WASTE OIL REDUCTION FOR DIESEL ENGINES

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Contract Number CR-817011-01-0

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FOREWORD

The U.S. Environmental Protection Agency is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet this mandate, EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

The National Risk Management Research Laboratory is the Agency's center for investigation of technological and management approaches for reducing risks from threats to human health and the environment. The focus of the Laboratory's research program is on methods for the prevention and control of pollution to air, land, water and subsurface resources, protection of water quality in public water systems, remediation of contaminated sites and groundwater, and prevention and control of indoor air pollution. The goal of this research effort is to catalyze development and implementation of innovative, cost-effective environmental technologies, develop scientific and engineering information needed by EPA to support regulatory and policy decisions; and provide technical support and information transfer to ensure effective implementation of environmental regulations and strategies.

This publication has been produced as part of the Laboratory's strategic long-term research plan. It is published and made available by EPA's Office of Research and Development to assist the user community and to link researchers with their clients.

E. Timothy Oppelt, Director
National Risk Management Research Laboratory

ABSTRACT

This project reduced waste oil from diesel engines at remote sites in Alaska by extending oil change intervals using by-pass filters and a closed-loop reblending process in connection with portable field monitors and laboratory analysis. Incidents of normal and abnormal oil degradation were recorded and correlated between field and laboratory tests. A quality assurace program evaluated data precision and accuracy.

Waste oil from diesel engines represents an environmental problem in Alaska especially in remote areas where disposal/recycling are non-existent. Results of this project showed that small, isolated communities can reduce the amount of waste oil generated at the source with techniques that are easy to implement and inexpensive. However, they depend primarily on operator interest in closely monitoring the engine because degradation levels need to be determined individually for each engine and oil type by establishing baseline data. From the worker safety view, this project reduced or eliminated waste oil in several engines without the added risk of worker contamination by polynuclear aromatic hydrocarbons. One engine eliminated waste oil altogether by using reblending technology.

This report was submitted in fulfillment of Cooperative Agreement No. CR-817011-01-0 by Alaska Health Project under the partial sponsorship of the U.S. Environmental Protection Agency. This report covers a period of time from August 1990 to June 1994 and the work was completed as of June 1994.

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ACKNOWLEDGMENTS

We acknowledge the Department of the Army tank-automotive command and Allied Signal Inc. for their valuable comments on our draft report. We acknowledge those engine operators without whom this study and report could not have been accomplished. The villages and towns of; Kiana, Nunapitchuk, Pilot Station, Tooksook Bay, St. Mary's, Bethel, Seward, Tatitlek, Yakutat, Hoonah, Snettisham, and Unalaska.

SECTION 1

INTRODUCTION

Over one billion gallons of waste oil are generated each year in the U.S. (4). An Alaskan oil company spent over $10 million to clean up roads contaminated with waste oil in the Kenai National Wildlife Refuge (5). The U.S. government spent over $32 million to buy all the homes and seal off the town of Times Beach, a town whose roads were contaminated with waste oil (6). A gas pipeline company is paying over $400 million to clean up pits contaminated with waste oil (7). No one knows the total cost from these damages, but we do know that displacing entire communities shreds the fabric which binds societies together.

Although it was not the oil that caused these problems, the ease with which toxic substances are introduced into oil, due to inadequate controls (5), continues to cause millions of dollars of damages. Even a careful generator of waste oil may not be able to prove that oil dumped years ago is not the source of newly discovered contamination.

The Environmental Protection Agency (EPA) designates source reduction as the preferred method of environmental management. Source reduction means any practice which reduces the amount of a pollutant prior to recycling, treatment, or disposal. Source reduction methods include equipment and procedure modifications in maintenance and training (1).

The generation of energy is critical to remote villages, marine vessels, and military bases throughout Alaska. The process of generating that energy with diesel generators produces large quantities of used oil. If not properly managed, used oil can be a health hazard, an environmental danger, and a costly expense. Engine operators change the oil at a rate recommended by the engine manufacturer.

Oil change intervals (OCIs) are recommended by manufacturers based on industry standard conditions. Most equipment operators change lubricating oil based on time without regard to engine use, such as once a month or every 500 hours. OCIs are time–based because of the simplicity in record keeping. Although time is a variable in oil degradation, fuel and lube oil consumption rates, sulfur content, and environmental conditions are the causative agents in oil degradation (2). Flexible OCIs based on analyses are not permitted for the general consumer, in part because consumer warranty damage claims related to engine failure would be difficult to refute without knowledge of engine operating conditions regarding potential contributions from extended OCIs (3). It would not be unreasonable for engine manufacturers to authorize OCIs based on analyses instead of time for professional fleet mechanics and large (>2,000 hp.) diesel engine operators who are able, and willing, to keep records to maintain warranty continuity.

Extending OCIs requires oil analyses and feedback from the laboratory; however, a remote site engine could log several thousand hours before sample results get back to the operator. Real–time oil monitoring permits OCIs adjusted to actual operating conditions. Sensitive on–site oil monitoring may detect abnormal wear in time to avoid catastrophic failure.

Every extra oil change increases the risk of a spill. Every extra barrel of waste oil increases the chance of leaks, contamination, or improper disposal. Every hour spent changing oil means an hour of down time. Until recently, the benefits associated with frequent oil changes outweighed the risks of engine wear. In the past, waste oil volumes depended on engine design and recommended oil change intervals. Early engines lost 10% of the oil every hour, along with an equivalent amount of the contamination. Because oil was cheap and disposal was free, oil changes were based on manufacturers' recommendations or seasons, regardless of oil condition. Now, engines are 100 times more oil efficient, meaning, much less contamination is lost in escaping oil (8) and disposal can be expensive. Increased OCIs allows decreased purchasing, handling, shipment, and storage costs.

PROJECT DESCRIPTION

This study is intended to bridge the gap between reports which identify waste oil as a problem and research on oil life extension and remote site recycling. The questions asked by this study are listed below:

1. Based on field and laboratory measurements of crankcase oil, can manufacturer recommended oil drain intervals be increased?

2. Do by–pass filters increase the life expectancy of lubricating oil? If so, how long can drain intervals be extended without increased engine wear? Which filters are efficient, effective, and economical? Can a closed–loop process eliminate waste oil? If so, how much? Is the closed–loop process efficient, effective, and affordable?

3. Can small, isolated communities recycle waste oil safely and economically using simple filtration technology and field tests? Does extending lubricating oil life increase the concentration of polynuclear aromatic hydrocarbons and place used oil handlers at an increased health risk? Filtration is defined for the purpose of this project to mean physical separation of liquids and solids. For example, present day technology uses screens, belts, drums, presses, flocculation, gravity sedimentation, freezing, centrifuges, and media filters to separate solids and liquids (9). The last two types are commonly used in by–pass filters.

Using several remote sites in Alaska, a study of the extension of Oil Change Intervals was carried out over a period of three years. The sites selected for this study included stationary electric generation facilities, one marine vessel, and one federal hydroelectric facility. The initial portion of the study was to extend OCI's by using analysis alone. Phase two of this study utilized by-pass filtration that is effective in the removal of water, unburned fuel, acids, and small metal contaminants below 20um. Phase three utilized a closed-loop process that blends oil removed from the engine at pre set rates to be burnt with the fuel to eliminate waste oil altogether. This process has the advantage of actually increasing the quality of the fuel, while using the oil at a rate equal to an oil change every 150 hr. to 300 hr. ,dependent on initial analysis.

DESCRIPTION OF SITES

The site locations are shown on Figure 1.

Kiana is a village located on the North bank of the Kobuk River above the Arctic Circle. It is 57 air miles from Kotzebue. Kiana is located in the transitional climate zone which is characterized by long cold winters and cool summers. The mean summer temperature is 60 F while the mean winter temperature is 22 F. The annual precipitation is 16 inches.

Pilot Station is a village located on the Northwest bank of the Yukon river, 11 miles east of St. Mary's in the Yukon-Kuskokwim Delta area. The climate of Pilot Station is more maritime that continental. The mean summer temperature is 56 F while the mean winter temperature is 20 F. The annual precipitation is 60 inches.

Nunapitchuk is a village located on the right bank of the Johnson River , 26 miles Northwest of Bethel in the Yukon-Kuskokwim Delta area. The climate of Nunapitchuk is more maritime than continental. The mean summer temperature is 56 F, while the mean winter temperature is 20 F. The annual precipitation is 60 inches.

St. Mary's is a village located on the North bank of the Andreafsky River in the Yukon-Kuskokwim Delta area. The climate of St. Mary's is both maritime and continental with greater maritime influence. The mean summer temperature is 56 F while the mean winter temperature is 25 F. The annual precipitation is 60 inches.

Tooksook Bay is a village located on Nelson Island in Southwestern Alaska. It is 506 air mails from Anchorage and 200 hundred miles to the west of Bethel. The climate of Tooksook Bay is maritime. The mean summer temperature is 48 F, while the mean winter temperature is 14 F. The annual precipitation is 25 inches.

Bethel is a village 90 miles from the mouth of the Kuskokwim River in Southwestern Alaska. The climate of Bethel is more maritime than continental with modifying daily temperatures during most of the year. The mean summer temperature is 53 F, while the mean winter temperature is 11 F. The annual precipitation is 18 inches.

Unalaska is a village located on Unalaska Island in the Aleutian chain across Iliuliuk Bay from the community of Dutch Harbor. By air it is 4 hours from Anchorage. The climate of Unalaska is maritime. The mean summer temperature is 48 F, while the mean winter temperature is 30 F. The annual precipitation is 58 inches.

Seward is a community located on Resurrection Bay on the Kenai Peninsula, in the Prince

William Sound area of South Central Alaska. The city is 128 highway miles south from Anchorage. The climate of Seward is more maritime than continental. The mean summer temperature is 56 F, while the mean winter temperature is 25 F. The annual precipitation is 65 inches.

Tatitlek is a community located in Prince William Sound of South Central Alaska , just south of Valdez on the Northeast shore of the Tatitlek Narrows. The climate of Tatitlek is more maritime than continental. The mean summer temperature is 55 F, while the mean winter temperature is 26 F. The annual precipitation is 167 inches.

Yakutat is an isolated coastal community situated in the lowlands along the Gulf of Alaska. The maritime climate of Yakutat is characterized by relatively mild but often rainy weather. The mean summer temperature is 51 F, while the mean winter temperature is 28 F. The annual precipitation is 132 inches.

Hoonah is a village located on the Northeast shore of Chichagof Island, about 40 miles Northwest of Juneau in the Southeast Alaska Panhandle. The maritime climate of Hoona is characterized by cool summers and mild winters. The mean summer temperature is 57 F, while the mean winter temperature is 33 F. The annual precipitation is 54 inches.

Snettisham is a village located on the mainland about 50 miles Southeast of Juneau in the Southeast Alaska Panhandle. The maritime climate of Snettisham is characterized by cool summers and mild winters. The mean summer temperature is 57 F, while the mean winter temperature is 33 F. The annual precipitation is 50 inches.

SUMMARY OF METHODS

A Quality Assurance Plan (QAP), prepared at the beginning of this study (AHP 1991) describes the detailed approach and scientific rationale used to extend oil life.

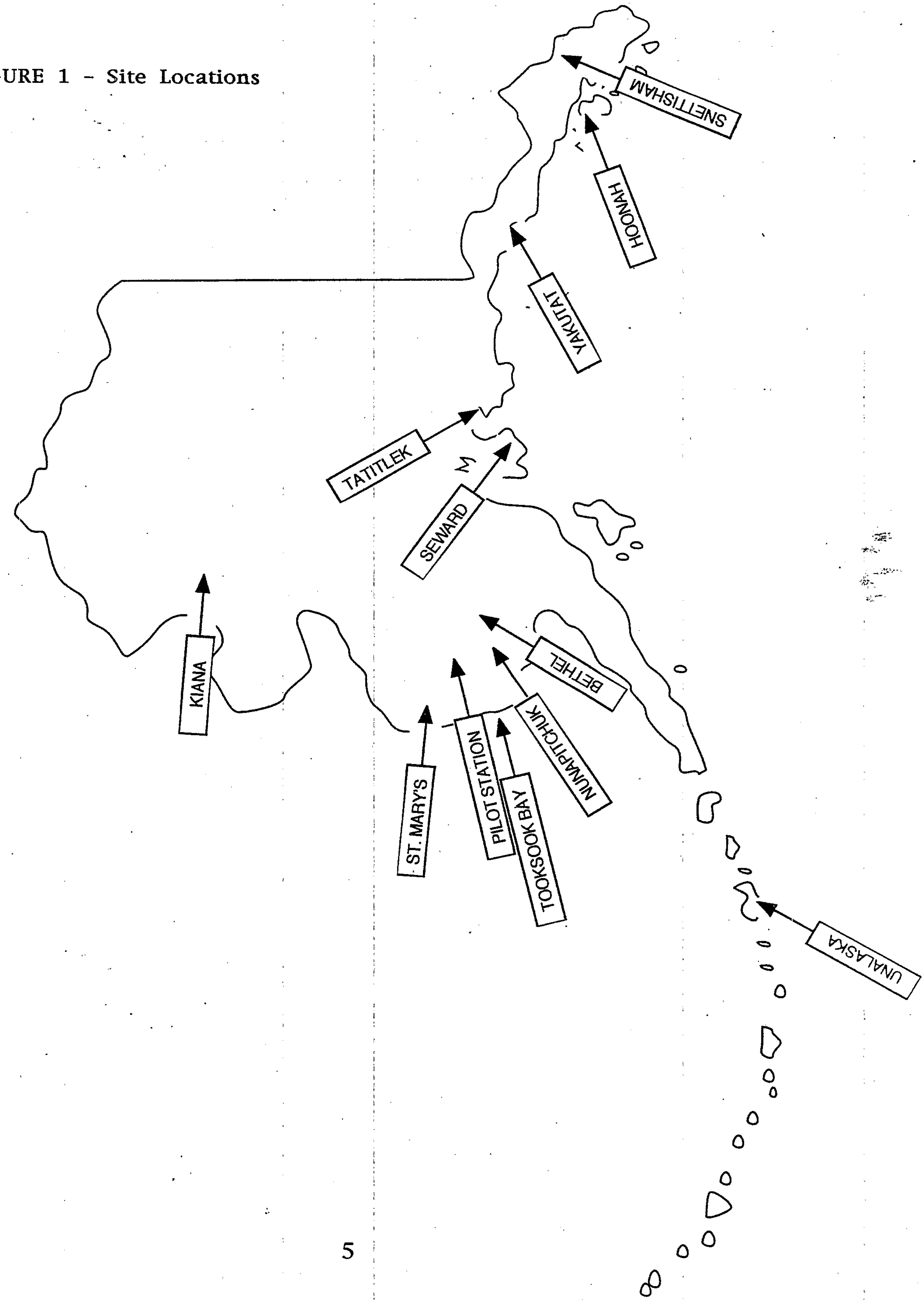
The experimental design of this study had three phases. A baseline was established to verify the condition of the engine for liability purposes and assessment of data reproductivity and representativeness. Upon completion of the baseline data, by–pass filters and a closed–loop re–blending process were run to monitor their effect on used oil.

