BY CHRIS WILKINSON, SPARTAN CONTROLS

Stationary Engines Benefit from Air Fuel Ratio Control

Micro Motion® Coriolis technology allows lean burn in natural gas supply

Installing Coriolis meters as part of air-fuel ratio control systems in more than 70 installations has solved many problems in antiquated natural gas piston engines that drive natural gas compressors. In addition to a payback as short as four months, the benefits include direct mass flow measurement, reduced maintenance, lower fuel consumption (15-20%), lower emissions (typically greater than 50%) and reduced engine wear.

Million-dollar machine

A typical natural gas compressor used in the natural gas pipelines throughout Canada and elsewhere uses piston engine fueled by the natural gas as the driving force. The function of a gas compressor is to pressurize natural gas into a pipeline for distribution. The function of the engine is to provide power to run the compressor. The purchase price of a large engine and compressor system can exceed one million dollars.

These engines can be compared to a car engine. They are piston driven also, but the source of most of the problems in these engines relate to the air-fuel ratio control (Figure 1). In basic terms, air is fed into the engine through an air intake, or carburetor, where it is mixed with fuel gas. A throttle valve and a governor control the rate of the air-fuel mix into an intake manifold. The fuel mixture enters the engine cylinders and is ignited by a spark plug. The explosion in the cylinders provides the energy to rotate the engine and sustain operation.

The exhaust from the burned fuel exits through the exhaust manifold and is used to turn a fan blade assembly known as the turbocharger prior to exiting the exhaust system. The turbocharger draws increased air into the engine.

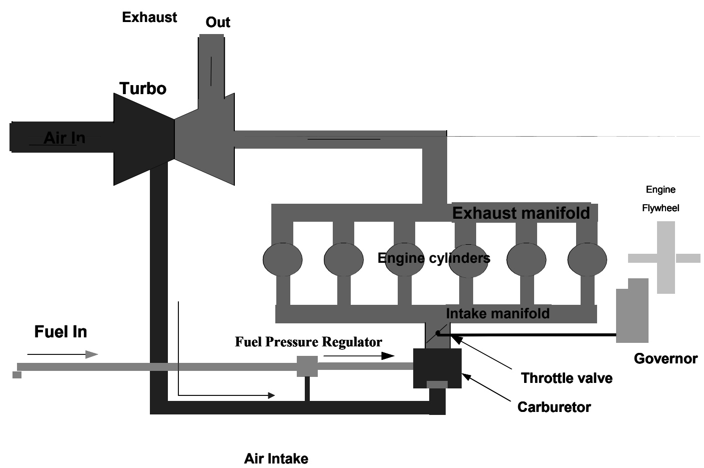
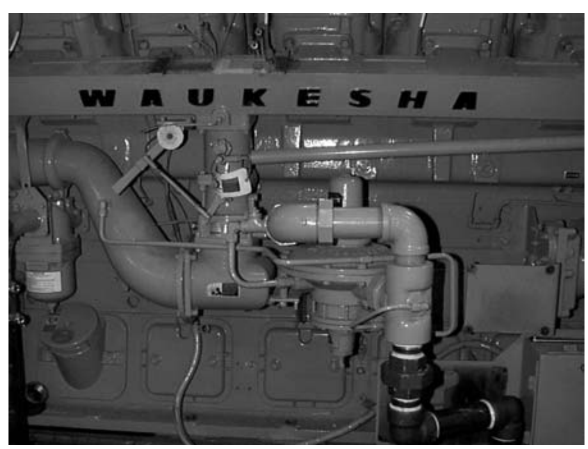


Figure 1. Air Fuel System

From an environmental standpoint, the natural gas (CH_4) engine is attractive as it provides a 30% reduction in global warming potential (GWP) per unit of heat energy over conventional gasoline (octane, C_8H_{18}) or diesel fuel ($C_{15}H_{32}$) engines.

Old engines

Studies performed by Rotating Equipment Automation (www.remtechnology.com) and others found that a high percentage of natural gas compressor engines have been in service in excess of ten years. These engines have exhibited many



problems, which include high exhaust emissions, high fuel consumption, excessive engine maintenance, poor compressor throughput and high frequency of shutdowns.

