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Premium Diesel Fuel "IS"

Worth "Much More" Than

The Extra Cost !

by

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Preface

The term "*Premium*" as it relates to a diesel fuel has been used and abused for many years. Accordingly, before the question of the value of a "*Premium Diesel Fuel"* can be answered, we must first determine precisely what is meant by "*Premium Diesel Fuel*" and what is actually delivered to the engine when a truly "*Premium Diesel Fuel"* is used.

This author wrote a series of articles ("**The Making Of Premium Diesel Fuel**") that fully identifies and details the physical parameters and the handling requirements that must be done in order to have a really "*Premium Diesel Fuel"*. This series of articles clearly describes and specifies precisely what the author believes is meant by the term "*Premium Diesel Fuel"*.

An actual "*Premium Diesel Fuel*" should be defined as a fuel that **(1)** eliminates ALL of the inherent natural issues encountered with typical diesel fuel and **(2)** compensates for the operational issues to be expected when using the diesel fuel in the identified application.

While this definition of a "*Premium Diesel Fuel"* may seem simple and straightforward, the application of the necessary technologies to accomplish these upgrades is not a simple matter. In fact, one of the biggest problems with accomplishing the task is rooted in the chemical mystic used to achieve the goal.

The belief that "… all diesel fuels are the same …" is completely unfounded and false. In actuality, all diesel fuels are NOT the same and most diesel fuels will react differently when treated with the same chemical additives to improve the quality and performance.

And, while much has been written over the years about the benefits of using an "upgraded" diesel fuel (incorrectly referred to as a "*Premium Diesel Fuel"*), one must be diligent and astute about just how the so-called "*Premium Diesel Fuel"* came into being before any effective analysis can be undertaken to determine its worth in an engine.

There are only three sources for "*Premium Diesel Fuels"*. They can be made **(1)** at the refinery gate or **(2)** at some point in the fuel distribution chain or **(3)** at the fuel usage point. In all cases, the right chemical enhancement technologies in the **correct** concentrations **must** be incorporated into the diesel fuel in order to achieve the performance improvements advertised. Any shortcuts in the use of the proper chemicals (or treat rate dilution) will result in less-than-expected result.

The term "*premium*" from Websters Dictionary[1] says "… *a high value or a value in excess of that normally or usually expected*…" or "… *of exceptional quality or amount… generally sold at a higher price*…".[1]

Discussion

While these words may help to define what "*Premium"* can be, the application of these words regarding diesel fuel has often been overstated and underdelivered by the marketers of "*Premium Diesel Fuels"* and the chemical additives sold to upgrade diesel fuels into a "*Premium"* status.

The fuel buyer needs to understand that there are NO truly "*Premium Diesel Fuels*" produced by any petroleum refinery today. Plus, many of the so-called "*Premium Diesel Fuels*" offered by fuel suppliers provide woefully inadequate results regarding the benefits claimed.

Therefore, the **buyer** of "*Premium Diesel Fuel"* as well as the purchaser of chemical additive treatments advertised to upgrade a diesel fuel into a "*Premium"* status **must** investigate the prospective products thoroughly before any money changes hands.

This does not mean that "*Premium Diesel Fuels"* or the chemical treatments necessary to make "*Premium Diesel Fuels"* are not worth the extra money it takes to acquire them. Quite the contrary, it only means the phrase "buyer beware" is appropriate. If the "*Premium Diesel Fuel"* is truly a "*Premium"* product and if the chemical additives purchased to upgrade a diesel fuel into a "*Premium"* status DO in fact accomplish the goal, then a "*Premium*" price is appropriate.

There are four areas of concern that must be addressed regarding a "*Premium Diesel Fuel"*:

1. Improvement of the physical properties of the fuel product
2. Correction of any manufacturing deficiencies in the fuel product
3. Neutralization of the negative engine side effects caused by using the fuel product
4. Countering of the negative fuel system side effects caused in handing the fuel product.

If the above four items can be properly addressed with the fuel or chemical treatment, then the possibility exists that the term "*Premium Diesel Fuel"* could be used to describe the final product. However, TESTING is a must in ALL applications where the term "*Premium"* is used to depict a diesel fuel and extra money must be spent to acquire an improved product.

Research Laboratories, Inc. (testing facility in Ft. Wayne, IN) [2]

Nearly all aspects and performance claims made by *Premium Diesel Fuel* and upgrade additive sales people can easily be tested in a qualified laboratory.

This testing will prove or disprove the benefits (advertised claims) associated with any so-called *Premium Diesel Fuel* and the upgrade chemical additives promoted to achieve the *Premium* status of a diesel fuel.

Discussion (cont)

These laboratory testing parameters for "*Premium Diesel Fuel"* benefits include:

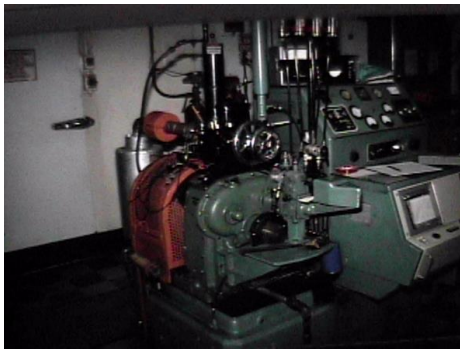
(a) Engine Cetane Number
(b) Detergency Level
(c) Lubricity Enhancement
(d) Stabilization Improvement
(e) Corrosion Inhibition
(f) Cold Flow Properties Improvement (CFPP, Cloud & Pour Point, Wax Dispersancy)
(g) De-Ice Protection
(h) Biocide Protection (if active microbial growth is found to be present in the fuel)
(i) Conductivity Improvement
(j) Brake Horsepower Increase (for the relevant BTU - energy content)
(k) Emissions & Pollution Reductions
(l) Real World Cold Room Filterability Improvement.

Unfortunately, there are no easy, short term tests for Fuel Economy Improvement or Component Life Cycle Extension (wear reduction) or Maintenance Cost Savings applicable to "*Premium Diesel Fuels"* and the additives used to upgrade diesel fuels into a "*Premium"* status. These long term benefits require long term trend line evaluations with astute and diligent reviews of numerous data points in order to determine the benefits of using a "*Premium Diesel Fuel"* or the chemical additives sold to deliver such "*Premium"* performance and quality improvements.

What Is Really Needed - Higher Engine Cetane Number

First and foremost, a true "*Premium Diesel Fuel"* must have a **50+ Engine Cetane Number**. The Engine Cetane Number is a measure of how well a diesel fuel combusts as it relates to ignition delay time in each cylinder (shorter ignition delay provides more time for the entire fuel injection amount to burn properly). Europe (with three times more experience in diesel engines than the USA) is set to raise their minimum Engine Cetane Number requirement from 51 to 55 by 2018. Unfortunately, the America specification is still "stuck" with a minimum 40 number.

The Engine Cetane Number test unit is a single cylinder diesel engine with an adjustable cylinder head. The engine is standardized on a known liquid fuel with a known Engine Cetane Number. The compression ratio is then increased and decreased over several minutes of time during the use of the test fuel until a "knocking" sound (from poor combustion ignition) is detected. A formulation calculation is made to determine the actual Engine Cetane Number of the test fuel.



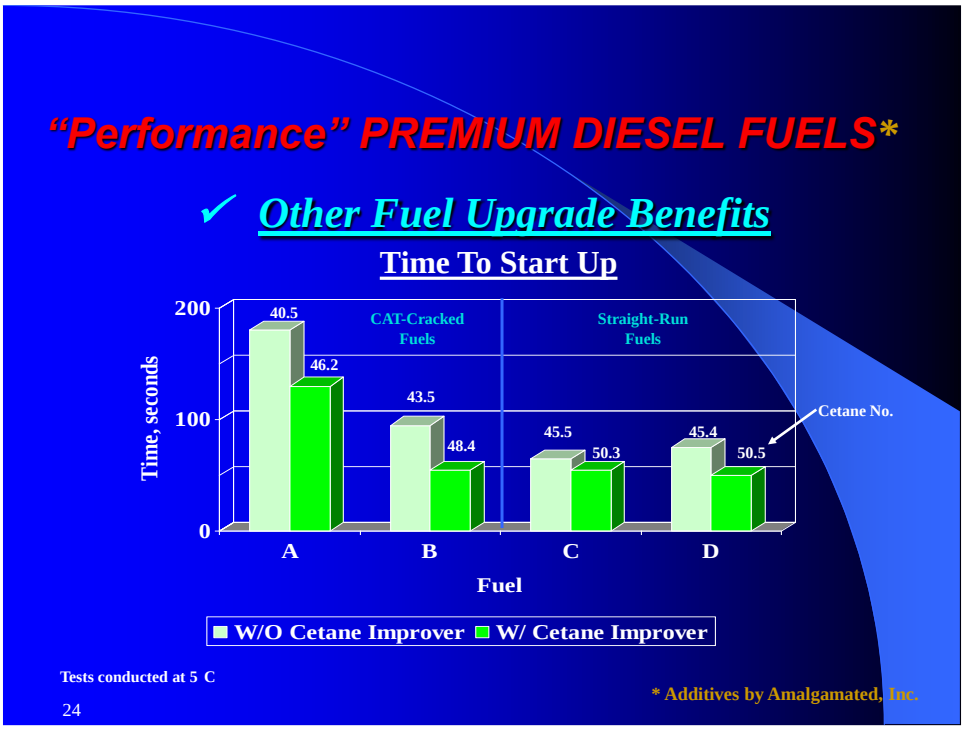
Cetane Engine Test Unit

Cetane Improver Additives, such as 2-ethylhexyl nitrate, can effectively reduce the ignition delay time of the diesel fuel (raise the Engine Cetane Number when tested in an engine).

