Continental Controls Corporation

Installation and Operating Manual

Gas Substitution System, GSS

Class I, Div 1, 2, Group D:T4 **ISO 9001:2015 Certified**

Introduction

This manual provides instruction and maintenance information for the Gas Substitution System (GSS).

It is highly recommended that the user read this manual in its entirety before commencing operations. It is the policy of Continental Controls Corporation that it is neither our intention nor our obligation to instruct others on how to design or implement engine control systems. Continental Controls Corporation will not assume responsibility for engine controls not designed or installed by our authorized representatives.

This manual is intended to help the end user install and operate the Gas Substitution System (GSS) in the manner in which they were intended and, in a way, to minimize risk of injury to personnel or damage to engine or equipment.

Do **NOT** attempt to operate, maintain, or repair the Gas Substitution System (GSS) until the contents of this document have been read and are thoroughly understood.

Every attempt has been made to provide sufficient information in this manual for the proper operation and maintenance of the Gas Substitution System (GSS).

All information contained within shall be considered proprietary information and its release to unauthorized personnel is strictly prohibited.

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Safety Warning!

The Continental Controls Gas Substitution System (GSS) are normally used with natural gas. Natural Gas and Air, when combined together, the mixture becomes very combustible. When contained within an enclosure, such as exhaust system can explode in a violent manner when ignited. It is necessary to always use extreme caution when working with any fuel system.

Controls for Gas Engines should always be designed to provide redundant fuel shutdowns. Towards this goal, the Fuel System plays an important part in the safety of the whole system. Gas Substitution System (GSS) is not the primary control to shut down the engine.

Shutoff valves should be used in addition to the Gas Substitution System (GSS). The fuel system should be designed in such a way that:

1. **No single failure of a component will cause the fuel system to admit fuel to the engine when the engine has been shut down.**
2. **No single failure can result in grossly over-fueling the engine when attempting to start.**

WARNING:

1. When using CNG, it's extremely important to install relief valve sized properly between the CNG regulator block and the GSS Manifold (GSM5) in the case of CNG regulator and shutoff failure.
2. GSS Manifold (known as GSM5) if equipped with Pneumatic Actuated Ball Valves, minimum of 75 psi supply pressure (maximum 100 psi) are required to operate the pneumatic actuated ball valves.
3. It's extremely important to use 10–20 micron filtration prior to the inlet of the GSS Manifold (known as GSM5).
4. A periodic maintenance program needs to be established to ensure the Pneumatic Actuated Valves, the differential pressure regulator are serviced according to the original manufacturer maintenance program and procedure. In some cases where environment that is harsh than normal would require shorter term maintenance program that normal.
5. If the equipment is likely to come into contact with aggressive substances, then it is the responsibility of the user to take suitable precautions that prevent it from being adversely affected, thus ensuring that the type of protection provided by the equipment is not compromised.
6. Exposure to some chemicals may degrade the sealing properties of material used in the following devices:
    I. GSSI, RELAY, K1 & K2,

II. GSS manifold (Solenoid Valves, Pneumatic Actuated Ball Valves, Differential Pressure Regulator)

Aggressive substances: e.g. acidic liquids or gases that may attack metals or solvents that may affect polymeric materials.

Suitable precautions: e.g. regular checks as part of routine inspections or establishing from the material's data sheets that it is resistant to specific chemicals.

Translations of Caution and Warning of Front Cover:

1. **CAUTION: OPEN CIRCUIT BEFORE REMOVING COVER**

   I: ATTENZIONE: APRE CIRCUITO PRIMA DI TOGLIERE COPERCHIO L'L'IL

   G: ACHTUNG: OFFENER KREISLAUF VOR HERAUSNEHMEN VON DECKE

2. **WARNING:DO NOT DISCONNECT EQUIPMENT UNLESS POWER HAS BEEN SWITCHED OFF AND AREA IS KNOWN TO BE NON-HAZARDOUS**

   I: L'AVVERTIMENTO: NON DISINSERISCE L'APPARECCHIATURA A MENO CHE IL POTERE È STATO DISINSERITO Y L'AREA È SAPUTA PER ESSERE NON RISCHIOSO

   G: WARNEN: SCHALTEN Sie GERÄTE NICHT AB ES SEI DENN NETZSCHALTER AB UND GEBIET IST GEWUSST, SEI ZU SEIN

3. **KEEP COVER TIGHT WHILE CIRCUIT IS CLOSED**

   I: TENERE I COPERCHI STRETTI MENTRE CIRCUITO SONO VIVO

   G: BEHALTEN Sie DECKEN DICHT, WÄHREND KREISLAUF LEBEND IST

Failure to follow the above rules may possibly lead to serious damage to equipment or injury to personnel!

GSS Temperature Limit

The Gas Substitution System Interface is an interface where the GSS system parameters are set and components like the GV1, the primary pneumatic actuated ball valve, the secondary solenoid valve are controlled as well as discrete outputs are provided. The GSS Interface has gone through a tremendous amount of both electrical and temperature testing. The GSS Interface has gone through a temperature cycles -15° Celsius up to +60° Celsius for many hours in operation mode. The GSS Interface is a CSA approved product.

GV1 has gone through over half a million (500,000) endurance cycles (close to open to close), where 250,000 cycles were conducted at an ambient temperature of -42° Celsius. The valve was still operating at those conditions. Thus we have CSA certified at ambient temperature of -40° Celsius to +85° Celsius.

The Gas Supply Manifold consists of three major components: a differential pressure regulator, an internal pilot solenoid valve, and a pneumatic actuated electric ball valve.

1. The differential pressure regulator operating temperature limit is -40° Celsius to +60° Celsius.

2. The Solenoid Valve with Viton seal operating temperature limit is -15° Celsius to +120° Celsius. Although the Viton seal operating temperature limit is -29° Celsius to +205° Celsius.

3. The Pneumatic Actuated Electric ball valve consist of three major moving components:

    - **Ball Valve where the operating temperature limit** -18° Celsius to +180° Celsius -18to 180º C
    - **Actuator where the operating temperature limit** -18° Celsius to +82° Celsius
    - **Actuator Pilot Solenoid Valve where the operating temperature limit** -18° Celsius to +82° Celsius

The differential pressure gauges switch is a CSA approved product where the temperature limits are -40° Celsius to +93° Celsius. The low-pressure switch temperature limits are -55° Celsius to +105° Celsius.

CCC highly recommends that a liquid separator used to remove any liquid within the gas and at the same time, it bring the temperature of the gas where it is optimum. Gas substitution should not be allowed if the gas temperature is below the dew point of the gas. As these has been mentioned in the GSS Kit installation manual. The Continental Controls Corporation GSS Kit operating temperature limits are -18° Celsius to +60° Celsius and the ambient temperature limits are -18° Celsius to +60° Celsius.

Product Warranty

Continental Controls Corporation warrants that all goods furnished by CCC are free from defects in workmanship and material as of the time and place of delivery.

As a matter of general warranty policy, CCC honors an original buyer's warranty claim in the event of failure within 12 months of shipment to the end-user, when the equipment has been installed and operated under normal conditions and in accordance with installation instructions contained in the operating manual and generally accepted operating practices.

All warranty work must be performed and CCC's manufacturing facility in San Diego. The customer is responsible for shipment or delivery of the product to the CCC facility. CCC will pay return ground freight. The customer will pay any expedited freight fees.

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GV1/GV2 Specifications

Flow Capacity:	Pre-Turbo: 120 scfm Natural Gas Post-Turbo: 215 scfm Natural Gas
Fuel	Natural Gas, Gaseous Hydrocarbons (Wellhead & Biogas)
Maximum Operating Pressure:	65 psig (differential pressure between fuel and air reference should not exceed 8 PSID)
Filtration Requirement:	10 Micron Absolute
Operating Temperature:	-40° C (-40° F) to +85° C (+185° F)
Response Time:	90 ±10 milliseconds 10% - 90% Command
Accuracy:	±1.0% of reading or 0.5 % of full scale
Fuel Demand Signal [to Fuel Control Valve]:	4-20 mA, CANBus J1939
Fuel Feedback Signal [from Fuel Control Valve]:	4-20 mA, CANBus J1939
Power Input:	10-30 Vdc (5 Amp Maximum)
Electrical Interface:	MS Connector MS3102E18-1P (CANbus/4-20 mA / Stepper Motor)
Communication Interface:	Rs232 Modbus TRU, J1939 CANBus
Housing Materials:	6061-T6 Anodized Aluminum
Wetted Materials:	Stainless Steel, Carbon Steel, 6061-T6 Anodized Aluminum, Viton® Seals, Nitrile Seals
Flanges:	1-1/2" FNPT
Dimensions:	6.84”L x 5.65”H x 6.78”W
Approximate Weight:	6.90 pounds
Certifications:	**Class I, Division 1, Group D: T4**

ECV5 Specifications

Flow Capacity:	400 scfm (1120 lbs/hr) Natural Gas at 25 psig Gas Supply (supply pressure & fuel composition dependent)
Fuel	Natural Gas, Methane (Wellhead and Biogas)
Maximum Operating Pressure:	150 psig
Filtration Requirement:	10-20 Micron Absolute
Operating Temperature:	-40° C (-40° F) to +85° C (+185° F)
Response Time:	90 ±10 milliseconds 10% - 90% Stroke
Flow Accuracy:	±3.0% of reading or 0.5 % of full scale
Fuel Demand Signal [to Fuel Control Valve]:	4-20 mA, CANBus J1939
Fuel Feedback Signal [from Fuel Control Valve]:	4-20 mA, CANBus J1939
Power Input:	19-30 Vdc (5.0 Amp Maximum)
Electrical Interface:	MS Connector (D3899/20FE99PN)
Communication Interface:	RS232 Modbus RTU, CANBus J1939
Housing Materials:	6061-T6 Anodized Aluminum
Wetted Materials:	Stainless Steel, Carbon Steel, 6061-T6 Anodized Aluminum, Viton® Seals, Nitrile Seals
Flanges:	2" Class 150 Flange, 4-Bolt
Dimensions:	6.0”L x 12.3”H x 6.0”W
Approximate Weight:	13 pounds
Certifications:	**Class I, Division 1, Group D: T4**

GSS Overview

The Continental Controls Corporation GSS is a system for diesel engines designed to replace a percentage of diesel with natural gas. Since diesel engines do not have an ignition system, there will always be some diesel fuel required for ignition of the natural gas and its lubricating properties. The percentage of substitution greatly depends on load, gas quality and other operating conditions of the engine. Substitution above 70% is sometimes possible, but not recommended. The GSS will automatically control the maximum substitution rate at any given condition. When substituting natural gas in a diesel engine, "de-rating" of the horsepower is not required; the natural gas ignites at the same time as the diesel fuel, so the efficiency stays roughly the same.

There are two types of Bi-Fuel systems a fumigation system and an active injection system. The fumigation system injects natural gas directly into the air intake of the engines upstream of the turbochargers while the active injection system injects gas downstream of the turbochargers at a pressure much higher than the intake manifold pressure of the engine. The GSS system can function as either a fumigation or active injection system.

In conditions of natural gas over-fueling, the substitution rate becomes too high, and misfire or detonation may occur as a result. The GSS has several safety measures in place to prevent this from occurring. A vibration shutdown, a high-exhaust temperature shutdown and a high substitution rate limit ensure safe operation. In any shutdown condition, only the natural gas is removed from operation and the engine reverts to 100% diesel operation without interruption of service. The GSS will never prevent the operation of the engine running only on diesel fuel.
The GSS is in constant communication with the engine ECU through the CANBus interface. In order to use the GSS an engine must be equipped with an ECU with CANBus.

The GSS controller uses a high-resolution proportional valve to control the natural gas in the air inlet of the engine. The GSS controller reads the ECU to determine the optimal rate of substitution and constantly adjusts the amount of natural gas to the engine through the gas valve. At no load, the engine will be running on 100% diesel. At full load, the amount of diesel consumed will be approximately the same as running at a no-load condition.

The GSS gradually applies the gas, so there is no detectable bump when substituting natural gas. If the engine experiences strong off-load transients, the GSS system turns off the gas immediately, eliminating the possibility of over-fueling. The GSS does not require a load signal or manifold transducer for scheduling fuel.

A local display and an E-STOP (emergency stop) button are provided on the substitution interface. Using the local display programming, changes can be made and substitution rates can be recorded. Operating data is recorded on a thumb drive located on the controller which can be

used for diagnostic purposes. The GSS can be connected using a laptop via a 2.4 GHz radio through the USB port on the laptop. An optional satellite modem can provide telemetry and technical support at any location.

Different Venturi/mixers are required, depending on the configuration. The GSS can be installed either upstream or downstream of the turbocharger. Downstream installation of the venturi is the preferred configuration.

The GSS can operate with up to 120 psi to the fuel train. The minimum pressure required for operation is 5 psi above the turbo boost pressure for pre-turbo applications and 40 psi for post-turbo application when a standard Gas Supply Manifold (GSM5) is used. If the Gas Supply Manifold (GSM5) is equipped with pneumatic actuated ball valve, then a minimum of 75-80 psi gas supply pressure is required to operate the pneumatic actuator pilot stage. Reasonable attempts should be made to filter the gas to remove any liquids. **No filtration is provided with the GSS system**. It is the end user's responsibility to provide clean, dry gas. Highly recommend 10-micron absolute filtration.

It requires roughly 140 to 150 cubic feet of pipeline-quality natural gas to replace one gallon of diesel. A diesel engine uses about seven gallons of diesel per hour to produce 100 kW. At 70% substitution, the engine will require 686 to 735 cubic feet of gas per hour. When using metric units, the conversion is even simpler: one cubic meter of gas has roughly the same BTU content as one liter of diesel. This volume should be supplied above the minimum required pressure.

If the gas supply goes below the minimum pressure, the engine will revert to 100% diesel operation until the pressure returns. At that point, the GSS will automatically restart substituting natural gas.

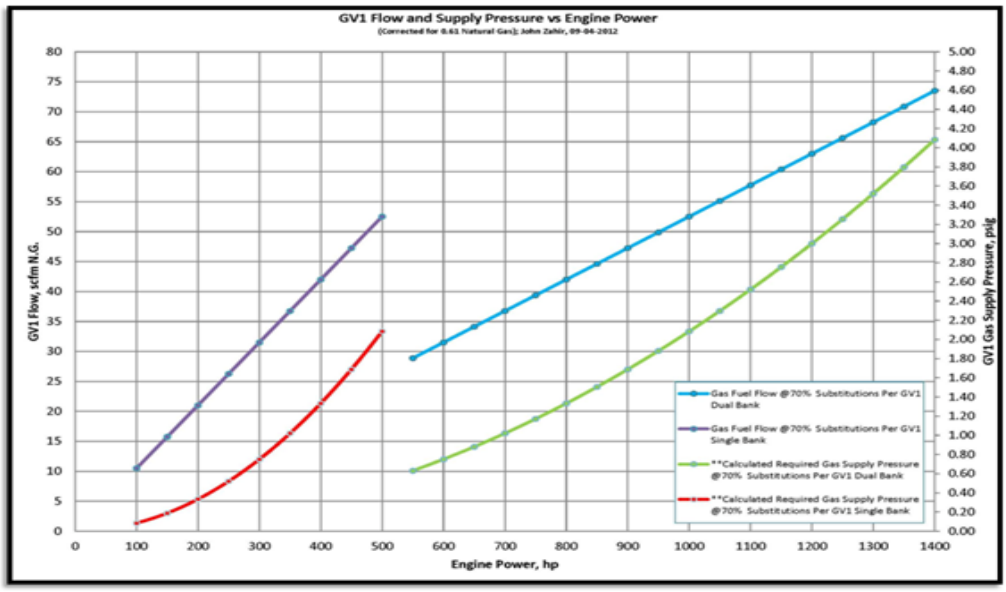


Figure 1 Required GV1 gas pressure/flow for engine horsepower.

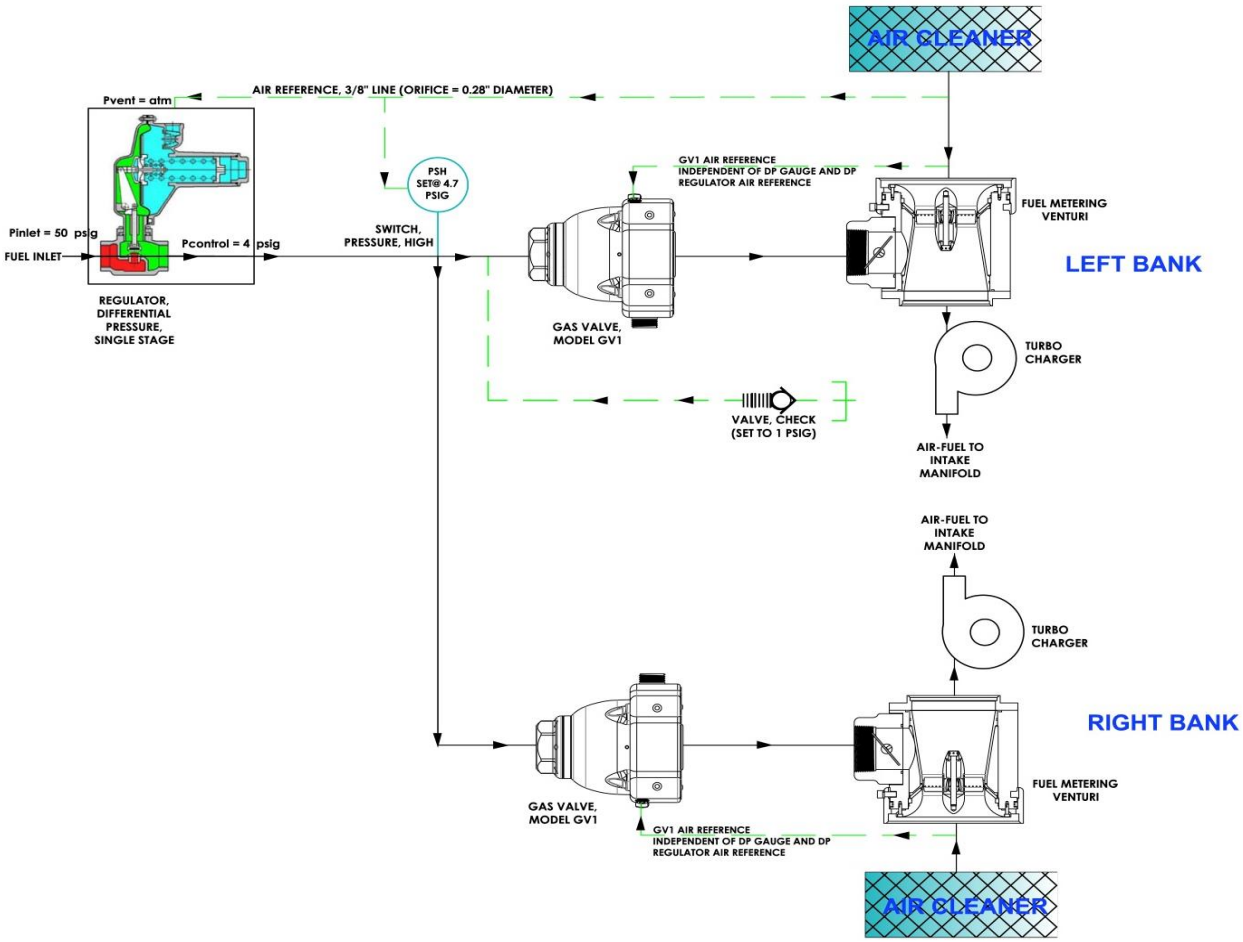


Figure 2: GSS Block Diagram

Safety Precautions

Natural gas is extremely flammable. If contained in a vessel or building, it can be explosive, causing physical harm or death. Proper ventilation, gas detection and/or flame detection should be in place when using natural gas. All government codes, regulations and accepted plumbing practices should be strictly enforced.

Installation should only be performed by trained individuals knowledgeable in natural gas systems and industrial engines. Do not attempt to install the GSS unless you have read and have a complete understanding of this manual. Do not alter or install the GSS in a way not described in this manual.

Warning: Never attempt to substitute gas for diesel while the engine is at idle or in a no load condition. Always set the minimum diesel fuel flow high enough to insure the GSS will shut off the gas system in unloaded conditions. Failure to do so may result in engine backfire.

Every installation is different - from pipeline gas to well-head gas. Gas filtration and treatment requirements vary widely; therefore, it is the consumer's responsibility to provide clean, dry fuel to the engine. A minimum of a 10-15 micron filter should be installed in the gas supply line and gas temperature should be maintained at 40°F above the dew point of the gas.

Warning: Substitution should not be allowed if the gas temperature is below the dew point of the gas. If icing occurs on the gas fuel train, close the manual valve until the gas temperature can be corrected.

If you have any doubt or questions, stop and call for support from your local dealer or Continental Controls Corporation.

Design Overview

The Gas Substitution System harnesses CCC's proven fuel control technologies to offer an affordable and efficient means of operating industrial diesel engines utilizing both diesel and natural gas (or other hydrocarbon gas) as fuel sources. This innovative, patented system, which requires no modification to the internal components of the engine, allows for operation on natural gas up to a maximum of 70% of the fuel required to maintain the desired speed and load. Reduced fuel costs and extended runtime are just a few of the benefits of GSS operation.

The Gas Substitution System operates by blending both diesel fuel and natural gas in the combustion chamber. This is achieved using a fumigated gas-charge design, whereby natural gas is pre-mixed with engine intake-air and delivered to the combustion chamber via the air-intake valve. The air-gas mixture is ignited when the diesel injector sprays a reduced quantity of diesel fuel into the chamber.

The GSS provides gas to the engine using fumigation technique to substitute the maximum amount of diesel at any given load conditions without compromising OEM engine specification's (performance, power and efficiency). The GSS supplies gas using variable fuel control valve to the engine using the original air intake system via proprietary air-fuel mixing venturi that are installed upstream or downstream of the turbocharger and then distributed to each cylinder by the engine air intake manifold.

Simplicity of Design: The simplicity of the Gas Substitution System does not interface with the diesel control governor, but instead remains independent. This allows the diesel governor to react to changes in genset load without interference of the gas system. In this manner, the diesel LEADS, and the gas LAGS. This philosophy ensures safe engine operation with no compromise in the operation of either fuel system.

A key feature of the system is its ability to switch fuel modes without interruption in engine power output. The engine can be switched between diesel and gas automatically while maintaining speed and load. his feature gives the user the flexibility to choose between gas and diesel modes as dictated by fuel pricing, fuel availability or other operational considerations.

All OEM engine specifications for injection timing, valve timing, compression ratio, etc., remain unchanged after installation of the Gas Substitution System, and no engine modifications are required.

The included control system monitors various engine parameters (depending on engine size and application) such as exhaust gas temperature, supply gas pressure and engine vibration, over speed and under speed limit. This data allows the system to determine when to activate or

deactivate GSS operation depending on load level, ambient conditions, knock limits, low or high gas pressure or a detected malfunction in the engine. The automatic default mode is always to 100% diesel operation.

Cost Savings: Displacing a percentage of diesel fuel with methane-based gas provides an immediate economic benefit based on the cost difference between the fuels and the amount of run time of the genset. In high usage gensets, the Gas Substitution System can pay for itself in a short period of time. Simple Excel-based spread sheets are available to assist in modeling the economic benefits of converting to Gas Substitution System.

Increased Run Time: Reducing the amount of diesel fuel used extends the run time in proportion to the substitution rate, providing extra hours of operation in critical applications.

- No modification to internal engine components is required.
- No power or efficiency losses.
- Low cost and easy to install.
- Reduces operating cost.
- Extends run-time of standby engines.
- No high-pressure gas supply.
- Cleaner burning natural gas reduces exhaust emissions.
- Reduces requirements for on-site fuel storage.
- State of the art controls and monitoring.

Mechanical Valve Design

Unlike many of the valves used in competing control systems, the GV1/GV2/ECV5 is specifically designed for gas turbine engines using gas fuel. It is not a modified pressure regulator, a biasing restrictor, or a valve borrowed from a different market sector or manufacturer. The valve is completely designed by Continental Controls Corporation for specific gas engine applications. Every valve is manufactured at our plant in San Diego California, including all CNC machined components and electronics assemblies. Following are some key mechanical design features that contribute to the superior performance of the GV1/GV2/ECV5 Fuel Control Valve.

Full Fuel Authority

The GV1/GV2/ECV5 is a built-in computer that meters all fuel entering the engine from no flow to full flow using a pressure control loop with embedded pressure transducer. This prevents the valve from running out of range in difficult applications. This feature also enables the valve to change the fuel flow very quickly in response to load transients.

High Speed Actuator

At the heart of the GV1/GV2/ECV5 is a high-speed, electromechanical, linear actuator that is used to drive the poppet. The actuator is comprised of a very powerful rare-earth magnet and a precision wound coil attached to the metering spool (piston). When the coil is energized it

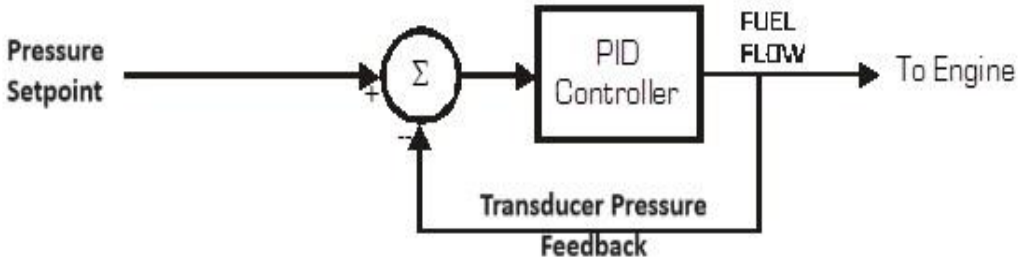
creates a magnetic field in the opposite direction of that created by the magnet. These opposing forces drive the flapper in the open direction. The actuator gives the valve unprecedented response to the ever-changing demands of the engine.

Pressure Sensors

Integrated pressure transducers constantly monitor the gas outlet pressure. The pressure sensor signal is used by the valve's internal computer for pressure control loop.

Proportional & Integral Control Logic

The GV1/GV2/ECV5 accomplishes fuel control using pressure feedback back from the internal pressure transducer. The Transducer is the pressure measurement downstream of the poppet actuator outlet, which opens the valve for gas flow. The Pressure Control loop is a proportional and integral control loop based upon measured fuel pressure at the outlet of the poppet inside the valve. The purpose of the control loop is to provide higher speed and better accuracy than what is available on most valves with Open loop control. This control loop is performed every two (2) millisecond (1000 Hz) (Average every 10 millisecond).



The measured fuel pressure is compared with the fuel demand signal. The PID controller adjusts the valve-throttling orifice to cause the fuel pressure to match the fuel pressure demand. The metered fuel is directly proportional to the fuel demand signal.

GSS Control Methods

The Gas Substitution System is designed to work using different methods to substitute the maximum percent of natural gas into the engine. Each method depends on the application and availability of engine ECU CANBus J1939 protocol.

1. **DIESEL FLOW Control**
   DIESEL FLOW Control is the preferred method. This method of control requires the Gas Substitution System to be connected via CANBus J1939 to the engine ECM / ECU. Most engines are equipped with ECM/ECU unless it's all mechanical governor control. Via CANBus J1939, we read the diesel fuel flow to substitute gas into the engine via intake manifold using fuel mixing Venturi. During this or any other method of gas substitution, the gas is controlled using the full authority Pressure Control Valve GV1.

   For Example: if the engine load is such that on diesel only it will consume 100 LPH, and the flow setpoint is set to 50 LPH, the substitution rate will be 50% (the GSS will increase GV1

gas fuel pressure until the diesel flow feedback is 50 LPH). Under the same conditions, if you increase this to 60 LPH, the substitution will decrease to 40%.

2. **LOAD Control**

LOAD Control is used in the case if the engine is all mechanical drive with no ECM/ECU or in the case of an engine application when the engine has ECM/ECU but the CANBus J1929 protocol is proprietary that does not provide diesel fuel flow reading. This method of control requires the Gas Substitution System to be connected using a Watt Meter Transducer to sense engine load or a Manifold Pressure Transducer. Using Watt Meter Transducer 4-20 mA output to measure engine load, the Gas Substitution System (GSS) are setup using engine load versus natural gas pressure injection schedule to achieve gas substitution in the air intake manifold as any given load conditions. 10 loads can be scheduled in the mapping (see figure 3 below).

