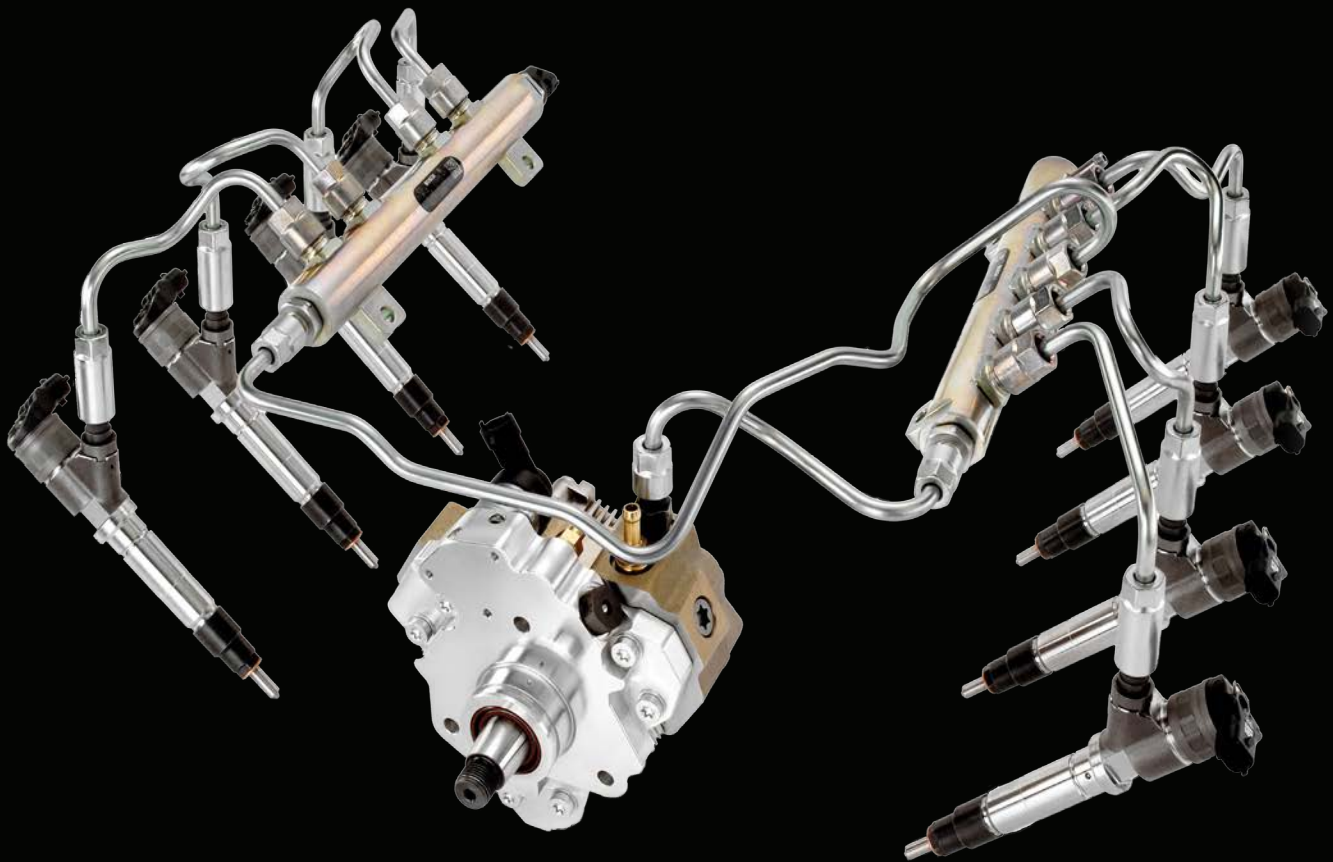


FASS[®]
Diesel Fuel Systems



SERVICE TOPIC

FUEL CONTAMINANTS

THIS IS THE BEGINNING OF ARTICLES DIGGING IN PERTAINING TO FUEL CO DEBRIS, AIR, VAPOR & WA AFFECTS ON THE DIESEL

Most of us understand how debris and water are introduced into the fuel; however

Do we completely understand how air and vapor enter a closed system?

Do we realize the negative impact they have on our diesel engines?

How does this affect my bottom line?

How will a FASS system provide more dependability & improve our bottom line?

How does FASS legitimately make the claims?

If it is so good why don't the engine manufacturers use it?



OF A SERIES TO THE PHYSICS CONTAMINANTS SUCH AS WATER AND THEIR ENGINE.

• **These questions and many more** will be answered throughout this series. We'll be covering all of the sources that introduce air & vapor into today's fuels and the negative impact they have on your bottom line (your pocket book). We will explain how a FASS system prolongs injector life, provides peace of mind, improves dependability, and may even surprise you with increased engine performance. We will also explain how our FASS system will decrease your maintenance cost (operation cost per mile) providing increased profitability.

The term "Engine Performance" will be used throughout this series. Many think of engine performance as pure raw

horsepower & torque. We certainly associate horsepower and torque as a measurement of performance. In the "Real World" of rising fuel and maintenance costs, EPA (emissions), life of engine components, throttle response and engine noise, we discover a virtual yard stick for measuring true engine performance.

Throughout this article, we'll be referencing documents from manufacturers such as Bosch, Caterpillar, Cummins, Detroit Diesel & Racor/ Parker just to name a few. We'll be covering their findings on how air & vapor develop and how it affects the dependability of your injectors and engine performance.

FIRST

let's identify the source of air and vapor, then we'll cover such areas as dependability & engine performance. Cummins Service Topic 5-135 does an excellent job identifying this. "The source of the vapor is the fuel itself. Much like water, fuel contains a certain amount of dissolved air, depending upon the fuel temperature, pressure on the fuel, specific gravity and the amount of aeration to which the fuel has been subjected". "Specific gravity" meaning the degree of vacuum applied to the fuel. Caterpillar Special Instruction 651-1250 states: "Normally No. 2 Diesel Fuel contains about 10% air in solution, although the air is not visible."