What Is Really Needed - Higher Engine Cetane Number (cont)

The **Engine Cetane Number** - combustibility of the diesel fuel affects the starting ability of a diesel engine (especially during cold weather) and promotes smooth engine running. Engine Cetane Number also is a direct determining factor in **(a)** the time required to achieve smooth, consistent engine operation, **(b)** the amount of smoke and unburned hydrocarbon emissions, **(c)** power production, **(d)** combustion area fuel related deposit formations and ultimately **(e)** fuel economy (efficiency).

The following chart shows the time in seconds required of a diesel engine to achieve engine start-up without and with the addition of 2-ethylhexyl nitrate Cetane Improver Additive in four different diesel fuels. Both cat cracked and straight run diesel fuels were tested.



Engine Start-up Time Chart In Seconds Without and With Cetane Improver Additive

In the bar chart, increasing the Engine Cetane Number (referenced on the top of each bar) reduced the start-up time in all four test fuels regardless of the base (beginning) Engine Cetane Number. Reducing the start-up time minimizes the wear on engine starters (less time engaged) and the drain on engine batteries (less power needed to start the engine) plus it lowers the potential for fuel related combustion area deposits in the cylinders caused by poor fuel ignition.

Poor fuel ignition can lead to "hot spots" in the cylinders that will cause pre-ignition during fuel injection. This puts a significant strain on the crankshaft as the fuel burns and the created pressure attempts to push the piston down before top dead center is reached in the compression cycle (the crankshaft can actually be twisted and broken into two pieces in the most severe situations).

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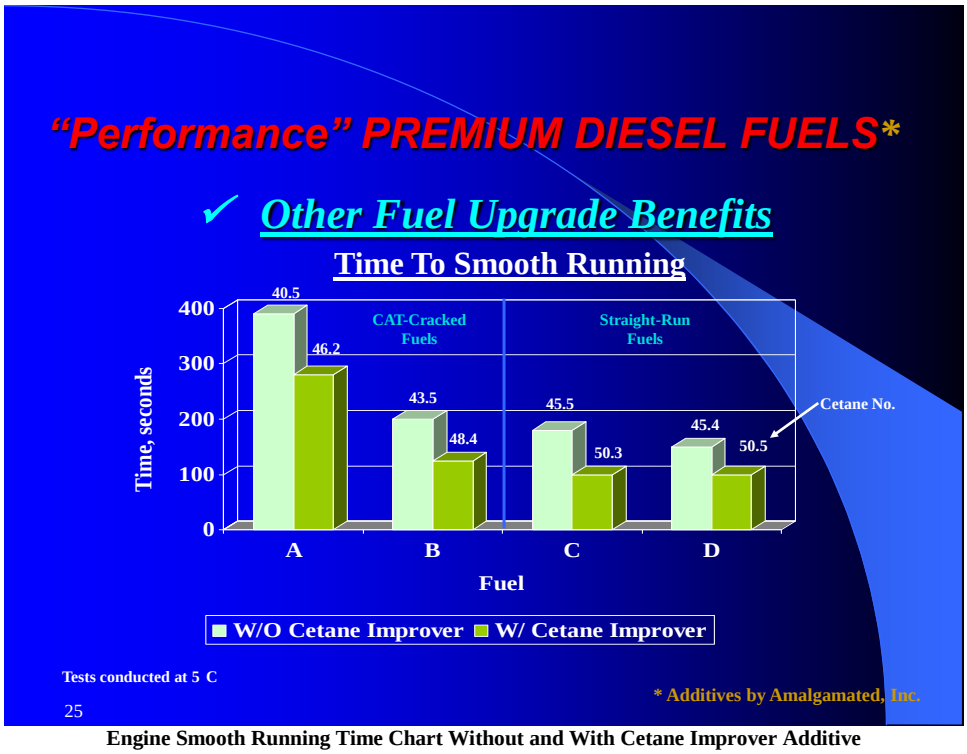
What Is Really Needed - Higher Engine Cetane Number (cont)

The **Engine Cetane Number** - also affects the time in seconds required to achieve "smooth running operations". This is a very important factor because the "warming" of the engine determines how quickly all of the engine component parts expand to their respective working temperatures. If adequate heat is not generated in the engine quickly enough, the engine oil may not lubricate the moving parts properly and increased wear will occur. A more rapid warming of the engine also affects the driver's attitude which ultimately determines how the vehicle is driven (especially during the initial few minutes and hours of daily operation at cold temperatures).



Engine Smooth Running Time Chart Without and With Cetane Improver Additive

Again, raising the Engine Cetane Number significantly reduces the time in seconds required to achieve smooth engine operation (engine warm up). Ultimately, reducing the time to smooth operation (engine warming in less time) will result in longer engine life because of the associated wear attributed to cold engine component parts being improperly lubricated with cold more viscous engine oils and greases.

Another area of concern for diesel engines, regardless of the fuel being used, is the air temperature as it relates to "misfires" within the cylinders. This is particularly important for diesel engines operating above the 38th parallel in North America because the air temperature can change significantly over night or within a short time period.

And, as the air temperature is reduced, the potential for misfires increases unless a higher Engine Cetane Number diesel fuel is used.

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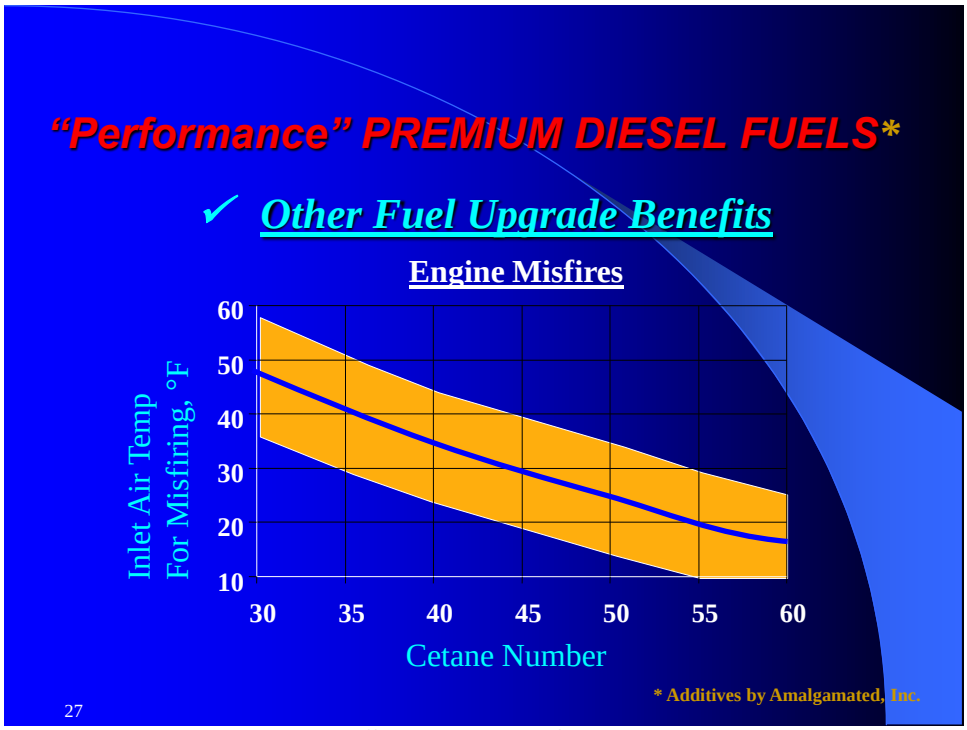
What Is Really Needed - Higher Engine Cetane Number (cont)

The following graph shows the effect on engine misfires at a range of temperatures (10F to 60F) with changes in the Engine Cetane Numbers. As the Engine Cetane Number is increased, the potential for engine misfires decreases regardless of the cylinder inlet air temperature.



Inlet Air Temperature Affects On Engine Misfire vs Engine Cetane Number

The vehicle driver (engine operator) has the most effect on the overall fuel efficiency (fuel economy - mpg) of all diesel engines. And, one of the best ways to influence fuel efficiency is to keep the engine operator satisfied with his diesel engine performance.

Engine noise is one of the most noticeable engine operating parameters that directly affects the driver (operator) and thus directly affects the fuel efficiency. And, engine noise is directly tied to the diesel fuel Engine Cetane Number (lower Engine Cetane Numbers create more engine noise).

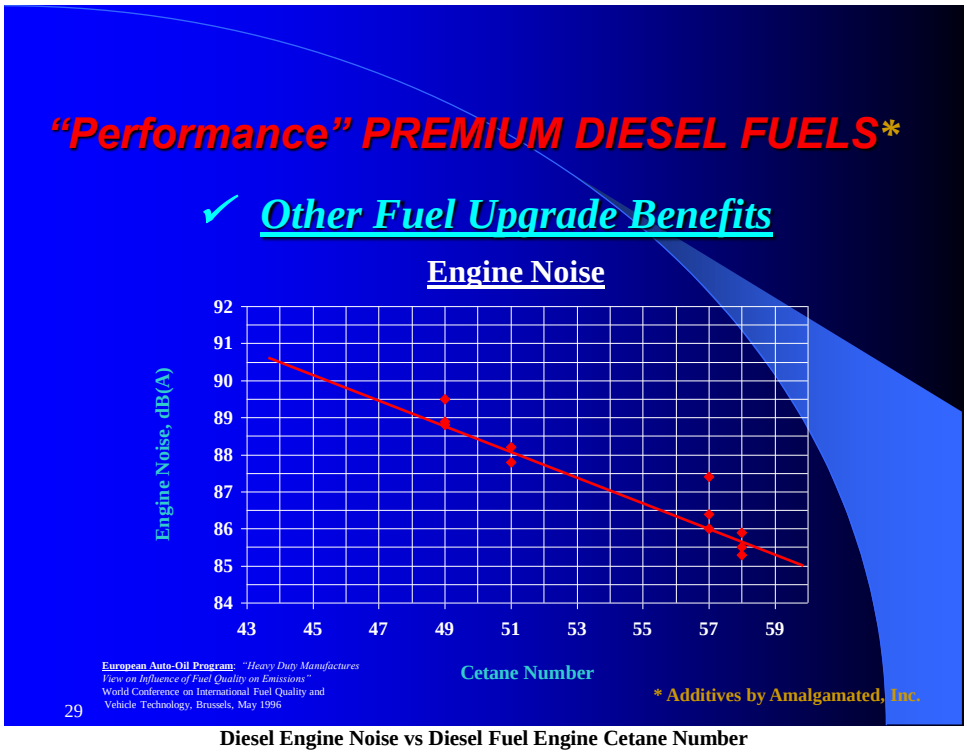
Ultimately the higher engine noise levels WILL affect how the driver operates the vehicle. These higher noise levels are irritants that cause a driver to be less forgiving of the engine's response to his requests for a particular operating status. Louder engines can make a driver uncomfortable and cause him to work the engine harder in order to achieve a desired engine power production. Quieter engines tend to be more acceptable to a driver, which tend to result in less irritation and the potential for more desirable driver operation of the vehicle.

