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Irrigation Pumping Plant Efficiency Testing

Diesel and Natural Gas Dual Fuel

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The direct-injection and compression combustion traits of the diesel process have consistently offered superior thermal efficiency compared to spark-ignition systems (Otto cycle). In addition to high efficiency, diesel fuel carries more energy value per gallon than other available liquid fuels and historically has sold at a discounted price, basically as a byproduct. These compounded benefits have led to the broad application of the diesel engine across many solid-set industrial applications – especially at irrigation pumping plants.

In recent years, personal and private demand for diesel fuel has increased and diesel fuel prices have steadily risen to that of a premium fuel. This evolution has had a dramatic effect on irrigation pumping costs, to the point where many farms cannot economically continue to pump irrigation water using diesel fuel. One technique that has proven very effective in reducing pumping costs at diesel pumping plants is injecting natural gas into the intake air stream, or dual fueling.

What is Dual Fuel?

Dual fueling is a process that injects a secondary, gaseous fuel into the air charge of an internal combustion engine to optimize engine performance. Think of it like nitrous oxide injection in a gasoline engine for racing or the more recent trend of adding propane or methane in diesel trucks. In the case of nitrous oxide, oxygen concentration is increased in the air fuel mixture, allowing for the injection of more fuel and thus more power. In the cases of energy fuels, more combustible material actually is forced into the combustion chamber and if sufficient oxygen can be supplied (usually through the use of a turbocharger), more power can be made. In a similar fashion, this process can be optimized for a reduction in consumed diesel fuel, basically replacing a portion of the energy needed from the primary fuel to accomplish the same amount of work.

Air cooled Deutz engine on dual fuel. This picture was taken during an evaluation using a torque cell, natural gas meter and diesel flow meter to ideally set fueling mixtures.

Table of common pumping plant fuels listed from lowest to highest with regard to cost per acre-inch of pumped water. Pumping parameters are 700 GPM, 400' lift, 20 psi, and 65 percent pump and well efficiency, requiring a 128 horsepower engine load. 50/50 dual fuel.

	BTU / Unit	Cost / Unit	Engine Efficiency	Fuel HP	Cost / Acre-In.
Natural Gas (MCF)	1,000,000	$ 4.50	23%	555	$ 4.11
Electricity (KWh)	3,413	$ 0.10	90%	135	$ 6.50
Dual Fuel (Diesel and NG)			29%	460	$ 9.24
Diesel (gal)	139,000	$ 3.50	35%	347	$ 14.36
Gasoline (gal)	124,000	$ 3.45	23%	555	$ 25.42
Propane (gal)	91,600	$ 2.80	23%	555	$ 27.93

Why Dual Fuel?

Diesel fuel currently is considered the third best option for powering an irrigation pumping plant, preceded by electricity and natural gas on a cost and operational basis. Diesel is the preferred liquid fuel in locations where continuously delivered electricity or natural gas is not available. Although it may be a more beneficial decision to convert completely to natural gas or electricity, locations with existing diesel engines, a nearby natural gas pipeline and a large horsepower requirement will see great economic benefits by fitting a diesel engine to be supplemented with natural gas fuel.

How to Dual Fuel?

The first step in an operational dual fuel system is the connection of the natural gas fuel supply to the diesel engine's intake tract. The simplest method is to directly plumb pressure regulated natural gas into a port between the turbocharger and intake manifold. A control valve (ideally a needle valve) is installed in this line to control the natural gas volume. More complex systems (recommended) include automatic shut-off solenoids and a dedicated fuel regulator to allow for more precise fuel control and natural gas shut-off in the case of unanticipated engine shutdown.

To operate the process, the diesel engine is started on 100 percent diesel and throttled up to operating speed under load. Then it's throttled back to a predetermined engine speed less than the desired operating speed. The natural gas is then injected into the air intake to bring the engine up to the desired operating speed. Determining the operating points typically requires trial and error since pumping conditions generally are unique to each location. To shut the engine down, the natural gas is turned off and then the engine is throttled down and turned off like a normal diesel engine. Many operators have found it is very helpful to use a control valve that can be locked into one position as a flow orifice to regulate the actual natural gas injection flow. A second valve is installed upstream of the control valve to turn the natural gas flow on or off as needed.

It is not recommended to exceed 50 percent natural gas mixture (based on Btu content), although field experience has shown many engines can operate safely with a 60 percent natural gas charge. If excess natural gas is injected, damage may occur to the engine, most notably witnessed by audible knock, blow-by and decreased compression. Further, engines that have been tested while operating on more than 60 percent natural gas typically show a dramatic reduction in thermal efficiency. The

At this dual fuel pumping plant, natural gas is injected along the intake line just prior to the turbocharger and regulated by a gate valve. (Notice the yellow valve handle in the middle of the photo marked with a white circle.)

simplest method for setting the natural gas injection is to incrementally increase the natural gas injection volume until an audible change in engine sound occurs and then to slightly reduce the amount of natural gas injected. The safest method is to meter both the diesel fuel and natural gas consumption to determine what throttle and natural gas valve settings correspond to certain operating conditions.

Other Information

Not all engines are good candidates for dual fuel applications. Repurposed diesel generator motors have proven difficult to dual fuel because of the mechanical governor design and operation. Although natural gas can be injected in these applications, the diesel fuel flow is very difficult to reduce. Older engines with reduced compression and existing blow-by also have shown to be poor candidates for dual fuel applications due to the increased stress from the additional combustion charge. Computer-controlled engines typically perform very well in a dual fuel setting and occasionally are fitted with a diesel flow meter that can be very helpful in setting fuel ratios.

It is not recommended to use natural gas injection to increase engine power in a solid-set situation. Engine ratings are given for continuous operating conditions and premature wear and/or engine failure are likely to ensue if the injection of natural gas allows the engine to be loaded beyond its rating. It also is very important to operate the engine in a manner that keeps engine and exhaust gas temperature low while dual fueling, since a large amount of raw natural gas is being expelled with the engine's exhaust (the natural gas fuel injected in the intake also is scavenging during the exhaust stroke). Exhaust combustion is much more likely to be catastrophic with dual fuel.

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