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FUEL CONTROL FOR GAS ENGINES

by
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Gas Fired reciprocating engines have been used for oil and gas compression for more than half a century. Until a few years ago, these engines all used mechanical governors for running at rated speed only. The methods used to start the engines were improvised using shut off valves and orifices. The engines often were hard to start and when they were running, they were very unstable and difficult to load. Now, thanks to advances in electronics, mechanical design and computer control, these old work horse engines can be started and "Governed" more effectively than ever before. The new fuel control methods combined with better ignition, air/fuel ratio control and load control, can improve fuel efficiency and reduce emissions.

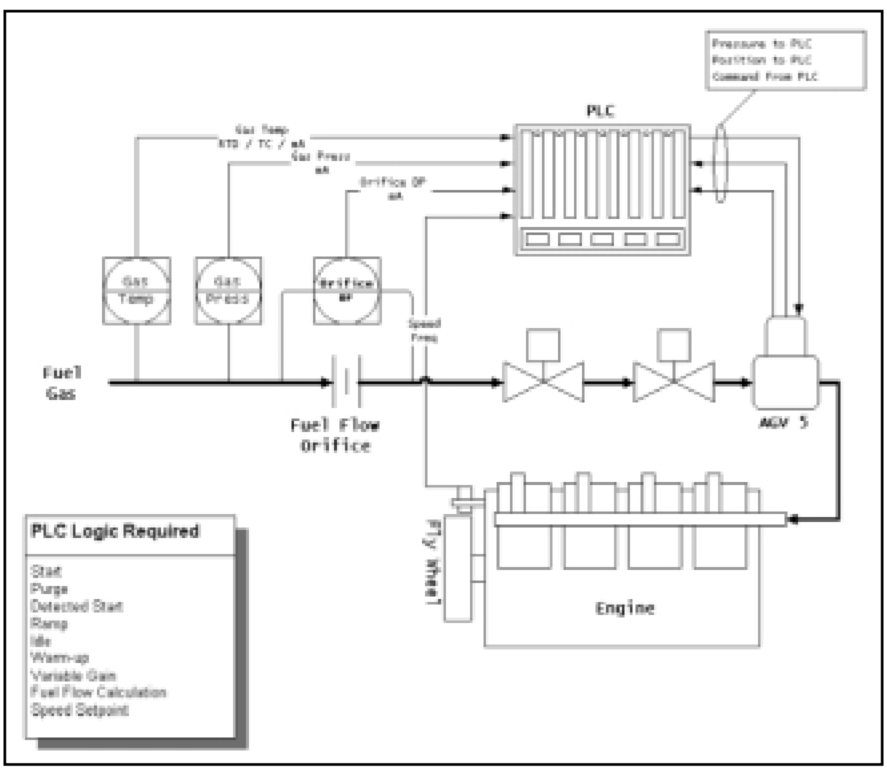
Basic Requirements for Effective Fuel Control

A primary prerequisite for all fuel control systems is that they must start the engine upon demand, and then run the engine in a stable manner during warm up. The fuel control must avoid flooding the engine and maintain a combustible air/fuel ratio when starting the engine with limited manifold air pressure. The fuel control system must allow for changes in load with minimal changes in speed. Additionally, the engine must operate safely, with safety shut downs preventing potentially catastrophic failures such as engine overspeed. With the advent of automation, the control must be capable of doing all of these things without human intervention.

Starting the Engine

The engine must have reliable starting characteristics if there is any hope of automating the operation of an engine. Without the ability to start the engine upon command, none of the other features of a fuel control system will ever be required or used.

All fuel systems must provide a method of metering the correct amount of fuel for the engine to light off and start. Some, like the Cooper GMV or GMW engines, are particularly easy to start and they tolerate inaccurate metering of fuel fairly well. On the other hand, some engines like the White Superior require much more accurate control of fuel for starting particularly when the engine is cold. Once the engine is lit, the fuel control will need to provide enough fuel to accelerate the engine while avoiding flooding. Flooding is when the fuel mixture is so rich it will not ignite and mis-firing occurs. This fills the exhaust manifold with gas, then when the engine shuts down, the fuel turns off and air is pumped into the manifold, igniting the gas/air mixture. The resulting explosion in the exhaust system is referred to as a backfire.



An accurate method for controlling the fuel when starting is to monitor the gas manifold pressure with a transducer and adjust the fuel flow to maintain the desired starting pressure. This requires a control loop to maintain the pressure. When the engine lights off and suddenly accelerates, the mixture will remain constant if the pressure is regulated.

