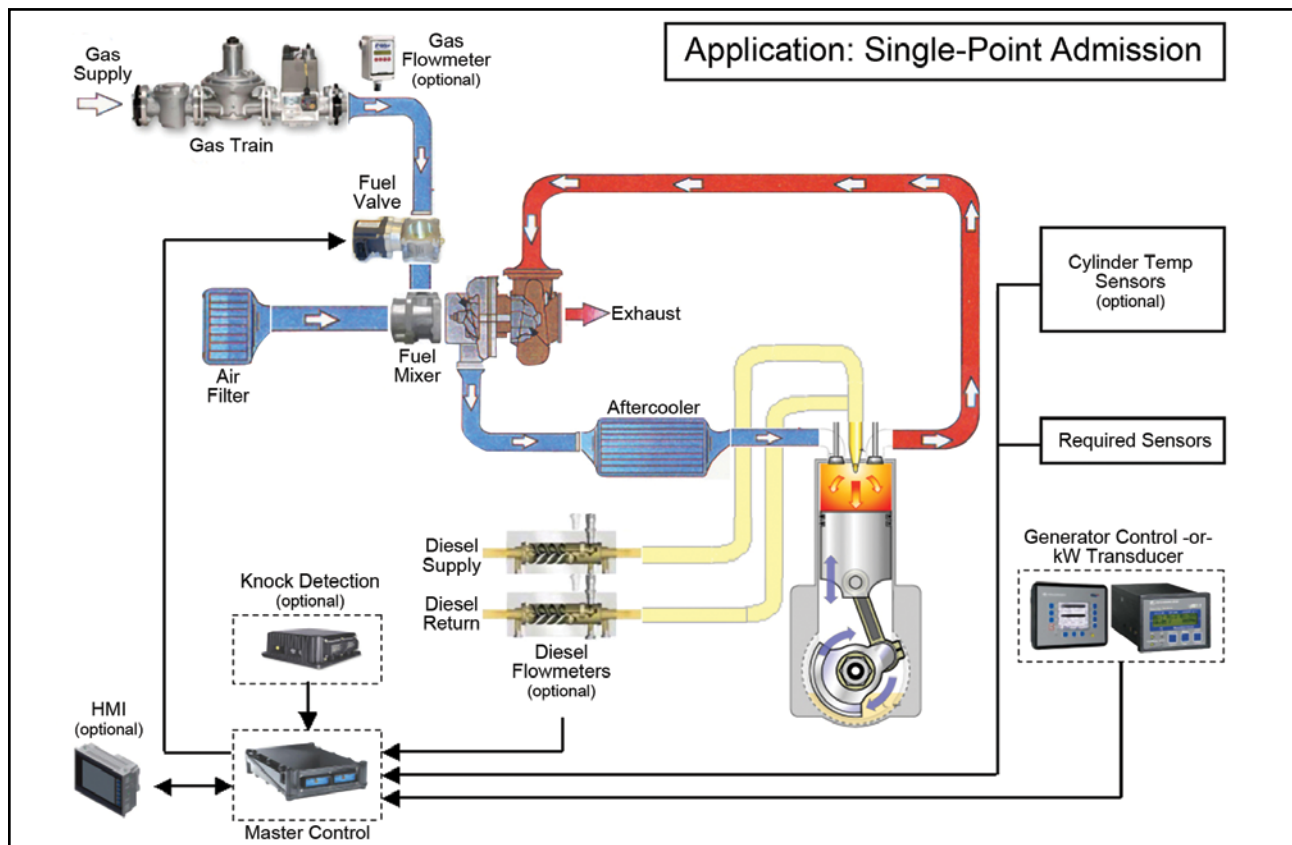




Dual-fuel system for high-speed engine.

