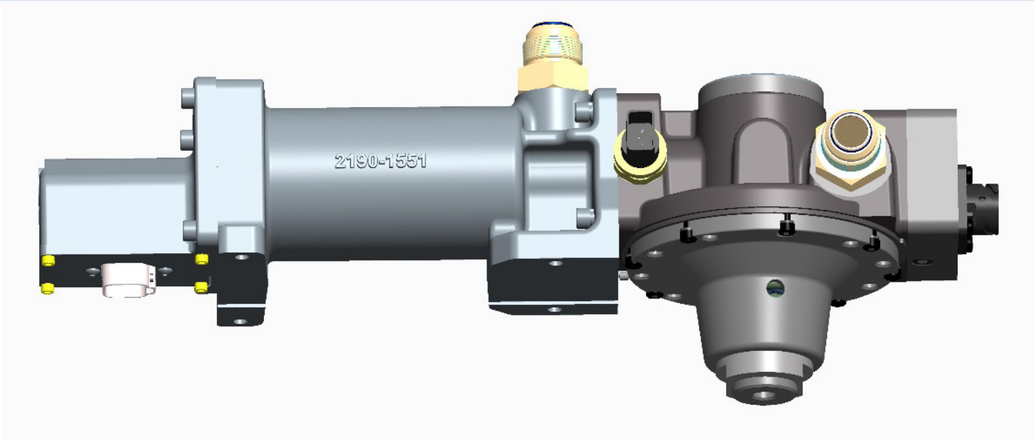
Released

WOODWARD

Product Manual 35055
(Revision C, 11/2024)
Original Instructions



Proportional Flow Area Valve (PFAV)

for CNG and LNG fuels

Installation and Operation Manual

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

Revisions	**This publication may have been revised or updated since this copy was produced. The latest version of most publications is available on the Woodward website.** **Woodward Industrial Support: Get Help** **If your publication is not there, please contact your customer service representative to get the latest copy.**

Proper Use	**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.**

Translated Publications	**If the cover of this publication states "Translation of the Original Instructions" please note:** **The original source of this publication may have been updated since this translation was made. The latest version of most publications is available on the Woodward website.** **Woodward Industrial Support: Get Help** **Always compare with the original for technical specifications and for proper and safe installation and operation procedures.** **If your publication is not on the Woodward website, please contact your customer service representative to get the latest copy.**

Revisions— A bold, black line alongside the text identifies changes in this publication since the last revision.

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Important Definitions

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

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

WARNING Lockout/Tagout LOTO	**Ensure that personnel are fully trained on LOTO procedures prior to attempting to replace or service equipment on a "live" running engine. All safety protective systems (overspeed, over temperature, overpressure, etc.) must be in proper operational condition prior to the start or operation of a running engine. Personnel should be equipped with appropriate personal protective equipment to minimize the potential for injury due to release of hot hydraulic fluids, exposure to hot surfaces and/or moving parts, or any moving parts that may be activated and are located in the area of control of the unit.**

WARNING Overspeed / Overtemperature / Overpressure	**The engine, turbine, or other type of prime mover should be equipped with an overspeed shutdown device to protect against runaway or damage to the prime mover with possible personal injury, loss of life, or property damage.** **The overspeed shutdown device must be totally independent of the prime mover control system. An overtemperature or overpressure shutdown device may also be needed for safety, as appropriate.**

WARNING Personal Protective Equipment	**The products described in this publication may present risks that could lead to personal injury, loss of life, or property damage. Always wear the appropriate personal protective equipment (PPE) for the job at hand. Equipment that should be considered includes but is not limited to:** • **Eye Protection** • **Hearing Protection** • **Hard Hat** • **Gloves** • **Safety Boots** • **Respirator** **Always read the proper Material Safety Data Sheet (MSDS) for any working fluid(s) and comply with recommended safety equipment.**

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

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

⚠WARNING

IOLOCK

IOLOCK: driving I/O into a known state condition. When a control fails to have all the conditions for normal operation, watchdog logic drives it into an IOLOCK condition where all output circuits and signals will default to their de-energized state as described below. ***The system MUST be applied such that IOLOCK and power OFF states will result in a SAFE condition of the controlled device.***

- **Microprocessor failures will send the module into an IOLOCK state.**
- **Discrete outputs / relay drivers will be non-active and de-energized.**
- **Analog and actuator outputs will be non-active and de-energized with zero voltage or zero current.**

Network connections like CAN stay active during IOLOCK. This is up to the application to drive actuators controlled over network into a safe state.

The IOLOCK state is asserted under various conditions, including:

- **Watchdog detected failures**
- **Microprocessor failure**
- **PowerUp and PowerDown conditions**
- **System reset and hardware/software initialization**
- **PC tool initiated**

NOTE—Additional watchdog details and any exceptions to these failure states are specified in the related section of the product manual.

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

⚠WARNING

Do Not Backflush

The PFAV should not be backflushed. Backflushing the PFAV may result in fluid retention in the actuator and could cause internal damage.

NOTICE

Battery Charging Device

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

Electrostatic Discharge Awareness

NOTICE

Electrostatic Precautions

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

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

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

Follow these precautions when working with or near the control.

1. Avoid the build-up of static electricity on your body by not wearing clothing made of synthetic materials. Wear cotton or cotton-blend materials as much as possible because these do not store static electric charges as much as synthetics.
2. Touch your finger to a grounded surface to discharge any potential before touching the control, smart valve, or valve driver, or installing cabling connectors. Alternatively, ESD mitigation may be used as well: ESD smocks, ankle or wrist straps and discharging to a reference grounds surface like chassis or earth are examples of ESD mitigation.
   - ESD build up can be substantial in some environments: the unit has been designed for immunity deemed to be satisfactory for most environments. ESD levels are extremely variable and, in some situations, may exceed the level of robustness designed into the control. Follow all ESD precautions when handling the unit or any electronics.
     - I/O pins within connectors have had ESD testing to a significant level of immunity to ESD, however do not touch these pins if it can be avoided.
       - Discharge yourself after picking up the cable harness before installing it as a precaution.
     - The unit is capable of not being damaged or improper operation when installed to a level of ESD immunity for most installation as described in the EMC specifications. Mitigation is needed beyond these specification levels.

IMPORTANT

External wiring connections for reverse-acting controls are identical to those for direct-acting controls.

Regulatory Compliance

International Compliance:
These listings are limited only to those units bearing the appropriate marking.

UNECE: Certified to United Nations Regulation No. 110 Part I, Uniform Provisions Concerning the Approval of Specific Components of Motor Vehicles Using Compressed Natural Gas (CNG) and/or Liquefied Natural Gas (LNG) in Their Propulsion System. Approval Mark E13 110 R-040448 “C”.

Consult Woodward engineering for options of ECE or non-ECE certified units.

Chapter 1.
General Information

This Proportional Flow Area Valve (PFAV) is intended for use on CNG and LNG engines. It consists of a lockoff valve, a boost-biased regulator, a proportional flow area metering valve, a metering valve inlet pressure and temperature sensor, and an optional post-lockoff pressure sensor.

The lockoff valve is a pilot operated valve controlled by a pilot solenoid. The regulator is a mechanical regulator that is biased via an internal passageway that connects to the valve outlet to maintain a constant delta pressure across the valve at any engine manifold pressure.

The metering valve consists of an H-bridge actuator that is controlled by an engine control module (SECM112) with aid of a position feedback sensor. The desired valve position is determined based on the desired flow, inlet pressure, inlet temperature, and outlet pressure. The SECM112's control software and calibration affect the speed of response, damping and overshoot parameters. The SECM112 must also control and limit the rate that the valve hits the end stops on each side of the valve (open and closed). The SECM112 should also control the level of current through the coil where it will not be damaged through excess heat dissipation.

The data in this document reflects these requirements and shows performance using a corresponding SECM112 control module, software and calibration.

Chapter 2.
Components and Operation

PFAV Operation

The valve control strategy uses equations for choked and sub-sonic compressible flow (depending on valve pressure ratio) to determine the desired effective area (EFA) of the valve and its associated position. The algorithm uses the valve inlet pressure, the temperature sensor (NGITP), and a virtual valve outlet pressure sensor (calculated based on MAP and estimated mixer pressure drop) to determine the required EFA to meet the flow demand. The valve is then positioned by closed loop feedback from the position sensor to the desired position correlating to the desired EFA.

Any errors in fuel flow are accounted for by the engine exhaust O2 sensor and correction factors are learned and stored in the SECM112 to ensure the valve can be repositioned accurately with minimal error once the correction factors are learned. This means there can be some driving time involved on new or replaced units before the valve and system achieve their optimal operation.

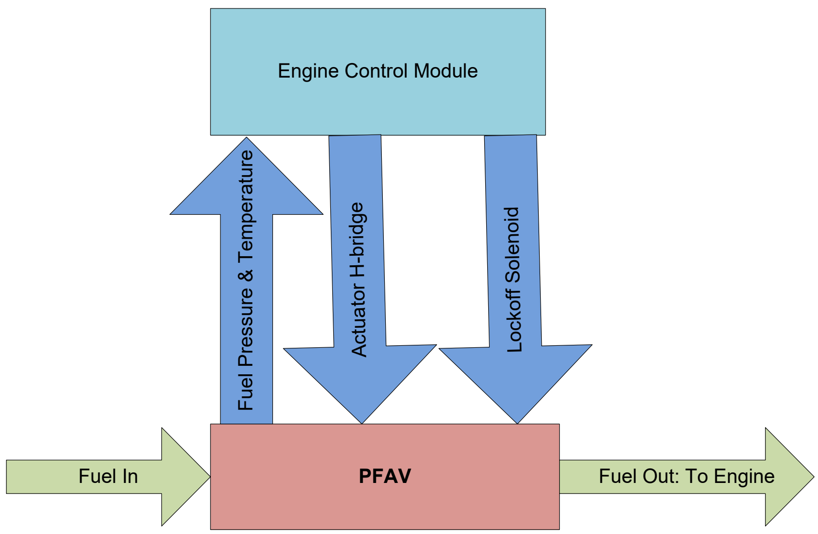


Figure 2-1. PFAV Operational Diagram

PFAV Components

The PFAV consists of a lockoff valve, regulator, metering valve, position sensor, valve inlet pressure and temperature sensor, and optional regulator inlet pressure sensor.

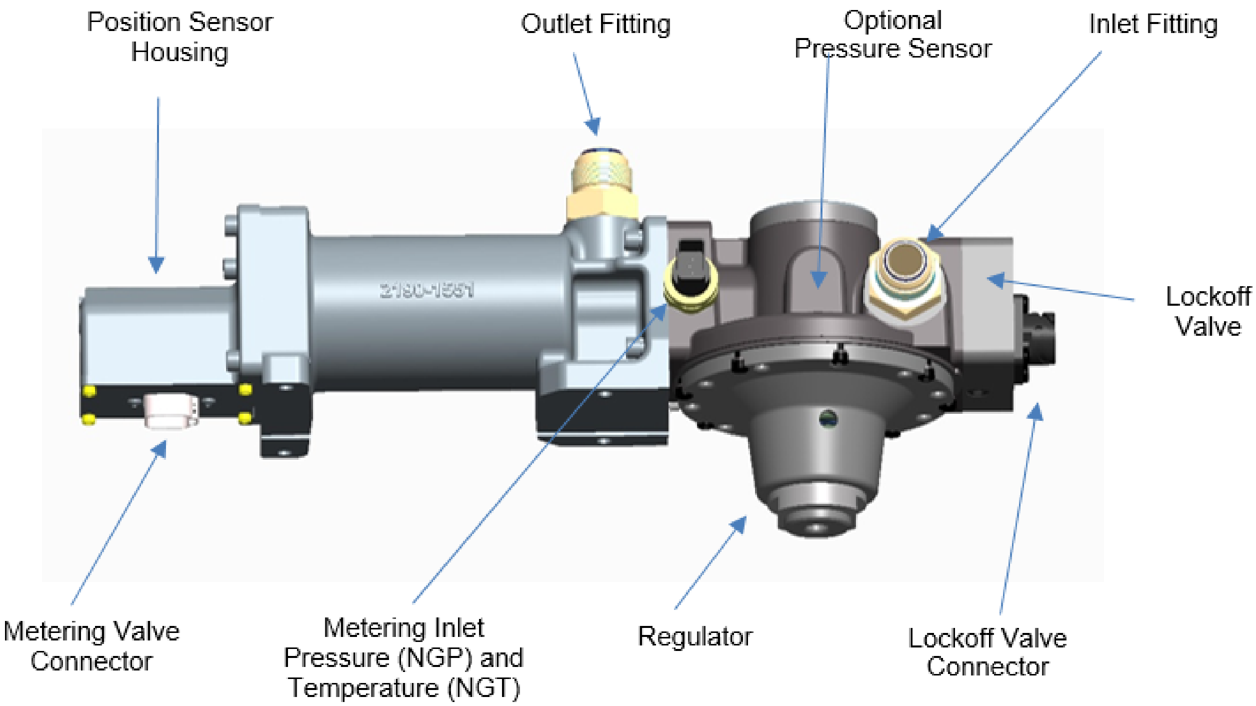


Figure 2-2. PFAV Components

Component Descriptions

- The valve is a piloted valve that uses a 3-way pilot solenoid to build pressure or release pressure above a main valve piston. The solenoid is driven by a peak-hold current strategy to make sure the solenoid can open under all conditions and then is held open with a lower current to avoid coil damage from overheating.
- The regulator is a mechanical regulator used to maintain a near fixed pressure differential across the metering valve to reduce the turn down requirement of the valve. The regulator is designed to take in the full range of LNG pressures that would be seen from a typical tank system from the lowest filling pressure up to the pressure relief valve set pressure (typically 18 barg). The regulator is boost biased by an internal passage from the valve to maintain the differential pressure across the valve at all manifold pressures.
- The metering valve consists of a variable area passageway that is uncovered as the valve is moved through its range of travel. The area has a progressive opening to achieve a consistent gain (% change in flow per % movement) through most of its operational range. The valve also has a relatively large stroke of 25.4mm (1 in) to achieve very fine resolution and high accuracy control.