BREAKING DOWN THE INFORMATION JUST REVIEWED, OBTAINING OPTIMUM FUEL CONDITIONS WOULD REQUIRE THE FOLLOWING:

**POSITIVE PRESSURE
ON THE FUEL**

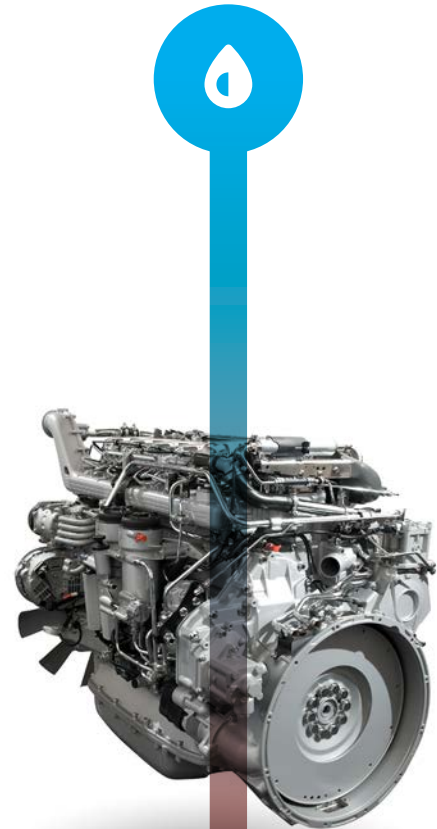
**A STATIONARY
FUEL TANK**

COOL FUEL

LOW ALTITUDE

MANUFACTURES TEST CELL

**AN ELEVATED
STATIONARY FUEL TANK
WITH COOL FUEL**



**A SEPARATE FUEL TANK
RECEIVING THE HOT AERATED
RETURN FUEL**

OPTIMAL FUEL CONDITIONS



THE FACTS:

TEST CELL VS. REAL WORLD CONDITIONS

1

In the “Test Cell”, the fuel tank is usually at least 10 feet above the engine vs. the “Real World” of at least 2 feet below and separated from the engine by at least another 5 feet.

Positive Flow vs. Vacuum: The boiling point of liquid, in our case diesel fuel, is directly related to the “specific gravity” (vacuum) in which it is subjected to. As fuel is subjected to any kind of vacuum, vapor will be produced. As fuel is subjected to various degrees of “Specific Gravity” (vacuum), vapors will be produced in various amounts. Engine performance is deteriorated as a result. An example of this, and routinely overlooked, is a dirty fuel filter, which increases vacuum, thus, increasing the vapor being produced. Real Life Example: Your engine performs best with clean fuel filters. They restrict little by little, while engine performance deteriorates little by little. Remember the measurements of engine performance we previously talked about! Once the filter reaches a point of restriction, to where the engine’s maintenance guide indicates changing or when you will no longer tolerate the lack of performance, you’ll change the filter, gaining back the lost performance. Up until this point, performance is constantly deteriorating with each mile. You now have a clean fuel filter, your performance is back and your engine is running more efficiently. What if you had the positive flow of fuel like that of the engine in the manufacturers test cell? You gained pressure when reducing vacuum from a restricted dirty filter to a restricted clean filter. Yes! Even with a clean filter, flow is restricted. Wouldn’t you gain again when totally removing all restriction?

Did you know that every 90° fuel line fitting is worth about 13 feet of fuel line restriction? This is why, without a FASS, you should be using mandrel bend fittings. A 90° or “T” fitting introduces what is referred to as a “Liquid Eddy Current”. A liquid eddy creates a restriction, while introducing more entrained air & vapor. Speaking of fuel line, when the inside diameter is doubled, the flow is quadrupled. Manufacturers have reduced the amount of air & vapor by simply enlarging the size of fuel line along with fuel filters.

2

Stationary vs. fuel tank subjected to agitation.

Stationary vs. fuel tanks subjected to agitation: Fuel agitation is the major cause of air in fuel. This is one reason why the diesel engine performs better after the truck has been sitting for some time. Have you ever noticed how much smoother, stronger, quieter your engine feels after sitting, compared to other times when in operation for hours upon hours? Studies have shown the amount of entrained air in fuel after 1 ½ hours of traveling is equivalent to the vapor being produced from a filter with 11.5 inches of vacuum/restriction! Most engine manufacturers “DO NOT” want to experience more than approximately 7 inches of restriction.



The manufacturers test cell fuel “supply” tank never experiences the hot aerated fuel as there is a separate collection tank vs. the “supplying” fuel tank receiving the hot aerated fuel.

There are 2 areas of concern related to this 1 condition:
 1st - Hot Fuel: As liquid is heated, several phenomena occur. The fuel expands, becoming thinner. Previously, we discovered the boiling point of liquid changes with “specific gravity”. It is the same with the viscosity of liquid. The thinner (less viscose) liquid becomes, the lower the boiling point. The Milwaukee School of Engineering states “The viscosity of an oil is highly dependent upon its temperature. The viscosity of an oil drops dramatically as its temperature increases.” Oils viscosity is cut in half for every 20° in increased temperature.” In short, this compounds the issue with a restricted filter, making it easier to increase the amount of vapor being created. It may be hard to grasp the boiling of liquid at ambient temperatures or even that of fuel temperatures nearing engine temperature. Here are some examples to clarify this condition: Watch an air bubble escape from a scuba-divers tank. As that pressure decreases, while rising to the surface, the bubble increases in size due to the lack of pressure. Now compare this to the “Specific Pressure” of space. In space your blood will boil without the application of pressure.



Hopefully, we now have a better understanding of where and what conditions contribute to the varying degrees, regarding the amount of air & vapor in fuel. Did you know there is a popular term for this condition? “Fuel Starvation” The term fuel starvation is heavily used in the diesel market when it comes to the performance of a diesel engine. Most people think of it as an absence of fuel, giving it no more thought. The truth is, the absence of fuel means the introduction of air &/or vapor!

