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TM2500+ POWER FOR HYDRAULIC FRACTURING

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Abstract

The TM2500+ trailer mounted gas turbine has proven to be a successful application to meet the power needs of the unconventional natural gas industry. The TM2500+ is a trailer mounted GE Aeroderivative LM2500+ gas turbine ready to be driven to the gas site. Evolution Well Services has applied the TM2500+ to power electric pump motors to create the high pressure necessary for hydraulic fracturing. The current practice of 30 or more diesel engines at the site each providing one megawatt of power leads to many operational difficulties. Evolution Well Services will report how the TM2500+ allows a smaller footprint, less noise, higher reliability, less manpower, and easier control of the power supplied. The first application of the TM2500+ for hydraulic fracturing occurred in Alberta, Canada in 2012. The successful results of this new application of trailer mounted gas turbines will be presented by Eldon D. Schelske, President, Evolution Well Services, and Tom Hausfeld, of GE Power & Water.

1.0 Introduction

The power demands of a hydraulic fracturing site require 16+ truck mounted, diesel powered, well pumps. This creates a great deal of traffic of large engine and diesel fuel trucks on rural, mostly dirt roads. Each of these trucks require their own operator, diesel fuel supply, and hydraulic lines. This increases the well site footprint. Diesel generators are also required for electrical power generation at remote sites. The logistics of such arrangements can be quite complex. Food, sanitation facilities, and overnight accommodations must be provided for a large crew in a rural area. Control and communication issues arise with such a large group. Safety issues are a

concern, such as “hot fueling”, refilling the pump truck diesel fuel tanks while operating.

There are also cost considerations. Diesel is currently priced at ~CA$1.10/liter, even in bulk rates. Due to the success of the unconventional gas industry, the price of natural gas, including compressed natural gas (CNG), and liquid natural gas (LNG), has fallen dramatically. As of September, 2013 the price of CNG was 23% lower than the price of diesel, on a Diesel Liter Equivalent (DLE) energy basis.

Diesel CA$1.10/liter compared to CNG CA$0.85 DLE on an equivalent energy basis.

Hydraulic Fracturing companies are converting to dual fuel operation, burning diesel and natural gas simultaneously to take advantage of this savings. Only a maximum 60% substitution rate of natural gas to diesel can be burned in the current diesel engines, however, and this is only if the natural gas is pipeline quality and energy content. If the gas has lower energy content per volume, that percentage is reduced to 40-50%. Field gas (the gas coming out of the well in the field) typically has lower energy content, reducing the amount of this fuel that can be burned in the diesel engines. The cost of this field gas is only the opportunity cost at which it can be processed and sold. Spark ignition 100% gas engines are considered too heavy to be transported on road legal trucks. Natural gas distribution and manifold systems to the hydraulic fracturing trucks must be installed, creating another well site complication.

Figure 1: A typical current technology hydraulic fracturing site

Evolution Well Service (EWS) developed innovative methods to offer high pressure, high rate, hydraulic fracturing, and stimulation treatments in any well environment. EWS’s new technology fracturing spreads are designed to address this problem. These frac spreads reduce the number of pumps required, minimizing well site footprint and reducing environmental impact to decrease the cost for this complex operational service. Evolution Well Services is also the first hydraulic fracturing

provider to use the GE Distributed Power TM2500+ Mobile Gas Turbine Generator to power the frac spread equipment. It provides quiet, reliable electrical power with lower emissions, and is easily transportable from site to site.

2.0 Hydraulic Fracturing

Hydraulic Fracturing is the fracturing of rock by a pressurized liquid. The technique has been used in the oil and gas industry since 1947 to release natural gas and liquid hydrocarbons from tight rock formations (1). Recently, the technology has been teamed with horizontal drilling capability to reach hydrocarbons in thin shale deposits deep under the earth. A well is drilled down to the shale depth, followed by the shaft being turned horizontal into the shale bed. Many layers of steel tubing and cement casings are used at shallow depths to protect groundwater from interaction with the hydraulic fracturing process. Hydraulic fluid made of water, lubricating polymers, anti-foaming surfactants, and proppants are then pumped into the well. A proppant is a solid material, typically treated sand or man-made ceramic materials, designed to keep an induced hydraulic fracture open, during or following a fracturing treatment. The high pressure hydraulic fluid fractures the shale, and the proppant keeps the tiny shale rock fissures from closing when the hydraulic pressure is released. Natural gas and other hydrocarbons are then released, and flow to the wellhead for consumer use.

