The Basics of Natural Gas Power & Fuel

First in a series of white papers concerning the use of natural gas to power drilling and hydraulic fracturing operations.
Future topics include: Dual Fuel and Bi-fuel, Turbine Power, Natural Gas Fueling, LNG, CNG, Field/Wellhead Gas, Cost, Electrification

As the reality of America's natural gas age comes into view, it seems fitting that more of the equipment used to free that gas will also be powered by it. As a cleaner fuel, natural gas offers the promise of ***reducing emissions, site footprint and cost.***

Operators and service companies are seeking answers even as the questions change. Purveyors of equipment are innovating to improve and adapt their technologies. The solutions for the near term may not be the best fit with the ultimate vision of all-gas power for drilling and hydraulic fracturing. Understanding the state of development for these technologies can assist in making informed decisions about investment in the near and longer term.

Together with our partners in industry and academia, the Environmentally Friendly Drilling Systems Program (EFD) is exploring the important issues around natural gas fuel. Technologies that will advance dual-fuel diesels, improve dedicated gas engines, and deliver turbine-electric power are being configured and deployed in new ways to make natural gas the fuel of choice for exploration and production.

Lower Cost, Fewer Emissions

Among the most attractive benefits in the use of natural gas fuel is reduction in combustion emissions as compared with conventional diesel. Of particular interest is the potential reduction in Oxides of Nitrogen (NOx) and Particulate Matter (PM) that have been a concern with diesel engine emissions. Expanded use of natural gas fuel for high-horsepower off-road engines directly supplants diesel. As such, natural gas fuel requirements are often calculated in Diesel Gallon Equivalent (DGE). This equivalency basis also serves as a means of calculating the relative cost of natural gas fuel as compared with diesel. Natural gas can deliver an equivalent amount of combustion energy at a fraction of the cost of diesel fuel.

Approximate energy relationships between liquid diesel fuel and natural gas:
1 DGE = 132 scf
1 DGE = 1.7 Gallons LNG
1 MMBTU = 6.8 DGEs

Fueling Options

Natural gas fuel can be obtained in the form of Liquefied Natural Gas (LNG), Compressed Natural Gas (CNG), or may be delivered from a nearby location where it is produced or processed. Where available, pipeline gas may be a desirable option. Transportation distances become a key factor in deciding which form of fuel is suitable for a particular situation and site. The most practical solution for fueling will be a function of proximity and availability of supply.

LNG is typically about 90 percent methane gas that has been liquefied by cryogenic cooling to -260 degrees Fahrenheit. LNG is transported and stored at relatively low, near-atmospheric pressures. LNG is delivered and stored on site as a liquid which is then vaporized with special equipment. When longer transport distances are involved, LNG is often a preferred fueling option that offers a high quality fuel delivered to the site in an energy-dense liquid form. At present, LNG availability is often limited.

CNG is stored and transported at relatively high pressures, on the order of 3,000 psi, in cylindrical or round containers specifically designed and constructed to safely contain these higher pressures. CNG has become increasingly used in fleet and passenger vehicles, spurring development of fueling stations and related infrastructure accessible to the public. For oilfield operations, CNG is best suited for situations where transport distances are relatively short.

Recognizing the limitations of centralized facilities and infrastructure to produce and deliver LNG and CNG, more small scale and modular processing technologies are becoming available. These types of systems are being used in energy production, transportation and mining.

Sometimes referred to as "Field Gas" or "Wellhead Gas", locally sourced produced gas is a highly desirable option. The great appeal in utilizing field gas is in reduced need for processing energy and transportation, thereby reducing cost and environmental impact.

Field gas composition and quality can vary greatly from one location to another, and must be conditioned for use as fuel. Natural Gas Liquids (NGLs) present in raw gas must be removed, along with other troublesome impurities such as Hydrogen Sulfide (H_2S). Innovative technologies and practices adapted to effectively treat and convey field gas for use as fuel are rapidly evolving. Advances in utilizing field gas will also support monetization of stranded gas and development of beneficial alternatives to flaring.

All fueling options, including conventional diesel, have accompanying health, safety and environmental considerations. Planning should include a review of applicable federal, state and local regulations. In some situations local authorities may not be familiar with material-specific handling and safety concerns such as firefighting, so engagement with local first responders is advisable so that all are properly prepared.

