop

Parameters Menu / Can Interface

In this window you can change the CAN settings (this is not advised). The "Protocol 98" should always be enabled, except when using very old TecJets (with separate electronics boxes, and TecJets with a software version older than 1.05)

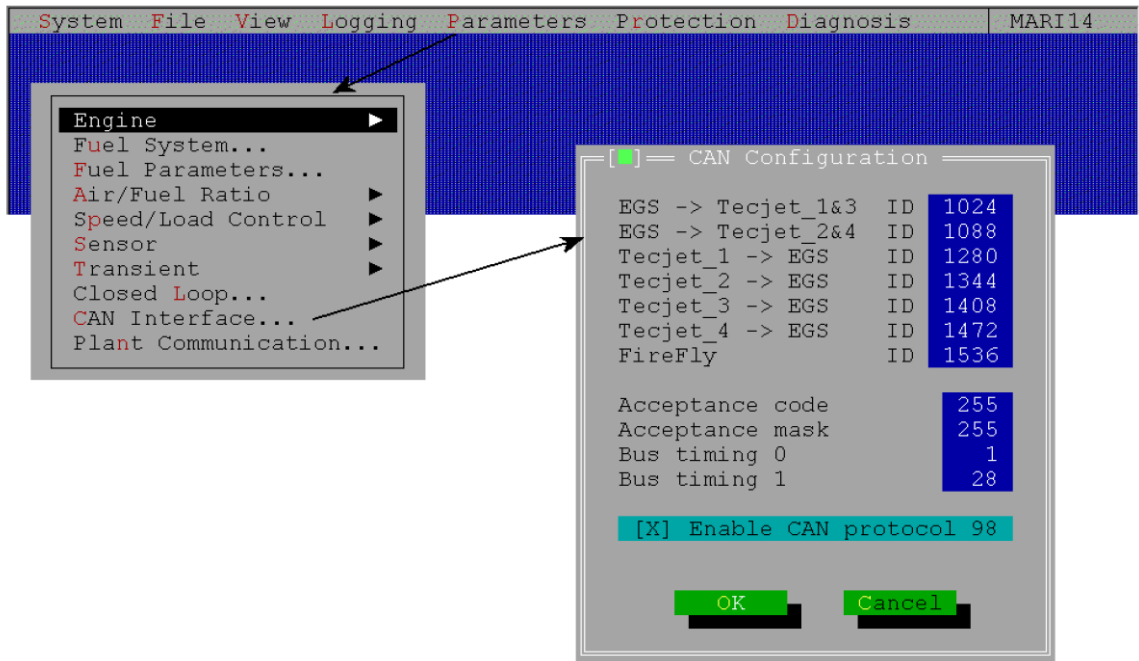


Figure 3-18. Parameters Menu / CAN Interface

Parameters Menu / Plant Communication

When "Plant communication" is enabled a list of parameters is sent to another control system, e.g. for (remote) monitoring systems. Additionally, the EGS can receive and use various input signals through plant communication (if selected) (see Figure 3-7).

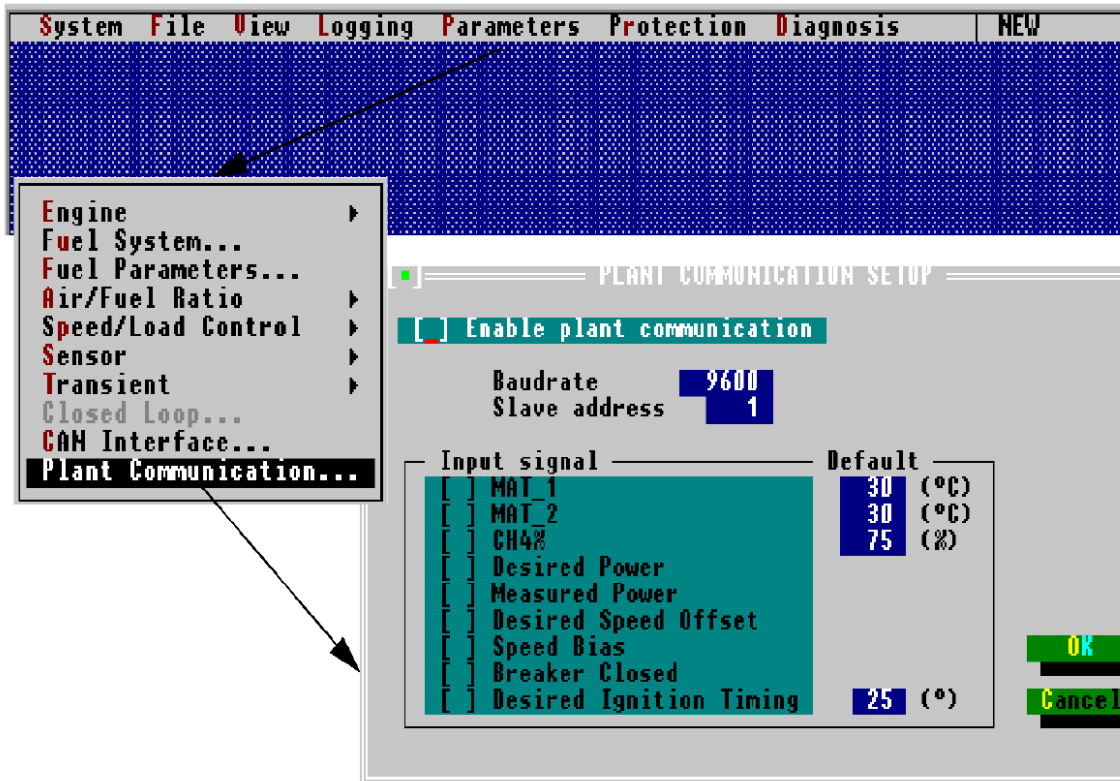


Figure 3-19. Parameters Menu / Plant Communication

Protection Menu

The "Protection" menu offers you a number of windows in which you can add values to protect your application against overspeed, overload or high temperatures.

The "Protection" menu contains the following windows:

- The Temp Protection window gives you the possibility to set a maximum temperature for thermocouples 1 and 2 to protect against high temperatures.
- In the PASTOR window you can adjust the level of alarm as a function of the load level.
- In the Overspeed Protection window you can set the maximum engine speed, maximum time and number of overspeed cycles before alarm.
- In the Overload Protection window you can set the maximum engine load and the maximum time to prevent an overload condition.
- The FireFly window for knock detection and protection. You can only make the FireFly window active if you enable the protocol-98 check box under "Parameters / CAN Interface".

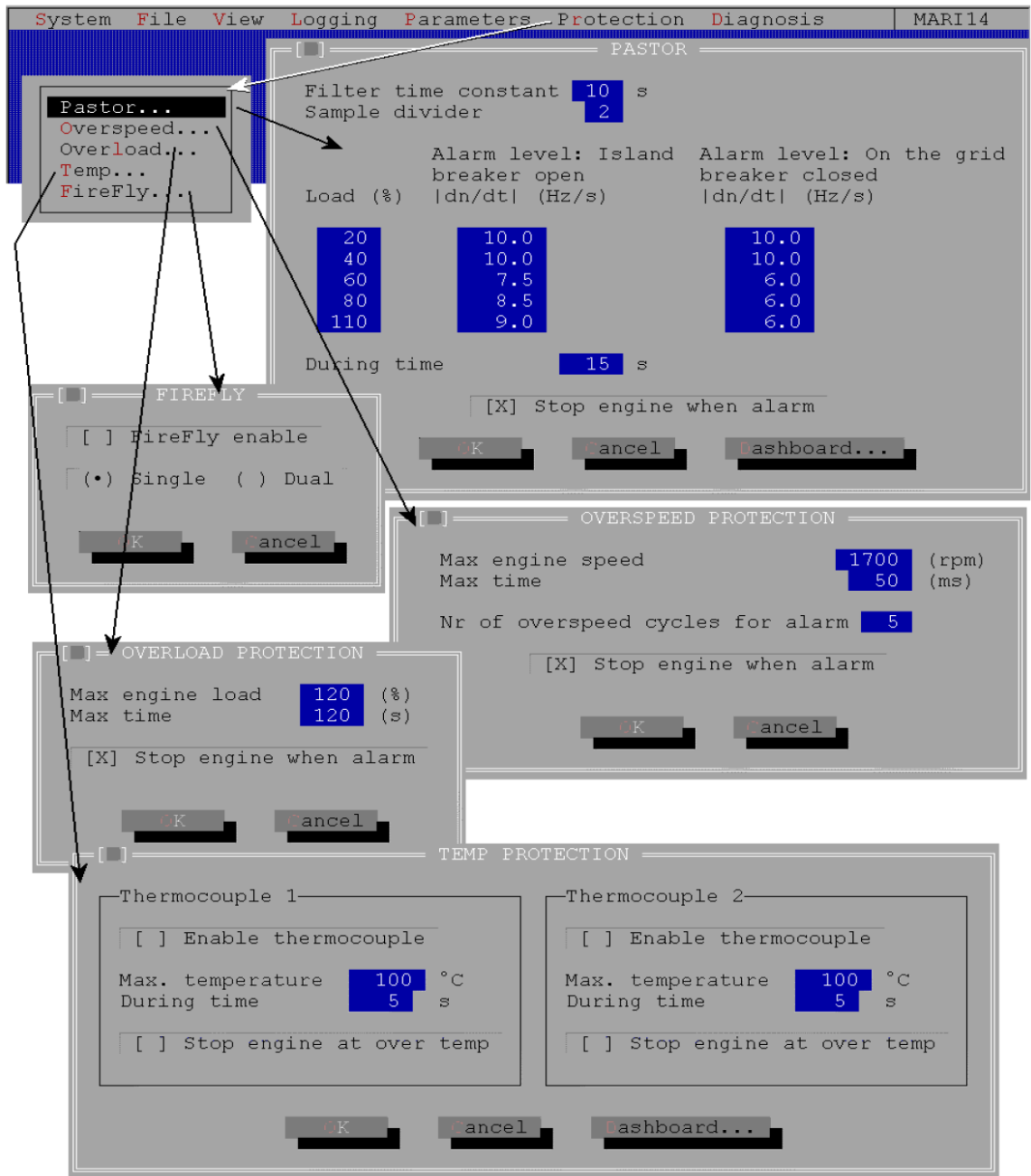


Figure 3-20. Protection Menu

Diagnosis Menu

The “Diagnosis” menu offers you a number of windows in which you can add diagnosis information, for example a sensor may operate in a certain range/time before an alarm comes on.

The “Diagnosis” menu contains the following windows:

- The “Sensor” window has a number of separate windows in which you can add the values in where the sensor may operate.
- The “Closed Loop” window. In the Closed Loop window you can add the max. time for closed loop out of range and to open the loop if the closed loop error remains. You can only change the “Closed Loop” window if you have selected a closed loop configuration in the “Change System Type” window under file menu.
- The “Lambda Difference Diagnosis” window. In the “Lambda Difference Diagnosis” window you can set the max. lambda difference and max. time the lambda difference may be out of range.
- The Speed Deviation window. In this window you can set the maximum speed deviation from rated speed. If speed deviation is less than the limit and the breaker is closed, the control immediately switches from kW control to speed control. To reset the control the engine must be stopped and the “breaker closed” signal must be low (i.e. the breaker is open).
- The “TecJet Diagnosis” window. In the “TecJet Diagnosis” window you can set the max. delta pressure and during time, malfunction when zero gas pressure is longer then the specified time and a malfunction when the flow is not reached within a certain time.
- The “Status” window contains three windows, the status setup window, the reset options window and the reset alarms window.
- The “Status Setup” window gives you the possibility to set warnings or alarms, and to stop the engine when there is an alarm for the listed malfunctions.
- The “Reset Options” window gives you the possibility to hold the alarm status when the system is OK.
- The “Reset Alarms” window, to reset the alarms.
- The “Plant Communication” window to set a malfunction when communication is lost. This is only possible when the check box in the “Parameters / Plant Communication is enabled.

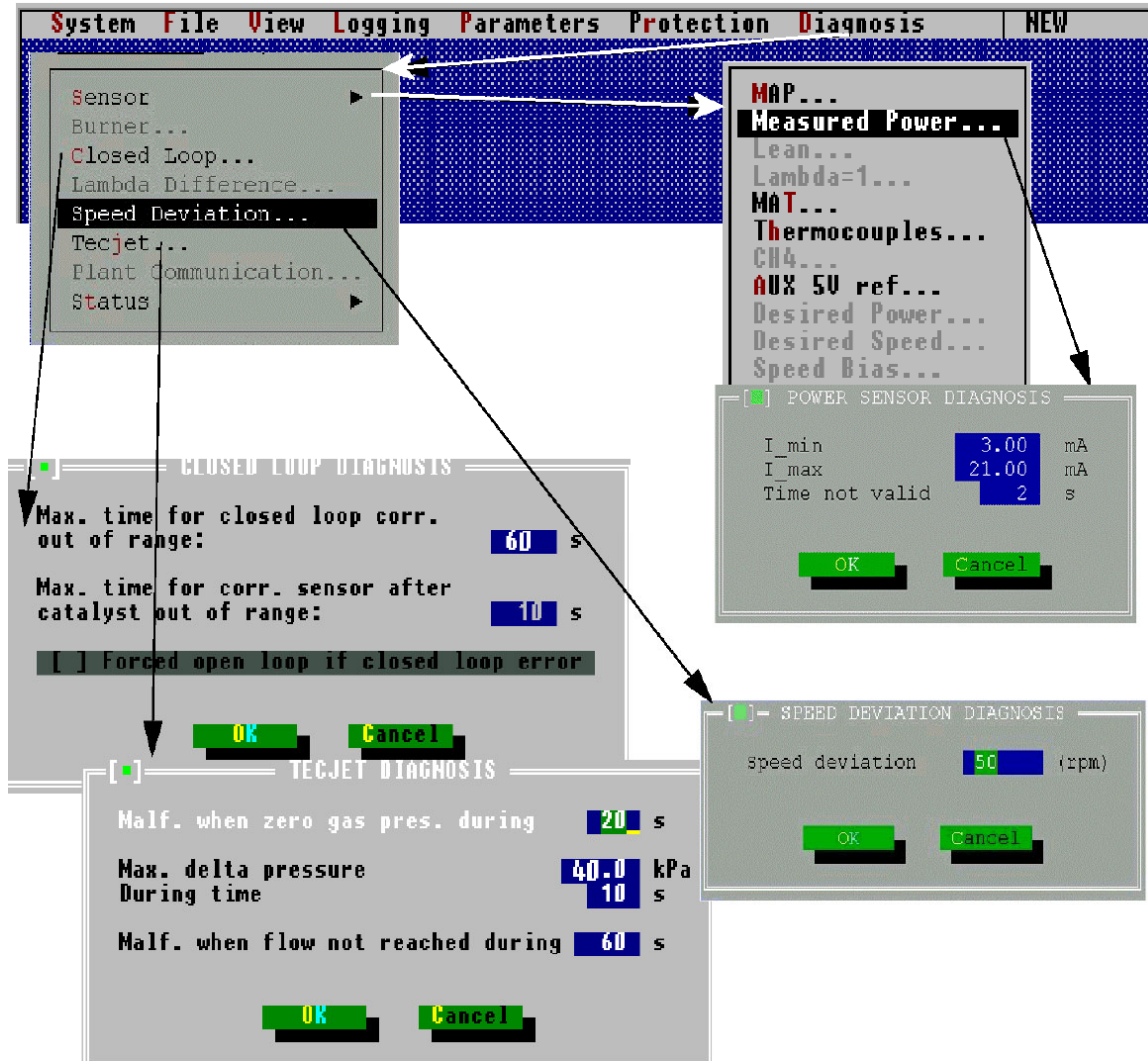


Figure 3-21. Diagnosis Menu, Part 1

In the “Diagnosis Status Setup” every error code can be set to give, a Warning, an Alarm, or an Alarm and Stop Engine command. The alarm relay is fail-safe and is thus in an activated condition when there is no alarm.

At a Warning:	The warning/alarm LED flashes at 1 Hz. A warning message appears on the monitor.
At an Alarm:	The warning/Alarm LED is continuously on. The alarm relay switches to the “alarm”. An alarm message appears on the monitor.
At an Alarm and Engine Stop:	The warning/Alarm LED is continuously on. The alarm relay switches to the “alarm” position. An alarm message appears on the monitor. The throttles and the TecJet close. The system ready relay switches to the “not ready”.

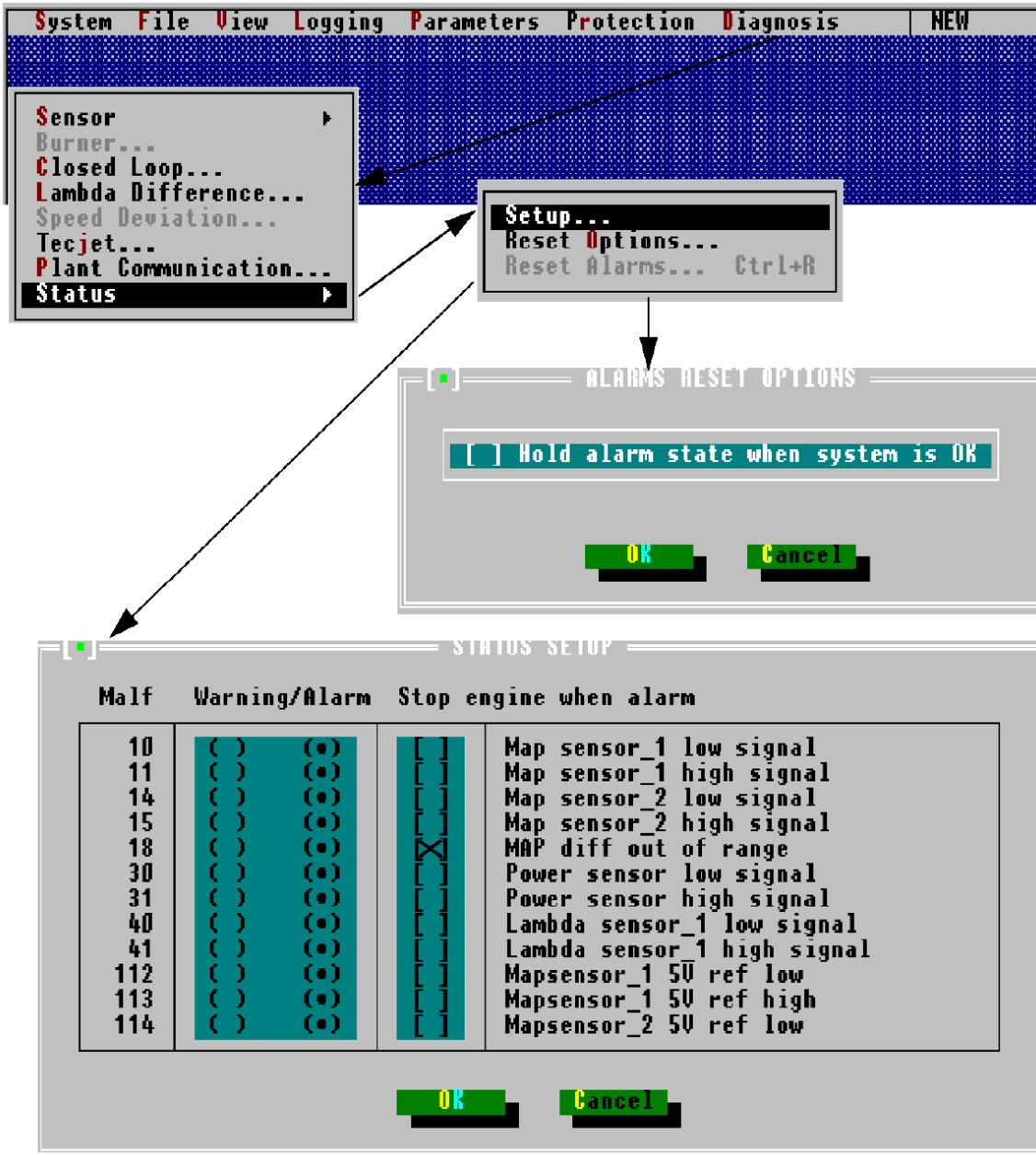


Figure 3-22. Diagnosis Menu, Part 2

Explanation of Various Parameters in the View Menu

Mono Engine & Lambda Control

Overview of the measured engine and lambda values and their meaning, if the EGS system operates in mono control.

Measured Values

n	Engine speed
M	Engine torque *
Pmech	Electrical power of the generator set *
Throttle	Throttle valve position
MAP	Manifold Absolute Pressure, measured downstream of the throttle valve.
MAT	Manifold Air Temperature, measured downstream of the throttle valve.

* If the torque is measured, than Pmech will be calculated ($P_{mech} = n \times M \times 2p / 60$).
If Pmech is measured, than the engine torque will be calculated ($M = P \times 60 / n \times 2p$)

Calculated Values

Qmn	Mixture flow, based on speed, MAP, MAT, cylinders displacement and volumetric efficiency and related to 1013 mbar and 0 °C conditions.
Qgn	Gas flow, based on Qmn, the stoichiometric A/F ratio of the fuel, the desired lambda and related to 1013 mbar and 0 °C conditions.
Pcal	The calculated power of the generator set, based on Qgn, the lower heat value of the gas and the efficiency of the engine/generator set.
Load	The percentage of initiated load, based on the fuel flow to the engine.
Inlet Temp.	The inlet temperature is calculated using the measured MAT.

Closed Loop Correction

C corr.	Correction factor that corrects Qgn in order to result in a Pcal that is equal to Pmech.
----------------	--

Lambda Control

Lambda sensor	The value shown here is the actual lambda that is measured by the lambda sensor that is located in the exhaust gas outlet of the engine.
Lambda ref.	This value shows the lambda value that has been programmed in the Parameters/ A/F-Ratio / ref map in order to get the correct emissions under reference conditions.
Lambda temp. corr.	This value shows the correction factor that has been programmed in the Parameters/ A/F-Ratio / Inlet Temp correction table in order to get the correct emissions at changing manifold temperatures.
Lambda CH4 corr.	This value shows the correction factor that has been calculated in order to get the correct emissions at changing CH4 percentages.
Lambda pot. corr.	This value shows the correction factor that has been set by turning the small blue potentiometer on the right side of the EGS-01 control.
Lambda desired	This value shows the desired lambda in order to obtain the correct emissions ($\lambda_{des} = \lambda_{ref} \times \lambda_{temp. corr.} \times \lambda_{CH4 corr.} \times \lambda_{pot. corr.}$).

IMPORTANT

The meaning of all values for stereo control are the same as in mono control with the exception that it displays the values for two banks. Another difference is that all values for mono control are displayed in one window and for stereo control in two windows (one for engine control and one for lambda control).

TecJet Bank 1

The TecJet Bank 1 window, which gives an overview of the output parameters of TecJet 1.

Qgn	The from the EGS-01 control requested gas flow command for the TecJet.
Density	The density of the gas through the TecJet as filled out in the Parameters/Fuel Parameters table and also corrected for the FGT and FGP. If the CH4% is measured, then the corresponding interpolated density is shown here and also corrected for FGT.
Delta_P	The pressure difference across the TecJet measured by the Delta P sensor inside the TecJet. (hPa = mbar).
FGP	The Fuel Gas Pressure, measured at the inlet of the TecJet.
FGT	The Fuel Gas Temperature.
Pos Ist	The actual position of the gas-metering piston inside the TecJet.

Ignition Timing

Overview of the ignition timing values and their meaning.

Basic timing	The basic timing is received from the Parameters Engine / Engine window. The basic timing field changes into the desired timing when the timing is through plant communication.
Timing retarding	The timing retarding is received from the FireFly. If no timing-retarding signal is received, then it displays a 0.
Actual timing	The actual timing is the basic timing minus the timing retarding.

Chapter 4.

