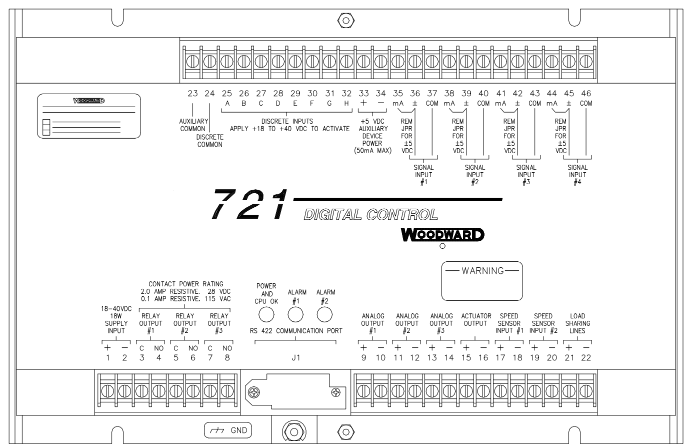
WOODWARD

Product Manual 02707
(Revision B)
Original Instructions



721 Digital Speed Control for Reciprocating Engines

9905-291, -381
9906-224, -226 (for GL, DNV, ABS)
9907-206, -207 (EU Directive Compliant; UL Listed E97763)

Installation and Operation Manual

IMPORTANT

DEFINITIONS

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

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

WARNING

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.

This publication may have been revised or updated since this copy was produced. To verify that you have the latest revision, be sure to check the *publications page* on the Woodward website:

www.woodward.com/publications

The current revision and distribution restriction of all publications are shown in manual *26311*.

The latest version of most publications is available on the *publications page*. If your publication is not there, please contact your customer service representative to get the latest copy.

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*.

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Regulatory Compliance

721 part numbers 9907-206 and 9907-207 are EU Directive Compliant (CE Mark) as follows:

In accordance with the EMC Directive 89/336/EEC and its amendments, this controlling device, manufactured by the Woodward Governor Company, is applied solely as a component to be incorporated into an engine prime mover system. Woodward declares that this controlling device complies with the requirements of EN50081-2 and EN50082-2 when put into service per the installation and operating instructions outlined in the product manual.

NOTICE: This controlling device is intended to be put into service only upon incorporation into an engine prime mover system that itself has met the requirements of the above Directive and bears the CE mark.

721 part numbers 9907-206 and 9907-207 are UL Listed, and are suitable for use in Class I, Division 2, Groups A, B, C, and D, or non-hazardous locations only.

WARNING

EXPLOSION HAZARD—Substitution of components may impair suitability for Class I, Division 2.

Do not disconnect equipment unless power has been switched off or the area is known to be non-hazardous.

AVERTISSEMENT

RISQUE D'EXPLOSION—La substitution de composants peut rendre ce matériel inacceptable pour les emplacements de Classe 1, Division 2.

Avant de déconnecter l'équipement, coupler le courant ou s'assurer que l'emplacement est désigné non dangereux.

IMPORTANT

Installation wiring must be in accordance with Class I, Division 2 wiring methods in Article 501-4(b) of the NEC, and in accordance with the authority having jurisdiction.

IMPORTANT

All peripheral equipment must be suitable for the location in which used.

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 the following Woodward 721 Digital Speed Control models:

9905-291 low voltage [replaced by 9907-206]
9905-381 high voltage [replaced by 9907-207]
9906-224 low voltage, GL, DNV, ABS
9906-226 high voltage, GL, DNV, ABS
9907-206 low voltage, CE Mark, UL Listed
9907-207 high voltage, CE Mark, UL Listed

Application

The 721 Digital Speed Control controls the speed and load of reciprocating engines in generator set service, including those with flexible couplings (see Figure 1-1). The control includes inputs for two magnetic pickups (MPUs) for monitoring flexible coupling torsionals, an input for a 4 to 20 mA remote speed or load setting, an input for output fuel limiting, an internal speed reference for local control of speed, and an input for a KW load sensor and load sharing connections for load sharing applications.

The 721 control system includes:
- a 721 Digital Speed Control;
- an external power source;
- one or two speed-sensing devices (as required);
- a proportional actuator to position the fuel rack;
- a terminal for adjusting control parameters;
- an optional KW load sensing device;
- an optional boost pressure or rack position sensing device for fuel limiting.

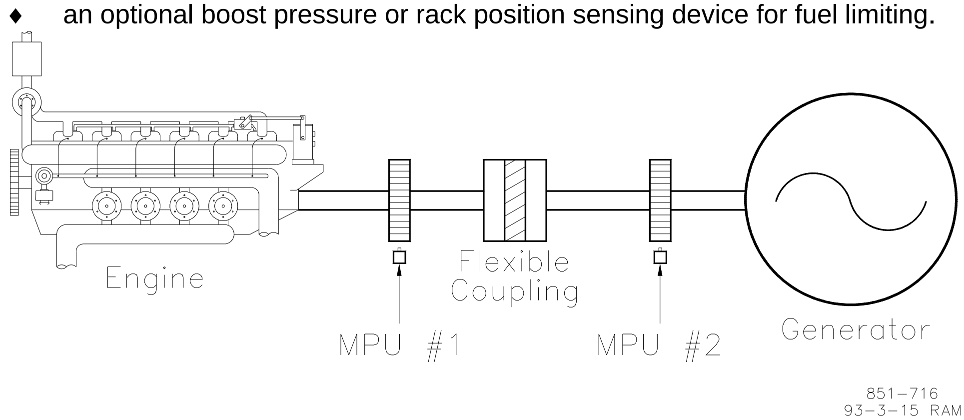

Figure 1-1. Flexible Coupled Generator Set

The 721 control (Figure 1-2) consists of a single printed circuit board in a sheet-metal chassis. Connections are via three terminal strips and a 9-pin subminiature D connector.

Control Options

The 721 control requires the following power supply input voltages, with 18 watts as the nominal power consumption at rated voltage:

- low voltage—18–32 Vdc (24 Vdc nominal);
- high voltage—88–132 Vac 45–65 Hz (120 Vac nominal) or 90–150 Vdc (125 Vdc nominal).

Discrete input voltages provide on/off command signals to the electronic control, such as Raise Speed/Load, Lower Speed/Load, etc. Each discrete input requires 10 mA at its 24 Vdc nominal voltage rating (for 24 volt switching logic).

Other control options are:

- 0–20 mA or 0–200 mA actuator output signals;
- tandem actuator outputs.

The minimum frequency for steady state speed control is 400 Hz. For more information, see the control specifications on the inside back cover of this manual.

721 Digital Speed Control Accessories

Hand Held Programmer (Figure 1-3) is used for adjusting the 721 control. It plugs into the serial port of the control.

SPM-A Synchronizer, for synchronizing the generator phase to that of the power bus. The synchronizer generates a close generator breaker signal to parallel the generator with the power bus.

Real Power Sensor, for load sharing or droop-parallel generator applications.

