Installation and Operating Manual

ECV5 and ECVI IOM 6-18

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Preface

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

This manual is designed to describe the installation and operation of the ECV5 Emission Control Valve for either rich or lean burn applications on natural gas engines. The ECV5 and optional ECVI Display represent the current state of the art in Air/Fuel Ratio Controllers. The combination of a sophisticated mechanical design of the balanced poppet valve, the advanced electronic design, and onboard microprocessor combines to provide the best available control technology for controlling gas engines.

This manual is intended to help the end user install and operate the ECV5 Emission Control Valve and the ECVI Display to minimize risk of injury to personnel or damage to engine or equipment. Do not attempt to operate, maintain, or repair the fuel control valve 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 of the ECV5 Emission Control Valve and the ECVI Display.

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

Regulatory Compliance

These listings are limited only to those units bearing the CSA identification:

CSA:

- CSA Certified for Class I, Division 2, Groups A, B, C, and D, T3 at 85°C ambient for use in Canada and the United States
- Certificate 1975931
- Type 3R Rainproof Enclosure

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

Wiring must be in accordance with North American Class I, Division 2 wiring methods, as applicable, and in accordance with the authority having jurisdiction.

Special Conditions for Safe Use:

- Field wiring must be suitable for at least 85°C.

WARNING!

Do not remove covers or connect/disconnect electrical connectors unless power has been switched off or the area is known to be non-hazardous.

Substitution of components my impair suitability for Class I, Division 2, or Zone 2.

Do not clean equipment unless the area is known to be non-hazardous.

NOTE:

Do not connect any cable grounds or "instrument ground," "control ground," or any non-earth ground system.

Safety

It is necessary to always use extreme caution when working with any fuel system. Altronic Fuel Control Valves are normally used with natural gas. Natural gas, when combined with air, becomes very combustible. Contained within an enclosure such as a gas turbine engine or its exhaust system, the mixture can explode in a violent manner when ignited. Controls for gas engines should always be designed to provide redundant fuel shut downs. The ECV5 plays an important part in the safety of the whole system.

The ECV5 is not a shutoff valve. The ECV5 is not the primary control to shut down the engine. Shutoff valves should be used in addition to the Emission Control Valve. The fuel system should be designed in such a way that:

- No single failure of a component will cause the fuel system to admit fuel to the engine when the engine has been shut down.
- No single failure can result in grossly over-fueling the engine when attempting to start.
- No fuel is trapped downstream of the ECV5 or potentially leaked into the engine fuel manifold. It is strongly recommended that the engine should be purged of any potential gas in the fuel manifold prior to turning on the ignition system. Additionally, the Ignition Permissive should be used to insure that the ignition system is on and operating prior to the ECV5 allowing gas to the engine.

Failure to follow the above rules may lead to possibly serious damage to equipment and/or injury to personnel.

Electrostatic Discharge Awareness

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

- Discharge body static before handling the control unit.
- Avoid all plastic, vinyl, and styrofoam around printed circuit boards.
- Do not touch the components or conductors on a printed circuit board with your bare hands or with conductive devices.

Follow these precautions when working with or near the control unit:

- Avoid the build-up of static electricity on your body by not wearing clothing made of synthetic materials. Wear cotton or cotton-blend materials when possible. These fabrics do not store static electric charges as much as synthetics do.
- Do not remove the printed circuit board (PCB) from the control cabinet unless absolutely necessary. If you must remove the PCB for the control cabinet, follow these precautions:
  - Do not touch any part of the PCB except by the edges.
  - Do not touch the electrical conductors, the connectors, or the components with conductive devices or with your bare hands.
  - When replacing a PCB, keep the new PCB in the plastic antistatic protective bag it comes in until you are ready to install it. Immediately after removing the old PCB from the control cabinet, place it in the antistatic protective bag.

Glossary of Terms

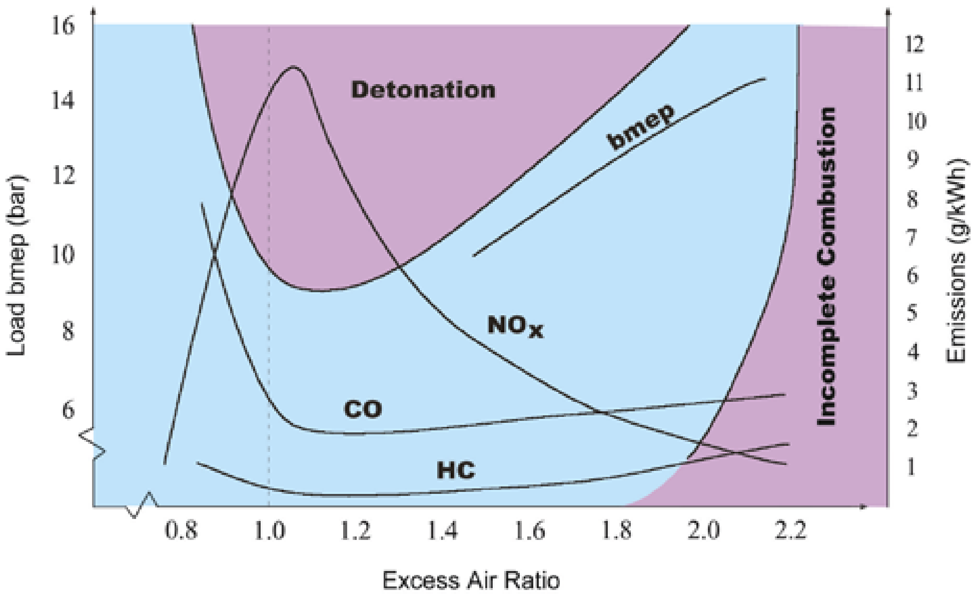
Term	Definition
Air/Fuel Ratio (AFR)	The ratio of mass air rate to mass fuel rate
CO	Carbon Monoxide
CO2	Carbon Dioxide
EGR	Engine Gas Regulator or Electronic Gas Regulator
EGT	Engine Gas Temperature
Excess Oxygen	> 10% O2
Lambda	Stoichiometric air/fuel ratio Lambda = 1.0 lean (fuel limited) being > 1.0 rich (O2 limited) being < 1.0
Lean Combustion	> 4% O2
LVDT	Linear Variable Differential Transformer
NOx	Oxides of Nitrogen (NO and NO2)
NSCR	Non-Selective Catalytic Reduction (see Three-Way Catalyst)
Rich Combustion	< 1% O2
SCR	Selective Catalytic Reduction
Sensor: O2 – Lamda	An exhaust sensing device. Outputs a low signal when lean of lambda and a high signal when rich of lambda.
Sensor: O2 – Wide band	An exhaust sensing device. Outputs a high signal when lean of lambda and a low signal when rich of lambda.
Stoichiometric	Theoretical air/fuel ratio where all fuel and oxygen are completely consumed leaving no O2 in the exhaust. Equals Lambda 1.0.
Supply Pressure	The fuel gas supply pressure immediately upstream of the ECV5
THCs	Total Hydrocarbons
Three-Way Catalyst	A device containing both reduction and oxidation materials to convert NOx, CO, and THC emissions to C, N, CO2, O2, and H2O
UHCs	Unburned Hydrocarbons
VOC	Volatile Organic Compound

1. Introduction

Before exhaust emissions were a concern, natural gas engines used mainly by the natural gas industry were designed to run with excess air. Air/Fuel ratio controllers were mechanical devices that were not very accurate and sometimes not even used. These engines ran very well with 5% to 20% excess air. The air/fuel ratio would often vary with load and as long as the engines would carry the load and didn't detonate or misfire, the operators were happy.

When exhaust emissions became important, it was discovered that these engines were running with very high NOx levels, sometimes at the peak of the NOx curve. Two strategies evolved to reduce the NOx while containing the CO and unburned hydrocarbons: Stoichiometric or Rich-Burn combustion and Lean-Burn Combustion.

The graph below is representative of the Cylinder Pressure on the vertical (Y-axis) and the actual air/fuel ratio divided by the stoichiometric air/fuel ratio on the horizontal (X-axis). The graph is not to scale and does not represent any particular engine.

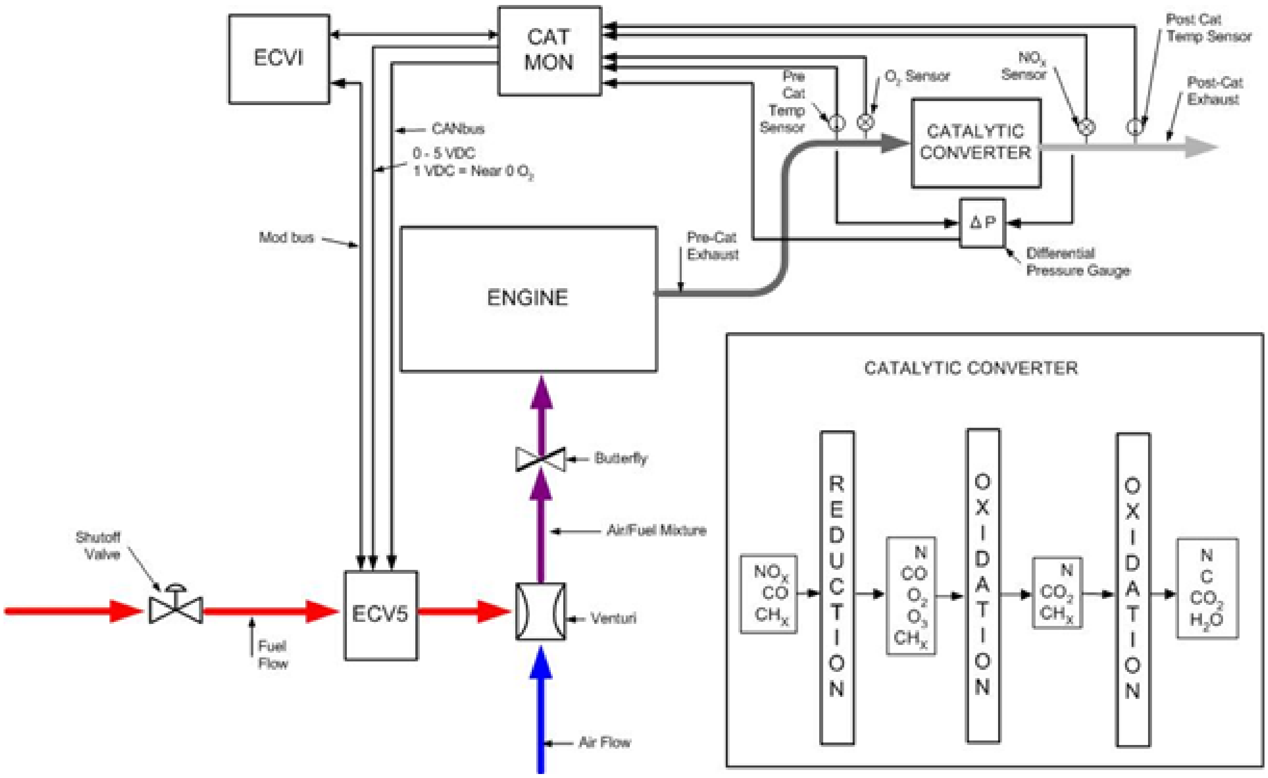


Typical Emission Curve without Exhaust Treatment

The Excess Air Ratio on the X-axis is referred to as Lambda. Stoichiometric air/fuel ratio is 1.0 in the figure above. Rich-burn operation is to the left of the stoichiometric point and lean-burn operation is any ratio to the right of the stoichiometric point. As seen in the graph above, the Excess Air Ratio, Lambda, needs to be much higher than 1.0, to reduce the NOx significantly. Operation in the detonation or knock region and the incomplete combustion region must be avoided. According to the graph, the engine can be operated at a higher load or BMEP without detonating when operating with a large amount of excess air. The higher BMEP means more horsepower is available and the engine will be a little more efficient because of the higher cylinder pressure.

Rich-Burn Combustion

The first, and easiest to implement method is to operate the engines at a stoichiometric fuel mixture. This is also referred to as “rich-burn” operation. A stoichiometric mixture is the chemically correct fuel mixture for combustion, with near zero oxygen left over in the exhaust. This method of operation is suitable for a three-way catalytic converter. The mixture must be precisely controlled in order for the reaction in a catalytic converter to oxidize the CO to CO2 and reduce the NO and NO2 to N2 and O2 and not have undesirable products left over.



Block Diagram of EVC5 and Cat Monitor in Rich Burn Combustion Configuration

Rich-Burn Oxygen Sensor

To achieve the mixture control precision required for the catalyst, an oxygen (O2) sensor is placed in the exhaust ahead of the catalytic converter. The output of the O2 sensor is fed back to the control device to close the loop on the amount of oxygen in the exhaust. The mixture is controlled to maintain very small oxygen content, less than 0.02% in the exhaust, as indicated by the voltage produced by the O2 sensor. This indicates that the combustion process is consuming nearly all of the oxygen. If a higher oxygen content is indicated, the engine is running too lean and a lower oxygen content indicates the mixture is too rich.

Benefits of Rich-Burn

One of the benefits of a catalytic converter on engines running in a Rich-Burn mode is that they operate with very small quantities of NOx and CO in the exhaust. At the discharge of the catalytic converter, NOx in the range of a few parts per million is achievable.

Lean-Burn Combustion

The second strategy for reducing emissions is to run the engine with as much excess air as possible. Any air/fuel reaction requires an energy source to initiate combustion. In natural gas engines, the spark plug performs this function. In the lean-burn engines, the combustion process is enhanced by pre-mixing the air and fuel upstream of the turbocharger before introduction into the cylinder. This creates a more concentrated mixture in the combustion chamber and reduces the occurrence of "knocking" or detonation. To prevent either knocking or misfiring, the combustion process must be controlled within a narrow operating window. Input air temperatures and volume, together with air to fuel ratio and compression ratio, are constantly monitored. The microprocessor-based engine controller regulates the fuel flow, air/gas mixture and ignition timing. Lean-Burn engines are designed to operate at a lean air/gas ratio of Lambda = 1.7 (traditional stoichiometric natural gas engines have an air/gas ratio of Lambda = 1.0). In the preceding graph that plots Break Mean Effective Pressure (BMEP) against Air Excess (Lambda), the operating window is a very narrow band where efficiency peaks and NOx is near its minimum. A richer mixture (stoichiometric) can potentially produce knocking and higher NOx emissions. A leaner mixture than Lambda 1.7 may not combust reliably and could cause misfiring, which raises hydrocarbon (HC) emissions.

Full-authority electronic engines, sensors, and microprocessors in newer lean-burn engines are critical for maintaining combustion within these boundaries. The design of the lean-burn engine incorporates a simple open combustion chamber housed in the piston crown. The shape of the piston crown introduces turbulence in the incoming air/fuel mixture that promotes more complete combustion by thoroughly exposing it to the advancing flame front. The flame plate of the cylinder head is regular (flat) and the spark plug is centrally located. The air and gas are mixed using a governor controlled gas nozzle operating in a Venturi. If a power cylinder has more air compressed into it, the specific heat of the air charge in the cylinder is higher, which means it can absorb the same quantity of heat with less temperature rise. The reduction in temperature causes a reduction in the oxidation of the nitrogen. Engines running with large amounts of excess air can achieve levels of NOx below 2 grams/BHP-hr without a catalytic converter. A selective catalytic converter can be used to reduce the NOx level further but has the disadvantage of requiring the injection of urea or ammonia.

Air/fuel ratio in lean burn engines can be as high as 22:1. When full power is needed, such as during acceleration or hill climbing, a lean burn engine reverts to a stoichiometric (14.7:1) ratio or richer.

Lean-Burn Oxygen Sensor

The Wide Range Oxygen Sensor Interface used for Lean Burn and Rich Burn engines indicates a very wide range of oxygen in the exhaust and is often referred to as a Lambda sensor. Lambda is the air-fuel ratio that the engine is running, divided by the stoichiometric air/fuel ratio, as shown in the graph on page 8.

Benefits of Lean-Burn

Engines running in the Lean-Burn mode offer several important advantages:

- lowered combustion temperatures
- reduced emissions
- fuel flexibility

One of the results of this technology is significantly reduced emission in the exhaust. Lean-burn gas engine generators can have NOx emissions as low as .85 grams/BHP-hr and produce low amounts of hydrocarbons (HC), carbon monoxide (CO) and particulate matter (PM), allowing generator sets to meet the most stringent air quality regulations without after treatment devices in the exhaust stream. For even lower emissions, lean-burn gas engine generator sets are also available with factory-integrated after treatment options such as Selective Catalytic Reduction (SCR) and Oxidation Catalysts, resulting in NOx levels at or below 0.85 grams/BHP-hr. With these after treatment options, gas engine generators have been shown to meet the most stringent prime power emissions regulations anywhere in the world.

Another advantage of the lean-burn technology with full-authority electronic engine controls is the ability to operate on gas with a wide range of quality. The Methane Number (MN) measurement is used to determine fuel gas suitability as an engine fuel. Most natural gas has an MN from 70 to 97. Pipeline quality gas typically has an MN of about 75. Resource recovery gas from landfills or sewage treatment facilities is typically of lower quality, but is often suitable for use in lean-burn engines. Some lean-burn gas engine generators will operate on gas with an MN of 50 or greater, providing excellent fuel flexibility. However, gas with a MN below 70 may require de-rating of the generator output.

Lean-burn gas engine generator sets are setting a new standard for fuel efficiency, high power output for their size, and low emissions. In regions with supplies of natural gas, these generator sets are providing highly reliable electric power for utility peaking, distributed generation, prime power, and combined heat and power systems.

Achieving Emission Compliance

Emission performance necessitates that a number of systems and components operate together consistently and flawlessly over a long period of time. This requirement translates into the following:

- Superior air/fuel ratio controller set to optimize catalyst performance and capable of maintaining the air/fuel ratio within a favorable lambda range regardless of changes in fuel composition, ambient conditions, or engine operating load
- Wide-band oxygen sensors – narrow-band sensors do not have this capability
- NOx sensor connected in a feedback control loop to trim the AFR controller as it seeks lowest NOx emissions
- Advanced fuel control valves with very fast, very precise, control capabilities
- Well maintained engine ignition timing that does not deviate too advanced or retarded, both of which effect engine emissions
- High quality NSCR catalyst with high surface area, high catalytic activity, and long service life
- Catalyst designed with low gas hourly space velocity, i.e., high catalyst volume
- Catalyst housing with superior seals to eliminate exhaust gas bypass around the catalyst

Under these conditions and in a "clean" exhaust environment, a good quality, properly sized, NSCR catalyst should achieve high performance over an extended period of time. However, even with tight lambda control, low-load operating conditions are likely to reduce the engine exhaust gas temperature and possibly reduce the performance efficiency of the NSCR catalyst.

A stringent performance specification minimizes performance loss over thousands of hours of operation. Even the most exceptionally designed catalyst loses performance because external factors over time. These factors include:

- Contaminants like ash and sulfur mask and plug the surface and the pores of the catalyst
- Chemical contaminants react with, and poison the precious metal active ingredients, or engine malfunction causes excessive temperatures in the catalyst as fuel combusts across the catalyst resulting in catalyst sintering

Therefore, long-term, high catalyst performance also imposes the following system requirements:

- Very low-ash engine lube oil to completely eliminate the deposition of ash on the catalyst surface
- Absence of any chemicals that poison the catalyst coming from the fuel, the combustion air, the lube oil, the antifreeze, poor in-cylinder combustion, and any or all other sources.
- Absence of ignition system problems that result in unburned fuel reaching the catalyst and causing an over-temperature condition

From a system standpoint long-term emission performance requires monitoring and maintenance of:

- The engine, its ignition system, its lube oil system, its coolant system, etc.
- Fuel pressure control, fuel flow control, fuel flow measurement
- The air-fuel ratio controller, the wide band oxygen sensors, the NOx sensor, the temperature sensors
- Measurement and documentation of emission performance for the new system to establish benchmark performance

From a catalyst standpoint:

- Chemical washing may be required periodically to remove contaminants to maintain performance during the warranty period. A well-designed catalyst should respond well to chemical washing but cannot reverse the effects of thermal sintering or certain contaminants that irreversibly poison the precious metals.
- It may be prudent to have a spare set of catalyst onsite to minimize downtime when chemical cleaning is required.

In summary, emission performance requires a system approach that includes equipment, operating conditions and routine maintenance that extend far beyond the scope of the catalyst.

2. ECV5 for Rich or Lean-Burn Configurations

The ECV5 is the heart of the AFR system. The logic and electronic circuitry for closed loop control of an engine AFR is within the ECV5. The Cat Monitor is the interface between the O2 sensors and NOx sensors to the ECV5. The ECVI (I for interface) provides a junction point for all interconnections between the different devices and a graphical user interface. No control logic or settings are saved in the display.

The AFR can be used for rich burn or lean burn engines simply by picking a different O2 sensor input. The O2 sensor inputs from the Cat Monitor are 0 to 5Vdc with the higher the voltage, the more oxygen in the exhaust. This is opposite of narrow band sensors commonly used. Stoichiometric or (Lambda 1.0) will be near 1.0Vdc. 20.8 percent O2 is 5.0Vdc. So a lean setpoint will be from 2.25Vdc to 3.0Vdc. By using this signal, the ECV5 can sense if the engine is running too rich or too lean. If the O2 sensor voltage is higher than the O2 setpoint, the engine is running too lean. The ECV5 will respond by increasing the internal pressure setpoint. Likewise, if the voltage is lower, the engine is too rich, and the pressure setpoint will be decreased. The pressure setpoint always starts at the default pressure. The default pressure is the pressure the valve maintains for starting the engine, or if the O2 sensor fails. There are programmable high and low limits. For safety, these limits should be set to the normal operating range of that particular engine.

The NOx sensor can be used either on a rich burn engine or lean burn. The NOx sensor on a rich burn engine is installed in the exhaust after the catalyst. In a lean burn engine, there is no catalyst therefore, the NOx sensor would be installed directly in the exhaust. The NOx sensor is connected to the Cat Monitor via the CANbus. The Cat Monitor will trim the O2 sensor setpoint leaner or richer to reach the desired NOx level, or tune the AFR to the optimal setting for best performance from the catalyst.