Description of Speed and Load Control

General Information

IMPORTANT

This chapter is only applicable for an EGS with speed and load control.

The EGS-01 incorporates a "state of the art" digital speed and load control, specially designed to control the speed and load of reciprocating gas engines. The EGS-01 speed control takes into account that the actuator is coupled to the mixture throttle valve of a turbo charged gas engine, instead to a fuel rack at diesel engines. The EGS-01 also incorporates an easy-to-use waste-gate control option.

IMPORTANT

In this chapter the terms "power control" and kW-PID" are used instead of "load control".

IMPORTANT

Refer to the Parameters Menu section of Chapter 3 to see the sub-menu structure.

The EGS-01 speed control algorithms are similar to those used in the Woodward ProAct™ speed control. Due to the sophisticated digital engine speed measurement, the actuator will not react on every speed change caused by combustion, without making the actuator slow.

The speed control can be used in "isochronous mode" as well as in "droop mode". When running parallel to the grid the power will be controlled by the "power control", by comparing the desired and the measured power. Alternatively the power can be controlled using the speed control with droop and raising or lowering of the speed setpoint. See Chapter 5 for more detailed information about control modes.

Applications

The EGS-01 Speed & Load control controls the speed and power of gas engines in mechanical drive or generator set service, in island or parallel operation.

The engine speed and/or the produced power are controlled with three actuators, e.g. two mixture throttle valves and one waste-gate control valve. The actuator outputs of the EGS-01 are PWM "push-pull" outputs, which can be directly connected to small Flo-Tech™ or Glo-Tech™ actuator/throttle combinations.

See the Actuators section below for all available actuators.

Waste-gate Control

The EGS-01 can also provide "waste-gate control" in the speed or power control in combination with a Woodward Glo-Tech waste-gate valve connected directly to the EGS (other valves can also be used, for example ProAct actuator and driver box).

With waste-gate control, low loads operation is done with the "waste-gate" fully open and the mixture throttle valve(s) are used to control the speed or load of the engine. When the mixture throttle valve(s) are fully open, the waste-gate starts to close to increase the engine output further. See the Control Dynamics section below.

Actuators

Actuator Sizes

Woodward ProAct, Flo-Tech and Glo-Tech actuators all have an internal closed loop position feedback, giving them excellent performance.

The Woodward Flo-Tech small integrated actuator/throttle combinations are available in the diameters of 33 mm, 48 mm, 60 mm, 68 mm and 75 mm. These small Flo-Tech sizes can be directly connected to the EGS-01.

The Woodward ProAct actuator can be coupled to a throttle valve shaft directly, or by using a linkage. The ProAct actuators are used in the ProAct 75 mm, 85 mm and 95 mm, and in the large Flo-Tech 107 mm, 120 mm and 135 mm.

The ProAct actuator uses a separate ProAct driver between the EGS-01 and the actuator.

For waste-gate application the Glo-Tech actuator/valve combination is available, and this can be connected directly to the EGS-01 output.

Woodward gas engines specialists can advise you on actuator and throttle sizing and advise you how to install throttle valves on the engine. More detailed information can be found in the related actuator manuals. Please contact Woodward for more information.

Throttle Linearization and Calibration

The EGS-01 incorporates throttle valve linearization maps. When the 75-degree rotating Woodward actuators are directly coupled to the throttle valve shaft, there is no need to use progressive linkage systems to compensate for throttle characteristics.

The EGS-01 speed & load control incorporates three linearization tables/maps, one for each throttle (see the "Parameters" → "Speed/Load Control" → "Throttle Setpoints" sub-menu). With these tables/maps you can define the relation between the output of the speed or power control and the throttle angle. In practice, however, a linear table/map works satisfactorily on turbo-charged engines.

With the "duty cycle setpoints" tables/maps you can calibrate the relationship between desired throttle angle and the PWM output signal, for each individual actuator. Using the "test mode", in which you can force any desired throttle angle, you can check if the duty cycle calibration of the throttle is correct.

NOTICE

Be very careful when using "test mode". DO NOT USE "test mode" when the engine is running!

IMPORTANT

The test mode will not work when the EGS is in an alarm.

In the "Parameters" → "Speed/Load Control" → "Throttle Setpoints" sub-menu (see the Parameters Menu / Speed/Load Control section in Chapter 3), you will also find the input field for the "start PID% level". This level is the initial throttle valve position, when during starting; the engine speed exceeds 50 rpm.

The "start ramp rate" is the opening speed of the throttle from the start PID% position, until "engine running" is detected and the throttle valve position is controlled by the speed control. More information can be found in the Start, Idle, and Rated Speed Setpoints and Actuator Output section below.

Electrical Connections EGS-01 and Actuator (or Driver)

The actuator outputs of the EGS-01 are "push/pull" PWM outputs which switch between supply and ground. These outputs can be directly connected to one or more Woodward Flo-Tech actuator/throttle combinations, or one or more ProAct drivers with ProAct actuators. See Figure 4-1.

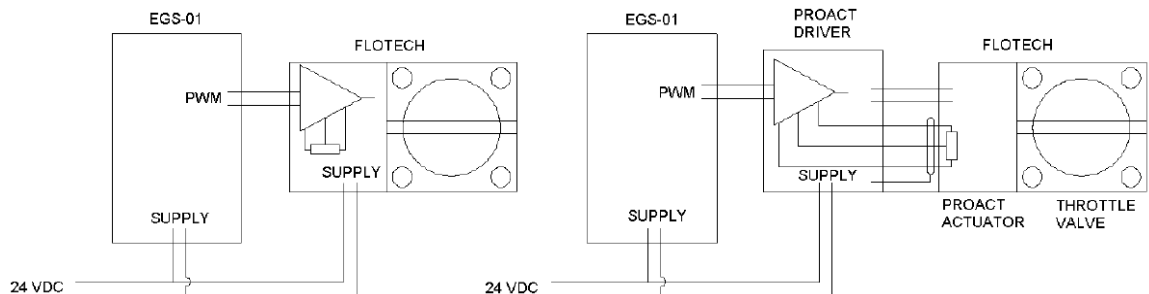


Figure 4-1. EGS-01 Actuator Outputs

For more detailed information please refer to the related actuator manual.

Control Modes

This section describes the following modes:

- "Generator Control Mode" against "Compressor Control Mode"
- "Isochronous" against "Droop Mode"
- "Speed Control Mode" against "Power Control Mode" ("kW-PID").

"Generator Control Mode" against "Compressor Control Mode"

"Generator Control" has to be selected at (more or less) constant speed applications. "Compressor control" has to be selected in variable speed applications (compressor drives).

When selecting "Generator Control" you can control the following applications:

Single generator in island operation	Speed control mode (isochronous or droop)	
Multiple generator sets in island operation	Speed control (with droop for load sharing or isochronous with LSM for load sharing)	
Generator set(s) parallel to the grid	Breaker open	Speed control (for synchronization)
	Breaker closed	Power control ("kW-PID")

Alternatively:

Generator set(s) parallel to the grid	Breaker open	Speed control (for synchronization)
	Breaker closed	Speed control (kW-droop method)

- In island operation (EGS-breaker signal low) and with the synchronization option enabled, the speed setpoint can be adjusted using the "speed bias" input and/or the "raise/lower" inputs.
- In parallel operation and in "kW-PID" mode (circuit breaker closed, EGS-breaker signal high, and kW-PID enabled) the desired power must be set using the "desired power" input and/or the "raise/lower" inputs. The desired load signal is advised to be a 4–20 mA signal.
- The recommended load signal is 4–20 mA. When using a PLC output (4–20 mA signal) for the required load signal, galvanic problems can occur. Make sure the signal is grounded at one side only. It is also possible to install a galvanic isolator 4–20 mA/4–20 mA between the EGS and the device that supplies the desired load signal (make sure that one side is grounded; select this in EGS).
- In parallel operation but in speed control with kW-droop (circuit breaker closed, but EGS breaker signal low) the power can be changed using the "speed bias" input and/or the "raise/lower" inputs.
- With multiple gen-sets in island operation it is also possible to run isochronous and share the load with load-sharing modules. Synchronization can be done by using a separate synchronizer connected to the synchronizer input of the LSM. The output of the LSM is connected to the speed-bias input of the EGS.
- The discrete input of the EGS-01 can only be used once, either for synchronizing or for kW_PID.

All mode selections are under the "Parameters" → "Speed/Load control" → "Control Mode" sub-menu, and all input selections are under the "Parameters→"Sensor" sub-menu. These settings can only be changed when the engine is stopped.

When selecting "Compressor Control mode" it is possible to control the following variable speed applications in island operation:

Table 4-1.

One engine driving one compressor set	Speed control (isochronous or droop)
Multiple engines on one compressor set	Speed control with droop

In compressor mode

- The speed setpoint can be increased from the rated speed setpoint, by the "desired speed input" and/or using the inputs "raise/lower"
- It is not possible to select "synchronization enable" or "KW-PID enable".

All mode selections are under the "Parameters" → "Speed/Load Control" → "Control Mode" sub-menus. This menu cannot be changed when the engine is running. All input selections are under the "Parameters" → "Sensor" sub-menus.

"Isochronous" or "Droop Mode"

The EGS-01 speed control can be used in "isochronous mode" or in "droop mode". For an engine in island operation using "isochronous mode", the engine speed is kept constant at the desired speed setpoint, independent of engine load.

In "droop mode" the engine speed setpoint decreases with increasing engine load. See Figure 4-2 where 5% droop is programmed:

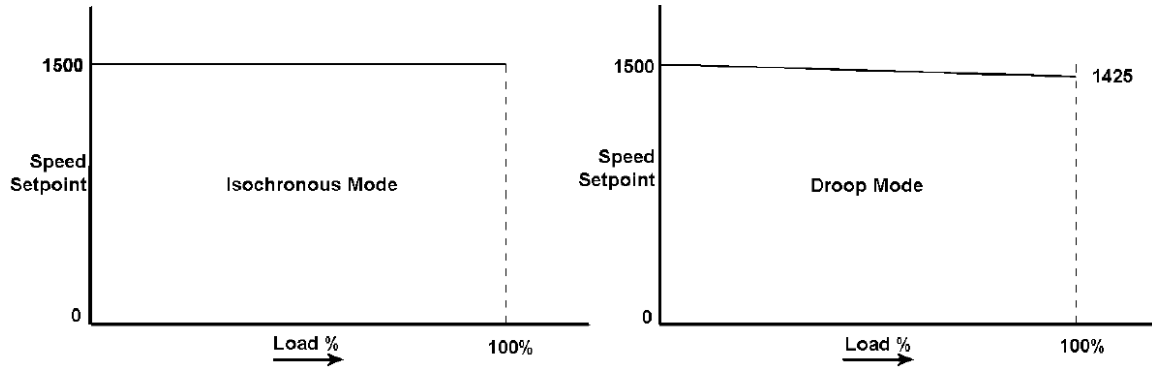


Figure 4-2. Isochronous or Droop Mode

"Droop mode" can be used when multiple engines are coupled in island operation and must share the island load together. As a result, the frequency at full load is slightly lower than at zero load. If you want to keep the frequency constant in this application, you can add a device that will correct the speed setpoint of all engines to get a correct frequency. Alternatively you can run one engine in "isochronous mode" and this engine will then hold the bus frequency at a constant value. The other engines are in droop mode parallel to the isochronous engine. The droop mode can also be used to improve the stability of single island operated gas engines.

In compressor mode the amount of droop is based on "load%", where in generator mode the amount of droop is based on the "measured power" (kW-droop).

IMPORTANT

In "droop mode" the speed setpoint is based on actual engine load and not on actuator angle.

"Speed Control" against "Power Control" ("kW-PID")

When the circuit breaker is closed and the engine runs parallel to the grid, the throttle valve(s) will dictate the produced power. When the breaker input of the EGS-01 is high, the EGS runs in "power control mode". The power control moves the actuator to equal the measured power and the desired power. When the breaker signal is low, the EGS-01 expects the circuit breaker to be open, and that the engine runs in "island operation". In this situation the EGS-01 is in "speed control mode".

Because the EGS-01 Speed and Load Control uses different control dynamics in "Power Control mode" ("kW-PID") than in "Speed Control mode", the "Power Control mode" is preferred to "Speed Control mode" with kW-droop when running parallel to the grid.

Normally, in parallel generator set applications, the speed control is only used for synchronizing to the grid, and if an unexpected speed deviation occurs, such as a sudden opening of the circuit breaker and an erratic or high EGS-breaker signal. In this situation the control will switch back immediately from "kW-PID" to "Speed Control mode". In the event of a speed deviation alarm, this alarm can only be reset when the engine is stopped.

You can enable droop by entering the required desired droop percentage in the "LOAD SETPOINTS" menu.

Control Dynamics

General information about Control Techniques

By assuming that a gas engine is a simple linear first order process, it can be described by the formula:

$$H(s) = 1 / (1 + s \cdot \tau)$$

This means that if, for example, a load step or a fuel step is applied to an engine without speed control, the speed change will follow an exponential curve:

$$\text{Speed}(t) = c * (1 - e^{-t/\tau})$$

The time constant (τ) of a first order system can be found by measuring the time required to give 63% of the expected final output change. This can be understood, because when $t = \tau$, the output is $(1 - e^{-1})$ which equals 0.632.

After $3 * \tau$ the output (speed) is at 95.0% of its final value (see Figure 4-3).

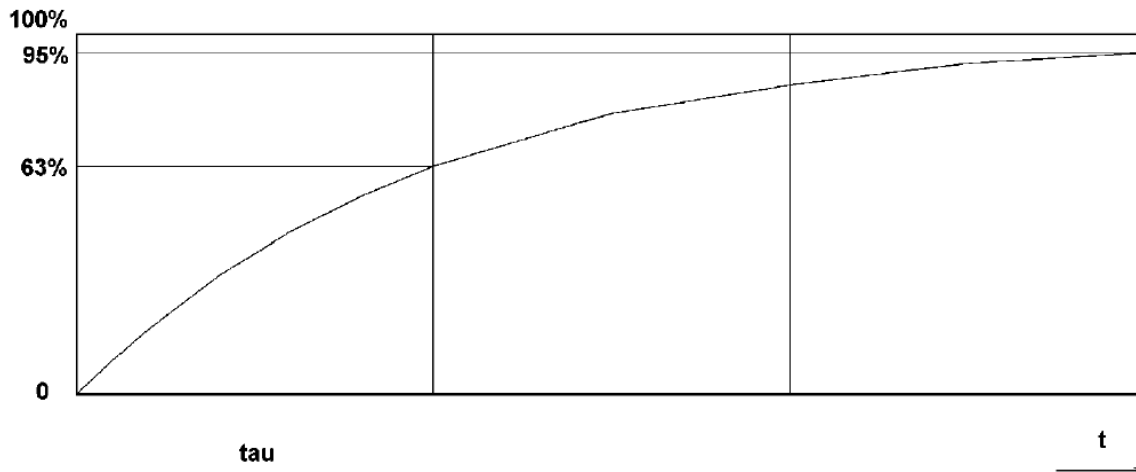


Figure 4-3. Output Speed

If a first order process is being controlled, i.e. if an island-operated engine must be kept at a constant speed even when the load changes, a process controller that compensates for the slowness (τ) of the process using "D-action" is required.

In this situation the speed control controls the amount of power required to maintain a desired engine speed even when the engine load changes.

The EGS-01 uses standard "PID" control techniques in the speed and load control, and as a result the actuator moves:

- Proportional to the speed error, this is called "gain"
- To the Derivative of the speed (speed change) called "stability"; this D-action compensates for the slowness (t) of the engine
- And it will integrate trying to equal the actual speed to the desired speed. (In the EGS-01 the amount of integrator action is fixed versus gain.)

In addition, the speed control compensates the first order slowness (t) of the actuator by putting another "D-action" in the signal to the actuator. This is called actuator "compensation".

As mentioned before, the EGS-01 Speed and Load control incorporates separate control dynamics for "speed control" and separate control dynamics for "power control" or "kW-PID".

The parameters which have to be adjusted are the above-mentioned "gain", "stability" and (actuator) "compensation". Also refer to the Speed Control Dynamics and Power Control Dynamics sections below for more information about speed control dynamics and power control dynamics. The Commissioning section below gives practical tips on the commissioning of the EGS-01 Speed and Load control.

"Linear Dynamics" vs. "Constant Dynamics"

To improve stability the EGS-01 Speed & Load control offers the possibility to use the "Linear Dynamics MAP" option. In this mode the "gain" changes linearly against speed.

When "Linear Dynamics Map" is not selected the "gain" is constant against speed.

Suggested uses:

Compressor drives	Use linear dynamics
Generator drives against the grid	Use constant dynamics
Generator drives in island mode	Use constant dynamics

Field experience

Isochronous generator control in island mode and the average speed is more or less constantly lower than the nominal speed. For example engine rpm 1494-1498 versus 1498-1502 and nominal speed setpoint = 1500, no droop. You are probably running in linear dynamics. Switching the system to constant dynamics will bring the average engine speed back up to nominal speed.

Switching between constant dynamics and linear dynamics can be done only when the engine is stopped. It can be found under "Parameters" → "Speed/Load Control" → "Control mode" menu.

Speed Control Dynamics

Under the "Parameters" → "Speed/Load Control" → "Speed Dynamics" menu, you will find the input screens for "gain", "stability" and (actuator) "compensation" as mentioned before.

There is no linear relation between the throttle angle and the actual engine load on most turbocharged gas engines. As a result there is no relation between the "engine slowness" or (t) and the actuator position, and that is why it is recommended that the "gain versus load%" table is used instead of the "gain versus PID%" table. The table that is not used should have its values set at 1.000 since both tables are multiplied.

The gain versus PID% table is exactly the same as that used in the ProAct speed control.

The "stability" is the D-action that compensates for the time constant (t) of the engine, and the "compensation" is the D-action that compensates for the time constant (t) of the actuator. The actual or guessed time constants for the engine and the actuator can be filled in at "stability" and at actuator "compensation". The "gain" and the "stability" are the two major parameters necessary to tune to obtain a stable engine speed.

Furthermore you will find a speed "window" and a "gain ratio". Outside this speed "window" the gain will be multiplied by the gain ratio, which improves reaction on heavy load steps or quick unloading of the engine. The "gain" outside the window should not be so large that the engine becomes un-stable and stays outside the speed window continuously.

Remarks:

- The "compensation" and "stability" should be tuned at full load, with correct A/F ratio.
- Part load performance should be tuned afterwards using the "gain vs. load%" table. Also, the A/F ratio must be in limits.
- Without any stability an engine will not become stable.

See also the Before Starting, Set Speed Dynamics section below.

Power Control Dynamics

Under "Parameters" → "Speed/Load Control" → "Power Dynamics" the desired "gain versus power" for engines running parallel to the grid in "kW-PID" can be entered. See the Before Starting, Set Power Dynamics section below for practical default settings.

Furthermore the desired load change [kW/s] can be limited under "Parameters" → "Sensors" → "Desired Power".

IMPORTANT

In power control do not make the gain too low or slow load ramping can occur, and load steps can cause an overspeed. See also the Before Starting, Set Power Dynamics section below.

Start, Idle, and Rated Speed Setpoints and Actuator Output

When engine speed is less than 50 rpm, the engine status is "stopped" and the actuator(s) are closed. From 50 rpm up to the programmable "Engine Running Speed" the EGS-01 is in the status "starting". In this status the throttle valve(s) open from the programmed "Start PID Level" (e.g. 15%) following a programmable "Start ramp rate" (e.g. 5%/s) until the "Engine Running speed" is reached (this can be found under "Parameters" → "Speed/Load Control" → "Speed setpoints"). Normal value is 400 rpm. At that speed the control starts to control the engine.

After the engine has started it runs at the programmable "idle speed", during the programmable "idle time". After the "idle time" has elapsed, the setpoint of the speed control rises within the "idle/rated" time to "rated speed" (see Figure 4-4).

If the idle input is enabled and activated, the engine stays at idle speed.

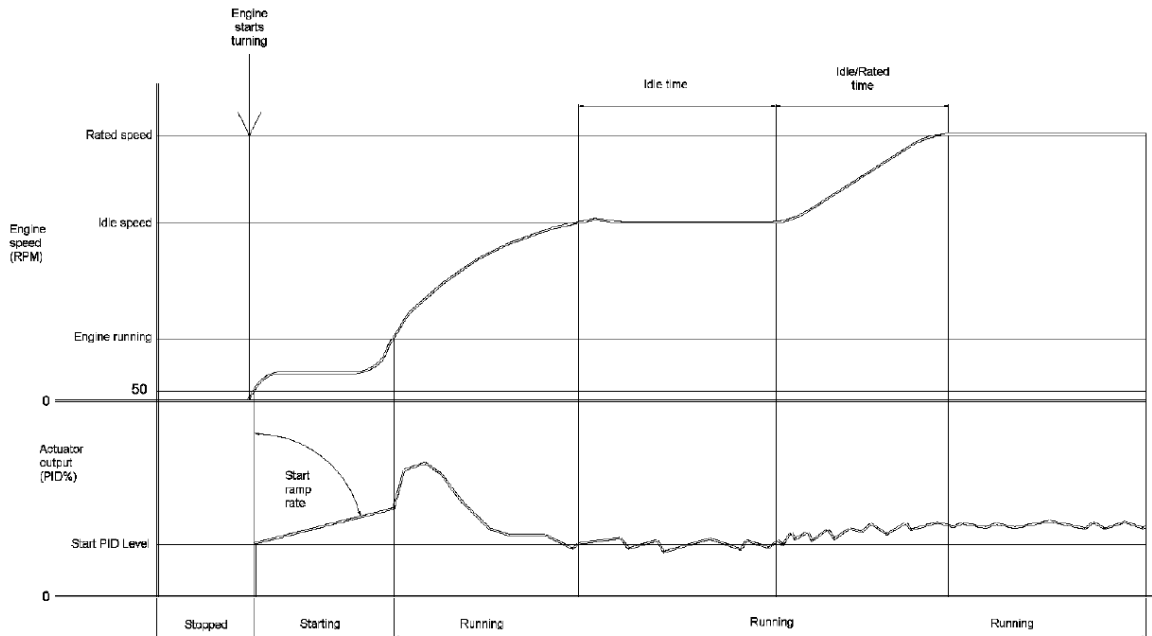


Figure 4-4. Start, Idle and Rated Speed Control

Compressor Mode, Torque Limiter/Load Setpoints

With some compressor applications, where the torque exceeds the maximum allowable torque at high speeds, the torque of the engine can be limited by adjusting the maximum throttle angle versus load% in the "Load Setpoints" sub-menu. The throttle will close to a programmed angle if the torque reaches this limit, and the decreasing speed limits the engine torque. The engine will stabilize at its maximum torque limit.

Overspeed Handling



WARNING

Never use the overspeed protection for the EGS-01 as the only overspeed protection of an engine.

The maximum engine speed must be set in the "protection, overspeed" menu. We advise that maximum engine speed is set just below the setpoint of the external overspeed protection device.

Every overspeed can be seen in the engine alarm status menu.

As soon as this maximum speed is reached, the TecJet gas valve and the mixture throttles close immediately and stay closed until the speed has fallen to 50% of the overspeed rpm. After a programmable number of overspeeds within 1 minute, the alarm relay switches. If "stop engine on alarm" is enabled the EGS stops the engine by closing the TecJet and throttles.

