Executive Development

Recommendations for Implementing New Oil-drain Procedures in the City of Raleigh Fire Department's Apparatus Fleet

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Abstract

Oil changes were expensive, placed fire companies out of service and created opportunity costs for service technicians. This research described engine-lubricating technologies and developed recommendations for extending oil-drain intervals. Descriptive research answered the following questions:

1. What technologies allow extended oil-drain intervals?
2. What benefits might result from advanced lubricating technologies?
3. What lubrication technologies can be integrated with engine manufacturers' maintenance schedules?
4. What are the recommendations for new oil-drain procedures in the City of Raleigh Fire Department's apparatus fleet?

A literature review and interviews revealed synthetic motor oil and high-efficiency filtration allow extended oil drains. Based on significant evidence that well-filtered synthetic oil has many benefits, recommendations were made to utilize high-technology lubrication to reap those benefits.

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Recommendations for Implementing New Oil-drain Procedures in the City of Raleigh Fire Department's Apparatus Fleet

Introduction

Motor oil changes are a key part of preventive maintenance for internal combustion engines (T. J. Menges, personal communication, August 20, 2004). As the costs of fire apparatus climb into the hundreds of thousands of dollars (P. C. Woodlief, personal communication, March 22, 2004) and governments "are being challenged to provide quality services at less costs," (D. E. Benton, Jr., personal communication, May 3, 1994) proper care of the taxpayers' investment in fire apparatus, of which the engine is a major component, has never been more critical. Motor oil's importance to engines has been compared to that of blood (Unrein & Dick, 2003). In addition to its primary function of lubricating, Unrein, et al. and Ableson (1998) describe the secondary functions of motor oil including conducting heat away from internal engine parts, operating internal hydraulic functions, cleansing the engine's interior and holding contaminants in suspension until a filter can remove them. The Cummins Engine Company, Incorporated's *Operation and Maintenance Manual* (1999) specifies guidelines for oil-drain intervals. Further, the Cummins factory warranty for fire apparatus stipulates that the engine "owner is responsible for the operation and maintenance of the engine as specified in…*Operation and Maintenance Manuals*" (Cummins Engine Company, Incorporated 2001). Fire apparatus fleet managers face the burden of complying with guidelines and responsibilities such as these.

The problem is that oil changes for apparatus fleets are expensive, place fire companies out of service and create opportunity costs for service technicians. The purpose of this research is to describe various engine lubricating technologies and to develop recommendations for

extending oil-drain intervals in the apparatus fleet of the City of Raleigh Fire Department. Questions this research will answer include:

5. What technologies exist that allow for extended oil-drain intervals?
6. What benefits might result from advanced lubricating technologies?
7. What lubrication technologies can be integrated with engine manufacturers' maintenance schedules and warranties?
8. What are the recommendations for implementing a new oil-drain procedure in the City of Raleigh Fire Department's apparatus fleet?

Background and Significance

The City of Raleigh Fire Department's Support Services Division is responsible for the maintenance and repair of nearly 60 pieces of heavy equipment, including fire engines, aerial trucks, tractor-trailers, medium-duty ambulances and specialty vehicles (A. H. Griffin, personal communication, August 20, 2004). Preventive maintenance, including oil changes, is performed on these vehicles every six months at the fire department's garage facility (R. J. Spangler, personal communication, March 22, 2004). Except for the replacement of certain worn parts such as tires and brake components, the most expensive part of scheduled maintenance is changing the oil and oil filters (T. J. Menges, personal communication, August 20, 2004). Menges said fire apparatus engines hold between six and ten gallons of motor oil. A typical oil filter costs more than $25 (M. Hall, personal communication, March 22, 2004). At least in the near term, the cost of oil changes is unlikely to fall, as oil prices are higher now than they have been in over a decade (Tran, 2004). Maintaining an adequate supply of new oil and filters takes up valuable storage space in the garage area. Additionally, used oil and filters must be stored until a sufficient quantity is on hand for a disposal company to pick up the used components

without billing the fire department for the pickup (A. H. Griffin, personal communication, August 12, 2004). The Support Services budget funds not only fleet maintenance costs, but also equipment such as thermal imaging cameras, self-contained breathing apparatus and other health and safety equipment (City of Raleigh, 2004). If the cost of oil changes can be reduced, more funds may become available to purchase health and safety equipment.

The City of Raleigh currently covers over 127 square miles and has a population growth rate of 3.4%, annually (City of Raleigh, 2003). As Raleigh's footprint grows, the logistics of performing oil changes become more complicated. Some fire companies must travel nearly 22 miles, one way, to get to the fire department's garage facility (S. A. Moody, personal communication, August 29, 2004). Once there, companies transfer equipment and supplies to a reserve fire engine and return to their assigned territory while preventive maintenance is being performed. When maintenance is complete, fire companies return to the garage, transfer equipment off the reserve fire engine and again return to their assigned territory. Moody says depending on weather and traffic conditions, it is conceivable for fire companies to be out of service, leaving parts of the city without coverage, for three hours in the name of preventive maintenance. During this three-hour period, customers face the potential for a delayed response because a fire company is out of service for reasons unrelated to emergency response or training. Low response times are essential for "an early aggressive and offensive primary interior attack on a working fire," (National Fire Protection Association (NFPA), 2001, p. 1710-15) which is "usually the most effective strategy to reduce loss of lives and property damage" (NFPA, 2001, p. 1710-15). Hence, the ability to keep fire companies in service more of the time strikes at the heart of the United States Fire Administration's 5-year objective to "reduce the loss of life from fire by 15%" (2004, ¶ 1). Additionally, fire crews that *are* in service, but utilizing a reserve

apparatus, cannot provide the same level of customer service as crews using front-line apparatus. In general, reserve fire engines are smaller, slower and lack amenities such as electric power generators, scene lighting, pre-piped master stream appliances and enclosed climate-controlled cabs that are common on newer apparatus (A. H. Griffin, personal communication, August 12, 2004).

Performing oil changes and other preventive maintenance tasks are not the only responsibilities with which fire department service technicians are charged. Over the course of a day, the technicians perform various non-scheduled repairs that can be expected from an apparatus fleet as large and as often used as Raleigh's. A sampling of tasks includes brake work, pump valve repair and tire replacement (T. J. Menges, personal communication, August 20, 2004). Being only one part of the equation that comprises the total of all jobs service technicians try to accomplish in a workday, oil changes present an opportunity cost. If oil-drain intervals are less frequent, technicians will be able to dedicate more time to performing non-scheduled repairs.

This research project will use descriptive research to provide information about technologies that may allow for extended oil-drain intervals. It will also recommend a plan to evaluate some of these technologies on fire engines in Raleigh. Extended oil-drain intervals may provide an opportunity to save money, save lives and increase the productivity of employees. These are three items with which all executive fire officers should be concerned.

Literature Review

A number of entities espouse two primary technologies that allow for extended motor oil drain intervals: synthetic lubricants (ExxonMobile Oil Corporation, 2002; Shell Oil Company, 2002; Amsoil, Incorporated, 2003; Royal Purple, Limited, 2004; Enviro Kleen, n.d.) and high-

efficiency oil filters (Amsoil, Incorporated, 2003; MTM Industrial, 2004; puraDYN, 2004; Enviro Kleen, n.d.). There is general agreement that synthetic oil can go longer periods of time without needing to be drained and replaced. Ultra fine, or bypass, filtration is proclaimed as a method to allow longer intervals between oil changes, but there is some disparity as to the best way to accomplish this type of filtration.