Engine misfires (poor combustion of the fuel) also increase fuel dilution into the oil crankcase. This increased fuel dilution WILL, over time, increase lower engine component part wear.

What Is Really Needed - Higher Engine Cetane Number (cont)

This louder knocking noise (especially at startup during cold weather) also increases the stress and strain (wear) on all of the moving parts of the diesel engine. Plus, with lower Engine Cetane Number diesel fuels, this increased pressure on the moving parts continues after the engine is warmed which increases the long-term potential for trauma (wear) to every engine part involved in the production of power (from fuel injection to horsepower delivered to the wheels).

The following chart shows how the engine noise level (sound decibel level) is reduced with increased fuel Engine Cetane Numbers.



Diesel Engine Noise vs Diesel Fuel Engine Cetane Number

What Is Really Needed - Higher Fuel Detergency Level

The **Second** most important "*Premium Diesel Fuel*" parameter is how well the fuel being used prevents fuel related engine deposits - i.e. the amount of detergency in the diesel fuel being used. Diesel fuel by itself is not a good cleaner and it will not keep fuel related deposits out of the engine and fuel delivery system. Therefore, a good Diesel Fuel Detergent **must** be added to the diesel fuel if the diesel fuel is to be upgraded to a truly "*Premium*" status.

For many years, diesel fuel Detergents in America were judged (evaluated) using a test known as the Cummins L-10 Injector Cleanliness Test. This test compared **(a)** the "Plunger Rating" based on the deposits built up in a specified set of fuel injectors and **(b)** the "Flow Loss" through the same set of fuel injectors tested for a specified period of time and with a specified diesel test fuel.

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What Is Really Needed - Higher Fuel Detergency Level (cont)

A diesel fuel Detergent additive would need to achieve a Plunger Rating of less than 10 on the scale and keep the Flow Loss through the injectors at less than 6 percent to "Pass" the test. The Detergent additive supplier was only required to pass the test once for each Detergent additive marketed and all suppliers of the manufactured Detergent additive could claim a "Pass in the Cummins L-10 Injector Cleanliness Test".

Unfortunately, the specific fuel injectors for the Cummins L-10 Test are no longer manufactured, so the Detergent manufacturers have asked ASTM[3] (American Society for Testing of Materials - the entity that writes specifications for diesel fuels and all components added to diesel fuels) to develop a new test for certifying Detergent additives for diesel fuels.

As of this time, ASTM has not yet produced a new test method, but two other Detergent tests are being referenced in the market today. One is the European Peugeot XUD9 Fuel Injector Test and the second is the Cummins N-14 Fuel Injector Test. Both tests require a sophisticated laboratory to conduct and both are extremely expensive to complete.

Peugeot XUD9 Fuel Injector Test Apparatus & Test Injector Tip Photos

The above photos show a much cleaner fuel injector tip after testing with the Detergent additive treated diesel fuel (bottom photo) compared to the fuel injector tip (upper photo) tested without Detergent additive. Clearly, the cleaner the tip remains, the better the diesel fuel will be atomized (mixed with the combustion air) when injected into each cylinder. And, higher Detergent levels will minimize EGR (exhaust gas recirculation) valve plugging plus assist in cleaning DPF (diesel particulate filters) as a result of improved combustibility of the diesel fuel.

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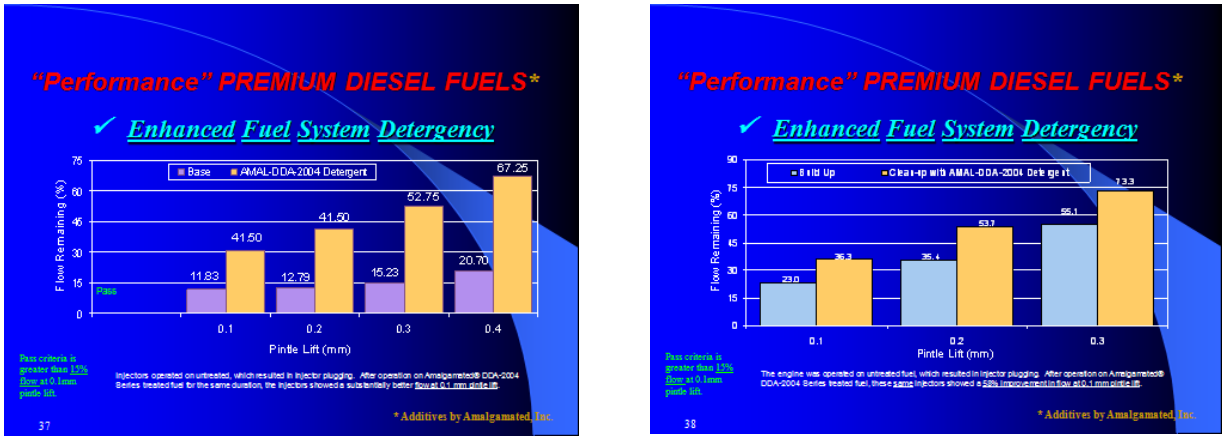
What Is Really Needed - Higher Fuel Detergency Level (cont)

The following two bar charts show improved fuel flow through the fuel injector at different millimeters of injector pintle lift (opening) when a "good" diesel fuel Detergent additive is included in the test diesel fuel compared to the same base diesel fuel without Detergent additive.

Both test results clearly show the cleanup capabilities (increased flow when using Detergent Additive) through the same fuel injectors compared to the typical decreased fuel flow through a "dirty" (partially plugged) fuel injector when Detergent Additive in not treated in the diesel fuel.



Improved Fuel Flow Through The Fuel Injector and Cleanup Capabilities With Detergent Additive

Diesel fuel atomization in the combustion chamber is key to ensuring that ALL of the diesel fuel is completely burned at every engine power (throttle) setting. Any diesel fuel that is not completely burned is lost dollars for the operator because no power will have been generated from the diesel fuel injected into the engine.

In addition, the unburned diesel fuel will:

(1) Create more fuel related engine deposits in the engine combustion chamber
(2) Increase deposits in the post combustion areas (exhaust valves, EGR valves, DPF, etc.)
(3) Increase smoke and unburned hydrocarbon emissions
(4) Increase fuel dilution in the crankcase oil
(5) Shorten the engine maintenance overhaul time period
(6) Decrease the power production from the engine
(7) Decrease the vehicle/engine fuel efficiency - poorer fuel economy/MPG.

These are only the major impacts to be expected from running a diesel engine with dirty fuel injectors. If a diesel engine vehicle experiences a plugged injector (or two) while operating away from home base, the cost of replacing the fuel injector(s) will be sizable. And, the repair cost does not count the untold revenue dollar losses for the downtime of an "out-of-service" truck.

Whether on the road or in stationary equipment, changing the fuel injector(s) in just one engine will pay for the use of a good Detergent additive in that vehicle for many YEARS!

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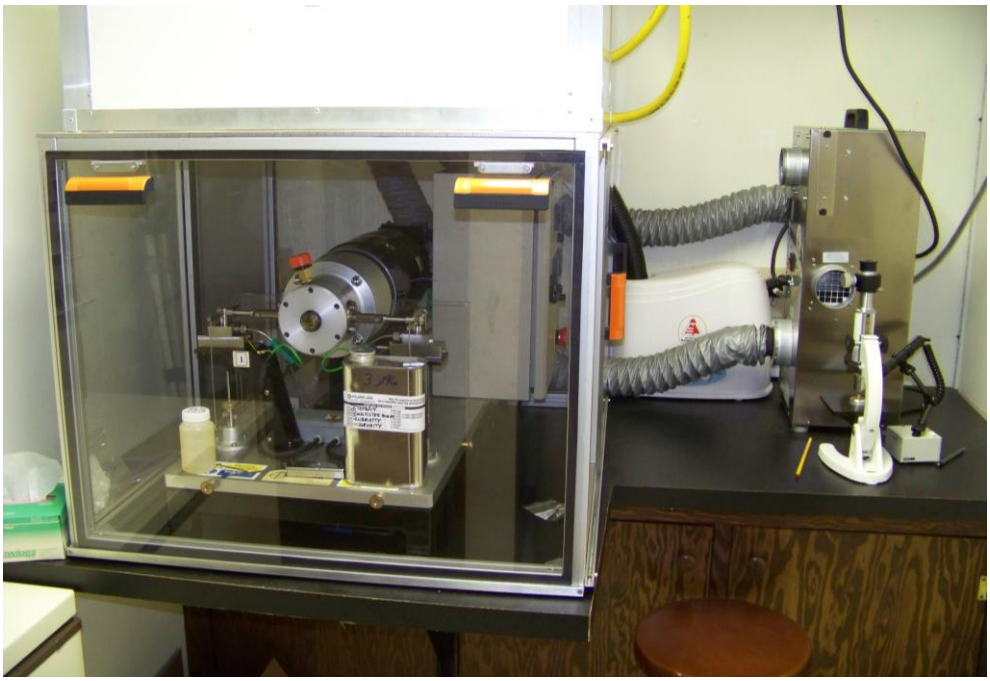
What Is Really Needed - Better Lubricity

The **Third** most important "*Premium Diesel Fuel*" parameter is the Lubrication Value of the diesel fuel being used. Like all other things requiring lubrication, the fuel system components (injectors, pumps, etc.) WILL wear out much faster if proper lubrication is not provided by the diesel fuel when the diesel fuel is the source (or major source) of the lubrication.

