By-Pass Filters:
Taking Your Fleet the Extra Mile

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There has been an industry-wide push over the last few years to extend oil drain intervals on fleet equipment. This industry demand is an effort to reduce downtime, reduce waste oil generation, and cut maintenance costs. Extended oil drain intervals can offer huge benefits for DOT fleets, providing that the extended program is structured to ensure that engine life is not compromised. The oil manufacturers have responded to this demand by developing new oils with improved additive packages to extend oil drain intervals. Many manufacturers advertise their new oil in many of the fleet maintenance magazines, with claims of extending oil drain intervals up to 40,000 miles. However, the question must be asked whether the use of these new oils in a "pour-in-and-go" program is the best approach to achieving satisfactory extended oil drain intervals.

This paper describes an approach to achieving effective and safe extended lube oil drain intervals. This approach has achieved extended equipment life with reductions in downtime, maintenance man-hours, waste oil generation, and costs. This approach utilizes ultra fine (UF) by-pass lube oil filters, an effective technology in use for over 20 years, along with a comprehensive monitoring process for tracking of wear and oil condition and detection of potential problems. This paper also addresses problems and hurdles encountered when extended oil drain programs are explored.

INTRODUCTION

The basic approach described in this paper utilizes standard petroleum lube oils, UF by-pass lube oil filters, portable oil quality analyzers, and laboratory oil analysis (see Figure 1). The standard American Petroleum Institute (API CG) rated petroleum-based lube oils are used in lieu of more expensive blended or full synthetic oils. There is no need for synthetics to achieve extended oil drains when UF by-pass filters are being used. However, certain fleets should look at other benefits, such as low pour points for cold weather applications. The UF by-pass lube oil filters are used to remove solid and moisture contamination from the lube oil. These filters, in conjunction with new make-up oil added at the time these filters are serviced, will keep the equipment running on clean oil, thereby reducing wear and eliminating the need for routine oil drains. Using a portable oil quality analyzer will allow maintenance personnel to test the quality and condition of lube oils and to monitor equipment condition in their own shops. By using this process, one can detect potential problems before unnecessary downtime occurs. In addition, complete laboratory used oil analysis is used to monitor wear rates and compile information on equipment for use in long-term trending analysis.

DISCUSSION

The majority of DOT fleets in the United States operate equipment with standard factory filtration and manage it with a standard factory-recommended P/M (preventive maintenance) program. Most equipment utilizes standard filtration in the form of factory full-flow filters only. There are a few cases in which the factory full-flow filters are coupled with by-pass filtration. The standard P/M program is the manufacturer's recommended routine oil and filter drain intervals. In some cases a complete laboratory used-oil analysis is used as a P/M tool. This type of P/M program is sufficient for normal equipment life. However, experience has shown that most highly successful fleets do not become successful by doing what is considered normal.

The recommended P/M program described in this paper, developed and proved over a 20-y period by Gulf Coast Filters, Inc., will move a fleet's preventive maintenance program toward a predictive maintenance program. The utilization of UF by-pass filters with this approach is a key factor. The by-pass filter performs the job of removing solid and moisture contamination to prevent additive depletion of the oil and reduces wear to the engine. Beyond extending the lube oil drain interval, this approach will

1. extend or eliminate routine oil drains, or both;
2. reduce wear within the equipment;
3. reduce equipment downtime;
4. reduce maintenance man-hours;
5. reduce waste oil generation; and
6. reduce costs.

