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Bulk Fuel Filtration for Off-Road Applications

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INTRODUCTION

In previous conferences, I have had the opportunity to talk about the importance of fuel cleanliness in the reliability and durability of diesel fuel systems. The very first production diesel tractor engine was developed by Cat in 1931.

Ninety years ago, the Caterpillar Operator's Manual stated that dirt and water causes 90% of all the problems with diesel fuel systems. The same is true today. Some things never change.

What has changed over the years is the power density of engines and resultant injection pressures of the fuel systems. Rigid new exhaust emission standards are also causing significant design changes, cost increases and reliability losses in modern engines, Figure 1.

A number of factors are driving the need for very clean fuel. The major factors are:

- Very difficult exhaust emission standards
- A growing shortage of service technicians to repair increasing complex and sophisticated equipment
- The cost of failures caused by dirty fuel. These failures result in downtime and loss of machine productivity.

Figure 1. Government-Mandated Regulations also Apply to Mining Machines such as these 240-Ton Capacity Haul Trucks

Tier 4 Emission Standards

New Tier 4 Emissions Standards either mandate or directly cause the following:

- Dramatic reductions in allowable exhaust emissions
- Significant product cost increases from the addition of:
  - After-treatment
  - Common rail fuel systems
  - Increased onboard fuel filtration
  - Mandated low and ultra-low sulfur diesel with poor lubricity

As a result, new high pressure fuel systems simply cannot provide adequate performance and service life without very clean fuel. As fuel system performance degrades, exhaust emissions increase.

Figure 2. KCGM (Kalgoorlie Consolidated Gold Mines)— Largest Open Pit Mine in Australia

Worldwide Service Technician Shortage

New generations prefer working with computers more than with their hands. The rapid growth of computers, computer based games and wireless technology has reduced the available pool of people interested in doing difficult manual labor.

In addition, engines and systems are getting very complex, difficult, and expensive to service. New service technicians must be more intelligent and better trained than ever before.

In the Australian Mining Industry alone:

- There is a projected shortage of 20,000 technicians over the next five years.
- These jobs pay over $100,000 per year.
- Machine population is expected to rise by 50%

We simply cannot afford to waste technician's time with frequent, expensive and unnecessary fuel system problems.

Figure 3. KCGM Mine Haul Road. Tiny Objects on Haul Road are 240-Ton Trucks. A Truck Breakdown on the Haul Road Can Shut Down Much of a Mine.

Cost of Dirty Fuel

Two factors drive accelerated fuel system wearout and failure:

- Elevated injection pressures
- Contaminated fuel

Modern common rail fuel systems must have very clean fuel to provide adequate service life. For example, New Caterpillar systems use 3-stage filtration.

- 10 um primary
- 4 um secondary
- 4 um tertiary (series)

Putting dirty fuel in the tank causes rapid filter plugging and short component

What Is Clean Fuel?

The question of what is clean fuel has been the subject of debate for many years. Until recently, the definition of clean fuel was "Clear and bright". What does that mean? How clear? How bright?

There is only one acceptable and meaningful way to measure and discuss fuel cleanliness. That is ISO cleanliness level. What do we mean today when we say "Clean fuel"?

Caterpillar's current ***minimum*** recommendation for fuel going into the machine fuel tank is:

EUI & Earlier Pump & Lines Systems:	ISO 18/16/13 or better
High Pressure Common Rail Systems	ISO 16/13/11 or better
Free Water	500 ppm or less

Bulk fuels are simply not delivered to sites at these cleanliness levels. Further confusion is introduced when sites attempt to determine fuel cleanliness by bottle sampling. The only reliable way to sample fuel is in dynamic flow with a laser particle counter.

Contaminated fuels and the associated cost of failures is something which can be controlled or eliminated by the effective use of bulk filtration.