  The valve is actuated by a moving magnet actuator that is driven by an H-bridge to give rapid response in both directions. The valve also contains a return spring that returns the valve near the closed position on loss of power (if set to 1 bar differential pressure) and helps to counteract pressure forces on the valve. The valve contains a soft seat and can be driven closed by the H-bridge to achieve extremely small leak rates and virtually eliminate fuel flow on motoring events.

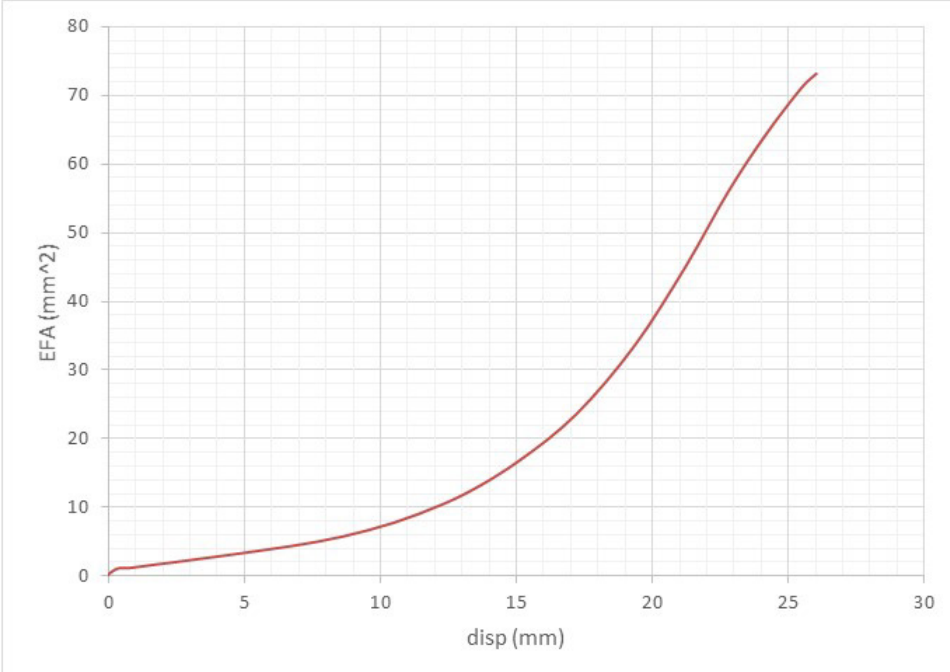


Figure 2-3. Metering Valve Effective Flow Area (EFA) vs. Displacement

- The valve position sensor is a non-contact sensor used to position the valve accurately for the desired position and EFA. The position sensor uses a sensor magnet embedded in the valve shaft to relay the position to a sensor chip that is isolated from the gas. The position sensor chip is calibrated at the end of the Woodward assembly process to ensure that each valve matches the nominal or "family" EFA vs. position curve programmed into the SECM112. Each valve is interchangeable with each ECM after this calibration process has been completed.

- The Natural Gas Injection Temperature and Pressure (NGITP) sensor has two measurement functions integrated into a single unit. The pressure sensor portion features an electronic circuit that converts pressure at the sensor port to an analog voltage output. The relationship between pressure and voltage is the characteristic curve of the pressure sensor and allows the engine control module algorithm to convert the signal to the correct pressure value. The temperature sensor integrated into the NGITP sensor is a Negative Temperature Coefficient (NTC) thermistor. The thermistor has a known characteristic resistance curve versus temperature. The engine control module reads the change in resistance via an internal voltage divider circuit, such that the final voltage signal is converted to a temperature value in the engine control algorithm.

Setting the PFAV Pressure

The following procedure is used to set the PFAV regulator's pressure on engine.

Tools required:
- 1-3/4 inch spanner wrench or adjustable jaw pliers
- 1/4 inch Allen wrench
- Computer running OH6 application software

The factory uses an inlet pressure of 6.9 bar (100 psig) and sets the delta pressure at 112 Kpa (16.24 psid). This should work in most cases. However, at higher inlet pressures the delta pressure may drop too low to provide adequate gas flow. For every 0.689 bar (10 psig) increase in inlet pressure, the regulator secondary pressure will drop by -2.4 Kpa (-0.35 psid). It may be necessary to readjust the regulator for a certain application (see Procedure below).

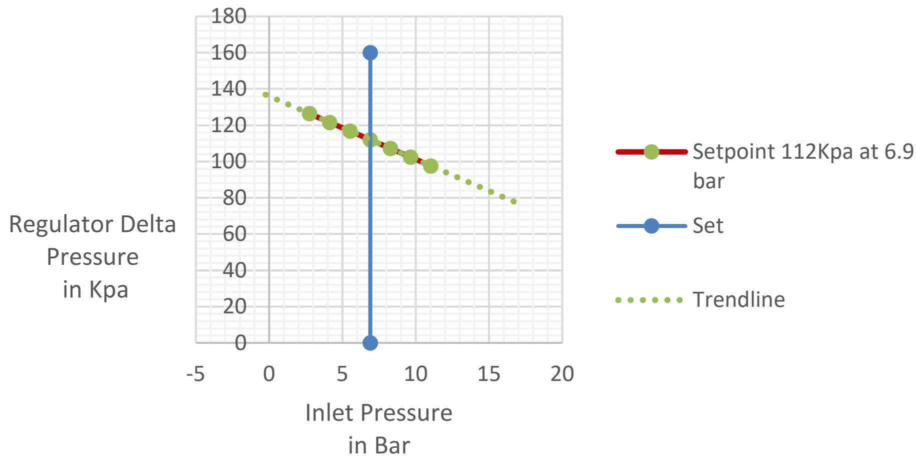


Figure 2-4. Inlet Pressure Effect on Regulator Delta Pressure

Procedure:

1. Connect the computer to the ECU.
2. Start the engine and read the pressure.

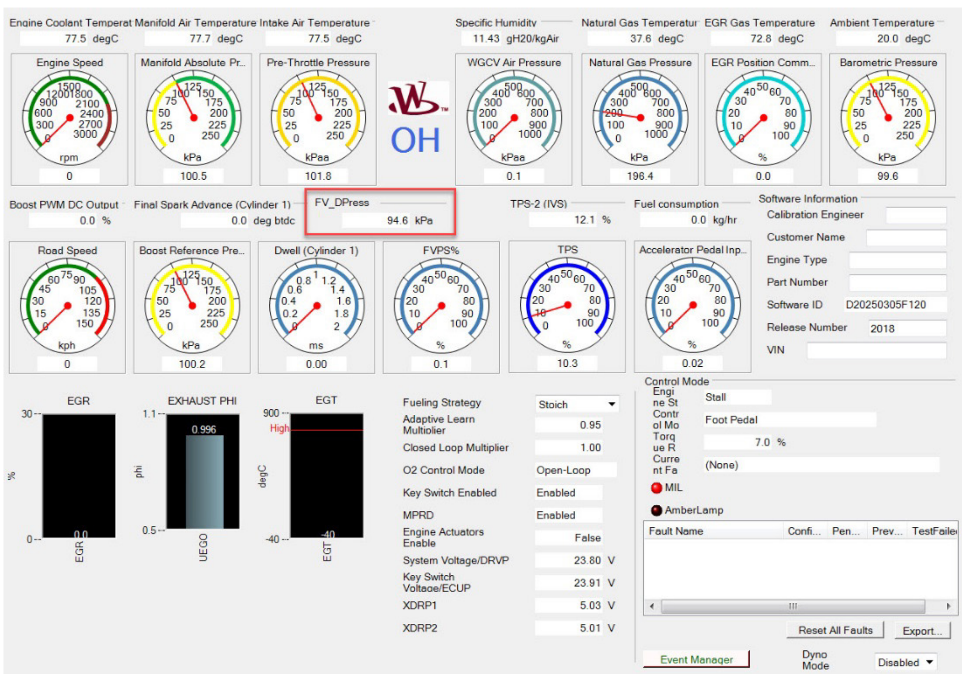


Figure 2-5. Initial Procedure for Readjustment of the Regulator

3. Use the spanner wrench or pliers to remove the adjuster cap on the top of the bonnet.
   Note: Make sure you do not lose the O-ring. It may stay in the cap.

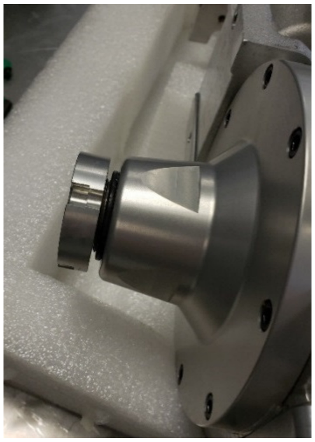


Figure 2-6. Removal of Adjuster Cap

4. Remove the short jam screw.

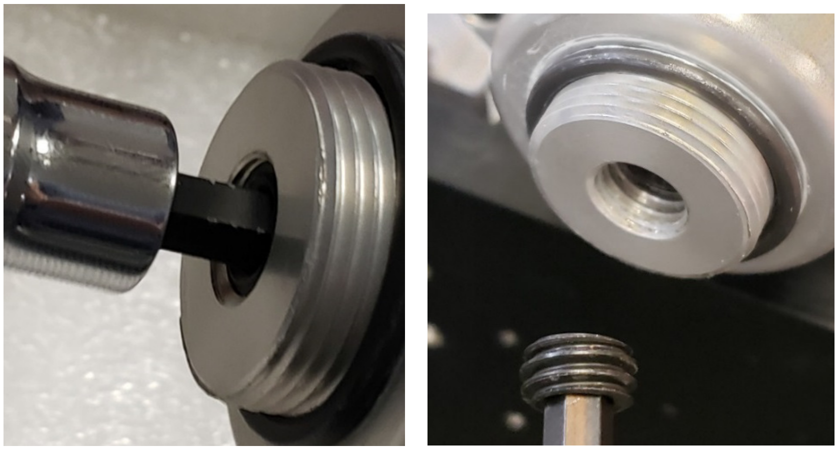


Figure 2-7. Removal of Short Jam Screw

5. Insert the Allen wrench into the internal adjuster screw.

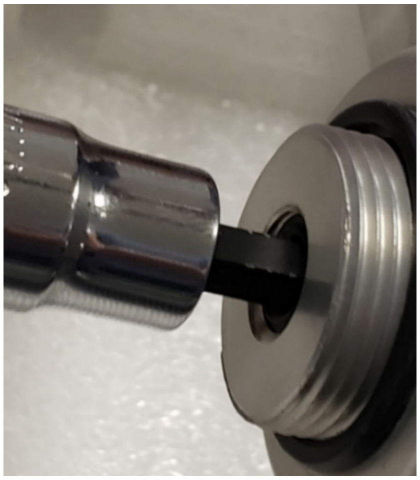


Figure 2-8. Insertion of Allen Wrench into Internal Adjuster Screw

Start the engine and turn the adjuster screw clockwise to increase the pressure and counter-clockwise to decrease the pressure.