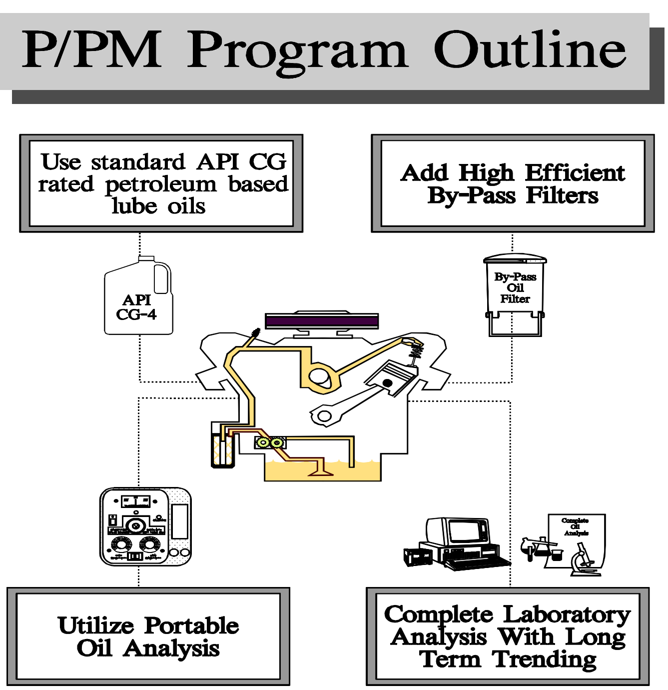


FIGURE 1 Basic approach using by-pass filters in P/M program.

Lube Oil Job Functions

There are several jobs that the lube oil is designed to perform: lubrication of moving parts, cooling, cleaning, corrosion control, and so forth. The oil companies work diligently to produce oils to meet engine manufacturers' ever-increasing requirements, creating better and better oils each year. Over the years, using vastly improved oils, the engine manufacturers have increased their recommended oil drain intervals for engines, but most fleets continue to drain oil on a routine basis. When most maintenance personnel are asked why oil must be changed, they usually answer in one of the following ways: "because it breaks down," or "because it wears out."

The concept that oil breaks down or wears out is not correct. The petroleum base of lube oil does not wear out, but rather it is the additives within the oil that become depleted due to the presence of contamination. Therefore, if one could remove these contaminants, the oil could be used for a longer period of time, but how long the decontaminated oil could be used is not known.

New Engines

The major contaminant produced in a diesel engine is soot. In recent years' changes in engine design to comply with higher Environmental Protection Agency (EPA) emission standards, engine manufacturers have fabricated engines that produce higher levels of soot in the oil. Therefore, contaminants that once were going up in smoke are remaining in the engine and winding up in the lube oil. These newer engines emit fewer contaminants through the exhaust; therefore, higher carbon soot levels are being detected within the engine. Several Society of Automotive Engineers (SAE) papers have shown how soot contributes to diesel engine wear (for example, SAE papers 810499, 852126, 881825, 881827, and 912344). One of these papers (912344) indicates that soot enters the lubricating oil at a rate of 0.0048 oz for every gallon of fuel burned. At 7 mpg, a truck will burn 1,786 gallons of fuel every 12,500 miles, with more than half a pound (8.57 oz) of soot entering the lubrication system.

The majority of soot particles generated within the engine are 10 microns or less. The standard full-flow filters will remove and control particles 15 microns and greater. Full-flow filters are designed to protect the engine from large particles that could damage vital parts. These filters must be porous enough to allow high flow rates of oil to the engine for lubrication of parts. The typical flow rate for a full-flow filter within a diesel engine is 15–20 quarts per minute. The filters are not designed to remove contaminants that are small in size.

Engine Oil Contaminants

The problem of soot contaminants in engines will increase in the years to come. EPA emission requirements for the year 2004 will force the diesel industry to deal with exhaust gas recirculation (EGR). In March 1998, at API's Lubricants Committee meeting in San Francisco, as reported in the May 1998 issue of *Lubes-n-Greases* magazine (*1*), a representative of Cummins Engine Company noted that "Diesel engine manufacturers face the prospect of having to reduce their drain interval recommendations significantly because of increasing levels of soot, caused by the need to introduce EGR."

