



Troubleshooting Guide



Solenoid Troubleshooting Guide

Internally & Externally Switched Solenoids
Push & Pull Type Solenoids

Manual 36541



WARNING

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.

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.



CAUTION

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.

In systems where large inductive loads are switched on the DC power buss, surge impulse energy will be present due to the switching. To address surge energy affects on the control, appropriate suppression devices must be installed in the DC power buss prior to the control's power connection.

Electronic controls contain static-sensitive parts. Observe the following precautions to prevent damage to these parts.

- Discharge body static before handling the control (with power to the control turned off, contact a grounded surface and maintain contact while handling the control).
- Avoid all plastic, vinyl, and Styrofoam (except antistatic versions) around printed circuit boards.
- Do not touch the components or conductors on a printed circuit board with your hands or with conductive devices.



IMPORTANT DEFINITIONS

WARNING—indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury.



CAUTION—indicates a potentially hazardous situation which, if not avoided, could result in damage to equipment.



NOTE—provides other helpful information that does not fall under the warning or caution categories.

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.



CAUTION

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

Solenoid Operation

Single Coil Solenoid

A solenoid is a device that converts electrical energy into mechanical force. The basic single coil solenoid is made of a free moving steel plunger that sits within a wound coil of copper wire. When electric current is introduced, a magnetic field forms which draws the plunger in. The exposed end of the plunger can be attached to equipment, and when the solenoid is activated, the plunger will move to open, close, turn on or turn off that equipment.

Solenoids are configured in many ways for different applications and operating characteristics. In most automotive applications, solenoids are used for operating engine run/stop levers, throttle control levers, chokes, valves, and clutches and to protect expensive diesel equipment from overspeed, low lube pressure, and high temperature.

Figure 1 shows the various parts of a basic single coil solenoid.

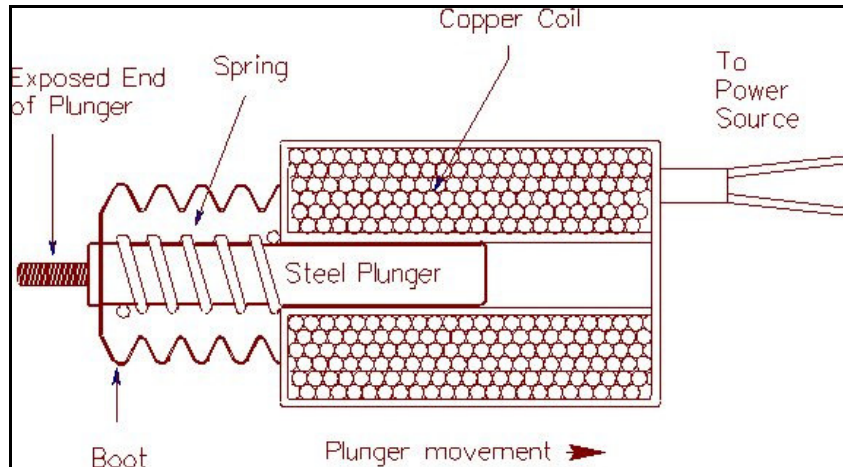


Figure 1. Basic Single Coil Solenoid

Dual Coil Solenoid

The dual coil solenoid offers high actuation force in a small package compared to a single coil solenoid. This type of solenoid uses two separate coil windings to allow the solenoid to be held energized for longer periods. The first wound coil (pull coil) operates at a high current level to provide maximum pull or push. The second wound coil (hold coil) simply holds the plunger in after it has completed its stroke and “bottomed out.”

Since the current required to hold the plunger is low (typically 1.2 amps), the hold coil can be energized continuously without overheating. This unique design results in a highly efficient and compact solenoid approximately one-half the size of a comparable single coil unit.

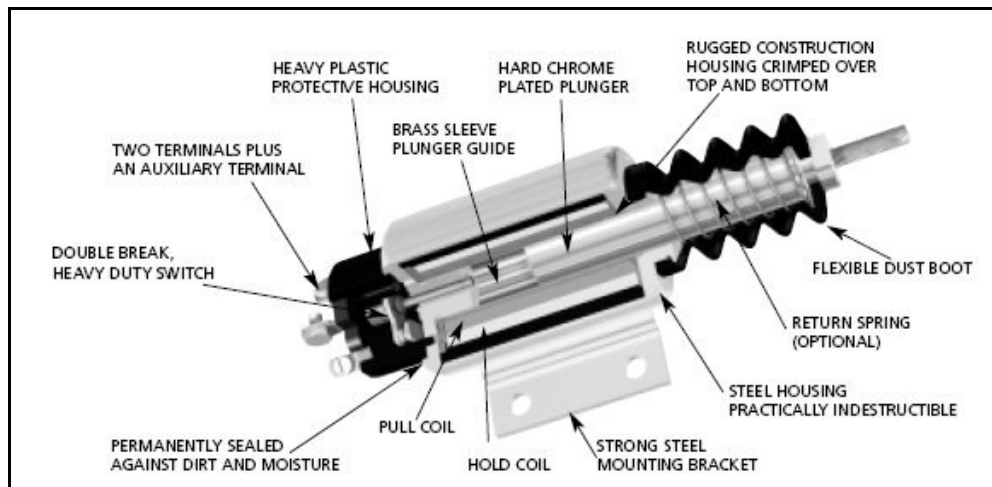


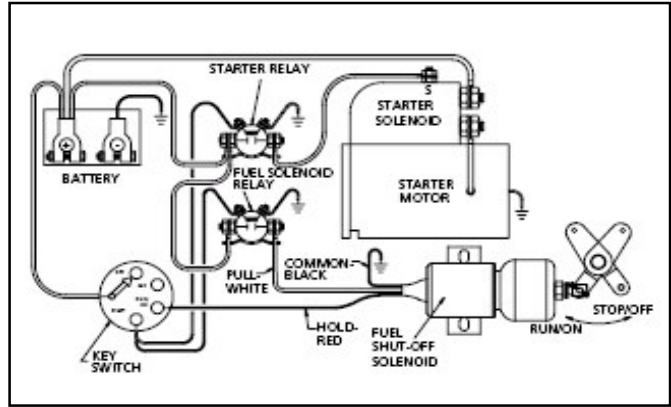
Figure 2. Components of a Dual Coil Solenoid

Three Methods for Turning Off the Pull Coil

After energizing and pulling in the plunger, the pull coil in a dual coil solenoid must be turned off as soon as possible to prevent overheating. The three basic methods for switching off the pull coil are discussed below.