Governing Speed

The primary purpose of the governor is to control engine speed at a set point with as little variation as possible, which will minimize the emissions. It is desirable to be able to adjust the speed of the engine by changing the speed set point in order to control the process gas flow without changing the pocket settings. The best fuel economy is achieved by operating the engine at its rated torque at all times and changing the engine speed to adjust the process flow. The governor must maintain speed within an acceptable tolerance with the ability to accept load changes with only a momentary speed transient.

The governor system must be able to compensate for engine sensitivity to fuel change. With no load on the engine it only requires a small change in fuel to change speed. While running under load the engine requires a larger change in fuel to cause the same change in speed. The change in this sensitivity requires a compensating change in the gain of the governor loop. Without this compensation, the engine will either be unstable with light load, or it will be slow in responding to load changes when running near full load.

Mechanical governors (fly ball type) exhibit a gain change because of the change in geometry as the fly balls move out due to centrifugal force. This is not an adjustable characteristic. A second factor is how the linkage between the governor and the valve is connected. This has an effect on the gain but is cumbersome to adjust.

With the advent of electronic governors, the ability to adjust the gain of the control loop became available. Some governors used dual dynamics to improve stability, which means there are two gain adjustments and the control switches to different gain setting when the load increases. In the most advanced governors today the gain is adjusted continuously with an analog proportional to load or fuel flow. This adjusts the governor gain through out the entire range of fuel flow.

Other Requirements for Today's Fuel Control

With the integration of internal CPU's or communications with external PLC's, other features have now become a part of the more sophisticated gas engine governors. Governors should be able to run in stand alone mode or switch to remote to be able to accept a speed set point from a PLC. Logic can be incorporated in the governors to provide a warm up period when the engine reaches idle speed or until the oil temperature activates a switch allowing the governor to ramp up to full speed. Safety shut downs like high gas manifold pressure or redundant engine overspeed protection can now be included in the governor providing safer operation than in the past. Fuel Flow Measurement can now be included in the governor with an output to schedule air/fuel ratio control.

Mechanical Governors

Mechanical Governors, while once considered to be technological marvels, now barely provide the minimum control and other features necessary to control gas fired engines. Because of their inability to communicate with today's control systems and because of the inherent problems associated with mechanical linkage, they are quickly becoming obsolete. These governors were only part of the fuel control system that was originally necessary to start and run these engines. The fuel systems with mechanical governors often required human assistance to provide functions the governor could not perform. Quite often a fuel bypass valve with an orifice was used to start the engine.

In recent years with automation it has become necessary to provide automatic starting capability. Normally, mechanical governors are replaced with electronic governors and PLC control systems to automate the starting and automation of the gas engines.

Some of the limitations of the mechanical governor systems include:

- The Governor does not control fuel to start the engine.
- The engine is often unstable at light loads due to the dynamics of a mechanical governor.

- The Governor does not hold the engine speed set point precisely.
- When loading the engine, the speed droops as the load increases.
- The linkage wears and requires mechanical adjustment and increasingly makes the engine unstable.
- Mechanical Governors require periodic maintenance such as oil changes and overhauls. These older Governors do not provide any electronic interface for data and diagnostic information.

PLC Based Governors

Programmable Logic Controllers are often used as a centralized control system for reciprocating engines. The fuel control system can be incorporated into the PLC with the addition of a fuel control valve and external sensors. In order for the fuel system to start and operate the engine in a reliable manner, the following design criteria should be considered:

Starting the Engine

The preferred method of starting the engine is to hold the manifold pressure at a desired pressure for the best light off, then slowly increase the pressure as the air manifold pressure comes up. Some engines flood easily and the gas manifold pressure is critical. A PID controller is used to adjust the fuel valve to maintain the desired pressure. On many engines, metering the fuel through a fixed orifice for starting does not work very well because the flow has to increase as the speed increases.

No Load Operation

Engines are started without load and run for a while to warm up before they are loaded. The gain of the control loop must be much lower to achieve stable operation with no load than it does with full load. In order to have effective control, the gain of the controller must increase as the load increases to compensate for the change in characteristics of the engine. This can be achieved by monitoring fuel flow at the PLC and adjusting the gain of the controller based on fuel flow.