- **Set pressure to 95 Kpa**

6. Reinstall the jam screw and tighten until it makes contact with the inner adjustment screw and tighten jam nut until pressure reaches 108 to 116 Kpa.

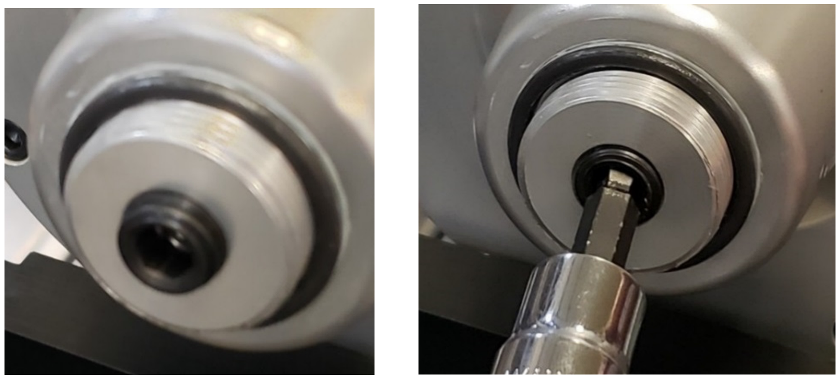


Figure 2-9. Reinstallation of Jam Screw

7. Reinstall adjuster cap and tighten to 28±2 lb-in.

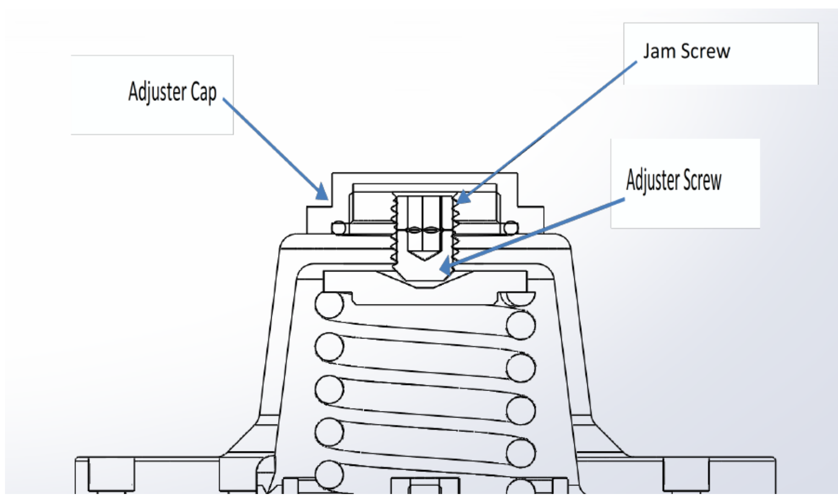


Figure 2-10. Reinstallation of Adjuster Cap

Chapter 3.
PFAV Options

The PFAV can be ordered in various arrangements of position sensor housing (valve connector), valve outlet, and regulator (valve inlet). However, some options may not be possible or may drive additional tooling and validation cost. Please review installation drawing 9999-1814 for available configurations and consult Woodward about any applications requiring an alternative from those shown. The regulator and position sensor can be rotated in 90° increments about the axis as shown in Figure 3-1.

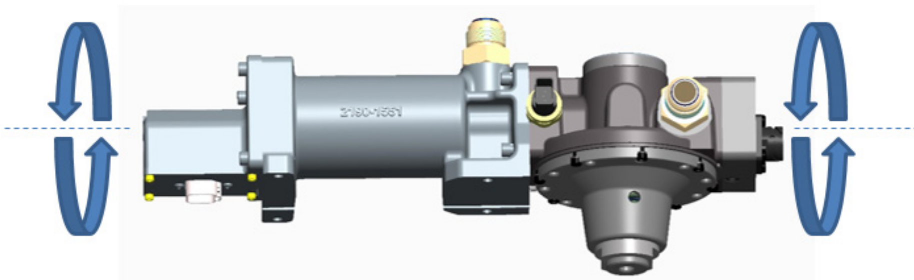


Figure 3-1. Rotation of Regulator and Position Sensor around Axis

The PFAV also has the option of an inlet pressure sensor to help in diagnosing low pressure conditions in the supply or upstream restrictions. The sensor is mounted between the lockoff and regulator.

The PFAV regulator may also be set at pressures between 1 and 2 bar. The desired set pressure must be indicated by the part number and is set at the factory. Note as the pressure is increased from 1 to 2 bar the resting position of the valve when pressurized and unpowered will no longer be in the closed position.

The PFAV will have multiple metering tube size options for different engine size ranges and supply pressure requirements.

Table 3-1. Available PFAV Metering Tube Sizes

	Guaranteed Effective Flow Area	Typical Effective Flow Area
	mm²	mm²
-8 fitting size	1.5 to 52	1.5 to 55
-10 fitting size	1.5 to 55	1.5 to 60
-12 fitting size	1.5 to 63	1.5 to 68

⚠WARNING **The use of a methane detection system to capture gas leaks can prevent a dangerous condition. LNG gas has no odor or color and can be dangerous.**

Chapter 4.
Installation

Typical System Installation Diagram

Figure 4-1 illustrates the typical CNG industrial vehicle fuel system layout, highlighting the location of the PFAV in relation to other components. Not all details of the CNG system are shown.

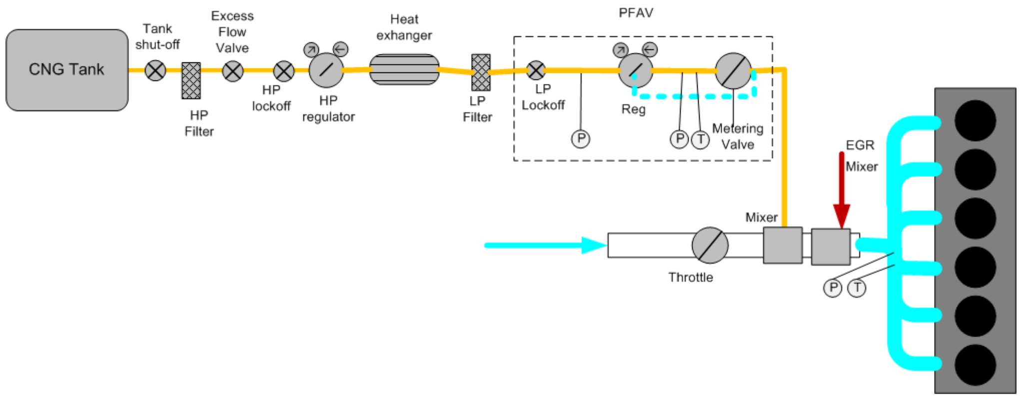


Figure 4-1. Typical Fuel System Configuration (CNG)

Figure 4-2 illustrates the typical LNG industrial vehicle fuel system layout, highlighting the location of the PFAV in relation to other components. Not all details of the LNG tank & fuel conditioning are shown. Depending on the rating of components downstream of the overpressure regulator in the system it may be possible to remove the overpressure regulator from LNG systems (consult Woodward and LNG system supplier).

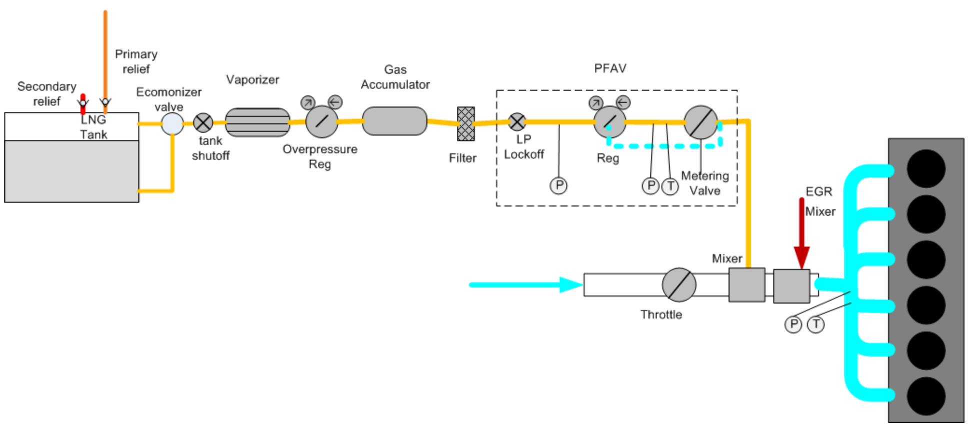


Figure 4-2. Typical Fuel System Configuration (LNG)

⚠WARNING	**The PFAV is not compatible with liquid-phase natural gas. Exposure to liquid natural gas may cause component failure including external fuel leakage; serious injury or death may occur.**

⚠WARNING	**The use of a methane detection system to capture gas leaks can prevent a dangerous condition. LNG gas has no odor or color and can be dangerous.**

Pressure Relief Device (PRD)

CNG and LNG fuel systems must contain at least one Pressure Relief Device (PRD) in key segments of the fuel system.

⚠WARNING	**Failure to install PRD devices in the fuel system may lead to component damage or personal injury.**

For CNG systems, the fuel system between the regulator and PFAV should contain a PRD with a set point of 13.8 barg, and sufficient flow capacity such that in the case of a failed-open regulator at full tank pressure, the downstream pressure will not exceed 87 barg. Woodward offers several pressure regulator configurations with integrated PRDs designed to work with the PFAV.

LNG vehicle fuel systems typically feature primary and secondary PRDs at the storage tanks. If the configuration of the downstream fuel system has the potential to trap fuel, the corresponding volumes should have PRD functionality.

Installation Details

- The PFAV should be mounted with the axis of the valve in the horizontal plane (+/- TBD angle), preferably aligned with the axis of the engine crankshaft.

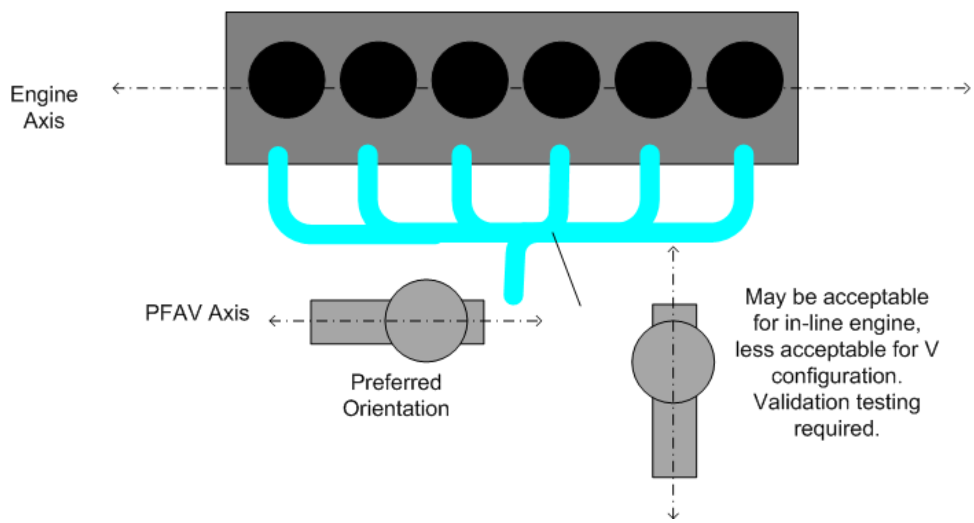


Figure 4-3. Preferred Orientation of PFAV Relative to Engine Axis

- The electrical connectors are preferred to be facing the side or down to avoid accumulation of condensation or other fluids inside the connector.
- The PFAV position sensor and wire harness should not be in close proximity to devices generating large amounts of electrical noise.
- Remove all connectors prior to welding.
- Mask PFAV before welding to protect plastic components.
- After installation or replacement of a PFAV, the system will take some time to learn closed loop correction factors for the specific valve in order to bring the air fuel ratio precisely to its target value. The engine must operate over all RPM and load ranges to completely fill in the closed loop correction table. During this learning time fuel flow may be slightly off during transient operation leading to reduced engine performance.

  Note: Recommend installing a methane detection system as an additional safety measure.

⚠WARNING **Because liquid natural gas is colorless and odorless, the installation of a methane detection system is recommended to avoid dangerous operating conditions.**

Mounting

The fasteners should feature a secondary locking mechanism, such as a serrated washer or thread locking compound. The recommended fastener torque value is 12 N-m with grade 9.8 or better alloy steel 6mm screw.

