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Point of Delivery Fuel Filtration (Fuel Bays, Service Islands)

1. Preamble.

Many sites around the world have installed "filter/coalescer" systems in their fuel bays as part of their strategy to improve the cleanliness of the diesel fuel being delivered to their equipment.

These systems are relatively expensive investments. Are sites receiving value for money by installing and maintaining these installations?

Our findings worldwide indicate the equipment being purchased and installed is not nearly as effective as they need to be. Most sites do not monitor the level of cleanliness of the fuel post "filter/coalescer". Where we have obtained samples and furnished the results to site personnel they too are disappointed with the outcome.

This paper discusses a number of considerations - when contemplating installing "filter/coalescer" systems at both the fuel farm and point of delivery.

2. Discussion

Why is it important that diesel fuel is "clean"? What is clean? How do we measure the cleanliness? How can we minimise the cost of installing a system?

2.1 The Importance of Clean Diesel Fuel.

The obvious and visible effect of dirty fuel is under-performing engines and blocked fuel filters resulting in downtime.

Other issues not normally considered include poor combustion, high fuel consumption, excessive wear in fuel injection systems, reduced engine component life, reduced oil life and of course excessive exhaust emissions

Given the complex design and tighter tolerances used in fuel injection systems today, the cleanliness of the fuel required is far better than in years gone by.

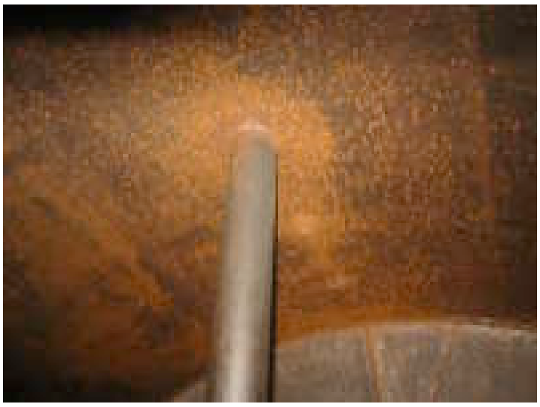
The rapid development and introduction of even more complex fuel injection systems with even tighter tolerances dictates that we will need to ensure our diesel fuel is even cleaner in the future.

A fuel company representative recently commented that some of the strategies being recommended to improve diesel fuel cleanliness were applicable to aviation fuel only and that diesel equipment did not need the same level of cleanliness. It was not their normal practice, (ie: they have never done it to date) and he considered the cost of implementation uneconomical. (maybe uneconomical for the supplier – not the end user!)

Diesel fuel injection systems have far more moving parts and are far more complex than the fuel system of a jet engine. Given the greater number of moving parts in a fuel injection system, the higher pressures and tighter tolerances, it can be reasonably argued diesel engines of today and those of the future, require even cleaner fuel than aviation equipment.

Bulk fuel installations and associated equipment (eg: filter/coalescers) require a large capital investment, but the infrastructure is expected to operate well into the future. (installations 20 to 30 years old are not uncommon).

When designing and purchasing a facility with such a long projected life span, should we not be looking towards what will be acceptable in the future, rather than what was acceptable in the past?



Interior view of a horizontal diesel fuel tank. This is a picture of the ceiling showing large amounts of rust and corrosion that will further contaminate the diesel fuel. What is the more effective, reliable and proactive option? Paint the interior of the tank with a protective coating or rely on filtration?

Should we accept what the supplier provides in the way of product and storage facilities, and then be encumbered with installing and maintaining a filter/coalescer system in an effort to provide fuel of the desired cleanliness to the equipment?