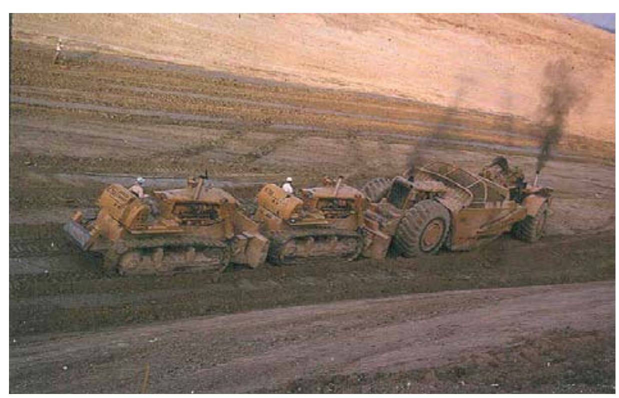


Figure 4. Black Smoke Was a Sign of Power for Early Pump and Lines Fuel Systems

Pump & Lines Systems (Early 90s and before)

Looking back in time, fuel systems were much simpler, and much less sensitive to dirt.

Injection pressures for pump and lines systems were low: typically 15,000 psi or less. Parts were inexpensive and easy to replace. Emissions regulations were very limited or non-existent. Deterioration of fuel system components impact on emissions was not understood or even cared about.

In fact, until the 1990s, the earthmoving machine operator's measure of producing good power was the amount of visible black smoke. It took many years and new generations of operators to understand and believe that engines could produce rated power without black smoke.

Mechanical Unit Injectors (Early to mid 90s)

The next step in fuel system evolution was mechanically actuated, mechanically controlled unit injectors.

Injector pressures were higher: typically in the 18,000 – 20,000 psi range. Parts were more expensive and difficult to replace, but still very reasonable. Emissions regulations were still limited and easily met. Deterioration of fuel system components impact on emissions was starting to be understood, and cared about—at least by the engine manufacturers.

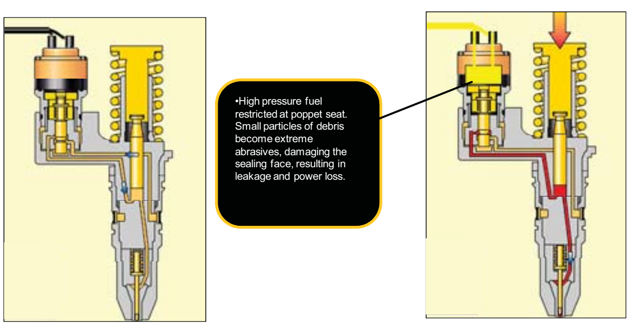


Figure 5. Caterpillar EUI Injector

Electronic Unit Injectors (mid 90s to 2007)

By the mid-90s, technology was rapidly advancing to meet increasingly tough emissions standards. Controlling injectors through mechanical governors quickly became obsolete as electronically controlled injectors (Figure 5) were developed and introduced. There was also an undeclared race to increase peak injection pressure in order to better atomize fuel for cleaner combustion.

EUI injection pressures were higher at 22,000–30,000 psi. Parts were much more expensive. On-highway emissions regulations were getting much tougher, and the deterioration of fuel system components impact on emissions was better understood.

In general, EUI injectors are individual mechanically actuated high pressure fuel pumps. Fuel is pressurized up to 30,000 psi, but only during the injection cycle. This is only about 6% of engine crankshaft rotation. This short, high pressure duration is much different than current common rail systems.

New emission standards also required that engines remain emission compliant for much longer. That meant that fuel system degradation became very important.

Studies were made to understand the causes of injector wear, and attempts were made to simulate accelerated wear.

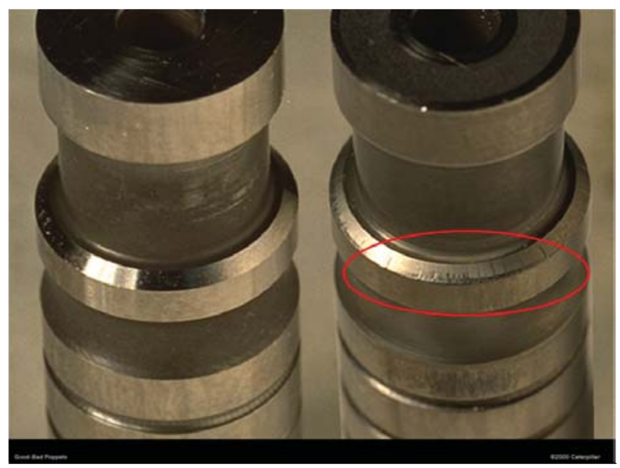


Figure 6. EUI Poppet Valve

The wear component in a Caterpillar EUI injector is the poppet valve. The poppet seat actually seals the 30,000 psi fuel pressure directly. Any leakage by the poppet seat during injection is a direct deduction in the intended fuel delivery and results in loss of power.