ASTM incorporated a Lubricity Specification in the ASTM D-975[4] Specification for diesel fuels in January, 2005. This specification requires all diesel fuels to meet a minimum lubrication wear scar of 520μm when tested on the HFRR (high frequency reciprocating rig) Test.



Two Place HFRR Lubricity Test Apparatus

This test moves a metal ball held in a sleeve back and forth over a 1mm polished metal disk while both pieces are immersed in the test diesel fuel. The ball pressure on the disk is maintained at 200g and the reciprocation speed is maintained at 50hz for a period of 75 minutes in a temperature controlled (60 degrees C) and humidity controlled (30+%) atmosphere.

When the test is completed, the depth and width of the wear scar on the disk are measured and reported as micrometers (μm) of wear. The better the Lubricity Value of the diesel fuel, the lower will be the wear scar result.

While the United States lubricity specification for diesel fuel was arbitrarily set at 520μm maximum, the European diesel engine manufacturers (with more long term experience in the lubrication needs of diesel engines) have set their diesel fuel lubricity specification at less than 400μm. This author believes the **400μm** number should be used for "*Premium Diesel Fuels*".

What Is Really Needed - Better Lubricity

In addition to fuel system wear, Lubricity content in a diesel fuel plays an important part in the combustion of the diesel fuel. If the fuel injectors "stick - chatter" because of poor lubrication, the atomization of each diesel fuel droplet injected into the diesel cylinders will be affected.

Because proper Lubrication value and Detergency act together to create the possible spray pattern in the diesel engine cylinders, if Lubricity is lacking in a diesel fuel, **all** of the same items associated with the lack of proper Detergency will become even bigger problems and:

(1) Create more fuel related engine deposits in the engine combustion chamber
(2) Increase deposits in the post combustion areas (exhaust valves, EGR valves, DPF, etc.)
(3) Increase smoke and unburned hydrocarbon emissions
(4) Increase fuel dilution in the crankcase oil
(5) Shorten the engine maintenance overhaul time period
(6) Decrease the power production from the engine
(7) Decrease the vehicle/engine fuel efficiency - poorer fuel economy/MPG.

One of the most important things to remember about making a "*Premium Diesel Fuel*" is that all of the physical characteristics of the diesel fuel act in a synergistic manner with each other in order to provide good combustion in all cylinders. If any one or more of these parameters are less than optimum, the engine will not produce optimum power from the diesel fuel injected.

What Is Really Needed - Improved Long Term Storage Stability

The **Fourth** most important "*Premium Diesel Fuel*" parameter is Long Term Storage Stability. This parameter item is often overlooked as an important factor in the quality of a diesel fuel because many in the petroleum industry and fuel users believe ***the fuel will not be around for any great length of time before it is consumed, so Storage Stability is not an issue***.

Unfortunately, no one can say for certain that a diesel fuel made today will absolutely be consumed tomorrow. In fact, no one can say for certain that the diesel fuel that is purchased today was actually made in the recent past. Often petroleum products can be stored for several weeks to months within the fuel distribution chain before they are actually purchased by a fuel user. And, the fuel user could store the fuels for several more months after he purchases them before the fuel actually gets used.

Also, just because a refiner makes a diesel fuel today does not mean that same fuel will be stable tomorrow. In fact, the belief that the diesel fuel coming out of the refinery is always very stable and will remain so for a long period of time is completely untrue.

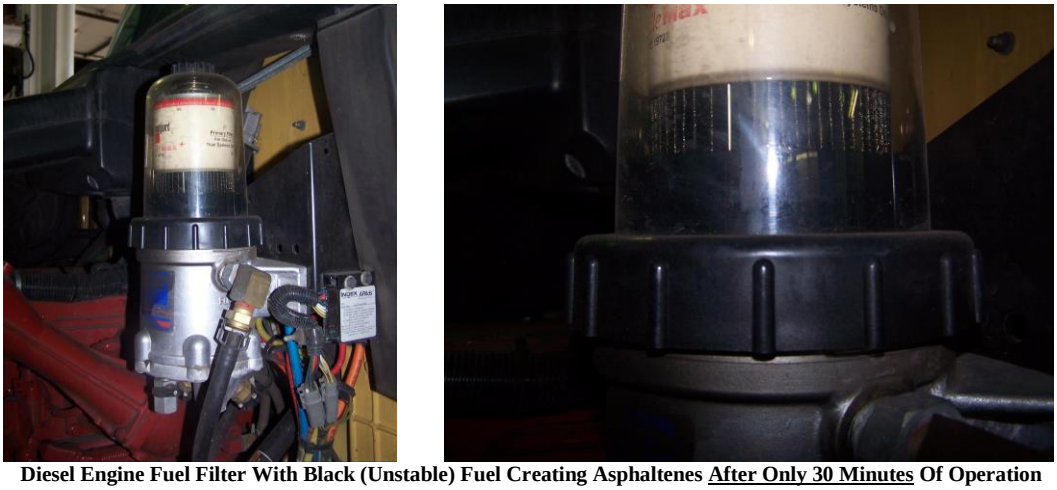
Petroleum products are "organic" materials made from decayed vegetation and animals and as such the manufactured "finished" fuel products from this decayed matter begin a degradation process of their own from the moment they are manufactured into diesel fuel until they are finally consumed.

What Is Really Needed - Improved Long Term Storage Stability (cont)

The petroleum refiner *could* treat his finished fuel productions to slow the degradation process, but the degradation process cannot be stopped entirely. Unfortunately, the petroleum refiners generally believe that fuel storage stability is an issue to be dealt with by the fuel consumer, so as a rule, little if any, stability protection is added at the refinery gate.

Another thing to remember about fuel stability is that heat and oxygenation are the two worst enemies of a diesel fuel when it comes to how long the fuel will remain stable.

And, a large amount of "return fuel" goes back to the tank from the engine and fuel pump (generally 75 to 85 percent of the diesel fuel pumped from a vehicle tank is continually retuned to the vehicle tank). This "recirculation' of the diesel fuel agitates the fuel adding oxygen (bubbles) to the hot fuel being returned - i.e. heat and oxygenation. Some diesel fuels are actually degraded and form insoluble particulates and asphaltene particles in the vehicle tanks while the engine is running. This causes the fuel to turn black in a very short period of time.

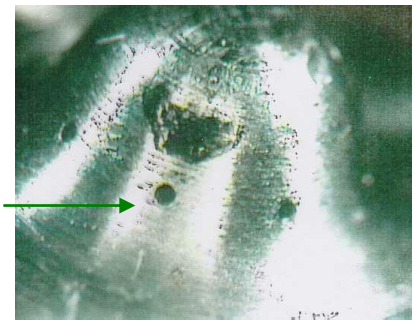


Diesel Engine Fuel Filter With Black (Unstable) Fuel Creating Asphaltenes After Only 30 Minutes Of Operation

The fuel filter elements turn black while collecting some of the particulates which results in replacement of the fuel filters in a fraction of the time of normal change intervals. And, some of the smaller particles will travel through the filter and into the injectors where they cause deposits that ultimately will plug the injector tip holes (expensive injector replacement is the end result).

Injector Tip With Deposit Buildup And Plugged Holes From Using Unstable Fuel

Injector Tip Without Deposit Buildup And No Plugged Holes From Using Stable Fuel



What Is Really Needed - Improved Long Term Storage Stability (cont)

Injector deposits affect the spray pattern out of the fuel injector which causes poor atomization of the fuel droplets and results in poor combustion.

Diesel Injector Spray Pattern With Partially Plugged Tip Holes (Uneven Spray Pattern)

Thermal Stability of a diesel fuel can be tested in a qualified laboratory to determine how degraded the fuel is at the time of testing and how much stabilizing chemical treatment is needed to thoroughly protect the diesel fuel in storage. The ASTM D-975[4] specification for diesel fuels does not include a requirement for Storage Stability. However, the appendix does list several different laboratory tests as a guidance to fuel users desiring to attempt to determine the stability of diesel fuels. Several of these tests are time consuming and somewhat difficult to conduct.

ASTM D-2274[5] is a long term (16 hour) test that requires the flowing of 3 liters per hour of pure oxygen through the 95 degree C heated fuel (203F) in a specified apparatus.

ASTM D-5304[6] is a long term (16 hour) test that requires the fuel to be placed in a pressure borosilicate glass container and then the container is placed in a pressure vessel preheated to 90 degrees C and pressurized to 800 kPa (100psig).