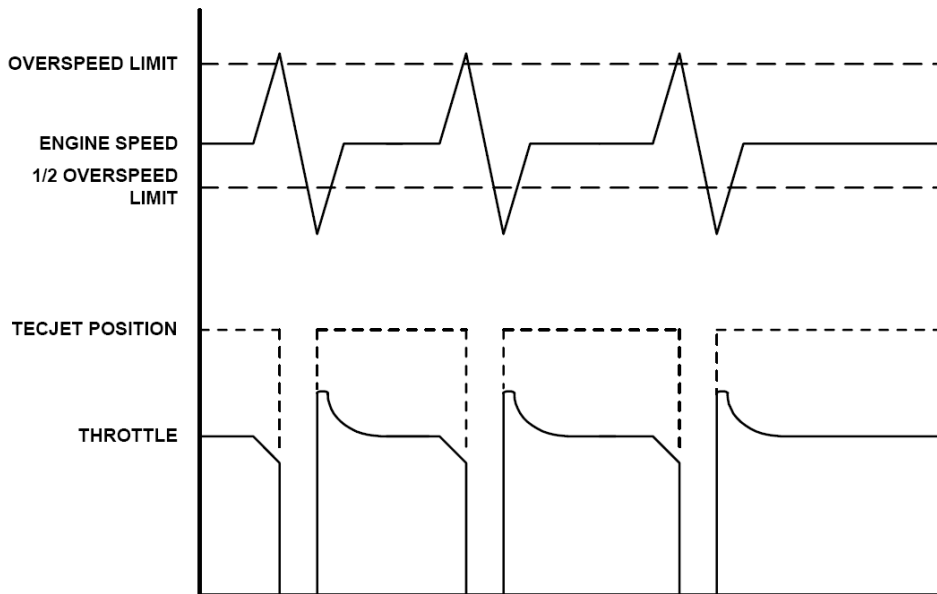


Figure 4-5. Overspeed Handling

Commissioning of the EGS-01 Speed and Load Control

Before Starting, Select Control Mode

Select the correct control modes and the control options in the "Parameters" → "Speed/Load Control" → "Control Mode" sub-menu.

The droop input screen can be found in the "Parameters" → "Speed/Load Control" → "Load Setpoints" sub-menu. If droop is used, a default value for the droop can be between 3 and 5%. See the Control Modes section earlier in this chapter for more information.

Before Starting, Select and Check All Inputs

Select the correct "desired power" sensor/input configuration in the "Parameters" → "Sensor" → "Desired Power" menu. Note that the desired load change can be limited by setting the ramp limit, e.g. to 180 [kW/s].

For applications with synchronizers select the correct "speed bias" sensor/input configuration in the "Parameters" → "Sensor" → "Speed Bias" menu. The speed bias will always be added to the rated speed; for example 0–10 Vdc will give –25 [rpm] and +25 [rpm]. If discrete inputs are used, the raise and lower limits can be set, for example, at +25 [rpm] and –25 [rpm] and the raise and lower rate at, for example, 3 [rpm/s].

Select the correct "desired speed" sensor/input configuration for compressor applications, in "Parameters" → "Sensor" → "Desired Speed". The desired speed will always be added to the rated speed; for example 0–10 Vdc will give 0–500 [rpm] on top of the rated speed. The rated speed can be found under "Parameters" → "Speed/Load Control" → "speed setpoints".

Check the correct functioning of all inputs under the "View" → "Measured Values" menu, especially signals like the breaker signal and measured and desired load signals.

The "idle input" is an analog input (on terminal 73) which can be configured as a 0–10 Vdc or 0–20 mA input. If you want to use a 24 Vdc logical signal, configure this input as a mA input, and use an external 10k series resistor to make a 2.4 mA signal.

Before Starting, Set Speed, Throttle, and Duty Cycle Setpoints

Fill in all parameters in the "Parameters" → "Speed/Load Control" → "Speed Setpoints" sub-menu. See the Start, Idle, and Rated Speed Setpoints and Actuator Output section above.

Suggested settings:

Idle speed setpoint	1000–1200 rpm
Idle time	3 s
Rated speed setpoint	1500–1800 rpm
Idle/Rated time	3 s
Engine running speed	350–400 rpm

Fill in the applicable parameters under the "Parameters" → "Speed/Load Control" → "Throttle Setpoints" sub-menu. See also the Throttle Linearization and Calibration section above and the actuator or driver manual.

Suggested settings:

Start PID level	10%
Start ramp rate	5%/s
Actuator 1, 2 and 3	linear PID% to angle table/map

If a waste-gate is connected to the EGS-01, you probably want the waste-gate to be open at low load, and to start closing when the mixture throttle valves are fully open, until the desired speed or power is reached. In that case you have to fill in the "Throttle Setpoint" as shown in Figure 4-6.

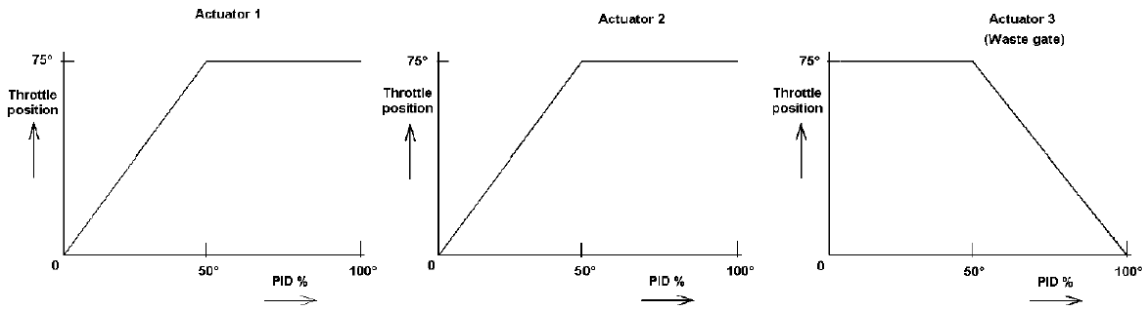


Figure 4-6. Throttle Setpoint

Enter the parameters under the "Parameters" → "Speed/Load Control" → "Duty Cycle" sub-menu to match the PWM value to the throttle angle. "Test Mode" can be used to check and calibrate the throttle(s). See also the Throttle Linearization and Calibration section above.

WARNING

Do not use test mode when running the engine.

Commonly used settings for actuators 1, 2 and 3 (depending on the actuator) are 0–75 [°], giving 10–90 [%] duty cycle.

Before Starting, Set Speed Dynamics

Enter the applicable parameters under the "Parameters" → "Speed/Load Control" → "Speed Dynamics" sub-menu.

Practical default (start) settings are:

Load vs Gain	
20	1.000
* 40	1.000
60	1.000
80	1.000
100	1.000

PID% vs Gain	
20	0.020
40	0.020
* 60	0.020
80	0.020
100	0.020

Stability	1.80
Compensation	0.25
Gain ratio	1.0
Window	50

Or:

Load vs Gain	
20	1.000
40	1.000
60	1.000
80	1.000
100	1.000

PID% vs Gain	
20	0.020
40	0.020
60	0.020
80	0.020
100	0.020

Stability	4.0
Compensation	0.11
Gain ratio	1.0
Window	50



* EXAMPLE

When the PID% = 60 and engine load = 40% the gains of both tables are multiplied. So in this example the total gain is $0.020 \times 1.000 = 0.020$, thus the gain stays 0.020. This gives the extra option to make the gain also dependant on engine load.

It is also possible to use only gain vs load. Give all the gains vs PID values a value of 1.000, and program the desired gains depending on engine load in the Gain vs Load table.

Typical settings for load vs. gain are:

Load vs Gain	
20	1.000
40	1.000
60	1.000
80	1.000
100	1.000

PID% vs Gain	
20	0.010
40	0.020
60	0.020
80	0.022
100	0.022

Stability	1.8
Compensation	0.10
Gain ratio	1.5
Window	40

The (actuator) "compensation" is "D-action" to compensate for the (first order) response or inertia of the actuator. This value has to be programmed once, using information of the specific actuator. Alternatively, the actuator response can be measured when the engine is not running by connecting the position feedback signal to a chart recorder or a spare analog input of the EGS-01 and using the data-logging function. Then put a step, for example from 5° to 70° , on the desired actuator position using Test Mode. Measure the time taken to get 63% of the final position; this is the time to enter at "compensation".

Before Starting, Set Power Dynamics

Fill in the applicable parameters under the "Parameters" → "Speed/Load Control" → "Power Dynamics" sub-menu. Practical default settings are:

Power *	Gain
200	0.1100
400	0.1200
600	0.1200
800	0.1400
1000	0.1600

Compensation	0.25
Stability	1.15

* kW figures given are for example only. Use your own engine kW outputs.

Take note of the following points:

- In power control the gains are much higher than in speed control.
- If the gain is too small slow load ramping and overspeed on a loadstep can occur.
- Make sure that maximum desired power is entered correctly in "Parameters" → "Sensor" → "Measured Power".
- The filtering time of the measured power signal can have affect the stability of the engine load control. A default value of between 0.05 and 0.2 second is advised.
- Also enter the filtering time for the measured power under "Parameters" → "Sensor" → "Measured Power".

Safety Checks before Starting

Before starting the engine make sure of the following:

- The "Test Mode" option of the EGS-01 must be switched off.
- All emergency stop buttons must function correctly.
- Check that the main engine overspeed protection is set correctly and that the EGS overspeed limit is set 50–100 rpm below the main overspeed limit.
- The EGS overload protection must be set to stop the engine if an overload condition occurs.
- Check that the throttle valves and/or linkages are calibrated correctly, and can move freely (move actuators through full stroke).
- Check that the desired lambda and volumetric efficiency tables are correctly filled-in.
- Check that the gas composition, the displacement and the number of teeth, etc., are correctly filled in. See also Chapter 6 'Commissioning' for more detailed information about commissioning.
- The transient part of the EGS-01 gas flow calculation, under sub-menu "Parameters" → "Transient" → "Delta Map" must be correctly filled-in. If the manifold volume is unknown use engine displacement as an approximate value. A proven value to use as the number of samples is 7. See also the Parameters / Transient / Delta MAP section in Chapter 6.

IMPORTANT

You can limit the maximum throttle angle to a maximum value for the first starting by completing the table in the "Parameters" → "Speed/Load Control" → "Throttle Setpoints" sub-menu using, for example these settings:

PID [%]	0	4	8	20	40	60	80	100
Throttle pos. [°]	0	3	6	15	30	30	30	30

After obtaining stable operation, re-adjust the "Throttle Setpoints" to the desired values, as described in the Before Starting, Setspeed, Throttle, and Duty Cycle Setpoints section above.

First Time Starting

The engine can now be started for the first time. If the gas line upstream of the TecJet and gas valves have been purged the first attempt should be successful.

If the A/F-ratio is incorrect the speed control will have difficulty stabilizing the engine. If the A/F-ratio is almost correct it should be easy to stabilize the engine at zero load by making small adjustments to the gain. Use the "dashboard function" when tuning the speed & load control.

Tuning the Speed Control

All parameters concerning speed control dynamics are in the "Parameters" → "Speed / Load control" → "Speed dynamics" sub-menu.

IMPORTANT

Plotting both the engine speed and the actuator position on a chart recorder (or using the data logging function of the EGS then using, for example, a spread sheet to create a graph) can be very useful when solving stability problems.

It should only be necessary to program the actuator "compensation" value once, using information of the specific actuator. A value between 0.1 and 0.3 [s] is normal (see the Before Starting, Set Speed Dynamics section above).

A "gain" value to start with is 0.01 at all loads. Practical gain values will be between just less than 0.01 and 0.03. Start tuning the speed control with "gain ratio = 1.00" so the gain is not outside the programmed window (see the Before Starting, Set Speed Dynamics section above).

The "stability" is a programmable D-action to compensate for the time constant or inertia of the engine and turbos. Normal values will be between 1–5 [s] where 1 [s] is low D-action and 5 [s] is high D-action (see the Before Starting, Set Speed Dynamics section above).

The "gain" and "stability" should be tuned with the engine running at full load, with the correct A/F-ratio or correct exhaust-gas emission:

- Slow hunting can be caused by insufficient stability, and/or too much gain
- Very quick actuator movement is often caused by too much stability

You can use a step speed change to assess the step response and stability of the system by changing the rated speed in the "Speed Setpoints" sub-menu from, for example, 1475 to 1525. You also can use load steps at constant speed to assess the response and stability of the system.

After the full load condition is satisfactory tuned, the part load performance should be tuned by only changing the "gain" value at part load conditions.

To improve the engine performance during large load changes, you can increase the gain during these load steps using the "gain ratio". The gain is multiplied by the "gain ratio" as long as the engine speed is outside the (speed) window. A practical "gain ratio" setting is between 1.5 and 2, and a practical "window" width is 40 [rpm]. Make sure that the engine is stable with this higher gain value to prevent the engine hunting outside the "window".

Speed and Load Control Troubleshooting

This section is for troubleshooting the speed and load control function of the EGS-01. For troubleshooting of other EGS-01 functions, see Chapter 8.

Engine is unstable in speed or kW-PID control mode

Problem	Action
Incorrect A/F-parameters or incorrect speed and load control parameters	Compare parameters of A/F-control and EGS-01 speed and load control with values from commissioning and correct if necessary.
Faulty ignition system	Check coils, extenders, spark plugs, HT-leads, wiring, timing, etc.
Faulty engine	Check the whole engine, including compression, turbos, leakage's etc.
Faulty speed MPU signal	Check speed MPU and MPU wiring and compare voltage with value from commissioning.
Faulty actuator or excess free play in linkage	Check actuators and linkages using "Test Mode" (Makes sure the engine is stopped)
Filtering time of measured power is too small or too high	Normal values = 0.01–0.2 s. (Set in "Parameters" → "Sensor" → "Measured power".)

Engine continuously in overspeed

Problem	Action
Incorrect A/F-parameters or incorrect speed and load control parameters	Compare parameters of A/F-control and EGS-01 speed and load control with values from commissioning and correct if necessary.
Actuator or throttle valve is stuck in (fully) open position	Replace throttle valve and/or actuator.
Throttle valve movement is heavy or restricted	Service or replace the throttle valve.
Actuator does not operate the (correctly functioning) throttle valve	Check actuator (and driver) and wiring, and replace if necessary.

Engine does not start

Problem	Action
Incorrect A/F-parameters or incorrect speed and load control parameters	Compare parameters of A/F-control and EGS-01 speed and load control with values from commissioning and correct if necessary.
Throttle(s) will not go to the starting position	Check speed signal and check if the EGS-01 reaches the "starting" condition. Check actuator(s), driver(s), wiring and supply.
Throttle(s) O.K. but no or incorrect gas flow	See the Engine Will Not Start section in Chapter 8.

Chapter 5.

EGS Control Description of Operation

Introduction

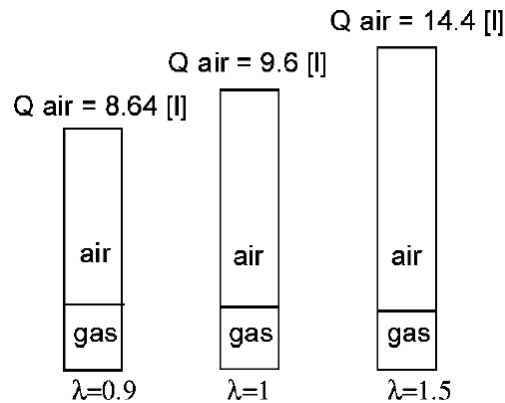
This chapter gives an overview of the functions which are possible with your EGS-01 control:

- For Speed and Load Control, see Chapter 4.
- For the Air Fuel Ratio part, see Chapter 5.
- For the FireFly part, see Chapter 9.
- For the PASTOR part, see Chapter 8.
- For the Ignition Timing Control, see Chapter 5.

Air Fuel Ratio

A/F Ratio can be expressed as Lambda (λ) or in Phi (Φ). In this manual and in the monitor and calibration software Woodward only uses the expression Lambda. Lambda is the air excess factor: air flow / stoichiometric air flow.

Stoichiometric combustion means that the quantity of air in the air/gas mixture is sufficient to get a complete combustion of the quantity of gas. This ratio is called lambda =1 ($\lambda =1$) ($\lambda =1/\Phi$). The stoichiometric ratio of a gas is expressed as λ_{st} . The example shows a gas quality where 9.6 liters of air are required to combust 1 liter of gas.



To accurately calculate the gas flow to the engine to get the desired lambda at a certain load and speed condition of the engine, the speed/density calculation method is used. The mixture flow to the engine is calculated using the following formula:

$$Q_{mix} = \frac{n * V * V_e * MAP * T_n}{2 * 60 * P_n * MAT} \quad [l/s]$$

where:

- n = engine speed (1/min.)
- V = engine displacement (liters)
- V_e = Volumetric Efficiency.
- MAP = Manifold Absolute Pressure (kPa)
- T_n = 273 °K (normalized temperature)
- P_n = 101.3 kPa (normalized pressure)
- MAT = Manifold Air (or mixture) Temperature (°K)

When you have calculated the mixture flow, then the gas flow can be calculated with the following formula:

$$\begin{aligned} Q_{\text{mix}} &= Q_{\text{gas}} + Q_{\text{air}} \\ Q_{\text{mix}} &= Q_{\text{gas}} + (Q_{\text{gas}} * \lambda_{\text{st}} * \lambda_{\text{des}}) \\ Q_{\text{mix}} &= Q_{\text{gas}} * (1 + \lambda_{\text{st}} * \lambda_{\text{des}}) \end{aligned}$$

$$Q_{\text{gas}} = \frac{Q_{\text{mix}}}{(1 + \lambda_{\text{st}} * \lambda_{\text{des}})}$$

On V-engines with two butterfly valves you can calculate the mixture and gas flow for each cylinder bank. This is called "stereo". The EGS-01 system then controls two TecJet gas control valves independently.

Control Characteristics

The algorithms used in the EGS-01 control are designed specially for reciprocating gas engine applications. Similar to what happened in the automotive industry, carburetors on engines are replaced more and more by more flexible and more accurate fuel injection systems. To drive an injector on a gasoline fuel engine, an engine-management system is required. To drive a TecJet, the low gas-pressure injection valve developed by Woodward, the EGS-01 is the engine management system.

In the control 3-dimensional maps can be filled to achieve the ideal fuel flow to the engine under different conditions. The whole power range of gas engines can be covered because the only variable component is the TecJet.

Variables such as engine displacement, gas composition or volumetric efficiency, and control modes like stoichiometric, lean burn, closed loop or open loop simply can be programmed using software.

The EGS-01 control is also capable of compensating for variable gas heat values, and switching between fuels is possible without changing the hardware.

Sensors to measure engine speed, manifold pressure, manifold mixture temperature are vital in this system however, and the principles of these sensors are simple and proven to be reliable. For maximum reliability Woodward has designed two inputs for MAP sensors. Also in compressor applications the optimum settings can be made for all speeds. Additional features such as over-temperature protection, over-fuelling protection, crankshaft angular speed monitor (PASTOR), and knock detection via the FireFly, are available in the EGS.

Automatic Volumetric Efficiency Determination

Together with engine speed, the MAP and the MAT, the engine volumetric efficiency plays a key role in the mixture flow calculation.

Most engine manufacturers know the volumetric efficiency (V_e) of their engines. If not, you have to fill them out in the field by yourself. For this the EGS-01 control has a feature to fill the V_e maps automatically. Based on a known gas quality and stoichiometric ratio of that gas, on the measured lambda in the exhaust of the engine and based on the gas flow through the TecJet, the EGS-01 control can calculate the airflow and thus the mixture flow.

Using the calculated mixture flow at a known cylinder displacement, the speed, the MAP and MAT, the actual V_e is calculated and stored in the 3-dimensional map. This map has manifold pressure and engine speed as X and Y-axes.

$$Q_{\text{mix_measured}} = Q_{\text{gas_measured}} * (1 + \lambda_{\text{st}} * \lambda_{\text{measured}})$$

$$Q_{\text{mix_calculated}} = \frac{n * V * V_e * \text{MAP} * T_n}{2 * 60 * P_n * \text{MAT}}$$

$$V_e = \frac{Q_{\text{gas_measured}} * (1 + \lambda_{\text{st}} * \lambda_{\text{measured}}) * 2 * 60 * P_n * \text{MAT}}{n * V * \text{MAP} * T_n}$$

Automatic Generator Set Efficiency Determination

Normally the electrical power that an engine/generator combination supplies to the grid or to a plant is measured by sensors. Also, the power that goes into the engine can be determined by multiplying the gas flow that flows through the TecJet with the heat value of the gas.

The efficiency is stored by the EGS-01 control in a three-dimensional map, with ignition timing and load as the x and y-axes.

Ignition Timing Control

The EGS-01 does not control the ignition timing, although the EGS-01 should always be informed if ignition timing is changed, in order to keep the NOx at the correct value when using the "GQCL" algorithm. The ignition timing can be changed by using, for example, a knock detection and controlling system such as the Woodward FireFly (see Chapter 10).

The following "knock controlling" systems can be implemented:

Retarding the Ignition

The Woodward "FireFly" system is used to detect knocking combustion, and to retard the ignition using its mA output or the RS-422 communication line, which is connected to the ignition system. The amount of retarding controlled by the FireFly is transmitted to the EGS-01 by CAN so the correct total efficiency values are selected from the "Total Efficiency" map used by the "GQCL" algorithm. This method keeps the NOx level constantly low, even when the ignition is retarded.

GQCL control without ignition retarding information brings the NOx back to almost the same level as just before the retarding.

Load Reduction

In addition to retarding the ignition, the FireFly can reduce engine load to cure the detonation. If the EGS-01 is controlling the load, the FireFly will force a certain amount of load reduction (this can be programmed in the FireFly) through the CAN communication. If the EGS-01 does not control the load, the FireFly can force the "upper control system" to reduce the load through the RS-422 line of the FireFly or an mA-output.

It is only possible to use the mA-output of the FireFly once for either:

- Load reduction (for non-Woodward load control)
- Ignition retarding

For example, the FireFly in combination with EGS and load control can have both options (ignition retarding and load reduction) where the mA output of the FireFly can be connected to the ignition system, and can retard the timing. If this is not sufficient the FireFly will request the EGS by CAN to lower the engine load.

If a non-Woodward device is used for detecting detonation and controlling the ignition timing of the engine, the timing value should be transferred to the EGS-01 through the plant communication in order to keep the NOx on a constant level if the ignition is retarded.

There are no other parameters to set except enabling the FireFly under the "Protection" → "FireFly" sub-menu, and, if necessary, enabling the "desired timing input" in the "Parameters" → "Plant Communication" sub-menu.

IMPORTANT

Please note that "Protocol 98" should be enabled when connecting a FireFly to the EGS-01 by CAN.

Chapter 6. Commissioning

General

To start commissioning you have to make a communication link between the EGS-01 control and the PC in accordance with the Cable Connection section of Chapter 3. We recommend, if possible, to re-use a parameter file of the same engine type, running with the same fuel and operated in the same control mode. Even if the application is a 100% copy of an earlier application the settings should be checked before cranking the engine.

Set-up before Starting the Engine

Before you start the engine, check all the parameters in this section.

IMPORTANT

Variables between square brackets [...] are only used for information and are not used in calculations.

Parameters / Engine / Engine

Parameter	Value	Unit
[Make]		
[License holder]		
[Compression ratio]	11	
[Number of cylinders]	16	
[Aspiration]	TurboCharged	
[Max. torque]	6300	(Nm)
[at]	1500	(rpm)
Engine displacement-total	56.00	(l)
-bank_1	56.00	(l)
-bank_2	0.00	(l)
Max. speed	1500	(rpm)
Max. power output	1000	(kW)
Max. MAP	225	(kPa)
Ignition timing	12	(°)

Engine displacement	For this mono control application only the total engine displacement has to be entered.
Max. Speed	Used for scaling internal load%. This value is the maximum rated speed and is not used for overspeed.
Max. Power output	Is used for scaling internal load%.
Max. MAP	This value equals 100% MAP (used in various tables).
Ignition timing	This is the basic ignition timing used to calculate the actual timing which is used in the "Total Efficiency" table.