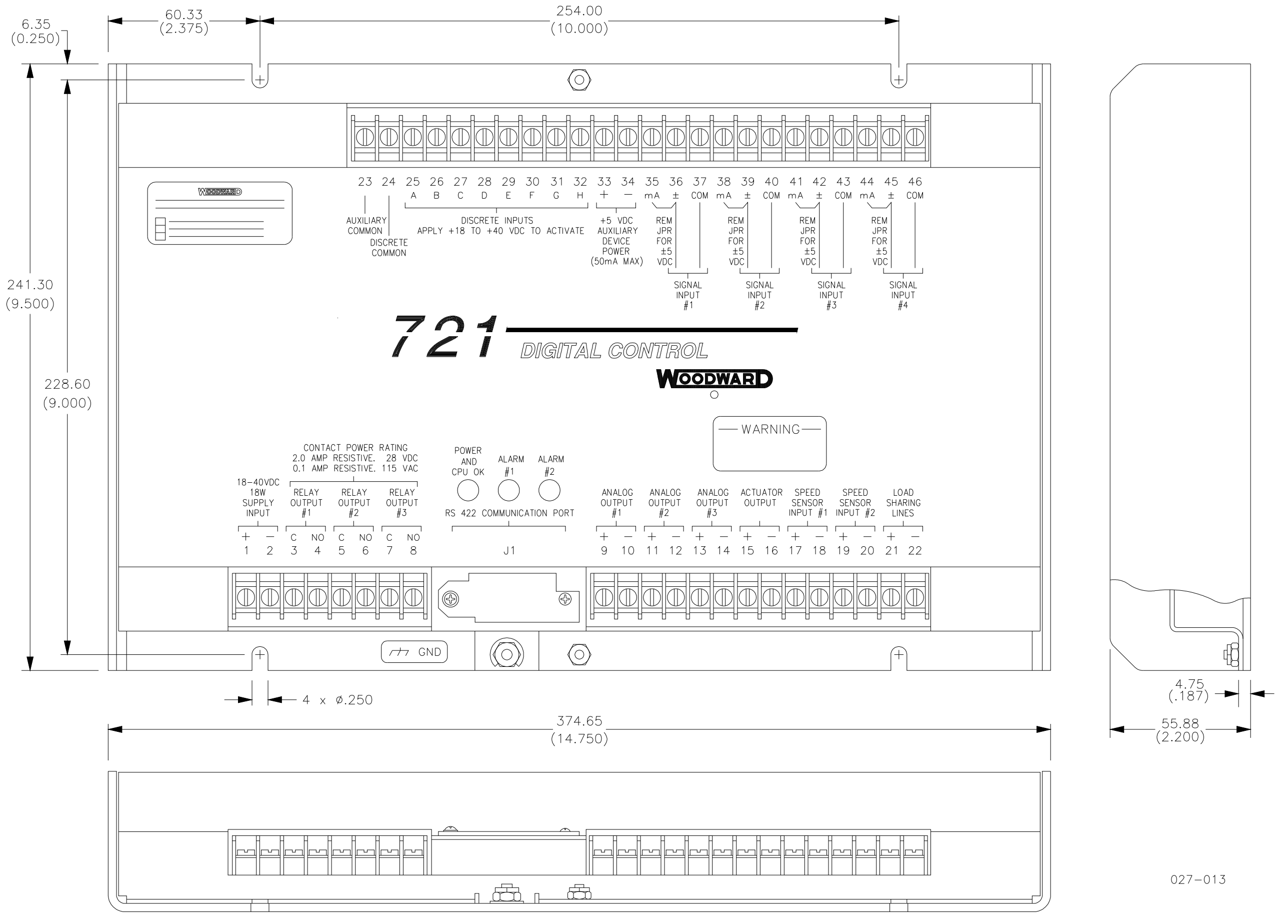

Figure 1-2. 721 Digital Speed Control

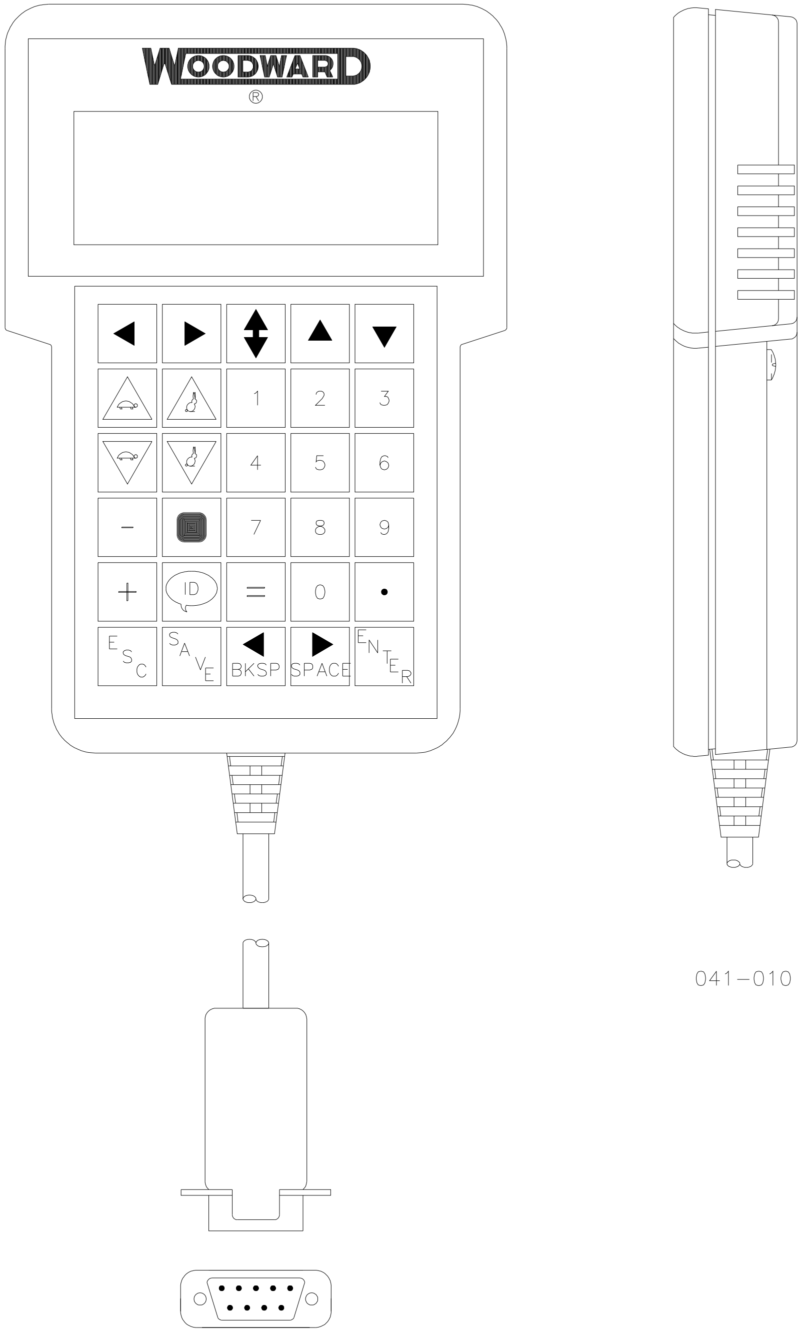

Figure 1-3. Hand Held Programmer

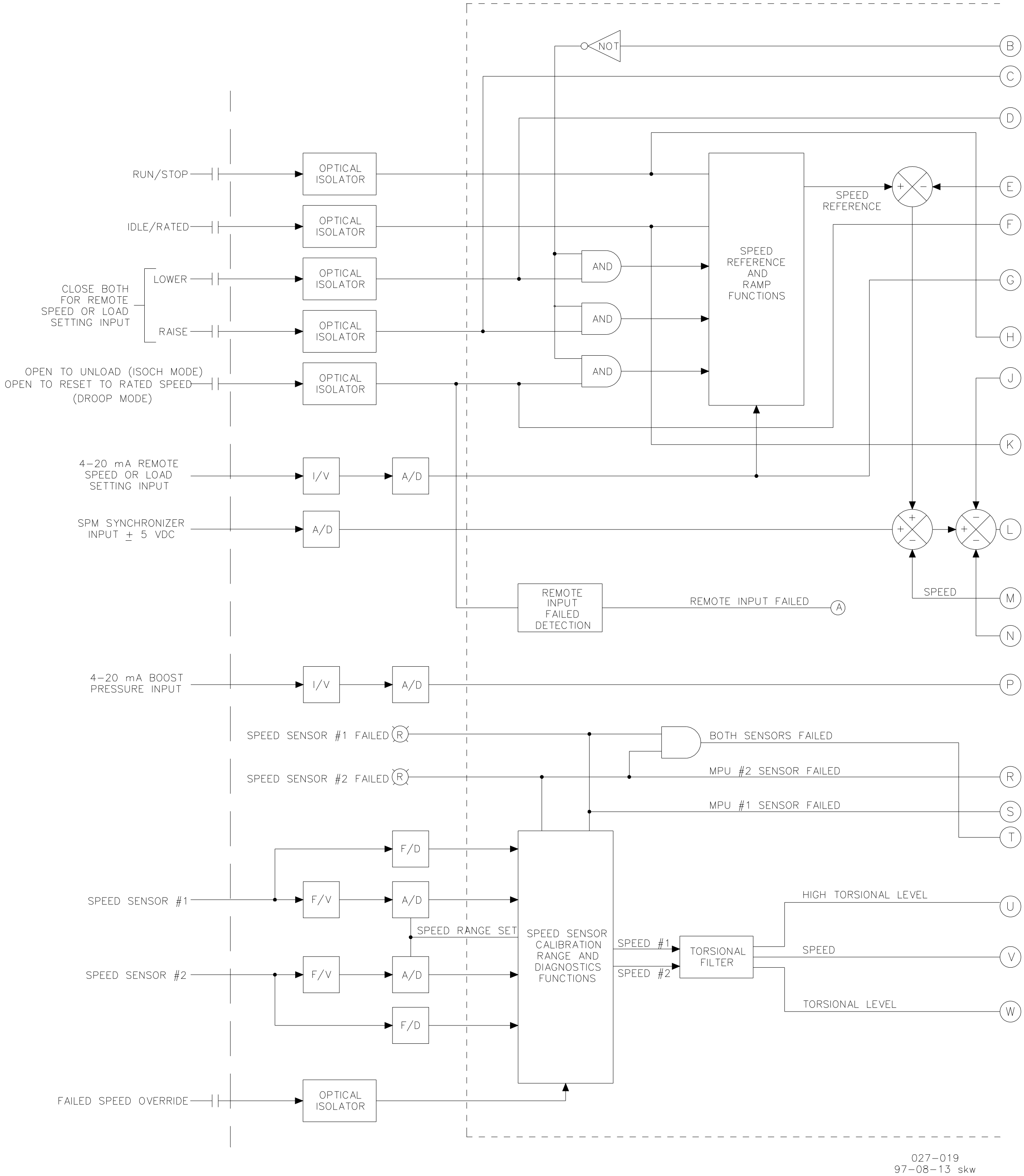

Figure 1-4a. Detailed Block Diagram

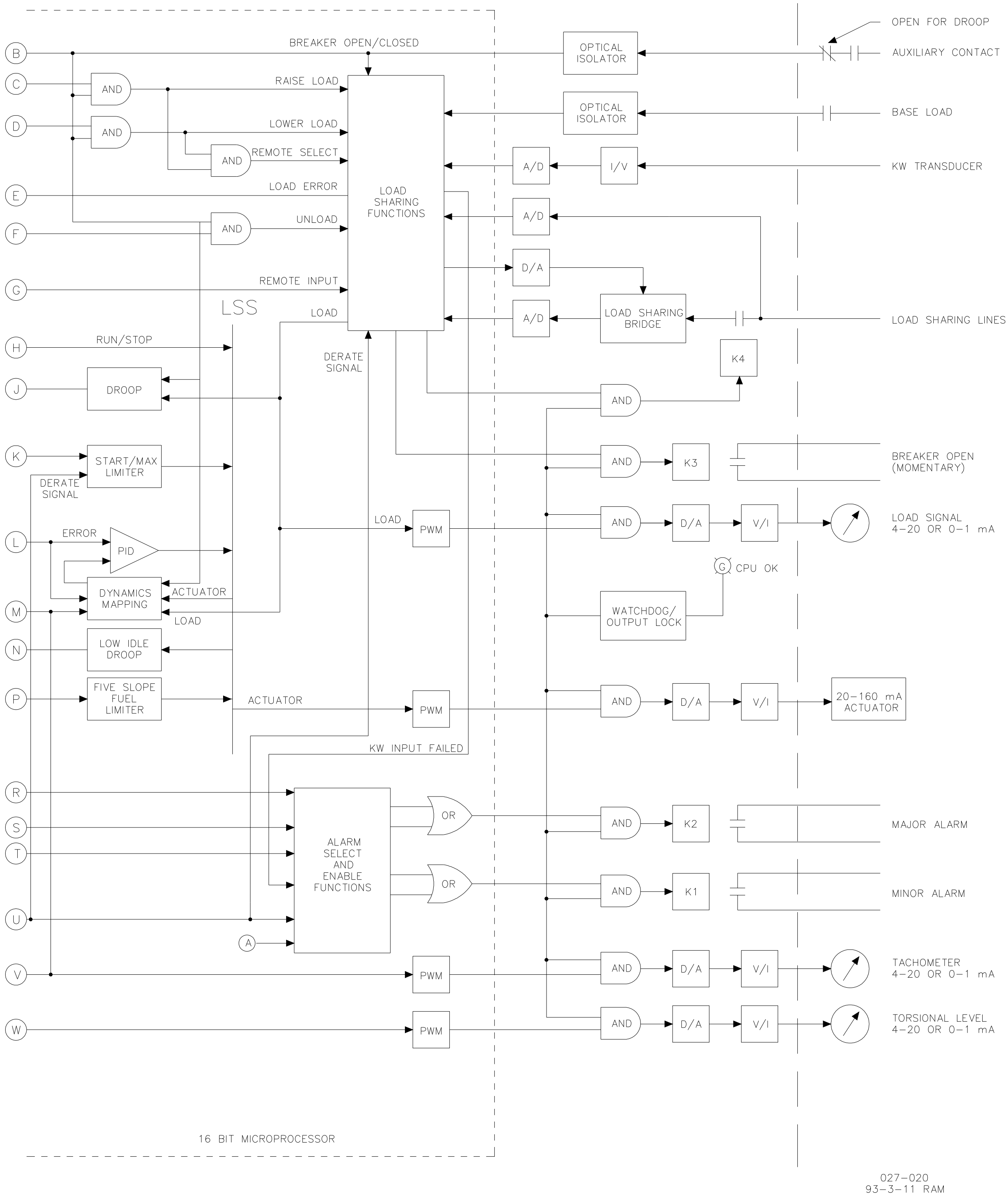

Figure 1-4b. Detailed Block Diagram

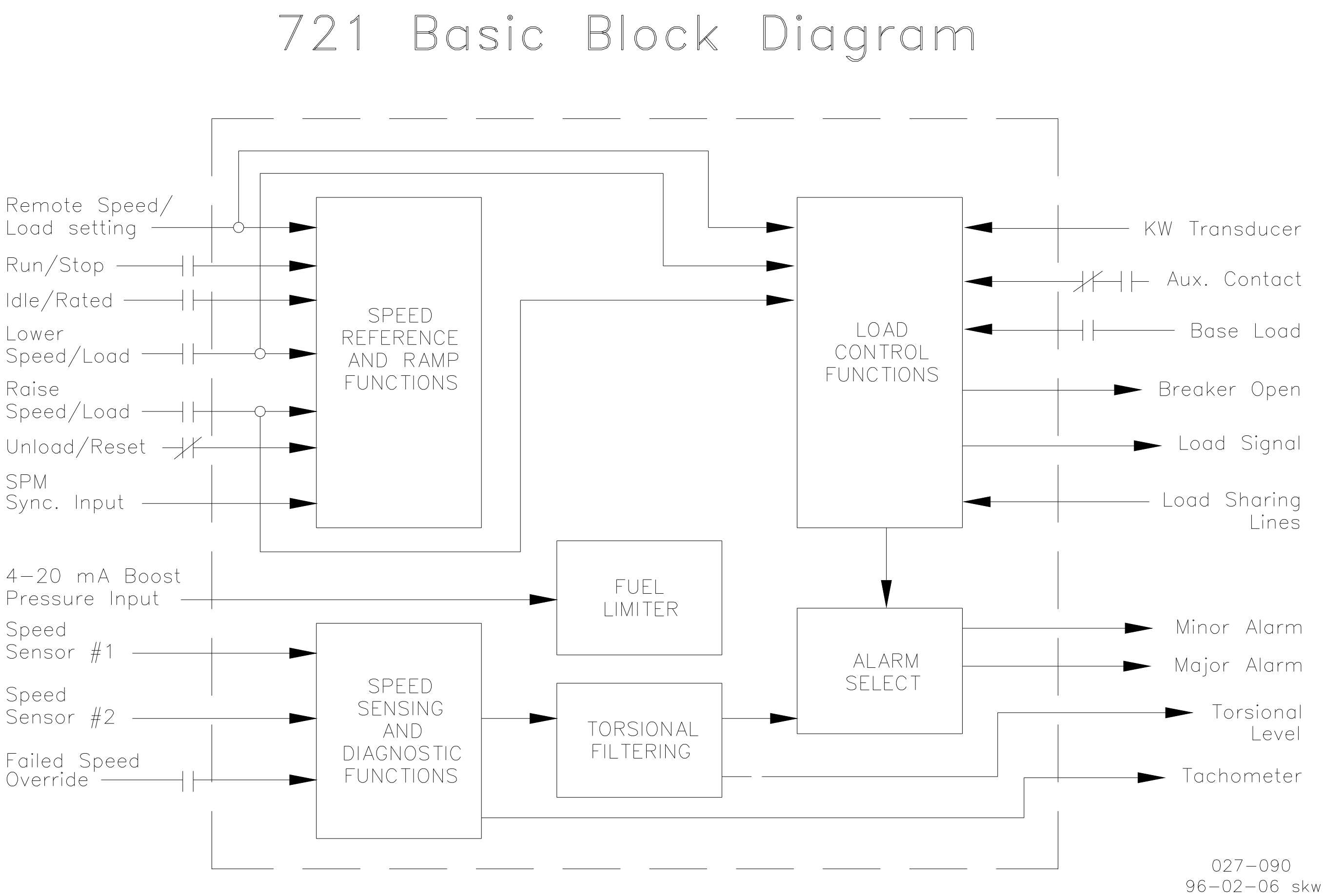

Figure 1-5. Simplified Block Diagram

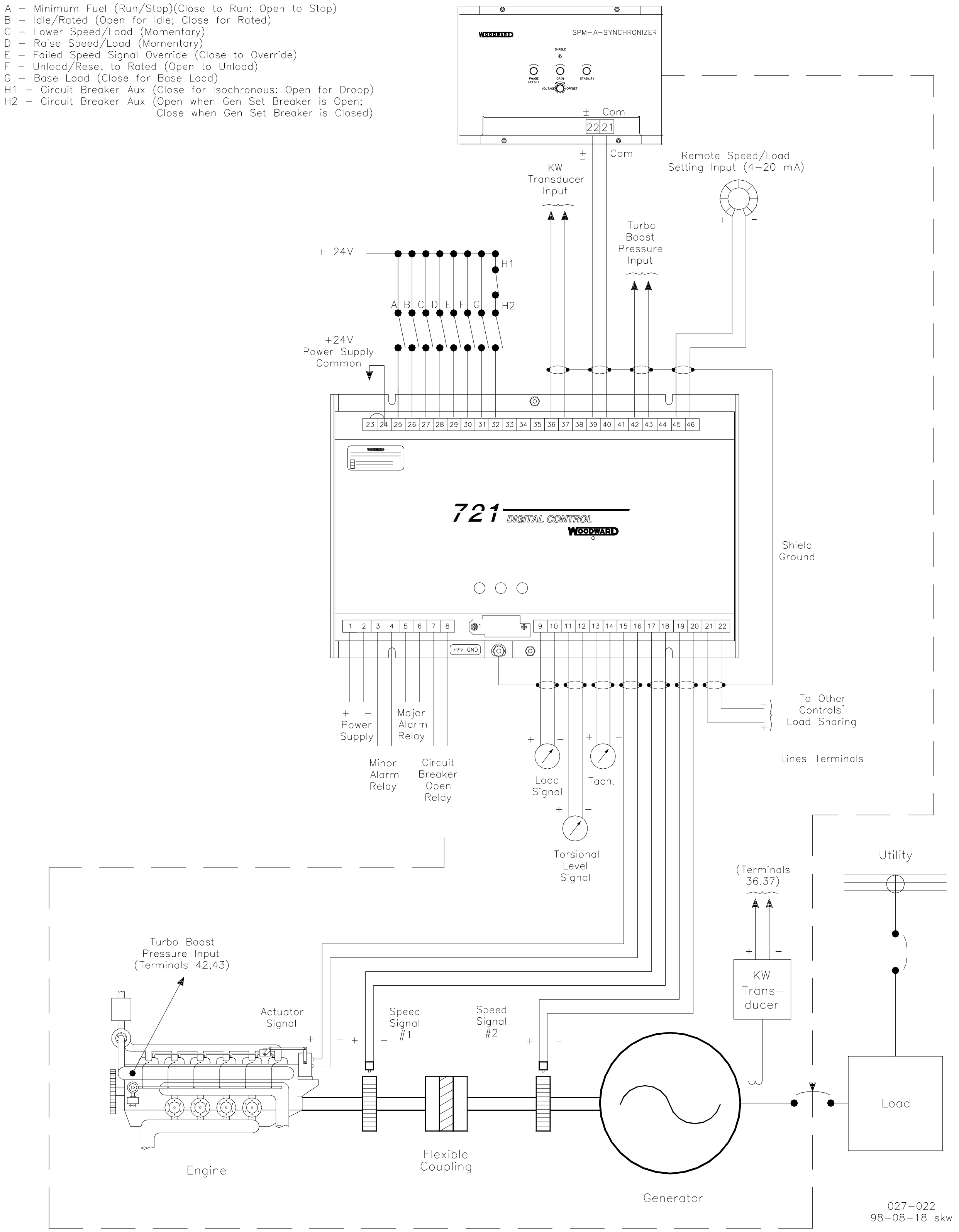

Figure 1-6. Typical 721 Connections

Plant Wiring Diagram

NOTES:

1. Shielded wires are twisted pairs, with shield grounded at one end only. When mounting control to bulkhead, use the grounding stud and hardware supplied with the chassis to ensure proper grounding.
2. Shields must not be grounded at any external point unless otherwise noted.
3. All shields must be carried continuously through all terminal blocks and must not be tied to other shields except at the common ground point. The shields are tied together at the ground stud.
4. Remove jumper for voltage input.
5. Close for isochronous, open for droop.
6. Analog input signals from other systems must be isolated from ground either by design or employment of isolation amplifiers.
7. Analog output signal to other systems must be isolated from ground either by design or employment of isolation amplifiers.
8. Discrete inputs are isolated from other circuits and intended to be powered by the same source as control supply voltage. Input current is nominally 10 mA per input into 2100 A.
9. Unless otherwise specified:
   A. relays shown de-energized
   B. relays energize for function
   C. relay contact ratings for minimum 100 000 operations:
   resistive—2.0 amperes at 28 Vdc
   0.1 amperes at 115 Vac 50 to 400 Hz
   inductive—0.75 amperes at 28 Vdc 0.2 henry
   0.1 amperes at 28 Vdc lamp
10. Confirm each connection before operating unit.
11. Factory set for MPU input.
12. Factory set for 20–160 mA output.
13. Factory set for 4–20 mA output.
14. Use RIS PCE-20 series transducer or Woodward Real Power Sensor 8272-387 or 8272-394.
15. These analog outputs may connect to metering/controlling devices. The shield should be continuous between all connected devices with a single shield termination point to ground.
16. Internal power supply provides dc isolation between the power source and all other inputs and outputs.
17. Terminals marked “NO CONNECTION” must remain open.
18. When using remote load or speed reference input, analog input or remote select must be removed when switching aux input at terminal 32.
19. Speed reference is selected when terminal 32 is open. Load reference is selected when terminal 32 is closed.
20. See option chart.

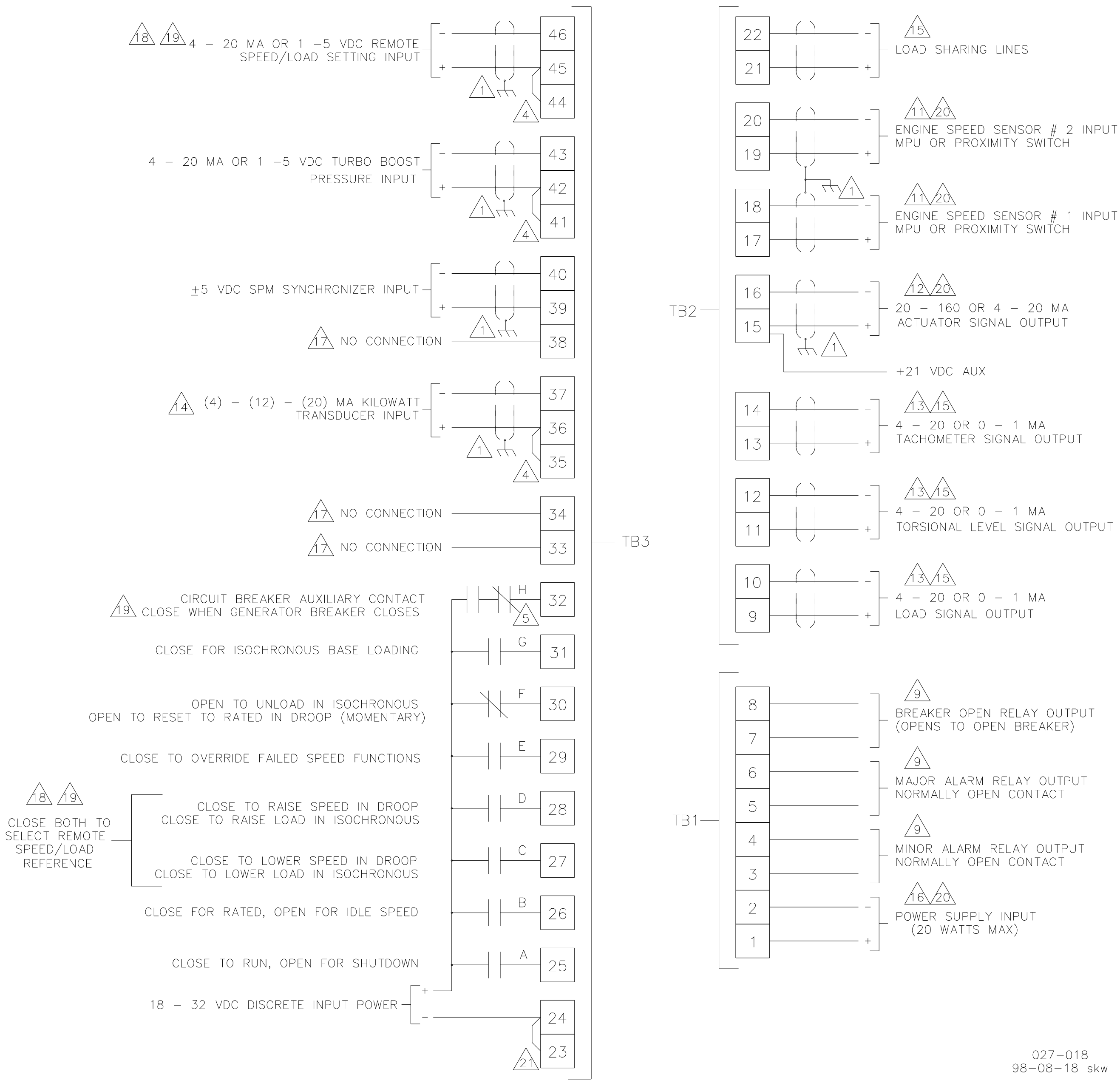

Figure 1-7. Plant Wiring Diagram

Chapter 2. Installation

Scope

This chapter contains general installation instructions for the 721 control. Power requirements, environmental precautions, and location considerations are included to help you determine the best location for the control. Additional information includes unpacking instructions, electrical connections, and installation checkout procedures.

Unpacking

Before handling the control, read page iv, Electrostatic Discharge Awareness. Be careful when unpacking the electronic control. Check the control for signs of damage such as bent panels, scratches, and loose or broken parts. If any damage is found, immediately notify the shipper.

Power Requirements

The high-voltage versions of the 721 Digital Speed Control require a voltage source of 88 to 132 Vac 45 to 65 Hz or 90 to 150 Vdc. The low-voltage versions require a voltage source of 18 to 32 Vdc.

NOTICE	**To prevent damage to the control, do not exceed the input voltage range.**

IMPORTANT	**If a battery is used for operating power, an alternator or other battery-charging device is necessary to maintain a stable supply voltage.**

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

Location Considerations

Consider these requirements when selecting the mounting location:

- adequate ventilation for cooling;
- space for servicing and repair;
- protection from direct exposure to water or to a condensation-prone environment;
- protection from high-voltage or high-current devices, or devices which produce electromagnetic interference;
- avoidance of vibration;
- selection of a location that will provide an operating temperature range of –40 to +70 °C (–40 to +158 °F).

The control must NOT be mounted on the engine.

Internal Jumpers

The 721 control has nine, two-position internal jumpers (JPR1 through JPR18) located on the top of the printed circuit board. If you need to change any jumper to match your control needs, be sure to read page iv, Electrostatic Discharge Awareness, before proceeding.

With the power off, remove the control cover. With your fingers or a small pair of tweezers, carefully remove the appropriate jumper and replace it securely over the proper two connectors (see Figure 2-1).

The jumper connections are listed here. Factory settings are shown with an "*".

JPR4 analog output #1 0–1 mA
* JPR1 analog output #1 0–20 mA

JPR5 analog output #2 0–1 mA
* JPR2 analog output #2 0–20 mA

JPR6 analog output #3 0–1 mA
* JPR3 analog output #3 0–20 mA

* JPR7 and JPR14 actuator output 0–200 mA, single
JPR7 and JPR9 actuator output 0–20 mA, single
JPR8 and JPR14 actuator output 0–200 mA, tandem

* JPR11 and JPR16 speed sensor #1 magnetic pickup
* JPR13 and JPR18 speed sensor #2 magnetic pickup

Electrical Connections

External wiring connections and shielding requirements for a typical control installation are shown in Figures 1-6 and 1-7. The plant wiring connections are explained in the rest of this chapter.

Shielded Wiring

All shielded cable must be twisted conductor pairs. Do not attempt to tin the braided shield. All signal lines should be shielded to prevent picking up stray signals from adjacent equipment. Connect the shields to the nearest chassis ground. Wire exposed beyond the shield should be as short as possible, not exceeding 50 mm (2 inches). The other end of the shields must be left open and insulated from any other conductor. DO NOT run shielded signal wires along with other wires carrying large currents. See Woodward application note 50532, *Interference Control in Electronic Governing Systems* for more information.

Where shielded cable is required, cut the cable to the desired length and prepare the cable as instructed below.

1. Strip outer insulation from BOTH ENDS, exposing the braided or spiral wrapped shield. DO NOT CUT THE SHIELD.
2. Using a sharp, pointed tool, carefully spread the strands of the shield.
3. Pull inner conductor(s) out of the shield. If the shield is the braided type, twist it to prevent fraying.
4. Remove 6 mm (1/4 inch) of insulation from the inner conductors.

Installations with severe electromagnetic interference (EMI) may require additional shielding precautions. Contact Woodward for more information.

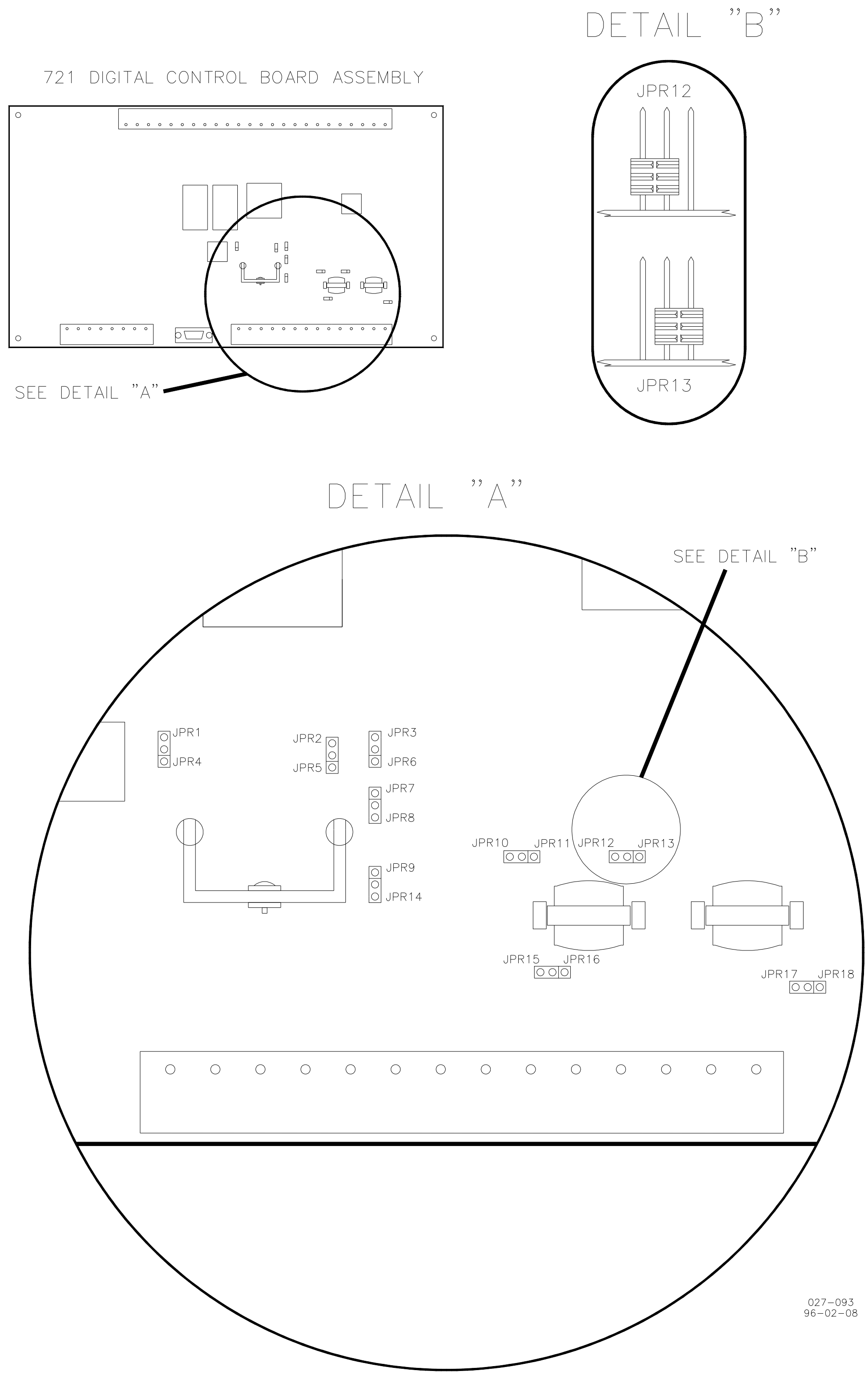

Figure 2-1. 721 Control Internal Jumpers

Power Supply (Terminals 1/2)

Power supply output must be low impedance (for example, directly from batteries). DO NOT power the control from high-voltage sources with resistors and zener diodes in series with the control power input. The 721 control contains a switching power supply which requires a current surge to start properly.

NOTICE

To prevent damage to the control, do not power a low-voltage control from high-voltage sources, and do not power any control from high-voltage sources with resistors and zener diodes in series with the power input.

Run the power leads directly from the power source to the control. DO NOT POWER OTHER DEVICES WITH LEADS COMMON TO THE CONTROL. Avoid long wire lengths. Connect the positive (line) to terminal 1 and negative (common) to terminal 2. If the power source is a battery, be sure the system includes an alternator or other battery-charging device.

If possible, do NOT turn off control power as part of a normal shutdown procedure. Use the Minimum Fuel (Run/Stop) discrete input (terminal 25) for normal shutdown. Leave the control powered except for service of the system and extended periods of disuse.

NOTICE

Do NOT apply power to the control at this time. Applying power may damage the control.

NOTICE

To prevent damage to the engine, apply power to the 721 control at least ten seconds prior to starting the engine. The control must have time to do its power up diagnostics and become operational. Do not start the engine unless the green POWER AND CPU OK indicator on the 721 control cover comes on, because test failure turns off the output of the control.