It quickly became apparent that microscopic abrasive particles in the fuel were the major source of injector wear. Increases in fuel filter efficiency were introduced and made standard equipment. But single stage high efficiency filters could only slow wear, but not stop it.

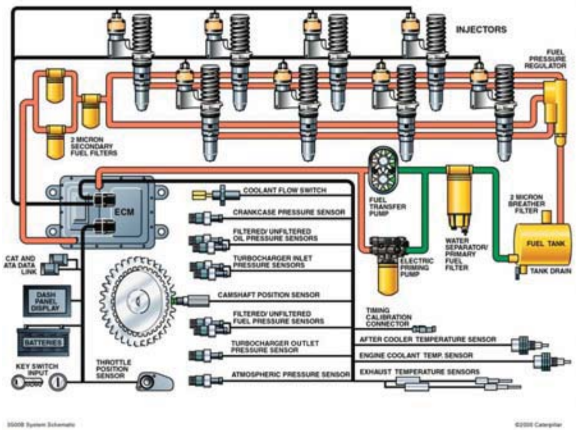


Figure 7. Typical EUI Fuel System

Typical EUI Fuel System

Although a typical EUI fuel system has many components and sensors, there is a key difference to point out between the EUI system and newer common rail systems.

In the EUI system, fuel flows from the tank through the:

- Primary fuel filter
- Fuel transfer pump
- Electronic control module (for cooling)
- Secondary fuel filters
- Engine cylinder heads to the injectors
- Fuel pressure regulator
- Back to tank

This bypass type system returns 3–4 gallons of fuel back to the tank for every gallon burned. This extra fuel flow through the cylinder heads cools the injector nozzles and helps to prevent fuel from cooking due to the high temperatures at the injector nozzle.

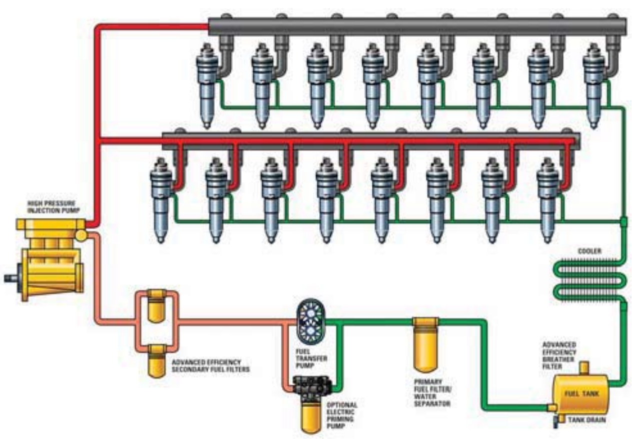


Figure 8. Typical Common Rail Fuel System

Typical High Pressure Common Rail Fuel System

Compared to EUI fuel systems, modern common rail systems have a number of advantages, Figure 8. These include:

- Higher mean injector pressures of up to 30,000 psi
- Faster start and end of injection, and injection rate shaping capability.

However, repair parts for common rail systems are much more expensive, and the parts and systems are extremely sensitive to dirt. This is a significant problem where large mining equipment is repaired. Fuel system repairs take place in unavoidably dirty conditions. Sometimes repairs must be performed outdoors, in a windy and dusty environment.

As emissions regulations continue to get tougher, fuel systems and combustion design alone are no longer able to meet emission standards without significant after-treatment. The addition of catalytic converters, particulate trap and exhaust gas recirculation systems is becoming common. However, for after-treatments to work properly; the fuel system must continue to function efficiently.