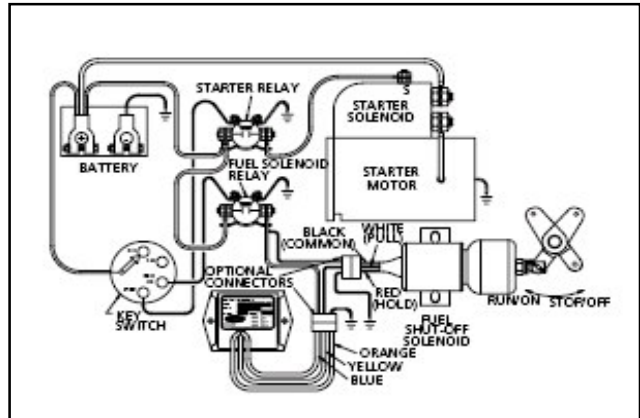
EXTERNAL SWITCHING

The externally switched (3-wire) solenoid is used in applications where an operator/driver manually turns a key switch that temporarily energizes the pull coil to pull in the plunger. The most popular application is for start-stop control of engines in trucks and mobile equipment where moisture, dirt, dust, and high vibration are present. The sealed 3-wire solenoid is well suited for these harsh conditions.



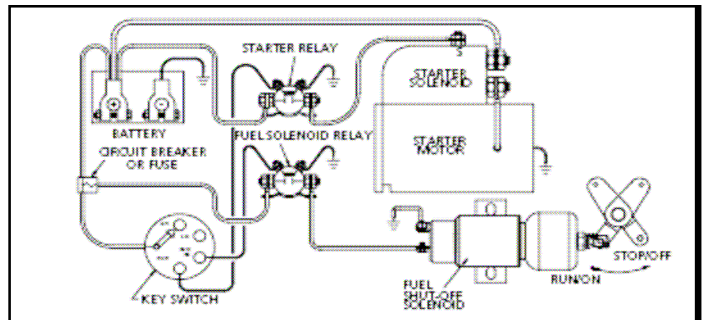
EXTERNAL SWITCHING WITH TIMER MODULE

With the addition of a Woodward pull coil timer module, the externally switched (3-wire) solenoid can be used not only in operator/driver controlled vehicles, but also in unattended equipment, throttle, and choke controls. The timer ensures that the pull coil is turned off within approximately 1-1/2 seconds after energizing, which prevents overheating of the coil in situations such as abusive overcranking of an engine.



INTERNAL SWITCHING

The internally switched solenoid utilizes a mechanical double contact switch, mounted on the rear of the solenoid, to turn off the pull coil. Best suited for applications such as standby generator sets or other applications where vibration, dirt, moisture, and excessive cycling are not present.



Externally Switched Solenoid Terminations

Externally switched solenoids are available with the standard leads termination. They are also available with switch caps and either screw or blade type terminals. See Figure 3.

1. Pigtail (leaded) termination: designed for leads to be fitted to a connector
2. Switch cap with spade type terminals: designed for harness leads to be connected without soldering
3. Switch cap with screw type terminals: designed for harness leads to be be screwed on

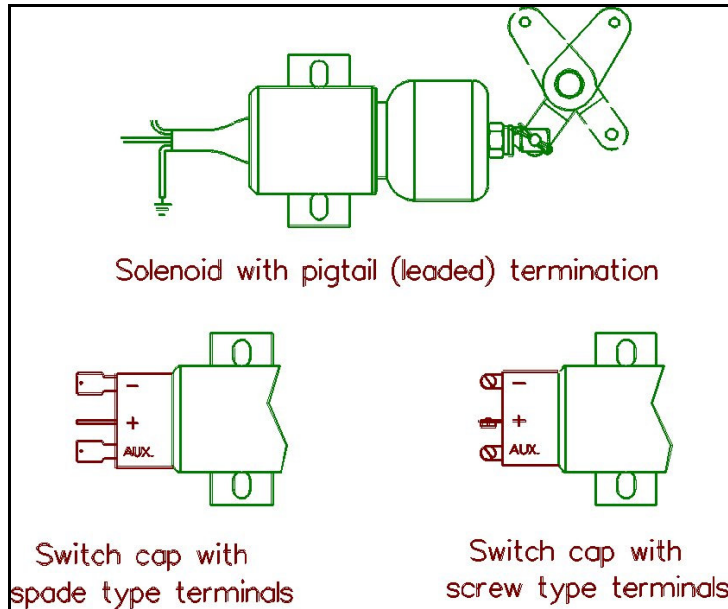


Figure 3. Terminations on Externally Switched Solenoids

Pull vs. Push Solenoids

Solenoids can be pull type or push type. In a pull type solenoid, which is the more common type, when the solenoid is energized the plunger pulls in towards the solenoid. Pull type solenoids can be internally or externally switched.

In a push type solenoid, when the solenoid is energized the plunger pushes out away from the solenoid. All push type solenoids are externally switched.

Both pull and push type solenoids are constructed in a similar manner and operate on the same principle. It is usually the application, mounting considerations, and direction of plunger motion needed that determine what type of solenoid will be used.

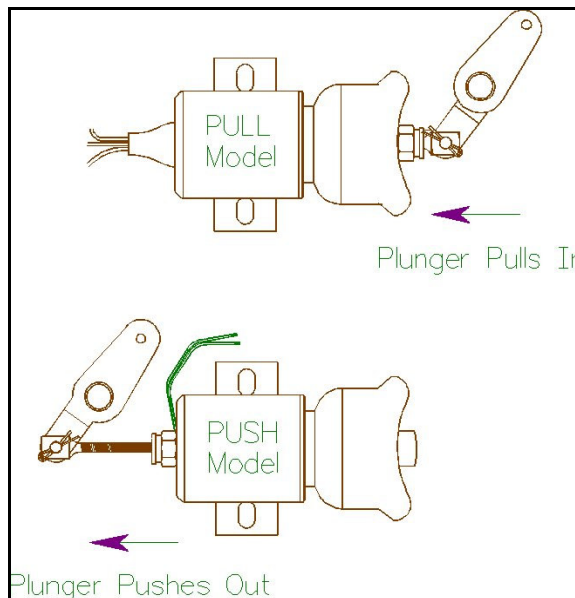


Figure 4. Pull and Push Type Solenoids

Energized-to-Run vs. Energized-to-Stop Applications

Solenoids can be used in both Energized-to-Run (ETR) and Energized-to-Stop (ETS) Applications.