A specific function of fuel is to provide “Lubrication” and “Fluid Dampening” to the fuel injection system.

Fuel starvation (air & vapor) drastically affect these functions in a negative way. With the evolution of the diesel engine improving from yesterday’s engines to today’s high technological high output engines, these functions are in much greater demand, as you will see.

MSOE, Milwaukee School of Engineering, a premier school in hydraulics, estimates “75 to 85 percent of hydraulic system failures are a direct result of fluid contamination.” They also state, “Probably the most destructive fluid contaminant is “Air”.”

You may ask yourself why we are comparing hydraulics to fuel injection systems? The 2 are very similar, as they both contain pumps, valves & actuators with other components related to their specific field.

Yesterday’s diesel engines had much lower injection pressures compared to today’s diesel engines. Some of those injection pressures were as low as 2,000psi. You may be saying to yourself this seems pretty high, and it would be if your foot was subjected to this pressure. If this was the case, your foot would be about as thick as a piece of paper. But in the fuel injection world this is now extremely low. Today’s injections pressures reach as high as 30,000psi with some even pushing 40,000psi! This is an increase of at least 15X’s the injection pressure of today’s vs. yesterday’s injection system.

SERVICE TOPIC: FUEL CONTAMINANTS

Just to give you an idea of the extreme pressure this represents, water jet cutters generate between 30,000 – 90,000psi, which enables them to slice through various metals and rock, including granite.

To reach these extremely high fuel injection pressures, many fuel injection systems have been dramatically improved or new systems have been designed from the ground up, incorporating extremely tight tolerances to achieve these pressures. Many of yesterday's engines required the fuel to travel through a 10 – 20 micron final fuel filter before entering the engine. Today's injectors & fuel injection components would prematurely fail with "old" filtration specifications. Fuel filter specifications have tightened by at least 3X's, with specs ranging from 3 – 5 micron ratings. These tight ratings directly relate to the tight tolerances of today's injection systems.

Manufacturers of engine filters have made improvements in removing debris and water, thus improving the expected service life of an injector and associated components. However, situations still exist that actually increase the amount of air and vapor being introduced into your engine, thus decreasing injector life.

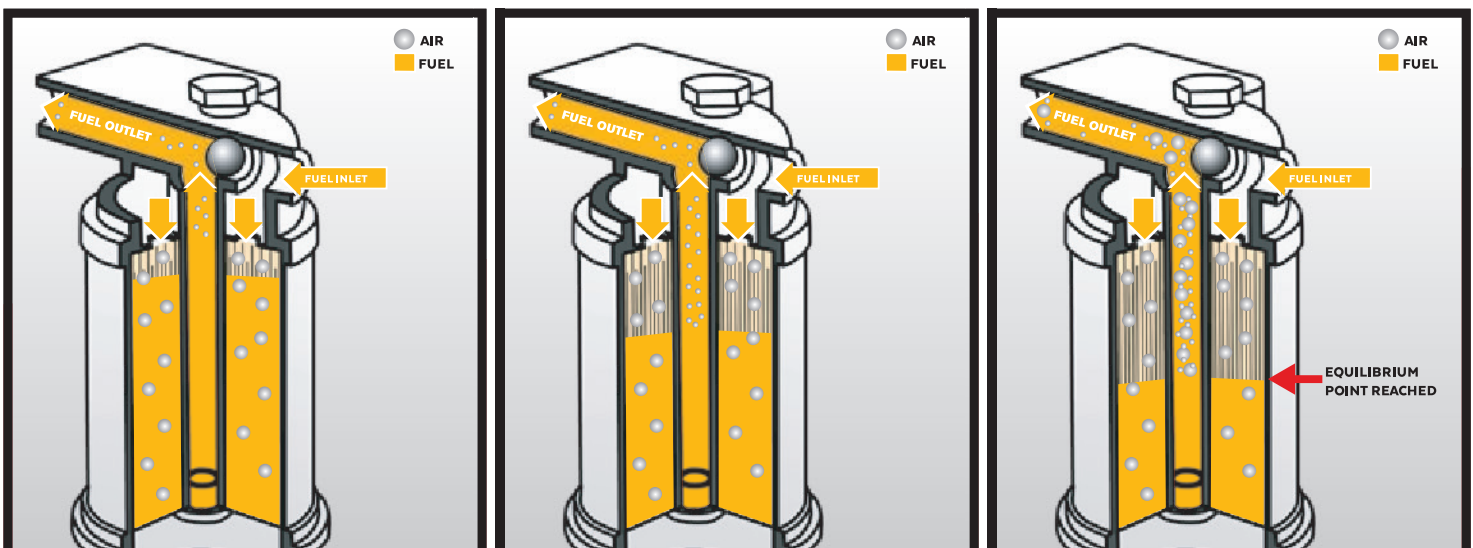
"Fuel Starvation", air & vapor, steals lubricating properties of fuel to the injection system.

Fuel creates a barrier between the metal surfaces, like oil creates a barrier between the connecting rods and the crank shaft. Whenever there is a lack of lubrication, i.e. air & vapor, galling and scoring will occur from metal to metal contact. Some metal to metal contact will completely seize the operation of that component. Have you ever heard of a hung plunger? Lack of lubrication is the major cause of this situation.

However, galling and scoring of the barrel & plunger typically will not hang a plunger. It will typically operate over a period of time causing the tight tolerances to erode, opening up the tolerances. This will create a situation many of us call "Blow-By". This is where fuel is blowing back up between the barrel and plunger instead of out the tip of the injector into the combustion chamber, thus losing efficiency of that injection & powerstroke. Fuel mileage, horsepower, cold starts and emissions are some of the performances that deteriorate over time that will cost you money. This deterioration will affect performance until that injector completely fails and you must be towed in or limp into a service repair shop. Where will you be, what will you be hauling, where were you supposed to be when this happened? How could this have been prevented?