Initially, a diagnostic screening was used to determine if the potential candidate had any problems which would complicate the study such as a coolant leak or excessive engine wear. Approximately twice as many engines as needed were screened to assure enough were available for the study.

Phase I, baseline, selected engines and determined the baseline trend of oil degradation during the cycle of a normal oil change interval. This phase judged if the oil change interval could be extended based on analysis alone.

Phase II, methods, used oil analysis to monitor the effects of several by–pass filters on oil degradation. Both the laboratory and project manager recommended an increase or decrease of oil

FIGURE 1 - Site Locations



change intervals based on information available from engine manufacturers and literature, but the actual decision was made by the operator. Regardless of the decision, the quality assurance plan guaranteed that the data collected was of a known quality and useful in the statistical analysis.

Phase III consisted of recycling used oil and blending it with unused diesel fuel. Based on cost and effectiveness, a closed–loop filter was selected to improve the quality of oil removed from engines. The filtered oil was blended for use in the diesel engine or as heating fuel.

Used oil samples were taken from the diesel engines as often as every two days. Each sample by a Lubrisensor field monitor was tested for deviations in the dielectric constant. This test was conducted by the engine operator on-site as well as at the AHP office by the Project Manager. Next, the sample was sent to the lab for analysis of the physical and chemical properties of the oil. The lab results were sent to AHP for review and then forwarded to the engine operator. A quality control sample was sent to the lab with every fifth used oil sample.

SECTION 2
BACKGROUND INFORMATION

PAST STUDIES

Past studies have evaluated lubricating oil life and the potential to extend oil drain intervals by using filtration units and improved maintenance. In 1973, it was known that engine manufacturers' warranty recommendations were very conservative and that marketed oils were capable of extended oil drain intervals if good maintenance was followed. Today there still remains a need to extend OCIs in order to reduce equipment downtime, waste oil, and maintenance costs (10) (See Figure 1).

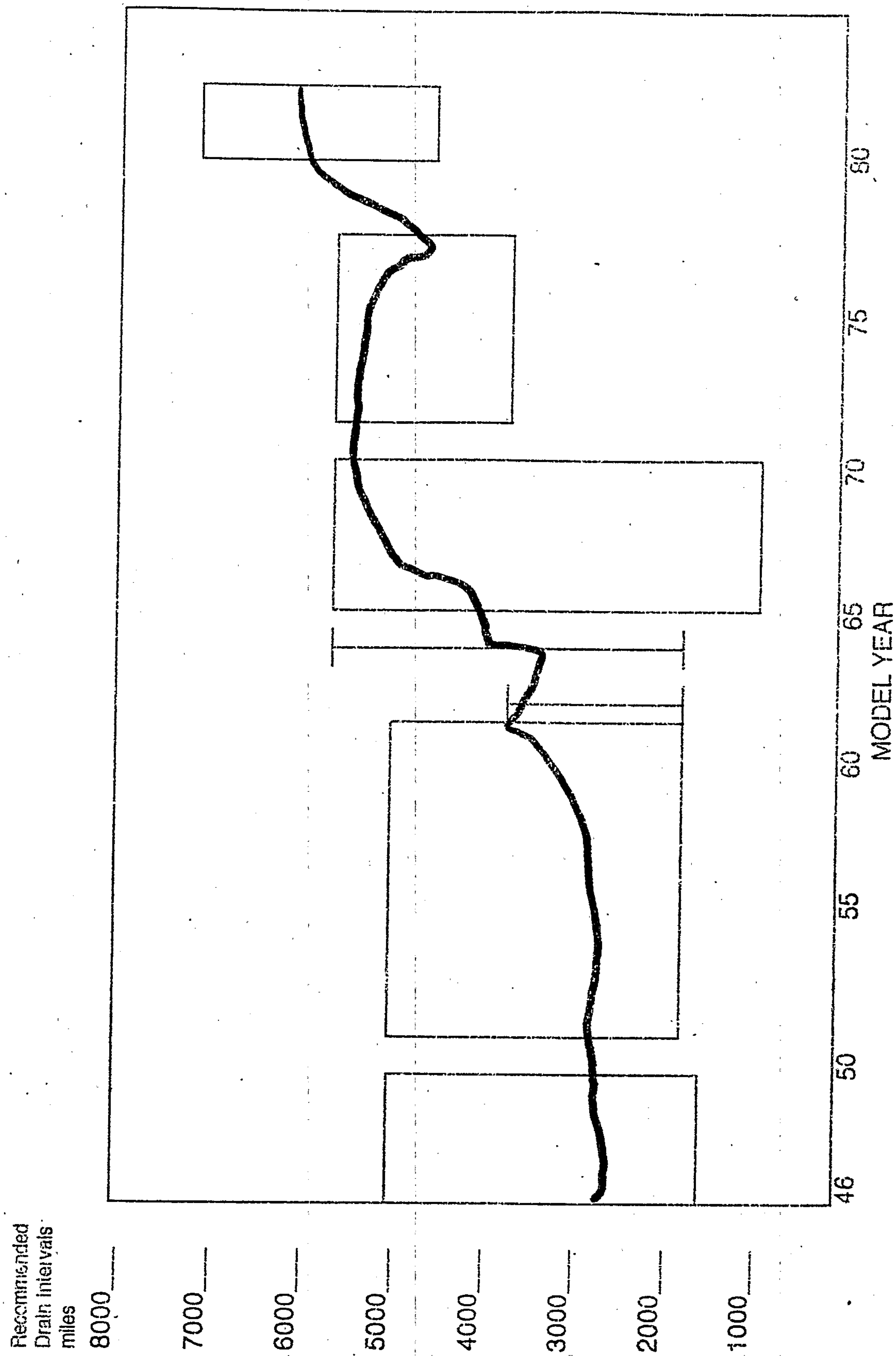
Since 1973, studies have evaluated the ability of by–pass filters to extend oil life and reduce wear. It has been shown that by–pass filters have improved filtration compared to full–flow filters. This reduces engine wear while allowing oil drain interval extensions up to 25,000 miles (11). Controlling the abrasive contaminants in the range of 2 to 22 microns in the lube oil is necessary for controlling engine wear (12). By improving filtration and reducing engine wear, by–pass filters can also provide the lowest total cost to the engine operator (13). Full–flow filters do not screen particles smaller than 20 microns, whereas most by–pass filters can screen particles below 5 microns. Compared to a 40 micron filter, a 30 micron filter was found to reduce wear 50%. Likewise, wear was reduced 70% with 15% micron filtration (12).

A study which used half full–flow filters and half by–pass filters on engines concluded that the combination resulted in extension of engine wear life up to two or three times the wear life obtainable with only good full–flow filtration (14). Previous studies indicate that by–pass filters can decrease engine wear by 50% in truck fleets as well (15). Trucking fleets have conducted tests using by–pass filters to reduce engine wear and to extend the life of lubricating oil (16,17). In each case, the filters were found to reduce engine wear, but rarely does a trucking fleet extend the OCI with or without the by-pass filters in fear of voiding their engine warranties. Therefore, it is difficult to quantify the ability of the by–pass filter to extend oil life beyond the ability of the oil itself to sustain longer oil change intervals.

The military has found that by–pass filters can reduce engine wear and reduce the generation of waste oil in remote sites in Alaska in an economically feasible fashion, but they did not study the extension of OCI without the aid of filters as baseline data (18). A survey of 137 users of by–pass filters in Austria concluded that by–pass filters can significantly increase oil changing intervals and thus reduce the need and cost for fresh oil while reducing waste (19).

An extended oil drain interval study conducted on 56 subjects (three types of diesel engines, both with and without by–pass filters) using four types of oil, found only relatively small differences based on engine inspections after 100,000 miles (10). Recent tests have shown that use of a high

FIGURE 2 – Trends in Oil Change Intervals



performance by–pass filter combined with a low–soot dispersancy oil could raise the soot trapping efficiency at the filter 85% and extend the diesel engine oil drain interval more than twice the recommended miles by engine manufacturers (20).

In 1976, certain engine manufacturers recommended oil change intervals every 7,500 miles, triple the levels of the 1940's, due mainly to superior lubricants and additives. 7,500 miles was believed to be the maximum OCI recommendation and any further increase would require development of new technology. Technical limitations for extension of OCI remain to be control of engine wear, engine deposits, and resistance to lubricant thickening (21).

Regular filters have been shown to begin to plug when oil drain intervals exceed 18,000 miles. Good maintenance, not larger filters, is the key to successfully extending oil drain intervals (22). Extended drains with taxi fleet show that API SE oils did not control engine wear (12).

Periodical lubricating oil analysis is essential because, if the concentrations of bearing elements increases, then the engine can be stopped for thorough checking, thus avoiding disastrous damage (23).

LUBRICATING OIL

Motor oil is used to lubricate engines and prevent component wear. Motor oil is composed of a base stock and additives. The base stock lubricates the internal moving parts, removes heat, and seals pistons. The functions of the additives include anti–wear, anti–foam, corrosion protection, acid neutralization, maintenance of viscosity, detergency, and dispersancy. The quality of additive systems varies throughout the lubrication industry, ranging from a bare minimum to high quality.

The four primary purposes of engine oil are: cooling of the engine, controlling contamination and corrosion, sealing piston rings, and lubricating the moving internal parts to minimize friction and wear.

Sources of Lubricating Oil

Lubricating oils are derived from crude oil. About 0.9% of crude oil production is diverted into lubricating oils and greases (24). When boiled under a vacuum, crude oil yields a base oil with a 700 to 900 degree Fahrenheit true boiling point (25). Several base oils may contribute to a blended lube stock. A lube stock may be further treated to remove undesirable components such as volatile hydrocarbons, asphalt, wax, and unstable compounds. Steam strips out volatile compounds.

Propane extracts asphalt under high pressures. Methyl ethyl ketone dissolves wax which can be cooled, crystallized, then filtered out. Hydrofinishing with heat and hydrogen slightly changes the molecular structure and produces a more thermally stable, lighter colored oil (26). These technologies are examples of those commonly used for producing lubricants from crude oil.

Annual consumption of synthetic lubricants is about 45 to 50 million gallons per year at a cost of 3 to 30-times greater than crude oil lubricants (27). Synthetic lubricating oils are more thermally stable and resistant to changes in viscosity due to temperature effect. Oils decompose near the top of the piston ring leaving deposits which accumulate, increasing friction, and eventually causing failure if left unchecked. Deposits are half carbon and half metal ash from additives (28). Synthetic oils leave less ash and are more stable. The most common synthetics used in motor oils are synthesized hydrocarbons, organic or phosphate esters, and polyglycols (29). The raw materials for synthetic lubricants are usually petroleum derived. In spite of the improved properties of synthetics, these oils still require many of the same additives as petroleum oils.

Lubricating Oil Life Expectancy

Lubricating oil is a petroleum product consisting of oil and additives used for lubrication in engines. The lubricating oil itself does not wear out, but it must be replaced to effectively protect the engine against wear, corrosion and deterioration. An oil filter only removes the large particles, so the oil must be drained at a frequent interval or the oil will become contaminated from condensation, acids, and fuel dilution. The life expectancy of the oil is determined by the recommended oil drain interval. The method of operation, the driving conditions, and the quality of the oil are all factors in this process. If the engine operator neglects to follow the recommended oil drain interval, then any damage to the engine due to this neglect may not be covered by the engine warranty.

Oil change intervals are recommended by individual engine manufacturers. Some manufacturers publish rigid intervals and openly state "they will never publish wear limits based on oil analysis." Other manufacturers allow substantial changes of intervals if regular testing indicates the oil is within limits of acceptability. In addition to manufacturers' recommendations, individual owners make independent decisions based on additional criteria, such as service needs, current operating costs, life–cycle/overhaul ratio, and dependability requirements. Some authorities claim engine tests at this time cannot predict lubricant suitability for extended oil change intervals (21). Laboratory analyses used to determine oil degradation are discussed in Summary of Methods.

Lubricating oil failure can originate from normal oil degradation, environmental conditions, and engine malfunction. For the purposes of this study, engine malfunctions are considered an aberrant cause of oil failure. Examples of oil failure caused by faulty engines are inadequate air filtration, leaky fuel injectors, cracked blocks, and failed water pump seals. Fuel and water leaks decrease oil viscosity, plug filters, precipitate additives and can lead to catastrophic failure. Engine operators in this study were notified of engine problems as soon as they were discovered and their participation suspended until the engine was repaired.

The type of fuel used in an engine influences the mode of normal oil degradation. Oil in gasoline powered engines most commonly degrades due to water contamination and oxidation (30,31).

Diesel powered engine oil degrades from soot particles which blow by the rings due to higher compression ratios and unburned fuel. The aqueous phase of diesel exhaust can be as acid as pH 0.4 from sulfur, but when combined with water, contamination synergistically affects the precipitation of additives. Another mode of oil degradation in diesel engines is through higher operating temperatures which increase the rate of oxidation and varnish formation.