In Energized-to-Run applications, which are more common, the equipment is turned on when the solenoid is energized.

In Energized-to-Stop applications the equipment is turned off when the solenoid is energized. For example, in marine applications, it is desirable to keep the engine running at all times while at sea. Therefore, the engine fuel control lever is held in the run position. To stop the engine, a solenoid is energized long enough to stop fuel completely and shut the engine off. When de-energized, the solenoid returns the lever to its minimum fuel lever for the next engine start.

In ETR applications, the solenoid is on continuously and therefore the ES solenoid requires some form of coil protection such as a Coil Commander unit to protect from engine over cranking. In ETS operation, since the application is being turned off, the need for protection is minimum.

Shutdown vs. Throttle (Choke) Applications

Shutdown applications control via the fuel shutoff lever. The lever controls fuel flow to the engine or application. Usually a relay in the engine start system switches from the pull coil to the hold coil. However, over cranking by the operator can burn out the solenoid and therefore including a timing device is preferred as a safety measure.

Throttle (Choke) applications use a solenoid to increase the amount of fuel going to the engine. It pushes or pulls the throttle control lever to a preset position. With an externally switched solenoid, a timing device (such as a Coil Commander) to switch from the pull coil to the hold coil is needed to limit the pull coil on time. As an alternative, an internally switched solenoid can also be used.

Shutdown solenoids are prone to failure because of over cranking by the operator, resulting in overheating, while throttle solenoids are prone to failure because of likely problems in the system.

Coil Protection

In an internally switched dual coil solenoid, the pull coil is energized at the same time as the hold coil, with the key switch in the “Run” position. The plunger switches off the pull coil when it bottoms out, provided there is enough voltage and the linkage is adjusted correctly.

In an externally switched dual coil solenoid, the hold coil is designed to be energized continuously with the key switch in the “Run” position. There is little or no danger of the hold coil failing.

The pull coil is designed to be energized for a short time during engine cranking with the key switch in the “Start” position. Thus, the pull coil current is considerably higher (30-50 amps depending on the model) than that of the hold coil.

Energizing the pull coil causes a significant rise in the internal temperature of the solenoid. Burnout of the coil can occur with excessive engine cranking. Therefore, the pull coil must be turned off, as soon as possible, after pulling the plunger to the “bottomed out” position.

For both internally switched and externally switched solenoids, it is recommended that engine cranking be limited to three 30-second attempts with a cool-down period of two minutes (120 seconds) between each cranking attempt. After three cranking attempts (total elapsed time of 5½ minutes), the solenoid must be allowed to cool down to ambient temperature before making further cranking attempts.

Chapter 2.

Basic Troubleshooting

General Guidelines

Any troubleshooting process involves the following steps:

- Reviewing customer complaint to understand the problem.
- Analyzing information and symptoms to determine probable cause.
- Taking appropriate corrective action to fix the problem.

This section contains some basic troubleshooting instructions. Chapter 3 contains detailed step-step instructions for diagnosing and troubleshooting solenoid related problems.

Tools and Equipment

The use of a digital multimeter is recommended for troubleshooting. Other tools usually found in a mechanic's tool box should be sufficient for most repairs.

- Wire cutters/strippers
- Screwdrivers
- Adjustable wrenches
- Soldering iron

The following parts are not essential but may be needed:

- Tie wraps
- Electrical tape
- Wire
- Crimp-ons

Troubleshooting Techniques

In order to efficiently troubleshoot a system or a piece of equipment, it is important to take a systematic, step-by-step approach to narrow and identify the probable cause of the problem. Troubleshooting is a process in which "trail fixing" should not be attempted.

Many times troubleshooting is a matter of finding out what is "not wrong" with the system. Therefore, begin with the most obvious and proceed step-by-step in an orderly fashion.

Be aware that when several items of equipment are connected together it is not easy to pinpoint the one item that is faulty. Also be aware that in many cases, the problem may be that the operator is not using the equipment properly or that there is some misadjustment.

Approach each situation using the following precautions:

- Understand the problem.
- Check the symptoms to determine probable cause.
- Take appropriate action to fix the problem.

Once the repairs are completed, test to see if the equipment is functioning normally. If not, look for other probable causes and take corrective action until the system is returned to service.

Safety Precautions

Nothing is more important than safety. The simple rule of safety is that if you think safety is for the other person; let the job be, too. Keep in mind that beside yourself, you are also responsible for the safety of everyone around you.

- Information provided in this guide is intended for use by qualified technicians. Attempting repairs without the proper training, tools and equipment can result in personal injury and/or property damage.
- Some of the procedures described in this guide require the use of specialized tools or equipment. Make sure the proper tools or equipment are available before attempting repairs.
- Be aware of the work environment (rotating equipment and hazardous exhaust fumes etc). Be sure protective shields are in place and the work area is properly ventilated.
- Wear eye and ear protection when needed. Wear protective shoes as required by job conditions.
- Be aware of high voltages and take adequate precautions to avoid getting shocked.
- When you need to replace parts, use only the recommended replacement parts. Do not use parts of inferior quality.
- Observe all cautionary notices to reduce or avoid the risk of personal injury or equipment damage.
- Work carefully around machinery that is in operation.

Solenoid Troubleshooting Process

Solenoid troubleshooting can be approached in a couple of ways:

1. You can decide to remove the solenoid from the installation and bench test it first. After making sure the solenoid is working, you can re-install the solenoid and test it on the application.

OR

2. You can test the solenoid while still installed on the application and remove it for bench testing only after eliminating other possible sources of trouble.

Which approach should be followed?

Both approaches are equally valid and it is generally at the technician's discretion to determine the best possible approach to use for each specific situation.

In some instances, one approach may be more practical than the other. For example, if the solenoid is especially difficult to remove and re-install, it may be better to investigate all possible engine related causes before removing the solenoid for bench testing.

At other times, especially from the solenoid manufacturer's perspective, it may make more sense to bench test the solenoid first and eliminate it as the source of the problem before investigating other causes.