THE BASICS OF CONVERTING DIESELS TO DUAL-FUEL OPERATION

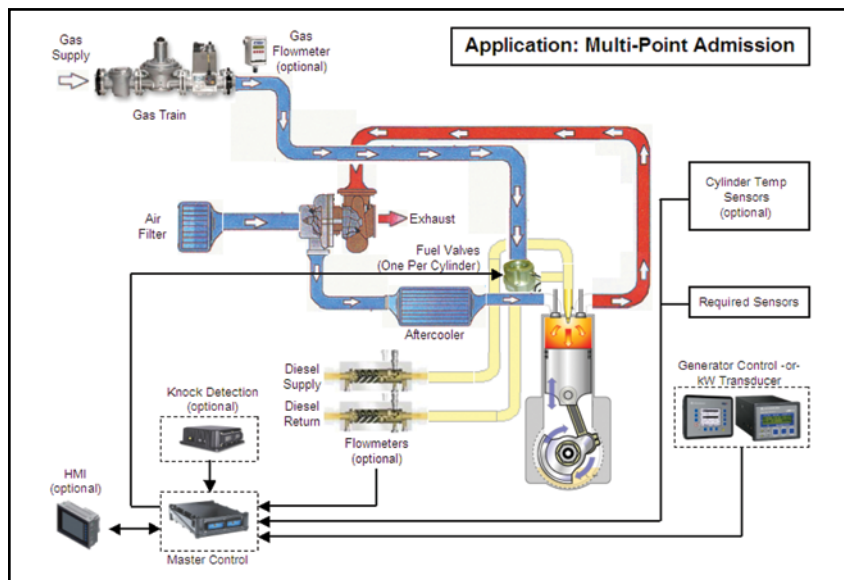
Advanced electronic controls invigorate an established technology

By Jim Martz

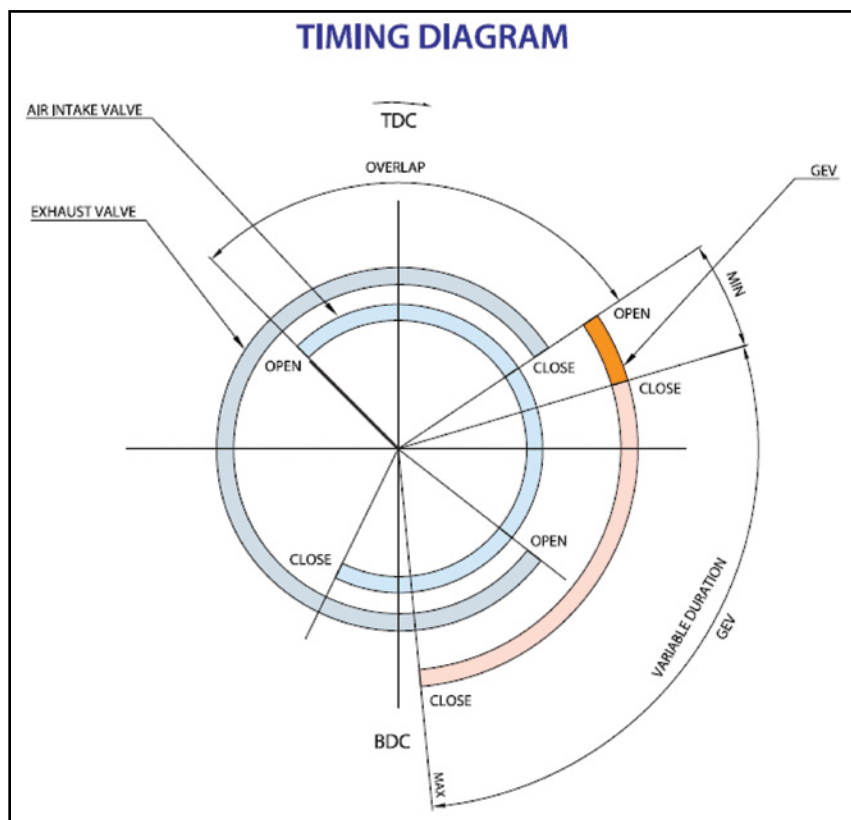
The fundamental concept of a dual-fueled reciprocating engine is not new. In the 1890s, Rudolf Diesel experimented with this approach during his research and development of the diesel engine. He introduced what is commonly referred to as pipeline natural gas into the air intake and observed improvements in engine performance.

Since then, dual-fuel engines have been available in many markets, including stationary applications in the gas

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Dual-fuel system for low-speed engine.



Multi-point fuel admission timing diagram.

compression industry. These types of engines were used as early as the 1930s.

Today, the topic of decreasing dependence on imported oil is a recurring issue. Emissions regulation and a renewed push for clean technologies are at the forefront of many government initiatives.

With the prices of diesel fuel rising and increasing regulation of emissions, machinery operators are searching for alternatives to conventional fuel. Modern dual-fuel systems incorporating electronic controls that enhance system performance represent a viable answer to the growing concerns for the widespread installed base of diesel engines.