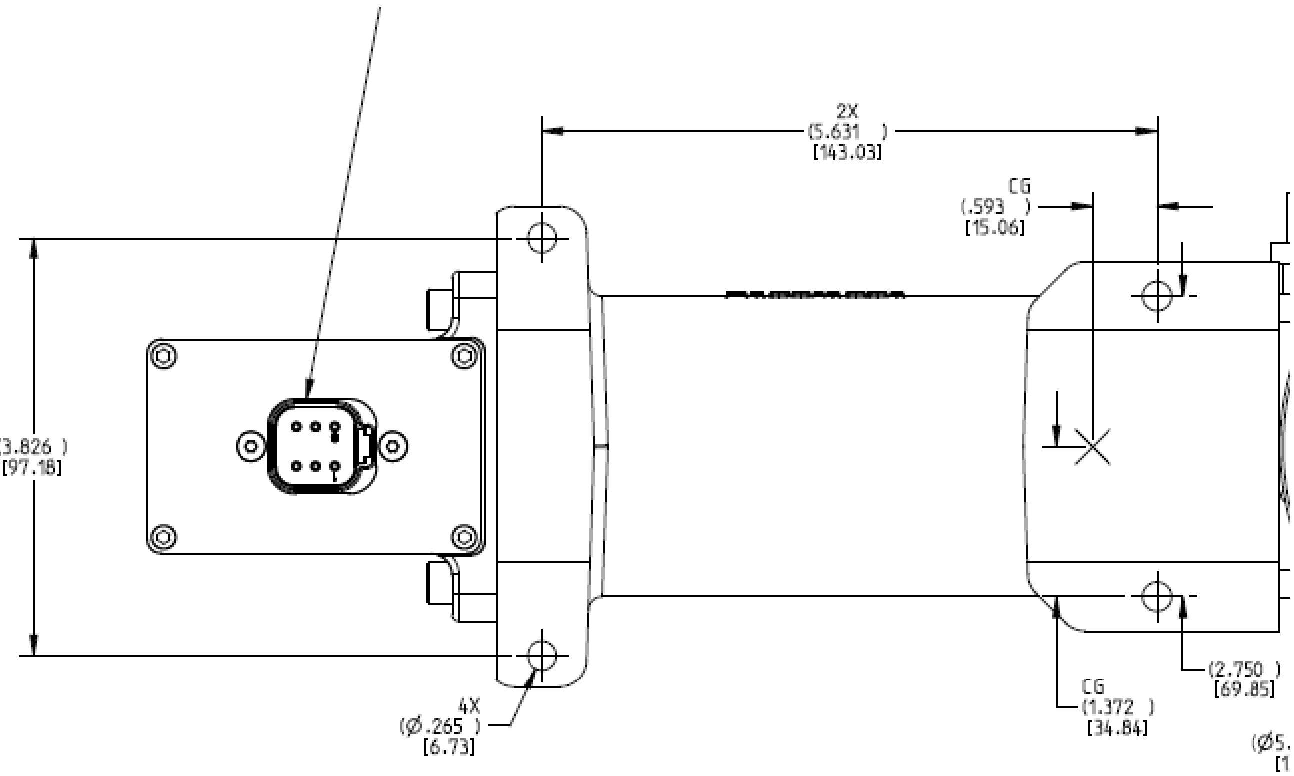
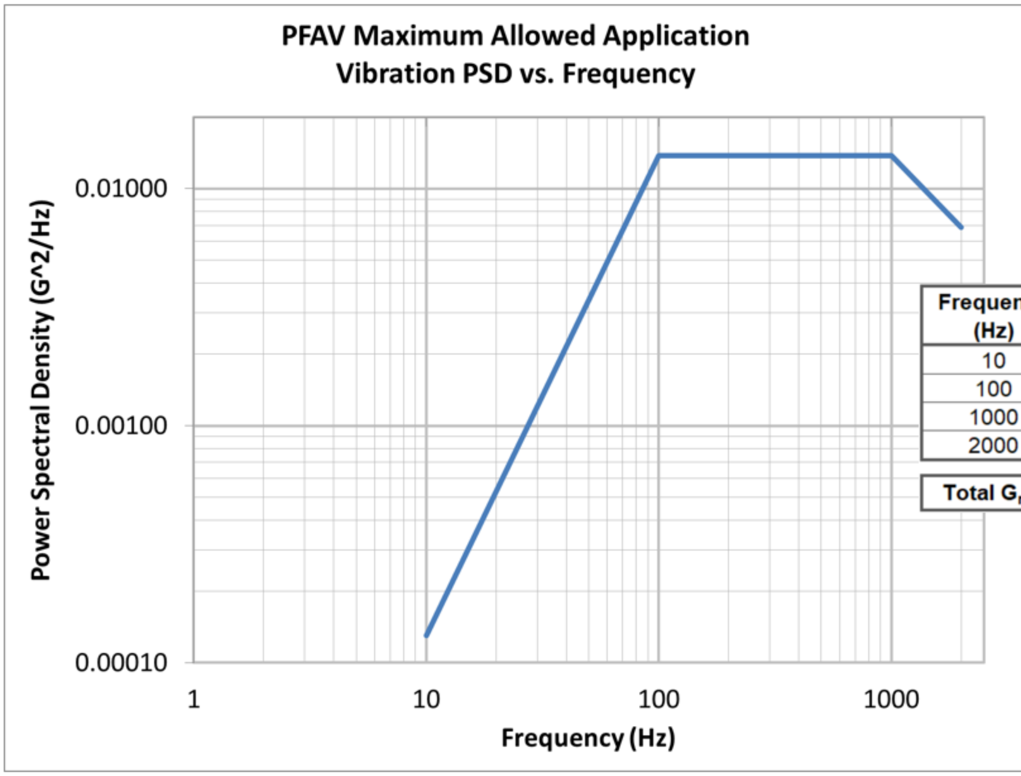


Figure 4-4. Mounting Fastener Pattern

Vibration

As part of product qualification, the PFAV has been tested to a random vibration (RV) profile based on MIL-STD 202F, M214A, TC (F) and SAE J1455 engine data. This accelerated RV testing helps to demonstrate that the PFAV is suitable for vibration exposure over the lifetime of the product in a typical application.

The RV profile shown in Figure 4-5 is derived from the accelerated profile used to qualify the PFAV and has been scaled to typical application levels. This profile is to be used for evaluation of on-engine data collected at the PFAV per instructions in this section.



Frequency (Hz)	Allowed PSD Level (G^2/Hz)
10	0.00013
100	0.01376
1000	0.01376
2000	0.00688
Total G_{rms}	**4.73**

Figure 4-5. Application Random Vibration Limits at PFAV

Determining Vibration Levels for PFAV

All applications should confirm through accelerometer testing that the vibration levels seen on engine over the life of the vehicle will not exceed this accelerated profile. Follow the instructions below to measure in-service vibration levels at the PFAV. Consult Woodward application engineering for test planning and for assessment of field vibration data.

When collecting vibration measurements in application, ensure the following is done:

1. Take measurements at each point in three orthogonal axes: X, Y, and Z.
2. Ideally, orient X along the axis of the engine's crankshaft, Y normal to the crankshaft in the horizontal plane, and Z in the vertical direction. If this orientation is not achievable, orient axes as close as possible. Document axis and accelerometer locations with pictures for future reference.
3. Take at least one measurement as close as possible to the mounting point (i.e., close to the mounting bolt) on the PFAV per Figure 4-6.

4. If possible, measure vibration at one mounting point and at a point on the PFAV where a high response, or vibration amplification, is expected such as location #2 in Figure 4-6. It is critical to document accelerometer locations and provide this information to Woodward with the collected vibration data.
5. If the PFAV is mounted to a bracket, ensure measurements are taken where the PFAV mounts to the bracket (as explained in Step 3 above) and at the base of the bracket where the bracket connects to the engine.
6. For the most accurate assessment of PFAV vibration life in application, take measurements at representative operating conditions and provide a schedule or typical mission profile of time at each operating condition. Data collected at up to nine operating conditions will help Woodward more accurately assess the vibration data for the PFAV.
7. Where there is no concern for damaging parts, it is recommended that the accelerometer be screwed into a drilled and tapped hole when possible. This can safely be done on the flange next to the mounting bolt shown in Figure 4-6. Apply Loctite 243 or equivalent to the accelerometer's thread before installing in a tapped hole. If adhesive is used to apply the accelerometer to the PFAV or engine surfaces, it is recommended to use high-strength, high-temperature adhesive.
8. Use the following settings in the vibration measurement device.
   a. Windowing: Hanning
   b. Number of Averages: 100 or 200 lines
   c. Record Grms measurements
   d. Bandwidth: 20 Hz
   e. Frequency Span: 2 kHz
   f. High Pass Filter: 3 Hz
   g. Low Pass Filter: 5 kHz

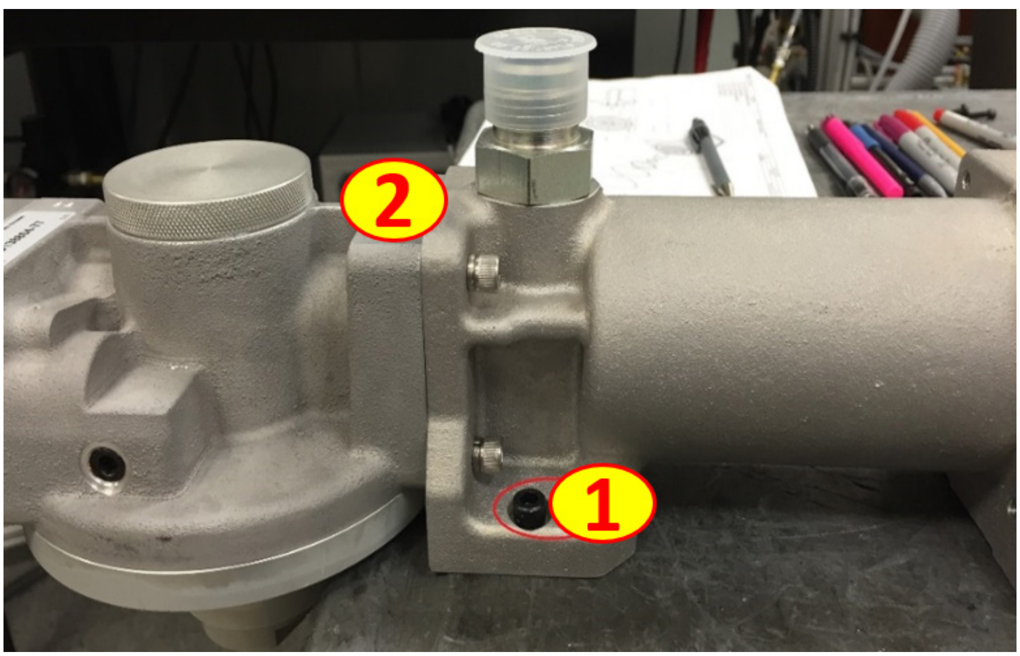


Figure 4-6. Accelerometer Mounting Area

Temperature in Operation

In-use PFAV temperature measurements are recommended. It should be confirmed that at worst case conditions the PFAV shell temperature does not exceed 130 °C. Temperature data should be measured at the PFAV surface location shown in Figure 4-7.