Relay Outputs (Terminals 3/4, 5/6, 7/8)

(See Plant Wiring Notes for contact ratings.)

Connect the Circuit Breaker Open relay, if used, to terminals 7/8 (normally closed). The contacts open momentarily to open the generator breaker.

Connect the Major Alarm relay, if used, to terminals 5/6 (normally open). The contacts close to energize the relay (major alarm condition).

Connect the Minor Alarm relay, if used, to terminal 3/4 (normally open). The contacts close to energize the relay (minor alarm condition).

Load Signal Output (Analog Output #1; Terminals 9/10)

The Load Signal readout wires connect to terminals 9(+) and 10(–). Use shielded twisted-pair wires. For an electrically isolated input device such as a 4 to 20 mA input analog meter, the shield should be grounded at the control end of the cable. For input to other devices, use the recommendation of the device manufacturer.

NOTICE	**To prevent possible damage to the control or poor control performance resulting from ground loop problems, follow these instructions. The control common is electrically isolated from the power supply input; however, the Actuator and Circuit Breaker Aux outputs are current sources and have a common mode voltage on them with respect to the control's internal common (terminal 23–Auxiliary Common). The analog inputs to the control use this same common. Connecting the actuator or the analog outputs to external circuits that are not isolated from the remote speed/load setting 4 to 20 mA current source will create ground loop problems. We recommend using current-loop isolators if the 721 control's analog inputs and outputs must both be used with non-isolated devices. A number of manufacturers offer 20 mA loop isolators. Consult Woodward for further information.**

Torsional Level Output (Analog Output #2; Terminals 11/12)

The Torsional Level readout wires connect to terminals 11(+) and 12(–). Use shielded twisted-pair wires. For an electrically isolated input device such as a 4 to 20 mA input analog meter, the shield should be grounded at the control end of the cable. For input to other devices, use the recommendation of the device manufacturer.

Tachometer Output (Analog Output #3; Terminals 13/14)

The tachometer readout wires connect to terminals 13(+) and 14(–). Use shielded twisted-pair wires. For an electrically isolated input device such as a 4 to 20 mA input analog meter, the shield should be grounded at the control end of the cable. For input to other devices, use the recommendation of the device manufacturer.

Actuator Output (Terminals 15/16)

The actuator wires connect to terminals 15(+) and 16(–). Use shielded wires with the shield connected to chassis at the control.

Speed Signal Inputs (Terminals 17/18 and 19/20)

Connect a magnetic pick-up (MPU) to terminals 17 and 18. You may need to connect a second MPU to terminals 19 and 20. If you have a flexible coupling between the engine and generator set, you must connect the first MPU (terminals 17/18) to detect engine speed, and the second MPU (terminals 19/20) to detect generator set speed. The MPUs must be on shafts rotating at exactly the same speed (not a camshaft, nor on each side of a gearbox, etc). Use shielded wire for all speed sensor connections. Connect the shield to the chassis. Make sure the shield has continuity the entire distance to the speed sensor, and make sure the shield is insulated from all other conducting surfaces.

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

Aux Voltage Input (Load Sharing Lines; Terminals 21/22)

Connect the output of a Woodward Load Sensor to terminals 21(+) and 22(–). Use a shielded twisted-pair cable. Wire the remainder of the load sensor in accordance with the wiring diagram for the sensor used.

Discrete Inputs

Discrete inputs are the switch input commands to the 721 control. In low voltage systems, or other systems where nominal 24 Vdc is available, the discrete inputs should be powered by this external voltage (see Figure 1-6).

If you are using the control-supplied aux voltage, which is recommended only for high voltage systems where 24 Vdc is not available, jumper terminal 23 to terminal 24. This connects the control's common to the discrete input common. Terminal 15 then supplies power (approximately +21 Vdc) to the discrete inputs. Since the aux voltage is not isolated from other control circuits, use only isolated contacts (dry or signal voltage rated) for the discrete circuits. DO NOT POWER ANY OTHER DEVICES WITH THE AUX VOLTAGE SOURCE.

If you are supplying the discrete input voltage (24 Vdc), connect the voltage source negative (–) to terminal 24. Then run the voltage source positive (+) to the appropriate switch or relay contact and then to the corresponding discrete input.

Minimum Fuel (Run/Stop) Contact (Input A; Terminal 25)

The Minimum Fuel (Run/Stop) contact is the preferred means for a normal shutdown of the engine. It connects to terminal 25 (discrete input A) of the control. The control will not operate without voltage applied to terminal 25. When the contact is closed, the voltage applied to terminal 25 allows the control to move the actuator to any position required for operating conditions.

⚠WARNING	**The Minimum Fuel (Run/Stop) contact is not intended for use in any emergency stop sequence. To prevent possible serious injury from an overspeeding engine, do NOT use the Minimum Fuel contact as part of any emergency stop sequence.**

Idle/Rated Contact (Input B; Terminal 26)

The Idle/Rated contact (open for idle, closed for rated) connects to terminal 26 (discrete input B). This contact also determines which fuel limiter is in effect. In idle, the control uses the Idle Fuel Limit set point. In rated, the control uses the Maximum Fuel Limit set point. When the Idle/Rated contact is closed, the control immediately switches the fuel limit to the maximum limit and ramps engine speed to the rated speed set point (or the speed specified by the Remote Speed/Load Setting input). When the Idle/Rated contact is opened, the control immediately switches on the Idle Fuel Limit and ramps engine speed to the idle speed setting.

The idle set point cannot be set above the rated set point. The fuel limiters (idle or maximum) remain effective regardless of the local/remote selection.

Lower Speed/Load Contact (Input C; Terminal 27)

The Lower Speed/Load contact connects to terminal 27 (discrete input C). When the 721 is in Speed Control Mode (terminal 32 open) and the Lower Speed/Load contact is closed, the control lowers speed at a rate determined by the Lower Speed Rate set point. When the contact is open, speed remains at its current value. Closing the Lower Speed/Load contact with the 721 in Speed Control Mode will cancel the ramps started by the Idle/Rated contact.

When the 721 is in Load Control Mode (terminal 32 closed) and the Lower Speed/Load contact is closed, the control lowers the load at a rate determined by the Lower Load Rate set point. When the contact is open, load remains at its current value. Closing the Lower Speed/Load contact with the 721 in Load Control Mode will cancel the ramps started by the Unload/Reset to Rated and Base Load contacts.

The Lower Speed/Load contact input is disabled when the remote speed/load setting mode is selected by closing both the Lower Speed/Load and Raise Speed/Load contacts.

Raise Speed/Load Contact (Input D; Terminal 28)

The Raise Speed/Load contact connects to terminal 28 (discrete input D). When the 721 is in Speed Control Mode (terminal 32 open) and the Raise Speed/Load contact is closed, the control raises speed at a rate determined by the Raise Speed Rate set point. When the contact is open, speed remains at its current value. Closing the Raise Speed/Load contact with the 721 in Speed Control Mode will cancel the ramps started by the Idle/Rated contact.

When the 721 is in Load Control Mode (terminal 32 closed) and the Raise Speed/Load contact is closed, the control raises the load at a rate determined by the Raise Load Rate set point. When the contact is open, load remains at its current value. Closing the Raise Speed/Load contact with the 721 in Load Control Mode will cancel the ramps started by the Unload/Reset to Rated and Base Load contacts.

The Raise Speed/Load contact input is disabled when the remote speed setting mode is selected by closing both the Lower Speed/Load and Raise Speed/Load contacts.

Failed Speed Signal Override (Input E; Terminal 29)

The Failed Speed Signal Override is connected to terminal 29 (discrete input E). When the contact is open, the control operates normally, reducing control output to minimum fuel in the event of a loss of speed signal.

Closing the contact overrides the failed speed signal function, which may be required for start-up. Prior to engine start-up, the speed signal is nonexistent. On engines requiring fuel during cranking, the Failed Speed Signal Override allows the actuator to open and provide fuel for starting.

Unload/Reset to Rated Contact (Input F; Terminal 30)

Input F has two functions:

If the control is in baseload mode (inputs G and H both closed), or in isochronous load sharing mode (input H closed and input G open), then opening this contact will cause the control to start ramping toward the unload trip level at the unload rate. In normal operation, this contact is closed and opened only to unload. In baseload mode or in isochronous load sharing mode, if the contact is opened and then reclosed, the control will ramp back to the baseload level or to the isochronous load sharing level, depending on the status of contact G.

If the control is in droop mode (inputs G and H both open), then opening this contact will cause the control to reset to rated speed. For example, if rated speed is set to 1000 rpm, droop load percentage is set to 5%, and the engine is at 100% load, then the speed reference will be at 1050 rpm. When contact F is opened, the engine will shed all load immediately. In droop operation, this contact must not be used to unload the engine. That must be done with the Lower Speed/Load contact. In droop mode, this contact is used to reset accurately to rated speed after manually unloading the engine.

IMPORTANT **Do not open input F in single unit isochronous operation.**

Base Load Contact (Input G; Terminal 31)

The Base Load contact connects to terminal 31 (discrete input G). When the Base Load contact is closed (and the Circuit Breaker Aux and Unload/Reset to Rated contacts are also closed), the control ramps the load at the load ramp rate (or unload ramp rate) to the Base Load Reference set point, and holds it there.

Circuit Breaker Aux Contact (Input H; Terminal 32)

The Circuit Breaker Aux contact connects to terminal 32 (discrete input H). This contact changes the control state between droop and isochronous.

When the contact is open, the control uses the standard dynamics from Menu 1, runs in droop (but note that 0 droop = isochronous), and the load control functions are disabled. When the contact is closed, the control uses the auxiliary dynamics from Menu 2, runs isochronously, and enables the load control functions.

See the table below for a complete comparison of the control states based on the status of the Circuit Breaker Aux contact.

Effects of Circuit Breaker Aux Contact Status

	CB Aux contact open (droop)	CB Aux contact closed (isoch.)
Load Control Function	disabled	enabled
Speed Reference	N/A	rated set point
Speed Control Mode	droop	isochronous
Remote Reference Input	speed reference	load reference
Raise Speed/Load Contact	raise speed	raise load
Lower Speed/Load Contact	lower speed	lower load
Unload/Reset to Rated Contact	reset to rated (momentary)	unload (continuous)
Remote Enabled	remote speed ref. enabled	remote load ref. enabled
Idle/Rated Contact	active	still active
Load Sharing Lines	open	closed
Breaker Open Contact	disabled	enabled
Dynamics	main	auxiliary

*—Raise and Lower contacts both closed

KW Transducer Input (Signal Input #1; Terminals 36/37)

Connect a 4/12/20 mA kilowatt transducer input to terminals 36(+) and 37(–) for the KW Transducer input. Use a shielded, twisted-pair cable. Make sure a jumper is installed between terminals 35 and 36 for the mA input. This input is not isolated from the other control inputs and outputs (except the power supply input and the discrete inputs). If any other analog input or output is used in a common ground system, an isolator must be installed. A number of manufacturers offer 20 mA loop isolators. Consult Woodward for further information. The transducer should produce 12 mA at zero generator load.

SPM Synchronizer Input (Signal Input #2; Terminals 39/40)

Connect the low-impedance output from an SPM-A synchronizer across terminals 39(+) and 40(–).

Turbo Boost Pressure Input (Signal Input #3; Terminals 42/43)

Connect a 4 to 20 mA current transmitter or 1 to 5 Vdc voltage transmitter to terminals 42(+) and 43(–) for the Turbo Boost Pressure Input (you can use turbo boost pressure, manifold pressure, or any other source that indicates engine load). Use a shielded, twisted-pair cable. When using a 4 to 20 mA transmitter, you must install a jumper between terminals 41 and 42 to connect a 243 ohm burden resistor in the loop. This input is not isolated from the other control inputs and outputs (except the power supply input and the discrete inputs). If any other analog input or output is used in a common ground system, an isolator must be installed. A number of manufacturers offer 20 mA loop isolators. Consult Woodward for further information.

Remote Speed/Load Setting Input (Signal Input #4; Terminals 45/46)

Connect a 4 to 20 mA current transmitter or 1 to 5 Vdc voltage transmitter to terminals 45(+) and 46(–) for the Remote Speed/Load Setting input. Use a shielded, twisted-pair cable. When using a 4 to 20 mA transmitter, you must install a jumper between terminals 44 and 45 to connect a 243 ohm burden resistor in the loop. This input is not isolated from the other control inputs and outputs (except the power supply input and the discrete inputs). If any other analog input or output is used in a common ground system, an isolator must be installed. A number of manufacturers offer 20 mA loop isolators. Consult Woodward for further information.

Installation Checkout Procedure

With the installation complete as described in this chapter, do the following checkout procedure before beginning set point entry (Chapter 3) or initial start-up adjustments (Chapter 4).

1. Visual inspection

   A. Check the linkage between the actuator and fuel metering device for looseness or binding. Refer to the appropriate actuator manual, and Manual 25070, *Electric Governor Installation Guide* for additional information on linkage.

⚠WARNING **To prevent possible serious injury from an overspeeding engine, the actuator lever or stroke should be near but not at the minimum position when the fuel valve or fuel rack is at the minimum fuel delivery position.**

   B. Check for correct wiring in accordance with the plant wiring diagram, Figure 1-7.

   C. Check for broken terminals and loose terminal screws.

   D. Check the speed sensor(s) for visible damage. If the sensor is a magnetic pickup, check the clearance between the gear and the sensor, and adjust if necessary. Clearance should be between 0.25 and 1.25 mm (0.010 and 0.050 inch) at the closest point. Make sure the gear runout does not exceed the pickup gap.

2. Check for grounds

   Check for grounds by measuring the resistance from all control terminals to chassis. All terminals except terminals 2 and 24 should measure infinite resistance (the resistance of terminals 2 and 24 depends on whether a floating or grounded power source is used). If a resistance less than infinite is obtained, remove the connections from each terminal one at a time until the resistance is infinite. Check the line that was removed last to locate the fault.

Chapter 3.
Entering Control Set Points

Introduction

Because of the variety of installations, plus system and component tolerances, the 721 control must be tuned to each system for optimum performance.

This chapter contains information on how to enter control set points through the control's menu system using the Hand Held Programmer. See the next chapter for prestart-up and start-up settings and adjustments.

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

Hand Held Programmer and Menus

The Hand Held Programmer is a hand-held computer terminal that gets its power from the 721 control. The terminal connects to the RS-422 communication serial port on the control (terminal J1). To connect the terminal, slightly loosen the right-hand screw in the cover over J1 and rotate the cover clockwise to expose the 9-pin connector. Then firmly seat the connector on the terminal into J1.

The programmer does a power-up self-test whenever it is plugged into the control. When the self-test is complete, the screen will be blank. Press the “ID” key to display the part number and revision level of the software in the control. Refer to this number and revision level in any correspondence with Woodward (write this information in Appendix A).

The set points or adjustments of the control are arranged in ten menus. You access these menus with the number keys (1, 2, 3, 4, 5, 6, 7, 8, 9, 0). Pressing the appropriate key selects the first item on each menu.

The programmer screen is a four-line, backlighted LCD display. The display permits you to look at two separate functions or menu items at the same time. Use the “Up/Down Arrow” key to toggle between the two displayed items (the first letter of the active menu item will blink).

The programmer keys do the following functions (see Figure 3-1):

(left arrow)	Not used.
(right arrow)	Not used.
(up/down arrow)	Toggles between the two displayed items (the first letter of the active menu item will blink).
(up arrow)	Moves backward through each menu, one step at a time.
(down arrow)	Advances through each menu, one step at a time.
(turtle up)	Increases the displayed set point value slowly.
(turtle down)	Decreases the displayed set point value slowly.
(rabbit up)	Increases the displayed set point value quickly (about 10 times faster than the turtle keys).
(rabbit down)	Decreases the displayed set point value quickly (about 10 times faster than the turtle keys).
– (minus)	Not used.
+ (plus)	Not used.
(solid square)	Blanks the display.
ID	Displays the 721 control part number and software revision level.
ESC	Not used.
SAVE	Saves entered values (set points).
BKSP	Not used.
SPACE	Not used.
ENTER	Not used.
= (equals)	Not used.
(decimal)	Not used.
1	Selects Menu 1.
2	Selects Menu 2.
3	Selects Menu 3.
4	Selects Menu 4.
5	Selects Menu 5.
6	Selects Menu 6.
7	Selects Menu 7.
8	Selects Menu 8.
9	Selects Menu 9.
0	Selects Menu 0.

Name	Min. Value	Max. Value	Step Size	Initial Value	Dimen-sion
Menu 1 , Dynamics Menu					
1. Gain	0.00015	10.000	0.001	0.100	—
2. Stability	0.00	10.00	0.01	0.35	seconds
3. Compensation	0.00	10.00	0.01	0.20	seconds
4. Gain Ratio	1.0	20.0	0.1	1.0	—
5. Window Width	0	rated speed		1	60 rpm
6. Gain Slope Breakpoint	0	100	1	20	% actuator
7. Gain Slope	–50.0	+50.0	0.1	0.0	—
8. Speed Filter	0.1	20.0	0.1	15.0	Hz

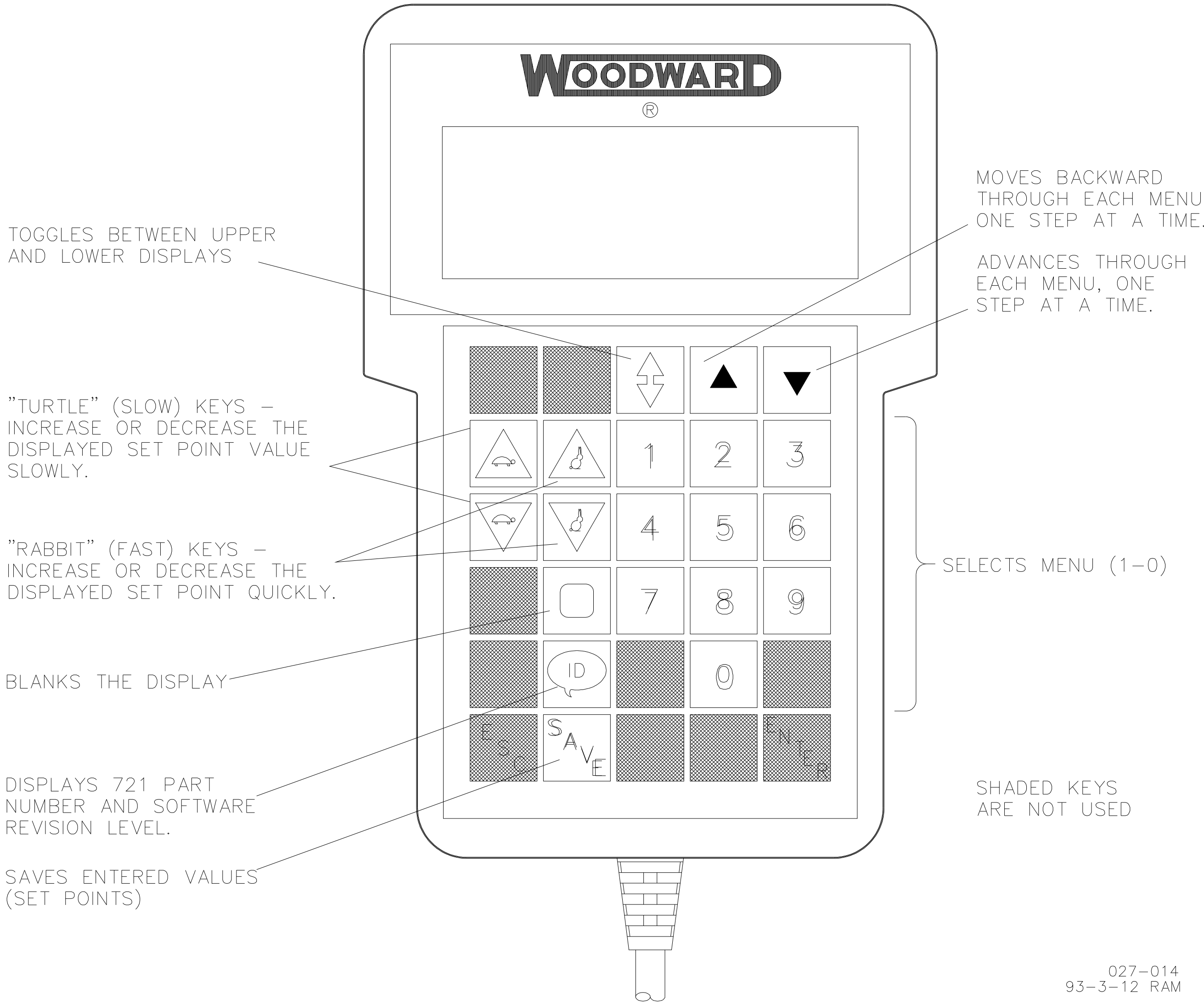

Figure 3-1. Hand Held Programmer Functions

Name	Min. Value	Max. Value	Step Size	Initial Value	Dimen-sion
Menu 2 , Auxiliary Dynamics Menu					
1. Aux Gain	0.00015	10.000	0.001	0.100	—
2. Aux Stability	0.00	10.00	0.01	0.35	seconds
3. Aux Compensation	0.00	10.00	0.01	0.20	seconds
4. Aux Gain Ratio	1.0	20.0	0.1	1.0	—
5. Aux Window Width	0	rated speed		1	60 rpm
6. Aux Gain Slope Breakpoint	0	100	1	20	% actuator
7. Aux Gain Slope	–50.0	+50.0	0.1	0.0	—
8. Aux Speed Filter	0.1	20.0	0.1	15.0	Hz