How an engine is used also influences oil degradation. Engines run at low speeds or excessively idled may have low oil operating temperatures. Consequently, water condenses and builds up causing precipitation of additives and loss of dispersancy. Additive precipitants plug filters. Dispersant failure can result in soot particle "dump out" (22), a term used to describe the condition when a filter capable of holding only a pound of contaminants is overloaded with the several pounds of soot typically dispersed in a 10 gallon capacity engine oil sump.

Environmental conditions can cause similar failures. Ambient temperature, humidity, and changing atmospheric conditions can cause condensation which would not occur in an identical engine under different climatic conditions. Airborne particulates not trapped by air filters abrade bearings and cause a rise in wear metals and plugging of filters.

Lubricating oil is chemically resistant to breakdown. However, used oil becomes waste oil when metal particles exceed filtration capability, essential additives are exhausted, or fuel and water contaminate the system. The lubricating oil effective life may be extended with ultra filtration, and monitoring for both engine wear and oil performance. In fact, recyclers of used oil claim oil "doesn't wear out it only gets dirty" (33).

Used Lubrication Oil

Used oil becomes waste oil when the physical or chemical properties exceed limits of condemnation for use in an engine. Some waste oil may still be suitable for service if the oil change intervals are more frequent than needed. However, used oil, once removed from the engine, often gets contaminated with water, gasoline, diesel, solvents, and paint, making the mixture unsuitable for almost any use. Waste oil which becomes contaminated is a regulated hazardous waste.

Carefully managed, used oil retains economic value. If specifications can be met, such as flash point and lead concentration (34), used oil may be burned as a fuel for heat or in diesel powered engines. In Alaska, as elsewhere in the United States, ocean ports are required to accept waste oil generated aboard ships. However, small coastal communities and villages have neither the experience nor the knowledge to evaluate the condition of used oil or to determine a reasonable means of recycling. Consequently, much of the accumulated used oil and oil contaminated with water is transported many miles at substantial costs. Indiscriminate dumping is common. For example in Nome, Alaska a small lake was used as the unpermitted city dump (CERCLA site No. AKD980722540) and was observed to have over a foot of waste oil floating on the surface. A creek flowing through the dump was contaminated with enough lead to nearly exceed the allowable limit for hazardous waste as tested by the EPA during a site inspection in June 1986. Nome has a year round resident environmental inspector, but in more remote villages which are inspected infrequently at best, waste oil disposal is unrestricted and undocumented. Current filtration technology may make possible the processing of used oil on site, providing a recycled oil which meets specifications for burning (35).

Direct observations such as carbon and ash build–up behind piston rings and cylinder varnish deposits require taking an engine apart. Furthermore, varnish formation is, in part, a function of fuel type and engine operating conditions (36). Waste oil which meets specification is commonly blended with either heating oil and burned in a boiler or with diesel fuel in a 5% ratio to power the engine source. Both Cummins Engines and International Harvester publish guidelines for recycling crankcase oil through engines.

OIL ANALYSIS

The objectives of an effective oil analysis program are to measure (in terms of engine condition) oil contamination, oil deterioration, and engine wear metals. From this it should be possible to determine oil suitability for further use, protect the customer from costly premature engine overhauls, and thus provide an optimum balance between engine life and effective maintenance practices. If the conditions of use are not too demanding, a simple lube stock may not need additives. However, most applications require additives to stabilize the oil and protect the engine. Lubricant additives affect both the physical and chemical properties of oil. Some additives enhance inherent properties, others prevent undesirable changes. Additives can also impart new lubricating properties to the oil.

The most commonly used additives are viscosity improvers, dispensers, detergents, anti wear agents, antioxidants, corrosion inhibitors, friction modifiers, foam inhibitors, and pour point depressants (20). Viscosity improvers alter the change of oil viscosity with temperature. Viscosity changes can be stabilized when the oil is doped with small quantities of polyisobutylenes or polymethacrylates (37). The viscosity of an oil refers to the internal cohesiveness of the oil or its resistance to flow. Viscosity Index Improvers are chemicals found in modern oil designed to extend the viscosity range.

Dispersants hold contaminants in suspension, preventing varnish formation on engine parts. Dispersants are similar to detergents in structure: long and ashless. Alkeenylsuccinic esters and Mannich bases from high molecular weight alkylphenols are two common dispersant additives.

Usually it is not the oil going bad that necessitates an oil change-it is the depletion of additives. Anti–wear additives protect the engine by bonding to metal surfaces and forming a protective layer between moving parts. This layer does not prevent their rubbing together, but minimizes the effects of this contact.

Detergents are metallo–organic compounds, such as barium, calcium and magnesium salts of sulfonic acids, phenols, salicylic acids, or thio–phosphonic acids, these compounds lift deposits from critical surfaces such as the upper piston ring belt area (20). Anti wear agents resist scouring and scuffing that occurs under high pressure and temperatures. Under severe wear conditions, surfaces can temporarily weld together. Mild wear agents are polar compounds like fatty oils, acids, and esters. Extreme wear agents (either individually or in combination): contain chlorine, sulfur, phosphorous, and lead. Antioxidants limit the degradation of oil due to oxygen exposure. The rate of oxidation increases exponentially with temperature and is affected by free radical chain reactions and metal catalysts. Zinc dithiophosphate is an antioxidant that both inactivates the chain reaction and forms a protective coat on metal surfaces. Corrosion inhibitors neutralize acids such as sulfuric acid, a corrosive product of diesel fuel combustion. Some detergents and antioxidants can also serve as corrosion inhibitors. Friction modifiers labeled as "energy conserving" improve fuel economy and were developed as a result of the energy embargo two decades ago (20). Some of these modifiers are colloids of molybdenum, copper soaps, sulfurized fats, and esters. Foam inhibitors collapse air bubbles preventing frothy mixtures of air and oil. Silicone polymers at only a few hundred parts per million are widely used to defoam oil. Pour point depressants control wax formation and crystal growth at low temperatures. Under cold conditions oil may solidify and resist pumping. Styrene–based polyesters and cross–linked alkyl phenols are two common depressants.

Oxidation is the chemical breakdown of oil which occurs due to the extreme heat in an engine and can cause sludge or acidic gasses to develop which can cause corrosion or rust. Corrosion is critical in diesel engines due to the high sulfur content in diesel fuel. To counteract the effects of acids, neutralizing additives are blended into oil. This neutralizing capability is measured by an oil's TBN. Oxidation rate is also affected by the type and amount of antioxidant and by the presence of fuel in the oil.

In 1947, engine oil contained 2.5% to 6.5% additives. Today about 15% of automotive oil consists of additives, although specialty formulations may range from 0.05% to 30% or more. Finished oils are screened in bench tests before more expensive full–scale engine testing. The final formulation of a lubricating oil relies heavily on experience and judgment.

OIL QUALITY

The quality of oil is related to its ability to lubricate and protect an engine from wear over time without losing its additives or becoming contaminated. The quality of lubricating oil is essential information to consumers as well as engine manufacturers in establishing oil change intervals.

The American Petroleum Institute (API) administers the certification program, allowing engine manufacturers to place a label on each oil that has met the program's requirements. This label, known as the "donut seal of approval," assures that the oil satisfies the minimum standard quality of oil. This level of quality assures that the oil will: 1) permit easy starting, 2) lubricate and prevent wear, 3) reduce friction, 4) protect against rust and erosion, 5) keep engine parts clean, 6) minimize combustion and chamber deposits, 7) cool engine parts, 8) seal combustion pressures, 9) be non foaming, and 10) aid fuel economy. The API engine oil service classification symbol is a representation and warranty by the oil marketer to the purchaser that the product conforms to the applicable standards and speculations for engine oils established by the automotive and oil industries. Oil manufacturers have the responsibility to assure that all performance standards have been met and then decide which class applies.

Oil Performance Standards

Oil performance standards are developed as a minimum standard for engine oils that engine manufacturers deem necessary for maintaining equipment life and performance. The oil marketers use the standard as a performance guide for oil.

A minimum oil performance standard is defined by the American Automotive Manufacturers Association (AAMA) based on technical and marketing input from technical societies, trade associations, the U.S. Army and individual consumers. A development fund supported by both the automotive and oil industries provides funding for new test development to modify the definition and timeliness of a minimum oil performance standard which reflects changes in equipment design, customer usage, or fuels.

Most standards include performance requirements and chemical/physical properties of those engine oils that engine manufacturers deem necessary for satisfactory equipment life and performance. The Society of Automotive Engineers (SAE) Crankcase Oil Viscosity and API Engine Service are two necessary standards to adequately define a motor oil's characteristics when deciding what oil an engine requires. The SAE Viscosity standard defines 11 grades of Viscosity; OW, 5W, 10W, 15W, 20W, 25W, 20, 30, 40, 50, 60, (W= winter conditions). The API Engine Service standard classifies and describes crankcase oil by factors other than viscosity in order to aid in service requirements and communication between engine manufacturers, oil companies and the consumer. API, SAE, and ASTM devised the Engine Service Classification System with SE, SF, SG, SH, CC, CD–II and CE suitable for today's cars. S stands for Service and C stands for Commercial. The S categories are for use with gasoline engines, the C categories for diesel engines. The oil marketers use the standard as a performance guide
for oil.

AAMA and JAMA jointly established the ILSAC standard. It is composed of five parts: 1) SAE viscosity classification, 2) API SG performance standard, 3) bench test requirements, 4) an informal standard that may be applicable in the future, and 5) engine sequence tests. Performance standards often need to be revised to keep pace with changes in engine performance requirements and changes in formulation
technology.

Quality Assurance

Quality Assurance is the level of guarantee that the product is equal to the quality expressed on the label. A consumer who purchases a container of oil needs assurance that the quality of the oil meets the minimum performance standard expressed on the label. An assurance of oil quality may offer the consumer confidence, and allow engine manufacturers to add flexibility to recommended oil drain intervals further it may enable them to develop improved technology.

Certification labels are placed on the outside of the oil container to inform the consumer of the quality and characteristics of the oil. Recent studies by the U.S. Army and the Society of Automotive Engineers (SAE) have concluded that many oils on the market are questionably labeled. In 1979, the Army tested the quality of 17 commercial oils and concluded that 11 products failed to meet one or more of the specification's physical/chemical requirements and six of the products had insufficient additives (38). All of the products were advertised to meet the API performance level. OLAP, established by the U.S. Army and SAE in 1987, in order to get reasonable assurance that marketed oil actually met industry standards, has shown as high as 16.5% of the oils sampled were questionably labeled. 80% of those oils that were questionably labeled had the API certification label (39).

The dangers of questionable labeling practices affect the entire spectrum of the oil market. Consumers may purchase low quality oil and have potential engine failure, engine manufacturers pay the cost of an increase in warranty claims and must delay advances in engine technology, while oil marketers lose credibility. Oil drain intervals remain restricted due to the low minimum standard and waste oil increases. Questionable labeling practices can be limited by a number of ways: tougher certification process, an increase in testing, a more stringent post–market program, and tougher enforcement actions which are addressed in the new engine oil certification system being jointly established by API and AAMA.

In 1983, General Motors research labs conducted a survey on 250 lubricating oils. Of 41 oils specified as SAE 10W–40 SF/CC, 40 were apparently mislabeled and unsuitable for diesel engine use. Six 10W–40 oils had very low additive content and two others had no additives at all. Also, 6 out of 36 tested for performance according to their specifications of 10W–30 SF/CC were not properly formulated (40). The new oil certification process will use the Multiple Test Acceptance Criteria as a pre–market test to discover if a given oil meets the minimum performance requirements. The old API approved process only required a single pass for each oil. This means an oil marketer could re-test the oil an unlimited number of times and if it passed once, it is certified, but under the new system, the mean value of each parameter must be a pass. The oil marketer will also have to provide a product traceability code when applying for a license in addition to random engine testing. Any violation could result in temporary or permanent suspension of the license and a recall of oils in the market (41). The new quality assurance elements of the engine oil licensing system aim to tighten up the quality of oil, regain consumer confidence and answer needs of the engine manufacturers. The new engine oil license system will also include the Chemical Manufacturers Association (CMA) Product Approval Code of Practice. This, in addition to the license agreement and industry code of ethics, will increase the assurance of quality of oils on the market as well as the ethical obligation of oil manufacturers.

ENGINE WARRANTIES

Due to the important role the oil industry and engine manufacturers have in the decision of an engine operator to extend OCI's, AHP conducted extensive legal research to analyze the impact of engine warranty claims on the opportunity to extend oil life. Conservative maintenance requirements recommended in engine manufacturer warranties are one of the barriers in extending OCI's. Engine manufacturers claim that these strict requirements are necessary to protect themselves against:

1) The difficulty in defending a warranty claim made by an engine operator whose engine may be damaged by low oil quality assurance, and

2) The inability for oil performance standards and quality to keep pace with advances in engine technology.

In consideration for buying an automobile or engine from a dealer, a consumer is given a warranty. The purpose of the warranty is to guarantee that the product is of good workmanship, has no defects, and is similar to what was in the mind of the buyer.

The standard warranty covers cost of all parts and labor needed to repair any item on a vehicle that is defective in material, workmanship or factory preparation noted during the expressed warranty period. Along with the warranty, each engine company recommends a maintenance schedule which includes a recommended oil drain interval. This indicates how often the engine operator should drain the oil in order to comply with the warranty. Each consumer must use reasonable and necessary maintenance to comply with the warranty.

