

Application of Full Authority Fuel Control Valve For Non Selective Catalytic Reduction On Large-Bore, Four-Stroke Cycle, Natural Gas Fired Reciprocating Engine

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Background

The pipeline that supports the natural gas industry was originally installed with the intent to bring the available gas to the consumer over long distances. Compression from a mechanical source was required and that source quickly became a natural gas fired reciprocating engine with integral design where the compressors were mounted directly to the crankshaft. Little thought had gone into the emissions that were being emitted from the units because the main concern had been reliable compression capable of operating over many years. Eventually federal and state agencies were developed to investigate and control emissions from any polluting source and the stationary engines found on the pipeline were singled out as a major source. Engine manufacturers began developing technologies to reduce emissions, however large portions of the engines were already installed and operating on the pipelines without these technologies.

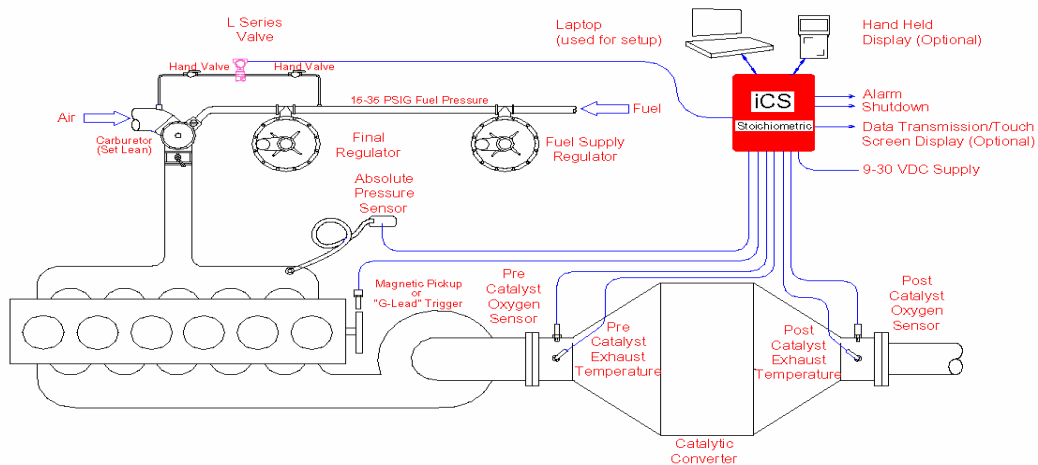
Supplemental Fuel Control Development

Many of the rich-burn reciprocating internal combustion engines (RICE) made use of a carburetor as a way to introduce the air/fuel mixture to the engine power cylinders. These engines operate with an exhaust stream oxygen concentration of no greater than 4% by volume. A carburetor is tuned for a certain engine-operating envelope and that envelope may be very small for emissions compliance. Remember - engine performance is not the same as emissions performance. If the carburetor is set up for best fuel consumption it may be operating at an air/fuel ratio rich or lean of the set point for best emissions.

As non-selective catalytic reduction (NSCR) applications began appearing in the marketplace for after treatment of the exhaust stream, tighter control of air/fuel ratio was needed than the carburetor could provide. A common modification made in order to add accuracy to the carburetor performance was the addition of a “slip stream” or “supplemental” fuel valve utilized to adjust or add fuel to a carburetor set lean (see Single Bank Slip Stream Configuration graphic). The carburetor provides 90-95% of the fuel flow while the supplemental valve provides the remaining 5-10% to bring the fuel flow up to the optimum value. This adjustment is accomplished with a controller that processes the exhaust stream oxygen content with an automotive oxygen sensor and inlet air manifold pressure sensor to precisely measure air/fuel ratio and provide the optimum air/fuel ratio setpoint at all loads. This is intended to provide the catalyst element, plated with precious metals such as Palladium or Platinum, the optimum exhaust composition necessary to promote the reduction of NO_x to nitrogen and oxygen while oxidizing the CO and HC to carbon dioxide and water. The supplemental fuel valve system had the advantage of

allowing the engine to pick up load without interference from the valve and also allow very fine air/fuel ratio adjustments due to the fact that 1% valve position adjustment represented maybe 0.1% total fuel adjustment or even less. The disadvantage was that properly sizing this valve was difficult. The fuel authority this valve required depended on several factors, some of which are difficult to quantify, e.g. carburetor nonlinearity, engine operating range, environmental temperature extremes, fuel composition variations. While the intent is good the result was that too often the valve was undersized and the solution limited the operating window of the engine, if the small supplemental fuel valve did not have enough fuel authority to operate across the full load range of some engine models.