Parameters / Engine / Volumetric Efficiency

Parameters / Engine / Volumetric Efficiency / Axes

Continue the commissioning procedure by checking and/or changing the Volumetric-efficiency (V_e) parameters. At first the scaling of the axes must be adjusted. For an optimal resolution it is better to fill the axes close to the reality. It does not make sense to scale the rpm axes up to 3500 rpm when the engine will be operated at 1500 rpm. Introducing 1450, 1500, and 1550 rpm are more logical engine speeds. Also it is better to fill out the MAP table up to 110% MAP. During overload situations or at a too lean setting of the lambda, the MAP can be higher than the MAP at rated power and the correct lambda.

[] = VOLUMETRICAL EFFICIENCY AXIS

n (rpm)	MAP (%)
0	10
250	20
500	30
750	40
1000	50
1100	60
1200	70
1300	80
1400	90
1450	100
1500	110
1550	
1600	
1700	
1800	

OK Cancel

Parameters / Engine / Volumetric Efficiency / Learn

In this window, the Learn vol. eff.-mode check box must be set. The settings for the parameters in this field and the instructions on how to apply the automatic table filling mode are explained in the Parameters/Engine/Volumetric Efficiency/Edit Table section below.

[] VOLUMETRICAL EFFICIENCY LEARN

Learn vol. eff.

Kp	0.100	()
Corr. Tint	20	(s)
CorrLimit	10	(%)
VeffTint	60	(s)

OK Cancel

Parameters / Engine / Volumetric Efficiency / Edit Table

Click the "Edit Table" button to open the Ve table. As a default, Ve value 0.80 can be used. The table can be left as it is when an earlier engine calibration is applied. Because in a later stage of the calibration the values in the table will be automatically optimized by the learn feature of the EGS control, it makes no sense to put too much effort in collecting the correct values.

VOLUMETRICAL EFFICIENCY TABLE BANK_1

n / MAP%	10	20	30	40	50	60	70	80	90
0	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900
250	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900
500	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900
750	0.805	0.870	0.851	0.874	0.894	0.928	0.938	0.940	0.946
1000	0.805	0.870	0.851	0.874	0.894	0.928	0.938	0.940	0.946
1100	0.805	0.870	0.851	0.874	0.894	0.928	0.938	0.940	0.946
1200	0.805	0.870	0.851	0.874	0.894	0.928	0.938	0.940	0.946
1300	0.805	0.870	0.851	0.874	0.894	0.928	0.938	0.940	0.946
1400	0.790	0.870	0.870	0.875	0.880	0.888	0.894	0.920	0.924
1450	0.790	0.850	0.870	0.875	0.880	0.888	0.894	0.897	0.901
1500	0.790	0.850	0.870	0.875	0.880	0.888	0.894	0.897	0.901
1550	0.790	0.850	0.870	0.875	0.880	0.888	0.894	0.897	0.901
1600	0.790	0.850	0.870	0.875	0.880	0.888	0.894	0.897	0.901
1700	0.805	0.850	0.870	0.875	0.880	0.888	0.898	0.897	0.901
1800	0.805	0.850	0.870	0.875	0.880	0.888	0.898	0.897	0.901

OK Cancel Dashboard...

Parameters / Engine / Total Efficiency

Parameters / Engine / Total Efficiency / Axes

Check or change the y-axes in the Total Efficiency Axes table. The ignition advance timing can be changed as required. In this table it is also better to scale the x-axes to 110% load.

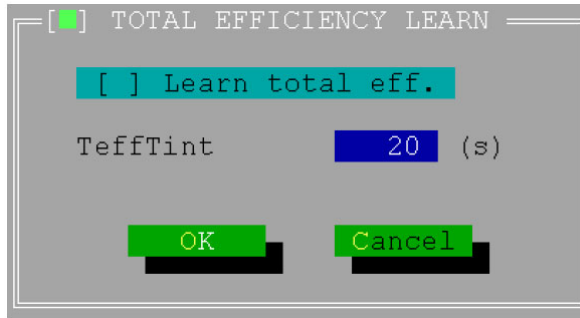
TOTAL EFFICIENCY AXIS

Ign. Time	Load (%)	Filter (s)
12.0	10	0.497
15.0	20	
20.0	30	
25.0	40	
30.0	50	
	60	
	70	
	80	
	90	
	100	
	110	

OK Cancel

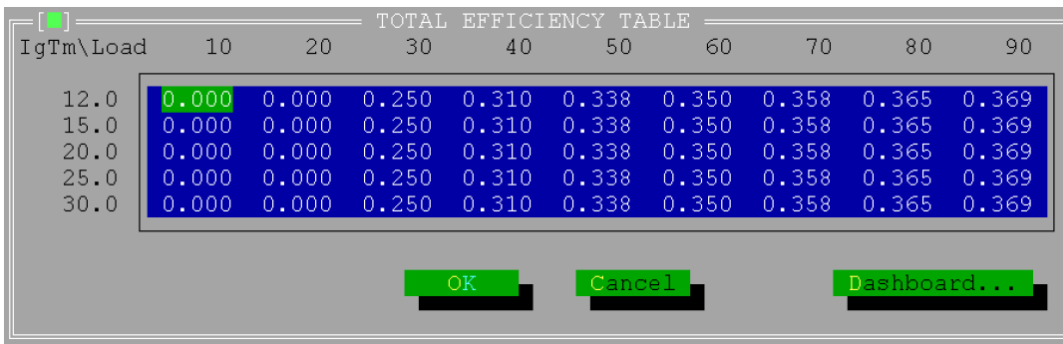
Parameters / Engine / Total Efficiency / Learn

The Learn Total. Eff.-mode must be disabled in this window. The settings for the parameters in this field and the instructions how to apply the automatic table filling mode are explained in the Parameters/Engine/Volumetric Efficiency/Edit Table section below.



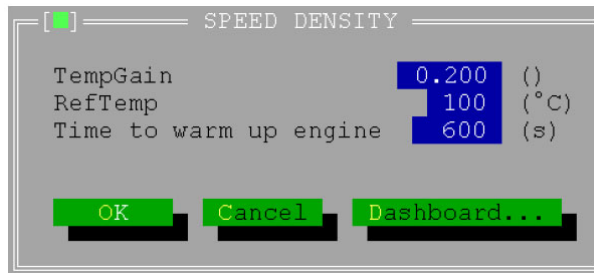
Parameters / Engine / Total Efficiency / Edit Table

The default values in the Total Efficiency Table do not affect the engine performance in the start-up stage. The value will be used to calculate the generator set power. A default value of 0.0 at no load and increasing to 0.35 at full load will be sufficient for system set-up.



Parameters / Engine / Speed Density

In particular during the warming up of a cold engine, but also in normal operating conditions of the engine, there are differences between the manifold mixture temperature (the measured MAT) and the actual mixture temperature as it enters the cylinders (the Inlet Temp). This is caused by engine parts that have a coolant temperature-related surface temperature, such as the ports of the cylinder head. The EGS-01 control compensates for the effect of heated-up or cooled-down mixture by calculating the Inlet Temp using a model. No extra engine temperature sensors are required for this calculation.



Parameters / Fuel System

Choose for single TecJet mode if there is one TecJet per gas flow calculation.
Choose for dual TecJet mode if there are two TecJets per gas flow calculation.

```

[MIXING UNIT & TECJET]

[Mixing Unit] 72450002
[Throat] 116.0 (mm)
[Profile type] Cross
[Profile dimension] 16 (mm)
[Number of metering holes] 36
[Diameter of metering holes] 4.7 (mm)
[Venturi location] UpStream
[Throttle valve] 120
[Tecjet type] 50

Dual tecjet [ ] enable

OK Cancel
  
```

Parameters / Fuel Parameters

Enter the gas type (natural, digester, propane, etc.).

Check the box if there is a signal from a CH₄-analyser connected to the EGS control.

Enter the gas data, or enter the gas data of two gas qualities if "Measure CH₄" was enabled. In this mode the EGS control will interpolate between the two stored gas qualities dependent on the measured CH₄ value.

```

[FUEL PARAMETERS]

[Gas] landfill

[X] Measure CH4

Density 0.80 (kg/m3) @ p_n, T_n
Lower heat value 32.60 (MJ/m3) @ p_n, T_n
Lambda stoichiometric 8.40

CH4 percentage 40.00 50.00 (%)
Density 1.47 1.34 (kg/m3) @ p_n, T_n
Lower heat value 14.32 18.08 (MJ/m3) @ p_n, T_n
Lambda stoichiometric 3.81 4.76 @ p_n, T_n

OK Cancel Dashboard...
  
```

Parameters / Air-Fuel Ratio

Parameters / Air/Fuel Ratio / Ref / Axis

Enter or modify the rpm (y) and the Load (x) axes and confirm the values by clicking the OK button. The filter value is used to improve the transient response. If the value is too high the fuel mixture can become too rich, which can cause damage to the engine.

n (rpm)	Load (%)	Filter (s)
0	10	0.407
250	20	
500	30	
750	40	
1000	50	
1100	60	
1200	70	
1300	80	
1400	90	
1450	100	
1500	110	
1550		
1600		
1700		
1800		

Parameters / Air/Fuel Ratio / Edit Table

Use an earlier completed table from a similar engine or modify the table by entering values according to the engine manufacturer's specifications.

NOTICE

You will damage the engine using stoichiometric settings on a lean burn engine.

For the quick completion of the table the Alt-A-F-M-X and Y features also apply in this window.

During initial system start-up it might be possible that the speed control does not match the engine. In practice the correct lambda values can only be filled out when accurate analyzers for NOX, CO and CO are connected to the engine.

LAMBDA REF TABLE BANK_1

n\Load	10	20	30	40	50	60	70	80	90
0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
250	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
500	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
750	1.092	1.092	1.093	1.093	1.093	1.093	1.093	1.093	1.093
1000	1.112	1.112	1.112	1.112	1.112	1.112	1.112	1.112	1.112
1100	1.112	1.142	1.142	1.142	1.142	1.142	1.142	1.142	1.142
1200	1.112	1.192	1.192	1.192	1.192	1.192	1.192	1.192	1.192
1300	1.112	1.192	1.202	1.290	1.316	1.316	1.316	1.336	1.367
1400	1.112	1.221	1.261	1.360	1.367	1.367	1.418	1.438	1.470
1450	1.112	1.261	1.370	1.440	1.490	1.544	1.567	1.586	1.598
1500	1.112	1.261	1.370	1.440	1.490	1.544	1.567	1.586	1.598
1550	1.112	1.261	1.370	1.440	1.490	1.544	1.567	1.586	1.598
1600	1.112	1.261	1.370	1.440	1.490	1.544	1.567	1.586	1.598
1700	1.112	1.261	1.370	1.440	1.490	1.544	1.567	1.586	1.598
1800	1.112	1.261	1.370	1.440	1.490	1.544	1.567	1.586	1.598

OK Cancel Dashboard...

Parameters / Air/Fuel Ratio / Temp

Keep the Lambda Inlet Temp correction at the default at any temperature, during initial start up.

Later a fine-tuning of the table can be done once the engine is warmed-up and also the after cooler water temperature can be varied.

Click the button to open the Dashboard window and check the reading of the Inlet Temp.

LAMBDA INLET TEMP CORRECTION

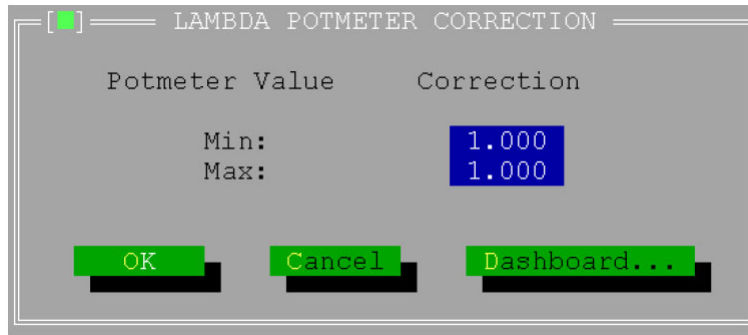
Inlet Temp (°C)	CORR. FACTOR
0	0.915
10	0.915
20	0.915
30	0.930
40	0.950
50	0.970
60	0.990
70	1.000
80	1.010
90	1.020
100	1.030

OK Cancel Dashboard...

Parameters / Air/Fuel Ratio / Potmeter

The range of the lambda potmeter correction can be limited. During the initial start up a wide range can be helpful for quick lambda setting changes. However, because this setting can be changed even by unauthorized people and with a simple screwdriver, it can be dangerous to leave a wide range programmed in the system.

Dependent on the sensitivity for detonation and emission levels, a correction factor of 1.000 is recommended.

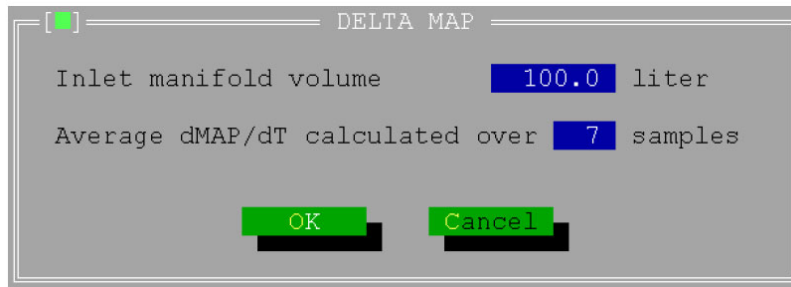


Parameters / Sensor

Configure all sensors connected to the EGS-01 control.

Parameters / Transient / Delta MAP

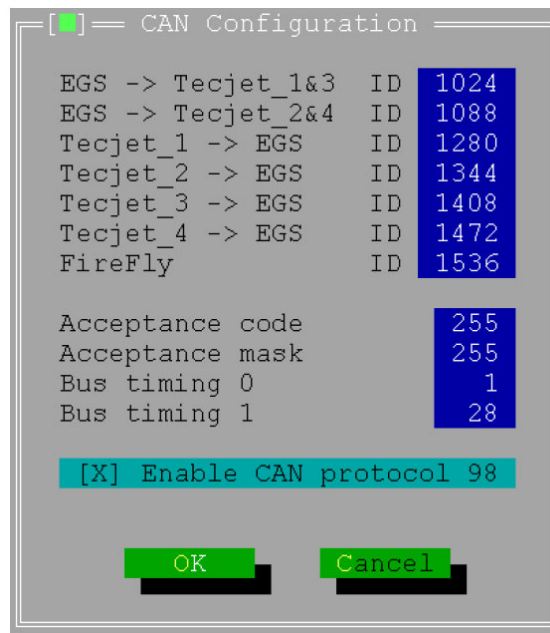
In the Delta MAP window enter the estimated inlet manifold volume. Enter the average dMAP/dT calculated over 6 samples. Click the "OK" button to close the window.



Parameters / CAN Interface

The default CAN settings are standard and should not be changed (see the standard settings below). If the CAN settings of the (old type) TecJet are not the same, change the CAN settings of the TecJet, using the TecJet monitor software, to match the EGS-01 CAN settings. Do not change the settings of the EGS-01 control.

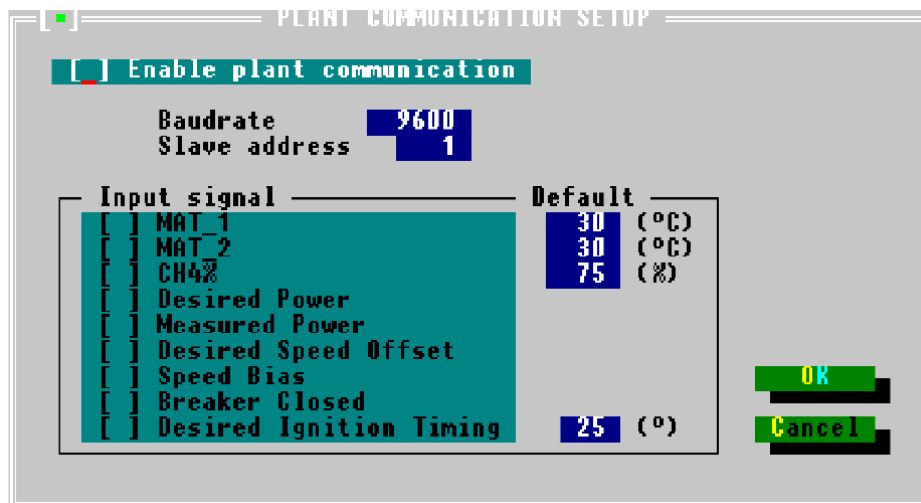
CAN Protocol 98 should always be enabled except when very old TecJets or TecJets with software version <1.05 are used. When using a FireFly, CAN Protocol 98 must be used.



Parameters/Plant Communication

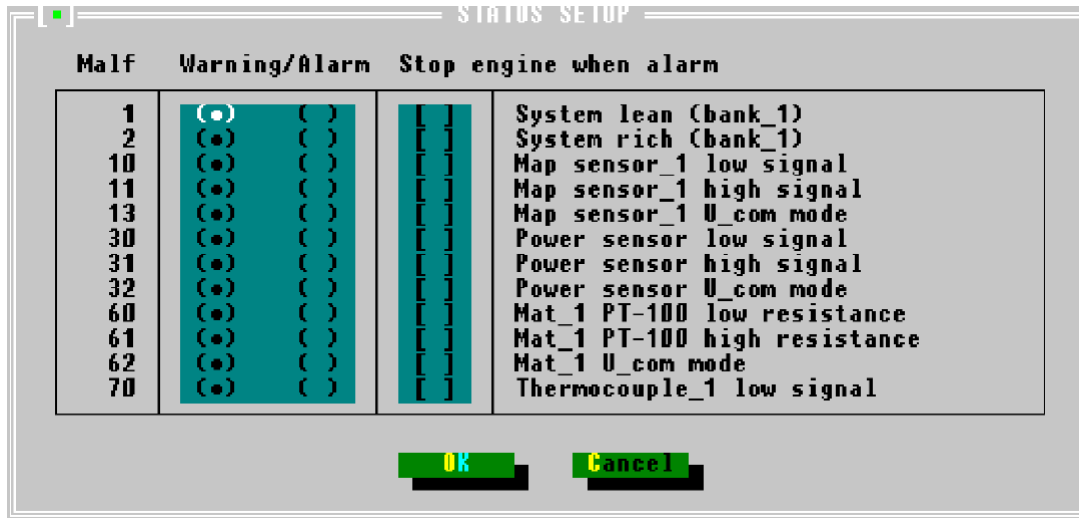
In the Plant Communication Setup window:

1. Click the "Enable plant communication" check box to have plant communication (when available).
2. Click the applicable "Input signal" check boxes that are applicable for your system.
3. Close this window by clicking the "OK" button.



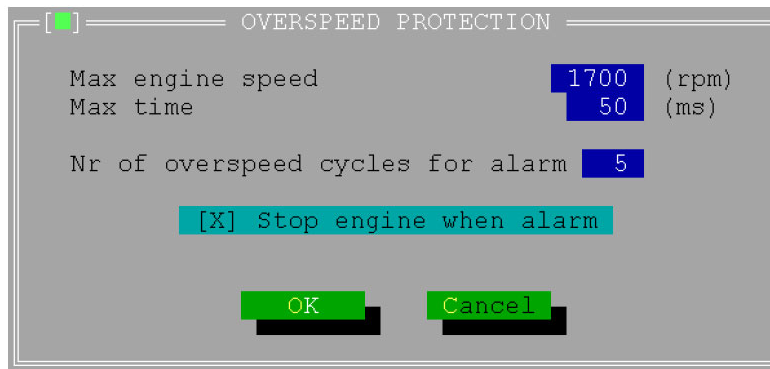
Diagnosis / Status / Setup

Before you start the engine, make sure that in the Status Setup Window all malfunctions are set to "Warning". Close this window by clicking the "OK" button.



Protection / Overspeed

In the Overspeed Protection window fill in the overspeed limit. Close this window by clicking the "OK" button.



Install the UEGO Sensor

1. Connect the UEGO-sensor to the EGS control and a 12 V dc power supply.

Wiring colors: Orange—12 Vdc supply / Yellow GND supply
 Green—signal High (connect to EGS 21)
 Black—signal Low (connect to EGS 22)

2. Do not install the sensor in the exhaust yet, but leave it in open air.



WARNING

The sensor has a heating element and will become very hot.

3. After the sensor has been switched on for approximately 5 minutes, check the signal from the UEGO sensor using a multimeter or the "View/Measured Values" window (Lambda1). The signal should be 4.50 ± 0.02 V.
4. If the signal is higher or lower, adjust the UEGO controller (see Figure 6-1).
5. When the signal is 4.50 ± 0.02 V, the sensor can be installed in the exhaust.

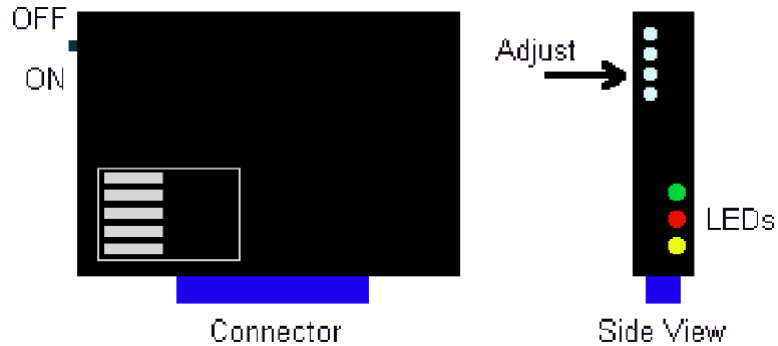


Figure 6-1. UEGO Controller

IMPORTANT

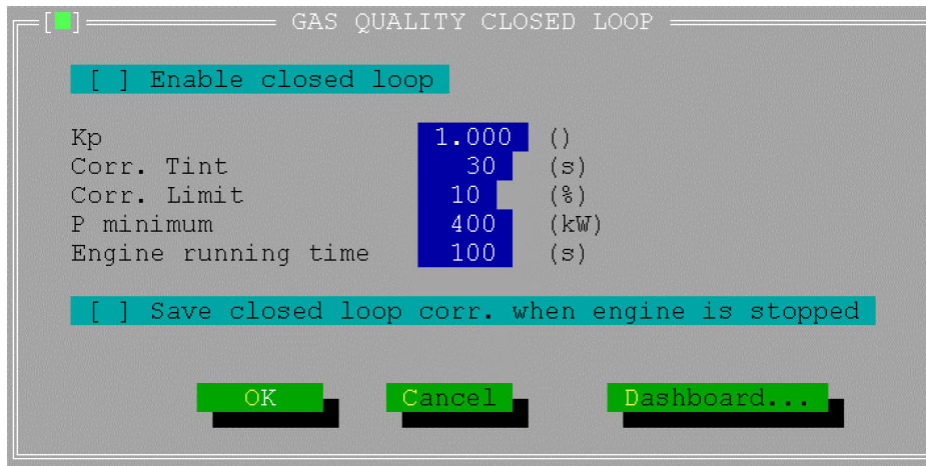
The newest type of UEGO sensor and controller (colored blue) can not be calibrated. This type operates on both 12 Vdc and 24 Vdc.

Communication Check Between EGS and TecJet

1. In the "View Menu", open the Mono Control window and the TecJet Bank 1 window.
2. In the Mono Control window check the measured values such as MAP and MAT.
3. In the TecJet Bank 1 window check the values for Delta_p, FGP, FGT and Pos Ist. If these values are at 0.0, then there is no communication between the EGS and the TecJet.
4. Check the wiring and the CAN settings in the "Parameters Menu" and open the CAN Interface window.