Getting Started

Before beginning the actual troubleshooting, complete the following:

1. Identify and learn about the type of engine or application on which the solenoid is installed (consult with the customer).
2. Identify the type of solenoid being used. Refer to Safety Precautions section. Refer to Chapter 3 to begin step-by-step testing and troubleshooting.

Identifying Solenoid Type

It is important to correctly identify the type of solenoid unit you have. This can help during troubleshooting and when communicating with the factory about a problem.

The label on the solenoid contains a model number descriptor and a part number descriptor. The part number descriptor specifies the type of features the solenoid has.

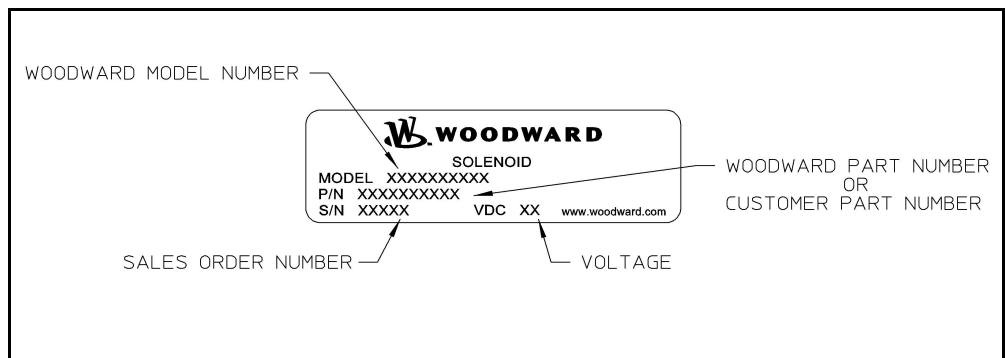


Figure 5. Woodward Solenoid Label

Part Number Descriptor

Below is an explanation of a part number descriptor found on a typical solenoid.

Example: Part Number 12A2U1B1S1A

Reading from left to right:

12 Indicates **volts**: a solenoid can be 12 Vdc or 24 Vdc

A indicates the **mounting** style

- A = Flanged
- B = Threaded
- C = Based

2 Indicates **plunger** type

- 2 = Ext. Thread 1/4-28
- 3 = Ext. Thread M-6
- 6 = Int. Thread 1/4-28
- 7 = Int. Thread M-6

U Indicates **grounding**

- G = Grounded
- U = Ungrounded

1 Indicates **termination** type

- 1 = Screw
- 2 = Spade
- C = Connector
- L = 3 Wire Leads

B1 Indicates **boot** type

- B1 = Constant Volume
- B2 = Bellows

S1 Indicates **return spring forces**

Consult the factory for ratings

A Indicates **special options**

- A = Aux Terminal
- C = Conduct Cover
- CC = Coil Commander

Consult the factory for additional information or explanation.

Chapter 3.

Detailed Troubleshooting

Preliminary Check

The purpose of this check is to do a quick visual scan of the setup and look for some obvious damage or problem. Frequently, such an inspection can save a technician valuable time and effort.

1. Check for broken parts. Inspect the rubber boot. A torn boot can allow dirt to enter and increase the drag or friction on the plunger.
2. Check for blown fuse, broken wires or loose connections. Check for burned out solenoid coil—usually evident by pungent odor.
3. Check the solenoid mounting. Look for loose mounting screws that can cause misalignment, resulting in reduced solenoid force.
4. Check the location. Although the solenoid is designed to operate in harsh environments, locations with excessive heat buildup, constant exposure to liquid and particulate contaminants can effect the solenoid operation.

Power to the Solenoid

1. Disconnect the solenoid from the linkage and the control lever. Apply power and see if the solenoid pulls in. If the solenoid pulls in, it is getting power to operate.
2. If the solenoid does not pull in, check voltage at the connector and confirm at least 10 Vdc is being delivered to a 12 Vdc system and 20 Vdc to a 24 Vdc system. This is the minimum acceptable voltage.
3. If the voltage reading is not acceptable, check the wiring harness and make sure battery voltage at the battery posts is within manufacturer's specifications. Replace battery if needed.
4. If the voltage readings are acceptable, but the solenoid does not pull in, prepare to remove the solenoid from the application and test it on the bench.

Wiring to the “S” Terminal of Starter



WARNING

Make sure the solenoid is NOT wired to the “S” terminal of the starter. Wiring the solenoid to the “S” terminal of the starter or to the relay that is connected to the “S” terminal will VOID the manufacturer’s warranty for the solenoid.

Perform the following test to determine if the pull coil is incorrectly wired to the “S” terminal of the starter.

1. Turn the ignition switch to the OFF position.
2. Disconnect the solenoid electrical connector from the OEM wiring harness.
3. Locate the pin on the OEM side of the connector that is opposite the white wire (pull coil) of the solenoid side of the connector. Place one lead of the multimeter on this pin.
4. Place the other lead of the multimeter on the “S” terminal of the starter.
5. Measure the resistance between these two points. The resistance should be infinite (open circuit) if the solenoid is wired correctly.

If the resistance is not infinite, the solenoid is incorrectly wired to the “S” terminal of the starter. Re-wire the solenoid correctly. (Refer to the publication SE-3024 for recommended wiring schemes).

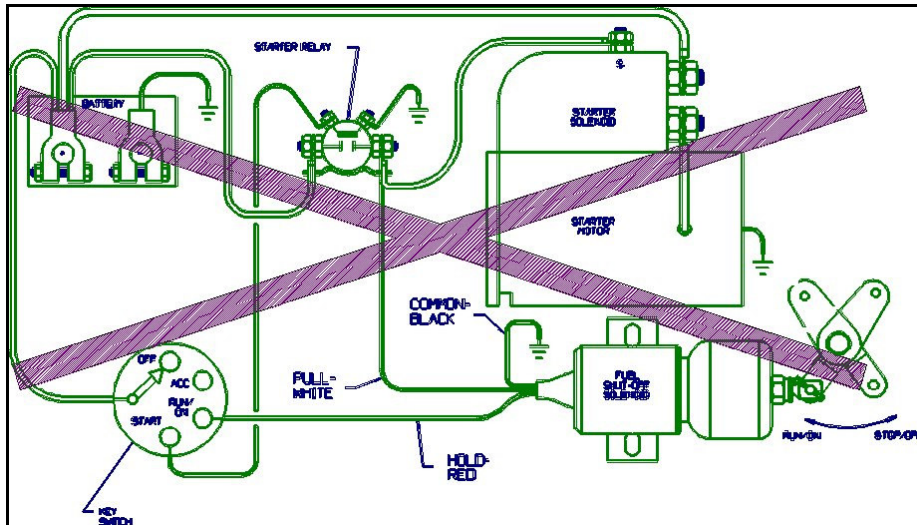


Figure 6. Connection to the “S” Terminal is Not Recommended.