Amsoil, Incorporated (2003), a manufacturer of synthetic lubricants and premium oil filters promotes its Heavy Duty Diesel and Marine Oil as being specially formulated for extended oil drains. The company claims that its products are as much as ten times more capable of withstanding thermal and oxidative breakdown when compared to petroleum oils. Amsoil also claims that its motor oil can run for extended time periods because the stable properties of synthetics help stave off the production of carbon deposits, varnish, and sludge that form in engines. Amsoil is promoted to be better able to neutralize acids that form in motor oil over time compared to conventional motor oil.

Extensive studies by ExxonMobile Research and Engineering Company have concluded synthetic lubricants are capable of drain intervals as long as 100,000 miles in heavy-duty diesel engines (Kelly, Kennedy and Spagnoli, 2000). In a similar study performed jointly by researchers at Mobile Oil Corporation and Caterpillar, Incorporated, it was concluded that extended oil-drain periods of three to four times those recommended by engine manufacturers produced no ill effects in diesel engines over a period of 500,000 road miles (Jetter, et al., 1998).

In *The Motor Oil Bible* (2002), Kaufman goes into great detail about synthetic and conventional motor oils. His discussion runs the gamut from the function of motor oil to how the Magnuson-Moss Warranty Act applies to the use of synthetic oil and aftermarket oil filters. After a thorough discussion of technical points about motor oil, Kaufman makes his primary

point about synthetic motor oil: “oil drains can be extended” (p. 57). Kaufman says the improved chemical properties of synthetic oil allow oil drain periods to be extended by a factor of four in automotive applications. The specific information Kaufman reports on synthetic motor oil in *The Motor Oil Bible* is affirmed by Hackett (1995) and Andrews (2000).

The John Deere Company (2004) has recently introduced synthetic motor oil that the company advises will double recommended oil-drain intervals in some engines. John Deere cites “greater thermal stability and resistance to oxidation and corrosion” (¶ 8) as reasons for achieving extended drain intervals.

Following the same trend as Amsoil, Incorporated and John Deere Company is a company called Enviro Kleen, which sells synthetic heavy-duty diesel engine oil labeled Syn-O-Gen 711. Syn-O-Gen 711 is formulated for extended drain intervals and to resist deposits, oxidation and sludge that can build up in diesel engines over time (Baudo, n.d.).

In promotional literature, Royal Purple, Limited (2004) confirms the claims of other manufacturers: synthetics can extend drain intervals, resist oxidation and withstand thermal stresses in an engine better than conventional motor oils. Royal Purple has something few others do to back their claims. From the Royal Purple home page on the World Wide Web, there is a link to a test report published by the Mechanical and Aerospace Engineering Department at North Carolina State University. This research is unique because it was performed for the North Carolina State Highway Patrol, not a lubricant manufacturer. Road tests compared Royal Purple synthetic motor oil to Chevron Texaco Corporation’s Havoline conventional motor oil in highway patrol cars and compared Royal Purple synthetic to ConocoPhillips’s Kendall conventional motor oil in a fleet of Coca-Cola delivery trucks in Raleigh, North Carolina (Kilian, Rutherford, Afify, & Leach, 2002). In these on-the-road tests, laboratory analysis of the Royal

Purple oil showed that it had the ability to provide satisfactory lubrication for a period at least twice as long as the traditional oil-drain interval. Researchers also concluded that synthetics are generally superior to and do not deteriorate as quickly as their conventional-oil counterparts.

At least one company has a product that virtually eliminates the need for oil changes, however not by way of a super lubricant or ultra-fine filtration. Cummins Engine Company, Incorporated's Centinel system continuously meters a small amount of engine oil into a vehicle's fuel tank where it mixes with the fuel and ultimately is burned in an engine's combustion chambers (Ableson, 1998). Oil removed from the system is replaced from an on-board tank. Ableson says the oil is never totally clean. Rather, it is perpetually in a state of being acceptably clean due to the continuous addition of fresh oil. The Centinel system requires an oil-drain every 525,000 miles (Cummins Atlantic, Incorporated, 1999). Use of the Centinel system requires the owner to report oil purchases as fuel and pay taxes accordingly. The Centinel system is exclusive to Cummins engines and is not approved for use in California.

Thus far, the literature review has revealed a consensus among researchers and synthetic oil manufacturers that synthetic motor oil provides a means for extended oil-drain intervals when compared to conventional motor oil. Even the makers of conventional motor oil do not dispute this claim, as many of those manufacturers also have fully synthetic oil on the market with claims that the synthetic products can be used to extend drain intervals (ExxonMobile Oil Corporation, 2002; Shell Oil Company, 2002; John Deere Company, 2004). Like manufacturers of synthetic lubricants, producers of high-efficiency filters agree that their products can extend oil-drain intervals. All of these high-efficiency devices are commonly known as bypass filters. These filters clean a small amount of the total oil volume at a time and are used in conjunction with the standard full-flow oil filter provided by the engine manufacturer. There seems to be

some agreement that bypass filters need to be capable of filtering particles down to about two microns in size in order to trap the contaminants in oil that cause most engine wear (Cavette, 2001). A micron is 1/1,000,000th of a meter, about 0.00003937 inches or approximately 500 times smaller than an 11-point period (Zirker and Francfort, 2003). In order to allow adequate oil pressure and volume to the engine, most full flow filters are only capable of filtering particles 10 to 20 microns in size (Cavette, 2001). Finer filtering would require greater restriction inside the oil filter, cutting oil pressure and volume. But, because a bypass filter is not in line with the primary oil flow and only cleans a small amount of oil at a time, it can have filter media capable of removing particles as small as one micron (Cavette, 2001). What bypass filter manufacturers cannot agree upon, however, is how high-efficiency filtration is best accomplished.

In addition to its line of synthetic lubricants, Amsoil, Incorporated (2003) makes bypass oil filters capable of filtering particles in oil as small as one tenth of a micron. The company says the filter, utilizing a dense stack of cellulose disks, super cleans motor oil and allows for substantially longer drain intervals.

Enviro Kleen, the same company that produces the Syn-O-Gen 711 synthetic motor oil reviewed previously, manufactures a bypass oil filter the company claims is capable of filtering particles in motor oil as small as one micron with a filter made of wound cotton string and lined with charcoal (Baudo, n.d.). Baudo, Enviro Kleen's United States Installation and Sales Coordinator, says the Enviro Kleen filter is capable of extending oil life indefinitely so long as a chemical analysis of the oil is performed periodically and necessary additives in oil are replaced. *Indefinitely* seems to be a relative term; the Enviro Kleen (n.d.) product literature recommends an oil drain every 60,000 miles when using conventional motor oil and every 160,000 miles when using synthetic motor oil.

Another company utilizing a wound-string filter design is Oilguard (MTM Industrial, 2004). It claims its filter is capable of removing contaminants in oil as small as one micron. Oilguard states “oil doesn’t wear out-it is the additive pack that wears out because it can no longer battle the amount of contamination contained within an oil” (¶ 4). The company says by using its filter with high-quality motor oil, drain intervals suggested by an engine manufacturer can be at least doubled. For drain intervals longer than double, Oilguard recommends a chemical analysis of the oil to assess its continued ability to lubricate the engine and counter pollutants.

Gulf Coast Filters, Incorporated (2002) sells bypass filters that give the owner a choice of filter elements: one is a proprietary cellulose media element the company claims has the ability to filter particles as small as one micron. The other element option is a roll of Bounty brand paper towels (J. Sims, personal communication, August 10, 2004; B. Thompson, personal communication, August 12, 2004). The Gulf Coast product is unique in its capacity. Where most bypass filters hold one to three quarts of oil, Gulf Coast’s smallest filter holds three gallons.