In an effort to reduce nitrogen oxide (NO_x) emissions in the year 2004, it will be necessary to incorporate EGR for diesel engines. EGR exhaust is cooled and recirculated through the engine in order to reduce oxygen concentrations within the cylinder, thereby lowering flame temperature and nitrogen oxide (NO_x). Soot and fuel sulfur oxides are critical issues with EGR. In the opinion of the representative from Cummins, the only current way to handle increased levels of EGR soot is to remove it by changing the oil more frequently. He further noted that a dramatic decrease in oil change intervals to, say, around 10,000 miles would be needed. Instead of trying to solve this problem of higher soot levels by adding additional filtration, the engine manufacturers and oil companies are relying on those new oils to solve the problem—and if the oil companies cannot come up with new oils that can contend with EGR soot, the only option will be to shorten oil drain intervals. Is this the only option?

There is a very common-sense approach to the dilemma facing the engine and oil manufacturers. Soot is not a gas or liquid; it is solid particulate. A by-pass oil filter only filters about 10 percent of the oil each minute through a very dense element. It does not supply the engine with oil for the purpose of lubrication. Its sole purpose is to clean the oil. By-pass filters can control the higher levels of soot and other solid contaminants within today's engines, as well as into the future, without the need to go to a higher-tech oil. There are three basic types of contaminants that must be addressed: solid, moisture, and condition-caused contaminants.

Numerous tests and studies have shown that solid contaminants in the 1–15 micron range are responsible for the majority of normal wear within an engine. The standard factory full-flow filter does not control 1–15 micron particles, due its porous design required to supply engine parts with a high flow rate of oil. UF filtration, however, is capable of controlling solids in the 1–15 micron range.

Moisture within the lube oil causes viscosity to increase, VI polymer to decrease, and TBN to decrease, along with acid formation and accelerated oxidation and nitration. If left unchecked, moisture will contribute to accelerated wear, filter plugging, sludge formation, and corrosion of parts. Utilizing by-pass filters with absorbent filter media, such as cellulose or cotton, will remove suspended moisture from the lube oil.

There are three major condition-caused contaminants that are formed within the lube oil during normal use: oxidation, nitration, and acid. These contaminants are formed when solid contaminants and moisture are present and certain operating conditions exist within the engine.

Oxidation occurs when the hydrocarbon constituents of lube oil combine chemically with oxygen. Lube oil in engines will combine with available oxygen under certain conditions to form a wide variety of oxidation products. Many of these direct or primary oxidation products combine with other materials such as wear metals, solid contaminants, and moisture, to form second and third derivative products. As with most chemical reactions, oil oxidation is accelerated by heat and pressure. Effects of oxidation within the engine can be seen in the form of accelerated acid formation, corrosion, oil thickening, deposit formation, and accelerated wear. The presence of engine wear metals accelerates the oxidation process. Wear metals and other solids tend to hold heat, thereby increasing the lube oil temperature around the solid contaminants to accelerate the oxidation process. Combine this effect with the presence of moisture (H_2O) from normal condensation within the engine, and the oxidation process accelerates even faster.

Moisture within the lube oil offers a readily available source of oxygen to accelerate the oxidation process. Utilizing UF by-pass filters to remove solid and moisture contamination drastically reduces the oxidation process. Factor in fresh additives introduced by new oil added at the time of servicing by-pass filters and oxidation can be held in check.

The combustion chambers of engines provide one of the few environments where there is sufficient heat and pressure to break the atmospheric nitrogen molecule down to two atoms that can react with oxygen to form nitrogen oxide (NO_x). When nitrogen oxide products enter the lube oil through normal blow-by, they react with moisture present in the lube and become very acidic and rapidly accelerate the oxidation rate of the oil. Proper by-pass filters can control the effects of nitration in the same ways they control oxidation.

Acids are formed within the lube by several sources, two of which are oxidation and nitration. In almost all forms of fuel for internal combustion engines, trace amounts of sulfur are present. Sulfuric oxides are formed in the combustion chamber when sulfur molecules react with oxygen. These sulfur oxides then are blown past the rings and enter the oil. Here the sulfur oxides mix with moisture to form the highly corrosive sulfuric acid. It takes two components to make sulfuric acid: sulfur oxides and water. Proper UF by-pass filters remove the moisture from the lube and keep it chemically dry, thus controlling the formation of sulfuric acid.

