



## IMPORTANT



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

## DEFINITIONS

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

## WARNING

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

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



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



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

## NOTICE

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

## NOTICE

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

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

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## Electrostatic Discharge Awareness

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

Follow these precautions when working with or near the control.

1. Before doing maintenance on the electronic control, discharge the static electricity on your body to ground by touching and holding a grounded metal object (pipes, cabinets, equipment, etc.).
2. Avoid the build-up of static electricity on your body by not wearing clothing made of synthetic materials. Wear cotton or cotton-blend materials as much as possible because these do not store static electric charges as much as synthetics.
3. Keep plastic, vinyl, and Styrofoam materials (such as plastic or Styrofoam cups, cup holders, cigarette packages, cellophane wrappers, vinyl books or folders, plastic bottles, and plastic ash trays) away from the control, the modules, and the work area as much as possible.
4. Do not remove the printed circuit board (PCB) from the control cabinet unless absolutely necessary. If you must remove the PCB from the control cabinet, follow these precautions:
  - Do not touch any part of the PCB except the edges.
  - Do not touch the electrical conductors, the connectors, or the components with conductive devices or with your hands.
  - When replacing a PCB, keep the new PCB in the plastic antistatic protective bag it comes in until you are ready to install it. Immediately after removing the old PCB from the control cabinet, place it in the antistatic protective bag.

### **NOTICE**

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



# Chapter 1

## General Information

### Introduction

Woodward's APECS 2000 (Advanced Proportional Engine Control System) is an isochronous engine governor that provides a means of controlling and limiting engine speed by adjusting the fuel control lever with a proportional actuator.

The system consists of a powerful microprocessor-based controller driving a precision proportional actuator which is connected to the engine's fuel control lever. The controller processes the signal received from an engine speed sensor and compares it to the desired speed setting. The output of the controller is a pulse-width-modulated signal that drives the actuator. The actuator converts the signal to an output shaft position, proportional to the duty cycle of the PWM signal.

APECS 2000 is suitable for use on both compression ignition (diesel) and spark ignition (gasoline, CNG, LPG) engines. Typical on- and off-highway applications include generator sets, construction machinery and farm vehicles.

### System Features

- Microprocessor based digital control
- Isochronous governing ( $\pm 0.25\%$ )
- Rugged construction
- Low cost system
- Surface mount technology
- Remote speed adjustment
- Reverse polarity protection
- Controller compatible with the complete line of APECS actuators
- Fail safe operation using spring to return actuator to minimum fuel position
- Diagnostics for broken wire, over speed, and internal component check
- Potted for environmental protection
- No special maintenance required

### System Components

The three major components of the APECS 2000 governor system are the controller, actuator, and speed sensor (magnetic pickup, Mini-Gen™ signal generator, or ignition input).

A typical system layout is shown in **Figure 1**.

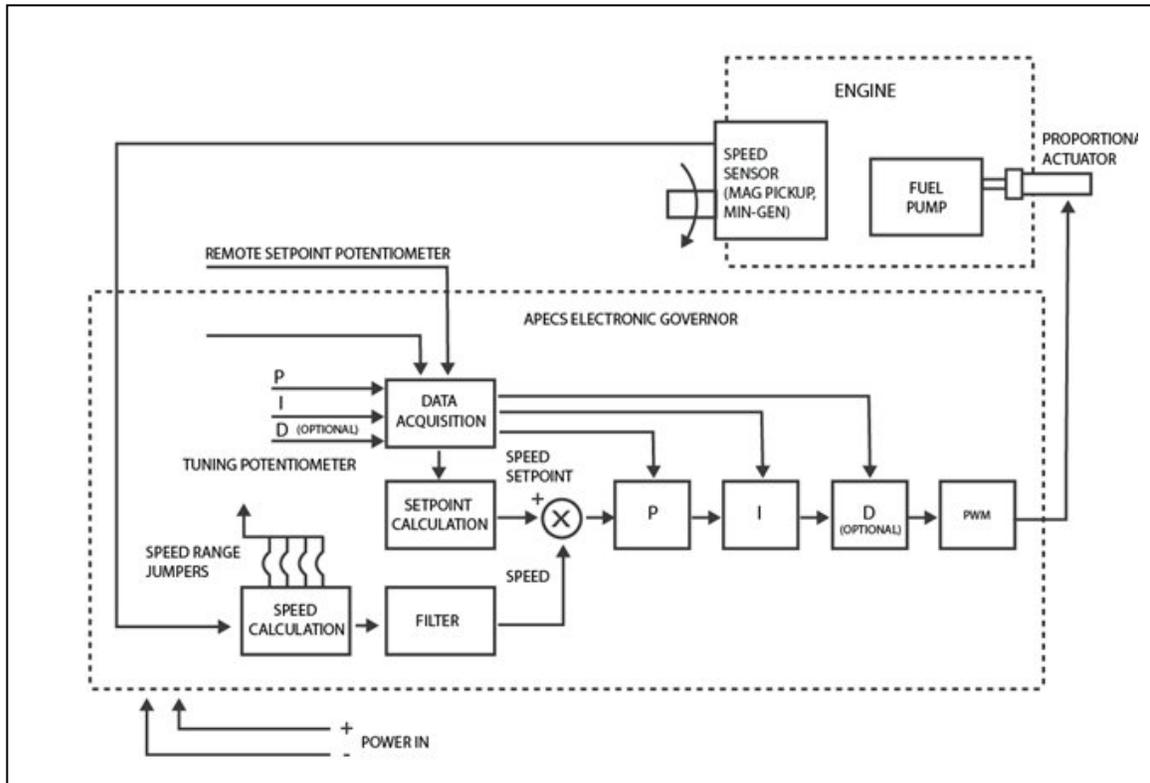
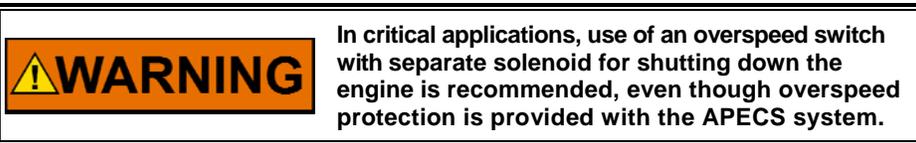


Figure 1. APECS 2000 Block Diagram



## Controller

The controller is the brain of the APECS system. It processes the speed signal received from the engine speed sensor and compares it to a reference speed set with a potentiometer. The output of the controller is a pulse-width-modulated signal to the actuator. The APECS 2000 controller has adjustments for Proportional, Integral and Derivative (PID) feedback gains.

The controller does not provide torque limiting; it will continue to increase the actuator position as long as the engine is operating below the desired speed. The engine should have some alternate means for limiting the maximum fueling, such as a mechanical governor, if it is possible for the actuator to overfuel the engine under any operating condition.

In general, for diesel engines with mechanical governors, it is sufficient to adjust the mechanical governor so that the governed speed under full load is 100-200 rpm higher than the set speed for the APECS controller.

## Chapter 2 Specifications

### Controller Performance Specifications

<b>Operating Voltage</b>	9 to 30 Vdc (wide voltage) Use of a 10 amp fuse is recommended.
<b>Output</b>	PWM up to 8 amps
<b>Gain Settings</b>	Proportional, Integral and Derivative
<b>Isochronous Governing</b>	±0.25% steady state
<b>Internal Speed Setpoint Adjustment</b>	25-turn nominal potentiometer
<b>Remote Speed Setpoint (user selectable)</b>	10% of internal setpoint or full authority control
<b>Signal Input</b>	Minimum 2V RMS at cranking
<b>Speed Input Signal</b>	250 Hz to 10,000 Hz (16 ranges)
<b>Signal Source</b>	Magnetic pickup or Mini-Gen signal generator
<b>Overspeed</b>	Automatic shutdown at 125% of setpoint speed
<b>Diagnostics</b>	<p>Detects broken signal leads and responds in failsafe manner:</p> <ul style="list-style-type: none"> <li>• Speed input (defaults to minimum fuel)</li> <li>• Remote speed setpoint (defaults to module setpoint)</li> <li>• Failed actuator or broken lead: spring returns to minimum fuel position, actuator output is disabled</li> </ul>

### Controller Environmental Specifications

<b>Operating Temperature</b>	-40° C to 85° C (-40° F to 185° F)
<b>Vibration</b>	6 Gs
<b>Enclosure</b>	Rugged 1/4" cast aluminum enclosure Potted for environmental protection

### Actuator Performance Specifications

(for both push and pull linear actuators)