Solid fuel, free of debris, water and fuel starvation (air & vapor) will increase fuel lubricity throughout your entire fuel system. Remember, we've covered only the fuel injectors! We didn't cover the fuel pump, actuators, valves & other vital components.

"Fuel Starvation", air & vapor, steals the "Fluid Dampening" of fuel from the injector tip. As the injector plunger (Referred to as the check by Caterpillar) compresses the fuel, the fuel dampens the impact between the plunger tip and housing. Caterpillar states, "Fluid trapped between the tip and the check at the end of the injection acts as a shock absorber, minimizing check impact." Caterpillar then states, "An air bubble in the tip provides no fluid dampening, allowing the check to impact the tip with up to 50% greater force. Over time this dramatically increased load may cause a fatigue crack to form in the tip, which can eventually lead to tip failure".



With the air bubble present at the point of compressing the fluid, there are now 2 conditions to be concerned with, cavitation and combustion/pre-combustion.

MSOE states, "Cavitation wear is caused by high impact pressures created when vapor and gas bubbles in a liquid violently collapse due to gross changes in fluid pressures. They go even deeper and state, "Air causes severe cavitation and can destroy a pump in a matter of minutes". These bubbles collapse with explosive force, which can actually rip small pieces of metal from the pump's housing and wear plates causing increased leakage. The higher the vacuum at the pumps suction port, the greater the chance that cavitation will occur. Therefore, the inlet vacuum should be reduced as much as possible by removing any restrictions in the suction line."

At times the injector cup will have the correct mixture of air & fuel for combustion in the injector. This combustion will occur when the plunger applies the pressure to inject the fuel into the cylinder. Think about it, this is exactly what happens in the cylinder of the engine: As the piston is coming up for the powerstroke, fuel and air are added to the cylinder. When the proper amount of pressure is applied to the fuel & air, combustion takes place. With the information you have now gathered, the injector can be the perfect place for combustion.

As this "Pre-Combustion" takes place within the injector tip, the injector housing is now subjected to an "Acetylene Torch" affect. This affect is actually eroding the orifices of the injector, little by little. This will weaken the injector housing along with opening up the orifice which, will cause a reduction in pressure at the injector tip, reducing efficiency & performance over the duration of the injector's life. Take this "Pre-Combustion" and compound it with the increased force of up to 50% due to the lack of fluid dampening, and you can really start to understand a

major reason why injector tips are damaged. A percentage of these damaged injector tips actually separate from the injector body causing damage to pistons, valves, turbo's and other engine components.

Another very important function of the fuel is to cool the fuel injection system. This is accomplished by cooler fuel entering the fuel system from the supply tank or tanks, and distributing the heat developed from these injection components away from the injection system downstream to the supply tanks. This is one of the reasons for the "High Flow" fuel systems in today's engines. It is not uncommon to see 60 - 90gph, and more, fuel flow in today's semi class 8 engines where in the old days it was common to see flow rates in the range of 20 - 30gph for similar class engines. Please take into account the technical differences when we are trying to compare yesterday's to today's engine!

Fuel starvation is compounded, even on stock engines. Today's fuel systems may flow up to 3x more fuel than needed for combustion. The excess fuel will redistribute heat back to the supply tanks. You may be wondering why the cooling of the injection components exacerbates fuel starvation. Please go back and review Subject #3 under comparing "Test Cell vs. Real World Conditions". While you are revisiting this step keep in mind the fuel is subjected to higher levels of vacuum/restriction with the much higher flow rates while the fuel is continually thinning from the distribution of the heat developed in the injection system and transported to the fuel tanks. After reviewing this, it is easy to understand how fuel starvation (air/vapor) is increased with these conditions.

"FUEL STARVATION", AIR & VAPOR, STEALS LUBRICATING PROPERTIES OF FUEL TO THE INJECTION SYSTEM.

SERVICE TOPIC: FUEL CONTAMINANTS

The return fuel from the fuel system is to the fuel system as coolant from a radiator is to an engine, in regards to cooling. If you were to restrict or stop the flow of coolant in any combustion engine, it would amass excess heat. The same would be evident in an injection system. What are examples of interruption? It could be as simple as a collapsing/deteriorating fuel line, or a clogged fuel vent or another system introducing more fuel in the same return line. If the factory supply cannot maintain the correct pressures to return the fuel it will also amass heat. Injection pumps are supplied with fuel at certain pressures to open a preset return valve. Providing less than this preset pressure will cause the return valve to close, thus reducing the amount of cooling. This can lead to cavitation and cavitation creates massive amounts of heat. For example, racing boats can melt aluminum propellers in 50 degree water if they cavitate too much during a race. With this, the heat is not transferred properly thus causing severe damage to injection system components! Remember what Milwaukee School of Engineering states, "Oil's viscosity is cut in half for every 20° in increased temperature."

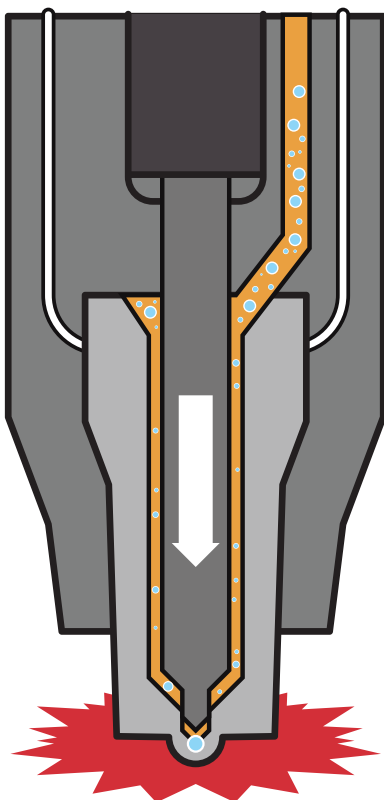
As we review this information keep in mind that these conditions lead to and increase fuel starvation. These conditions are never experienced in the manufactures test cell as ideal/optimum conditions are preserved for ideal/optimum engine performance.