WEAR REDUCTION WITH USE OF UF BY-PASS FILTERS

As the UF by-pass filter removes and controls contamination limits within the engine to extend oil drain intervals, another major benefit can be realized. With less contamination in the lubrication system, significant wear reduction is achieved. Consider these facts:

1. More than 80 percent of normal wear generated within an engine becomes contaminants that the factory full-flow filter allows to pass;
2. Ninety-eight percent of the solid contaminants generated within engines is below 10 microns in size; and
3. the factory full-flow filters are only effective in controlling particles 15 microns and larger (see Figure 2). A UF by-pass filter can be added to reduce normal wear and thereby extend the life of the equipment. If an engine runs on clean oil 100 percent of the time, the engine will last longer. With UF by-pass filters, wear can be reduced from 25 to 50 percent. In cases in which equipment is operating in adverse environmental conditions, such as dusty conditions, the use of UF by-pass filters can reduce wear up to 400 percent. The fact that UF by-pass filters drastically reduce wear has been well documented by SAE.

A factory full-flow filter is designed to remove large particles that could damage vital parts. The full-flow filter does little to reduce normal wear within the engine. The vast majority of solid contaminants generated within the engine are below 10 microns in size. As shown below, the full-flow filter is only capable of controlling 15-micron-and-up particles, allowing the smaller size contaminants to pass into the lube oil. Once introduced to the lubrication system, the oil has the job of suspending these tiny particles within the additive package. However, abrasive contaminants in the oil tend to grind away at bearings, cams, and other engine parts, causing the normal wear. UF by-pass filters are capable of removing and controlling particles down to 1-micron size range. By using UF by-pass filtration, fleets can accomplish extended engine life.

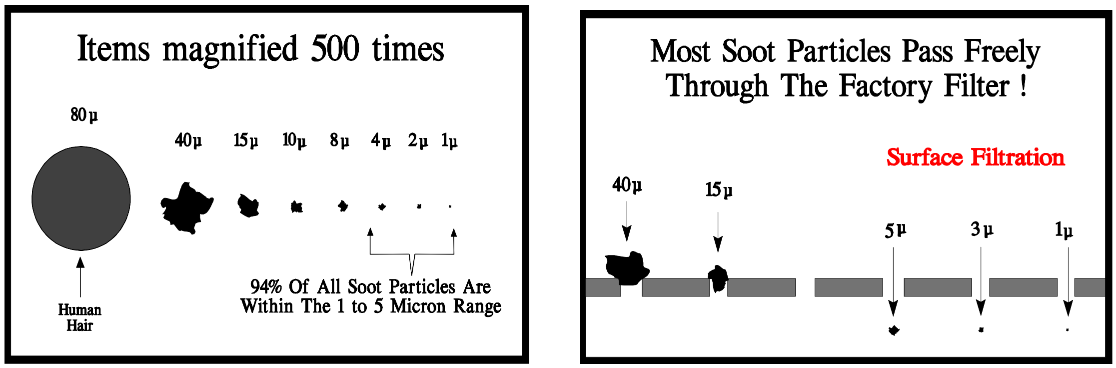


FIGURE 2 Filtration of soot particles.

FIELD RESULTS: EXTENDED OIL DRAIN PROGRAM

For many years numerous fleets have been utilizing UF by-pass filters and this type of P/M program. The level of oil drain extension depends on the goals to be achieved, as well as on the maintenance personnel's ability to carry out the P/M program needed to reach those goals. The following are three working examples of this program.

North Carolina Department of Transportation (NCDOT) used to change lube oil on its dump trucks at intervals of 5,000 miles. After a comprehensive test period using by-pass filters, NCDOT now changes the by-pass filter at 5,000 miles and performs a complete oil drain at 10,000 miles, doubling the oil drain interval. After successfully utilizing this program for over 2 years, NCDOT is now considering extending its oil drain further.

The North Carolina Ferries Division has more than doubled its diesel oil drain intervals. On small bore Cat engines, the oil drain intervals have been extended from 250 to 1,000 h. On big bore Cats, the oil drain intervals have been quadrupled, moving from 1,000 to 4,000 h.