SPECIFICATION	ACTUATOR MODEL		
	0175	0250	0300
<b>Voltage</b>	12 or 24 Vdc $\pm$ 20%		
<b>Current: 12 Vdc</b>	4.5 A	6.5 A	6.0 A
<b>24 Vdc</b>	2.0 A	3.5 A	3.2 A
<b>Stroke (maximum)</b>	0.8" (20.3 mm)	1.0" (25.4 mm)	1.0" (25.4 mm)
<b>Net Force</b>	4.0 lb (17.8 N)	6.0 lb (26.7 N)	15.0 lb (66.8 N)
<b>Spring Shutdown Force @ Full Stroke</b>	0.50 lb (2.2 N)	1.70 lb (7.6 N)	4.50 lb (20.0N)
<b>Work Ratings</b>	0.3 ft-lb (0.36 J)	0.5 ft-lb (0.68 J)	0.3 ft-lb (1.70 J)
<b>Response Time (10%-90% of stroke)</b>	30 msec	65 msec	80 msec

### Actuator Environmental Specifications

SPECIFICATION	ACTUATOR MODEL		
	0175	0250	0300
<b>Ambient Temperature</b>	-40° C to 121° C (-40° F to 250° F)		
<b>Vibration</b>	15 Gs		
<b>Shock</b>	200 Gs		
<b>Weight</b>	1.6 lbs (0.7 kg)	3.0 lbs (1.4 kg)	6.5 lbs (3.0 kg)

## Speed Sensor

Woodward manufactures two types of engine speed sensors that can be used with the APECS electronic governor: magnetic pickups and Mini-Gen signal generators. Other types of speed sensors may also be compatible with the APECS 2000.

### Magnetic Pickup

Magnetic pickups convert mechanical motion to an AC voltage without external power. The sensor transmits a signal each time the magnetic flux path across the pole is interrupted by a gear tooth.

### Magnetic Pickup Specifications

<b>Operating Temperature</b>	-54° C to 107° C (-65° F to 225° F)
<b>Storage Temperature</b>	-73° C to 107° C (100° F to 225° F)
<b>Resistance</b>	144-198 ohms @ 25.5° C (78° F)
<b>Inductance</b>	85 mH max
<b>Output Voltage</b>	17 V <sub>pp</sub> or 6 V <sub>rms</sub> (min) at the following conditions: <ul style="list-style-type: none"> <li>• Airgap :0.015</li> <li>• Test wheel: 8 pitch gear</li> <li>• Surface speed: 300 IPS</li> <li>• Load: 2.2K ohm</li> </ul>

### Mini-Gen™ Signal Generator

The Mini-Gen was specifically designed by Woodward to be mounted on the transmissions of buses and trucks to measure road speed or on diesel engines to measure engine speed. The sensor measures speed by means of a magnet that converts mechanical rotations into electrical signals.

### Mini-Gen Specifications

<b>Operating Temperature</b>	-40° C to 107° C (-40° F to 225° F)
<b>Minimum Output</b>	25 V <sub>rms</sub> at 1750 rpm
<b>Maximum Output</b>	55 V <sub>rms</sub> at 1750 rpm
<b>Magnet</b>	60 pole
<b>Thread Torque</b>	15 ft-lbs max
<b>Lead Pull Test (feed thru)</b>	10 lbs max
<b>Vibration</b>	20 Gs (5-2000 Hz)

*NOTE:* Exposure to moisture, salt, fuel, oil, lubricant or transmission fluid will not degenerate performance or shorten life of Mini-Gen Signal Generator.

## Chapter 3. Installation

The APECS governing system consists of the following components:

- APECS controller
- Proportional actuator
- Actuator bracket and linkage
- Speed sensor

Each of the above components contributes to the overall system performance and shortcomings in any of the components will detract from system that performance. The installation instructions provided in this chapter must be closely followed in order to obtain optimum performance from your system.

1. Use proper gauges of wire with appropriate wire insulation.
2. Provide appropriate case ground for the controller.
3. Although the controller is insensitive to battery voltage, actuator must be selected for either 12 or 24 Vdc charging system.



### Controller Installation Guidelines

Refer to **Figure 2** as a guide to wiring the controller.

1. Power leads are to be connected directly to the SWITCHED POWER SOURCE (i.e. battery). Use of a 10 amp, slow-blow fuse is recommended in the battery (positive) wire.
2. Use the proper gauges of wire as shown in Table 1 "System Wiring." Wire insulation should be appropriate for engine applications.
3. A short to ground fault of the actuator wires could result in an overspeed condition. Use of convoluted tubing, conduit or other wire shielding is recommended to minimize the likelihood of mechanical damage to these wires. Cautious routing of the actuator wires is critical to avoid sharp edges, pinching and wear.
4. Elevated resistance in wires or terminations can result in limited current to the actuator which will prevent full actuator travel. To avoid these problems, it is important to use good quality terminations and proper crimping technique. Terminations must be impervious to moisture to prevent shorts and corrosion.
5. Use shielded cable for external speed potentiometer and speed signal source. Shields should be connected to the case ground (use one of the mounting screws) only.

6. Mount the unit in a location where the effects of vibration and temperature are within the specified range.
7. Four mounting holes are provided on the APECS 2000 case. Use 10-32 or M6 screws to mount the unit to *an electrically grounded mounting plate*. Use star washers for good electrical connection of the case to ground. If the case is mounted on an insulated surface, an acceptable case ground can be achieved by connecting terminal pin 1 (GND) to one of the four screws on the case cover.

## NOTICE

Failure to provide an appropriate case ground will result in poor operation of the governor

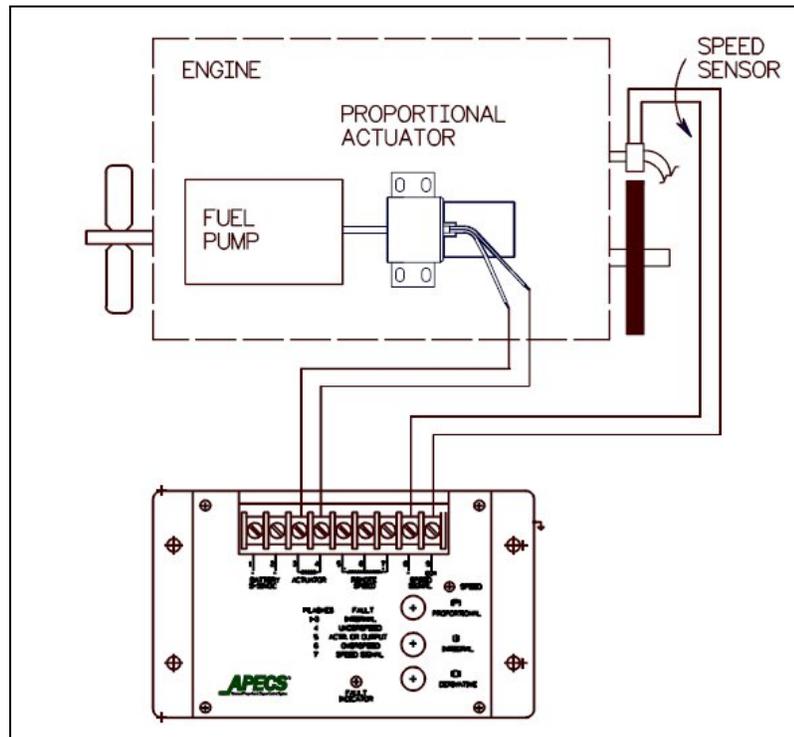


Figure 2. Controller Wiring Diagram

## Actuator Installation Guidelines

The actuator installation process involves several steps as outlined below.

1. Actuator selection
2. Actuator bracket design
3. Actuator linkage design
4. Bracket and linkage installation
5. Bracket and linkage adjustment

## Actuator Selection

Selecting the correct actuator is essentially a matter of selecting the actuator with:

- Sufficient force to overcome the resistance of the engine's control lever
- Sufficient travel to move the control lever from the minimum fuel or shutoff position to the maximum fuel position.

### Actuator Selection Table

Actuator Model	Force *		Work		Travel	Shutdown Force	
	N	Lbf	J	Ft-lbf		N	Lbf
<b>0175</b>	17.8	4.0	4.34	3.2	20.3mm (0.8")	2.22	0.5
<b>0225</b>	28.9	6.5	0.34	0.25	26.03mm (1.02")	4.45	1.0
<b>0250</b>	26.7	6.0	8.13	6.0	25.5mm (1.0")	7.78	1.75
<b>0275</b>	57.8	13.0	0.68	0.5	26.03mm (1.02")	8.9	2.0
<b>0300</b>	66.7	15.0	20.34	15.0	25.5mm (1.0")	20.02	4.5

(\*) Force at 25 °C (77 °F), nominal voltage, maximum recommended operating travel.

