WOODWARD

Product Manual 26841
(Revision NEW, 3/2016)
Original Instructions
RESTRICTED—LIMITED DISTRIBUTION

Side-Feed Gaseous Fuel Metering Valve (SFG FMV)

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. To verify that you have the latest revision, check manual *26455*, *Customer Publication Cross Reference and Revision Status & Distribution Restrictions*, on the *publications page* of the Woodward website:

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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. Be sure to check manual *26455*, *Customer Publication Cross Reference and Revision Status & Distribution Restrictions*, to verify whether this translation is up to date. Out-of-date translations are marked with ⚠. Always compare with the original for technical specifications and for proper and safe installation and operation procedures.

Revisions—Changes in this publication since the last revision are indicated by a black line alongside the text.

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Important Definitions

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

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

⚠WARNING

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.

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. 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.

Regulatory Compliance

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

UNECE: Type approved to UNECE Regulation 110: E4 110R-010392 C

This product is certified as a component for use in other equipment. The final combination is subject to acceptance by the authority having jurisdiction or local inspection.

Chapter 1.
General Information

The Side Feed Gaseous (SFG) injector Fuel Metering Valve (FMV) is an assembly of fittings, injectors, and a sensor that meter mass flow of natural gas fuel to engines. Figure 1-1 shows the key features of the SFG FMV. This product is designed to function in Compressed Natural Gas (CNG) and Liquefied Natural Gas (LNG) vehicle fuel systems. For operation with CNG vehicles, the pressure regulator upstream of the SFG FMV maintains a constant delivery pressure to the FMV; typically 7-10 bar absolute. For operation with LNG systems, the fuel is first heated to vapor phase and a pressure of approximately 6 to 9 bar absolute.

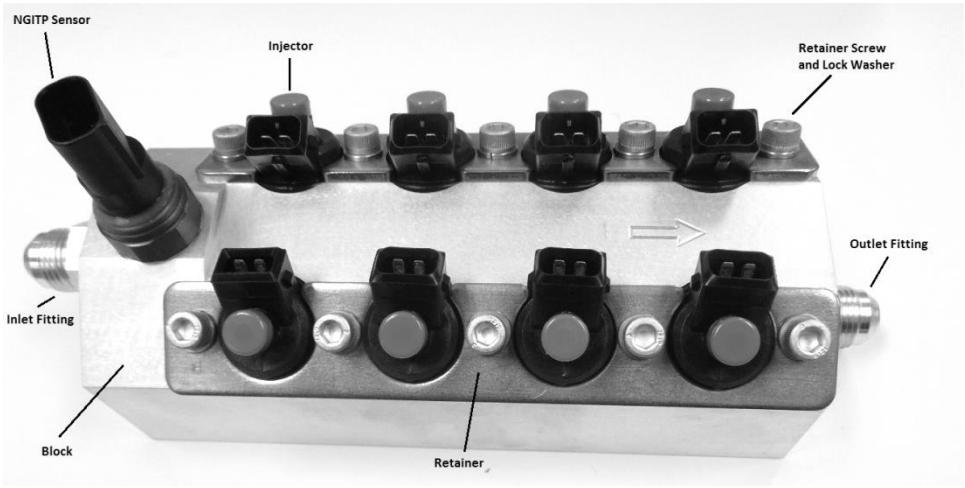


Figure 1-1. SFG FMV Features

WARNING

The SFG FMV 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.

The SFG FMV operates in conjunction with an engine control module (ECM). The ECM monitors the required fuel delivery to the engine during operation and, by determining fuel density from the temperature and pressure values measured from the FMV sensor, delivers the appropriate pulse width to the SFG injectors. The SFG injectors provide a broad flow control range, allowing precise control of relatively low fuel mass to facilitate engine idle or relatively high flow rate to allow operation at rated engine power. Figure 1-2 is a block diagram illustrating the basic functionality of the SFG FMV with the ECM.

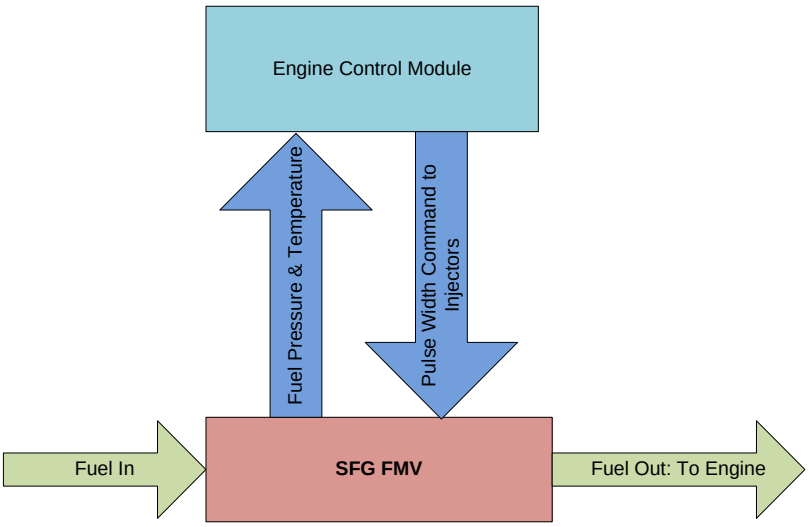


Figure 1-2. SFG FMV Operational Diagram

Table 1-1 below lists the Woodward part numbers for the key subcomponents of the SFG FMV. Various FMV configurations and part numbers are available—contact Woodward for details.

Table 1-1. SFG FMV Part Numbers

FMV Injector Quantity	Woodward Part Number	Outline Drawing
3, 4, 5, 6, 8, 10	various	various

FMV Subcomponent	Woodward Part Number	Outline Drawing
SFG Injector	1309-6234	1309-6234
NGITP Sensor	1680-1067	1680-1067

Chapter 2.
Operation

Flow Path

The SFG FMV admits fuel through the inlet fitting and distributes the flow down a single internal passage to the SFG injector glands. The fuel is metered through the injectors (when energized), then the flow combines to a single outlet path through the outlet fitting.

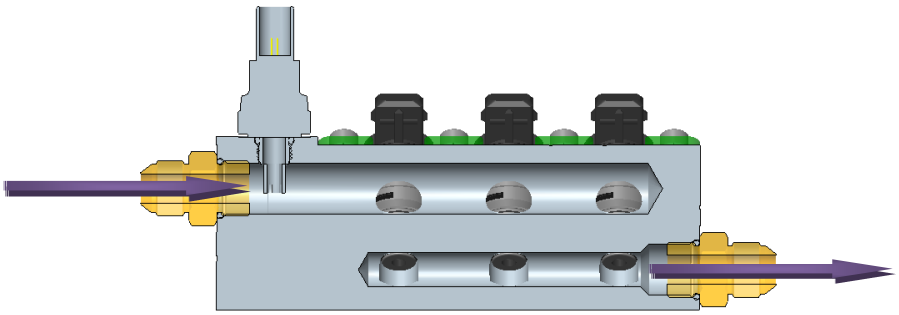


Figure 2-1. FMV Flow Path Diagram

Fuel Metering: Sonic Flow

The SFG FMV design is optimized to operate with sonic flow through the metering area (or “throat”) of the injectors. Sub-sonic operation is possible if the control system algorithm can provide the required compensation. Sonic flow implies that the velocity of the fuel through the metering throat of the injector is equal to the speed of sound, whereas sub-sonic flow implies the velocity is slower than the speed of sound. Sonic fuel metering is not dependent on the outlet pressure at the injector, and thus provides a benefit that downstream pressure compensation is not required, which allows the FMV to function accurately without a downstream pressure sensor.

In order to ensure that the SFG FMV operates in the sonic regime, the delivery pressure to the injectors as well as the outlet restriction downstream of the injectors must be managed in the fuel system. Specifically, the ratio of outlet pressure to inlet pressure must be below the critical pressure ratio of the fuel. The critical pressure ratio is the transition point between sonic and sub-sonic flow for a given gas. The critical pressure ratio is a function of the specific fuel composition, but for natural gas is approximately at the point where outlet pressure is 54% of the inlet pressure. In order to ensure sonic flow, the outlet pressure must be maintained below 54% of the inlet pressure (see Chapter 3 for tips to ensure sonic flow is maintained in the application).

SFG Injector Operation

The SFG injector is a solenoid operated, fixed-lift valve. When sufficient voltage is applied across the terminals of the injector, electrical current flows through an internal coil wire winding that creates a magnetic field. The magnetic force pulls open the armature of the injector, which then allows fuel to flow through the throat. When electrical voltage is removed, the spring inside the injector pushes the armature in the closed position, and a rubber seal prevents the fuel from leaking past the injector.