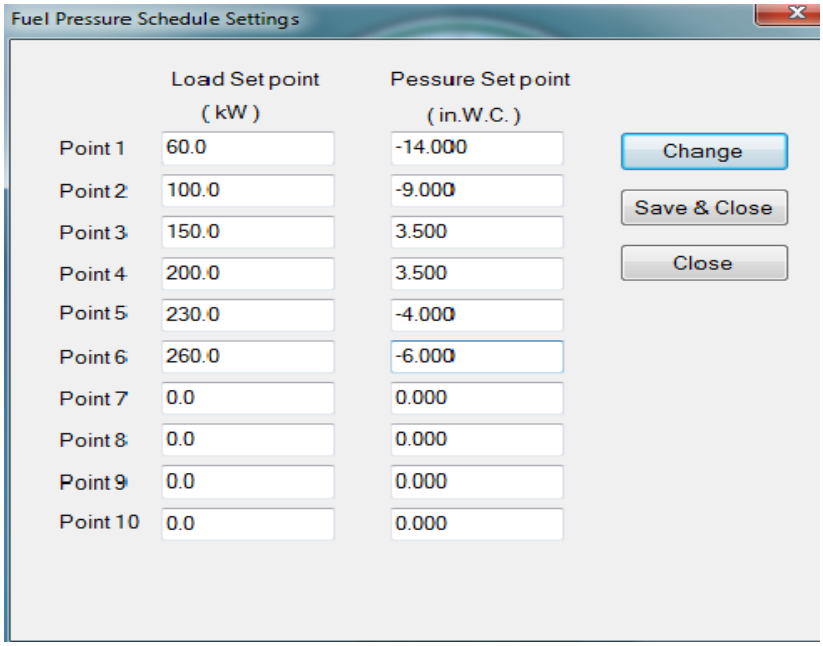


Figure 3: Load vs. GV1 Pressure Set Point Schedule

For Example: Application is 300 kW engine where 300 kW watt meter transducer is installed to read the load. The output of the transducer is 4-20 mA (4 mA = 0 kW, 20 mA = 300 kW). The fuel pressure schedule is set to user preference of gas substitution to a specific load as shown in the figure above. Let's say the engine load is 200 kW, the operator / user has set the GV1 pressure to inject fuel into the engine using the GV1 pressure set point which is directly proportional to gas flow. Operator will increase or decrease the pressure setpoint to achieve the maximum possible gas substitution (70% max.).

3. **SPEED Control**
   Like the LOAD Control method, SPEED Control is used in the case where the engine is variable speed with ECM/ECU CANBus J1939 provide engine speed only. Using the engine speed as indication of engine load to map gas fuel substitution with the GV1 pressure set point. The Gas Substitution System (GSS) is set up using engine load versus natural gas pressure injection schedule to achieve gas substitution in the air intake manifold as any given load conditions. 10 speed conditions can be scheduled in the mapping (see figure 3). Let's say the engine load is 600 rpm, the operator / user has set the GV1 pressure to inject fuel into the engine using the GV1 pressure set point which is directly proportional to gas flow. Operator will increase or decrease the pressure setpoint to achieve the maximum possible gas substitution (70% max.). Load vs. GV1 Pressure Set Point Schedule used in SPEED Method as well.

4. **MANIFOLD PRESSURE Control**
   Like the LOAD Control method, MANIFOLD PRESSURE Control is all mechanical drive with no ECM/ECU or in the case of an engine application when the engine has ECM/ECU but the CANBus J1929 protocol is proprietary that does not provide diesel fuel flow reading. The engine manifold pressure is an indication of engine load to map gas fuel substitution with the GV1 pressure set point. The Gas Substitution System (GSS) is set up using engine load versus natural gas pressure injection schedule to achieve gas substitution in the air intake manifold as any given load conditions. 10 map point conditions can be scheduled in the mapping (see figure 3).

Fuel Flow Source

In the Gas Substitution System when DIESEL Flow control method is selected, there are two options for diesel fuel flow feedback.

1. **Diesel Flow Source: ECU**
   The most economical and preferred method is when the GSS is connected to the engine ECM/ECU via CANBus J1939 to read the diesel flow feedback via the bus.

2. **Diesel Flow Source: Diesel Flowmeter**
   If in the case of an engine that is all mechanical drive with no ECM/ECU or in the case of an engine application when the engine has ECM/ECU but the CANBus J1929 protocol is proprietary that does not provide diesel fuel flow reading, the Customer has the options of adding diesel fuel flowmeter on the engine with 0-5V analog output. This analog output can be connected to the GSS to control the gas injection into the air intake manifold using the DIESEL Flow control method as explained above.

Pressure Switch Theory

The gas train is the first intermediate component between the pressurized natural gas supply and the air intake manifold. Pressurized gas travels through the gas train which can be monitored by inspection of the gauges during operation. The high (PSH) and low (PSL) pressure switches electronically monitor the natural gas and send a signal to the PC interface (GSSI) if the pressure

becomes too high or too low. This will set the desired substitution rate to 0%, deactivating the GSS and the engine will return to full diesel operation. If this occurs, gas substitution can be restarted by setting a non-zero substitution rate. High Delta pressure from the outlet of the regulator to the turbo boost pressure. Operating pressure should be 4-5 psid at the outlet of the regulator. Alarms, unlike permissive, must be acknowledged before the GSS resumes gas substitution. Alarms are acknowledged by pushing in the "stop" button and pulling it back out.

Gas Substitution System Interface (GSSI)

The Gas Substitution System comes with an interface that is not only an HMI (Human Machine Interface) but also a controller that controls the amount of gas to displace in the diesel engine. Furthermore, the GSSI takes various digital discrete for various inputs / outputs.

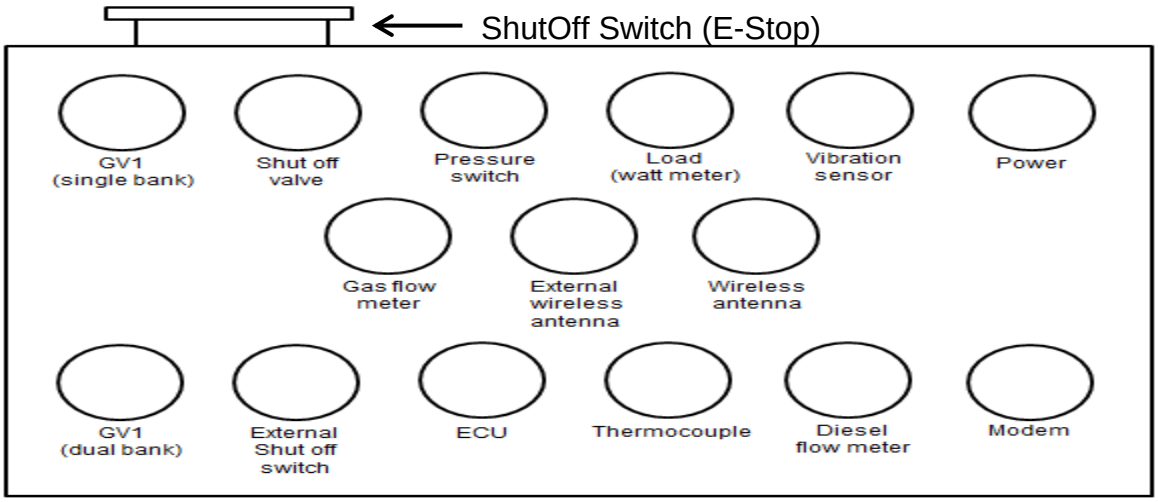


Figure 4A View from bottom of substitution interface

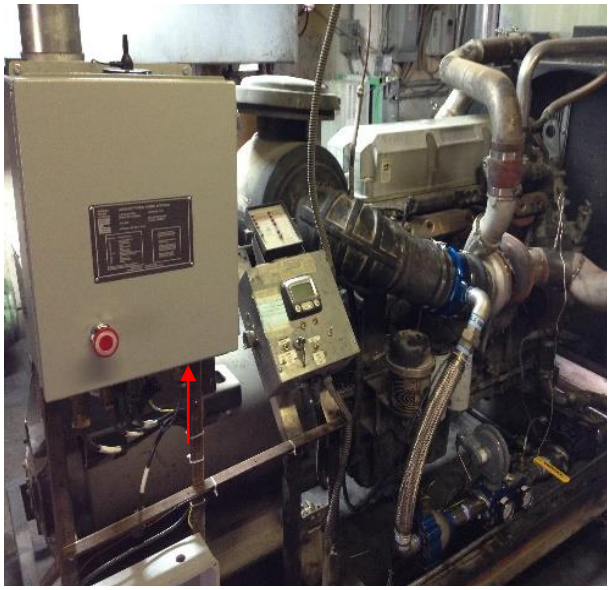


Figure 4B GSSI Installation Illustration

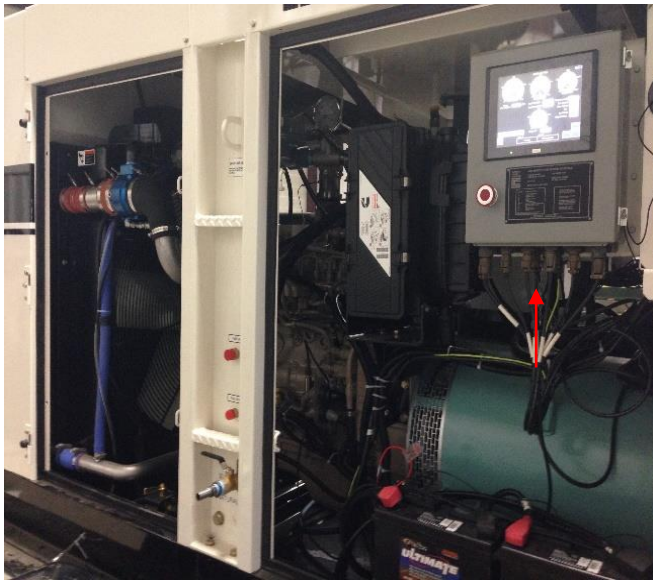


Figure 4C GSSI Installation Illustration

Installation Instructions

When installing the Gas Substitution System (GSS), the possibility exists that welding slag or tubing cuttings, or other debris may foul the Shutoff valves, the dP Regulator, the GV1 (or ECV5) in the GSS if allowed to enter. If this occurs, the Shutoff valves, the dP Regulator, the GV1 (or ECV5) in the GSS may not function properly, due to the valve setting or dP regulator and GV1 Poppet assembly being improperly seated. To this effect Continental Controls recommends that one (1) of two (2) types of safeties be installed to monitor the amount of fuel present in the engine during light off. The installation of these items provides a redundant safety measure, ensuring that there is no single point failure of the fuel system.

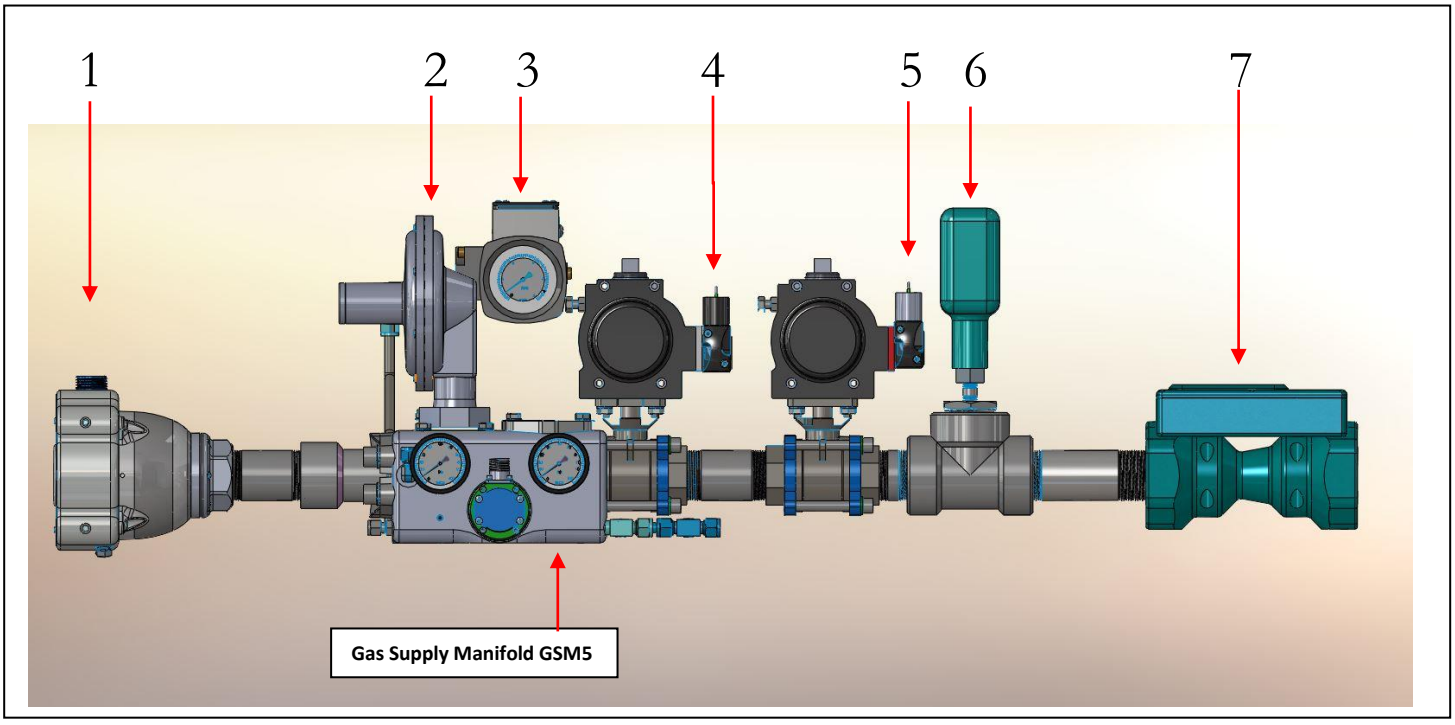


Figure 4: Gas Substitution System using **pneumatic actuator ball valves**

Item	Component	Cable
1	CCC Gas Pressure Control Valve GV1	60401507-1
2	Differential Pressure Regulator	-
3	High pressure switch w/ gauge	60401527-1
4	Asco Namur Solenoid valve	60401517-1
5	Asco Namur Solenoid valve	60401517-1
6	Low Pressure Switch	60401527-1
7	CCC Gas Flowmeter FM50	54701507-3

Item	Manufacturer	Part number	Temp rating	Certification mark	Cable
1	Omega	PSW-236	-54°C to +71°C	UL and cUL Div 2	60401527-1
2	ASCO	8551	-15°C to +25°C	CSA Div2	60401517-1
3	ASCO	8551	-15°C to +25°C	CAS Div2	60401517-1
4	Mid-West	142-AA-00-O (FA)	-40°C to +93°C	CSA-C22.2 No. 14.25 and 30	60401527-1
5	CCC	52600008	-40°C to +85°C	CSA Class 1 Div2	60401507-1
6	CCC	54700008	-40°C to +85°C	CSA Class 1 Div2	54701507-3

ITEM 1	N.O. CONTACT	60401527-1 RED
OMEGA PSW-236	COMMON	60401527-1 BLACK

ITEM 4	N.C. CONTACT	60401527-1 ORANGE
MID-WEST 143-AA-00-O (FA)	COMMON	60401527-1 BROWN

Item	Manufacturer	Part number	Temp rating	Certification mark	Cable
1	Omega	PSW-236	-54°C to +71°C	UL and cUL Div 2	60401527-1
2	ASCO	8551	-15°C to +25°C	CSA Div2	60401517-1
3	ASCO	8551	-15°C to +25°C	CAS Div2	60401517-1
4	Mid-West	142-AA-00-O (FA)	-40°C to +93°C	CSA-C22.2 No. 14.25 and 30	60401527-1
5	CCC	52600008	-40°C to +85°C	CSA Class 1 Div2	60401507-1
6	CCC	54700008	-40°C to +85°C	CSA Class 1 Div2	54701507-3

The following two tables represent the components included in the GSS kit for single bank engine applications and dual bank engine applications.

KIT, Gas Substitution System; Application Configuration: Single Bank Engine, Control Option 1: GV1, HMI Option: 8" Display; P/N: 60400008-S-GV1

Item	Qty	Description	Part Number
1	1	Manifold, GSS; Application Configuration: Single Bank Engine	60400058-S
2	1	Gas Valve, Model GV1; Control Option: CANBUS, Pressure Transducer Configuration: 5 PSI	52600008-CANBUS-5PSI
3 (5)	1	Assembly, Gas Substitution System Interface	60401008-X-GV1-X
4 (4)	1	Sensor, Vibration, 0-2 inch per sec, 4-20 Looped Power	640B0X02
5	1	Thermocouple, Type K, 6" Long	TJ36-CAIN-14U-6CC-XCIB
6 (3)	1	Antenna, Magnetic Mount, RPSMA, 2.45 GHZ	60401059
7 (1)	1	Cable, GV1	60401507-1-30
8 (1)	1	Cable, Shutoff Valve	60401517-1-30
9 (1)	1	Cable, Pressure Switch	60401527-1-30
10 (1)	1	Cable, Vibration Sensor	60401547-1-30
11 (1)	1	Cable, Power	60401557-1-30
12 (1)	1	Cable, External Shutoff Switch	60401567-1-30
13 (1)	1	Cable, ECU	60401577-1-30
14 (1)	1	Cable, Thermocouple	60401587-30
15	1	Hose, Flexible, 1/4" ID, 1/4" Flare Female Swival, 5 feet Length, AeroEquip	A-GH781-4FJ-4FJ-4-5FT
16	1	Hose, Flexible, 3/8" ID, 3/8" Flare Female Swival, 5 feet Length, AeroEquip	A-GH781-6FJ-6FJ-6-5FT
17 (2)	1	Hose, Flexible, Braided, Natural Gas, 1 1/2 MNPT S.S., 2 Feet Length	701C24X24NPTSS_CUSTOM ASSEMBLY NATURAL GAS
18	1	Adapter, Male AN-Thread, 1/4" Tube X 1/4" AN Flare, S.S.	SS-4-TA-1-4AN
19	1	Adapter, Male AN-Thread, 3/8" Tube X 3/8" AN Flare, S.S.	SS-6-TA-1-6AN
20	1	Connector, Male NPT, 1/4" Tube X 1/4 MNPT, S.S.	SS-400-1-4
21	1	Connector, Male NPT, 3/8" Tube X 3/8 MNPT, S.S.	SS-600-1-6
22	1	Connector, 1/4" Tube X 1/4" MNPT, Bore Thru, S.S.	SS-400-1-4BT
23	1	Plug, 1/4" Tube, S.S.	SS-400-P
24	1	Elbow, 1/4" MNPT X3/8" Tube, S.S.	SS-600-2-4
25	1	Elbow, 3/8" MNPT X 3/8" Tube, S.S.	SS-600-2-6
26	1	Nipple, Pipe, Sch. 40, 1 1/2" Pipe, 2" Length, S.S., Sch 80	37504120
27	1	Coupling, Union, 1 1/2" Pipe, S.S., Sch 80	37456760

KIT, Gas Substitution System; Application Configuration: Dual Bank Engine, Control Option 1: GV1, HMI Option: 8" Display; P/N: 60400008-D-GV1

Item	Qty	Description	Part Number
1	1	Manifold, GSS; Application Configuration: Single Bank Engine	60400058-S
2	2	Gas Valve, Model GV1; Control Option: CANBUS, Pressure Transducer Configuration: 5 PSI	52600008-CANBUS-5PSI
3 (5)	1	Assembly, Gas Substitution System Interface	60401008-X-GV1-X
4 (4)	1	Sensor, Vibration, 0-2 inch per sec, 4-20 Looped Power	640B0X02
5	1	Thermocouple, Type K, 6" Long	TJ36-CAIN-14U-6CC-XCIB
6 (3)	1	Antenna, Magnetic Mount, RPSMA, 2.45 GHZ	60401059
7 (1)	2	Cable, GV1	60401507-1-30
8 (1)	1	Cable, Shutoff Valve	60401517-1-30
9 (1)	1	Cable, Pressure Switch	60401527-1-30
10 (1)	1	Cable, Vibration Sensor	60401547-1-30
11 (1)	1	Cable, Power	60401557-1-30
12 (1)	1	Cable, External Shutoff Switch	60401567-1-30
13 (1)	1	Cable, ECU	60401577-1-30
14 (1)	1	Cable, Thermocouple	60401587-30
15	1	Hose, Flexible, 1/4" ID, 1/4" Flare Female Swival, 5 feet Length, AeroEquip	A-GH781-4FJ-4FJ-4-5FT
16	1	Hose, Flexible, 3/8" ID, 3/8" Flare Female Swival, 5 feet Length, AeroEquip	A-GH781-6FJ-6FJ-6-5FT
17 (2)	2	Hose, Flexible, Braided, Natural Gas, 1 1/2 MNPT S.S., 2 Feet Length	701C24X24NPTSS_CUSTOM ASSEMBLY NATURAL GAS
18	1	Adapter, Male AN-Thread, 1/4" Tube X 1/4" AN Flare, S.S.	SS-4-TA-1-4AN
19	1	Adapter, Male AN-Thread, 3/8" Tube X 3/8" AN Flare, S.S.	SS-6-TA-1-6AN
20	1	Connector, Male NPT, 1/4" Tube X 1/4 MNPT, S.S.	SS-400-1-4
21	1	Connector, Male NPT, 3/8" Tube X 3/8 MNPT, S.S.	SS-600-1-6
22	1	Connector, 1/4" Tube X 1/4" MNPT, Bore Thru, S.S.	SS-400-1-4BT
23	1	Plug, 1/4" Tube, S.S.	SS-400-P
24	2	Elbow, 1/4" MNPT X3/8" Tube, S.S.	SS-600-2-4
25	2	Elbow, 3/8" MNPT X 3/8" Tube, S.S.	SS-600-2-6
26	2	Nipple, Pipe, Sch. 40, 1 1/2" Pipe, 2" Length, S.S., Sch 80	37504120
27	2	Coupling, Union, 1 1/2" Pipe, S.S., Sch 80	37456760

KIT, VENTURI, AFM4, NATURAL GAS, GSS, P/N: 60400088-1

Item	Qty	Description	Part Number
1	1	Advanced Fuel Mixer, Model AFM4; Venturi Option: Standard Natural Gas	53800008-VNR
2	1	Nipple, Pipe, Sch. 40, 1 1/2" Pipe, 4" Length, S.S.	Windustrial
3	2	Coupler, Hose, Straight, Silicone, 4.0" - Black	SIL000470
4	4	Clamp, T-Bolt, 4" Silicone Hose Coupler, S.S.	CLA000310

KIT, VENTURI, AFM7, NATURAL GAS, GSS, P/N: 60400078-1

Item	Qty	Description	Part Number
1	1	Advanced Fuel Mixer, Model AFM7; Venturi Option: Standard Natural Gas	53700008-VNR
2	1	Nipple, Pipe, Sch. 40, 1 1/2" Pipe, 4" Length, S.S., Sch 80	Windustrial
3	2	Reducer, Hump Hose, EPDM, 7" to 5" - Black	7H5
4	2	Clamp, T-Bolt, 5" Hose, S.S.	94100-0550
5	2	Clamp, T-Bolt, 7" Hose, S.S.	94100-0750

KIT, Gas Flowmeter, 60400038-1 or (-2 for dual bank engine)

Item	Qty	Description	Part Number
1	1	Flowmeter, Model FM50, Supply Pressure= , Gas Type=	54700008-1 or -2
2	1	CABLE, INTERFACE, FM50 TO GSS, 30' LONG	54701507-3-30
3	1	FM50 FLANGE KIT; THREADED FLANGE HEAD	54709009-2

KIT, WATT METER, ____ kW, 3 PHASE, 3 / 4 WIRE CONNECTION, 4-20 mA, UL / CSA APPROVED, P/N: 60400128-_____

Item	Qty	Description	Part Number
1	1	WATT TRANSDUCER, 3 PHASE, 3 / 4 WIRE CONNECTION, 4-20 mA, UL / CSA APPROVED	AGW-008E
2	2	CURRENT TRANSFORMERS, 600V CLASS, CURRENT RATIO 1000:__, ___ kW, CSA / UL APPROVED	19RL-____
3	1	SHORTING BLOCK, 6 POLE, 600V	1706SC
4 (1)	1	Cable, Load	60401537-1-30

WATT-METER KIT P/N:	CT P/N:
60400128-0480	19RL-601
60400128-0640	19RL-801
60400128-0800	19RL-102
60400128-0960	19RL-122
60400128-1200	19RL-152
60400128-1600	19RL-202

*Dash number at the end of Watt-Meter Kit represent Kilowatt range

Installation Tips and Steps

The following steps below are some important steps and tips to be considered during installation:

- Insure that the systems are installed in a location that is easily accessible, not subject to damage by rig personnel and is easily removed. Some good locations for the install are:
  - Above the storage closet in the buildings
  - On the base rails of the engines preferably not in the access corridor between engines
  - Above the engine frame itself.
- Mount to Control box on the wall near the engines being controlled.
- Ensure that the vent line from the regulator is vented to outside atmosphere.
- In all cases mount the gas sensing heads as close to the valve trains as possible and close to the radiators
- Set the controls and shutdown set points as highlighted later in this documentation.

During installation the following tips should be adhered to:

1. **Piping**
    - All the piping should be Sch80 stainless. To prevent gall non stainless steel piping can be used.
    - It is preferred that 1 ½" piping be used in the valve train.
    - Leak test all of the piping to at least 150 psig
    - Ensure that all of the piping is thoroughly cleaned prior to use
    - A filter screen is required upstream of the turbine meter and upstream of the regulator, solenoid valve.
    - All hoses feeding gas properly labelled
2. **Left/Right GV1**
    - Each of the GV1 units are designated as left bank or right bank and these have to be confirmed and checked prior to installation. If the GV1 needs to be configured for left bank (ModBus ID 1) and right bank (ModBus ID 2), use the GV1 Valve Viewer to configure each valve separately. Ensure one valve is connected to the GSSI when performing such step.
    - All of the old GVI units (silver and black) are designated as left bank and only usable on the old non-display systems
    - Cannot install two left or two right bank units or they will compete
3. **Pressure Sense lines**
    - Post Turbo Installations:
        - One sense runs from the air intake upstream of venturi to low pressure side of DPI and to reference side of regulator.
        - One sense line runs from reference port on the venturi to the reference port on the GV1
        - One sense line from engine intake manifold downstream of venturi to HP side of DPI and also to tap downstream of regulator (via check valve allowing flow from engine intake to the valve train)
    - Pre-Turbo Installations:
        - One sense line runs from reference port on the venturi to the reference port on the GV1
        - Regulator is to be vented outside
    - Looking at writing on GV1 ensure that sense line is connected to Left bottom reference port
    - Watch for open plugs on the GVI as you can overpressure the internal transducer of the unit
    - Similarly watch for sintered brass filter plugs on the GVI

- All reference ports on the AFM4 / AFM7 venturi (larger red units) all reference upstream or air intake pressure.

4. **Protect cabling**
    - All end connections should be reinforced, protected and checked
    - Ensure that no cable is subject to rig operators being able to step on or kink and damage the wiring.
5. **Mounting of train**
    - Preferred location is above engines
    - Alternatively put on non-traffic access side of engine
    - Set up so that engines can be removed quickly with minimal disconnect. Disconnects required for watt meter, vibration, EGT, ECU, Sense lines and main gas supply lines.
    - Should only have one disconnect (fuel line from injection venturi)
    - The GVI units are generally heavy and with engine vibration there is a possibility of disconnecting the gas line from the venture. Ensure that the venturi is bracketed/Clamped and supported.
6. **Set points on gas supply or ITT regulators**
    - Should 50-60 psi which is high enough to feed gas to post turbo injection. If Pneumatic actuated valves are used, then minimum of 75-80 psi supply is required.
    - Need a pressure that is low enough so that we minimize instability in regulators but still high enough to inject at turbo boost pressures.
7. **Length of hoses**
    - Minimize hose length so that we do not have shut down lag and also
    - Want to minimize the amount of hose that could have combustible air/gas mixture
8. **Power supply**
    - Ensure there is a 12-15 AMP fuse at power source so that the chance of blowing the onboard fuses is minimized
    - Ensure there is a switch to shut off main power to the GSS display and control unit.
9. **diesel meters (if Installed)**
    - Use only 5/8” or larger hoses.
    - Smaller hoses have restrictions.
    - Do not use any Teflon tape as the internal components of the meter can be damaged by Teflon tape winding around the turbine.
10. **Remote Access computer needs to be set- up with the following:**

- Each Bi-fuel computer needs to have a Synapse USB radio stick which communicates with the GSS stem.
- The computer needs to have GSS viewer (V1.31) installed on the desktop.

Other components are installed with the Bi-fuel systems. The installation and maintenance instructions from the manufacturer should be adhered to but the following tips can mitigate problems with operational reliability of the units.

Pre Commissioning and Startup Checklist

The following are startup checklist of the Gas Substitution System.

- ☐ Check all connection and installation on Main gas line
  - All equipment installed.
  - All connections tight.
  - No open Thread-o-lets.
  - Witches hat/Strainer installed upstream of manual block valve.
  - Manual valve handle on correctly.
  - Correct spring in regulator.
  - Regulator has 10mm port.
- ☐ Leak test and pressure integrity test with compressed air
  - Pressure line to 20 psig check for leaks.
  - Manual valve closed and holding.
  - Manual valve open and solenoid valve closed and holding.
  - Solenoid valve open and regulator regulating to 4-5 psi.
  - All valves to GV1 open and tested.
  - Repeat tests at 100 psig as above for integrity test.
- ☐ Cabling
  - Confirm all new version cables used (Part number 15xx…).
  - All cables tested for pin to ground shorts.
  - All cables tested for pin to pin shorts.
  - Shield cable on solenoid valve cable removed.
  - Diode in solenoid valve in place (Bar on Diode to +ve red (terminal 2))).
  - End devices all connected and snug.
  - GSS ends connected to cabinet and snug.
  - Hawke flow meter cables connected and tight.
  - All cable wire ends protected and tight.
- ☐ End devices checked for function.
  - Low pressure switch switches at 30 psi.
  - DPI high pressure switch switches at 5PSI.
  - Solenoid valve opens and closes.