The APECS actuator is connected to the primary engine control lever by a mechanical linkage and is mounted directly on the engine (see Figure 3). The function of the engine control lever differs somewhat between spark ignition (gasoline, natural gas, propane) engines and compression ignition (diesel) engines.

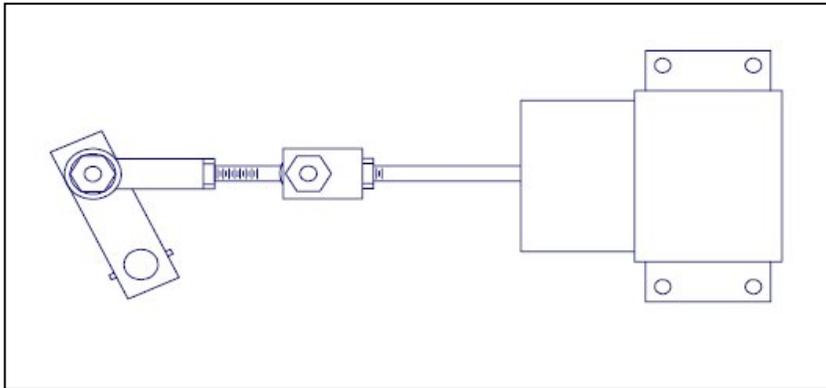


Figure 3. Actuator with Linkage Adjustment

On spark ignition engines, the engine control lever is the throttle lever which controls airflow into the engine. On compression ignition engines, the engine control lever is attached to the fuel injection pump which controls fuel flow into the engine. Some diesel injection pumps (e.g. Bosch inline pump with RSV governor) are equipped with two levers, one for controlling the input to the mechanical governor, and the other for providing a manual fuel shutoff. The shutoff lever typically connects directly to the injector pump rack.

When possible, it is preferable to connect the actuator to the shutoff lever in order to avoid unwanted dynamic interactions with the mechanical governor. On diesel injection pumps that do not have a separate shutoff lever or those where the shutoff lever does not provide smooth control of

the pump rack, it may be necessary to connect the actuator to the mechanical governor lever.

It is always desirable to use the smallest actuator that will do the job in order to reduce cost and simplify mounting requirements. To that end, it may be possible to remove external control lever springs on some engines in order to reduce the force requirements of the actuator.

While it is convenient to use the control lever and attachment holes currently on the engine, it may be advantageous to redesign or modify the lever to optimize travel and mounting of the actuator.

**NOTICE**

While controller is insensitive to battery voltage, actuator must be selected for either 12 or 24 Vdc charging system.

Once the actuator *size* has been selected, it is necessary to select the specific actuator model based on available *mounting location* and available *battery voltage*.

The available mounting location will help determine if a push or a pull-type actuator is required and if a flange or a base mount is best. When selecting between push and pull-type actuators, keep in mind that re-positioning the control lever 180° can change the need from a pull-type to a push-type or vice-versa.

The actuator selected must be capable of overcoming the force required to shut the engine down or return it to idle (even under conditions of low battery voltage). If the actuator selected lacks sufficient force, use the Actuator Selection Table to select the actuator with enough shutdown force.

### Actuator Bracket Design

Once the actuator has been selected, a bracket for mounting the actuator to the engine can be designed. The most important aspect of the bracket design is the alignment between the actuator shaft and the control lever (see **Figure 4**). The centerline of the actuator shaft must be parallel to the plane created by the control lever as it rotates. While rod-end bearings in the linkage can compensate for some misalignment (13-16°), misalignment detracts from the actuator force available to rotate the control lever and must be minimized.

**NOTICE**

Failure to properly design the bracket and/or linkage may detract from the performance of the APECS system. It is strongly recommended that the bracket be made out of 114" (5mm) cold rolled steel.

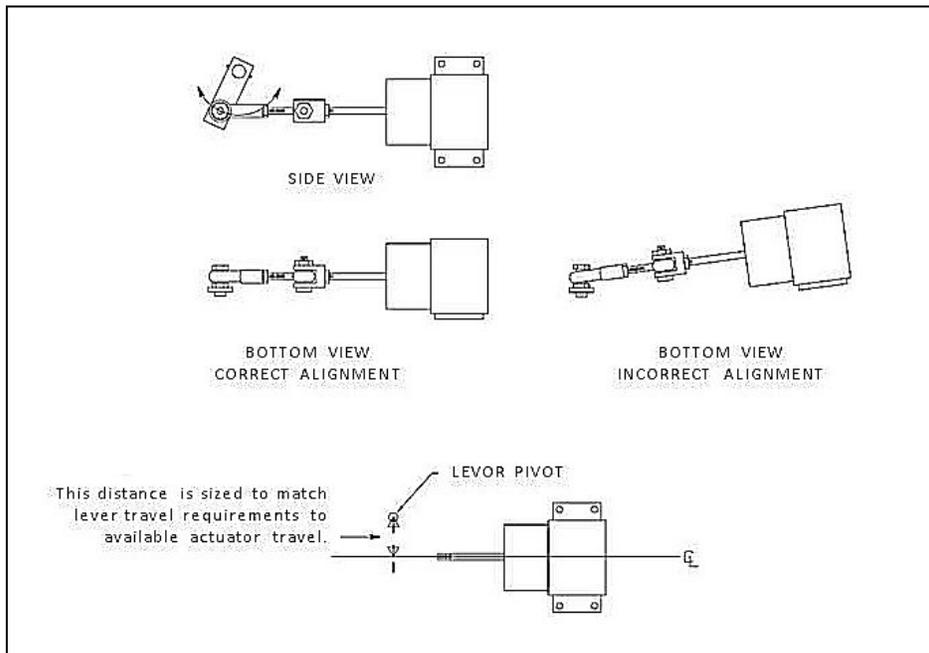


Figure 4. Actuator Shaft and Control Lever Alignment

Where possible, the bracket should take advantage of available mounting holes, bolts, etc. on the engine. The bracket must not interfere with other components on the engine or in the engine compartment (e.g. fuel lines, hoses, filters, dipsticks etc.).

Some applications have the actuator mounted directly to the mechanical governor on the injection pump. This is permissible as long as the actuator and bracket can withstand the increased vibration level on the pump. Vibration levels seem to be particularly high on pumps that are supported only in the front.

### Actuator Linkage Design

The actuator linkage is responsible for connecting the actuator shaft to the engine control lever. The linkage must have minimal friction, binding and backlash in order to assure accurate, responsive performance of the APECS 2000 governor. Friction, binding and backlash can all contribute to governor limit cycling and instability.

The link consists of two rotating joints, fastening hardware, and a control lever (where required). A common design for the linkage consists of the following components:

- Clevis with locknut, attached to actuator shaft
- Bolt with nut and lockwasher for clevis
- Spherical rod-end bearing with locknut (2)
- Threaded rod
- Bolt with nut and lockwasher for connecting rod-end bearing to control lever
- Control lever (optional)

An example of this type of linkage is shown in **Figure 5**. Options for the link design include the following:

- Two female rod-end bearings with threaded rod or turnbuckle for length adjustment

- One male and one female rod-end bearing for shorter linkages
- Spring-loaded ball joint to replace clevis and rod-end
- Rod end bearing with stud for attaching to lever

It is critical that properly fitted wear- and corrosion resistant components be used, especially for the rod-end bearings. Bearings with plastic races should be avoided as they have a tendency to wear quickly, especially at the high temperatures and vibration levels typically encountered in an engine compartment.

In order to provide the greatest mechanical efficiency, and to assure that the greatest part of the actuator force is applied to the control lever, the linkage length and lever alignment should be adjusted so that the linkage and lever are perpendicular in the center of the lever travel. This maximizes the force available and also assures a linear relationship between actuator current and lever position.

The length of the linkage should be sufficiently adjustable to compensate for any tolerances in the actuator, bracket, and control lever travel. This will assure that the actuator can control from the minimum fuel/shutoff fuel position to the maximum fuel position. Excessive linkage length should be avoided to minimize the extent of linkage flex. Excessive linkage length will also increase the weight and inertia of the linkage, which is not desirable.