Production of Emissions

Operation of any fuel-fired power generating equipment results in emissions of exhaust gases. Principal among these are carbon dioxide (CO2), water vapor (H2O), oxides of nitrogen (NO and NO2, generally referred to as NOx), oxides of sulfur (SOx), carbon monoxide (CO), unburned hydrocarbons (UHC), and particulates. The environmental permitting requirements for onsite generation impose restrictions on emissions of NOx, SOx, CO, and particulates because of their contributions to smog and acid rain. Regions of the U.S. with significant air quality problems are classified as "Non-Attainment Zones" and severe limits are placed on annual emissions of these pollutants in those areas. As a consequence, requirements for pollution abatement equipment are more stringent in these areas.

The rates of emissions depend on the quantities of fuel consumed, the type of fuel used, and the temperature of combustion. "Thermal" NOx emissions are a consequence of the high combustion temperatures; the higher the temperature level the greater the formation rate for NOx. This is true no matter what fuel is used. "Fuel based" NOx emissions are negligible in systems using natural gas, but they can be a significant source of pollution when fuel oil is used. SOx formation is a consequence of sulfur contained in the fuel and is insignificant for natural gas but must be considered when fuel oil or other fuels are used. Generally, technologies for reducing NOx and SOx emissions increase emissions of CO and UHCs.

As a fuel is burned in an engine, various exhaust emissions are produced:

- Hydrocarbons (HC's) from unburned fuel are formed from a rich fuel mixture (or a lean fuel mixture where there is excess air, leading to a lean misfire.
- Carbon Monoxide (CO) from a rich fuel mixture, and never from a lean fuel mixture.
- Carbon Dioxide (CO2) formed during any combustion process when oxygen and carbon are present in the primary combustion ingredients.
- Oxygen (O2) from a lean fuel mixture.
- Oxides of Nitrogen (Nitrogen Oxide) NOx. Nitrogen is present in the air we breathe, and the engines air it consumes. Nitrogen displaces the air by approximately 75%. Nitrogen doesn't burn, but it can oxidize at temperatures over 2,500°F. NOx is a health hazard and one of the EPA's primary emission problems.

One method of controlling NOx is to reduce combustion temperatures. An EGR valve is the easiest device to use. It bleeds a small amount of inert exhaust gas into the incoming air stream, diluting the oxygen, and reducing combustion temperatures.

Another method of NOx reduction is to run a richer fuel mixture. By adding more fuel, the amount of air is displaced, reducing NOx. The exhaust catalyst, converting the CO and HC into CO2, handles the left over fuel. With a liquid fuel engine, the addition of more fuel also lowers the combustion temperature by the condensing effect. Here the fuel is evaporating and absorbing combustion heat. With a vapor fuel, the reverse is true. If the engine is running lean (over λ=1.2), the exhaust actually begins to cool down, thus reducing exhaust and combustion temperatures.

Exhaust Gas Treatment

Generally, there are trade-offs between low NOx emissions and high efficiency for any engine. There are also trade-offs between low NOx emissions and emissions of the products of incomplete combustion (CO and unburned hydrocarbons). There are three main approaches to these trade-offs that come into play depending on regulations and economics. One approach is to control for lowest NOx, accepting a fuel efficiency penalty and possibly higher CO and hydrocarbon emissions. A second option is finding an optimal balance between emissions and efficiency. A third option is to design for highest efficiency and use post-combustion exhaust treatment.

There are several types of catalytic exhaust gas treatment processes that are applicable to various types of reciprocating engines — three-way catalyst, selective catalytic reduction, oxidation catalysts, and lean NOx catalysts.

The catalytic three-way conversion process (TWC) is the basic automotive catalytic converter process that reduces concentrations of all three major criteria pollutants — NOx, CO and VOCs. The TWC is also called non-selective catalytic reduction (NSCR). NOx and CO reductions are generally greater than 90%, and VOCs are reduced approximately 80% in a properly controlled TWC system. Because the conversions of NOx to N2 and CO and hydrocarbons to CO2 and H2O will not take place in an atmosphere with excess oxygen (exhaust gas must contain less than 0.5% O2), TWCs are only effective with stoichiometric or rich-burning engines. Typical “engine out” NOx emission rates for a rich burn engine are 10 to 15 gm/bhp-hr. NOx emissions with TWC control are as low as 0.15 gm/bhp-hr. The ECV5 used in conjunction with a NOx sensor guarantees the best possible emissions. It is not uncommon to be able to control below 1ppm of NOx over a period of months using a NOx sensor with a patented emission minimization algorithm.

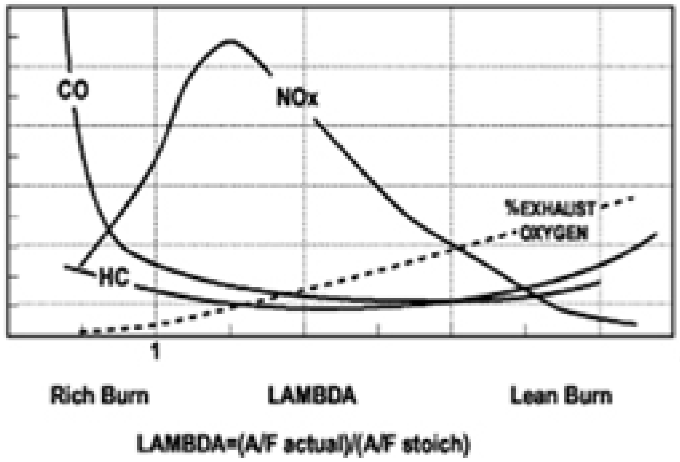
Stoichiometric and rich burn engines generally have lower efficiencies than lean burn engines. The TWC system also increases maintenance costs by as much as 25%. TWCs are based on noble metal catalysts that are vulnerable to poisoning and masking, limiting their use to engines operated with clean fuels, e.g., natural gas and unleaded gasoline. Also, the engines must use lubricants that generate catalyst-poisoning compounds and have low concentrations of heavy and base metal additives. Unburned fuel, unburned lube oil, and particulate matter can also foul the catalyst. TWC technology is not applicable to lean burn gas engines or diesels.

Lean burn engines equipped with selective catalytic reduction (SCR) technology selectively reduces NOx to N2 in the presence of a reducing agent. NOx reductions of 80% to 90% are achievable with SCR. Higher reductions are possible with the use of more catalyst, more reducing agent, or both. The two agents used commercially are ammonia (NH3 in anhydrous liquid form or aqueous solution) and aqueous urea. Urea decomposes in the hot exhaust gas and SCR reactor releasing ammonia. Approximately 0.9 to 1.0 moles of ammonia is required per mole of NOx at the SCR reactor inlet in order to achieve an 80% to 90% NOx reduction.

SCR systems add a significant cost to the installation and maintenance of an engine system and can severely impact the economic feasibility of smaller engine projects. SCR requires on-site storage of ammonia, a hazardous chemical. In addition, ammonia can “slip” through the process unreacted and contribute to environmental health concerns.

Oxidation catalysts generally are precious metal compounds that promote oxidation of CO and hydrocarbons to CO2 and H2O in the presence of excess O2. CO and NMHC conversion levels of 98% to 99% are achievable. Methane conversion may approach 60% to 70%. Oxidation catalysts are now widely used with all types of engines, including diesel engines. They are being used increasingly with lean burn gas engines to reduce their relatively high CO and hydrocarbon emissions.

Lean-NOx catalysts utilize a hydrocarbon reductant (usually the engine fuel) injected upstream of the catalyst to reduce NOx. While still under development, it appears that NOx reduction of 80% and both CO and NMHC emissions reductions of 60% may be possible. Long-term testing, however, has raised issues about sustained performance of the catalysts. Current lean-NOx catalysts are prone to poisoning by both lube oil and fuel sulfur. Both precious metal and base metal catalysts are highly intolerant of sulfur. Fuel use can be significant with this technology in that the high NOx output of diesel engines would require approximately 3% of the engine fuel consumption for the catalyst system.



Emissions with Catalyst in Rich Burn Combustion Configuration

3. ECV5 General Information

Specifications

Electrical Input Characteristics	
Input Voltage Range	19 – 30 VDC Range; 24Vdc Nominal
Maximum Steady State Input Current	3A Nominal
Maximum Transient Input Current	5A Max

Mechanical Characteristics	
Valve Maximum Effective Area	.560 in2
Valve Minimum Effective Area	0
Weight	17.3 lbs.
Mounting	ANSI Class 150 2” Pipe Flange (See envelope drawing)

Temperature	
Steady State Ambient Temp	-40° to +185°F
Storage Temp	-40° to +185°F
Fuel Gas Inlet Temp	-40° to +185°F

Fuel Connections	
Filter Requirements	Less than 50 µm

Dynamics	
Step Response Slew Time	< 100ms for a 10 – 90% and 90 – 10% step
Overshoot	< 2% of step

Environment

EMC

EN61000-6-2 (2005) Immunity for Industrial Environments
EN61000-6-4 (2001) Emissions for Industrial Environments

Fuel Type

The ECV5 operates on gases ranging from pipeline quality natural gas to specialty gas (such as landfill, digester, or other biogases). The ECV5 also operates on gases ranging from pipeline quality natural gas to propane. Proper application of the valve for fuel flow, FGP, energy content, etc., is the responsibility of the OEM/packager/customer. The fuel gas flowing through the valve can consist of the following compounds with limits if they apply:

Component	Specification
Gaseous hydrocarbons (methane, ethane, propane, etc.)	No limit
CO	No limit
CO2	No limit
Hydrogen	< 10%
Oxygen	No limit
Nitrogen	No limit
Sulfur compounds including Hydrogen sulfide	< 500mg/10kWh (< 2000mg/10kWh)
Chlorine and fluorine compounds (typically chlorofluorocarbons)	< 100mg/10kWh (< 400mg/10kWh)
Silicon	< 5mg/10kWh (<20mg/10kWh)
Ammonia	< 50mg/10kWh
Oil or hydrocarbons in liquid (mist form)	< 5mg/10kWh
Fine particulates, including silicon (less than 1.0µm)	< 3mg/10kWh

Overall, the gas Specific Gravity should be between 0.4 and 2.0 for the ECV5. The energy content should be between 1 and 9.5kWh/nm3. The values in parenthesis ( ) are allowed, but may result in reduced valve life. The above fuel limits can be converted to ppm by multiplying the given number by the LHV of the fuel in question, then dividing by 36. The LHV must be in units of MJ/kg.

Inlet Fuel Gas Pressure

The maximum inlet fuel gas pressure (FGP) for the ECV5 is 50psig. Most applications will have a much lower FGP. If the FGP is too high, the required ECV5 stroke will be reduced and instability may result.

FGP Adjustment

With the engine running at max load and the target air fuel ratio, adjust the inlet FGP so that the ECV5 stroke is approximately 75%.

Fuel and Service Gas

> ***NOTE:***
>
> ***Operators are urged to consult local legislative authority for sulfur limitations on fuels. Antipollution legislation may require a lower sulfur content than specified in the fuel table.***
>
> ***The selection of a satisfactory fuel depends on the physical and chemical composition of the fuel. Natural gas fuel requirements are given in the following table.***

Natural Gas Fuel Physical and Chemical Requirements

Gas Temperature	-40°F to +185°F (-40°C to +85°C)
Lower Heating Value	700 to 2,500Btu/scf. Lower heating values outside this range are acceptable with approval of Altronic Engineering.
Composition	Gas composition shall be such that dew point at engine supply pressure of 150 psig (10.5kg/cm2) must be at least 10°F (6°C) below gas fuel supply temperature. Dew point can be calculated from the composition or determined experimentally with an instrument such as the Alnor Dew Pointer, manufactured by Alnor Instrument Company, Chicago, Illinois.
Contaminants: Fuel Gas	Total contaminants shall not exceed: 30ppm x (lower heating value by weight Btu/lb)/(19000Btu/lb) or 30ppm x (kg-cal/kg)/(10534kg-cal/kg)
	Particles larger than 10 microns shall not exceed: 0.3ppm x (lower heating value by weight Btu/lb)/(19000Btu/kg) or 0.3ppm x (kg-cal/kg)/(10534kg-cal/kg)
	No entrained water is allowed; i.e., no water in excess of saturation of at 150psig (10.5kg/cm2) pressure or maximum operating pressure.
	Percent-by-weight total sulfur, including hydrogen sulfide, shall not exceed: 1% x (lower heating value by weight Btu/lb)/(19000Btu/lb)
Service Gas (If separate supply for pneumatic started and auxiliary pump gas motors)	No more than 0.7 grams of solid contaminants per 1000cu ft. (28.3cu m) of gas are allowed; 99 percent of these solids shall be smaller than 10 microns.
	No entrained water is allowed; i.e., no water in excess saturation at maximum operating pressure.
	No more than 0.5 pound (0.23kg) sulfur per 1000cu ft. (28.3cu m) of gas (including hydrogen sulfide) is allowed.

4. Features

Range

The ECV5 is a true full-authority fuel valve, the range of the ECV5 is much greater than a system relying on a pressure regulator with a bypass valve or a restrictor stepper motor.

The range of the ECV5 will help tremendously when working with applications where any of the following may occur:

- Load Changes
- BTU Value of the fuel gas changes
- Ambient Air Temperature Changes

Bypass type systems are normally set up on the lean limit and they add fuel to control in the desired range. In the event that a large load is removed, the system cannot control beyond this lean limit. In the event that the BTU value of the gas declines, the unit sometimes cannot add enough fuel to keep up with the change. This control range on a bypass type system is normally a maximum of 10% to 15% change.

A restrictor valve type of system is normally set up to run rich and the restrictor valve pinches off fuel to control in the acceptable range. This system also lacks the range to keep up with large load changes or BTU swings.

Closed Loop Pressure Control

This control technique is really what separates the ECV5 from other controllers when it comes to reducing emissions. The ECV5 operates as a variable pressure controller where the O2 sensor constantly readjusts the control pressure setpoint as required to meet emissions. This technique helps to stabilize the engine control by controlling the moving setpoint and reducing droop in the regulator. This integrated pressure control concept is patented and is unlike any other controller. By reducing or increasing the pressure gain settings in the ECV5, the valve will react as quickly or can be dampened as much as is required by the application.

Fully Automatic Control

The ECV5 is fully automatic. This means that no matter what the operational changes are in the engine, the ECV5 will keep up with the changes. There is no need to call an operator to reset a setpoint or adjust the controller. These changes are automatic.

Variable Dynamic Gain

The ECV5 automatically adjusts the amount of gain applied based on the stroke of the valve. This means that if the valve is barely being stroked, the gains are barely applied, and as the stroke increases, so do the gains. At maximum stroke, the gains are still appropriate for this amount of stroke. This unique control technique allows the ECV5 to control effectively at startup, light loads, or fully loaded.

Communications

The circuit board inside the ECVI serves as a junction point for all connections between the ECVI, the Cat Monitor, ECV5, and optionally, the FM50 Flow Meter. Communication from each device is of two different protocols: CANbus J1939 and Modbus RTU. (See available registers in appendix) Modbus gives the HMI (ECVI display) the ability to interface with each device, while CANbus is used for communication between the devices.

All devices use the following RS232 communication settings:

RS232 Setting	Value
Baud rate	9600
Data bits	8
Stop bit	1
Parity	None
Flow Control	None
Default Modbus ID	1

The ECV5, Cat Monitor, and flow meters each have an RS232 serial port built into each device. The ECVI circuit board has multiple RS232 to RS485 converters that link all serial communications to a single RS485 bus for communication to the display. Each device on the RS485 Modbus network must have a unique Modbus address which should be set as follows:

Device	Modbus Address (ID)
ECV5 Left bank	1
ECV5 Right Bank (dual bank configuration only)	2
Catalyst Monitor	3
Flow Meter	25

There are two terminals on the circuit board that are connected to this RS485 Modbus. These terminals are for an optional user interface such as a SCADA system or PLC. However only one device may be the Modbus master. If another device is acting as the Modbus master, the HMI (ECVI display) may not be connected. Modbus TCP/IP is available through the Cat Monitor.

5. Theory of Operation

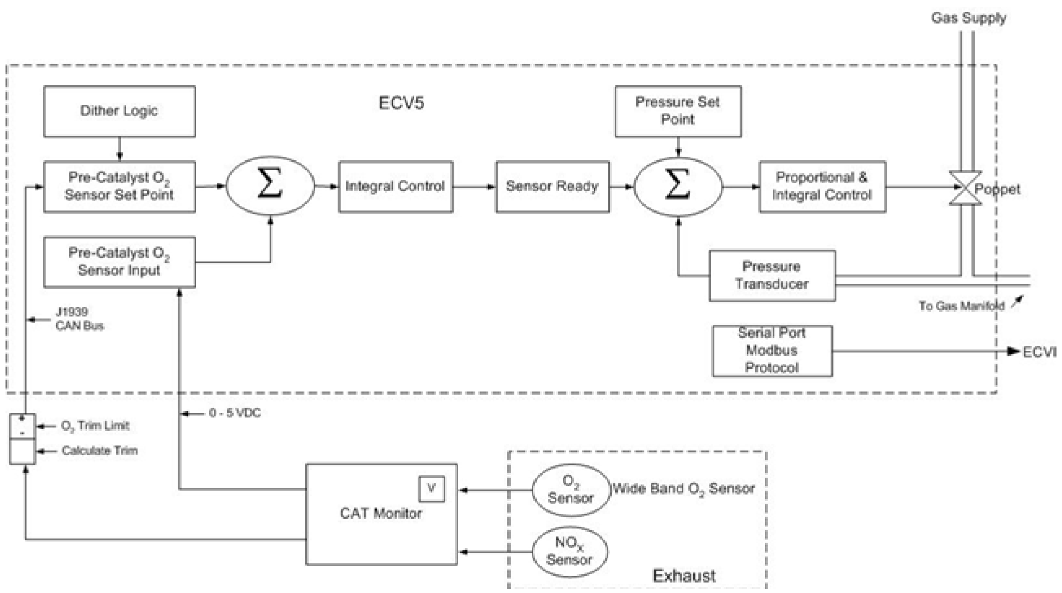
The ECVI is the user interface for the ECV5 and the Catalyst Monitor. It serves as the central hub where all of the separate components of the system are connected. The individual components communicate with each other via CANbus while the user interface communicates to each device with a Modbus serial port.

The ECV5 is essentially an electronic pressure regulator. When the system receives an ignition confirm signal, the ECV5 will open and control the fuel pressure to the default pressure setting for startup. When running in default mode or startup, the ECV5 regulates fuel pressure to the venturi mixer just like a pressure regulator. If the O2 sensor fails, the system will run in default mode until shut down. The ECV5 will stay in default mode until the Warmup Timer expires and the ECV5 is receiving a valid O2 sensor signal from the Catalyst Monitor. Once the warm up period is over and a valid O2 reading is received, the ECV5 will go in to AFR mode. At this point, the ECV5 will vary the fuel pressure in order to maintain a desired air-to-fuel ratio. If a NOx sensor is installed on the system, the Cat Monitor will adjust the O2 sensor set-point to compensate for changes (i.e., ambient air temperature, load, or even degradation of the catalyst) throughout the day. If the ignition confirm signal drops, the ECV5 valve will close, the heater for the O2 sensors and NOx sensor will turn off, and the system will wait for the engine to re-start.

The System

The system consists of the following components:

- **ECVI box and display.** The ECVI box contains terminal strips to connect wire from various other components.
- **ECV5 AFR control valve.** The ECV5 contains a microprocessor that reads a voltage from an oxygen sensor and modulates the outlet pressure of the valve to control the air to fuel ratio of the engine. The system configuration may contain one or two ECV5s depending on if the application is a single or dual bank engine.
- **Catalyst (Cat) Monitor.** The Cat Monitor interfaces the wide band O2 sensors and NOx sensors with the ECV5. The Cat Monitor can make minor adjustments to the O2 sensor setpoint within the ECV5 by looking at the NOx sensor. The Catalyst Monitor should be mounted near the exhaust and no more than 30 feet from the O2 sensors. The NOx sensor is connected to the Cat Monitor via CANbus. The NOx sensor cable length should be no more than 50 ft. distance from the Cat Monitor to the ECVI.
- **Oxygen (O2) sensors.** The Catalyst Monitor can connect up to two wide band O2 sensors. One O2 sensor for the left bank and one for the right bank. The Cat Monitor uses a Bosch LSU4.2 O2 sensor.
- **NOx sensors.** The NOx sensor is located in the exhaust. On rich-burn engines, the NOx sensor is located after the catalyst. The NOx sensor is connected to the Cat Monitor via CANbus.
- **Venturi.** The venturi serves as a fuel mixer assuring even distribution of the fuel through the airflow. The venturi is located downstream of the ECV5 and somewhere on the air inlet of the engine. The venturi may be standalone or a “drop-in” style that replaces the diaphragm assembly inside the carburetor.



Functional Diagram of ECV5 and System

Full Fuel-Authority

The ECV5 meters all fuel entering the engine from no flow to full flow. This prevents the valve from running out of range in difficult applications such as those with large swings in the heating value of the gas. This feature also enables the valve to change the fuel flow very quickly in response to load transients. The full fuel authority of the ECV5 is key to keeping the emissions within required limits under all conditions.

Pressure Sensor

The ECV5 functions as a high-speed, precision pressure regulator with a setpoint that is electrically driven by an oxygen sensor. An integrated pressure transducer constantly monitors the outlet pressure of the valve. This pressure is communicated to the valve's on-board electronics where it is compared to either the default pressure setpoint or the dynamic setpoint derived from the oxygen sensor input. Any difference between the pressure measurement and the setpoint is corrected by adjusting the poppet position. This process is repeated every 1 millisecond and the pressure is adjustable from -8 to 24 in. H_2O. The end result is an electronic pressure regulator that does not suffer from the common problems associated with mechanical regulators such as droop and limited range.

Mechanical Valve Design

Unlike many of the valves used in competing emissions control systems, the ECV5 was specifically designed for reciprocating engines using gaseous fuels. It is not a modified pressure regulator, a biasing restrictor, or a valve borrowed from a different market sector or manufacturer. Following are some of the key mechanical design features that contribute to the superior performance of the ECV5.