The injector is designed to use a peak-and-hold electrical controller (usually built into the Engine Control Module) for 24 V systems. A peak-and-hold controller applies a regulated signal to the injector to provide sufficient electrical current to open the injector, then while the injector is flowing in the open position, the current is reduced to prevent overheating and damage to the coil.

The SFG should use the following peak and hold control settings to ensure durability and performance:

Peak Current: 3.0 A
Hold Current: 0.75 to 1.0 A

For further description of the SFG Injector, see Woodward Product Specification 03428.

NGITP Sensor Operation

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.

For further details on the NGITP pressure and temperature characteristic curves and specifications, see Woodward Product Specification 03403.

Chapter 3. Installation

Introduction

Proper installation of the SFG FMV will allow the product to perform as designed for long life on the vehicle. This chapter will cover some important information regarding proper installation of the SFG FMV.

Typical System Installation Diagram

Figure 3-1 illustrates the typical CNG industrial vehicle fuel system layout, highlighting the location of the SFG FMV in relation to other components.

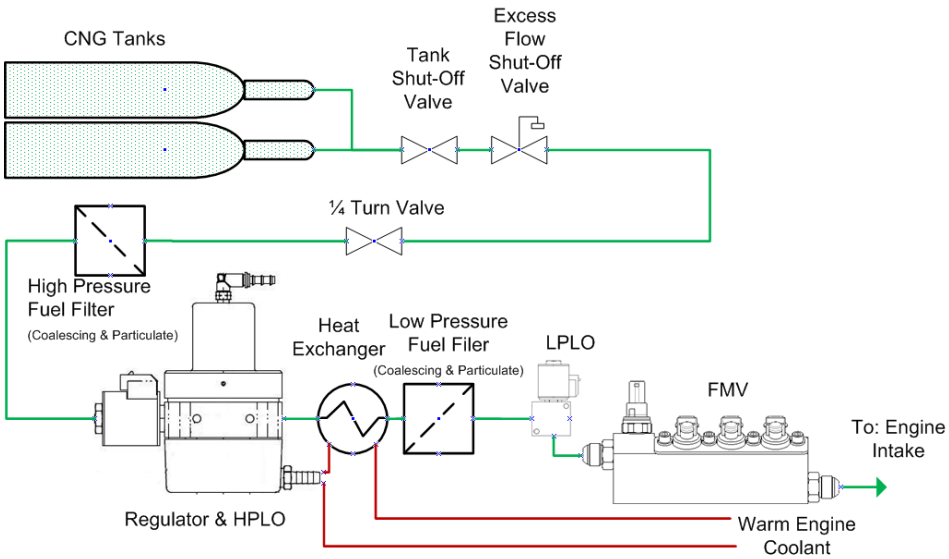


Figure 3-1. Typical Fuel System Configuration (CNG)

Figure 3-2 illustrates the typical LNG industrial vehicle fuel system layout, highlighting the location of the SFG FMV in relation to other components. Not all details of the LNG tank & fuel conditioning are shown.

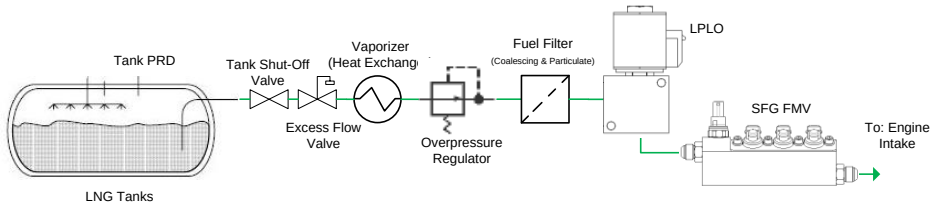


Figure 3-2. Typical Fuel System Configuration (LNG)

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 FMV should contain a PRD with a set point of 13.8 bar g, 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 bar g. Woodward offers several pressure regulator configurations with integrated PRDs designed to work with the SFG FMV.

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 (FMV)

Flow Direction

An arrow on the FMV block indicates the flow direction through the FMV. The NGITP sensor is closest to the inlet port. Figures 3-1 and 3-2 shows the correct flow direction.

Mounting Location

The SFG FMV should be mounted in a location on the vehicle chassis or engine that protects the unit from severe load or impact damage (such as road debris) during normal and severe vehicle operation. Mounting on-engine is permitted provided the in-use vibration spectrum does not exceed the standard provided in the Specifications section of this manual.

Mounting Orientation

The SFG FMV is to be mounted with the flow path within ± 90° of horizontal, as illustrated in Figure 3-3.

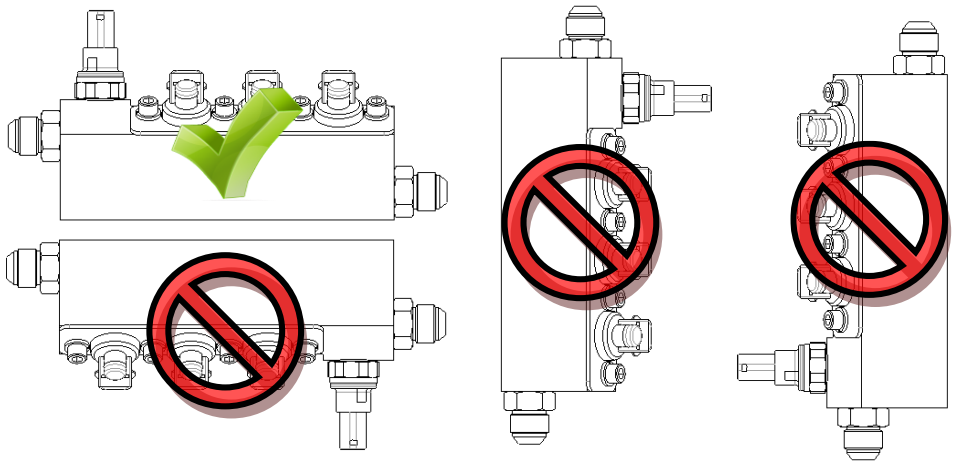


Figure 3-3. Mounting Orientations: Allowed and Not Allowed

The connector of the NGITP sensor should point straight upwards such that side-to-side rotation of the FMV is minimized (no greater than ± 10°)

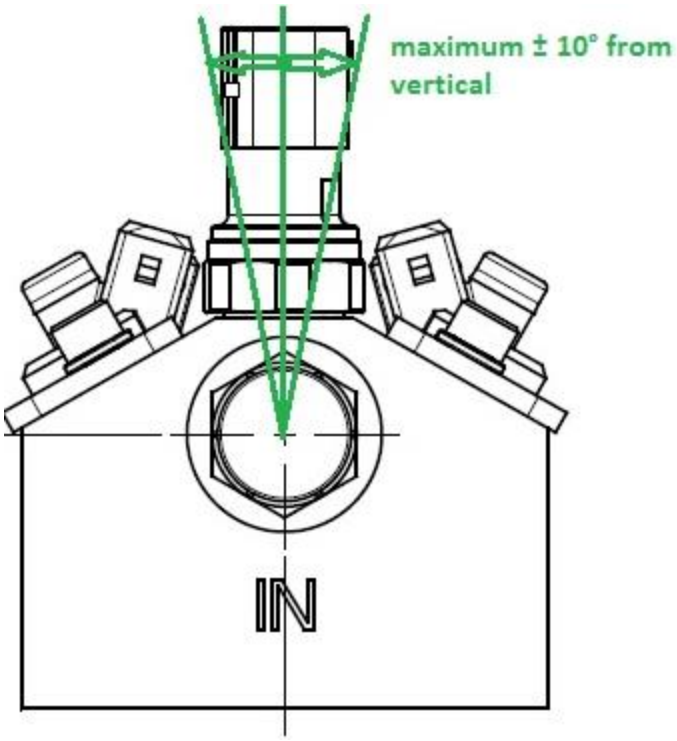


Figure 3-4. Mounting Orientations: NGITP Connector Should be Vertical

Mounting Fasteners

Mounting accommodation is provided by four, M8 x 1.25 blind-threaded holes, 18 mm deep. Mounting fastener pattern dimensions are shown in Figure 3-5. For the larger FMV sizes, the block length increases downstream relative to the mounting holes (see specific outline drawing for specific product dimensions). The fasteners should feature a locking mechanism, such as a serrated washer or thread locking compound. The recommended fastener torque value is 20 N·m with grade 9.8 or better alloy steel screw with at least 16 mm thread engagement; install torque must not exceed 27 N·m.

