

**Introduction to Bi-Fuel Technology
for
Diesel Engine Applications**

Presented at

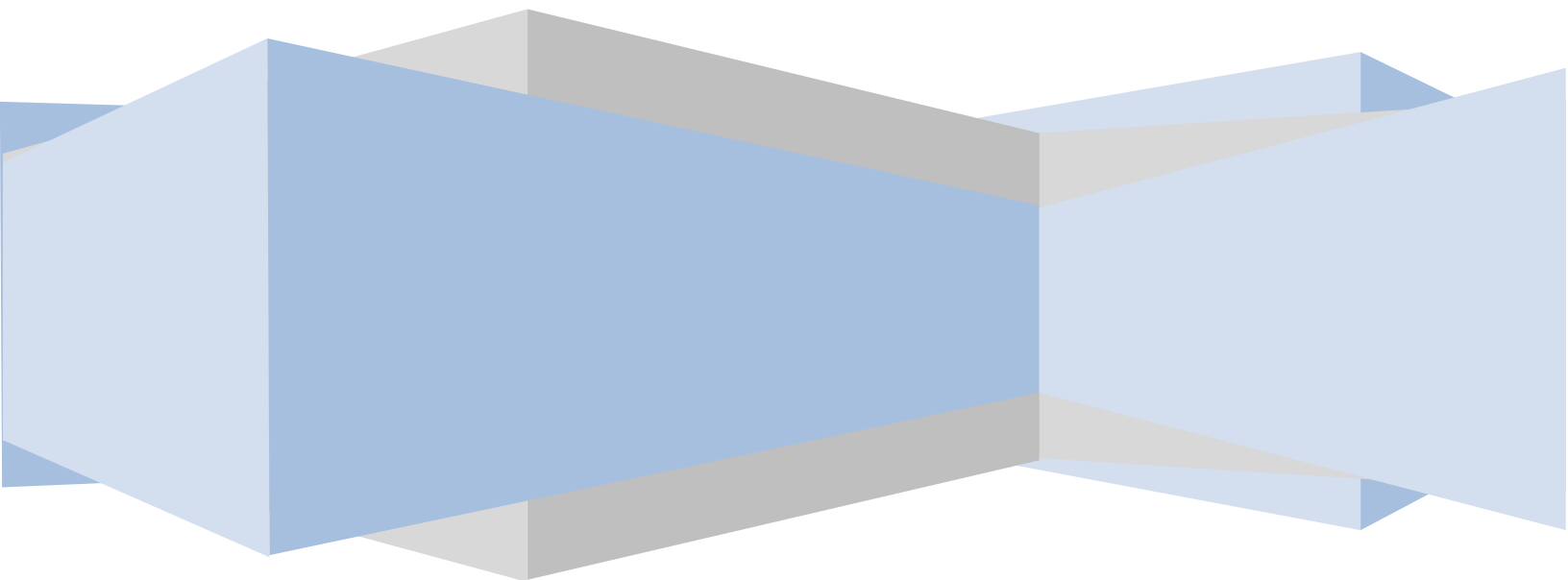
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Summary

Bi-Fuel is a 'co-firing' of two fuels, diesel and natural gas, where both fuels contribute a significant amount of energy produced by the combustion process.

The traditional diesel 'dual fuel' is where only one fuel, natural gas, is used to produce power once the dual fuel mode is activated. A very small amount (4 to 6 %) of diesel is retained only as an ignition source.

The Bi-Fuel technology employs the fumigation method to introduce natural gas into the engine via an air/gas mixer installed in the engine air intake piping.

With well over 1700 Mw and 1000 units installed, Bi-Fuel is proven to be a very good alternative fuel supplemental technology in light of today's high fuel cost.

Application of the Bi-Fuel Technology

Bi-Fuel Technology is applicable to most medium and high speed diesel engines. Following is a list of some applications:

- Prime Power Generation
- Peak Load Shaving
- Standby Power Generation
- Distributed Power Generation
- Water Pumping Processes
- Oil Pumping
- Gas Compression

Characteristics of a well-designed Bi-Fuel System

The following are critical requirements of a well-designed system:

- Maintain diesel-like performance and output rating
- Maintain compression ignition
- Low intake air flow restriction
- Data communication for record keeping and trending
- Requires low supply fuel gas pressure
- Includes significant engine safety protections
- Automatic switching between operating fuel modes
- Non-intrusive to existing engine OEM systems
- Simple to install
- Simple to operate
- Safe and reliable

Fuel Gas Compatibility

Although there are other types of gases being tested for performance and compatibility, the following gases are most compatible with the Bi-Fuel technology:

- Pipeline Natural Gas
- Compressed Natural Gas (CNG)
- Liquefied Natural Gas (LNG)
- Well-head Gas*
- Coal-bed Gas*
- Bio-gas (Landfill, Waste Water)*

*To meet the engine fuel quality requirement this type of gas requires proper pre-treatments. Treatments may include filtration and liquid removal and or impurity removal.