- Regulator maintains pressure.

☐ Sense an reference lines
- Venturi reference to Left port on GVI.
- Air intake – LP on DPI – Regulator reference.
- Engine manifold – HP on DPI thru check valve – Tee downstream of regulator.
- GV1(s) installed properly.
- All tubing closed off and capped.
- All ports on GV1 plugged and no sintered brass filter.
- On non-turbo systems (fumigation) reference line only from venturi to GV1.

☐ GSS system Display Unit
- Board fuses all checked for continuity.
- Most recent HMI firmware installed.
- Most recent GSS firmware installed.
- USB logging memory stick installed.
- Main shutoff switch and fuse (12A+ installed).
- System powered up and ready.
- Magnetic antenna mounted high and outside of building.
- Label Red button (Push to stop / Pull to Start Gas /Recycle).
- Initial set points set on panel/GSS.

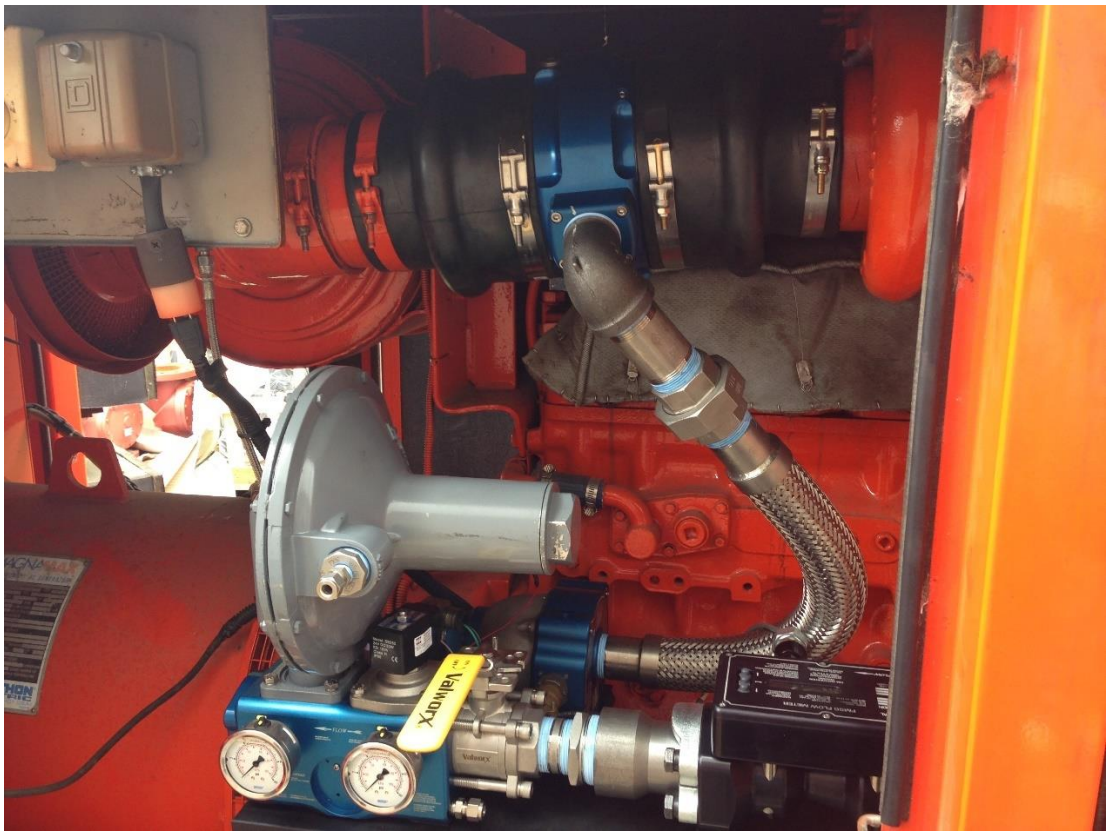


Figure 5: Installation Illustration

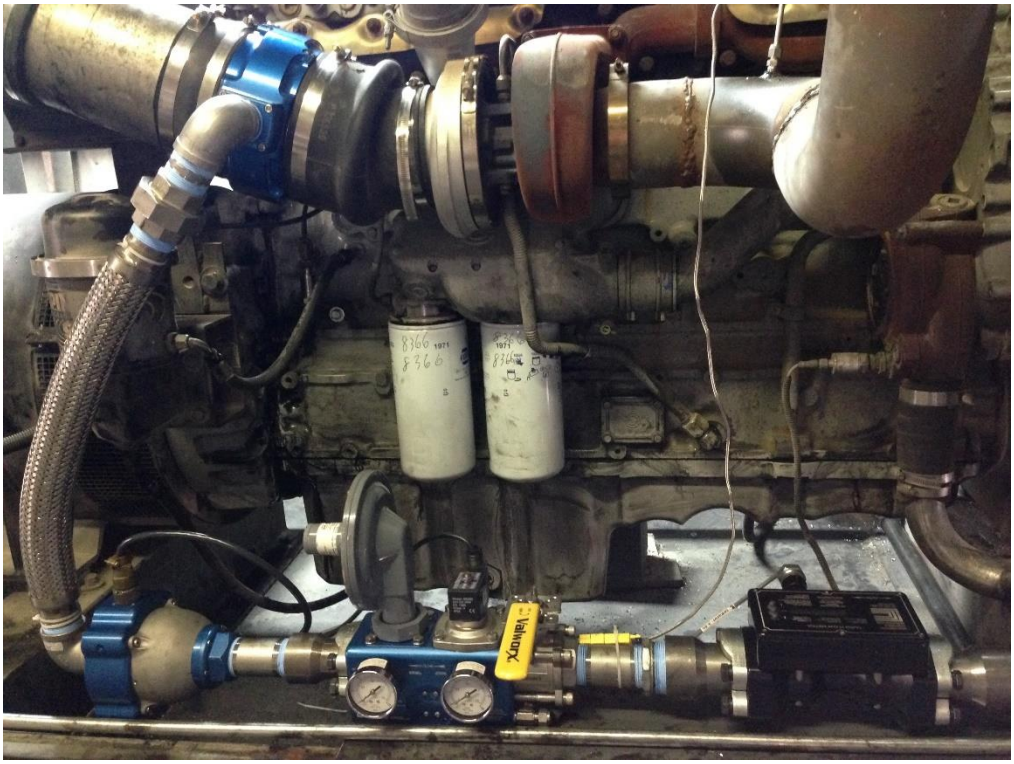


Figure 6: Installation Illustration

Mechanical Connection

Before beginning the assembly of the GSS, remove all parts from the shipping box and check that all required components are present. Use the list in the previous section to verify. Below are the steps to follow.

Preliminary Steps

1. Select a location on the engine's air intake manifold to introduce natural gas. The location can be either pre or post-turbo. The manifold must be cut to leave enough room to properly place the venturi with the rubber reducers.

Sensors

2. Attach the thermocouple to the engine exhaust manifold. The thermocouple can be attached with the ¼" MNPT compression fitting.
3. Attach the vibration sensor with a ¼" bolt (bolt included) to the engine block at a location where it can be fastened. Preferably in the center of the engine block
4. *(Optional):* Install the watt meter, based on the wiring schematic shown in Section (Load Sensor) of this manual.

GV1 & Venturi

5. Use rubber sleeves and fasteners to secure the Venturi to the desired location on the air intake manifold. Be aware of the direction of air flow conveyed by the arrow on the side of the Venturi. The Venturi should also be oriented such that the gas inlet is facing downward (Figure 5 & Figure 6).
6. Use the figure below to assemble the FMV6/AFM7 to the GV1/ECV5 with the proper fittings.

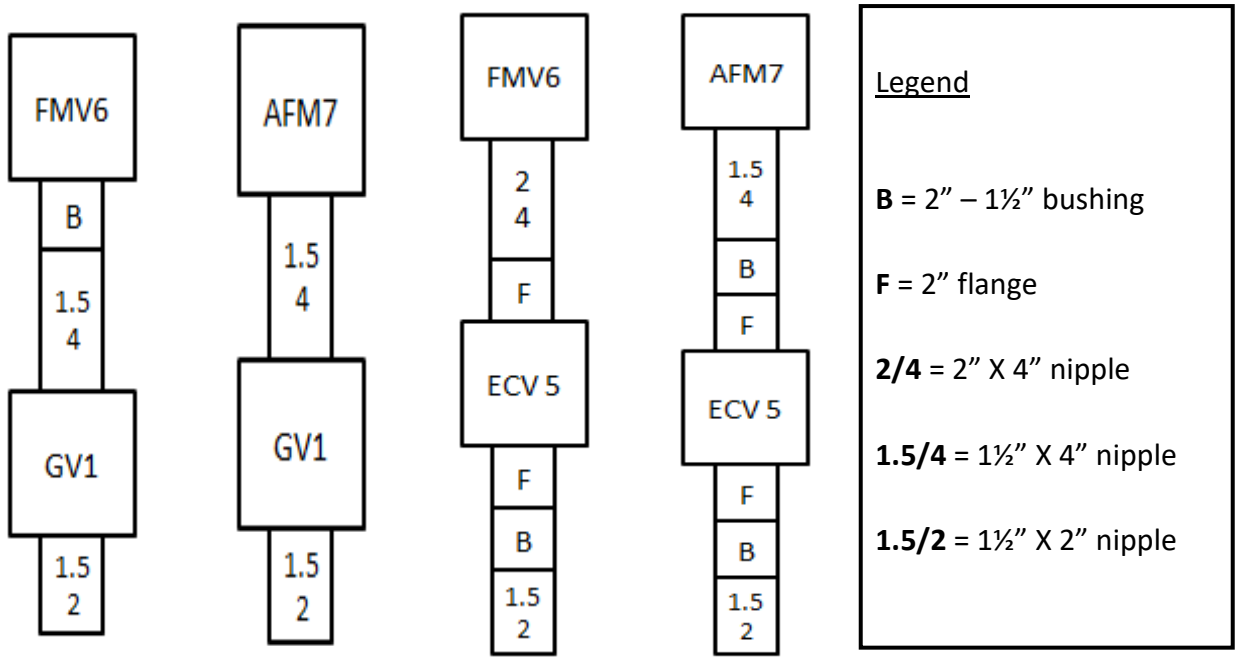


Figure 7 Gas control assembly for FMV6/AFM7 and GV1/ECV5.

Note: The GV1 should be oriented such that the flat side with the black cover is facing upward.

7. Connect the ⅜" tube X ¼" MNPT to the GV1's (Figure 8) or the ECV5's (Figure 9) reference port marked by the arrow.
8. Connect the ⅜" tube X 3/8" MNPT to the tapped hole in the Venturi.

Figure 8 Reference port of GV1.

Figure 9 Reference port for ECV5.

Figure 10 ⅜" tubing for pressure reference.

Gas Manifold

9. Secure the gas manifold to the engine such that the flow output of the gas manifold is near the flow inlet to the GV1/ECV5. It must be close enough so the 1½" stainless steel hose can be attached (Figure 11).
10. Attach the 1½" stainless steel hose to the outlet side of the gas supply manifold using series 61 SAE flange. Attach the other end of the hose to the inlet side of the GV1/ECV5.
11. Connect 3/8" air reference hose from the venturi pre-tapped 3/8" NPT port to the ¼" npt port of the GV1 (figure 8).
12. Connect 3/8" air reference hose from the venturi pre-tapped 3/8" NPT port to the Gas Supply Manifold fuel inlet 3/8" swage fitting (Figure 12). The GV1 and the Gas Supply Manifold air reference hose MUST be separate by preventing lag between the fuel supply and air reference in the GV1. If the installation is downstream of the turbocharger, the turbo air pressure is referenced.

Note: The AFM4 / AFM77 has three reference ports shown in Figure 13 and it does not matter which of these the operator chooses.

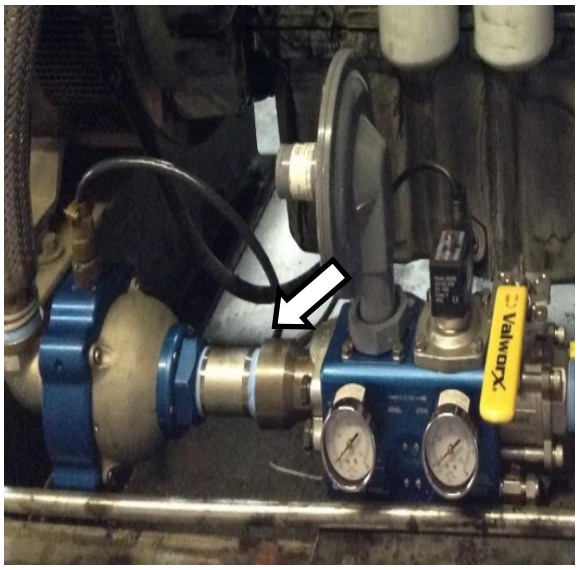


Figure 11 Stainless steel hose attachment.

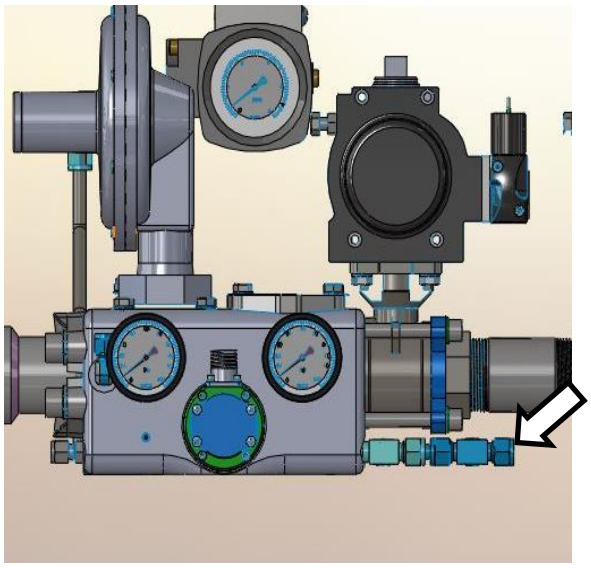


Figure 12 ¼" Hose attachment.

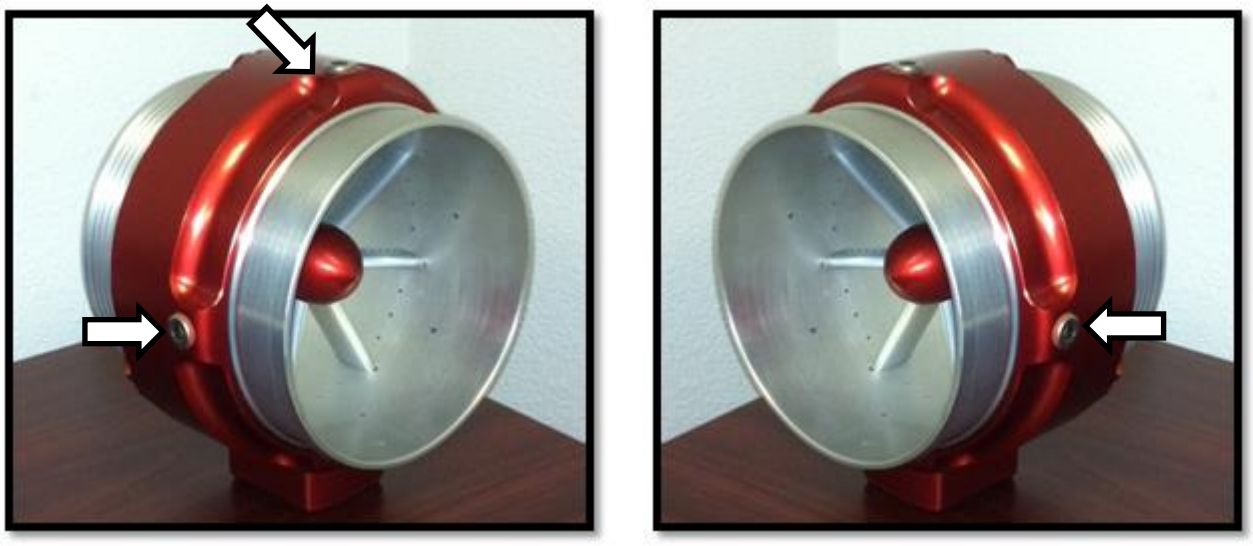


Figure 13 Reference ports for AFM4 / AFM7

Diesel Flow Meters (Optional)

13. Mount the "forward flow sensor" to the engine near the fuel pump. Connect the outlet port of the flow meter to the fuel pump using the ½" flare flexible hose. Connect the inlet port of the flow meter to a diesel fuel supply using another ½" flare flexible hose.

14. Mount the "return flow sensor" to the engine near the fuel return line of the engine block. Connect the flow meter's inlet port to the engine block's fuel return line using the ½" flare flexible hose. Connect the outlet of the flow meter to a diesel fuel return using another ½" flare flexible hose.

Gas Flow Meter (Optional)

15. Connect the outlet of the gas flow meter to the inlet of the gas train using a ½" hose (not provided).

Final Steps

The GSS is now set up mechanically and will require a supply of pressurized natural gas and connections from all the electronics to the PC interface. The electronic connections are discussed in the following section on wiring. For proper operation of the GSS, the range of gas pressure is 40 – 100 psi for post-turbo applications and 5 – 100 psi for pre-turbo applications. Connect a ½" NPT male hose to the inlet of the gas train (or gas flow meter) and the other end of the hose to the regulated natural gas supply.

Wiring and Cabling

The sensors, transducers and flow meters all send electronic signals to the substitution interface to display the information to the operator. The substitution interface has several terminals located underneath its case with the appropriate labels clearly marked for each connector, shown in Figure 14 below.

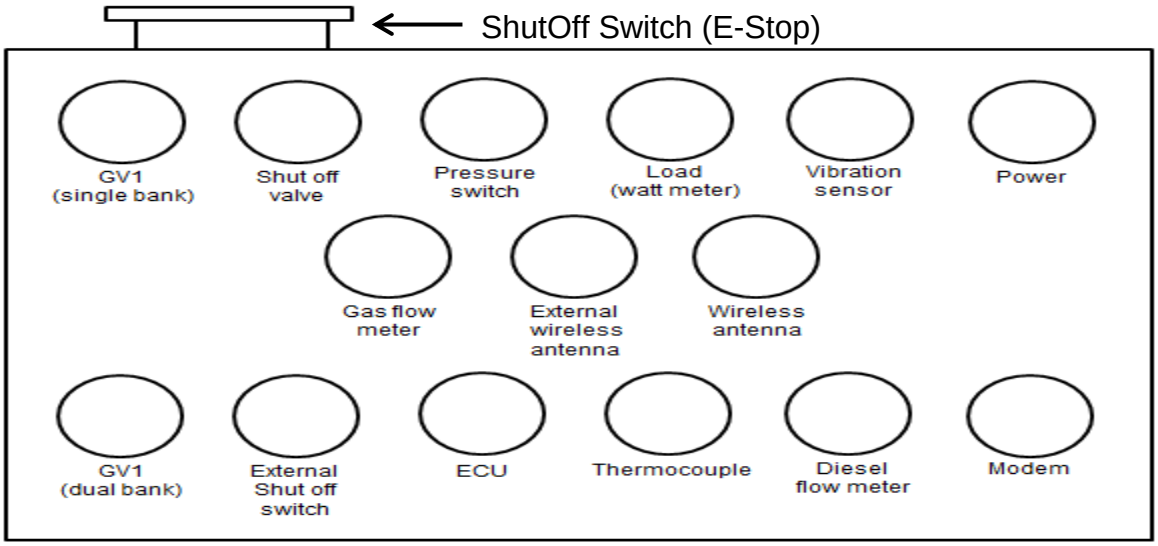


Figure 14 View from bottom of substitution interface.

GSS and ECU Communication

The GSS and ECU communication link is mandatory for the operation of the system. The GSS reads diesel fuel flow and RPM from the ECU using the CANBus J3919 port. Engines that do not have an ECU or have an ECU that does not support J3919 are not compatible with the GSS and installation should not be attempted. CANBus is a two-wire protocol. The GSS had a dedicated cable for connecting to the ECU CANBus. There is normally access to the CANBus pins directly on the ECU (Refer to your engine's user manual). Another area that provides easy access to the CANBus is the diagnostic port.

The CAT industrial connector has the following pin out:

A: +12VDC
B: GND
C: CAN Shield
D: CAT Data Link Hi
E: CAT Data Link Lo
F: CAN_H (J1939)
G: CAN_L (J1939)
H: J1708 Hi
J: J1708 Lo

The standard 9-pin diagnostic connector pin out is:
A: GND
B: +12VDC
C: CAN_H (J1939)
D: CAN_L (J1939)
E: CAN Shield
F: J1708 Hi
G: J1708 Lo
H: OEM Specific
J: OEM Specific

You can measure the polarity of pins A & B to determine which one it is.

GSSI Settings Configuration

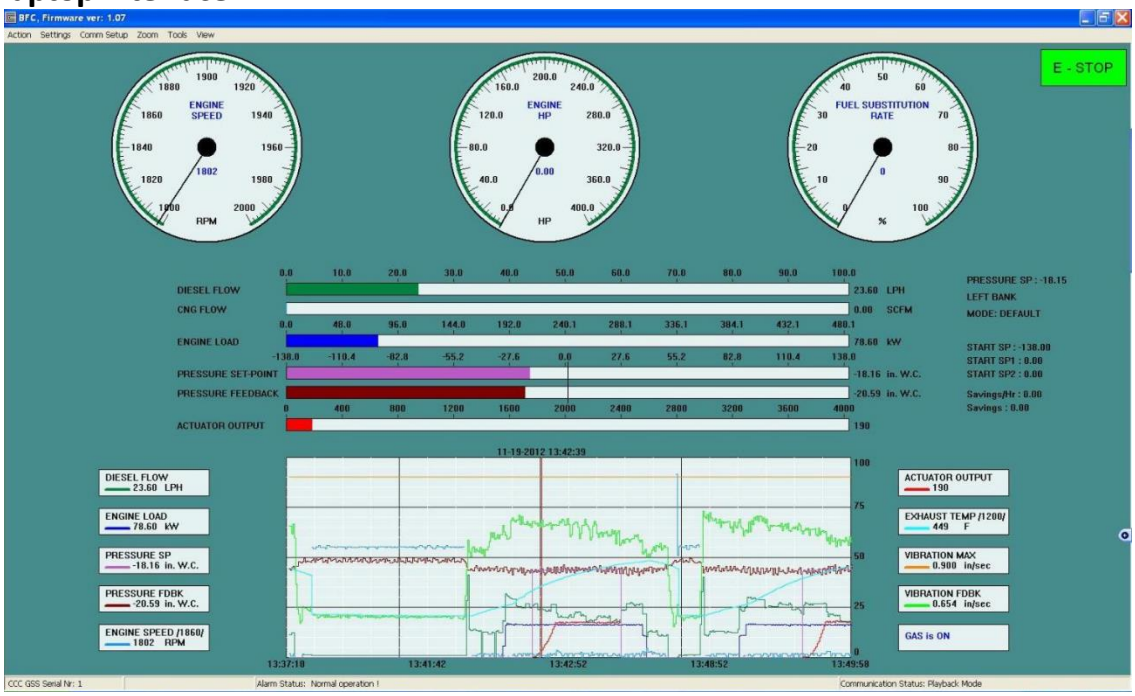
There are relatively few software settings in the GSS system. These settings are simple to understand and set. Some of the settings relate to safety, so it's important to understand the meaning of each setting and how they affect the operation of the engine. Complicated mapping of the substitution rate-to-engine load is not required for the GSS system. Only two operating parameters are required: a diesel flow set point and a minimum diesel flow limit. The GSS uses a unique and patented method where the fuel flow is read from the ECU and fed back into a closed loop control. The GSS meters gas proportionally into the air stream lowering the diesel flow to the desired set point.

A diesel engine has a minimum required fuel flow for proper ignition in each engine cylinder. If the flow drops below this point, there will be no ignition in one or more cylinders. The un-burnt combination of diesel and gas is a combustible mixture and can cause the cylinder to burn or explode in a different location. If there is an insufficient amount of diesel to cause good ignition, the controller needs to detect this and cease emitting natural gas into the engine. This is what the minimum diesel flow limit is for**.** For example, if load on the engine is removed and the governor reacts by reducing the diesel flow to below the required minimum, the GSS will react by temporarily shutting off the gas supply. After the engine has stabilized, the GSS slowly starts substituting natural gas again.

The substitution amount depends on the load amount. High rates of substitution at low loads are not possible because the introduction of gas drives the diesel below the safe minimum limit. There is a maximum programmable substitution rate. This limit cannot be set above 80%. The substitution rate will only work if the required instrumentation is provided to calculate substitution. On a generator, a watt meter and diesel flow-to-load schedule is needed. On pump or mechanical drive units, a gas flow meter is required.

Vibration and exhaust temperature are two indicators of incomplete ignition, or a rate of gas substitution that is too high. Unfortunately, what are considered normal vibration and exhaust temperatures vary widely from engine to engine. You will see some rise in exhaust temperature when substituting natural gas for diesel. Natural gas is a slow-burning fuel. Not all of the gas may be burned by the time the exhaust leaves the cylinder. You can expect a 10% rise in exhaust temperature when substituting natural gas.

GSS Laptop Interface



All set-up and monitoring can be done via the laptop interface. The laptop is connected to the GSS through a 2.4GHz radio installed in a USB port. The range of the radio is up to one mile, line of sight (in perfect conditions), but realistically, communication is limited to about 500 yards. If there are multiple GSS systems at the same site, **care must be taken that each GSS system has a unique modbus address**. Some of the items on the display are only available if optional equipment is installed.

The three gauges across the top of the display are:

1) ENGINE SPEED – from the ECU
2) ENGINE HP (optional equipment required.)
3) FUEL SUBSTITUTION RATE (optional equipment required.)

In the upper right corner is the E-STOP button that the user can click to disable the GSS system from his laptop.

The horizontal bars directly below, from top to bottom, are:

1) DIESEL FLOW (can be read from the ECU or external flow meter).
2) CNG FLOW (optional equipment required).
3) ENGINE LOAD (optional equipment required).
4) PRESSURE SET POINT to the gas fuel valve.
5) PRESSURE FEEDBACK from the gas fuel valve.

The chart record section displays the vibration and temperature levels.

When you are connected to the GSS, the laptop will automatically record a log file. This log file is tie date stamped, along with the serial number, and is small enough to be emailed. This is a useful tool for field support from Continental Controls Corporation.

GSS Local Interface

P/N: 60401008-GV1-CANBUS

The substitution interface allows the operator to monitor the GSS performance such as the diesel flow and fuel substitution rate. Below is the layout for the monitor of the interface.

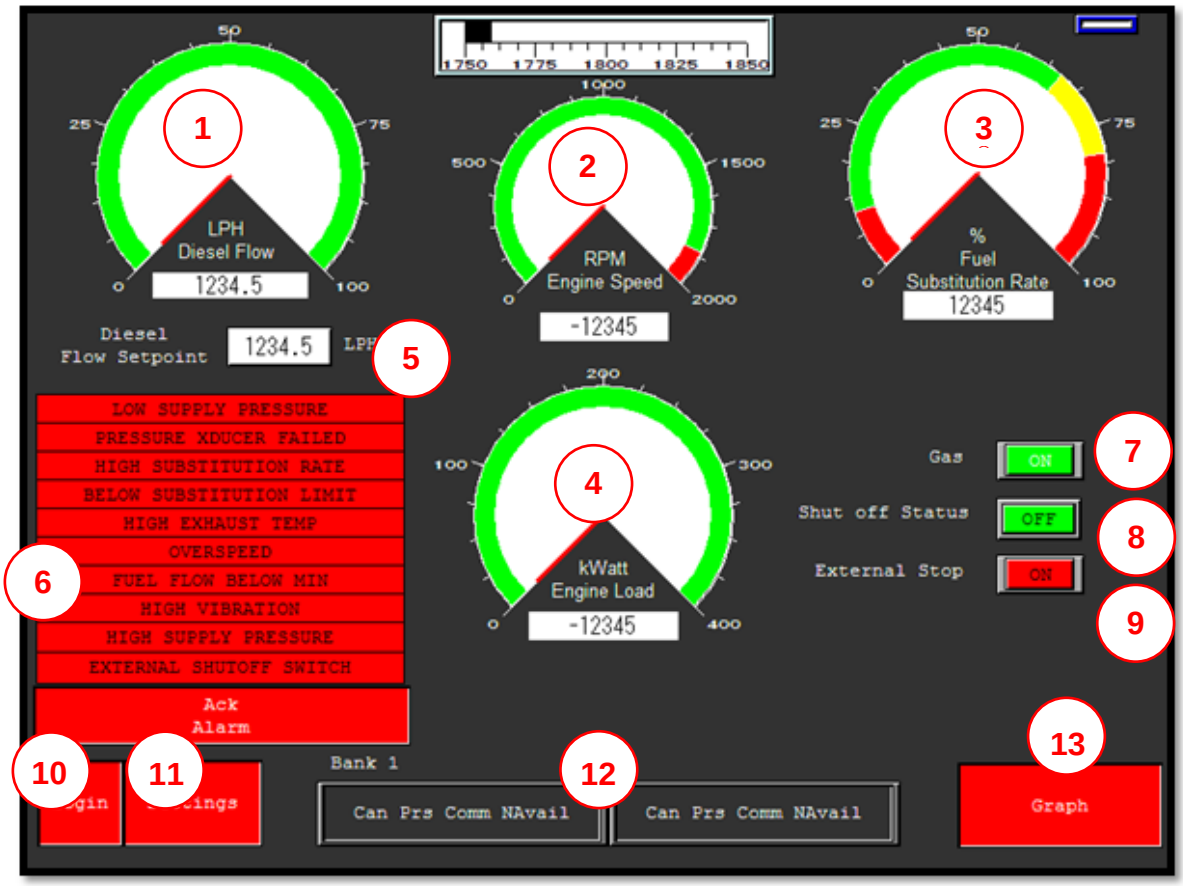


Figure 15 Monitor for substitution interface.

