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FILTRATION

Coal Fired Power Plant Case Study:

Coal Crusher Gearbox Lube Filtration
Total System Cleanliness Approach

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The Problem - Coal fired power plants typically operate several ball mills or coal pulverizing mills to crush the incoming coal to the optimum size for combustion. This means that each power generation unit has five or six mills. The gearboxes that run these coal mills are usually lubricated with high viscosity oil, such as ISO VG320 or ISO VG460. Traditionally, these large gearboxes have no filtration and the oil is changed on a service interval. Oil analysis, and even visual inspection, revealed that the oil in the gearboxes was contaminated to levels not suitable for any lube or hydraulic system. Oil that is so highly contaminated leads to premature gearbox failures that, unfortunately, have become accepted by operators as the normal life cycle of their equipment. Even though the oil is drained and replaced with new oil, there is no protection for the gears and bearings in the time before the oil change occurs, causing them to suffer tremendous wear at the end of each service interval. There also exists an inherent problem with the drain and refill routine as a whole: while the gearbox is turned off in preparation for an oil exchange, the lubricant is no longer agitated, and suspended contaminants will fall out of suspension and collect in the sump area of the gearbox, which is usually slightly lower than the drain valve. A high quantity of that solid contaminant then remains in the gearbox to be stirred up and held in suspension by the new oil and, because “unfiltered new oil is dirty oil,” this creates even more wear for the gearbox.

The Costs & Opportunity - It only takes a moment of considering these problems to realize that poor maintenance of the lubricated gearbox can bring about high costs and long equipment downtime. A service interval flush program has its inherent cost in the rising price of oil, which for the ISO VG320 and VG460 oil used to lubricate the gearboxes is $538.41 per barrel. Another cost can be found in the 4.5 hours required by the drain and refill routine for the oil. Once drained, the oil must be disposed of properly, which again produces cost. The big, ugly expenses lurking in the background occur when the gearbox fails outright and must be rebuilt, often costing up to $610,000. By achieving and maintaining clean fluid there is a great opportunity to have a positive impact on productivity and the bottom line. This application also presents the opportunity to break the decades of stigma that “drain and replace” is the only way to maintain lubricated machinery.

The Solution - Applying a total system cleanliness approach is necessary to maximize uptime, extend gearbox life, extend fluid life, reduce limited maintenance resource demands, reduce fluid disposal costs and even save money on power consumption. Installing a dedicated filtration system and applying the following strategies can prove to be very effective.

Step 1 - Set a target for fluid cleanliness to be verified by periodic oil analysis with the results reported per ISO4406:1999. The ISO code results should be expressed in a three number code that uses the latest particle counter calibration $4\mu_{[c]}$ /$6\mu_{[c]}$ /$14\mu_{[c]}$. Table 1 details potential life extension of bearings as fluid cleanliness is improved.

A review of how ISO codes are determined is provided on page seven.

Table 1

Current ISO Code	Target ISO Code	Target ISO Code	Target ISO Code	Target ISO Code
Start	**2 x Life**	**3 x Life**	**4 x Life**	**5 x Life**
28/26/23	25/22/19	22/20/17	20/18/15	19/17/14
27/25/22	23/21/18	21/19/16	19/17/14	18/16/13
26/24/21	22/20/17	20/18/15	19/17/14	17/15/12
25/23/20	21/19/16	19/17/14	17/15/12	16/14/11
25/22/19	20/18/15	18/16/13	16/14/11	15/13/10
23/21/18	19/17/14	17/15/12	15/13/10	14/12/9
22/20/17	18/16/13	16/14/11	15/13/10	13/11/8
21/19/16	17/15/12	15/13/10	13/11/8	-
20/18/15	16/14/11	14/12/9	-	-
19/17/14	15/13/10	13/11/8	-	-
18/16/13	14/12/9	-	-	-

Step 2 - Install high efficiency glass media or desiccant breathers on all gearbox vent ports. Many coal mill gearboxes have no breather protection which allows coal dust to enter the unit after the oil has begun being filtered. Unprotected vent ports can be one of the worst sources of ingression. While ingression can also come from unfiltered new oil, filtering all new oil will also help to minimize contaminant ingression.