Exhaust emissions are under continued scrutiny by governments around the world. Global warming concerns have accelerated the pressure to reduce emissions. The exhaust emissions from these engines are very high and environmental pressures are forcing these gas transmission companies to control emissions. Moreover, studies found that carbon monoxide (CO), nitrogen oxides (NOX), and hydrocarbon (HC) emissions could be significantly reduced with proper control strategies.

Unfortunately, some control strategies include running the engines rich as opposed to a lean burning engine. One reason why these companies run the engines rich is to reduce NOX emissions because NOX is one of the emissions that is of extreme interest to the governments.

Fuel consumption was not considered an issue in the past. From studies, the engines were run rich to reduce NOX and fuel consumption suffered accordingly.

In addition to engine age, when running an engine in its original form, rich burning engines cause many problems, such as plugs fouling, oil contamination because of the excess gas, engine stalling, and in general, high maintenance. As a result, these engines cause a lot of downtime in the industry.

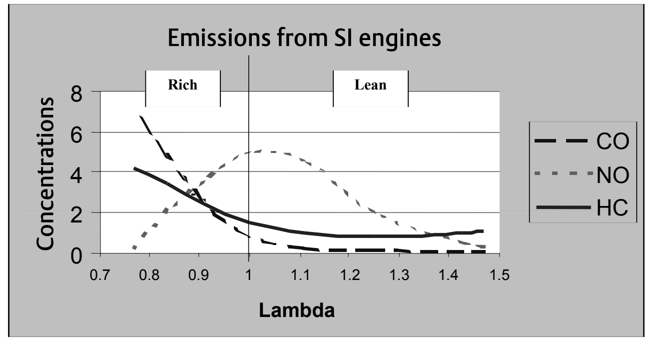
Rotating Equipment Automation's studies found that engine maintenance was a major concern to a transmission company. Maintenance and repairs on a million-dollar engine can be very expensive. Any method in reducing maintenance is a direct saving off the bottom-line operating cost for the transmission company.

Poor compressor throughput is a result of a poor running engine because of two factors. One is a reduction in compression because of poor performance from an engine. The way an engine runs affects the throughput of the compressor, not only the downtime but also the way the compressor operates. If the compressor is not operating efficiently, compressor loses throughput, thereby hurting the bottom line of the gas production company at these gas prices.

The second factor is downtime because of an engine's poor running conditions. Both inadequate compression and downtime result in lost throughput for the operating company.

The older engines were found to have a high frequency of shutdowns. When an engine is running too rich or too lean, it runs the risk of stalling. In many cases when this occurs, the engine is very difficult to restart, causing lost production.

Figure 2 shows the relationship of air fuel ratio and exhaust emissions. A 17-to-1 air-fuel ratio is the point where the air-fuel ratio is balanced, also known as stoichiometric flow. This stoichiometric condition is assigned lambda value of 1.0, or there the air-fuel mixture is exactly balanced for a complete fuel burn. The graph illustrates how running lean can reduce CO, NOX and HC emissions.



Production of NO, CO, and HCs over a wide range of air to fuel ratios. Lambda = 1 at stoichiometry

Figure 2. Emissions And Fuel Economy

Anything below a lambda of 1.0 is considered running rich, or richer as lambda decreases (higher fuel concentration). Conversely, anything above a lambda of 1 is considered running lean, or leaner as lambda increases (lower fuel concentration).

CO is generated when insufficient oxygen is present in the combustion. The CO reduction is obvious related to the lean burn.

NOX emissions are tied directly to the heat of combustion. By increasing the air intake manifold pressure with lean burn, the exhaust gas heat is reduced through increased airflow. In some cases, additional cooling may be required for the air intake to maintain a low standard of NOX emissions.

HC emissions are high in rich burning control due to the unburned fuel in the exhaust gas. In lean burn control the HC emissions are reduced by the reduction of excess hydrocarbons in the burn cycle. Another benefit not illustrated in the graph is the reduction in fuel consumption. By running lean, the amount of operating fuel is reduced, thus reducing operating cost.