Name	Min. Value	Max. Value	Step Size	Initial Value	Dimen-sion
Menu 3 , Speed Setting Menu					
1. Raise Speed Limit	rated spd	*	1	1300	rpm
2. Lower Speed Limit	8	raise spd lim	1	1100	rpm
3. Idle Speed Reference	8	rated speed	1	750	rpm
4. Accel Ramp Time	0	500	1	8	seconds
5. Decel Ramp Time	0	500	1	8	seconds
6. Raise Speed Rate	0	5000	1	100	rpm/minute
7. Lower Speed Rate	0	5000	1	100	rpm/minute
8. 4 mA Remote Reference	lwr spd lim	raise spd lim	1	1100	rpm
9. 20 mA Remote Reference	lwr spd lim	raise spd lim	1	1300	rpm
10. Tach at 4 mA Output	–500	5000	1	400	rpm
11. Tach at 20 mA Output	–500	5000	1	2000	rpm
12. Low Idle Droop	0	100	1	25	%
13. Low Idle Breakpoint	0	100	1	0	% actuator
* + 1.15 x rated speed OR 2100					
Menu 4 , Torsional Filter Menu					
1. Torsional Filter	0.00	1.00	0.01	0.50	—
2. Torsional Level 4 mA	0	100	1	0	%
3. Torsional Level 20 mA	0	100	1	100	%
4. Derated Fuel Limit	0	100	1	100	% actuator
5. Derated Trip Level	derat. clr lvl	100	1	100	%
6. Derated Clear Level	0	derat. trip lvl	1	0	%
Menu 5 , KW Setting Menu					
1. Maximum Load	0	30 000	1	1000	KW
2. Load Gain Voltage	4.0	7.0	0.1	6.0	volts
3. Loadshare Error Gain	_____	_____	_____	_____	_____
[not present in part numbers 9905-291/-381]					
4. 4 mA KW Load Input	–30 000	+30 000	1	–1000	KW
5. 20 mA KW Load Input	–30 000	+30 000	1	1000	KW
6. Base Load Reference	unld trp lvl	30 000	1	800	KW
7. Unload Trip Level	0	base load	1	50	KW
8. Load Ramp Time	0	5000	1	20	seconds
9. Unload Ramp Time	0	5000	1	20	seconds
10. Raise Load Rate	0	30 000	1	1000	KW/minute
11. Lower Load Rate	0	30 000	1	1000	KW/minute
12. 4 mA Remote KW Ref.	–30 000	+30 000	1	0	KW
13. 20 mA Remote KW Ref.	–30 000	+30 000	1	1000	KW
14. Load Droop Percent	0.0	100.0	0.1	5.0	%
15. Load at 4 mA Output	–30 000	+30 000	1	0	KW
16. Load at 20 mA Output	–30 000	+30 000	1	1000	KW
Menu 6 , Fuel Limiters and Control Output Menu					
1. Idle Fuel Limit	0	100	1	0	% actuator
2. Maximum Fuel Limit	0	100	1	0	% actuator
3. External Fuel Limit	enabled	disabled	—	disabled	—
4. Fuel Limit Breakpoint A	0.0	brkpnt B	0.1	6.0	mA
5. Fuel Limit at Breakpoint A	0	100	1	20	% actuator
6. Fuel Limit Breakpoint B	brkpnt A	brkpnt C	0.1	8.0	mA
7. Fuel Limit at Breakpoint B	0	100	1	40	% actuator
8. Fuel Limit Breakpoint C	brkpnt B	brkpnt D	0.1	10.0	mA
9. Fuel Limit at Breakpoint C	0	100	1	60	% actuator
10. Fuel Limit Breakpoint D	brkpnt C	brkpnt E	0.1	15.0	mA
11. Fuel Limit at Breakpoint D	0	100	1	80	% actuator
12. Fuel Limit Breakpoint E	brkpnt D	20.0	0.1	20.0	mA
13. Fuel Limit at Breakpoint E	0	100	1	100	% actuator

Name	Displayed Value
Menu 7 , Display Menu 1	
1. Engine Speed	rpm
2. Speed Reference	rpm
3. Generator Load	KW
4. Load Reference	KW
5. Actuator Output	%
6. Torsional Level	%
7. Speed Control Mode	Stop/Failsafe/Fuel Limiter/Speed Control
8. Load Control Mode	Droop/Unload Trip/Load Ramp/Base Load/ Load Sharing/Remote/Unload Ramp

Name	Min. Value	Max. Value	Step Size	Initial Value	Dimen-sion
Menu 8 , Configuration Menu					
1. Configuration Key	0	100	1	0	—
2. Rated Speed	idle speed	raise spd lim	1	1200	rpm
3. Gear #1 Teeth	4	500	1	60	—
4. Gear #2 Teeth	4	500	1	60	—
5. Actuator Sense	forward, reverse		—	forward	—
6. Dynamics Map —	constant, linear, non-linear			—	linear
7. MPU1 Failed Alarm	none, minor, major		—	minor	—
8. MPU2 Failed Alarm	none, minor, major		—	minor	—
9. Both MPUs Failed Alarm	none, minor, major		—	major	—
10. Load Sensor Failed Alarm	none, minor, major		—	minor	—
11. Sequence Error Alarm	none, minor, major		—	minor	—
12. High Torsional Level Alarm	none, minor, major		—	minor	—
13. Remote Input Failed Alarm	none, minor, major		—	minor	—

Name	Displayed Value
Menu 9 , Calibration Menu	
1. Calibration Key	[actual value]
2. KW Load Input	[actual value]
3. Synchronizer Input	[actual value]
4. Fuel Limiter Input	[actual value]
5. Remote Reference Input	[actual value]
6. Parallel Line Input	[actual value]
7. Load Sharing Error	[actual value]
8. De-Droop	[actual value]
9. Load Sharing Output	[actual value]
10. Load Sharing Offset	[actual value]
11. Torsional Level	[actual value]
12. KW Load Output	[actual value]
13. Tachometer Output	[actual value]
14. Actuator Output	[actual value]
15. Analog Speed #1	[actual value]
16. Analog Speed #2	[actual value]

Name	Displayed Value
Menu 0 , Display Menu 2	
1. Analog Speed #1	rpm
2. Analog Speed #2	rpm
3. Digital Speed #1	rpm
4. Digital Speed #2	rpm
5. Run/Stop Contact Status	open/closed
6. Idle/Rated Contact Status	open/closed
7. Lower Speed Contact Status	open/closed
8. Raise Speed Contact Status	open/closed
9. Failsafe Override Cont. St.	open/closed
10. Unload Contact Status	open/closed
11. Base Load Contact Status	open/closed
12. Circuit Breaker Contact St.	open/closed
13. Load Share Relay Status	open/closed
14. Major Alarm Relay Status	open/closed
15. Minor Alarm Relay Status	open/closed
16. Breaker Open Relay Status	open/closed
17. MPU #1 LED Status	on/off
18. MPU #2 LED Status	on/off
19. Watchdog Status	OK
20. Diagnostics Results	49
21. ROM Checksum	[variable with application]

Pressing the appropriate number key (1, 2, 3, 4, 5, 6, 7, 8, 9, 0) selects the desired menu. To step through the menu, use the “Up Arrow” and “Down Arrow” keys. The “Down Arrow” key advances through the menu and the “Up Arrow” key moves backward through the menu. The menus are continuous; that is, pressing the “Down Arrow” at the last menu item takes the menu to the first item, or pressing the “Up Arrow” at the beginning of the menu takes the menu to the last item.

To adjust a set point, use the “Turtle Up” or the “Rabbit Up” keys to increase the value, and the “Turtle Down” or “Rabbit Down” keys to decrease the value. The “Rabbit Up” and “Rabbit Down” keys will make the rate of change faster than the “Turtle Up” and “Turtle Down” keys. This is useful during initial setup where a value may need to be changed significantly.

Finally, use the “SAVE” key to save entered values. After you are satisfied with all entries and adjustments, press the “SAVE” key to transfer all new set point values into EEPROM memory. The EEPROM retains all set points when power is removed from the control.

NOTICE

To prevent possible damage to the engine resulting from improper control settings, make sure you save the set points before removing power from the control. Failure to save the set points before removing power from the control causes them to revert to the previously saved settings.

The control ignores all other keys on the Hand Held Programmer.

Menu (Set Point) Descriptions

Menu 1—Dynamics Menu
Menu 2—Auxiliary Dynamics Menu

Dynamic adjustments are settings that affect the stability and transient performance of the engine. There are two sets of dynamics provided. The set being used is selected by the Circuit Breaker Aux contact input. The control uses the Menu 1 (standard) dynamics when the Circuit Breaker Aux contact is open, and it uses the Menu 2 (auxiliary) dynamics when the contact is closed.

The following descriptions of each menu item apply to either set. Also see Figures 3-2, 3-3, and 3-4.

1. Gain determines how fast the control responds to an error in engine speed from the speed-reference setting. The Gain is set to provide stable control of the engine at light or unloaded conditions.

2. Stability compensates for the lag time of the engine. It adjusts the time required for the control to return the speed to zero error after a disturbance. Stability is adjusted to prevent slow hunting and to minimize speed overshoot after a load disturbance.

3. Compensation compensates for the actuator and fuel system time constant.

4. Gain Ratio is the ratio of the Gain setting at steady state to the Gain setting during transient conditions. The Gain Ratio operates in conjunction with the Window Width and Gain adjustments by multiplying the Gain set point by the Gain Ratio when the speed error is greater than the Window Width. This makes the control dynamics fast enough to minimize engine-speed overshoot on start-up and to reduce the magnitude of speed error when loads are changing. This allows a lower gain at steady state for better stability and reduced steady-state actuator linkage movement.

5. Window Width is the magnitude (in rpm) of a speed error at which the control automatically switches to fast response. The control does not use the absolute value of speed error, but “anticipated” speed error to make this switch. This method provides for quick switching to the high Gain value when an offspeed occurs and early switching to the low Gain value when recovering from the speed transient. This provides smoother switching than if the absolute speed error was used for the window.

6. Gain Slope Breakpoint sets the percent output above which the Gain Slope becomes effective. It should usually be set just above the minimum load output.

7. Gain Slope changes Gain as a function of actuator output. Since actuator output is proportional to engine load, this makes Gain a function of engine load. Gain Slope operates in conjunction with the Gain Slope Breakpoint adjustment to increase (or decrease) Gain when percent Actuator Output is greater than the breakpoint. This compensates for systems having high (or low) gain at low load levels. This allows the Gain setting to be lower at light or no load for engine stability, yet provide good control performance under loaded conditions.

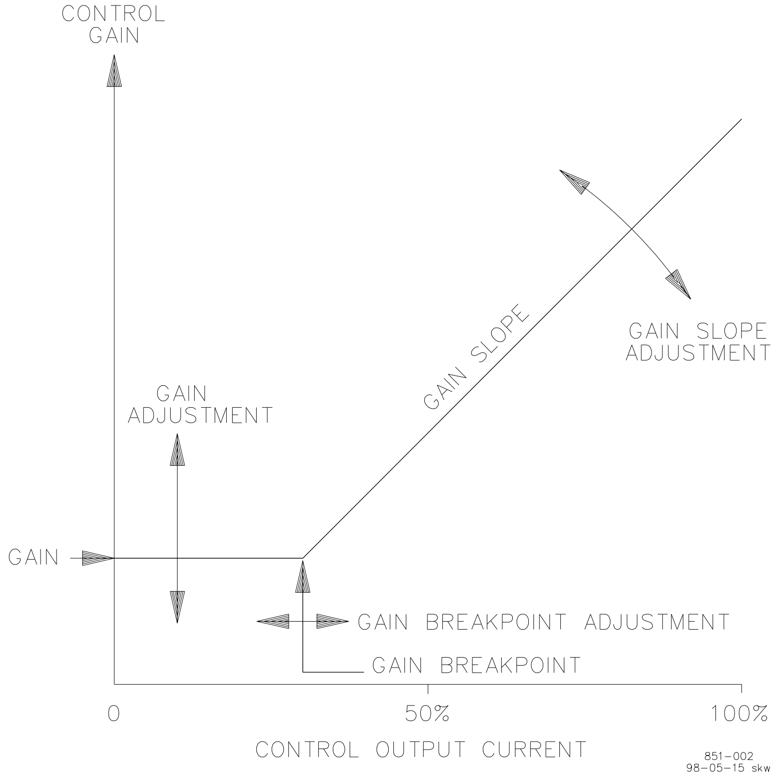

Figure 3-2. Control Gain as a Function of Speed Error

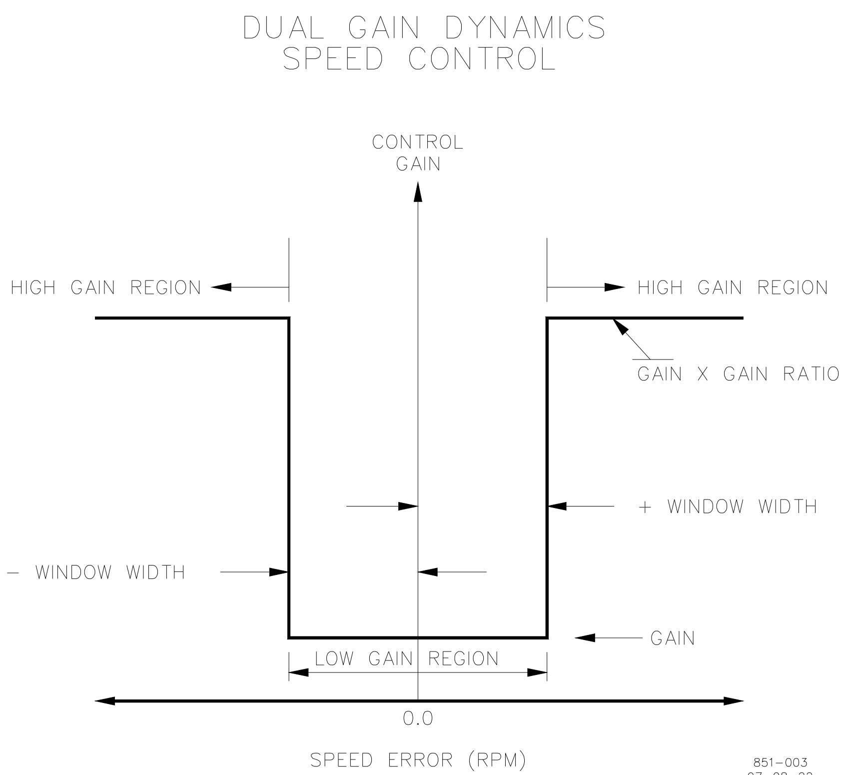

Figure 3-3. Control Gain as a Function of Control Output

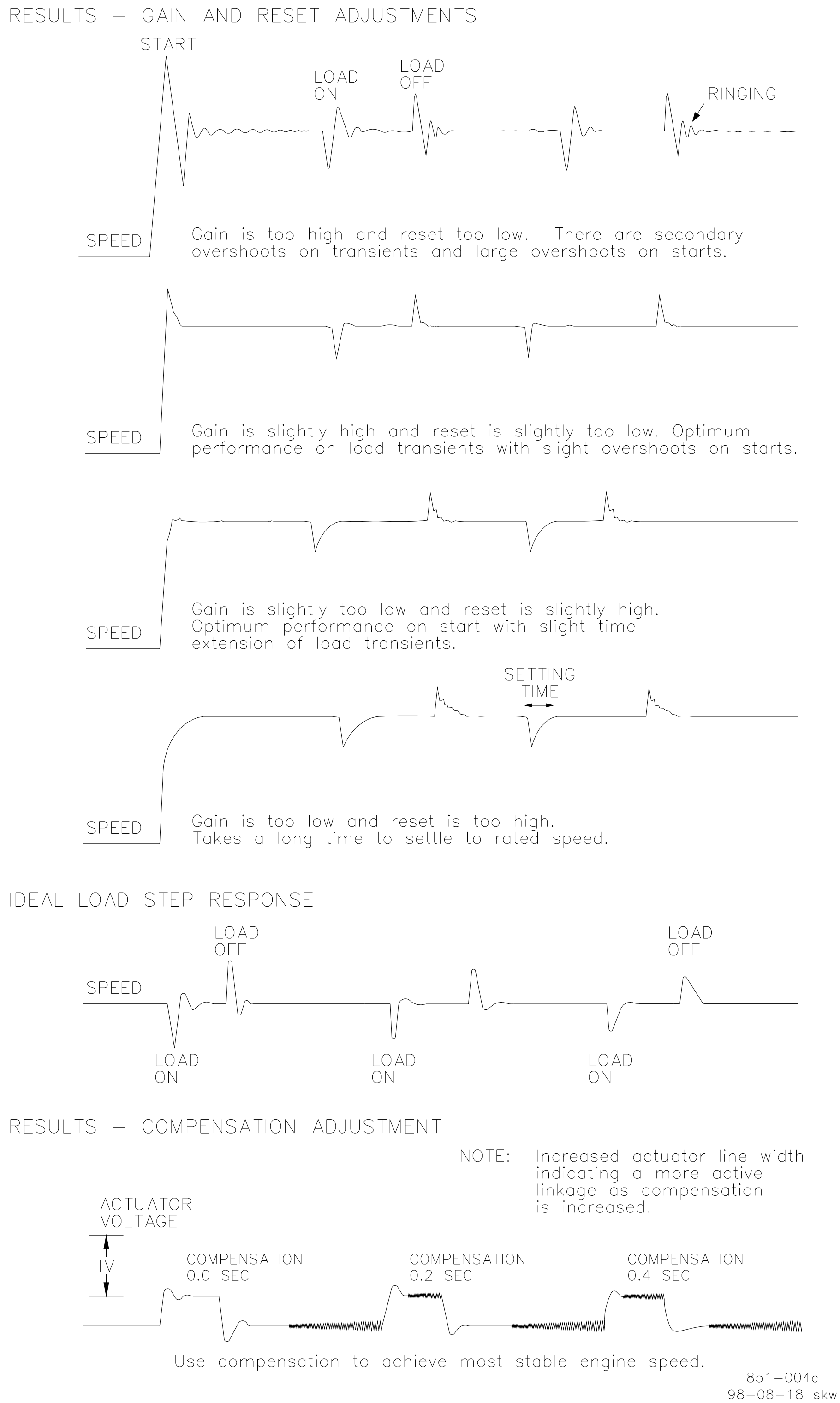

Figure 3-4. Typical Transient Response Curves

8. Speed Filter adjusts the cutoff frequency of a low pass filter used on the speed sensing input (see Figure 3-5). The filter is used to attenuate engine firing frequencies. To calculate the desired filter cutoff point, use the following formula:

   camshaft frequency = (engine rpm)/60 [for 2-cycle engines]
   camshaft frequency = (engine rpm)/120 [for 4-cycle engines]
   firing (cutoff) frequency = (camshaft frequency)(number of engine cylinders)

Always try to use the minimum frequency for good steady state response.

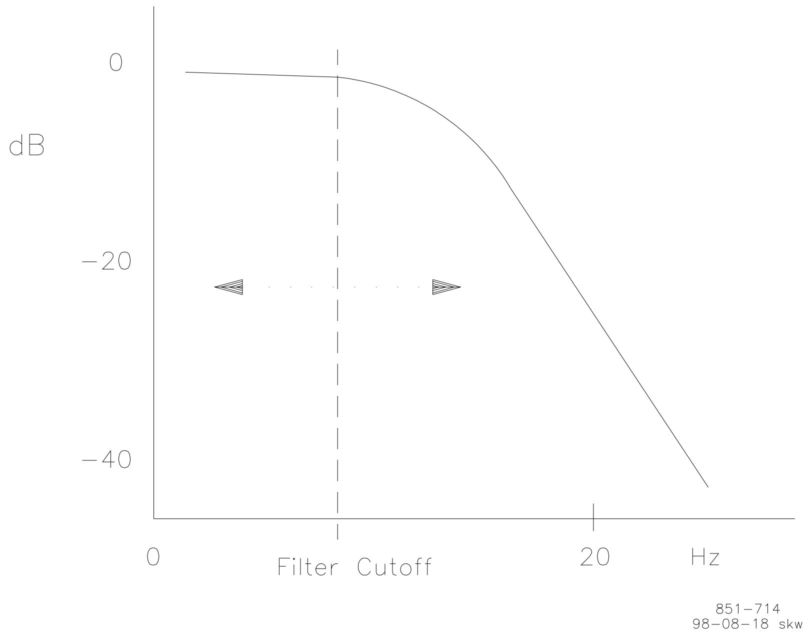

Figure 3-5. Speed Filter

Menu 3—Speed Setting Menu

Speed adjustments are the settings that affect the speed reference.

1. Raise Speed Limit is the maximum speed reference setting. It is used to limit the Raise Speed/Load and Remote Speed/Load Setting inputs to a maximum. It normally is set at the maximum rated engine speed.

2. Lower Speed Limit is the minimum speed reference setting. It is used to limit the Lower Speed/Load and Remote Speed/Load Setting inputs to a minimum. It normally is set at the minimum operating speed of the engine.

3. Idle Speed Reference sets the speed at which the engine is operated at start-up. It sometimes is used during cool down.

4. Accel Ramp Time is the time required for the control to ramp the engine speed from Idle speed to Rated speed. The ramp is started whenever the Idle/Rated contact is closed.

5. Decel Ramp Time is the time required for the control to ramp the engine speed from Rated speed to Idle speed. The ramp is started whenever the Idle/Rated contact is opened.

IMPORTANT **Actual engine deceleration may be slower than set by the Decel Ramp Time set point. This occurs when the Decel Ramp Time set point is faster than system inertias will allow the engine to come down in speed. This condition is indicated by the control actuator output going to the minimum fuel position. See Low Idle Droop below.**

6. Raise Speed Rate is the rate at which the speed reference is ramped when using the Raise command as well as when the Remote Speed/Load Setting input is changed in the increase direction. A step change on the remote input does not cause an immediate change in the reference, which is ramped to the new setting at the Raise Speed Rate.