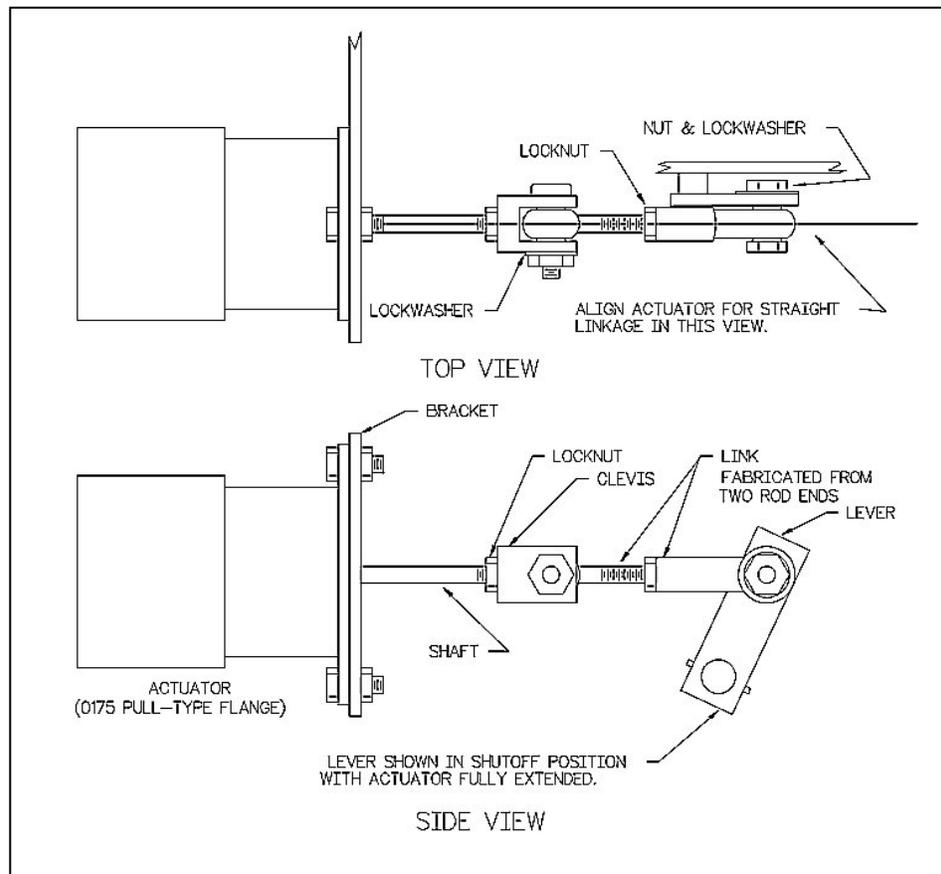


Figure 5. Actuator Linkage Design

To achieve the correct travel and alignment, it may be necessary to design a custom control lever to replace the original lever on the engine. The two major criteria for the control lever are the orientation and the radius from the pivot to

the linkage attachment point (see **Figure 6**). Orientation should be set to achieve perpendicularity. Changing the orientation of the control lever by 180° permits the use of either a push-type or a pull-type actuator.

Some caution is necessary in designing this lever in order to assure that it mounts correctly to the engine. One particular concern has been levers for the Bosch RSV pump, which may require hardening to avoid excessive wear at the point where the lever attaches to the pump.

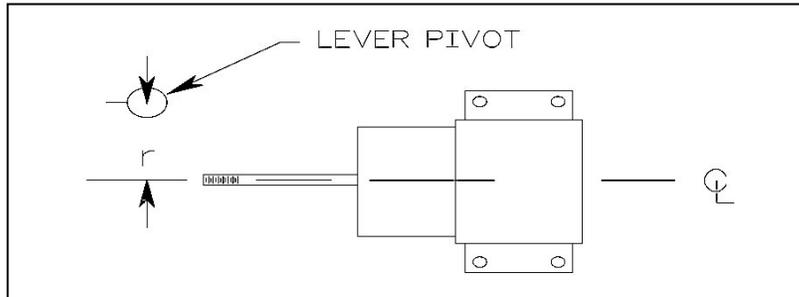


Figure 6. Control Lever Design

The linkage and control lever must be designed with sufficient strength to transmit the force of the actuator to the control lever without perceptible flexing. Under normal operating conditions on the engine, flexing of the linkage should not cause variation in steady-state engine speed exceeding 0.25% of the engine speed setpoint.

Linkage weight should be minimized to reduce the linkage inertia and increase response of the governor.

## Bracket and Linkage Installation

Follow the steps below to correctly install bracket and linkage.

1. If the engine is equipped with a mechanical governor, the mechanical governor should be adjusted (prior to the installation of the APECS governor) to a speed setting higher than the speed setting of the APECS governor when the engine is unloaded. When operating at full load, the mechanically governed speed must still be higher than the speed setting of the APECS governor.

### **NOTICE**

**For diesel engines, it is important to confirm that the APECS governor does not interfere with the mechanical governor. This is a particular concern on mechanical governors that have a separate shutoff lever.**

2. Fasten actuator to bracket (use all actuator mounting holes) and bracket to engine. Some brackets may require mounting the bracket to the engine first. Mount bracket securely to the engine block on two axes. Lock washers should be used on all bolted joints.
3. Remove pre-existing linkage or any other device attached to the fuel control lever or throttle. If a new engine control lever is required, install it.
4. Attach clevis to actuator shaft and tighten associated locknut. Attach necessary linkages between clevis and fuel shutoff lever and tighten at

both ends. Heavy duty spherical rod and bearings are recommended for this purpose. Avoid use of plastic, nylon, or Teflon-lined rod-end bearings. Rod-end bearings with hardened steel races are preferred.

## NOTICE

Because the bracket and linkage will operate in a high-vibration environment, use of thread-locking compound, lockwashers and locknuts is recommended.

5. Move linkage end-to-end to confirm correct travel. Adjust linkage length if required.
6. Connect actuator wires to wiring harness. See “Wiring Harness” section below for more information on wiring.

## Bracket and Linkage Adjustment

After installation of bracket and linkage, perform the steps below for proper adjustment.

1. Adjust linkage to position fuel control lever to shutdown engine with actuator control shaft fully de-energized.
2. Manually move linkage from shutdown to maximum fuel, ensuring actuator spring will return linkage to shutdown position and full travel of linkage is smooth, uninhibited, and does not exceed specified stroke.
3. Tighten all nuts and bolts of the linkage and actuator mounting flange. Repeat previous steps to ensure desired operation.
4. Use a tachometer or frequency meter connected to the engine speed signal to measure engine speed.
5. Start the engine.
6. Manually move linkage from shutdown to maximum fuel position.
7. Adjust linkage until maximum speed is attained.
8. Release actuator and insure linkage is returned to the shutdown position. If it is not possible to attain both the maximum fuel and the shutdown positions it may be necessary to shorten the lever length. Conversely, if full lever travel uses only a small portion of the actuator travel, it may be necessary to lengthen the lever length.
9. The return spring should return the linkage to the minimum fuel position, and shut down the engine. Repeat previous steps to ensure desired operation.

## WARNING

While all APECS actuators are equipped with return springs to shut off fuel in the event of loss of electrical power, it is imperative that the engine fuel control lever be equipped with its own return spring to assure engine shutoff in the event of a linkage failure. If this is not possible, use of an engine protection system which will shut off fuel in the event of an overspeed condition is recommended.

## Magnetic Pickup Installation Guidelines

Follow the steps below for proper installation of magnetic pickup speed sensor.

1. The mounting of the pickup unit must be rigid; excessive vibration relative to the sensed gear causes spurious signals and may cause unacceptable performance of the system.
2. Air gap between the pickup and the sensed gear must be sufficient to prevent pole piece damage. Gear tooth run-out (eccentricity) and bearing wear must be considered. The gap should be as small as practical to obtain a reliable, high level signal at low speed.
3. Generally, 0.015" to 0.020" gap is satisfactory. If the gap cannot be measured directly, turn the pickup in until it touches the gear O.D. Screw out between 95° and 130° to obtain a 0.015" to 0.020" gap. It is imperative that the pickup be installed at the correct gap and the correct mounting orientation.
4. Use proper mating connectors or shielded cable assembly as specified. The cable shield is to be grounded at the control module only.