Legend

1. Diesel Flow Rate (LPH)
2. Engine Speed (RPM)
3. Fuel Substitution Rate (%)
4. Engine Load (Watts)
5. Diesel Flow Setpoint
6. Alarms
7. Gas Indicator
8. Shut Off Indicator
9. External Stop Indicator
10. Login
11. Settings
12. CanBusChannels
13. Graph Feature

GSS Variable Definition:

1. **Diesel Flow Rate**
   This measurement displays the difference between the diesel supply and return flow rate in liters per hour (LPH). This is the rate at which diesel fuel is being used by the engine and is determined from the engine's ECU or external flow meter.
2. **Engine Speed**
   The speed of the engine is determined from the engine's ECU in revolutions per minute (RPM).
3. **Substitution Rate**
   The substitution rate is a percentage of how much diesel flow is being substituted by natural gas for a given load.
4. **Engine Load**
   The engine load is measured from an optional watt meter to the display via a 4-20ma signal.
5. **Diesel Flow Setpoint**
   This is the amount of diesel flow required in order to achieve a desired substitution rate of natural gas. The value is displayed in liters per hour (LPH).
6. **Alarms**
   There are certain circumstances that will cause the GSS to automatically shut off for performance and safety reasons. The alarms are based on the following:
   - 1. Low supply pressure
   - 2. Failure of the pressure transducer
   - 3. High substitution rate
   - 4. Below the substitution rate limit
   - 5. High exhaust temperature
   - 6. Engine over speed
   - 7. Low fuel flow rates
   - 8. High vibration
   - 9. High supply pressure
   - 10. External shutoff switch engaged
7. **Gas Indicator**
   This is an On/Off display that indicates whether or not natural gas is being introduced into the engine.
8. **Shut-Off Status Indicator**
   This display indicates if the shut off switch on the substitution interface is engaged. The GSS will not be able to run until this switch is disengaged.
9. **External Stop Indicator**
   This display is used for an additional shut off switch if the operator wishes to have a separate switch not located on the substitution interface.
10. **Login**
    Users must log in to make any setting adjustments to the GSS. After 5 minutes the user will be automatically logged out to help prevent any unauthorized changes to the settings.
11. **Settings**
    This menu is only displayed when the user is logged in. Users are able to make changes to fuel substitution rates, exhaust temperature limits, Mod Bus addresses and vibration settings.

12. CanBus Channels

This display indicates the channel(s) being used by the CanBus for communication with the engine's ECU. Two channels will be displayed for dual bank operation.

13. Graph Feature

This feature displays all sensor values graphically in real-time while the GSS is in operation.

GSS Flow Control Settings Overview Summary

The following GSS settings are accessible via GSS Viewer and GSS Display. Navigate Flow Control Settings Dialog Box via

Main Menu -> Settings –> Flow Control (see full description below).

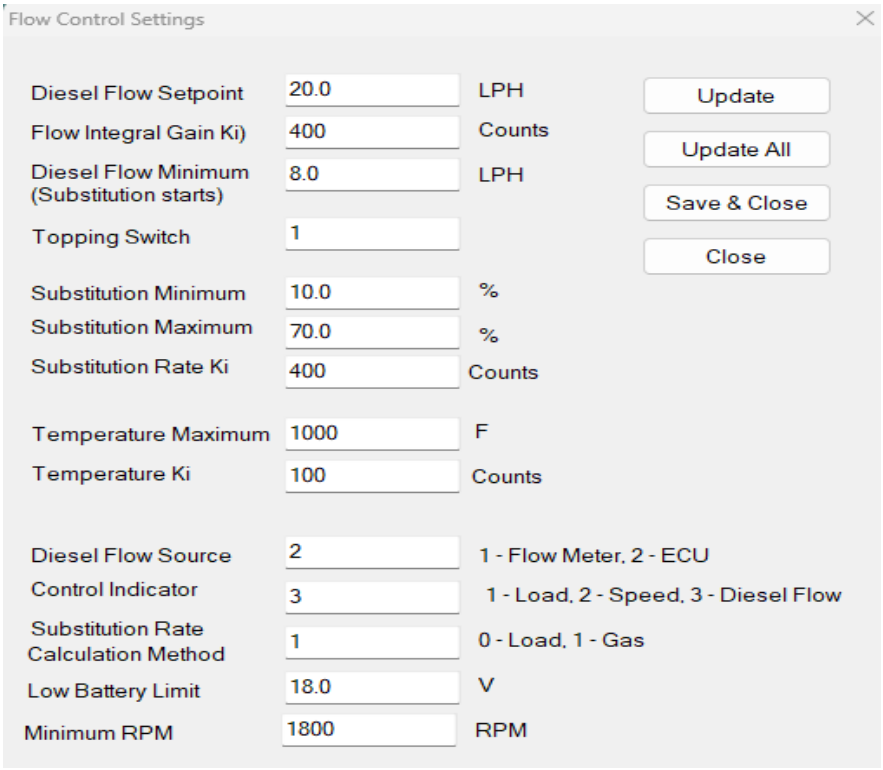


Figure 16

GSS Setting	Description	Range /Default	Scaling Factor	Units
Diesel Flow Setpoint	Diesel flow set-point that the GSS will control to in order to achieve desired substitution rate (See note 1)	Default:20.0	0.1	LPH
Flow Integral Gain (KI)	Controls how fast diesel flow setpoint is reached (See note 2)	Default: 400	1	Counts
Diesel Flow Minimum	Diesel flow setting where substitution starts (See note 3)	Default: 8.0	0.1	LPH
Topping Switch	Enable/Disable switch for Substitution Topping Control (It allows for additional control to keep the substitution below the substitution maximum)	1 – Enable 0 – Disable	1	NA
Substitution Minimum	Minimum achievable steady substitution rate at any engine load	Default: 10.0	0.1	%
Substitution Maximum	Maximum achievable substitution rate at maximum engine load	Default: 70.0	0.1	%
Substitution Rate Integral Gain (KI)	Controls how fast the substitution rate is being decreased to get below the Maximum Substitution setting (Used in Topping control)	400	1	Counts
Temperature Maximum	Maximum allowable exhaust temperature	1000	0.1	F
Temperature Integral Gain (KI)	Controls how fast the substitution rate is being decreased to get below the Maximum Temperature setting (Used in Topping control)	100	1	Counts
Diesel Flow Source	Indicates source for reading current diesel flow	1 – Diesel Flow Meter 2 – Engine ECU	1	NA
Control Indicator	Specifies control logic for substituting diesel with gas	1 – Load 2 – Speed 3 – Diesel Flow 4 – Manifold Pressure	1	NA
Substitution Rate Calculation Method		0 – Load Meter 1 – Gas Flow Meter		
Low Battery Limit	Minimum battery voltage required to enable fuel substitution	Default: 18.0	0.1	Volts
Minimum RPM	Minimum engine speed required to enable fuel substitution	Default: 1800	1	RPM

NOTES:

1. This is the diesel flow setpoint that the GSS will control to. Changing this setting will result in substitution rate adjustment. For example, if the engine load is such that on diesel only it will consume 100 LPH, and the flow setpoint is set to 50 LPH, the substitution rate will be 50% (the GSS will increase GV1 gas fuel pressure until the diesel flow feedback is 50 LPH). Under the same conditions, if you increase this to 60 LPH, the substitution will decrease to 40%.
2. Flow KI setting is the integral gain value to speed up or slow down the flow setpoint control (the speed at which gas fuel pressure changes to reach the desired diesel flow setpoint).
3. Diesel flow value where substitution would begin. This setting also affects off load transients. If the flow momentarily drops below this value during a transient, the system shuts off the gas, so we don't over substitute.

Configurating GV1

In dual bank application, the GSS requires the Gas Pressure Control valve GV1 to be configured for left bank and right bank by changing the Modbus address within the GV1. From factory, the dual bank GSS Kit already have been configured as left and right bank. In the case of replacing the GV1, the Modbus address needs to be changed and saved or in the case of troubleshooting, verified. If the Modbus address is not changed to the specific banks, the Gas Substitution System Interface (GSSI) will NOT recognize the right bank.

The Following are the steps to configure / verify GV1 Modbus address:

Warning: All changes should be made with engine stopped and GSS E-STOP engaged.

1. Turn off the power to GSS system.
2. Locate GV1 Left Bank and Right Bank DB9 connectors on GSS PCB board.

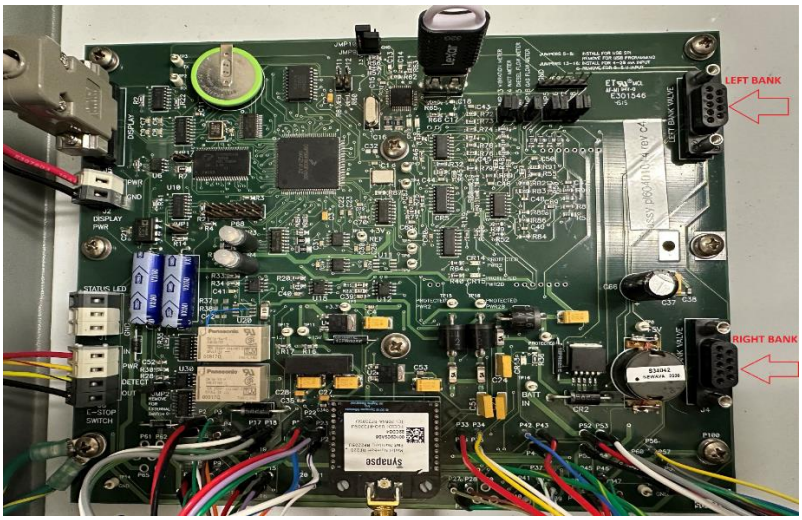


Figure 17

3. Connect straight-through serial cable with DB9 connector to the LEFT or RIGHT bank GV1 as shown in Fig.18, depending on which bank needs to be reconfigured. The other end of cable should be connected to user's laptop. The USB to Serial Adapter might be needed.
4. If you need to convert LEFT Bank GV1 Valve to the RIGHT Bank, connect your serial cable to the RIGHT Bank DB9 connector:
   - Make sure GV1 valve is connected to the RIGHT BANK valve connector on the bottom of GSS system box.
   - Disconnect the LEFT BANK GV1 valve from the GSS box (if connected).
5. If you need to convert RIGHT Bank GV1 Valve to the LEFT Bank, connect your serial cable to the LEFT Bank DB9 connector:
   - Make sure GV1 valve is connected to the LEFT BANK valve connector on the bottom of GSS system box.
   - Disconnect the RIGHT BANK GV1 valve from the GSS box (if connected).
6. Open Device Manager, check which communication port is assigned to USB adapter.

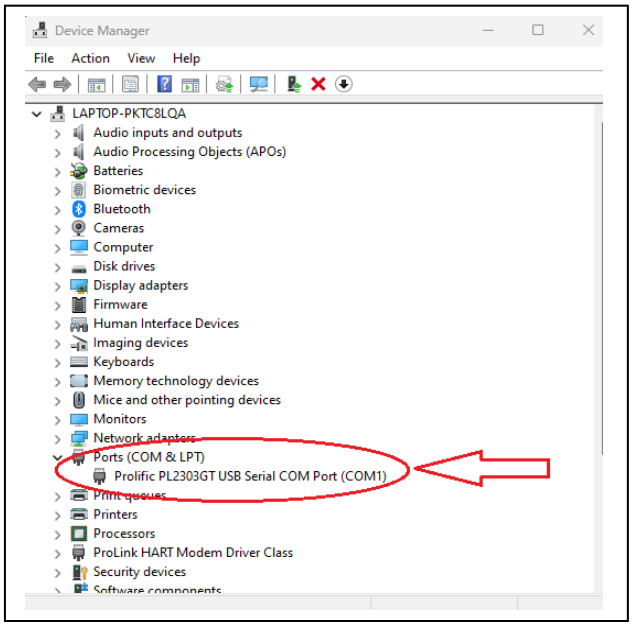


Figure 18

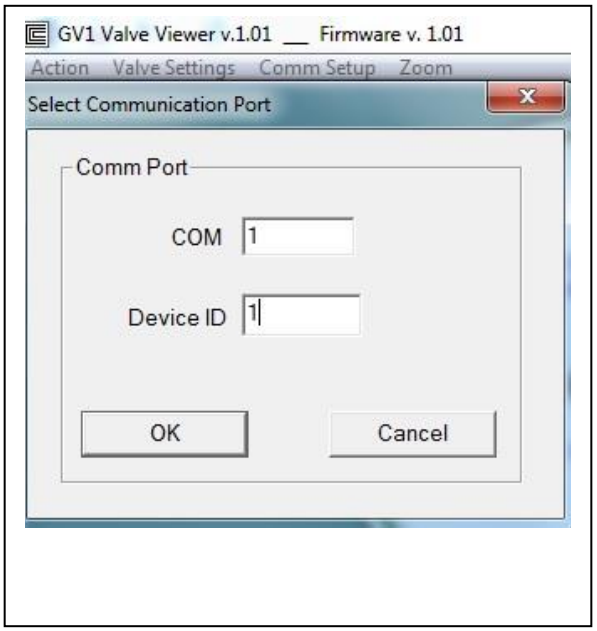


Figure 19

7. Turn on the GSS system.
8. Open GV1 Viewer, select Main Menu -> Comm Setup -> Comm Port option.
9. Enter the correct communication port number (as seen in Device Manager) e.g.:
   - Enter 1 for port COM 1, 2 for COM2, etc.
10. Enter the correct Device ID:
    - Enter 1 if GV1 is currently used as LEFT BANK valve;
    - Enter 2 if GV1 is currently used as RIGHT BANK valve.

11. Port Settings Dialog box should open. Do not modify any settings, click OK to proceed.

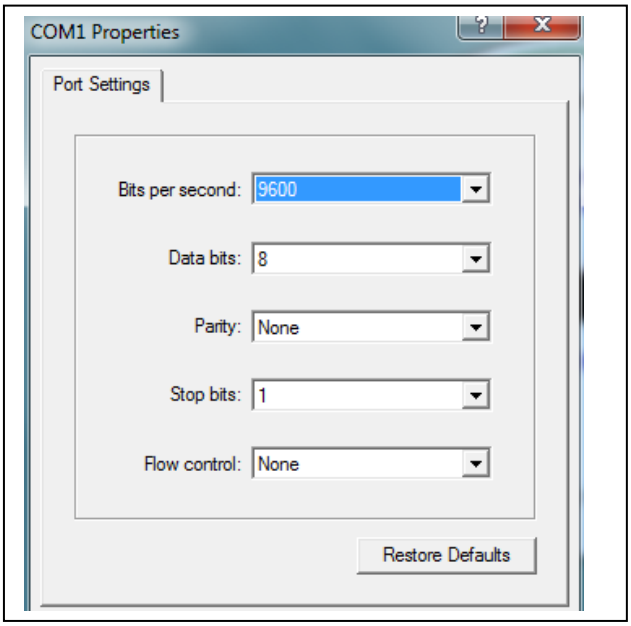


Figure 20

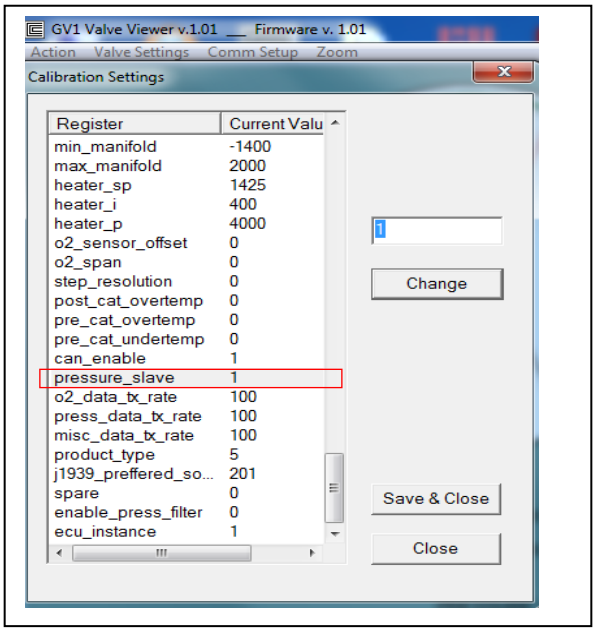


Figure 21

12. GV1 Viewer should be connected to the valve now. The graphics on the screen such as bar graphs, needles on the gauges, etc. should display live data.
13. Select Main Menu -> Valve Settings -> Calibrate Valve.
14. Enter password 1133 when prompted.
15. Calibration Settings Dialog box should open.
16. Locate **pressure_slave** setting, make sure it is set to 1:
17. Locate **ecu_instance** setting, change it as follows:
    - Enter 1 to reconfigure the valve for LEFT BANK;
    - Enter 2 to reconfigure the valve for RIGHT BANK.

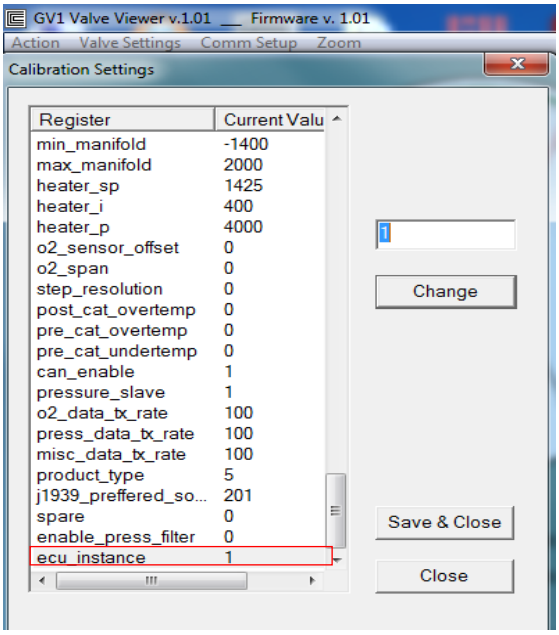


Figure 21

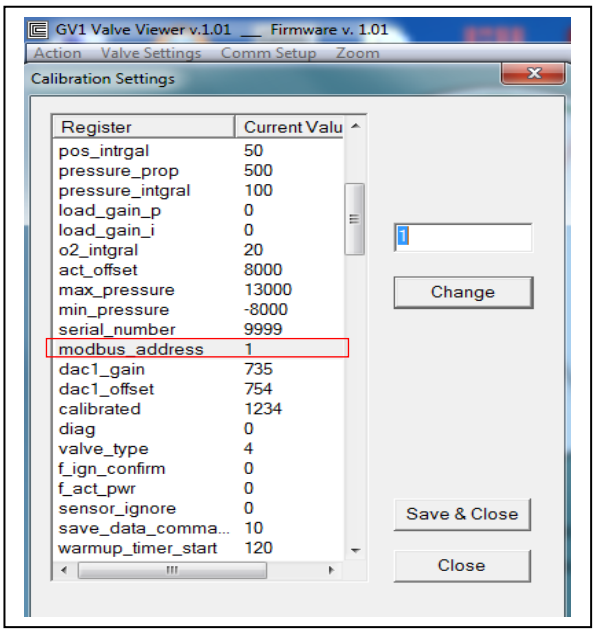


Figure 22

18. Locate **modbus_address** setting, change it as follows:
    - Enter 1 to reconfigure the valve for LEFT BANK;
    - Enter 2 to reconfigure the valve for RIGHT BANK.
19. Once all the settings are changed, press Save & Close button.
20. Close GV1 Viewer.
21. Turn off the power to GSS system, wait 3-5 seconds.
22. Turn on the GSS system.
23. You should be able to see reconfigured GV1 valve under the correct engine bank on GSS Display.
24. Repeat steps 4 through 23 for another GV1 valve as needed.

GV1 Fuel Pressure Limits

From factory, the limits (Min and Max pressure) are set as ±138 "H2O (in the software its ±13800). This is the allowable control pressure the GV1 will control the gas into the engine. The fuel pressure limits are an additional safety feature built in the GV1 to prevent over fuel of the engine at the maximum load conditions to achieve 70% gas substitution. The limits are user settable to the application.

The maximum pressure limit (Pressure_Max) in some application at 70% gas substitution, the GV1 will operate at 24" H2O, therefore your max pressure limits should be set to 30" H2O. In other application at 70% substitution the GV1 might be operating at 50" H2O. Therefore set the max pressure in the GV1 at 55" H2O.

The minimum pressure limit (Pressure_Min) are determined when the engine is running on 100% diesel at idle. During the engine idling at 100% diesel, monitor the GV1 pressure reading either when using GSSI (Gas Substitution System Interface) or your laptop using the GSS Viewer. In almost every case, during engine idling, the GV1 internal pressure transducer will be reading vacuum. In some case this vacuum might be -10" H2O the internal pressure transducer in the GV1 will be reading and other case it might be -20" H2O. The reading varies on the application. In any case, the minimum pressure limit must be set 10" H2O above the current vacuum reading in the GV1.

For example, Caterpillar C15 at 100% diesel idling, the GV1 internal transducer reads -5" H2O. Therefore, the minimum pressure (Pressure_Min) must be set at -15" H2O and saved. When entering -15" H2O, it's entered as -1500.

Warning: GSS E-STOP should be engaged during any settings adjustment.

For the safety reasons make sure gas pressure limits are set as follows:

1. Using GSS Viewer select Main Menu -> Settings –> Calibrate.
2. Calibrate Settings Dialog box should open.
3. Locate **pressure_min** setting. It should be set to -5000 (raw value). This corresponds to -50 in.W.C. The scaling factor applied is 0.01.
   - Based on the size of the engine and application in case minimum pressure setting could be reduced up to -20 in.W.C.

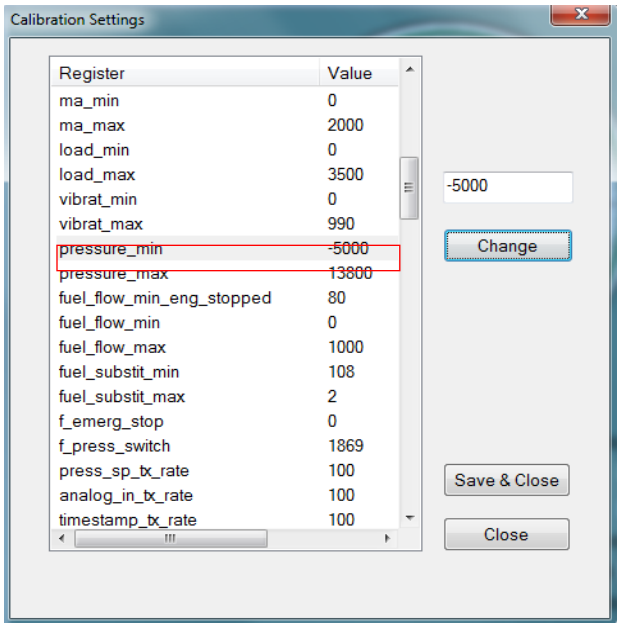


Figure 21

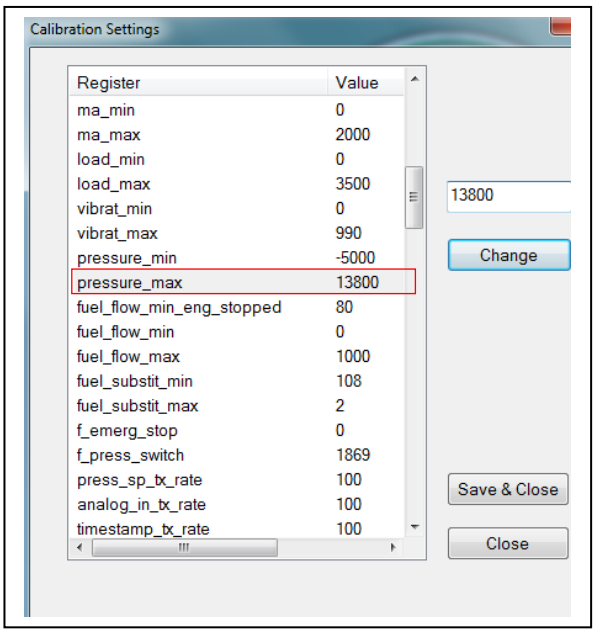


Figure 22

4. Locate **pressure_max** setting. The default value is set -13800 (raw value). This corresponds to 138 in.W.C. The scaling factor applied is 0.01.

- Based on the size of the engine and application, maximum pressure could be reduced as needed.

5. Enter a new setting if needed and press the Change button.
6. Press the Save & Close button.
7. Gas fuel pressure limits will take effect during the next engine run.

Recommended Initial Set-up

Flow Control Settings:

1. Diesel Flow Setpoint:

a. Disable the GSS by pushing in the "Stop" button on the GSS display box.

b. At full load (or the highest load you are able to run in your application) read the Diesel Flow on the GSS display. This number is your diesel fuel consumption at zero substitution. Set the Diesel Flow Set point to 60% of this value. The value cannot be below the Diesel Flow Minimum. This initial set point is for 40% substitution and is a safe starting point.

c. Engage the GSS by pulling the stop button out. The GSS will slowly start emitting gas to the engine.

d. Watch the diesel flow on the gauge, it should come down and control to the level you have entered in the diesel flow set point.

e. Note the vibration level and the exhaust temperature. If they have risen to an unacceptable level, reduce the level of substitution by increasing the diesel flow set point.

f. If more substitution is desired, reduce the diesel flow set point and go to step d. Do not attempt to substitute greater than 70%.

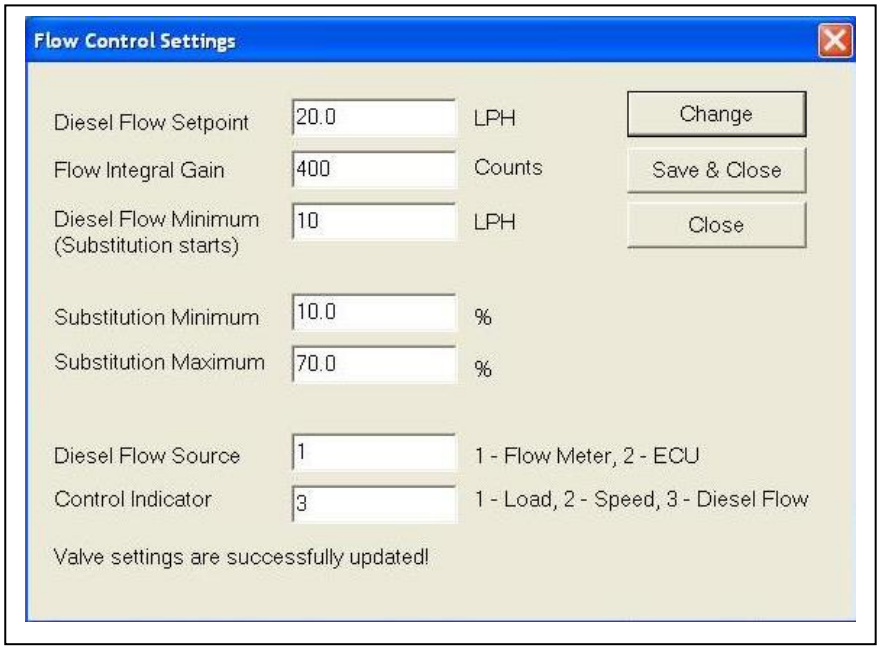


Figure 23

2. Flow Integral Gain:
    a. This controls how rapidly the GSS will try to adjust the fuel flow. The higher the number, the faster the change. The default is 400.
3. Diesel Flow Minimum:
    a. The low limit should be just above the fuel flow required to run in a no-load condition at operating speed. Read the Diesel Flow consumption on the GSS display (Figure 3.10). Set the Diesel Flow Minimum to 5% above this number. This number cannot be set below ten liters per hour. If you are unable to run the engine unloaded, the engine data from the manufacturer may include a no-load consumption rate.
4. Minimum substitution rate.
    a. While temperature topping, if the substitution rate is pushed below the minimum the system will shut off the gas.

5. Maximum substitution rate:
    a. Default is 70%, max is 80%. The maximum substitution rate may require a lower limit on some applications. The GSS will reduce the substitution rate and try to control equal to or below this maximum limit.
6. Diesel flow source:
    a. This is the source for calculated savings or calculating substitution rate. The ECU flow measurement is always the process variable used for control.
7. Scheduling method.
    a. Three different methods are available for control. Diesel flow is the default and preferred method.