Parameters/Closed Loop/Gas Quality

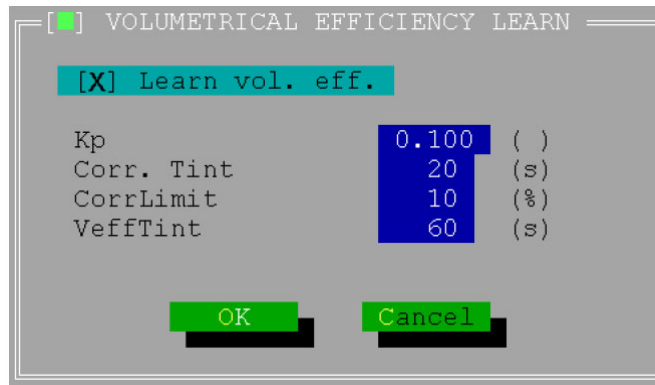
Open the "Parameters/Closed Loop/Gas Quality" window and click the check box to disable closed loop. Click "OK" to exit from this window.

**IMPORTANT**

P minimum should be 40% of maximum engine load.

Parameters/Engine/Volumetric Efficiency/Learn

Open the “Parameters/Engine/Volumetric Efficiency/Learn”, and click the check box to enable/activate the learn mode.



By activating the learn volumetric efficiency mode, the system will behave like a conventional closed loop system, comparing desired and measured lambda and adjusting the gas flow to make measured lambda equal to desired lambda. By changing the values at “Kp” and “Corr. Tint” you can speed up or slow down this closed loop process. By changing the value at “VeffTint” you can speed up or slow down the updating of the table value (see Determine Speed Density Temperature Gain and/or Determine Volumetric Efficiency). “CorrLimit” limits the maximum correction factor.

Normal values for:

Parameter	Normal Values
Kp	0.020–0.1
Corr. Tint	5–10 s
CorrLimit	10–20%
VeffTint	30–60 s

Click “OK” to exit from this window.

Parameters/Air Fuel Ratio/Ref/Edit Table

1. Open the “Parameters / Air/Fuel Ratio / Ref / Edit Table” window. For starting, it is necessary on most engines to use low RefLambda values at low engine speeds, even at high load percentages.
2. Change the values in the table, if necessary.
3. Close the table by clicking “OK”.

n\Load	10	20	30	40	50	60	70	80	90
0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
250	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
500	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
750	1.092	1.092	1.093	1.093	1.093	1.093	1.093	1.093	1.093
1000	1.112	1.112	1.112	1.112	1.112	1.112	1.112	1.112	1.112
1100	1.112	1.142	1.142	1.142	1.142	1.142	1.142	1.142	1.142
1200	1.112	1.192	1.192	1.192	1.192	1.192	1.192	1.192	1.192
1300	1.112	1.192	1.202	1.290	1.316	1.316	1.316	1.336	1.367
1400	1.112	1.221	1.261	1.360	1.367	1.367	1.418	1.438	1.470
1450	1.112	1.261	1.370	1.440	1.490	1.544	1.567	1.586	1.598
1500	1.112	1.261	1.370	1.440	1.490	1.544	1.567	1.586	1.598
1550	1.112	1.261	1.370	1.440	1.490	1.544	1.567	1.586	1.598
1600	1.112	1.261	1.370	1.440	1.490	1.544	1.567	1.586	1.598
1700	1.112	1.261	1.370	1.440	1.490	1.544	1.567	1.586	1.598
1800	1.112	1.261	1.370	1.440	1.490	1.544	1.567	1.586	1.598

OK Cancel Dashboard...

Parameters/Sensors/MAP

1. Open the “Parameters/Sensors/MAP” window and its dashboard, and check the readings of the MAP sensors.
2. Compare the readings with the FGP reading in the “TECJET BANK1” window.

IMPORTANT

The MAP readings are in kPa and the FGP readings are in hPa (1 kPa = 10 hPa).

3. MAP sensor readings must be within 1 kPa. If the difference is more than 1 kPa check the scaling of the sensors and the mechanical connection of the sensors.
4. If necessary change the scaling of one or both sensors.
5. Close the dashboard and the MAP SENSORS window by clicking “OK”.
6. Calibrate and Install the Emission Measuring Device.

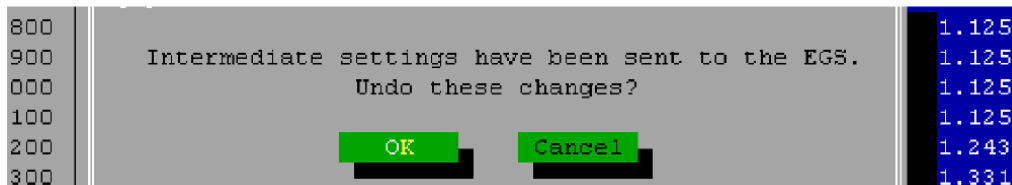
Start Engine

Start the engine. During cranking, make sure that the EGS receives the rpm signal from the magnetic pick-up by checking the rpm reading in the Measured Values section of the Mono Control window. If there is no rpm reading, check the wiring and adjustment of the MPU. When the gas shut-off valves open check the Delta_p and FGP readings in the TecJet Bank1 window. If there is no change in the values for Delta_p and FGP make sure that the shut-off valves are really opening by measuring pressure downstream of the valves.

Run the engine without load. If necessary adjust the speed dynamics. Now the Ccorr value in the Closed Loop Section of the Mono Control window will change until the "Lambda sensor" = "Lambda desired" in the Lambda control section. If "Lambda sensor" ≠ "Lambda desired" and Ccorr remains at 1.000, check the minimum and maximum voltage settings for the Lambda sensor. Go to the "Diagnosis/Lambda difference" menu and enable the Lambda difference check. Go to "Diagnosis/Sensor/Lean" and check the settings. If necessary change the settings and close the window by clicking the OK button. Go back to the "Diagnosis/Lambda difference" menu, disable the "Lambda difference check", and close the window by clicking the OK button.

Check the emissions and if necessary adjust the Ref Lambda table in the "Parameters / Air/Fuel Ratio / Ref / Edit Table" window. (Accurate emission control is not required at this moment; it is only necessary to make sure the engine is not far too lean or far too rich.) Click "Dashboard" button to find out at which Load % position is in the table to make the change. Close the dashboard and make the required changes. By opening the dashboard the changes are transmitted from the PC to the EGS, and the EGS will control air/fuel ratio according to these changes. If the air/fuel ratio is still not as required close the dashboard, make the necessary changes and open the dashboard again. If the emissions are correct (according to the manufacturer's specification and the emission regulations) close the dashboard.

Closing the table by clicking "OK" will make the changes permanent. By clicking "Cancel" the changes can be undone. A dialog box will appear asking if you are sure you want to undo the changes. Clicking "OK" will restore the table contents to the original values as they were when the table was opened. Clicking "Cancel" will make the changes permanent.



Perform the following sections A through L to complete the commissioning.

A. Increase Load

1. Gradually increase the engine load.
2. Check the emissions and if necessary make adjustments to the RefLambda table as described in Start Engine above.
3. If necessary adjust speed or power dynamics for stable engine operation.
4. Run the engine at full load until temperatures and emissions are stabilized.
5. Open the "RefLambda", the "Volumetric Efficiency" and the "Total Efficiency" table and their dashboards to make sure the engine is running within the range of the tables.
6. If this is not the case, change the axes of the table, as described in the Parameters / Engine / Total Efficiency section above and in the Parameters / Air-Fuel Ratio section above. Make sure that you use the same values on the Load% axis in the "Total Efficiency" table and in the "RefLambda" table.
7. Open the "Parameters/Sensors/MAP" window and its dashboard.
8. Check the readings of the MAP sensors. If possible compare the readings with the readings of another pressure gauge. MAP sensor readings must be within 1kPa. If the difference is more than 1 kPa, check the scaling of the sensors and the mechanical connection of the sensors. If necessary change the scaling of one or both sensors.
9. Close the dashboard and the MAP SENSORS window by clicking "OK".

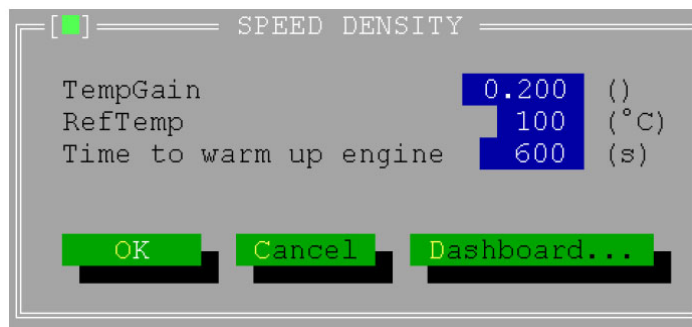
10. Open the “Parameters/Sensors/Measured Power” window and its dashboard.
11. Check the scaling of the measured power sensor. If necessary change the scaling.
12. Close the window by clicking “OK”.
13. Continue with the next section.

B. Determine Speed Density Temperature Gain

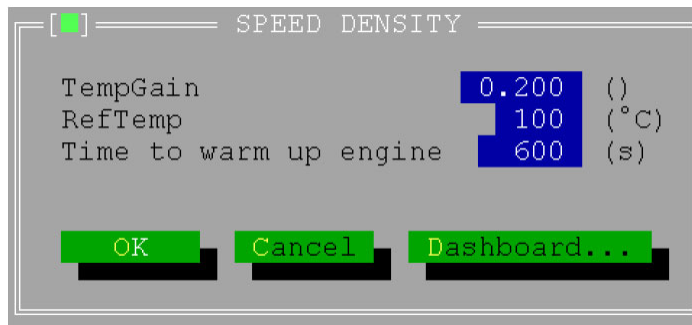
IMPORTANT

If the basic settings used are of an identical engine, and the MAT sensor at the same location, it is not necessary to determine the Temperature Gain. You can use the valves as they are and proceed with the next section.

1. Increase the manifold temperature to the maximum attainable value. This can be done for example by reducing the water-flow to the aftercooler, or increasing the temperature of the aftercooler water.
2. Open the “Parameters/Engine/Speed density” window and set the TempGain to zero. In the “RefTemp” field, enter the actual measured MAT. In the “Time to warm up engine field”, enter the time it takes the engine to reach a stabilized coolant temperature.
3. Close the window by clicking “OK”.



4. Open the volumetric efficiency table in the “Parameters/Engine/Volumetric Efficiency/Edit Table” window.
5. Open the dashboard to find out at which position in the table the engine is running.
6. Adjust the load until MAP is at the maximum MAP% value. The closer to the table points the engine is running, the better the accuracy of the system.
7. In the dashboard click “update” to activate the update of the volumetric efficiency. Now the volumetric efficiency value is changed automatically until Ccorr is back at 1.000. Once Ccorr = 1.000 (± 0.002) close the dashboard. The position in the volumetric efficiency table will be updated to the learned value.
8. Repeat this for the next lower MAP% value.
9. Decrease the manifold temperature to the lowest possible temperature. (It may be necessary to enrich the mixture to prevent misfire. Change the RefLambda table to achieve this.)
10. Let the engine run until temperatures are stabilized. By now Ccorr will most probably have changed to a lower value.
11. Open the “Parameters/Engine/Speed density” window and increase the TempGain until Ccorr. = 1.000 (± 0.002) again. After this, enter the coolant temperature (in the cylinder head area) at normal engine operation in the RefTemp field.

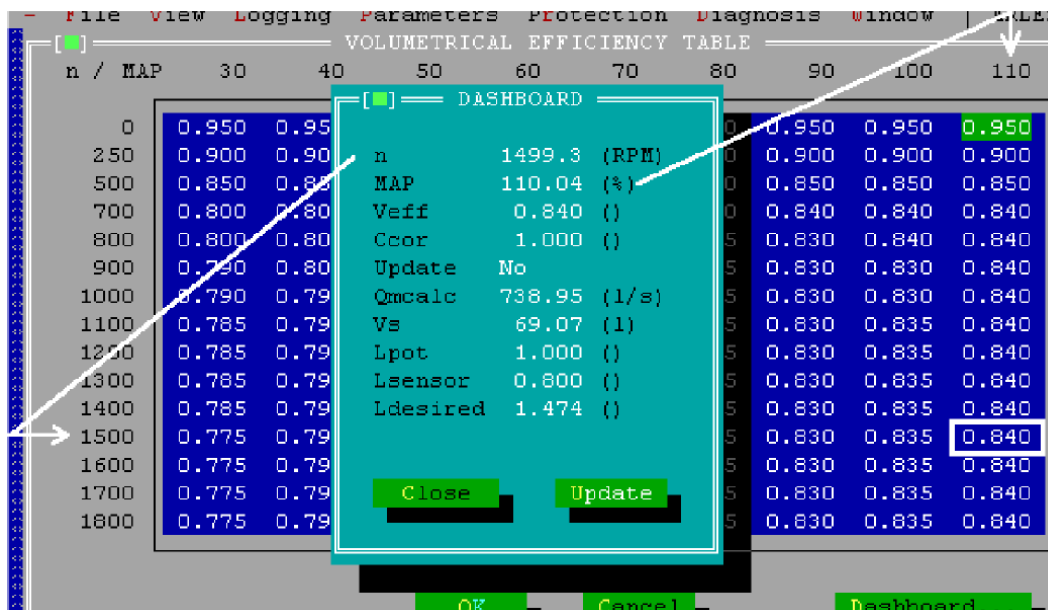


(Settings shown are for example only.)

12. Close the window by clicking "OK".
13. Change the manifold temperature back to the normal temperature.
14. Continue with next section.

C. Determine Volumetric Efficiency

1. Open the volumetric efficiency table in the "Parameters/Engine/Volumetric Efficiency/Edit Table 1" window.
2. Open the dashboard to find out at which position in the table the engine is running.



3. Adjust the load until MAP is at the maximum MAP% value.
4. In the dashboard click "update" to activate the update of the volumetric efficiency. Now the volumetric efficiency value is changed automatically until Ccorr is back at 1.000. Once Ccorr = 1.000 (± 0.002), close the dashboard. The position in the volumetric efficiency table will be updated to the learned value.
5. Repeat this for all the other MAP% values. If the engine will run at different speeds during normal operation, repeat for the speeds at which the engine will be running.

IMPORTANT

Make sure there are no large differences between adjacent cells. It may be necessary to change other cells to smooth out large steps between adjacent cells over a larger number of cells See examples.

Example 1: Large Steps

MAP	20	30	40
1200	0.71	0.74	0.77
1300	0.71	0.74	0.77
1400	0.71	0.74	0.77
1500	0.61	0.64	0.67
1600	0.61	0.64	0.67

Example 2: Smooth Steps

MAP	20	30	40
1200	0.71	0.74	0.77
1300	0.67	0.70	0.73
1400	0.64	0.67	0.70
1500	0.61	0.64	0.67
1600	0.61	0.64	0.67

Underlined values are the learned values as described above.

- Open the “Parameters/Engine/Volumetric Efficiency/Learn” window and switch off the learn mode by moving the cursor to the “Learn vol. eff.” field and pressing the space bar of the computer so that the field reads “No”.
- Continue with next section.

D. Determine Full Load Ref Lambda and Full Load Total Efficiency

- Open the RefLambda table and the dashboard and increase the load again until Load is at the maximum Load% value and let the temperatures stabilize. Close the dashboard.
- Check emissions, and if necessary change the ref lambda values in the area where the engine is running.
- Transmit the changes to the EGS control by opening the dashboard and check emissions again.
- If necessary make more changes to the table. If emissions are correct, close dashboard and close the table by clicking “OK”.
- Open the “Parameters/Engine/Total Efficiency/Learn” window and switch on the learn total efficiency mode. By changing the TeffTint value it is possible to speed up or slow down the learn process. Normal value for TeffTint is 20 (s). Close the window by clicking “OK”.
- Open the Total Efficiency table in the “Parameters/Engine/Total Efficiency/Edit Table” window.
- Open the dashboard and click “update”. Now the total efficiency value will be changed, until Pcal = Pmech. Once Pcal = Pmech, close the dashboard, and the value in the table will be updated.
- Repeat these steps for the next lower Load% value.
- Continue with next section.

E. Determine Inlet Temperature Correction

IMPORTANT

If the basic settings used are from an identical engine, it is not necessary to determine the Inlet Temperature Correction. You can use the valves as they are and proceed with the next section.

- Run the engine at full load and open the “Parameters/Engine/Total Efficiency/Learn” window and switch off the learn total efficiency mode.
- Open the “Parameters/Closed Loop/Gas Quality” window and switch on the Gas Quality Closed Loop.

Run the engine at different manifold temperatures and adjust the Inlet Temp. Correction table in the “Parameters/Air/Fuel Ratio/Inlet Temp” window in such a way that the emissions are correct for all the different manifold temperatures. Close this window by clicking “OK”.

[] LAMBDA INLET TEMP CORRECTION

Inlet Temp (°C)	CORR. FACTOR
0	0.915
10	0.915
20	0.915
30	0.930
40	0.950
50	0.970
60	0.990
70	1.000
80	1.010
90	1.020
100	1.030

OK Cancel Dashboard...

(Settings shown are for example only.)

Continue with next section.

F. Determine Part Load Ref Lambda and Part Load Total Efficiency

1. Open the "Parameters/Closed Loop/Gas Quality" window again and switch off the Gas Quality Closed Loop.
2. Open the "Parameters/Engine/Total Efficiency/Learn" window and switch the learn total efficiency mode back on.
3. Open the RefLambda table and the dashboard and reduce the load until Load is at the desired value. (In this case it is the next lower value compared to the Load value while determining full load RefLambda.)
4. Check emissions. If necessary change the ref lambda values in the area where the engine is running.
5. Transmit the changes to the EGS control by opening the dashboard and check the emissions again. If necessary make more changes to the table. If emissions are correct, close dashboard and close the table by clicking "OK".
6. Open the Total Efficiency table in the "Parameters/Engine/Total Efficiency/Edit Table" window.
7. Open the dashboard and click "update". Now the total efficiency value will be changed, until $P_{cal} = P_{mech}$. Once $P_{cal} = P_{mech}$, close the dashboard, and the value in the table will be updated.
8. Repeat steps 3 to 7 for all other Load% values.
9. If there is a signal for ignition timing, determine the total efficiency at the different load/ignition timings, as described above. If there is no ignition timing signal, use the same values for the different ignition timings.

IMPORTANT

Make sure that there are no large differences between adjacent cells. If may be necessary to change other cells to smooth out large steps between adjacent cells over a large number of cells.

Continue with next section.

G. Change to Gas Quality Closed Loop

Open the “Parameters/Engine/Total Efficiency/Learn” window and switch off the learn total efficiency mode.

Open the “Parameters/Closed Loop/Gas Quality” window and switch on the Gas Quality Closed Loop.

Depending on the update rate of the kW signal, it is possible to make the gas quality closed loop more responsive by increasing the Kp (=Gain) value and/or decreasing the Corr. Tint value. If sudden changes in gas quality are to be expected, make the closed loop as fast as possible. However do not make the closed loop too fast (faster than the update of the kW signal. This may cause instability and less accurate air/fuel ratio control.

CorrLimit limits the closed loop correction Ccorr (see closed loop correction section of the Mono Control window), for example 10 % means 1.000 ± 0.100 . Ccorr can vary from 0.900 to 1.100, if Ccorr reaches the limits, there will be an alarm/warning. CorrLimit must always be more than the expected change in gas quality.

P minimum is the minimum calculated power at which the engine has to run before the gas quality closed loop is enabled. Gas quality closed loop is based on the total efficiency of the engine and generator. At very low loads the efficiency calculation and the GQCL algorithm become inaccurate, therefore the closed loop can only be enabled if the engine is running at more than 30–40 % of load.

Engine running time is the time after Pminimum (calculated) is reached. After this time and Pcal > Pminimum the closed loop becomes active. Engine efficiency is influenced by the various temperatures in the engine (coolant, oil, etc.). Therefore the closed loop can only be enabled after the time it takes the engine to reach normal running conditions.

Parameters	Normal Values
Kp	0.2–1.0
Corr Tint	20–60 s
CorrLimit	5–15%
P minimum	30–40% of full load kW
Engine running time	120 s

Run the engine at different loads and check the emissions and Ccorr. If necessary minor adjustments can be made to either the RefLambda table or to the Total Efficiency table. If the composition of the gas has not changed, Ccorr should remain between 0.980 and 1.020 if the gas quality closed loop is enabled.

If the engine is running too rich and Ccorr > 1.010, enter a slightly lower value in the Total Efficiency table at the position at which the engine is running. This makes the mixture leaner and decrease down the Ccorr value.

If the engine is running too lean and Ccorr < 0.990, enter a slightly higher value in the Total Efficiency table at the position at which the engine is running too lean. This will richen the mixture and increase the Ccorr value.

In other cases, change the RefLambda table at the position at which the engine is running too rich or too lean.

Continue with next section.

H. Check Emissions at Different CH4 Levels

IMPORTANT

This section describes how to check and adjust the emissions at different CH4 levels. This section is only applicable to EGS controls that have an input from a CH4 analyzer and measure CH4 (click the box “Measure CH4” in the “Parameters/Fuel Parameters” window). If there is no CH4 signal and/or “MeasureCH4”, then leave the check box open and proceed with the Setup Diagnosis Warnings/Alarms section below.

1. Make sure the CH4 analyzer is calibrated.
2. Run the engine at full load.
3. Change the gas quality to bring down the CH4 level, for example by closing the wells with high CH4 content gas and opening the wells with low CH4 content gas.
4. Check the emissions.
5. If the engine runs too rich or too lean at these low gas qualities, open the “Parameters/Fuel Parameters” window.
6. If the engine runs too lean, increase the value in the “Lower heat value” field in the low CH4 percentage (= left) column using small steps, until the emissions are correct.
7. If the engine runs too rich, decrease the value in the “Lower heat value” field in the low CH4 percentage (= left) column using small steps, until the emissions are correct.
8. Close this window by clicking “OK”.

FUEL PARAMETERS					
[Gas]	landfill				
<input checked="" type="checkbox"/> Measure CH4					
Density	0.80			(kg/m3)	@ p_n, T_n
Lower heat value	32.60			(MJ/m3)	@ p_n, T_n
Lambda stoichiometric	8.40				
CH4 percentage	40.00	50.00		(%)	
Density	1.47	1.34		(kg/m3)	@ p_n, T_n
Lower heat value	14.32	18.08		(MJ/m3)	@ p_n, T_n
Lambda stoichiometric	3.81	4.76			@ p_n, T_n
<input type="button" value="OK"/> <input type="button" value="Cancel"/> <input type="button" value="Dashboard..."/>					

9. Change the gas quality to bring up the CH4 level, for example by closing off the wells with low CH4 content gas and opening the wells with high CH4 content gas.
10. Check the emissions.
11. If the engine runs too rich or too lean at these high gas qualities, open the “Parameters/Fuel Parameters” window.
12. If the engine runs too lean, increase the value in the “Lower heat value” field in the high CH4 percentage (= right) column using small steps, until the emissions are correct.
13. If the engine runs too rich, decrease the value in the “Lower heat value” field in the high CH4 percentage (= right) column using small steps, until the emissions are correct.
14. Close this window by clicking “OK”.

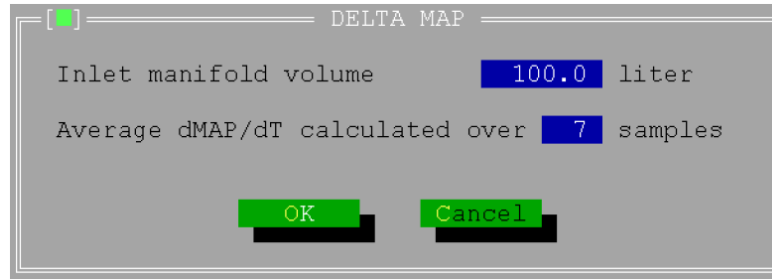
Continue with next section.

I. Optimize Transient Behavior

IMPORTANT

The transient behavior of a turbo-charged OTTO engine is limited by the time required to speed up the turbo-charger. If the measured Lambda is correct during a transient, then the transient behavior cannot be improved further, using the transient model. The transient model will only correct the changing amount of mixture in the intake manifold.