Now, there are a few ways to add "Efficient" horsepower that will not add to the "Fuel Starvation" over OEM settings. However, most consumers/ performance shops will 1st add a device to enhance/modify the engines ECM (computer), this may be in the form of a downloader, a reprogrammed ECM or an external box that modifies the signals from the stock ECM. Injectors are usually added shortly after, thus demanding even more fuel. These devices work extremely well when proper preparation are 1st performed. Proper preparations will include correct fuel delivery and possible exhaust and air intake modifications to mention just a few.

These software & injector enhancements will immediately require more fuel flow, leading to the increased harmful effects of fuel starvation. An easy way to see what is actually experienced in the way of fuel starvation is to install fuel pressure gauges. Some loss of fuel pressure is typically experienced immediately as demands for horsepower increase.

This can (and usually does) mean that there is an immediate reduction in lubricity and cooling. So far we have only been discussing OEM (stock-rated) horsepower engines and how fuel starvation is developed. There is a way to immediately rob your fuel injection system components/injectors of the fuel lubricity and fluid dampening functions of the fuel, "Add Horsepower"!

Note: There are many benefits to adding horsepower when the horsepower is added "Properly"!



-  Acts as **shock absorber**
-  **Prevents** the cutting torch effect
-  Increases **Lubricity**
-  Prevents ***Galling Effect** by increasing lubrication

*Galling occurs frequently whenever metal surfaces are in contact, sliding against each other, especially with poor lubrication.

Please note: A FASS System will NOT fix an already bad injector.

*An air bubble in the tip provides no fluid damping, allowing the plunger to impact the tip with up to 50% greater force, resulting in damage to the tip and injector.**

*** According to Caterpillar**



SERVICE TOPIC: FUEL CONTAMINANTS

Many improvements added to a diesel engine are installed in hopes of greater performance. However, before you improve upon anything, you must first address what is inadequate. If you wanted to make a building larger, you would have to improve or enhance the foundation. On diesel engines it comes down to air flow and fuel supply. Many truck owners will buy what is called the “trifecta”. This consists of air intake, exhaust, and a tuner. The user would immediately experience an enhanced feel in the vehicle. However if we were to truly make a great foundation for reliable horsepower we would address what is inadequate first in the hopes that all the other modifications work as designed.

As you study the FASS Fuel System by way of a brochure, website or other means it is easy to see how the FASS addresses the subject, “Fuel Starvation”. The FASS is basically delivering to the fuel injection system “Test Cell” condition fuel while working in the “Real World”. We’ll dig into the FASS System later in the series, If you have questions or comments regarding fuel starvation you can email them to techsupport@fassride.com.

Now we are going to move on to engine performance, specifically horsepower/torque and more importantly to most of us “Fuel Mileage”. 1st lets understand why fuel injection was engineered:
“to deliver a predetermined amount of fuel at a predetermined time”.

In the test cell this is accomplished, in the real working world it isn’t without a FASS. The engines performance output is directly affected by how much fuel is injected and at what time.

We’ve covered the source of the fuel starvation (air/vapor) from the Cummins Service Topic; we’ve covered the damaging effects fuel starvation has on fuel injection components, let’s take a step back before moving into engine performance and learn how the suction side fuel filter affects the way air/vapor enters the engine.

1st we are going to quote another area from the Cummins Service Topic 5-135 discussing how the filter passes the air/vapor, applying this information to actual performance and operations.

“Assume that we have installed a new filter filled with fuel. When we begin cranking the engine, the gear pump begins evacuating air from the fuel plumbing. Air Evacuated from the tank to filter plumbing passes through the paper at the extreme top. The filter remains full of fuel. Fuel rises from the supply tank as the vacuum increases. Fuel begins entering the filter and begins passing through the paper. At this point, the filter is full of fuel on both sides of the paper. When fuel begins passing through the paper at the top where air was formerly passing, the phenomenon of resistance to air-vapor flow becomes evident. Air-vapor which is released from the fuel due to vacuum are prevented from passing through the paper. As this vapor accumulates, it displaces fuel on the dirty side of the paper and the fuel level drops slowly. While the vapor cavity is increasing in volume, more fuel is being discharged from the filter than is entering. The fuel level on the dirty side drops until the equilibrium point is reached where the pressure differential across the paper is equal to the wetted paper resistance to air passage. For instance, in actual operation the absolute pressures in the filter would be as illustrated” “When the equilibrium point is reached, any further air or vapor released from the fuel or brought in with the fuel through an air leak passes through the paper immediately at the extreme top.”

This quote not only explains exactly why your suction side fuel filter is not full of fuel when it is removed it also gives reason as to why your diesel engines operate/perform inconsistently. Every engine has a troubleshooting guide from the manufacture, they cover such topics as poor fuel mileage, low horsepower, inconsistent performance, hard starts, rough idle, excessive smoke and etc. Each one of these categories have one common denominator listed – fuel restriction and/or air in fuel.

Let's review this quote and apply it to your operation. A conventional fuel filter will provide its best engine performance when it is clean and "FULL" of fuel. As the vehicle is put into operation the air created from the fuel tanks will collect on the dirty side of the fuel filter. Note: at this point your engine will be receiving some air from the center of the fuel filter, due to the simple reason the fuel is subjected to a vacuum/restriction. Your engine will perform better until the dirty side of the element has collected enough air forcing the fuel level down to its equilibrium point at which time the surplus of air, entering the filter, will start passing through to the engine. Up until the point of which the equilibrium point is reached there is less air entering your engine, thus providing better engine performance. Once that equilibrium point is reached engine performance will drop significantly.

Now here is a test for anyone with a suction side filter application: 1st fill up your suction side filter. Operate the vehicle until you notice the performance dropping, laboring more to do the same job as earlier in the day. When you notice this performance drop, take the necessary steps to fill the fuel filter. You will notice the engine performance increase. This is due to the surplus air collecting on the dirty side of the filter element; this surplus will begin to pass to the engine once the equilibrium point is reached again. Preventing this performance robbing occurrence is only one of the advantages of the FASS. Another small FASS advantage, no need to stop, top off the fuel filter nor dirty your hands.