3.0 Demonstrated Use

Figure 2: The demonstration frac spread located near Lethbridge, Alberta

Components of the frac spread include:

- **A)** Frac Pump Modules
- **B)** Blender

C) Mobile Data Van

D) Chemical Addition Module

E) Blender Motor Control

F) Sand Conveyer Belt Module

G) Sand Storage Module

H) TM2500+ Gas Turbine Generator

I) Pump Motor Control

Evolution Well Services demonstrated their new hybrid powered fracturing technology for the first time on February 5, 2013 in Lethbridge, Alberta. This new technology allows for the use of electrical power to deliver fracturing fluids to the wellbore during fracturing operations. This eliminates the use of conventional diesel engines, transmissions along with their associated emissions, eco-footprint, maintenance issues and manpower.

3.1 Frac Pump Modules

Evolution Well Services' Quintuplex Pumping Module is a designed "fit for purpose equipment" powered by ac motors. The advantages of electrically driven equipment are operational and control efficiencies from a central location. Evolution's Quintuplex Pumping Module combines four motors and pumps into a single pump package.

3.1.1 Equipment

- Quintuplex 2500 Well Service Pump
- Permanent magnet 2500HP motor
- Remote control of rates and pressures
- Electronic over-pressure control
- Discharge iron 4" API 5b Figure 1502 design

3.1.2 Performance

- Maximum Rate: 908GPM - 3438 LPM (4.5" plungers)
- Maximum Pressure: 10,000 PSI - 68,947 Kpa

3.2 Blender

Evolution's "Twin 120 bpm per side" Blender Module combines the hydraulic fluid made of water, lubricating polymers, anti-foaming surfactants, and proppants that are then pumped into the well

3.2.1 Equipment

- Radioactive Density Gauges (Thermal Fisher)
- Turbine and magnetic flow meters for clean and slurry flow rates

- Remote control and monitoring of the additive rates/concentrations and proppant proportioning
- Integrated control with Data Van and Chemical Van
- Climate controlled operator cab

3.2.2 Performance

- Proppant concentration to 2,000kg/m3 (17ppg)
- Up to 19 m3/min (up to 120 bpm) fluid rate
- 9,000 kg/min (20,000 lbs/min) proppant rate through 4 x 305 mm (12") augers

3.3 Mobile Data Van

The computerized digital data van provides monitoring at multiple rates and pressures with the capability for remote control of pumping equipment and blenders, increasing control of the fracturing treatment while enhancing overall safety.

3.3.1 Equipment

- Instrumentation and Control Systems
- Computerized data van
- PLC based control system

3.3.2 Performance

- Operational process monitoring
- Auto rate and pressure control capability
- Electronic overpressure protection
- Emergency shutdown safety feature
- Ability to operate remotely or from control panel
- Multi-unit control by single operator

3.4 Chemical Addition Module

The chemical addition module stores the lubricating polymers and the anti-foaming surfactants, and pumps them to the blender.

3.4.1 Equipment

- Fully enclosed, heated storage module
- 8 pumps for liquid additives
- 8 chemical mass flow meters

3.4.2 Performance

- Capable of carrying up to 6 totes of liquid chemicals
- Full transfer capability of all chemicals
- Automated control of up to 14 chemicals
- 6 backup liquid add pumps and flow meters are located on the blender

3.5 Sand Conveyor Belt Module

The sand conveyor belt module transports the sand used as proppant to the blender.

3.5.1 Equipment

- Used on large sand jobs with multiple sand bins and blenders

3.6 Sand Storage Module

The sand storage module stores the sand proppant until the sand conveyor belt module dispenses it to the blender.

3.6.1 Equipment

- 88 MT dual compartment sand storage bins

3.7 TM2500+ Mobile Power Generator

The TM2500+ provides distributed electrical power that combines high efficiency and fuel flexibility, coupled with lower emissions in both the 50- and 60-hertz segments. GE offers a faster, more reliable solution for mobile power generation.