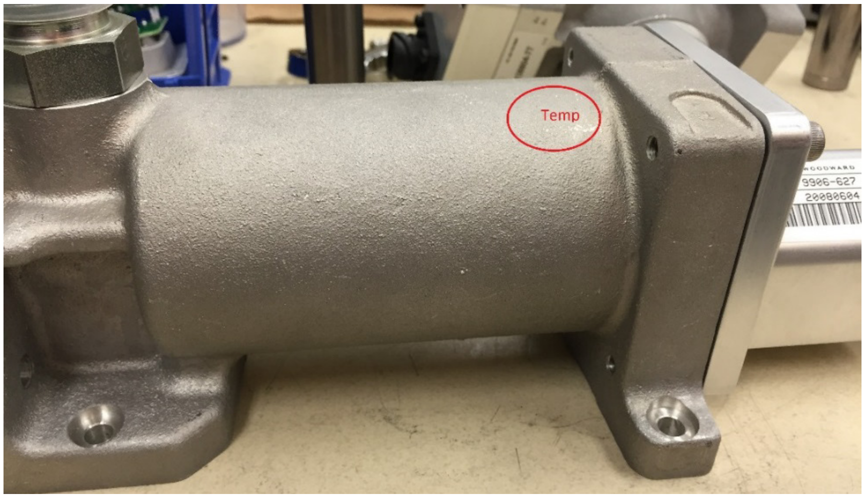


Figure 4-7. Thermocouple Mounting Area

Fuel Line and Fitting Requirements

Inlet Fuel Line

The inlet fuel line must be selected to meet the following requirements:

- The temperature rating of the inlet fuel line must be –40 °C to +125 °C or better.
  - Inlet fuel temperature can be very cold after expansion in CNG systems or during cold-startup or insufficient heat exchanger efficiency in LNG systems. In these situations, the fuel at the PFAV can be much colder than the ambient temperature. Likewise, the PFAV may be mounted in a location where, at idle, the combination of a hot heat exchanger and engine compartment, the fuel temperature may be very warm. Use of fuel line with the required temperature range will allow the fuel system to operate to the extents of the PFAV temperature specification.
- For CNG systems (assuming use with Woodward pressure regulator such as 1326-4080), the burst pressure rating of the inlet fuel line, and all upstream components up to the pressure regulator, must be 114 barg or higher.
  - In the event of a regulator failure that results in the orifice sticking wide-open, the discharge pressure will spike to high levels until the PRD is able to deplete the upstream fuel.
  - If a high pressure CNG regulator is used, the customer should ensure that the burst pressure rating of the inlet fuel line exceeds the actual maximum supply pressure in the event of a failed-open regulator.
- For LNG systems, the burst pressure rating should be 4x the highest-relief stage of the PRD in the LNG tank system (commonly 17.25 barg secondary tank relief, for a burst strength requirement of 69 barg).

⚠WARNING	**Inlet fuel line (downstream of the regulator and upstream of the PFAV) and all upstream fuel system components should have a burst pressure rating as follows:** • **114 barg or higher, for CNG systems** • **4 x the highest-stage PRD relief setting in the LNG tank system**

- The inlet fuel line must be compatible with natural gas and the typical contaminants (compressor oils).
- The inlet fuel line should be supported to limit the bending moment at the inlet fuel fitting to ≤ 5 N·m.
- If the inlet fuel line connects between a chassis-mount component and the PFAV on-engine, ensure the line is robust against the relative motion (vibration) between the chassis and engine. In this case, a flexible hose is usually the best choice, as a metal tube may fail from fatigue.

In addition, the inlet fuel line size must be selected to avoid excessive pressure drop between the regulator and the PFAV. If excessive pressure is introduced, the engine maximum available power may be limited. The appropriate fuel line size will vary depending on the application.

The following tips should be also followed to minimize pressure drop:

- Minimize fittings, elbows, and line length in the fuel system (also applies to the outlet plumbing).
- Regularly maintain the fuel filter(s) in the vehicle to avoid inlet pressure drop due to clogging.
- Use a quality LNG tank system that provides vaporized fuel at a steady pressure.
- During validation of the application, perform a power curve on the engine-dynamometer or full-load vehicle test with the supply pressure at its minimum and all components in the fuel system installed.

Inlet Fuel Fitting

The PFAV is typically provided with a -8 JIC 37° Triple-Lok fitting installed to minimize pressure drop in the supply system. However, other fittings can be installed that conform to the -12 O-ring boss (ORB) thread type.

- Before re-installing the fuel hoses, lubricate the threads, O-ring (if equipped), and the entire surface of the 37° face with hydraulic fluid or a light lubricant before installing.

NOTICE **Thread sealant is not required and is prohibited on the inlet fuel fitting.**

- To tighten the fuel line to the outlet fitting with the proper sealing force, use one of the following methods that best fits the given tube connection. Do not exceed the assembly torque using the Flats-From-Finger-Tight (FFFT) method: first tighten the nut onto the fitting to finger-tight, then tighten with a wrench to the number of hex-flats (1 hex-flat = 1/6th turn) as indicated in Table 4-1.

Table 4-1. Tightening the Fuel Line to the Outlet Fitting Using FFFT Method

SAE Dash Size	Thread Size	Assembly Torque (+10% -) in. lb.	Assembly Torque (+10% -) ft. lb.	Tube Connection FFFT	Swivel Nut or Hose Connection FFFT
-2	5/16-24	35	2	—	—
-3	3/8-24	65	5	—	—
-4	7/16-20	130	11	2	2
-5	1/2-20	165	14	2	2
-6	9/16-18	235	20	1-1/2	1-1/4
-8	3/4-16	525	43	1-1/2	1
-10	7/8-14	650	55	1-1/2	1
-12	1-1/16-12	950	80	1-1/4	1

Discharge Line (to Mixer at Engine Intake)

The PFAV outlet fuel line must be selected to meet the following requirements:

- The temperature rating of the outlet fuel line must be –40 °C to 125 °C or better.
- The inner diameter of the outlet fuel line should be no smaller than 18 mm to reduce system pressure drop and ensure accurate fuel control. The length of this line should be minimized by mounting the PFAV as close to the mixer as possible, while also avoiding the use of 90° elbows and other restrictions as much as possible. If elbows are used, they should be the “swept” type with smooth and large radius bends.

NOTICE

Since the control algorithm of the PFAV uses an estimate of mixer pressure drop it is critical for accuracy to keep the pressure drop of the mixer and mixer hose as small as possible to keep the error in the pressure drop estimate as small as possible. It is recommended to keep the hose and mixer pressure drop less than .2 bar at maximum fuel flow conditions.

The line should be supported to limit the bending moment at the outlet fuel fitting to ≤ 5 N·m.

Outlet Fuel Fitting

The PFAV is provided with a -8 JIC 37° Triple-Lok outlet fitting installed. This provides a leak-tight seal when used with an appropriate 37° fuel hose connection with proper installation procedure.

- Before re-installing the fuel hoses, lubricate the threads, O-ring (if equipped), and the entire surface of the 37° face with hydraulic fluid or a light lubricant before installing.

NOTICE

Thread sealant is not required and is prohibited on the inlet fuel fitting.

- To tighten the fuel line to the outlet fitting with the proper sealing force, see Table 4-1.

Fuel Filter Requirements

The PFAV requires fuel filtration, rated at 10 µm or smaller in the removal of particulates.

- CNG Systems: a high pressure coalescing filter is usually required for the regulator. An additional, low-pressure filter is required to further remove aerosols and particulates.
- LNG systems: only a low pressure filter is required.

Filter service intervals are difficult to predict and will be driven by the amount of contamination (solid and liquid-phase) in the application fuel, the cleanliness of the fuel system components during assembly and maintenance, and the type of filter housing selected. A minimum sump volume of 15 cm^3 is recommended for fuel sites with relatively low oil contamination; a sump volume greater than 100 cm^3 is recommended for fuels with higher oil contamination.

During the initial production of the vehicle and any subsequent service, great care must be taken with fuel lines and components that are mounted downstream of the fuel filter to prevent contamination of the fuel components.

⚠WARNING

Failure to use a suitable fuel filter may lead to poor performance and reduced reliability, and vehicle emissions may increase above regulations.

⚠WARNING	**Operation without a methane detection system can result in dangerous operating conditions because liquid natural gas is colorless and odorless, and detection is not possible.**

⚠WARNING	**Use of a methane detection unit is required when installing the PFAV in an enclosed environment.**

Chapter 5. Specifications

IMPORTANT To maximize valve life, operating at extreme rating conditions should be avoided.

Table 5-1. PFAV Assembly

Characteristic	Value
Rated Voltage	18-32 V *
Nominal Voltage	27.6
Low Voltage Range (limited performance)	12-18 V
Fuel Temperature	-40° to 93°C
Ambient Temperature	-40° to 105°C
Fuel Types	CNG, LNG
Mounting Location	On Engine
Input Pressure Maximum Continuous	17 barg
Random Vibration	22.1 G_{rms}, 10-2000 Hz, 0.3 G^2/Hz, 3 hr/axis based on MIL-STD 202F, M214A, TC (F), SAE J1455 engine data
Mechanical Shock	US MIL-STD-810C, Method 516.3, 516.4 Procedure 1: 40 G peak, 11 ms sawtooth pulse
Ingress Protection	IP69k per IEC 60529

Table 5-2. Metering Valve Actuator Data

Characteristic	Value
Rated Voltage	18-32 V *
Nominal Voltage	27.6
Low Voltage Range (limited performance)	12-18 V
PWM Drive Frequency	5000 Hz
Maximum Continuous RMS Current at 105 °C (221 °F) Ambient	2.5 A (with 70 °C fuel, 2.0 g/s min flow)
Maximum Peak Current	5 A (<2 seconds)
Resistance at Room Temp	4.8 Ohms ± 5%
Inductance at 1 kHz	.01 mH ± 10%

(*) PCM/ECM control ensures that current limits are not exceeded with increasing voltage (derated).

Table 5-3. Position Sensor Data

Characteristic	Value
Input Voltage	5 +/- .5 V
Supply Current Required	15 ma
Output Voltage (in range)	0.8-4.8V = 0-27 mm
Sensor Fault	0-.4 V
Ground Fault	0.5-0.7 V
Position Range	0-27 mm (0-1.06in)
Output Current	Max 15 ma
Recommended Pull-Down Resistor in ECM	51k
Closed Position (typical)	+/- 0.2 mm

Lockoff Valve Solenoid Data

Table 5-4. Lockoff Valve Solenoid Data

Characteristic	Value
Rated Voltage	9-32 V *
Nominal Voltage	27.6
Low Voltage Range (limited performance)	6-9 V
PWM Drive Frequency	1000 Hz
Maximum Continuous Current	400 mA
Peak-Hold Current Profile	600 mA peak 3s, 400 mA hold
Resistance at Room Temp	5.4 Ohms ± 5%

(*) The lockoff solenoid is driven with a current controlled peak-hold current profile. It was originally designed for 12V but is used on 24V applications by PWM controlling the current through the solenoid.

Table 5-5. Pressure Temperature Sensor Data

Characteristic	Value
Rated Voltage	5 +/- .1 V
Supply Current Required	10 ma
Pressure Output Voltage (in range)	0.5-4.5V
Pressure Range	50-450 kPa abs
Output Resistance Range	316181 to 271 Ohms typical

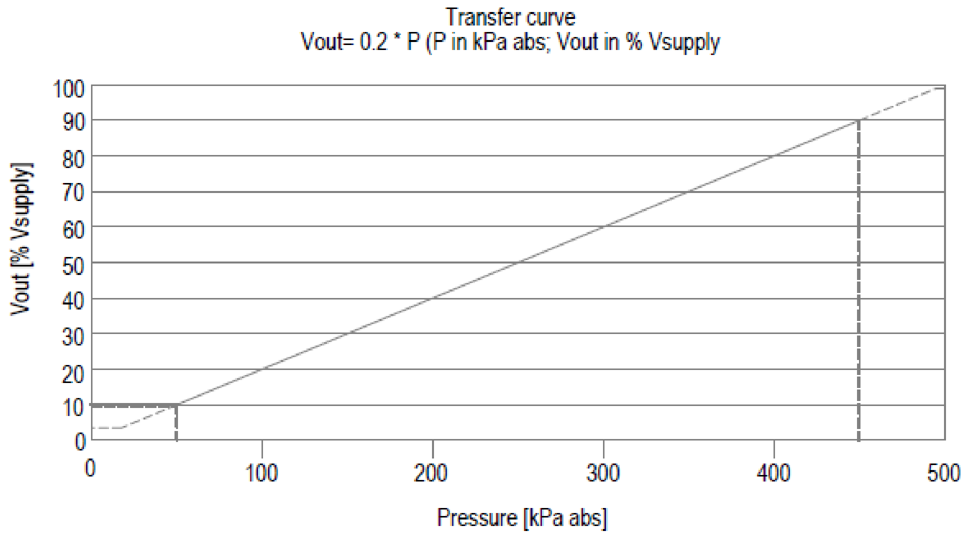


Figure 5-1. Transfer Curve

Table 5-6. Thermistor Resistance

T [°C]	R_nom [Ω]	R_min [Ω]	R_max [Ω]
-40	316181	301183	331179
-30	169149	162304	175994
-20	94143	90938	97349
-10	54308	52781	55836
0	32014	31290	32738
10	19691	19346	20036
20	12474	12315	12633
25	10000	9900	10100
30	8080	7977	8182
40	5372	5282	5462
50	3661	3585	3737
60	2536	2474	2598
70	1794	1744	1844
80	1290	1250	1330
90	941.8	909.6	974.0
100	697.2	671.3	723.1
110	524.9	504.0	545.9
120	399.6	382.6	416.6
130	308.4	294.6	322.3
135	271.3	258.6	2839

Flow Capability

Table 5-7 shows the flow capability of the PFAV at varying outlet pressure P2 (manifold pressure + mixer fuel delta P), delta pressure setting, and inlet pressure P1 (to lockoff). These values are for methane at 40 °C. This analysis also requires that the designer know the maximum manifold pressure, and the pressure drop through the fuel hose on the fuel mixer to determine the outlet pressure P2. In order to achieve the maximum mass flow rate through the valve the system designer must ensure the upstream components can supply the required pressure at the inlet to the PFAV. If this cannot be achieved the maximum flow of the PFAV will be less.