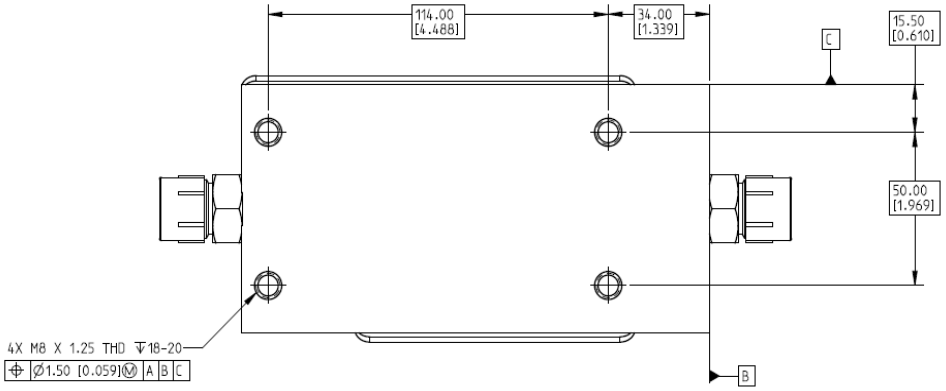


Figure 3-5. Mounting Fastener Pattern

Accelerometer Mounting Location

The vibration profile of the FMV installation environment must be checked in the application to ensure the FMV will provide long life. This is achieved by fixing an accelerometer directly to the FMV block in the area shown in the figure below (either side of the FMV block is acceptable), and recording Power Spectral Density data as the vehicle is operated across a typical driving cycle.

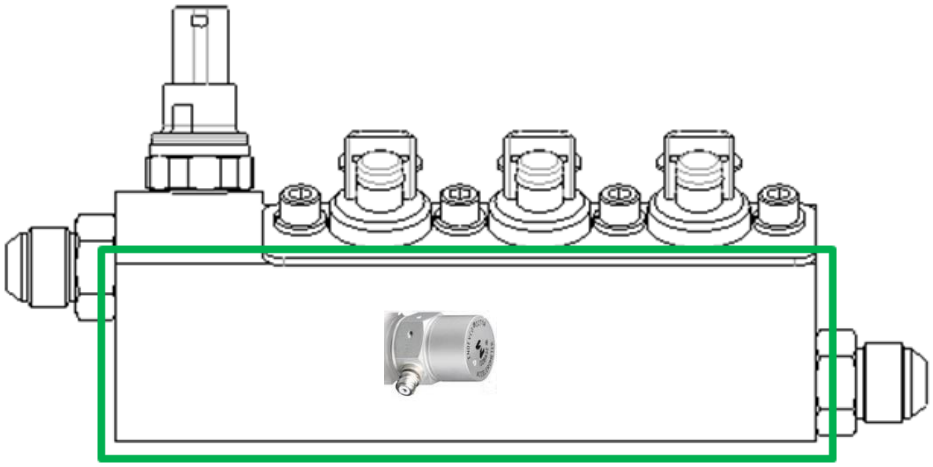


Figure 3-6. Accelerometer Mounting Area

Fuel Line and Fitting Requirements

Inlet Fuel Line

The SFG FMV 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.
  - FMV 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 FMV can be much colder than the ambient temperature. Likewise, the FMV 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 FMV 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 bar gauge 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 non-Woodward pressure 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 bar g secondary tank relief, for a burst strength requirement of 69 bar g).

WARNING

Inlet fuel line (downstream of the regulator and upstream of the SFG FMV) and all upstream fuel system components should have a burst pressure rating as follows:

- **114 bar gauge 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 so as to induce no more than 5 N·m of bending moment at the inlet fuel fitting.
- If the inlet fuel line connects between a chassis-mount component and the FMV 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 SFG FMV. If excessive pressure drop (called “droop”) is introduced, the engine maximum available power may be limited and/or the loss of sonic flow may occur. The appropriate fuel line size will vary depending on the application, but Figure 3-7 can be used as a general guideline to select an acceptable fuel line diameter.

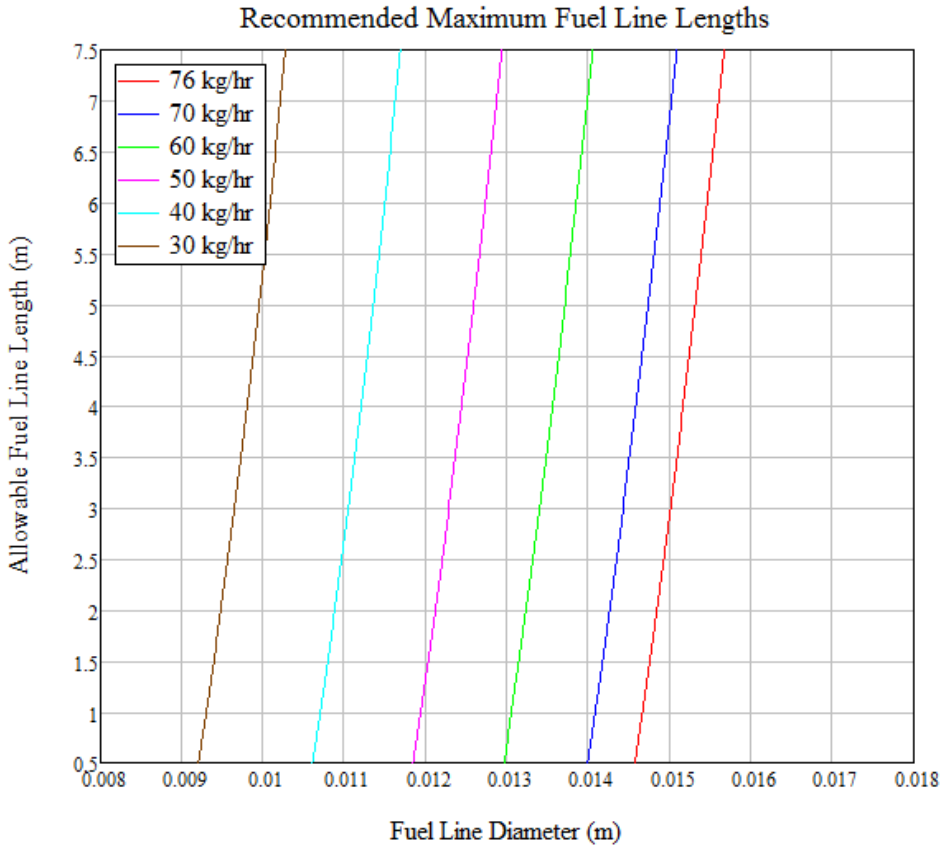


Figure 3-7. Recommended Minimum Fuel Plumbing Diameter to FMV

Example of using Figure 3-7: *A vehicle will consume 50 kg/hr of fuel at maximum power. The FMV inlet fuel line is approximately 2 meters long. Reading the chart, a 12 mm fuel line ID is recommended for this application.*

The following tips should be also followed to minimize droop and ensure sonic flow:

- Minimize fittings, elbows, and line length in the fuel system (also applies to the FMV 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, while measuring inlet pressure and outlet pressure at the FMV. Make changes as required to the fuel system to ensure outlet pressure is always less than 54% of the inlet pressure.

Inlet Fuel Fitting
The SFG FMV is provided with a JIC 37° -8 AN inlet fitting installed in the FMV block. This fitting minimizes pressure loss and excessive turbulence and provides a leak-tight seal when used with an appropriate 37° fuel hose connection with proper installation procedure. Lubricate the threads, O-ring (if equipped), and the entire surface of the 37° face with hydraulic fluid or a light lubricant before installing. To tighten the fuel line to the inlet fitting with the proper sealing force, use 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 below:

- For Tube-Connection: 1.5 hex flats
- For Swivel-Nut Hose Connection: 1.0 hex flats

Always use a backing-wrench to support the inlet fuel fitting when the connecting fuel line is being tightened.

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

Discharge Line (to Mixer at Engine Intake)
The SFG FMV 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 10 mm diameter to avoid excessive back-pressure at the injectors. The length of this line should be minimized by mounting the FMV as close to the mixer as possible, while also avoiding the use of 90° elbows and other restrictions as much as possible. This requirement will help to minimize occurrence of sub-sonic flow through the injector and potential loss of engine power at high-load conditions.
- The line should be supported so as to induce no more than 5 N·m of bending moment at the outlet fuel fitting.

Outlet Fuel Fitting
The SFG FMV is provided with a JIC 37° -8 AN outlet fitting installed in the FMV block. This fitting minimizes pressure loss and excessive turbulence and provides a leak-tight seal when used with an appropriate 37° fuel hose connection with proper installation procedure. Lubricate the threads, O-ring (if equipped), and the entire surface of the 37° face with hydraulic fluid or a light lubricant before installing. To tighten the fuel line to the outlet fitting with the proper sealing force, use 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 below:

- For Tube-Connection: 1.5 hex flats
- For Swivel-Nut Hose Connection: 1.0 hex flats

Always use a backing-wrench to support the outlet fuel fitting when the connecting fuel line is being tightened.