7. Lower Speed Rate is the rate at which the speed reference is ramped when using the Lower Speed/Load input, as well as when the Remote Speed/Load Setting input is changed in the decrease direction. A step change on the remote input does not cause an immediate change in the reference, which is ramped to the new setting at the Lower Speed Rate.

8. 4 mA Remote Reference is the engine speed desired when 4 mA is applied to the Remote Speed/Load Setting input.

9. 20 mA Remote Reference is the engine speed desired when 20 mA is applied to the Remote Speed/Load Setting input.

10. Tach at 4 mA Output is the engine speed when the Tachometer output is 4 mA.

11. Tach at 20 mA Output is the engine speed when the Tachometer output is 20 mA.

12. Low Idle Droop is based on the control output current when it drops below the Low Idle Breakpoint setting. Dependencies on linkage make the Low Idle Droop percentage relative, so large droop settings may be required to achieve the desired results.

13. Low Idle Breakpoint is normally set equal to the control output obtained when the engine is unloaded and at low idle. When the output of the control drops below this setting or goes to minimum fuel during rapid engine deceleration, Low Idle Droop temporarily raises the speed reference. This brings engine speed back under control sooner and reduces undershoot. Undershoot may occur because the time required for the control to return to the new fuel setting takes time dependent on control dynamics and linkage adjustment.

Menu 4—Torsional Filter Menu

Torsional filter adjustments are the settings that affect the control's ability to reject to flexible coupling torsionals.

1. Torsional Filter is the inertia ratio setting between the engine inertia and the system inertia. Set the value equal to engine inertia divided by (engine inertia + generator inertia).

2. Torsional Level 4 mA is the torsional level when the Torsional Level Output is 4 mA.

3. Torsional Level 20 mA is the torsional level when the Torsional Level Output is 20 mA.

4. Derated Fuel Limit is the percentage of Actuator Output the actuator output will be limited to when the input torsional level exceeds the Derated Trip Level. The Derated Fuel Limit is low signal selected with the Turbo Boost Pressure input and the Maximum Fuel Limit.

5. Derated Trip Level is the torsional level at which the Derated Fuel Limit is activated and the alarm state is triggered (if used).

6. Derated Clear Level is the torsional level at which the Derated Fuel Limit is deactivated and the alarm state is cleared (if used).

Menu 5—KW Load Setting Menu

KW load adjustments are the settings that affect the KW load reference.

1. Maximum Load is the maximum load reference setting. It is used to limit the Raise Load command and Remote Speed/Load Setting input to a maximum. It normally is set at the maximum rated engine KW load.

2. Load Gain Voltage is a voltage representation of the amount of load on the generator. It is used to balance the generator loads when in isochronous parallel operation. It normally is set to 6 volts at the maximum rated generator load.

3. Loadshare Error Gain [not present in part numbers 9905-291/-381] adjusts the amount of speed bias applied to the speed reference as a function of the load share error bridge output. It is used in conjunction with the Load Gain Voltage to balance the generator loads when in isochronous parallel operation. The default value is 1.67% of rated speed per volt output from the load share error bridge.

4. 4 mA KW Load Input is the amount of KW load on the generator when 4 mA is input from the load sensor.

5. 20 mA KW Load Input is the amount of KW load on the generator when 20 mA is input from the load sensor.

IMPORTANT

This control will accommodate 4–12–20 mA transducers and 4–20 mA transducers. When using a 4–12–20 transducer, the 4 mA setting will equal 100% reverse power. This type of transducer is recommended because it provides better load control at very light loads. If your system has critical import or reverse power considerations, then a 4–12–20 mA transducer is required.

6. Base Load Reference is the amount of load on the generator which the control will ramp to when the Base Load contact is closed and the Unload/Reset to Rated contact is closed.

7. Unload Trip Level is the amount of load on the generator which opens the Breaker Open relay contact output when generator unload has been selected by opening the Unload/Reset to Rated contact.

8. Load Ramp Time is the time required for the control to ramp the generator load from the Unload Trip Level to the Base Load Reference. The ramp is started whenever the Unload/Reset to Rated and Base Load contacts are closed.

9. Unload Ramp Time is the time required for the control to ramp the generator load from the Base Load Reference to the Unload Trip Level. The ramp is started whenever the Unload/Reset to Rated contact is opened.

IMPORTANT	**Actual generator unloading may be slower than set by the Unload Ramp Time set point. This occurs when the Unload Ramp Time set point is faster than system dynamics will allow the engine to reduce load. This condition is indicated by the control actuator output going to the minimum fuel position during unloading.**

10. Raise Load Rate is the rate at which the load reference is ramped when using the Raise Load command as well as when the Remote Speed/Load Setting input is changed in the increase direction. A step change on the remote input does not cause an immediate change in the reference, which is ramped to the new setting at the Raise Load Rate.

11. Lower Load Rate is the rate at which the load reference is ramped when using the Lower Load command as well as when the Remote Speed/Load Setting input is changed in the decrease direction. A step change on the remote input does not cause an immediate change in the reference, which is ramped to the new setting at the Lower Load Rate.

12. 4 mA Remote KW Reference is the generator load desired when 4 mA is applied to the Remote Speed/Load Setting input.

13. 20 mA Remote KW Reference is the generator load desired when 20 mA is applied to the Remote Speed/Load Setting input.

14. Load Droop Percent is the percentage of speed droop when the generator load is at maximum.

15. Load at 4 mA Output is the generator load when the KW load signal output is 4 mA.

16. Load at 20 mA Output is the generator load when the KW load signal output is 20 mA.

Menu 6—Fuel Limiters and Control Output Menu

Fuel limiters limit the actuator output current from the control.

1. Idle Fuel Limit sets the maximum percent actuator output current when idle speed is selected. The limit is usually set at the fuel level required to start the engine and maintain idle speed.

2. Maximum Fuel Limit sets the maximum percent actuator output current when rated speed is selected. Maximum (100%) is based on 200 mA. The limit is usually set just above the output at full load. The percent output is displayed in Menu 7.

IMPORTANT **Maximum and Idle Fuel Limiters are effective in both local and remote modes. Even in remote mode, the Idle/Rated contact must still be used to select the appropriate fuel limit.**

3. External Fuel Limit enables and disables the fuel limiter, which uses the Turbo Boost Pressure input to limit the actuator output. If the fuel limiter is disabled, the fuel limiter breakpoint settings will not be used.

4. Fuel Limit Breakpoint A is the milliamp input of the Turbo Boost Pressure input where the slope of the fuel limiter output changes (x-axis input in Figure 3-6). Breakpoint A must be set between 2 mA and Breakpoint B.

5. Fuel Limit at Breakpoint A is the percent actuator output current allowed when the Turbo Boost Pressure input is at or below Breakpoint A (y-axis input in Figure 3-6). The fuel limiter interpolates between Breakpoint A and Breakpoint B when the Turbo Boost Pressure input is between these two settings.

6. Fuel Limit Breakpoint B is the milliamp input of the Turbo Boost Pressure input where the slope of the fuel limiter output changes (x-axis input in Figure 3-6). Breakpoint B must be set between Breakpoint A and Breakpoint C.

7. Fuel Limit at Breakpoint B is the percent actuator output current allowed when the Turbo Boost Pressure input is at Breakpoint B (y-axis input in Figure 3-6). The fuel limiter interpolates between Breakpoint B and Breakpoint C when the Turbo Boost Pressure input is between these two settings.

8. Fuel Limit Breakpoint C is the milliamp input of the Turbo Boost Pressure input where the slope of the fuel limiter output changes (x-axis input in Figure 3-6). Breakpoint C must be set between Breakpoint B and Breakpoint D.

9. Fuel Limit at Breakpoint C is the percent actuator output current allowed when the Turbo Boost Pressure input is at Breakpoint C (y-axis input in Figure 3-6). The fuel limiter interpolates between Breakpoint C and Breakpoint D when the Turbo Boost Pressure input is between these two settings.

10. Fuel Limit Breakpoint D is the milliamp input of the Turbo Boost Pressure input where the slope of the fuel limiter output changes (x-axis input in Figure 3-6). Breakpoint D must be set between Breakpoint C and Breakpoint E.

11. Fuel Limit at Breakpoint D is the percent actuator output current allowed when the Turbo Boost Pressure input is at Breakpoint D (y-axis input in Figure 3-6). The fuel limiter interpolates between Breakpoint D and Breakpoint E when the Turbo Boost Pressure input is between these two settings.

12. Fuel Limit Breakpoint E is the milliamp input of the Turbo Boost Pressure input where the slope of the fuel limiter output changes (x-axis input in Figure 3-6). Breakpoint E must be set between Breakpoint D and 20 mA.

13. Fuel Limit at Breakpoint E is the percent actuator output current allowed when the Turbo Boost Pressure input is at or above Breakpoint E (y-axis input in Figure 3-6).

Figure 3-6 illustrates these breakpoints and adjustments.

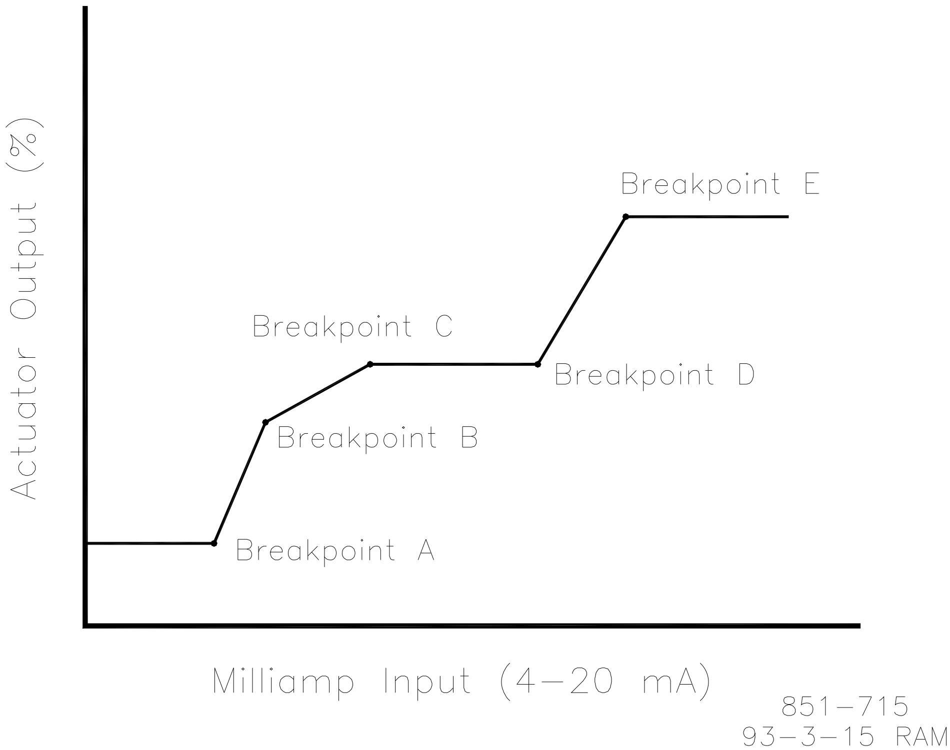

Figure 3-6. Fuel Limit Breakpoints

Menu 7—Display Menu 1

The programmer displays input and output values as each item is selected. The control automatically updates the display.

1. Engine Speed displays the current engine speed in rpm.

2. Speed Reference displays the current speed reference in rpm. Note that this may not be the speed the engine is currently running at due to the effect of droop, fuel limiters, etc.

3. Generator Load displays the current generator load in KW.

4. Load Reference displays the current load reference in KW. Note that this may not be the load the generator is currently outputting due to the effect of fuel limiters and other factors.

5. Actuator Output displays the current percent of output. Maximum (100%) is 200 mA (0 mA for reverse-acting). This is useful for setup of the control fuel limiters, and Gain Slope Breakpoint settings.

6. Torsional Level displays the current torsional level (the percent of speed that the engine and generator are out of phase) in percent.

7. Speed Control Mode displays the current Speed Control Mode status. The possible modes are Stop, Failsafe, Fuel Limiter, and Speed Control. This is useful for testing and system troubleshooting.

8. Load Control Mode displays the current Load Control Mode status. The possible modes are Base Load, Unload Ramp, Unload Trip, Load Ramp, Droop, Load Sharing, and Remote. This is useful for testing and system troubleshooting.

Menu 8—Configuration Menu

1. Configuration Key is a code which you must enter before you can change any of the set points on the configuration menu. This helps prevent accidental modification of the set points. The code is factory set to “49”. Use the “Turtle Up” and “Turtle Down” keys to select the code. Engine speed must be 0 rpm, and the Minimum Fuel (Run/Stop) contact must be open to enter this menu. Whenever the Minimum Fuel (Run/Stop) input is changed, the code will be reset to “0”.

IMPORTANT

The Minimum Fuel (Run/Stop) contact must be open, engine speed must be 0, and the Configuration Key must be set to “49” to change any of the set points on the Configuration menu. Failure to meet any of these conditions will result in an error message being displayed on the Hand Held Programmer.

2. Rated Speed (synchronous speed) sets the normal operating speed of the engine. It should be set at the speed at which the engine is operated at full load.

3. Gear #1 Teeth is the number of teeth or holes in the gear or flywheel that speed sensor #1 is on. If the gear is running at camshaft speed (one-half engine speed) then you must enter one-half the number of teeth on the gear. The control requires the number of teeth per engine revolution. If a flexible coupling is being used, gear #1 must be on the engine side of the coupling.

4. Gear #2 Teeth is the number of teeth or holes in the gear or flywheel that speed sensor #2 is on. If the gear is running at camshaft speed (one-half engine speed) then you must enter one-half the number of teeth on the gear. The control requires the number of teeth per engine revolution. If a flexible coupling is being used, gear #2 should be on the generator side of the coupling.

IMPORTANT

Best control performance will be obtained when sensing speed from a gear rotating at full engine speed. Slower-speed gears (such as the camshaft) provide a lower sampling rate which impairs control response time.

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

5. Actuator Sense sets the direction of the control actuator output to increase fuel. Forward-acting actuators require increased current to increase fuel. Reverse-acting actuators require decreased current to increase fuel (reverse-acting actuators should always incorporate a mechanical ballhead backup governor, such as the Woodward EGB).

6. Dynamics Map selects the mapping algorithm used to map dynamics as a function of engine speed. Figure 3-7 illustrates how dynamics vary as a function of engine speed for each map. The 721 control provides three dynamics maps: linear, non-linear, and constant.

   The Linear Map is normally suitable for all medium- to high-speed engines. With the Linear Map, Gain is proportional to engine speed and Stability and Compensation are held constant. The Gain set point may be adjusted at any engine speed, but the value is normalized to the rated speed reference. For example, if Gain is set to 0.1 and current engine speed is 50 percent of the maximum, then the actual gain used in the control algorithm will be 0.05, or 50 percent of the set point value. If engine speed is at rated, actual gain will be 100 percent of the set point value.

   The Nonlinear Map provides additional Stability and Compensation inversely proportional to engine speed for low- to medium-speed engines. Gain for the Nonlinear Map is proportional to the square of engine speed. For example, at 50 percent of maximum speed, the actual gain will be 25 percent of the set point value and Stability and Compensation values will be two times greater than at maximum speed.

   The Constant Map provides a Gain which is constant at all engine speeds for some medium- to high-speed engines. Stability and Compensation are also held constant.

   The final decision on which map to use depends on engine performance obtained throughout the operating speed and load range. After tuning the control for desired performance under rated speed and load conditions, performance at low speed and light loads should be evaluated. If low frequency speed oscillation occurs at low speeds using the Linear Map, the Nonlinear Map will provide additional Stability. If performance is poor at low speed using the Nonlinear Map, the Linear and Constant Maps will provide higher performance. Select the map that provides the best overall performance for all operating conditions.

7. MPU1 Failed Alarm sets the alarm condition which will occur when a loss of the speed sensor #1 input signal has been detected. Alarm selection may be Major Alarm, Minor Alarm, or None.

8. MPU2 Failed Alarm sets the alarm condition which will occur when a loss of the speed sensor #2 input signal has been detected. Alarm selection may be Major Alarm, Minor Alarm, or None.

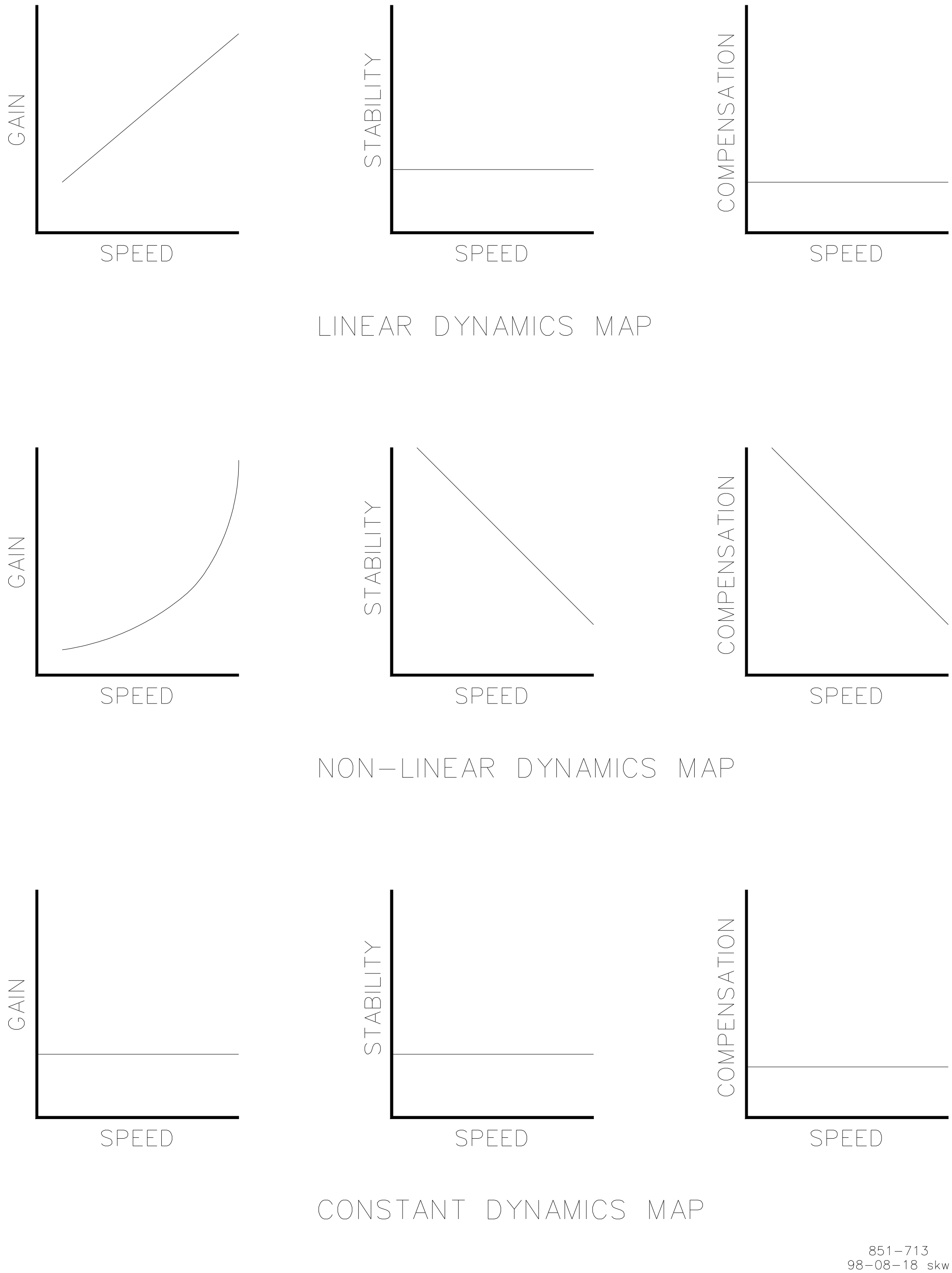

Figure 3-7. Dynamics Map Curves

9. Both MPUs Failed Alarm sets the alarm condition which will occur when a loss of the speed sensor #1 and #2 input signals has been detected. Alarm selection may be Major Alarm, Minor Alarm, or None.

10. Load Sensor Failed Alarm sets the alarm condition which will occur when the KW Transducer input drops below 2 mA. Alarm selection may be Major Alarm, Minor Alarm, or None.

11. Sequence Error Alarm sets the alarm condition which will occur when a sequence error has been detected. Alarm selection may be Major Alarm, Minor Alarm, or None.

12. High Torsional Level Alarm sets the alarm condition which will occur when the torsional Derated Trip Level set point (Menu 4) has been exceeded. Alarm selection may be Major Alarm, Minor Alarm, or None.

13. Remote Input Failed Alarm sets the alarm condition which will occur when the Remote Speed/Load Setting input drops below 2 mA. Alarm selection may be Major Alarm, Minor Alarm, or None.

Menu 9—Calibration Menu

Input and output values are displayed once when each item is selected.

IMPORTANT

Many items in this menu are adjusted at the factory and generally will not need to be changed. These are marked as "(FACTORY SETTING)". All other settings may be adjusted by the end user depending on the accuracy of your signals. For instance if your KW transducer is supposed to supply 4 mA at zero load but actually supplies 4.1 mA, you can compensate for this. However, if it is providing a 6 mA signal or a signal that has a lot of variation, then you need to determine why.

1. Calibration Key is a code which you must enter before you can change any of the set points on the calibration menu. This helps prevent accidental modification of the set points. You must adjust this value to "49" before making changes to the rest of the items in this menu.

IMPORTANT

The Minimum Fuel (Run/Stop) contact must be open, engine speed must be 0, and the Calibration Key must be set to "49" to change any of the set points on the Calibration menu. Failure to meet any of these conditions will result in an error message being displayed on the Hand Held Programmer.

2. KW Load Input is used to compensate for KW transducer error. Set the engine at zero load and make sure that the transducer is powered up. This will require that an ammeter be put in line with the input. Adjust the KW Load Input value until the 721 readout matches your target value, which will usually be 4 mA or 12 mA depending on the type of transducer you are using.