NOTICE

Even if the required flow is less than in the maximum table values, the inlet to the lockoff valve should always be at least 1 bar above the outlet pressure, otherwise the valve accuracy will be negatively impacted.

Table 5-7. PFAV Flow Capability

68mm^2 Valve							
P0 into Lockoff (bar abs)	**Temp in °C**	**P1 into Valve (bar abs)**	**Delta P Valve (bar)**	**P2 Valve Out (bar abs)**	**ACD (mm^2)**	**Mass Flow (g/s)**	**Mass Flow (kg/hr)**
3.95	40	3	1	2	68	32.60	117
4.7	40	3.5	1.5	2	68	39.34	142
5.4	40	4	2	2	68	44.82	161
4.3	40	3.25	1	2.25	68	34.70	125
5.1	40	3.75	1.5	2.25	68	41.93	151
5.8	40	4.25	2	2.25	68	47.82	172
4.6	40	3.5	1	2.5	68	36.68	132
5.4	40	4	1.5	2.5	68	44.37	160
6.1	40	4.5	2	2.5	68	50.65	182
4.85	40	3.75	1	2.75	68	38.56	139
5.7	40	4.25	1.5	2.75	68	46.69	168
6.4	40	4.75	2	2.75	68	53.34	192

Note: Table flow values are for example only. See Table 3-1 for actual max flow area based on fitting size.

To achieve the required inlet pressures to the PFAV, hose sizing and fitting selection is very important. To aid in hose and fitting selection, an analysis was performed to illustrate the effects of hose and fitting size, and fitting style. The analysis was run on a 1m long hose with one straight fitting and one swept 90° fitting.

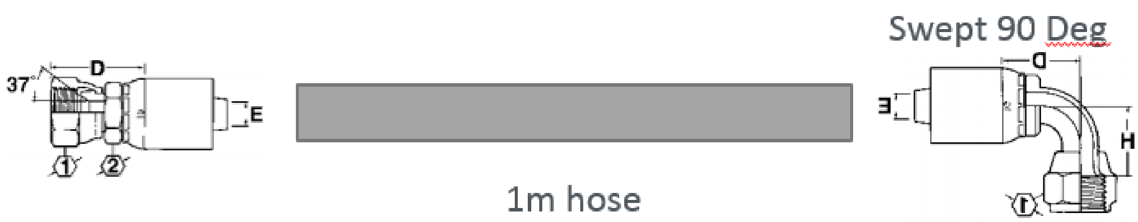


Figure 5-2. PFAV Hose Sizing and Fitting Analysis

The analysis was run for several hose sizes at 61 kg/hr methane at 40 °C. See Figure 5-3 below.

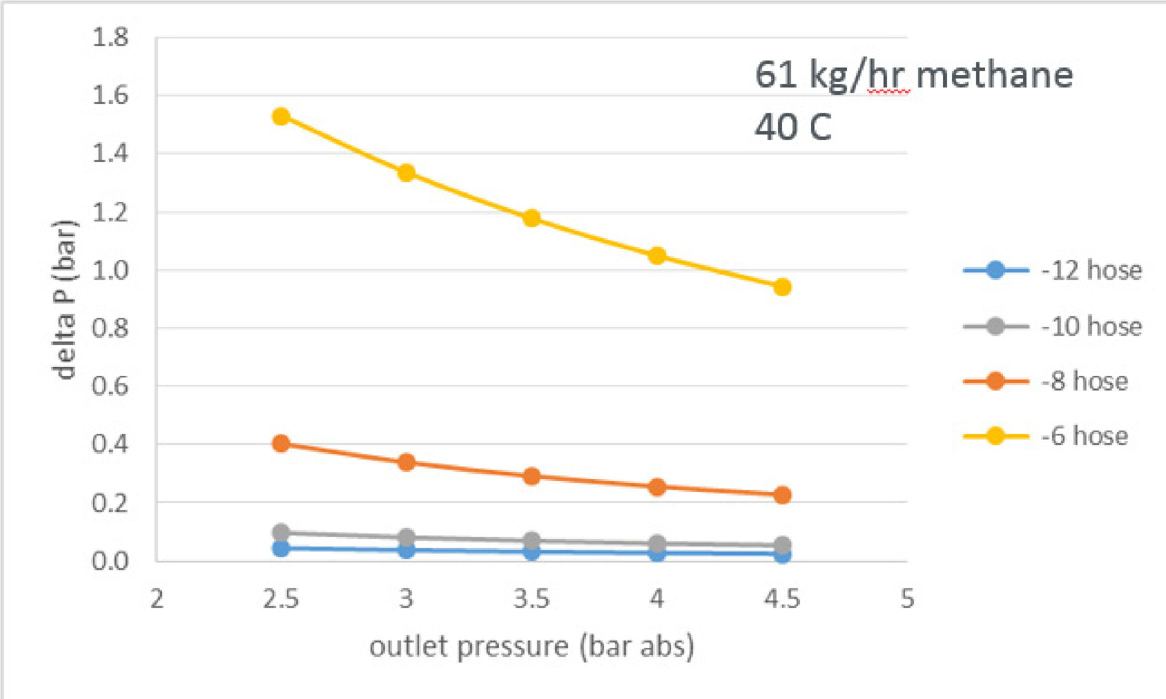


Figure 5-3. Effects of Hose and Fitting Size on Inlet Pressure

Fitting type is also very important. A hard 90° fitting can have several times the pressure drop of a 1m length of hose. The following chart shows the relative contribution to pressure drop of several fittings compared to a 1m length of the same sized hose. Note the fitting ID is typically about 3mm (1/8") smaller than the ID of the hose it goes with. If 90° bend is required always use swept 90° fittings. If a tight 90° fitting must be used it may require stepping up one hose size if high flow rates are critical.

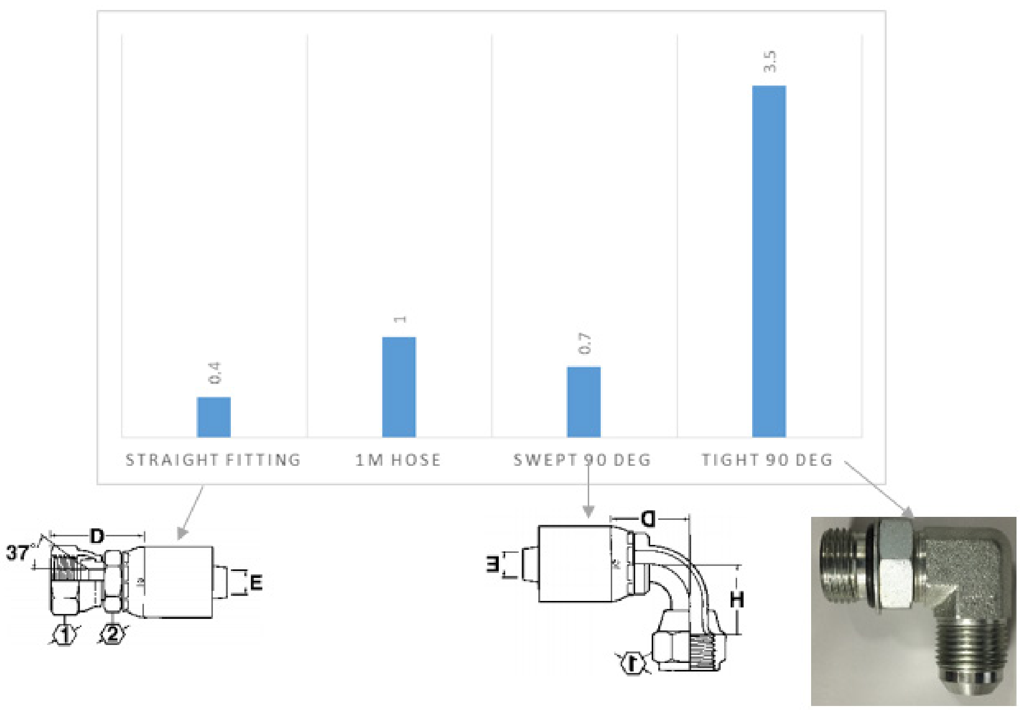


Figure 5-4. Effects of Fitting Type on Inlet Pressure

Chapter 6.
Electrical Connections and Wiring Requirements

The tables below will help you select the proper mating connector for the PFAV, temperature and pressure sensor, and the lockoff valve.

Table 6-1a. PFAV Control Connector

PIN	Connection
1	N/C
2	H-bridge Positive
3	H-bridge Negative
4	Sensor Ground
5	Position Sensor Signal
6	5V Supply

Table 6-1b. PFAV Control Mating Connector

Description	Supplier P/N	Manufacturer
Connector	DT06-6S	Deutsch
Terminal	0462-201-16141	Deutsch
Wedge Lock	W6S	Deutsch
Seal Plug	114017	Deutsch

Recommended wire insulation range for the PFAV control mating connector is Ø 2.24 – 3.68 mm. Seal plugs must be installed in all unused locations (PIN 1).

Table 6-2a. Temp and Pressure Sensor (NGITP) Connector

PIN	Connection
1	Sensor Ground
2	Pressure Signal
3	Temperature Signal
4	5V Supply

Table 6-2b. Temp and Pressure Sensor (NGITP) Mating Connector

Description	Supplier P/N	Manufacturer
Connector	1-967640-1	AMP
Terminal - Tin	962885-1	AMP
Cable Seal	967067-1	AMP

Recommended wire insulation range for the temperature and pressure sensor (NGITP) mating connector is Ø 1.4 – 2.1 mm.

Table 6-3a. Lockoff Valve (LPLO) Connector

PIN	Connection
1	Battery Voltage Supply
2	Low Side Drive

Table 6-3b. Lockoff Valve (LPLO) Mating Connector

Description	Supplier P/N	Manufacturer
Connector	1201973	Packard
Connector Body	1-967325-3	Tyco
Socket Contact	929974-1	Tyco
Wire Seal	828920-1	Tyco

Recommended wire insulation range for the lockoff valve (LPLO) mating connector is Ø 1.2 – 2.1 mm.

Connecting Cable Requirements, Parallel Configurations

All wires shall be automotive grade rated for -40 °C/F to 135 °C (275 °F) ambient or better for under hood installation.

All wires shall be 18 AWG, (0.75 mm² [M(+), M(-), W1, GND, (+), W2].

IMPORTANT

Wire size 18 AWG is recommended for PFAV connector compatibility. For system compatibility the user should refer to the plant wire diagram for the system (example PCM128 may use a different wire size than SECM 112).

Wire insulation diameter requirements vary with the mating connectors used with the PFAV. Wire insulation diameter information is provided below tables 6-1b, 6-2b, and 6-3b.

All mating type terminals must be tin-plated to match PFAV type terminals.

Wiring Practice

For harness wire, SAE J1128 Type GXL (General Purpose, Cross (X) Linked Polyolefin Insulated) or Type TXL (Thin Wall, Cross (X) Linked Polyolefin Insulated) is recommended, but more specific requirements may be driven by the connector of the control unit commanding the operation of the PFAV. The SECM112 module requires TXL wire.

Take care to route the connecting harness in a manner that will not expose the wire to sharp corners or relative motion where rubbing may cause wear through the insulation. The harness length should not exceed 6 meters between the PFAV and control module. Refer to SAE J1292 for other vehicle wiring guidelines.

To maintain electrical contact integrity, the harness should be secured at 300 mm from the connectors. If a loop is required, it should have a minimum radius of 50 mm. A wire loop with its low point at a level below the termination itself may be provided to prevent water from following the wire back to the termination.