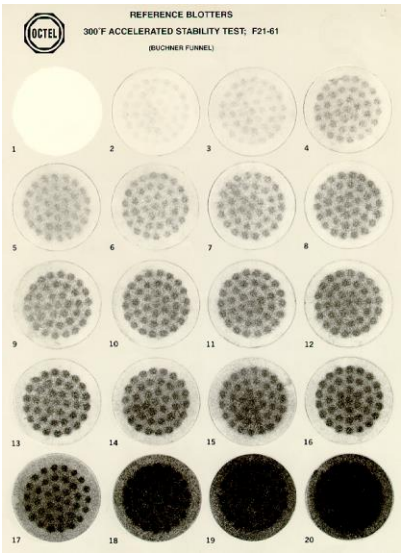
ASTM D-4625[7] is a long term test that requires 400ml of diesel fuel to be aged in a borosilicate glass container at 43 degrees C (110F) for periods of 0, 4, 8, 12, 18 and 24 weeks. After each aging time period, the fuels are filtered through specified pad filters and analyzed for filterable insolubles and adherent insolubles. As indicated, each of the above test methods is extremely cumbersome to complete and the end results do not guarantee the stability of the diesel fuel.

What Is Really Needed - Improved Long Term Storage Stability (cont)

A much simpler (non- ASTM[3]) test for storage stability is the DuPont F-21 Oxidation Stability Test[8] method. This procedure requires 100ml of diesel fuel to be heated to 300 degrees F for a period of 180 minutes then cooled and filtered through a pad filter to collect the particulate material generated during the test.

Dupont F-21 Stability Chart – Pad Readings

The filtered pads are compared using a light reflectance apparatus with a higher percentage of reflected light indicating less particulate material generated and <u>therefore a more stable fuel</u>. The pads can also be compared visually to the chart shown here of pads filters from 0 to 20 (0 being white and 20 being black).



The Stable fuels will generate very little filtered particulates and unstable fuels will generate much higher pad numbers. The higher the pad result, the more unstable the fuel is at the time of testing. Again, unfortunately, this test does not provide an absolute guarantee of the stability of the diesel fuel.

Again, all of the same issues noted for low Engine Cetane Number or poor Detergency or inadequate Lubricity will be encountered for the fuel user when a diesel fuel becomes unstable - i.e. more fuel related engine deposits in the engine combustion chamber, increased deposits in the post combustion areas (exhaust valves, EGR valves, DPF, etc.), increased smoke and unburned hydrocarbon emissions, increased fuel dilution in the crankcase oil, shortened engine maintenance overhaul time period, decreased power production from the engine, decreased vehicle/engine fuel efficiency - poorer fuel economy / reduced MPG.

What Is Really Needed - Inhibited Rust And Corrosion

The **Fifth** most important "*Premium Diesel Fuel*" parameter is the Inhibition of Rust and Corrosion in the fuel delivery system. But, while this condition is often thought to occur only if associated with Microbiological Growth (which will in fact aggravate the condition), moisture is the real culprit with regard to Rust and Corrosion. And, since moisture is always a contaminant in diesel fuel and since moisture is always present as a part of the air, moisture is always present in the fuel system.

Even in today's sophisticatedly designed and engineered high performance electronically controlled diesel engines, many parts still contain dissimilar metals that can spark corrosion in the presences of moisture.

What Is Really Needed - Inhibited Rust And Corrosion (cont)

So, because there is a real potential for Rust and Corrosion in any diesel engine, if a diesel fuel is to be termed a true "*Premium Diesel Fuel*", it must not contribute to or advance Rust and Corrosion in the engine or fuel delivery system. And, any diesel fuel additive used to upgrade a diesel fuel into a "*Premium*" status, must Inhibit Rust and Corrosion in the engine and within the fuel delivery system.

Diesel Fuel Storage Tank Pump/Meter Assembly and Island Filter With Corrosion From Fuel

The above picture shows the corrosive effects a diesel fuel can have on the fuel delivery system in a diesel fueling facility (after six months of continual use). A good "*Premium Diesel Fuel*" product must not create such a problem and a good "*Premium Diesel Fuel Additive*" product must correct such a problem.

What Is Really Needed - Winterization

All diesel fuels used in cold weather climates (and some high paraffinic crude derived diesel fuels used in warmer regions) **must be correctly treated** with cold weather Winterization additives.

Accordingly, the **Sixth** most essential parameter for a truly "*Premium Diesel Fuel*" is the proper, adequate and effective Winterization of the diesel fuel for the expected operational region and its climatic conditions. The four areas of concern in a diesel fuel that must be addressed are:

(1) Reduction of the fuel **CFPP** (Cold Filter Plugging Point) temperature
(2) Reduction of the fuel **Pour Point** handling temperature
(3) Reduction of the moisture freeze point (**De-Icing**) temperature
(4) Dispersion and Suspension (**Wax Dispersing**) of the paraffin wax formations.

Each of these physical properties must be chemically treated in order to prevent the negative effects on the diesel engine fuel delivery system. This will permit the engine to operate at its designed efficiency and optimum parameters at any temperature and during any type of cold weather.

What Is Really Needed - Winterization (cont)

If, the diesel fuel being consumed is truly a "*Premium Diesel Fuel*" or the additive purchased to upgrade the diesel fuel is an effective "*Premium Diesel Fuel Additive*", none of these physical parameters will impede the operation of the engine regardless of the cold weather condition.

CFPP is a laboratory test procedure that has been used in Europe for several decades to predict the fuel temperature at which the fuel filter will begin plugging from an accumulation of paraffin wax crystals in the cold diesel fuel.

Automatic CFPP Test Machine

CFPP Test Apparatus

The CFPP test is conducted by the machine vacuuming fuel from a test tube up through a 45 micron screen filter past an initial light sensor into a 20-ml chamber of the test assembly and then past a second light sensor. The CFPP temperature is reached when 20-ml of fuel fails to reach the second light sensor during the 60-second test cycle. The temperature of the diesel fuel is electronically monitored throughout the test and the test cycles are at every 1 degree C (2 degrees F).

This testing began to be used in the USA in the early 1990's and today is used extensively throughout the petroleum industry and the fuel consuming public. However, as of this time, no CFPP requirement has been incorporated into the ASTM D-975[4] specification for diesel fuels. Despite the lack of a qualifying diesel fuel CFPP specification, the ASTM D-6371[9] CFPP test is the most widely used laboratory test for predicting operability of diesel engines in North America. And, **if** the diesel fuel being used is truly a "*Premium Diesel Fuel*", the diesel fuel will show exceptional CFPP test results and the diesel fuel will not cause winter time operational problems in the field - regardless of the outside temperature.

It should be noted that there are two other laboratory tests listed in the ASTM D-975[4] specification for diesel fuels that can be used in an attempt to predict operability of diesel engines during cold weather.

Cloud Point (ASTM D-5771[10]) is a measure of the temperature at which the paraffin content in the diesel fuel changes to a solid wax component and a visable amount of wax accumulates in the bottom of a laboratory test tube (paraffin wax is heavier than the diesel fuel, so it will fall to the bottom of the sample).

What Is Really Needed - Winterization (cont)

Unfortunately, Cloud Point temperature determinations will not provide an accurate failure point of the diesel engine operating on a fuel in the field because the diesel fuel Cloud Point results are extremely conservative (the resultant temperature essentially is when wax first becomes evident in the fuel). Additionally, some diesel engine fuel filtering systems can tolerate more paraffin wax during operation depending on their particular design and the location of the fuel filters.

Also, the measurement of Cloud Point is of little value in determining engine cold weather operability **if** the diesel fuel has been properly treated with the right concentration of the right Winterization chemical additives.

A properly Winterized diesel fuel will still cloud, but the right Winterization additives will "disperse the wax crystals" throughout the fuel (preventing settling) and the right chemical additives will cause the paraffin content to make very small wax crystals capable of passing through the fuel filter elements instead of accumulating on the filters and blocking the flow.

LTFT is another test cited by ASTM[3] in the ASTM D-975[4] specification for diesel fuels in an attempt to predict operability of diesel engines during cold weather (ASTM D-4539[11]). However, like Cloud Point, the LTFT test also will not provide an accurate failure point of the diesel engine operating on the fuel in the field. Because of the methods employed in conducting LTFT (the diesel fuel is "stirred" prior to testing at each test point temperature), the test results are "not duplicatable" in real world operating conditions in the field. Plus, again, some diesel engine fuel filtering systems can tolerate more paraffin wax during operation depending on their particular design and the location of the fuel filters.

Additionally, the LTFT test is extremely difficult to conduct because the test temperature is lowered by only 1 degree C (2 degrees F) per hour and the test requires a significant amount of diesel fuel sample (200ml of diesel fuel for each test temperature). And, the laboratory technician must "guess" how many test temperatures it will take to reach the failure point temperature. If 20 test temperatures are believed to be needed to determine the failure point temperature, the cooling bath to be used must accommodate all 20 @ 200ml sample containers.

Plus, if the LTFT failure point temperature is NOT reached during the 20 hours of test time required to run the 20 test samples, the test must be set up and run again with new samples of even more diesel fuel! This is why this *nightmare of a test* is offered by only a very few laboratories.

Pour Point is a laboratory test measurement to determine a diesel fuel's solidification temperature. The diesel fuel Pour Point temperature is often referred to as the "gell" point because the fuel will be completely solid (gelled) and will no longer "pour" out of a container.

However, it should be noted that the diesel will likely stop flowing several degrees "before" the actual laboratory Pour Point temperature is reached because the fuel viscosity will become extremely thick prior to reaching the Pour Point temperature.

What Is Really Needed - Winterization (cont)

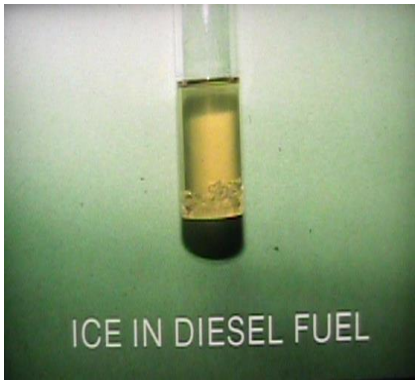
While not an appropriate "filtering test", the Pour Point test result **is** useful for pumping and fuel handling purposes as it can be lowered in most diesel fuels to nearly any temperature with the right chemical additives. If a diesel fuel is to be labeled as a "*Premium Diesel Fuel*", the Pour Point of the fuel should be well below any expected ambient air and pumping temperature for the use application.

