UNDERSTANDING DUAL-FUEL TECHNOLOGY

2Fuel is classified as a Diesel Dual-Fuel (DDF) system. When operating any diesel engine in the DDF mode, with our 2Fuel system, the engine will consume a reduced amount of diesel fuel and a proportional amount of an alternative fuel will be substituted to maintain the engines original torque and horsepower, while blending the fuels, at a much lower operating cost.

There are numerous DDF technologies in the market place today and the following information will aid in comparing 2Fuel with other products. 2Fuel Technologies uses an advanced software based Electronic Control System, precise fuel metering strategies, and the safest method of introducing the alternative fuel.

Understanding the differences between our advanced technology platform and others, will assure your expectations can be met with actual "End of Day Diesel Fuel Displacement Savings".

The Electronic Control System:

The first significant difference between various dual fuel systems is the method in which the fuel system is controlled. All dual fuel systems will utilize some level of electronic controller to manage the alternative fuel delivery system.

There are three levels of Electronic Controllers (ECM) to manage fuel delivery:

2Fuel Technologies	Others
The Third and Highest Level of fuel system control will be connected to the J1939 data link and a **two-way communication is maintained between the alternative fuel controller and the OEM engine controller.** This control method will utilize all J1939 data from the OEM controller to determine the precise amount of fuel to be delivered by the alternative fuel injectors to maintain OEM torque and horsepower specifications. Subsequently when the alternative fuel controller determines the correct amount of alternative fuel to be delivered the controller, the alternative fuel ECM will send a fuel correction command to the OEM engine controller to reduce the diesel fuel injection. **This is referred to as "Pre-Event Control" and assures the engine is never outside of OEM spec while in the DDF mode.** This advanced control logic will insure that there are no over or under fueling conditions anywhere in the	**Entry Level** of fuel system controller, will connect to the OEM engine J1939 data output port to read the basic base engine parameters, such as RPM, Boost Pressure, Engine Coolant Temperature, and other data output. This control system will allow for the introduction of the alternative Fuel if certain engine parameters are met. Once these parameters are met the controller will open the alternative fuel lock offs and allow fuel to flow to a mixer at a predetermined fixed rate until the engine senses an increase in power due to the addition of the alternative fuel and the engine controller (Governor) begins to reduce the diesel fuel flow rate. This method can only substitute a low percentage as each engine controller will have a maximum pull back limit and subsequently if the DDF controller exceeds the engine pull back limit and continues to over fuel engine knocking or damage can occur.

engine operational RPM and load ranges due to fuel overlap. Variations in fuel consistency, fuel supply pressures and loading conditions can be easily modified by varying injector PWM and dwell time which cannot be accomplished with a mixer based system. This superior two way communication allows 2Fuel to continue blending fuels throughout the complete full load, high torque curve and maintain the OEM specified performance while blending, leading to the highest possible "End of Day Dilution" attainable. **A higher percentage of diesel fuel dilution, providing the highest percentage of fuel cost savings.**	**This is referred to as "Post Event Control" and only reacts to reduce the flow of diesel after the engine has been over fueled.** All products using this control strategy must stop blending fuels when the engine is under full load, high torque to assure they do not cause serious harm to the engine. **As a result, these systems can only substitute a low percentage of diesel fuel.** **The Second Level** of fuel system control will use the generator control data parameter to allow for controlling the fuel being delivered to the mixer as describe in the first level. In some systems' they will utilize both the generator control data as well as the J1939 data from the engine. If both are used, more precise metering can be maintained which will allow for more stable engine operation. Again, all products using this control strategy must also stop blending fuels when the engine is under high torque to assure they do not cause serious harm to the engine. **This approach is also limited in the amount of alternative fuel that can be introduced to the engine, resulting in a low percentage of diesel substitution.**

Metering the Alternative Fuels:

All fuel introduced to an engine must utilize a metering strategy:

2Fuel Technologies	Others
Post-turbo system Utilizing an alternative fuel injector is the most effective fuel method to meter and introduce the alternative fuel into the air stream. As diesel fuel energy flow is reduced by the 2Fuel ECU the alternative fuel injectors introduce the alternative fuel on an "energy for energy basis", by accurately measuring an equal amount of alternative fuel to replace the displaced diesel energy. These control features allow for higher fuel substitution rates and stable engine operation (no hunting) in high transient load cycling. In this method, injectors are fitted to a common fuel rail, the fuel is discharged into a "mixer pin" fitted in the air stream just ahead of the inlet to the intake manifold. ***The advantage to this method of fuel metering is a more precise fuel metering, faster fuel delivery response time, and a much safer environment for the engine.*** ***This metering control is an integral part of "Pre-Event Control" and further assures the engine is never subject to any unsafe operating conditions, such as introducing Natural Gas into the turbo inlet.***	**Pre-turbo system** Utilizes a mixer to introduce the alternative fuel. Mixer type fueling utilizes a mechanical device which will react when there is a change in the inlet air stream pressure of the turbo. As the pressure increases or decrease in the intake system, due to changes in engine RPM or load, the mixer valve moves in an upward or downward direction causing a metering valve to open or close to increase or decrease the alternative fuel flow. The **disadvantage with this strategy** is the slow response to fast engine transient cycling, which will cause "hunting" in generator sets which are often exposed to frequent and severe load cycling. In trucks the same issues apply with the slow response, creating under fueling—lack of power, over fueling - possible engine damage or waste of fuel and pre-wear on the engines turbo. **Turbo's are not designed to have any type of fuel delivered through them.** In addition, regardless of the application, the mixer type fueling systems are reliant on the engine control monitoring the engine and reducing the flow of diesel fuel with the governor, and must stop introducing alternative fuel during the high torque load cycles. **These systems cannot reach optimum dilution percentages on any engine subject to frequent high torque demand.**

Introducing the Alternative Fuel:

Introducing fuel into the combustion process can be accomplished in two methods, fuel can be introduced into the combustion chamber directly or it can be introduced by the fumigation method. The cost for a direct injection method is prohibitive and therefore, to maintain an affordable system cost, the fuel is introduced into the diesel air induction system, the common term is known as "fumigation".