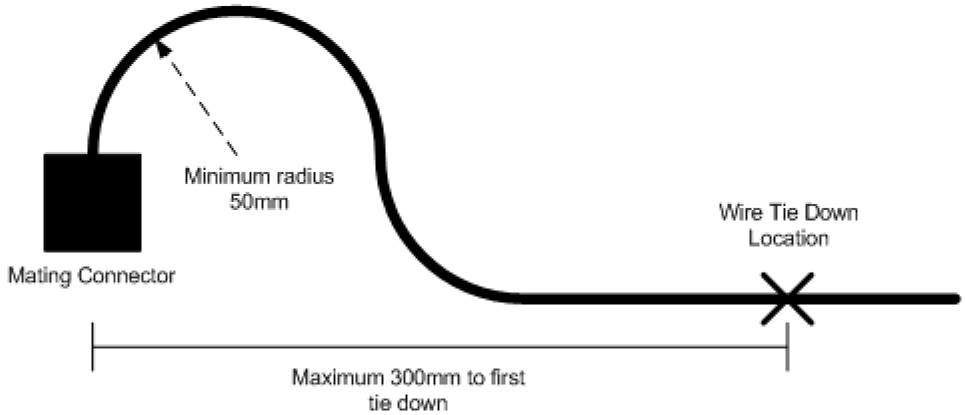


Figure 6-1. Recommended Wiring

Ingress protection ratings (Chapter 5) are applicable only when appropriate mating connectors are installed.

For more wiring practices reference Woodward manual 26675.

Chapter 7.
Maintenance

Introduction

The PFAV is designed to be a low-maintenance device, however there are maintenance steps recommended for the vehicle support systems to ensure maximum product life and safety. Additional cleaning procedures may be carried out on the unit for use in markets where fuel contamination cannot be avoided.

⚠WARNING	**Never evacuate the high pressure side of the fuel system (upstream of regulator) by opening the fuel system to the atmosphere. Injury may result from the rapid release of pressure, and seals may be damaged by the rapid decompression.**

⚠WARNING	**Before performing any maintenance on the fuel system, be sure to safely discharge the pressure in the entire fuel system. It is recommended to shut off the manual tank valves, then start the vehicle and allow it to idle until it has consumed all the fuel and stalled. If the vehicle is inoperable, then a fuel line on the outlet-side of the regulator may be slightly loosened to start relieving pressure. Allow the pressure of the system to deplete no faster than 2 minutes and use extreme care to ensure there are no ignition sources (no sparks, no cigarette smoking, etc.) nearby. Once the system is completely drained, carefully continue to loosen the fuel connection(s) as required for maintenance.**

⚠WARNING Do Not Backflush	**The PFAV should not be backflushed. Backflushing the PFAV may result in fluid retention in the actuator and could cause internal damage.**

IMPORTANT	**Always use a backing wrench to support the fittings in the PFAV when loosening or tightening the fuel line connections.**

IMPORTANT	**This PFAV should be replaced or repaired any time there is any external leakage.**

IMPORTANT	**If the inlet and outlet -12 O-ring boss fittings are removed, orient fitting downward while removing to avoid possible debris contamination into the PFAV. Ensure no debris is introduced into the PFAV. Replace the O-ring boss seal with Woodward part number 1355-1024 ONLY.**

Coalescing Fuel Filter Maintenance

If present in the system, the high pressure and low pressure fuel filters should be drained periodically, and the cartridge element should be changed as needed. The optimal service interval will depend on the amount of debris and liquid contamination in the fuel supply, but it is recommended to drain the filter sump every 2500 km, and replace the filter cartridge every 5000 km (as recommended by Parker for the FFC-113 filter—actual service conditions may vary).

PFAV Cleaning

Cleaning details to be negotiated with the customer. Consult Woodward.

PFAV Replacement

If replacement of the PFAV is required, the following procedure should be followed:

1. Move the vehicle to safe location to perform maintenance.
2. Close the manual fuel shut-off valve(s) at the fuel tank.

⚠WARNING	**Do not rely on the HPLO solenoid valve to act as the positive fuel shutoff for performing fuel system maintenance. Always close the manual shut-off valve(s) at the vehicle fuel tanks.**

3. Start the vehicle and allow the engine to idle and consume the fuel trapped in the fuel lines until the engine stalls. Turn the ignition switch to the off position.
4. Disconnect the negative cable from the battery.
5. Clean as much debris from the PFAV fittings and area as possible before removing from the vehicle. This will minimize the potential for contamination to enter the PFAV during the replacement.
6. Unplug the connectors at the PFAV.
7. Using a backing wrench to support the fuel fittings, remove the fuel line connections at the inlet and the outlet. Cap the open fittings! Fittings must be capped if PFAV is returned or will void any warranty.

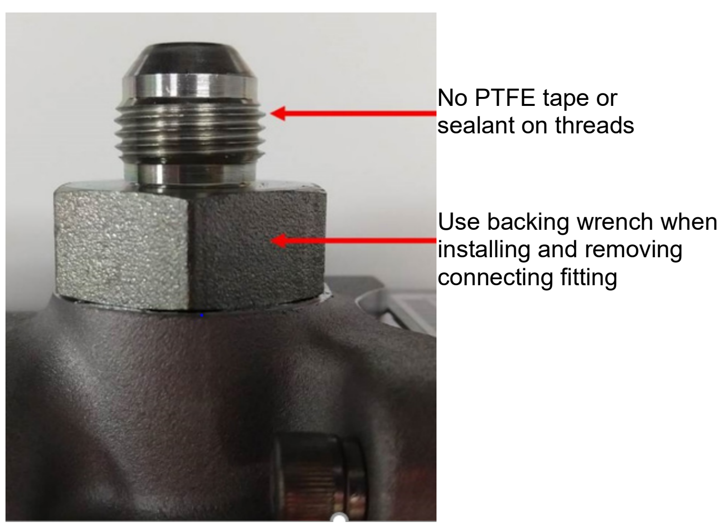


Figure 7-1. Fitting on PFAV Without Fuel Hose Installed

8. Remove the fasteners that attach the PFAV to the bracket.
9. Remove the PFAV from the vehicle.

10. Install the new PFAV on the mounting bracket on the vehicle, and tighten the fasteners to 12 N-m.
11. Before re-installing the fuel hoses, lubricate the threads, and the entire surface of the 37° face with hydraulic fluid or a light lubricant before installing.
12. Thread sealant is not required and is prohibited on the inlet fuel fitting.
13. To tighten fittings, see Figure 4-1.
14. Connect the harness leads to the PFAV.
15. Slowly open the tank shutoff valves.
16. Connect the negative cable to the battery terminal.
17. Turn the ignition switch to the on position but do not start the vehicle.
18. Check the PFAV for external fuel leaks using a bubble solution – repair any leaks before starting vehicle.
19. Start vehicle and double check for leaks before departing the service station.
20. After installation or replacement of a PFAV the system will take some time to learn closed loop correction factors for the specific valve in order to bring the air fuel ratio precisely to its target value. The engine must operate over all RPM and load ranges to completely fill in the closed loop correction table. During this learning time fuel flow may be slightly off during transient operation leading to reduced engine performance.

Chapter 8.
Troubleshooting

For general faults and the most up-to-date information, contact your Woodward customer service representative for an application specific service manual.

Some common PFAV specific error codes and the corrective actions are listed below.

Table 8-1. P1007: FVPS Voltage Low

DTC: P1007: FVPS Voltage Low
SPN/FMI: 1442/4
SFC: 971

Description	Enabling Conditions
FVPS Voltage Range Low Fault This fault indicates FVPS signal line has shorted to XDRG or ground, or FVPS signal line has opened.	Following Faults in Suspected or Test Failed or confirmed state disables this fault 'XDRP1RangeHigh', 'XDRP1RangeLow' 'XDRP2RangeHigh', 'XDRP2RangeLow' After clearing this code, a total of 0 key cycles must occur before this fault can be set again
Malfunction Criteria	
FVPS_Raw Voltage < 'FVPS_InputLoFltPos' [0.05] Volt	
Effect of Failure	**Service Guidance – First Check**
• Possible low power and poor running caused by torque derating. • Poor fuel control possible engine stall	• Check PFAV connector to find loose pin, damaged pin or corrosion. • Check open or short circuit on FVPS. • Check continuity between ECU pin to FVPS pin. • Check short circuit between ECU FVPS pin and XDRG.
Related Component/Subsystem	
Fuel Valve (PFAV)	

Table 8-2. P1008: FVPS Voltage High

DTC: P1008: FVPS Voltage High
SPN/FMI: 1442/3
SFC: 972

Description	Enabling Conditions
FVPS Voltage Range High Faults This fault indicates FVPS signal line has shorted to XDRP or power line.	Following Faults in Suspected or Test Failed or confirmed state disables this fault 'XDRP1RangeHigh', 'XDRP1RangeLow' 'XDRP2RangeHigh', 'XDRP2RangeLow' After clearing this code, a total of 0 key cycles must occur before this fault can be set again
Malfunction Criteria	
FVPS_Raw Voltage > 'FVPS_InputHiFltPos' [4.95] Volt	
Effect of Failure	**Service Guidance – First Check**
• Possible low power and poor running caused by torque derating. • Poor fuel control possible engine stall	• Check PFAV connector to find loose pin, damaged pin or corrosion. • Check open or short circuit on FVPS. • Check short circuit between ECU FVPS and XDRP.
Related Component/Subsystem	
Fuel Valve (PFAV)	

Table 8-3. P1009: FVPS Lower than Expected

DTC: P1009: FVPS Lower than Expected
SPN/FMI: 1442/1
SFC: 973

Description	Enabling Conditions
FVPS Low Adapt Min Faults The purpose of this diagnostic is to make sure the FVPS voltage is above a rational low threshold. This fault can be caused by FVPS sensor drifting or PFAV mechanism failure.	Following Faults in Suspected or Test Failed or confirmed state disables this fault 'XDRP1RangeHigh', 'XDRP1RangeLow' 'XDRP2RangeHigh', 'XDRP2RangeLow' After clearing this code, a total of 0 key cycles must occur before this fault can be set again
Malfunction Criteria	
FV_ClosedPcnt < 'FV_ClosedPcnt_Min' [-2] % limit	
Effect of Failure	**Service Guidance – First Check**
• Possible poor fuel (phi) control	• Check PFAV connector to find loose pin, damaged pin or corrosion. • Check FVPS voltage with minimum PFAV position to find FVPS drifting or mechanical failure.
Related Component/Subsystem	
Fuel Valve (PFAV)	

Table 8-4. P100A: FVPS Higher than Expected

DTC: P100A: FVPS Higher than Expected
SPN/FMI: 1442/0
SFC: 974

Description	**Enabling Conditions**
FVPS Low Adapt Max Faults The purpose of this diagnostic is to make sure the FVPS voltage is below a rational high threshold. This fault can be caused by FVPS sensor drifting or PFAV mechanism failure.	Following Faults in Suspected or Test Failed or confirmed state disables this fault 'XDRP1RangeHigh', 'XDRP1RangeLow' 'XDRP2RangeHigh', 'XDRP2RangeLow' After clearing this code, a total of 0 key cycles must occur before this fault can be set again
Malfunction Criteria	
FV_ClosedPcnt >'FV_ClosedPcnt_Max' [2] % limit	
Effect of Failure	**Service Guidance – First Check**
• Possible poor fuel (phi) control	• Check PFAV connector to find loose pin, damaged pin or corrosion. • Check FVPS voltage with minimum PFAV position to find FVPS drifting or mechanical failure.
Related Component/Subsystem	
Fuel Valve (PFAV)	

Table 8-5. P100B: FVPS Intermittent

DTC: P100B: FVPS Intermittent
SPN/FMI: 1442/2
SFC: 975

Description	**Enabling Conditions**
FVPS Intermittent Faults The purpose of this diagnostic is to monitor both Range High/Low FVPS faults suspected or Failed condition. The fault can be caused by FVPS short to ground/5V, or open FVPS conditions.	Key = ON After clearing this code, a total of 1 key cycles must occur before this fault can be set again
Malfunction Criteria	
FVPSRangeHigh Fault in suspected AND not in Test Failed OR FVPSRangeLow Fault in Suspected AND not in Test Failed	
Effect of Failure	**Service Guidance – First Check**
• Possible low power and poor running caused by torque derating. • Poor fuel control possible engine stall	• Check PFAV connector to find loose pin, damaged pin or corrosion. • Check the possibility of intermittent short circuit between ECU FVPS and XDRP. • Check the possibility of intermittent short circuit between ECU FVPS and XDRG. • Check the possibility of intermittent open circuit between ECU FVPS and XDRG. • Check FVPS mechanical failure.
Related Component/Subsystem	
Fuel Valve (PFAV)	

Table 8-6. P1004: Fuel Valve Stuck

DTC: P1004: Fuel Valve Stuck
SPN/FMI: 5447/7
SFC: 976

Description	Enabling Conditions
Fuel Valve Sticking Faults The purpose of this diagnostics is to monitor if the PFAV is sticking and not tracking the setpoint. The fault can be caused by mechanical PFAV failures.	FV_ShutdownState == 0 AND FV Hbridge Enabled AND FV Open Loop control not active AND FV Lockoff Open DC override not active AND FV_Dpress < 'FV_Sticking_MaxDPress' [300] kPa AND abs(FV_DriveCurrent) > 'FV_Sticking_MinCurrent' [100] mA After clearing this code, a total of 1 key cycles must occur before this fault can be set again

Malfunction Criteria
(Position Error > 'FV_StickingThresh' [10] AND NO FV Control Error sign Change) for 'C_FV_Sticking_ErrorTime' [1] Second within 'C_FV_Sticking_MaxErrorTime' [1] Second

Effect of Failure	Service Guidance – First Check
• Possible low power and poor running caused by torque derating. • Poor fuel control possible engine stall	• Check too much friction or sticking on fuel valve to find mechanical failure. Use plastic/non-metallic tool to push valve inward. • Check for contamination and/or scoring on inner sleeve.