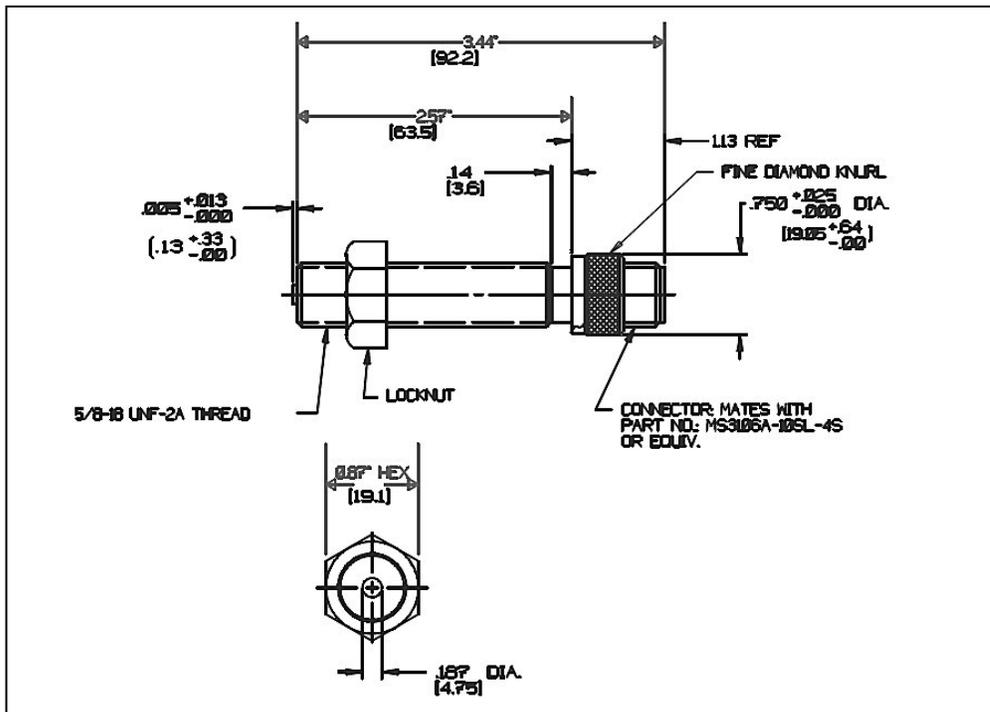


Figure 7. Typical Magnetic Pickup Mounting Dimensions

## Mini-Gen Installation Guidelines

Follow the steps below for proper installation of Mini-Gen signal generator.

1. Check Mini-Gen signal generator to assure proper size drive tang is inserted fully into the generator body. The drive tang is snapped into place, but is free to move allowing for normal eccentricity.
2. Carefully insert the tip of the male drive tang into the female drive and screw down the Mini-Gen finger tight. Tighten drive fitting securely; torque must not exceed the specified limit for non-feed thru and feed-thru models.
3. For electrical connections, two conductor shielded cable is preferred to minimize electrical interference. The shield should be grounded at the control module only.
4. A twisted pair cable must be used if shielded cable is not available to minimize electrical interference. The use of a single wire and common ground is not recommended.
5. An ohmmeter may be used to check the Mini-Gen. The resistance should be within the range specified for the unit.

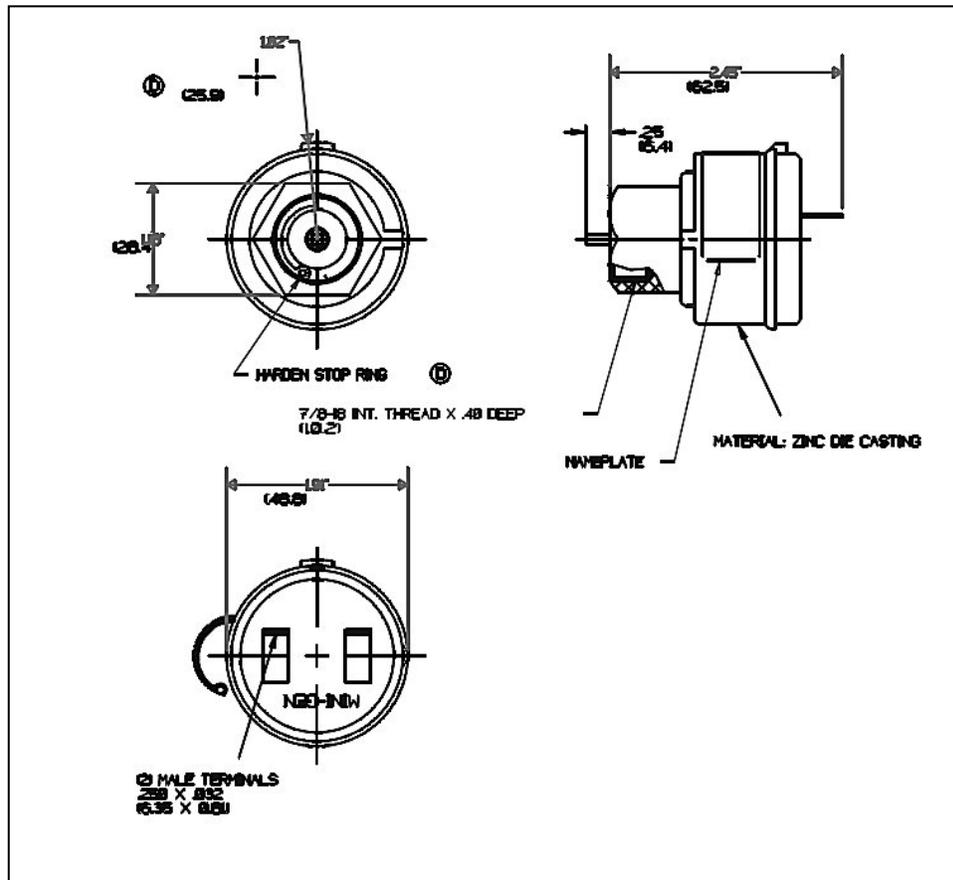


Figure 8. Typical Mini-Gen Mounting Dimensions

## Wiring Harness

Excessive resistance in the wiring harness will result in insufficient force from the actuator. Resistance can result from excessive harness length or inadequate wire gauge. It is recommended that harness lengths and gauges assure a force reduction of less than 5%.

**Table 1** shows the length of connecting wires that will result in a 5% force reduction at room temperature. Wire length is the total length (to and from) used to connect the actuator to the controller and the controller to the system power.

Table 1. System Wiring

ACTUATOR MODEL	RESISTANCE (NOM. OHMS)		AWG 14 (2.50mm <sup>2</sup> )	AWG 16 (1.50mm <sup>2</sup> )	AWG 18 (1.00mm <sup>2</sup> )
	12V	24V			
<b>0175</b>	2.80	10.63	66 ft (20m)	33 ft (10m)	22 ft (6.7m)
<b>0250</b>	1.76	6.84	46 ft (14m)	23 ft (7m)	15 ft (4.6m)
<b>0300</b>	1.72	6.57	46 ft (14m)	23 ft (7m)	15ft (4.6m)

**NOTE:** All resistance  $\pm$  5%. Resistance will change with temperature.

## Chapter 4. Calibration

Follow the procedures outlined below to calibrate the APECS 2000 controller.

1. Calculate the frequency of the input speed signal in Hertz (Hz).

*Magnetic Pickup:*

Engine Speed (rpm) x number of teeth on flywheel

---

60 seconds

*Mini-Gen Signal Generator:*

Engine speed (rpm) at Mini-Gen Signal Generator

---

2

2. Use the frequency calculated in the previous step and **Table 2** to determine the combination of jumpers to be cut. Because there is considerable overlap in the frequency ranges, select a range where the frequency is near the top of the range. The jumpers can be located by removing the top cover of the controller box (see Figure 9). Be sure cut jumper wires cannot short to cover or any other wiring. If the application will require multiple set speeds, calculate all frequencies and confirm that the frequencies fit within the desired range.