It makes far greater sense to take a more holistic approach and ensure:

a. the supplier is providing clean fuel, (regular test when receiving fuel)

b. the storage tank is sealed and has effective filter/vent/breathers (to prevent the ingression of external contaminates) (for some reason fuel facilities are always located in the most dusty part of the mine – near the stockpile etc!!)

c. a suitable internal protective coating (to prevent the formation of rust and corrosion that cause further contamination problems)

d. an effective maintenance management plan is in place to ensure accumulated water and sediment is regularly scoured from the reservoir. (including a recovery system to reclaim the diesel from the product scoured)

e. an effective filter/coalescer system installed as a secondary defence (safety barrier) against a breach in the primary means of maintaining the fuel cleanliness. (a single system should be configured so it can be utilised for incoming and outgoing fuel, transferring fuel between reservoirs and for circulating a single reservoir should it inadvertently become contaminated.)

A holistic approach will minimise the overall cost of providing clean diesel fuel. Relying on the filter/coalescer alone is an expensive approach. It is far more effective to rely on the filter/coalescer to polish the fuel, provide a safety barrier and provide a warning (premature consumption of filter elements) if a breach in other strategies occurs.

Improved diesel fuel cleanliness is required now to minimise fuel system problems.

Even cleaner diesel fuel will be required in the future.

2.2 Diesel Fuel Cleanliness (Particulate)

The quality and cleanliness of diesel fuel varies greatly around the world. Our findings indicate it can vary greatly across a single site!

Diesel can exhibit a wide variety of solid particulates such as dust, rust, sediments and oxidation products. A major and problematic contaminate often found is water.

The amount of contaminate present (either solids, water or water and solids) is traditionally measured and expressed gravimetrically. (ie: mg/litre, ppm, %)

The allowable limits (ppm, mg/ltr) documented in the many standards available around the world are very generous. (Is it because the fuel suppliers themselves formulated the standards and not the equipment manufacturers?)

For example AS3570-1998 (Australian Standard for Automotive Diesel Fuel) states:

a.	Water	% (by volume)	= 0.05 (max) using ASTM D95-IP 74
	Sediment	% (by mass)	= 0.01 (max) using ASTM 473-IP 53
b.	Water & Sediment	% (by volume)	= 0.05 (max) using ASTM 1796-IP 75 or D 2709

Using method "a" - indicates an allowable level of 500ppm of water and 100ppm of sediment (particulates).

These levels are very, very generous and do not fall in line with the levels of cleanliness we know are required to optimise the design life of components.

Sediments (fine silts and particulate that can be submicron in size) are a major problem in diesel fuel and as such gravimetric measurement is an acceptable method to quantify their presence.

Over the last few years there has been a trend towards determining the cleanliness level of diesel using ISO 4406-1999 (Hydraulic Fluid Power – Fluids – Method for coding the level of contamination by solid particles).

The traditionalists argue that this standard is inappropriate and not applicable to diesel fuel.

This standard (ISO 4406-1999), although initially developed for the hydraulic fluid power industry, is used widely across all applications of lubricated equipment to quantify the level of contamination present.

A diesel fuel injection certainly contains many of the same components and functions as that found in a hydraulic or lubrication system. There are valves, pistons, sleeves, orifices, bearings and the like just as you would find in a hydraulic system. The same principles of lubrication and wear apply in a diesel fuel injection system as that of a hydraulic system. In fact the tolerances are far tighter in many instances than a hydraulic system.

The results of fuel filter efficiency are obtained in the same manner as that of hydraulic filters. (the tests are different, but the manner of sizing and counting the particles is the same) If it is acceptable for the fuel filter efficiency to be determined by particle counting then why not determine the cleanliness of the diesel by particle counting. After all, if we want to determine the effectiveness of a single pass filter we do nothing more than "particle count" a sample of the fluid post filter.

There are mutterings within the industry that a major OEM recommends a code of ISO -/12/9 and another likewise, for diesel fuel cleanliness for their fuel injection systems.

However, gravimetric measurement cannot be abandoned entirely in favour of particle counting and reporting the cleanliness level in accordance with ISO 4406-1999. They should be used in conjunction with each other. A high level of sediment (submicron particles) may go undetected if particle counting only is conducted.

Determining the cleanliness of diesel fuel on site is easily accomplished using a “Black and White Kit” (patch kit), microscope and a comparator atlas. A high level of sediment is easily recognised by discolouration of the filter membrane (patch) through which the sample was processed.