Scott Paper Company was changing lube oil within its woodlands equipment each 100 h of operation, due to severe and dusty operating conditions. Scott elected to install by-pass lube oil filters and utilize the rest of the P/M program. The by-pass filters were serviced every 100 h in lieu of performing complete oil drains. The factory full-flow filters were changed every 500 h. The oil was sampled weekly with a portable oil analyzer and complete laboratory oil analysis was performed every 500 h. After 9 mo of testing, Scott elected to move the rest of its equipment to this program. Scott continued to service the by-pass filters as outlined above, but elected to perform a complete lube oil drain and filter change at 1,000 h even though lab analysis showed the oil to be in excellent condition.

Shell Oil has utilized by-pass filters in a P/M Program on its engines within the Gulf of Mexico for longer than 9years. After 2 years of rigorous testing and extending of oil drains further and further, Shell Oil now only performs an oil drain when laboratory analysis deems it necessary. Some of its equipment has not had a routine oil drain in over 8 years. Shell personnel now service by-pass filters and sample the equipment with portable oil analysis units on a routine basis. Complete laboratory analysis is performed on a quarterly basis. Extending lube oil drains by the use of UF by-pass filters in a P/M program has streamlined Shell's lube oil maintenance operations, has drastically reduced downtime, and has led to dramatic savings on new oil purchases and disposal cost of waste oil. Also, Shell Oil has experienced wear reduction and extended engine life. Figure 3 illustrates the effects of using UF by-pass filters.

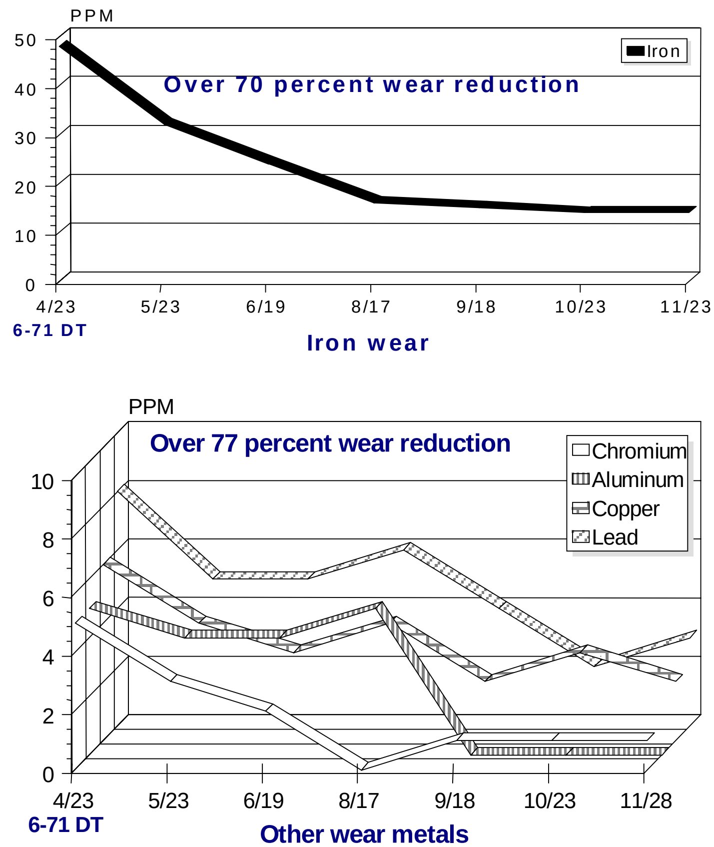


FIGURE 3 Shell Oil engine wear reduction.