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

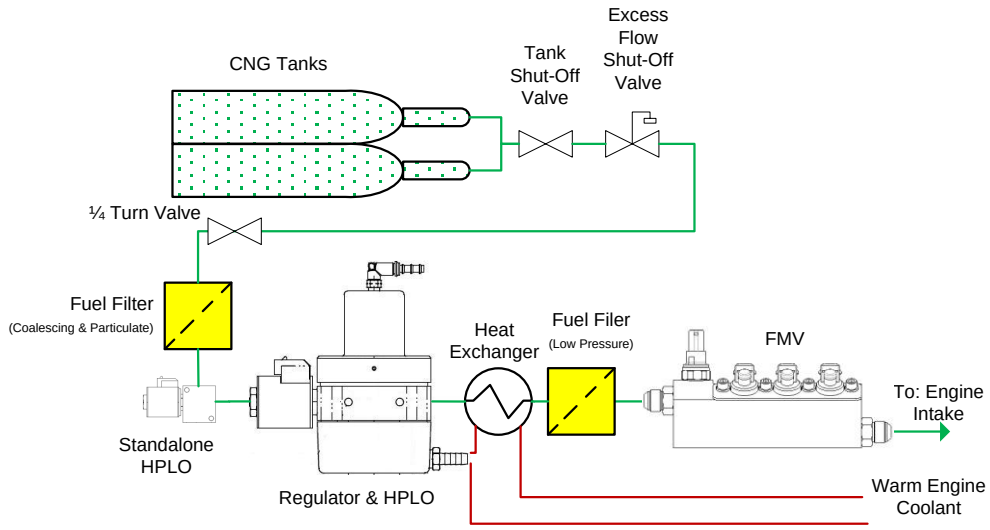
Fuel Filter Requirements

The SFG FMV requires fuel filtration, rated at 1 µm or smaller in the removal of particulates and condensates.

- 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 for the injectors.
- LNG systems: only a low pressure filter is required.

Figure 3-8 below highlights the proper location of high and low pressure fuel filters in the typical CNG and LNG fuel systems.

a)



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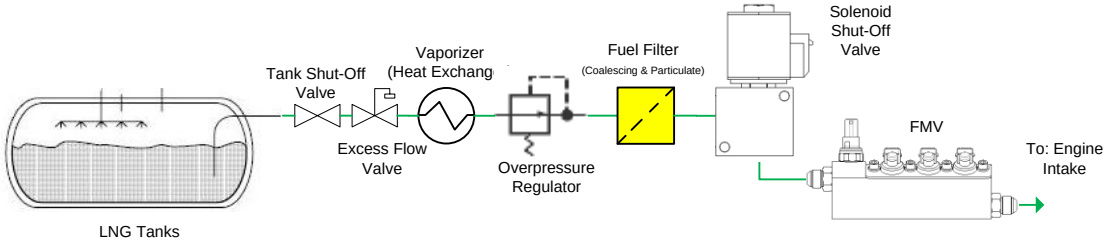


Figure 3-8. Fuel Filter Locations (a, CNG; b, LNG)

Woodward recommends Parker filters as they are designed specifically for natural gas vehicles and provide the proper level of filtration to ensure long life for the SFG FMV. Parker offers filter housings and elements in several models. Filter elements are classified as either Grade 10 or Grade 6. The details of each element performance are given below in Table 3-1.

Table 3-1. Parker Filter Element Specifications

Parker Grade Designation	Coalescing Efficiency 0.3 to 0.6 µm	Maximum Oil Carryover[1] (ppm W/W)	Micron Rating
Grade 6	99.97%	0.008	0.01
Grade 10	95%	0.85	1

[1] Tested per ISO 12500-1 at 40 ppm inlet.

The Grade 6 element offers the most protection, but also induces more pressure drop than the Grade 10 element. The Grade 6 element is recommended for the best filtration for applications that can allow the pressure drop, but the Grade 10 meets the minimum requirements. Table 3-2 provide general guidelines for recommended Parker filter housings and elements based on fuel type and FMV selection:

Table 3-2. Recommended Parker Filter Housings and Elements

CNG Fuel: 6 or Fewer Injectors					
Filter Location	**Protection**	**Pressure Drop**	**Housing**	**Element**	**Comments**
High Pressure	Best	Lowest	FFC113	Grade 6	High capacity and best filtration
	Good	Moderate	FFC112	Grade 10	More pressure drop at low tank pressure
Low Pressure	Best	Low	2 X FFC110L	Grade 6	Parallel flow configuration
	Good	Lowest	FFC110L	Grade 10	Single filter option
CNG Fuel: 8 or more SFG Injectors					
Filter Location	**Protection**	**Pressure Drop**	**Housing**	**Element**	**Comments**
High Pressure	Good	Lowest	FFC113	Grade 10	High capacity
	Good	Moderate	2 x FFC112	Grade 10	More pressure drop at low tank pressure
Low Pressure	Good	Lowest	2 x FFC110L	Grade 10	Parallel flow configuration
	Good	Moderate	FFC110L	Grade 10	May need 2nd filter, application specific
LNG Fuel: Up to 6 Injectors					
Filter Location	**Protection**	**Pressure Drop**	**Housing**	**Element**	**Comments**
Low Pressure	Best	Low	2 x FFC110L	Grade 06	Best filtration, parallel flow
	Good	Lowest	FFC110L	Grade 10	Lowest cost and pressure drop
LNG Fuel: 8 or more Injectors					
Filter Location	**Protection**	**Pressure Drop**	**Housing**	**Element**	**Comments**
Low Pressure	Good	Lowest	2 X FFC110L	Grade 10	Parallel flow configuration
	Good	Moderate	FFC110L	Grade 10	May need 2nd filter, application specific

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.

For more information regarding Parker fuel filters, visit www.parker.com.

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.

The SFG injectors are assembled in a state-of-the-art clean-room to prevent foreign materials hindering the performance of the fuel system, but the benefit of this practice will be negated if poor fuel system assembly practices introduce contamination.

WARNING

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

Electrical Connections & Wiring Requirements

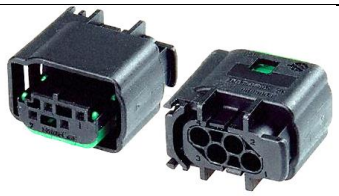
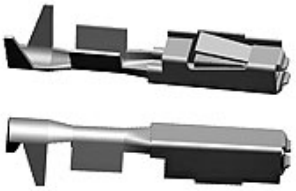
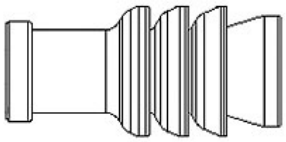
Injector Connection

The SFG injector utilizes an industry standard connector that has been used on gasoline fuel injectors for decades. There are various manufacturers that offer mating connectors for the SFG connector that allow sufficient clearance with the FMV block, including FCI Connectors (240PC02S6001), Tyco (85202-1), AMP (12129140), and Packard (15369127). Other part numbers may be substituted as functional equivalents; however these guidelines should be followed when selecting the injector connector:

- Mating terminals must be tin-plated. Gold-plated connectors may cause galvanic corrosion of the connection interface and ultimately prevent the injector from operating.
- Weather seals must be used between the connector bodies, and at the cable ports.

NGITP Sensor Connection

The NGITP sensor body connects with the AMP 4-pin Micro Quadlok System. Part numbers for the connector components are given in the table below.

Component	OEM Part Number	Number Required	Picture
Connector Body	1-967640-1	1	
Terminal (must be Tin)	962885-1	4	
Cable Seal	967067-1	4	

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 SFG FMV.

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 orientation of the injectors in the FMV block was chosen to minimize strain at the harness connector, but along the remaining length of the harness bend radii should be as large as practicable. The harness length should not exceed 10 m between the FMV and control module. Refer to SAE J1292 for other vehicle wiring guidelines.

Fuse Protection

Figure 3-9 below shows a generic wiring diagram for a vehicle using an 8-injector SFG FMV. In this diagram, “F1” is the fuse that supplies electrical power to the injectors.