In addition to dirt sensitivity, common rail systems have another undesirable characteristic. Pressurized fuel can become very hot and remain hot for an extended period of time. This can cause the fuel to literally cook in the fuel rail; especially in large engine.

Common rail fuel systems have no return flow other than very small amounts of high pressure leakage from the fuel nozzles. This means that the fuel is pressurized to 30,000 psi and flows very slowly from the high pressure pump to the injector nozzles where it is consumed. The temperature of the pressurized fuel is increased about 125 – 150°F above ambient due to the heat of pressurization alone. It also has time to soak up additional heat from the engine. In high ambient temperature environments, this provides much more time, temperature and opportunity for asphaltines to form in the fuel than an EUI fuel system.

These high temperatures also mean lower fuel viscosity. This reduces the critical size of wear particles and makes very clean fuel essential.

Figure 9. Mine Fuel Island in South America, Circa 2000 (How well do you think Common Rail fuel systems would do in this environment?)

Figure 10. Recommended Heavy Duty Onboard Filtration Arrangement, Circa 1998

Relationship Between Fuel Cleanliness and Injector Life

In the mid 1990's and before, there was little understanding of how fuel abrasives caused accelerated injector wear. Short injector life was nearly always blamed on poor product quality. Dirt in the fuel was thought to cause plunger seizure, and water in fuel was not considered a problem, Figure 9.

Generational ignorance of abrasive wear and fuel contamination has been embedded for decades. It has always been easier to just blame the injectors for poor quality rather than the fuel. There was no distinction between wearout and failure: it just quit working right. Customers did not understand because they were never educated. There was little incentive for customers to change fuel practices because warranty and policy allowances subsidized using contaminated fuel. Even most Caterpillar engineers did not understand or believe filtration was all that important. Product groups were often not willing to improve filtration due to added product cost unless it was absolutely unavoidable. Short injector life came to be expected and accepted by customers and dealers.

Heavy Duty Filtration Arrangement

By the late 1990s, field tests proved that better onboard filtration dramatically improved EUI injector life. An optional heavy duty filtration arrangement for severe applications was proposed. It consisted of the following:

- Fuel tank breather filter
- 3-stage filtration
    - 10 um primary
    - 4 um secondary
    - 4 um tertiary (series)

The proposal was rejected as too costly and unnecessary

Figure 10 shows the heavy duty filtration arrangement being tested on a mining truck in Arizona in 1998. The test was successful. In an application where mid-life injector set replacement was a standard maintenance practice, this test showed that injectors with clean fuel could last to engine overhaul. This test was key in proving that fuel cleanliness had the most impact on injector wear life.

Following the filtration field test in Arizona, combined with a vast amount of other evidence, it became obvious that the standard filtration arrangement on many Cat machines was inadequate. What also became obvious was that few engineers within Cat understood this relationship. A huge training effort was needed to train large numbers of engineers, and documentation was needed to make the message stick.

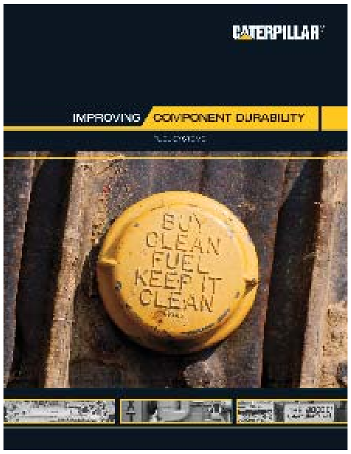


Figure 11. Improving Component Durability Booklet for Fuel Systems

Training the World on Fuel Cleanliness and Filtration

The answer was not another PowerPoint presentation or other type of electronic media which was easily created and just as easily discarded and forgotten. The answer was to create a visually appealing, high quality printed document that was interesting to read and too expensive to throw away

This unconventional approach met unbelievable internal resistance. First, the latest fad at the time was that everything had to be electronic so it could be easily copied and forwarded. This document was to be high quality, full-color paper and was expensive to produce. Also, there would be no electronic version. Paper only.

The first fuel cleanliness booklet was published in mid-2000, and was only intended for Cat design engineers as an internal document. However, a few dealers soon saw the books and demanded they be printed for dealers and customers. This created a second internal uproar because the book clearly stated that excessive amounts of abrasives in the fuel caused injectors to wear out and excessive water caused plunger seizures. There was huge internal resistance to admitting this to dealers, customers and competition.