PuraDYN [*sic*] Filter Technologies, Incorporated (2004) manufactures a filter that is in some ways unlike any other bypass filter on the market. Similarly to the Oilguard and the Enviro Kleen, the puraDYN product uses a cotton filtering element. However, the puraDYN filter incorporates three other features. One is filter media that is treated to chemically attract contaminants in the oil less than one micron in size. The second is a time-release additive pack enhancer that acts to boost oil’s ability to deal with acids that build up over time. The third feature of the puraDYN is an evaporation chamber to cook off impurities such as fuel and water that may have accumulated in the oil. After being filtered by the cotton media, oil passes through the evaporation chamber powered by a vehicle’s electrical system, where it is heated to about 200 degrees Fahrenheit. All of these features combine to safely allow extended drain

intervals and reduce new oil purchases by 90%, according to the company. In a puraDYN press release, the Fleet Services Manager for the Miami-Dade, Florida General Services Administration says garbage trucks in the Miami-Dade fleet with puraDYN filters get an oil change once a year instead of six times a year that would be required without the puraDYN filter (Florida County Specifies puraDYN, 2004).

Another unusual type of high-efficiency oil filter "operates on an entirely different principle than the barrier-type filters" (Brezonick, 1998, ¶ 6) that have been reviewed so far. Several companies manufacture oil-cleaning centrifuges (Brezonick, 1998; T. F. Hudgins, Incorporated, 2000; Mann+Hummel, Limited, 2002; Industrial Diesel Products, Incorporated, n.d.). These devices are driven by an engine's oil pressure or a vehicle's air system and spin motor oil at high speed, causing solid particles in oil to be thrown to the outside of the filter housing where they form a cake that can be disposed of after removal (Industrial Diesel Products, Incorporated, n.d.). Centrifuges are capable of generating a centrifugal force up to 4,500 times the force of gravity and remove particles less than one micron in size, including soot that accumulates in the lubricating oil of diesel engines (T. F. Hudgins, 2000; Mann+Hummel, Limited, 2002). This is noteworthy as new emissions regulations cause more soot to be held in suspension by the oil rather than being vented out through the exhaust system (Brezonick, 1998; Jetter, et al., 1998; M. B. Styron, personal communication, August 18, 2004). Styron, with several years' experience using bypass filtration systems on school buses, says newer engines with tight emission controls deposit more soot in oil than some element-type bypass filters can remove. As a result of the heavy soot loading, extended drain intervals are not possible.

It is apparent that various manufacturers offer a number of products that give vehicle owners the option of extending oil-drain intervals. The literature review will proceed to investigate additional benefits provided by advanced lubricating technologies.

Longer Engine Life

All synthetic oil and bypass filter manufacturers suggest the use of their products can extend engine life. "Synthetic lubricants are chemically more uniform, and are stable under extreme pressures and temperatures and usually do not decompose as rapidly as petroleum base lubricants" (Synlube, Incorporated, 2004, ¶ 2). And, "studies have shown that the majority of engine wear is caused by particles in the 2- to 20-micron range," (Cavette, 2001, p. 10) which all bypass filters in the literature review are promoted to remove. Gulf Coast Filters, Incorporated (2002) makes an equivalent point, saying 80% of wear in an engine is caused by particles standard full-flow filters allow to pass. Motor oil that reduces an engine's production of soot (Kilian, et al., 2002) or a filter able to remove soot from motor oil (Brezonick, 1998; Mann+Hummel, 2002) stands to prevent clogging of vehicle catalytic converters and reduce wear on engine parts, particularly the exhaust valve seat (Kilian, et al., 2002). In promotional literature from Amsoil, Incorporated (2003), Haywood Gray, a long-distance truck driver, says the engine in his road tractor was torn down for inspection after running 409,000 miles using synthetic oil and bypass filters. An independent engine rater inspected the internal engine components and found wear consistent with an engine lubricated with conventional motor oil changed at 15,000 to 20,000 mile intervals.

Additional Sump Capacity

Evans (2001) establishes that motor oil's ability to suspend contaminants and prolong additive depletion is proportional to how much oil an engine contains. He also says bypass filter

systems can add to an engine's oil volume. Some bypass systems will add three gallons or more to a fire apparatus engine's capacity (Gulf Coast Filters, Incorporated, 2002), an amount equal to 33% to 50% of an engine's original volume (T. J. Menges, personal communication, August 20, 2004). Even if the oil is not changed, when bypass filters are changed, the oil that must be added to replace what is contained in the filter will boost the additive pack properties of the remaining oil (Paradise Garage, n.d.).

Oil Analysis

With very few exceptions, synthetic oil and bypass filter manufacturers recommend the use of oil analysis if the consumer attempts to extend oil-drain intervals more than double an engine manufacturer's recommendation. Through analysis, a laboratory is able to determine contaminate levels and the condition of the additive pack in motor oil (MTM Industrial, 2004). Blackstone Laboratories (2004) performs a motor oil analysis that checks for the following: oil viscosity [ability to flow], acidity or alkalinity, fuel contamination, water content, dirt content, soot contamination, silicates that indicate the presence of airborne dirt, antifreeze/coolant contamination and oil additive pack condition. They also perform a spectrochemical analysis to detect the presence of 20 metallic elements, registered in parts per million. Regardless of what the analysis results say about the oil, the detection of a contaminant or wear metal in the oil may be an indication that some engine part is wearing abnormally or is about to fail. For example, high levels of aluminum may indicate unusual piston wear (Blackstone Laboratories, 2004).

Cost Savings

It seems logical that if less oil is being purchased, less money is being spent. Oil analysis in a fleet of Coca-Cola delivery trucks using synthetic oil in Raleigh, North Carolina indicated drain intervals could be extended long enough beyond what conventional motor oils would

require to make the synthetic oil more economical than conventional motor oil (Kilian, et al., 2002). PuraDYN [*sic*] Filter Technologies, Incorporated (2004), the company that manufactures bypass filters with additive pack stabilizers and evaporation chamber, claims the use of its filter reduces new oil purchases by up to 90%. T. J. Menges (personal communication, August 20, 2004) says less frequent oil changes also help reduce the amount of storage space consumed by an adequate supply of new oil and filters. Additionally, he says there is less used oil and fewer dirty oil filters that require storage space while awaiting proper disposal.

Decreased Downtime

Menges goes on to say that if oil drain intervals can be extended, fire apparatus will be out of service less often for oil changes. He says that with properly equipped service vehicles, it is likely preventive maintenance of fire apparatus can be performed at fire stations as opposed to at a garage facility. At a minimum, this will greatly reduce out-of-service time for fire companies traveling to and from a maintenance facility.

Engine Efficiency

Synthetic oils provide a better seal between piston rings and cylinder walls; combustion efficiency is improved (Royal Purple Limited, 2004). In a test of synthetic and conventional motor oils in a laboratory test engine, researchers at North Carolina State University concluded synthetic oils can improve engine efficiency (Kilian, et al., 2002). Amsoil, Incorporated's (2003) product literature claims similar findings. The company says because thinner synthetic oils can protect as well as thicker conventional oils, an engine does not have to work as hard to overcome oil's resistance to flow. As a result of having the option to use thinner oils, an 8% gain in fuel efficiency was achieved in tests with long-haul road tractors.

Environmental Benefits

Environmental benefits can be derived through the use of synthetic motor oil. The laboratory research by Kilian, et al. found that synthetic oil is capable of reducing diesel exhaust emissions.