Companies have tried running engines in rich burn operation to reduce the NOX emissions as a means to comply with government regulations.

There are many disadvantages to this approach. First, the reason for using natural gas as the fuel for an engine is to reduce the GWP. A natural gas engine is know to have a 30% reduction in GWP per unit of heat energy over a gasoline or diesel engine simply due to the chemistry of the hydrocarbon. The problem that is not evident is the main component of natural gas is methane. Unburned methane is a major contributor to GWP.

It is stated that running an engine 20% rich to reduce NOX emissions can increase the GWP by 200% because of the emission of unburned methane gas. Any benefit to GWP by running a natural gas engine can be quickly eliminated by poor air-fuel control. By going to rich burn, CO and HC emissions are increased, as well as increased fuel consumption. The only reason the NOX emissions are reduced with rich burn is the combustion temperature decreases.

Rich burn creates some hidden problems, including reliability concerns. Engines can easily stall with excess fuel mixtures. This can lead to spark plug fouling that makes restarting the engine very difficult, causing lost production.

Coriolis aids air-fuel ratio control

Resolution to these problems were achieved by adding automatic air fuel ratio control to the engine (Figure 3), including a Micro Motion® Coriolis mass flowmeter installed in the fuel line. A Coriolis meter provided a reliable mass flow measurement that was independent of temperature, pressure and composition changes. Additionally, the governor was replaced with a flow control valve for precise mixture flow control.

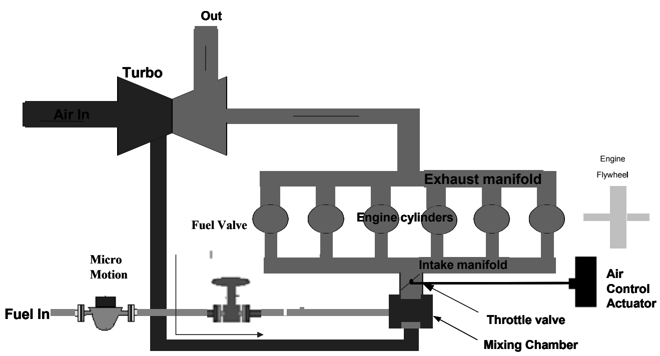


Figure 3. Modifications To Fuel System

To get more air, the turbocharger is usually modified by changing the nozzle ring, the blade or the pitch of the blade. Often, the turbo has to be replaced with a larger unit. Increasing the airflow reduces the NOX emissions by lowering combustion temperatures. Often an intercooler is added to further reduce air temperatures, thereby reducing NOX emissions.

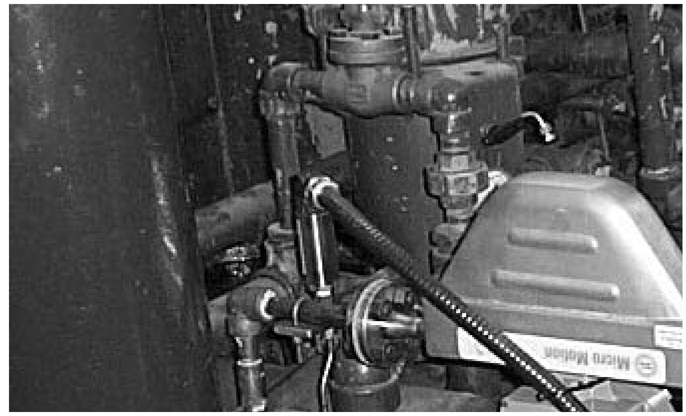
The Coriolis meter was a significant improvement because it measured mass flow directly. The mass measurement allows for compensation for any changes in the fuel composition.

Typically, the industry uses a volumetric flowmeter, usually an orifice meter. Unlike a volumetric meter, a Coriolis meter is not affected by changes in temperature, pressure and composition.

If a gas temperature increases, the volume increases but the mass remains constant. If the pressure on a gas increases, the volume decreases but once again the mass remains constant. Most importantly, if the gas composition changes, the mass will correspond to the composition change.

With a volumetric meter, the temperature and pressure must be compensated but the composition change goes undetected.