Balanced Poppet

The ECV5 utilizes a balanced metering poppet. This is a proven design that has been used for decades in numerous industries using flow control valves. Low friction rolling diaphragms counterbalance the forces exerted on the valve poppet by upstream and downstream pressures. This eliminates the need for additional spring and actuator forces to be wasted on overcoming these pressure forces. The result is an efficient valve that uses less power over a wide range of pressures.

Position Sensor

The performance of the ECV5 is further improved using closed loop position control. An LVDT position sensor continually communicates the poppet position to the valve's computer. This signal is then compared to the position setpoint generated by the pressure control loop. Any error in position is quickly corrected. This feature improves transient performance and helps eliminate instability caused by flow forces on the poppet. The position sensor is also a useful diagnostic tool.

High Speed Actuator

At the heart of the ECV5 is a high-speed, electromechanical, linear actuator that is used to drive the metering poppet. The actuator is comprised of a powerful rare-earth magnet and a precision wound coil attached to the poppet shaft. 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 poppet in the open direction. The closing force is generated by a stainless steel compression spring, making the valve fail-safe in the closed direction. The actuator is capable of generating forces in excess of 20 pounds and going from the fully closed to the fully open position in less than 50 milliseconds. This gives the valve unprecedented response to the ever-changing demands of the engine.

Catalyst (Cat) Monitor

The Cat Monitor is available in three different configurations:

- **CM1** – Thermocouple, 4-20mA input, relay output, CANbus interface, Modbus RTU RS232 interface. Modbus TCP/IP Ethernet interface and an optional 2.4GHz radio interface.
- **CM2** – All the functions of a CM1 plus one wide range O2 sensor. This is what is typically used for a single bank engine.
- **CM3** – All the functions of a CM2 with an additional wide range O2 sensor for a dual bank engine with two exhausts.

The Cat Monitor serves several functions:

- The Cat Monitor controls the heater of the O2 sensor and pump current converts the reading to a linear voltage to percent O2 signal. One volt is near stoichiometric or lambda one and five volts is atmospheric or 20.9 percent oxygen. This signal is used as a process variable input to the ECV5. On a dual bank system there are individual signals for each bank.
- Reads the exhaust temperature pre- and post-catalyst. A relay output is provided for a high temperature output.
- A 4-20mA input is provided for a “Delta-P” transducer. The Delta-P transducer is installed with one side measuring the upstream pressure of the catalyst and the other side to the downstream side of the catalyst. The purpose is to measure the pressure drop across the device to detect fouling of the element.
- The Cat Monitor is the interface to the NOx sensor. The Cat Monitor will adjust the O2 sensor setpoint of each of the ECV5 valves though the CANbus according to the NOx minimization logic.
- Most of the data read by the Cat Monitor is logged to the thumb drive installed inside the Cat Monitor. This is a CSV spread sheet file. The end user can periodically remove the thumb drive for diagnostic purposes or for logging data required under RICE/NESHAP. The light blinking on the Cat Monitor’s cover indicates that it is writing to the thumb drive. Do not remove the thumb drive while it’s in the process of writing. The frequency of the logging is programmable and the data amount that can be stored is dependent on the installed drive’s storage capability. With the default settings and 4 GB drive that are installed at the factory, the Cat Monitor can store up to 4 years of data.
- An Ethernet interface is provided for use with a SCADA system or plant PLC.

Wide-Range Oxygen Sensor

When controlling air/fuel mix on an engine running in Rich or Lean Burn mode, it is necessary to use a wide-range oxygen sensor, which has a much greater range than a traditional 2 wire Lambda sensor. The Wide-Range Oxygen sensor, used in conjunction with the ECV5, is a planar dual-cell limit-current sensor. The sensor element of the wide-range sensor is the combination of a Nernst concentration cell with an oxygen pump cell. When used with its control electronics, the sensor is capable of precise measurement throughout a wide Lambda range ($0.7 < \lambda <$ air). The Nernst concentration cell is held to the stoichiometric voltage (450mv) by oxygen pumped from the oxygen pump cell where the current to the oxygen pump cell is proportional to the oxygen concentration.

There are several versions of the Bosch sensor. Only Bosch LSU4.2 should be used.

Wide-Range Sensor Heater Power Control

The heater control circuitry of the unit does the following:

- Provides power to the heater when an Ignition Confirm signal is received from the ECVI.
- Limits the current to the heater at initial turn-on.
- Ramps up heater current after a delay until the operating point is reached.
- Controls power to the heater so that the internal temperature of the sensor maintains at about 800ºC (1472ºF).

The control region is determined by measuring the internal ac resistance of the Nernst cell. The Nernst cell resistance is about 80 ohms when the internal temperature is about 800ºC. As the internal resistance drops toward 80 ohms the heater controller takes over and increases/decreases current to the heater to maintain 80 ohms.

The current to the heater must be closely controlled because the accuracy of the measurement is a function of the temperature of the sensor. The connector of the oxygen sensor contains a calibration resistor to normalize current to the oxygen pump cell. The cable from the control electronics to the sensor requires six leads: circuit common, Nernst cell output, two leads for current to the oxygen pump cell and two leads to the heater.

ECVI

The ECVI provides an interface for changing and viewing parameters in an ECV5 AFR system during initial setup and operation. The display communicates with the ECV5 (two ECV5s in a dual bank installation) and the Catalyst Monitor over a Modbus network, and provides access to settings such as default pressure or oxygen sensor setpoint. Parameters displayed include catalyst temperatures and differential pressure from the Catalyst Monitor, and valve position, fuel pressure, and current oxygen sensor reading from the ECV5.

The ECVI provides a central location for system wiring as well as parameter touch screens. CANbus communication between devices, analog signals between devices, and power distribution to each device are wired on the board located inside the ECVI.

NOx Sensor

The ECV5 system incorporates a patented method for using a NOx sensor in rich burn applications. The NOx sensor is installed after the catalyst in the exhaust and connected to the Cat Monitor via the CANbus. The Cat Monitor continually reads the NOx sensor and adjusts the O2 sensor setpoint to the optimal setpoint reducing NOx without raising the level of CO significantly.

Using the NOx sensor, the Cat Monitor can detect whether the engine is running too rich or too lean. It's common for the O2 sensor setpoint to vary throughout the day depending on a number of factors: load, ambient temperature, engine speed, or catalyst temperature. It is not uncommon for the O2 sensor input to adjust more than .005 lambda in the course of a day. Furthermore, the system can make corrections for changes in the condition of the catalyst or oxygen sensor due to age and degradation. NOx readings below 1ppm are typical when implementing NOx sensor control depending upon the condition of the catalyst elements.

Dithering is an important control feature when implementing. Using the NOx sensor without dithering may cause large spikes in CO to occur.

WARNING!

The NOx sensor cable has 24Vdc on one of its contacts. If the NOx sensor is not connected, care must be taken not to let the wires short across each other or to ground.

DO NOT TAPE THEM TOGETHER.

Thermocouples

The supplied thermocouple is a type K in a stainless steel probe for a ¼ inch thermo well. The wire is stranded type K with Teflon insulation for heat resistance and standard size thermocouple connector with 2 male contacts. The cable supplied with the thermocouple assembly is stranded, twisted pair, shielded, type K with a mating connector and has the same insulation. Although the shielding may not be required in all installations it is recommended that it be used.

4-20ma Input for a Delta-P Transducer

The Cat monitor has the provision to connect a 4-20mA loop-powered pressure transducer to measure the delta-pressure across the catalyst. These connections are made via a two-wire Belden-type cable that is connected to the main cable harness (see cable drawing). The Cat monitor can be programmed to generate a fault or shutdown based on the level of delta pressure. This data is also logged on the thumb drive.

WARNING!

The Delta-P transducer has 24Vdc on one of its contacts. If the Delta-P sensor is not connected, care must be taken not to let the wires short across each other or to ground.

DO NOT TAPE THEM TOGETHER.

6. ECV5 Installation Instructions

The ECV5 gas-metering valve should be inspected immediately after unpacking. Check for any damage that may have occurred during shipping. If there are any questions regarding the physical integrity of the valve, call Altronic immediately.

NOTE:
If possible, keep the original shipping container. If future transportation or storage of the valve is necessary, this container will provide the optimum protection.

Things to keep in mind:

- Always provide an adequate supply pressure for the application. Ideally, the valve should stroke about 70% at full steady state load.
- Supply the valve with 24Vdc, 5 amps at the valve. Dual bank units need 5 amps per valve. Using small gauge wire may cause a large voltage drop resulting in an inadequate power source at the valve.
- Avoid ground loops when connecting the ECV5.
- Never install valve wires within the same conduit or in close proximity to high voltage power sources.
- Never paint the valve.
- Do not install the valve in such a manner where condensate may build up inside the electronics housing.
- Do not weld.

The ECV5 is designed to be installed on natural gas fired reciprocating engines.

Locate the ECV5 so that there is a minimum of flow restrictions between it and the carburetor or mixing venturi. There should be no valves other than a potential bleed valve downstream of the ECV5.

The ECV5 should be installed downstream of the shut off valve. The ECV5 is generally able to overcome problems with pressure control at various distances from the carburetor or mixing bowl. The optimum distance from the ECV5 to the carburetor or mixing bowl is approximately 20-25 in. Maintain the least amount of pressure drop as possible (i.e., no 90 degree elbows, reducers, and close nipples) sweep 90’s are ideal.

Vibration on rigid piping supply lines may cause metal fatigue. Use flexible hose somewhere in the fuel supply to the valve rather than installing completely rigid piping, allowing engine vibration to be absorbed rather than transferred to the carburetor or mixing venturi.

On dual bank units, it is ideal to mirror the installation on both sides of the engine as closely as possible, so that the pressure drop to each carburetor or mixing venturi is essentially the same.

A balance line should be connected from the air box side of the carburetor or mixing venturi to the reference port on the side of the ECV5 control housing on turbocharged units. The reference port is an Allen head plug with a hole in the center. This port is a #4 SAE straight thread, O-ring port. The thread size is 7/16 – 20.

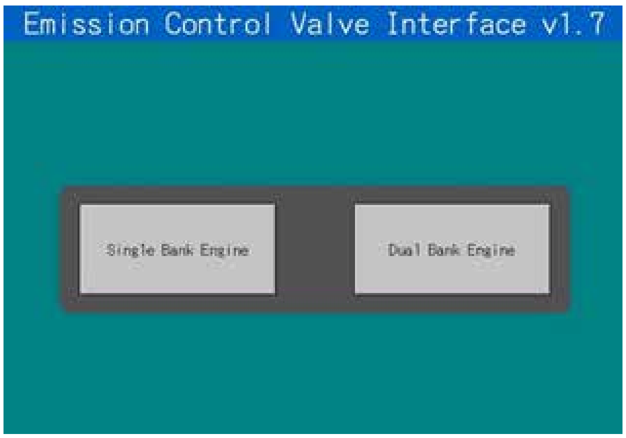
NOTE: DO NOT USE NPT FITTINGS!

7. ECVI Monitor Screens

This section describes the ECVI monitor screens for single or dual bank engines. The ECVI monitor screens display the ECV5 and Catalyst Monitor functions such as flow rate, pressure, actuator position, pressure setpoints, pre- and post-Cat temperatures, etc., via a graphical interface in real time. Screens for single bank engine configuration are pictured on the left side of the pages; screens for dual bank engine configuration are pictured on the right. Where there is only one screen shown, it applies to both configurations.

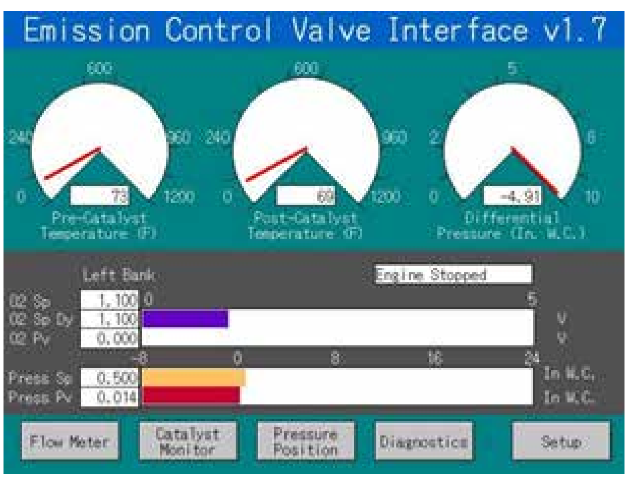
Initial Display Screen

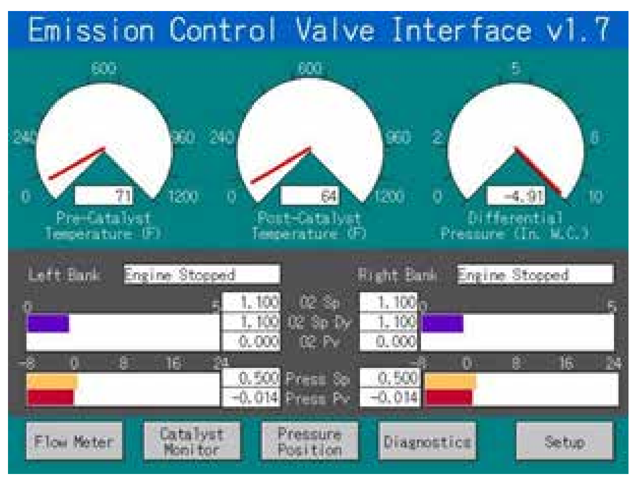
The Initial Display Screen appears upon power up of the ECVI. Either a single bank engine configuration or a dual bank engine configuration may be selected. The Main screen for the selected configuration will be displayed and accessible.



Main Screen

The Main Screen displays an overview of the ECV5/Cat Monitor system. It is accessed by pressing either the Single Bank Engine or the Dual Bank Engine button. The Main Screen lets the operator see at a glance how the system is operating such as pre- and post-catalyst temperatures, differential pressure, O2 setpoint, and pressure setpoint.

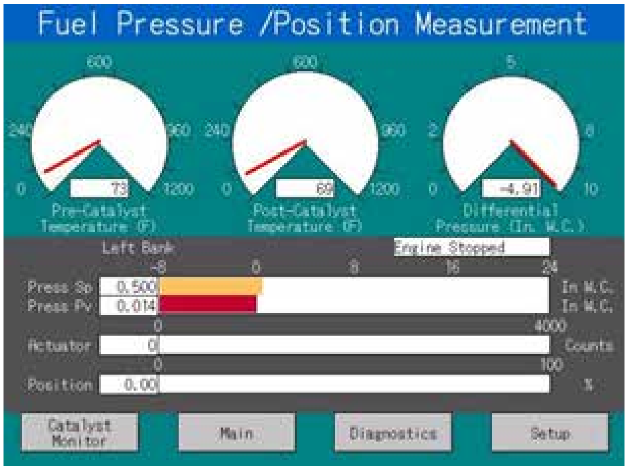


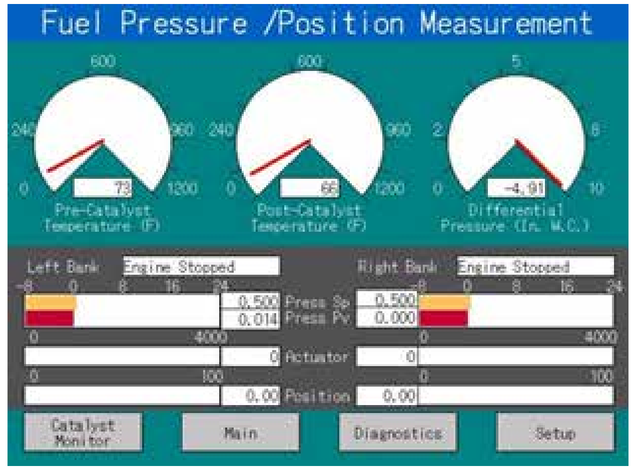


Press any of the buttons at the bottom of the screen to access other screens and functions.

Pressure/Position Measurement Screen

The Pressure/Position screen lets the operator view the downstream pressure measured in inches of water column. It also lets you see the position of the valve actuator and the percentage the valve is open.





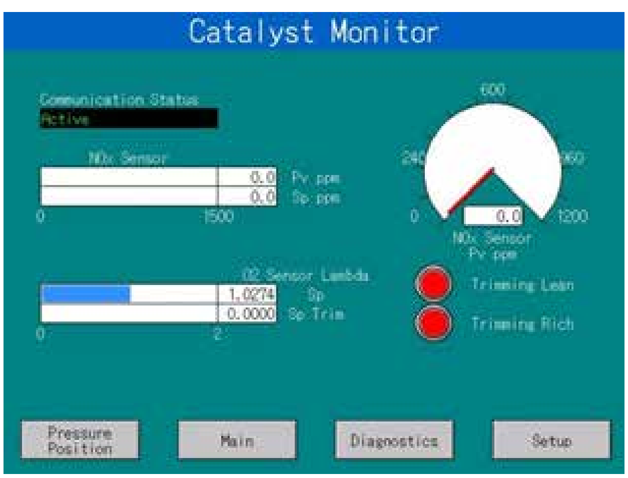
The Pressure/Position Measurement Screen displays the following parameters:

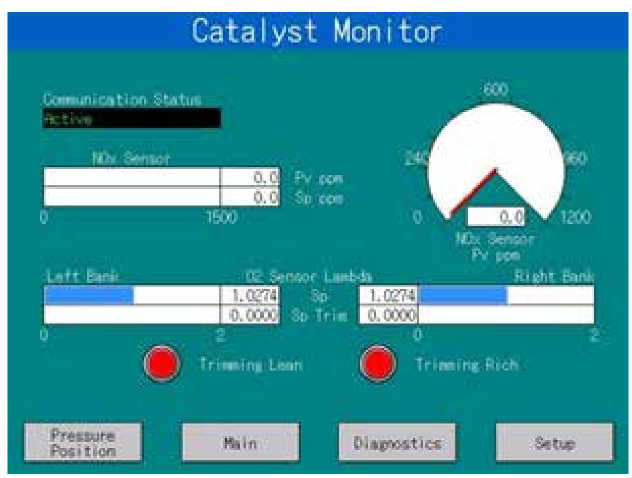
- Fuel pressure setpoint (Sp)
- Fuel pressure process variable (Pv)
- Pre-catalyst temperature
- Post-catalyst temperature
- Differential pressure
- ECV5 control mode:
  - Engine Stopped
  - Default Control
  - AFR Control

Press any of the buttons at the bottom of the screen to access other screens and functions.

Catalyst Monitor Screen

The Catalyst Monitor Screen lets the operator view the O2 level setpoint and trim values, NOx sensor output, whether the engine is running lean or rich, and the trimming direction. It also shows the communication status between the Cat Monitor and the ECVI.





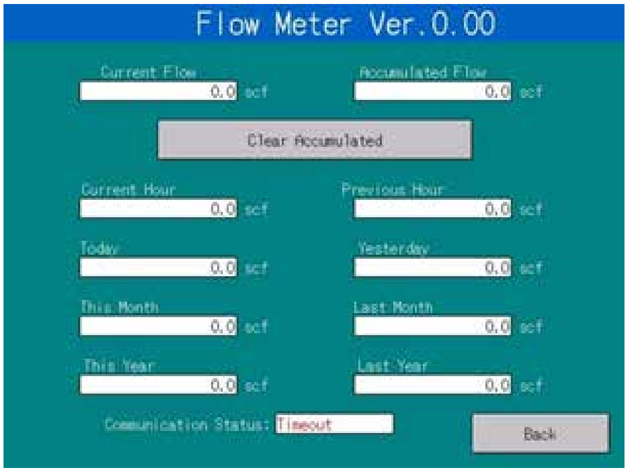
The Catalyst Monitor Screen displays the following parameters:

- NOx sensor setpoint (Sp) – only used on lean-burn applications
- NOX sensor process variable (Pv)
- O2 sensor setpoint dynamic (expressed in Lambda)
- O2 trim (expressed in Lambda)
- O2 trim direction:
- Leaner
- Richer
- Communication Status:
  - Active
  - Timeout

Press any of the buttons at the bottom of the screen to access other screens and functions.

Flow Meter

The Flow Meter Screen lets the operator view the fuel flow rate. It also keeps track of flow for various time periods.



The Flow Meter displays the following parameters:

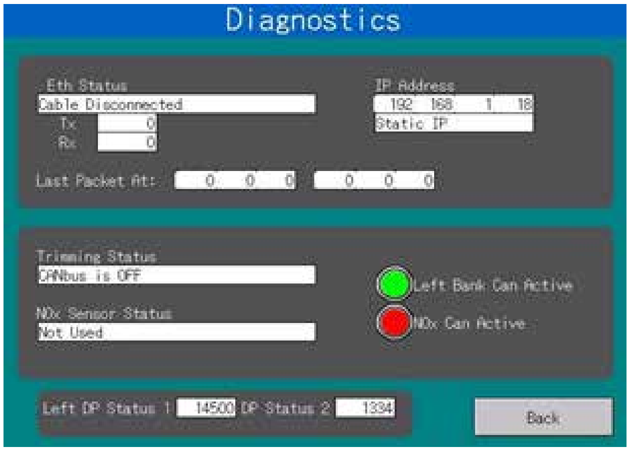
- Current flow
- Accumulated flow
- Current hour accumulated flow
- Current day accumulated flow
- Current month accumulated flow
- Current year accumulated flow
- Previous hour accumulated flow
- Yesterday accumulated flow
- Last month accumulated flow
- Last year accumulated flow
- Communication Status:
  - Active
  - Timeout

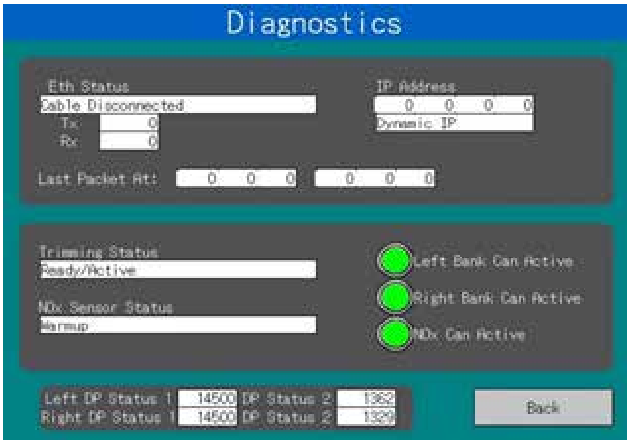
Pressing the **Clear Accumulated** button will zero the Accumulated flow parameter.