> The environmental impact of vehicles is a major problem that is being addressed with increasing urgency worldwide. In the atmosphere, hydrocarbon compounds acts as irritants and odorants, and some are carcinogenic. All components except CH_4 react with other gases to form photochemical smog. (Kilian, et al., 2002, p. 9)

Researchers also established that internal combustion engines in motor vehicles are one of the world's major producers of carbon dioxide, a greenhouse gas, and that oxides of nitrogen present in diesel exhaust contribute to the production of smog and acid rain and can act to deplete atmospheric ozone. Because it reduces overall emissions, synthetic oil helps lower the amount of harmful pollutants produced by diesel engines.

Thus far, the literature review has shown that the use of synthetic motor oil and/or a high efficiency oil filter can provide multiple positive benefits for fire departments and their apparatus fleets, including extended oil-drain intervals. However, it seems prudent to be mindful that much of the literature is published by oil and filter manufacturers and is promotional in nature. This research would be incomplete without consulting engine manufacturers to get opinions on extending oil-drain intervals, especially since replacing an engine not covered by warranty can cost $20,000 (A. H. Griffin, personal communication, August 24, 2004).

Cummins Engine Company is one of two primary engine manufacturers that supplies engines to companies that build fire apparatus for the City of Raleigh Fire Department. The warranty from Cummins Engine Company, Incorporated states the "owner is responsible for the

operation and maintenance of the Engine as specified in *Cummins Operation and Maintenance Manuals*. Owner is also responsible for providing proof that all recommended maintenance has been performed" (2001, p. 1). Further, the warranty states, "Cummins is not responsible for failures or damage resulting from what Cummins considers to be abuse or neglect, including but not limited to: …lack of maintenance of lubricating, cooling or intake systems" (2001, p. 2). The Cummins Engine Company, Incorporated *Heavy Duty Maintenance Vocational Market Quick Reference Guide* (1995) speaks specifically about synthetic motor oil and oil analysis. The guide states synthetic oil "should NOT BE USED to extend oil drain intervals. Ability to hold soot in suspension is no better than petroleum based oils" (p. 1). In reference to oil analysis, the guide states, "oil analysis as a method to extend drain intervals is not recommended." Both the warranty and the *Quick Reference Guide* are included in the documentation accompanying all fire apparatus with Cummins engines purchased by the City of Raleigh Fire Department.

Detroit Diesel Corporation is the other primary supplier of engines to manufacturers of apparatus purchased by the City of Raleigh Fire Department. The Pierce Manufacturing Company *Service Manual* (1996) that accompanies the last eight Pierce fire pumpers purchased by the fire department includes a supplement by Detroit Diesel Corporation titled *Lubricating Oil, Fuel, and Filters: Engine Requirements*. This supplement discusses synthetic motor oil and states, "their use does not permit extension of recommended oil drain intervals" (p. 6). Further, the Detroit Diesel supplement discusses aftermarket filtration and states,

> Aftermarket supplemental filtration systems may be used, provided they do not replace the factory-installed system or reduce oil volumes, pressures, or flow rates delivered to the engine. The use of such systems does not address oil degradation

> from normal use and, therefore, does not permit extension of oil drain intervals. (p. 16)

In regard to motor oil analysis, the supplement states, “Since oil analysis cannot completely assess the lubricating oil for continued service, it should not be used to extend oil drain intervals” (Detroit Diesel Corporation, n.d., p. 10). While documents from Cummins Engine Company, Incorporated and Detroit Diesel Corporation are clear regarding both companies’ opposition to extended oil drain intervals, neither company prohibits the use of synthetic lubricants or high-efficiency filtration systems. It seems warranted to review the third research question: What lubrication technologies can be integrated with engine manufacturers’ maintenance schedules and warranties? For Cummins engines, the answer is the Centinel system. For technologies that apply to all manufacturers, the answer to the question is: synthetic motor oil and high-efficiency filtration, as long as the manufacturers’ maintenance schedules are not altered. The catch is that altering the maintenance schedule is the primary objective of using synthetics and bypass filters. Some synthetic lubricant companies and bypass filter makers have warranties of their own that may supersede engine manufacturer warranties. Following is a review of warranties by companies supplying synthetic oil and bypass filters that have a warranty.

Amsoil, Incorporated (2003) “warrants that its lubricants are fit for use according to the written recommendations of AMSOIL INC” (¶ 1). The company’s warranty also states it will cover “the cost, including labor and materials, to repair damaged equipment, or at the option of AMSOIL INC., the cost to replace damaged equipment, resulting from the use of AMSOIL INC. lubricants when used in the proper applications” (¶ 4). Further, the warranty states coverage may not be extended to cover equipment failures “when Amsoil lubricants are not used in strict accordance with either the written recommendations of AMSOIL INC. or the OEM [original

equipment manufacturer] for warranty coverage" (¶ 20). Coverage may be rejected as a result of "failure to follow all OEM recommendations for warranty coverage, including lubricants, maintenance, and drain intervals, prior to the first installation of AMSOIL lubricants" (¶ 25).

MTM Industrial's *Warranty Policy* (2004) clearly says the use of the company's Oilguard bypass filters "does NOT violate any existing engine warranty" (¶ 1) and "is NOT prohibited by any manufacturer" (¶ 1). Oilguard provides excerpts of letters received from numerous engine manufacturers regarding the use of the Oilguard product. Following, are excerpts for manufacturers of engines used by the City of Raleigh Fire Department:

Caterpillar

> Caterpillar's position on the use of aftermarket products is as follows: When auxiliary devices, accessories, and/or consumables (filters, oil and fuel additives, synthetic oil, catalysts, etc.) made by other manufacturers are used on Caterpillar products, the Caterpillar warranty is not affected simply because of their use. (¶ 1)

Cummins Engine Company

> Cummins Engine Company neither approves nor disapproves any product not manufactured or sold by Cummins Engine Company. The use of these products would not be recognized as a Cummins Engine Company responsibility. Cummins Engine Company's warranty covers defect in workmanship and/or material as manufactured and sold by Cummins; therefore, any product sold in the marketplace not manufactured by Cummins does not affect our warranty. (¶ 2)

Detroit Diesel

"Detroit Diesel Corporation does not approve, disapprove or [*sic*] endorse the use of the OilGuard Filter Element. The use of the OilGuard Filter will not in itself void the Detroit Diesel warranty as it covers defects in material and workmanship" (¶ 3).

Navistar International

"When auxiliary devices, accessories, and/or consumables (filters, oil, catalysts, etc.) made by other manufacturers are used on International products, the International warranty is not affected simply because of their use" (¶ 8).

Gulf Coast Filters, Incorporated states, "Specific acknowledgement has been received from all the major engine manufacturers that the installation of add-on devices such as the GCF filter will not affect their warranties" (2002, ¶ 11).

PuraDYN [*sic*] Filter Technologies, Incorporated (2004) says extending oil-drain intervals through the use of its product will not void an engine manufacturer's warranty. The company substantiates this claim by saying engine manufacturers recommend, but do not require, oil changes. Further, puraDYN says the oil only needs to meet minimum engine manufacturer specifications and use of the puraDYN system keeps oil in a condition that exceeds what engine manufacturers require. The company suggests an oil analysis be taken at every interval the engine manufacturer recommends an oil change to prove the oil is capable of continued use.

Enviro Kleen (n.d.) claims they have obtained acknowledgements from engine manufacturers that *installation* of the Enviro Kleen system will not affect an engine's warranty. The company says the Enviro Kleen system is able to keep oil cleaner than what is required by the manufacturer.

Royal Purple, Limited (2004) recommends following engine manufacturers' oil-drain recommendations while the engine is under warranty. D. Canitz, Royal Purple's Technical Services Manager, said Royal Purple's warranty and liability insurance would supersede the engine warranty and cover engine failure directly attributable to Royal Purple Motor Oil up to one million dollars (personal communication, August 24, 2004).