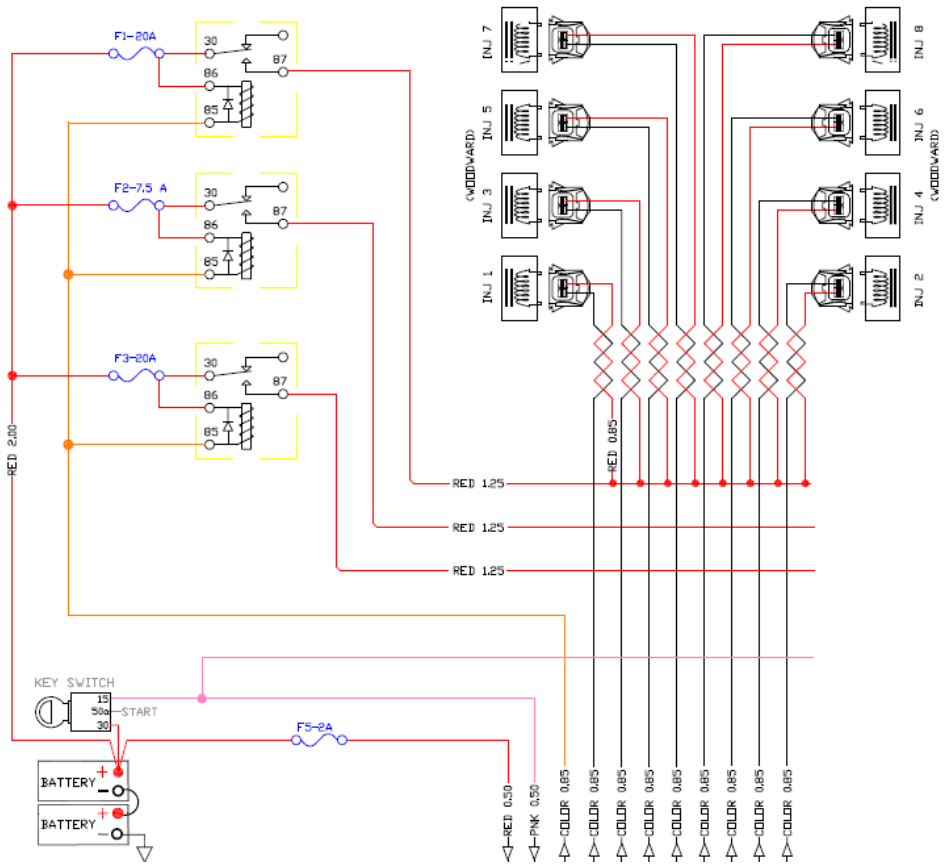


Figure 3-9. SFG FMV Wiring Schematic (Typical)

The current rating for this fuse will depend upon the number of injectors as shown in Table 3-3 below. Fuse analysis is based on SAE J1284. If other electrical loads share the fuse, this must be taken into account when sizing the fuse for the vehicle.

Table 3-3. SFG FMV Fuse Sizing for Injectors

Injector Count	Fuse Size for Injectors Alone
3	7.5 A
4	7.5 A
5	10 A
6	15 A
8	15 A
10	20 A

Chapter 4. Maintenance

Introduction

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.

IMPORTANT

Always use a backing wrench to support the fittings in the SFG FMV when loosening or tightening the fuel line connections.

IMPORTANT

This SFG FMV should be replaced or repaired any time there is any external leakage.

The SFG FMV 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 injectors for use in markets where fuel contamination cannot be avoided.

Fuel Fittings

Anytime a fuel fitting is removed from the SFG FMV block, the fitting O-rings should be lightly lubricated with light oil or synthetic grease before reinstallation. Replace the O-rings if they are damaged.

Coalescing Fuel Filter Maintenance

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).

Injector Cleaning

Many CNG fueling distribution systems utilize compressors that transfer some quantity of crankcase oil into the fuel stream. This oil, if not 100% removed before vehicle filling, will propagate through the fuel system and may gradually foul the SFG injectors. The fouling can reduce the flow rate of the injector and eventually a vehicle fault code or loss of power will result. It is a simple matter of cleaning the injectors with an approved solution to restore the SFG injectors to like-new performance. The maintenance interval for cleaning will depend upon the level of fuel contamination from the filling station, as well as quality of the coalescing filter and maintenance routine.

The following solutions are NOT allowed as cleaning solutions for the SFG:

- Any solution containing methanol
- Any acidic solution

⚠WARNING

Use of cleaning solution that is NOT allowed with the SFG may result in product failure, including damage to the internal seals which may result in permanent fuel leakage through the injector.

The following solutions are the only approved cleaning solutions for the SFG:

- n-Heptane
- Stoddard solvent

Use of a fluid besides those approved may damage the injector and will void the warranty.

IMPORTANT

When using an approved cleaning solution, do not expose the injectors to prolonged soak periods in the solutions. The cleaning process should briefly flush the injectors with an approved solution for a few minutes, and then the injectors should be purged with clean natural gas to remove any residual liquids. Long term exposure to cleaning solutions, even those in the recommended category, may damage the seals in the SFG injector.

The cleaning solution may be admitted to the FMV through the inlet fitting. The solution should be forced through the injectors with pressure as the injectors are cycled. The engine control system should feature a diagnostic mode that actuates the injectors when prompted by a diagnostic tool. In some markets there are dedicated natural gas injector cleaning hardware kits available to make the process quick and effective. For LNG applications, the cleaning procedure must be followed by a re-oiling procedure to ensure long injector life with the dry fuel. See manual 51490 for detailed instructions for the injector cleaning procedure.

Injector Replacement

When replacing the SFG injectors, 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. Allow the engine to idle and consume the fuel trapped in the fuel lines until the engine stalls. Turn the ignition switch to off position.
4. Disconnect the negative cable from the battery.
5. Clean as much debris from the FMV as possible before removing from the vehicle. This minimizes the potential for contamination to enter the FMV during the injector replacement.
6. Unplug the connectors at the SFG injectors and NGITP sensor.
7. Using a backing wrench to support the fuel fittings in the FMV block, loosen the fuel line connections at the inlet and the outlet of the FMV.
8. Remove the fasteners that attach the FMV to the bracket.
9. Remove the FMV from the vehicle.
10. Clean FMV external surfaces that could not be accessed in the vehicle.
11. Loosen the socket head screws that secure the injector retainers.
12. Remove the retainer from the FMV block.
13. While applying a back-and-forth rotation, gently pull the injectors from the FMV block—use care not to damage the injector(s) if they are to be reused.
14. Remove the NGITP sensor from the block by gently loosening it with a wrench.
15. Thoroughly clean the FMV block and retainer plates with a mild Stoddard solvent or n-Heptane—take care that all debris is removed from the internal passages of the FMV block.
16. When the FMV block is thoroughly dry, apply caps to the inlet and outlet fittings.
17. Remove the injector O-rings, apply a thin coat of clean motor oil to new O-rings and FMV glands, then install the new O-rings onto the injectors using care to not tear or over-stretch the seals.
18. While applying a back-and-forth rotation, gently insert the injectors into the glands of the FMV block, fully seating them so that the flange is flush with the top of the block.
19. Install the retainer plates onto each side of the FMV and reinstall the socket head screws and lock washers.
20. Tighten the socket head screws to 10.8 N·m.
21. Ensure that the NGITP sensor O-ring is clean, then apply a thin coat of clean motor oil to the O-ring.
22. Install the NGITP sensor into the FMV port and tighten to 7 N·m.
23. Install the FMV on the mounting bracket on the vehicle, and tighten the fasteners to 20 N·m.
24. Connect fuel hoses to the FMV finger-tight; use a backing wrench to support the fittings at the block Tighten the connections 1.5 hex flats for a tube connection, or 1.0 hex flats for a swivel-nut hose connection. 1 hex flat = 1/6th turn.
25. Connect the harness leads to the injectors and NGITP sensor.
26. Slowly open the tank shutoff valves.
27. Connect the negative cable to the battery terminal.
28. Turn the ignition switch to the on position but do not start the vehicle.
29. Check the FMV for external fuel leaks using a bubble solution – repair any leaks before starting vehicle.
30. Start vehicle. Double check for leaks before departing the service station.

Chapter 5. Troubleshooting

Leakage—External

Often times the human nose can detect the presence of CNG leakage. LNG does not carry odorant and in such cases, electronic leak detectors or “sniffers” may be used to check natural gas fuel systems for leakage. If the SFG FMV is suspected of leakage, the most precise method to isolate a potential leak is the use of a bubble solution. With the FMV pressurized with normal fuel pressure, apply the leakage solution around the fittings, sensor, tank valve, and injectors.