Press the Back button to return to the Main Screen.

Diagnostics Screen

The Diagnostics Screen is used for diagnosing problems dealing with Ethernet connections, NOx Sensor, O2 trim, and CANbus setup. The Left Bank CAN Active indicator should be green on both single and dual bank configurations. If not, check Left bank CAN address = 1. The Right Bank CAN indicator should be green for dual bank configurations. If not, check Right bank CAN address = 2. The NOx CAN active indicator should be green if the NOx Sensor is present. If not, check the NOx Sensor status or NOx Sensor wiring. Power must be cycled for a CAN address change to take effect.





The Diagnostics Screen displays the following parameters:

Ethernet connection status:

- Cable Disconnected
- IP Address Not Set
- Waiting for IP Address
- MAC Address not Set
- Not Connected
- Connected

Trimming status:

- Ready/Active
- CANbus is OFF
- Not in AFR Mode
- NOx Signal not ready
- NOx Heater Error
- NOx Error
- Trim Limits not set

NOx Sensor status:

- Warmup
- Valid
- Not used
- OFF

IP Address:

- Dynamic IP
- Static IP

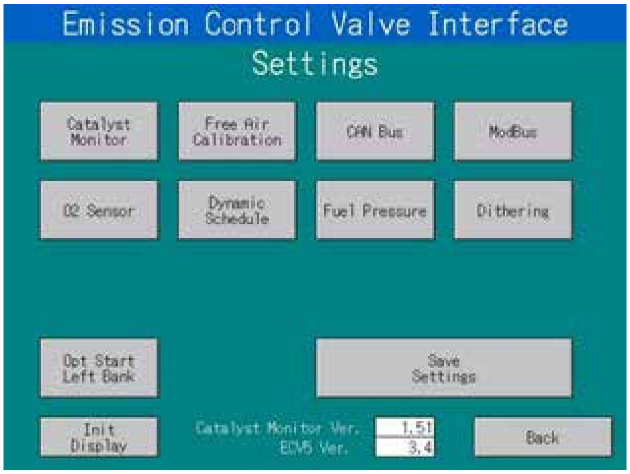
CANbus status:

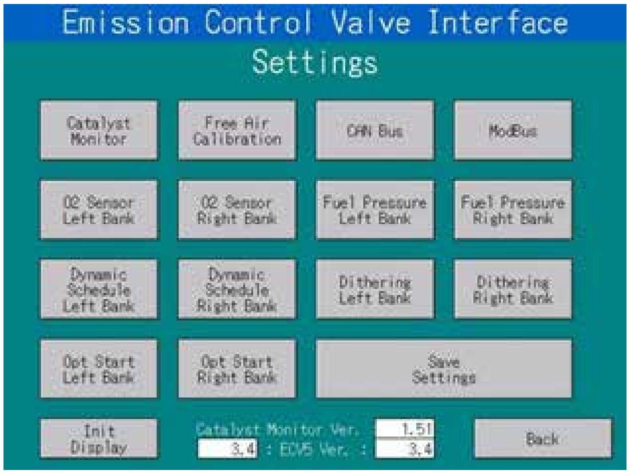
- Active – Green button
- Inactive – Red button

Press the Back button to return to the Main Screen.

Settings Screen

The Settings Screen is used to enter the parameters and functions that the other screens monitor. Pressing a particular screen button displays that setup screen for entering parameters (i.e., pressing the Modbus button displays the Modbus Setup Screen). After parameters have been entered, press Save Settings to store the new parameters.





Press the Init Display button to return to the Initial Display Screen.

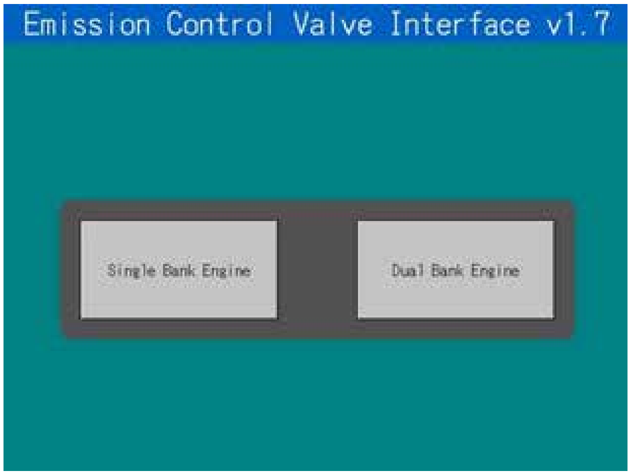
Press the Back button to return to the Main Screen.

8. ECVI Settings Screens

This section describes the ECVI Settings screens for single or dual bank engine configurations. The ECVI settings screens are used to enter various parameters and functions for the ECV5 and Catalyst Monitor via a graphical interface such as flow rate, pressure and actuator position, pressure setpoints, pre and post Cat temperatures, etc. Screens for single bank engine configuration are pictured on the left side (left bank) of the pages; screens for dual bank engine configuration are pictured on the right (right bank). Where there is only one screen shown, it applies to both configurations.

Initial Display Screen

The Initial Display Screen appears upon power up of the ECVI. From there either a single bank engine configuration or a dual bank engine configuration may be selected. The Main screen for the selected configuration will be displayed and accessible.



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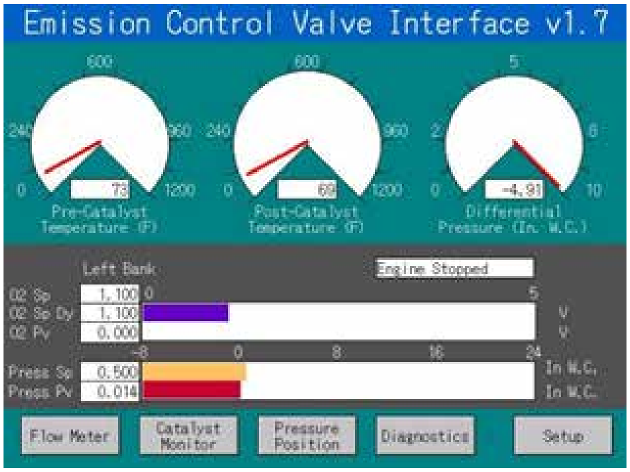
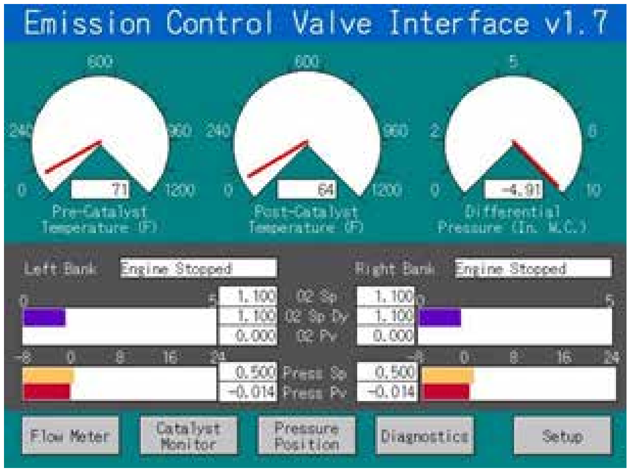
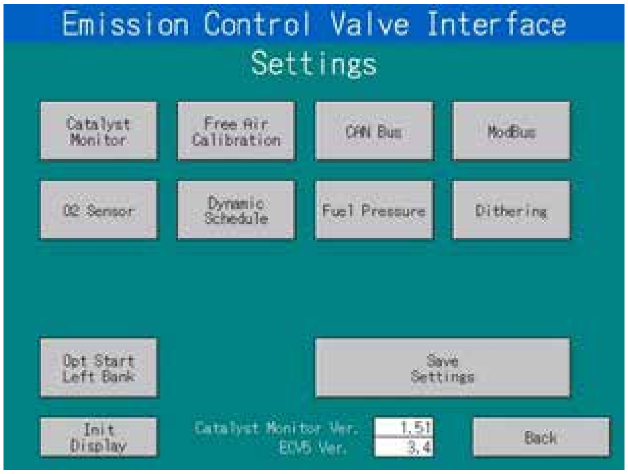


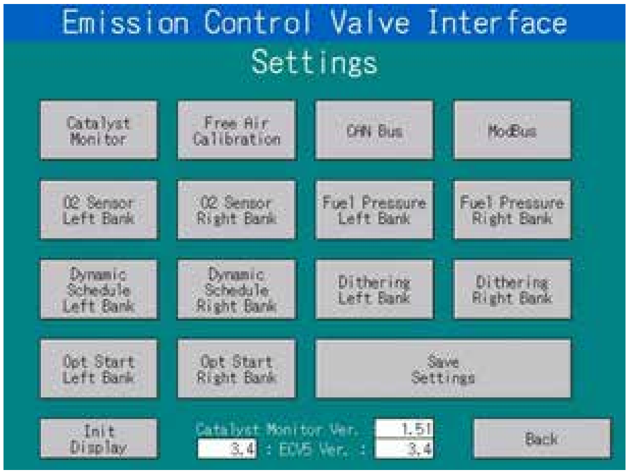


Press the Setup button at the bottom of the screen to access the Setup Screen.

Settings Screen

The Settings Screen is the interface used to select the various screens to enter parameters and functions for monitoring. Pressing a particular screen button displays that setup screen for entering parameters (i.e., pressing the Modbus button displays the Modbus Setup Screen). After parameters have been entered, press the Save Settings button to store the new parameters. To enter parameters on the various screens, see Procedure for Entering Parameters on Setup Screens in this section.



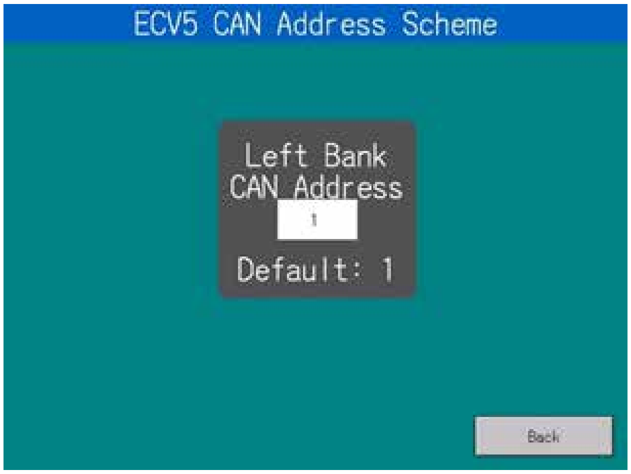


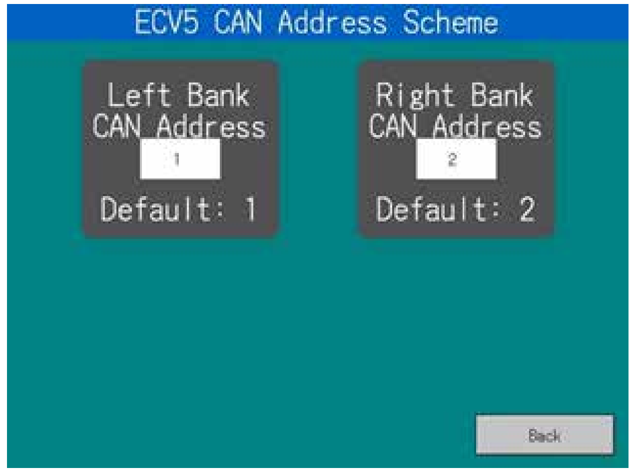
Press the Init Display button to return to the Initial Display Screen.

Press the Back button at the bottom of the screen to return to the Main Screen.

CANbus Setup Screen

The CANbus assignment screens are intended to display and allow correcting of CANbus addressing. The number shown in the box should match the default listed. If not, it can be changed manually.



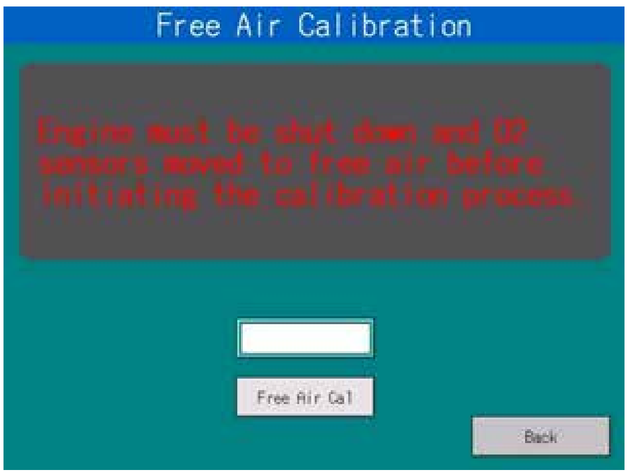


Press the Back button to return to the Settings Screen.

Free Air Cal Screen

The Free Air Cal screen is a required calibration for O2 Sensor functionality. On screen directions must be followed. Once setup is complete, pressing the Free Air Cal button begins the process. The status above the button will display the status of the calibration.

NOTE: Do not change screens during the Cal process.

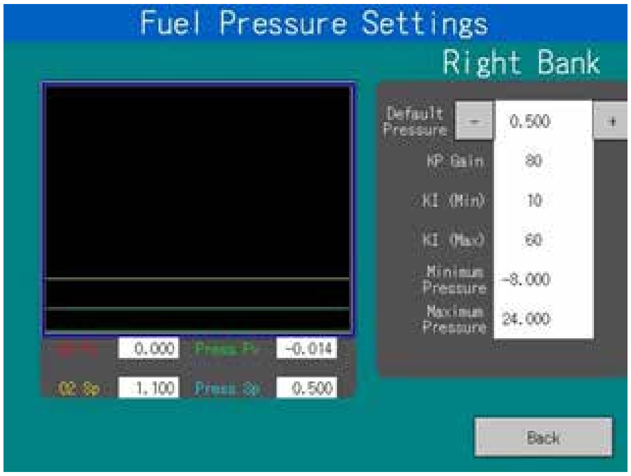


Press the Back button to return to the Settings Screen.

To perform the Free Air Cal procedure, see Setup of the ECV5 with Cat Monitor with IDEC Display in Chapter 9.

Fuel Pressure Setup Screen

The Fuel Pressure Setup screen allows the operator to set ECV5 fuel pressure parameters. The graph screen provides a line chart to show device status over time. The controls on this page allow for numeric input:



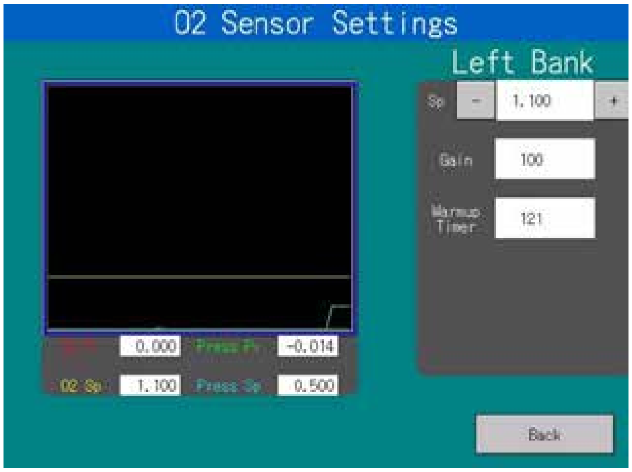
Parameter Overview:

- **Default Pressure** – Discharge pressure setpoint the ECV5 will aim to reach/maintain in Default control mode.
- **KP Gain** – The starting value for the proportional gain (KP), used to calculate proportional output which is set in proportion to the current error. The proportional gain accelerates the movement of the process variable towards setpoint while in closed pressure control loop. The proportional component depends only on the error, which is the difference between the setpoint and the process variable.
- **KI (min)** – The starting value for the Minimum Integral Gain (KI) used to dynamically calculate the actual integral gain based on the valve's current position.
- **KI (max)** – The starting value for the Maximum Integral Gain (KI) used to dynamically calculate the actual integral gain dynamically based on the valve's current position. The integral gain accelerates the movement of the process variable towards setpoint, integrating the error over time, and eliminating the residual steady-state error that occurs with a pure proportional controller.
- **Minimum Pressure** – Absolute minimum limit for the operational fuel pressure.
- **Maximum Pressure** – Absolute maximum limit for the operational fuel pressure.

Press the Back button to return to the Settings Screen.

O2 Sensor Setup Screen

The O2 Sensor Setup screen allows the operator to set the O2 Sensor values. The graph screen provides a line graph to show device status over time (controls all for numeric input of the O2 setpoint and O2 gain). This is where the duration is set for Default Mode.



Parameter Overview:

- **O2 Sensor Setpoint** – The starting value for the target O2 setpoint used in closed O2 control loop.
  - The ECV5 will aim to reach/maintain this setpoint while in Air Fuel Ratio control mode.
  - The O2 setpoint could be further adjusted by dynamically calculated O2 trim (computed within Catalyst Monitor, and sent to ECV5 via CANbus)
- **O2 Gain** – Integral gain used in O2 closed control loop.
  - The integral term accelerates the movement of the process variable towards setpoint, integrating the error over time.
- **Warmup Timer** – The wait period (in seconds) to allow the oxygen sensor to reach the operating temperature. The Warmup Timer starts counting down when the ECV5 control mode is changed from Stopped to Default (Ignition Confirm signal is active). When the Warmup Timer expires and the O2 sensor feedback is within operational range, the valve will switch to Air Fuel Ratio control mode.

Press the Back button to return to the Settings Screen.

O2 Dithering Setup Screen

The O2 Dithering Setup screen allows the operator to set the O2 dithering values.

Parameter Overview:

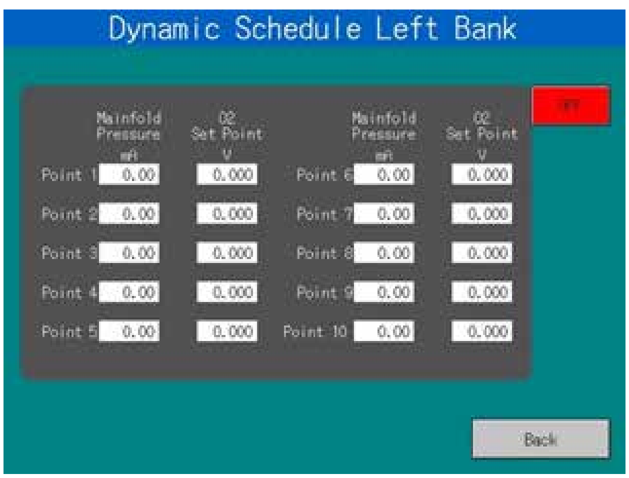
- **O2 Dithering** – Enable/Disable toggle switch
- **Dithering Rate** – The starting value for the dither frequency.
- **Dithering Amplitude** – The dither adjustment over a single period.

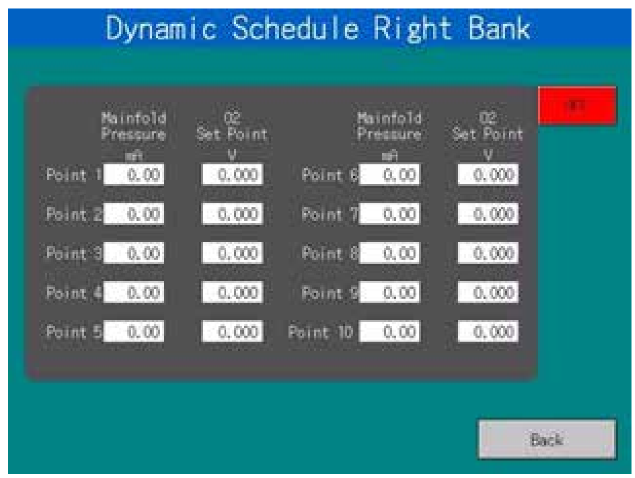
Press the Back button to return to the Settings Screen.

To perform the Dithering procedure, see Setup Dithering and NOx Sensor Trim Using the IDEC Display in Chapter 9.

Dynamic O2 Schedule Setup Screen

The Dynamic O2 Schedule allows for automatic adjustment of the O2 setpoint based on manifold pressure input (4-20mA).





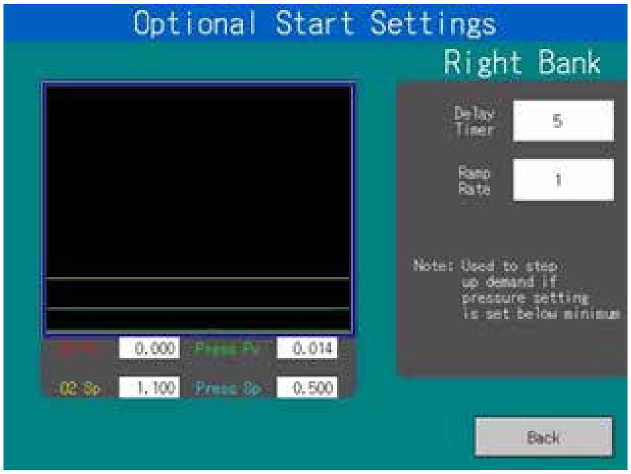
Parameter Overview:

- **ON/OFF** – Enable/Disable toggle switch
  Dynamic schedule will be automatically disabled if none of the points are set.
- **Schedule Points 1-10** – At minimum 2 schedule points should be configured if dynamic schedule is to be used.

Press the Back button to return to the Settings Screen.

Optional Start Pressure Settings Screen

The Optional Start Pressure Setup screen allows for optional engine startup with default pressure set below the minimum pressure limit. The graph screen provides a line graph to show device status over time.