Procedures

The information used to answer this project's research questions was obtained from electronic sources, journal articles and interviews during the months of March and August 2004. Google (http://www.google.com/webhp?sourceid=navclient&ie=UTF-8) was the primary search engine used to locate electronic sources. Because so much information is available on the Internet, the "advanced search" feature in Google was relied upon heavily in order to refine the search results. Through an advanced search, one can search for a specific combination of words or for an exact phrase. This feature also allows one to search for results that exclude specific words. A few references were obtained by selecting links from primary sites located by Google. Examples of keywords and phrases used to conduct Internet searches include "extended oil drains," "bypass filtration," and "synthetic motor oil." Journal articles were identified by searching the Online Card Catalog at the Learning Resource Center located on the grounds of the National Emergency Training Center in Emmitsburg, Maryland. Some of these were retrieved in person, on campus in March 2004. Others were received electronically via interlibrary loan through D. H. Hill Library at North Carolina State University in August 2004. Interviews were conducted in March and August 2004 by telephone and email. Interviewees were selected by personal knowledge.

On March 22, 2004 City of Raleigh Assistant Fire Chief P. C. Woodlief was interviewed by telephone and asked the approximate purchase price of a fire pumper. This information was used to establish the importance of proper care of the significant investment taxpayers make in fire apparatus.

On March 22, 2004, Fire Department Shop Supervisor R. J. Spangler was interviewed by telephone and asked questions regarding preventive maintenance schedules and service intervals for apparatus in the Raleigh fleet. From Spangler, various engine specifications, including manufacturer and displacement were obtained. Spangler provided part numbers for oil filters currently used in servicing fire apparatus. He was also asked the price of motor oil currently used by the department. This information was gathered in order to see what is currently happening in regard to apparatus maintenance and expenses.

On March 22, 2004, M. Hall at CarQuest Auto Parts on South Saunders Street in Raleigh, North Carolina was contacted via telephone and asked the fire department's price for a WIX model 54778XD oil filter. Again, this was in order to investigate costs in the current situation.

J. Sims, president of Gulf Coast Filters, Incorporated, was interviewed by email on August 10, 2004. Sims answered questions regarding filter elements used in the Gulf Coast products. This interview was necessary in order to be clear on the material of which the Gulf Coast filter element is composed.

On August 12, 2004, B. Thompson in the maintenance division of the North Carolina Department of Transportation (NCDOT) was contacted by telephone. NCDOT is listed by Gulf Coast Filters, Incorporated as a major customer. Thompson was asked to give an overview of the Gulf Coast Filters system.

In email interviews on August 12 and 23, 2004, A. H. Griffin, Senior Support Specialist in the City of Raleigh Fire Department Services Division, was asked about used oil disposal, apparatus fuel mileage and engine replacement costs. This was further information gathering about the current situation.

In a telephone interview on August 20, 2004, T. J. Menges, Fire Equipment Mechanic in the City of Raleigh Fire Department Services Division, was asked questions about apparatus service intervals, oil viscosities, and typical non-scheduled work performed by service technicians. He was also asked about the costs associated with oil drains and specifics about storing used oil and oil filters. Again, the purpose of this interview was to gain insight into the current situation.

On August 20, 2004, M. B. Styron, Maintenance Coordinator for the Wake County, North Carolina Public School System, was interviewed by telephone and asked about a bypass filter system currently in use on the school system's bus fleet. Styron was asked to give an overview of the program from conception to the present. This was in order to learn objective information about a bypass filter system in use by a local heavy vehicle fleet.

On August 24, 2004, D. Canitz, Technical Services Manager at Royal Purple, Limited, was interviewed by telephone and asked about the Royal Purple Motor Oil warranty so this information could be included in the literature review. When he learned the nature of this project, he volunteered information regarding drain intervals, filters and the chemical properties of synthetic lubricants.

Results

Two primary methods exist for extending motor oil drain intervals: the use of synthetic motor oil and the use of a high-efficiency motor oil filtration system. These two approaches can be used individually, or in tandem.

Synthetic Lubricants

In order to do its job, motor oil must be capable of withstanding the hostile environment inside an internal combustion engine. All quality motor oil, both conventional and synthetic is capable of doing a satisfactory job in an engine (Kaufman, 2002). However, synthetic motor oil possesses particular characteristics that provide for better than satisfactory performance. These characteristics allow synthetic oil to endure extended periods in an engine without requiring replacement. Unlike conventional motor oil, which is produced by refining crude oil, synthetic oil is manufactured in a laboratory with the sole intent of being used for lubrication (Kaufman, 2002; D. Canitz, personal communication, August 24, 2004). Kaufman and Canitz each provided similar information on synthetic oil properties. Most synthetic motor oil is made from one of two types of base stocks: polyalphaolefins (PAOs) or diesters. They are free of impurities. They are thermally stable and resist being broken down by the heat generated in an engine. They have a uniform molecular structure leading to good flow properties. That is, they can be poured at very low temperatures and do not become too thin at high temperatures. PAOs have one drawback: they do not resist oxidation well; oxidation occurs when oxygen combines chemically with motor oil. Oxidation causes chemical deposits to form on the interior surfaces of an engine and causes motor oil to become undesirably thick. During production, additives are incorporated into PAOs so they are able to resist oxidation. A key characteristic of motor oil intended for long drain periods is a high total base number (TBN). TBN provides an indication

of how well oil is able to compensate for acid buildup that occurs in oil as a byproduct of the internal combustion process. This is especially important in diesel engines; diesels cause more acid to be deposited in oil than do gasoline engines. Synthetic oil formulated for use in diesel engines nearly always has TBN's higher than conventional diesel oil (Kaufman, 2002). Synthetic and conventional motor oils do the exact same things, including lubricate, cool and clean. But, synthetic oil does these things much better. Synthetic motor oil that can be kept clean is able to perform required tasks for intervals four to ten times longer than can conventional motor oil (Kaufman, 2002; Amsoil, Incorporated, 2003; Red Line Synthetic Oil Corporation, 2004; D. Canitz, personal communication, August 24, 2004).

High-efficiency Filtration

Motor oil must be drained and replaced not because it wears out, but because it gets dirty and additives are used up (Evans, 2001; Haehl, 2002; MTM Industrial, 2004). As an engine operates, internal parts wear. As these tiny particles of metal wear off moving parts, they are washed into the motor oil. Soot is produced, especially in diesel engines, as a byproduct of combustion. It is washed into the oil where it chemically combines with the oil's additives and reduces their effectiveness (Abelson, 1998). Fuel may seep past piston rings and dilute engine oil. A faulty cooling system can allow water and antifreeze/coolant into oil. As an engine runs, it must intake air required for combustion. Air contains dust, dirt and silicates. Some of these tiny particles that are not filtered by an engine's air cleaner make their way into the oil. From tiny fragments of wear metals to products of combustion to airborne particles, motor oil is required to suspend contaminants until the oil filter can remove them (Unrein and Dick, 2003). A problem is that an oil filter must remove these contaminants while still allowing adequate oil to the engine for lubrication and cooling. A standard oil filter is not able to take out all

contaminants because the restriction required in the filter would be so great as to starve the engine of oil (Cavette, 2001). In order to super clean oil and remove these fine particles, a filtering system is required that only filters a small amount of oil at the time (Cavette, 2001). Where standard manufacturer-provided full-flow oil filters are capable of removing particles as small as about 20 microns, bypass filters can remove particles smaller than one micron (Mann+Hummel, Limited, 2002). Bypass filters accomplish their task of superfine filtering in several ways. Most employ a metal canister that holds filtration media. The media is composed of various materials including a compressed stack of cellulose disks (Amsoil, Incorporated, 2003), cotton string wound around a metal tube (MTM Industrial, 2004) and a roll of paper towels (J. Sims, personal communication, August 24, 2004). At least one uses an evaporation chamber to distil impurities in addition to filtering with a cellulose media (puraDYN Filter Technologies, Incorporated, 2004). Filters by Federal-Mogul (Brezonick, 1998), Mann+Hummel (2002) and SpinClean (Industrial Diesel Products, n.d.) do not employ any filter media at all. These companies manufacture oil-cleaning centrifuges that spin oil at high velocity and produce a cake of solid contaminants on the inside walls of the centrifuge.