Leakage Source Identified	Possible Causes	Solutions
Hose fittings at FMV	Hose is loose	Tighten hose using procedure described in installation section of this manual
	Hose-fitting connection is contaminated	Clean connection
	Hose fitting is damaged or incorrect type	Replace hose assembly with proper type
Fittings at FMV block	Fitting is loose	Tighten fitting to 20.3 N-m
	O-ring gland is dirty	Remove fitting, clean, reinstall to 20.3 N-m
	O-ring is damaged	Replace O-ring
	Fitting is damaged	Replace fitting
	FMV thread is damaged	Replace FMV
NGITP sensor fitting (Natural Gas Injection Temperature and Pressure sensor)	Fitting is loose	Tighten sensor to 6.8 N-m
	O-ring gland is dirty	Remove sensor, clean, reinstall to 6.8 N-m
	O-ring is damaged	Replace sensor O-ring
	Sensor is damaged	Replace sensor
	FMV thread is damaged	Replace FMV
Injectors	Injector retainer plate is loose	Check retainer screws for tightness – do not tighten above 11 N-m
	Injector upper O-ring is dirty	Carefully remove injectors, clean O-ring surfaces, lightly oil O-rings
	Injector upper O-ring is damaged	Replace injector O-ring
	Injector is damaged	Replace injector

Leakage—Internal

An internal leak through the FMV may be more difficult to detect than an external leak. Symptoms of an internal leak include depletion of system pressure without external leakage or excessive fuel odor detected in the engine intake system when the vehicle is shut off. To confirm an internal leak, disconnect the outlet hose from the FMV fitting, and use a bubble solution to confirm presence of gas passing through the FMV when the vehicle is shutoff without power to the injectors. If an internal leak is confirmed, perform the following checks:

1. Remove injectors from the FMV block and replace the upper and lower O-rings. Lightly oil the new O-rings prior to installation.

2. If the FMV still exhibits external leakage, replace the injectors.

Deviation of Flow

The flow rate of the FMV will degrade with normal use, if the fuel supply contains contamination such as compressor oil or particulates. The best prevention against flow degradation is installation and proper maintenance of fuel filters in the vehicle fuel system. The most common cause of flow degradation is contamination fouling. The control system may feature diagnostic information such as trouble codes that can help diagnose a suspected flow problem from the SFG FMV. Rare cases of excessive flow through the FMV may be indication of an internal leak.

Flow Problem Identified	Possible Causes	Solutions
Insufficient flow	Contamination from fuel	Perform injector cleaning maintenance
	Injectors are damaged	Check resistance of injectors, replace if greater than 4.9 Ω or less than 3.5 Ω
Excessive flow	Internal leakage	See troubleshooting for internal leakage

NGITP Implausible Output

The NGITP sensor relies on the integrity of the wiring in the vehicle. If a faulty sensor is suspected, the wiring harness (including the connector and the pins at the control module) should be inspected.

Implausible Pressure Signal Problem	Possible Causes	Solutions
Pressure reads implausibly high	Fuel system over-pressure	Confirm pressure reading with pressure gauge inline with FMV inlet
	Wire harness failure	Check wire harness, refer to the open/short fault condition matrix
	Faulty sensor	Bleed down system pressure (by vehicle idle), remove sensor from FMV, confirm pressure reading is near atmospheric (1 bar at sea level, 0.8 bar at 2000 m elevation Replace sensor
Pressure reads implausibly low	Fuel system not pressurized	Confirm pressure reading with pressure gauge inline with FMV inlet
	Wire harness failure	Check wire harness, refer to the open/short fault condition matrix
	Faulty sensor	Bleed down system pressure (by vehicle idle), remove sensor from FMV, confirm pressure reading is near atmospheric (1 bar at sea level, 0.8 bar at 2000 m elevation Replace sensor

Wiring Fault Conditions

The following table provides useful sensor behavior for various wiring fault conditions.

Condition	ADC	Voltage	Value	Comments
TEMPERATURE SIGNAL				
Signal open	1018	4.98	-40° C	NGT voltage high
Signal short to ground	0	0.00	-130° C	NGT voltage low
Signal short to 5V	1023	5.00	-40° C	NGT voltage high
Ground open	1000	4.89	-40° C	NGT voltage high
5V open	NA	NA	NA	*Not a failure mode for NGT*
PRESSURE SIGNAL				
Signal open	0	0.00	-1.31 bar absolute	NGP voltage low
Signal short to ground	0	0.00	-1.31 bar absolute	NGP voltage low
Signal short to 5V	1023	5.00	16.79 bar absolute	NGP voltage high
Ground open	980	4.79	16.02 bar absolute	NGP voltage high
5V open	0	0.00	-1.31 bar absolute	NGP voltage low

Chapter 6.
Engineering Specifications

Allowable Fuel Type: CNG

CNG - Allowed

LPG - Not Allowed

Compressed Natural Gas (CNG) is hydrocarbon gaseous fuel that is stored in a compressed gaseous state before being expanded (pressure-reduced) prior to delivery to the Fuel Metering Valve. This fuel typically bears trace amounts of compressor oil that can provide beneficial lubricity to fuel metering components (injectors), but can also have the potential to foul injectors, affecting opening capability and flow performance.

Typical natural gas composition:

88.5% Methane, 6.86% Ethane, 2.96% Propane, 0.7% Methylpropane, 0.72% n-butane, 0.03% 2-methylbutane, 0.01% n-pentane

Specific Gravity = 0.639, F/A stoich (mass) = 0.05872, ratio of specific heats = 1.28, critical pressure ratio = 0.55, Total LHV gas 49.1 MJ/kg

Allowable Fuel Type: LNG

LNG - Allowed

Liquefied Natural Gas (LNG) is hydrocarbon gaseous fuel that is stored in a liquid (cryogenic) state, then vaporized before delivery to the Fuel Metering Valve. The Fuel Metering Valve will be destroyed if it comes in contact with liquid-form LNG. Generally, LNG is typically higher in methane concentration then CNG. This gas is generally completely dry with no oil or water present.

Sulfur Contamination:

Sulfur (H2S) — fuel sulfur levels < 120 mg/m^3 according to ISO15403-2:2006.

Oil Fouling:

The FMV is chemically compatible with typical synthetic and mineral based compressor oils, however diester oils may cause seal swell and should be avoided. Any liquid phase contamination, including moisture and oil, may degrade the flow performance of the FMV. Coalescing filtration must be used to ensure proper flow performance of the FMV (further details below).

Filtration Required:

For CNG Systems: high-pressure and low pressure coalescing and particulate filters are to be used. Parker Grade 10 element meets the minimum filtration requirements; Grade 6 elements provide the best filtration and should be used on the low pressure side when possible (pressure drop must be considered).

For LNG Systems: low-pressure coalescing and particulate filter is to be used. Parker Grade 10 element meets the minimum filtration requirements;

Grade 6 elements provide the best filtration and should be used on the low pressure side when possible (pressure drop must be considered).

Water Contamination:

Typical gas pipeline dew points are allowed and should not adversely affect FMV performance. However, abnormally high water content may cause internal corrosion, or freezing of injection components which may result in decreased performance. See "Filtration Required" section above.

Inlet Side Working Fuel Pressure:

Operating inlet pressure range: 5 - 10 bar absolute

Maximum Opening Pressure:

Capable of initiating flow at inlet pressure up to 13.8 bar gauge (inlet pressure above outlet pressure).

Cold opening performance in oily environments shall meet the following:

25% of injectors shall open at 11 bar g or greater at -40 °C after internal components are wetted with 15W-40 CNG compressor oil.

Pressure Spikes:

Capable of withstanding short term operation with pressure spikes up to 21.7 bar gauge (inlet pressure above atmosphere and outlet). Long term exposure to pressure pulsation may reduce FMV life.

Burst Pressure:

The fuel metering assembly must withstand a pressure of 114 bar g without releasing parts or shrapnel. Internal failure/loss of function is allowed.

Outlet Side Working Pressure:

0.1 to 3 bar absolute

NGITP Pressure Transducer:

The inlet fuel pressure transducer in the NGITP sensor is an active electronic device with a variable voltage output that scales linearly with pressure.

For full product details:

- See Woodward Specification 03403
- See Woodward Calibration Guide 103633R049

Fuel Pressure Sensor Range:

(0 - 15) bar absolute

Fuel Pressure Sensor Voltage Output:

(0.5 -4.5) V dc

NGITP Temperature Transducer:

The inlet fuel temperature transducer in the NGITP sensor is a negative temperature coefficient thermistor that is read into a voltage divider circuit in the engine control module.

For full product details:

- See Woodward Specification 03403
- See Woodward Calibration Guide 103633R049

Fuel Temperature Sensor Range:

(-40 - 130) °C

Temperature Sensor Output:

Resistive type device to that can provide 0-5 V output of sensor value across full temperature range when used with the following voltage divider:

- 10 kΩ pull-up resistor

Other voltage divider configurations may be possible. Consideration to the change in the voltage curve must be given.