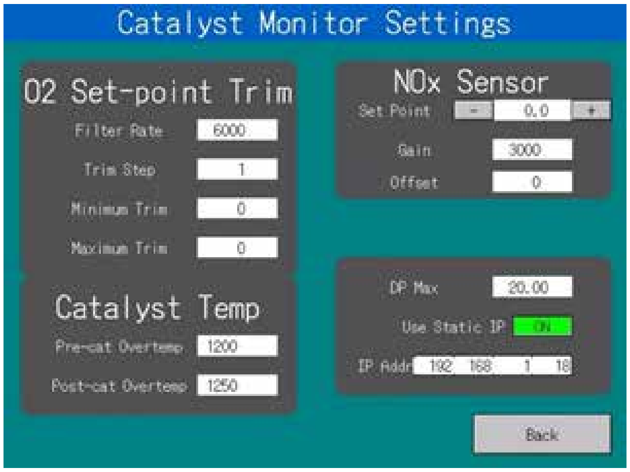
Parameter Overview:

- **Delay Timer** – The wait period (in seconds) prior to pressure demand adjustment.
- **Ramp Rate** – The frequency (in miliseconds) at which fuel pressure demand will be increased in steps of 0.001 in. W. C.

Press the Back button to return to the Settings Screen.

Cat Monitor Setup Screen

The Cat Monitor Setup screen allows the operator to enter parameters for the Cat Monitor.



Parameter Overview:

O2 Set point Trim

- **Filter rate** – Represents the frequency rate at which NOx sensor feedback is sampled.
- **Trim Step** – O2 trim adjustment step for the O2 setpoint.
- **Minimum Trim** – The absolute minimum limit for the O2 trim adjustment.
- **Maximum Trim** – The absolute maximum limit for the O2 trim adjustment.

Catalyst Temperature

- **Pre-Cat/Post Cat Overtemp** – The maximum pre-catalyst and post-catalyst temperature limits for triggering engine shutdown.

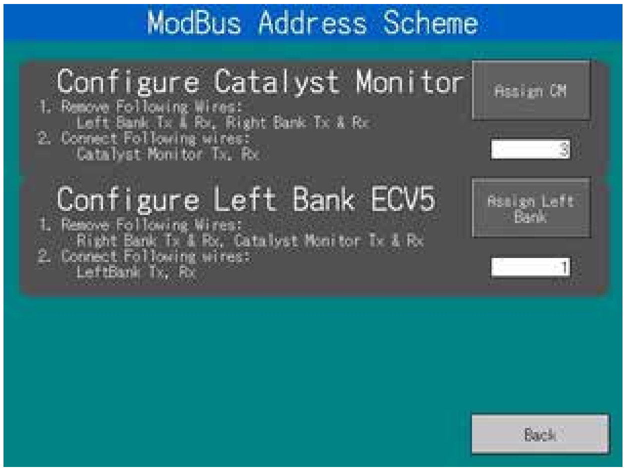
NOx Sensor

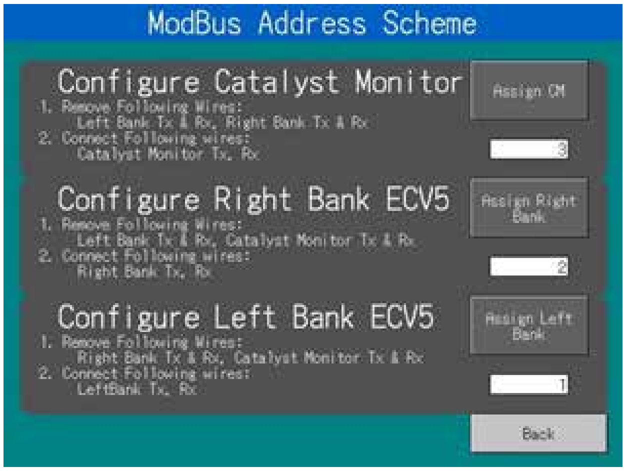
- **For lean burn only:**
  - Setpoint – The starting value for the target NOx setpoint used in minimization control algorithm.
  - **Gain** – The starting value for the integral gain in NOx minimization control loop.
  - **Offset** – The starting value for the offset adjustment in NOx minimization control loop.
- **DP Max** – Differential pressure maximum setting used to scale 4-20mA DP input
- **For use with Ethernet**
  - **Use Static IP** – Enable/Disable toggle switch. If disabled, the IP address will be assigned dynamically.
  - **IP Address** – Internet Protocol address assigned to Catalyst Monitor — IP address is a 32-bit number consisting of 4 octets in accordance with Internet Protocol Version 4 (IPv4)

Press the Back button to return to the Settings Screen.

Modbus Address Setup Screen

Only one device can be connected to the ECV5 while setting the Modbus addresses. Remove wires for all devices except the device you are configuring. Failure to do so may corrupt values stored in the valves or Cat Monitor which my yield unpredictable results. Do not disconnect the valve at the cannon plug. The unconnected cable will act as an antenna for electronic noise, and prevent communication to the other devices.





The Modbus Setup screen controls how the HMI communicates with the devices:

- Catalyst Monitor = 3
- Right Bank = 2
- Left Bank = 1

WARNING!

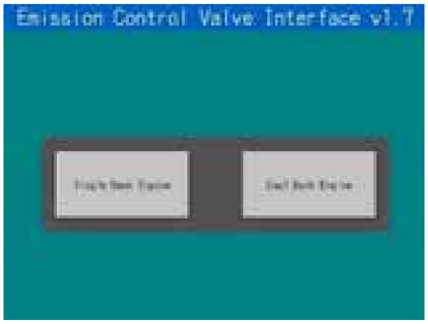
Left and right assignments can be easily reversed programmatically or by being wired in reverse.
Follow installation instructions carefully and precisely.

Press the Back button to return to the Settings Screen.

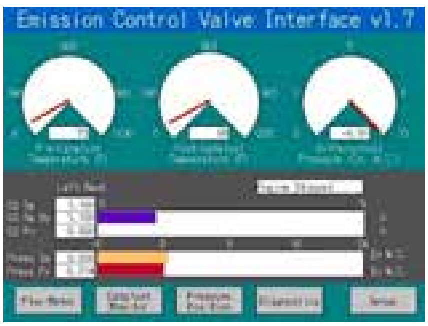
Procedure for Entering Parameters on Setup Screens

To enter parameters on a setup screen, do the following:

On the Main screen, select the button according to engine configuration.

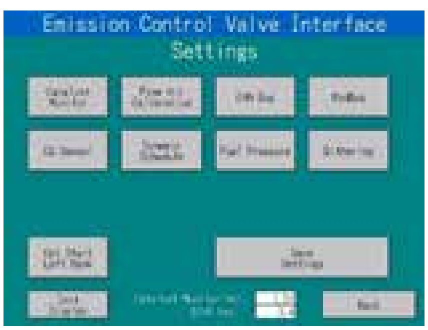


The Interface Screen appears.



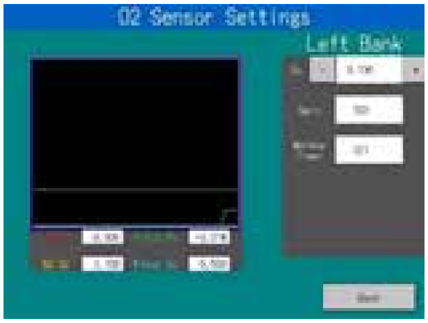
Press **Setup**.

Settings screen appears.

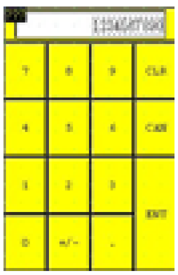


Press the button for the screen you wish to change/modify parameters (in this example, the O2 Sensor button has been pressed.)

The O2 Sensor Settings screen is displayed.



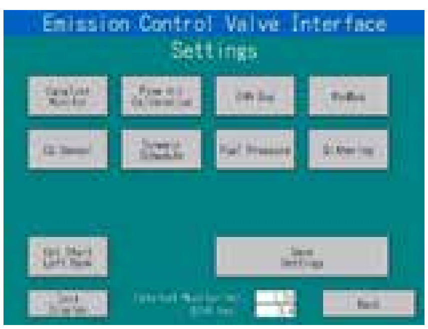
Press the pad for the parameter you wish to change/modify. Keypad appears.



Enter the parameters on the keypad and press **ENT**. Keypad disappears.
Repeat as necessary for entering other parameters.

Press **BACK** when finished.

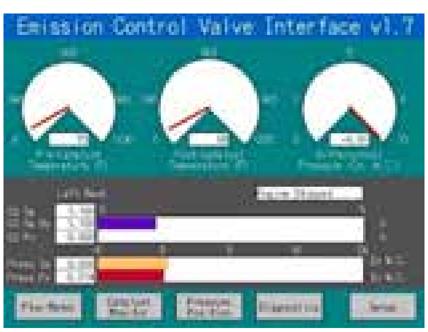
The Settings Screen appears.



Press **Save Settings**

Repeat as desired to change/modify parameters on a different screen. When finished, press **Back**.

The Interface screen appears.



9. ECVI/ECV5 Setup Procedures

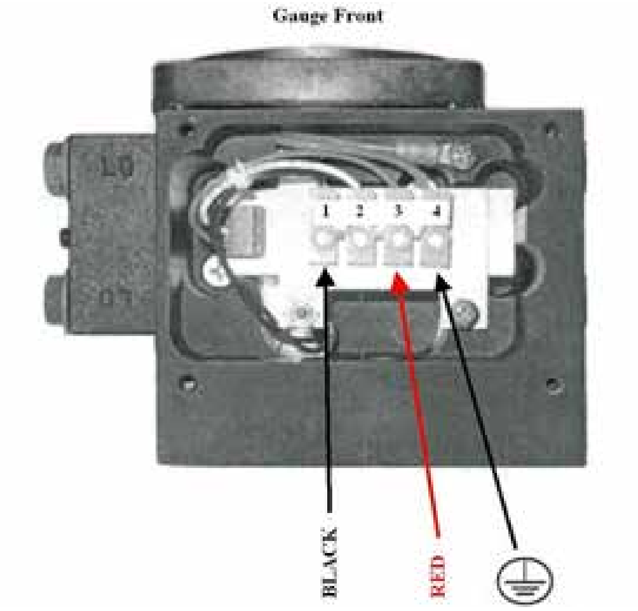
Setup of the ECV5 with Cat Monitor Using the ECVI with IDEC Display

Configuring the Unit

1. Upon receipt of equipment, inspect all equipment for damage or missing parts.
2. Ensure cable lengths meet requirements for installation.

> ***NOTE:***
>
> ***ECV5 cables are 25- or 50-foot lengths, Catalyst Monitor cables are 30-foot lengths, and 02 sensor cables are 30-foot lengths. NOx sensor extension cables are 10- and 30-foot lengths.***

3. Install required equipment where desired, paying attention to the cable lengths.
4. After installing the venturi inserts, locate and close the load screw, paying attention to the number of turns needed to screw it all the way in. Then turn the load screw out to approximately 4 turns and mark it.
5. Run all cables through conduit desired by customer (flex or rigid). When pulling wiring for the O2 Sensor and NOx Sensor through conduit, ensure the connector is removed from the wires. For the O2 Sensor wires a special tool is required. For the NOx Sensor wire, a paper clip will suffice. Record the wire color to number on each of the connectors.
6. If not using the Differential Pressure (DP) Gauge with the Catalyst Monitor, the cable end needs to be trimmed and taped to prevent a short. This cable will have 24Vdc positive supplied to it when 24Vdc power is supplied to the Catalyst Monitor.
7. If using the Differential Pressure Gauge with the Catalyst Monitor, do the following:



- Remove cover on top of DP Gauge.
- Connect black wire to terminal 1 on DP Gauge 4-20mA Return.
- Connect red wire to terminal 3 on DP Gauge 4-20mA Loop Power.
- Connect the shield to the DP Gauge Ground terminal.
- Leave terminal 2 empty.
- Replace cover to top of DP Gauge.
- Trim all open-ended excess wires and connect to the ECVI.

> ***NOTE:***
>
> ***The customer must provide a 24Vdc positive and negative lead (ensuring the correct amperage — 5 amps per ECV5 and 5 amps for the Catalyst Monitor) to the ECVI for power to the equipment and a 24Vdc positive for the ignition confirm. The ignition confirm signal from the customer should be from a source that will remove power if a fault occurs, which will allow both ECV5's to shut, thus shutting off the fuel to the engine. Some sources of 24Vdc positive can be from the PLC, the electrically-operated fuel solenoid, an oil pressure switch, etc.***
>
> ***DO NOT CONNECT THE CUSTOMER'S 24Vdc POWER WIRES AT THIS TIME.***

8. Disconnect the ECV5 Cables from the ECV5's.
9. Disconnect the O2 Sensor cables from the Cat Monitor.
10. Disconnect the Cat Monitor Cable from the Cat Monitor.
11. With power shut off, connect the customer's 24Vdc power wires.
12. Turn the customer's power on.
13. Using a voltage tester, measure all red wires as power or hot and all black wires as return or negative, ensuring correct polarity and DC Voltage.

Once correct set up is complete, shut off the customer power and reconnect all equipment – ONE AT A TIME (Cat Monitor, ECV5 Left Bank, ECV5 Right Bank and O2 Sensor cables.

- Turn on power from the customer after connecting the Cat Monitor.
- Ensure the Cat Monitor powers up.
- Shut off power from the customer and reconnect the ECV5 Left Bank.
- Turn on power from the customer after connecting the ECV5 Left Bank.
- Ensure the ECV5 Left Bank powers up.
- Shut off power from the customer and reconnect the ECV5 Right Bank.
- Turn on power from the customer after connecting the ECV5 Right Bank.
- Ensure the ECV5 Right Bank powers up.

The Cat Monitor, ECV5 Left Bank and ECV5 Right Bank are now powered.

Setting Device ID's on the IDEC Display

> ***NOTE:***
>
> ***The default factory setting for the Catalyst Monitor Modbus/Device ID is set to 3 and the ECV5 has the Modbus/Device ID set to 1. Previously the catalyst monitor and both ECV5 Modbus/Device ID were set to 1.***
>
> ***If the Catalyst Monitor to be used will be with the Vision 120 Display, the Modbus/Device ID will have to be changed to Modbus/Device ID 1 using the Catalyst Monitor Valve Viewer program.***

Equipment	Modbus ID	Tx Color	Rx Color
Left Bank ECV5	1	Green	White/Green
Right Bank ECV5	2	Green	White/Green
Cat Monitor	3	Green	Brown

1. Assign **Cat Monitor** (this step is not be required on a new system)
   - Shut off customer power to equipment.
   - On the ECVI PWB, remove the Tx and Rx connections to the Right and Left Bank ECV5's. (**ONLY** the Cat Monitor communication wires should be connected)
   - Turn on customer power to equipment.
   - From the main screen of the IDEC Display press the **SETUP** button.
   - Press the **MODBUS ID** button.
   - To the right of **CONFIGURE Cat Monitor**, press **ASSIGN Cat Monitor**. The number 3 will appear in the field.
   - Press the **BACK** button, then press the **SAVE SETTINGS** button.
2. Assign **Right Bank ECV5**
   - Shut off customer power to equipment.
   - On the ECVI PWB, remove the Tx and Rx connections to the Cat Monitor. (the Left Bank ECV5 is already disconnected)
   - On the ECVI PWB connect the Tx and Rx connections to the Right Bank ECV5. (**ONLY** the Right Bank communication wires should be connected)
   - Turn on customer power to equipment.
   - From the main screen of the IDEC Display press the **SETUP** button.
   - Press the **MODBUS ID** button.
   - To the right of **CONFIGURE RIGHT BANK ECV5**, press the **ASSIGN RIGHT BANK** button. The number 2 will appear in the field.
   - Press the **BACK** button, then press the **SAVE SETTINGS** button.
3. Assign Left Bank ECV5 (this step is not be required on a new system)
   - Shut off customer power to equipment.
   - On the ECVI PWB, remove the Tx and Rx connections to the Right Bank ECV5. (the Cat Monitor is already disconnected)
   - On the ECVI PWB connect the Tx and Rx connections to the Left Bank ECV5. (**ONLY** the Left Bank communication wires should be connected)
   - Turn on customer power to equipment.
   - From the main screen of the IDEC Display press the **SETUP** button.
   - Press the **MODBUS ID** button.
   - To the right of **CONFIGURE LEFT BANK ECV5**, press the **ASSIGN LEFT BANK** button. The number 1 will appear in the field.
   - Press the **BACK** button, then press the **SAVE SETTINGS** button.
   - Shut off customer power to equipment.
   - Connect the Cat Monitor and Right Bank Tx and Rx (All communication wires should now be connected).
   - Turn on customer power to equipment and check;
     - On the Main Screen you should see (if done correctly) Engine Stopped on both the Right and Left Bank ECV5's.
     - Press the CATALYST MONITOR button and look at the top of the new screen and you should see (if done correctly) ACTIVE under Communication Status.

Setting Up CANbus

Ensure that the Left Bank CANbus address is set to 1 and the Right Bank CANbus address is set to 2.

- From the Main screen press the **SETUP** button.
- Press the **CANbus** button.
- After setting the Can Bus Id's, press the **BACK** button then press the **SAVE SETTINGS** button.
- Cycle power for changes to take effect.

Initial Startup Settings

The following are settings that must be changed for initial startup.

- Press the **SETUP** button then press the **FUEL PRESSURE LEFT BANK** button.
- Change the Default Pressure from 4.5" to 0.050".
- Press the **BACK** button and then press **SAVE SETTINGS**.
- Press the **FUEL PRESSURE RIGHT BANK** button and change the Default Pressure from 4.5" to 0.050".
- Press the **BACK** button and then press **SAVE SETTINGS**.
- Press the **O2 SENSOR LEFT BANK** button
- Change the O2 Setpoint from 1.000 to the following; for a Rich Burn, ensure the O2 setpoint is 0.980 and for a Lean Burn 2.000. Now change the Warmup Timer to 300 seconds.
- Press the **BACK** button and then press **SAVE SETTINGS**.
- Press the **O2 SENSOR RIGHT BANK** button.
- Change the O2 Setpoint from 1.000 to the following; for a Rich Burn, ensure the O2 setpoint is 0.980 and for a Lean Burn 2.000. Now change the Warmup Timer to 300 seconds.
- Press the **BACK** button and then press **SAVE SETTINGS**.

All other settings should be at the correct value for engine starting operation.

Conducting a Free Air Calibration

The following are the steps for conducting a Free Air Calibration of the O2 Sensors.

- Ensure the O2 Sensors are removed from the exhaust and are still plugged in to the connector.
- From the Main Screen press the **SETUP** button.
- Press the **FREE AIR CALIBRATION** button.
- Read the instructions and then press the **FREE AIR CAL** button.
- After approximately 3 minutes, the test will tell you if the Free Air Calibration was successful or if it failed. If the Free Air Calibration failed, carefully touch each O2 sensor and feel which one is hot. If the O2 Sensors are hot but not too hot to hold, that is a good O2 sensor. If the O2 sensor is cold or too hot to hold, that is a bad O2 sensor. Replace the bad O2 sensor and conduct another Free Air Calibration.

  ***CAUTION: Careful handling is a must! They will burn you!**
- Once the Free Air Calibration is successful, press the **BACK** button and the press the **SAVE SETTINGS** button.
- Re-install the O2 sensors into the exhaust system.

Starting the Engine

Start the engine and run at low idle with no load. The Default Pressure may need adjustment for engine starting because the Default Pressure is sometimes engine specific. The setting of 0.050 is the correct setting for most engines using the external venturi or the venturi inserts.

- Watch the IDEC Display and listen to the engine, monitoring engine stability and ensuring the Pressure Feedback or Pressure PV (Processed Voltage) is meeting the Pressure Setpoint. If the engine is unstable, adjust the pressure gains as required.
- When the engine is stable and all conditions appear to be normal, watch for the engine go into Air Fuel Ratio. Just prior to the engine going into Air Fuel Ratio, an O2 Sensor Feedback Voltage is displayed. If the voltage is to the right of the O2 Sensor Setpoint, the engine is Lean. If the voltage is to the left of the O2 Sensor Setpoint, the engine is Rich.
- You will see (via the display) when the engine goes into Air Fuel Ratio. Check the Main Screen of the display to ensure that both banks go into Air Fuel Ratio. Then monitor the Pressure Setpoint ensuring that the pressures

are not excessive (above 4.000 inches) or too low (into a negative). If either condition exists, adjust the carburetor load screw (for venturi inserts, for venturi standalone use venturi adjustment) to maintain approximately 1.000 inch. Use the left, then right load screws and bring pressures up or down to 1.000 inch slowly and with minimal separation between banks.

> ***NOTE:***
> ***Turning the load screw in (tightening) will increase the pressure setpoint and turning the load screw out (loosening) will reduce the pressure setpoint. This can only be done when both ECV5's are in the Air Fuel Ratio mode. Adjustments are not immediate. Let the pressure setpoint settle out, then adjust again if needed.***

- Once all pressures are correct and the O2 Sensor Process Voltage is meeting the setpoint, take the engine to rated speed. Monitor all pressures and voltages.
- Once satisfied, start bringing on load. Start with a light load, monitoring all pressures and voltages and adjust as necessary.

> ***NOTE:***
> ***Once the pressure loop is adjusted in default mode, there is no reason to readjust. Once the engine is running in Air Fuel Ratio mode, the only gain that might need to be adjusted is the O2 sensor gain, and this is usually when there is a light load or no load condition.***

- When the engine is at full load and operating normally, adjust supply pressure to bring the ECV5 valve position to approximately 60% to 75%. For a lean burn engine, the position is lower because you have to ensure that the Pre Combustion Gas Pressure is correct for the engine.
- Once all conditions are normal, bring the engine into compliance **USING THE LEFT AND RIGHT O2 SENSOR SETPOINT ONLY.** No adjustment of the Load/Power Screw is required to bring the engine into compliance.
- When the engine is running at full load and in compliance, adjust the load screw to bring each ECV5 Pressure Setpoint from between 1.000" to 4.000". When adjusting the load screw only turn 1 flat of the Hex Bolt at a time. Let the bank that is being adjusted settle out, then adjust the other side as necessary to balance each bank.