Bi-Fuel System Components

A typical Bi-Fuel system should include the following high standard and high quality components (see figure 1):

- Gas Train with Filter, Regulator and Control Valve
- Air/Gas Mixer
- Power/Gas Flow Adjusting Valve
- Electronic controller and Monitor of the following parameters:
 - Engine Air Intake Pressure
 - Engine Air Intake Temperature
 - Engine Vacuum Depression
 - Engine Exhaust Temperature
 - Engine Vibration/Knock
 - Supply Fuel Gas pressure up-stream and down-stream of the gas train
 - Generator Output KW
 - Gas Fuel Valve Position
 - Data Communication

Benefits of Bi-Fuel Technology

Bi-Fuel technology was developed primarily for economic reasons to reduce operating costs by reducing diesel fuel consumption. Some other benefits that have been enjoyed by engine users include:

- Reduced diesel fuel consumption – reduced costs
- Interruptible gas and electricity rates
- Fuel flexibility
- Reduced exhaust emissions
- Reduced environmental liabilities
- Reduced initial cost for power packages
- Rapid pay-back on investment
- Extended run time for emergency power generation

Extended Run Time on Standby Power Generation

The operation (run) time of any emergency standby power generation package is limited to the designed quantity of diesel fuel storage tank.

Without the ability to re-fill this storage tank the package will stop within the designed limitation. Applying the Bi-Fuel technology to reduce the diesel fuel consumption at a gas substitution rate of 70% and the operation (run) time will be extended to three times the normal designed as the following example:

- A 1000 KW emergency power package with a 1500 gallons diesel fuel storage tank.
 - Diesel fuel consumption rate = 54 gallons per hour
 - 100% diesel fuel run time = $1500/54 = 28$ hours
 - Bi-Fuel mode with a 70% gas substitution rate, run time
= $1500 / (54 \times 0.3) = 92.6$ hours

Bi-Fuel Technology compares to a dedicated gas engine

- Lower initial costs
- Fuel flexibility
- Higher efficiency
- Reduced operating and maintaining costs
- Smaller footprint for equal output capacity

Bi-Fuel is a well proven technology

There are over 1000 units and over 1700 MW of Bi-Fuel equipped power generation in successful operation. We can say with confidence that the Bi-Fuel Technology is safe and practical for today's application.

The Bi-Fuel concept is not new. Rudolf Diesel tested this concept in early 1900's using what was known as 'Luminary Gas' in his early designed engine with success.

Today, we can join those pioneers who have embraced the Bi-Fuel technology, and enjoy the benefits it provides throughout the world.

Following is a list of some of the successful users at user and packager levels:

- The Luxor Hotel and Casino
- Fort Myer Hospital
- Publix Super Market
- Motorola
- FG Wilson
- Wagner Power System
- Ring Power System
- Warren Equipment
- Petrobrass

- M & M Aerospace
- Marriott Hotels
- Miami Dade County Community College
- Winnebago County Justice Center
- Union Gas Company
- Yamaha Manufacturing Plant
- Michelin Manufacturing Plant
- Pertamina Oil Company
- Eglin AFB Credit Union
- Mega Mall
- Petronas Oil Company
- Coca Cola
- Powersecure, Inc.
- Gas Service International
- Precision Drilling Company
- Thompson Cat
- Toromont Cat
- Cummins N Power
- Cummins Eastern Canada
- Elliot Power Systems
- Enercon Engineering, Inc.
- Finning Chile, S.A.

Bi-Fuel Economic Calculation Results

The economic calculation results will depend on the price of liquid fuel, the price of alternate (gas) fuel, the service duty of the package and the ability of the specific engine to accept the gaseous fuel.

Factors that will limit the engine tolerance are fuel gas quality, engine types, package packaging practices, service duty and location of the package.

Factors to consider when calculating the cost savings:

- Natural Gas is = 1000 BTU/SCF @ \$ 6.75/MSCF
- Diesel Fuel is = 140,000 BTU/gallon @ \$ 3.05/gallon

therefore

- 140 SCF of Natural Gas is = 1 gallon of Diesel Fuel

Or

- 0.14 MSCF of Natural Gas is = 1 Gas Equivalent Gallon (GEG)

therefore

- Natural Gas GEG is $(6.75 \times 0.14) = \$ 0.95$

Applying the above mentioned facts to a 1000KW Prime Power Generation with a 95% up time (8, 322 hours/year).