NGITP Power Supply:

5 V dc supply with 10 mA available

NGITP Ground:

Requires internally isolated ground for referencing 5V and analog sensor inputs.

Injector Electrical Power Supply:

Typical scheme: System (+) voltage activated by the engine controller output to a relay which provides battery potential to the injector coils. Low-side driver (-) at control module used to control current supply to injectors.

Operating Voltage:

FMV Designed for 24 V systems (nominal 27.6 V dc)

Operating voltage range: (18 - 32) V dc

12 V Systems:

Not recommended. May operate in some 12 V systems (nominal 13.8 V dc) but with reduced opening capability performance especially at cranking voltages.

Injector Driver:

The injector driver shall use 3 Amp peak, (0.75 - 1.0) Amp hold profile. Specific injector driver calibration settings are available in Woodward document 103633R049.

Injector Performance Characteristics:

- See Woodward Product Specification 03428
- See Woodward Calibration Guide 103633R049

Injector Coil Impedance:

4.2 ± 0.5 Ω @ 20 °C

Product Variations:

FMV configurations are available as follows:

- 3 injector FMV
- 4 injector FMV
- 5 injector FMV
- 6 injector FMV
- 8 injector FMV
- 10 injector FMV

Orientation:

FMV must be mounted with the axis of the NGITP sensor pointed vertically ± 10° (sideways orientation may promote uneven oil drainage or fouling on the lower bank).

Injectors in MPI applications shall be mounted such that the injector is vertical to horizontal, but not below horizontal. (This is to prevent fuel contaminants from back-flowing into injector from outlet galley.)

Electrical Connections:

Injector: Sealed Automotive Connector, AMP Mini Timer (integral over-molded)

NGITP: AMP 4-pin Micro Quadlok System

FMV Unpowered (Flow) Position:

Closed

Pressure & Temperature Sensor Connector Type:

AMP 4-pin Micro Quadlok

Injector Connector Type:

Connector: Packard P/N 12129140 or equivalent

Terminal (2 required): Packard P/N 12077939 or equivalent

Fuel Inlet Fitting:

SAE -8 37° (available with or without "Flare-O" face seal)

Fuel Outlet Fitting:

SAE -8 37° (available with or without "Flare-O" face seal)

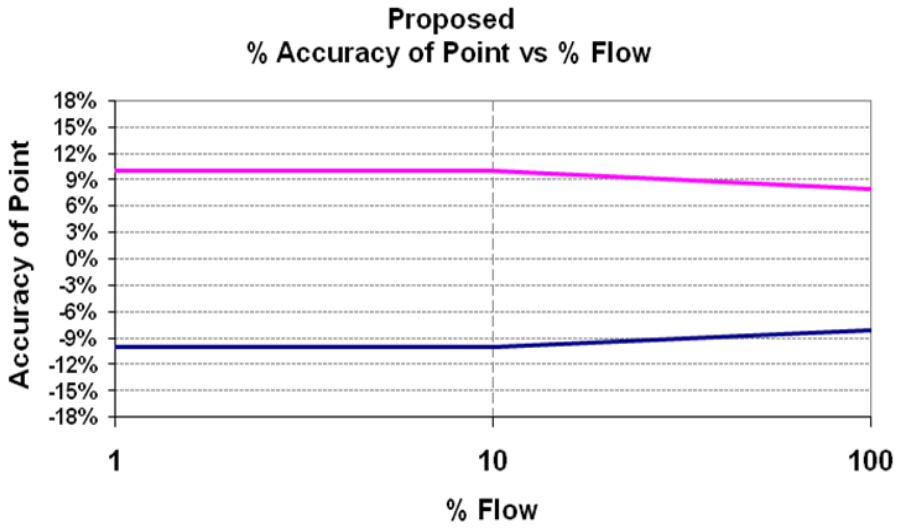
Accuracy (FMV):

The following is the mass flow accuracy for the FMV assembly, including effects from injector tolerance, sensor tolerance, and assumed control module signal read accuracy.

At 1% flow: ± 10%

At 10% flow: ± 10%

At 100% flow: ± 8%



Accuracy (Injectors):

New Injectors:

See Flow Performance, Injector, Static and Dynamic

Limits for aged Injectors (such as field returns, durability, vibration)

See Test As Received

FMV Product Line Flow Capacity:

The FMV product line shall be capable of supplying the following mass air flow rates at 100% injector duty cycle, at 7 bar absolute, 25 °C.

- 3 injector ≥ 37.7 kg/hr
- 4 injector ≥ 50.3 kg/hr
- 5 injector ≥ 61.1 kg/hr
- 6 injector ≥ 73.4 kg/hr
- 8 injector ≥ 95.0 kg/hr
- 10 injector ≥ 118.8 kg/hr

Injector Static Flow (End of Line Test):

Static flow specification is 19.69 kg/hr N_2 at 10.0 ± 0.01 bar absolute and 25 ± 1 °C

For reference: Injector static effective flow area at specified conditions is 2.36 mm²

$$ACd\_static := \frac{mdot\_static \cdot \sqrt{Z \cdot Rgas \cdot Temp}}{Pinlet} \cdot \left[\gamma \cdot \frac{1}{2} \cdot \left(\frac{2}{\gamma + 1} \right)^{\frac{(\gamma+1)}{[2 \cdot (\gamma-1)]}} \right]^{-1}$$

Where:

- ACd_static = static flow area from 1D isentropic sonic flow equation, including discharge coefficient
- mdot_static = 20.08 kg/hr
- Z = compressibility factor, 0.998 (for N_2 at 10 bar, 25 °C)
- Rgas = specific gas constant, 296.797 Pa*m³/(kg*K)
- Temp = 25°C
- γ = ratio of specific heats, 1.417 (for N_2 at 10 bar, 25 °C)
- Pinlet = inlet stagnation absolute pressure, 10 bar

Equation can be used to calculate expected static flow rate for other media and conditions.

Injector Dynamic Flow (End of Line Test):

Dynamic flow specification is 15.87 ± 7% mg/pulse, with a 3 ms pulse over a 10 ms period at 10 ± 0.01 bar absolute and 25 ± 1 °C.

Response Time:

Injector-based fuel metering valve is capable of infinite changes in pulse width between engine cycles. Response time is therefore dominated by changes in flow demand from the controller.

Linearity:

± 5% down to injector minimum pulse width

Minimum Injector Pulse Width:

Minimum linear pulse width at ± 5% linearity: 2.5 ms

Minimum pulse width at > -5% linearity (point below which, injector is nearly incapable of flow): 1.35 ms

Injector Internal Leakage:

Internal leakage ≤ 0.25 std cm³/min with 9 bar differential nitrogen at 25 ± 1 °C

Injector External Leakage:

External leakage ≤ 0.25 std cm³/min with 9 bar differential nitrogen at 25 ± 1 °C

FMV Internal Leakage:

Internal ≤ (0.25 x N injectors) std cm^3/min with 10 ± 0.01 bar absolute inlet nitrogen or air at 20 ± 1 °C

Not specified as a fuel-system shutoff per ECE R110

FMV External Leakage:

External leakage ≤ 0.25 std cm^3/min with 10 ± 0.01 bar absolute inlet nitrogen or air at 20 ± 1 °C

ECE R110:

Product shall be designed and tested in accordance with UN ECE R110

Isolation Resistance Test:

Per ECE R110 (injector)

Overpressure Test:

Per ECE R110

External Leakage with Temperature Test:

Per ECE R110

(ECE R110 Internal Leakage Not Required: LPLO Valve Function)

(ECE R110 Durability Test Not Required)

CNG Compatibility:

Per ECE R110

Corrosion Resistance:

Per ECE R110

Resistance to Dry Heat:

Per ECE R110

Ozone Ageing:

Per ECE R110

Temperature Cycle Test:

Per ECE R110

Vibration Resistance:

Per ECE R110

Minimum Storage Temperature:

-40° C

Maximum Storage Temperature:

60° C

Minimum Operating Temperature:

-40° C

Maximum Operating Temperature:

125° C (ECE R110 certification temperature maximum 120° C)