PORTABLE OIL ANALYSIS

Knowing the condition of oil and equipment in the field is extremely beneficial to maintenance managers and maintenance personnel. A portable oil quality analyzer can deliver the above information. Most fleets that perform analysis on lubes utilize complete laboratory used-oil analysis. Primarily due to the cost of laboratory analysis, these tests are only performed on a routine basis—that is, monthly or at each oil drain interval. Laboratory oil analysis serves two basic functions. The first is to monitor the condition of the lube oil. Complete lab analysis is very effective in accomplishing this goal. However, it is in the second function that lab analysis falls a little short: it does not give sufficient warning of possible failures such as coolant leaks and stress-related metal failures. Many fleets sample equipment lube oil on a routine basis, usually monthly or at the time of oil drain. While this is an interval sufficient to safely monitor the lube condition, many times this frequency is not sufficient for detection of engine problems. *Engine problems* is used here, not *engine failures*, because oil analysis is used to detect the problem before failure and downtime occur. An example of this situation is as follows. A company samples equipment oil on a monthly basis. On the first day of the month, a sample of the used oil is taken, and it is sent to the lab for analysis. On the second day, unbeknownst to the maintenance personnel and the oil lab, a coolant leak develops within the engine. The next scheduled time for a complete laboratory analysis sample to be taken is 29 days away. On the fifth of the month the operator receives the lab's results—which, of course, were taken before the problem occurred and therefore show everything to be OK and that the oil is suitable for further use. On the seventh, the operator notices that the oil is becoming cloudy. So much for detecting engine problems—the routine monthly sampling of the used oil has not been effective in achieving its goal of detecting engine problems.

The need is immense for a truly portable device that can be used on a more-frequent basis for determining the condition of the lube and equipment. A portable oil-quality analyzer is an accurate means of determining whether the oil and equipment are in normal or abnormal condition. The unit utilizes a dielectric testing method to test and determine the quality and condition of lube oil and equipment. Oil in its new state conducts very little electricity and is considered to be an insulator. However, as the new oil is subjected to use within equipment such as an internal combustion engine, it becomes contaminated, increasing its ability to conduct electricity. Oils used within engines collect contaminants such as copper, iron, other various wear metals, carbon from incomplete combustion, acids formed from oxidation, and more.

The oil-quality analyzer is electronically calibrated with new oil of the same type as is used within the engine. Then used oil of the same type from within the equipment is placed on the sensor, and the same electric charge is passed through the used oil. The contaminants within the used oil allow more current to flow, and this deviation from that of the new oil is shown on the meter, which gives a numerical increase to indicate the amount of contamination present. The increased current flow is in direct proportion to the amount of contamination in the used oil.

For over 20 years, Gulf Coast Filters conducted research to compare dielectric readings of portable oil quality analyzers to those of laboratory spectrographic analysis, particle counts, and other various laboratory analyses taken at the same time. During the course of the research, thousands of readings were taken with the portable oil analyzers on oil in many different types of equipment. Gulf Coast Filters was able to establish common parallels in the readings taken by the portable dielectric equipment and contamination levels indicated by complete laboratory analysis. This experience allowed the development of easy-to-use charts for almost every engine and equipment application. These charts allow the user to track equipment and to determine proper by-pass filter change intervals or, if the user is not using by-pass filters, complete lube oil drain intervals.

UTILIZING COMPLETE OIL ANALYSIS

Even though one is utilizing a portable oil-quality analyzer, one should utilize the benefits of complete laboratory used-oil analysis (see Figure 4). A spectrographic lab analysis can be used to confirm problems detected by a portable oil-analysis program. In addition, other lab samples should be periodically taken on equipment for the purpose of obtaining information for long-term trending of equipment condition. The interval at which lab samples should be taken should be determined by equipment runtime hours, severe-duty application, and many other factors. In many cases, only one routine sample per year may be necessary. The type of lab analysis should consist of full spectrographic analysis of 6 wear metals, silicon, and 13 additives. Also, physical tests should include viscosity, SAE grade, fuel soot, water, fuel dilution, antifreeze, and, last but not least, TBN (total base number). One should choose a reputable laboratory with numerous references and, once the lab is selected, stay with the same lab. It is not advisable to utilize two or three different labs for analysis on the fleet. Each laboratory's equipment can vary, causing the organization to receive different readings on the same equipment.