Modifications made to a vehicle such as extending the OCI or adding filtration units do not void the warranty unless the manufacturer can prove that the engine failure occurred as a result of such modification or operator negligence. Since such negligence is difficult and expensive for the manufacture to prove, maintenance requirements in a warranty are kept conservative. Another reason engine manufacturers have conservative maintenance requirements is the low assurance of oil quality on the market. Studies performed by the SAE Oil Labeling Assessment Program (OLAP), the military, and engine manufacturers have concluded that there has been a 10% to 20% rate of low quality oil or mislabeled oil on the market. Even API indicated that too often the API symbol is used to sell inferior lubricant products. An Exxon lab technician was found guilty of falsifying data in order to meet lubricant requirements (42). Engine manufacturers are concerned about oil which is placed on the market that does not meet certification requirements. The low quality oil purchased by consumers for use in vehicles may lead to engine failure. See Appendix A for a complete discussion and legal analysis of the implication of warranties and the Magnuson–Moss Act in the extension of oil life.

OIL CERTIFICATION

Certification labels are placed on the outside of the oil container to inform the consumer of the quality and characteristics of the oil. Along with performance categories, adequate test methods are established to verify performance of the oil. By certifying oil before it enters the marketplace, oil manufacturers can be assured that consumers will select oil based on performance characteristics and the type of service for which the oil is intended.

In 1970, the Society of Automotive Engineers (SAE), American Petroleum Industry (API) and the American Society for Testing and Materials (ASTM) agreed to form the tripartite system and develop an engine oil performance and classification system that assured the minimum standard quality of oil.

The tripartite designed the API "donut seal of approval" which displayed the appropriate API service category, the SAE viscosity grade, and, if applicable, the energy conserving features of the oil.

The API symbol is a representation by the oil marketer to the purchaser that the product conforms to the applicable standards and speculations for engine oils established by the automotive and oil industries.

Improper blending or falsification of testing that results in low quality or mislabeled oil contribute to low consumer confidence, potential engine failure, additional costs to engine manufacturers in warranty claims, delay in engine technology advances, a loss of credibility to oil manufacturers, and the waste disposal problem. For a complete discussion on the changes in oil certification, the newest developments, and the history of oil drain intervals, see Appendix B.

INTERESTED PARTIES

Oil quality and used oil disposal is a concern for many segments of society, specifically:

Oil Manufacturers

The American Petroleum Institute (API) directs the certification program that licenses many of the large oil manufacturers, API's members, and helps set standards for oil quality. Oil manufacturers want to produce a product of high quality and assurance to remain competitive, but are concerned with the expense that added testing requirements and regulations place on a product.

Engine Manufacturers

The membership of the Society of Automotive Engineers (SAE) and the AAMA consists of the major engine manufacturers in the United States. This group, along with smaller engine manufacturers, strongly encourage a high quality oil to be placed on the market in conjunction with strict certification programs to assure that quality standards are met. Engine manufacturers are concerned with oil quality in establishing oil change interval recommendations and in the development of new engine technology. If oil quality is poor or the assurance of oil quality is low, then recommended oil change intervals are conservative so that the engine manufacturer can be assured of protection from engine failure claims. For years, engine manufacturers have tested the quality of lubricating oil and possible drain intervals, but this information is in the private sector and difficult to find.

Engine Operators

Engine operators of diesel generators demand high quality oil to protect their investment in expensive engine equipment. Also conservative oil change intervals require are costly to an engine operator due to increased oil purchase and disposal fees. Engine operators are often wary to extend oil change intervals or add filtration equipment for fear of voiding the engine warranty.

International Lubricant Manufacturers Association (ILMA)

ILMA represents small oil manufacturers who are concerned that increased testing and other oil certification requirements to improve oil quality may be unfair to them since larger oil manufacturers could absorb the expenses more easily.

Consumers

The average automobile owner is a major reason to attempt to improve oil quality and reduce waste oil. Do–it–your–selfers dispose of the majority of waste oil in the United States. Automobile owners desire quality oil to protect their automobile, but cost is often the largest factor in oil selection. Increased consumer awareness of oil quality, certification, and engine warranty implications is necessary. Consumers can extend their oil change intervals without engine wear, but the fear of break down, and voiding of warranties has prevented this effort.

Government

The Environmental Protection Agency (EPA) is concerned about the amount of waste oil that is improperly disposed of each year. It is an environmental threat and costly to remediate. They are also concerned with oil quality as it relates to reducing dirty emissions from automobiles. Since the U.S. military purchases oil in large amounts, they are very concerned with oil quality. The military operates expensive and important equipment under harsh conditions, therefore, the need for high quality oil is a priority. For years they have been behind a push for strict performance standards and testing of marketed oil. The U.S. military helped to fund the now defunct OLAP program in an attempt to identify and correct questionably labeled oil on the market. The military wants to protect its investment in equipment and demands that the quality of the oil on the market is equal to what is stated on the label API's willingness to make improvements in the new certification program was motivated by concerns expressed by the AMMA. Due to the tremendous amount of oil disposed of by the military, they remain interested in new technology that can reduce the amount of waste oil.

HEALTH EFFECTS OF PAHS DUE TO BURNING WASTE OIL

Waste oil contains toxic constituents at levels ranging from one hundred to ten million times greater than any health based standard (43). Consequently, when only a small amount of waste oil escapes into the environment, a substantial risk to human health and the environment is possible.

Some of the toxic constituents found in waste oil are intentionally introduced such as tetrachloroethylene and 1,1,1–trichloroethane. Other toxins such as polynuclear aromatic hydrocarbons (PAHs) are always present. The PAH concentration in waste oils averages from less than 5 to over one hundred parts per million. PAHs are composed of carbon and hydrogen atoms forming clusters of six-membered aromatic rings. Waste oil contains a higher concentration of PAHs than most heating fuels, with the exception of No. 6 fuel which contains similar concentrations.

Lab tests were conducted by Analytical Resources on a new oil sample and used oil samples at 10 hours, 55 hours, 183.7 hours, 227 hours, and 208.5 hours to evaluate the potential health effects from PAHs. PAHs are a by-product created by improperly burning used oil or extending oil change intervals.

Test methods used were EPA–SW 846 and included testing for Napthalene, 2–Methylnaphthalene, Acenaphthylene, Acenaphthene, Dibenzofuran, Fluorine, Phenanthrene, Anthracene, Fluoranthene, Pyrene, Benzo(a)Anthracene, Chrysene, Benzo(b)Pyrene, Indeno(1,2,3–cd)Pyrene, Dibenz(a,H)Anthracene, Benzo(ghi)Perylene with a detection limit of 20,000 g/Kg. Results of each sample for each test were below detection levels except for Phenanthrene. At 308.5 hours Phenanthrene was detected at 23,000 g/Kg and at 10 hours Phenanthrene was detected at 21,000 g/Kg. These tests show no significant health hazard from PAHs in the used oil sampled resulting from oil exchange intervals or burning used oil.

SECTION 3

MATERIALS AND METHODS

SITE SELECTION AND DEMOGRAPHY

This project began with twenty diesel engines at thirteen sites throughout Alaska. Some sites have been successful participants while others have failed to participate in each phase of the project.

In Phase I, extension of oil change intervals using only analysis was conducted on twenty diesel engines ranging from 23 to 3,000 horsepower at thirteen sites over an eleven month period. All engines were at remote sites. The majority of engines were stationary electric generating power plants in rural locations from the Arctic through the Aleutian Islands to Southeast Alaska. In addition, an isolated federal hydroelectric facility volunteered road equipment. One offshore marine vessel participated. Participants were asked to gradually extend OCI based on laboratory data and a field oil analyzer.

In Phase II, by–pass filters were used on nine different diesel engines at four different sites. Data was compiled from four diesel engines at Unalaska, two diesel engines at Yakutat, two diesel engines at Kiana, and one diesel engine at Hoonah.

In Phase III, a closed–loop process was used on two engines at different sites. Data was compiled from one stationary diesel engine at Unalaska and one marine diesel engine at Seward. Each site was informed, visited, trained, and given information about the potential benefits of the project. Each site was offered technical assistance, supplies, and follow up contact.

The Alaska Health Project (AHP) was the central location for the project. All used oil samples were sent to AHP from the remote sites where they were tested by a comparative dielectric analyzer (CDA) before being sent to the laboratory for further testing. All information and data was kept at AHP.

The sites, engines, and total number of samples for each phase is described in Table 1.

Selection

The following criteria was used in selecting sites for this project: suitable equipment, good record keeping, waste oil generation, willingness to cooperate, representative engine loads, adequate maintenance practices, sufficient hour/mileage accumulation, engine type, cumulative hours, oil consumption rate, oil drain interval and filter change history, periodic maintenance record, and major repairs.

TABLE 1 – Sites, Engines and Total Number of Samples

SITE	ENGINE	SAMPLES	EXTENDED	FILTERS	CLOSED LOOP
Unalaska	CAT 3512-4 CAT 3512-5 CAT 3516-6 CAT 3516-8	20 20 24 20	8 8 7 5	12 12 6 15	11
Yakutat	CAT 3412 CAT 3512	16 23	6 7	10 16	
Hoonah	CAT 3508 CAT 3512	8 3	8 0	0 3	
Kiana	CAT 3406 (summer) Cummins KTA1150 (winter only)	9 27	7 19	2 8	
Seward (Mobile)	Volvo MD 11C	51	35	0	16
St. Mary's	CAT 3508D1	10			
Pilot Station	Cummins KTA19G2	9			
Nunapitchuk	CAT 3412	4			
Tatitlek	CAT 330 4PL	1			
Toksook Bay	Cummins KTA19G2	0			
Bethel	CAT 3412	0			
Snettisham	Deere 4239T CAT 3204 CAT 3406	0			

Description

Phase II and III of the project were conducted on ten diesel engines at five different sites. Data was compiled from four diesel engines at Unalaska, one marine diesel engine at Seward, two diesel engines at Yakutat, two diesel engines at Kiana, and one diesel engine at Hoonah.

The following is a summary of any problems or reasons for attrition for the sites:

Unalaska

While there were no major problems, minor problems included: delay due to engine overhaul, a filter leak, a lab result with a low TBN, and difficulty assembling the closed–loop process.

Yakutat

The mechanic, who is not paid per oil change, was kept informed and interested. The OCI was extended to 350 hours and the filter filament changed to 500 hours. The Gulf Coast by–pass filter reduced soot content of 20% for the first 350 hours. This could have been extended but the CAT 3512 engine ran into cam and soot problems due to a poor overhaul. The Purifiner by–pass filter would have helped more, but the metal content in an engine was high due to an overdue overhaul. Yakutat sends its waste oil to the city to burn for fuel. This saves the city disposal costs and saves the city $5,000 per year in fuel. Yakutat decided not to extend oil drain intervals further for these reasons: 1) risk of replacing a $450,000 engine was too high since it is the only energy source for the local cannery and FAA emergency runway; 2) in May 1993, both engines used in the project needed an overhaul, but Yakutat shut them down and purchased a CAT 3516; and 3) the engine manufacturer, CAT, informed Yakutat in a letter that extending the OCI might void their warranty. CAT also told them that the 3412 would need to be overhauled at 11,000 hours instead of the 20,000 hours promised at time of purchase.

Hoonah

A problem arose when the CAT 3508, for which baseline data was collected, was replaced by the CAT 3512 to handle the winter increase in electrical needs. The by–pass filter was previously installed on 3508, so Hoonah was asked to install a filter on the 3512 as well. The operations manager became ill in November 1992 causing delay of filter installation.

Kiana

Problems were: 1) the mechanic quit in October 1992 causing a delay; 2) the CAT 3406 is used only in summer and the Cummins KTA1150 only in winter when there are more electrical needs; 3) due to fear of voiding their warranty, they only extended OCI a few times; and 4) it was extremely difficult to communicate with the mechanic.

Seward

There was a cooling system failure which caused oil degradation and accelerated engine wear. Since it was a marine vessel it did not run the entire calendar year.

Bethel

They would not participate in the project unless we guaranteed to replace their engine, at a cost of approximately $500,000.00, if it was damaged.

Snettisham

This DOE site began the project at the beginning of the snow removal season and did not send any samples. They dropped the project due to difficulties at the site and because they use mobile diesel engines instead of stationary engines.

Tooksook Bay

Samples were sent without any information, making it impossible to record data. They have no phone and due to its remote location and cultural and language differences, communication was unreliable.

St. Mary's, Pilot Station, and Tatitlek had various obstacles that lead to attrition, many of which are discussed below.

General Obstacles To Site Participation

1) Lack of flexibility of engine manufacturers to allow OCI extensions.
2) Fear of management to risk expensive and important equipment by extending OCI without assurance from engine manufacturer.
3) Low quality assurance of oil on market– 10–20% of oils on market are questionably labeled.
4) Number of subject sites and samples were cut to keep within budget after adding TFOUT test.
5) Remoteness of Alaskan villages.
6) Small size of Alaskan villages where one engine is usually the only source of energy.
7) Plant operators do not know incentives for reducing waste oil.
8) Engine shut down due to overhaul and high hours on engine affects impact of filters.
9) In winter when the temperature drops to –30 degrees Fahrenheit or lower.
10) Difficulty getting JOAP which was necessary to set condemnation limits for engines.
11) Cultural and language barriers of remote Alaskan villages.
12) Reducing pollution or waste oil is not a primary priority in some remote villages.

TECHNICAL EQUIPMENT

Many technologies exist for extending oil life. Technologies selected for this project include oil drain interval extension, field monitoring, lab analysis, by–pass filtration, and a closed–loop re–blending process.

Comparative Dielectric Analyzer (CDA)

A portable battery-powered field CDA, the Lubrisensor model NI–2B, was selected to conduct field monitoring oil quality based on its cost, useability, and documentation ability in the field.

The project used the Lubrisensor field monitor to test used oil samples. The Lubrisensor is a field test instrument used to determine the deterioration in motor oil from continued use. By measuring any deviation of the dielectric constant between fresh and used oil, it indicates the overall condition of the oil and helps determine the optimal oil change interval.

An independent technical evaluation completed in West Germany concluded that there is a correlation between results obtained through lab methods and the change of the oil's dielectric constant measured by the Lubrisensor. The dielectric constant of an oil is the substance's ability to transfer electricity as compared to a vacuum. In oil systems, this value is dependent upon the base oil plus additives or contaminants present.