Since a diesel engine is a compression ignition engine and does not have spark plugs or an ignition system, the primary diesel fuel is used as the ignition source or pilot ignition for the mixture in the combustion chamber.

Dual-fuel engines, therefore, retain the fundamental principles of diesel engine operation and the efficiency of the diesel engine compression ratio while enabling the engine to run on a cheaper, cleaner fuel.

Industrial dual-fuel engine applications are typically separated into two segments: low speed and high speed. Low speed is defined as 1000 rpm or lower. High-speed engines generally run between 1200 and 1800 rpm.

Single-Point Fuel Admission

Gaseous fuel admission in a high-speed industrial diesel engine is similar to the methodology used on a traditional gas engine. The gaseous fuel is admitted into the engine's air intake through mixers installed upstream of the turbocharger(s) in a concept referred to as fumigation or single-point admission. The incoming gas supply is filtered prior to the pressure regulator and shutoff valves.

The fuel flow is regulated through the use of a butterfly-style throttle valve, which is governed by the main control system, before being admitted through the mixer(s). The control system uses a series of sensors and transducers including fuel pressure, manifold air pressure, and temperature to calculate the optimum diesel-to-gas ratio and position the fuel valve(s) to the optimum position to admit the proper amount of gaseous fuel. This technique commonly allows between 50 and 70% gas substitution rates and higher in some applications.

Multi-Point Fuel Admission

Gaseous fuel is not admitted into a low-speed engine in the same manner as in a high-speed engine. On low-speed engines, fuel is injected through individual valves on each cylinder in a concept referred to as multi-point admission or injection as

opposed to using pre-turbocharger fuel mixers.

The driving factor for the different methodology is intake and exhaust valve timing. There is a period of time during the engine cycle when the intake and exhaust valves are open at the same time. It is during this valve overlap period that the cylinder is flushed with clean, cool air, often called "scavenging."

In order for this operation to be maintained in a dual-fuel engine, the gas flow to the cylinder must be shut off for a period of time to eliminate the possibility of gas in the exhaust manifold, which could be potentially dangerous and explosive.

This interruption of the gas supply to the cylinder is accomplished through the use of electrically operated solenoid valves. On a high-speed engine, the overlap time of the valves is much shorter than that of a low-speed engine, so a continuous supply of gaseous fuel flow is possible.

In low-speed applications, an electronic control drives the individual fuel solenoid valves, regulating timing and duration of fuel injection into the cylinder. This technique commonly allows

Fuel	Chemical Formula	Description	Energy Density
Diesel	C10H20 to C15H28	A combustible hydrocarbon mixture, however, unlike petrol, ignites when compressed in an internal combustion engine.	
Gasoline (Petrol)	C8H18	A combustible mixture of various hydrocarbons and additives. The hydrocarbon makeup of this mixture is modified to obtain different octane ratings.	Approx 90% the content of diesel
Liquefied Petroleum Gas (LPG)	C3H8	A hydrocarbon mixture and, similarly to petrol or diesel, is obtained from the refining of fossil fuels.	Approx 65% the content of diesel
Natural Gas		A mixture of combustible gases primarily consisting of methane found beneath the earth's surface.	Approx 18% the content of diesel
Comp. Natural Gas (CNG)	CH4	Obtained by compressing natural gas typically between 2900-3600 psi.	Approx 25% the content of diesel
Liquefied Natural Gas (LNG)		Obtained by super-cooling natural gas to approximately -260 °F.	Approx 60% the content of diesel

Comparison of fuels for dual-fuel diesels.

between 60 and 80% gas substitution rates, and higher in some applications.

Benefits Of Dual-Fuel Operation

With the rising cost of diesel fuel, and the fact that dual-fuel engines considerably reduce diesel fuel usage, converting an engine to operate primarily on a cheaper gaseous fuel is economically attractive.

In addition, spark plugs and an ignition system are not required. That eliminates the costly spark plug maintenance associated with traditional natural gas engines and helps to further reduce the overall cost of operation.

Depending on the expected number of run-hours and the cost of diesel and gaseous fuel, the up-front installation cost of retrofitting an existing diesel engine to dual-fuel operation can be quickly recovered.