Table 2. Jumper Wiring

INPUT SPEED SIGNAL FREQUENCY (Hz)	RED	YELLOW	GREEN	BLUE
200-650				
400-1300				X
600-1950			X	
800-2600			X	X
1000-3250		X		
1200-3900		X		X
1400-4550		X	X	
1600-5200		X	X	X
1800-5850	X			
2000-6500	X			X
2200-7150	X		X	
2400-7800	X		X	X
2600-8450	X	X		
2800-9100	X	X		X
3000-9750	X	X	X	
3200-10400	X	X	X	X

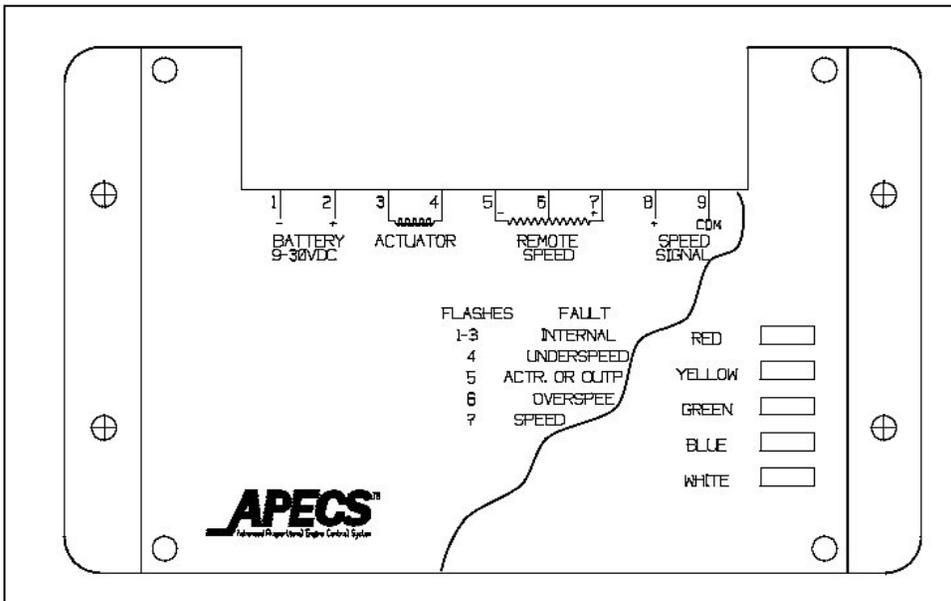


Figure 9. Jumper Location

3. Connect tachometer or frequency counter to the engine speed source to monitor engine speed (The tachometer or the frequency counter can be connected to terminals 8 and 9 of the APECS controller.)
4. Confirm initial proportional gain setting to the 12 o'clock or mid-range position (factory adjusted). Adjust integral gain to fully counter-clockwise (zero position). If using PID controller set derivative gain to zero position also.
5. If a remote speed potentiometer is to be used, select Remote Speed mode.
  - a) *White jumper installed (+1- 10% mode):* In this mode, both internal and external pots are active. The internal pot can adjust the speed setting within the range selected by the speed jumpers.
 

If the remote pot is connected, the remote pot can adjust the speed to +/- 10% of the internal speed setting. Adjust the remote pot to mid-range before adjusting the internal speed pot.

If the remote pot is disconnected, the internal pot is the default speed setting.
  - b) *White jumper removed (2 speed mode):* Only one pot is active at a time and the two speed pots operate independently. The active pot can adjust the speed setting from 0 rpm to the highest speed in the range selected by the speed jumpers.
 

If the remote pot is connected, the remote pot is active. The remote pot sets the desired speed.

If the remote pot is disconnected, the internal pot is active. The internal pot sets the desired speed,

**IMPORTANT**

With the white jumper cut, turning the active potentiometer to a low voltage will cause the engine to stop.

6. Start engine with no load. If the controller immediately shuts down and flashes the fault lamp six times (overspeed fault) the speed pot is probably set too low. Increase the speed pot setting, cycle power to the controller (to clear the fault) and restart the engine.  

If the controller again shuts down and indicates an overspeed fault (when an overspeed condition has not occurred), repeat this step until the engine will start and run.
7. Adjust active speed pot (dependent on the mode, step 5 above). The 25-turn internal speed pot is factory adjusted to minimum speed.
8. Proportional gain is used to improve response time. A maximum amount of proportional gain should be used while still maintaining stability. Increase proportional gain until speed begins to oscillate, then decrease until oscillation stops. If oscillations do not occur, bump actuator lever, then decrease proportional gain until oscillation stops.
9. Integral gain is used to remove steady state errors. Increase integral gain until speed begins to oscillate, then decrease until oscillation stops. If oscillations do not occur, bump actuator lever, then decrease integral gain until oscillation stops.
10. Derivative gain is used to improve stability. Increase derivative gain until response has a slight overshoot on load transients.  

If derivative gain is too high, response may exhibit high frequency oscillations. If derivative gain is too low, response will have a large overshoot, and the settling time may be too long.
11. Apply a variety of loads on and off (up to 100%) to check performance and stability.
12. Repeat steps 8 thru 11 until response has a fast rise time with minimum overshoot and settling time. In multiple speed systems response should be optimized for all speed settings.
13. Test for overshoot by turning controller off, letting speed drop to about 50%, then turning controller back on. If overshoot exceeds 4%, decrease integral gain slightly and try again.
14. Test for cold start stability by turning engine off and waiting until engine is cold. Start the engine. If engine speed oscillates, decrease proportional and integral gains slightly until oscillation stops.
15. During cranking, the actuator should always move the engine control lever to its full travel. If it does not, a problem may exist with the engine speed signal—either its amplitude is less than  $2 V_{rms}$ , or its frequency is too low.

Confirm signal amplitude with a multi-meter set to measure AC voltage. If voltage is adequate, select a different speed jumper combination to move the operating speed higher in the frequency range (this may require reconnecting one or more jumpers).

**IMPORTANT**

To reset controller after a fault condition, power must be interrupted to controller (typically done by turning key switch to off position).