Power Technologies

There are three principal categories of engine/power technology considered:

- Diesel Displacement (Dual Fuel and Bi-fuel)
- Spark-Ignited Dedicated
- Turbine

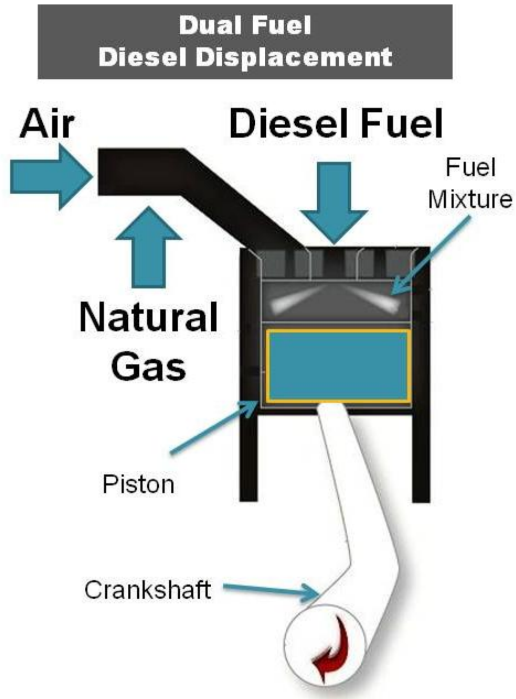
Each of these power technologies offer advantages specific to the application. Diesel displacement by means of introducing natural gas fuel into the diesel combustion process is well-developed and flexible, finding broad and growing adoption.

Turbine technology is highly versatile and well-suited to many energy development power needs. Turbines can be configured to accommodate a number of combustible fuels, and are increasingly being deployed in various ways.

Spark-ignited (SI), dedicated gas engines running exclusively on natural gas fuel have a strong history of reliability in high-horsepower service. The burgeoning gas-powered equipment market is driving advances in SI engines for power generation and other applications.

Diesel displacement by introducing natural gas as a concurrently combusted fuel source is known as "dual fuel" or "bi-fuel" technology. Though both of these terms are used to describe this approach, there are subtleties of nomenclature to be understood in a more in-depth examination. In general, both terms are broadly used to designate the use of natural gas with diesel combustion.

Dual fuel diesel displacement can be implemented with a number of available equipment options. In these systems, natural gas fuel in vapor phase is introduced into the air intake system of the engine. The two fuels are blended together and are ignited by compression in the engine cylinder.



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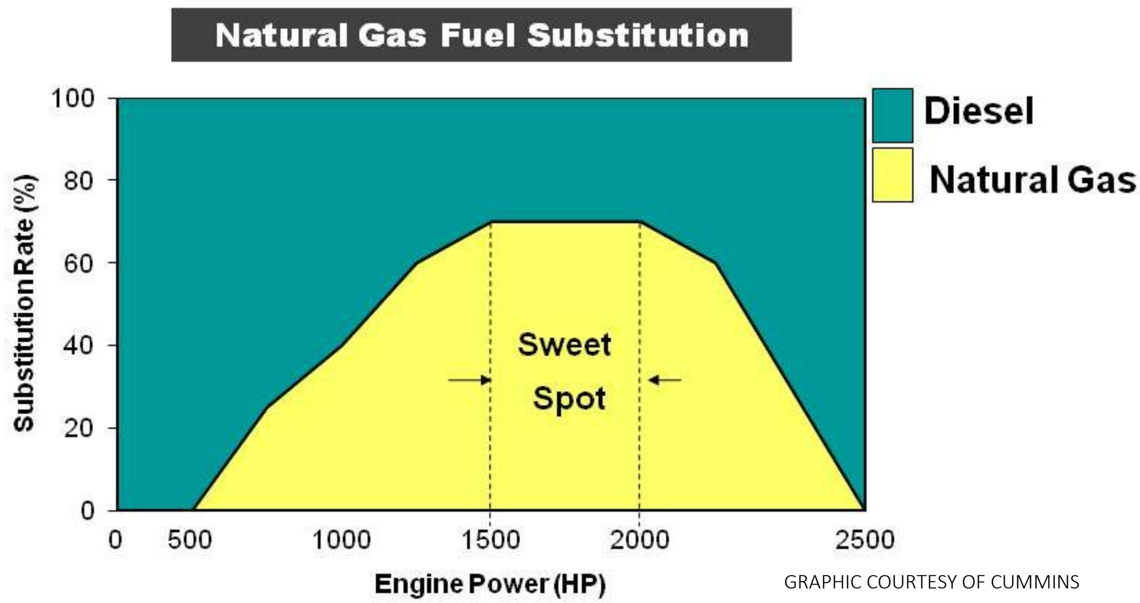
Systems of this type are available as aftermarket retrofit kits for existing diesel engines or as part of an Original Equipment Manufacturer (OEM) package. There are important Environmental Protection Agency (EPA) regulations concerning the certification of diesel engines to meet emissions standards. These regulations and standards also apply to the systems designed to integrate natural gas fuel, either as part of an OEM package or an aftermarket kit.