De-Icing the moisture content (reducing the freeze point temperature) in a diesel fuel is another very important part of proper Winterization of a diesel fuel. In fact, all diesel fuel will contain a certain amount of water (typically 40 to 100 parts per million) and this moisture content will begin to freeze at 32 degrees F, changing to ice crystals. As such, the moisture content in a diesel fuel will be one of the first problem issues to be experienced when cold weather hits.

So, if a diesel fuel being used is truly a "*Premium Diesel Fuel*", the right chemical "De-Icing Agents" **must** be added to the diesel fuel to deal with the water content in order to eliminate the problems associated with the moisture (i.e. fuel line freeze-up and fuel filter plugging).

Nearly all De-Icing additives used in diesel fuel today are glycol ether chemistries. These products are used exclusively in the jet fuel industry and they have been applied for many years to on-highway and off-highway diesel fuels with exceptional success. Used as directed, these chemical additives will not harm the engine components. However, the success of using glycol ether De-Icing additives in a diesel fuel depends completely on:

(a) Draining or removing any significant amount of free (settled) water out of the fuel tanks
(b) Knowing how much water/moisture content (ppm) is suspended within a diesel fuel
(c) Adding the proper amount of De-Icing agent to counteract the water content in the diesel fuel.



Ice Crystals In Diesel Fuel

As a general rule in order to reduce the moisture freeze point to an acceptable level (-40F), "the *De-Icing agents must be added in equal parts per million (ppm) for the amount of moisture in parts per million in the diesel fuel*"
(i.e. 80ppm of moisture will require 80ppm of De-Icing additive to lower the freeze point of the moisture to -40F).

Fuel line freeze-up (or a restricted fuel line or fuel filter) as the result of moisture in the diesel fuel will cause low power production and can lead to engine shut down from fuel starvation. And, while isopropyl alcohol has been used in the past as a De-Icing additive, it is specifically not recommended by the Engine Manufacturers Association (EMA) and may void engine warranties.

What Is Really Needed - Winterization (cont)

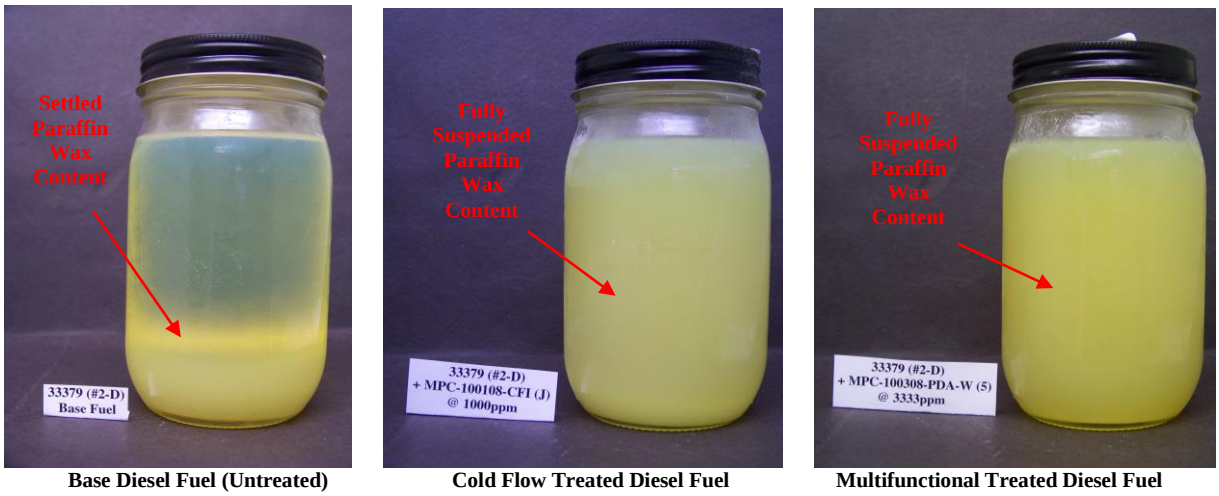
Wax Dispersing (and suspending) of the paraffin wax formations in a diesel fuel during cold weather is probably the "most" crucial part of diesel fuel Winterization.

The liquid paraffin content in a diesel fuel will change into solid paraffin wax crystals at fuel temperatures below the fuel Cloud Point. These solid paraffin wax crystals will tend to agglomerate together to form large wax crystal matrixes and as they get heavier than the liquid diesel fuel, these wax crystals will fall to the bottom of whatever containment they are in and accumulate until warmed back into a liquid.

The solid wax crystals settle and agglomerate in the bulk fuel storage tanks, vehicle fuel tanks, fuel lines, fuel pumps and fuel filters. Additionally, the wax crystals will readily "stick" to any ice crystals forming in the diesel fuel to make complex crystal formations. These formations will rapidly plug the fuel filters and the fuel lines ultimately starving the engine of fuel. Complete engine shut-down is the result.

If a diesel fuel is to be a truly "*Premium Diesel Fuel*", the fuel must be treated with an effective **Wax Dispersing Additive** (**WDA™**) product that will **(1)** create a very small wax crystal when they form, **(2)** disperse the paraffin wax crystals throughout the fuel and **(3)** prevent their precipitation (settling) in all areas of the fuel delivery system.

The following photos show a base diesel fuel (left) with precipitated paraffin wax compared to the same fuel treated only with a Cold Flow Improver Additive (center) and the same diesel fuel treated with a properly formulated Multifunctional winter "*Premium Diesel Fuel*" additive.



Base Diesel Fuel (Untreated) | **Cold Flow Treated Diesel Fuel** | **Multifunctional Treated Diesel Fuel**

If the paraffin content in the diesel fuel is permitted to settle in the fuel delivery system, the engine will not perform properly during temperatures below the fuel Cloud Point and the engine will likely shut down completely. Once a diesel fuel forms solid paraffin wax crystals, the fuel cannot be made liquid again without raising the temperature of the diesel fuel (i.e. heating the diesel fuel or diluting the fuel with a warmer liquid).

What Is Really Needed - Winterization (cont)

Whether treating the diesel fuel only with a Cold Flow Improver Additive (CFPP Reducer, Pour Point Depressant, De-Icer Agent and **WDA™**) or treating the diesel fuel with a fully formulated "Multifunctional" Winter Diesel Additive (Cetane Improver, Detergent, Lubricity, Stabilizer, Corrosion Inhibitor, CFPP reducer, Pour Point Depressant, De-Icer, Deposit Modifier and **WDA™**), the additive product must include good and effective **WDA™** Wax Dispersing Additive capabilities.

What Is Really Needed - Winterization A 'Real World' Testing Approach

Research Laboratories, Inc.[2] (www.researchlaboratoriesinc.com) has developed the most realistic and completely reliable '**Real World**' test method for determining the cold weather operability of any diesel fuel. This testing procedure involves placing 2.5-gallon containers of a diesel fuel in a custom-made, electronically computer controlled (10' x 10') Cold Room and slowly lowering the fuel temperature from a selected start point to designated test temperatures over a 24-hour period of time.

The fuel samples (with temperature probes inserted) are placed on a moveable cart fitted with electric OEM diesel fuel pumps, OEM fuel filters (2µm, 5µm, 7µm and 10µm can be tested), inlet fuel filter pressure gauges and secondary containment vessels for collecting and monitoring the fuel flow through each filter at each test temperature.

Accordingly, a 'Real World' determination of fuel filter operation at low temperatures can be determined and compared for all fuels (without and with chemical additive treatments).

What Is Really Needed - Fuel Economy & Operating Efficiency

The above items and the discussions thus far all center on the operational benefits to be achieved from properly defining and sourcing a truly "*Premium Diesel Fuel*" product. While each of the comments presented attempt to clarify and qualify the advantages as real cost savings (or the reduction in operational costs), the ultimate benefits from using a truly "*Premium Diesel Fuel*" product is its positive effects on engine fuel efficiency (**Improved MPG - fuel economy**).

Unfortunately, documenting an actual fuel economy improvement in a particular diesel engine based on changing the fuel used or adding chemistry to the fuel used is perhaps the single most difficult task to complete accurately.

Although a great deal of testing has been done with numerous different diesel fuel additive chemistries claiming to "improve the fuel efficiency" and/or "increase the fuel economy" of diesel engines, the data generated often is suspect and many times not verifiable. The belief is that some of these "so called" improving chemistries have not been thoroughly tested and thus their respective advertisements are more theory than fact.

What Is Really Needed - Fuel Economy & Operating Efficiency (cont)

This is not to say that adding the right chemistries in the right concentrations cannot achieve actual MPG improvements - because, in fact, **they can**. It is correctly controlling the testing method and procedures that is the issue.

Additionally, various, so called, "*Premium Diesel Fuels*" have been put forth by petroleum refiners and fuel suppliers advertising "better fuel economy" and "improved MPG". Unfortunately, again the data generated is often sketchy and the real proof remains elusive. Again, the testing methods used to document the MPG improvement are more of a concern than the actual performance improvements achieved with the fuels.

The task of proving fuel economy improvements in a diesel vehicle is further complicated by the manner in which these tests are set up and the inability to compensate for the fact that:

(1) All diesel engines operate differently
(2) All diesel fuels are different and provide differing power/performance levels
(3) All diesel engine operators run their respective equipment differently at different times and under different conditions and power requirements.