Step 3 - Change the criteria for replacing the oil from a time interval to a decision based on the oil condition determined by oil analysis. If the oil is kept clean and is not subjected to excessive temperature, the oil life should be defined based on the health of the oil and the additive package. Replacing the current oil with new oil at this point would also increase the speed at which results are noticed. It is also suitable to consider using a synthetic oil that will yield better performance when kept clean and lower amp draw for the coal mill.

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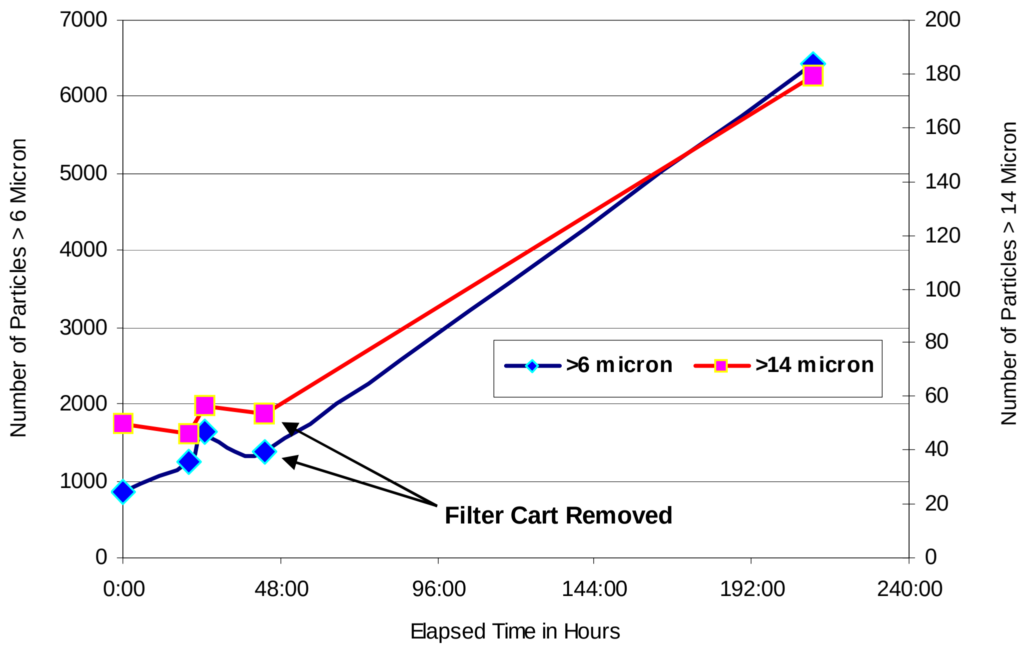
Step 4 - Install a dedicated filtration system on each individual gearbox to filter the oil continuously during operation. Photo 1 shows the Hy-Pro FSL series self contained filtration unit that was used in the Edison St. Claire application. There are many important features to consider when selecting a side loop unit: the unit should feature a large filter element because they provide good performance in cold start situations, they have a longer element life compared to similarly rated elements of a smaller size, and they permit the use of finer filtration that can even be combined with water removal media. Maintenance friendly top loading filter housings are a plus for minimizing oil spills. Oil sampling ports should be included before and after the fluid passes through the filter element so that the true condition of the gearbox oil can be measured (before the filter) and the filter performance may be quantified (after the filter). It is also important to have a true differential pressure gauge with color coded indication so that true element condition may be monitored.

If a mineral based oil is used, replacing it with new synthetic oil in conjunction with the installation of the side loop filtration system is recommended.