Natural gas fuel can be substituted for diesel fuel in varying proportions according to operating conditions. Dual fuel substitution rate is optimized with a system of sensors and control logic integral to the engine equipment package. Though many factors affect actual diesel substitution rates that can be attained, rates of 50 to 70 percent gas on an energy basis have been reported. The graphic below illustrates possible substitution rates of natural gas for a typical hydraulic fracturing horsepower operating range. Importantly, there is an optimal range of operating load at which gas substitution is maximized, known as the "sweet spot".



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High Pressure Direct Injection (HPDI) is a means of introducing natural gas fuel directly into the combustion chamber at high pressure. Some amount of pilot fuel such as diesel is still needed for compression ignition. HPDI technology enables the use of higher proportions of gas, improving efficiency and further reducing emissions.

SI dedicated gas reciprocating engines use 100 percent natural gas fuel without the necessity of a pilot fuel such as diesel. Use of all gas fuel affords maximum fuel savings and emissions reduction opportunity while minimizing the need for storage and transport of diesel fuel.

SI engines have an impressive history of service with continuous steady load or stationary installations. However, SI engines tend to be significantly larger and heavier as compared with equivalent horsepower diesel engines. And, because methane fuel has a slower flame speed in the combustion chamber these engines have often not been well-suited for high transient load demand. To compensate for these shortcomings, gas fuel is sometimes enriched with hydrogen to improve combustion characteristics. Improvements in energy storage technologies that can be utilized in conjunction with SI power generation have also expanded applications in drilling. Growing demand for technologies that are powered with natural gas fuel is driving advances in SI engine development.

Electrification

Drilling and hydraulic fracturing with electric power generated using natural gas fuel offers tremendous opportunity for maximum gas utilization and environmental benefit. The trend of increased electrification in drilling is well established, drawing innovation to adapt power and mechanical systems to meet operating demands. While diesel and dual fuel engines are well-suited to the demanding power, torque and transient load response needed for hydraulic fracturing, electrically-powered hydraulic fracturing is a logical and attainable goal.

Electrification is a highly efficient mode of powering exploration and production that can and will be increasingly exploited. Limitations of the existing power grid and mobile generation technology present daunting challenges in many locations. The increasing availability of natural gas supports expansion of distributed power generation, mobile and modular power, and innovative strategies for power distribution. These trends in turn support increased electrification of energy development equipment and operations.

As compared with truck-mounted reciprocating engines that now drive hydraulic fracturing pumps, electric motors have a significantly smaller physical footprint. Considering the efficiencies and advances that will bring electric power to the drilling site, overall environmental impacts will be accordingly reduced. Reduced need for fueling discrete equipment at the site reduces all aspects of environmental risk associated with transport, storage and handling of fuel.

Prototype Electric Hydraulic Fracturing Equipment

PHOTOS COURTESY OF EVOLUTION WELL SERVICES

Automation that is increasingly important for control functions, data gathering and risk mitigation can be readily integrated with electric equipment. The collection and analysis of data from automation is an important tool in understanding how operations can be made safer and more efficient. Trends to greater electrification and automation are aligned for synergy to facilitate advances in many aspects of exploration and production.

Looking Ahead

A greater abundance of natural gas is boosting development of technologies that utilize this resource as fuel. The enormous economic attraction to provide these technologies, equipment and services is driving innovation and commercialization. Reducing emissions, site footprint and overall environmental impact are key elements in these endeavors.

"POWERED BY NATURAL GAS" is an ongoing research initiative of the Environmentally Friendly Drilling Systems Program.

"Utilizing Natural Gas as a Primary Fuel Source for the Equipment Used in Drilling and Hydraulic Fracturing"

Look for additional materials and resources coming to www.efdsystems.org

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