Solenoid Coil Resistance Check

1. Make sure the solenoid is at room temperature (70°F / 21°C) before checking the resistance.
2. Disconnect solenoid electrical connector from the wiring harness connector if solenoid is installed on the application.
3. Use an ohmmeter capable of measuring at least tenths of ohms or better. "Zero" adjust the meter before measuring.
4. For internally switched solenoids, pull the plunger all the way out and then check the reading between positive and negative terminals for pull coil resistance. Now, manually move the plunger all the way in to activate the internal switch. Hold the plunger in this position and check the reading again between the positive and negative terminals to obtain hold coil resistance.
5. For externally switched solenoids, pull coil resistance is read between White and Black wires and hold coil resistance is read between Red and Black wires. For externally switched solenoids with switch caps and screw or blade type terminals, use the label to identify and measure the pull coil and hold coil resistance.
6. Refer to the coil resistance chart (1A or 1B) for the correct values.



NOTE

Some specially manufactured solenoid units may not follow the general wire color scheme presented here.

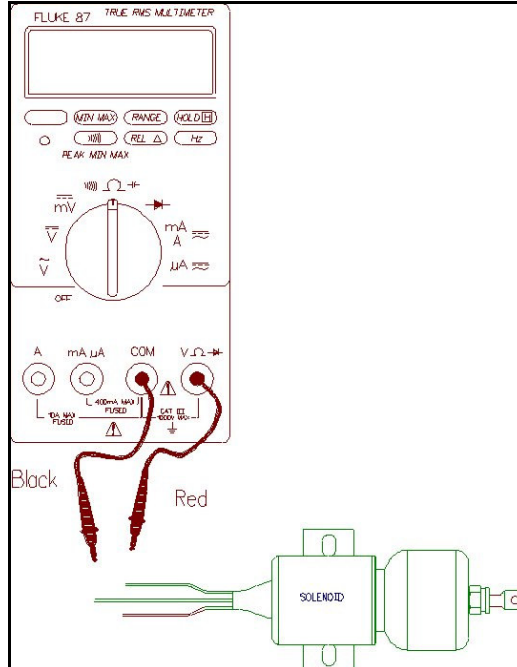


Figure 7. An Ohmmeter to Measure Resistance is Recommended.

**Table 1A. Coil Resistance
Externally Switched Solenoids**

Model No.	Voltage	Measurement Range	
		Pull Coil Resistance (White/Black Wire)	Hold Coil Resistance (Red/Black Wire)
1502ES	12	0.308-0.376	14.365-14.655
	24	1.280-1.255	48.897-59.763
1503ES	12	0.348-0.426	13.45-16.43
1751ES	12	0.232-0.284	9.819-12.001
	24	0.878-1.073	46.548-56.892
1751ES/ 1756ES	12	0.232-0.284	9.82-12.00
	24	0.878-1.073	46.55-56.89
1752ES	12	0.195-0.239	10.04-12.27
1755ES	24	0.735-0.899	37.22-45.49
1753ES/	12	0.324-0.396	12.97-15.85
1757ES	24	1.208-1.477	54.73-66.89
2001ES	12	0.248-0.302	17.48-21.36
	24	0.936-1.144	71.03-86.79
	SB-2776-12	0.240-0.294	16.77-20.49
2003ES	12	0.179-0.219	13.33-16.29
	24	0.577-0.706	48.78-59.62
2003ES	12	0.175-0.213	12.75-15.59
	24	0.554-0.678	46.76-57.15
2003ES	12	0.175-0.213	12.75-15.58
	24	0.554-0.678	46.76-57.15
	24	0.895-1.093	35.76-43.70
2370ES	12	0.221-0.258	5.761-7.041
	24	0.798-0.976	21.08-25.76

**Table 1B. Coil Resistance
Internally Switched Solenoids**

Model No.	Voltage	Measurement Range Between Pos (+) and Neg (-) Terminals	
		Pull Coil Resistance	Hold Coil Resistance
1502	12	0.359-0.438	15.28-18.67
	24	1.350-1.650	89.10-108.90
	32	2.466-3.014	145.35-177.65
	48	4.563-5.577	359.73-439.67
	64	7.884-9.636	394.65-482.35
1504	12	0.261-0.319	14.13-17.27
	24	0.977-1.193	58.90-71.98
	36	2.430-2.970	114.12-139.48
1751	12	0.232-0.284	9.82-12.00
	24	0.878-1.073	46.55-56.89
	36	6.363-7.777	226.26-276.54
1753	12	0.324-0.396	12.97-15.85
	24	1.208-1.477	54.72-66.89
	64	8.730-10.670	296.10-361.40
1755	12	0.195-0.239	10.04-12.27
	24	0.754-0.922	47.94-58.60
2001	12	0.248-0.303	17.48-21.36
	24	0.936-1.144	71.01-86.81
2003	12	0.179-0.219	13.33-16.29
	24	0.577-0.706	48.78-59.62
2370	12	0.185-0.227	6.50-7.94
	24	0.703-0.859	37.27-45.55
	24	0.496-0.606	18.90-23.10
	12	0.185-0.227	6.50-7.94
	24	0.703-0.850	37.27-45.55
	24	0.358-0.438	23.98-19.62

Solenoid Operation on the Engine or Application

The procedure outlined below refers to shutdown applications that are the most common solenoid applications. For other type of applications, use the installed switching mechanism (relay, switch, etc.) to energize and de-energize the solenoid.

Use Table 2 below to observe solenoid operation on the engine and follow the suggested course of action.