Additionally, the Coriolis meter is less expensive to install than a standard orifice run because there is no expensive meter runs and no required temperature transmitter, pressure transmitter and flow computer.



In many installations, there is no space to install long meter runs. It becomes very difficult, if not impossible, to retrofit existing piping to install the required upstream and downstream pipe diameters to accommodate a volumetric flowmeter. A Coriolis meter reduces the installation cost over a volumetric meter by “elbowing” into and out of the meter.

Less maintenance

A Coriolis meter has no moving parts in the flow stream and is known for long term reliable and stable flow measurement. The maintenance costs of a Coriolis meter are very appealing because of its simple design and lower cost than an orifice run.

The Coriolis provides excellent accuracy, approximately plus or minus one percent, lower than any other technology for this type of installation. Turndown is larger than any other type of meter installation, including orifice meters.

Before & after comparisons

On every installation Rotating Equipment Automation does a pre and post audit to verify performance improvements using portable test meters. These improved control techniques not only reduced emissions but also reduced fuel consumption.

Figure 4 shows a comparison guide illustrating the reductions in emissions and fuel consumption after implementation of the air fuel ratio control. In this exceptional example, reductions in emissions and fuel consumption amounted to 99% for CO, 27% for CO2, 35% for NOX and 33.5% for fuel. However, typically there is a reduction of 15 to 20 percent in fuel gas savings and the emissions are reduced by more than 50 percent.

Maintenance is another very important part of these conversions. Many operators question what the effect of running the engine lean has on engine wear, oil changes and spark plug changes.

In response to those inquiries, Figure 5 is from a study from two engines that were running for six months. The graph shows a comparison of metal components in engine oil for rich burn control engine (C5B) and lean burn control engine (C5A). The engine oil was changed and analyzed for metal components after every 100 hours of operation.

The rich burn engine had a much higher concentration of metal components in the majority of all oil changes. The rich

	Before		After		
Emissions	g / kW-h	g / bhp-h	g / kW-h	g / bhp-h	Reduction
CO	57.1	42.6	0.6	0.4	99%
CO_2	643	478	418	311	27%
NO_x	12.7	9.5	2.74	2.05	35%
Fuel Gas	11,810	scfd	7,845	scfd	33.5%
Speed	980	rpm	980	rpm	
Torque	86%		86%		

Figure 4. Marten Hills Waukesha 7042

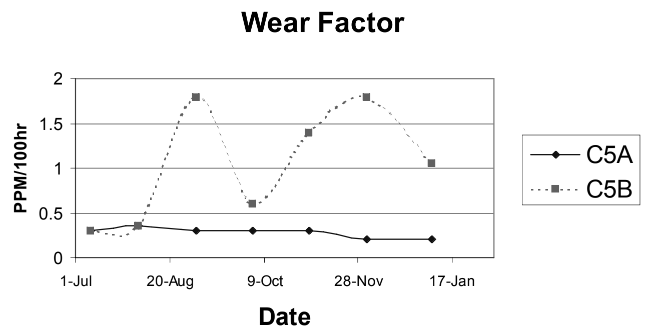


Figure 5. Waukesha 9390: Oil Contamination

burn control never had lower concentrations of contaminates than the lean burn engine. This factor indicates the life of an engine can be increased by lean burn control. In most cases, the oil change frequency is doubled.

The number of spark plug changes is also reduced. Some installations have problems with natural gas scrubber operations. As a consequence, wet gas is carried into the engine and causes it to stall because the air-fuel mixture is too rich. This wet gas carryover also fouls the plugs, requiring new plugs.

The new air-fuel control system compensates for wet gas carryover and keeps the air-fuel ratio constant. The engine does not stall and the spark plugs are unaffected.

These air-fuel ratio control systems have been installed in more than 70 locations in the U.S., Canada, the North Sea and on offshore platforms in the Gulf of Mexico.

The payback from a basic air-fuel ratio control system averages 4 months, but the payback can increase to 12 months for a more advanced system that includes additional monitoring and functionality, such as vibration analysis for diagnostic purposes.

About the author

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