Related Component/Subsystem
Fuel Valve (PFAV)

Table 8-7. P1005: Fuel Valve Spring Test Fault

DTC: P1005: Fuel Valve Spring Test Fault
SPN/FMI: 5447/2
SFC: 977

Description	**Enabling Conditions**
Fuel Valve Spring Test Faults The purpose of this diagnostic is to monitor if the internal spring in the PFAV closes the valve when no h-bridge current is present. This fault caused by mechanical PFAV failures.	FV_ShutdownState == 4 (Complete) After clearing this code, a total of 1 key cycles must occur before this fault can be set again
Malfunction Criteria	
'FV_SpringTestTime' > 'FV_SpringTestTimerThresh' [2] Second AND NGP - Baro <= 'FV_LockOffStuckThresh' (20) kPa	
Effect of Failure	**Service Guidance – First Check**
Possible poor fuel (phi) control	Check retention capability for closed position without power to find mechanical failure. Use plastic/non-metallic tool to push valve inward.
Related Component/Subsystem	
Fuel Valve (PFAV)	

Table 8-8. P1006: Fuel Valve Lockoff Stuck Open

DTC: P1006: Fuel Valve Lockoff Stuck Open
SPN/FMI: 5447/10
SFC: 978

Description	**Enabling Conditions**
Fuel Valve Lockoff Stuck Open Faults The purpose of this diagnostics is to monitor if integrated PFAV lockoff valve is not closing, which could result in possible leakage after shutdown. The fault can be caused by contaminated lockoff valve, failed lockoff, or NGP sensor drifting high.	FV Spring Test Complete AND FV_ShutdownState == 4 After clearing this code, a total of 1 key cycles must occur before this fault can be set again
Malfunction Criteria	
NGP - Baro >= 'FV_LockOffStuckThresh' (20) kPa	
Effect of Failure	**Service Guidance – First Check**
Possible fuel leakage after shutdown	• Check for short to ground on lockoff circuit. • Verify NGP sensor reads barometric pressure with no gas supply.
Related Component/Subsystem	
Fuel Valve (PFAV)	

Table 8-9. P0001: Fuel Valve Open Fault

DTC: P0001: Fuel Valve Open Fault
SPN/FMI: 5447/6
SFC: 979

Description	Enabling Conditions
Fuel Valve Open Faults The purpose of this diagnostic is to monitor if the H-Bridge PFAV circuit is open, which would result in the loss of PFAV control. This fault can be caused by PFAV failures or overdriven PFAVs.	FV_DriverDutyCycle > 'FV_OC_MIN' [10] % AND Key = ON AND FV Hbridge Enabled After clearing this code, a total of 1 key cycles must occur before this fault can be set again
Malfunction Criteria	
'FV_DriveCurrent' < 'FV_I_MIN' [100] mA for 'C_FV_Open_ErrorTime' [1] Second time within 'C_FV_Open_MaxErrorTime' [1] Seconds period	
Effect of Failure	**Service Guidance – First Check**
• Possible low power and poor running caused by torque derating. • Poor fuel control possible engine stall	• Check PFAV connector to find loose pin, damaged pin or corrosion. • Check open circuit on Fuel Valve actuator. • Check continuity between ECU pin to Fuel Valve hbridge pins.
Related Component/Subsystem	
Fuel Valve (PFAV)	

Table 8-10. P0003: Fuel Valve H Bridge Fault

DTC: P0003: Fuel Valve H Bridge Fault
SPN/FMI: 5447/5
SFC: 981

Description	Enabling Conditions
Fuel Valve Driver H-Bridge Faults The purpose of this diagnostic is to monitor the PFAV H-Bridge driver chip condition. The H-Bridge chip senses overtemp condition due to high current outputs. The fault can be caused by PFAV failures or overdriven PFAVs.	FV Hbridge Enabled After clearing this code, a total of 1 key cycles must occur before this fault can be set again
Malfunction Criteria	
'FV_HBridgeFaultState' == 1	
Effect of Failure	**Service Guidance – First Check**
• Possible low power and poor running caused by torque derating. • Poor fuel control possible engine stall	• Check FVPS voltage tracking with fuel valve position to find mechanical failure. Use plastic/non-metallic tool to push valve inward. • Check too much friction or sticking on throttle valve to find mechanical failure.
Related Component/Subsystem	
Fuel Valve (PFAV)	

Table 8-11. P1090: Fuel Valve Leak Fault

DTC: P1090: Fuel Valve Leak Fault
SPN/FMI: 1240/7
SFC: 982

Description	Enabling Conditions
NGP is leaking After engine shutdown this diagnosis monitors the NGP to determine if a possible leak is occurring in the fuel system. This fault indicates leakage either leaking tank pressure to fuel rail or leaking rail pressure to outside.	Test enables if FV_DPress > 'FV_LeakEnable_DPress' [50] kPa at KeyOff, Fault enables with rising edge of LeakTestComplete which occurs after 'FV_LeakTestPeriod' [4] sec completes After clearing this code, a total of 1 key cycles must occur before this fault can be set again
Malfunction Criteria	
FV_LeakTestInitNGP - NGP >= 'FV_LoLeakThresh' [20] kPa OR NGP - FV_LeakTestInitNGP >= 'FV_HiLeakThresh' [20] kPa OR NGP <= Baro + 'FV_BaroThresh' [20] kPa	
Effect of Failure	**Service Guidance – First Check**
Possible low power or poor running or shutdown engine	• Check fuel line faults, loose pipe connection or damage on pipe fitting or fuel pipe or fuel device, between tank lockoff, heat exchanger, and PFAV. • Check for gas leak from inlet to outlet when HP Lock-off valve is closed. • If leakage is through PFAV, check for contamination on inner sleeve and between regulator/PFAV • Verify NGP sensor reads barometric pressure with no gas supply.
Related Component/Subsystem	
Fuel Valve (PFAV)	

Chapter 9.
Product Support and Service Options

Product Support Options

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

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

OEM 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 current list of Woodward Business Partners is available at:
https://www.woodward.com/en/support/industrial/service-and-spare-parts/find-a-local-partner

Product Service Options

The following factory options for servicing Woodward products are available through your local Full-Service Distributor or the OEM or Packager of the equipment system, based on the standard Woodward Product and Service Warranty (Woodward North American Terms and Conditions of Sale 5-09-0690) that is in effect at the time the product is originally shipped from Woodward or a service is performed:

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

Replacement/Exchange: Replacement/Exchange is a premium program designed for the user who is in need of immediate service. It allows you to request and receive a like-new replacement unit in minimum time (usually within 24 hours of the request), providing a suitable unit is available at the time of the request, thereby minimizing costly downtime. This is a flat-rate program and includes the full standard Woodward product warranty (Woodward North American Terms and Conditions of Sale 5-09-0690).

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

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

Flat Rate Repair: Flat Rate Repair is available for the majority of standard products in the field. This program offers you repair service for your products with the advantage of knowing in advance what the cost will be. All repair work carries the standard Woodward service warranty (Woodward North American Terms and Conditions of Sale 5-09-0690) 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 North American Terms and Conditions of Sale 5-09-0690). 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 authorization number
- Name and location where the control is installed
- Name and phone number of contact person
- Complete Woodward part number(s) and serial number(s)
- Description of the problem
- Instructions describing the desired type of repair

Packing a Control

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

NOTICE

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

Replacement Parts

When ordering replacement parts for controls, include the following information:

- The part number(s) (XXXX-XXXX) that is on the enclosure nameplate
- The unit serial number, which is also on the nameplate

Engineering Services

Woodward offers various Engineering Services for our products. For these services, you can contact us by telephone, by email, or through the Woodward website.

- Technical Support
- Product Training
- Field Service

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

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

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

For information on these services, please contact one of the Full-Service Distributors listed at **https://www.woodward.com/en/support/industrial/service-and-spare-parts/find-a-local-partner**

Contacting Woodward's Support Organization

For the name of your nearest Woodward Full-Service Distributor or service facility, please consult our worldwide directory at **https://www.woodward.com/support**, which also contains the most current product support and contact information.

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

Products Used in Electrical Power Systems

Facility	Phone Number
Brazil	+55 (19) 3708 4800
China	+86 (512) 8818 5515
Germany	+49 (711) 78954-510
India	+91 (124) 4399500
Japan	+81 (43) 213-2191
Korea	+82 (51) 636-7080
Poland	+48 (12) 295 13 00
United States	+1 (970) 482-5811

Products Used in Engine Systems

Facility	Phone Number
Brazil	+55 (19) 3708 4800
China	+86 (512) 8818 5515
Germany	+49 (711) 78954-510
India	+91 (124) 4399500
Japan	+81 (43) 213-2191
Korea	+82 (51) 636-7080
The Netherlands	+31 (23) 5661111
United States	+1 (970) 482-5811

Products Used in Industrial Turbomachinery Systems

Facility	Phone Number
Brazil	+55 (19) 3708 4800
China	+86 (512) 8818 5515
India	+91 (124) 4399500
Japan	+81 (43) 213-2191
Korea	+82 (51) 636-7080
The Netherlands	+31 (23) 5661111
Poland	+48 (12) 295 13 00
United States	+1 (970) 482-5811

Technical Assistance

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

General

Your Name ______________________

Site Location ______________________

Phone Number ______________________

Fax Number ______________________

Prime Mover Information

Manufacturer ______________________

Engine Model Number ______________________

Number of Cylinders ______________________

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

Power Output Rating ______________________

Application (power generation, marine, etc.) ______________________

Control/Governor Information

Control/Governor #1

Woodward Part Number & Rev. Letter ______________________

Control Description or Governor Type ______________________

Serial Number ______________________

Control/Governor #2

Woodward Part Number & Rev. Letter ______________________

Control Description or Governor Type ______________________

Serial Number ______________________

Control/Governor #3

Woodward Part Number & Rev. Letter ______________________

Control Description or Governor Type ______________________

Serial Number ______________________

Symptoms

Description ______________________

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

Revision History

Changes in Revision C—
- Revised Table 3-1
- Added note to Table 5-7

Changes in Revision B—
- Added Do Not Backflush warning to Warnings and Notices section
- Updated Regulatory Compliance section
- Revised Procedures in Setting the PFAV Pressure section (Chapter 2)
- Revised PFAV Options section (Chapter 3)
- Added methane detection warnings (Chapter 4)
- Revised Vibration section (Chapter 4)
- Added Temperature in Operation heading (Chapter 4)
- Differentiated between absolute pressure (bar) and gauge pressure (barg) in appropriate references (Chapter 4)
- Revised Tables 5-1 and 5-2 (Chapter 5)
- Added recommended wire insulation ranges to Tables 6-1b, 6-2b, and 6-3 (Chapter 6)
- Added Do Not Backflush warning to Maintenance section (Chapter 7)
- Replaced Figure 7-1 and updated procedures in PFAV Replacement section (Chapter 7)

Changes in Revision A—
- Added warnings regarding installation of methane detection system (Chapter 4)

We appreciate your comments about the content of our publications.

Send comments to: industrial.support@woodward.com

Please reference publication 35055.

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