1. Run the engine at part load, for example 50%.
2. Open the "Parameters/Transient/Delta Map" window.



3. Use a lean-burn Lambda sensor and a chart recorder, or a fast log to judge the transient Air/Fuel ratio.
4. Perform a load-step.
5. If transient behavior is not adequate, decrease the value in the "Average dMAP/dT calculated over..... samples" field. Be careful not to decrease this value too much or instability can occur.
6. Close the window by clicking the "OK" button.
7. Perform another load step.
8. If transient behavior is still not adequate increase the value in the "Inlet manifold volume" by approximately 25%.
9. Close the window by clicking the "OK" button and perform another load step.
10. If this gives an improvement, try finding the optimum value, however do not use a value higher than 2 x the estimated manifold volume.
11. If transient behavior get worse, reduce the original value in the "Inlet manifold volume" by approximately 25%.
12. Close the window by clicking the "OK" button and perform another load-step.
13. If this gives an improvement, try finding the optimum value, however do not use a value lower than 0.5 x the estimated manifold volume.

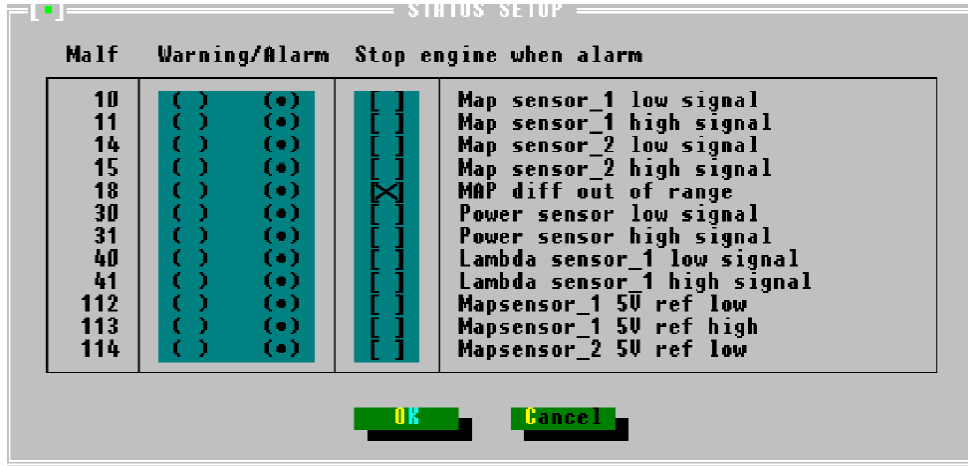
Inlet manifold volume	0.5–2 x real manifold volume
Average dMAP/dT calculated over	5–8 samples

Continue with next section.

J. Setup Diagnosis Warnings/Alarms

1. Open the "Diagnosis/Sensor" window and set the limits and timers for the different sensors.
2. Open the "Diagnosis/Closed Loop" window and set the timer. Also choose if you want to go to open loop in case the closed loop correction is at it's minimum or maximum value (see "Parameters/Closed Loop/Gas Quality" for the limit) during the time set.
3. Open the "Diagnosis/Status/Setup" window and for each malfunction select whether it will cause a warning or an alarm.

4. If you choose an alarm, you can decide whether the EGS should switch the alarm relay and stop the engine if an alarm occurs by closing the TecJet, or only to switch the alarm relay.
5. Close the window by clicking the "OK" button.



6. Save settings file, using "File/Save as" command.
7. Go off-line, using the "File/Work Offline" command and exit the monitor program.
8. Continue with next section.

K. Enter the EGS Password

Access to the EGS control system during remote monitoring using a modem is password-protected. The password must first be entered in a new EGS before remote access using a modem can be used.

Enter the password using the "System/Change EGS password" menu. Type the new password twice, then close the window by clicking the OK button.

IMPORTANT

The EGS modem access password is stored in the EGS unit, whereas the user password for the monitoring program is stored in the PC.

When the password has been entered go off-line, using the "File/Work Offline" command and exit the monitor program. Continue with next section.

L. Remove UEGO Sensor and Emission Measuring Device

1. Stop the engine.
2. Remove the UEGO sensor from the exhaust and disconnect the UEGO wiring.
3. Plug the sensor hole where the UEGO sensor was installed.
4. Remove the emission analyzer.

Chapter 7. Logging

Logging Menu

IMPORTANT

It is recommended that a “Logging” directory is created to store logging data files, and a “Settings” directory is created to store engine calibration files (*.EGS). Create the directories under “C:\EGS\EGS_nnn\ <directory>”.

1. In the Logging menu, click the Parameters field to open the “Logging Parameters” window.
2. Fill-in the operator name.
3. Fill-in the logging mode.

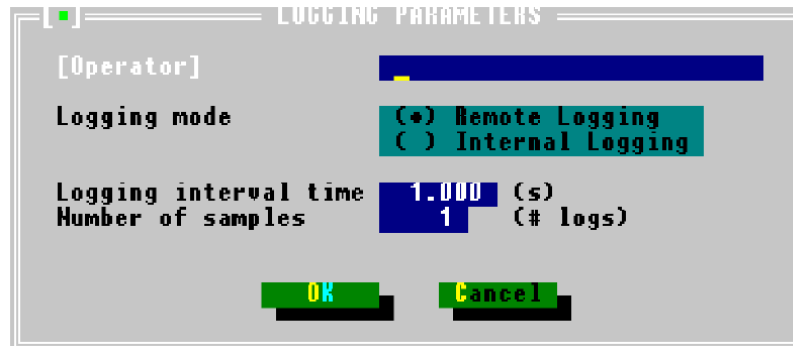


Figure 7-1. Logging Parameters

Remote Logging

Remote logging means that the logging data will be stored in the internal RAM memory of the EGS-01 control.

The RAM memory has the advantage of logging with a fast interval time of 0.005 second, but has the disadvantage that the capacity of this memory is limited to 2250 samples (rows) with 20 parameters (columns) in mono control or 30 parameters in stereo control. Also the stored data will be lost during supply voltage interruptions.

The remote logging mode is ideal for tuning the transient behavior of an engine or to check the set for signal and actuator errors.

Internal Logging

Internal logging means that the data will be stored on the solid state disk of the EGS-01 control.

Using the solid-state memory has the advantage that the data cannot be lost during supply voltage interruptions. Also the storage capacity is much larger than the RAM-memory, however the fastest log interval time is one second. The memory capacity of the solid state disk is about 0.8 Mbytes.

This leads to the following examples:

Logging duration	At time interval
2 hours	1 s
7 days	60 s
3 months	800 s

Number of Samples

In the “Remote logging” mode it is not possible to split the number of samples into more than one file. Files that are made in this mode are stored with the extension *.log.

In the “Internal logging” mode new files are automatically created after the programmed number of samples have been reached. It is not convenient to edit large files in a DOS-editor or in spreadsheet programs. Therefore we recommend not creating very large files. Files that are made in this mode are stored with the extensions *.000, *.001, *.003, etc.

Logging Options

During the installation of the EGS-01 monitor software, a directory that is called C:\EGS_***\DELTEC\LOGGING will be created. It is advisable to store logging data in this directory.

Use the “Tree” button to select a directory to store the data.



Figure 7-2. Logging Options

On Line with the EGS-01 Control

The Start, Stop, Clear and Receive fields are only active when you are on line with the EGS-01 control and when the signal “FUEL ON” on terminal 10 is high.

When the control is in the “Remote Logging”-mode the display shows the remaining percentage of storage capacity.

In the “Internal Logging” mode only the sign “LOGGING” will be displayed.

By clicking the “CLEAR” field, the logging memory of the EGS-01 control will be made empty.

Receive

In the “Receive” window, a file name for the logging data can be allocated. A file extension is not required and will be made automatically.

In both logging modes, the files with the extensions *.PAR and *.EGS will be created automatically. The logging related parameters will be stored in the *.PAR file.

The EGS-01 control-related parameters will be stored in the *.EGS file. These two files will get the same file name as allocated earlier for the logging data files.

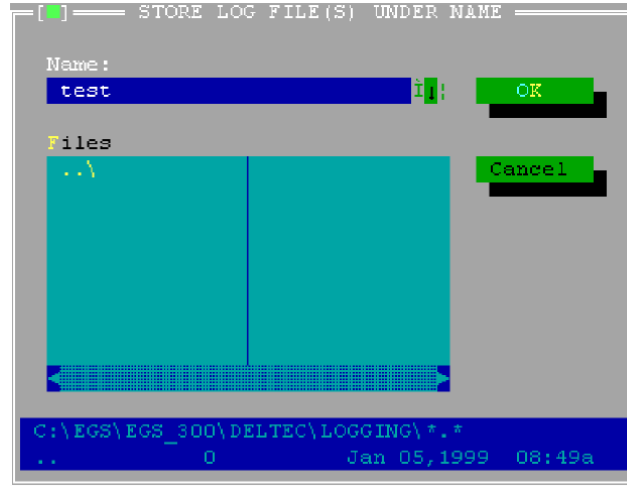


Figure 7-3. Logging Data Allocation

Chapter 8.

Troubleshooting

Introduction

This chapter provides a number of examples with faults (questions), possible causes, and what to do. If your EGS control does not function correctly, check this chapter to find a solution for your problem or ask Woodward for technical assistance. The following problems are covered in this chapter:


- Unable to work online with EGS
- Engine will not start
- Engine starts, but will not accelerate
- Engine speed unstable
- Engine will not accept full load
- Engine misfires
- Engine detonates
- Incorrect NOx emissions
- Malfunctions

For troubleshooting information on the speed and load control, see Chapter 4.

Unable to Work Online with EGS

Possible Cause	What to do
No power supply to the EGS	Check for supply voltage to the EGS terminals 81 (+) to 82 (-). Repair if incorrect.
No Fuel On signal to the EGS	Check for Fuel On voltage to EGS terminal 10 (-) to 82 (-). Repair if incorrect.
EGS does not boot	Replace the EGS.
Incorrect COM port settings	Check the COM port settings in SYSTEM menu. Change settings if incorrect
Faulty interface cable	Check cable according to diagram in the Cable Connection section of Chapter 3. Repair or replace cable if incorrect.
EGS monitor program version different from software version in the EGS	Use the correct version of the monitor program.

Engine Will Not Start

Possible Cause	What to do
No gas pressure present.	<p>Check gas pressure upstream of the gas shut-off valves.</p> <div style="border: 2px solid black; padding: 5px; margin: 10px 0;">  WARNING </div> <p>Gas may escape when connecting a pressure gauge. Gas/air mixture is highly flammable. Make sure there are no open flames, sparks or hot surface that may ignite the gas/air mixture.</p> <p>If gas pressure is not present check and repair the gas supply system upstream of the shut-off valves.</p>

Possible Cause	What to do
Gas shut-off valves do not open.	<ul style="list-style-type: none"> Open the "TecJet bank1" window in the View menu. Check the FGP value before and during cranking. Before cranking the FGP value is at ambient absolute pressure. During cranking the FGP should increase to the ambient absolute pressure + gas supply gauge pressure. No increase of the FGP during cranking indicates gas shut-off valves are not opening. Check and repair shut-off valve operation.
After cranking, FGP pressure stays the same value as before cranking.	<ul style="list-style-type: none"> Check shut-off valve operation. TecJet installed in incorrect direction.
No ignition or incorrect ignition timing.	Check ignition system for correct operation.
EGS alarm or engine alarm present.	<ul style="list-style-type: none"> Check the "Diagnosis Alarm Status" and the "Engine Alarm Status" windows in the View menu. Reset alarms. If an alarm returns, see Malfunctions below.
No rpm detected by EGS.	<ul style="list-style-type: none"> Open the "Mono Control" window in View menu. Check rpm reading during cranking. If the reading remains at zero, check the voltage and the frequency of signal on the EGS terminals 57 to 58. If voltage/frequency incorrect/not present, check wiring for correct connection. Check shields for correct installation. Check the sensor for correct spacing. Make sure there are no metal chips on the end of the pickup. Magnetic pickup may have short or open circuit. Perform a resistance check with the leads disconnected from the EGS. Should be 100 to 300 Ω. If the voltage/frequency is correct, check the number of teeth seen by the MPU per engine revolution against the number entered in the "RPM-TDC SENSOR" window in the Parameters/Sensor menu. Check the rpm sensor type against the type entered in the "RPM-TDC SENSOR" window.
Mixture too rich or too lean due to faulty TecJet operation.	<ul style="list-style-type: none"> Open the "TECJET BANK1" window in the View menu. Before cranking check the TecJet position Pos1st. Before cranking this value should be 0.0 mm. A deviation smaller than 2.0 mm will not have a big influence on starting behavior. If Pos1st before cranking < -2.0 mm or > 2.0 mm replace the TecJet. During cranking check Pos1st value. After opening shutoff valves TecJet should open, Pos1st should increase.
Fqp – pressure stays the same value before and during cranking	<ul style="list-style-type: none"> Check gas shut off valves. TecJet connected in opposite direction.
CH4 signal is incorrect. (For systems using CH4 input only).	<ul style="list-style-type: none"> Check signal from the CH4 analyzer to the EGS terminals 35 (+) to 36 (-). If signal is not present, check the wiring and the CH4 analyzer operation. Check calibration of CH4 analyzer. Compare the CH4 analyzer signal type and the scaling against values entered in the "CH4 SENSOR" window in the Parameters/Sensor/CH4 menu.
Desired Lambda too high or too low.	<ul style="list-style-type: none"> During cranking check the Lambda desired value. For most engines this should be approximately 1.00 to 1.25. If the desired Lambda is incorrect, open the "Lambda Ref table" in the Parameters/Air/Fuel Ratio menu. Change the values in crank speed area of the table.
Actuator does not move to start position (for systems with separate speed control).	Refer to speed/load control in Chapter 4.

Engine Starts, But Will Not Accelerate

Possible Cause	What to do
Mixture too lean.	Check the exhaust emissions. Even at the correct air/fuel ratio O ₂ % reading may be too high due to misfire. See Engine Does Not Start in Chapter 4.
Misfire.	Check ignition system for correct operation. Check engine condition.

Engine Speed Unstable

Possible Cause	What to do
Incorrect dynamics programmed in the speed control.	Refer to the speed control manual.
Air fuel ratio control unstable.	<ul style="list-style-type: none"> Check the "Lambda Ref table" in the Parameters/Air/Fuel Ratio menu for irregularities. Avoid large differences in lambda ref value in adjacent cells. Check the Volumetric Efficiency table in the Parameters/Engine menu for irregularities. Avoid large differences in lambda ref value in adjacent cells.
Incorrect transient settings.	Improve settings in the "DELTA MAP" window in the Parameters/Transient menu.
Severe misfire.	Check ignition system and engine condition.
Ignition timing unstable.	Check ignition system for correct operation.
Necessary external wires are not correctly connected and/or shielded.	Check the wiring for correct connection and/or improve the shielding.
Actuator and/or driver problem.	Refer to actuator and driver manual.

Engine Will Not Accept Full Load

Possible Cause	What to do
Mixture too lean.	Check the emissions. Even at the correct air/fuel ratio O ₂ % reading may be too high due to misfire.
Engine does not operate correctly.	Engine may be misfiring, waste gate out of adjustment, failed turbocharger, excessive air filter restriction, general engine condition.

Engine Misfires

Possible Cause	What to do
Mixture too lean.	Check emissions.
Ignition system.	Check ignition system for correct operation. Even at the correct air/fuel ratio O ₂ % reading may be too high due to misfire. Check air/fuel ratio by means of UEGO sensor.
Engine condition.	Check engine. Valve clearances, compression end pressure, etc.

Engine Detonates

Possible Cause	What to do
Mixture too rich.	Check emissions. Lean off if necessary.
Ignition timing incorrect	Check real ignition timing. Correct timing if necessary.
Engine overloaded.	Check engine output. Reduce output if necessary.
Detonation caused by Overload by misfire.	Deposits in combustion chamber. Cure the phenomena that caused the deposits, and clean the combustion chamber.

Incorrect NOx Emissions (NOx emissions now unsatisfactory with "GQCL" operating)

In-service experience has shown that engines running in the Gas Quality Closed Loop (GQCL) mode show very stable NOx readings, even over longer periods. If however the engine runs too rich or too lean compared to the original setting, the following procedure can be followed to get the engine back to that original setting.

IMPORTANT

Note that a change of the gas quality or a change in the TecJet accuracy will not lead to any change of the NOx reading. Only the value "correction closed loop" or Ccorr will change.

IMPORTANT

For future reference make notes of all changes made to the settings. Also note the engine running hours.

1. Are you sure that the engine has incorrect NOx emission?
First make sure that the measuring instruments are working correctly.

When a lean-burn gas engine runs too lean, the NOx reading will be too low and the O₂ reading will be too high. During rich running the NOx will be too high and the O₂ reading will be too low.

If you have a (calibrated) UEGO sensor installed, you can use the lambda reading as confirmation. Also, the exhaust-gas temperature can give an indication of the A/F-ratio. If the O₂ reading is high and fluctuating but the NOx reading is not low, the cause can be a misfire. The misfire will reduce the total efficiency and will enrich the engine giving high NOx, but the misfire also contributes to the high and/or unstable O₂ readings.

2. Changed or damaged sensors or modified engine:
Check for changes to the following "speed density" related items:
 - + MAP-sensors: Position, wiring, tubing, dirt, ambient temperature and leakage. You can compare the reading with an accurate (barometric) sensor. For an accurate barometric reading, call your nearest airport. Compare this reading with your reading, and the values taken during commissioning.
 - + MAT-sensor: Position, dirt, wiring, and installation. You can compare the reading with other sensors.
 - + Volumetric efficiency (Ve): Check if anything has changed on the intake system such as the flame arrestors, cleaning or adjusting valves, or cleaning/servicing of the heads.

Check for changes the following "total efficiency" items:

- + Ignition system: Check that the spark plugs, wiring, coils and HT-leads are serviceable, and finally that the actual ignition timing is correct. Some ignition systems require re-calibrating after changing various components to prevent erratic readings on the service tool.
- + Check for changes on the kW-signal, such as wiring, kW-transducer, the cosΦ set point or controller.
- + Check for changes at the waste-gate (setting) or the turbo-chargers.
- + Has anything been added or removed from the crank shaft, such as pumps or gears?
- + Has anything that affects the internal friction losses of the engine been changed?

3. Other causes:
 If none of the above-mentioned items has caused the change to the exhaust gas emission, the parameters of the EGS must still be changed to return the NOx reading to its original value. Use the settings in this table:

NOx	λ	Ccorr	Reason(s)	First solutions	Second solutions
OK	OK	$\neq 1.00$	Gas quality has changed TecJet has changed	No action No action	Take a gas sample Change the TecJet.
Too high	Too low	< 0.99	Real Total.eff. decreased MAP reading is too high	Clean the engine Clean the engine	Lower the V_e table and raise the total efficiency table (use ALT-M)
Too high	Too low	> 1.01	kW transducer reading is low	Check the engine Check the kW transducer	Lower the Total.eff table (use ALT-M) or lower the LHV.

IMPORTANT

Instead of changing the Total Efficiency table value (by using Alt-M) you can change the value of the LHV in the same direction in order to fine-tune the NOx. If you increase the LHV (or increase the “total.eff”) the calculated power will increase and the gas-mixture will become richer due to the increase in Ccorr.

Thus by carefully tuning the Volumetric Efficiency and the Total Efficiency in small steps, e.g. of 0.5% (Alt-M 0.995 or Alt-M 1.005), the correct NOx level can be attained at a satisfactory Ccorr value.

Malfunctions

Malfunction	Description	Remedy
01/03	System lean (bank_1/2).	<ul style="list-style-type: none"> Calibrate the UEGO sensor at 4.50 V in ambient air. Check the emissions. Check the general engine condition.
02/04	System rich (bank_1/2).	<ul style="list-style-type: none"> Calibrate the UEGO sensor at 4.50 V in ambient air. Check the emissions. Check the general engine condition.
10/14	MAP sensor_1/2 low signal.	<ul style="list-style-type: none"> Measure the MAP signal on EGS terminals 26 (+) to 27 (-). Check the MAP sensor wiring. Replace the MAP sensor. Check the setting for U_min (I_min) in the MAP SENSORS DIAGNOSIS window under Diagnosis/Sensor menu.
11/15	MAP sensor_1/2 high signal.	<ul style="list-style-type: none"> Measure the MAP signal on EGS terminals 26 (+) to 27 (-). Check the MAP sensor wiring. Replace the MAP sensor. Check the setting for U_max (I_max) in the MAP SENSORS DIAGNOSIS window under Diagnosis/Sensor menu.
13/17	MAP sensor_1/2 U-com mode high.	<ul style="list-style-type: none"> Internal EGS failure. If the failure persists, replace the EGS unit.

Malfunction	Description	Remedy
18	MAP difference out of range.	<ul style="list-style-type: none"> If only one sensor is used, open the MAP SENSORS DIAGNOSIS window in the Diagnosis menu and switch off the "Enable MAP difference check". In the MAP SENSORS window in the Parameters/Sensor menu, check MAP readings in dashboard. Compare readings to pressure measured on separate gauge to locate faulty sensor. Check Max difference value in the MAP SENSORS DIAGNOSIS window in the Diagnosis/Sensor menu. For most applications this value should not be higher than 5 kPa. Check process connections to sensors. Check the MAP sensor wiring. Replace the faulty sensor.
20	No rpm signal in PC-104	<ul style="list-style-type: none"> Internal EGS failure. If failure persists, replace the EGS unit.
30	Power sensor low signal.	<ul style="list-style-type: none"> Measure the signal on EGS terminals 33 (+) and 34(-). Check Measured Power signal wiring to EGS. Check the setting for U_min (I_min) in POWER SENSOR DIAGNOSIS window in the Diagnosis/Sensor menu.
31	Power sensor high signal.	<ul style="list-style-type: none"> Measure the signal on EGS terminals 33 (+) and 34(-). Check Measured Power signal wiring to EGS. Check the setting for U_max (I_max) in POWER SENSOR DIAGNOSIS window in Diagnosis/Sensor menu.
32	Power sensor U_com mode high.	<ul style="list-style-type: none"> This can be due to galvanic problems. Connect a galvanic isolator between the EGS and the power signal. When an mA signal is used make sure it is grounded on one side. If the failure persists, replace the EGS unit.
40	Lambda sensor_1 low signal.	<ul style="list-style-type: none"> If no lambda sensor installed, open the LAMBDA DIFFERENCE DIAGNOSIS window in the Diagnosis menu. Switch off "Lambda difference check enable". Calibrate UEGO sensor at 4.50 V in ambient air. Measure the signal on EGS terminals 21 (+) and 22(-). Check the lambda sensor wiring to the EGS. Replace the UEGO sensor and/or UEGO controller. Check setting for U_min in LEAN SENSOR DIAGNOSIS window in Diagnosis/Sensor menu.