Gaseous fuels, and natural gas in particular, are much cleaner burning than diesel. Diesel engines that have been converted to dual-fuel operation have exhibited significant reductions in NO_x and CO₂ over their original diesel operation. This is important in areas with increasingly tough emissions regulations. In addition, on-site diesel storage capacity can be reduced.

Retrofit systems can be installed in the field in a short timeframe, minimizing engine downtime. No modifications are required to the core engine itself or to the factory fuel management system.

With the engine's main fuel becoming gaseous fuel rather than diesel and the electronic control system maximizing fuel efficiency, installing an alternative fuel system enables the on-site diesel supply to last much longer, extending engine uptime without compromising performance.

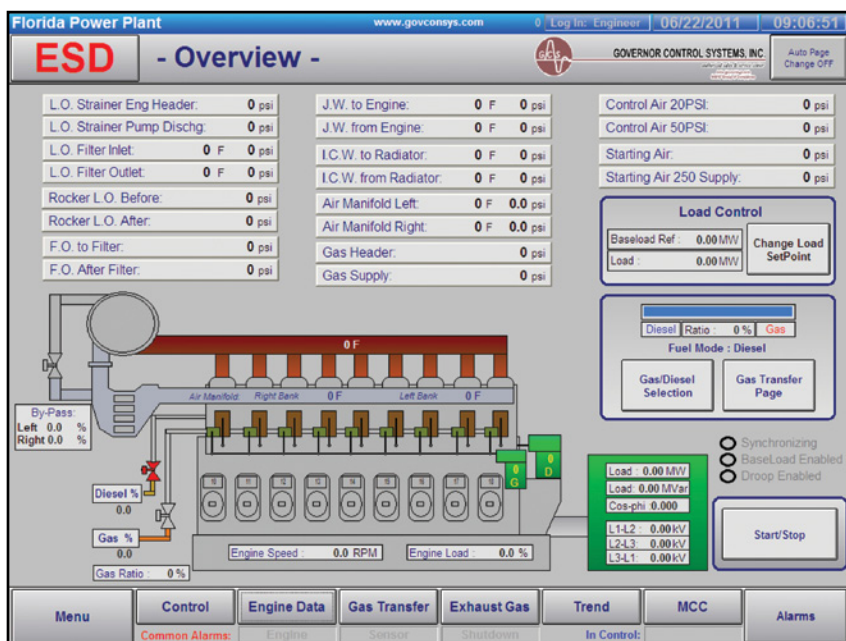
Replacing diesel fuel with natural gas typically extends engine maintenance intervals and overall engine life. For example, the life expectancy of cylinder head valve seats has been shown to improve due to the cleaner combustion that gaseous fuel exhibits over diesel.

Benefits of the factory diesel engine, including hardware ruggedness and operational efficiency, are maintained and returning to operation on 100% diesel fuel is possible at any time.

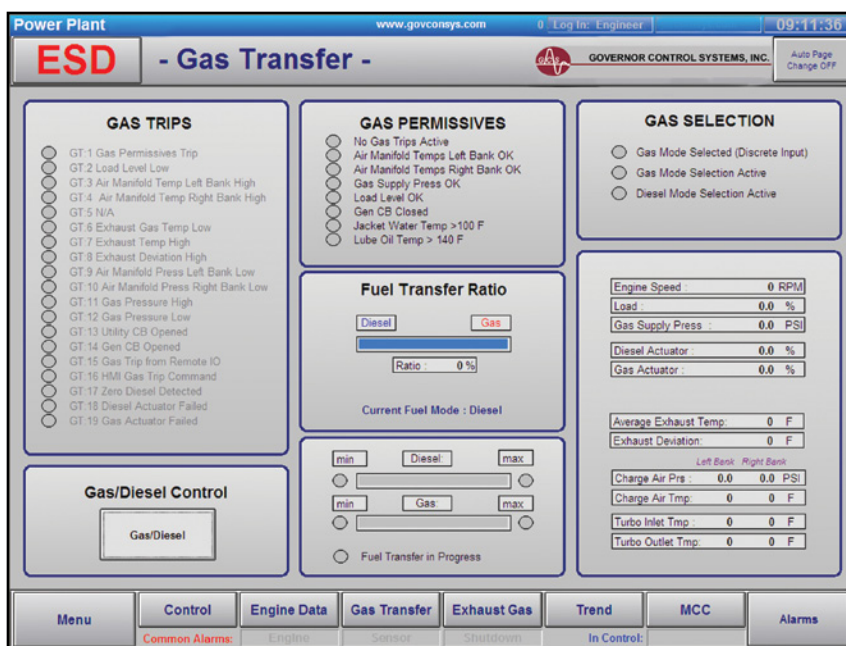
Gasoline is a volatile fuel that is easily ignited. While diesel fuel is less volatile, it presents the same storage and handling problems.