SINGLE BANK SLIP STREAM CONFIGURATION

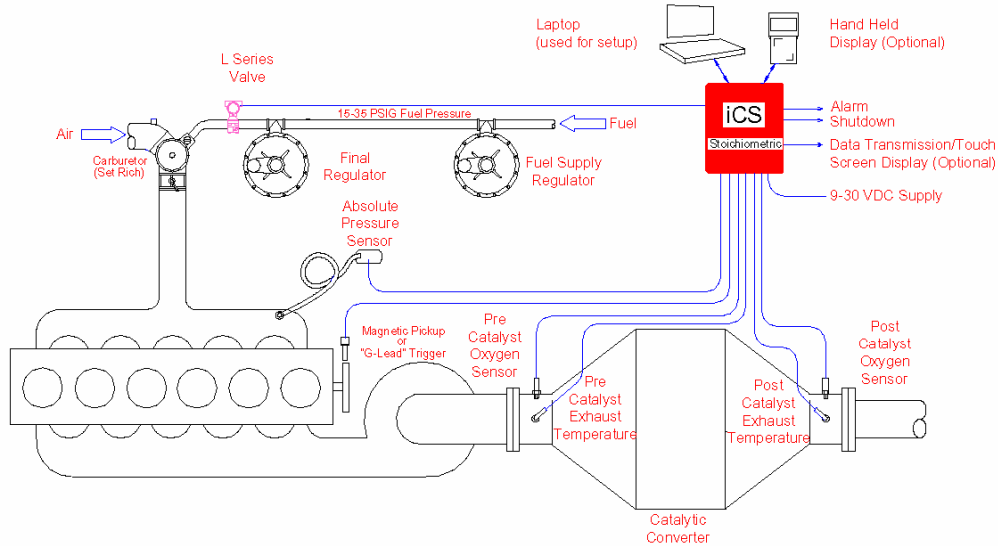


Full Authority Fuel Valve Control Development

The supplemental fuel valve often “ran out of gas” simply because the carburetor, already tuned to operate the engine at one load point, would shift so lean at a new load point that the limited fuel delivery could not make up the difference.

A slight variation was implemented by Enginuity to increase the range of adjustment of the control while still utilizing the after treatment solution of an NSCR catalyst. With the development of a control valve that was large enough to handle the full carburetor fuel flow, fast enough to move out of the way when sudden fuel flow increases are needed, and had a signal response small enough to make the fine fuel adjustments that are necessary, Enginuity began to use full fuel control where the main fuel supply was directly controlled prior to delivery into the carburetor(s) (mass control) that were now set rich of stoichiometric. Enginuity found that the mass fuel control allowed successful engine control across a broader load range of engine operation by limiting fuel to the carburetor in order to achieve correct air/fuel ratio for successful catalyst operation. (See Single Bank Mass Flow Configuration graphic.)

SINGLE BANK MASS FLOW CONFIGURATION



Air/Fuel Ratio Controllers

During the development of a cost effective solution for proper engine operation and emissions performance Engenuity reviewed air/fuel ratio controllers (AFRC's) on the market that provided the most usable features. Due to a large number of AFRC's on the market and the features that are available from the different manufacturers certain criteria was deemed necessary. Alarm and shutdown capability was included as part of the criteria to minimize risk in damaging the catalyst element rendering it ineffective due to excessive temperature spiking, engine tuning or poor ignition. Other features included: data transmission to a unit or station PLC in order to track or log the operating parameters of the system, open loop operation where the controller "learns" the best fuel valve position for that operating parameter and offering downstream catalyst element feedback to correct for fuel variations, oxygen sensor and catalyst aging allowing extended engine operation.

Catalyst technology has come a long way since industrial versions were first installed on stationary engines. Originally the catalyst elements did not have stiffening plates or rigid mounting in order to withstand the harsh environment of vibration or backfire events from the engine. The process in migrating from automotive to industrial catalyst elements took some time, however today many of the manufacturers have included additional internal support of the catalyst to alleviate some of the concern. With the application of an AFRC capable of properly maintaining the air/fuel ratio at a net oxygen value between .2% - .7% by volume utilizing feedback from pre and post thermocouples and oxygen sensors the catalyst can effectively reduce the pollutant criteria at 80-95% efficiency. Today the reciprocating engine can successfully meet the emissions regulations while offering years of additional service to the pipeline industry.