Malfunction	Description	Remedy
41	Lambda sensor_1 high signal.	<ul style="list-style-type: none"> • If no lambda sensor installed, open LAMBDA DIFFERENCE DIAGNOSIS window in DIAGNOSIS menu. Switch of "Lambda difference check enable". • Calibrate the UEGO sensor at 4.50 V in ambient air. • Measure the signal on EGS terminals 21 (+) and 22(-). • Check the lambda sensor wiring to the EGS. Replace the UEGO sensor and/or UEGO controller. • Check setting for U_max in LEAN SENSOR DIAGNOSIS window in Diagnosis/Sensor menu.
42	Lambda sensor_1 U_com mode high.	<ul style="list-style-type: none"> • Internal EGS failure. If the failure persists, replace the EGS unit.
60	MAT_1 PT 100 low resistance.	<ul style="list-style-type: none"> • Measure the PT-100 resistance (disconnect wiring from EGS before measuring). • Check the MAT sensor wiring to the EGS. Replace the MAT sensor. • Check setting for R_min in MAT SENSOR DIAGNOSIS window in Diagnosis/Sensor menu.
61	MAT_1 PT 100 high resistance.	<p>After the engine has stopped heat conduction can cause the MAT sensor temperature to increase to the engine jacket water temperature. Make sure that the R_max for the MAT sensor is set sufficiently high to prevent MAT alarms when the engine is stopped.</p> <ul style="list-style-type: none"> • Measure the PT-100 resistance (disconnect wiring from EGS terminals 37/38 before measuring). • Check the MAT sensor wiring to the EGS. • Replace the MAT sensor. • Check setting for R_max in MAT SENSOR DIAGNOSIS window in Diagnosis /Sensor menu.
70/73	Thermocouple_1/2 low signal.	<ul style="list-style-type: none"> • If no thermocouples installed, open the TEMP PROTECTION window in Protection menu. Switch off "Enable thermocouple". • Measure signal on EGS terminals 39/79 (+) and 40/80(-). • Check the thermocouple wiring to the EGS. Replace the thermocouple. • Check setting for U_min in the THERMOCOUPLE DIAGNOSIS window in Diagnosis/Sensor menu.

Malfunction	Description	Remedy
71/74	Thermocouple_1/2 high signal.	<ul style="list-style-type: none"> • If no thermocouples installed, open TEMP PROTECTION window in Protection menu. Switch off "Enable thermocouple". • Measure signal on EGS terminals 39/79 (+) and 40/80(-). • Check the thermocouple wiring to the EGS. Replace the thermocouple. • Check setting for U_max in THERMOCOUPLE DIAGNOSIS window in Diagnosis/Sensor menu.
72/75	Thermocouple_1/2 U_com mode high.	<ul style="list-style-type: none"> • Internal EGS failure. If the failure persists, replace the EGS unit.
80	CH4 sensor low signal.	<ul style="list-style-type: none"> • If CH4 input is not used, open the FUEL PARAMETERS window in Parameters menu, switch off "Measure CH4" and make sure correct fuel parameters are used. • Measure signal on EGS terminals 35 (+) and 36 (-). • Check the CH4 signal wiring to the EGS. • Check the CH4 analyzer for correct operation. • Check setting for U_min (I_min) in the CH4 SENSOR DIAGNOSIS window in Diagnosis/Sensor menu.
81	CH4 sensor high signal.	<ul style="list-style-type: none"> • If CH4 input is not used, open the FUEL PARAMETERS window in Parameters menu, switch off "Measure CH4" and make sure correct fuel parameters are used. • Measure signal on EGS terminals 35 (+) and 36 (-). Check the CH4 signal wiring to the EGS. • Check the CH4 analyzer for correct operation. • Check setting for U_max (I_max) in the CH4 SENSOR DIAGNOSIS window in Diagnosis/Sensor menu.
82	CH4 sensor U_com mode high.	<ul style="list-style-type: none"> • Internal EGS failure. This alarm can be caused by galvanic problems. Install a galvanic isolator between analyzer and EGS. When an mA signal is used make sure it is grounded on one side. If the failure persists, replace the EGS unit.
90	Desired power input low signal.	<ul style="list-style-type: none"> • Measure the desired power signal on EGS terminals 31 (+) to 32 (-). • Check desired power signal wiring. • Check the settings in the DESIRED POWER window under Parameters/Sensor menu. • Check the settings for U_min (I_min) in the DESIRED POWER DIAGNOSIS window under Diagnosis/Sensor menu.

Malfunction	Description	Remedy
91	Desired power input high signal.	<ul style="list-style-type: none"> • Measure the desired power signal on EGS terminals 31 (+) to 32 (-). • Check desired power signal wiring. • Check the settings in the DESIRED POWER window under Parameters/Sensor menu. • Check the settings for U_max (I_max) in the DESIRED POWER DIAGNOSIS window under Diagnosis/Sensor menu.
92	Desired power input U_com mode high.	<ul style="list-style-type: none"> • Internal EGS failure. This alarm can be caused by galvanic problems. Install a galvanic isolator between analyzer and EGS. When an mA signal is used make sure it is grounded on one side. If the failure persists, replace the EGS unit.
110	Aux 5 V ref low.	<ul style="list-style-type: none"> • If auxiliary 5 V reference output is not used, open the AUX 5V REF DIAGNOSIS window in Diagnosis/Sensor menu and switch off "Use auxiliary ref". • If auxiliary 5 V reference output is used, measure the current drawn from the EGS terminals 63 (+) and 64 (-), maximum current is 100 mA. • Check the wiring connected to EGS terminals 63 and 64. • Replace the EGS unit if necessary.
111	Aux 5 V ref high.	<ul style="list-style-type: none"> • If auxiliary 5 V reference output is not used, open the AUX 5V REF DIAGNOSIS window in Diagnosis/Sensor menu and switch off "Use auxiliary ref". • If auxiliary 5 V reference output is used, make sure there is no higher voltage supplied to the EGS terminals 63 (+) and 64 (-). • Replace the EGS unit if necessary.
112/114	MAP sensor_1/2 5 V ref low.	<ul style="list-style-type: none"> • If the MAP sensors don't use 5 V reference voltage, open MAP SENSORS DIAGNOSIS window in Diagnosis/Sensor menu and switch off "Use reference voltage". Check the MAP sensor wiring to the EGS. Check the MAP sensor operation, replace if necessary. Replace the EGS unit if necessary.
113/115	MAP sensor_1/2 5 V ref high.	<ul style="list-style-type: none"> • If the MAP sensors don't use 5 V reference voltage, open MAP SENSORS DIAGNOSIS window in Diagnosis/Sensor menu and switch off "Use reference voltage". • Check the MAP sensor wiring to the EGS. • Check the MAP sensor operation, replace if necessary. • Replace the EGS unit if necessary.

Malfunction	Description	Remedy
130	Closed loop corr>max.	<ul style="list-style-type: none"> • If closed loop becomes less than maximum value while engine is idling and EGS is set-up for GQCL the "Engine running time" may be set too low. A normal time is 100–200 seconds. • Check if power signal coming from generator or real power sensor scaling is still the same as during commissioning. • Check the TecJet(s) for correct operation. • Check the engine for correct operation. • Check the gas quality. • Check the CH4 analyzer for correct operation. • Check the CH4 signal and wiring. • Check closed loop limits in Gas Quality Closed Loop window in Parameters menu.
131	Closed loop corr<min.	<ul style="list-style-type: none"> • Check if power signal coming from generator or real power sensor scaling is still the same as during commissioning. • Check the TecJet(s) for correct operation. • Check the engine for correct operation. • Check the gas quality. • Check the CH4 analyzer for correct operation. • Check CH4 signal and wiring. • Check closed loop limits in GAS QUALITY CLOSED LOOP window in Parameters menu.
140	Lambda sensor not ready time out.	<ul style="list-style-type: none"> • If no lambda sensor installed, open the LAMBDA DIFFERENCE DIAGNOSIS window in Diagnosis menu. Switch off "Lambda difference check enable". • Measure signal on EGS terminals 21 (+) and 22(-). • Replace the UEGO sensor and/or controller. • Check setting for U_min, U_max and the time at "Malfunction if sensor not ready after:" in LEAN SENSOR DIAGNOSIS window in Diagnosis/ Sensor menu.
150	CAN controller error status.	<ul style="list-style-type: none"> • Makes sure the grounding between the EGS and TecJet is correct, and uses the special ground connections. Make sure the shield of the TecJet cable is connected to the EGS ground connection. • Check the CAN wiring. Make sure the 120 Ω "end of line" resistors are present. • Check CAN settings in the CAN Interface window in the Parameters menu. • Check CAN settings in TecJet(s) and FireFly. Check the TecJet(s) and FireFly for correct operation. • Disconnect the TecJet connector and check using an ohmmeter that its shield has no connection to the connector on the cable.

Malfunction	Description	Remedy
151	CAN controller bus off status.	<ul style="list-style-type: none"> Check the CAN wiring. Make sure the 120 Ω "end of line" resistors are present. Check CAN settings in the CAN Interface window in the Parameters menu. Check CAN settings in TecJet(s) and FireFly. Check the TecJet(s) and FireFly for correct operation.
160	PC-104 failure.	<ul style="list-style-type: none"> Check power supply and "fuel on" sequence, make sure power supply is present before "fuel on" is switched on and after "fuel on" is switched off. Internal EGS failure. If failure persists, replace the EGS unit.
161	PC-104 software hang.	<ul style="list-style-type: none"> See remedy malfunction 160.
162	Dual ported RAM failure.	<ul style="list-style-type: none"> See remedy malfunction 160.
170	Micro controller failure.	<ul style="list-style-type: none"> Check power supply and "fuel on" sequence, make sure power supply is present before "fuel on" is switched on and after "fuel on" is switched off. Internal EGS failure. If failure persists, replace the EGS unit.
171	Micro controller RAM failure.	<ul style="list-style-type: none"> See remedy malfunction 170.
172	EPROM checksum error.	<ul style="list-style-type: none"> See remedy malfunction 170.
173	E2prom checksum error.	<ul style="list-style-type: none"> See remedy malfunction 170.
174	Dual ported RAM failure.	<ul style="list-style-type: none"> See remedy malfunction 170.
175	Micro-controller software hang up.	<ul style="list-style-type: none"> See remedy malfunction 170.
180	Supply voltage low.	<ul style="list-style-type: none"> Check power supply voltage. Malfunction occurs if supply voltage is lower than 10 V during 1 minute.
181	Supply voltage high.	<ul style="list-style-type: none"> Check power supply voltage. Malfunction occurs if supply voltage is higher than 32 V during 1 minute.
182	Ambient temperature low.	<ul style="list-style-type: none"> Check temperature in control panel in which the EGS is installed. Malfunction occurs if temperature is lower than 0 $^{\circ}\text{C}$ (32 $^{\circ}\text{F}$) during 1 minute. Install heater if necessary.
183	Ambient temperature high.	<ul style="list-style-type: none"> Check temperature in control panel in which the EGS is installed. Malfunction occurs if temperature is higher than 70 $^{\circ}\text{C}$ (160 $^{\circ}\text{F}$) during 1 minute. Improve ventilation if necessary.
190	5 Volt digital low.	<ul style="list-style-type: none"> Internal EGS failure. If failure persists, replace the EGS unit.
191	5 Volt digital high.	<ul style="list-style-type: none"> See remedy malfunction 190.
192	+8.5 Volt supply low.	<ul style="list-style-type: none"> See remedy malfunction 190.
193	+8.5 Volt supply high.	<ul style="list-style-type: none"> See remedy malfunction 190.
194	+18 Volt supply low.	<ul style="list-style-type: none"> See remedy malfunction 190.
195	+18 Volt supply high.	<ul style="list-style-type: none"> See remedy malfunction 190.
196	-12 Volt supply low.	<ul style="list-style-type: none"> See remedy malfunction 190.
197	-12 Volt supply high.	<ul style="list-style-type: none"> See remedy malfunction 190.
198	V_high supply low.	<ul style="list-style-type: none"> See remedy malfunction 190.
199	V_high supply high.	<ul style="list-style-type: none"> See remedy malfunction 190.
200	SPC processor failure.	<ul style="list-style-type: none"> Internal EGS failure. If failure persists, replace the EGS unit.
201	SPC board RAM failure.	<ul style="list-style-type: none"> Internal EGS failure. If failure persists, replace the EGS unit.
202	SPC board Flash EPROM failure.	<ul style="list-style-type: none"> Internal EGS failure. If failure persists, replace the EGS unit.

Malfunction	Description	Remedy
203	No rpm signal on SPC board.	<ul style="list-style-type: none"> Open EGS unit and check flat-cable connection between main circuit board and Speed Control printed circuit board.
204	Speed deviation.	<ul style="list-style-type: none"> Check "breaker closed" signal on EGS pin 11. Make sure signal is low when engine is not running parallel to utility. Check settings in SPEED DEVIATION DIAGNOSIS window under Diagnosis menu, if necessary increase setting. Check Rated Speed setpoint in Parameters/Speed/Load Control/Speed Setpoints menu. <p>To reset this malfunction, engine must be stopped and "breaker closed" signal must be low.</p>
210	Desired speed input low signal.	<ul style="list-style-type: none"> Measure the desired speed signal on EGS terminals 31 (+) to 32 (-). Check desired speed signal wiring. Check the settings in the DESIRED SPEED window under Parameters/Sensor menu. Check the settings for U_min (I_min) in the DESIRED SPEED DIAGNOSIS window under Diagnosis/Sensor menu.
211	Desired speed input high signal.	<ul style="list-style-type: none"> Measure the desired speed signal on EGS terminals 31 (+) to 32 (-). Check desired speed signal wiring. Check the settings in the DESIRED SPEED window under Parameters/Sensor menu. Check the settings for U_max (I_max) in the DESIRED SPEED DIAGNOSIS window under Diagnosis/Sensor menu.
212	Desired speed input U_com. mode high	<ul style="list-style-type: none"> Internal EGS failure. This alarm can be caused by galvanic problems. Install a galvanic isolator between analyzer and EGS. Make sure that mA signal is grounded on one side. If the failure persists, replace the EGS unit.
220	Speed bias input low signal.	<ul style="list-style-type: none"> Measure the speed bias signal on EGS terminals 29 (+) to 30 (-). Check speed bias signal wiring. Check the settings in the SPEED BIAS window under Parameters/Sensor menu. Check the settings for U_min (I_min) in the SPEED BIAS DIAGNOSIS window under Diagnosis/Sensor menu.
221	Speed bias input high signal.	<ul style="list-style-type: none"> Measure the speed bias signal on EGS terminals 29 (+) to 30 (-). Check speed bias signal wiring. Check the settings in the SPEED BIAS window under Parameters/Sensor menu. Check the settings for U_max (I_max) in the SPEED BIAS DIAGNOSIS window under Diagnosis/Sensor menu.
222	Speed bias input U_com. mode high.	<ul style="list-style-type: none"> Internal EGS failure. This alarm can be caused by galvanic problems. Install a galvanic isolator between analyzer and EGS. Make sure that mA signal is grounded on one side. If the failure persists, replace the EGS unit.

Malfunction	Description	Remedy
230/240	TecJet_1/2 no communication.	<ul style="list-style-type: none"> • Check the TecJet software version. If version is 1.04 or lower, open the CAN Interface window in the Parameters menu and switch off the "Enable CAN protocol 98" option. If the TecJet has 1.05 or higher software version, the "Enable CAN protocol 98" option must be switched on. • Refer to TecJet manual for details. • Check CAN wiring. Make sure the 120 Ω "end of line" resistors are present. • Check CAN settings in the CAN INTERFACE window in the Parameters menu. • Check the CAN settings in the TecJet (see malfunction 150). • Check the TecJet for correct operation. • Refer to TecJet manual.
231/241	TecJet_1/2 zero gas pressure.	<ul style="list-style-type: none"> • Check the Delta_p in the TECJET BANK 1 window. • Check the gas supply to TecJet, measure actual pressures upstream and downstream of the TecJet. • Refer to TecJet manual.
232/242	TecJet_1/2 high delta pressure.	<ul style="list-style-type: none"> • Check the Delta_p in the TECJET BANK 1 window. • Check the actual pressures before and after the TecJet. • Check the setting of pressure regulator upstream of the TecJet. • Check the setting for Max. delta pressure in the TECJET DIAGNOSIS window in the Diagnosis menu and compare this setting with the TecJet specifications. • Refer to TecJet manual.
233/243	TecJet_1/2 flow not reached.	<ul style="list-style-type: none"> • Check that holes in the insert are not blocked due to oil coming from the breather system. • Check the gas supply to the TecJet, measure gas pressure upstream of the TecJet. Check the gas filter. • Check the gas supply for obstructions. • Check the engine output, make sure engine is not overloaded. • Check the engine for correct operation. • Check the gas quality. • Refer to TecJet manual.
234/244	TecJet_1/2 malfunction.	<ul style="list-style-type: none"> • Refer to TecJet manual.
235/245	TecJet_1/2 closed due to error.	<ul style="list-style-type: none"> • Refer to TecJet manual.

Malfunction	Description	Remedy
270	No plant communication.	<ul style="list-style-type: none"> • If plant communication is not used, open the PLANT COMMUNICATION SETUP window in the Parameter menu and switch off the "Enable plant communication" option. • Check the plant communication wiring. Check the settings for "Baud rate" and "Slave address" in the PLANT COMMUNICATION SETUP window in the Parameter menu. Check the time setting in the COMMUNICATION DIAGNOSTICS window in the Diagnosis menu and compare to the update rate of the plant communication. Check the device that is connected to EGS for plant communication for correct operation.
280/285	FireFly_1/2 no communication.	<ul style="list-style-type: none"> • Check the CAN wiring. Make sure the 120 Ω "end of line" resistors are present. • Check the CAN settings in the CAN Interface window in the Parameters menu. CAN setting in EGS = 1536, CAN setting in FireFly = 600. (See malfunction 150.)
281/286	FireFly_1/2 malfunction.	<ul style="list-style-type: none"> • Refer to FireFly manual 36106. • Refer to FireFly manual 36106.

Resetting the EGS

A reset of the EGS can be done in two ways depending on the setting:

Auto reset

The EGS resets itself when an alarm is no longer valid. For example, if the CH4 signal has decreased then an alarm is given. When the signal returns (e.g. after repairing the analyzer) the EGS waits 1 minute then switches to the OK status, and the engine can be restarted. The alarm, and the number of times it has occurred, is shown in "View" → "Diagnosis Alarm Status" or "Engine Alarm Status List". The alarm can only be cleared by using the Monitor program.

Manual Reset

Once an alarm has occurred the EGS switches to the alarm state and stays in that state, even if the alarm is removed. This is enabled in "Diagnosis" → "Status" → "Reset Options". Resetting the EGS can only be done using the Monitor program, or externally by supplying a current of more than 10 mA to terminal 71.

A 24 Vdc logical signal can also be used by configuring analog input 1 ("Parameters" → "Sensor" → "Universal Input 1") as an mA input. Use an external 1k8 Ω resistor in series on terminal 71 to make a 13 mA signal.

Chapter 9. PASTOR

Introduction

The software PASTOR (Prime-mover Angular-speed Stability MoniTOR) is a part of the EGS-01 control module, and it is built-in as the “misfire detection system”. It can be found under the “Protection” menu. The software PASTOR replaces the previously-used analog PASTOR circuit board. PASTOR measures the irregularity of the engine speed, caused by every individual combustion cycle. When this irregularity level exceeds an error limit, the alarm “engine unstable” is given. If activated, the EGS-01 control can shutdown the engine.

A highly irregular signal can be caused by ignition problems (spark plugs, coils, extenders, HT-leads, wiring, etc.) or by mechanical failure of the engine. Also an erratic A/F-ratio (too lean) can cause a misfire and a PASTOR alarm.

The PASTOR alarm prevents the engine running in an overload or over-fuelled condition, caused by one or more failed cylinders. On applications with a two-way or three-way catalyst the PASTOR system also protects the catalyst from over-heating caused by unburnt mixture which will be burnt in the catalyst.

IMPORTANT

When using the “Gas Quality Closed Loop” algorithm, the PASTOR system must be activated to prevent the engine running too rich if a cylinder failure occurs. Specifically at landfill applications where the amount of closed loop cannot be limited too much, the PASTOR is very important.

Knocking combustion (detonation) will not be detected by the PASTOR system. However knock detection is possible with the FireFly system, which can be connected to the EGS-01 control.

Basic Irregularity $|dn/dt|$

Internal combustion engines which use the Otto or the Diesel cycle do not have continuous combustion like turbines. The speed of the flywheel increases and decreases all the time, even when the engine runs parallel to the grid, due to the force of each individual combustion. This irregularity is calculated from the speed signal and is called $|dn/dt|$ and the units are in Hz/s.

When an engine runs with correct A/F-ratio and correct spark advance, and all cylinders are firing normally, we call the irregularity “the basic irregularity”. The level of this irregularity depends on the engine and its application (number of cylinders, firing order, island or parallel operation, inertia of the engine plus generator, and lean or stoichiometric mixture) and of the so called “sample divider” (see next section).

Sample Divider

Since the EGS control measures the speed every 5 ms (at 200 Hz) it can occur that the EGS is measuring the $|dn/dt|$ of the combustion itself, depending on the number of cylinders and the firing order. To overcome this phenomena, it is necessary to slow down the sample rate using the sample divider. In practice the optimal value for a specific engine type has to be found, and this value is usually between 1 and 4.

$|dn/dt|$ Filter

To avoid erratic alarms caused by, for example, block loads or noise, the $|dn/dt|$ signal is (low pass) filtered. A practical filter value is 10 seconds.

Software PASTOR Commissioning

It is important that the engine is operating fully satisfactorily and with the correct NO_x during the adjustments to PASTOR.

If you already know the optimal sample divider for this engine, go to Setting the Limits Versus Load below.

IMPORTANT

During commissioning disable the “shutdown” function on the PASTOR alarm.

Finding the Optimal Sample Divider

WARNING

HIGH VOLTAGE—Modern ignition systems can produce very high voltages, even on the primary side, which can be dangerous. Take extra care when working on or near an ignition system.

WARNING

A mounted oxidation catalyst can easily be destroyed by forcing the engine to misfire. The unburnt fuel mixture will react with the catalytic converter, thus causing the temperature to rise dramatically.

1. Install switch in the primary side of one coil to simulate misfire and make sure that the software PASTOR alarm is inactive during commissioning.
2. Adjust the $|dn/dt|$ filter to 10 seconds.
3. Run the engine at full load and measure the $|dn/dt|$ when the engine runs on all cylinders. Compare this with the $|dn/dt|$ when one cylinder is not firing. Do this with different sample divider values.
4. Select the sample divider which gives the biggest difference between normal running and running with one cylinder missing, usually a value between 1 and 4.

Setting the Limits Versus Load

In the “Pastor” window (under the Protection Menu) the alarm limits for the $|dn/dt|$ versus load can be set. There is a separate table for “island operation” and a table for running parallel “on the grid”.

Set the software PASTOR:

1. Run a few different load-steps, e.g. the load values of the software PASTOR table, with the optimal sample divider value (see previous section) and a $|dn/dt|$ filter value of 10 s.
2. Make notes of the $|dn/dt|$ at normal running and the $|dn/dt|$ with one cylinder "failed".
3. Choose alarm limits for every load somewhere in between the two values.

Probably some field experience is needed to select the correct limit values.

Example

At 100% Load:

Divider	Normal running engine	1 cylinder misfire
	dn/dt	dn/dt
2	3.4–3.8	5.7–6.3
3	2.6–2.7	5.7–5.9
4	1.9–2.1	5.4–5.7
5*	1.8–1.9*	5.2–5.6*
6	1.7–1.6	5.0–4.9
7	1.6–1.7	4.6–4.7
8	1.5–2.0	4.1–5.8

* Sample 5 gives the biggest difference between normal running engine and engine with 1 cylinder misfiring.

Set sample divider at the ideal value found at 100% load (5 in this example). Measure the difference:

Load	Divider	Normal running engine	1 cylinder misfire
		dn/dt	dn/dt
80%	5	1.6–1.5	4.4–4.6
60% *	5	1.4–1.3	3.4–3.5
50% *	5	1.1–1.2	2.5–2.4

* Set trip values between normal running value and misfire value.