Table 2. Solenoid Operation of the Engine

Step	Condition	Corrective Action
1	With one person at the key switch and one person watching the solenoid, inspect the shutdown system during several cycles of the ignition switch. Check for complete shutoff lever travel, from stop to run position.	If the solenoid does not pull in (engine will crank but not start), go to the "NO START" Table 3.
		If the solenoid pulls in but will not hold in (engine stops with the key in run position), go to the "NO RUN" Table 4.
		If the solenoid pulls in but does not return to the shutdown position when switched off (engine will not shut-off), go to the "NO SHUTDOWN" Table 5.
		If the solenoid pulls in and operates normally but the engine will not start, the problem is probably application related. <ul style="list-style-type: none"> a) Check fuel, pump and injectors b) Check air cleaner and filter c) Check switches and system grounds d) Check relays (at least 60 A) e) Refer to the OEM manual



NOTE

Remember to limit cranking to three 30-second attempts with a cool-down period of two minutes (120 seconds) between each cranking attempt. After three cranking attempts, the solenoid must be allowed to cool down to ambient temperature (5½ minutes total elapsed time) before any further attempts are made.

**Table 3. “NO START”
(Solenoid does not pull in)**

Step	Condition/Action
1	<p>Measure solenoid pull coil voltage (refer to Solenoid Voltage Check section).</p> <p>If voltage is in range, refer to Step 2.</p> <p>If voltage is out-of-range, bench test the solenoid (refer to Solenoid Bench Testing section).</p>
2	<p>Check linkage assembly for correct length and/or binding. Adjust linkage if needed (refer to Solenoid Linkage Adjustment section).</p> <p>If the linkage checks OK, bench test the solenoid (refer to Solenoid Bench Testing section).</p>

**Table 4. “NO RUN”
(Solenoid pulls in but will not hold in)**

Step	Condition/Action
1	<p>Measure the hold coil voltage (refer to Solenoid Voltage Check section).</p> <p>If voltage is in range, refer to Step 2.</p> <p>If voltage is out-of-range, bench test the solenoid (refer to Solenoid Bench Testing section).</p>
2	<p>Check linkage assembly for correct length and/or binding. Adjust linkage if needed (refer to Solenoid Linkage Adjustment section).</p> <p>If the linkage checks OK, bench test the solenoid (refer to Solenoid Bench Testing section).</p>

**Table 5. “NO SHUTDOWN”
(Solenoid pulls in but does not return to shutdown)**

Step	Condition/Action
1	<p>Measure the hold coil voltage with the ignition switch in the OFF position.</p> <p>If voltage is in range, refer to Step 2.</p> <p>If voltage is out-of-range, test the solenoid (refer to Solenoid Bench Testing section).</p>
2	<p>Check linkage assembly for correct length and/or binding. Adjust linkage if needed (refer to Solenoid Linkage Adjustment section).</p> <p>If the linkage checks OK, bench test the solenoid (refer to Solenoid Bench Testing section).</p> <p>NOTE: Be aware that there can be non-solenoid related causes for this condition such as alternator circuit feeding back through the hold coil or OEM wiring problem.</p>

Solenoid Voltage Check

Improper voltage affects the solenoid's work output. Low voltage reduces the work output. When the voltage is excessive, it overheats the solenoid and destroys the insulation on the coil and burns out the solenoid. Use Table 6 to check if the solenoid is getting proper voltage.

The solenoid must remain in-circuit (connected to the wiring harness) when checking the voltage. For externally switched solenoids, you can make a jumper harness with mating connectors (as shown in **Figure 8**) to check the voltage while keeping the solenoid connected to the wiring harness. For internally switched solenoids, use the positive (+) and negative (-) terminals to check the voltage.

For externally switched solenoids, the typical wiring scheme is as follows:

<u>Solenoid Wire Marking</u>	<u>Solenoid Wire Color</u>
Hold	Red
Pull	White
Common	Black



NOTE

Some specially manufactured solenoid units may not follow the general wire color scheme presented above.

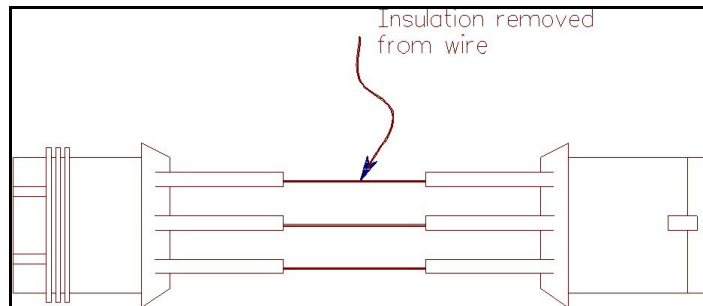


Figure 8. Jumper Harness

Table 6. Solenoid Voltage

Step	Action	Response
1 Check pull-in voltage available to solenoid during cranking	Attach the clips of a voltmeter to the Pull and Common wires in the harness. Hold the run/stop lever in the stop position. Turn the key Switch to "Start" and crank the engine for a few seconds until you get a steady reading on the meter.	The voltage must be a minimum of 75% of rated voltage. If the voltage is below these values (10 Vdc for 12 Vdc units and 20 Vdc for 24 Vdc units), the solenoid may not pull in.
2 Check the hold-in voltage available to the solenoid during cranking	Attach the clips of a voltmeter to the Hold and Common wires in the harness. Hold the run/stop lever in the stop position. Turn the Key Switch to "Start" and crank the engine for a few seconds until you get a steady reading on the meter.	The voltage must be a minimum of 75% of rated voltage. If the voltage is below these values (10 Vdc for 12 Vdc units and 20 Vdc for 24 Vdc units), the plunger will not hold in at the moment cranking stops and the Key Switch is released to the "Run/On" position.
3 Check the hold-in voltage available to the solenoid when NOT cranking	Attach the clips of a voltmeter to the Hold and Common wires in the harness. Turn the Key Switch to "Run/On" and check the voltage. Check continuity between the "Start" and "On" positions on the key switch.	The voltage must not be below, and must remain at, a minimum of 75% of rated voltage. If the voltage is below these values (10 Vdc for 12 Vdc units and 20 Vdc for 24 Vdc units), the plunger will not hold in.
4 Check the voltage between the Pull and Common wires when NOT cranking	Attach the clips of a multimeter to the Pull and Common wires in the harness and check the voltage.	There should NOT be any voltage because the Pull-in coil is only energized when the Key Switch is in the "Start" position. If there is a voltage reading, disconnect the solenoid to prevent burn-out. Inspect application wiring to locate the problem.