To demonstrate just how generous the standards are regarding the maximum amount of particulate allowable, consider this:

0.09ppm (0.09 mg/lt) of ACFTD (AC fine test dust) is roughly the equivalent to ISO –/12/9. (recommended cleanliness level by 2 major OEMs)

The max level for solids (100ppm) recommended in the “Australian Diesel Fuel Standard” is some 1111 times dirtier than the requirements Caterpillar and Bosch.

We would never allow a hydraulic system to operate with such a level of solids.

If we ensured our diesel fuel cleanliness was similar to that of a hydraulic system (eg: ISO -/13/10 or ISO -/14/12) do you think it would be more reliable and long lasting?

One could be absolutely positive it will!

The claim that the cleanliness meets the “standard” (country dependant) certainly does not provide you with a guarantee that the fuel is clean.

When a representative from a fuel supplier attempts to convince you it is acceptable, process a sample using a patch kit and microscope, let him inspect it first hand and elicit his response.

No doubt he will be in a state of shock and lost for words!

This is a typical microphoto of diesel fuel. This sample was taken at the fuel bay post filter/coalescer at a mine site. (100ml of diesel, 47mm diameter membrane, 1.2 micron. Magnification 100x approx.

Thus the probable definition of clean fuel is one that exhibits a particle count in accordance with ISO 4406-1999 of ISO -/13/10 or better and contains less than 0.1 mg/ltr (ppm) of solids gravimetrically.

2.3 Fuel Cleanliness - Water.

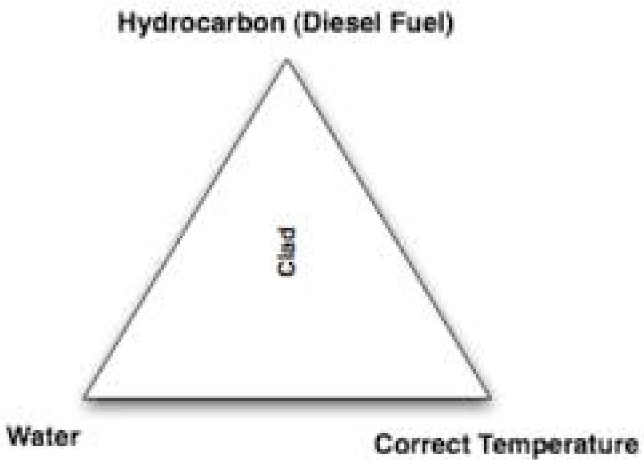
Again dismiss the level indicated in the standard. It is far too high for what we know is needed today. The water content should be as low as reasonably achievable. (ALARA)

The target water content should be well below the saturation point of the fuel. This will prevent any free water forming when the temperature drops.

Again, our fuel management and handling practices should aim to minimise the existence of water in the diesel fuel.

Water is harmful in numerous ways to fuel injection systems but perhaps the most common and obvious effect of water is the formation of Cladosporium Resinae (Clad, Diesel Bug, Black Death etc) a fungus that can exist between the fuel and water interface.

The survival of clad can be described in much the same manner as with the fire triangle.



Cladosporium Resinae is like any other fungus. It is lying dormant in the atmosphere waiting for the right conditions for it to flourish. (Anybody who has attempted home brewing of beer will be well aware of wild yeast in the atmosphere and the horrible taste after an attack on your wort – same principle applies here) Research suggests it can lay dormant for in excess of 3 years.

Like fire (oxygen, fuel and heat) removal of just one of the conditions (hydrocarbon, water or correct temperature) prevents it from flourishing.

Since the fungus is an air borne organism there is little we can do to eliminate it.

We cannot eliminate the hydrocarbon (diesel fuel) as that is the product we are storing.

It is difficult to control the temperature.

But, we can control the water. (and we want to control the water for many other reasons as well!)

Settling of reservoirs and regular scouring (draining of the free water) from the bottom of the reservoir minimises the formation of clad.

Little is to be gained by carrying out microbial testing for Clad. It is usually too late…….The organism exists naturally in the air anyway.