S.A.E.[12] (Society of Automotive Engineers) in conjunction with TMC[13] (Truck Maintenance Council) has developed procedures for a specific testing program for determining fuel economy improvements (SAE J1321 / TMC RP-1102 Type II Fuel Consumption Test[14]). Unfortunately, this SAE Type II testing program cannot be applied to diesel fuel additive product evaluations because of two reasons:

First, many of the performance improvement benefits to be derived from fuel additives require use of the additive in the fuel delivery system over a long period of time (i.e. fuel injector cleanup, deposit modification, etc). However, the SAE Type II Test is conducted for a very short time period with only 50 miles driven with additive treated fuel compared to the same 50 miles driven with untreated fuel. This is an inadequate amount of time to allow the additives to do the job they have been formulated to accomplish within the diesel engine systems.

Secondly, the SAE Type II Test eliminates the biggest influence on fuel economy - the driver. If the equipment is operating properly as a result of better quality fuel or improved fuel parameters and the associated improved performance, the driver will drive appropriately and achieve optimum fuel efficiency. However, if the diesel engine is not running correctly because of poor fuel quality or uncorrected fuel attributes and physical properties issues, the driver will likely drive less appropriately and fuel economy will suffer. The SAE Type II Test is conducted with the vehicle set on cruise control at 60 mph during each of the monitored test periods.

The only real method of proving a fuel economy improvement with "*Premium Diesel Fuels*" or "*Premium Diesel Fuel Additives*" is a long-term (6 months or more), strictly monitored, data collection approach, with multiple vehicles, using Trend Line Analysis.

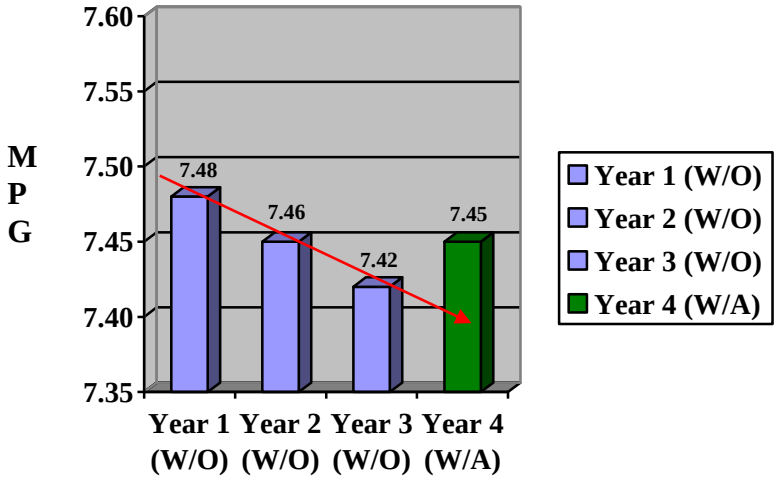
What Is Really Needed - Fuel Economy & Operating Efficiency (cont)

Trend Line Analysis for diesel equipment fuel economy is conducted by reviewing the past history of the individual diesel vehicles (engines) and plotting their respective fuel economies (efficiencies) in graphic form. Three years of data point history on the same units are required in order to determine an accurate Trend Line of the activities of the particular diesel powered units.

Once an historic Trend Line is established, the fuel economy "trends" for each vehicle can be projected into the future to predetermine which vehicles are continuing on their respective Trend Lines and which are not. This allows for easy comparison of any improved (or unimproved) fuel economies that relate to a change in the operation of the individual diesel vehicles as a result of changes in the fuel being used (or any performance additives added to the diesel fuel).

A Trend Line Analysis also permits one group/type of diesel vehicles (or a specific location of vehicles) using one particular diesel fuel or fuel additive to accurately be compared to another group/type at another location not using the same diesel fuel or fuel additive.

Four Year Trend Line Analysis of Fuel Economy



The red Trend Line for the first three years data indicates the progression of downward fuel economy that is changed by using the fuel additive in the 4th year.

The above graph is a simplified depiction of a downward vehicle fuel economy Trend Line that was projected to be 7.38 in the 4th year. While the data in the 4th year shows only an MPG increase of 4.04% over the previous 3rd year MPG, the actual fuel economy improvement with the additive treated diesel fuel based on Trend Line analysis was **+9.49%!**

The Trend Line Analysis of the four year MPG data shows that with correct chemical additive treatments in the diesel fuel the "projected" fuel economy for the unit in the 4th year increased to 7.45 from an 7.38 expected MPG (i.e. 7.45 - 7.38 divided by 7.38 = **+9.49% increased MPG**). This above referenced mileage improvement was possible only because the "right" chemical additives in the "right" concentrations were used in the diesel fuel. Anything less would not have achieved the benefits needed to generate the improved MPG.

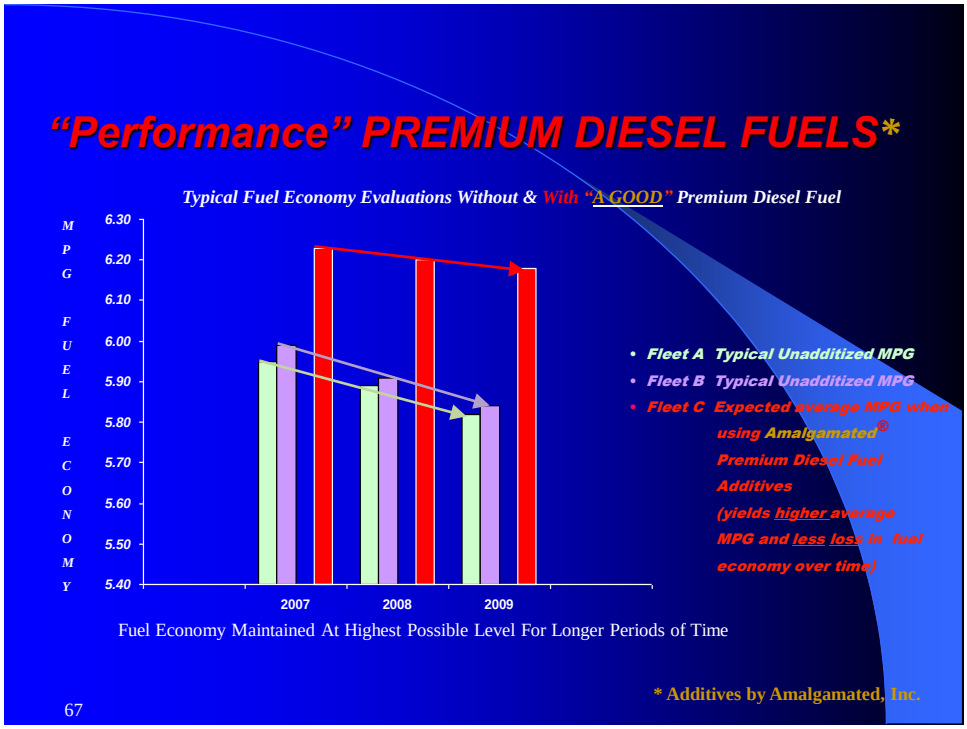
What Is Really Needed - Fuel Economy & Operating Efficiency (cont)

The following graph shows a second comparison of fuel economy Trends with three different vehicle groups from the same fleet over a three year period of time. Two of the terminal locations used regular grade ULSD fuel and one used ULSD treated with the proper chemical additivess to make the diesel fuel a truly "*Premium Diesel Fuel*".

The MPG data indicates a downward Trend in all three fleets which is typical of most fleets over time (i.e. lower fuel economy usually occurs over time unless steps are taken to improve the fuel economy from year to year).

However, in this organization, the "*Premium Diesel Fuel*" fleet shows **(1)** a downward Trend starting at a higher MPG with the better quality fuel and **(2)** a downward Trend with a less declining "slope" of the Trend Line (this indicates the MPG is declining less over time which will **prolong** the required intervals of maintenance practices to address lowering MPG in a fleet).

Three Year Trend Line Analysis of Fuel Economy



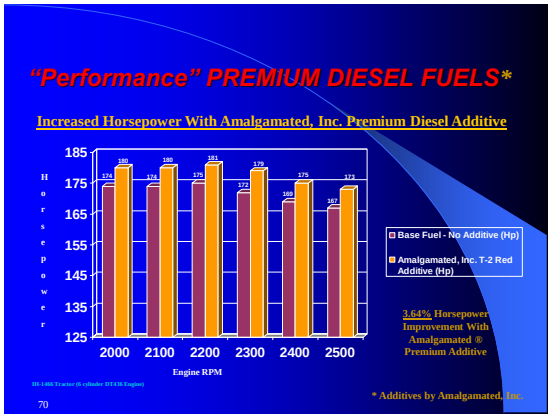
The individual Trend Lines for the three fleets' data indicates the MPG of the fleet using "Premium Diesel Fuel" is lowering at a slower rate (less line slope).

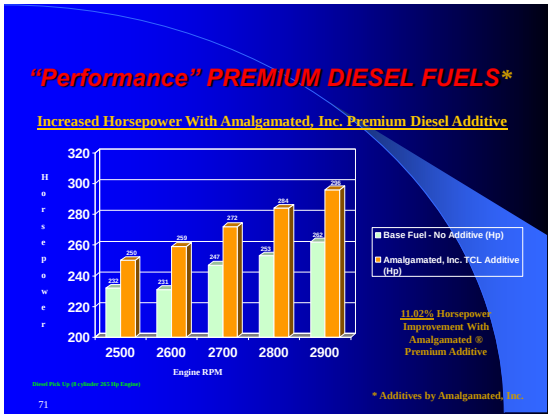
Another indication of MPG improvement with a true "*Premium Diesel Fuel*" can be demonstrated by measuring the BHP (brake horsepower) produced from a given amount of diesel fuel. If a diesel engine produces added brake horsepower using a "*Premium Diesel Fuel*" compared to a regular grade diesel fuel, then the engine will use less diesel fuel to pull the load over the same number of miles traveled (i.e. **Improved fuel economy - MPG**).