The study and the manufacturer recommend the Lubrisensor for the following:

1) Maximization of intervals between oil changes.
2) Early detection of mechanical failures in conjunction with preventive maintenance.
3) Avoidance of engine damage resulting from over used lubricants.
4) Reduction in the number of costly laboratory analyzed oil samples.

Field CDA analysis requires 10 to 15 minutes including sample collection, calibration, and record keeping. All that is required is a sample of the new oil, a non aqueous/non halogenated solvent cleaner, and tissues. The portable field oil testing units results were compared to more rigorous laboratory analysis. Both laboratory and field tests need to monitor engine failures and oil degradation. Engine failures are caused by worn bearings, rings, and other components. Worn components shed metal particles. Micron sized metal particles are measured with a fluid analysis spectrometer. Microscopic metal particles from engine wear are counted electronically or manually with a microscope. Larger metal particles are monitored with chip detectors in critical applications such as helicopter gear boxes. Coolant leaks accelerate component wear by introducing salts which can be tested with the same equipment used to measure metal wear. Water from cooling system failure is measured qualitatively by observing water spattering from moisture contaminated oil when dripped onto a hot plate or quantified with infrared spectroscopy (IR).

A lubricating oil's ability to protect an engine can be evaluated with test engines, or physical and chemical analyses. The only definitive test for measuring the ability of an oil to lubricate an engine is actual usage in a test engine followed by engine dismantlement and component inspection. This procedure is routinely used only for lubricant certification and costs tens of thousands of dollars per oil sample. Therefore, physical and chemical properties of oil are tested as a substitute. Physical oil tests measure viscosity at different temperatures. Chemical tests quantify additive content. A more elaborate and seldom used test called thin–film–oxidation–uptake, or TFOUT, measures the performance of antioxidants. Buffering capacity, called TBN, can be easily measured; however, other types of additives can only be evaluated with in–engine performance tests. Total Base Number (TBN) of used engine oil measured by ASTM D664 seems to correlate with copper corrosivity, the limit being at or below 2. Comparative IR spectroscopy evaluates oxidation, nitration, and contamination from fuel, carbon soot, and water. The procedures listed above require specialized training, equipment, and support facilities and are consequently performed in a laboratory dedicated to used oil analyses.

Engines

Stationary diesel engines and one marine diesel engine were chosen to participate in this project. A description of the engines at Unalaska are listed in Table 2.

The Seward site engine is a diesel-fueled Volvo Penta model MD11C with a 3.05 quart capacity oil sump, operated at 1,800 RPM which is 75% of rated maximum RPM. Fuel consumption is .50 gallons/hour. The only lubricating oil used is Chevron Delo 400, ISW040.

Filters

After an extensive review process based on product quality, product information, experience, and cost, the following filter systems were chosen for use in the project: Gulf Coast, Spinner, Purifiner, Harvard, and Power Plus.

TABLE 2 – Engine Information for Unalaska

UNIT	GEN. 4	GEN. 5	GEN. 6	GEN. 8
TYPE	3512	3512	3516	3516
SERIAL #	67Z00553	67Z00498	73Z00272	73Z00272
AR. #	2W8869	1W4217	2W8404	2W8871
OT.NO. #	6336	3894	-	6377
GEN. SER.#	5YA0064	89649	6SA649	96420
GEN. AR. #	5N8448	CAT#6P61475	7C2628	CAT#6P6-3000
GEN. TYPE	SR4	A22250000	SR4	A24736000
VOLTAGE	480V	4160V	4160V	4160V
FUEL TIMING	86.6	87.64	87.1	86.9
KW-CONT	675	500	1200	1180
KW-PRIME	830	620	1420	1130
KW-STB	900	650	1600	1200
HP	1042	830	1902	1615
RPM	1200	1200	1800	1200
WEIGHT	22000	22000	27000	27000
G.P.H.	330	330	400	330
25% GPH KW OUT	17.6 204	14.91 155	31.7 355	18.4 282
50% GPH KW OUT	31.2 427.5	23.3 310	52 710	37.8 565
75% GPH KW OUT	45.2 641	33.56 465	74.5 1065	56.8 847
100% GPH KW OUT	59.4 855	42.88 620	98.7 1420	75.67 1130
UNIT	GEN. 4	GEN. 5	GEN. 6	GEN. 8
OIL CAPACITY	81	81	106	219

Experimental Design

Stage and Phase	Description	Sampling
<u>Stage 1</u>		
Diagnostic Screening	Check for abnormal engine conditions.	One sample at oil change
<u>Stage 2</u>		
Phase I Baseline	Oil changed at manufacturer's recommended intervals and oil interval extended without by–pass filters.	One sample at oil change
Phase II Method	Installation of a by–pass filter and extension of oil change interval.	One sample at oil change
Phase III	Installation of technology to recycle waste oil with diesel fuel and extension of oil change interval.	Fuel analysis

Diagnostic Screening

A diagnostic screening was used to determine if the potential candidate had any problems which would complicate the study such as a coolant leak or excessive engine wear. Approximately twice as many engines as needed were screened to assure that enough were available for the study.

In one case, diagnostic screening revealed an engine with potentially serious problems unknown to the owner/operator. Useful information was collected. The portable oil analyzer clearly identified a lubricant problem during the on site inspection. Laboratory analysis both confirmed the lubricant problem and suggested potential sources.

Phase I: Baseline

Engines are run at normal and extended oil drain intervals without added filtration.

Phase II: Methods

By–pass filters were added to the engines and oil drain intervals were extended. Different brands of filters were rotated on each engine.

Phase III: Blending

The Power Plus Smart Tank was used to recycle waste oil on engine #6 at Unalaska. The closed–loop process was also used on the Volvo MD11C marine diesel engine at Seward.

Field Testing CDA

Numerous field tests were evaluated. The tests evaluate solids, viscosity, TBN, and the oil's dielectric constant. Suspended solids can be qualitatively evaluated by spotting oil on blotted paper and quantitatively measured by solvent extraction. Viscosity measurements are occasionally done with calibrated glass tubes or less frequently with semi permeable membranes. TBN can be field tested with test kits. A lightweight, kg, battery powered electronic instrument compares the dielectric constant of new to used oil as an indicator of both oxidation by-products and contamination from water or metals. The sensor is a capacitance bridge operating at a frequency of 5 megahertz (44). This instrument will be referred to as comparative dielectric analyzer (CDA).

A portable battery-powered field CDA was selected based on cost, use, and documentation. Field CDA analysis requires 10 to 15 minutes including sample collection, calibration, and record keeping, and can be done on site. The field unit selected was the Lubrisensor model NI–2B. The only additional equipment required was a sample of the new oil, a non–aqueous/non halogenated solvent cleaner, and tissues. One out of twelve units needed a minor repair during the course of this study.

Each oil sample is tested by a Lubrisensor at each site by the engine operator and at AHP before being sent to the lab for analysis. The project compared the Lubrisensor readings with lab analysis to discover whether the Lubrisensor was a good indicator for contamination in the oil. AHP ordered ten lubrisensors from MRO Sales in September 1992 for a cost of $6,930 and borrowed two from the Alaska Department of Environmental Conservation.

Laboratory Analysis

A national search was conducted and a laboratory selected based on quality assurance manuals, experience, and commercial availability. The laboratory was monitored with a 20% frequency of blanks, spikes, and standards.

The samples taken in this project have been sent to the Analysts Incorporated Laboratory in Oakland, California. Analysts Inc. is an independent oil and fuel testing laboratory, founded in 1960, specializing in controlled maintenance and correct oil drain interval programs through the analyses of used lubricating oil. Through spectrochemical analysis and related physical property tests, they quickly determine the condition of oil and fuels, as well as, the condition of the engine. Their oil analysis program follows six steps:

1)	Identification forms;	2)	Collect samples;
3)	Label samples;	4)	Send samples;
5)	Lab reports	6)	Feedback on computerized summary reports

For this project, Analysts test each sample of used oil for twenty–one metals and the total base number at approximately $16.00 per used oil sample. It analyzes each oil sample for depletion of additives, and liquid and solid contamination. Lab analysis can be a more efficient, inexpensive, and productive means of determining oil contamination or engine wear than conducting periodic maintenance and overhauls.

Equipment manufacturers, oil companies, engine operators, supervisors, plant engineers, service managers, and filter suppliers have all benefited from lab analysis. It has also been utilized by the military, marine fleets, truck fleets, pipelines, and other users of industrial equipment.

In a study completed in 1990, a used oil sample and a coolant-spiked sample, were sent to seven labs throughout the United States to compare the results of the analysis. The study rated Analysts Incorporated of Oakland, California as scoring well on most parts of the test, including detection of the coolant spiked oil sample. See Table 3.

MAINTENANCE

In addition to oil analyses, a uniform maintenance log will be kept on each piece of equipment, including information such as; oil added, repairs, hours of operation, load, changes in operating conditions, fuel consumption, and maintenance.

TECHNOLOGY

A Quality Assurance Plan (QAP), prepared at the beginning of this study (AHP 1991) described the detailed approach and scientific rationale used to extend oil life.

The extension of OCI's, by–pass filtration units and a closed–loop process were used on this project to reduce waste oil.

Extension of Oil Drain Interval

Phase I, baseline, selected engines and determined the baseline trend of oil degradation during the cycle of a normal oil change interval. This phase determined if the oil change interval can be extended based on analysis alone.

By–Pass Filters

The project used filtration as a means to extend oil life and reduce the amount of waste oil in remote areas of Alaska. The purpose of filtration is to remove abrasive particles, and fuel product's from lubricating oil. As the demands on engines have increased, the need for finer filtration has become more important.

Oil is commonly filtered between the oil pump and the engine by diverting 100% of the oil through a "full flow" filter able to remove large particles (greater than 20 microns). Full–flow filters, which are standard

TABLE 3 – Lab Selection Process

LAB NAME	SCORE				COMMENTS
	Cost	QA	Data Mgt.	Total	
	/20	/60	/20	/100	
Prof. Services Ind.	20	50	18	88	Good QA, round robin used oil testing program, long term experience in used oils, modem link
SW Research Inst.	8	60	18	86	Very good QA, Fed-Ex data, broad based automotive research capabilities
Analysts Inc.	20	60	18	98	Excellent QA, long term experience in used oils, JOAP participation, LOAMs database
Spectra Petroleum	20	-	-	-	Price package only
Oregon Analytical	0	40	5	45	EPA CLP program, very good QA for drinking water/RCRA analysis, site audit, little experience in used engine oil analysis and interpretation
Titan Labs	20	5	10	35	One check sample per 50 analysis, QA too brief
NC Machinery	20	20	10	50	CAT used oil verification samples good but QA too brief
Spectro Metrics	20	15	10	45	Data management Spec Net, QA okay but toc brief
Spectro Metrics	19	20	20	59	Excellent data base management (ROAST), quarterly participation in used oil cooperative lab evaluation, brief QA description

in every engine, treat the full flow of oil as it flows from the pump to the engine components. The purpose of a full–flow filter is to screen out large, abrasive particles which could damage the engine, but not to clean oil or control engine wear. The problem with using only a full–flow filter is that they are inefficient at removing liquid materials (such as water, unburned fuel, or acids) and small metal contaminants below 20um from the oil. Used lube oil contains particles smaller than 5um which can cause engine wear. Particles in the 2 – 20 micron size can cause as much wear on piston rings, main and rod bearings as larger particles; therefore, some equipment manufacturers use by–pass filters to remove particles in the range below 20 microns. By–pass filters are given their name because a portion of the oil flow is intercepted and "passes by" the main oil flow. This portion is about 10% of the main flow.

During Phase II, the project used by–pass filters to reduce waste oil on diesel engines in Alaska. They filter finer particles than full–flow filters without restricting the ability of lubricants to reach the engine components.

Recent studies by the U.S. Army indicate that by–pass filters lessen the concentration of ferromagnetic wear particles in diesel trucks without any adverse effects on calcium, magnesium, silicon, or zinc lubricant additives (43). Accelerated wear tests using by–pass filters found that normal engine wear was reduced in proportion to the filter micron rating (14) with a correlation coefficient of 0.996 (12). The concentration of wear metals decreased up to 80% with increased filtration. However, used oil analysis from field operated vehicles will not be as clearly correlated due to decreased wear rates during normal oil change intervals.

A by–pass filter is secondary to the full–flow filter. The primary requirement is a direct attempt to reduce long term wear by lowering the gross contamination level in the system.

After the selection review process, the project selected the following by–pass filters:

1) Gulf Coast
2) Spinner
3) Purifiner
4) Harvard

Phase II methods used oil analysis to monitor the effects of several by–pass filters on oil degradation. The analytical laboratory and project manager recommended an increase or decrease of oil change intervals based on the best information available from engine manufacturers and literature, but the actual decision was made by the operator. Regardless of the decision, the quality assurance plan guaranteed that the data collected was of a known quality and useful in the statistical analysis.

By–pass filters are popular because they can be added to equipment with simple modifications. Recently, several manufacturers such as Cummins and AC Rochester improved standard equipment filters to the point that a stand alone by–pass filter may not be necessary. In using by–pass filters, the oil is removed from the lubricating system, passed through the by–pass filter where some of the insoluble contamination is removed, then returned to the system. It is a continuous process which is able to filter particles down to <1 micron, eliminate sulfuric acid buildup, and absorb water by diverting the oil by the pump to a second filter system and returning it to the sump. For optimum filtration, it is important to change the filter element when clogged with particles and add fresh oil, then hot drain and crush the old element for disposal.

Closed–Loop Process

Phase III consisted of recycling used oil and blending it with unused diesel fuel. Based on cost and effectiveness, a closed–loop filter was selected to improve the quality of the oil which was removed from engines. The filtered oil was blended for use in the diesel engine or as heating fuel.

After receiving brochures, information packets, and prices from various distributors, AHP reviewed the information and discussed the options with the engine operators. Based on all of the factors, the Power Plus Smart Tank was chosen for the project. Power Plus ED3500S costs approximately $1600 and may allow an energy tax credit up to 20%. The Seward facility constructed its own blending system for the Volvo MD11C.