M. B. Styron (personal communication, August 18, 2004) provided information regarding the use of Amsoil, Incorporated's bypass filtering system on school buses in Wake County, North Carolina. Styron is the maintenance coordinator for the Wake County Public School System, claiming the 23rd largest school bus fleet in the United States. Styron said the school system chose the Amsoil product because of its competitive price and high efficiency. In a pilot program, school buses were fitted with Amsoil bypass filters. Some buses used conventional 15W-40 motor oil and some used Amsoil synthetic 15W-40 Heavy Duty Diesel and Marine Oil. Regular oil analyses were performed and it was discovered that oil changes could essentially be

eliminated in buses whether they used conventional oil or synthetic. Styron said he is sure synthetic oil is better than conventional oil, but for prolonging oil drains, the filter seems to be the key. Styron said the pilot program involved the use of older buses that had to meet emissions standards that were less strict than those in effect today. When the Amsoil system was installed on new buses meeting stricter Environmental Protection Agency standards for emissions, it was ineffective. Styron said oil analyses from the newer engines show oil often needs to be changed even earlier than the engine manufacturers' recommendations. He believes this is the case because motor oil is now holding in suspension soot that was allowed to be exhausted into the air under the older emissions standards. Styron's postulate was confirmed by Ableson (1998), Brezonick (1998) and Jetter, et al. (1998). Styron said, even with the capability to filter particles smaller than a micron, the Amsoil filter cannot remove a sufficient quantity of soot to provide for extended oil-drain intervals.

Positive Externalities of Using Synthetic Motor Oil and High-efficiency Filtration

In addition to extending oil-drain intervals, the use of synthetic lubricants and high-efficiency filtration can provide other benefits. These include longer engine life, additional oil capacity, cost savings, decreased vehicle downtime, improved engine efficiency and reduced emissions.

Literature suggested drain intervals with synthetic oil can be extended four to ten times longer than drain intervals with conventional motor oil (Kaufman, 2002). Because motor oil must be drained less frequently, cost savings result from purchasing less new motor oil.

Engine life can be extended through the use of synthetic oil and fine filtration. On a molecular level, synthetic oil is more uniform than conventional oil (Kaufman, 2002). Thus, it is able to control wear better than conventional motor oil. As reduced wear allows a tire to last

longer, reduced wear in an engine increases its life also. Studies showed that engines using synthetic lubricants produce fewer of the abrasive contaminants that get into oil during combustion (Kilian, et al., 2002). And, for contaminants that are produced, synthetic oil was better able to hold them in suspension until an oil filter can remove them. There is not complete agreement on exactly how small a particle has to be not to cause wear, but everyone agreed that a one-micron particle does not cause wear. All bypass filters discussed in this research project are capable of filtering particles at least as fine as one micron (Mann+Hummel, Limited, 2002; Amsoil, Incorporated, 2003; Industrial Diesel Products, 2004; MTM Industrial, 2004; puraDYN Filter Technologies, Incorporated, 2004). Hence, major contributors to wear can be eliminated from the lubrication system.

It has already been established that motor oil does not wear out. It gets dirty and its additive pack loses effectiveness. The time required for oil to get dirty and deplete its additive pack is directly related to the volume of oil (Evans, 2001). All bypass filters add to the total volume of oil in an engine, some add about a quart (Amsoil, Incorporated, 2003), some add three gallons or more (Gulf Coast Filters, Incorporated, 2002). Even before it filters a single particle, a bypass filter adds to motor oil longevity merely by holding some volume of oil.

Cost savings can be realized by using synthetic motor oil and bypass filters. Extended drain intervals lead to a reduced demand for new oil. At least one bypass filter manufacturer claimed the use of its filter reduces new oil purchases by 90% (puraDYN, Filter Technologies, Incorporated, 2004). Costly engine repairs may be averted if oil analysis shows a problem prior to catastrophic failure.

Currently, fire companies must be placed out of service for up to three hours for the performance of preventive maintenance. T. J. Menges (personal interview, August 20, 2004)

established that less frequent oil drains require fire companies to be out of service for the performance of preventive maintenance less often. Having companies in service more often holds response times down and increases customer service.

Engine efficiency is improved when using synthetic motor oil. On a molecular level, synthetic oil is more uniform than conventional motor oil (Kaufman, 2002). This gives synthetics superior lubricating properties compared to conventional motor oils. Because of increased lubricity, engines operate more efficiently and burn less fuel to overcome internal friction (Amsoil, Incorporated, 2003). Synthetics were shown to provide a better seal between piston rings and cylinder walls (Kaufman, 2002, Kilian, et al., 2002). This results in greater combustion energy being directed toward driving a vehicle's wheels rather than into the oil pan below the pistons.

Synthetic oil caused engines to be friendlier to the environment. As stated in the preceding paragraph, engines using synthetic oil burned less fuel. Burning less fuel results in a lower volume of exhaust emissions. Laboratory research by Kilian, et al. (2002), found synthetic oils to be effective in cutting exhaust emissions. In doing so, synthetic lubricants effectively reduced the production of pollutants that have been linked to global warming, smog, acid rain and ozone depletion.

Warranty and Service Schedule Implications

Research for this project in regard to engine manufacturer warranties and service schedules cannot provide a definite direction for apparatus fleet managers. For every source and testimony promoting synthetic motor oil and high-efficiency filtration as a means to prolong oil drain intervals, there was a document from an engine manufacturer saying not to use such methods. Many engine manufacturers address extended drain intervals in corporate literature.

None said the synthetic oil and bypass filter systems do not work. At least one engine manufacturer, Caterpillar, Incorporated, participated in a study touting the extended-drain capabilities of synthetic oil (Jetter, et al., 1998). Some specifically said, though, that synthetic oil and bypass filtration are not to be used as a method to extend oil-drain intervals (Cummins Engine Company, 2001; Detroit Diesel Corporation, n.d.). Amsoil, Incorporated (2003), MTM Industrial (2004) and Royal Purple, Limited (2004) have warranties that appear to supersede any engine warranty and promise repair or replacement of an engine when the cause of failure can be traced to the prescribed use of their products. Of note is that synthetic oil maker Royal Purple, Limited recommended following engine manufacturers' oil-drain recommendations so long as the engine warranty is in effect. PuraDYN [*sic*] Filter Technologies, Incorporated (2004) said use of the company's product would not void engine manufacturers' warranties. Gulf Coast Filters, Incorporated, (2002) and Enviro Kleen (n.d.) each claimed to have obtained documentation from major engine manufacturers stating that the *installation* of their filter systems do not void engine warranties.

Interviews

In conducting research for this project, interviews were performed by telephone and email. Most were brief and sought a specific piece of information.

P. C. Woodlief, Assistant Chief of the City of Raleigh Fire Department said that a typical fire pumper costs about $325,000 after being outfitted with various tools, appliances, hose and radios.