Changing Settings for Normal Operation

When the engine is running at full load and is in compliance, the following settings must be changed for normal operation:

- From the Main Screen of the Display, press the **SETUP** button.
- Press the **O2 SENSOR LEFT BANK** button.
- Change the O2 Sensor Warmup Timer from 300 seconds (where it was first set for initial start-up) to whatever is desired by the customer. From the factory it is set to 60 seconds. It has been noticed that at times the customer will operate the engine at a light or no load condition until the Oil temp reaches a certain point. If this is the case then the O2 Sensor Warmup Timer should be set to allow for engine warmup time before going into Air Fuel Ratio Mode. Usually 120 seconds is sufficient.
- Once the O2 Sensor Warmup Timer is changed to the customer's specification, press the **BACK** button and then Press the **SAVE SETTINGS** button.
- Press the **O2 SENSOR RIGHT BANK** button.
- Repeat the **O2 SENSOR LEFT BANK** process as described above for **O2 SENSOR RIGHT BANK**.
- Once the O2 Sensor Warmup Timer is changed to the customer's specification, press the **BACK** button and then Press the **SAVE SETTINGS** button.
- Press the **FUEL PRESSURE LEFT BANK** button.

- Change the Minimum and Maximum pressure to a point that will allow the ECV5's to fully operate between these points.
- Previously, the load screw was adjusted to bring each ECV5 Pressure Setpoint to approximately 1.000" to 4.000" when operating at a full load.

NOTE:
The minimum and maximum pressure setpoints are software rails that protect the catalyst and engine. If an O2 sensor fails, it will fail in the rich position (down to "0" on the O2 setpoint). Once the ECV5 sees "100" on the O2 setpoint, it automattically tranfers from Air/Fuel Ratio mode to Default mode. Without these software rails, the affected bank could over-fuel and damage the catalyst or engine.

- Setting Minimum Pressure rail to -1.000" and the Maximum rail to 8.000" is sufficient for normal engine operation; however, when an engine has not been operated for a couple of days and the atmosphere is cold, the pressure Setpoint can be higher than normal (in Air/Fuel Ratio mode) until the engine warms up. The spread between the Minimum and Maximum Pressures must be set so as to not impede the operation of the engine and allow the engine to meet its emissions requirements.
- Once changed to the desired limits, press the **BACK** button and then press the **SAVE SETTINGS** button.
- Press the **FUEL PRESSURE RIGHT BANK** button.
- Change the Minimum and Maximum Pressure to the same as the previous bank.
- Press the **BACK** button then press the **SAVE SETTINGS** button.

Setup NOx Sensor Trim and Dithering Using the IDEC Display

Checking Stability of the NOx Sensor Pv (Feedback)

After the engine has been set up and running normally through all loads and meeting Emission compliance, follow these steps to enable NOx Sensor Trim and O2 Dithering.

- Press the **CATALYST MONITOR** button located at the bottom left of the Main screen.
- Observe the NOx Sensor PV bar and the NOX Sensor Feedback dial. The ideal reading for these two readings will be flat and stable. If not, then some gain adjustment will be necessary.
- If there are numerous "BUMPS" in the NOx Sensor PV Bar and the NOx Sensor Feedback Dial, it means that the engine is not as finely tuned as is desired.

NOTE:
DO NOT MAKE LARGE ADJUSTMENTS. Make small adjustments and observe the NOx sensor feedback. Continue to make small adjustments until the NOx sensor feedback is stable. Do not adjust pressure gains or O2 sensor gains too high or too low. If unusually high or low gains are needed to flat-line the "bumps", stop, put the gains back to default, and contact Altronic for further guidance. It is not unusual (using the ECV5 pressure and O2 sensor gains) to get completely flat NOx sensor feedback. This can occur if the catalyst or catalyst elements are inefficient or need to be replaced. Contact Altronic.

Setting Up and Enabling O2 Sensor Dithering

Once the NOx Sensor, Pv Bar and the NOx Sensor Feedback Dial are stable (by adjusting Pressure and O2 Sensor Gains). Set up and Enable the O2 Dithering as follows:

- Factory default values for the Left and Right Bank:

Left Bank		Right Bank	
Enable/Disable	OFF	Enable/Disable	OFF
Rate	500	Rate	500
Amplitude	10	Amplitude	10
O2 Dither Slave	OFF	O2 Dither Slave	OFF

- Press the **SETUP** tab at the bottom of the Main Screen. Locate the **DITHERING LEFT BANK** and **DITHERING RIGHT BANK** buttons on the third row and change the Default values to the values below.

Left Bank		Right Bank	
Enable/Disable	OFF	Enable/Disable	OFF
Rate	500	Rate	500
Amplitude	150	Amplitude	150
O2 Dither Slave	OFF	O2 Dither Slave	OFF

- Enable the O2 Sensor Dithering by pressing the **ON/OFF** button located directly to the right of the label **"O2 DITHERING"**.

  Press the **BACK** button located at the bottom of the current screen.

If running a Dual Bank, press the **DITHERING RIGHT BANK** button and turn on the **O2 SENSOR DITHERING** and the **O2 DITHERING SLAVE**. The values after completion are listed in the next table:

Left Bank		Right Bank	
Enable/Disable	ON	Enable/Disable	ON
Rate	500	Rate	500
Amplitude	150	Amplitude	150
O2 Dither Slave	OFF	O2 Dither Slave	ON

- Press the **BACK** button located at the bottom of the current screen.
- Press the **SAVE SETTINGS** button located at the bottom of the current screen.
- Press the **BACK** button located at the bottom of the current screen. You will now be back at the Main Screen.

NOTE:

Pay attention when turning the Dithering Slave on for the Right Bank only. Left is off and right is on.

If running dual banks (two ECV5's), the Left Bank O2 Dithering Slave should be off, and the Right Bank O2 Dithering Slave should be on.

If running a single bank (one ECV5), the Left Bank O2 dithering slave should be off.

- Observe the NOx Sensor PV bar and the NOx Sensor Feedback dial. After the settings have been changed, as listed above, the NOX SENSOR Bar and Dial should have smoothed out. Do not be concerned with the occasional "BUMP".

Setting Up and Enabling the NOx Sensor Trim

With the ECV5's O2 Setpoint Dithering enabled and operating normally, follow the below steps to Set Up and Enable the NOX Sensor Trim:

- From the Main Screen press the SETUP button located on the bottom of the screen.
- Press the CATALYST MONITOR button located in the upper left.
- Under the left column, the O2 SET-POINT TRIM the Default values are as follows:

Filter Rate	6000
Trim Step	1
Minimum Trim	0
Maximum Trim	0

- Change the Default values to as follows:

Filter Rate	6000
Trim Step	1
Minimum Trim	-100
Maximum Trim	+100

NOTE:

When the minimum trim and the maximum trim values are zero (0) the NOx sensor trim is disabled. When a value is placed in both minimum and maximum trim, the NOx sensor trim is enabled.

- Press the **BACK** button located at the bottom of the current screen.
- Press the **SAVE SETTINGS** button located in the fourth row of tabs.
- Press the **BACK** button located at the bottom of the current screen. You should now be back at the Main screen.
- Press the **CATALYST MONITOR** button located on the bottom left of the current screen and observe the Left and Right Bank SP Trim. This trim will maintain .0000 for approximately 5 minutes, then it will change either Richer or Leaner, whatever is required by the NOx Sensor. Once you have noticed a visual change in the trim, the engine will be running in a stable condition, and the emissions will be maintaining compliance.

THE ENGINE HAS NOW BEEN FINE TUNED AND THE O2 SETPOINT DITHERING AND NOx SENSOR TRIM ARE ENABLED. QUESTIONS CONCERNING THESE ADJUSTMENTS SHOULD BE DIRECTED TO ALTRONIC.

10. Optional Equipment

Cables

The ECV5 interface cable is a custom cable, which includes all necessary wires between the ECV5 and ECVI interface. The wire is sized appropriately for its use and the wires are color-coded. This cable comes in 25 foot lengths, but can be ordered in 50 foot lengths.

The FM-50 (Flow Meter) comes with a 30 foot cable, but a 60 foot cable can be ordered.

NOx Sensor

Our method for using a NOx Sensor in both rich burn and lean burn applications is patented.

The NOx Sensor is installed after the catalyst, in the exhaust stream and communicates to the CAT Monitor via CanBus. The CAT Monitor continually reads the NOx Sensor and adjusts the O2 Sensor Set Point to the optimal set point reducing NOx without raising the level of CO significantly.

Catalyst Delta-P Transducer

The Cat Monitor can connect a 4-20mA loop-powered pressure transducer to measure the Delta-Pressure across the catalyst. These connections are made via a two-wire Beldon type cable that is manufactured into the CAT Monitor cable. The CAT Monitor can be programmed to generate a fault or shutdown, based on the level of Delta-Pressure. This data is also logged on a thumb drive mounted inside of the Catalyst Monitor. The actual Delta-Pressure can be read on the ECVI display or on the gauge itself.

FM-50 Fuel Flow Meter

The FM-50 provides a true Mass Flow Calculation which corrects for temperature and pressure fluctuations.

Various agencies now require fuel measurement on individual gas engines. The FM-50 offers a very simple-to-install option that can provide instantaneous flow or totalized flow over a period of hours, days or months. The FM-50 data can be read on the ECVI display or the FM-50 itself.

Mixing Venturi's

The Mixing Venturi is designed to precisely mix the fuel and air to be admitted the engine. It is used with the ECV5 Emissions Control Valve to replace the carburetor and pressure regulator on both Rich Burn and Lean Burn engines.

11. Troubleshooting

Valve Stroke Limited

Check the stroke of the valve at full load. If the stroke is less than 70% on position (40% – 50% is ideal), lower the supply pressure to the fuel valve.

Pressure Control Loop

Check the pressure control loop. What pressure is required for no load? What pressure is required for full load?

Compare the pressure measured by the valve to an external measurement on each bank.

Using the scope, check the pressure control response to load changes with O2 sensor active.

Governor Control

Measure the manifold pressure on each bank. Observe if the butterfly/butterflies match.

O2 Sensor

Observe the output of the O2 sensor(s).

Vary the injection pressure to change the mixture. See if the O2 Sensor Voltage changes and how much pressure change is required to do so. Sensitivity to mixture varies (default mode only).

Are there differences in the carburetors' performance? Do they track?

Check the inlet pressure to the carburetors. Check the adjustments on the carburetors.

12. Product Warranty

Altronic, LLC warrants that all goods are free from defects in workmanship and material as of the time and place of delivery.

As a matter of general warranty policy, Altronic, LLC 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 at the Altronic manufacturing facility in Girard, Ohio. The customer is responsible for shipment or delivery of the product to the facility. Altronic will pay return ground freight. The customer will pay any expedited freight fees.

13. Technical Assistance

If you need technical assistance, please gather the following information and have it handy before contacting us.

General

Your name ______________________

Your Address ______________________

Phone number ______________________

Site Location ______________________

Engine Information

Manufacturer ______________________

Engine Model Number ______________________

Number of Banks ______________________

Fuel type ______________________

Power Output Rating ______________________

ECV5 Information

Serial Number ______________________

ECVI Information

Serial Number ______________________

altronic
HOERBIGER Engine Division

712 Trumbull Avenue
Girard, Ohio 44420
Phone: 330.545.9768; Fax: 330.545.3231
E-mail: altronic-girard@hoerbiger.com

14. Appendicies

A1. ECV5_B Modbus Registers
40x Input Registers

Register	Description	Scaling Factor
40012	02 Sensor Process Variable	1.0E-03
40013	Ignore	
40014	Ignore	
40015	Ignore	
40016	Ignore	
40017	Position process variable	1.0E-02
40018	Position demand	1.0E-02
40019	Manifold pressure	1.0E-03
40020	Pressure demand	1.0E-03
40021	Actuator output	Actual
40022	Ignition confirm	Actual
40023	Actuator power	Actual
40024	Sensor ignore	Actual
40025	Sp adjusted	1.0E-03
40026	Analog input 4-20mA	1.0E-02
40027	Ignore	
40028	Ignore	
40029	Ignore	
40030	Position proportional contribution	Actual
40031	Position integral contribution	Actual
40032	Pressure proportional contribution	Actual
40033	Pressure integral contribution	Actual
40034	02 integral contribution	Actual
40035	Ingore	
40036	Ignore	
40037	Ignore	
40038	Ignore	
40039	Warmup timer	Actual
40040	Ignore	
40041	Ignore	
40042	Default mode	Actual
40043	Sequence	Actual
40044	Ignore	
40045	02 Sensor Sp selected	1.0E-03
40046	02 Sensor Sp selected in lambda	1.0E-04
40047	Start timer	Actual
40048	CAN Tx Error	Actual
40049	CAN Rx Error	Actual

Register	Description	Scaling Factor
40050	CAN pressure demand	1.0E-03
40051	O2 dither value	1.0E-04
40052	CAN O2 dither	1.0E-04
40053	Pressure dither value	1.0E-03
40054	CAN pressure dither	1.0E-03
40055	CM O2 Sp trim in lambda	1.0E-04
40056	O2 Pv in percent O2	1.0E-03
40057	O2 Sp in percent O2	1.0E-03
40058	O2 Pv in lambda	1.0E-04
40059	O2 Sp in lambda	1.0E-04
40060	Ignore	
40061	Current pressure integral gain	Actual

401x Holding Registers

Register	Description	Scaling Factor
40112	Stroke gain	Actual
40113	Stroke offset	Actual
40114	O2 Set-point	1.0E-03
40115	Demand gain	Actual
40116	Demand offset	Actual
40117	mA gain	Actual
40118	mA offset	Actual
40119	O2 gain	Actual
40120	O2 offset	Actual
40121	Manifold pressure gain	Actual
40122	Manifold pressure offset	Actual
40123	Default Pressure	1.0E-03
40124	Position proportional gain	Actual
40125	Position integral gain	Actual
40126	Pressure proportional gain	Actual
40127	Pressure integral gain	Actual
40128	Load gain prop.	Actual
40129	Load gain int	Actual
40130	O2 integral	Actual
40131	Actuator offset	Actual
40132	Maximum pressure	1.0E-03
40133	Minimum pressure	1.0E-03
40134	Serial Number	Actual
40135	Modbus address	Actual
40136	DAC1 gain	Actual
40137	Dac1 offset	Actual
40138	Calibrated	Actual

Register	Description	Scaling Factor
40139	Diag	Actual
40140	Valve type	Actual
40141	Force ignition confirm	Actual
40142	Force actuator power	Actual
40143	Force sensor ignore	Actual
40144	Save data	Actual
40145	Warmup timer start	Actual
40146	O2 Fail timer start	Actual
40147	Actuator limit	Actual
40148	mA minimum	1.0E-02
40149	mA maximum	1.0E-02
40150	Set-point minimum	1.0E-03
40151	Set-point maximum	1.0E-03
40152	Sp enable	Actual
40153	Zeroing	Actual
40154	KI minimum	Actual
40155	KI maximum	Actual
40156	Start_timer_start	Actual
40157	Ramp Rate	Actual
40158	Lvdt Limit	Actual
40159	ManPressure Point 0	1.0E-03
40160	ManPressure Point 1	1.0E-03
40161	ManPressure Point 2	1.0E-03
40162	ManPressure Point 3	1.0E-03
40163	ManPressure Point 4	1.0E-03
40164	ManPressure Point 5	1.0E-03
40165	ManPressure Point 6	1.0E-03
40166	ManPressure Point 7	1.0E-03
40167	ManPressure Point 8	1.0E-03
40168	ManPressure Point 9	1.0E-03
40169	O2 Set-point Point 0	1.0E-03
40170	O2 Set-point Point 1	1.0E-03
40171	O2 Set-point Point 2	1.0E-03
40172	O2 Set-point Point 3	1.0E-03
40173	O2 Set-point Point 4	1.0E-03
40174	O2 Set-point Point 5	1.0E-03
40175	O2 Set-point Point 6	1.0E-03
40176	O2 Set-point Point 7	1.0E-03
40177	O2 Set-point Point 8	1.0E-03
40178	O2 Set-point Point 9	1.0E-03
40179	O2 standard free air	Actual
40180	O2 standard zero	Actual

Register	Description	Scaling Factor
40181	O2 calibration value	Actual
40182	O2 calibration slope	Actual
40183	O2 calibration offset	Actual
40184	Init calibration	Actual
40185	O2 calibration complete	Actual
40186	O2 correction factor	Actual
40187	Dither Slave enabled	Actual
40188	Pressure Slave enabled	Actual
40189	CAN enabled	Actual
40190	O2 Dither enabled	Actual
40191	O2 Dither period	Actual
40192	O2 Dither amplitude	Actual
40193	Pressure Dither enabled	Actual
40194	Pressure Dither period	Actual
40195	Pressure Dither amplitude	Actual
40196	Minimum O2 Sp Trim	Actual
40197	Maximum O2 Sp Trim	Actual
40198	O2 Pv Minimum	1.0E-03
40199	CAN Address	Actual
40200	O2 Percent Minimum	1.0E-03
40201	O2 Percent Maximum	1.0E-03

Scaling:

1. To convert data from the valve represented in fixed-point type to engineering units,multiply the value by the scaling factor.

   Example:
   You read 3200 from register 40123 (Default Pressure).
   3200*0.001 = 3.2
   Default pressure = 3.2 in W.C.

2. To send data to the valve, convert it to fixed-point format by multiplying the actual setting by reverse scaling factor, then write data to Modbus register.

   You need to set Default Pressure to 4 in. W.C.
   4 * 1000 = 4000
   Write 4000 to Modbus register 40123.

Register 40144:

Value 0x1234(Hex) written to this register, directs the valve's processor to save holding registers (401x) into static memory for the next power cycle.

A2. CANbus Communications

ECV5 and Catalyst Monitor devices support CAN communications. All messages use the CAN.2.0 B 29-bit
Extended Data Form format, bus speed – 250 Kbit/s.

ECV5

Packet Description	02 Info
CAN ID	0x19010000
Byte 0	02 Set point high byte
Byte 1	02 Set point low byte
Byte 2	02 Feedback high byte
Byte 3	02 Feedback low byte
Byte 4	0
Byte 5	0
Byte 6	0
Byte 7	0

Packet Description	Pressure Info
CAN ID	0x1A010000
Byte 0	Pressure Setpoint High Byte
Byte 1	Fuel Pressure Setpoint Low Byte
Byte 2	Fuel Pressure Feedback High Byte
Byte 3	Fuel Pressure Feedback Low Byte
Byte 4	Manifold Pressure High Byte
Byte 5	Manifold Pressure Low Byte
Byte 6	0
Byte 7	0

Packet Description	Misc Info
CAN ID	0x1B010000
Byte 0	Actuator Output High Byte
Byte 1	Actuator Output Low Byte
Byte 2	Speed High Byte
Byte 3	Speed Low Byte
Byte 4	Sequence High Byte
Byte 5	Sequence Low Byte
Byte 6	0
Byte 7	0

Cat Monitor

Packet Description	CM Info
CAN ID	0x17050000
Byte 0	Pre-Cat Temp High Byte
Byte 1	Pre-Cat Temp Low Byte
Byte 2	Post-Cat Temp High Byte
Byte 3	Post-Cat Temp Low Byte
Byte 4	Differential Pressure High Byte
Byte 5	Differential Pressure Low Byte
Byte 6	0
Byte 7	0

Packet Description	NOx Sensor Refresh
CAN ID	0x18FEDF00
Byte 0	0
Byte 1	0
Byte 2	0
Byte 3	0
Byte 4	0
Byte 5	0
Byte 6	0
Byte 7	5 = Heater ON; 0 = Heater OFF

Packet Description	O2 Setpoint Trim
CAN ID	0x10050000
Byte 0	O2 Trim High Byte
Byte 1	O2 Trim Low Byte
Byte 2	0
Byte 3	0
Byte 4	0
Byte 5	0
Byte 6	0
Byte 7	0

NOx Sensor

Packet Description	NOx Data
CAN ID	0x18F00F52
Byte 0	NOx Low Byte
Byte 1	NOx High Byte
Byte 2	O2 Low Byte
Byte 3	O2 High Byte
Byte 4	Status
Byte 5	Heater Status and Error
Byte 6	NOx Error
Byte 7	O2 Error

Description		Scale	Range	Unit
O2 info (EGC2/ECV5)	O2 Set point	0.0001	0-50	Lambda
O2 info (EGC2/ECV5)	O2 Feedback	0.0001	0-50	Lambda
Pressure info (EGC2/ECV5)	Fuel Pressure Setpoint	0.001	Min - Max Pressure Setpoint	in.W.C.
Pressure info (EGC2/ECV5)	Fuel Pressure Feedback	0.001	Min - Max Pressure Setpoint	in.W.C.
Pressure info (EGC2/ECV5)	Manifold Pressure	0.001	-50	in.Hg
Misc info (EGC2/ECV5)	Actuator	1	0-4000	Counts
Misc info (EGC2/ECV5)	Speed	1	0-3000	RPM
Misc info (EGC2/ECV5)	Sequence	1	0-4	Counts