What Is Really Needed - Fuel Economy & Operating Efficiency (cont)

The following two graphs show increased BHP at each engine RPM (revolutions per minute) tested when using a good "*Premium Diesel Fuel*" product.

Brake Horsepower Production at Varying Engine RPM

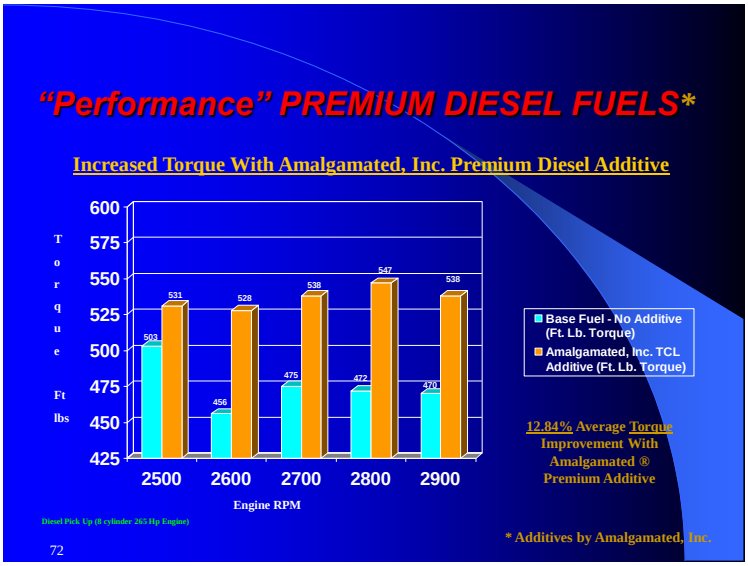




BHP increases = Better MPG (less diesel fuel required to travel the same distance)

Another indication of improved fuel economy is the measurement of engine torque. Torque relates to the power generated by the engine at a given engine RPM setting and this directly relates to fuel consumption. If the engine torque is increased, the required diesel fuel consumed to pull a given load will be less. Again, this will show up as improved fuel economy - MPG. The following graph shows the engine torque increase at varying engine RPM levels in the same engine using a properly treated "*Premium Diesel Fuel*" compared to a regular grade diesel fuel.

Engine Torque vs RPM With and Without "*Premium Diesel Fuel*"

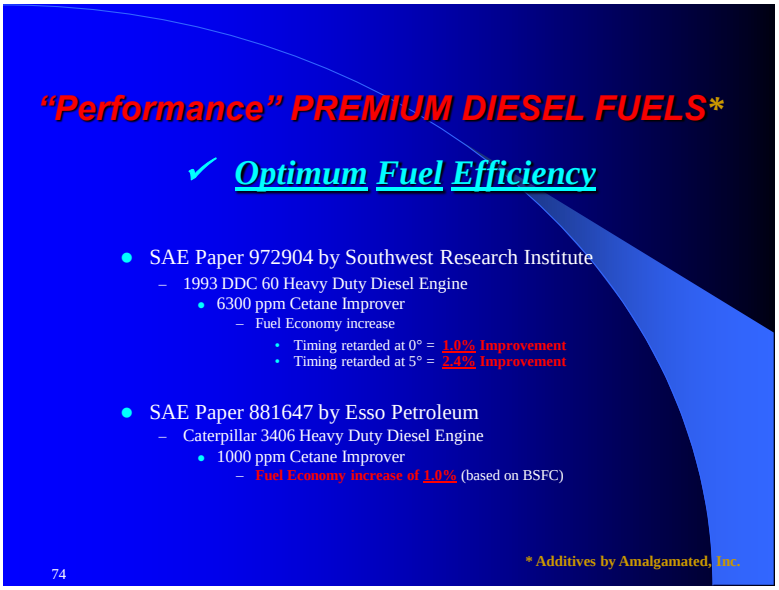


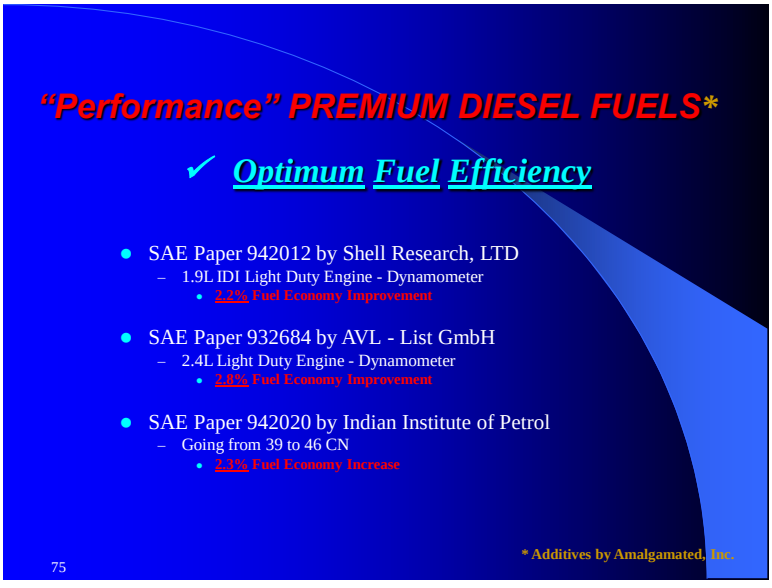
Increased Engine Torque = Improved MPG

What Is Really Needed - Fuel Economy & Operating Efficiency (cont)

As indicated previously, increasing the Engine Cetane Number will improve combustibility (burning quality) of a diesel fuel. If the combustibility of a diesel fuel is improved, we can expect a corresponding improvement in the engine fuel efficiency - improved MPG.

Numerous SAE papers have been written supporting improved fuel economy (1 - 3%) with higher diesel fuel Engine Cetane Numbers.





What Is Really Needed - CONCLUSIONS

The synergistic effects created by adding the right "*Premium Diesel Fuel Chemical Additives*" into a good quality base diesel fuel in order to make a truly "*Premium Diesel Fuel*" **will** optimize the performance potential of that diesel fuel in any diesel engine application. And, if optimization is the goal, then the many parts contributing to this synergism **CAN** be dealt with if the fuel maker or the fuel user takes the time to acquire the right chemical additives.

Unfortunately, the opportunity in today's world of acquiring a truly "*Premium Diesel Fuel*" from the fuel producers is virtually nil. Accordingly, the burden of upgrading the diesel fuel into a really "*Premium Diesel Fuel*" is left to the fuel supplier or the fuel user to accomplish.

But, is it worth the effort and the extra cost? The answer to this question is simply - "**YES**".

If, the diesel fuel to be used contains the right upgrade additives in right concentrations to correct all of the diesel fuel's potential shortcomings and eliminate all of the operational issues noted in this article, then the "*Premium*" to be paid **is more than worth the extra cost** due to fewer maintenance issues, expanded regular maintenance intervals, better fuel efficiency/MPG and etc.

On the other hand, if the "*Premium Diesel Fuel*" (or "*Premium Diesel Fuel Additive*") is nothing more than "*marketing fluff*" and "*exaggerated advertising claims*" with no real substance or proof, then the money spent is wasted. As always, the consumer must do his homework and diligently research the fuel provider and the fuel additive supplier and challenge them to provide solid technology and documentation of the products they want to sell.

But, ultimately, the fuel user MUST conduct his own testing of the "*Premium Diesel Fuel*" product (or the "*Premium Diesel Fuel Additive*" upgrade chemicals) in order to verify that the upgrade diesel fuel provides the benefits desired in his own application.

Once this effort is made and the right chemical treatments are acquired and applied as directed, then the performance benefits will more than pay for the costs incurred to make the regular grade diesel fuel into a truly "*Premium Diesel Fuel*".

The fuel user will recoup the extra cost in multiple short-term and long-term maintenance benefits plus realize optimum fuel efficiency from each and every gallon of diesel fuel consumed. That is the ultimate benefit from using a really "*Premium Diesel Fuel*".

Then, and only then, **Premium Diesel Fuel "IS" Worth "Much More" Than The Extra Cost !**

Authored by: Gary Pipenger

APPENDEX - Footnotes

[1] **Webster's Collegiate Dictionary 2009**

[2] **Research Laboratories, Inc., 6209 Discount Drive, Fort Wayne, Indiana 46818 (260-489-2551)**

[3] **ASTM - American Society for Testing of Materials**

[4] **ASTM - D-975 Specification from D02 Committee, ASTM Book of Standards Sec 5, Vol 05.01, 2010**

[5] **ASTM - D-2274 Specification from D02 Committee, ASTM Book of Standards, Sec 5, Vol 05.01, 2010**

[6] **ASTM - D-5304 Specification from D02 Committee, ASTM Book of Standards, Sec 5, Vol 05.02, 2009**

[7] **ASTM - D-4625 Specification from D02 Committee, ASTM Book of Standards, Sec 5, Vol 05.02, 2009**

[8] **E.I.duPont de Nemours and Company, Wilmington, DE USA (302-774-1000)**

[9] **ASTM - D-6371 Specification from D02 Committee, ASTM Book of Standards, Sec 5, Vol 05.03, 2009**

[10] **ASTM - D-5771 Specification from D02 Committee, ASTM Book of Standards, Sec 5, Vol 05.03, 2009**

[11] **ASTM - D-4539 Specification from D02 Committee, ASTM Book of Standards, Sec 5, Vol 05.03, 2009**

[12] **S.A.E. Society of Automotive Engineers**

[13] **TMC Truck Maintenance Council**

[14] **S.A.E. J1321 / TMC RP-1102 Type II fuel Consumption Test**