- Average diesel fuel consumption is 54 gallons/hour
- Average cost for diesel fuel is \$ 3.05/gallon
- 100% diesel fuel operating cost is $(54 \times 3.05) = \$ 164.70/\text{hour}$

or

- \$ 0.165 /KWH
- Annual operating fuel cost is $(8,322 \times 0.165 \times 1000) = \$ 1,373,130.00$

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When the Bi-Fuel technology is applied to the same operating conditions with a 70% gas substitution rate, we find the following cost savings:

- Diesel fuel consumption is $(54 \times 3) = 16.2$ gallons \times \$ 3.05 = \$ 49.41
- Gas consumption is $(54 \times 7) = 37.8$ GEG \times \$ 0.95 = \$ 35.91
- Total fuel cost is $(49.41 + 35.91) = \$ 85.32 = \$ 0.0853/\text{KWH}$

or

- A cost savings of $(164.70 - 85.32) = \$ 79.38/\text{hour}$
- The total cost savings per year is \$ 660,600.36
- Bi-Fuel system cost \$ 35,000.00
- Installation cost \$ 5,000.00
- The return on investment (ROI) is $(40,000 / 79.38) = 503.9$ hours or 21 days of operation

When applying similar operating cost to a 1000 KW peak load shaving package with 1500 operating hours per year, we can expect the following savings:

- An average On-peak cost of electricity is \$ 0.180/KWH
- The Bi-Fuel operating cost for fuels is \$ 0.085/KWH
- Maintenance cost is \$ 0.044/KWH
- Total Bi-Fuel operating cost is $(.085 + .044) = \$ 0.13/\text{KWH}$
- The total savings is \$ 0.05/KWH or \$ 75,000.00/year (1500 hours)

Conclusion

Considering that there are over 1000 units (over 1700 MW) of Bi-Fuel systems in successful operation. The Bi-Fuel is a viable technology to contribute to the need for today's energy conservation policy. With Natural Gas being one of the nation's strongest energy resources, we can take a significant step in the direction of reducing foreign energy dependency.

Bi-Fuel System Components

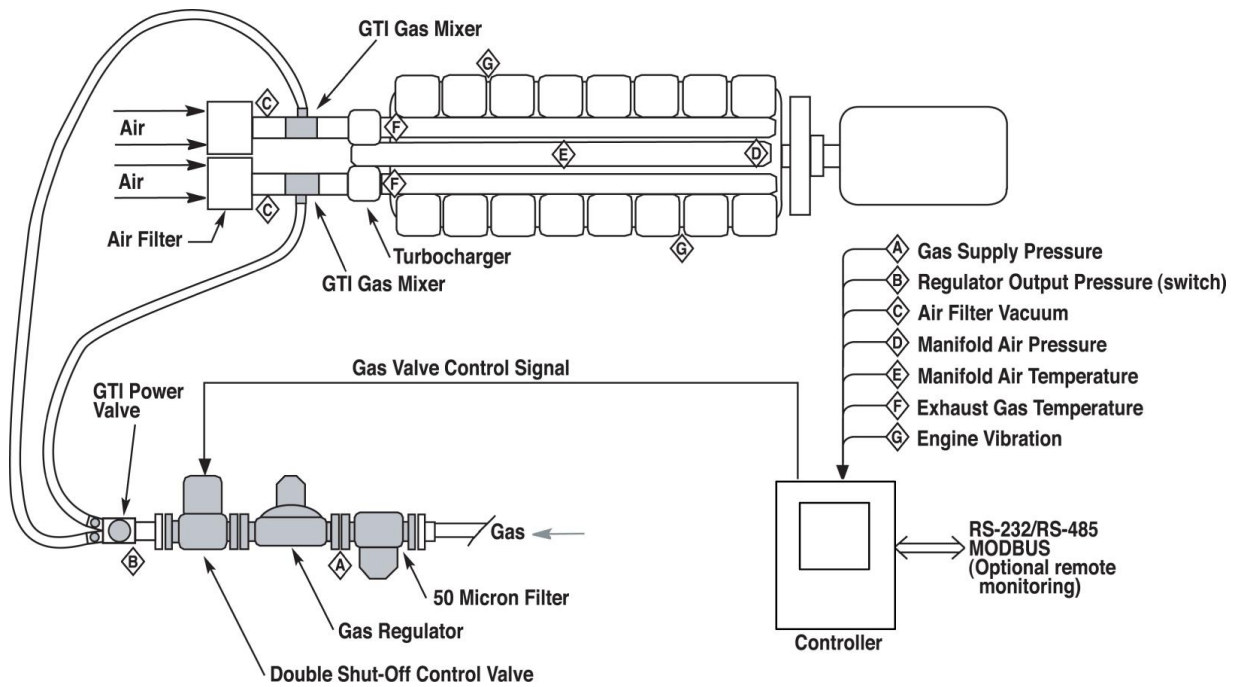


Figure 1