Vibration Settings

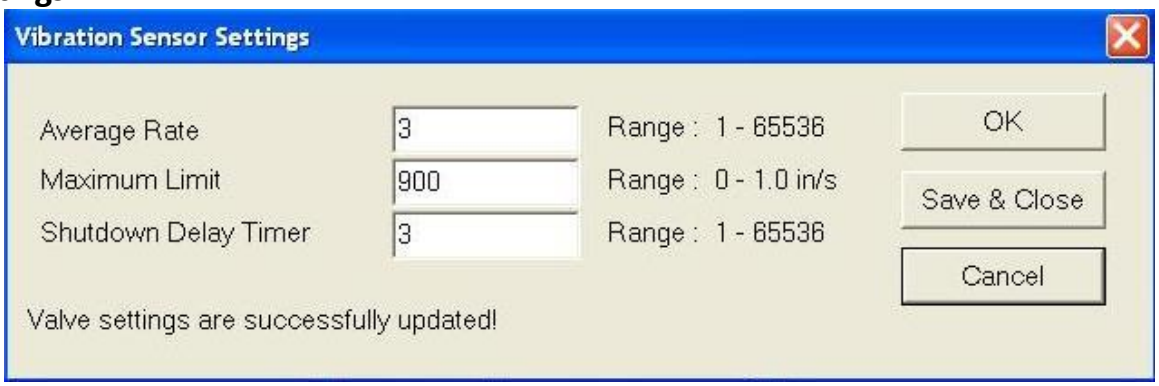


Figure 24

1. Average rate

a. The number of times the signal is read and averaged. This number is used to filter the incoming signal. The higher the number the greater the filter.

2. Maximum Limit
   a. Vibration limit measured in inches per second.
3. Shutdown Delay Timer.
   a. The vibration must be above the limit for the number of seconds displayed to trigger a shutdown.

Temperature Settings

Figure 25

1) Average Rate
   The number of times the signal is read and averaged. This number is used to filter the incoming signal. The higher the number, the greater the filter.
2) Temperature Limit
   The temperature is in degrees Fahrenheit that the GSS will shut the gas off.
3) Shutdown Delay Timer
   The temperature must be above the limit for the number of seconds displayed to trigger a shutdown.

Alarms and Run Permissive

The GSS has number of run permissive and alarms. Run permissive are conditions that must exist in order for the GSS to allow gas substitution. All of the following must be true for the GSS to substitute gas:

1. The stop button must be pulled out.
2. The GSS must be able to communicate with the engine ECU.
3. The diesel flow must be above the minimum diesel flow limit.
4. The diesel flow must be above or equal to the diesel flow set point.
5. The supply pressure must be above 25psi.
6. The manual shutoff valve must be open.
7. The laptop interface "E-STOP" must not be active.
8. Over speed this is a settable value, the default is 1860.

Statuses of permissive are displayed on both the laptop interface and the local interface. The alarms are only checked while the GSS is substituting gas.

The alarms in the GSS are:

1) High vibration alarm.
2) High exhaust temperature alarm.
3) High Delta pressure from the outlet of the regulator to the turbo boost presser. Operating pressure should be 1.1 psid < and > 4.5 psid at the outlet of the regulator. Alarms, unlike permissive, must be acknowledged before the GSS will resume gas substitution. Alarms are acknowledged by pushing in the "stop" button and pulling it back out.

Diagnostics

Data logging:

The GSS has a USB port on the board located inside the controller box. If a thumb drive is installed, the GSS will write a time and date-stamped log file as a Microsoft Excel spreadsheet. The file is logged to every 20 seconds. Each record contains the time and date, any alarms, status of each permissive, flow rates of the diesel and natural gas, and substitution rate. The USB thumb drive can be removed and the data can be reviewed on a PC, or emailed to Continental Controls Corporation for evaluation.

Automatic Email:

If the satellite option is installed, the GSS can be programmed to automatically generate an email notification on any permissive or alarm. Each condition can be enabled or disabled to generate an email. All emails are sent to a Continental Controls Corporation email account where the customer has mutual access with Continental Controls Corporation to review the email.

GSS Substitution Schedule Setup

In order to calculate the percentage of gas substitute in place of diesel, either a gas flowmeter are required to measure gas injection rate in scfm or a measuring sensor such as watt meter transducer or intake manifold sensor must be installed to measure load. One of these variable inputs is used in the "Diesel Flow Schedule / Substitution Settings" vs. Diesel flow at each load. The diesel flow is measured via CANBus J1939 when the engine is running on 100% diesel. The diesel flow reading at each load conditions are recorded and saved into the GSSI. There are only 4 points (load) can be mapped.

Warning: GSS E-STOP should be engaged for initial engine data collection and settings adjustment.

The Substitution Schedule is used to calculate the diesel fuel substitution rate in GSS System.

1. Run the engine and record diesel fuel flow at 4 different Load points starting from 0 kW (unloaded).
2. Using GSS Viewer select Main Menu -> Settings -> Fuel Substitution Schedule option.
3. Diesel Flow Schedule/Substitution Settings dialog box should open.

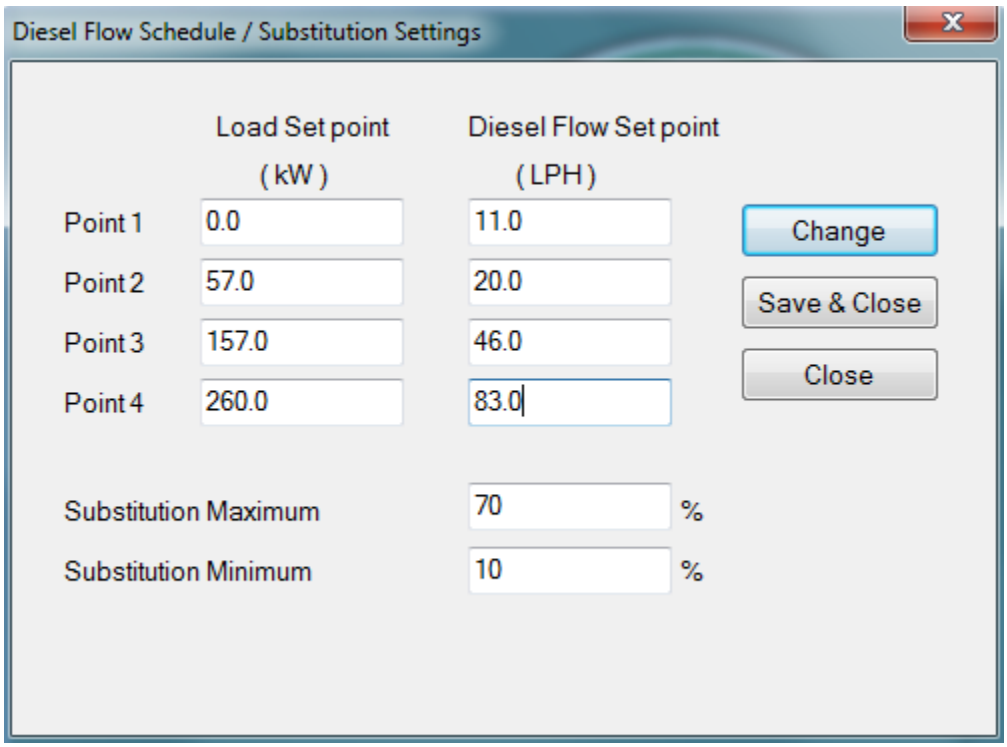


Figure 26

4. Enter recorded data, click Change.
5. Press Save and Close.
6. The schedule is ready for use.

Component Descriptions

Gas Manifold

P/N: 60400058-S

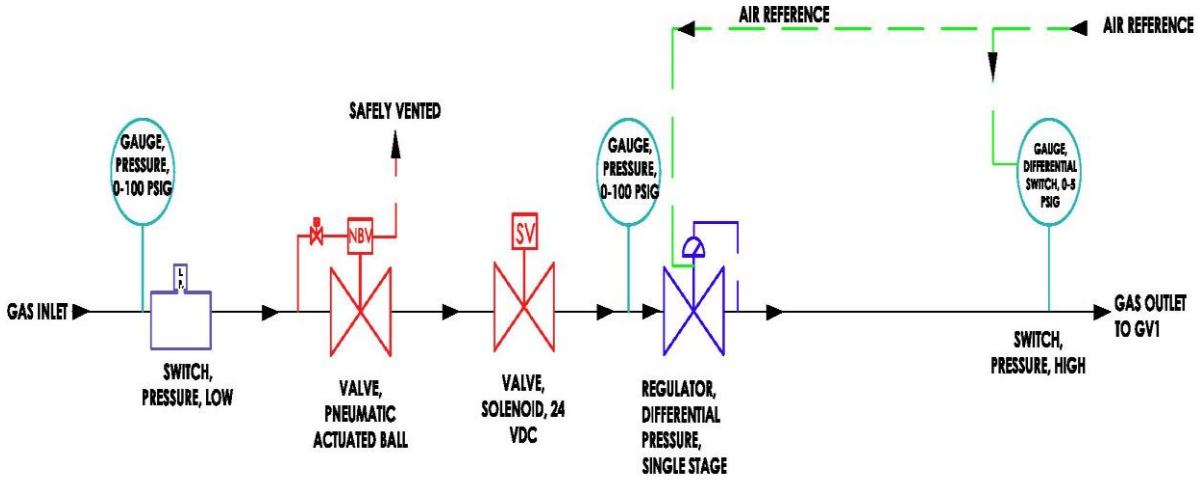


Figure 27 Gas manifold schematic.

The gas train is the first intermediate component between the pressurized natural gas supply and the air intake manifold. Pressurized gas travels through the gas train which can be monitored by inspection of the gauges during operation. The high- and low-pressure switches electronically monitor the natural gas and send a signal to the PC interface if the pressure becomes too high or too low. This will set the desired substitution rate to 0%, deactivating the GSS and the engine will return to full diesel operation. If this occurs, gas substitution can be restarted by setting a non-zero substitution rate.

GV1 Electronic Gas Valve

P/N: 52600008-CANBUS-5PSI

The GV1 gas valve is an electronic valve designed to operate as a variable pressure regulator to vary the gas pressure to the carburetor or mixing venturi. The gas valve uses closed-loop control logic to accurately command gas pressures in order to meet substitution requirements. A feedback signal based on the desired substitution rate and the actual performance of the engine is used to operate the valve.

Figure 27 Gas Valve GV1.

The electronic fuel valve includes an integrated pressure transducer, the electronic circuit, and a gas valve operated by a voice coil actuator. The transducer measures the gas injection pressure. The electronic circuit compares the gas injection pressure to its set point and adjusts the current in the voice coil actuator to regulate the gas flow in order to maintain the pressure at its set point. The control provides integral or "reset" control of the pressure, i.e. there is no drop in the pressure as the flow increases.

The GV1 is designed to be a full authority fuel valve, controlling all of the fuel to the engine before it gets to the carburetor or mixing venturi. It is designed to operate at about 2 psi above boost pressure for turbocharged application and uses turbo pressure as a reference to improve performance.

ECV5 Emissions Control Valve

P/N: 50500008-DX-GX-X-X-X

Figure 28 ECV5 fuel control valve.

On applications above 1.5megawatt, we recommend using the larger ECV5 valve in conjunction with the GSS system. The ECV5 is a fuel control with a balanced poppet design that can operate a higher supply pressures (up to 80 psi).

The regulator in the gas train should be modified to use the higher pressure spring. Call Continental Controls Corporation for recommendations when using the ECV5.

The GSS controller sends a pressure command to the ECV5 through the CanBus. The ECV5 has its own internal microprocessor and pressure transducer. The ECV5 operates as an electronic regulator controlling the downstream pressure to the pressure commanded.

The ECV5 requires a different cable than the GV1, however, functionally the GV1 and ECV operate exactly the same. No programming changes are within the GSS required for using the ECV5. One valve per bank is recommended.

AFM4 & AFM7, Advanced Fuel Metering Venturi

AFM4 P/N: 53800008-VNR & AFM7 P/N: 53700008-V1

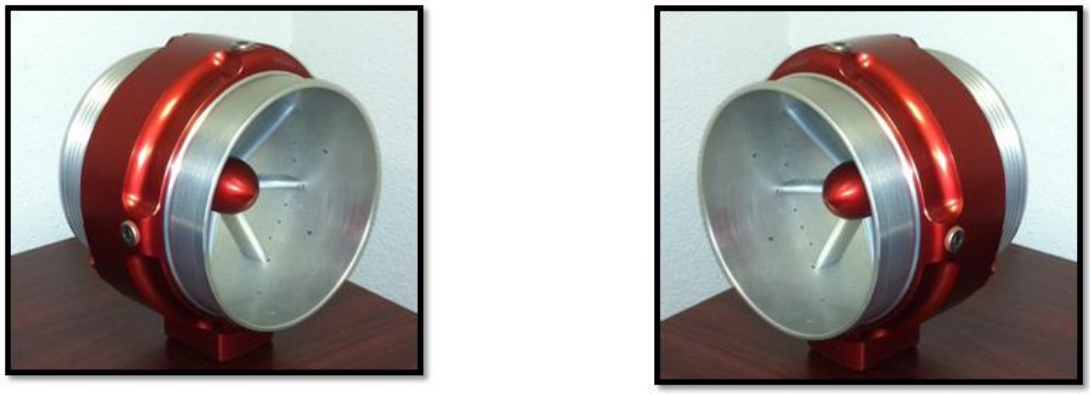


Figure 29 Mixing Venturi (AFM7 shown).

The mixing Venturi is designed to provide a multitude of fuel inlet vanes and passages evenly dispersed throughout the low-pressure region of the Venturi; evenly distributing the fuel and providing a more homogenous mixture to the engine.

The mixing Venturi has two size options: 4.5” and 7” – depending on the user’s needs The Venturi is carefully designed to specifically maintain a constant fuel mixture and any load by drawing the proper amount of fuel for the specific amount of air being drawn into the engine. This ensures that the ratio of fuel to air is constant and making the air fuel controller’s work much easier. This fuel metering Venturi is used in post-turbo applications for standard natural gas. It requires 4.5” to 4” reducers and stainless steel clamps (included) in order to attach to the engine.

This advanced fuel mixing venturi is used primarily in pre-turbo applications; but can also be used in post-turbo. It requires 7” to 5” reducers and stainless steel clamps (included) in order to attach to the engine.

Gas Flowmeter FM50

Flow meters are not required for normal operation of the GSS, however they are recommended. The GSS has the capability to calculate substitution rate and accumulated savings. The GSS can display this information locally to a remote laptop via the 2.4 GHz radio, or record it to the thumb drive in the USB port located inside the controller. Flow measurement can also serve as a useful diagnostic tool. The GSS reads the flow from the ECU over the CanBus. This measurement is not accurate enough for a savings calculation. On units without a watt meter, a gas flow meter *and* a diesel flow meter will also be required.

Figure 30 Gas flow meter, P/N 54700008-VX-CX

The gas flow meter is *never* required for operation of the GSS and is only an option. For engines without a watt meter, such as a pump or other mechanical drive package, a gas flow meter is needed if the customer would like to calculate fuel savings. For engines with a watt meter, the GSS simply calculates fuel savings based on diesel consumption with and without gas substitution at a particular load. If the GSS is using a gas flow meter, the GSS adds the cost of the amount of gas used to the cost of the diesel used, comparing it to the cost of running on 100% diesel.

The price of the diesel and the natural gas is programmable though the GSS display. Accuracy of this calculation is dependent on the accuracy of the two flow measurements and accuracy of the fuel costs programmed into the controller. Care should be taken to properly install the flow meters to ensure the maximum possible accuracy. The user should not attempt to install the gas flow meter without thoroughly reading the instruction manual provided by the manufacturer.

Note: The flow meters are not "custody transfer" rated. Flow measurements and savings are accurate, but should be viewed as estimates and are unsuitable for billing purposes.

Diesel Flowmeter (optional)

The diesel flow meter sold as an option is manufactured by Flow Scan. The model engine must be specified when ordering the flow meter. Each flow meter configuration and calibration is unique, depending on the application.

Watt Meter

The watt meter is an optional device that can be used for monitoring and displaying fuel savings based on the fuel consumption at a given load. Below is a wiring diagram showing connection to terminals on the watt meter. Pins 11 & 12 (INST POWER) are not used for this watt meter model. The CTs are oriented such that the dot on the face in the diagram is labeled with “H1” on the face of the CT. The dot on the wire is the wire labeled as “X1”.

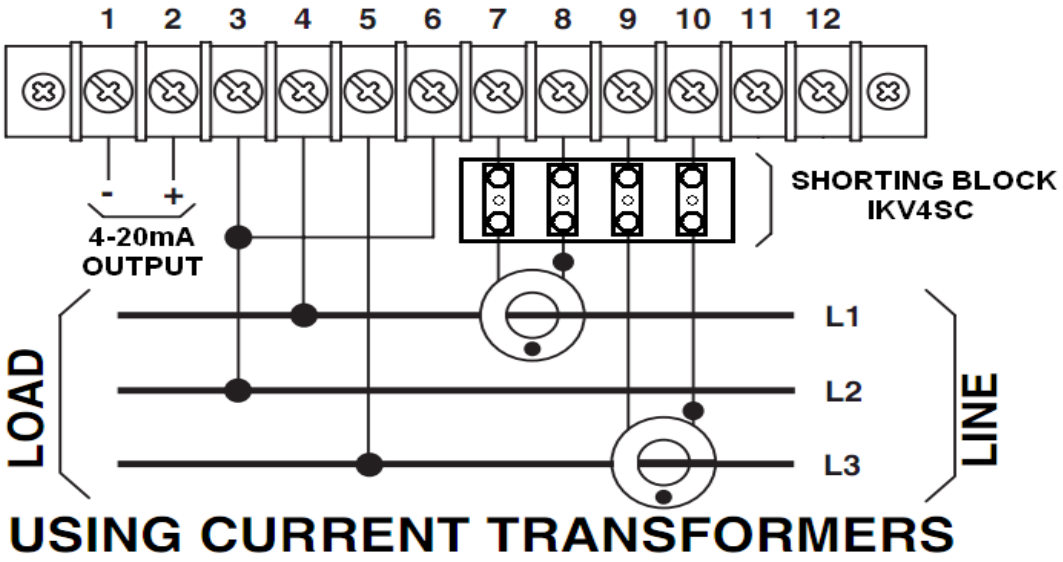


Figure 31 Schematic for watt meter using current transformers.

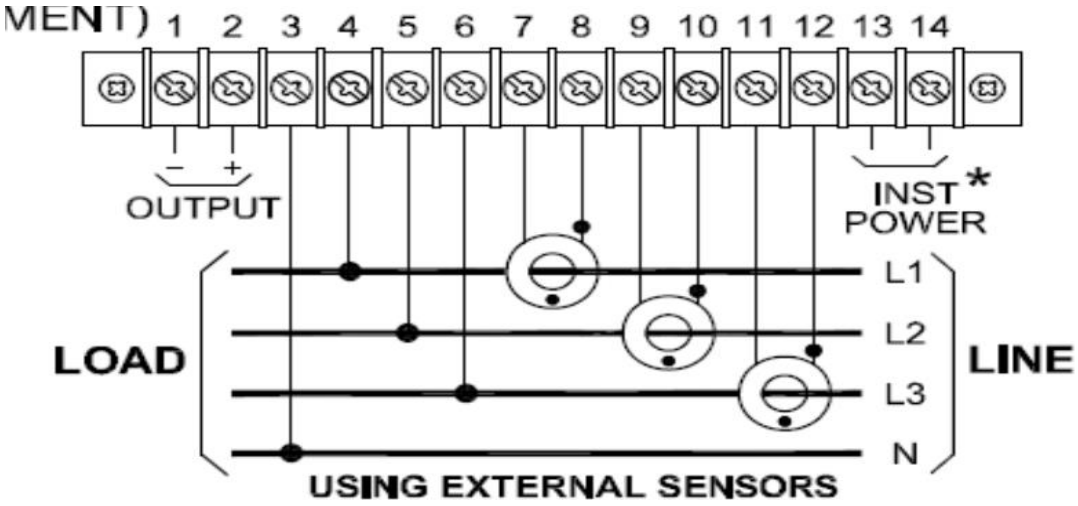


Figure 32 Schematic for watt meter for Three-Phase, Four-Wire Connections

Figure 32B, neutral wire is not connected to terminal 3. PC5-008E2 or AGW-008E Watt Transducer (meter) can be used on 3-phase, 3-wire connection as well. Only 2 CT can be used in such a case.

WARNING: If the current transformer wires are left open circuited and current is supplied to the primary, a high voltage will develop between the CT secondary wires. To avoid electric shock and damage to the CTs, be sure to short together the two wires on each CT if the watt meter isn't fully installed. This can be done with the shorting block by removing the four screws from their placeholders and installing them into the four center holes.

Vibration Sensor

The vibration sensor *P/N: 640B0X* used is a PCB Piezotronics velocity transducer. A 4 – 20 mA output is converted into inches per second and is shown on the substitution interface during operation.

Thermocouple

The thermocouple *P/N: TJ36-CAIN-14U-6CC-XCIB* used is a 6" Omega Type K thermocouple. A differential voltage is converted into degrees Fahrenheit and is shown on the substitution interface during operation.

Satellite Modem

The satellite modem *P/N: ASD-123.000-0001* is an optional feature that allows the operator to observe the performance and make changes to settings of the GSS via wireless internet. The advantage of having the satellite modem allows the user to monitor and control all options of the GSS at an off-site location.

Cables and Connectors

DEVICE	DESCRIPTION	P/N
1. GV1	10 PIN, SIZE 16 CONTACTS	MS3102E18-1P
2. Power	4 PIN, 2 #12 & 2 #16 CONTACTS	MS3102E16-9P
3. ECU	2 PIN, SIZE 16 CONTACTS	MS3102E10SL-4P
4. Load (watt meter)	6 PIN, SIZE 16 CONTACTS	MS3102E14S-6S
5. Pressure switch	5 PIN, SIZE 16 CONTACTS	MS3102E14S-5S
6. Thermocouple	3 PIN, SIZE 16 CONTACTS	MS3102E10SL-3S
7. Modem	7 PIN, SIZE 16 CONTACTS	MS3102E16S-1S
8. Vibration sensor	3 PIN, SIZE 16 CONTACTS	MS3102E14S-7S
9. Diesel flow meter	3 PIN, SIZE 16 CONTACTS	MS3102E10SL-3P
10. Shut off valve	3 PIN, SIZE 16 CONTACTS	MS3102E14S-7SW
11. External shut off valve	3 PIN, SIZE 16 CONTACTS	MS3102E14S-7SX
12. Gas flow meter	5 PIN, SIZE 16 CONTACTS	MS3102E14S-5SX

1. GV1 Connector (single bank), MS3102E18-1P

FUNCTION	WIRE COLOR	CONNECTOR PIN	PAD	WIRE LENGTH
4-20mA DEMAND +	-	A	-	-
GNDA	-	B	-	-
4-20mA OUTPUT +	-	C	-	-
4-20mA OUTPUT -	-	D	-	-
RS232 TX	GRN 24 AWG	E	P3	7.5"
RS232 RX	BRN 24 AWG	F	P4	7.5"
CAN_H	ORN 24 AWG	G	P5	7.5"
CAN_L	WHT/ORN 24 AWG	H	P6	7.5"
24VDC	RED 22 AWG	I	P2	7.5"
GND	BLK 22 AWG	J	P7	7.5"

1. GV1 Connector (dual bank), MS3102E18-1P

FUNCTION	WIRE COLOR	CONNECTOR PIN	PAD	WIRE LENGTH
4-20mA DEMAND +	-	A	-	-
GNDA	-	B	-	-
4-20mA OUTPUT +	-	C	-	-
4-20mA OUTPUT -	-	D	-	-
RS232 TX	GRN 24 AWG	E	P9	7"
RS232 RX	BRN 24 AWG	F	P10	7"
CAN_H	ORN 24 AWG	G	P11	7"
CAN_L	WHT/ORN 24 AWG	H	P12	7"
24VDC	RED 22 AWG	I	P8	7"
GND	BLK 22 AWG	J	P13	7"

2. Power Connector, MS3102E16-9P

FUNCTION	WIRE COLOR	CONNECTOR PIN	PAD	WIRE LENGTH
+24VDC [SYSTEM POWER]	RED 22 AWG	A	P52	7"
+24VDC [SOLENOID POWER]	WHT 20 AWG	B	P53	7"
GND [SYSTEM POWER]	BLK 22 AWG	C	P55	7"
GND [SOLENOID POWER]	GRY 20 AWG	D	P54	7"

3. ECU Connector, MS3102E10SL-4P

FUNCTION	WIRE COLOR	CONNECTOR PIN	PAD	WIRE LENGTH
CAN_H	ORN 24 AWG	A	P20	5"
CAN_L	WHT/ORN 24 AWG	B	P21	5"

4. Load (watt meter) Connector, MS3102E14S-6S

FUNCTION	WIRE COLOR	CONNECTOR PIN	PAD	WIRE LENGTH
WATT METER 4-20mA FDBK	YEL 24 AWG	A	P34	7"
GNDA	WHT/YEL 24 AWG	B	P35	7"
24VDC	RED 22 AWG	C	P33	7"
SHIELD	GRN/YEL 22 AWG	D	P36	7"

5. Pressure Switch Connector, MS3102E14S-5S

FUNCTION	WIRE COLOR	CONNECTOR PIN	PAD	WIRE LENGTH
DIGITAL INPUT LOW	VIO 22 AWG	A	P23	7"
24VDC	RED 22 AWG	B	P22	7"
DIGITAL INPUT HIGH	VIO/WHT 22 AWG	C	P24	7"
24VDC	BLU 22 AWG	D	P25	7"
SHIELD	GRN/YEL 22 AWG	E	P26	7"

6. Thermocouple Connector, MS3102E10SL-3S

FUNCTION	WIRE COLOR	CONNECTOR PIN	PAD	WIRE LENGTH
CHROMEL+	YEL THERMOCOUPLE FF-K-24S-TWSH-SLE	A	P27	5"
ALUMEL-	RED THERMOCOUPLE FF-K-24S-TWSH-SLE	B	P28	5"
SHIELD	GRN/YEL 22 AWG	C	P29	5"

7. Modem Connector, MS3102E16S-1S

FUNCTION	WIRE COLOR	CONNECTOR PIN	PAD	WIRE LENGTH
24VDC	RED 22 AWG	A	P45	5.25"
GND	BLK 22 AWG	B	P50	5.25"
RS232 RX	BRN 24 AWG	C	P47	5.25"
RS232 TX	GRN 24 AWG	D	P46	5.25"
CAN_H	ORN 24 AWG	E	P48	5.25"
CAN_L	WHT/ORN 24 AWG	F	P49	5.25"
SHIELD	GRN/YEL 22 AWG	G	P51	5.25"

8. Vibration Sensor Connector, MS3102E14S-7S

FUNCTION	WIRE COLOR	CONNECTOR PIN	PAD	WIRE LENGTH
VIBRATION SENSOR 4-20mA FDBK	BLU 24 AWG	A	P42	7"
24VDC	RED 22 AWG	B	P43	7"
SHIELD	GRN/YEL 22 AWG	C	P44	7"

9. Diesel Flow Meter Connector, MS3102E10SL-3P

FUNCTION	WIRE COLOR	CONNECTOR PIN	PAD	WIRE LENGTH
DIESEL FLOW FEEDBACK	WHT/GRN 24 AWG	A	P37	5"
FEEDBACK RTN	WHT/BLU 24 AWG	B	P38	5"
SHIELD	GRN/YEL 22 AWG	C	P41	5"

10. Shut Off Valve Connector, MS3102E14S-7SW

FUNCTION	WIRE COLOR	CONNECTOR PIN	PAD	WIRE LENGTH
DIGITAL OUTPUT (24V)	WHT/GRY 22 AWG	A	P17	7"
GND	GRY 20 AWG	B	P18	7"
SHIELD	GRN/YEL 22 AWG	C	P19	7"

11. External Shut Off Valve Connector, MS3102E14S-7SX

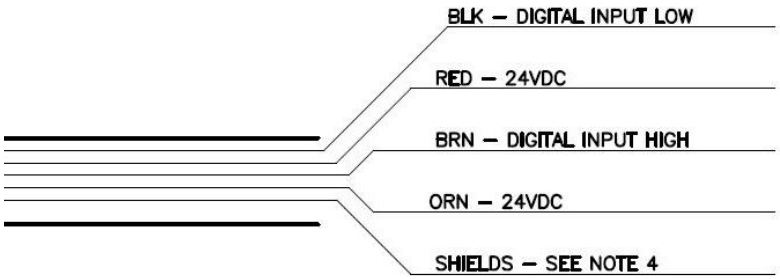
FUNCTION	WIRE COLOR	CONNECTOR PIN	PAD	WIRE LENGTH
24VDC	RED 22 AWG	A	P14	5"
EXTERNAL SWITCH RELAY	VIO 22 AWG	B	P15	5"
SHIELD	GRN/YEL 22 AWG	C	P16	5"