Filter Cart vs. Dedicated Filtration - Graph 1 is a useful tool in understanding the advantage that dedicated filtration has over rotating a filter cart among various pieces of equipment. A filter cart was placed in operation to condition several coal mills and was maintaining a stable amount of filtration while in service on this specific gearbox. After 48 hours of service, it was removed and the contamination increased in a matter of days from an ISO code of x/18/12 to x/20/15. An operator considering the use of a filter cart for cleaning gearbox oil on multiple units would do well to note the massive recontamination levels after the filter cart's removal from a specific unit. Dedicated filtration is the better solution. The filter cart's rotation schedule could be forgotten or forgone, and machines not hooked up to the filter cart receive high levels of contamination. Imagine the problem as plugging a hole in a leaky dam. The problem there is stopped, only to flare up elsewhere. Dedicated filtration plugs up all of the holes through which performance, reliability, and inevitably money, escape.

Graph 1 **Gearbox Recontamination (filter cart is removed after 48 hours).**



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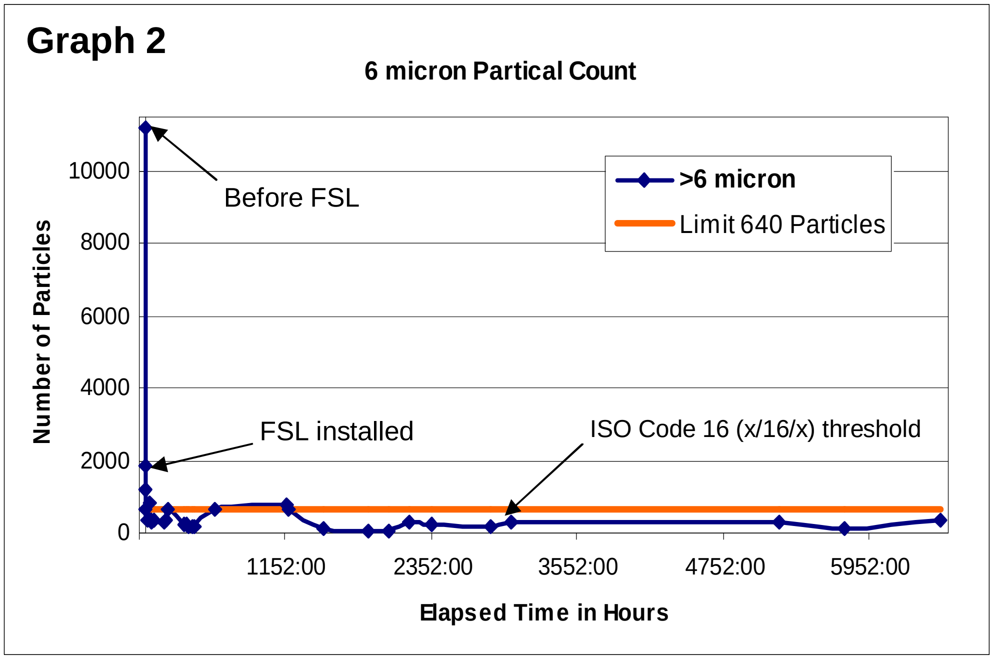
Immediate Results - A fluid cleanliness target of x/16/13 was established and the FSL side loop filtration system was installed along with fresh synthetic oil. Less than a day after the installation, gearbox oil contaminant levels were reduced significantly and the cleanliness target was achieved (see table 2).It is important to have a solid grasp on ISO codes to understand the magnitude of dropping the ISO code from x/21/16 to x/16/11 and lower. In this case the amount of particles per milliliter > 6 micron dropped from 11,184 to 360 and the number of particles per milliliter > 14 micron dropped from 323 to 11.This represents a 3,006% drop in particles > 6 micron and a 2,836% drop in particles > 14 micron. Approximately 2 1/2 months later the same filter element was in use and the ISO code was x/13/11 with only 71 particles > 6 micron and 13 particles > 14 micron per milliliter which represented a drop of 16,592% and 2,384% particles per milliliter respectively.