Referencing the two quotes directly from Cummins has provided a clear understanding why there is less fuel starvation when the vehicle has been at rest for some time, allowing the fuel to not only cool down but to also de-aerate. Accompany this with a brand new "FULL" fuel filter and there will be less fuel starvation than compared to a vehicle in motion for some time.

Perhaps we are now aware of the inconsistent performance that you have experienced from your diesel engine and the direct affect that air/vapor developed in the fuel filter has created.

Now the air/fuel starvation is passed to the engine and into a rail leading to an injector. Does all of this air travel to an injector, the answer is no. Not "ALL" the air travels to the injectors as some of the air travels with the return fuel back to the fuel tank. But now here is the twist. Typically all of the return fuel on older diesel engines is returned 100% back to the fuel tank. Now, many of today's diesel engines return only a small percentage of fuel back to the fuel tank. Let's take the Volvo VED engine for example. Only 3% of the fuel will return back to the fuel tank. That engine is recycling 97% of old fuel back in with the fresh fuel! Normally recycling is very healthy, not in this case. Recirculating the return fuel in this manner increases the amount of air/fuel starvation to the injection system along with the damaging effects of heated fuel.

In this type of configuration the return fuel must be re-routed to the fuel tanks to realize the full benefit of a FASS. Let me explain: earlier in this series we discussed how "Liquid Eddy Currents" occur at paths that have a "T" intersection or a sharp 90°s. When the fuel is subjected to these turbulent paths air/vapor/fuel starvation is created.

These turbulent paths are throughout the injection system, so there would be a reintroduction of air to the engine if this return system was not re-routed. These type of engines require a little more hardware and installation time to install a FASS, but there are typically larger benefits. For example, according to our FASS customers in the Class 8 Market with factory engines returning 100% of the fuel back to the fuel tanks, experience a solid increase of .4mpg. Now the FASS customers with the Volvo VED or the Mercedes MBE 4000 typically start at a solid .6mpg increase. While we are discussing fuel mileage many of our conservative customers operating pickup see about 80 -90 more mile per tank of fuel.

SERVICE TOPIC: FUEL CONTAMINANTS

In reviewing the documentation from “Major Corporations” we should agree there is normally at least 3 - 10% air present in the fuel. This doesn't take into account the “Real World” dynamics that produce and increase air/vapor like agitation & vacuum to name just a couple. To be conservative, take the 3 - 10% rule, which we truly believe is safe to say that FASS customers have increased the lubricity to their injection system by at least 3 - 10%. If we take into account the “Real World” working environment, agitation, vacuum, heated fuel & etc., it is safe to say that FASS will increase your lubricity by at least 10%. With this increased lubricity provided from the FASS System, fuel is now properly creating the protective barrier between the injector components as intended and designed by the manufacturer. Now there will be fewer tendencies for metal to metal contact thus less galling & scoring. Remember, it is this metal to metal contact that creates blow-by, seized or hung barrel and plungers & other damage to injection components, causing premature failure.

In addition to increasing lubricity to the injectors, the FASS is increasing the fluid dampening at the check of the injector. Caterpillar states, “An air bubble in the tip provides no fluid dampening, allowing the check to impact the tip with up to 50% greater force. Over time this dramatically increased load may cause a fatigue crack to form in the tip, which can eventually lead to tip failure”.

Now that we have covered how the FASS System can dramatically increase the life of the fuel injection system it is time to move to fuel mileage and horsepower.

Horsepower and fuel mileage work with one another so we will be covering them in tandem. If you change the amount of fuel being delivered, you change the performance. Change the timing of the fuel delivery, change the performance. Fuel injection was developed to increase performance of the engine. One of the ways this is accomplished is by injecting a precise amount of fuel at a predetermined time. The amount of fuel being delivered is just as important as when the fuel is delivered, as both influence the performance of the engine. When air infiltrates the fuel system, fuel volume is obviously decreased, which generates the damaging effects of fuel starvation. Considering all the dynamics that introduce air into the injection system during “Real World” operations, it is important that we now understand how the regulated amount of fuel is affected by infiltrated amount of air in the injection system.

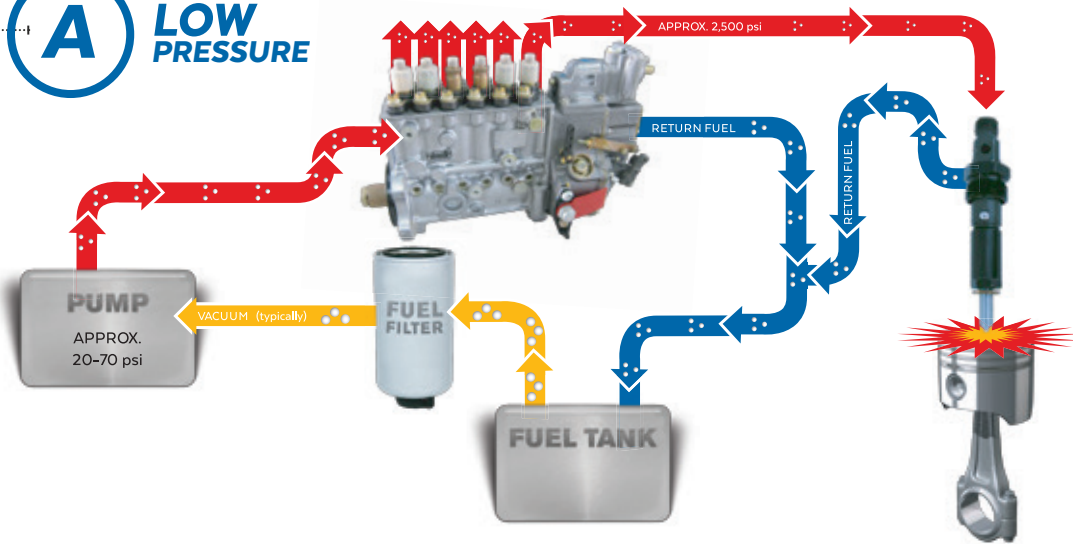
Fuel pressure will influence the size of the air bubble, thus influencing the space available/volume for fuel. The lower the pressure to which the air bubble is subjected to, the larger the bubble will be. As the pressure rises, the air bubble will reduce in size. An air bubble increases in size as it rises from the depths of a scuba divers tank when it surfaces. This is due to the pressure reduction on the air bubble.