After an extended debate, the publication was allowed to proceed on the assumption that very few would be willing to pay $4 per copy, and only be able to buy booklets in packages of ten. In December of 2000, 5,000 copies were printed and offered only to Caterpillar dealers. The initial 5,000 copies were estimated to be a 2–3 year supply, but lasted only 3 months. Then sales really took off — 5,000 more were printed and sold out in a month. Then 10,000 were printed. Then 5,000 more. Today that book has sold more than 60,000 copies. This is amazing considering that they can only be purchased internally within Caterpillar, or by 200 Caterpillar dealers worldwide.

The point is not that this booklet sold well. It is that customers and dealers are hungry for useful high-quality information. How is the OEM engine industry going to train masses of customers and dealers worldwide on the fuel cleanliness requirements of common rail fuel systems? Based on the current level of communication to date, it appears to be a subject best avoided.

The Beginning of Bulk Fuel Filtration Awareness at Caterpillar

Also in the late 1990s, Cat's awareness of bulk fuel filtration started. Thanks to Southwest Research and the earlier filtration conferences, we became aware of 50 year old aviation technology which removed dirt and water at very high flow rates. This technology was perfect for mining applications with very dirty fuel.

Ghana Bulk Fuel Filter

Figure 12. Bulk Filtration in Ghana

The first opportunity to try this came at a new mine in Ghana in 2004. The mine had purchased an entire new fleet of equipment, including 24 mining trucks, 4 large track-type tractors and numerous other types of support equipment. The local Caterpillar dealer had a five-year total maintenance contract to perform all maintenance and repairs on the fleet. Everything was going very well except the fleet suffered from fuel filter plugging in 150 to 200 hours. This caused unscheduled downtime and expense, and hurt machine availability. Because fuel is a customer responsibility, I suggested the dealer quit paying for filters and inform the customer that this was a fuel issue, not a product issue. Bulk filtration was recommended, and the customer found a supplier to build him a unit.

A month after the unit was installed I visited the site to document the unit's efficiency. I was shocked to find the fuel coming out was ISO 21 and only one ISO code cleaner than the inlet fuel. Upon questioning the manager of the fuel farm, (a Ghanese native,) I discovered he had no idea of what the unit did or what it was for. He only knew it had been installed the month before. Further inspection revealed the filters had plugged and collapsed. It then occurred to me that the unit had no protection for plugged filters or excessive water flow. Today, with proper oversight and maintenance, the unit is doing a reasonably good job.

However, it taught me an important lesson. There is a difference between bulk filtration in airports and mines. Only a few very large mines have babysitting crews to watch delta p gages on filters and replace filters when needed. The environment in a mine is usually much more harsh and maintenance personnel in high demand.

Packaged Solution for Bulk Fuel Filtration

Figure 13. Caterpillar 200 gpm Bulk Filtration

This led to developing purpose designed fully packaged units for mining applications and offering them through the Caterpillar parts system.

Adoption of bulk filtration has been slow but is now accelerating, largely thanks to common rail fuel systems. Fuel cleanliness that was tolerable for EUI injectors is not for common rail in off-road applications. In fact, in every single application where Cat bulk filters have been installed, they have been hugely successful. Then, why has adoption of this technology been slow?

There is a lesson I have personally learned through nearly forty years of working with Caterpillar customers and dealers. When proposing a new idea or making a suggestion for change, the first question always asked is:

"Who else is doing it?"

That is because nobody wants to be first, and nobody wants to be last.

In other words, nobody wants to be the guinea pig in case the new idea fails. That would be embarrassing. However, once a couple of other early adopters prove it is a good idea, no one wants to be left behind. This behavior is largely a result of being constantly bombarded with suggestions for improvement by various business segments within Cat. However, it is also a function of human nature. Whenever new ideas or technology are introduced, resistance to change makes early adoption very difficult.