12. Gas Flow Meter Connector, MS3102E14S-5SX

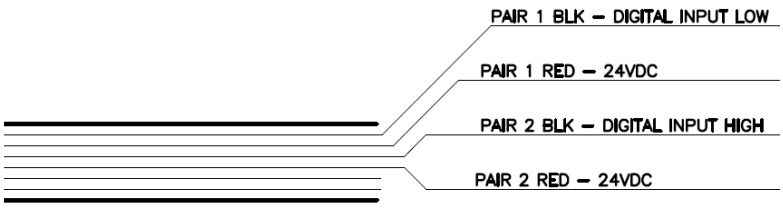
FUNCTION	WIRE COLOR	CONNECTOR PIN	PAD	WIRE LENGTH
24VDC	RED 22 AWG	A	P58	9.5"
GND	BLU 22 AWG	B	P59	9.5"
GAS FLOW FEEDBACK	YEL 24 AWG	C	P56	9.5"
FEEDBACK RTN	GRY 24 AWG	D	P57	9.5"
SHIELD	GRN/YEL 22 AWG	E	P60	9.5"

Pigtail end of Pressure Switch cable:

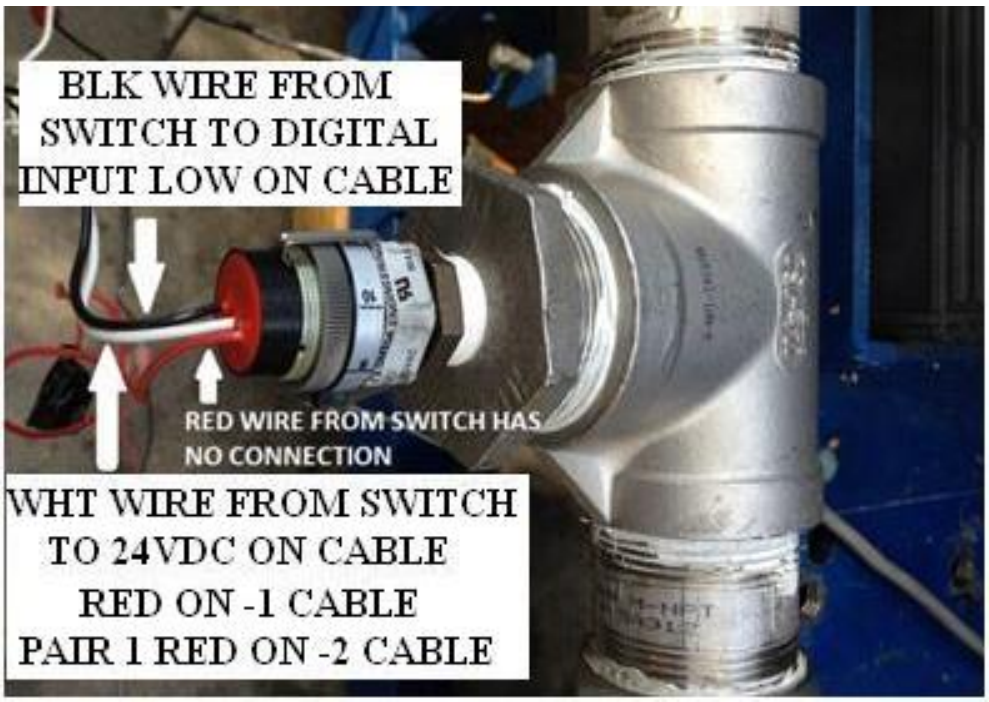
P/N: 60401527-1



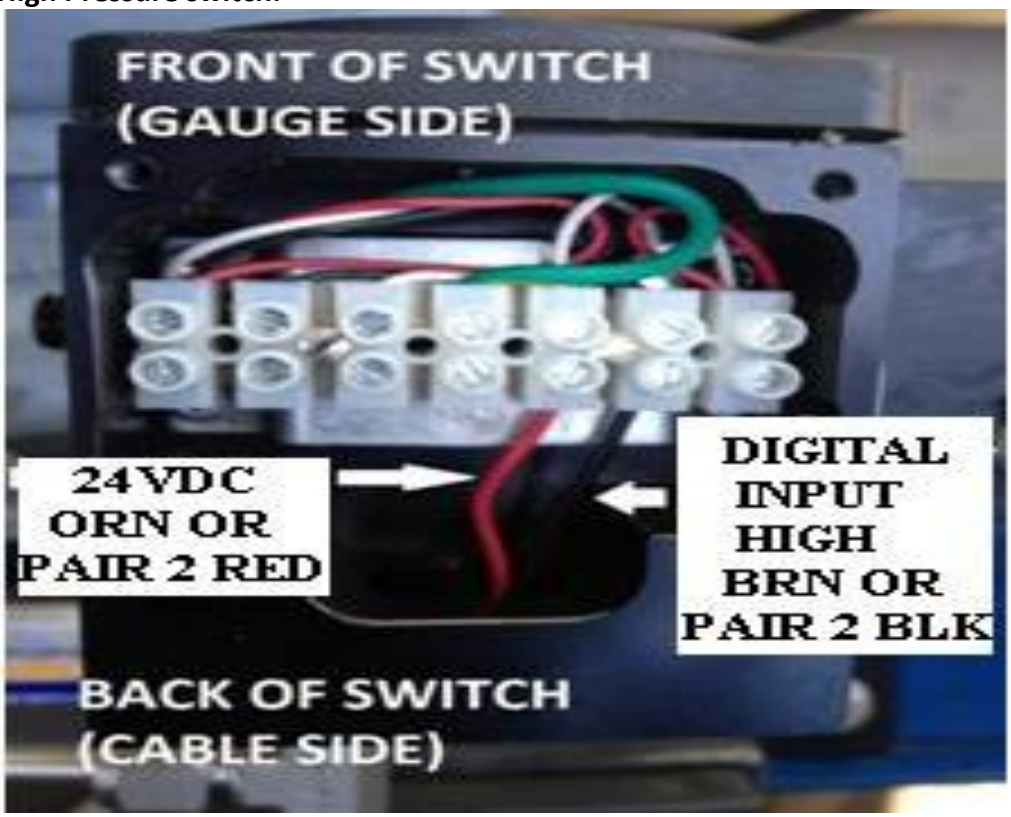
P/N: 60401527-2



Low Pressure Switch:

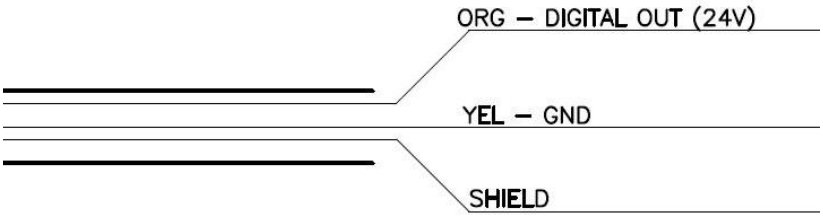


High Pressure switch:



Pigtail end of Shutoff Valve Cable:

P/N: 60401517-1



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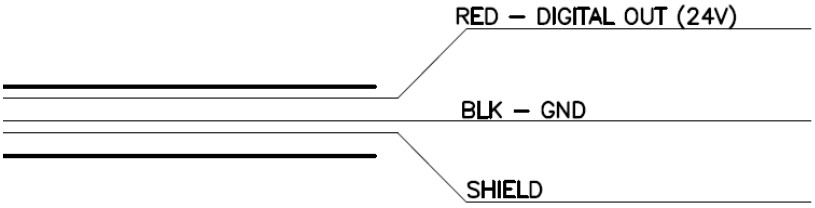
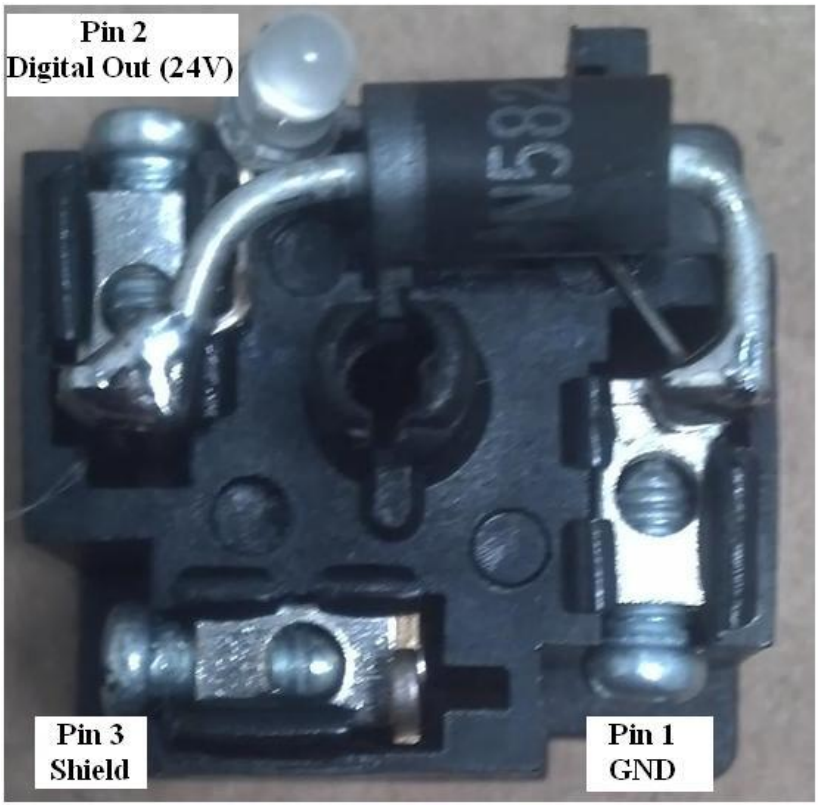




Troubleshooting of Problems

Problem	Solution
Low Supply Pressure	- Gas run out – connect gas - Frozen gas line – check gas or glycol operation and check if wet gas - Valving closed on line – open manual valve - Check low pressure switch - Check DPI on old systems
High Supply Pressure	- Regulator not working properly - replace - Sense reference line plugged – check - On Pre-Turbo system sense lines not installed properly
Unbalance GV1 Valve Output	- Reference lines not hooked up properly- check
Gas Flow indication on Shut Down	- Leaking solenoid valve – diaphragm replace
Unstable ramping (High Ki)	- Ki set too high - Set to 25 or 50
Unstable gas substitution	- Small venturi use larger size - Restricted airflow – unplug air filter
No load shown on Valve viewer	- Substitution based on Diesel flow - Watt meter not installed or Faulty - Check watt meter hookup wiring
No Substitution shown on valve viewer	- Engine gas meter faulty - No reading of diesel rate from ECU
Hi Ramp in rate	- Set ramp rate to lower value
High substitution rate	- Check fuel pressure schedule and reduce numbers (Old style system on Rig 10 and 27 Generators only) - Check diesel target rate and reduce.
No HP indication	- Not expected for generator
No Substitution Indication	- Faulty Engine Gas meter or watt meter
SD card takes too long	- Meter write rate to high – reduce to 1 per minute - Too much logged data reprogram meter
Cant access remote computer	- Confirm computer on and connected to internet - Check Logmein account status - Confirm Logmein running on remote computer
Computer will not talk to GSS	- Check if radio installed and connected to GSS - Confirm choose right ID (1 to 4 for engines from toolpush shack to boiler) - Check radio in place on remote computer
Poor pressure control	- Check spring installed in regulator - Confirm seat in regulator at 10mm
Diesel flow below min	- No load on engine

	- Tripping or connections on rig.
Topping too high	-
High Vibration or rough engine	- Too much gas -Reduce substitution rate - Liquids in gas or rich gas
EGT too high	- Reduce substitution rate
Host comm error	- Recycle power on display
Solenoid valve will not turn on	- Check LED installed - Confirm power to solenoid - Check on board 10 AMP fuse and solenoid relay - Check on board relay operation

What happens when the differential pressure regulator diaphragm rupture in the Gas Supply Manifold model GSM5?

In the Gas Substitution System (GSS), a direct acting differential pressure regulator is used to regulate the pressure to the inlet of the gas valve (model GV1). The direct acting differential pressure regulator in the Gas Substitution System is used to maintain a fixed low pressure drop across the gas valve (model GV1) in order for the gas valve to maintain a precise control over the range of operation and less internal leakage. The regulated pressure (i.e. The downstream pressure of the differential pressure regulator) is controlled with respect to the air cleaner pressure drop or turbo boost pressure. Thus, the pressure regulator would maintain a differential pressure at the desired pressure set point of the regulator. This is achieved by connecting a reference line to the backside of the pressure regulator diaphragm.

If the regulator diaphragm ever fails, gas fuel could enter the upper part of the regulator which is directly connected to the reference line. This would allow additional fuel to enter the engine at the reference connection point. In this case, the Gas Substitution System has five safety shutdown features that allows the Gas Substitution System to shutoff the gas into the engine. The five safety shutdown features:

1. Overspeed – In the case of overspeed, the Gas Substitution System will shutoff the gas fuel into the engine by closing the redundant fast acting electronic solenoid valves.
2. Diesel Flow Minimum – If the diesel flow feedback from the diesel flow measuring device goes below the diesel flow minimum setpoint due to the additional fuel, the Gas Substitution System will shutoff the gas fuel into the engine.
3. Gas Flow Maximum – If the gas flow feedback from the gas flow measuring device goes above the gas flow maximum setpoint due to the additional, the Gas Substitution System will shut off the gas fuel into the engine.
4. Exhaust Temperature Monitor – If the exhaust temperature exceeds the maximum allowable exhaust temperature limit due to the additional, the Gas Substitution System will shutoff the gas fuel into the engine.
5. Vibration Sensor Monitor – If the vibration of the engine exceeds the maximum allowable vibration limit and setpoint due to the additional and incomplete

combustion occurs, the Gas Substitution System will shutoff the gas fuel into the engine.

The above safety features are incorporated into the Gas Substitution System in the event of excess fuel due to failure of any Gas Substitution System component.

Continental Controls Corporation highly recommends following the instructions and maintenance guidelines of the differential pressure regulator manufacture. Any serviceable elements of the differential pressure regulator must be serviced according to the pressure regulator maintenance and service instructions.

Preventative Maintenance

The GSS is composed of CCC manufactured components as well as other manufactured components. The original manufactured maintenance / service program must be followed. Repair service kit must be purchased from the original manufacturer in order to service products such as: Solenoid Valves, Pneumatic Actuated Ball Valves, DP switch / gauge, Pressure Regulator.

- **Perform the following maintenance upon <u>every start-up, after every move, and with any new connection of gas to the system.</u>**
    - Perform visual inspection for loose components, damaged components, and damaged wiring.
    - Leak test the system check for leaks around all fitting using soap and water.

- **Perform the following maintenance <u>monthly</u>.**
    - Perform visual inspection for loose components, damaged components, and damaged wiring.

- **Perform the following maintenance <u>every 3 months.</u>**
    - Check mechanical function of shutdowns and set points!

- **Perform the following maintenance <u>every 6 months.</u>**
    - Visually inspect all flex hoses for material damage.

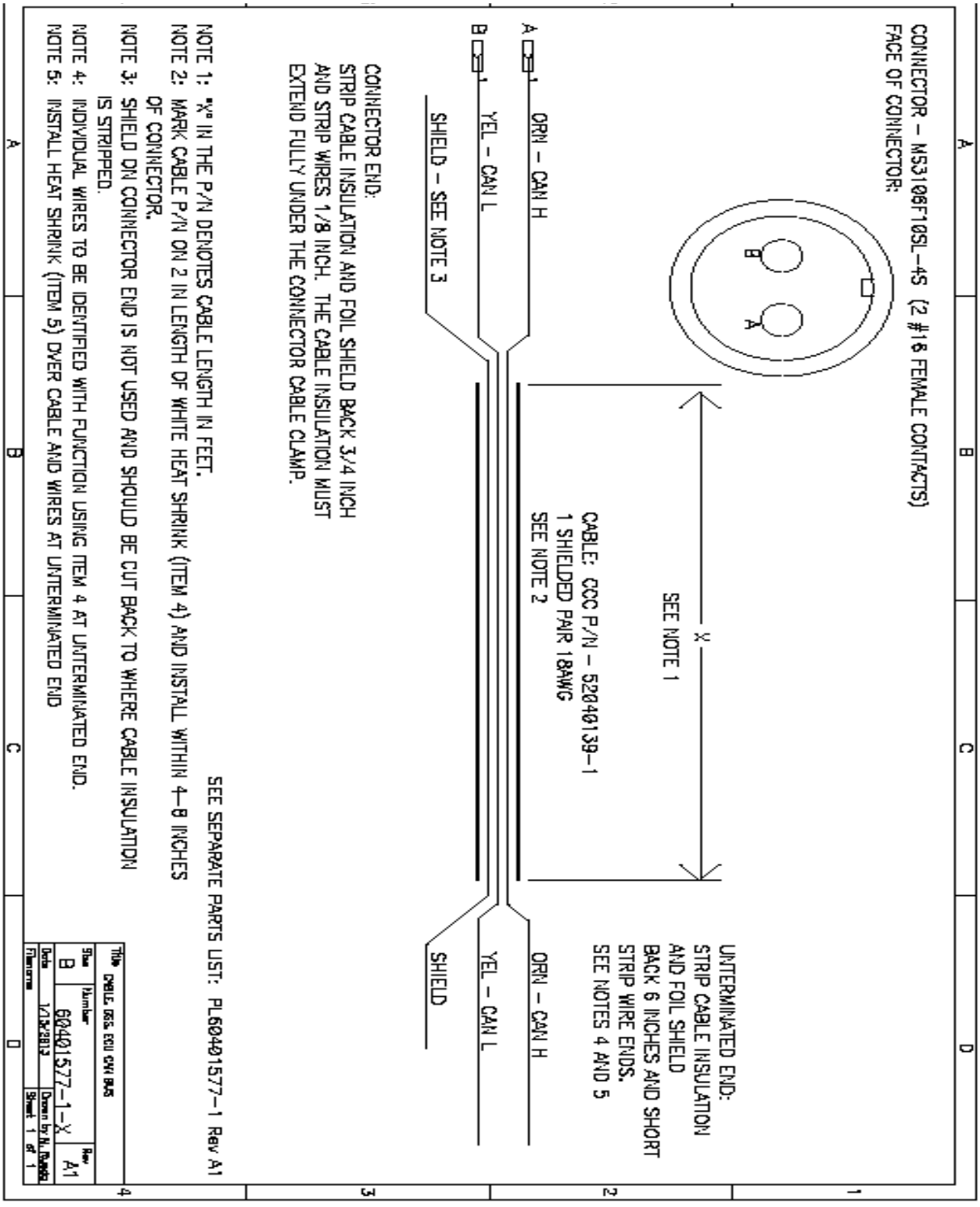
- **Perform the following maintenance <u>every 12 months.</u>**
    - Pressure test the system and check for leaks around all fittings using soap and water.
    - Calibrate differential pressure switch. Ensure the low point is set to 1.4 psig and the high point is set to 4.5psig.

- **Perform the following maintenance <u>every 24 months.</u>**
    - Change out diaphragm on solenoid valve and regulator valve.

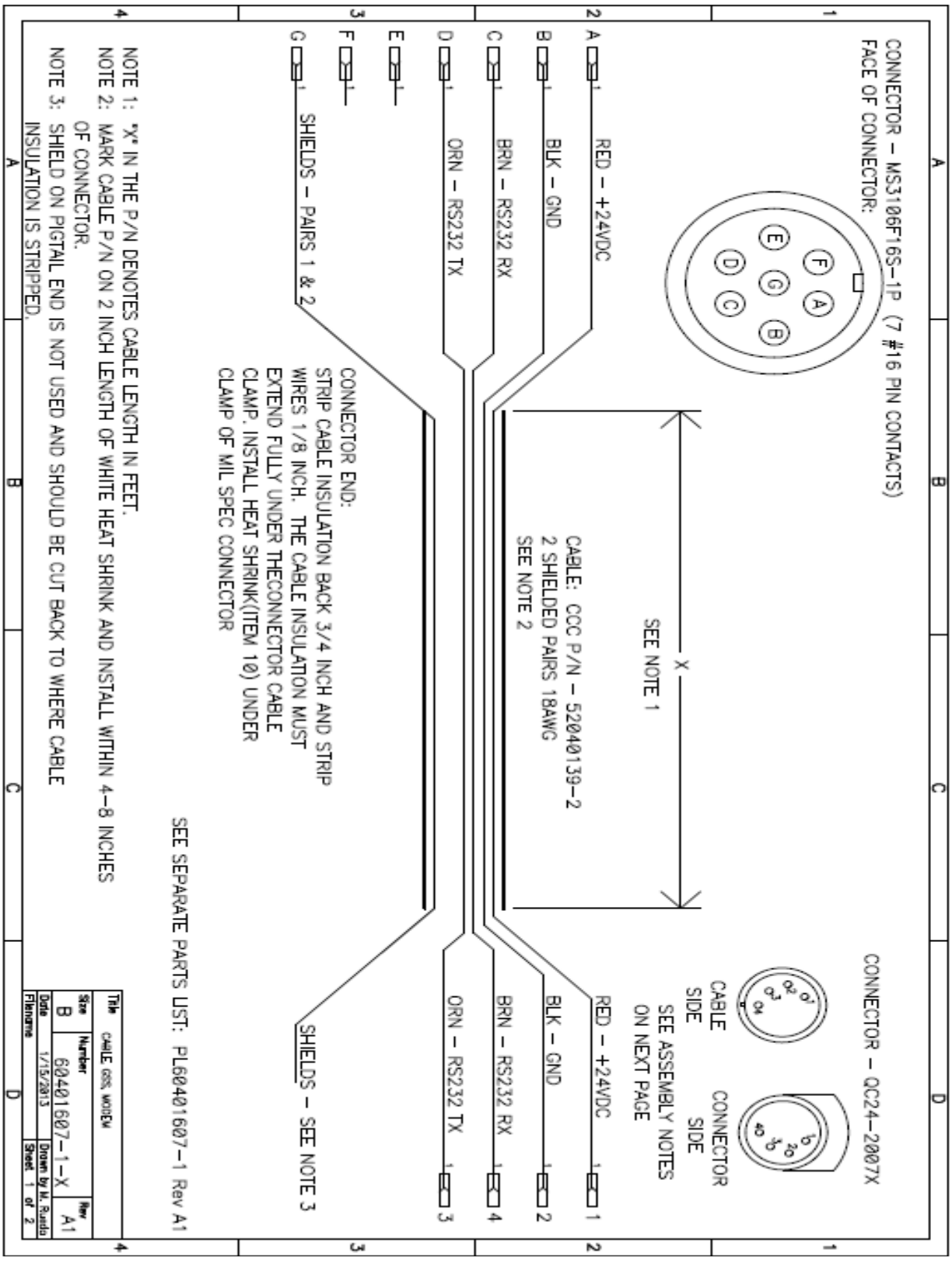
- **Perform original manufacturer maintenance program on the following products.**
    - Differential Pressure Regulator in the Gas Supply Manifold, poppet, seat, internal diaphragm must be checked based on the original manufacturer maintenance program. Such maintenance programs for servicing the pressure regulator will be reduced for harsh environment where a corrosive gas is present and application such as fracking.
    - Pneumatic Actuated Ball valves must be serviced to the original manufacturer service program.

GSS Cables Wiring Drawings

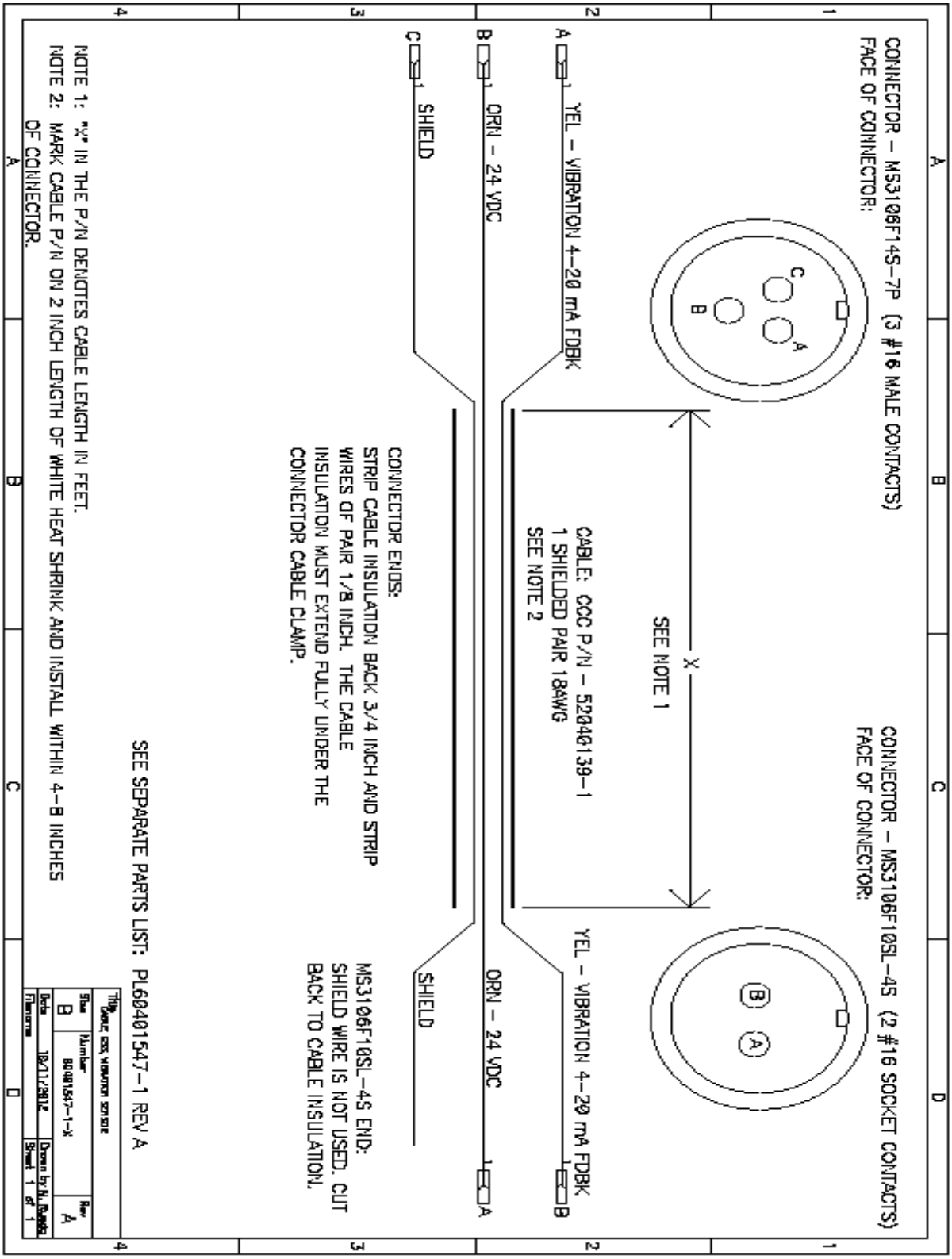
CANBUS CABLE - ER STYLE 60401577-1



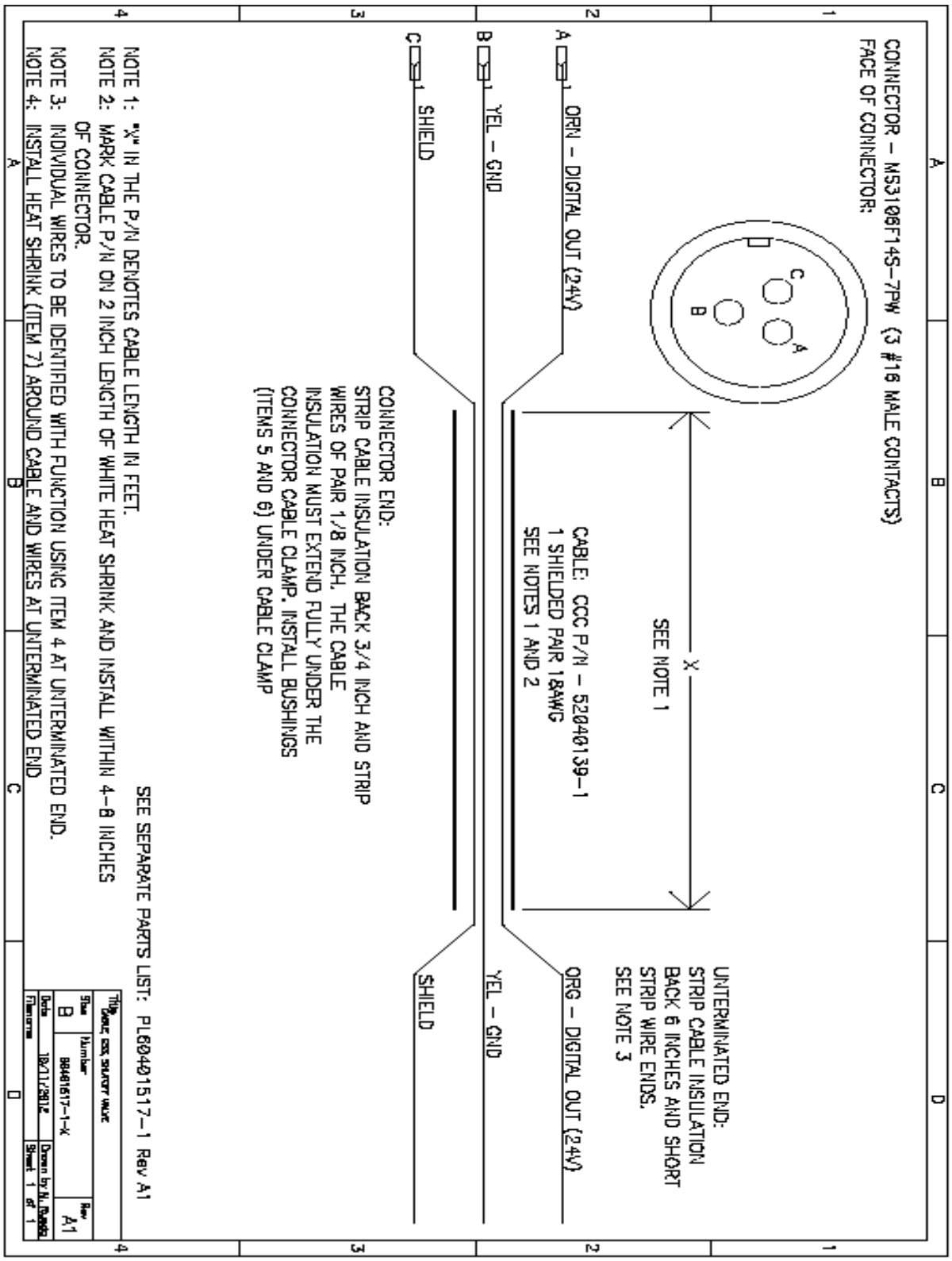
SATELLITE MODEM CABLE – ER STYLE 60401607-1