   Example: At zero load, your transducer is supposed to supply 4.0 mA, but suppose it is supplying a constant 4.2 mA. First try to calibrate the transducer. But if you cannot get any closer to 4.0 mA, your will have to compensate for this by adjusting the KW Load Input value until the 721 readout reads 4.0 mA even though you are supplying 4.2 mA.

3. Synchronizer Input calibrates the ±5.0 Vdc Synchronizer input. (FACTORY SETTING)

4. Fuel Limiter Input calibrates the 4–20 mA Turbo Boost Pressure input. You need to determine what the transducer is supposed to be supplying at some constant pressure. This might be 4 mA when the engine is off. It depends on your transducer and system setup. Adjust the Fuel Limiter Input until the 721 readout matches your target transducer value. Refer to the example in item 2.

5. Remote Reference Input calibrates the 4–20 mA Remote Speed/Load Setting input. Make sure that the transducer is supplying a constant value at a known point. Adjust the Remote Reference Input value until the 721 readout matches your target value. Refer to the example in item 2.

6. Parallel Line Input calibrates the Load Sharing Lines input. (FACTORY SETTING)

7. Load Sharing Error calibrates the internal load bridge offset. (FACTORY SETTING)

8. De-Droop calibrates the load sharing bridge offset by adjusting the value of the load sharing bridge voltage. (FACTORY SETTING)

IMPORTANT **Items 9 and 10 are a gain/offset pair of adjustments that work together to calibrate the load sharing signal.**

9. Load Sharing Output is a gain adjustment to the Load Sharing Lines output voltage. At zero load, this output should be 0 V, and at full load it is typically set to 3 V (as measure across terminals 21 and 22). (FACTORY SETTING)

10. Load Sharing Offset is an offset adjustment to the load sharing output voltage. (FACTORY SETTING)

11. Torsional Level calibrates the 4–20 mA Torsional Level output. (FACTORY SETTING)

12. KW Load Output calibrates the 4–20 mA Load Signal output. (FACTORY SETTING)

13. Tachometer Output calibrates the 4–20 mA Tachometer output. (FACTORY SETTING)

14. Actuator Output calibrates the 0–200 mA Actuator Output. (FACTORY SETTING)

15. Analog Speed #1 calibrates the analog Speed Sensor Input #1. (FACTORY SETTING)

16. Analog Speed #2 calibrates the analog Speed Sensor Input #2. (FACTORY SETTING)

Menu 0—Display Menu 2

The programmer displays input and output values as each item is selected. The control automatically updates the display.

1. Analog Speed #1 displays the rpm shown by speed sensor #1 (terminals 17/18) after conversion from a frequency to an analog voltage signal. The control uses the analog signal to determine the average speed of the engine and for torsional filtering.

2. Analog Speed #2 displays the rpm shown by speed sensor #2 (terminals 19/20) after conversion from a frequency to an analog voltage signal. The control uses the analog signal to determine the average speed of the engine and for torsional filtering.

3. Digital Speed #1 displays the rpm shown by speed sensor #1 (terminal 17/18) after conversion from a frequency to a digital signal. The control uses the digital signal to calibrate analog speed sensor #1.

4. Digital Speed #2 displays the rpm shown by speed sensor #2 (terminal 19/20) after conversion from a frequency to a digital signal. The control uses the digital signal to calibrate analog speed sensor #2.

5. Run/Stop Contact Status shows the status of the Minimum Fuel (Run/Stop) contact (open or closed).

6. Idle/Rated Contact Status shows the status of the contact (open or closed).

7. Lower Speed Contact Status shows the status of the contact (open or closed).

8. Raise Speed Contact Status shows the status of the contact (open or closed).

9. Failsafe Override Contact Status shows the status of the contact (open or closed).

10. Unload Contact Status shows the status of the contact (open or closed).

11. Base Load Contact Status shows the status of the contact (open or closed).

12. Circuit Breaker Contact Status shows the status of the contact (open or closed).

13. Load Share Relay Status shows the status of the contact (open or closed).

14. Major Alarm Relay Status shows the status of the relay (open or closed).

15. Minor Alarm Relay Status shows the status of the relay (open or closed).

16. Breaker Open Relay Status shows the status of the relay (open or closed).

17. MPU #1 LED Status shows the status of the Alarm #1 LED (on or off).

18. MPU #2 LED Status shows the status of the Alarm #2 LED (on or off).

19. Watchdog Status shows the status of the control CPU. The normal status displayed is CPU OK. If a CPU fault occurs, the POWER AND CPU OK indicator on the front of the control will turn off, the actuator output will decrease to minimum, and the Watchdog Status will display TIME OUT. To reset the watchdog, turn off power to the control for a minimum of 10 seconds.

20. Diagnostics Results shows the status of the internal control diagnostics (49; any other number indicates a problem).

21. ROM Checksum shows the status of the internal memory check and is used by Woodward during factory tests. An incorrect result will give a Diagnostics Results error also.

At this time, we recommend saving this setup by pressing the “SAVE” key on the Hand Held Programmer. The programmer will display the message “Set Points Saved”. Be sure to select a menu prior to continuing.

NOTICE

To prevent possible damage to the engine resulting from improper control settings, make sure you save the set points before removing power from the control. Failure to save the set points before removing power from the control causes them to revert to the previously saved settings.

Chapter 4.
Initial Adjustments

Introduction

This chapter contains information on control calibration. It includes initial prestart-up and start-up settings and adjustments.

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

Start-up Adjustments

1. Complete the installation checkout procedure in Chapter 2 and the prestart menu settings in Chapter 3.

2. Close the Minimum Fuel (Run/Stop) contact. Open the Failed Speed Signal Override contact. Be sure the Idle/Rated contact is in idle (open). Apply power to the control. Do NOT proceed unless the green POWER AND CPU OK indicator on the front of the control is on.

3. Check the speed sensor.

   Minimum voltage required from the speed sensor to operate the control is 1.0 Vrms, measured at cranking speed or the lowest controlling speed. For this test, measure the voltage while cranking, with the speed sensor connected to the control. Before cranking, be sure to prevent the engine from starting. At 5% of rated speed and 1.0 Vrms, the failed speed sensing circuit function is cleared. If the red Alarm #1 indicator remains on, shut down the engine.

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

4. Start the engine.

   If there is insufficient fuel to start the engine, increase the Idle Fuel Limit (Menu 6). (The control will reduce fuel as required when the speed setting is reached. It requires extra fuel to accelerate the engine to idle speed.) It may take a few starts to determine the final setting of the Idle Fuel Limit. If the start time is excessive, increase the Idle Fuel Limit. If the start time is too fast or flooding is occurring, decrease the Idle Fuel Limit. We recommend trying both hot and cold starts to determine a final setting.

5. Adjust for stable operation.

   If the engine is hunting at a rapid rate, slowly decrease the Gain (Menu 1) until performance is stable. If the engine is hunting at a slow rate, increase the Stability time. If increasing the Stability time does not stabilize the engine, it also may be necessary to slowly decrease the Gain OR to slowly decrease the Gain and increase the Compensation.

   This completes the start-up adjustments. We recommend saving the settings at this time by pressing the “SAVE” key on the Hand Held Programmer.

Dynamic Adjustments

The objective of the dynamic adjustments is to obtain the optimum, stable engine speed response from minimum speed/load to full speed and load. All adjustments apply to both standard dynamics (Circuit Breaker Aux contact open) and auxiliary dynamics (Circuit Breaker Aux contact closed).

Do the following adjustments first for standard dynamics (Circuit Breaker Aux contact open). Use Menu 1 to set the standard dynamics, if changes are needed.

Then repeat the adjustments for auxiliary dynamics (Circuit Breaker Aux contact closed). Use Menu 2 to set the auxiliary dynamics, if changes are needed.

1. No-Load Adjustments

   Do this adjustment without load applied.

   Slowly increase the Gain set point until the engine becomes slightly unstable, then reduce the Gain as necessary to stabilize the engine.

   After acceptable performance at no load, record the Actuator Output as read on Menu 7. Set the Gain Slope Breakpoint (Menu 1) to this reading.

2. Minimum Load Adjustment

   Do this adjustment at the minimum speed and load conditions at which the engine is operated. Be sure to select Rated Speed to switch to the Maximum Fuel Limit. Speed may be set either with the Raise and Lower commands in local control or with the 4 to 20 mA Remote Speed/Load Setting input in remote mode.

   Observe the movement of the actuator. If the activity of the actuator is excessive, reduce the Gain set point slightly to get the actuator movement to an acceptable level.

   If there is a slow periodic cycling of the engine speed above and below the speed setting, there are two possible causes:

   - Gain is too high and Stability is too low. Reduce the Gain by 50% (i.e., if the Gain was 0.02, reduce it to 0.01) and increase Stability slightly. Observe the movement of the actuator. Continue to increase Stability until the movement is acceptable but not excessive. A final value of Stability should be between 1.0 and 2.0 for most large engines. If the Stability value exceeds 2.0, but this procedure continues to improve performance, increase the Compensation set point 50% and repeat the procedure.

- Gain is too low. If the preceding procedure does not improve the slow periodic cycling of the engine speed, the control may be limiting cycling through the low gain control region set by the Window Width set point. Increase the Gain set point to minimize the cycling. If actuator movement becomes excessive, reduce the Compensation set point until movement is acceptable. In some cases, Compensation may be reduced to zero and only the Gain and Stability adjustments used. This should be done only if necessary to eliminate excessive actuator response to misfiring or other periodic disturbances. Reduce the Window Width set point until the limit cycle amplitude is acceptable without excessive rapid actuator movement.

3. Full Load Adjustment

   Do these adjustments at the speed and load at which the engine is most often operated.

   If operation in this range is satisfactory, no further dynamic adjustments are necessary. If during changes in speed or load, excessive speed errors occur, increase the Gain Slope adjustment until engine performance is satisfactory. If excessive actuator movement again occurs, do procedure 4, then repeat procedure 3. If the settling time after a speed or load change is too long, reduce the Stability set point slightly and increase the Gain slightly. If slow-speed hunting occurs after a load or speed change but decreases or stops in time, increase the Stability set point slightly and reduce the Gain set point. See Figure 3-4.

⚠WARNING

The use of negative Gain Slope should be considered carefully. Low gain at high fuel levels will result in poor load rejection response or possible overspeed. To prevent possible serious injury from an overspeeding engine, the Maximum Fuel Limit, Menu 6, must be set near the full load output current demand to prevent excessive integrator windup and a subsequent low gain condition.

4. When speed and load changes occur, the control should switch automatically to high gain to reduce the amplitude of the offspeeds. Reduce (or increase) the Window Width set point to just greater than the magnitude of acceptable speed error. A value of Gain Ratio too high will cause the control to hunt through the low-gain region. This normally will occur only if the Window Width is too low. If necessary to decrease the Window Width to control limit cycling (identified by the engine speed slowly cycling from below to above the speed setting by the amount of Window Width), the Gain Ratio may be reduced for more stable operation.

5. Verify that performance at all speed and load conditions is satisfactory and repeat the above procedures if necessary.

6. While operating at minimum speed and load, record the Actuator Output on Menu 7. Select the Idle Fuel Limit on Menu 6. Set at the recorded value.

7. While operating at full load, record the Actuator Output on Menu 7. Select the Maximum Fuel Limit set point on Menu 6. Set at approximately 10% over the full load output if desired, otherwise leave at 100%.

We recommend you check the operation from both hot and cold starts to obtain the optimum stability under all conditions.

Speed Adjustments

Adjustment of the idle, rated, raise, and lower references should not require further setting as they are precisely determined. The Remote Speed/Load Setting input and the Tachometer Output, however, involve analog circuits and may require adjustment.

1. 4 to 20 mA Remote Speed/Load Setting Input

   Apply 4 mA to the Remote Speed/Load Setting Input. Be sure remote operation is selected (Raise Speed/Load and Lower Speed/Load contacts both closed). Observe the operating speed of the engine as displayed on Menu 7. If the engine rpm is lower or higher than desired, increase or decrease the 4 mA Remote Reference set point on Menu 3 to obtain the correct speed. There may be a small difference between the set point and actual speed which compensates for the inaccuracies in the analog circuits.

   Now apply 20 mA to the Remote Speed/Load Setting Input. Wait until the ramp stops. Increase or decrease the 20 mA Remote Reference set point to obtain the tachometer speed desired.

   Repeat the above steps until the speeds at 4 mA and 20 mA are within your required range.

2. 4 to 20 mA Tachometer Output

   Set engine speed to the speed desired for 4 mA output. If this is not possible, skip this step or use a signal generator into the speed input with the correct frequency corresponding to the desired rpm. Trim the Tach at 4 mA Output rpm set point for 4 mA set point output.

   Set engine speed to the speed desired for 20 mA output. Trim the Tach at 20 mA Output rpm set point for 20 mA set point output.

   Repeat the above steps until the speeds at 4 mA and 20 mA are within your required range.

Automatic Generator Loading Functions

The 721 control's automatic generator loading functions are designed to be used with the speed control functions to automatically control the loading and unloading of the generator. This accomplishes a bumpless transfer when paralleling the generator to a load sharing or infinite bus system, or separating a generator from a system.

Load Control Mode Switching

Load control operation is determined by the status of the contacts to the Circuit Breaker Aux contact input (terminal 32) and the load control mode select contact inputs. The load control mode contacts are Base Load (terminal 31), and Unload (terminal 30). The two mode contacts determine the load control operating mode:

1.	Both open	isochronous load sharing at unload trip level
2.	Base Load only closed	isochronous load sharing at unload trip level
3.	Unload only closed	isochronous load sharing system
4.	Both closed	base load in parallel bus systems

When the CB Aux contact input is open, droop is the only available operating mode. In single unit operation, speed will decrease as load increases. In parallel with a bus, the generator is loaded by increasing the speed reference. The 721 will provide the droop signal required for stability. When the CB Aux contact input is closed when the generator is paralleled to a bus, the load control operating mode contact inputs become effective.

The 721 base load mode is selected by closing both the Base Load contact and the Unload contact. This function can be used in one of two modes: either as a control to load against a utility, or to isolate a single generator set from a load sharing system and load that set to a specific load. The second mode can also be used when a controlled unload is desired without taking the generator set off line.

Automatic Load Control Applications

Soft Loading into a Load Sharing System

Automatic soft loading into a load sharing system is selected by closing the Aux contact. The Unload contact should be closed to allow full load sharing operation. The loading function is activated when the oncoming generator set is properly synchronized and the paralleling generator breaker closes, closing the generator breaker auxiliary contacts to terminal 32.

The activated soft loading function compares the load on the oncoming unit with the load on the load sharing system. The load ramp then linearly increases the load on the unit at the rate set by the load ramp time set point. When the loads match, the ramp is shut off.

Soft Unloading from a Load Sharing System

The unload sequence is initiated by opening the Unload contact. The 721 then ramps the load down to the unload trip level at the preset rate. When the load reaches the unload trip level set point, the control momentarily energizes the Circuit Breaker Open relay (terminals 7/8) to initiate the opening of the generator breaker. This command can be used to separate the engine-generator set from the paralleled system.

Base Loading against a Utility

Close the Unload contact (terminal 30) to enable loading. To enable base loading, the Base Load contact (terminal 31) and the Circuit Breaker Aux contact (terminal 32) must be connected to a set of generator breaker auxiliary contacts. The relay logic of the Base Load contact must be such that base load is selected only when the generator is on line and paralleled with the utility. Typically, the Circuit Breaker Aux contact and the utility tie breaker contact are placed in series for this logic.

When both generator and utility breakers are closed, the ramp starts and the unit load is increased to match the base load set point. The base load can be adjusted up or down while in the base load mode with the Raise and Lower Load contact inputs. The load will follow at a rate set by the appropriate load or unload rate set points. The external 4–20 mA load setting input, if used, takes precedence over the internal base load set point when both the Raise and Lower Load contacts are closed.

The Unload input (terminal 30) will initiate the unload sequence. Opening the Unload switch contact commands the ramp to decrease the demand on the generator to the unload trip level. When the trip level is reached, the breaker open command relay is momentarily de-energized to separate the generator from the utility. When the Circuit Breaker Aux contact opens, the 721 will remove the bias signal from the speed control and reset the loading function for when the breaker is again closed.

Base Load and Load Sharing Systems

When the generator is paralleled and load sharing, closing the Base Load contact (terminal 31) activates the base load function. Load on any parallel load sharing units is disregarded. Load will ramp in the increasing or decreasing direction until the unit load matches the base load set point. The base load can be adjusted up or down while in the base load mode with the Raise and Lower Load contact inputs. The load will follow at a rate set by the appropriate raise load or lower load rate set points.

When both the Raise and Lower Load contacts are closed, the external 4–20 mA load setting input will take precedence over the internal base load set point (when above 4 mA/1 Vdc). Opening the Base Load contact initiates the return of the system to load sharing. The unit load is ramped up or down until it matches the system load sharing level, then ramps are disabled.

Conclusion of Setup Procedures

This completes the adjustment chapter. Save the set points by pressing the “SAVE” key on the Hand Held Programmer. Run through all the set points and record them in Appendix A for future reference. This can be useful if a replacement control is necessary or for start-up of another similar unit. Power down the control for about 10 seconds. Restore power and verify that all set points are as recorded.

NOTICE

To prevent possible damage to the engine resulting from improper control settings, make sure you save the set points before removing power from the control. Failure to save the set points before removing power from the control causes them to revert to the previously saved settings.

Disconnect the Hand Held Programmer from the control. Close the cover over J1 and retighten the retaining screw.

Chapter 5. Description of Operation

General

This section provides an overview of the features and operation of the 721 Digital Speed Control. Figures 1-4 and 1-5 show the control block diagram, and Figure 1-7 is the plant wiring diagram, for reference in the following descriptions.

The 721 Digital Speed Control uses a 16-bit microprocessor for all control functions. All control adjustments are made with a hand-held terminal/display that communicates with the control via a serial port. The terminal/display is disconnected from the control when not in service, to provide security against tampering.

The speed sensors contain a special tracking filter designed for reciprocating engines, which minimizes the effects of flexible coupling torsionals. This provides exceptionally smooth steady-state control and allows the control dynamics to be matched to the engine rather than detuned to compensate for coupling torsionals. The speed signal itself is usually provided by a magnetic pickup supplying from 1 to 60 Vrms to the control. The control has two red indicators which illuminate if a speed sensor signal is lost.

The control has a switching power supply with excellent spike, ripple, and EMI (electromagnetic interference) rejection. Discrete inputs are optically isolated and capable of rejecting EMI and variable resistance in switch or relay contacts. Analog inputs are differential type with extra filtering for common-mode noise rejection. This protects the control from spurious interference and noise, which can cause speed and load shifts.

An auxiliary analog input is provided to interface with Woodward Power Sensors to provide isochronous load sharing, base loading, or droop operation.

The control also provides 4 to 20 mA terminals for tachometer output, KW load output, and torsional level output. These outputs may be used for an analog meter or as input to a computer. The offset and span are adjustable for range.

Control Dynamics

The control algorithms used in the 721 control are designed specifically for reciprocating engine applications. Control dynamics are varied automatically as functions of both speed and load to provide better performance over the operating range of the engine.

The 721 control provides two mappings of control dynamics as a function of speed. The control automatically maps gain proportional to engine speed. This provides higher gain at normal operating speeds and lower gain at low speeds. This matches engine control requirements better than a constant-gain control. A second optional dynamics mapping provides additional stability as speed is decreased. This feature is useful particularly on large, low-speed engines where dead time between cylinder firings becomes an important factor in performance.

To provide better transient performance, the control can be operated automatically with two gain settings depending on engine speed error (speed error is the difference between the speed setting and the actual engine speed). During steady-state operation with a constant load, the control uses the base gain setting. This gain is adjusted by the user to a value to prevent the control from responding to minor fluctuations in engine speed, a common problem with gas-fueled, spark-ignited engines. This feature eliminates potentially damaging jiggle of the actuator and fuel system. The control automatically increases gain by an adjustable ratio when a speed error exceeding an adjustable window occurs. Operation with base gain is restored once the control senses the return to steady-state speed.

The control can also compensate for nonlinear fuel systems and changes in engine dynamics with load. The control dynamics are mapped as a function of actuator current (actuator current is proportional to engine load). This provides optimal dynamics and smooth steady-state operation for all conditions from no load to full engine load.

The control also provides two complete sets of dynamic adjustments which are selected when the Circuit Breaker Aux discrete input is activated. The two sets of dynamics are provided for use where engine operating conditions change, such as in systems with clutched-in loads, and electrical power generation where the unit may be operated stand alone or paralleled with an infinite bus.

Fuel Limiters

The 721 Digital Speed Control provides an idle fuel limiter to limit overfueling or flooding during start-up. The limiter is set to provide the desired maximum rack position during starts. The control will reduce the fuel when the speed set point is reached as required to control engine speed, but will not exceed the Idle Fuel Limit.

A Maximum Fuel Limit set point is provided to limit the maximum control output current to the actuator during normal engine operating conditions. See Figure 5-1.