*To convert NOx reading to ppm: (NOx reading * 0.05) - 200

**To convert O2 reading to %: (O2 reading * 0.000514) - 12

A3. Cat Monitor Modbus Registers
Input Registers

Register	Description	Definition
30001	pre_cat_nox	Ignore
30002	post_cat_nox	NOx reading from post-cat NOx sensor
30003	pre_cat_o2	Ignore
30004	post_cat_o2	O2 reading from post-cat NOx sensor
30005	pre_cat_temp	Pre-catalyst temperature
30006	post_cat_temp	Post-catalyst temperature
30007	pre_status_supply	Ignore
30008	pre_status_sensor_heater	Ignore
30009	pre_status_nox_signal	Ignore
30010	pre_status_o2_signal	Ignore
30011	post_status_supply	NOx sensor supply status
30012	post_status_sensor_heater	Nox sensor heater status
30013	post_status_nox_signal	NOx sensor NOx signal status
30014	post_status_o2_signal	NOx sensor O2 signal status
30015	pre_status_nox_error	Ignore
30016	pre_status_o2_error	Ignore
30017	post_status_nox_error	Error Code
30018	post_status_o2_error	Error Code
30019	rtc_sec	Real time clock: second
30020	rtc_min	Real time clock: minute
30021	rtc_hour	Real time clock: hour
30022	rtc_wday	Real time clock: week day
30023	rtc_mdate	Real time clock: date
30024	rtc_month	Real time clock: month
30025	rtc_year	Real time clock: year
30026	ecu_lb_can_off	Left bank valve CANbus not detected/turned off
30027	ecu_rb_can_off	Right bank valve CANbus not detected/turned off
30028	pre_nox_can_off	Ignore
30029	post_nox_can_off	NOx sensor CANbus not detected/turned off
30030	battery_voltage	Catalyst Monitor supply voltage
30031	milliamp_input	mA reading from DP
30032	catalyst_dp	Differential pressure across catalyst
30033	nox_heater	NOx heater ON/OFF flag
30034	nox_warmup_timer	Nox/O2 heater warmup timer
30035	left_bank_o2_setpoint	Left bank valve - O2 sensor setpoint
30036	left_bank_o2_feedback	Left bank valve - O2 sensor feedback
30037	left_bank_press_setpoint	Left bank valve - pressure setpoint
30038	left_bank_press_feedback	Left bank valve - pressure feedback
30039	left_bank_manifold_press	Left bank valve - manifold pressure
30040	left_bank_actuator_output	Left bank valve - actuator output

Register	Description	Definition
30041	left_bank_speed	Left bank valve - speed (if applicable)
30042	left_bank_sequence	Left bank valve - sequence
30043	right_bank_o2_setpoint	Right bank valve - O2 sensor setpoint
30044	right_bank_o2_feedback	Right bank valve - O2 sensor feedback
30045	right_bank_press_setpoint	Right bank valve - pressure setpoint
30046	right_bank_press_feedback	Right bank valve - pressure feedback
30047	right_bank_manifold_press	Right bank valve - manifold pressure
30048	right_bank_actuator_output	Right bank valve - actuator output
30049	right_bank_speed	Right bank valve - speed (if applicable)
30050	right_bank_sequence	Right bank valve - sequence
30051	o2_sp_trim	O2 sensor setpoint trim
30052	post_cat_nox_avg	Average post-cat Nox signal
30053	ign_confirm	Ignition confirm flag
30054	alarm_reset	Alarm reset flag
30055	pre_temp_avg	Average pre-catalyst temperature
30056	post_temp_avg	Average post-catalyst temperature
30057	dp_avg	Average catalyst differential pressure
30058	o2_1_avg	Average left bank O2 reading
30059	o2_2_avg	Average right bank O2 reading
30060	pre_temp_log	Long average/Log pre-catalyst temperature
30061	post_temp_log	Long average/Log post-catalyst temperature
30062	dp_log	Long average/Log catalyst differential pressure
30063	o2_1_log	Long average/Log left bank O2 reading
30064	o2_2_log	Long average/Log right bank O2 reading
30065	alarm_status_high	Over range alarm status
30066	alarm_status_low	Under range alarm status
30067	shutdown_status_high	Over range shutdowns status
30068	shutdown_status_low	Under range shutdown status
30069	filesize	Current log file size
30070	freespace	USB disk free space
30071	dac1_output	Left bank O2 DAC output
30072	dac2_output	Right Bank O2 DAC output
30073	o2_heater	O2 heater ON/OFF flag
30074	percent_o2_1	Left bank O2 percent
30075	o2_1_heater_pv	Left bank O2 heater feedback
30076	o2_1_heater_avg	Left bank O2 heater average feedback
30077	o2_1_heater_out	Left bank O2 heater output
30078	percent_o2_2	Right bank O2 percent
30079	o2_2_heater_pv	Right bank O2 heater feedback
30080	o2_2_heater_avg	Right bank O2 heater average feedback
30081	o2_2_heater_out	Right bank O2 heater output
30082	o2_1_status	Left bank O2 status

Register	Description	Definition
30083	o2_2_status	Right bank O2 status
30084	o2_warmup_timer	O2 warmup timer
30085	o2_trim_direction	O2 trim direction
30086	adc1	ADC reading channel1
30087	adc2	ADC reading channel2
30088	adc3	ADC reading channel3
30089	adc4	ADC reading channel4
30090	adc5	ADC reading channel5
30091	adc6	ADC reading channel6
30092	adc7	ADC reading channel7
30093	adc8	ADC reading channel8
30094	pre_status_o2_error	Not used
30095	o2_1_working	O2 sensor at operating temperature
30096	o2_2_working	O2 sensor at operating temperature
30097	eth_status	Diagnostics
30098	eth_txabrt	Diagnostics
30099	eth_reset	Diagnostics
30100	eth_tx	Diagnostics
30101	eth_rx	Diagnostics
30102	eth_packets_avail	Diagnostics
30103	eth_state	Diagnostics
30104	eth_rtc_sec	Diagnostics
30105	eth_rtc_min	Diagnostics
30106	eth_rtc_hour	Diagnostics
30107	eth_rtc_wday	Diagnostics
30108	eth_rtc_mdate	Diagnostics
30109	eth_rtc_month	Diagnostics
30110	eth_rtc_year	Diagnostics
30111	eth_ip_1	Diagnostics
30112	eth_ip_2	Diagnostics
30113	eth_ip_3	Diagnostics
30114	eth_ip_4	Diagnostics
30115	eth_use_static_ip	Diagnostics
30116	trimming_active	Diagnostics
30117	n3x_regs	Number of input(3x) registers

Holding Registers

Register	Description	Definition
40001	rtc_update	Update real time clock flag
40002	min_adjust_o2_trim	Minimum O2 trim adjustment
40003	max_adjust_o2_trim	Maximum O2 trim adjustment
40004	version	Software version
40005	milliamp_gain	mA input gain
40006	milliamp_offset	mA input offset
40007	serial_number	Serial number
40008	modbus_address	Modbus address
40009	calibrated	Original calibration flag
40010	f_ign_confirm	Force ignition confirm flag
40011	f_alarm_reset	Force Alarm reset flag
40012	save_data_command	Save holding registers to flash
40013	warmup_timer_start	Warmup timer duration
40014	ma_min	Minimum ma input
40015	ma_max	Maximum ma Input
40016	dp_min	Minimum catalyst differential pressure
40017	dp_max	Maximum catalyst differential pressure
40018	nox_transmit_rate	CAN transmit rate - NOx
40019	cm_info_transmit_rate	CAN transmit rate - Catalyst Monitor info
40020	o2_trim_transmit_rate	CAN transmit rate - O2 setpoint trim
40021	f_heater	Force Nox/O2 heater flag
40022	o2_trim_step	O2 setpoint trim increment
40023	nox_filter_rate	NOx averaging filter rate
40024	min_meter	Minute meter - Read Only
40025	hour_meter	Hour meter - Read Only
40026	data_log_enable	USB data logger enable flag
40027	log_rate	USB data logger rate
40028	sample_rate	O2 averaging rate
40029	overall_rate	Not used
40030	log_time_after_shutdown	Time in seconds to continue logging data after shutdown
40031	pre_temp_shutdown	Pre-catalyst temperature Shutdown/Alarm enable flag
40032	pre_temp_avg_shutdown	Average pre-catalyst temperature Shutdown/Alarm enable flag
40033	pre_temp_log_shutdown	Long average/Log pre-catalyst temperature Shutdown/Alarm enable flag
40034	pre_temp_avg_rate	Pre-catalyst temperature averaging rate
40035	pre_temp_alarm_min	Pre-catalyst temperature alarm minimum
40036	pre_temp_alarm_max	Pre-catalyst temperature alarm maximum
40037	pre_temp_alarm_delay	Pre-catalyst temperature alarm delay
40038	pre_temp_avg_alarm_min	Average pre-catalyst temperature alarm minimum
40039	pre_temp_avg_alarm_max	Average pre-catalyst temperature alarm maximum
40040	pre_temp_avg_alarm_delay	Average pre-catalyst temperature alarm delay
40041	pre_temp_log_alarm_min	Long average/Log pre-catalyst temperature alarm minimum

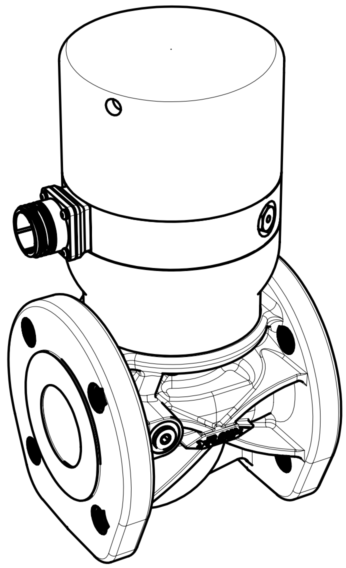
Register	Description	Definition
40042	pre_temp_log_alarm_max	Long average/Log pre-catalyst temperature alarm maximum
40043	pre_temp_log_alarm_delay	Long average/Log pre-catalyst temperature alarm delay
40044	pre_temp_shutdown_min	Pre-catalyst temperature shutdown minimum
40045	pre_temp_shutdown_max	Pre-catalyst temperature shutdown maximum
40046	pre_temp_shutdown_delay	Pre-catalyst temperature shutdown delay
40047	pre_temp_avg_shutdown_min	Average pre-catalyst temperature shutdown minimum
40048	pre_temp_avg_shutdown_max	Average pre-catalyst temperature shutdown maximum
40049	pre_temp_avg_shutdown_delay	Average pre-catalyst temperature shutdown delay
40050	pre_temp_log_shutdown_min	Long average/Log pre-catalyst temperature shutdown minimum
40051	pre_temp_log_shutdown_max	Long average/Log pre-catalyst temperature shutdown maximum
40052	pre_temp_log_shutdown_delay	Long average/Log pre-catalyst temperature shutdown delay
40053	post_temp_shutdown	Post-catalyst temperature Shutdown/Alarm enable flag
40054	post_temp_avg_shutdown	Average post-catalyst temperature Shutdown/Alarm enable flag
40055	post_temp_log_shutdown	Long average/Log post-catalyst temperature Shutdown/Alarm enable flag
40056	post_temp_avg_rate	Post-catalyst temperature averaging rate
40057	post_temp_alarm_min	Post-catalyst temperature alarm minimum
40058	post_temp_alarm_max	Post-catalyst temperature alarm maximum
40059	post_temp_alarm_delay	Post-catalyst temperature alarm delay
40060	post_temp_avg_alarm_min	Average post-catalyst temperature alarm minimum
40061	post_temp_avg_alarm_max	Average post-catalyst temperature alarm maximum
40062	post_temp_avg_alarm_delay	Average post-catalyst temperature alarm delay
40063	post_temp_log_alarm_min	Long average/Log post-catalyst temperature alarm minimum
40064	post_temp_log_alarm_max	Long average/Log post-catalyst temperature alarm maximum
40065	post_temp_log_alarm_delay	Long average/Log post-catalyst temperature alarm delay
40066	post_temp_shutdown_min	Post-catalyst temperature shutdown minimum
40067	post_temp_shutdown_max	Post-catalyst temperature shutdown maximum
40068	post_temp_shutdown_delay	Post-catalyst temperature shutdown delay
40069	post_temp_avg_shutdown_min	Average post-catalyst temperature shutdown minimum
40070	post_temp_avg_shutdown_max	Average post-catalyst temperature shutdown maximum
40071	post_temp_avg_shutdown_delay	Average post-catalyst temperature shutdown delay
40072	post_temp_log_shutdown_min	Long average/Log post-catalyst temperature shutdown minimum
40073	post_temp_log_shutdown_max	Long average/Log post-catalyst temperature shutdown maximum
40074	post_temp_log_shutdown_delay	Long average/Log post-catalyst temperature shutdown delay
40075	catalyst_dp_shutdown	Catalyst differential pressure Shutdown/Alarm enable flag
40076	catalyst_dp_avg_shutdown	Average catalyst differential pressure Shutdown/Alarm enable flag
40077	catalyst_dp_log_shutdown	Long average/Log catalyst differential pressure Shutdown/Alarm enable flag
40078	catalyst_dp_avg_rate	Catalyst differential pressure averaging rate
40079	catalyst_dp_alarm_min	Catalyst differential pressure alarm minimum
40080	catalyst_dp_alarm_max	Catalyst differential pressure alarm maximum
40081	catalyst_dp_alarm_delay	Catalyst differential pressure alarm delay
40082	catalyst_dp_avg_alarm_min	Average catalyst differential pressure alarm minimum

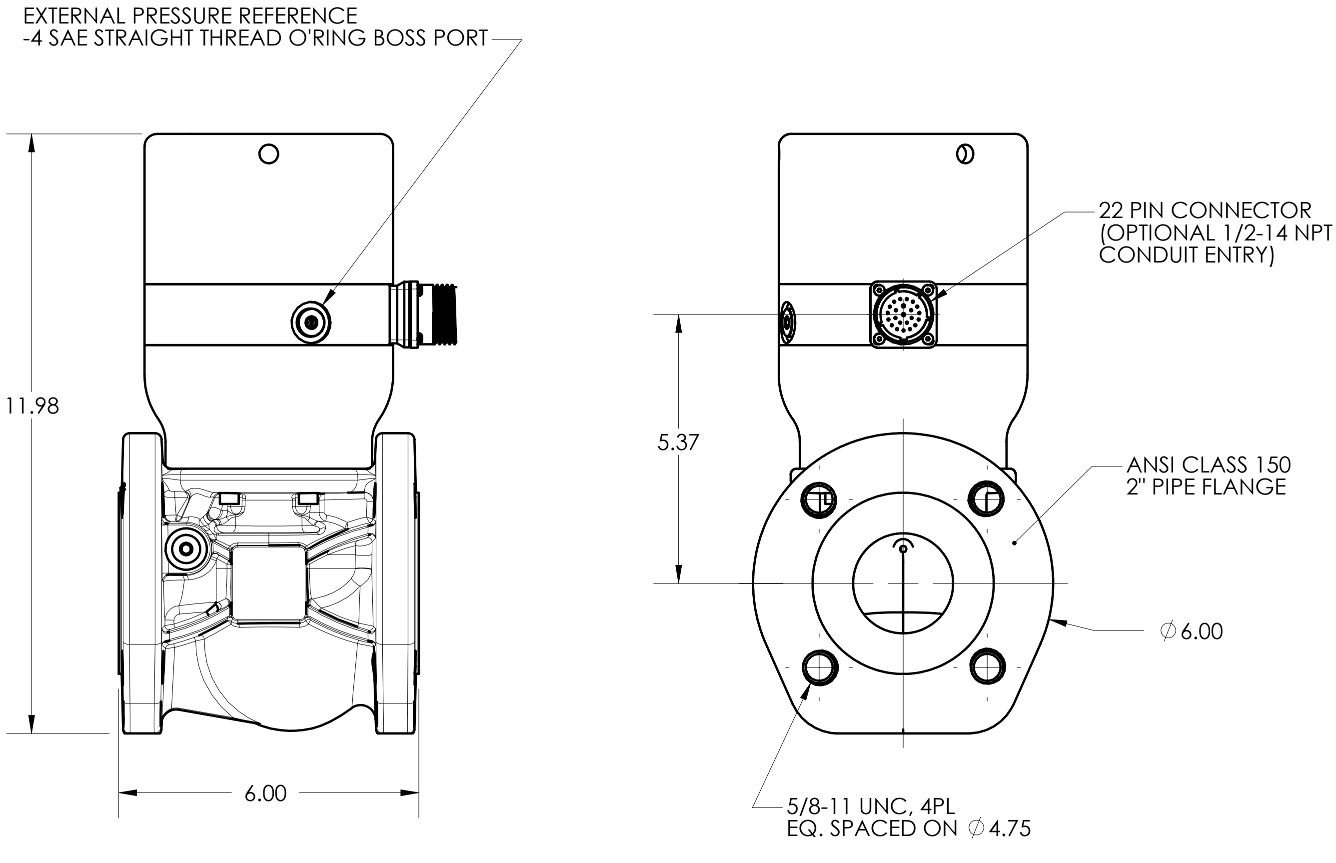
Register	Description	Definition
40083	catalyst_dp_avg_alarm_max	Average catalyst differential pressure alarm maximum
40084	catalyst_dp_avg_alarm_delay	Average catalyst differential pressure alarm delay
40085	catalyst_dp_log_alarm_min	Long average/Log catalyst differential pressure alarm minimum
40086	catalyst_dp_log_alarm_max	Long average/Log catalyst differential pressure alarm maximum
40087	catalyst_dp_log_alarm_delay	Long average/Log catalyst differential pressure alarm delay
40088	catalyst_dp_shutdown_min	Catalyst differential pressure shutdown minimum
40089	catalyst_dp_shutdown_max	Catalyst differential pressure shutdown maximum
40090	catalyst_dp_shutdown_delay	Catalyst differential pressure shutdown delay
40091	catalyst_dp_avg_shutdown_min	Average catalyst differential pressure shutdown minimum
40092	catalyst_dp_avg_shutdown_max	Average catalyst differential pressure shutdown maximum
40093	catalyst_dp_avg_shutdown_delay	Average catalyst differential pressure shutdown delay
40094	catalyst_dp_log_shutdown_min	Long average/Log catalyst differential pressure shutdown minimum
40095	catalyst_dp_log_shutdown_max	Long average/Log catalyst differential pressure shutdown maximum
40096	catalyst_dp_log_shutdown_delay	Long average/Log catalyst differential pressure shutdown delay
40097	delta_temp_shutdown	Catalyst differential temperature Shutdown/Alarm enable flag
40098	delta_temp_avg_shutdown	Average catalyst differential temperature Shutdown/Alarm enable flag
40099	delta_temp_log_shutdown	Long average/Log catalyst differential temperature Shutdown/Alarm enable flag
40100	delta_temp_avg_rate	Catalyst differential temperature averaging rate
40101	delta_temp_alarm_min	Catalyst differential temperature alarm minimum
40102	delta_temp_alarm_max	Catalyst differential temperature alarm maximum
40103	delta_temp_alarm_delay	Catalyst differential temperature alarm delay
40104	delta_temp_avg_alarm_min	Average catalyst differential temperature alarm minimum
40105	delta_temp_avg_alarm_max	Average catalyst differential temperature alarm maximum
40106	delta_temp_avg_alarm_delay	Average catalyst differential temperature alarm delay
40107	delta_temp_log_alarm_min	Long average/Log catalyst differential temperature alarm minimum
40108	delta_temp_log_alarm_max	Long average/Log catalyst differential temperature alarm maximum
40109	delta_temp_log_alarm_delay	Long average/Log catalyst differential temperature alarm delay
40110	delta_temp_shutdown_min	Catalyst differential temperature shutdown minimum
40111	delta_temp_shutdown_max	Catalyst differential temperature shutdown maximum
40112	delta_temp_shutdown_delay	Catalyst differential temperature shutdown delay
40113	delta_temp_avg_shutdown_min	Average catalyst differential temperature shutdown minimum
40114	delta_temp_avg_shutdown_max	Average catalyst differential temperature shutdown maximum
40115	delta_temp_avg_shutdown_delay	Average catalyst differential temperature shutdown delay
40116	delta_temp_log_shutdown_min	Long average/Log catalyst differential temperature shutdown minimum
40117	delta_temp_log_shutdown_max	Long average/Log catalyst differential temperature shutdown maximum
40118	delta_temp_log_shutdown_delay	Long average/Log catalyst differential temperature shutdown delay
40119	dac1_offset	Left bank O2 voltage output offset
40120	dac1_gain	Left bank O2 voltage output gain
40121	dac2_offset	Right bank O2 voltage output offset
40122	dac2_gain	Right bank O2 voltage output gain
40123	o2_1_offset	Left bank O2 offset

Register	Description	Definition
40124	o2_1_gain	Left bank O2 gain
40125	o2_2_offset	Right bank O2 offset
40126	o2_2_gain	Right bank O2 gain
40127	o2_heater_i	O2 heater integral gain
40128	o2_heater_p	O2 heater proportional gain
40129	o2_heater_sp	O2 heater setpoint
40130	o2_heater_ramp_rate	O2 heater warmup ramp rate
40131	o2_cal_timer_start	O2 calibration warmup timer duration
40132	o2_percent_max	O2 percent maximum
40133	o2_percent_min	O2 percent minimum
40134	o2_1_enable	Left bank O2 sensor enable
40135	o2_2_enable	Right bank O2 sensor enable
40136	alarm_relay_active_closed	Alarm relay polarity
40137	shutdown_relay_active_closed	Shutdown relay polarity
40138	config	Catalyst Monitor configuration
40139	do_cal	Initiate O2 sensor free air calibration
40140	o2_cal_complete	O2 calibration complete
40141	nox_setpoint	NOx sensor setpoint
40142	nox_integral_gain	NOx integral gain
40143	nox_offset	NOx offset
40144	f_dac	Force DAC flag
40145	mac_1	MAC address octet1
40146	mac_2	MAC address octet2
40147	mac_3	MAC address octet3
40148	mac_4	MAC address octet4
40149	mac_5	MAC address octet5
40150	mac_6	MAC address octet6
40151	ip_1	IP address octe1
40152	ip_2	IP address octe2
40153	ip_3	IP address octe3
40154	ip_4	IP address octe4
40155	use_static_ip	Static address flag
40156	set_sec	Set real time clock: second
40157	set_min	Set real time clock: minute
40158	set_hour	Set real time clock: hour
40159	set_wday	Set real time clock: week day
40160	set_mdate	Set real time clock: date
40161	set_month	Set real time clock: month
40162	set_year	Set real time clock: year
40163	modbus_address_2	Modbus address 2
40164	narrowband_output_en	Narrow band O2 output enable flag
40165	new_nox_alg_en	NOx algorithm enable flag