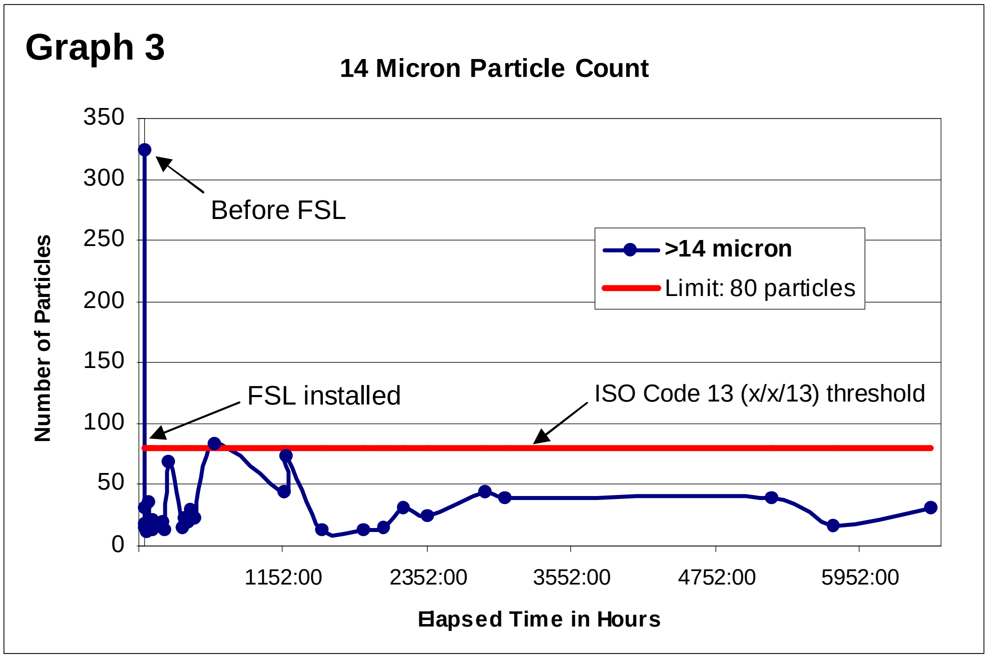
At the time of the last data point, the fluid in the specified gearbox had achieved servo quality cleanliness. One may argue that such cleanliness is not required for this application, but a quick recall of the component life extension table previously referenced in this study should mean that those concerned with reliability have one less thing to worry about.

Table 2

				ISO 4406 Code			Actual Counts	
Date	FSL Filter	Time Running (Hrs)	Running (Days)	ISO		Code	>6	>14
8/14/2006 14:00	OFF	0:00	0	21	/	15	11593	298
8/15/2006 8:00	OFF	0:00	0:00	21	/	16	11184	323
8/15/2006 10:30	ON	2:30	0.1	17	/	12	1848	32
8/15/2006 11:30	ON	3:30	0.15	17	/	11	1214	15
8/15/2006 15:00	ON	7:00	0.29	17	/	11	673	17
8/16/2006 6:30	ON	22:30	0.94	16	/	11	360	11
8/16/2006 14:00	ON	30:00:00	1.25	17	/	12	837	35
8/17/2006 8:30	ON	48:30:00	2.02	15	/	11	308	12
8/18/2006 8:00	ON	72:00:00	3	16	/	12	355	21
8/18/2006 12:00	ON	76:00:00	3.17	16	/	11	361	12
8/21/2006 10:30	ON	146:30:00	6.1	15	/	12	317	20
8/22/2006 6:30	ON	166:30:00	6.94	15	/	11	339	12
8/23/2006 9:00	ON	193:00:00	8.04	17	/	13	674	69
8/28/2006 11:30	ON	315:30:00	13.15	15	/	11	216	15
8/29/2006 11:00	ON	339:00:00	14.13	15	/	12	251	23
8/30/2006 9:00	ON	361:00:00	15.04	15	/	11	153	20
8/31/2006 8:00	ON	384:00:00	16	15	/	12	174	30
9/1/2006 10:00	ON	410:00:00	17.08	15	/	12	204	23
9/8/2006 8:00	ON	576:00:00	24	17	/	14	638	83
10/2/2006 11:45	ON	1155:45:00	48.16	17	/	12	777	44
10/3/2006 13:24	ON	1181:24:00	49.22	16	/	13	685	73
10/15/2006 13:24	ON	1469:24:00	61.22	14	/	11	138	13
10/30/2006 13:00	ON	1829:00:00	76.21	13	/	11	67	13