Lubricating oil is removed at the rate of 1.3 ounces/engine–hour and blended in the fuel tank at 2% oil:fuel. This removal rate uses the same amount of oil as changing the oil once every 150 hours.

Sampling began at every 25 hours and upon good lab analysis, the removal rate was reduced by 50% to .65 ounces/hr, and blended at 1% oil:fuel. This removal rate uses the same amount of oil as changing the oil once every 300 hours.

A closed–loop process is a process in which the oil is removed from the engine at a set rate and blended in the fuel tank at a varied percentage of oil to fuel blend. While the amount of oil used in the engine can vary, used oil is recycled back into the system.

The Power Plus claims to be the most complete engine lubricating control system for engines and ensures optimal operating conditions and extended engine life, while reducing maintenance costs and providing continuous protection.

It can be programmed as an automatic oil change system and replace removed oil with fresh oil. It can monitor and maintain the crankcase oil level and automatically change engine lube oil on a continual basis by removing a small amount of oil from crankcase and replacing it with fresh oil.

DATA EVALUATION

The potential of extending oil life by ultrafiltration and analysis was measured by the condition of the oil, the ability to extend the oil drain interval, and the ability to reduce the measured amount of waste oil each site must dispose.

During the project, the methods or independent variables were oil analysis and filtration systems. Oil change intervals and cost were the dependent variables.

Used oil samples of approximately one oz. were taken from the diesel engines as often as every two days. Each sample was tested for deviations in the dielectric constant by a Lubrisensor field monitor. This test was conducted by the engine operator on site as well as at the AHP office by the project manager. Next, the sample was sent to the lab to analyze the physical and chemical properties of the oil. The lab results were sent to AHP for review and then forwarded to the engine operator. A quality control sample was sent to the lab with every fifth used oil sample.

SECTION 4

RESULTS

The results of the data accumulated were plotted on graphs and are summarized below.

Figure 3 shows the CDA readings against engine hours on oil for each of the by–pass filters on engine No. 4. A higher CDA reading can be an indication of possible oil contamination. The control plot is an extension of the oil drain interval without a by–pass filter. On this engine, the control samples had lower CDA readings than samples from by–pass filters and were extended to a greater number of hours. This figure shows that the oil itself can be extended to at least 1000 hours without any CDA readings indicating oil contamination. The oil samples with by–pass filters extended oil drain intervals over 600 hours without any CDA readings indicating oil contamination.

Figure 4 shows the average oil life for an engine with a 105 gallon sump capacity at different OCI settings. Any engine following these recommendations should run their own control tests and monitor the engine and oil for any contamination.

Figure 5 shows the CDA readings against engine hours on oil for each of the by–pass filters on engine No. 5. On this engine the control samples had lower CDA readings than samples from using the Spinner Filter. The samples using the Purifiner filter had a lower CDA reading than the Spinner or control samples. All samples on this engine were able to extend their OCI to over 800 hours without any CDA readings indicating oil contamination.

Figure 6 is the same as Figure 5 except that it shows that all the samples were within 95% confidence.

Figure 7 shows the average oil life for engine No. 6 with different OCI settings. Any engine following these recommendations should run their own control tests and monitor the engine and oil for any contamination.

Figure 8 plots the engine hours against CDA readings for the first and last five used oil control samples from engine No. 6 within a 95% confidence level. The control plot is an extension of the oil drain interval without a by–pass filter. As the hours on the engine and the OCI increased, so did the CDA readings.

Figure 9 is the same as Figure 8 except that it plots the complete range of data points.

Figure 10 shows the CDA readings against engine hours on oil for each of the by–pass filters on engine No. 6. On this engine, the Purifiner filter had slightly lower CDA readings than the control samples and the samples using other filters. All sets of samples exceeded 600 hours on oil, but the Harvard and control samples CDA readings indicated possible oil contamination.

Figure 11 shows the CDA readings against the engine hours for the used oil control samples and the Purifiner used oil samples on engine No. 6. The control plot is an extension of oil drain interval without a by–pass filter. This figure plots the complete range of data points. Both set of samples extended OCI over 800 hours, but had some CDA readings which indicate possible oil contamination.

Figure 12 shows the CDA readings against the engine hours for the used oil control samples and the Gulf Coast used oil samples on engine No. 8. This figure shows that on this engine the control samples had lower CDA readings than the Gulf Coast samples, but that both sets of used oil samples were able to be extended to over 1200 hours without any CDA readings indicating oil contamination.

Figure 13 is the same as Figure 12 except it plots the complete range of data points.

Figure 14 plots the CDA and TBN readings against engine hours for the control samples on the Volvo MD11C engine. This figure shows a direct relationship between CDA and TBN readings within a 95% confidence level on this engine. This enables the engine operator to predict within a 95% confidence level the TBN level given the engine hours and a CDA reading. This aids the operator because lab analyses take time and are costly.

Figure 15 plots the TBN levels against the hours on oil for the control used oil samples and the 1.5% oil:fuel blend samples on the Volvo MD11C engine within a 95% confidence level. The control plot is an extension of oil drain interval without a by–pass filter. A lower TBN level is an indication of possible oil contamination. This figure shows that the blend samples were able to hold a higher TBN level over extended hours on the oil causing the engine less probability of oil contamination.

Figure 16 shows the CDA readings against the engine hours for the control used oil samples and the 1.5% oil:fuel blend samples on the Volvo MD11C engine within a 95% confidence level. The blend is a closed–loop process where used oil is blended with incoming fuel. This figure shows lower CDA readings than the control samples. The blend samples were extended to over 200 hours without CDA readings indicating any oil contamination. The control samples were able to extend the oil to over 350 hours, but had CDA readings indicating possible oil contamination.

Figure 17 is the same as Figure 14 except it plots the complete range of data points and extends the data to the point where TBN level would reach zero on the Volvo MD11C engine. This figure shows a direct relationship between CDA and TBN readings within a 95% confidence level on this engine extended to over 1000 hours. This enables the engine operator to predict within a 95% confidence level the TBN level given the engine hours and a CDA reading. This aids the operator because lab analyses take time and are costly.

Data from the Unalaska and Seward engines were used for final graphs. Data from the Hoonah and Yakutat sites was not as reliable. In Hoonah, used oil samples were taken from a CAT 3508 diesel engine for baseline data, but then for winter Hoonah began to use a CAT 3512. The 3508 had no by–pass filter and was baseline data, but the CAT 3512 had a by–pass filter but no baseline data.