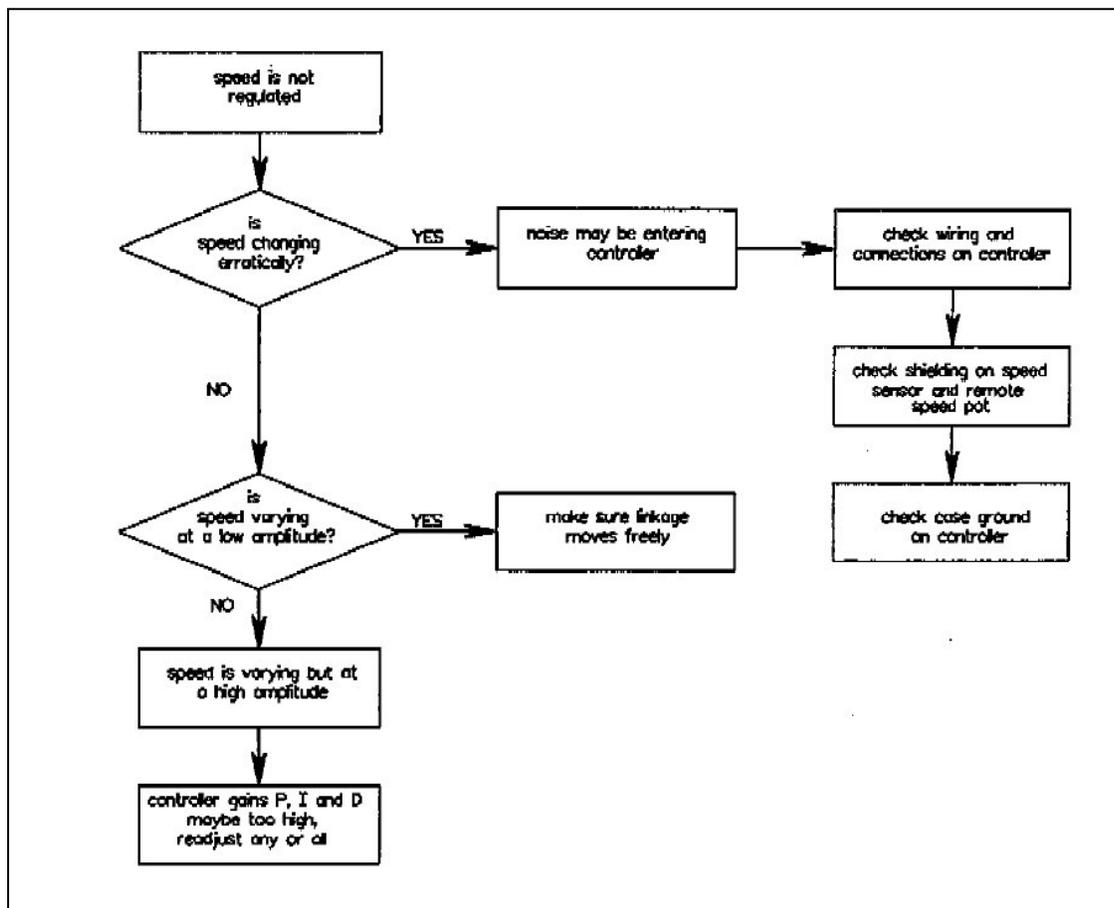
## Chapter 5. Troubleshooting

### Checklist

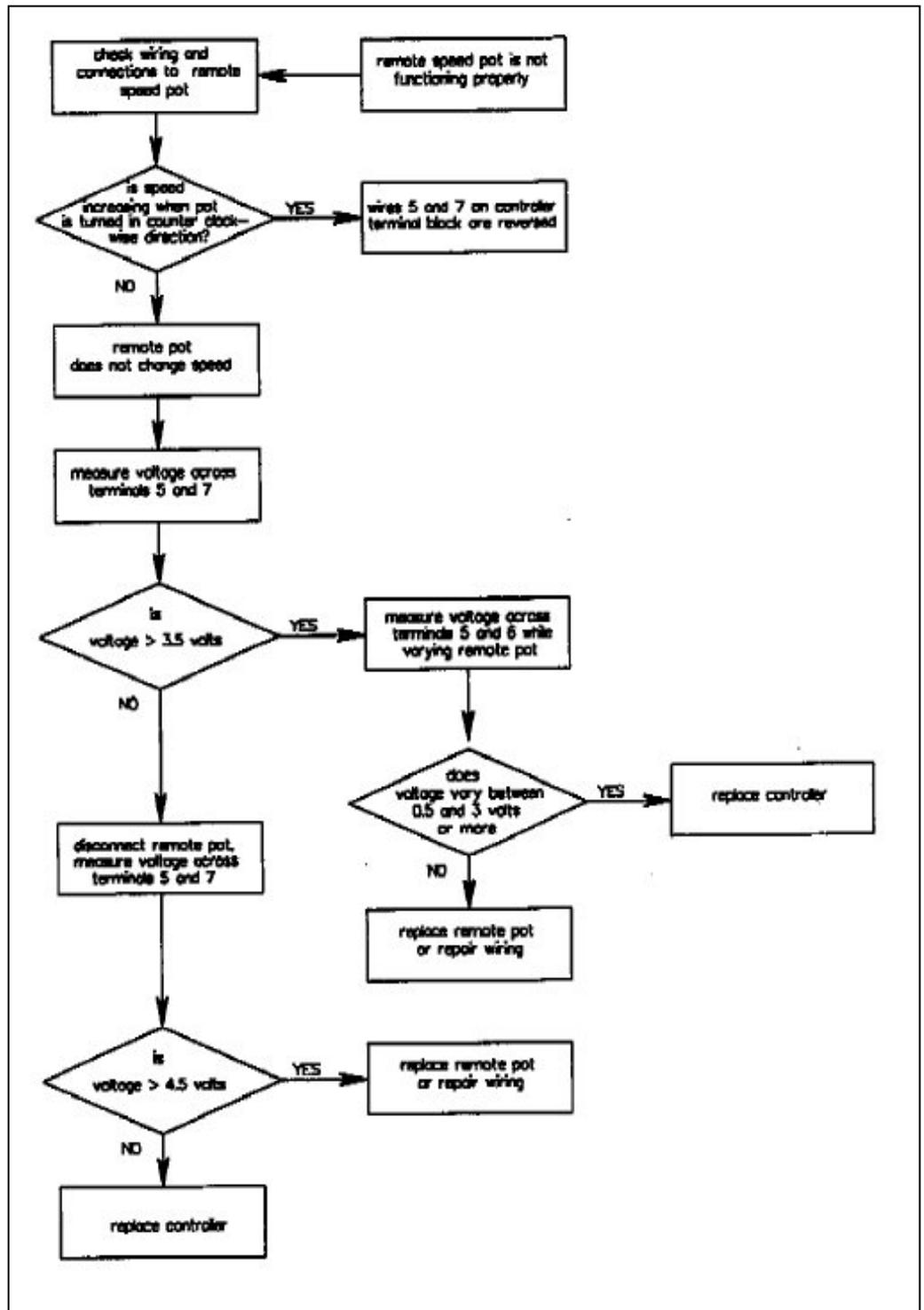
1. Check battery voltage for stability and correct value.
2. Check that speed signal is at least 2 V<sub>RMS</sub> using AC volts setting on voltmeter. Actuator should go to full travel during cranking.
3. Check linkage for binding and backlash.
4. Check that actuator has sufficient force.
5. Confirm normal operation of engine under manual control.
6. Confirm that load (e.g. voltage regulator on generator) is not inducing instability.
7. Try adjusting gains to achieve stability.
8. If all of the above are acceptable, proceed with the troubleshooting procedures indicated on the diagrams below.

### Troubleshooting Diagrams

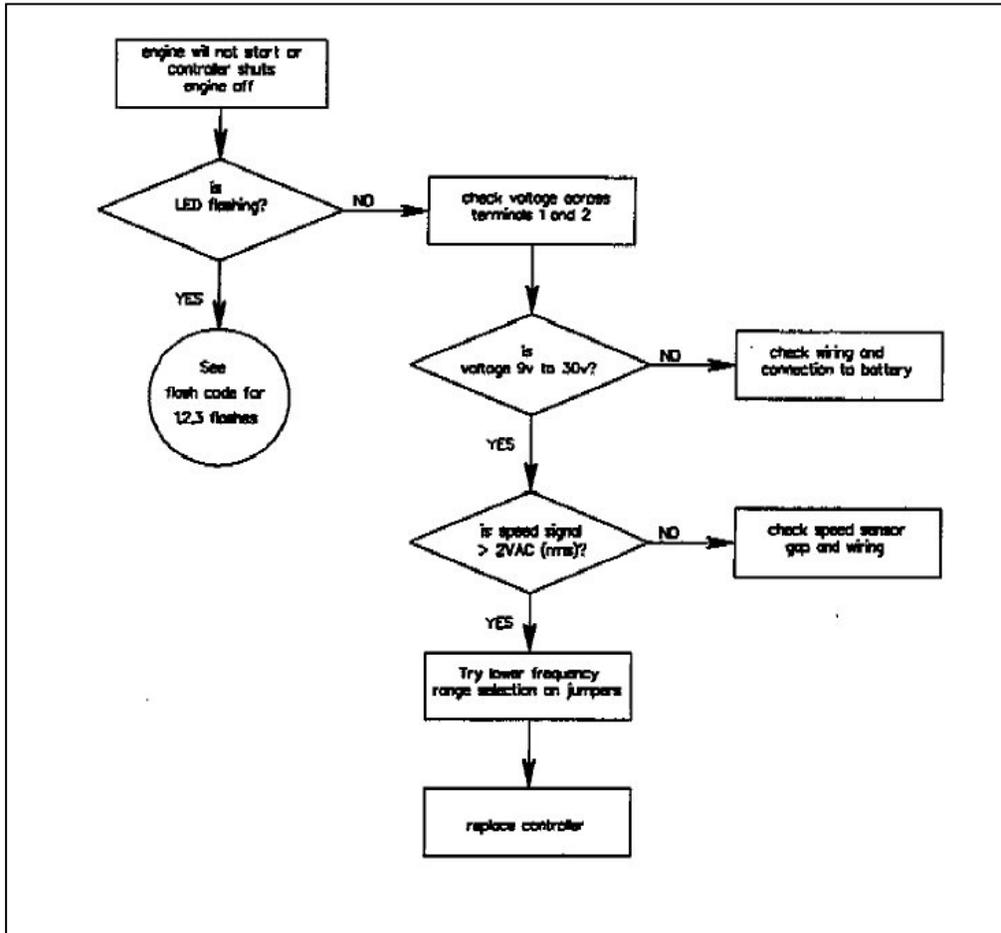
#### SYMPTOM 1. Speed is Not Regulated



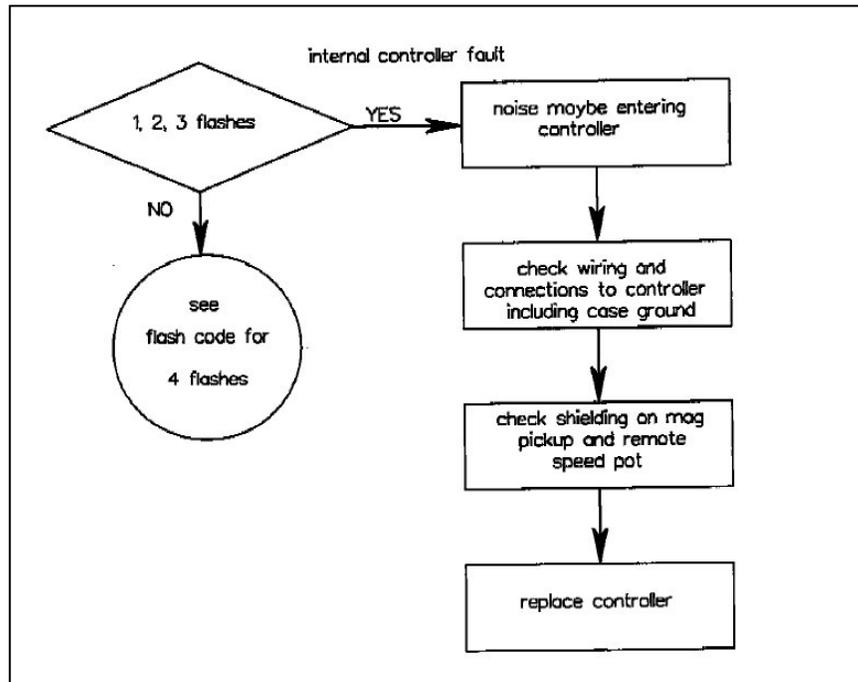
**SYMPTOM 2.**  
**Remote Speed Pot is Not Functioning Properly**