It is far more simple and proactive to monitor the water content in fuel as an indicator of the risk of clad.

No water – no risk of clad forming

A little water – a small risk of clad forming.

A lot of water – a big risk of clad forming.

Water being present doesn't mean you have clad. Remember all three favourable conditions must be met. All it means is that your risk is much higher. By managing the water content we are controlling the risk.

Numerous companies sell biocides for the control of clad. This really is an after the event solution. They are costly and dangerous and should be avoided. Their literature suggests their effectiveness is subject to the amount of water present anyway. That is, if you use such a product they still recommend remedial control of the water content.

Is it not more proactive and cost effective to manage the water content in the first instance? If you have an outbreak of clad, is it not safer and less costly just to drain the water more regularly ensuring the water and interfacial layer of fungus is removed? Is this not a more sensible approach than applying a biocide, killing and breaking up the fungus and distributing it throughout the fuel supply causing even more blocked filters and downtime?

Thus visual checks for free water (glass jar test) are perhaps the most effective practice for the control of water in diesel fuel. Regular scouring of reservoirs in climates where humidity is an issue is paramount.

Other simple techniques for monitoring for free water include such things as “water finding paste”. It is smeared on the volume dip tape and changes colour when it comes in contact with free water.

Traditional methods of actually measuring water content (Karl Fischer Titration etc) provide us with a mg/ltr (ppm) value. This value does not indicate if the water is in a dissolved or free state. We certainly do not want water in a free state.

To determine in what state the water exists the traditionalist needs to resort to saturation graphs and curves to calculate how the water exists. It is much easier and less expensive to measure the water saturation level directly using a water saturation meter.

The saturation level of the diesel fuel should be not more than 60 or 70% (The instruments are temperature compensated).

In terms of a mg/lt or ppm value this level is much less than the 500ppm indicated in the standard.

2.4 Filter/Coalescer Installations.

A number of variations on the theme are found.

Some sites use only a coalescer/separator predominantly for water removal.

Other sites have a combination unit with a filter first and coalescer/separator second.

It must be remembered that coalescence only removes free water. Any water in a dissolved state is invisible to the coalescing process.

A typical filter/coaleser/separator in a vertical configuration. Horizontal configurations are also available.

2.4.1 Coalescer/Separators basically consist of a set of coalescing elements first to coalesce the water into larger drops so they separate from the fuel and settle in the bottom of the vessel where it can be drained.

It may be drained off via an automatic function or manually. If it is not regularly drained the water will build up in the vessel and be carried over. The vessel itself can become a breeding ground for Cladosporium Resinae. (Clad, diesel bug, black death)

The vessel also contains a set of separator cartridges through which the diesel passes following the coalescing stage. The separator cartridge is generally constructed of a hydrophobic membrane (water repelling) to minimise any carry over water.

Coalescer/Separators in themselves provide little benefit in the removal of particulate. (particulate removal is not their primary purpose) If left unprotected (ie: without primary filtration) the coalescing elements will become blocked as will the separator cartridges.

The size of the separator cartridge is quite fine and is susceptible to blinding, and as such could be considered as providing a level of filtration. Some separator cartridges are claimed to be cleanable and reusable.

The preferred and most effective installation is one where filtration is provided prior to the coalescer/separator vessel.

Obviously, removing the particulate from the diesel fuel before it enters the coalescer/separator vessel minimises blockage of the coalescer and separator elements by particulate.

Manufacturers of this type of equipment commonly found on sites appear to be from a couple of predominant companies who also appear to be significant suppliers to the aviation industry.

Now, when one considers the high cost of these installations you would expect to see a significant improvement in the quality of the diesel fuel prior to filtration and after filtration.

Unfortunately, of all the installations around the world visited, inspected and sampled, no significant improvement has been measured!

A review of the technical specifications of products and advice offered by these companies provides some insight at to why this is so.

The efficiency or micron rating of the product supplied is nothing more than nominal. This coupled with the fact that the micron levels offered are quite coarse, especially where being used in a single pass application.