FIGURE 3 – Bypass Filter vs. Control Samples CAT 3512, Engine No. 4

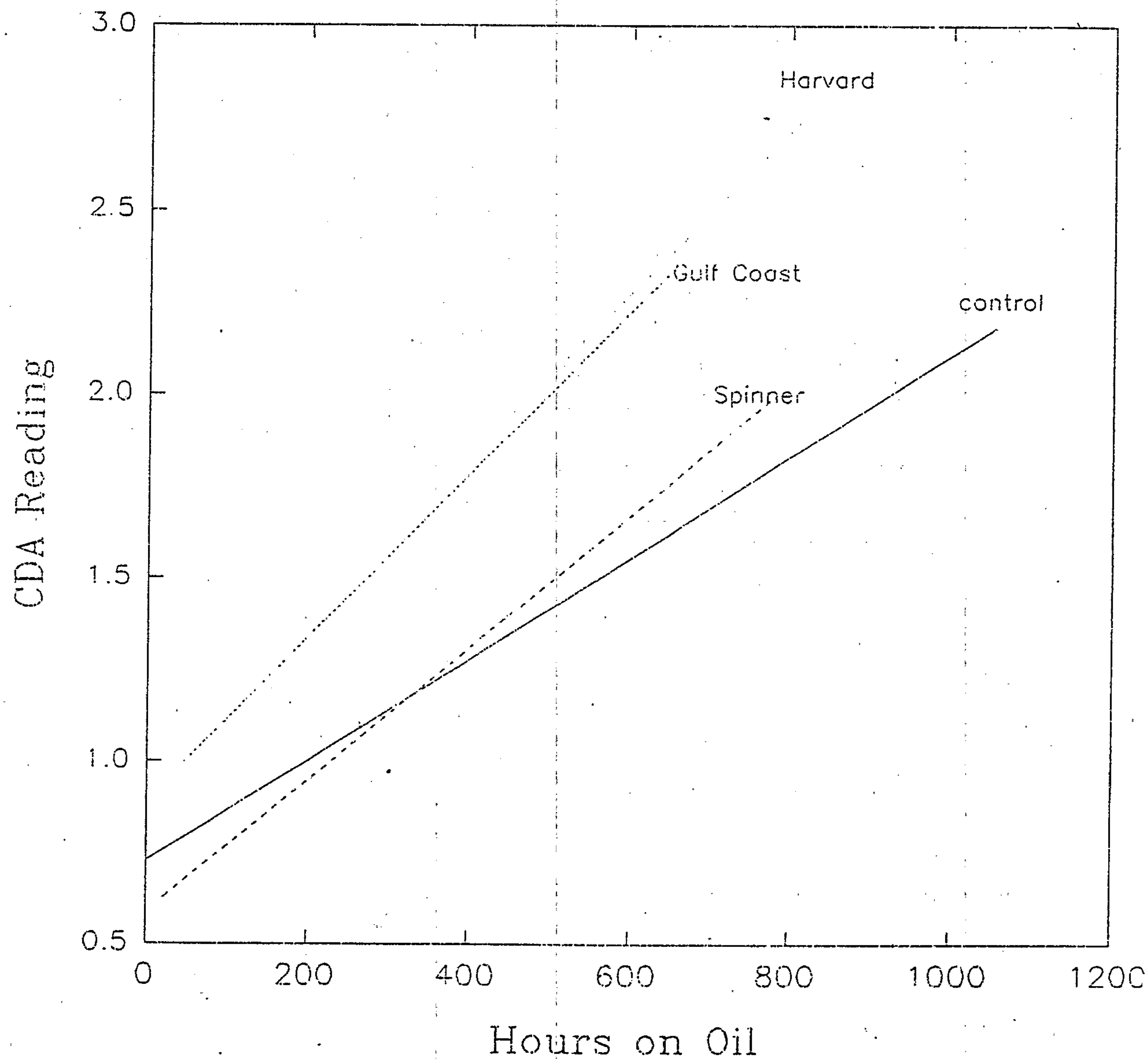


FIGURE 4 – Average Oil Life for Different Settings 105 g Oil Sump

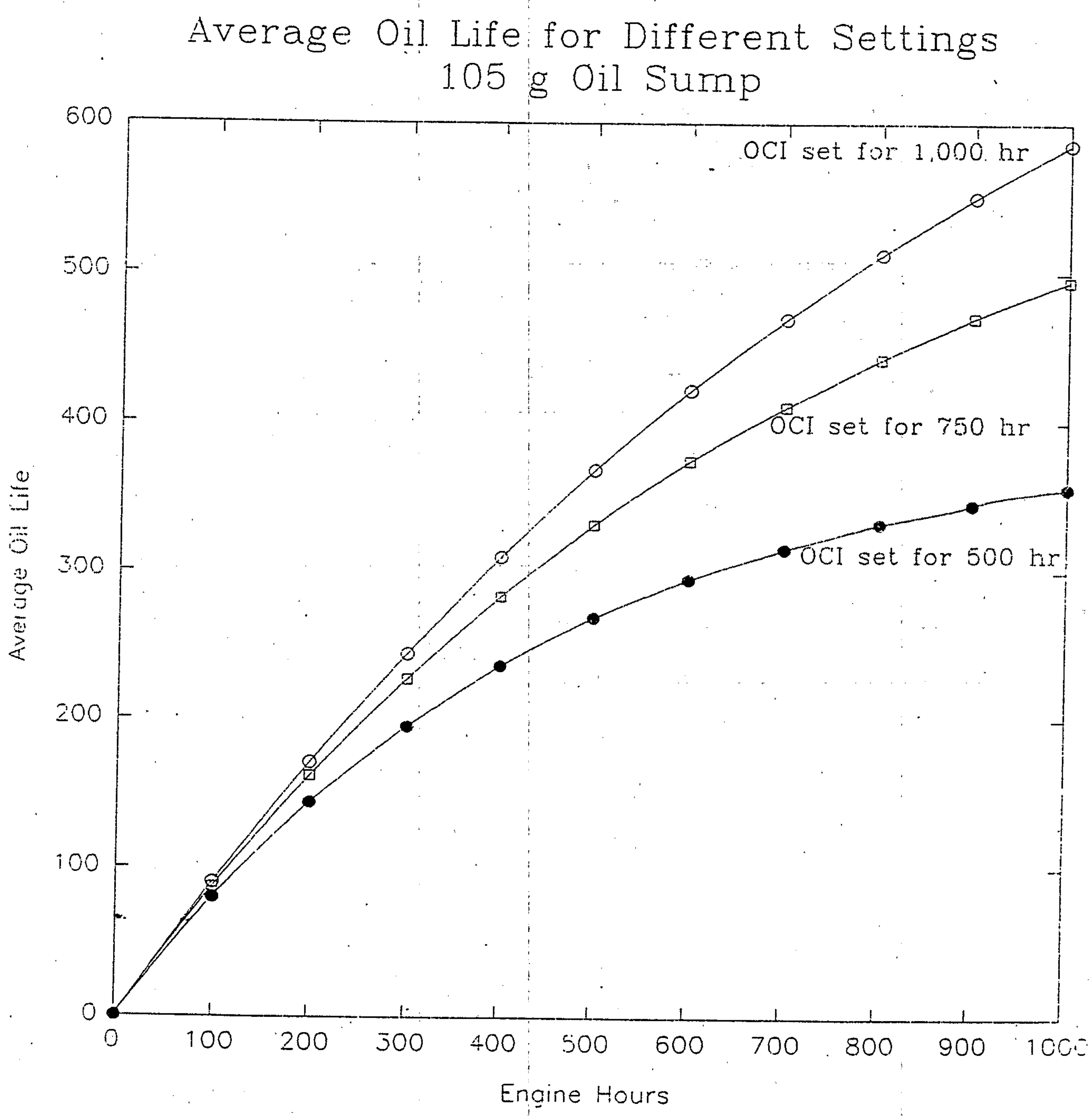


FIGURE 5 – Bypass Filter vs. Control Samples CAT 3512, Engine No. 5

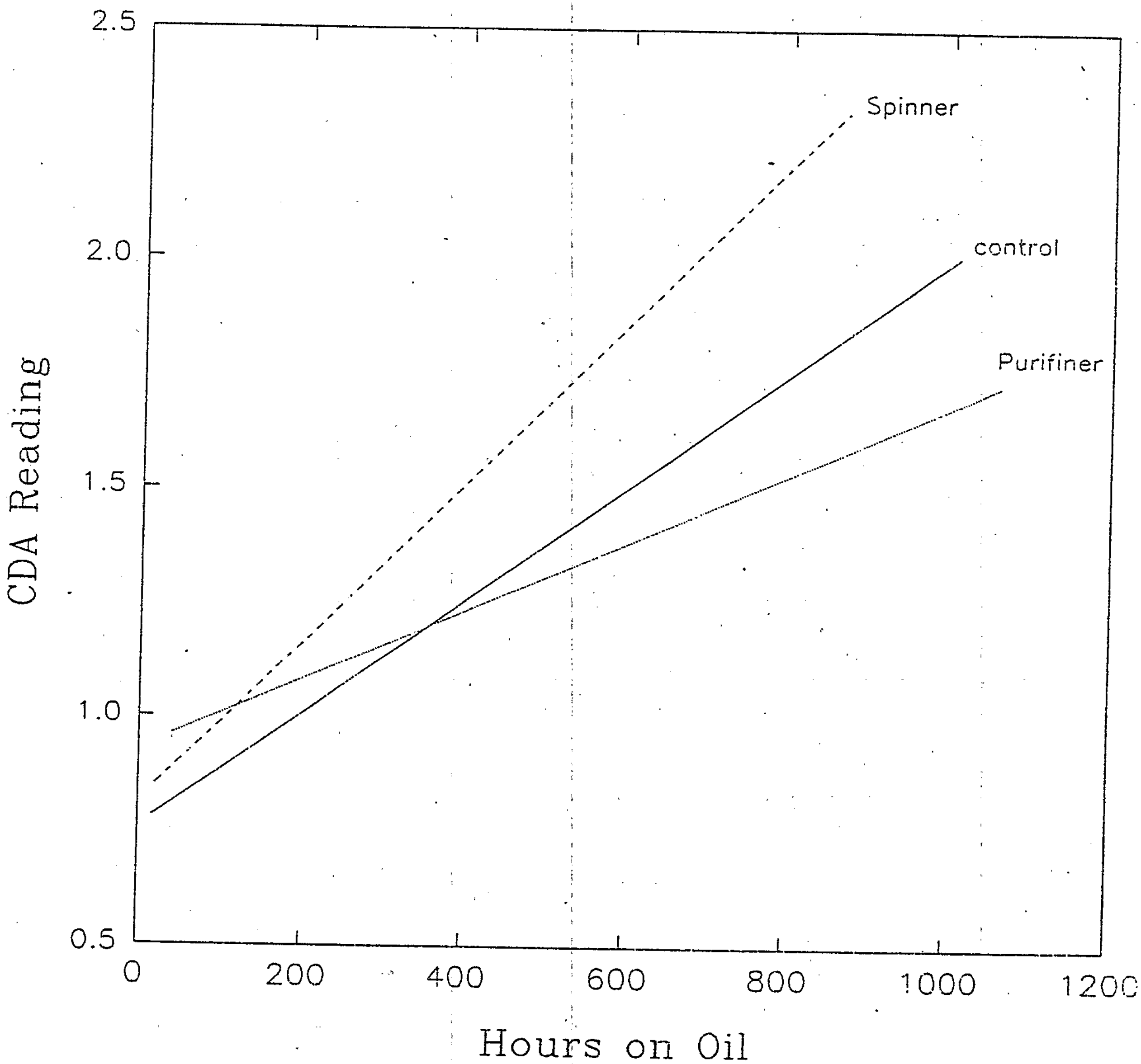


FIGURE 6 – Bypass Filter vs. Control Samples CAT 3512 Engine No. 5 with Confidence Level

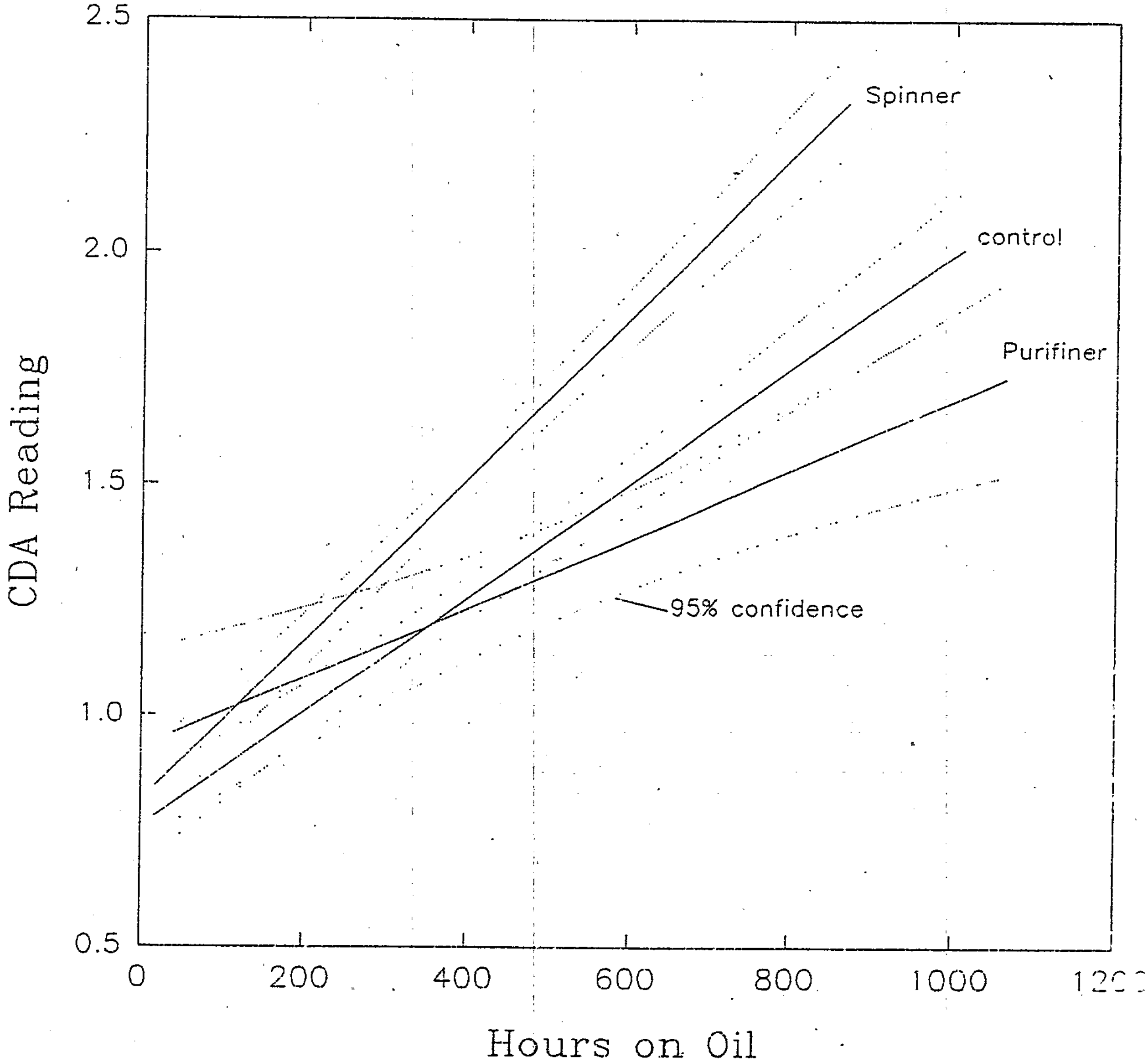


FIGURE 7 – Average Oil Life for Different Oil Change Interval (OCI) Settings CAT 3516, Engine No. 6