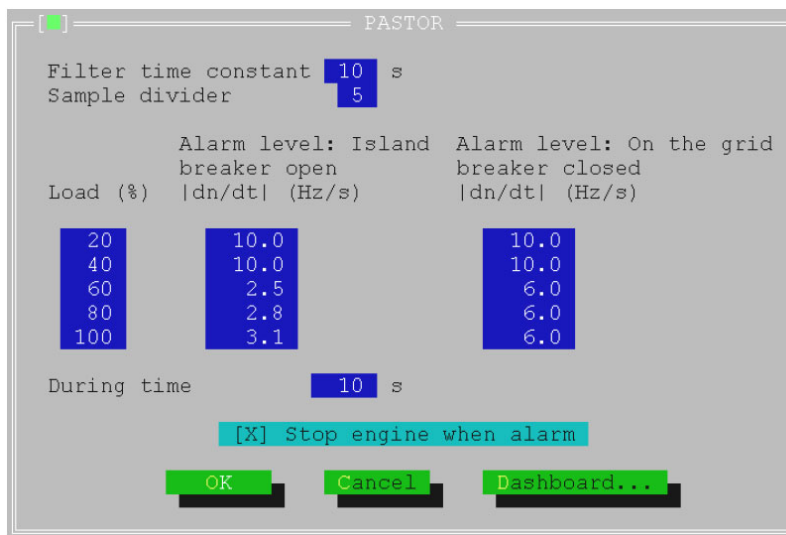


Figure 9-1. PASTOR Window

Testing the Software PASTOR

The software PASTOR will give an alarm, or an alarm plus “shut down”, when the $|dn/dt|$ signal is present for longer than a programmable time over the programmed limit.

Enter a useful time limit, such as between 10 to 15 seconds.

Now activate the “shut down function” in the PASTOR window, and run the engine on partial load. When you “fail” one cylinder, the engine will be stopped by the EGS control after the error time has elapsed.

Alarms will be stored and can be viewed in the “View / Engine Alarm Status” window.

The software PASTOR is now correctly set-up.

If in operation an “Engine Unstable” alarm occurs, please look very carefully at the engine and the A/F-ratio.

IMPORTANT

It should not be necessary to re-adjust the $|dn/dt|$ alarm limit in case of an alarm. Try to find the reason for the high $|dn/dt|$.

Chapter 10.

FireFly™

Introduction

This chapter describes the combination of the FireFly with the EGS-01 control. More information about the FireFly can be found in Woodward manual 36106.

Knocking combustion (or detonation) is a type of combustion which results in very-high peak pressure in the combustion chamber, and which will damage the engine very quickly. Detonation should normally always be avoided, and the EGS-01 control helps prevent it.

For example, detonation can be caused:

- Low methane number of the fuel
- Engine runs too rich
- Engine is overloaded or overheated
- Incorrect ignition timing
- Deposits in the combustion chamber, like ash from the lubricant or fuel

The EGS-01 control can protect an engine from detonation using a knock detection system—the FireFly. This system is not a standard part of the EGS delivery like the PASTOR and must be ordered separately.

Detonation Detection Module (FireFly)

The FireFly is a detonation detecting and controlling device which can detect knock on between 4 to 16 cylinders. It uses up to 8 piezo-electric knock sensors. If your engine needs more than 8 knock sensors a second FireFly can be used.

The FireFly forms an ideal combination with the EGS-01 control, but can also work as a stand-alone system, as described in the FireFly manual. The knock controlling strategy is located in the FireFly, and not in the EGS control. The FireFly is connected to the EGS-01 control by the (TecJet) CAN bus. Additionally, "Protocol 98" should be enabled under Parameters / CAN Interface to enable communication between the FireFly and the EGS-01 control.

The FireFly requires the following signals:

- Engine speed (rpm)
- Engine phase (camshaft sensor)
- Knock sensor signals
- Measured engine power (through the CAN bus)

The speed signal can be shared with the MPU of the EGS, although the use of a separate MPU is recommended.

The FireFly can control detonation by retarding the ignition timing through its analog output or RS-422/Modbus® * communication link. Depending on the selected strategy, the FireFly can also reduce the engine load by a request to a "higher system", such as the plant control, through the RS-422/Modbus. Alternatively, the FireFly can reduce the load by a request to the EGS-01 through the CAN bus.

*—Modbus is a trademark of Modicon, Inc.

Alternatively the FireFly can indicate the “engine knock severity” by an analog output or through the RS-422/Modbus communication link, to allow another system to control ignition timing and/or load.

Additionally, a relay output is available for shutdown and fault indication.

CAN Communication with the EGS-01 Control

The FireFly is the only extra system that can be connected to the (TecJet) CAN communication bus. All other communication between EGS-01 and, for example, the plant control is only possible through the EGS-01 RS-232/Modbus “plant communication” connection.

As mentioned before, the knock strategy which controls the detonation detection is located in the FireFly, which means that the FireFly can change system parameters like the ignition timing. Since the total efficiency (and the NOx emission) decreases when ignition timing is retarded, the EGS-01 needs to “know” when the ignition is retarded. In GQCL, no information about the ignition timing will make the engine richer until the NOx-emission is almost back to the level before retarding. For this reason the total efficiency table/map in the EGS-01 is a 3-D table, versus load% and actual ignition timing. Changing the total efficiency at the retarded timing makes the emission low again.

When using variable ignition timing, the EGS-01 needs to “know” the actual timing and the 3-D total efficiency table should be filled out completely. This can be done by retarding the ignition “manually” using the FireFly monitor software.

The EGS-01 receives the following information from the FireFly (simplified) through the CAN bus:

- Degrees of ignition retarding.
- Amount of desired load reduction.
- FireFly status (including “shut down” command).
- (Engine knock severity).

The EGS-01 sends the measured engine power to the FireFly (simplified).

Knock Strategy of the FireFly

There are four selectable strategies to use when controlling the detonation of a stationary engine. Please refer to the FireFly manual 36106 for more detailed information about these strategies.

Chapter 11.

Service Options

Product Service Options

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

- Consult the troubleshooting guide in the manual.
- Contact the manufacturer or packager of your system.
- Contact the Woodward Full Service Distributor serving your area.
- Contact Woodward technical assistance (see “How to Contact Woodward” later in this chapter) and discuss your problem. In many cases, your problem can be resolved over the phone. If not, you can select which course of action to pursue based on the available services listed in this chapter.

OEM and 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 **Recognized Turbine Retrofitter (RTR)** is an independent company that does both steam and gas turbine control retrofits and upgrades globally, and can provide the full line of Woodward systems and components for the retrofits and overhauls, long term service contracts, emergency repairs, etc.

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

Woodward Factory Servicing Options

The following factory options for servicing Woodward products are available through your local Full-Service Distributor or the OEM or Packager of the equipment system, based on the standard Woodward Product and Service Warranty (5-01-1205) that is in effect at the time the product is originally shipped from Woodward or a service is performed:

- 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 is a flat-rate program and includes the full standard Woodward product warranty (Woodward Product and Service Warranty 5-01-1205).

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.

Charges for the Replacement/Exchange service are based on a flat rate plus shipping expenses. You are invoiced the flat rate replacement/exchange charge plus a core charge at the time the replacement unit is shipped. If the core (field unit) is returned within 60 days, a credit for the core charge will be issued.

Flat Rate Repair: Flat Rate Repair is available for the majority of standard 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. All repair work carries the standard Woodward service warranty (Woodward Product and Service Warranty 5-01-1205) on replaced parts and labor.

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 and carry with it the full standard Woodward product warranty (Woodward Product and Service Warranty 5-01-1205). 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 offers various Engineering Services for our products. For these services, you can contact us by telephone, by email, or through the Woodward website.

- 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. Emergency assistance is also available during non-business hours by phoning Woodward and stating the urgency of your problem.

Product Training is available as standard classes at many of our worldwide locations. We also offer customized classes, which can be tailored to your needs and can be held at one of our 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 many of our worldwide locations or 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 us via telephone, email us, or use our website and reference www.woodward.com/support, and then **Customer Support**.

How to Contact Woodward

For assistance, call one of the following Woodward facilities to obtain the address and phone number of the facility nearest your location where you will be able to get information and service.

Electrical Power Systems		Engine Systems		Turbine Systems	
Facility	Phone Number	Facility	Phone Number	Facility	Phone Number
Australia	+61 (2) 9758 2322	Australia	+61 (2) 9758 2322	Australia	+61 (2) 9758 2322
Brazil	+55 (19) 3708 4800	Brazil	+55 (19) 3708 4800	Brazil	+55 (19) 3708 4800
China	+86 (512) 6762 6727	China	+86 (512) 6762 6727	China	+86 (512) 6762 6727
Germany:		Germany:			
Kempen	+49 (0) 21 52 14 51	Stuttgart	+49 (711) 78954-0		
Stuttgart	+49 (711) 78954-0	India	+91 (129) 4097100	India	+91 (129) 4097100
India	+91 (129) 4097100	Japan	+81 (43) 213-2191	Japan	+81 (43) 213-2191
Japan	+81 (43) 213-2191	Korea	+82 (51) 636-7080	Korea	+82 (51) 636-7080
Korea	+82 (51) 636-7080	The Netherlands	+31 (23) 5661111	The Netherlands	+31 (23) 5661111
Poland	+48 12 618 92 00	United States	+1 (970) 482-5811	United States	+1 (970) 482-5811
United States	+1 (970) 482-5811				

You can also contact the Woodward Customer Service Department or consult our worldwide directory on Woodward's website (www.woodward.com/support) for the name of your nearest Woodward distributor or service facility.

For the most current product support and contact information, please refer to the latest version of publication **51337** at www.woodward.com/publications.

Technical Assistance

If you need to telephone for technical assistance, you will need to provide the following information. Please write it down here before phoning:

General

Your Name _____

Site Location _____

Phone Number _____

Fax Number _____

Prime Mover Information

Engine/Turbine Model Number _____

Manufacturer _____

Number of Cylinders (if applicable) _____

Type of Fuel (gas, gaseous, steam, etc) _____

Rating _____

Application _____

Control/Governor Information

Please list all Woodward governors, actuators, and electronic controls in your system:

Woodward Part Number and Revision Letter

Control Description or Governor Type

Serial Number

Woodward Part Number and Revision Letter

Control Description or Governor Type

Serial Number

Woodward Part Number and Revision Letter

Control Description or Governor Type

Serial Number

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.

Appendix A.

EGS-01 Technical Specifications

Weight	2.87 kg (6.33 lb)
Power Supply Rating	10–32 Vdc nominal (7 V minimum)
Ambient Temperature Range	0 to 55 °C
Humidity/Moisture	85 % , IP20
EMI/RFI	Heavy Industrial, EN50081-2/EN50082-2 ISO 7637-2 (24 V system)
Analog Inputs	
Lambda_1 thru Lambda_3	0–2.5 V / 0–5 V
Map_1 thru Map_2	0–5 V / 0–10 V / 0–20 mA
TPS	0–5 V / 0–10 V / 0–20 mA
Detonation_1 thru Detonation_2	0–5 V / 0–10 V / 0–20 mA
Power	0–5 V / 0–10 V / 0–20 mA
CH4	0–5 V / 0–10 V / 0–20 mA
Analog_1 thru Analog_2	0–5 V / 0–10 V / 0–20 mA
For all analog inputs:	Accuracy 1 % of full scale / Linearity 0.1 % Resolution 12 bit / Stability 1 % per year Common mode voltage. Every input has an input range of –7 V up to + 14 V for the high and the low input.
PT-100 inputs	Resolution 11 bit over 120 °C Accuracy 0.5 % of 100 °C
Thermocouple Inputs	Range –40 to +40 mV Resolution 12 bit Accuracy
Phase Inputs	Maximum frequency 100 Hz Block signal: Turn-over 0 V / Hysteresis 0.2 V Min. amplitude 6 V / Max. amplitude 32 V Common mode 10 V on the Io input. AC signal: Turn-over 0 V Min. amplitude 6 V / Max. amplitude 60 V Common mode 10 V on the Io input. Bobbin signal: Turnover 100–150 V / Max. voltage 400 V
Speed Input	Accuracy 0.01 % Maximum frequency 9 kHz Block signal: Turn-over 2.5 V / Hysteresis 0.2 V Min. amplitude 5 V / Max. amplitude 32 V Common mode 10 V on the Io input AC signal: Min. amplitude 6 V / Max. amplitude 60 V Turnover 0 V Common mode 10 V on the Io input
Digital Inputs	Logic 0 → 0–6 V Logic 1 → 4–32 V
Relay	Current 1 A
TecJet Power Supply	Maximum current peak 10 A during 1 second. Continuous 6 A
TecJet on/off	Maximum current 10 mA
Heater Outputs	Duty cycle 0–100 % / Frequency f =25 Hz Accuracy 1 % / Resolution 8 bit Peak current 20 A during 1 second (one single peak) / Nominal current 5 A
PWM Output	Current 1.5 A / Frequency 1000 Hz Resolution 12 bit / Accuracy 0.1 % Push-pull
5 V Reference Output	Accuracy 0.5 % / Current 70 mA
RS-232 Cable	Plant communication port max. 9600 baud

Sensor Specifications

Woodward MAP Sensors	The Woodward MAP sensors have better temperature and EMC specifications than standard sensors. USE OTHER SENSORS AT YOUR OWN RISK!
MAT Sensor Installation	PT100 sensor (3 m silicon cable) (1/4" NPT) Suitable for installation on the engine. Mounting in inlet manifold after throttle valve. Sensor tip must be positioned sufficiently far into the inlet manifold, to ensure that the correct mixture temperature is measured.
Electrical connections	Fixed mounted 3 core silicon cable 3 m. Core with the brown color is the PT100 signal. The cores gray and black form the reference loop. Maximum cable length between sensor and EGS is 20 m.
Maximum temperature range	-50 °C to +200 °C
Maximum ambient temperature, cable	150 °C

Appendix B. Software Upgrade

Introduction

This chapter contains the software upgrade instructions for the EGS control software and the speed control software.

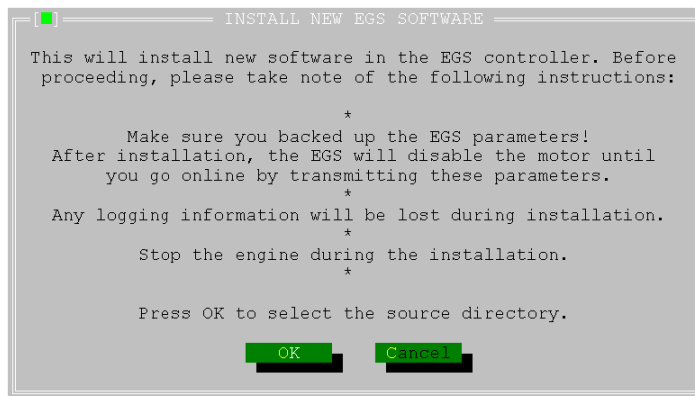
IMPORTANT

The speed control software upgrade is only applicable for an EGS with speed and load control.

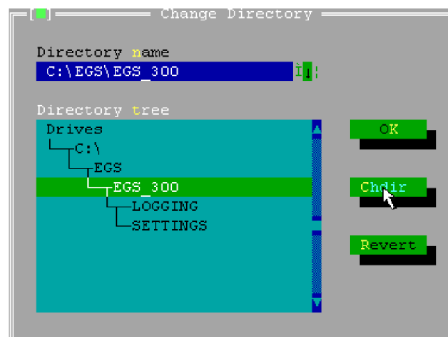
EGS Software Upgrade

Perform the following steps to upgrade the EGS software:

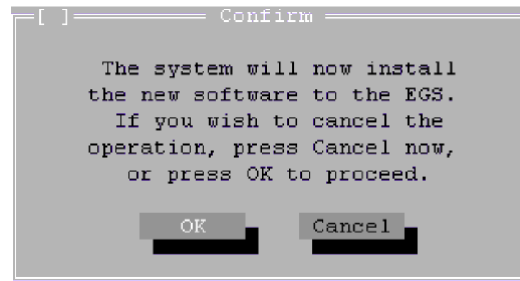
1. Stop the engine.
2. Make sure the EGS is connected to the power supply and the “fuel on” signal is present.
3. Go on-line with the same EGS monitor version as software version in the EGS.
4. Save the EGS settings file on the PC.
5. Go off-line and close the EGS monitor.
6. Start the new EGS monitor version, don’t go on-line.
7. Go to the SYSTEM menu and choose “Install EGS Software”. The information window as shown below will appear. Press OK.



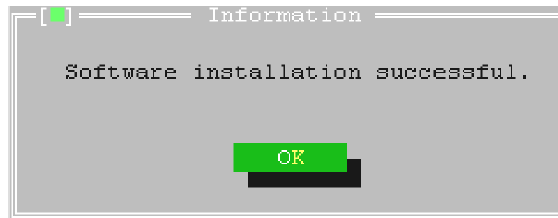
8. In the directory tree, choose the directory containing the new version EGSAPP.EXE and press the “Chdir” button. In the “Directory name” box you will now see the directory you have chosen.



9. Press "OK" button to start the software download process. After a few seconds the Confirm window appears for a last confirmation. Press the "OK" button.



10. After software download has been completed successfully, the Information window will appear. Press the "OK" button.



11. Open the old settings file using the new version monitor program.
12. Check all the settings in the Parameters, Protection and Diagnosis windows. Some settings may have been changed due to changes in the new software.
13. Go on-line by sending the settings file from the PC to the EGS.

Speed Control Software Upgrade

This upgrade is only applicable for an EGS with speed and load control. Perform the following steps to upgrade the EGS software (refer to Figures B-1 and B-2):

1. Stop the engine.
2. Remove the power supply and the "fuel on" signal from the EGS.
3. Remove the four small screws and the cover from the EGS.
4. Locate the speed control board in the top right corner of the EGS (with the EGS connectors pointing towards you). On the board look for the type number 5550A or 5550B. If the board is type number 5550A the software can only be upgraded to software version 1.09 (please contact Woodward if a later upgrade is necessary).
5. Locate board PC104 below the speed control board. Disconnect the small ribbon cable, which connects between the EGS board and board PC104, from board PC104. Connect the cable to the speed control board (this connects the speed control board to the communication port).
6. Connect the PC to the EGS plant communication port.
7. Start the PC in MS-DOS mode. Go to the directory that contains the new software.
8. Connect the EGS to the power supply and make sure the "fuel on" signal is present. Ignore the red alarm LED.
9. Run the "send.bat" file. Change the COM port if necessary.
10. When the software is uploaded remove the power supply and the "fuel on" signal from the EGS. Disconnect the PC from the EGS plant communication port.
11. Disconnect the small flat cable from the speed control board and connect it to board PC104.

12. Install the cover and the screws on the EGS.
13. Make sure all system connectors are correctly connected to the EGS. Supply power to the EGS.
14. Check the EGS for correct calibration and operation.

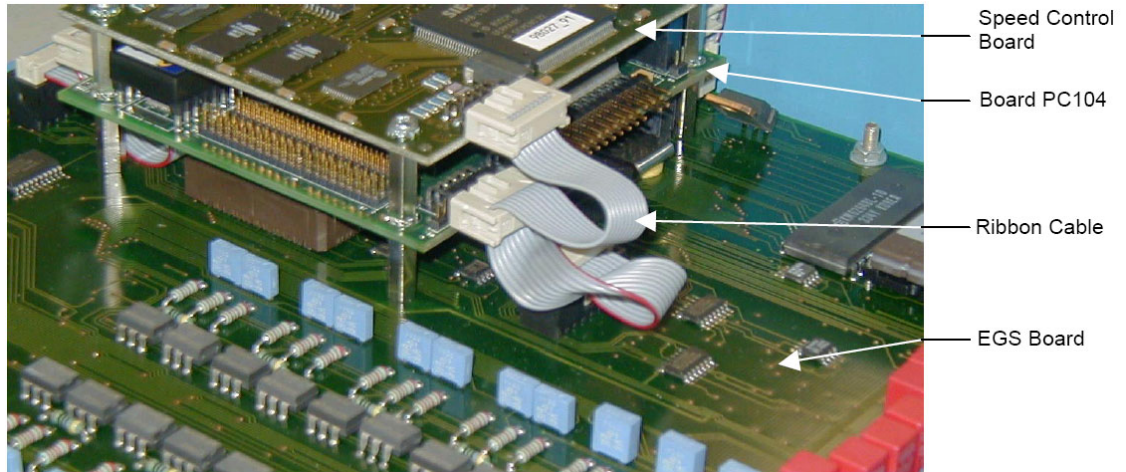


Figure B-1. Location of EGS, PC104 and Speed Control Boards

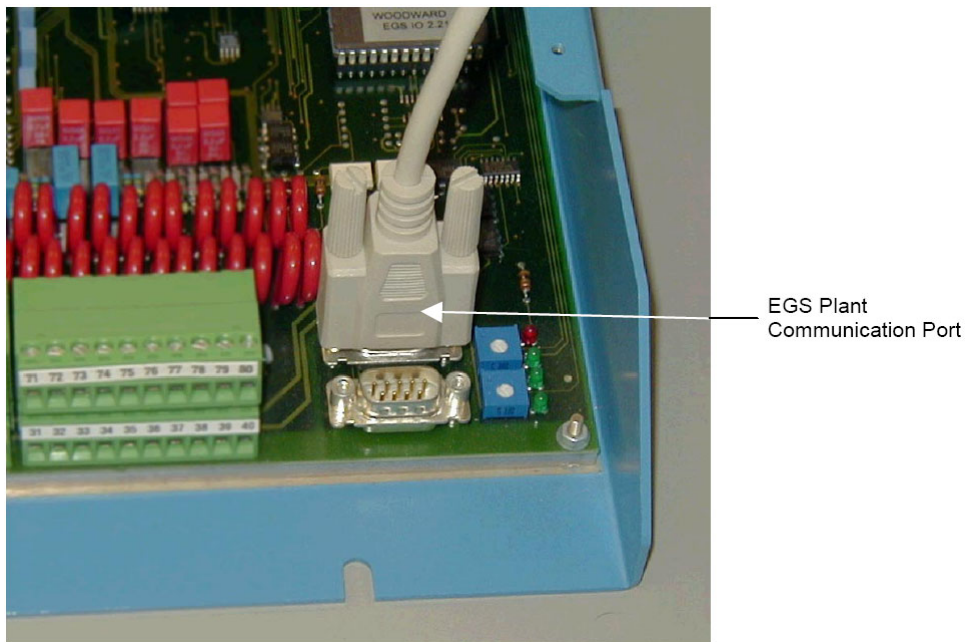


Figure B-2. Location of EGS Plant Communication Port

Appendix C.

List of Abbreviations

A/F ratio	Air/Fuel ratio
Ccorr	See Mono Engine & Lambda Control section in Chapter 3
CH ₄	Methane
dMAP/dt	Delta Manifold Air Pressure / time
DOS	Disk Operating System
dT	Delta Temperature
EGS	Engine Gas-metering System
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
FGP	Fuel Gas Pressure
FGT	Fuel Gas Temperature
GQCL	Gas Quality Closed Loop
hPa	hectopascal
HT	High Tension
Inlet Temp	Inlet Temperature
I	Air/Fuel ratio
kPa	kilopascal
M	See Mono Engine & Lambda Control section in Chapter 3
MAP	Manifold Air Pressure
MAT	Manifold Air Temperature
MPU	Magnetic Pickup
PASTOR	Prime-mover Angular-speed Stability moniTOR
PC	Personal Computer
PCB	Printed Circuit Board
Pcal	See Mono Engine & Lambda Control section in Chapter 3
Pmech	See Mono Engine & Lambda Control section in Chapter 3
PID	Proportional Integral Derivative
PWM	Pulse Width Modulation
Qgn	See Mono Engine & Lambda Control section in Chapter 3
Qmn	See Mono Engine & Lambda Control section in Chapter 3
Ref	Reference
RFI	Radio Frequency Interference
TDC	Top Dead Center
T-type	Thermocouple type
UEGO	Universal Exhaust Gas Oxygen
V	See Mono Engine & Lambda Control section in Chapter 3
Ve	Volumetric Efficiency

We appreciate your comments about the content of our publications.

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