We believe this is one of two reasons why engine manufactures are dramatically increasing the fuel pressures of today's diesel engines. Fuel pressure increases the effects air has on engine performance and damage is reduced as lubricity to the components is increased. Referring back to the diagrams and their claims: Keep in mind both examples are with conservative drivers looking for fuel mileage and hauling up to 80,000lb loads. Loads weighing over 80,000lbs will receive less mpg gain but the percentage of increase is typically the same. Typical fuel mileage gains are in the area of 6 - 12%. Pickup trucks traveling empty typically see 80 - 90 more miles to a tank of fuel but when hauling loads a safe rule of thumb is the same as the class 8 trucks, 6 - 12%.

In comparing the performances gained by the removal of air, you can see the affects air/vapor/fuel starvation has on systems with low and high fuel pressures, which in part relates to the volume of air/fuel in the injector tip. Lower pressure systems will have larger/more apparent air bubbles in the lines at approximately 2,500psi than that of the higher pressure systems at approximately 30,000psi. This variance will affect the amount of fuel injected and when it is injected. Simply, a larger air bubble under less pressure will affect those dynamics more than that of a smaller air bubble under more pressure.

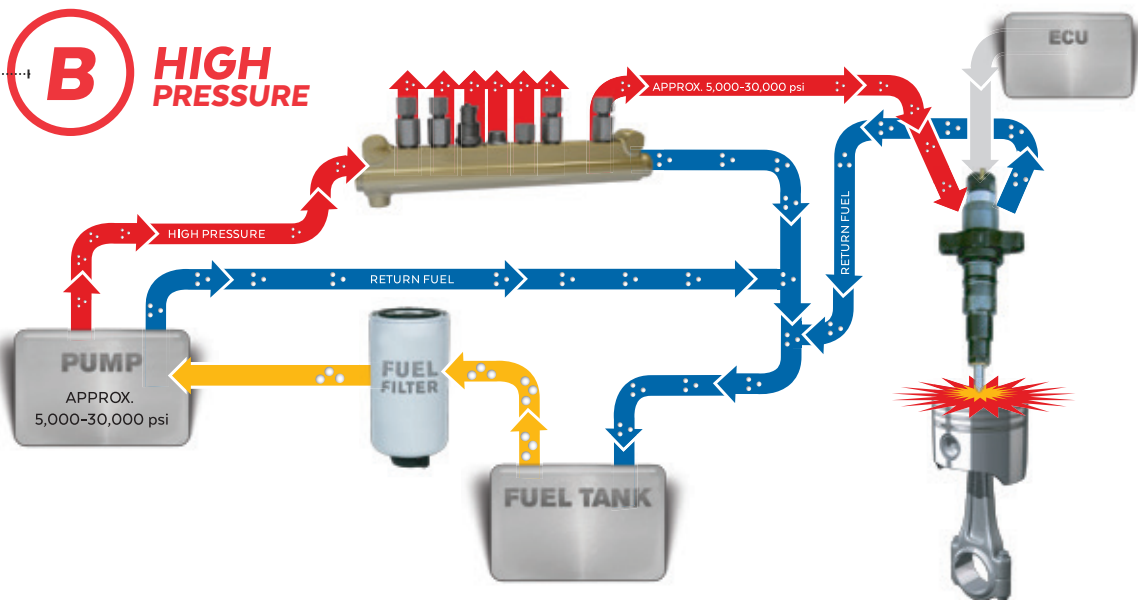
COMPARISON OF SYSTEMS LOW PRESSURE VS HIGH PRESSURE

A LOW PRESSURE



On Caterpillar A, B or mechanical C engines or similar engines with barrel and plunger (P-pump) type fuel systems, FASS customers typically experienced an increase of **.7-.9mpg (up to 80,000lbs loads, less on heavier loads) and 2 gears on the hills.**

B HIGH PRESSURE



Now on most electronic engines (higher pressure) FASS customers, conservatively experience a **.4mpg increase in fuel mile and 1 gear on the hills.** As stated earlier engines that recycle their fuel back into the fresh supply fuel like that of the Volvo VED and Mercedes MBE engines typically see a **.6mpg increase** in fuel economy.

SERVICE TOPIC: FUEL CONTAMINANTS

We just covered injectors and the importance of delivering the “Precise” amount of fuel. Now we are moving on to delivering fuel at a “Predetermined” time. What we are covering is referred to as “Rate Shaping”, the scheduling of the fuel injected. Rate shaping also covers the amount of fuel being delivered. Timing – “Predetermined Time” – of the fuel entering the cylinder has everything to do with the output of any engine. You may be curious how fuel starvation affects the timing when you have mechanical components injecting the fuel. Note: even electronic engines have mechanical components injecting the fuel. These mechanical components are simply being operated by electronic controls. Refer back to the example of a hydraulic brake system earlier in the article. You may be saying to yourself, “If there is a lack of fuel due to the presence of air, then there is less fuel to burn resulting in an increase in fuel mileage”. This simply is not the case as the engine is not working to its full efficiency thus resulting in poorer fuel mileage.

We are now at the point of directly answering why/how does this affect performance/fuel mileage.

As the pressure is increased, fuel atomization is increased. The increased atomization breaks the fuel into a finer mist providing more surface area of the fuel to burn. Air reduces the applied pressure in the injection system decreasing the finer mist to larger particles giving less surface area to burn, resulting in wasted fuel and decrease fuel mileage. Imagine a sprinkler vs. a mist sprayer. The sprinkler propels a large stream of water with larger water droplets, while spraying in a direct line, covering less surface area. A mist sprayer breaks the water down into a finer stream (fine mist) and propels fine mist more evenly over a larger surface area.

