# UTILIZING NATURAL GAS AS A FUEL SOURCE IN HYDRAULIC FRACTURING OPERATIONS

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ABSTRACT

In hydraulic fracturing operations, a large fleet of equipment is required to blend and pump fluid down a wellbore to fracture a formation. High horsepower diesel pumps create the power to create fractures thousands of feet below the surface, and in the process, can consume several thousand gallons of diesel fuel each day.

In an effort to counter this large consumption of fuel, new technology makes it possible to replace up to 70 percent of the engine's diesel consumption with natural gas during pumping operations. Bi-fuel systems are designed to operate without any loss of horsepower, and with a number of advantages over conventional diesel-only pumps: improved emissions, reduced diesel consumption, and safe use of natural gas as a fuel (without a spark-ignited engine).

With the increasing costs of diesel fuel and more stringent emission requirements being set forth by the United States Environmental Protection Agency, it is beneficial to have the ability to reduce operating costs and engine emissions by using cheaper, cleaner natural gas. This paper will explain the new technology, its benefits and important considerations for efficient use of bi-fuel pump technology.

## INTRODUCTION

Hydraulic fracturing is the practice of pumping a fluid down a wellbore to create a fracture in a particular rock formation to allow hydrocarbons to flow more freely. All hydraulic fracturing operations utilize high horsepower pumps, such as the pumping unit shown in Figure 1, to force fluids down a wellbore to fracture this zone of interest. The common design of these pumping units consists of a high horsepower engine, a transmission, and a high pressure triplex or quintiplex positive displacement pump.

The vast majority of wellbores that are hydraulically fractured require more than one of these units to create enough force and flow rate to create adequate fractures in the zone of interest. Depending on the fracturing job design, the number of pumping units can range from 2 units for smaller designs to upwards of 20 or more units for larger, high rate job designs. With each pumping unit typically having a 50 liter diesel engine providing power to turn the high pressure pump, diesel fuel consumption can be significant. An average diesel fuel consumption rate for a pumping unit is between 50-70 gallons per hour. Depending on the number of pumping units required and the number of hours the pumping units are in operation each day, diesel fuel consumption can be upwards of 10,000 gallons per day.

The main drawbacks of using large quantities of diesel fuel for hydraulic fracturing operations are high operating costs and diesel emission outputs. The rising price of diesel fuel over the past several years has also caused operating costs to rise as well lead to reduced margins and higher pricing for the customer. Also, with large quantities of diesel being consumed, large amounts of diesel emissions are created. To counter these issues, high horsepower engines are being outfitted with a system that allows natural gas to be introduced into the air intake of the engine and effectively reduce the amount of diesel being consumed.

## SOLUTION

To help reduce the amount of diesel fuel consumed and emissions produced during hydraulic fracturing operations, several pumping units were outfitted with bi-fuel systems. These systems allow natural gas to be introduced into the diesel engine's air intake in a controlled manner and effectively reduced the amount of diesel fuel being consumed by the engine. A bi-fuel system can safely reduce diesel usage along with emissions produced by the diesel engine by monitoring the operating conditions of the diesel engine and ensuring an adequate natural gas supply is available.

## OPERATION

A bi-fuel system generally consists of a control system, a gas train, and a catalytic silencer. An image of the gas train components are shown in Figure 2. The control system monitors various engine and bi-fuel system parameters, controls the amount of natural gas going into the engine, and provides an interface for the operator. The gas train contains filtration elements, natural gas control valves, pressure regulation, and a gas control valve. The gas train acts as the final gas process and control system before the natural gas enters the air intake of the engine. The catalytic silencer is an exhaust system that is required in order to reduce an increase in carbon monoxide emissions when the engine is consuming natural gas.

As natural gas is substituted into the engine, the natural gas provides more energy into the combustion chamber. This will cause the engine speed to increase. The engine control module (ECM) will detect this increase in speed and in turn reduce the amount of diesel fuel being injected into the engine to maintain the proper engine speed. This effectively replaces diesel fuel with natural gas.

In order to safely introduce natural gas into the air intake of the engine, all parameters being monitored by the bi-fuel system need to be satisfied. Engine parameters are monitored and include exhaust gas temperature, engine cylinder knock, engine load, boost air temperature and engine timing. With the bi-fuel system monitoring operating conditions of the engine, the system ensures the engine operates within its own limits specified by the manufacturer. Parameters monitored on the bi-fuel system are natural gas pressures—both high and low—and gas valve position. The high pressure switch provide a safety to prevent natural gas from being forced into the engine which could cause damage to the engine and the low pressure switch ensures there is an adequate supply of natural gas for the engine to operate on. If at any point during operation of the pumping unit these parameters exceed the safe operating limits of the engine, the bi-fuel system will stop the flow of natural gas into the engine and provide a fault to the operator. At this point, the operator can identify the fault, correct any issues, and reset the bi-fuel system. With the bi-fuel system reset, the natural gas substitution will resume automatically as long as all the operating parameters are satisfactory.

Once all these parameters are satisfactory, the bi-fuel with automatically begin substituting natural gas into the engine based on the engine load. The gas control valve will open to a predetermined set point based on the engine load. These set points are determined during a commissioning process after the bi-fuel system has been installed. During the commissioning process, the engine will be put under a given load. Natural gas will be gradually added to the air intake of the engine while the engine exhaust temperatures and engine cylinder knock are monitored to ensure that the engine manufacturer's operating limits are not exceeded. With the maximum amount of natural gas being introduced into the engine while not exceeding the upper operating limits of the engine, a set point for the natural gas control valve is created. This process is repeated for various engine load intervals to maximize natural gas substitution.