Graphs 2 and 3 provide a visual representation of Table 2 and show the dramatic change in contaminant levels that resulted from installing the FSL total cleanliness system. Graph 2 shows the particle counts for the 6 micron channel and Graph 3 shows the particle counts for the 14 micron channel. In this case the customer did not include the 4 micron channel in the analysis which is the first reported channel in the current ISO Code. If included, the numbers on the 4 micron channel likely would have been in the ISO 23 code or higher (40,000 ~ 80,000 particles per milliliter) before the installation of the Hy-Pro FSL unit.





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Installation Photos - Photos 2 and 3 show the installation on a coal mill gearbox with 250 gallon (946 L) volume. The suction line was connected to the drain port on the bottom of the gearbox and an auxiliary fill port/line was added to the plumbing so that new oil could be pulled into the FSL suction line and filtered during fluid top-off. A manual valve should be installed in the drain port to minimize mess during service of the top-loading housing.

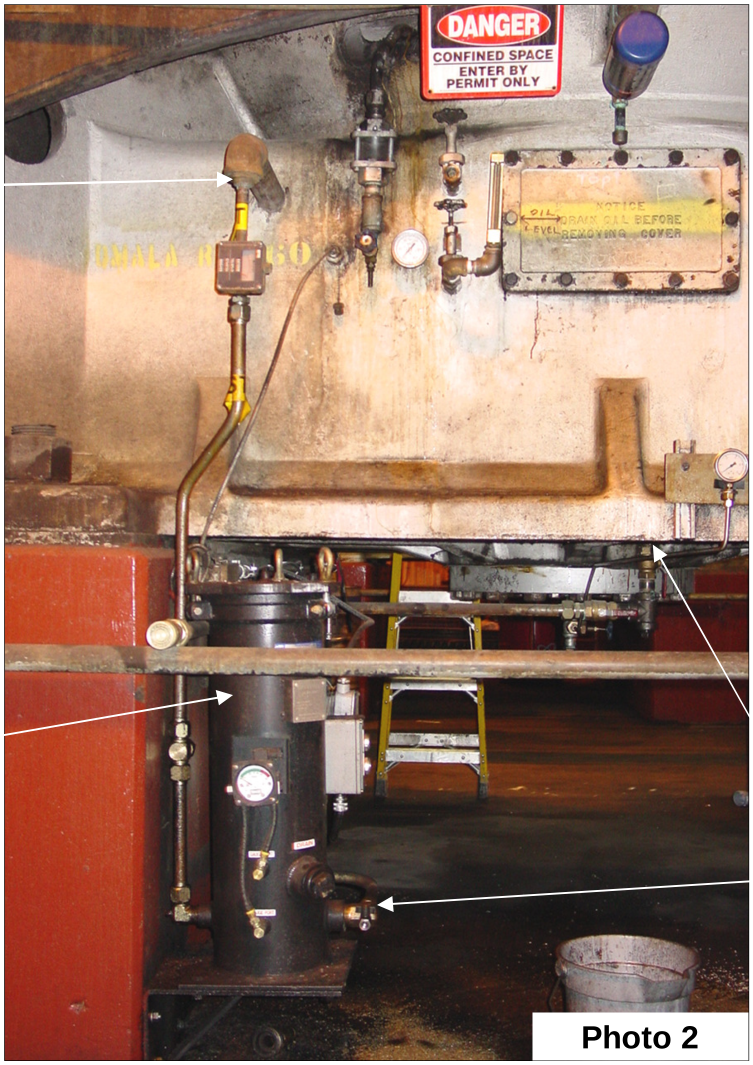


Photo 2

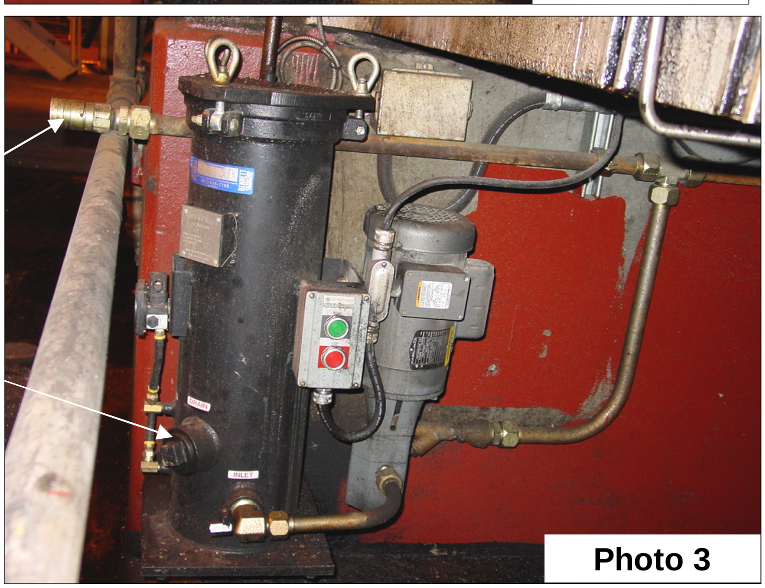


Photo 3