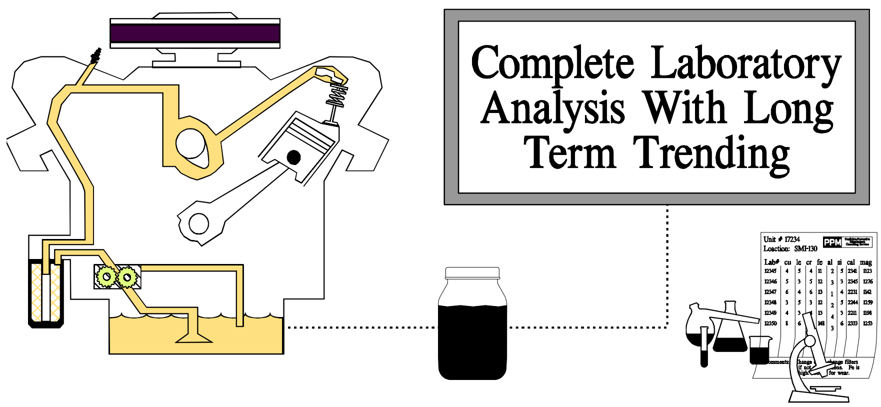
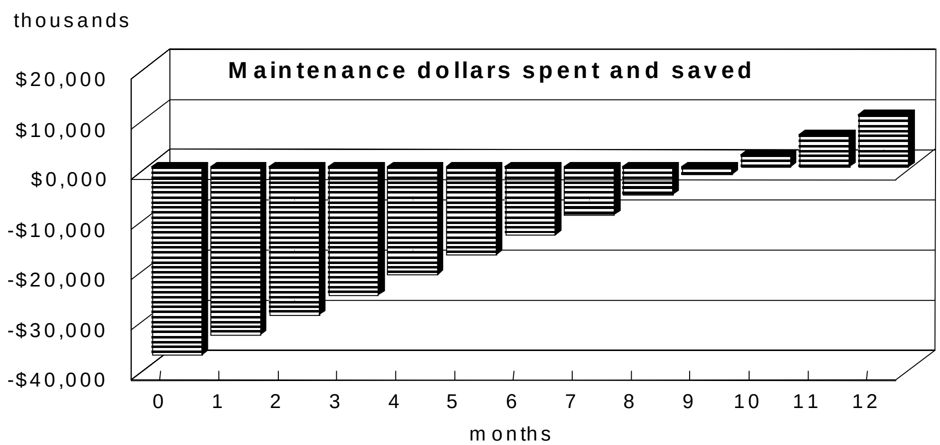


FIGURE 4 Complete laboratory analysis with long-term trending.

COST SAVINGS

The application of a UF by-pass filter program on equipment, such as DOT uses, from the small gasoline to large diesel engines has been shown to be cost effective. In most cases, return on investment is less than one year, when employing an indefinite oil drain interval. The following is an example of the application of this approach on a fleet of dump trucks (see Figure 5). Typically, a fleet of 100 dump trucks with an oil drain interval of once a month or 5,000 miles, using a cost of $50 for a routine monthly oil drain on each piece of equipment, including lube oil, factory full-flow filters, and labor would cost $60,000/year. This $60,000.00 maintains the lube oil and does not include complete laboratory oil analysis or any of its benefits, or disposal costs for the waste oil. With the use of UF by-pass filters, the monthly cost to maintain the lube oil in the same 100 trucks would be approximately $7.50 each, which includes a replacement filter element, oil, and labor. Also, each truck would require a maximum of two factory full-flow filter changes in per year at a total cost of $18.50 for the filters, oil, and labor. After 150 laboratory used oil samples per year at a cost of $8.00 each are added, the total yearly expense on the same 100 trucks under this program would $12,050. This includes $9,000 for by-pass filters, $1,850 for two factory full-flow filter changes, and $1,200 for oil samples. To this, one must add the cost to retrofit a dump truck with a by-pass filter at $375 per truck, which includes parts and labor, or approximately $37,500.00 for the 100 trucks. The return on investment for this fleet would be less than 10 months or, if by mileage, less than 50,000 miles. Also, a yearly savings of $47,950.00 or 79 percent would be seen each year.