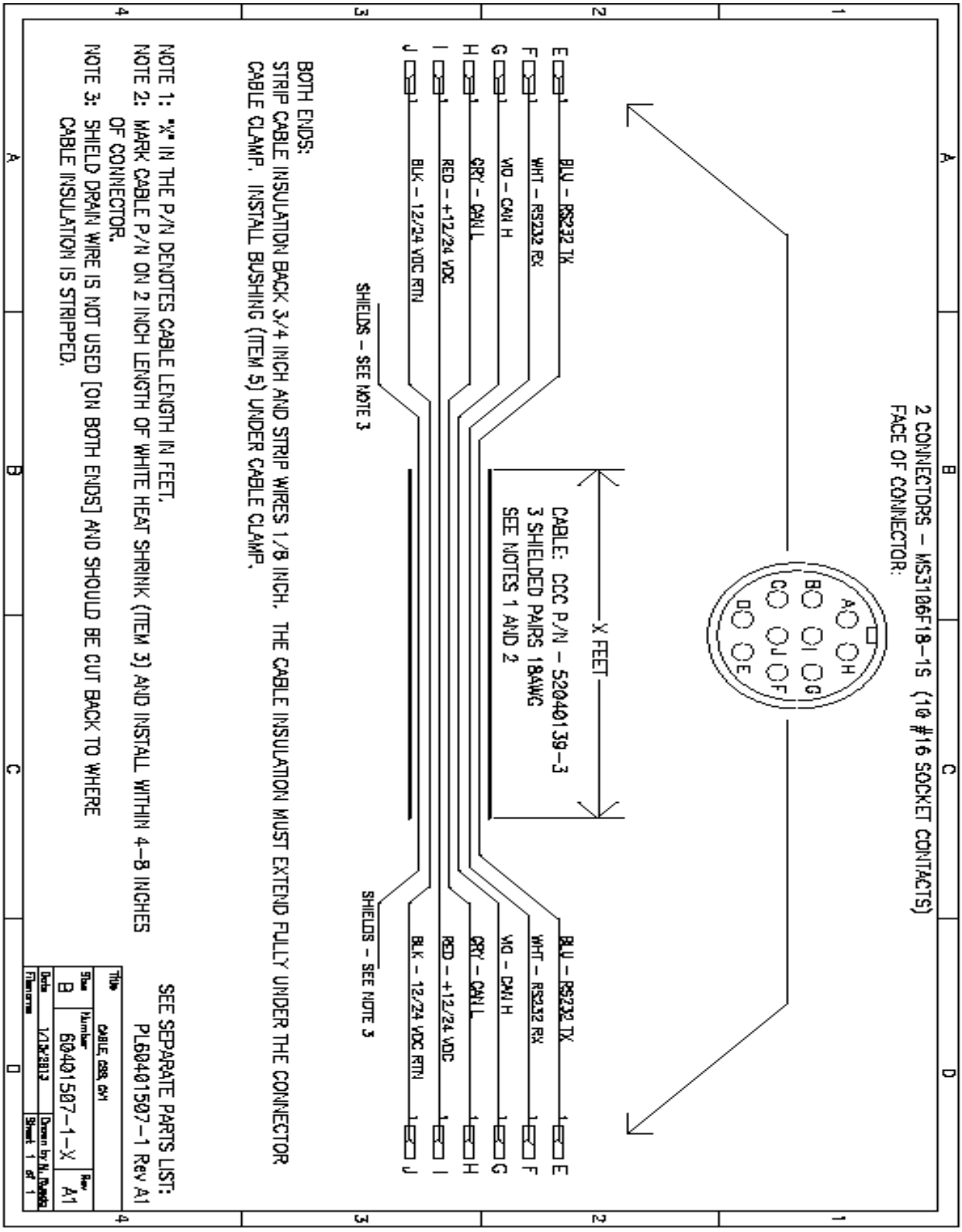
VIBRATION SENSOR CABLE – ER STYLE 60401547-1



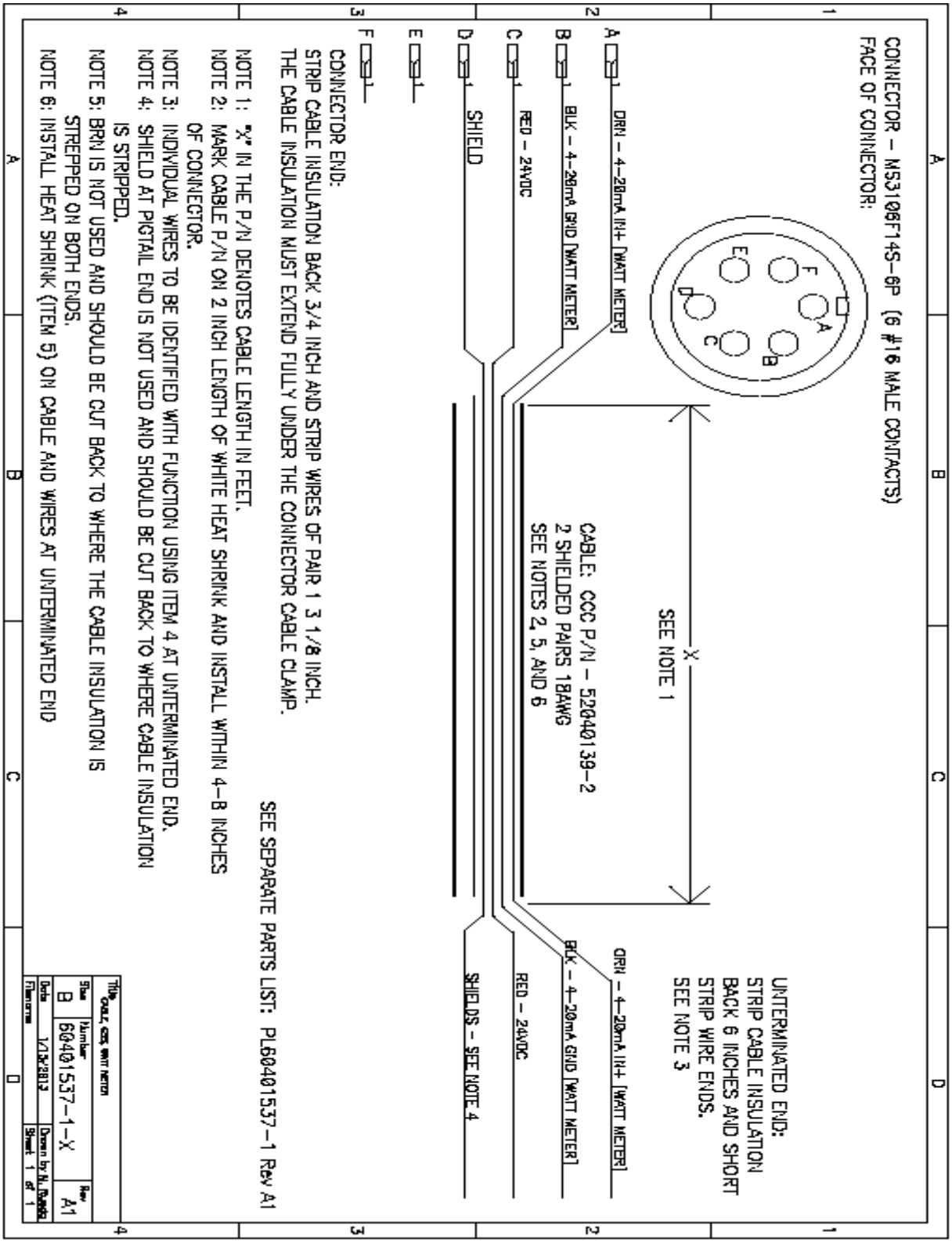
SHUTOFF VALVE CABLE - ER STYLE



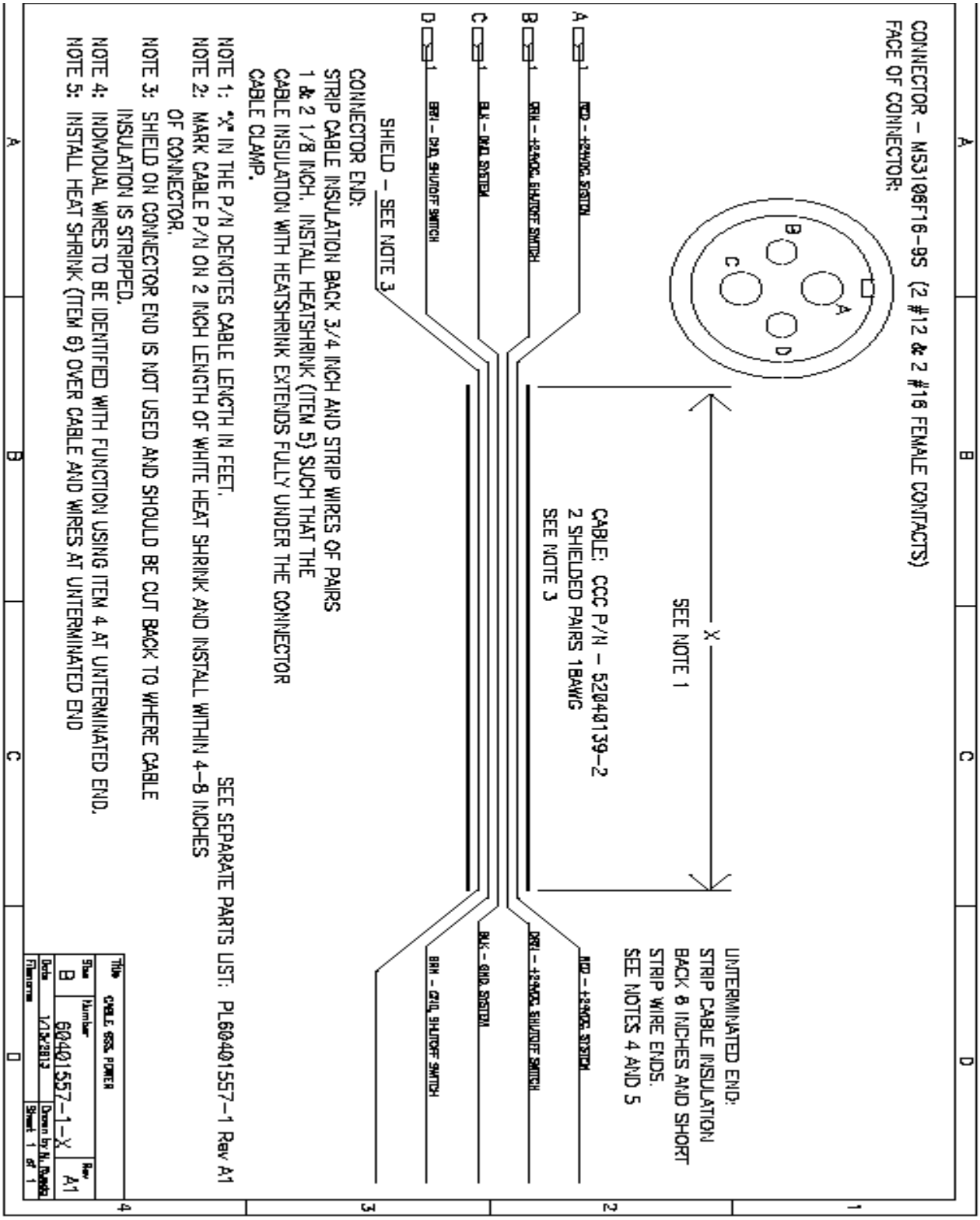
GV1 – ECV5 INTERFACE CABLE – ER STYLE 60401507-1