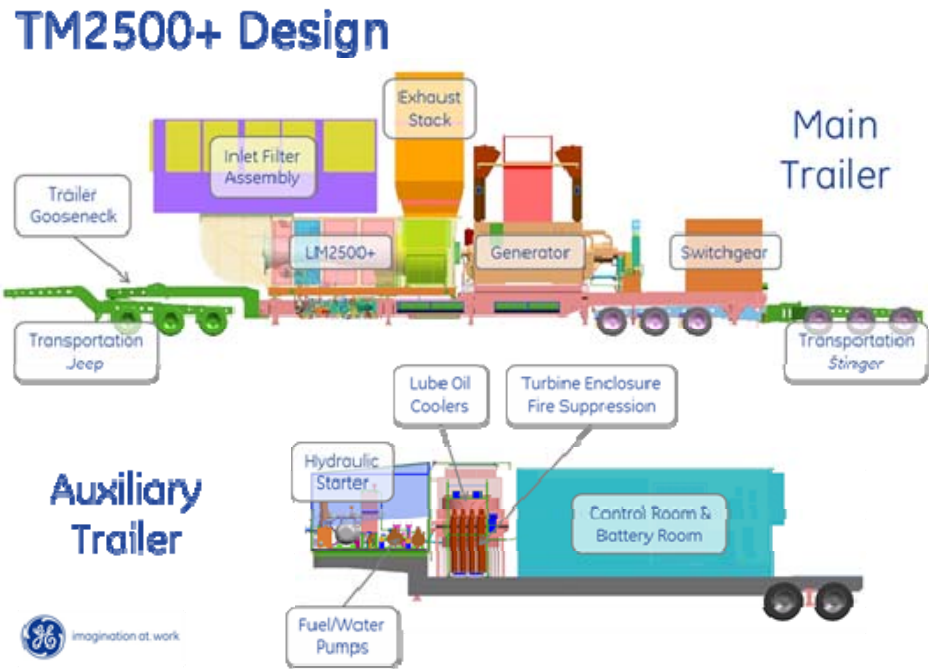

Figure 3: The TM2500+ Design consists of two trailers: One for the LM2500+ gas turbine, electrical generator, and switchgear, The second for the control room, hydraulic starter, and fuel/water pumps.

3.7.1 Equipment

The TM2500+ incorporates the lightweight LM2500+ aeroderivative gas turbine

packaged on a two-trailer system with a top-mounted air inlet filter and exhaust assemblies. Both the inlet filter assembly and the exhaust duct are mounted directly on top of the main trailer assembly, allowing for easier transport by ship, air, or road. The TM2500+ design has been modified for the unconventional gas industry. It offers an increased number of quick-disconnect fittings to simplify and accelerate the installation process, which can enable one day assembly and set-up.

GE's two-trailer design was enhanced to include the LM2500+ engine—allowing for higher megawatt output and efficiency performance. The LM2500+ offers multi-fuel flexibility on either natural gas or liquid distillate fuels and is easily converted from 50 Hz to 60 Hz. It can reach full power in less than 10 minutes and is capable of achieving nitrous oxide (NOx) emissions down to 25 ppm with water injection.

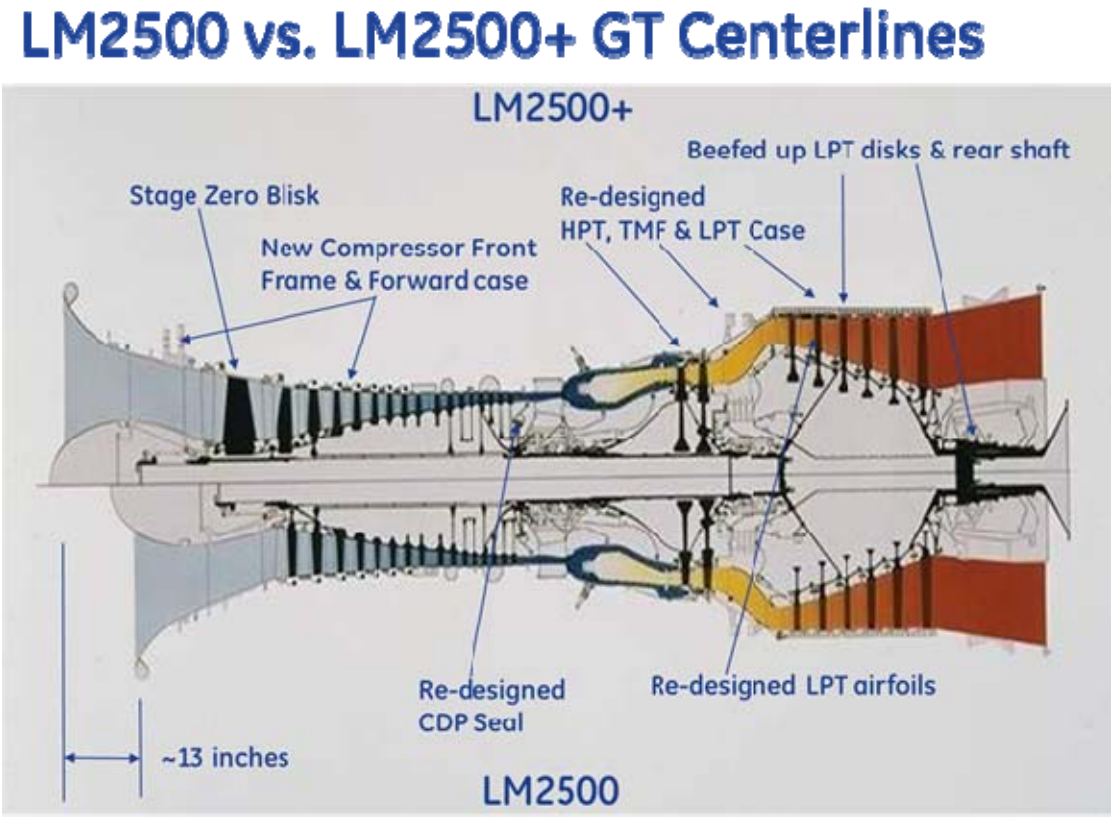

Figure 4: The LM2500+ adds a "zero stage" blisk to the LM2500 gas turbine to provide higher airflow, pressure ratio, and power output.