Caterpillar's Leader in Bulk Filtration

Figure 14. Walker Machinery – Caterpillar's Leader in Bulk Fuel Filtration

It takes leadership to boldly try something new, and pave the way for others to follow. The leader in bulk fuel filtration for Caterpillar is dealer Walker Machinery. Walker has been the Caterpillar dealer for West Virginia for 57 years. Their largest market is the coal mining industry with more than 20 large mining sites and over 1,000 mining machines.

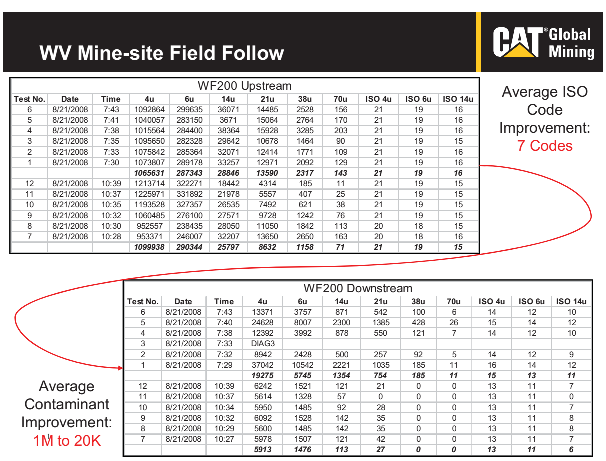
Coal mines *have always had* seriously contaminated fuel supplies and extraordinarily high costs from:

- Plugged fuel filters
- Injector failures
- Machine downtime and lost performance from fuel related problems

Figure 15. Bulk Fuel Filtration Test at the White Flame Mine — Particle Detectors were Connected to the Inlet and Outlet Sampling Valves for Dynamic Testing.

In 2008, Walker demonstrated a unit to a mine which agreed to purchase the unit if they could prove it worked. The White Flame Mine used a 5,000 gallon fuel truck to fuel the roughly 51 machines in the mine.

Frequent fuel filter plugging and injector failures had been around as long as anyone could remember. This mine averaged 5-6 plugged fuel filters per day. A 200 gpm bulk fuel unit was installed 11 days before the test was run. In that 11 day span, plugged fuel filters had stopped completely.



WF200 Upstream

Test No.	Date	Time	4u	6u	14u	21u	38u	70u	ISO 4u	ISO 6u	ISO 14u
6	8/21/2008	7:43	1092864	299635	36071	14485	2528	156	21	19	16
5	8/21/2008	7:41	1040057	283150	3671	15064	2764	170	21	19	16
4	8/21/2008	7:38	1015564	284400	38364	15928	3285	203	21	19	16
3	8/21/2008	7:35	1095650	282328	29642	10678	1464	90	21	19	15
2	8/21/2008	7:33	1075842	285364	32071	12414	1771	109	21	19	16
1	8/21/2008	7:30	1073807	289178	33257	12971	2092	129	21	19	16
			1065631	***287343***	***28846***	***13590***	***2317***	***143***	***21***	***19***	***16***
12	8/21/2008	10:39	1213714	322271	18442	4314	185	11	21	19	15
11	8/21/2008	10:37	1225971	331892	21978	5557	407	25	21	19	15
10	8/21/2008	10:35	1193528	327357	26535	7492	621	38	21	19	15
9	8/21/2008	10:32	1060485	276100	27571	9728	1242	76	21	19	15
8	8/21/2008	10:30	952557	238435	28050	11050	1842	113	20	18	15
7	8/21/2008	10:28	953371	246007	32207	13650	2650	163	20	18	16
			1099938	***290344***	***25797***	***8632***	***1158***	***71***	***21***	***19***	***15***