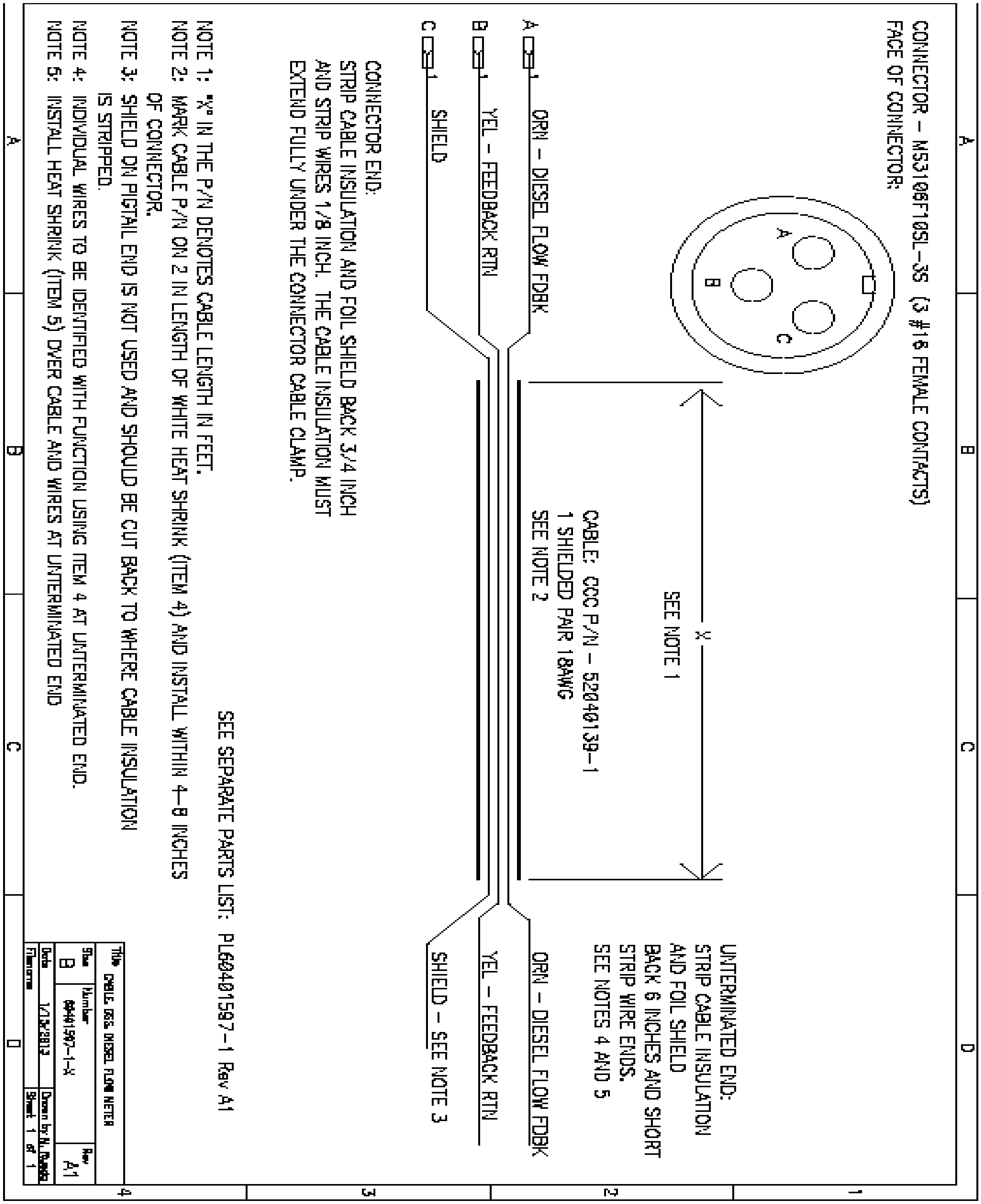
WATT METER CABLE – ER STYLE 60401537-1



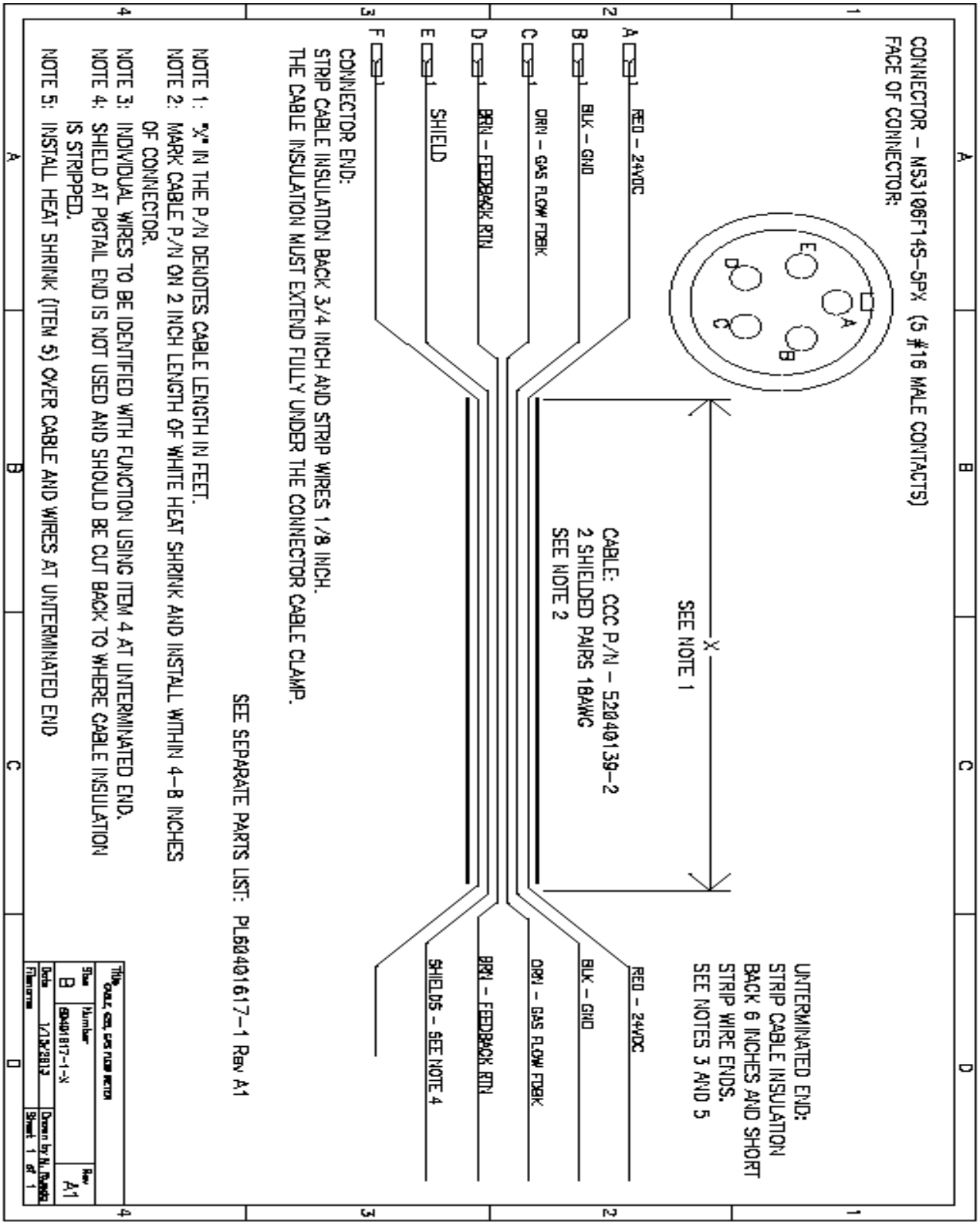
POWER CABLE – ER STYLE 60401557-1



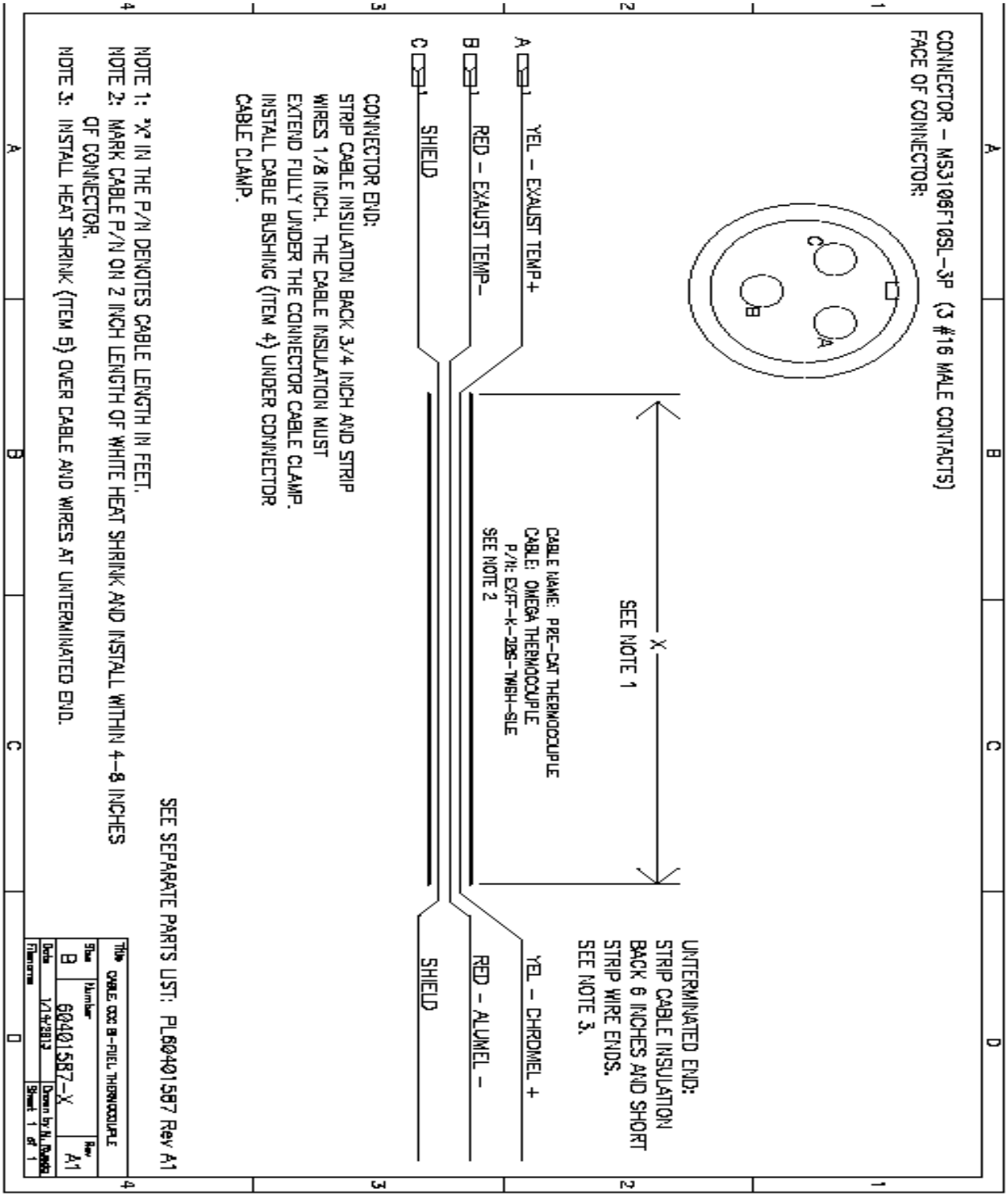
DIESEL FLOW METER – ER STYLE 6040187-1



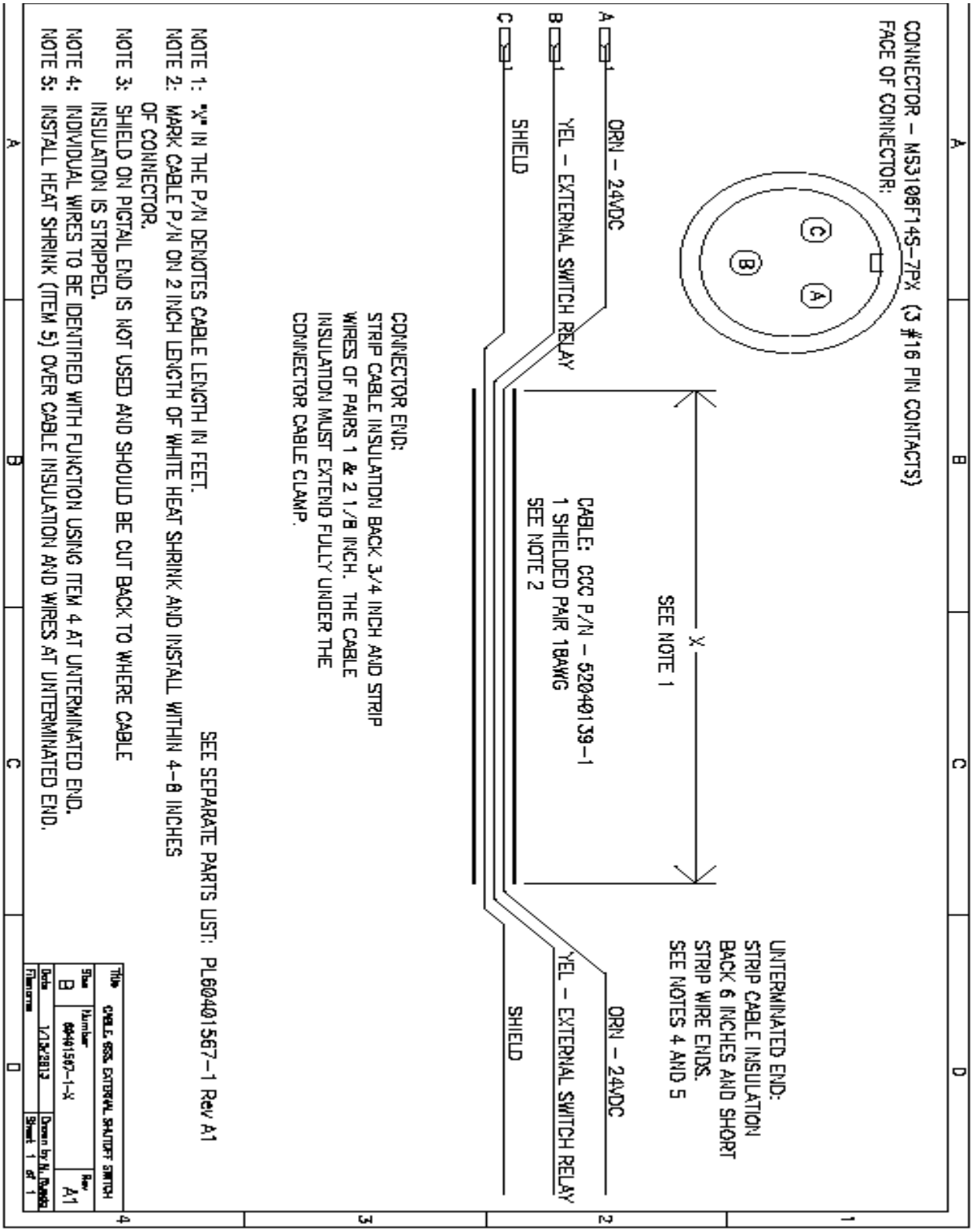
GAS FLOW METER – ER STYLE 60401617-1



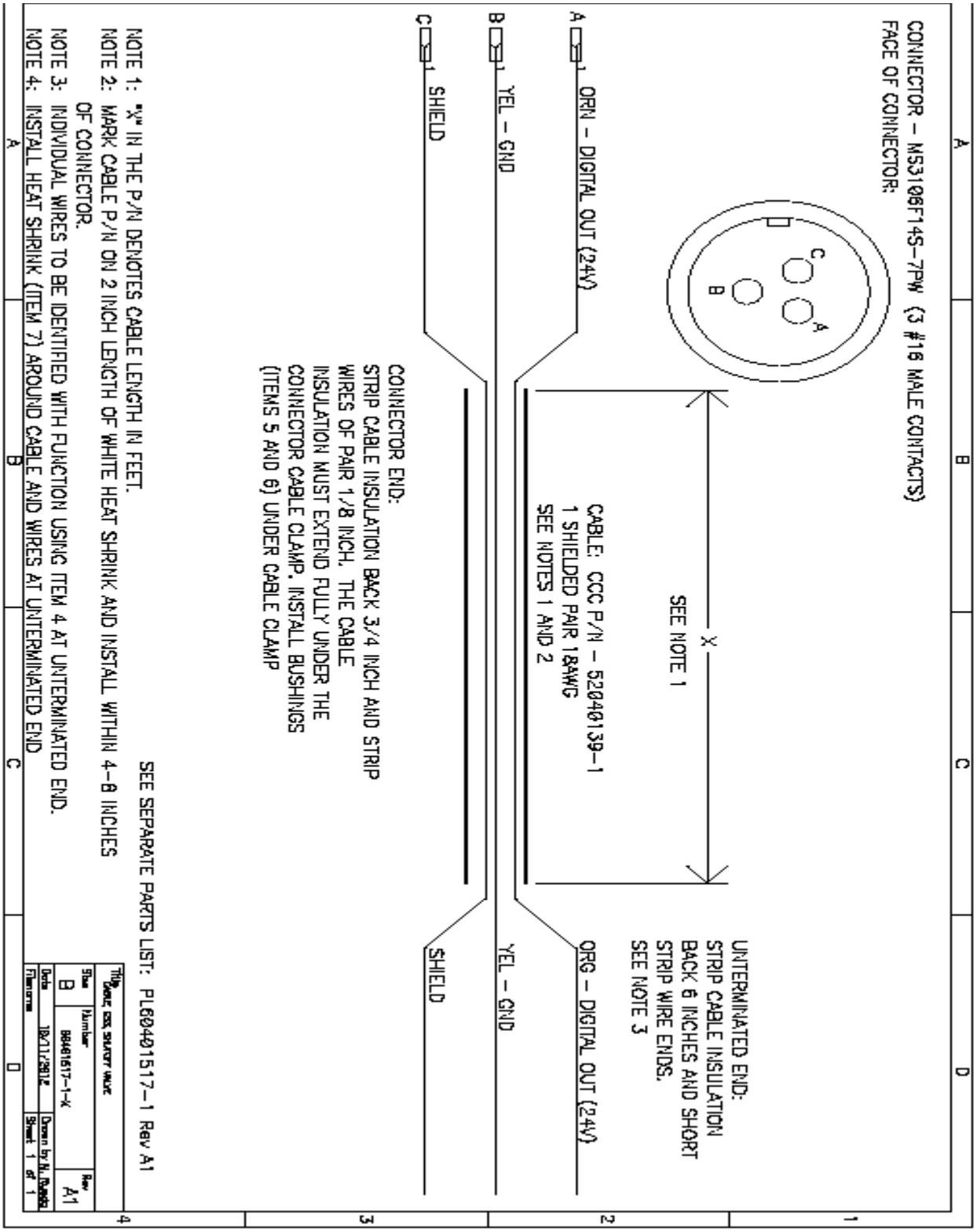
THERMOCOUPLE CABLE 60401587



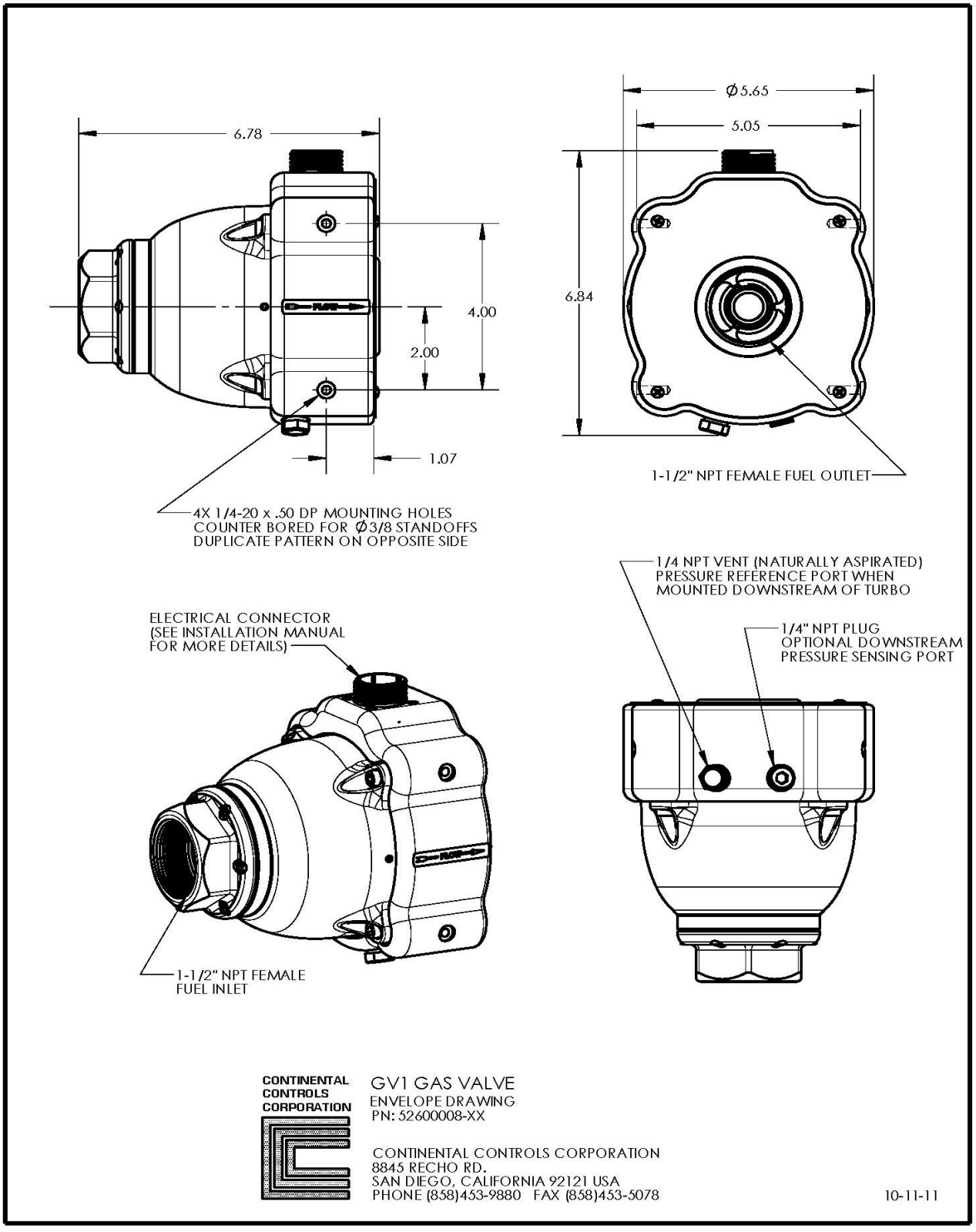
EXTERNAL SHUTOFF SWITCH – ER STYLE 60401567-1



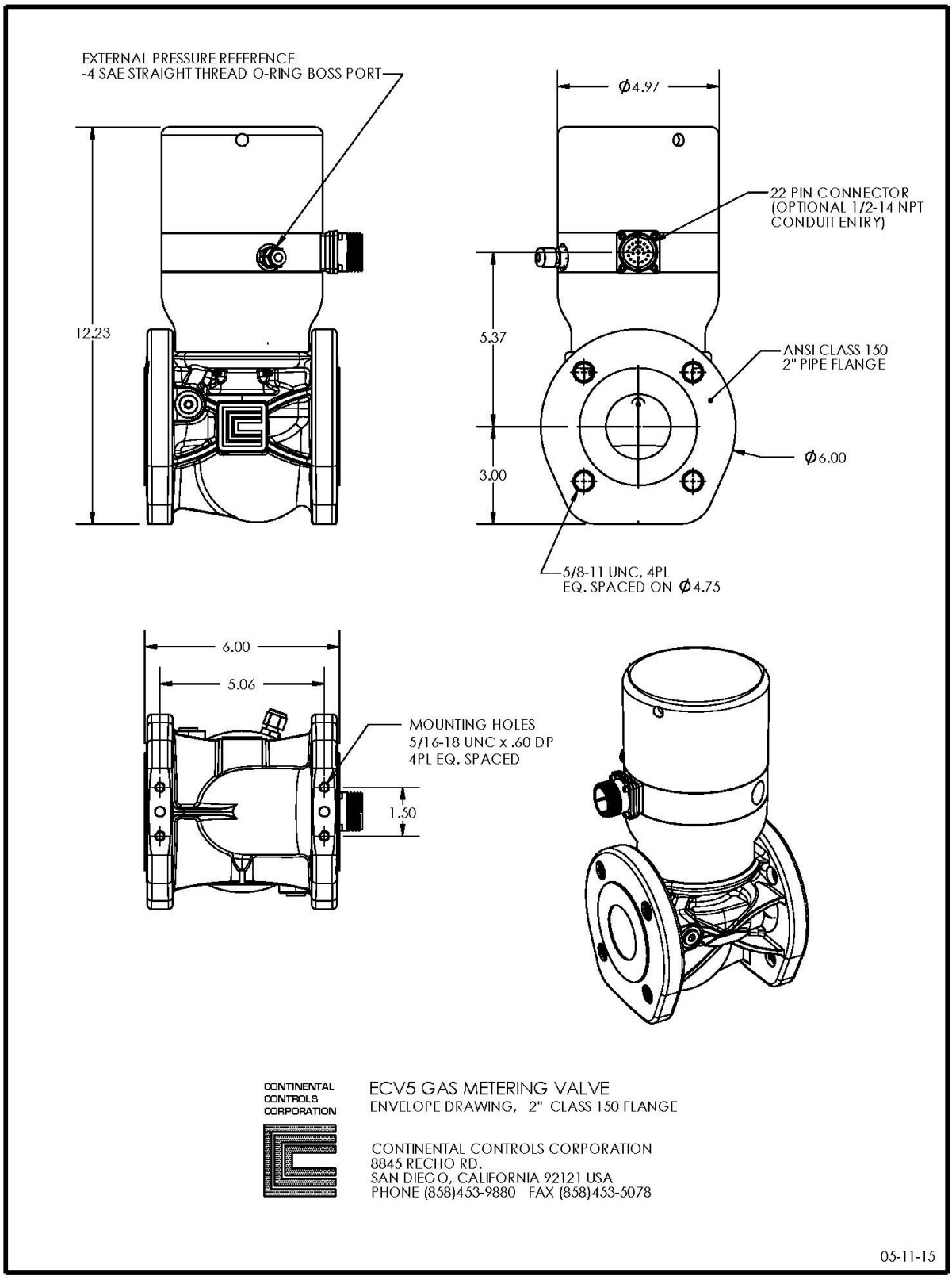
PRESSURE SWITCH CABLE – ER STYLE 60401517-1



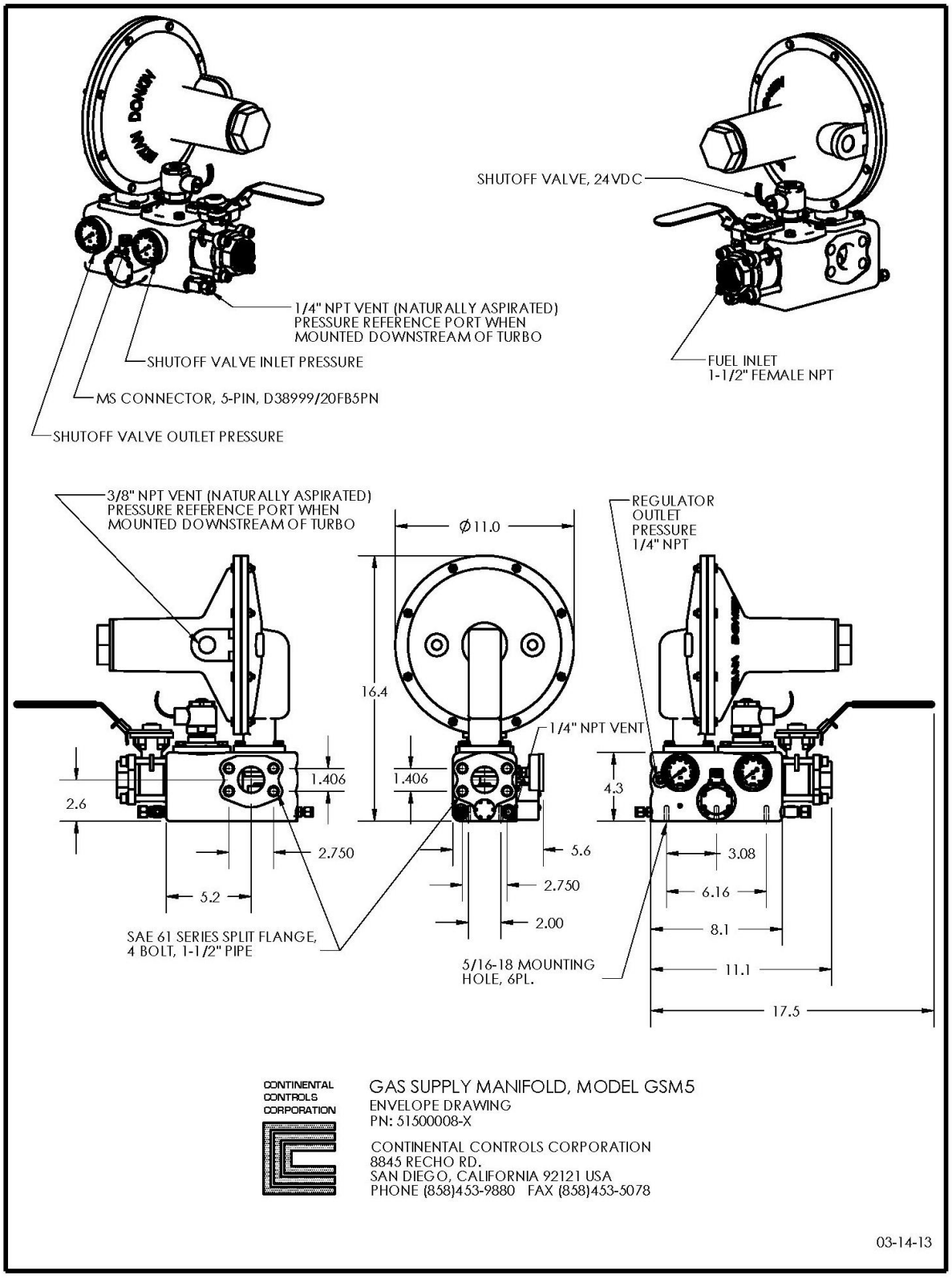
GV1 Envelope Drawing



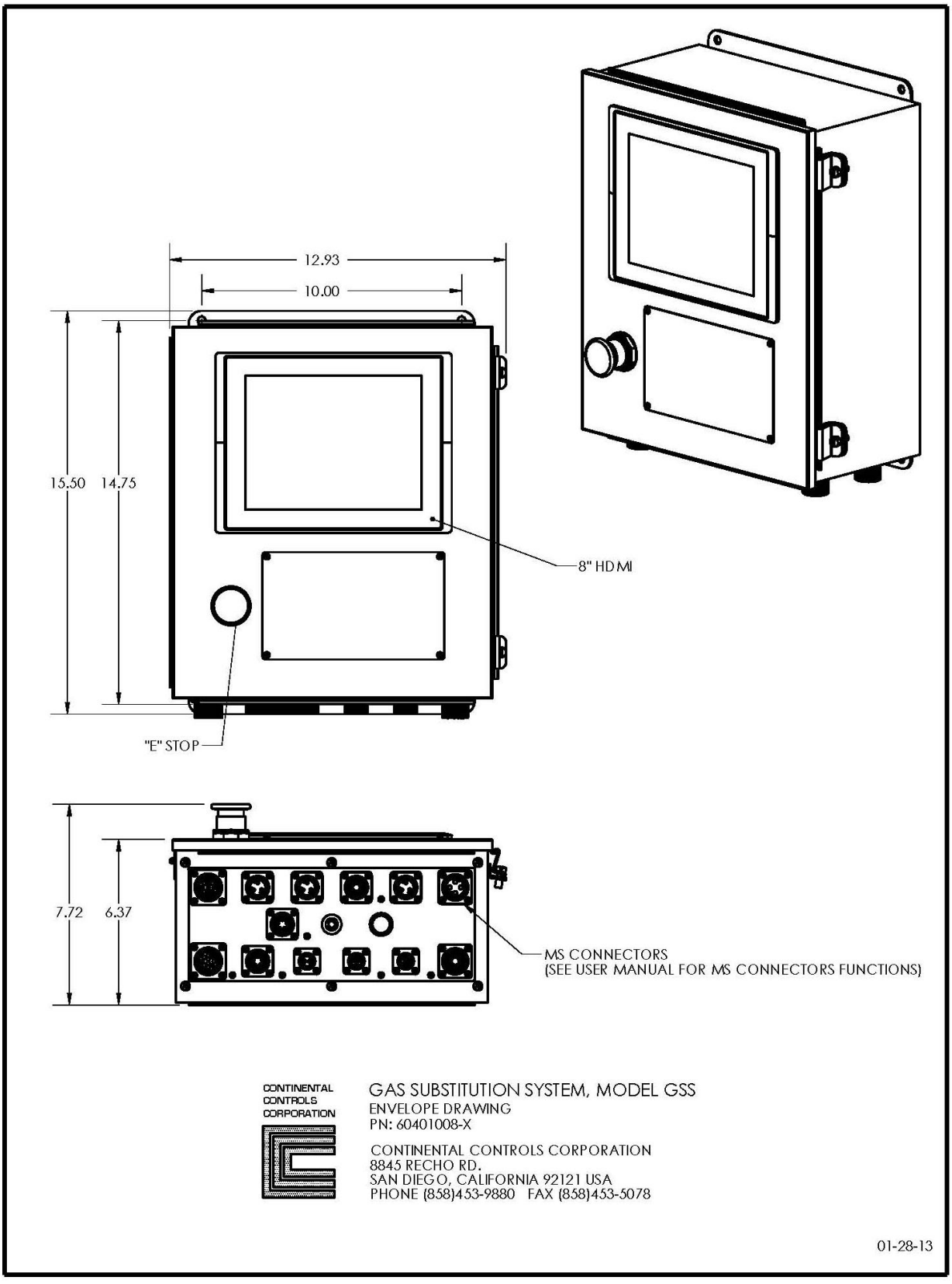
ECV5 Envelope Drawing



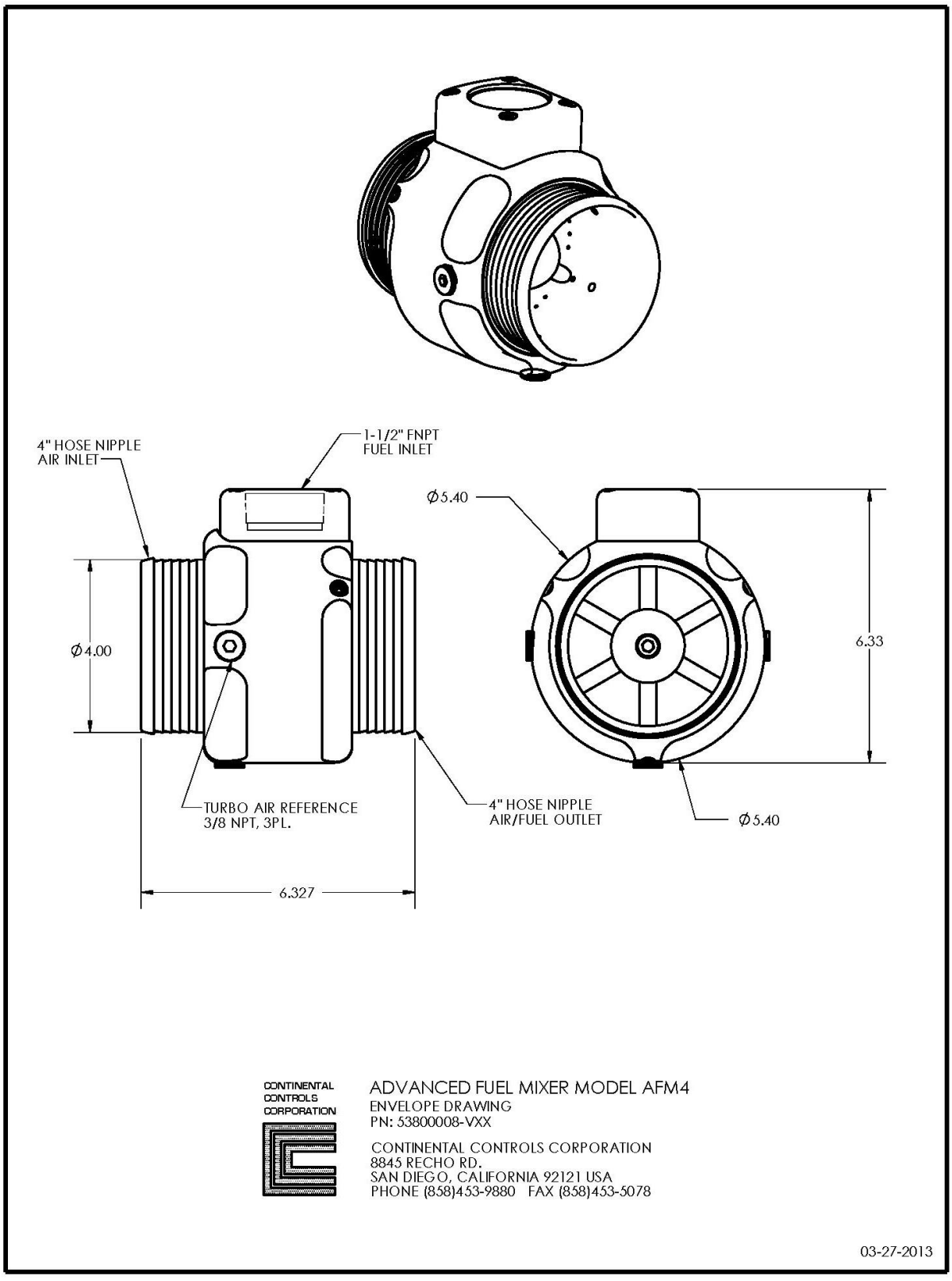
Gas Supply Manifold GSM5 Envelope Drawing



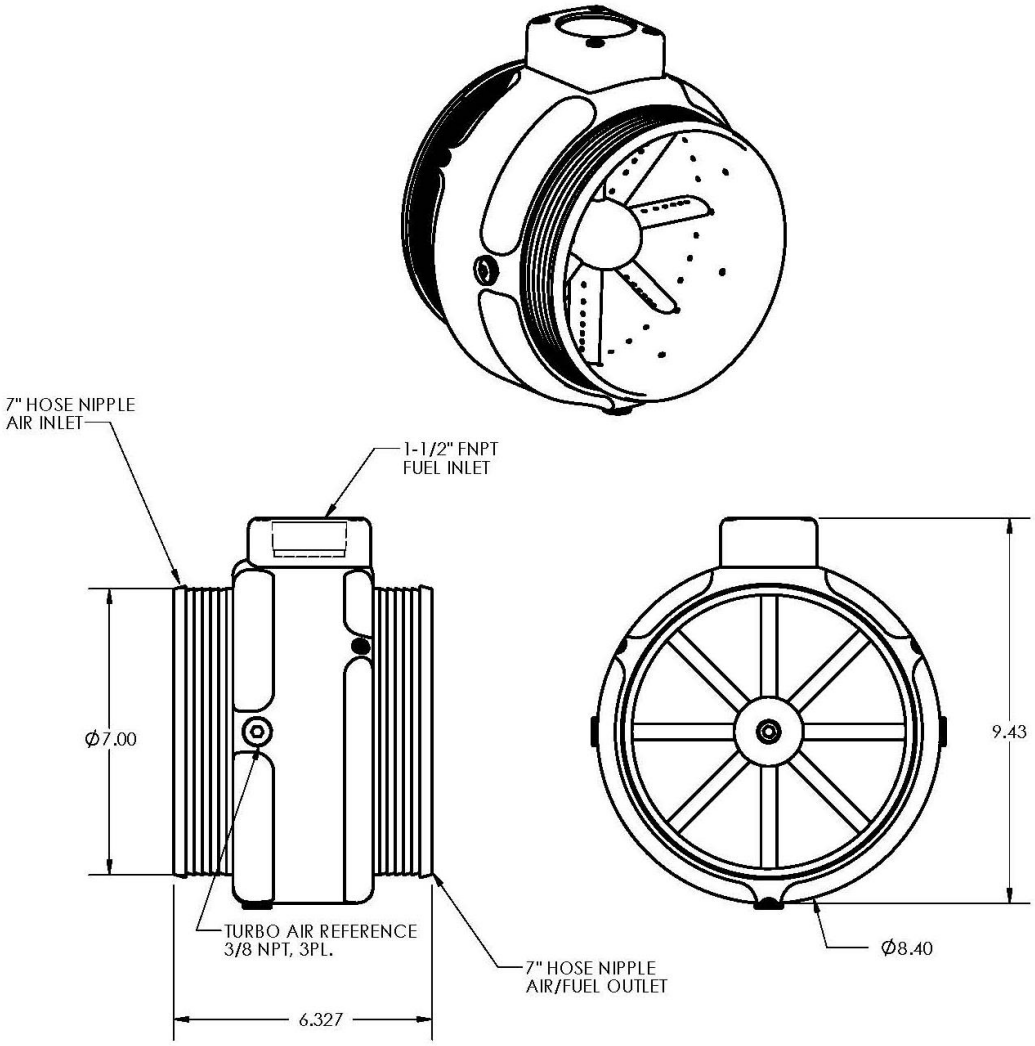
Gas Substitution System Interface, GSSI Envelope Drawing



Advanced Fuel Metering Venturi AFM4 Envelope Drawing



Advanced Fuel Metering Venturi AFM7 Envelope Drawing



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ADVANCED FUEL MIXER MODEL AFM7
ENVELOPE DRAWING
PN: 53700008-VXX

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8845 RECHO RD.
SAN DIEGO, CALIFORNIA 92121 USA
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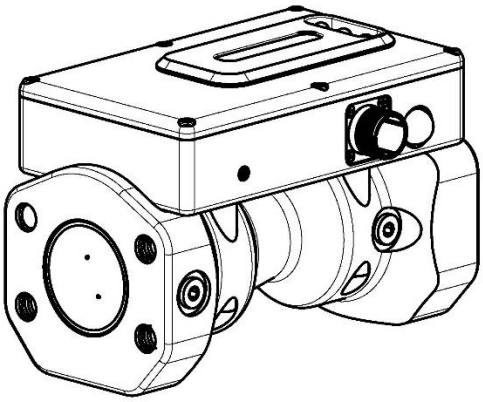
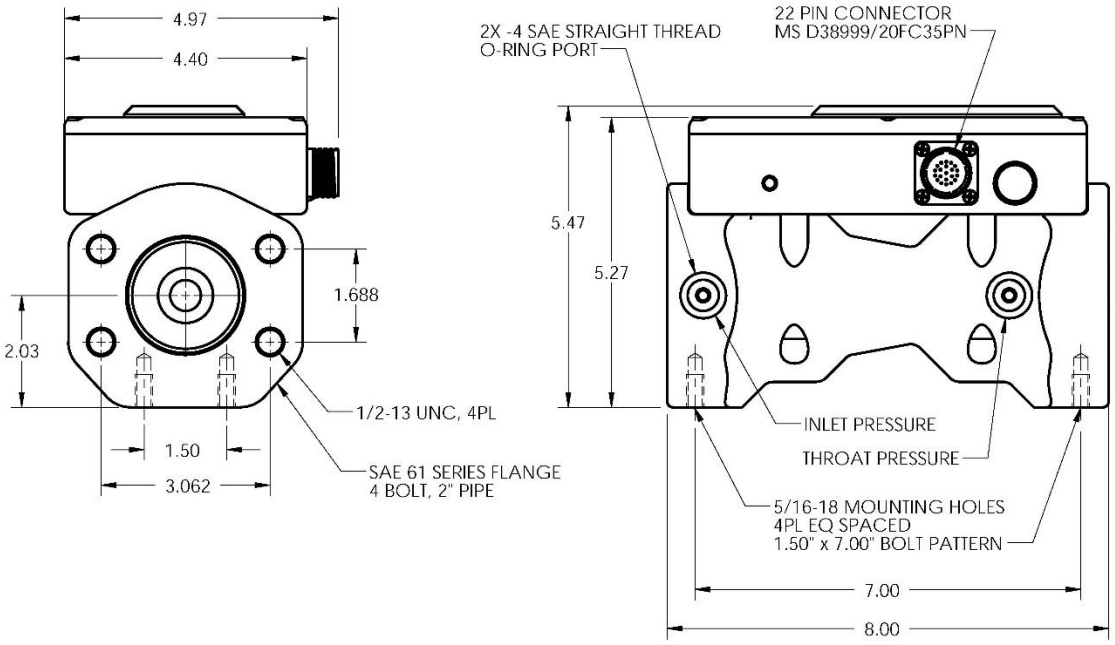
Flowmeter FM50 Envelope Drawing





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FLOW METER, MODEL FM50
ENVELOPE DRAWING
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04-17-2014