The LM2500+ is the growth version of the LM2500 gas turbine that was derived from the TF39/CF6-6 aircraft engine that powers the US Air Force C-5A transport and the DC-10 wide body aircraft. The LM2500 was introduced in 1969, and the LM2500 family has logged over 67 million hours in over 1400 industrial installations.

The LM2500+ provides 31% more power by adding a "zero stage" blisk to the front of the High Pressure Compressor (HPC), for a total of 17 HPC stages providing a 22.8 pressure ratio. The blisk is a one piece combination of blades and disk, to simplify

parts count. The 2 stage High Pressure Turbine (HPT) was redesigned to accommodate the higher air flow rate and firing temperature. The HPC and HPT rotate at over 10,000 rpm when at full power.

The Single Annular Combustor (SAC) can burn either liquid distillate fuel, or natural gas, including field gas at the well site. It can change fuel sources at any power level. Water injection reduces Nox levels down to 25 ppm for natural gas fuel. Together, the HPC, SAC combustor, and HPT form the Gas Generator that supplies high temperature, high pressure gas to the six stage Power Turbine (PT). There is no mechanical connection between the Gas Generator and the Power Turbine, but the airflow passing from the GG to the PT is referred to as an "aerodynamic coupling". The Power Turbine rotates at 3000 rpm for 50 hz operation, and 3600 rpm for 60 hz operation, allowing for flexible operation with no change in hardware. No gearbox is required between the PT and the electrical generator, further reducing weight, space, and improving reliability.

- Natural gas (CNG or LNG), field gas, or liquid distillate fuels
- 50Hz or 60 Hz operation
- Brush 170ER air cooled electric generator suitable for Class 1, Group , Div 2 areas
- Switchgear included
- Hydraulic starter, lube oil coolers, fuel & water pumps, on second Control Room Trailer

3.7.2 Performance

- 99% Reliability
- Small power plant footprint 24m x 7m (78ft x 21ft)
- 31 MW @ 60 Hz (ISO), 37 percent efficiency
- 25 ppm Nox with water injection
- Full power in < 10 minutes
- Natural Gas or Liquid distillate fuel capability
- 87 dBA average noise level

4.0 Comparison

A comparison of the conventional diesel fueled reciprocating engine system and the EWS gas turbine system demonstrates the overall benefits of the EWS system.

Table 1: System Comparison

	Diesel Truck Pumps	EWS Gas Turbine System
Prime Movers (15 MW)	16 Diesel Trucks	1 TM2500+
Pump Units	16	8
Fuel	Diesel	Diesel/NG/CNG/LNG

Power Efficiency	38.9%	36.8% (incl -1% elec mtr)
Noise (max pwr)	105 dB*	87 dB*
Nox Emissions (Kg/hr)	52.5 Diesel **	70.4 #2 Diesel (dry) 43.3 NG (dry) 13.0 #2 Diesel*** 7.6 NG***
Personnel	1 Controller 16 Pump Operators	2 Controllers 1 Gas Turbine Op'r
Power/Pump Footprint	778 sq m (8,375 sq ft)	464 sq m (5000 sq ft)
People Infrastructure	5x	1x

* Engine surface noise with attenuated intake noise (filter) - BL (free-field sound pressure level Lp, 1m distance, ISO 6798)
** Tier 4 limits attained, with SCR exhaust treatment
*** 42 ppm Nox #2 Diesel, 25 ppm Nox Natural Gas, both with water injection

While the Diesel Truck Pumps have higher efficiency, partially due to the losses of the electrical generator and the electric pump motors for the gas turbine generator application, all other categories list gas turbine benefits. Significant economic benefits arise from the use of field gas, reduced manpower, and smaller footprint.

4.0 Forecast

The unconventional gas industry is growing quickly and is expected to invest more than CA$40-$60 billion annually over the next six years in North America alone. By 2035, unconventional gas production is expected to account for 35 percent of the world's increased supply of energy.
The Evolutionary Well Services system of hydraulic fracturing using the TM2500+ aeroderivative gas turbine will provide a simpler, safer, more compact, and better economic solution to the needs of the unconventional gas industry.

5.0 References

1.) Montgomery, Carl T.; Smith, Michael B. (2010-12-105). "Hydraulic fracturing. History of an enduring technology" (PDF). JPT Online (Society of Petroleum Engineers): 26–41.

Figure 1. Michigan Department of Environmental Quality