WF200 Downstream

Test No.	Date	Time	4u	6u	14u	21u	38u	70u	ISO 4u	ISO 6u	ISO 14u
6	8/21/2008	7:43	13371	3757	871	542	100	6	14	12	10
5	8/21/2008	7:40	24628	8007	2300	1385	428	26	15	14	12
4	8/21/2008	7:38	12392	3992	878	550	121	7	14	12	10
3	8/21/2008	7:33	DIAG3								
2	8/21/2008	7:32	8942	2428	500	257	92	5	14	12	9
1	8/21/2008	7:29	37042	10542	2221	1035	185	11	16	14	12
			19275	***5745***	***1354***	***754***	***185***	***11***	***15***	***13***	***11***
12	8/21/2008	10:39	6242	1521	121	21	0	0	13	11	7
11	8/21/2008	10:37	5614	1328	57	0	0	0	13	11	0
10	8/21/2008	10:34	5950	1485	92	28	0	0	13	11	7
9	8/21/2008	10:32	6092	1528	142	35	0	0	13	11	8
8	8/21/2008	10:29	5600	1485	142	35	0	0	13	11	8
7	8/21/2008	10:27	5978	1507	121	42	0	0	13	11	7
			5913	***1476***	***113***	***27***	***0***	***0***	***13***	***11***	***6***

Figure 16. White Flame Test Results

Fuel samples were taken during two different fill cycles of the 5,000 gallon fuel truck with the bulk fuel unit operating at full capacity.

Two Parker LCM 20 laser particle counters were connected to the inlet and out sampling valves on the bulk filtration unit. The laser particle counters were provided and operated by Len Licursi of Parker. Six, two minute long sample were taken during each of the two truck fill cycles.

The results were dramatic:

- Inlet samples averaged ISO 21/19/16
- Outlet samples averaged ISO 15/13/11

This translates into 4-micron and larger particles being reduced from more than one million to less than 20,000 per sample. These very successful results at the White Flame Mine sparked immediate interest from other mines.

Figure 17. Patriot Coal Apogee Mine 300 gpm

Patriot Coal operates there large mines in Walkers territory. The Apogee, Hobet and Cantenary mines operate more than 350 pieces of equipment and each has Cat bulk filtration units. Each mine has a 300 gpm unit and two of the mines have additional 100 or 200 gpm units. The first 300 gpm bulk filtration was installed in early 2009. Before the bulk filter was installed, the three mines replaced on average of 12-15 injectors per week (at a cost of more than $1,000 each) and had personnel who largely did nothing but replace plugged fuel filters.

Three months after the bulk filter filtration was installed, injector replacement average had essentially stopped, and the personnel doing fuel filter changes were reassigned because there were no more plugged filters to replace.

Figure 18. Alpha Resouces – Brooks Run Mine – 200 gpm

A 200-gpm bulk fuel filter was installed in the Brooks Run mine in October 2009. Before the bulk filter was installed, the mine replaced (24) unscheduled fuel filters in the work shift prior to installing the bulk fuel filter.

One month after the bulk filtration was installed, the mine replaced (4) unscheduled fuel filters TOTAL.

Walker Machinery Customer Endorsements

- "The best money we ever spent."
- "The units have paid for themselves in 90 days or less."
- "Fuel filters now run to the 500 hour PM without plugging."
- "Injectors now run to engine overhaul. We no longer do mid-life injector set replacements."
- "The impact on machine availability and downtime are huge."
- These units have helped every machine in the fleet, especially the prime loaders."

Endorsements from Customer Maintenance Managers

The following maintenance managers have all endorsed the comments made based on personal experience. Their names and the number of Caterpillar bulk filtration units they use are below:

Roger Mullins
Alpha Resources
Paramount Div (5-200 gpm)

Jeff Reedy
Alpha Resources
Simmons Fork Div (1-200 gpm)

Pat Carr
Alpha Resources
Brooks Run Div (1-200 gpm)

Charles Amburgey
Alpha Resources
Calloway Div (4-200 gpm)

George Ferrell
Coal-Mac/Arch Minerals
Phoenix Div (1-200 gpm)

Mike Hall
Hobet Mine
Patriot Mining (2-200 gpm) (1-300 gpm)
142 machines

Customer Benefits

Customers have seen significant improvements in machine availability and cost savings since bulk filtration was installed. Specific examples include:

Increased Fuel Filter Life

At Coal-Mac, filter plugging between 500 hour PM intervals has been eliminated. They have also extended fuel filter PM intervals on several large wheel loaders to 750 hours, and plan to expand this to other machines in the fleet.