Understanding ISO Codes - The ISO cleanliness code (per ISO4406-1999) is used to quantify particulate contamination levels per milliliter of fluid at 3 sizes $4\mu_{[c]}$, $6\mu_{[c]}$ and $14\mu_{[c]}$. The ISO code is expressed in 3 numbers (example: 19/17/14). Each number represents a contaminant level code for the correlating particle size. The code includes all particles of the specified size and larger. It is important to note that each time a code increases the quantity range of particles is doubling.

ISO 4406:1999 Code Chart

Range Code	Particles per milliliter	
	More than	Up to/including
24	80000	160000
23	40000	80000
22	20000	40000
21	10000	20000
20	5000	10000
19	2500	5000
18	1300	2500
17	640	1300
16	320	640
15	160	320
14	80	160
13	40	80
12	20	40
11	10	20
10	5	10
9	2.5	5
8	1.3	2.5
7	0.64	1.3
6	0.32	0.64

Sample 1 (see photo 4)

Particle Size	Particles per milliliter	ISO 4406 Code range	ISO Code
4µm[c]	**151773**	**80000~160000**	**24**
6µm[c]	**38363**	**20000~40000**	**22**
10µm[c]	8229		
14µm[c]	**3339**	**2500~5000**	**19**
21µm[c]	1048		
38µm[c]	112		

Sample 2 (see photo 5)

Particle Size	Particles per milliliter	ISO 4406 Code range	ISO Code
4µm[c]	**492**	**320 ~ 640**	**16**
6µm[c]	**149**	**80 ~ 160**	**14**
10µm[c]	41		
14µm[c]	**15**	**10 ~ 20**	**11**
21µm[c]	5		
38µm[c]	1		