## SUBSTITUTION RATES

The result is a curve that determines natural gas substitution rates across the engine load range. An example of such a curve is shown in Figure 3. Note that there is no natural gas substitution at low engine loads and loads near 100 percent load. This is to ensure the engine does not operate at elevated operating temperatures at these ranges. Natural gas is not introduced until the predetermined minimum engine load at which the gas control valve will open. The same is true for the upper end of the engine load range. Once the load on the engine reaches 90 percent, the natural gas substitution rate drops sharply and the engine will resume operating on 100 percent diesel fuel. If natural gas was introduced at engine loads above 90 percent, the operating temperature of the engine would exceed the upper operating temperature limit set forth by the engine manufacturer.

## BENEFITS

The benefits of operating a bi-fuel system on a hydraulic fracturing pumping unit are numerous. By operating these systems on pumping units, operation costs are reduced, emissions are improved, and the performance of pumping unit is unchanged from 100 percent diesel operation. By replacing diesel fuel with natural gas while the engine is operating under a load, a significant quantity of diesel fuel is saved. In turn, this reduces operating costs for the service provider.

Another significant benefit is to the environment by reducing the amount of emissions that would normally be produced with the pumping units operating on 100 percent diesel. By reducing the amount of diesel fuel being consumed by the engine, the amount of diesel related emissions are also reduced. Nitrous oxides (NOx), carbon monoxide (CO), and particulate matter (PM) are the primary emissions that are reduced. Testing has shown that NOx can be reduced by up to 50 percent depending on the natural gas substitution rate as NOx is an emission related directly to diesel fuel. CO will actually increase significantly when natural gas is being substituted as CO is an emission of natural gas. To counter this increase, the catalytic silencer will reduce CO to virtually zero by converting the CO to carbon dioxide (CO2). Particulate matter is reduced by consuming less diesel fuel and testing has shown reductions of up to 70 percent.

The performance of the pumping unit is unaffected by the bi-fuel system. A common misconception is that by using natural gas in place of diesel fuel, the engine's horsepower will be de-rated. This is due to natural gas having a lower British thermal unit (Btu) content than that of an equivalent volume of diesel fuel. However, with a bi-fuel system, diesel is replaced on an energy basis, not volumetric as previously described in the operation section.

## CONCLUSION

Hydraulic fracturing pumping units that have the ability to operate on a mixture of diesel and natural gas have several benefits. These benefits prove beneficial to the service provider, the operator, and the surrounding environment. With the system allowing natural gas to be introduced into the engine while still utilizing diesel as a fuel source, fuel flexibility is created. Natural gas is able to be utilized during hydraulic fracturing operations as a fuel source while allowing the service provide to not be dedicated to spark ignited natural gas engines and be dependent on a natural gas supply.

FIGURE 1 – Hydraulic Fracturing Pumping Unit

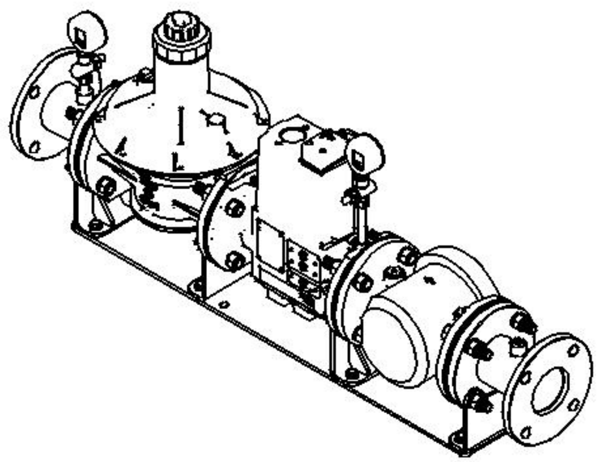

FIGURE 2 – Bi-fuel System Gas Train

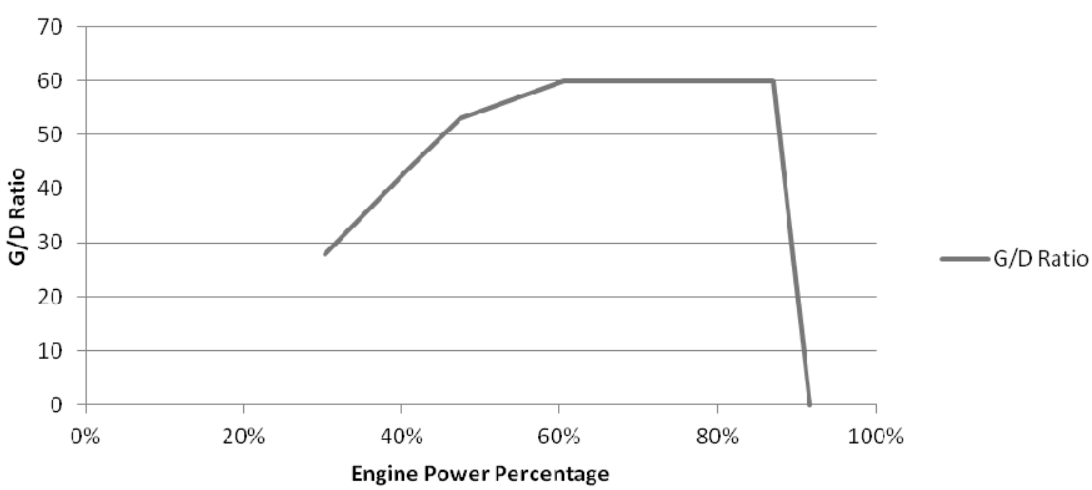


FIGURE 3 – Natural Gas Substitution Curve