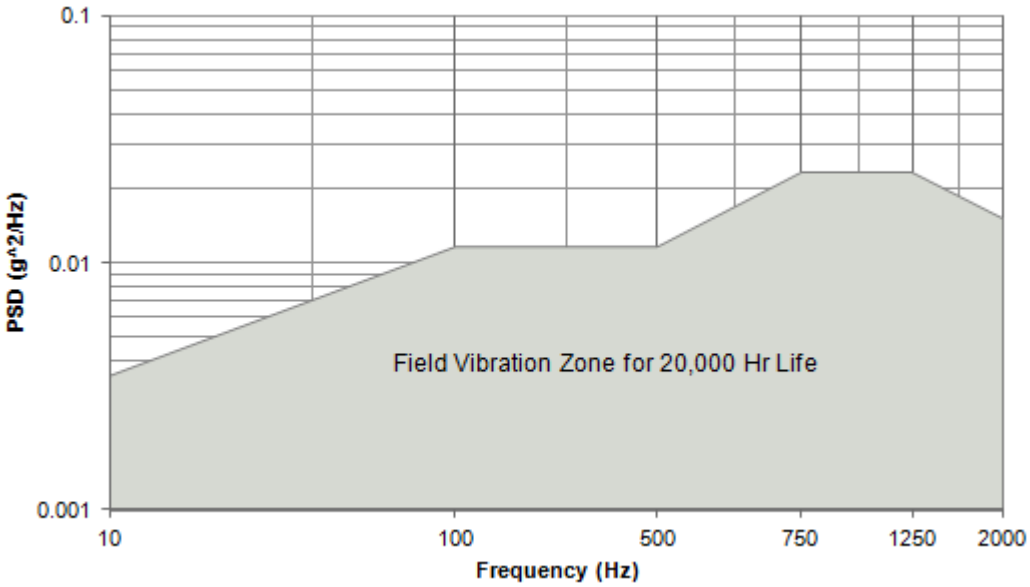
Humidity:

Operation in humid environments: 95% relative humidity at up to 60° C.

Thermal Shock:

The FMV shall function properly after exposure to 50 thermal shock cycles between -20° C and 105° C.

Vibration:



Mechanical Shock:

MIL-STD 810F, Method 516.2, Procedure 1, Basic Design Test at 40 g, 11 ms sawtooth pulse, in each of 3 planes, 3 shocks per axis.

Mechanical Shock, Drop:

FMV shall be subjected to a drop-test based on SAE J1455 Part 4.11.3.1. After each drop the component is to be evaluated for visibly damaged subcomponents. If any subcomponent is visibly damaged beyond minor scratches or dents, it is to be replaced with a new part, after which the reassembled unit must pass baseline testing. If no subcomponents are visibly damaged, the unit must pass baseline testing.

Chemical Compatibility:

The FMV shall function properly and shall not show signs of ingress or distress after exposure to fluids typically seen in an automotive under-hood,

on-engine environment. These fluids include, but are not limited to, gasoline, engine oil, hydraulic oil, transmission oil, ethylene glycol, liquid propane gas, ammonia-water and brake fluid. Test guidance per SAE J1455 part 4.4

Paint:

Electrostatic paint application is not allowed.

Traditional chemical painting is allowed.

Ingress Protection:

The FMV shall function properly after exposure to pressure washing spray representative to that according to SAE J1455. The requirement considered to provide verification of dust ingress protection as well.

Salt Exposure:

The fuel metering assembly shall function properly after exposure to an aqueous salt atmosphere of 5% NaCl by weight at 35 °C for 144 hours. Test method per MIL-STD 810D, Method 509.2, Procedure I or equivalent.

Atmospheric Pressure:

The fuel metering valve is operable at any barometric pressure from 62 kPa absolute (4000 m) to 104 kPa absolute.

EMC Requirements:

The specified tests address the industry standard requirements for Mobile/Vehicular applications as wells as the regulatory requirements for UN/ECE Regulation 10 and the European Vehicle EMC Directive 72/245/EEC (with current amendments).

ISO 10605 (2001): ESD Immunity - Packaging and Handling Classification

Contact Discharge = +/- 8 kV

10 pulse/polarity at each voltage level

Apply to all pins and potentially susceptible points/surfaces accessible during packaging and handling process

No permanent degradation or damage allowed

ISO 11452-4 (2005): Conducted Immunity (BCI method)

1 MHz - 20 MHz, 25 mA increasing to 150 mA, DBCI & CBCI method

20 MHz - 200 MHz, 150 mA, CBCI method

CW and 80% AM @ 1 kHz, Peak Conservation

Normal performance required up to the specified current level for each frequency range

ISO 11452-2 (2004): Radiated Immunity (ALSE method)

200 MHz - 1 GHz, 100 V/m, CW and 80% AM @ 1 kHz, Peak Conservation

800 MHz - 2 GHz, 30 V/m, CW and PM (PRR=217 Hz, PD=577 us)

Normal performance required up to the specified field strength level for each frequency range

ISO 7637-3 (2007): Coupled Transient Immunity

Fast Transient:

US = +/- 400 V (level IV x 5), CCC method

Test Duration = 10 minutes per polarity

Normal performance required up to US = +/- 280V (Level III x 5), momentary deviations permitted thereafter

Slow Transient:

US = +/- 50 V (level IV x 5), ICC method

Number of Pulses = 1000 per polarity

Normal performance required up to US = +/- 40V (Level III x 5), momentary deviations permitted thereafter

Woodward Procedure: Ignition Noise Immunity

30 kV secondary ignition lead coupling at 3.0 cm distance from housing and wiring harness for 2 minutes at each orientation

Normal performance required up to 30 kV

Injector B10:

Injector B10 ≥ $400x10^6$ injector cycles using the following performance criteria:

- dynamic flow shift ± 15% from 0-cycle value
- static flow shift ± 7% from 0-cycle value
- internal and external leakage meets spec at room temperature

For reference: for a 12 L engine undergoing the World Harmonized chassis dyno schedule, this would translate to roughly 480,000 km when injectors actuate once per engine cycle.

For reference: customers may experience increased reliability in CNG applications due to the improved lubricity compared to LNG. CNG injector 1309-6188 demonstrated > $600x10^6$ cycles without failure in the CNG durability tests but would not meet durability goals on LNG fuel. Individual application results will depend upon fuel filter maintenance, injector drive strategy, and fuel cleanliness.

Allowable Service Procedures:

Cleaning of wetted surfaces with approved injector cleaning solutions:

- Stoddard solvent
- n-Heptane

Packaging:

FMV and injectors shall be packaged for environmental protection during shipment by way of land, sea, and air.

Limits for Flow, Warranty Claims:

Warranty-eligible injectors shall pass the following flow specification:

- Static flow specification is 19.69 ± 7% kg/hr N_2 at 10.0 ± 0.01 bar absolute and 25 ± 1° C
- Dynamic flow specification is 15.87 -14/+16% mg/pulse, with a 3 ms pulse over a 10 ms period at 10 ± 0.01 bar absolute and 25 ± 1° C
- Cleaning is allowed, injector may be evaluated with the effects of contamination removed

Limits for Leakage, Warranty Claims:

Warranty-eligible injectors shall pass the following leakage specification:

- Internal leakage ≤ 0.25 std cm^3/min with 9 bar differential nitrogen at 25 ± 1° C
- External leakage ≤ 0.25 std cm^3/min with 9 bar differential nitrogen at 25 ± 1° C
- Cleaning is allowed, injector may be evaluated with the effects of contamination removed

Injector Cleaning in the Field

FMV and injectors may be cleaned in the field using only n-Heptane or Stoddard Solvent (recommended). See Woodward procedure B51490.

Chapter 7.
Product Support and Service Options

Product Support Options

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

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

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

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

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

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

Product Service Options

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

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

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

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

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

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

Returning Equipment for Repair

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

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

Packing a Control

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

NOTICE

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

Replacement Parts

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

Engineering Services

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

- Technical Support
- Product Training
- Field Service

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

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

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

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

Contacting Woodward's Support Organization

For the name of your nearest Woodward Full-Service Distributor or service facility, please consult our worldwide directory at **www.woodward.com/directory**, 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) 6762 6727
Germany:	
Kempen	+49 (0) 21 52 14 51
Stuttgart	+49 (711) 78954-510
India	+91 (129) 4097100
Japan	+81 (43) 213-2191
Korea	+82 (51) 636-7080
Poland	+48 12 295 13 00
United States	+1 (970) 482-5811

Products Used in Engine Systems

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

Products Used in Industrial Turbomachinery Systems

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

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.

We appreciate your comments about the content of our publications.

Send comments to: icinfo@woodward.com

Please reference publication 26841NEW.

WOODWARD

PO Box 1519, Fort Collins CO 80522-1519, USA
1000 East Drake Road, Fort Collins CO 80525, USA
Phone +1 (970) 482-5811 • Fax +1 (970) 498-3058

Email and Website—www.woodward.com

**Woodward has company-owned plants, subsidiaries, and branches,
as well as authorized distributors and other authorized service and sales facilities throughout the world.**

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