Comparatively, natural gas exhibits many different characteristics. It is buoyant at temperatures above -160°F (-106°C), does not pool on the ground, dissipates rapidly in the atmosphere, is non-toxic or corrosive, and is environmentally safe.

Natural gas also has a high auto-



Dual fuel overview on an HMI screen.



Dual fuel transferring on an HMI screen.

ignition temperature. The minimum temperature required for methane ignition without a spark or flame present is about 1076°F (580°C). This is over 500°F (260°C) higher than gasoline at 536°F (280°C) and is therefore difficult to auto-ignite.

The narrow range of flammability present with natural gas is also an important aspect to safety. Natural gas only burns in concentrations between 5% and 15%, making accidental ignition highly unlikely. Most importantly, natural gas does not detonate in an open environment.

Some applications and installations of dual-fuel engines are subject to safety

directives such as ATEX in the European Union or CSA in North America. These directives are enforced wherever a potentially explosive environment is present and the main requirement is to prevent the formation of this environment.

This is normally accomplished through the use of either double-walled gaseous fuel piping or single-walled piping installed in a separate compartment. In the case of double-walled piping, the space between the walls can be continuously ventilated.

In addition, gas detection sensors can be installed in the engine room to continuously monitor the environment for the presence of gas. These sensors

are connected to an alarm system that can switch the gaseous fuel supply off and either return the engine to operation on 100% diesel fuel or shut it down completely.

OEM Alternatives

A number of OEMs produce conventional gas engines. Generally, spark-ignited engines are designed by the OEM to operate on specific gaseous fuels, and therefore are optimized with a certain compression ratio, timing, and air/fuel ratio to produce the highest efficiency and power output with the lowest emissions possible.

However, there are a number of disadvantages to them as well. First, the power output of a spark-ignited gas engine is lower than that of a similar sized diesel engine. This translates to a higher capital investment during initial installation.

The spark ignition system itself has a high cost of maintenance as well. Although many manufacturers continue to invest in development of longer life spark plugs, their operational life continues to be a concern. Spark-ignited engines also run hotter than their diesel counterparts, which significantly increases valve seat wear rates.

A small number of OEMs produce a

factory dual-fuel engine. An engine designed specifically for dual-fuel operation can attain a higher diesel-to-gas ratio than a converted conventional diesel. While manufacturers of these engines claim operation on as little as 1% diesel fuel, they may not be economical for the general customer base with installed diesel engines due to the high initial cost of investment.

Converting a conventional diesel engine to an OEM factory style dual-fuel system requires change of major engine hardware such as pistons and heads, as opposed to a standard diesel conversion that requires no change to basic engine hardware.

Auxiliary Systems

In addition to the advantages of a standard dual-fuel conversion, additional features can be added to the system for enhanced benefit.

One such retrofit is a fuel flow metering system. When considering an alternative fuel system, it is necessary to know how much diesel fuel is actually being saved and how much gaseous fuel is being used. A flow metering system can be integrated to measure the supply of both fuels and the diesel return line to calculate fuel usage and associated cost savings.

Another example is a Human Machine Interface (HMI). This enables all controls in a given system to have their information displayed in one central location for operator control and system parameter monitoring. All basic engine parameters can be monitored along with diesel and gaseous fuel ratio, alarm status, real-time performance trending, and available remote access via the Internet.

Summary

Owners or operators of existing diesel engines interested in cost savings should evaluate the benefits of a dual-fuel conversion.

While the concept of a dual-fuel engine is not new, interest in this technology is increasing due to rising costs of diesel fuel, more emphasis on emission regulations, a desire to increase engine maintenance intervals, and a need to control overall cost of operation.

Offering ease of installation and relative low cost of capital investment, dual-fuel conversions provide the ability to realize this cost savings and adhere to regulations through the use of gaseous fuel in both low- and high-speed industrial engine applications. ©