**NOTE**

Remember to limit cranking to three 30-second attempts with a cool-down period of two minutes (120 seconds) between each cranking attempt. After three cranking attempts, the solenoid must be allowed to cool down to ambient temperature (5½ minutes total elapsed time) before any further attempts are made.

Solenoid Linkage Adjustment

The solenoid linkage connects the solenoid plunger shaft to the engine control lever. The linkage must have minimal friction, binding and backlash in order to assure accurate, responsive performance of the application. The setting of the linkage is critical to both the solenoid operation and to the performance of the application.

The linkage consists of rotating joints, fastening hardware, and, where required, a control lever. **Figure 9** displays various parts of a typical linkage.

Linkage Adjustment

A misaligned linkage may not allow the plunger to bottom out. Failure to “bottom out” will cause an internally switched solenoid to burn out and an externally switch solenoid to “drop out”.

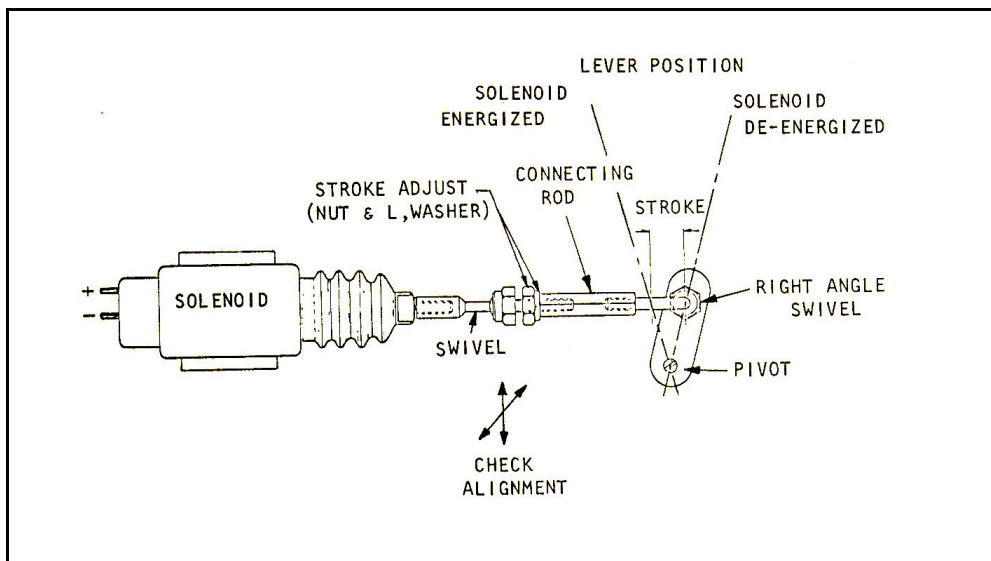


Figure 9. Solenoid with Connecting Rod

Table 7. Linkage Adjustment

Step	Action
1	<p>Examine the linkage and look for signs of corrosion, rust, oil and dirt, all of which can contribute to unacceptable performance of the solenoid. Make sure linkage moves freely without binding. If the linkage feels tight, check for bent linkage, misaligned bracket, improper spring on control lever, swivel head hitting control lever, etc. Loosen linkage as needed.</p> <p>The linkage and the plunger must all move freely with your fingers.</p>
2	<p>Turn the Key Switch to "Run/On" position.</p> <p>NOTE: Take precautions during these checks to prevent pull coil burnout.</p> <p>For internally switched solenoids, manually push the linkage all the way in. The plunger should hold in place. If the plunger does not hold in, measure resistance across the positive and negative terminals. The reading should match the hold coil resistance listed in the Solenoid Coil Resistance Check section. If the reading is not correct, the plunger is not activating the internal switch and linkage adjustment is too short. Adjust linkage until the plunger holds in.</p> <p>For externally switched solenoids, manually push the linkage as far as it will go. The plunger should hold in place. If the plunger does not hold in, linkage adjustment is too short (for push type solenoids the linkage adjustment is too long). Adjust linkage until the plunger holds in.</p>
3	<p>Manually move linkage from shutdown to maximum fuel, ensuring solenoid spring will return linkage to shut down position and full travel of linkage is smooth, uninhibited, and does not exceed specified stroke.</p>
4	<p>When a connecting rod is used, the stroke is adjusted by turning the rod on its threads and locking the rod in place with a lockwasher and nut. The solenoid should be energized during this adjustment. Use this procedure with ES solenoids only if the linkage length is incorrect.</p>
5	<p>When bead chain or cable is used, the solenoid should be energized and the bead chain or cable length adjusted to give the desired lever position.</p> <p>Plunger travel must be checked, especially when a bead chain or cable is used in a connecting device. The plunger travel must be limited to the solenoid's rated stroke when it is de-energized. An "L" bracket can be used to limit the plunger travel.</p>

Overload Protection

Internally Switched Solenoids

Woodward recommends using an overload device to protect solenoids from permanent overload damage. Since customers can choose from a number of devices available on the market (for example; circuit breakers), specific troubleshooting procedures cannot be outlined here.

Externally Switched Solenoids

Woodward recommends using a timer device such as a Coil Commander[®] to protect solenoids from permanent damage. Coil Commanders limit pull coil on-time to prevent solenoid burnout due to engine overcranking and misaligned linkages.



NOTE

When using a Coil Commander module, there will be a voltage loss to the solenoid. Application must supply additional voltage above the minimum hot-solenoid pull-in voltage.

Please consult the factory with questions regarding Coil Commanders.

Solenoid Bench Testing

Use the procedure outlined below to bench test the solenoid.

1. Carefully remove the solenoid from the application. Clean any debris from the solenoid. Remove and inspect the boot to see if foreign matter may have entered inside. Remove the plunger and inspect. Clear the cavity of any debris or foreign material.

Assemble solenoid back together and make sure plunger moves freely. Ensure the return spring is not preventing the plunger from bottoming out by becoming “compressed to solid.” Correct situation if needed.

2. Check solenoid coil resistance to determine if the coil is good (refer to Solenoid Coil Resistance Check section).

If the resistance readings are incorrect, the coil is probably defective. Replace solenoid and determine why the coil may have burnt out. The probable cause is usually misadjustment or low voltage.

On internally switched units, the most common reasons for a burnt coil is misadjustment that prevents the plunger from bottoming out and reaching the cutoff switch, or low voltage. On externally switched units the most common reason for a burnt coil is overcranking.