There are several methods of introducing the alternative fuel by the fumigation method:

2Fuel Technologies	Others
Post-turbo system (after the turbo Charger) An alternative fuel is introduced into the air stream after the turbo and before the intake manifold inlet. **The advantage to this method is, the volatile air fuel mixture is introduced into the air system downstream from the turbo and supports a more precise control of the fuel metering, while assuring there is never any combustion, in the turbo, due to alternative fuel having contact with the turbo fan blades.**	**Pre-turbo system** (before the turbo charger) An alternative fuel is introduced into the intake air stream between the air intake components and the inlet to the turbo. **The disadvantage of this method is a volatile air fuel mixture passes through the engine turbo that was not designed, or approved, for use with Natural Gas or LPG.** When a worn turbo creates a spark in the intake system a catastrophic explosion can occur and has been known to happen.

Other Differences in the DDF:

There are other significant differences in the DDF technologies, which are both critical to operation and effect substitution levels, and overall performance.

1) Continual Diagnostics

Systems offered today will have some level of on-board diagnostics for the alternative DDF system. The level of diagnostics is controlled by the level of Engine Control Module (ECM) technology utilized in the system.

a. Unless a full automotive level controller (which can detect the entire system operation including all the alternative fuels components) can measure the engine parameters and identify engine malfunctions can it than accurately maintain and control the fuel flow and protect the diesel engine.
b. The most significant element of ECM control is the ability to have a hierarchy of diagnostic monitoring. This is important in determining the reaction an ECM will take if a fault code is detected. The controller can employ stages of reaction, in other words, if the fault condition can be corrected by reducing substitution instead of shutting off the DDF system until the condition corrects itself and then return to regular fueling may be a first stage of reaction.

The 2Fuel system is a full automotive level controller that monitors the engine OEM controller fault codes and takes reaction based on the hierarchy of the engines OEM controller diagnostic codes, including stopping the flow of alternative fuel during a fault condition and re-engaging when the condition has corrected itself.

2) Claims of Dilution Percentages

All products promote their claims of savings stated as substitution rates, or Diesel Dilution Percentages. For clarity, there are two types of dilution percentages. The first and most common is the highest level of dilution attained during the day and the second less common is the average level of dilution during the day.

It is important to understand that while most products, and 2Fuel, can attain up to 70%+ dilution for brief moments in time, under certain parameters, these are not sustainable throughout the day and as a result are simply misleading.

The dilution percentage that is relied on to pay for the conversion is quite simply the "End of Day Average Dilution"

2Fuel always refers to the End of Day Average Dilution Rate, by fuel type, and application. Having the only technology available today that continues to provide precise blending of fuel, throughout the complete high load cycle, assures we will provide the highest end of day average dilution available.

3) No loss of Torque Claims

Dedicated Natural Gas spark engines lose torque and HP to their diesel counterparts simply due to the facts they have reduced compression ratio vs the diesel engine and the alternative fuels have less BTU than diesel.

While many dual fuel companies claim no loss of torque, it is important to understand how they do this. Their lower level control systems cannot measure fuel or react fast enough to maintain the OEM spec to power or protect the engine, during the high load cycles, and as a result they stop blending fuels during these periods. Their claim of no loss of torque is accurate, simply because when the engine is under high load, they are not blending, hence they do not affect the torque.

2Fuel uses an automotive level controller with advanced software to support 2way communication with the OEM ECU. This allows 2Fuel to meter fuel flow rates for both diesel and the alternative fuel, to assure the correct energy is always delivered to the cylinder, as per the OEM expectation. This is how 2Fuel continues to blend fuels throughout the complete high load cycle, all within OEM parameters.

2Fuel states our claim as "We maintain the OEM torque and HP spec, while blending the fuels, throughout the complete high load cycle."

2Fuel System

If you are considering a DDF system for your engine and application, the 2Fuel system is the highest level of DDF technology available today.

- **2Fuel** utilizes our patented automotive level controller, with high speed data processing, to deliver the optimum fuel substitution rates c/w full engine diagnostic control and protection.
- **2Fuel** deploys two-way communication, all J1939 parameter data being broadcast by the OEM engine controller, through the CAN BUS, are used in determining fuel substitution levels.
- **2Fuel** communicates the diesel fuel commands, to reduce diesel fuel flow, to the OEM engine controller when the **2Fuel** is in the enable mode. These communications occur in multiple millisecond of time which allows for the **2Fuel system** to respond and more precisely, and quickly, to changing engine parameters, such as engine speed, load and other operational parameters.
- **2Fuel** meters the alternative fuel through injectors mounted in a common fuel rail which feeds a mixer pin downstream of the turbo.
- **2Fuel** diagnostics are hierarchy based, to maintain optimum run time on the alternative fuel and prevent needless shut downs.