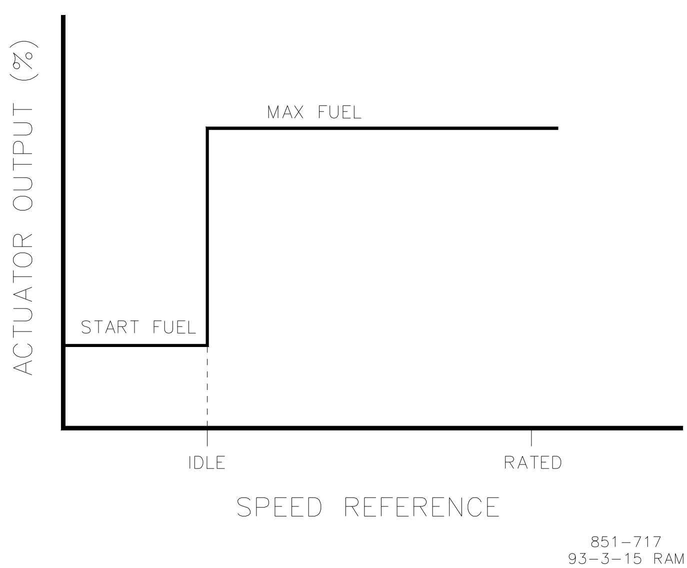

Figure 5-1. Fuel Limiters

Speed Reference and Ramps

The 721 control provides local control of the speed reference, with discrete inputs to issue raise and lower speed commands. For remote speed setting, the control provides a 4 to 20 mA/1 to 5 Vdc Remote Speed/Load Setting input which is used for the speed reference. Remote is selected by closing both the Raise Speed/Load contact and the Lower Speed/Load contact.

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

The control provides idle, lower limit, rated, and raise limit set points, accel and decel times, and raise and lower rates, for local operation. Accel time determines the time required for the engine to ramp from idle (low idle) to rated (fast idle) speed. Decel time determines the time required for the engine to ramp from rated speed to idle speed. Raise and lower rates determine how fast speed is increased or decreased by the raise and lower command inputs.

The idle speed set point is provided for engine start-up or cool down speed. Idle speed may be set equal to or less than the rated speed set point. Idle is independent of the lower limit set point and may be set to a lower speed. When idle is selected (Idle/Rated contact open), remote, raise, and lower inputs are all disabled. Idle speed cannot be changed except through adjustment of the idle speed set point. In idle, the Idle Fuel Limit is in effect, and the Maximum Fuel Limit and External Fuel Limit are disabled. This means the maximum fuel available is determined only by the Idle Fuel Limit set point, and the speed reference is determined only by the idle speed set point.

When rated speed (high or fast idle) is selected by closing the Idle/Rated contact, the fuel limit is set to the Maximum Fuel Limit set point value. Closing either the Raise or Lower contacts while ramping from idle to rated results in immediate cancellation of the idle to rated ramp.

After acceleration to rated speed is completed, the raise and lower commands increase and decrease engine speed based on the raise and lower rate set points. The raise and lower limits determine the limits of these commands.

If remote operation is selected after the engine reaches rated speed, the control will ramp speed to the reference value set by the Remote Speed/Load Setting milliamp input based on the raise or lower rate. The Remote Speed/Load Setting operates from 4 to 20 mA (1 to 5 Vdc). The values of the 4 mA and 20 mA remote reference set points must be set between the raise and lower limit set points. The 4 mA Remote Reference set point may be set to a lower or higher speed than the 20 mA set point, providing for either direct or reverse-acting remote speed setting.

If a remote input is present when the Idle/Rated contact is closed or during the idle to rated ramp, the speed reference will ramp to the speed reference value determined by the milliamps on the Remote Speed/Load Setting input, based on the raise rate set point. This may not be the desired mode of operation, so be sure to understand the implications of operating the control in this manner.

The control treats Remote Speed/Load Setting inputs between 2 and 4 mA (0.5 and 1 Vdc) as the minimum of 4 mA (1 Vdc). Below 2 mA (0.5 Vdc), the remote input is considered failed. Between 4 and 20 mA (1 and 5 Vdc), the control determines the required speed reference based on a straight line between the 4 mA Remote Reference and 20 mA Remote Reference set points. If a difference is detected between the current speed reference and the remote reference computed from the mA input, the current speed reference is raised or lowered at the rate determined by the raise or lower rate to bring the speed reference into agreement with the remote speed reference. The remote reference will not increase speed over the raise limit or lower it below the lower limit.

When in remote mode (Raise and Lower Speed/Load contacts both closed), if the remote input goes below 2 mA (0.5 Vdc), the speed reference remains at the current value. This also means that if the Idle/Rated contact is changed from idle to rated and the remote speed setting input is less than 2 mA (0.5 Vdc), speed will remain at idle. Speed will remain at idle until the remote input is increased to a value greater than 2 mA (0.5 Vdc), at which time speed will change based on the raise rate set point to the remote speed setting. (If local operation is then selected under these conditions, speed will remain at idle until the Idle/Rated contact is changed to idle and back to rated to restart the ramp, since selection of the remote input cancels the accel ramp.)

If the Idle/Rated contact is changed to idle after operating at rated, the control will immediately select the idle fuel limiter and ramp engine speed to idle based on the decel time set point.

KW Load Reference and Ramps

When the Circuit Breaker Aux contact is closed, the speed reference is locked at its present value, and the raise, lower, and remote inputs control the KW load reference instead of the speed reference. The load reference then biases the speed reference for load control.

The 721 control provides local control of the KW load reference with discrete inputs to issue raise and lower load commands. For remote KW load setting, the control provides a 4 to 20 mA/1 to 5 Vdc Remote Speed/Load Setting input which is used for the KW load reference. Remote is selected by closing both the Raise Speed/Load contact and the Lower Speed/Load contact.

The control provides Unload Trip Level, Base Load Reference, and Maximum Load set points, Load Ramp Time and Unload Ramp Time, and Raise Load Rate and Lower Load Rate, for local operation. Load Ramp Time determines the time required for the engine to ramp from the Unload Trip Level (minimum KW load) to Base Load Reference set point. Unload Ramp Time determines the time required for the engine to ramp from the present KW load to the Unload Trip Level. Raise Load and Lower Load Rates determine how fast KW load is increased or decreased by the raise and lower command inputs.

Low Idle Offset

A low idle offset (droop) feature is provided to reduce or prevent engine speed undershoot when reducing speed to low idle without using the time ramps. This is accomplished by increasing (offsetting) the speed reference proportional to rack movement below the normal low idle position.

Power-Up Diagnostics

The power-up diagnostics feature is provided to verify the proper operation of the microprocessor and memory components. The diagnostics take about ten seconds after the control is powered on. A failure of the test will turn off the output of the control. If diagnostic testing is successful, the green POWER AND CPU OK indicator on the control cover will light.

Power System Management Concepts

This section provides a review of the operation of droop, isochronous, droop/isochronous, isochronous load sharing, and base load. These concepts provide an understanding for power management.

Paralleling

There are two basic methods used for paralleling: droop, where speed decreases with load, and isochronous, where speed remains constant. The paralleling system shown in Figure 5-2 consists of a load matching circuit (1), a load scaling circuit (2), and a KW transducer (3).

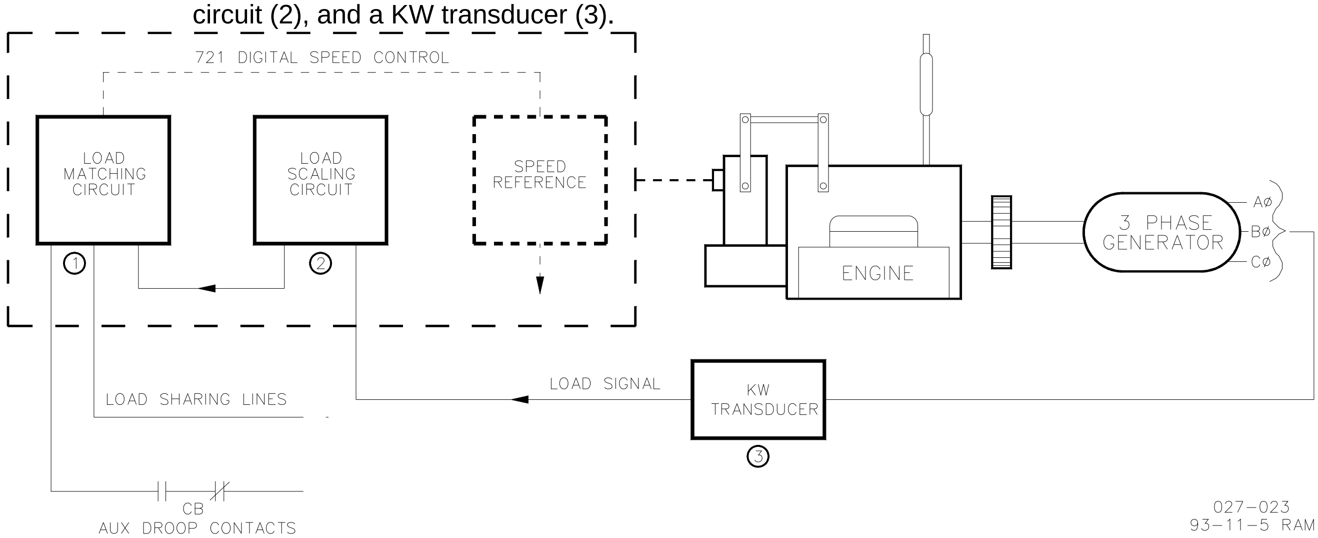

Figure 5-2. Paralleling System

An auxiliary contact on the generator tie breaker connected to terminal 31 is used to select isochronous load sharing operation. A contact in series with the auxiliary contact may be used to select either the droop or isochronous mode of operation.

When the input to the CB Aux contact is open, the control is in droop. When the CB Aux contact is closed, the control is in isochronous load sharing.

With only one unit on line, the generator picks up the available load and remains at isochronous speed. If additional units are on line, the load matching circuit corrects the fuel output to proportion load.

An amplifier in the KW transducer computes the load carried by each phase of the generator. The current load on each phase is multiplied by the cosine of the phase difference between the current and the voltage, and the three phases are added to determine the total load.

The output of the load amplifier is adjusted by the load gain set point. By setting the load gain voltage on each unit to the same level at full load, proportional load sharing is achieved. Regardless of differences in generator set capacities in the system, each generator set is loaded to the same percentage of its capacity. A final adjustment of the individual load gain adjustment will compensate for minor differences in the generator sets.

Droop mode allows operation of a generator on an infinite bus or in parallel with other engine generator units using hydromechanical governors. In droop, speed changes as the load on the generator changes. An increase in load results in a decrease in speed. The amount of speed change or droop is expressed in percent and is set by the load droop set point.

The 721 digital control is powered by a dc-dc isolated power supply, which allows operation over a wide voltage range without generating excessive heat. This isolation protects the system from interference caused by ground loops, particularly through the load sharing lines, and allows load sharing with earlier models of Woodward load sharing controls.

Droop Mode

Droop is a decrease in speed or frequency, proportional to load. That is, as the load increases, the speed or frequency decreases, as illustrated in Figure 5-3. This reduction in speed is accomplished with negative feedback. The feedback increases as the system is loaded.

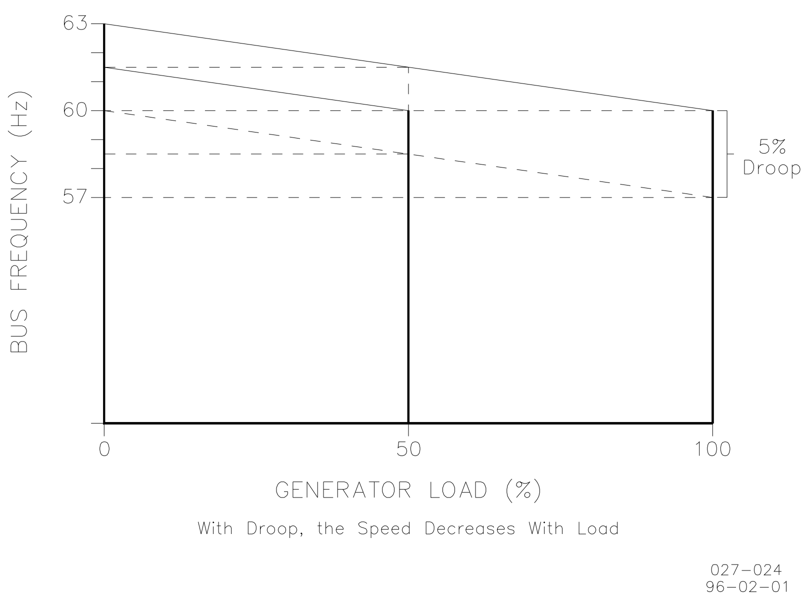

Figure 5-3. Droop Mode

Droop is expressed as the percentage reduction in speed that occurs when the generator is fully loaded. With a given droop setting, a generator set will always produce the same power output at a particular speed or frequency. Droop sometimes is called the percent speed regulation.

If all generator sets in a droop system have the same droop setting, they will each share load proportionally. The amount of load will depend on their speed settings. If the system load changes, the system frequency will also change. A change in speed setting will then be required to offset the change in feedback and return the system to its original speed or frequency. In order for each generator set in the system to maintain the same proportion of the shared load, each generator will require the same change in speed setting.

Isochronous Mode

Isochronous means repeating at a single rate or having a fixed frequency or period. A generator set operating in the isochronous mode will operate at the same set frequency regardless of the load it is supplying, up to the full load capability of the generator set (see Figure 5-4). This mode can be used on one generator set running by itself in an isolated system.

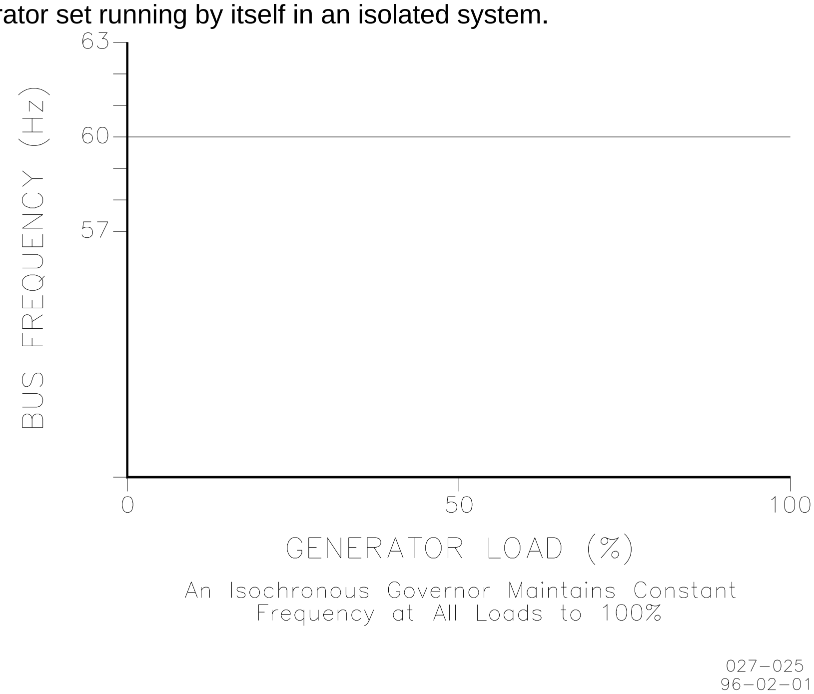

Figure 5-4. Isochronous Mode

The isochronous mode can also be used on a generator set connected in parallel with other generator sets. Unless the governors are load sharing and speed controls, however, no more than one of the generator sets operating in parallel can be in the isochronous mode. If two generator sets operating in the isochronous mode without load sharing controls are tied together to the same load, one of the units will try to carry the entire load and the other will shed all of its load. In order to share load with other units, some additional means must be used to keep each generator set from either trying to take all the load or from motoring.

Droop/Isochronous Load Sharing on an Isolated Bus

Droop/isochronous load sharing combines the first two modes. All generator sets in the system except one are operated in the droop mode. The one unit not in droop is operated in the isochronous mode. It is known as the swing machine. In this mode, the droop machines will run at the frequency of the isochronous unit. The droop and speed settings of each droop unit are adjusted so that each generates a fixed amount of power (see Figure 5-5). The output power of the swing machine will change to follow changes in the load demand.

Maximum load for this type of system is limited to the combined output of the swing machine and the total set power of the droop machines. The minimum system load cannot be allowed to decrease below the output set for the droop machines. If it does, the system frequency will change, and the swing machine can be motored.

The machine with the highest output capacity should be operated as the swing machine, so that the system will accept the largest load changes within its capacity.

Isochronous Load Sharing on an Isolated Bus

Isochronous load sharing operates all generator sets in a system in the isochronous mode. Load sharing is accomplished by adding a load sensor to each electric isochronous governor. The load sensors are interconnected by the load sharing lines. Any imbalance in load between units will cause a change to the regulating circuit in each governor. While each unit continues to run at isochronous speed, these changes force each machine to supply a proportional share of power to meet the total load demand on the system (see Figure 5-6).

Base Load on an Isolated Bus

Base Load is a method of setting a base or fixed load on a machine operating in parallel with an isolated bus. This is accomplished by using an isochronous load control and providing a reference at which to control the load. The governor will force the generator output to increase or decrease until the output of the load sensor is equal to the reference setting. At this point, the system is in balance.

This method can only be used where other generator sets are producing enough power to meet the changes in load demand. This operating mode is ideal for either soft loading additional units into an isochronous system, or for derating or unloading a machine (see Figure 5-7).

Base Load

Base Load for a system paralleled to an infinite bus or utility is the same as base load in an isolated system. The advantage of base loading over droop is that when separating from a utility, there is no frequency change. Simply removing the bias signal on breaking from the utility returns the system to isochronous.

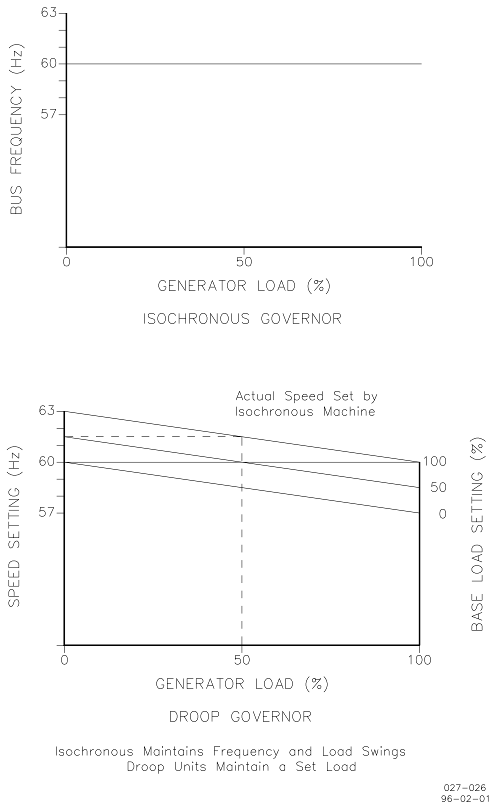

Figure 5-5. Droop/Isochronous Load Sharing

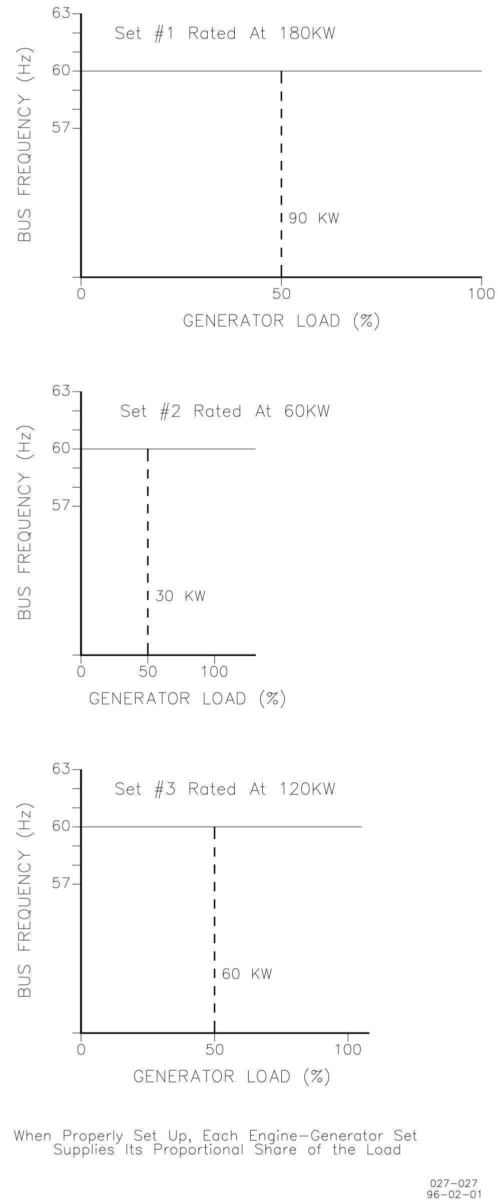

Figure 5-6. Isochronous Load Sharing

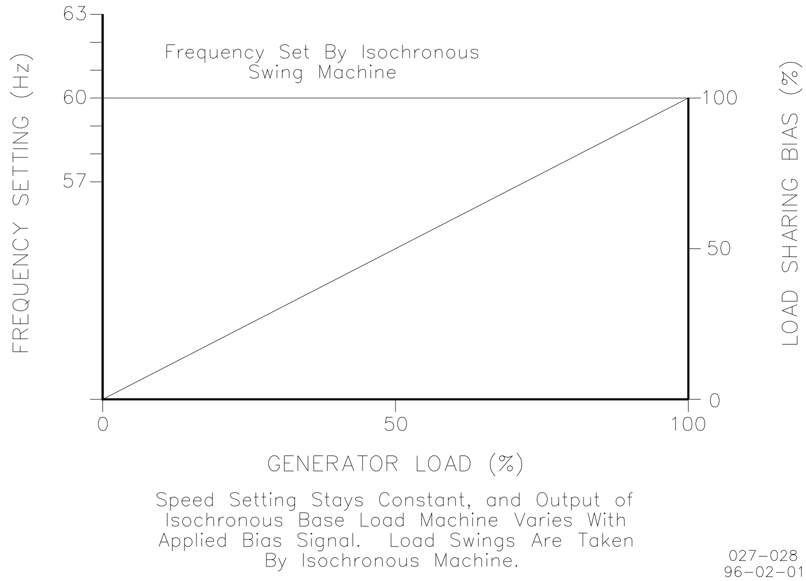

Figure 5-7. Isochronous Base Load on an Isolated Bus

Chapter 6.
Troubleshooting

General

The following troubleshooting guide is an aid in isolating trouble to the control box, actuator, plant wiring, or elsewhere. Troubleshooting beyond this level is recommended ONLY when a complete facility for control testing is available.