Photo 4: ISO code 24/22/19

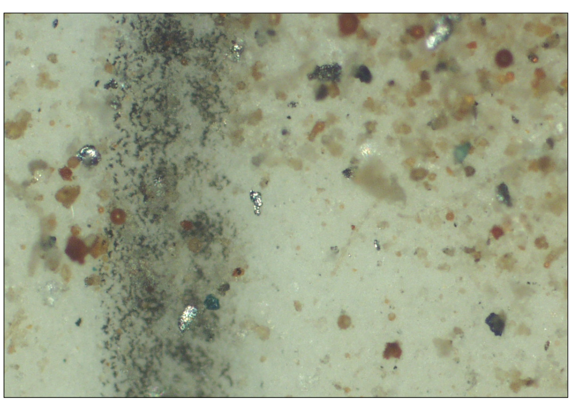
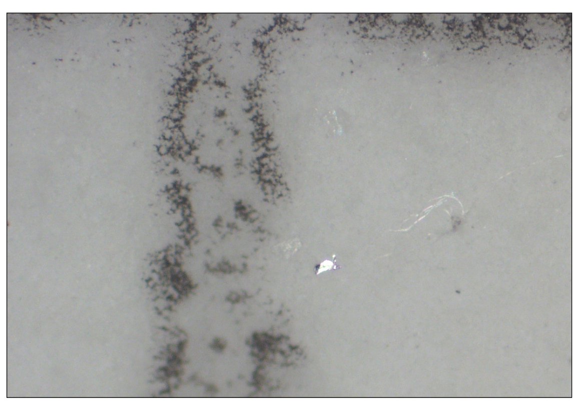


Photo 5: ISO code 16/14/11



Because several mills are employed to grind coal for a single unit, both the savings per mill and the savings per unit must be taken into account. While the previous page demonstrated that savings would continue to increase as years passed after the FSL installation, the two tables below show the savings that are possible with proper gearbox filtration in a large application such as the Detroit Edison Power Plant. These are the amounts noted just in the time immediately before and after the filtration began, and the numbers make it clear that gearbox oil filtration is the best choice when it comes to cutting costs produced by maintenance, oil exchanges, and gearbox rebuilds. (Note that the cost of the FSL unit and it's installation is subtracted from the total savings.)

Current Annual Cost and Savings per Mill

	Before Filtration	After Filtration	Savings
Oil Cost:	$3,915.71	$1,305.24	$2,610.47
Labor Cost:	$292.50	$97.50	$195.00
Rebuild:	$609,428.86	$0.00	$609,428.86
Totals:	$613,637.07	$1,402.74	$612,234.33

Current Annual Cost and Savings per Unit

	Before Filtration	After Filtration	Savings
Oil Cost:	$23,494.26	$7,831.44	$15,662.82
Labor Cost:	$1,755.00	$585.00	$1,170.00
Rebuild:	$3,656,573.16	$0.00	$3,656,573.16
Totals:	$3,681,822.42	$8,416.44	$3,673,405.98

Succeed with a Total Systems Cleanliness Approach

Developing a Total System Cleanliness approach to control contamination and care for fluids from arrival to disposal will ultimately result in more reliable plant operation and save money. Several steps to achieve Total Systems Cleanliness include: evaluate and survey all hydraulic and lubrication systems, establish an oil analysis program and schedule, insist on specific fluid cleanliness levels for all new fluids, establish a baseline and target fluid cleanliness for each system, filter all new fluids upon arrival and during transfer, seal all reservoirs and bulk tanks, install high quality particulate and desiccant breathers, enhance air and liquid filtration on existing systems wherever suitable, use portable or permanent off-line filtration to enhance existing filtration, improve bulk oil storage and handling during transfer, remove water, and make a commitment to fluid cleanliness.

The visible cost of proper contamination control and total systems cleanliness is less than 3% of the total cost of contamination when not kept under control. Keep your head above the surface and avoid the resource draining costs associated with fluid contamination issues including:

- Downtime and lost production
- Component repair, replacement
- Reduced useful fluid life
- Wasted materials and supplies ($)
- Root cause analysis meetings
- Maintenance labor costs
- Unreliable machine performance
- Wasted time and energy ($)

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