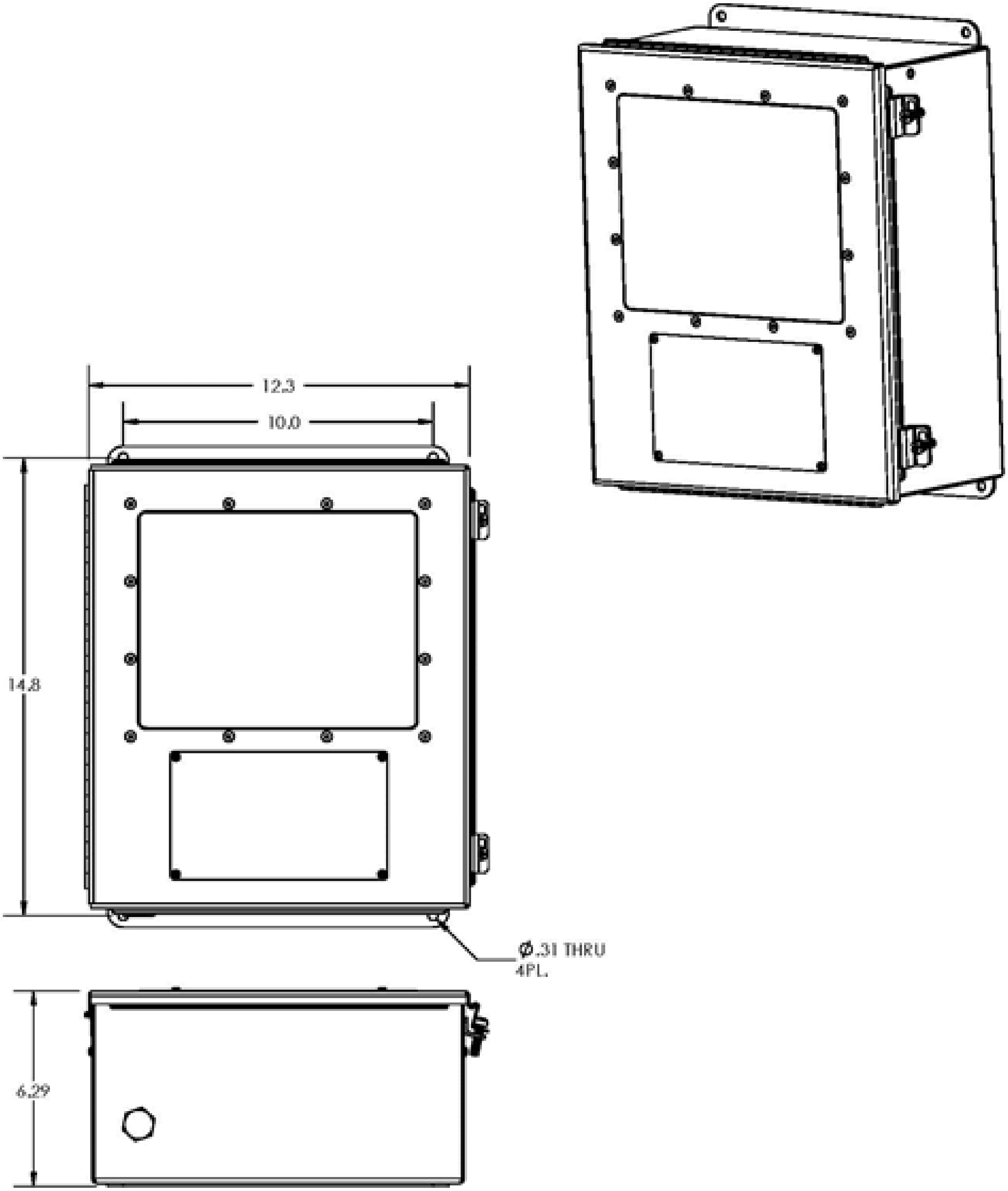
Register	Description	Definition
40166	lean_multiplier	Lean multiplier (algorithm)
40167	rich_multiplier	Rich multiplier (algorithm)
40168	adaptive_inc_table_0	Table setting0 (algorithm)
40169	adaptive_inc_table_1	Table setting0 (algorithm)
40170	adaptive_inc_table_2	Table setting0 (algorithm)
40171	adaptive_inc_table_3	Table setting0 (algorithm)
40172	adaptive_inc_table_4	Table setting0 (algorithm)
40173	adaptive_inc_table_5	Table setting0 (algorithm)
40174	adaptive_inc_table_6	Table setting0 (algorithm)
40175	spare0	Not used
40176	spare1	Not used
40177	spare2	Not used
40178	spare3	Not used
40179	n0regs	Not used
40180	nregs	Number of holding(4x) registers

A4. Envelope, ECV5, 2.0 in. ANSI Flange

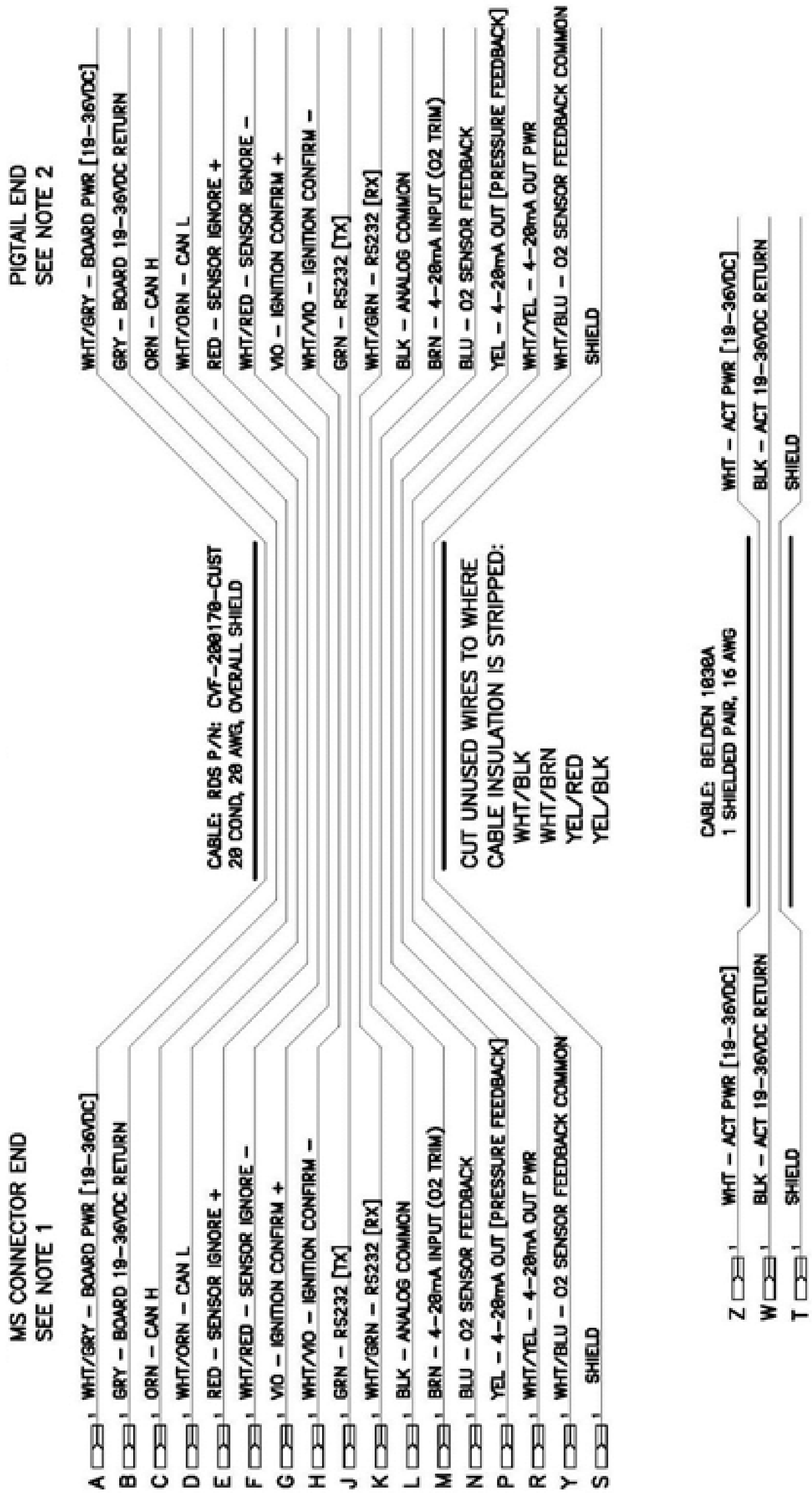




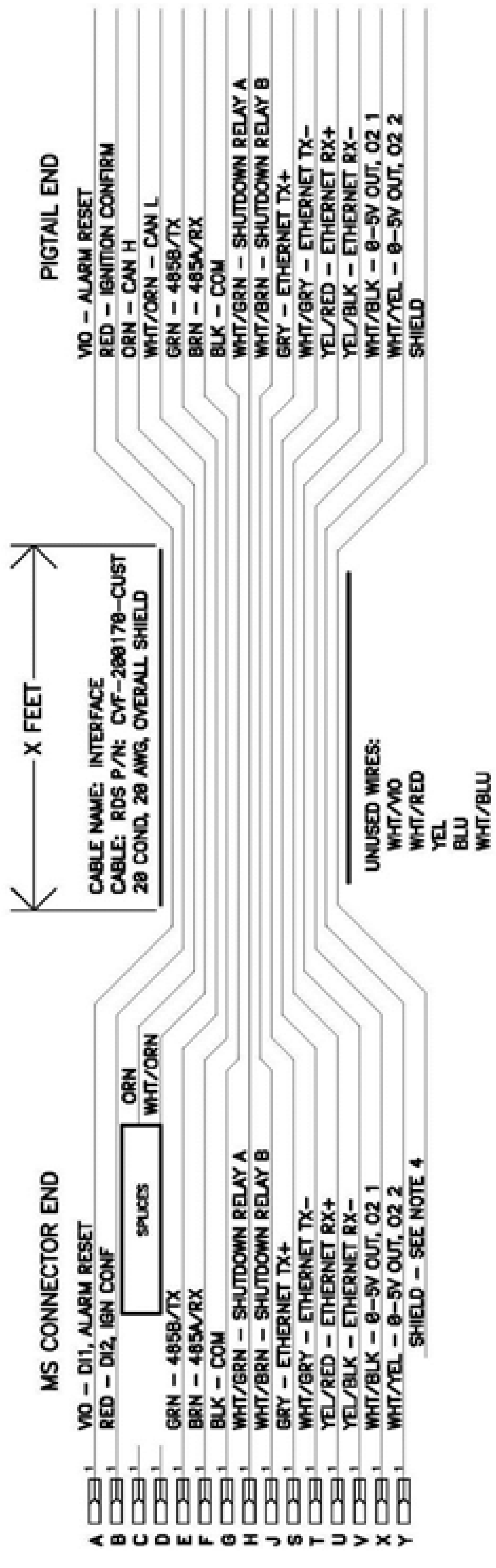
A5. Envelope, ECVI



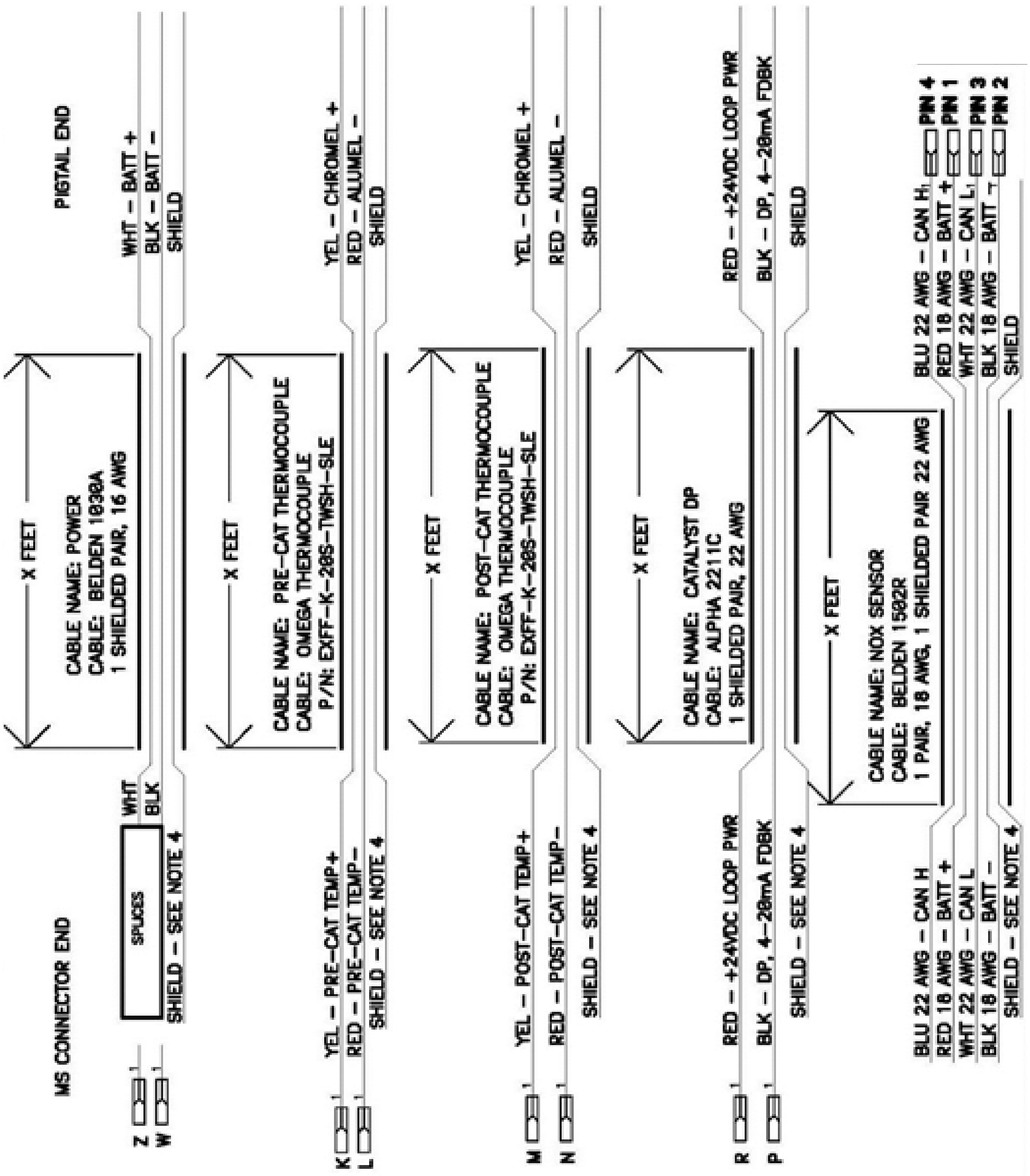
A6. ECV5 Cable



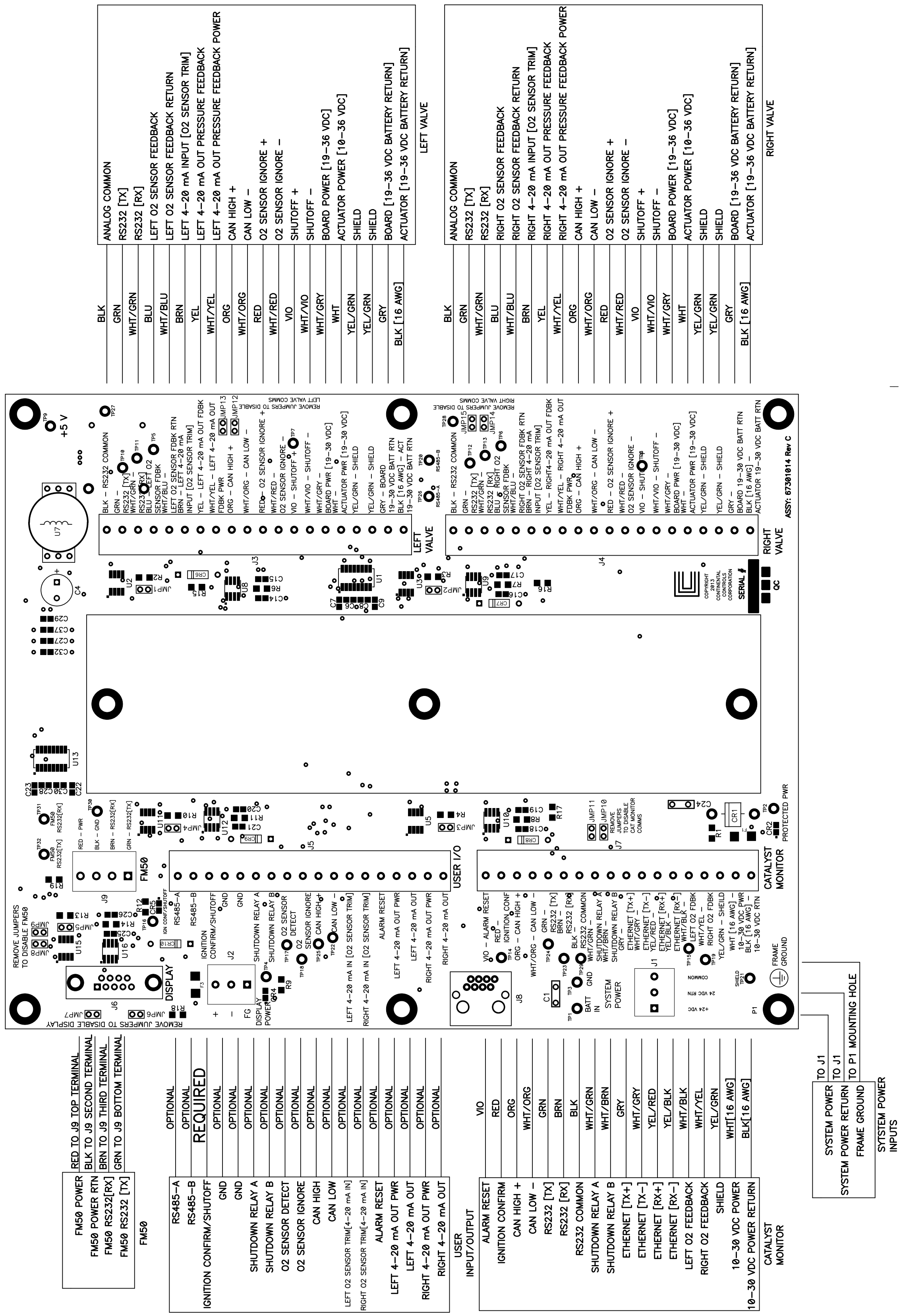
A7. Catalyst Monitor, Page 1



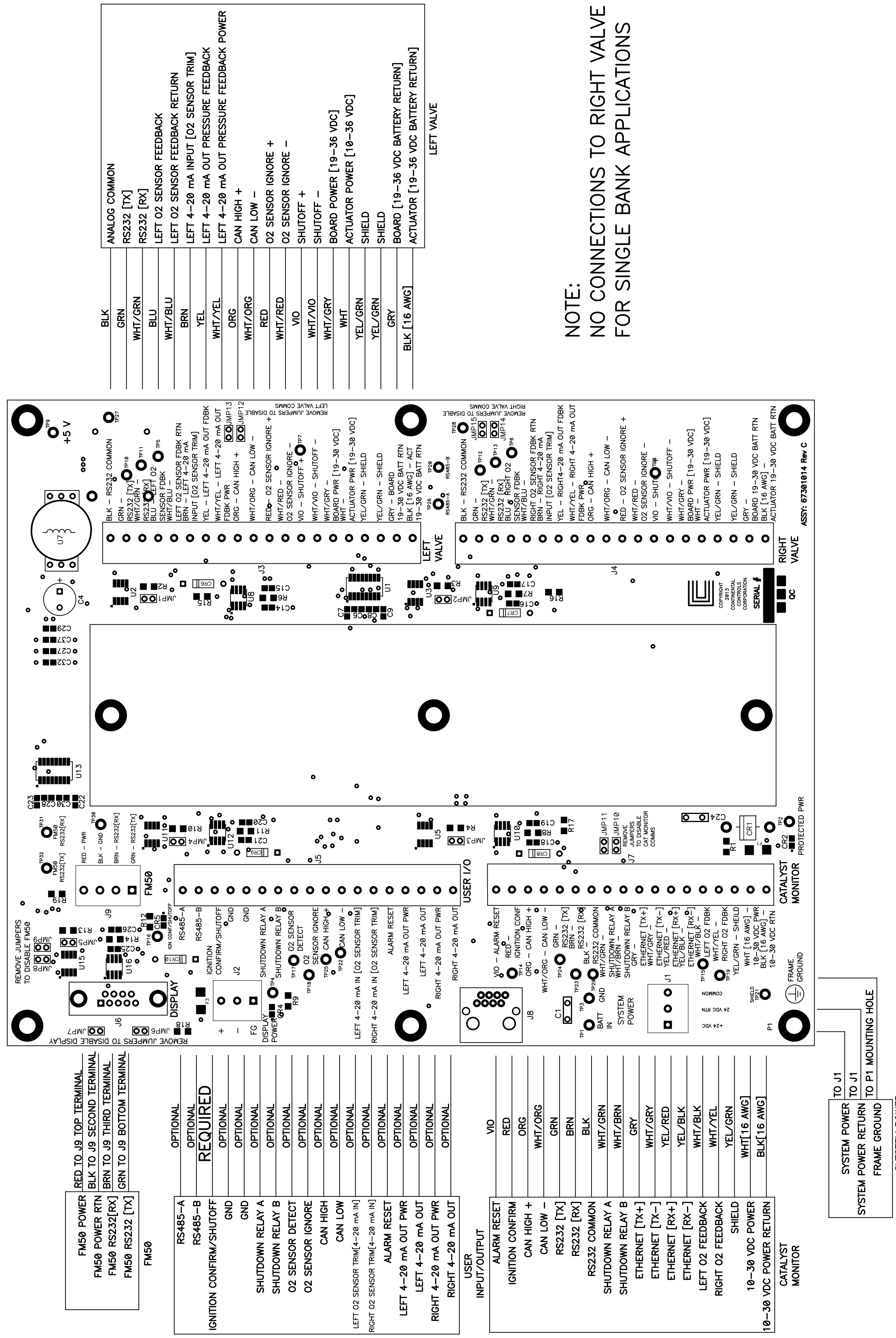
A8. Catalyst Monitor, Page 2



A9. ECVI PWB Wiring Diagram, Dual Bank



A10. ECVI PWB Wiring Diagram, Single Bank



A11. O2 Sensor Cable Wiring Diagram