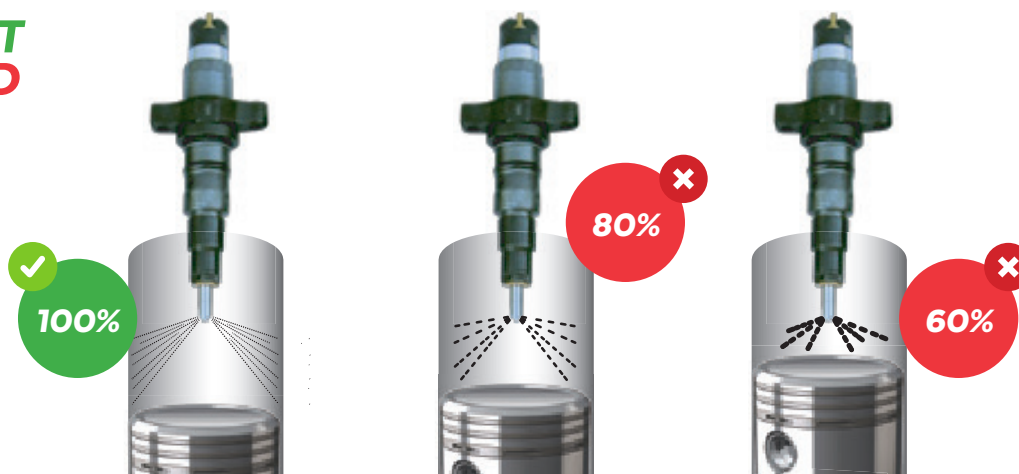
With the reduction of fuel pressure, the fuel is delayed and inconsistent, and “retarded timing” is occurring. Example of delayed injection - As the piston advances up the cylinder, cylinder pressure is increasing. This creates an increase in back pressure and cylinder temperature as the fuel enters the cylinder from the injector not only creating an uneven spray of fuel, but the fuel is not being distributed across the cylinder like that of the “Test Cell”. The shorter the time to inject fuel before combustion, the less fuel to air mixture will occur. The delay of fuel injection shortens the ignition delay, thus increasing fuel consumption. The air in the injection will cause an uneven spray/burn also affecting the fuel burn rate.

Examine the “Correct Timing” diagram with the fuel entering the cylinder at the precise predetermined time. The fuel reaches the furthest distance across the cylinder/piston due to the fact that pressure in the cylinder is reduced along with the cylinder temperatures. This condition increases the ignition delay allowing the fuel and air in the cylinder to better blend (don’t forget with solid fuel being injected the spray is more even). The higher quality blend from injecting the “Predetermined Amount” of fuel at the “Predetermined Time” will increase engine performance resulting in increased fuel mileage.

Examining the 80% diagram labeled “delayed/retarded” timing, you can see how the piston is traveling up the cylinder and the spray pattern is not reaching as far across the piston when compared to the “correct timing” diagram. The mist of fuel is not as fine either. This is due to the fact that there is not only a delay in time for the fuel to travel across the cylinder before pressure/heat ignites the fuel for combustion but there is more pressure for the fuel to travel through. This increase in pressure would be like comparing the energy it takes to travel into the wind or with the wind. It will take less energy to travel with the wind than against it, resulting in better fuel mileage.

INJECTOR TIMING

CORRECT
DELAYED



As you move on to the 60% diagram the dynamics only worsen. The ignition delay is shortened so combustion is reduced costing you more to operate.

You can clearly see the fuel mileage increases are larger with older engines than that of newer higher pressure engines. Now is the time to ask yourself at "What Cost"? In the old days of engines previously mentioned, it was not uncommon for those injectors to last over a million miles. It was not uncommon for the early model Dodge 5.9 Cummins injectors to last over half a million miles. Compared to injectors today it is not uncommon for a Duramax to go through 3 set of injectors before reaching 100,000 miles or for a Dodge or Ford to do the same. So again, ask yourself, at "What Cost"? FASS customers

might not be getting the same increases in fuel mileage as "Yesterdays" engines but they are saving more due to the fact that fuel prices have more than doubled over the years. Then add on top of fuel savings, FASS customers are saving in "Injection Components" maintenance and avoiding costly break downs.

While fuel pressures have been increasing, so has the amount of aeration and vapors (fuel starvation) being introduced into the injection system, thus offsetting the benefits of the higher fuel pressures. This is covered earlier in the series regarding the hot fuel, increased flow rates, increased vapor and aeration.



SERVICE TOPIC: **FUEL CONTAMINANTS**





FASS DIESEL FUEL SYSTEMS:

**INCREASE
LUBRICITY**

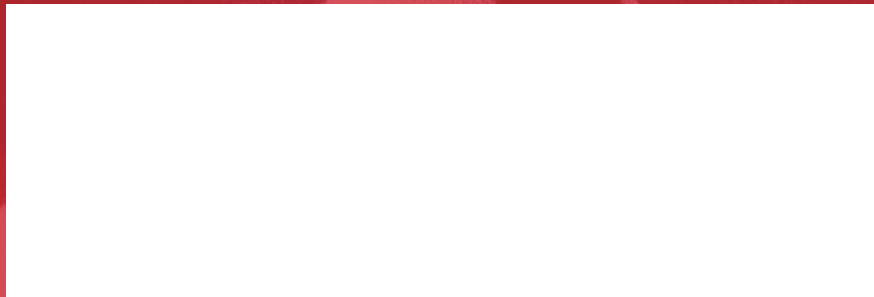
SAVE INJECTORS

**INCREASE
HORSEPOWER**

**INCREASE
FUEL MILEAGE**

**SMOOTHER
IDLE**

**EXCELLENT
COLD WEATHER STARTS**



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