Operation Under Load

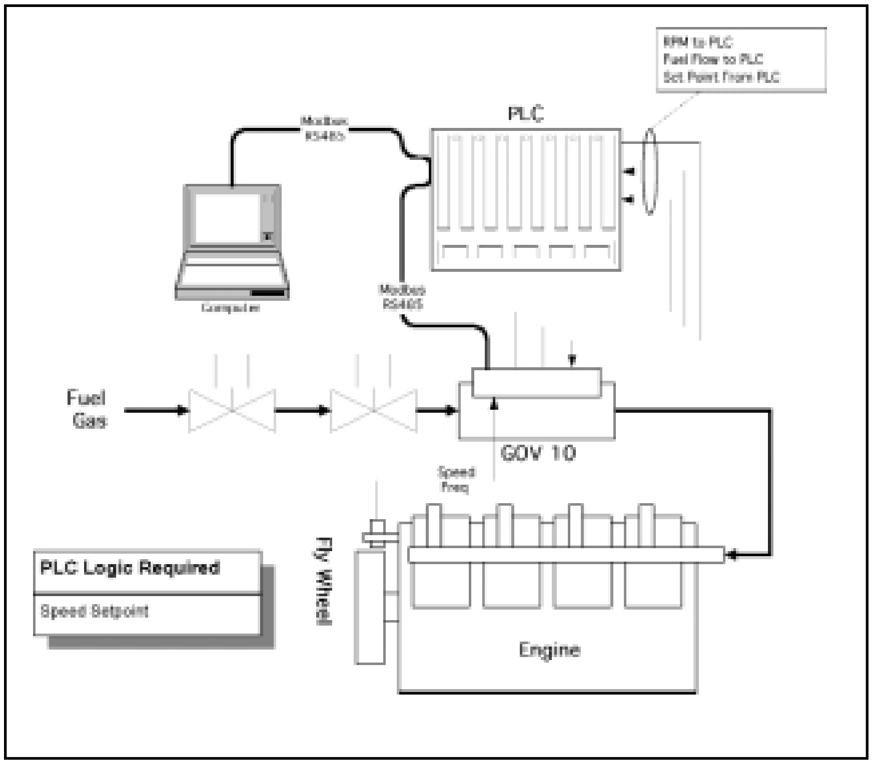
The PLC should be programmed with Proportional and integral gain (reset gain) in the speed control loop so the engine will not droop (change speed) when the load changes. The governor in the PLC controls fuel flow to maintain a constant engine speed even during load transients.

Fuel Valves for use with a PLC or for Use with Stand Alone Electronic Governors

The fuel metering valve is a key component in the governor system. The valve must control the flow over the required operating range and should not exhibit hysteresis or static friction. The valve should close on loss of power to prevent catastrophic failure. It should also report back position or pressure to the control system to allow for closed loop operation.

Axial Flow Valves - Many of the valves used have hydraulic or pneumatic powered actuators such as Axial Flow Valves. These valves have internal rubber bladders that expand or contract to change the area of the valve that restricts the gas flow. These valves generally work well at higher flows but often are not effective at low flows. Occasionally these type of bladder valves take a set after they have been in use for some period of time. It would also be good to check with the manufacturer to confirm that the valve will not remain open in case of failure of the bladder or other internal elements.

Direct Acting Valves - A new design of an electrically operated modulating valve was introduced last year. This valve was designed specifically for metering fuel to reciprocating engines. The Continental Controls model AGV 5 valve is powered from 24VDC. It utilizes an LVDT to sense the stroke of the valve and closes the internal control loop on valve position. It was specifically designed for this application and accepts a 4 to 20ma signal directly from the control system. The AGV 5 provides a 4-20ma output signal that indicates actual valve position so the control system can verify the valve is tracking the demand. The valve also contains an internal pressure transducer that senses the valve discharge or fuel manifold pressure. The valve provides a 4 - 20 ma signal proportional to pressure sensed by the transducer. This signal connects to the PLC control system to indicate the engine fuel manifold pressure. Using this type of valve, and a PLC, the start fuel can be controlled based on manifold pressure providing consistent starts.



Integrated Fuel Control (Continental Controls GOV 10)

The Continental Controls models GOV10 and GOV50 are both a fuel valve, electronic governor, along with a flow meter integrated into a single unit. Both models are for governing fuel injected gas engines. The GOV10 is used with engines up to 5000HP and the GOV50 is used with larger engines, up to 15000 HP. The governor system includes the valve, a magnetic pickup for speed sensing and a small panel-mounted terminal that provides inputs to the governor and displays outputs of the governor.

The electronic control of the gas flow through the governor is performed by a computer assembly located in the electronics cavity on top of the main valve assembly. The magnetic speed sensor is installed on the engine in a way that its frequency is proportional to engine speed.

The governor sets the manifold pressure for starting the engine, provides the logic to warm up the engine and then controls to maintain the speed at the commanded set point. The Gov 10 operates as a complete stand alone governor or it can accept a 4-20ma signal as a speed set point from a PLC.

Continental Controls Corporation is a manufacturer of controls and components for Gas Engines and Gas Turbines, specializing in fuel control systems for these engines. Ross Fisher is the President and he has been active in the development of fuel control and ignition systems for Gas Engines for more than 25 years. CCC also is active in the development of components and controls for the Gas Turbine market.

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