NOTICE **The control can be damaged with the wrong voltage. When replacing a control, check the power supply, battery, etc., for the correct voltage.**

Troubleshooting Procedure

This chapter is a general guide for isolating system problems. Before using this procedure, make sure that the system wiring, soldering connections, switch and relay contacts, and input and output connections are correct and in good working order. Make the checks in the order indicated. Each system check assumes that the prior checks have been properly done.

Control Test and Calibration

General

Do the following checks on the 721 control. Then verify the functioning of set points and adjustments.

1. Connect the Hand Held Programmer to the control in accordance with the instructions in Chapter 3. Verify that correct voltage and polarity are applied to the control. Verify that the programmer does its power-up tests. Failure to do the power up test indicates either the control or Hand Held Programmer has failed. If so, try this step with another Hand Held Programmer. If the test still fails, replace the 721 control. If the test passes with the second Hand Held Programmer, replace the Hand Held Programmer.

2. Press the “ID” key. The message “721 Speed Control P/N 5412-505/506” should appear. Failure indicates either the control or Hand Held Programmer has failed. If so, try this step with another Hand Held Programmer. If the test still fails, replace the 721 control. If the test passes with the second Hand Held Programmer, replace the Hand Held Programmer.

3. Select Menu 0. Step through the menu to the Diagnostics Result step. Verify that the displayed value is 49. If any other value is displayed, replace the control.

4. Select Menu 1. Verify that all set points are as recorded during installation. Repeat for the other menus. If any differences are found, change the set point(s) to the correct value. Press the “SAVE” key. The message “Set Points Saved” should be displayed. Remove power from the control for at least 10 seconds. Verify correct values were retained during power down. Failure indicates the control has failed and should be replaced.

Discrete Inputs

Do the following test to verify the function of the discrete inputs. Do NOT do these tests with the engine running.

1. Close the Minimum Fuel (Run/Stop) contact. Select Run/Stop Contact Status on Menu 0. The status should be closed. If the value does not change from closed to open when the contact is opened, verify the voltage at the control terminals. If correct voltage is verified, the control has failed and should be replaced.

2. Close the Idle/Rated contact. The Idle/Rated Contact Status in Menu 0 should be closed. If the value does not change from closed to open when the contact is opened, verify the voltage at the control terminals. If correct voltage is verified, the control has failed and should be replaced.

3. Close the Lower Speed/Load contact. The Lower Speed Contact Status in Menu 0 should be closed. If the value does not change from closed to open when the contact is opened, verify the voltage at the control terminals. If correct voltage is verified, the control has failed and should be replaced.

4. Close the Raise Speed/Load contact. The Raise Speed Contact Status in Menu 0 should be closed. If the value does not change from closed to open when the contact is opened, verify the voltage at the control terminals. If correct voltage is verified, the control has failed and should be replaced.

5. Close the Failsafe Override contact. The Failsafe Override Contact Status in Menu 0 should be closed. If the value does not change from closed to open when the contact is opened, verify the voltage at the control terminals. If correct voltage is verified, the control has failed and should be replaced.

6. Close the Unload/Reset to Rated contact. The Unload Contact Status in Menu 0 should be closed. If the value does not change from closed to open when the contact is opened, verify the voltage at the control terminals. If correct voltage is verified, the control has failed and should be replaced.

7. Close the Base Load contact. The Base Load Contact Status in Menu 0 should be closed. If the value does not change from closed to open when the contact is opened, verify the voltage at the control terminals. If correct voltage is verified, the control has failed and should be replaced.

8. Close the Circuit Breaker Aux contact. The Circuit Breaker Contact Status in Menu 0 should be closed. If the value does not change from closed to open when the contact is opened, verify the voltage at the control terminals. If correct voltage is verified, the control has failed and should be replaced.

Any discrete input with power applied should indicate a closed status. If proper voltage is determined at the terminal strip, failure indicates the control input is bad. Replace the control.

KW Transducer Input

The following tests calibrate and verify the function of the KW Transducer input (Signal Input #1).

1. Connect a 4 to 20 mA source to terminals 36(+) and 37(–). Make sure a jumper is installed across terminals 35 and 36. Connect a mA meter in series with the 4 to 20 mA source.

2. Set the source for 20.0 mA on the meter. Select Menu 9 on the Hand Held Programmer.

3. Set the Calibration Key to 49. Select KW Load Input.

4. Verify that the display reads 20.00 ± 0.01 mA.

5. Set the source for 4.0 mA. The KW Transducer input value should be 4.0 mA ± 0.2 mA. If the meter indicates proper currents are present on Signal Input #1, but readings on the Hand Held Programmer are incorrect, the 721 control is defective and should be replaced.

SPM Synchronizer Input

The following tests calibrate and verify the function of the SPM Synchronizer input (Signal Input #2).

1. Connect a 1 to 5 Vdc source to terminals 39(+) and 40(–). Connect a dc voltmeter across terminals 39(+) and 40(–).

2. Set the source for 5.0 Vdc on the meter. Select Menu 9 on the Hand Held Programmer.

3. Set the Calibration Key to 49. Select Synchronizer Input.

4. Verify that the display reads +5.0 ± 0.1 Vdc.

5. Set the source for -5.0 Vdc. The Synchronizer Input value should be -5.0 ± 0.1 Vdc. If the meter indicates proper voltages are present on Signal Input #2, but readings on the Hand Held Programmer are incorrect, the 721 control is defective and should be replaced.

Turbo Boost Pressure Input

The following tests calibrate and verify the function of the Turbo Boost Pressure input (Signal Input #3).

1. Connect a 4 to 20 mA or 1 to 5 Vdc source to terminals 42(+) and 43(–). If a mA source is used, a jumper must be installed across terminals 41 and 42. Connect a dc voltmeter across terminals 42(+) and 43(–). Optionally, a mA meter may be installed in series with the 4 to 20 mA source.

2. Set the source for 5.0 Vdc (20.0 mA) on the meter. Select Menu 9 on the Hand Held Programmer.

3. Set the Calibration Key to 49. Select Fuel Limiter Input.

4. Verify that the display reads 20.00 ± 0.01 mA.

5. Set the source for 1.0 Vdc (4.0 mA). The Fuel Limiter Input value should be 4.0 mA ± 0.2 mA. If the meter indicates proper voltages (or currents) are present on Signal Input #3, but readings on the Hand Held Programmer are incorrect, the 721 control is defective and should be replaced.

Remote Speed/Load Setting Input

The following tests calibrate and verify the function of the Remote Speed/Load Setting input (Signal Input #4).

1. Connect a 4 to 20 mA or 1 to 5 Vdc source to terminals 45(+) and 46(–). If a mA source is used, a jumper must be installed across terminals 44 and 45. Connect a dc voltmeter across terminals 45(+) and 46(–). Optionally, a mA meter may be installed in series with the 4 to 20 mA source.

2. Set the source for 5.0 Vdc (20.0 mA) on the meter. Select Menu 9 on the Hand Held Programmer.

3. Set the Calibration Key to 49. Select Remote Speed/Load Setting Input.

4. Verify that the display reads 20.00 ± 0.01 mA.

5. Set the source for 1.0 Vdc (4.0 mA). The Remote Speed/Load Setting input value should be 4.0 mA ± 0.2 mA. If the meter indicates proper voltages (or currents) are present on Signal Input #4, but readings on the Hand Held Programmer are incorrect, the 721 control is defective and should be replaced.

Actuator Output

The following tests verify the actuator output of the control.

1. Select Run (contact A closed) and Failed Speed Signal Override on (contact E closed). Connect a milliamp meter across terminals 15(+) and 16(–) if no actuator is connected. Connect the milliamp meter in series with the actuator if one is connected to the control. (Alternately, a dc voltmeter may be connected across the output when an actuator is connected. The correct output currents must be computed using the voltage measured and the input resistance of the actuator.)

2. Select Menu 9 on the Hand Held Programmer. Set the Calibration Key to "49".

3. Set Actuator Output to Forward Acting.

4. Select the Idle Fuel Limit set point on Menu 6. Set Idle Fuel Limit to 20%. The output current should be 42 ± 2 mA (4.2 ± 0.2 mA for the 4–20 mA output versions of the 721 control).

5. Set the Idle Fuel Limit to 100%. The output current should be 210 ± 10 mA (21 ± 1 mA for the 4–20 mA output versions of the 721 control). If with all connections verified, the output of the control fails to perform as above, replace the control.

Speed Inputs

The following tests verify the operation of the speed inputs.

1. Connect an audio frequency signal generator to Speed Sensor Input #1 (terminal 17/18). Set the output level above 1.0 Vrms. Record the Gear #1 Teeth set point from Menu 8. Temporarily set the Gear #1 Teeth set point to 60 (this causes the rpm values and Hertz values to be equal, which makes doing the tests easier).

2. Set the signal generator to 400 Hz. Read Engine Speed value of 400 rpm on Menu 7. Increase the signal generator frequency to 2000 Hz. The value read should follow the signal generator frequency.

3. Return the Gear #1 Teeth set point on Menu 8 to the previously recorded value for your engine.

4. Connect an audio frequency signal generator to Speed Sensor Input #2 (terminal 19/20). Set the output level above 1.0 Vrms. Record the Gear #2 Teeth set point from Menu 8. Temporarily set the Gear #2 Teeth set point to 60.

5. Set the signal generator to 400 Hz. Read Engine Speed value of 400 rpm on Menu 7. Increase the signal generator frequency to 2000 Hz. The value read should follow the signal generator frequency.

6. Return the Gear #2 Teeth set point on Menu 8 to the previously recorded value for your engine.

Conclusion of Test and Calibration Procedures

This completes the test and calibration chapter. Save the set points by pressing the “SAVE” key on the Hand Held Programmer. Power down the control for about 10 seconds. Restore power and verify that all set points are as recorded.

NOTICE

To prevent possible damage to the engine resulting from improper control settings, make sure you save the set points before removing power from the control. Failure to save the set points before removing power from the control causes them to revert to the previously saved settings.

Disconnect the Hand Held Programmer from the control. Close the cover over J1 and retighten the retaining screw.

WARNING

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

Chapter 7.
Product Support and Service Options

Product Support Options

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

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

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

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

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

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

Product Service Options

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

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

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

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

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

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

Returning Equipment for Repair

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

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

Packing a Control

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

NOTICE

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

Replacement Parts

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

Engineering Services

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

- Technical Support
- Product Training
- Field Service

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

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

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

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

Contacting Woodward's Support Organization

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

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

Products Used In Electrical Power Systems

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

Products Used In Engine Systems

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

Products Used In Industrial Turbomachinery Systems

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

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

Technical Assistance

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

General

Your Name ____________

Site Location ____________

Phone Number ____________

Fax Number ____________

Prime Mover Information

Manufacturer ____________

Engine Model Number ____________

Number of Cylinders ____________

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

Power Output Rating ____________

Application (power generation, marine, etc.) ____________

Control/Governor Information

Control/Governor #1

Woodward Part Number & Rev. Letter ____________

Control Description or Governor Type ____________

Serial Number ____________

Control/Governor #2

Woodward Part Number & Rev. Letter ____________

Control Description or Governor Type ____________

Serial Number ____________

Control/Governor #3

Woodward Part Number & Rev. Letter ____________

Control Description or Governor Type ____________

Serial Number ____________

Symptoms

Description ____________

____

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. Programming Checklist

We recommend you write down the final value of each menu item here so you will have a record if you later need to reprogram or replace the control.

______________________ Software Part Number and Revision Letter

1—Dynamics Menu

___________	1.	Gain
___________	2.	Stability
___________	3.	Compensation
___________	4.	Gain Ratio
___________	5.	Window Width
___________	6.	Gain Slope Breakpoint
___________	7.	Gain Slope
___________	8.	Speed Filter

2—Auxiliary Dynamics Menu

___________	1.	Aux Gain
___________	2.	Aux Stability
___________	3.	Aux Compensation
___________	4.	Aux Gain Ratio
___________	5.	Aux Window Width
___________	6.	Aux Gain Slope Breakpoint
___________	7.	Aux Gain Slope
___________	8.	Aux Speed Filter

3—Speed Setting Menu

___________	1.	Raise Speed Limit
___________	2.	Lower Speed Limit
___________	3.	Idle Speed Reference
___________	4.	Accel Ramp Time
___________	5.	Decel Ramp Time
___________	6.	Raise Speed Rate
___________	7.	Lower Speed Rate
___________	8.	4 mA Remote Reference
___________	9.	20 mA Remote Reference
___________	10.	Tach at 4 mA Output
___________	11.	Tach at 20 mA Output
___________	12.	Low Idle Droop
___________	13.	Low Idle Breakpoint

4—Torsional Filter Menu

___________	1.	Torsional Filter
___________	2.	Torsional Level 4 mA
___________	3.	Torsional Level 20 mA
___________	4.	Derated Fuel Limit
___________	5.	Derated Trip Level
___________	6.	Derated Clear Level

5—KW Setting Menu

__________	1.	Maximum Load
__________	2.	Load Gain Voltage
__________	3.	Loadshare Error Gain
__________	4.	4 mA KW Load Input
__________	5.	20 mA KW Load Input
__________	6.	Base Load Reference
__________	7.	Unload Trip Level
__________	8.	Load Ramp Time
__________	9.	Unload Ramp Time
__________	10.	Raise Load Rate
__________	11.	Lower Load Rate
__________	12.	4 mA Remote KW Reference
__________	13.	20 mA Remote KW Reference
__________	14.	Load Droop Percent
__________	15.	Load at 4 mA Output
__________	16.	Load at 20 mA Output

6—Fuel Limiters and Control Output Menu

__________	1.	Idle Fuel Limit
__________	2.	Maximum Fuel Limit
__________	3.	External Fuel Limit
__________	4.	Fuel Limit Breakpoint A
__________	5.	Fuel Limit at Breakpoint A
__________	6.	Fuel Limit Breakpoint B
__________	7.	Fuel Limit at Breakpoint B
__________	8.	Fuel Limit Breakpoint C
__________	9.	Fuel Limit at Breakpoint C
__________	10.	Fuel Limit Breakpoint D
__________	11.	Fuel Limit at Breakpoint D
__________	12.	Fuel Limit Breakpoint E
__________	13.	Fuel Limit at Breakpoint E

8—Configuration Menu

__________	1.	Configuration Key
__________	2.	Rated Speed
__________	3.	Gear #1 Teeth
__________	4.	Gear #2 Teeth
__________	5.	Actuator Sense
__________	6.	Dynamics Map
__________	7.	MPU1 Failed Alarm
__________	8.	MPU2 Failed Alarm
__________	9.	Both MPUs Failed Alarm
__________	10.	Load Sensor Failed Alarm
__________	11.	Sequence Error Alarm
__________	12.	High Torsional Level Alarm
__________	13.	Remote Input Failed Alarm

9—Calibration Menu

___________	1.	Calibration Key
___________	2.	KW Load Input
___________	3.	Synchronizer Input
___________	4.	Fuel Limiter Input
___________	5.	Remote Reference Input
___________	6.	Parallel Line Input
___________	7.	Load Sharing Error
___________	8.	De-Droop
___________	9.	Load Sharing Output
___________	10.	Load Sharing Offset
___________	11.	Torsional Level
___________	12.	KW Load Output
___________	13.	Tachometer Output
___________	14.	Actuator Output
___________	15.	Analog Speed #1
___________	16.	Analog Speed #2

721 Menu Summary

1—Dynamics
1. Gain
2. Stability
3. Compensation
4. Gain Ratio
5. Window Width
6. Gain Slope Breakpoint
7. Gain Slope
8. Speed Filter

2—Auxiliary Dynamics
1. Aux Gain
2. Aux Stability
3. Aux Compensation
4. Aux Gain Ratio
5. Aux Window Width
6. Aux Gain Slope Breakpoint
7. Aux Gain Slope
8. Aux Speed Filter

3—Speed Setting
1. Raise Speed Limit
2. Lower Speed Limit
3. Idle Speed Reference
4. Accel Ramp Time
5. Decel Ramp Time
6. Raise Speed Rate
7. Lower Speed Rate
8. 4 mA Remote Reference
9. 20 mA Remote Reference
10. Tach at 4 mA Output
11. Tach at 20 mA Output
12. Low Idle Droop
13. Low Idle Breakpoint

4—Torsional Filter
1. Torsional Filter
2. Torsional Level 4 mA
3. Torsional Level 20 mA
4. Derated Fuel Limit
5. Derated Trip Level
6. Derated Clear Level

5—KW Setting
1. Maximum Load
2. Load Gain Voltage
3. Loadshare Error Gain [not present in part numbers 9905-291/-381
4. 4 mA KW Load Input
5. 20 mA KW Load Input
6. Base Load Reference
7. Unload Trip Level
8. Load Ramp Time
9. Unload Ramp Time
10. Raise Load Rate
11. Lower Load Rate
12. 4 mA Remote KW Ref.
13. 20 mA Remote KW Ref.
14. Load Droop Percent
15. Load at 4 mA Output
16. Load at 20 mA Output

6—Fuel Limiters and Control Output
1. Idle Fuel Limit
2. Maximum Fuel Limit
3. External Fuel Limit
4. Fuel Limit Breakpoint A
5. Fuel Limit at Breakpoint A
6. Fuel Limit Breakpoint B
7. Fuel Limit at Breakpoint B
8. Fuel Limit Breakpoint C
9. Fuel Limit at Breakpoint C
10. Fuel Limit Breakpoint D
11. Fuel Limit at Breakpoint D
12. Fuel Limit Breakpoint E
13. Fuel Limit at Breakpoint E

7—Display 1
1. Engine Speed
2. Speed Reference (biased)
3. Generator Load
4. Load Reference (biased)
5. Actuator Output
6. Torsional Level
7. Speed Control Mode
8. Load Control Mode

8—Configuration
1. Configuration Key
2. Rated Speed
3. Gear #1 Teeth
4. Gear #2 Teeth
5. Actuator Sense
6. Dynamics Map
7. MPU1 Failed Alarm
8. MPU2 Failed Alarm
9. Both MPUs Failed Alarm
10. Load Sensor Failed Alarm
11. Sequence Error Alarm
12. High Torsional Level Alarm
13. Remote Input Failed Alarm

9—Calibration
1. Calibration Key
2. KW Load Input
3. Synchronizer Input
4. Fuel Limiter Input
5. Remote Reference Input
6. Parallel Line Input
7. Load Sharing Error
8. De-Droop
9. Load Sharing Output
10. Load Sharing Offset
11. Torsional Level
12. KW Load Output
13. Tachometer Output
14. Actuator Output
15. Analog Speed #1
16. Analog Speed #2

0—Display 2
1. Analog Speed #1
2. Analog Speed #2
3. Digital Speed #1
4. Digital Speed #2
5. Run/Stop Contact Status
6. Idle/Rated Contact Status
7. Lower Speed Contact Stat.
8. Raise Speed Contact Stat.
9. Failsafe O'ride Cont. Stat.
10. Unload Contact Status
11. Base Load Contact Status
12. Circuit Breaker Cont. Stat.
13. Load Share Relay Status
14. Major Alarm Relay Status
15. Minor Alarm Relay Status
16. Breaker Open Relay Status
17. MPU #1 LED Status
18. MPU #2 LED Status
19. Watchdog Status
20. Diagnostics Results
21. ROM Checksum

721 Control Specifications

Woodward Part Numbers:	
9905-291	[replaced by 9907-206]
9905-381	[replaced by 9907-207]
9906-224	721, GL, DNV, ABS, low voltage power supply
9906-226	721, GL, DNV, ABS, high voltage power supply
9907-206	721, CE Mark, UL Listed, low voltage power supply
9907-207	721, CE Mark, UL Listed, high voltage power supply
Power Supply Rating	18–32 Vdc (24 Vdc nominal) 88–132 Vac 50/60 Hz (120 Vac nominal) 90–150 Vdc (125 Vdc nominal)
Power Consumption	18 W nominal
Steady State Speed Band	magnetic pickup: 400–15 000 Hz (8–2100 rpm)
Discrete Inputs (8)	10 mA at 24 Vdc
Remote Speed/Load Setting Input	4–20 mA or 1–5 Vdc
Turbo Boost Pressure Input	4–20 mA or 1–5 Vdc
KW Transducer Input	4–20 mA or 1–5 Vdc
SPM Synchronizer Input	±5 Vdc from SPM-A synchronizer
Actuator Output	20–160 mA or 4–20 mA
Tachometer Output	4–20 mA or 0–1 mA to meter or computer
Torsional Level Signal Output	4–20 mA or 0–1 mA to meter or computer
Load Signal Output	4–20 mA or 0–1 mA to meter or computer
Relay Outputs	Breaker Open, Major Alarm, Minor Alarm
Programmer Serial Port	RS-422, 9-pin D connector, 1200 baud, full duplex
Ambient Operating Temperature	–40 to +70 °C (–40 to +158 °F)
Storage Temperature	–55 to +105 °C (–67 to +221°F)
Humidity	95% at 38 0C
EMI/RFI Susceptibility	US MIL-STD 461C (Parts 5 & 9)
Humidity	US MIL-STD 810D, Method 507.2, Procedure III
Mechanical Vibration	24–2000 Hz swept sine, 2.5 Gs constant acceleration, resonant dwells , 1 million cycles, total time , 6 hours/axis
Mechanical Shock	US MIL-STD 810C, Method 516.2, Procedure I (basic design test), Procedure II (transit drop test, packaged), Procedure V (bench handling)
Salt Spray	ASTM B 117-73

We appreciate your comments about the content of our publications.

Send comments to: icinfo@woodward.com

Please reference publication 02707B.

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