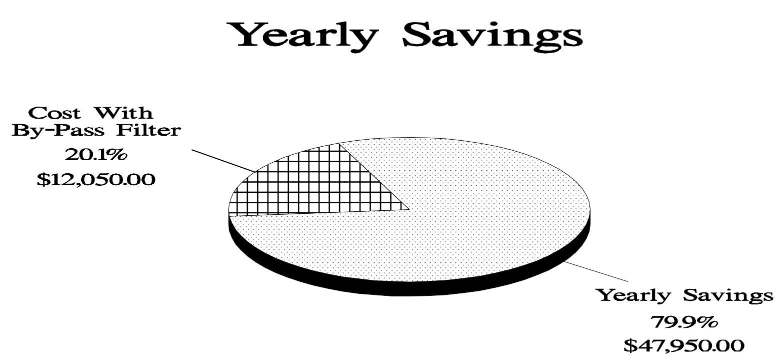


FIGURE 5 Return on investment and yearly savings for 100-dump-truck fleet.

SELECTING THE PROPER FILTRATION

An integral part of this process is the by-pass filter. There are many different types and brands of aftermarket filters and centrifugal equipment that boast claims of greatly extending or eliminating routine oil drains. Many of these claims are true; however, in some cases the truth has been stretched by marketing methods, claims based on in-house testing, and testimony from isolated customer bases. Also, many of these filters and centrifuges fall short of dealing with and controlling the amounts and types of contamination that need to be removed in order to achieve the goal of extending or eliminating routine oil drains. In order to choose the right filter for the job, look for one that meets the following criteria and offers the following benefits:

1. Choose a by-pass filter that can control 1–5-micron–sized particles within the quantity that the engine or equipment is generating. There are several depth-type by-pass filters on the market that have the capability of controlling particles of this size. However, be sure to ask to see several particle counts taken on actual working engines or equipment similar to yours, and ask that those particle counts show ISO cleanliness levels.
2. Choose a filtration system that can remove moisture from the lube and keep the lubricant chemically dry at all times. This is critical. To control oxidation, nitration, acid formation, viscosity increases, and the other problems linked to moisture contamination, the filtration system must have the capability of removing moisture. Most depth-type by-pass filters with absorbent filter media such as cellulose (paper) or cotton fibers have this capability.
3. Choose a filtration system that has been proved within your field as legitimate in field test results, the worth of which can be confirmed by several users. Ask for field test results on equipment similar to your own. If the filter manufacturer cannot produce this type of information, look elsewhere.
4. Choose a filtration system that is backed by a company that can offer a proven P/M program to coexist with its product and your existing P/M program. There are many companies that specialize in selling filters; however, there are few filter companies that sell filters and specialize in predictive preventive maintenance. Also, select a company that has a significant number of satisfied users. Be sure to ask for a user list and call these users for their comments.
5. Choose a filtration system that is cost effective. Many factors need to be considered when you are determining the cost effectiveness of a filter. Look at the long-term savings from the filter. Look for the lowest-cost filter element that will achieve your goal. Filter elements achieving the same results can vary in cost, ranging from less than $2 to as much as $38 each. Also, consider durability of the filter housing, ease of installation, ease of service, and other critical points.

CONCLUSIONS

The use of UF by-pass filters and a comprehensive oil and equipment monitoring program has proven to greatly extend or eliminate routine oil drains. The benefits available to DOT fleets are significant, in that one can cut maintenance costs, extend the life of equipment, reduce equipment downtime, and reduce waste oil generation. UF by-pass filters in this type of program can work for you. There are a number of satisfied users of UF by-pass filters and this type of P/M program. Will UF by-pass filters and this program work on your equipment, with your personnel running the program? The only way to answer this question is obvious. DOT fleets should take a very close look at this type of program to enhance their maintenance operations. The benefits are rewarding.

REFERENCES

1. McFall, D. Diesel's Dirtiest Word. *Lubes'n'Greases Magazine*, Vol. 4, No. 5, May 1998, pp. 8–13.