2.4.2 Are the sites wasting their time and effort?

Well, yes and no……….

Unfortunately, the site or end user never specifies the desired outcome to the supplier.

In many cases the site or end user simply has never had the exposure or gained the knowledge as to what the outcome should be, how it is measured or how it is reported.

He simply knows it is the right thing to do and relies on the representative of the equipment manufacturer for advice. Unfortunately, many representatives for this type of equipment are interested in the sale only and not the outcome. (Maybe this comment is a little cynical – maybe they too, simply do not understand what the outcome should be and how to measure it!)

Some of the recommendations made by the suppliers for this type of equipment never ceases to be a source of amazement.

A site visited recently had extremely dirty diesel fuel. They had installed filter coalescer/separators at all their service islands throughout the mine. They were concerned about the number of elements being consumed and approached the supplier.

His response was to relax the micron rating to something less efficient, so they would not block as often. *Is this not defeating the purpose of applying filtration?*

If the elements are blocking, does that not validate they are doing their job and capturing particulate? If they are blocking quickly, does that not alert you to the fact the incoming fuel is very dirty and needs to be cleaned?

Realising just how bad the fuel was, would it have not been more appropriate to improve the micron rating and capture even more of the dirt rather than letting more through?

This is not an isolated instance. On more than one occasion we have been advised by these suppliers against using finer filtration on diesel fuel because it is too dirty and will block the elements to quickly. Surely, the reason one would want to filter the diesel is because it is dirty!!

We have also been advised that the finer micron filters they provide are for clean fuel only. This is even more perplexing. *If the fuel is clean why am I filtering it?*

The fact that the elements being supplied are actually blocking means they are actually capturing at least some particulate, even if the final measurable outcome is not as desirable as need be.

Therefore, making the fuel cleaner than it was must be providing some benefit to the site, even if it is not an optimal outcome.

The fact that visible quantities of water can be drained from coalescer vessels also indicates some benefit is being achieved, even if the measurable outcome is still outside the desired requirements.

We hold a number of our other equipment suppliers to performance guarantees. Why do we not hold these suppliers accountable to a measurable outcome (cleanliness) of the fluid that has been filtered?

A major OEM currently calls for 2 micron (one can only assume a nominal rating) for diesel fuel filtration on their equipment. This is much finer than the general offering from these filter/coalescer manufacturers.

Mutterings in the heavy equipment industry suggests this OEM is sourcing even more efficient filter media for their next generation of engines and fuel injection systems.

Unless we improve the quality and cleanliness of the diesel fuel being dispatched from the refuelling bay it can be expected that blocked fuel filters will be an increasingly problematic occurrence when these engines are released into the field.

2.4.4 Another cause for concern with most installations found on mine sites is the over-capitalisation or under-utilisation of filter/coalescer systems.

Given the cost of these units it makes sense to minimise the number that needs to be purchased. It makes sense to ensure the full value of the unit is optimised.

A large mine site visited had quite a number of service islands. They had installed a number of filter/coalescers costing US$30,000 each.