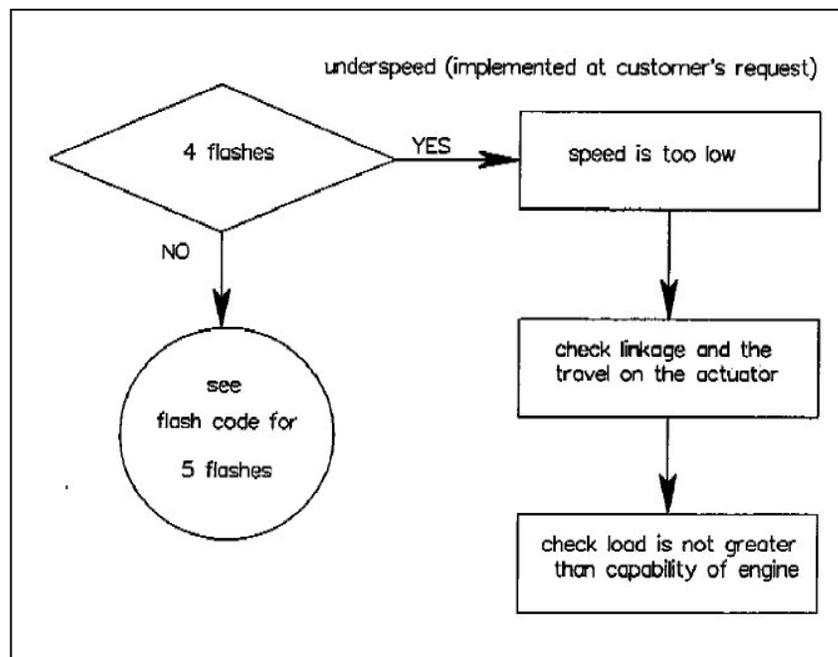
**SYMPTOM 3A.**  
**Engine Will Not Start or Controller Shuts Engine Off**



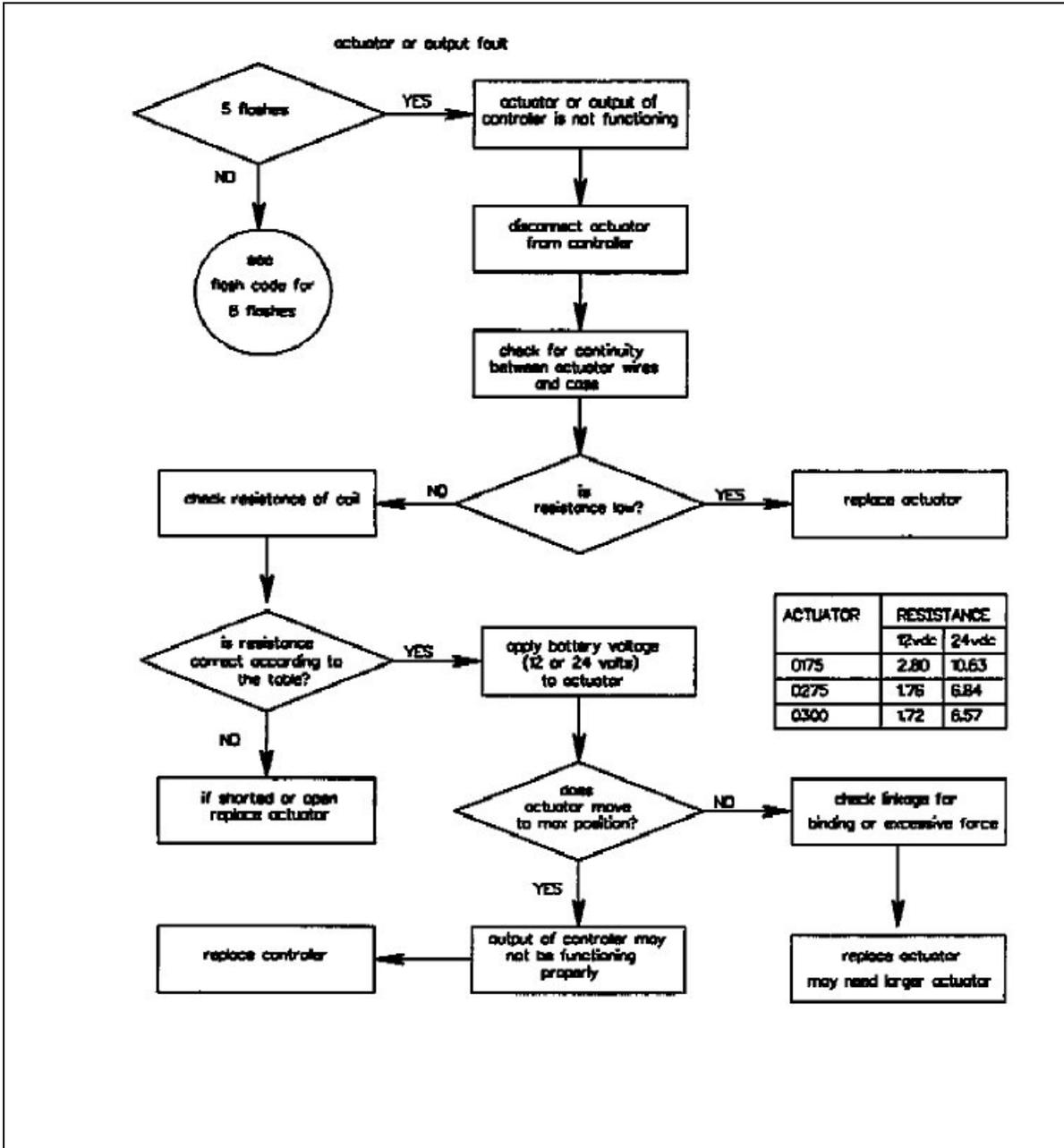
### SYMPTOM 3B. 1, 2, 3 Flashes



### SYMPTOM 3C 4 Flashes



SYMPTOM 3D  
5 Flashes



## Chapter 6.

# 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](mailto: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](http://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](http://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](http://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.

<b>Products Used In Electrical Power Systems</b>	<b>Products Used In Engine Systems</b>	<b>Products Used In Industrial Turbomachinery Systems</b>
<u>Facility</u> ----- <u>Phone Number</u>	<u>Facility</u> ----- <u>Phone Number</u>	<u>Facility</u> ----- <u>Phone Number</u>
Brazil -----+55 (19) 3708 4800	Brazil -----+55 (19) 3708 4800	Brazil -----+55 (19) 3708 4800
China -----+86 (512) 6762 6727	China -----+86 (512) 6762 6727	China -----+86 (512) 6762 6727
Germany:	Germany-----+49 (711) 78954-510	India -----+91 (129) 4097100
Kempen----+49 (0) 21 52 14 51	India -----+91 (129) 4097100	Japan-----+81 (43) 213-2191
Stuttgart--+49 (711) 78954-510	Japan-----+81 (43) 213-2191	Korea-----+82 (51) 636-7080
India -----+91 (129) 4097100	Korea-----+82 (51) 636-7080	The Netherlands- +31 (23) 5661111
Japan-----+81 (43) 213-2191	The Netherlands- +31 (23) 5661111	Poland-----+48 12 295 13 00
Korea-----+82 (51) 636-7080	United States----+1 (970) 482-5811	United States----+1 (970) 482-5811
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](http://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 \_\_\_\_\_

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**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.) \_\_\_\_\_

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**Control/Governor Information**

**Control/Governor #1**

Woodward Part Number & Rev. Letter \_\_\_\_\_

Control Description or Governor Type \_\_\_\_\_

Serial Number \_\_\_\_\_

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**Control/Governor #2**

Woodward Part Number & Rev. Letter \_\_\_\_\_

Control Description or Governor Type \_\_\_\_\_

Serial Number \_\_\_\_\_

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**Control/Governor #3**

Woodward Part Number & Rev. Letter \_\_\_\_\_

Control Description or Governor Type \_\_\_\_\_

Serial Number \_\_\_\_\_

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**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.*



We appreciate your comments about the content of our publications.

Send comments to: [icinfo@woodward.com](mailto:icinfo@woodward.com)

Please reference publication **36734**.



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