3. Arrange, by using a block or some other means, to restrict the stroke of the solenoid to about 1” maximum. Using a power supply, apply nominal power (12 Vdc for a 12 Vdc unit and 24 Vdc for a 24 Vdc unit) to the solenoid and see if the solenoid works.

NOTE: Make sure the power supply is functioning properly.

If the solenoid works, it is acceptable as manufactured. This completes the bench testing process. Reinstall the solenoid on the application.

Chapter 4.

Service Options

Product Service Options

The following factory options are available for servicing Woodward equipment, based on the standard Woodward Product and Service Warranty (5-01-1205) that is in effect at the time the product is purchased from Woodward or the service is performed:

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

If you are experiencing problems with installation or unsatisfactory performance of an installed system, the following options are available:

- Consult the troubleshooting guide in the manual.
- Contact Woodward technical assistance (see “How to Contact Woodward” later in this chapter) and discuss your problem. In most cases, your problem can be resolved over the phone. If not, you can select which course of action you wish to pursue based on the available services listed in this section.

Replacement/Exchange

Replacement/Exchange is a premium program designed for the user who is in need of immediate service. It allows you to request and receive a like-new replacement unit in minimum time (usually within 24 hours of the request), providing a suitable unit is available at the time of the request, thereby minimizing costly downtime. This is also a flat rate structured program and includes the full standard Woodward product warranty (Woodward Product and Service Warranty 5-01-1205).

This option allows you to call 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 Woodward facility as explained below (see “Returning Equipment for Repair” later in this chapter).

Charges for the Replacement/Exchange service are based on a flat rate plus shipping expenses. You are invoiced the flat rate replacement/exchange charge plus a core charge at the time the replacement unit is shipped. If the core (field unit) is returned to Woodward within 60 days, Woodward will issue a credit for the core charge. [The core charge is the average difference between the flat rate replacement/exchange charge and the current list price of a new unit.]

Return Shipment Authorization Label. To ensure prompt receipt of the core, and avoid additional charges, the package must be properly marked. A return authorization label is included with every Replacement/Exchange unit that leaves Woodward. The core should be repackaged and the return authorization label affixed to the outside of the package. Without the authorization label, receipt of the returned core could be delayed and cause additional charges to be applied.

Flat Rate Repair

Flat Rate Repair is available for the majority of standard products in the field. This program offers you repair service for your products with the advantage of knowing in advance what the cost will be. All repair work carries the standard Woodward service warranty (Woodward Product and Service Warranty 5-01-1205) on replaced parts and labor.

Flat Rate Remanufacture

Flat Rate Remanufacture is very similar to the Flat Rate Repair option with the exception that the unit will be returned to you in "like-new" condition and carry with it the full standard Woodward product warranty (Woodward Product and Service Warranty 5-01-1205). This option is applicable to mechanical products only.

Returning Equipment for Repair

If a control (or any part of an electronic control) is to be returned to Woodward for repair, please contact Woodward in advance to obtain a Return Authorization Number. When shipping the item(s), attach a tag with the following information:

- 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.



CAUTION

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*.

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.

Return Authorization Number

When returning equipment to Woodward, please telephone and ask for the Customer Service Department [1 (800) 523-2831 in North America or +1 (970) 482-5811]. They will help expedite the processing of your order through our distributors or local service facility. To expedite the repair process, contact Woodward in advance to obtain a Return Authorization Number, and arrange for issue of a purchase order for the item(s) to be repaired. No work can be started until a purchase order is received.



NOTE

We highly recommend that you make arrangement in advance for return shipments. Contact a Woodward customer service representative at 1 (800) 523-2831 in North America or +1 (970) 482-5811 for instructions and for a Return Authorization Number.

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.

How to Contact Woodward

In North America use the following address when shipping or corresponding:

Woodward Governor Company
PO Box 1519
1000 East Drake Rd
Fort Collins CO 80522-1519, USA

Telephone—+1 (970) 482-5811 (24 hours a day)
Toll-free Phone (in North America)—1 (800) 523-2831
Fax—+1 (970) 498-3058

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

<u>Facility</u>	<u>Phone Number</u>
Brazil	+55 (19) 3708 4800
India	+91 (129) 230 7111
Japan	+81 (476) 93-4661
The Netherlands	+31 (23) 5661111

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

Engineering Services

Woodward Industrial Controls Engineering Services offers the following after-sales support for Woodward products. For these services, you can contact us by telephone, by email, or through the Woodward website.

- Technical Support
- Product Training
- Field Service

Contact information:

Telephone—+1 (970) 482-5811

Toll-free Phone (in North America)—1 (800) 523-2831

Email—icinfo@woodward.com

Website—www.woodward.com

Technical Support is available through our many worldwide locations or our authorized distributors, depending upon the product. This service can assist you with technical questions or problem solving during normal business hours. Emergency assistance is also available during non-business hours by phoning our toll-free number and stating the urgency of your problem. For technical support, please contact us via telephone, email us, or use our website and reference **Customer Services** and then **Technical Support**.

Product Training is available at many of our worldwide locations (standard classes). We also offer customized classes, which can be tailored to your needs and can be held at one of our locations or at your site. This training, conducted by experienced personnel, will assure that you will be able to maintain system reliability and availability. For information concerning training, please contact us via telephone, email us, or use our website and reference **Customer Services** and then **Product Training**.

Field Service engineering on-site support is available, depending on the product and location, from one of our many worldwide locations or from one of our authorized 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 field service engineering assistance, please contact us via telephone, email us, or use our website and reference **Customer Services** and then **Technical Support**.

Technical Assistance

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

General

Your Name _____

Site Location _____

Phone Number _____

Fax Number _____

Prime Mover Information

Engine/Turbine Model Number _____

Manufacturer _____

Number of Cylinders (if applicable) _____

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

Rating _____

Application _____

Control/Governor Information

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

Woodward Part Number and Revision Letter

Control Description or Governor Type

Serial Number

Woodward Part Number and Revision Letter

Control Description or Governor Type

Serial Number

Woodward Part Number and Revision Letter

Control Description or Governor Type

Serial Number

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

We appreciate your comments about the content of our publications.

Send comments to: icinfo@woodward.com

Please include the manual number from the front cover of this publication.



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