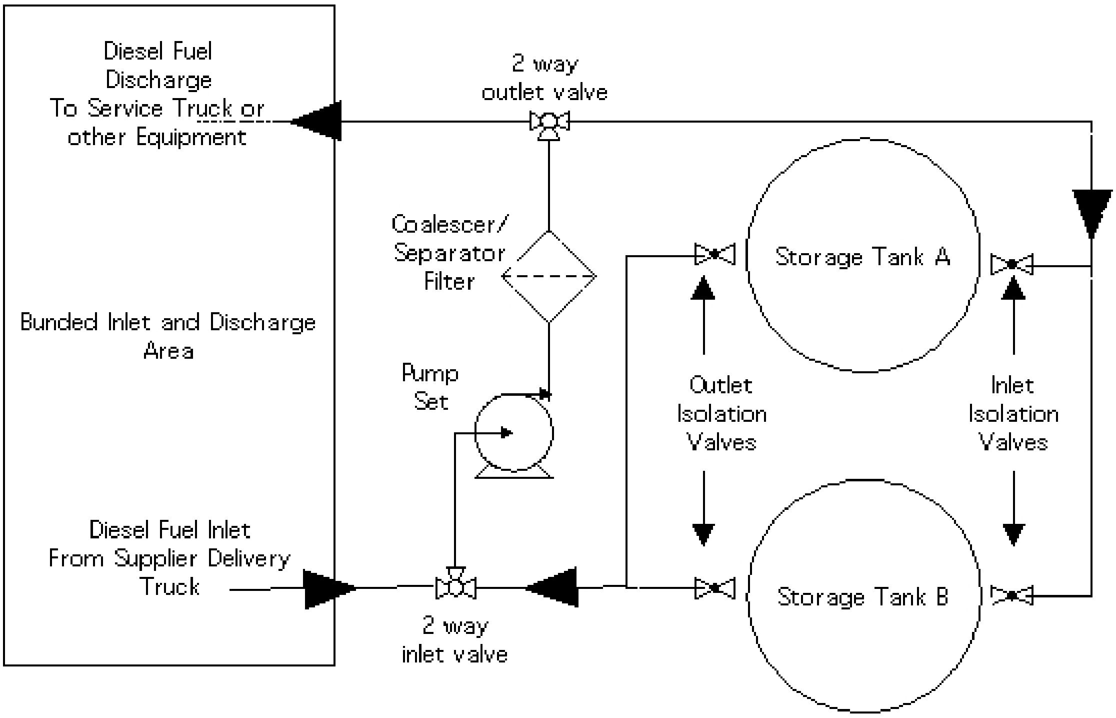
They had installed 2 systems per service island – one on the in-loading point and one on the dispatch point, thus the cost of each service island amounted to US$60,000.

Why?

Is it not more cost effective just to install one assembly and provide a system of pipe-work and valves to allow the single assembly to fulfil both functions?

By incorporating appropriate valving you can not only use the single assembly to fulfil both functions (in-loading and out-loading), but it can also be used to filter the fuel when transferring from one tank to another. It can also be used to circulate the fuel in one tank to clean it should it become inadvertently contaminated.

The initial investment is optimised.



Typical layout of a diesel fuel facility optimising the value from just a singlefilter/coalescer/ separator assembly.

3.0 Summary

A filter/coalescer should not be used as the first line of defence against contamination in diesel fuel. It is ineffective and too expensive.

It is wiser to employ a more holistic approach ensuring our fuel management and handling practices preserve or even improve the quality and cleanliness of fuel we receive.

The filter/coalescer should be used as a safeguard against any breakdown in our management and handling practices. It should be used as a warning device that a problem exists.

As the requirement for even cleaner diesel by fuel injection systems becomes more evident, the more important our fuel management and handling practices will become.

The quality, efficiency and advice provided by the major suppliers of the fuel storage and filtration equipment needs to be questioned by the end user or site.

The end user needs to ensure any potential supplier is aware that a quantifiable, measurable outcome of the filtered diesel fuel will need to be evident. The cleanliness of the filtered fuel will be quantified using both ISO 4406-1999 and traditional gravimetric methods.

It also needs to be pointed out that the outcome will be to those limits applied by the site or customer and not defined as meeting the "Australian Standard for Diesel Fuel" (or any other country's standard regarding diesel fuel).

Merely stating a micron rating for the filter to be used does not provide a guarantee of the fuel cleanliness..

The result of the filtration process is what is important, not what micron rating a company uses. Define the outcome. Define the quality and cleanliness level and hold the manufacturer or supplier to it.

Define and measure the result.

Remember: ***"In God we trust. Anyone else, show us the data!"***

References:

AS 3570-1998, Australian Standard for Automotive Diesel Fuel.
ISO 4406-1999, Method for coding the level of contamination by solid particles.
ASTM D95-IP24, 473-IP53, 1796-IP, D2709
ISO 4406-1999
Schroeder Industries
Caterpillar
Facet International
Velcon
Fuel Quality Control - RAAF