Injector Life

Injector replacement overall has been reduced by more than 90%. Walker field servicemen used to carry 2-3 injectors in their service trucks because they were used so often. Even customers used to stock replacement injectors. That is no longer necessary, since the failure rate has dropped dramatically. An additional benefit to customers is the elimination of maintenance cost for personnel who formerly replaced plugged fuel filters and replaced failed injectors.

Improved Machine Availability and Lower Operating Cost

In every case, customers have experienced improved reliability, improved machine availability, and lower operating costs after bulk filtration was installed. This cost savings for haul trucks is significant. But the cost for prime movers in a mine, such as a D11 tractor or mass excavator can be huge.

Typical costs of downtime in lost revenue to the mine for prime movers are:

- D11 dozer - $40,000 per day (single machine)
- Mass excavator - $120,000 per day (also idles D11 and 3-4 trucks)

Dealer Benefits

Reduced Warranty Costs
In addition, historically numerous and expensive warranty claims from Walker to Caterpillar for failed injectors have become almost non-existent. This has resulted in a significant loss in injector sales revenue to Walker, but has been offset by increased sales of other repair commodities as a result of the increased customer trust.

Increased PM Revenue
Walker also provides a total solution to customer fuel quality issues. They don't just sell a unit and drop it off at the customer. They install the unit and maintain it. All Caterpillar bulk filtration units sold by Walker Machinery are under PM contracts for filter changes and all maintenance. This includes periodic sampling of customer bulk tanks and treating for bacteria when required.

Of benefit to both Walker and the customer is the robust design of the units. They were specifically designed for severe mine use.

Comments by Walker
"These units are built to last a lifetime. They are also skid mounted and easily portable. We are impressed with the design, function and performance of the units".

Unintended Benefits

During different times in the year, Walker has experienced frequent plugging of coalescer elements. Fuel analysis has shown the plugging is due to corrosion inhibitors added to fuel by pipelines. This corrosion inhibitor causes injector failures of competitive injectors in prime movers.

Coalescing elements in the bulk filtration units effectively remove the corrosion inhibitors and prevent injector failures. However, coalescing elements can plug quickly from the corrosion inhibitor. Sometimes in as little as a week. But the cost of replacement elements is insignificant compared to the savings from not having failed injectors. There is not a single customer who complains about the cost of filter replacement because of the cost savings from injector failures.

Other Applications Worldwide

Although most units to date have been sold in the United States, there is a growing international market. Units are currently operating in South America, Australia, Europe and Africa.

An interesting example was recently documented in a Caterpillar mining publication.

Figure19. Zangezur Mine – Armenia – 200gpm

Zangezur mine was established in 1952, and is the largest mine in Armenia and one of the largest deposits of molybdenum in the world, Figure 19. The site operates thirty machines, including mining trucks, wheel loaders, track-type tractors and an excavator. Injector failures due to contaminated fuel have always been a problem. The remote location of the mine makes getting parts and making repairs a real challenge. The mine is located at an altitude of 7,217 feet and is surrounded by mountains. It can sometimes take 30 days to procure parts and repair machines.

After a 200 gpm bulk filter unit was installed, all fuel related problems stopped. The immediate results prompted the following comment from the customer.

"*All of the problems disappeared. I have recommended to every mine site that they install this system. The impact it had on our site was immediate and significant. We have seen improvements in every machine we operate."*

Rubik Abramyan,
Transportation Manager
Zangezur Mine

Summary

It is clear that rapidly increasing fuel system complexity and sensitivity to abrasive debris is driving the need for unprecedented levels of fuel cleanliness:

There are still massive fuel cleanliness problems throughout the mining world.

However, I leave you with a few thoughts:

1) In many cases, bulk fuel filtration is a far more efficient and effective option to clean fuel than loading up machines with additional filtration capacity.

2) Fuel cleanliness must be clearly defined in terms of ISO cleanliness levels.

3) Measuring of fuel cleanliness must be done dynamically, using laser particle counters.

Finally, engine manufacturers clearly define requirements for engine lube oil viscosity, rating, and oil change interval. They also specify requirements for engine coolant, additives and change intervals. Why then, is it so difficult to define and clearly state required fuel cleanliness levels?