R. J. Spangler, Shop Supervisor for the Services Division of the City of Raleigh Fire Department, advised that Raleigh fire apparatus are scheduled for maintenance, including oil changes, every six months. Spangler said pumpers recently purchased by Raleigh were equipped

with Cummins ISL turbocharged diesel engines rated at 370 horsepower. These engines utilize a WIX 54778XD oil filter.

M. Hall, a counter salesperson at CarQuest Auto Supply in Raleigh, North Carolina, where the fire department's service shop buys many automotive parts, advised that the price for a WIX model 54778XD oil filter to fit a Cummins ISL engine costs $25.90.

The Gulf Coast Filters, Incorporated web site was unclear as to whether or not one can actually use a roll of Bounty brand paper towels as a replacement element in the company's bypass filter. J. Sims, president of Gulf Coast Filters, was contacted by email and asked if a roll of paper towels would work and he stated it would.

B. Thompson from the Maintenance Division of the North Carolina Department of Transportation (NCDOT) was contacted to learn information about the NCDOT's use of the Gulf Coast Filters system. Thompson was asked to provide an overview of the setup and an idea of the success NCDOT had had with the system. Thompson said that NCDOT had done its own research on what system to use and had selected the Gulf Coast system primarily because one of its employees had experience with the system while he was a mechanic in the United States Air Force. Thompson said NCDOT does not use the system as a means to prolong drain intervals. He said the nature of their business requires vehicles to make frequent short trips, which deposits a lot of soot and fuel in the oil. They use the Gulf Coast system as a way to filter some of the soot and to add to the vehicle's total oil volume.

A. H. Griffin, Senior Support Specialist in the City of Raleigh Fire Department Services Division, said that used motor oil was stored at the department's maintenance facility until enough was on hand for a company called Noble Oil Services to pick it up at no charge. She was also able to estimate that the city's expense for replacing a fire truck engine is about $20,000.

T. J. Menges, Fire Equipment Mechanic in the City of Raleigh Fire Department Services Division said an oil drain is the most expensive part of preventive maintenance. Menges said typical tasks that could be accomplished if technicians were not performing oil changes include brake jobs, tire replacements and fire pump valve repair. He confirmed the information provided by A. H. Griffin regarding used oil disposal and further stated that used oil filters were crushed and picked up by a disposal company.

The interview with M. B. Styron is discussed thoroughly in paragraph four of this section.

D. Canitz, the Technical Services Manager at Royal Purple, Limited, gave a verbal account of his company's warranty, and said if a Royal Purple product caused an engine failure, the warranty would cover engine repair or replacement up to one million dollars. The author requested a copy of this warranty but it had not been received by the time of publication. Canitz volunteered information on drain intervals, oil chemistry and filtering systems. He said synthetic lubricants provide the option of at least doubling oil-drain intervals, and that with bypass filtration, intervals can be safely quadrupled. Canitz said an oil analysis should be taken at each drain interval recommended by an engine's manufacturer. When asked what type of bypass filter he would put on his own diesel pickup truck, he said a centrifugal filter would be his choice. He said a centrifugal filter would provide the longest drain intervals due to its ability to remove soot from motor oil.

Discussion

Information indicates synthetic motor oil is superior in every way to conventional motor oil. Except for a few engine manufacturers' warranties that seem overly cautious and hint of being written by attorneys, there is no contradiction to the previous statement. Multiple synthetic

lubricant manufacturers, including Amsoil, Incorporated (2003), John Deere Company (2004), Red Line Synthetic Oil Company (2004) and Royal Purple, Limited (2004) promote their products to be capable of better lubrication, to have better low-temperature pour points and high-temperature stability, to reduce friction, to lower fuel consumption, to reduce emissions and to extend oil-drain intervals. Synthetic lubricant manufacturers are in agreement on these points; each company's oil may have a slightly different formulation, but they have one thing in common: all produce their lubricants in a laboratory, under controlled conditions with the express purpose of making a superior automotive engine oil (Kaufman, 2002). Claims of these companies are supported by the opinions and research of Hackett (1995), Jetter, et al. (1998), Kelly, et al., (2000) and Kilian, et al. (2002). With such overwhelming agreement "that synthetic motor oil is superior to petroleum based motor oil," (Andrews, 2000, ¶ 37) there is little point in further discussing why synthetic motor oil has so many virtues.

While the opinions, research and experience of others substantiate that micro-fine filtration to remove wear particles, soot and ingested contaminants is a key factor in maintaining oil's effectiveness over long drain periods, the best method to accomplish this high-efficiency filtration is less clear. It is important to note that studies show filtration must remove particles larger than one micron in order to effectively reduce wear in an engine (Cavette, 2001; Kaufman, 2002; Amsoil, Incorporated, 2003; puraDYN Filter Technologies, Incorporated, 2004; Industrial Diesel Products, Incorporated, n.d.). All bypass filters are capable of this level of filtration regardless of the type of filter media or process used. What bears further discussion is features and benefits that set one filter apart from another.

The Amsoil, MTM Industrial (Oilguard), Gulf Coast Filter and Enviro Kleen products are all similar. They each use a cellulose or cotton filter media to super clean motor oil. An added

feature of these filters is that they have the capacity to remove water from oil. Also, the reader should be reminded that the minimum oil capacity of the Gulf Coast filter is three gallons. Simply changing the Gulf Coast filter without ever changing the oil adds a lot of new oil to the system. This is not an attempt to call the effectiveness of the Gulf Coast product into question, but it is entirely possible that Gulf Coast's success in extending drain intervals is more solidly grounded in adding a lot of fresh oil to the system rather than super filtration.

The puraDYN Filter Technologies (2004) product also uses a cellulose filter media but incorporates two other features. The puraDYN filter contains time-release additives that are supposed to stabilize oil's additive pack. It also has a distillation chamber that heats oil to about 200 degrees Fahrenheit as it passes through the filter. In this step of cleaning, contaminants such as water, antifreeze/coolant and fuel are supposed to be removed from the oil by reaching a high enough temperature to be cooked off. According to puraDYN, its filter flows six gallons per hour; it is questionable how effectively these contaminants can be removed in the short time they are exposed to the elevated temperature. Further, it has been shown that heat is a main contributor to the oxidative breakdown that occurs in motor oil over time. For every 18-degree increment over 180 degrees Fahrenheit, the rate of oxidation approximately doubles (Gulf Coast Filters, Incorporated, 2002; Barnes, 2003).

The testimony of M. B. Styron (personal communication, August 20, 2004) is compelling, as it suggests new Environmental Protection Agency emissions standards require oil to suspend diesel soot in amounts that overwhelm its additive package and cannot be removed by cellulose or cotton bypass filters. This adds to the appeal of centrifugal oil cleaners. About 70% of the total solids removed by centrifugal oil cleaners is soot (Brezonick, 1998). While

centrifuges are promoted to excel at removing soot, they do not remove water, antifreeze/coolant or fuel as do cellulose or cotton filters.

The next point of discussion revolves around engine service schedules and warranties. Most engine manufacturers say the use of synthetic motor oil and bypass filtration is acceptable so long as drain intervals are not altered (Cummins Engine Company, 2001; Detroit Diesel Corporation, n.d.). This is in stark contrast to the prescription of most producers of synthetic lubricants and bypass filtration systems who say drain intervals can be extended four to ten times (Amsoil, Incorporated, 2003; D. Canitz, personal communication, August 24, 2004) so long as oil analysis is used as a guide and common sense is exercised. Testimonials of successful oil-drain extensions abound while documented cases of failed engines resulting from oil-drain extensions are essentially non-existent. It appears that the potential benefits resulting from prudent use of advanced lubricants and high-efficiency filtration in order to extend oil-drain intervals largely overshadow the slight possibility that an engine may fail and not be covered by its manufacturer's warranty.

Finally, a conclusion has to be made as to the best oil and filter if a fleet manager is to attempt extended oil-drain intervals. The oil should be a quality synthetic designed for extended drain intervals. It should meet the recommended viscosity requirements of the engine. Diesel engines in fire apparatus are subjected to abuse not seen in some other diesel engines. In an emergency response application, engines are often started cold and must instantly provide full power. Short trips are frequent; engines sometimes do not reach operating temperature before they return to idle. Emergency scenes require engines to either idle or to run stationary at high speed for long periods. On top of routine wear of internal parts and ingested airborne contaminants, new engines must meet strict emissions standards that require oil to hold more

soot than ever before. The findings of Ableson (1998), Brezonick (1998) and Jetter, et al. (1998), as well as the testimony of M. B. Styron (personal communication, August 18, 2004) give strong evidence that soot should be the primary target of any filtering system. Jetter, et al. concluded "the primary oil contaminant was soot…water, coolant, and silicon (dirt) contamination was minimal and of no concern" (p. 5). This conclusion was reached after performing oil analyses every 10,000 miles on 59 heavy-duty diesel engines that accrued over 30 million road miles under a variety of conditions. With this information in hand, the most appropriate bypass filter is a centrifugal oil cleaner. Approximately 70% of the sub-micron sized contaminants removed by a centrifugal filter is soot (Brezonick, 1998).

For fire apparatus fleet managers, the findings of this research have significant implications. By using synthetic lubricants and bypass filtration, a number of benefits will result.

Fewer oil drains will require fire companies to spend less time out of service for the performance of preventive maintenance. Customer service will be improved through decreased response times. Greater fire fighter safety will be achieved because most front-line engines have fully enclosed cabs as opposed to the open cabs found on reserve engines used while service is being performed.

Cost savings will result from a reduction in the amount of oil purchased. While synthetic motor oil costs more than conventional motor oil, its ability to run for extended drain intervals will make it more economical in the long term. And, oil analyses taken as part of the oil monitoring process might give advanced warning of impending engine problems.

Exhaust emissions will be reduced. Compared to conventional oil, synthetic oil has superior lubricity, better flow characteristics and is better able to seal the tiny space between

piston rings and cylinder walls in engines. These properties allow an engine to run more efficiently, burn less fuel and emit lower amounts of pollutants.

Apparatus service technicians will have more time to dedicate to other repairs and maintenance. Less time spent changing oil equals more time to turn brakes, replace alternators and fix fire pump valves.

Better customer service, lower costs, less pollutants and more effective employees. Can fire chiefs, municipal managers or politicians ask for more?

Recommendations

In order for an extended oil drain program to provide the most benefits for the City of Raleigh Fire Department, the following recommendations are made:

- The proper attitude must be developed. Information should be made available touting the advantages of the new procedure. Administrators, service technicians and fire personnel must accept a change in engine lubrication practices and work to make the program successful.
- Apparatus engine oil leaks must be fixed before initiating the program. Because synthetic oils have better flow and detergent properties, an engine that leaks a tiny amount of conventional motor oil will leak a lot of synthetic oil. Losing oil to leakage will be counter to two goals of extended oil drains: lowering costs and being friendly to the environment.
- A test of synthetic lubricants and bypass filter systems should be run on a portion of the fleet for at least 12 months before a complete switch is made. This will allow time to evaluate effectiveness, resolve any problems and perform a precise analysis of costs and benefits.

- To provide for proper break in of new engines, they should be run on conventional motor oil until the manufacturer's first recommended oil drain, at which time they can be switched to synthetic oil.
- Lubricants and filters must be chosen.
    - The recommended motor oil is Amsoil 15W-40 Heavy Duty Diesel and Marine Oil. With its beefy additive package, including a heavy dose of corrosion inhibitors, Amsoil is designed for extended drain intervals (Amsoil, Incorporated, 2003). It meets the viscosity requirements of most heavy-duty diesel engines. Amsoil is produced from a diester base stock, so it adheres to metal well and has good thermal stability and detergent properties (Kaufman, 2002).
    - The recommended centrifugal oil filter is a Spinner II manufactured by T. F. Hudgins, Incorporated. Unlike others that are driven by oil pressure, the Spinner II is driven by a vehicle's air system. By not relying on oil pressure, which fluctuates with engine speed, the Spinner II will work more effectively as apparatus sit on a scene with engines operating at or near idle. Air usage is insufficient to interfere with air horns or brakes.
- Prior to draining the conventional oil from selected test engines, a sample of the current oil should be taken and sent to a lab for analysis. This sample will reveal any current wear or contaminant anomalies present before the installation of the new synthetic lubricant.
- A sample of the new oil should be taken and analyzed prior to installation to get a baseline reading of its makeup. This will provide a way to see what contaminants the oil

is suspending after being in the engine for a certain time and will provide a means of projecting how long the oil is likely to last before replacement is necessary.

- Filters should be mounted according to manufacturers' recommendations and new synthetic lubricant installed. Follow manufacturers' recommendations for ensuring filter systems are functioning properly.
- Personnel assigned to apparatus equipped with synthetic lubricants and bypass filters should be educated about their function and care. Conventional motor oil should be removed from inventory at fire stations housing apparatus using synthetic oil. While synthetic oils and conventional oils are compatible, mixing the two would result in diluting the synthetic oil's superior properties. A general memorandum should be sent to all personnel giving an overview of the new program.
- The reader may note that most of the oil-drain interval references in this paper are based on mileage. While mileage is the most accepted metric upon which drain intervals are based, time is also accepted, either in hours or months (Cummins Engine Company, Incorporated, 1999). Planning is important to a fire department, and performing preventive maintenance based upon time, in months, rather than mileage is more practical. A time-based schedule allows for more regularity and better accommodates training agendas and holidays. Furthermore, call and staffing data may indicate a period during the calendar year when preventive maintenance can be scheduled to have less potential to cause service interruptions.
- At six-month intervals, an oil sample should be taken following the instructions provided with the sample kit. Full-flow filter(s) should be changed. Makeup oil should be added to the system to replace oil lost in the old filter(s) and to the sample.

- At 12-month intervals, the centrifugal filter should be cleaned and reassembled. Add makeup oil as necessary.
- The schedule of changing full-flow filter(s) every 6 months and cleaning the centrifugal filter every 12 months repeats indefinitely or at least until adequate experience has been gained to safely extend the interval of changing full-flow filters to 12 months. A period longer than 12 months for changing and cleaning filters and taking an oil sample is not recommended.
- Drain oil and replace when an oil analysis says a drain is necessary. Keep in mind how long the oil must go until the next sample is taken if an analysis shows oil to be in a marginal condition.
- Fleet Services vehicles should be equipped to perform preventive maintenance, including oil drains, filter changes and oil sampling at fire stations. This will drastically reduce the time fire companies are out of service in the name of preventive maintenance.

At some future time, other researchers may find that oil and filter technology has evolved beyond the information contained here. Before one implements the recommendations above, time will be well spent researching the very latest technology.

While both synthetic motor oil and bypass filtration are necessary ingredients in maximizing oil-drain intervals, research has revealed that filtering is more important than synthetic oil. It is highly possible that oil drains may be extended with premium conventional oils. The author's recommendation is to use both synthetic oil and centrifugal filtration in order to achieve premium engine protection. But, it would be interesting to learn the results of using the filtering system and schedule described in Recommendations with conventional motor oil.

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