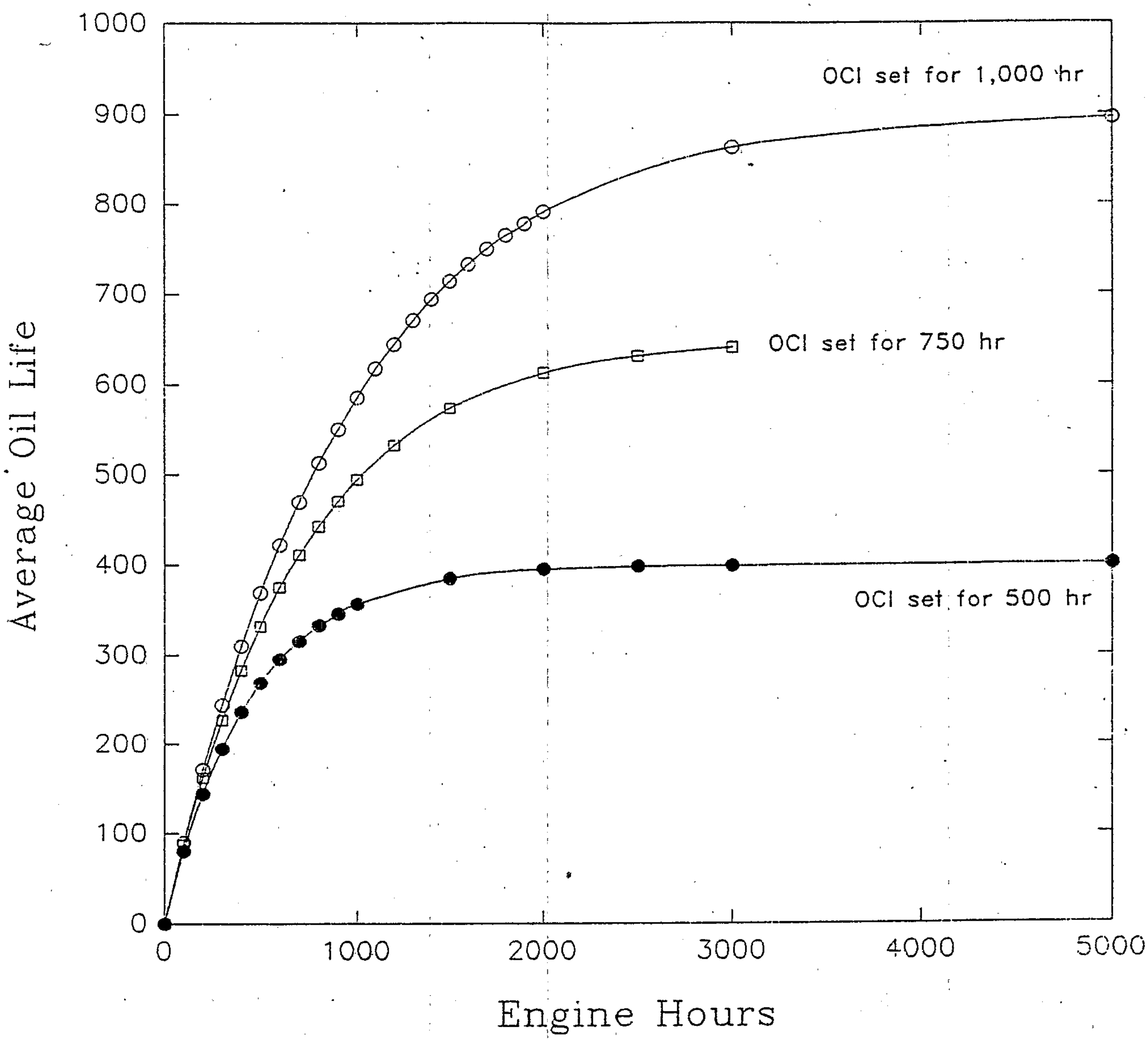


FIGURE 8 – Control Sample Variation with Time CAT 3516, Engine No. 6

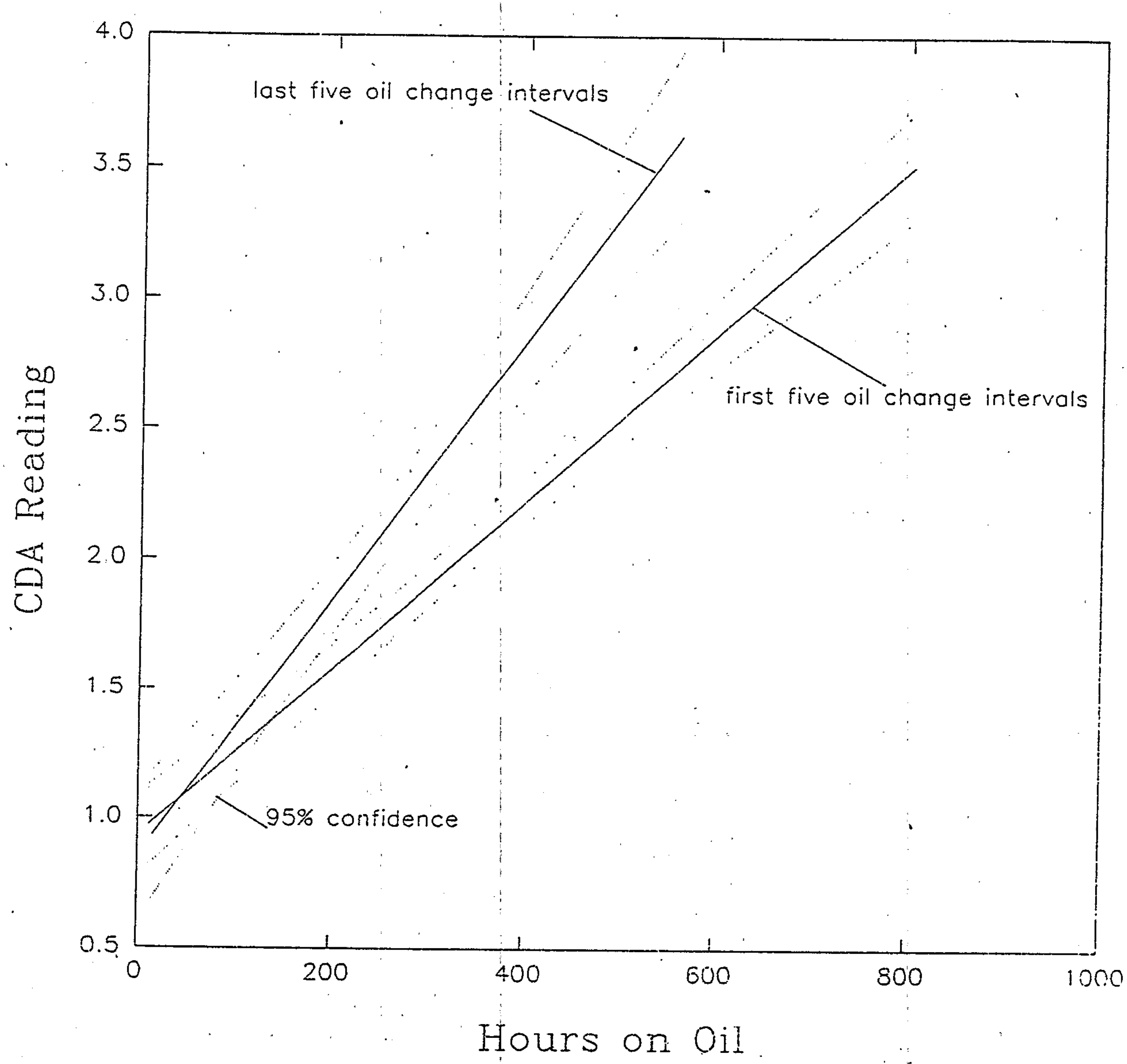


FIGURE 9 – Control Sample Variation with Time CAT 3516, Engine No. 6

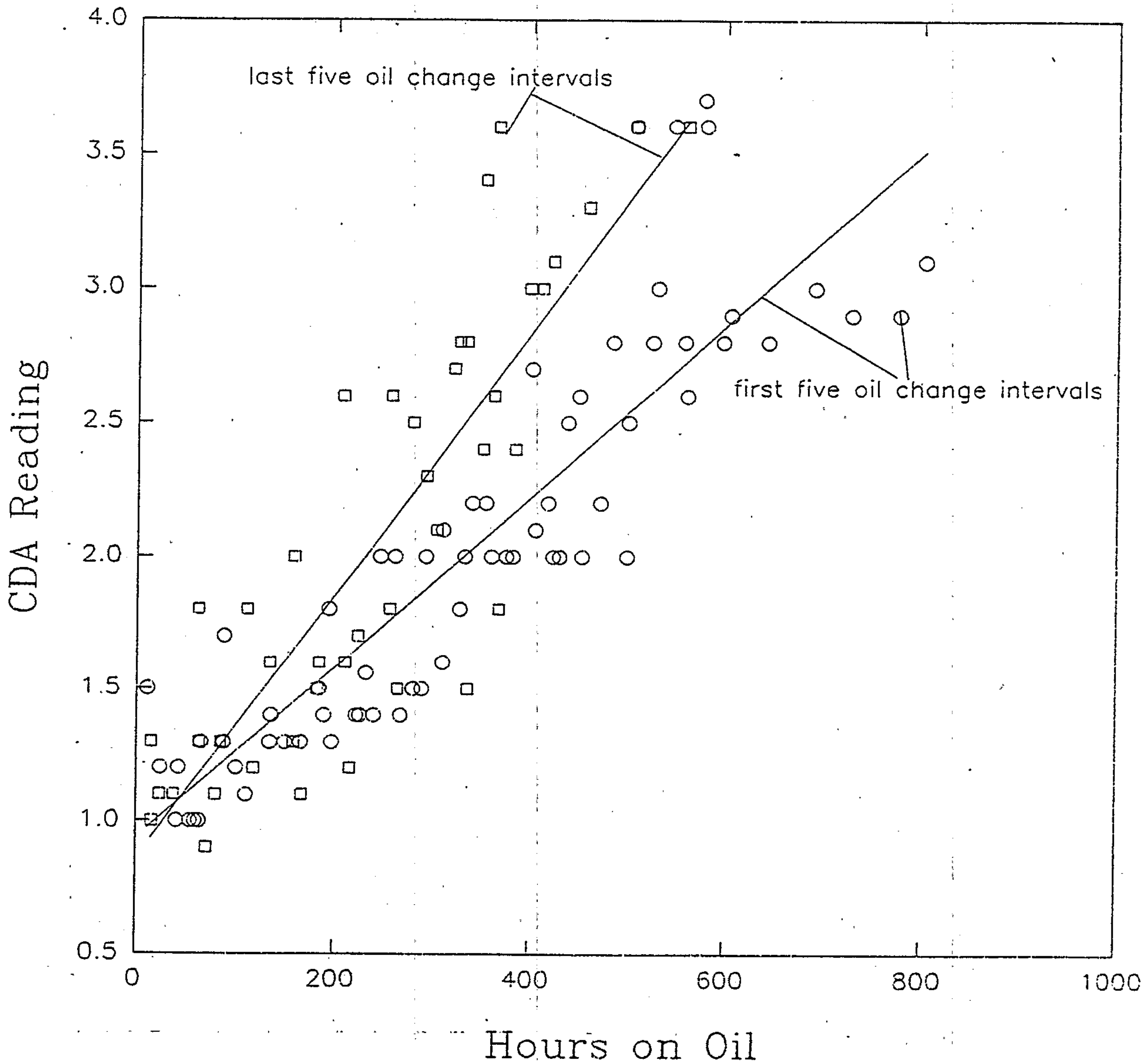


FIGURE 10 – Bypass Filter vs. Control Samples CAT 3516, Engine No. 6

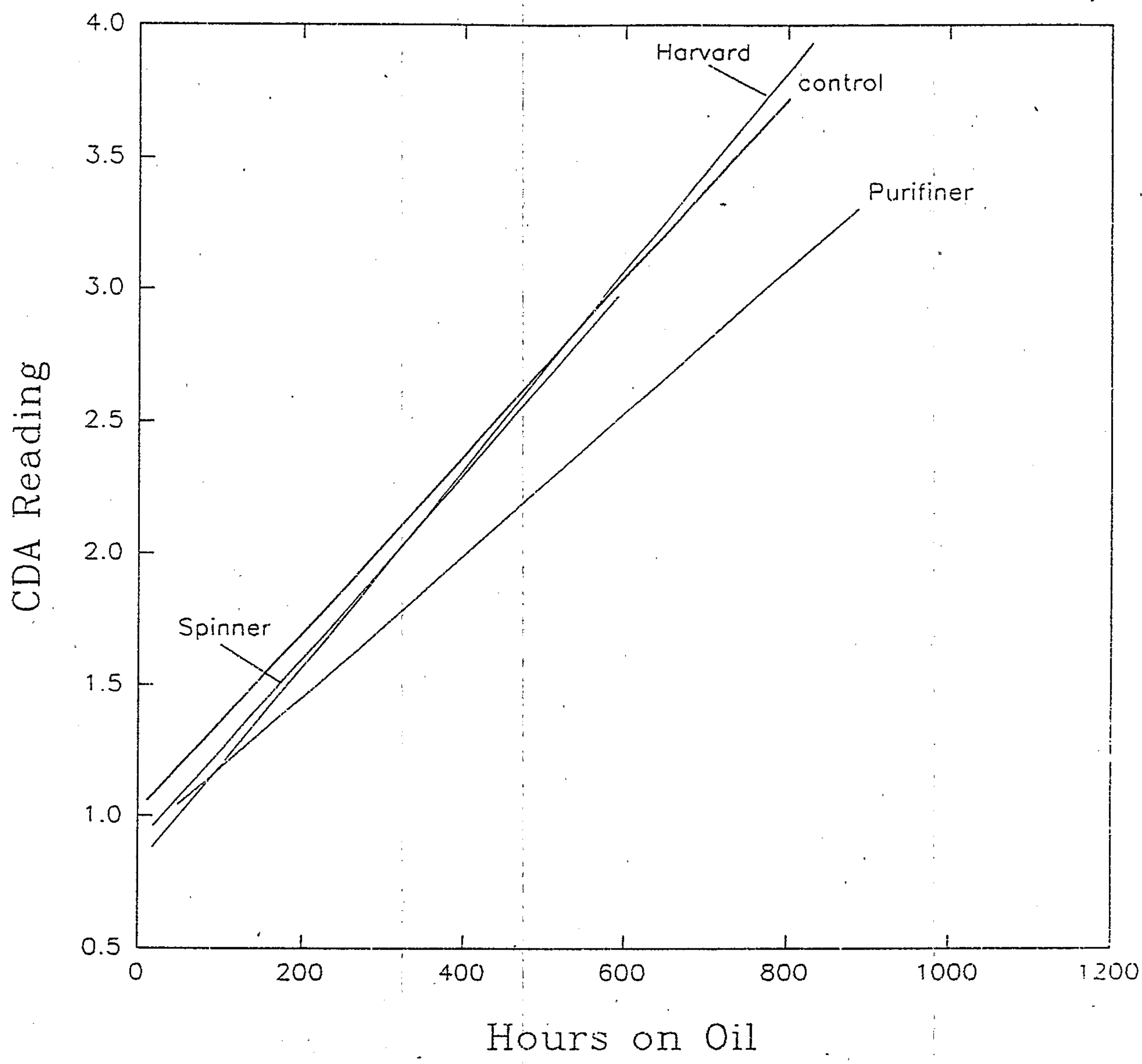


FIGURE 11 – Bypass Filter vs. Control Samples CAT 3516, Engine No. 6 With Data

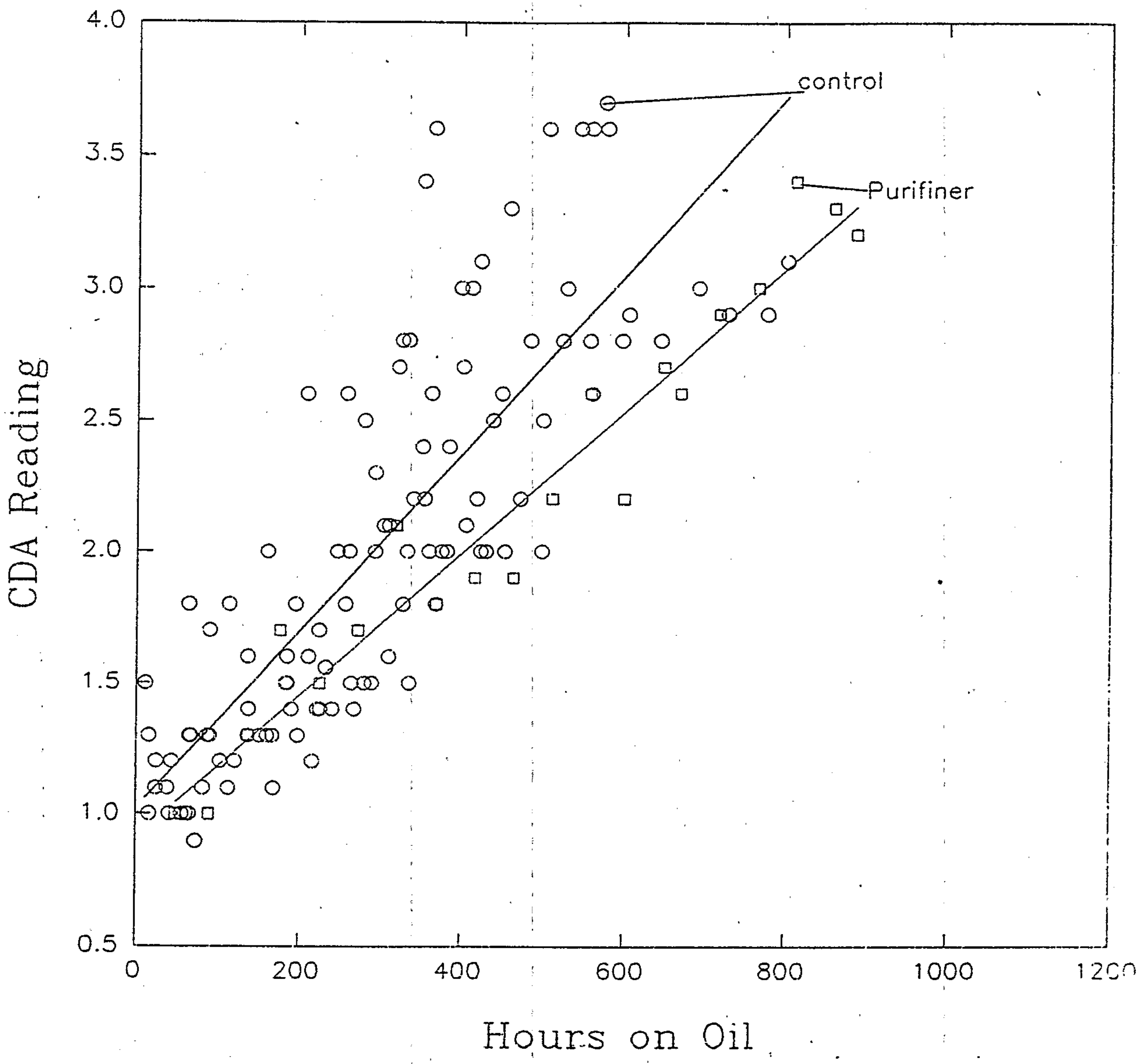


FIGURE 12 – Bypass Filter vs. Control Samples CAT 3516, Engine No. 8

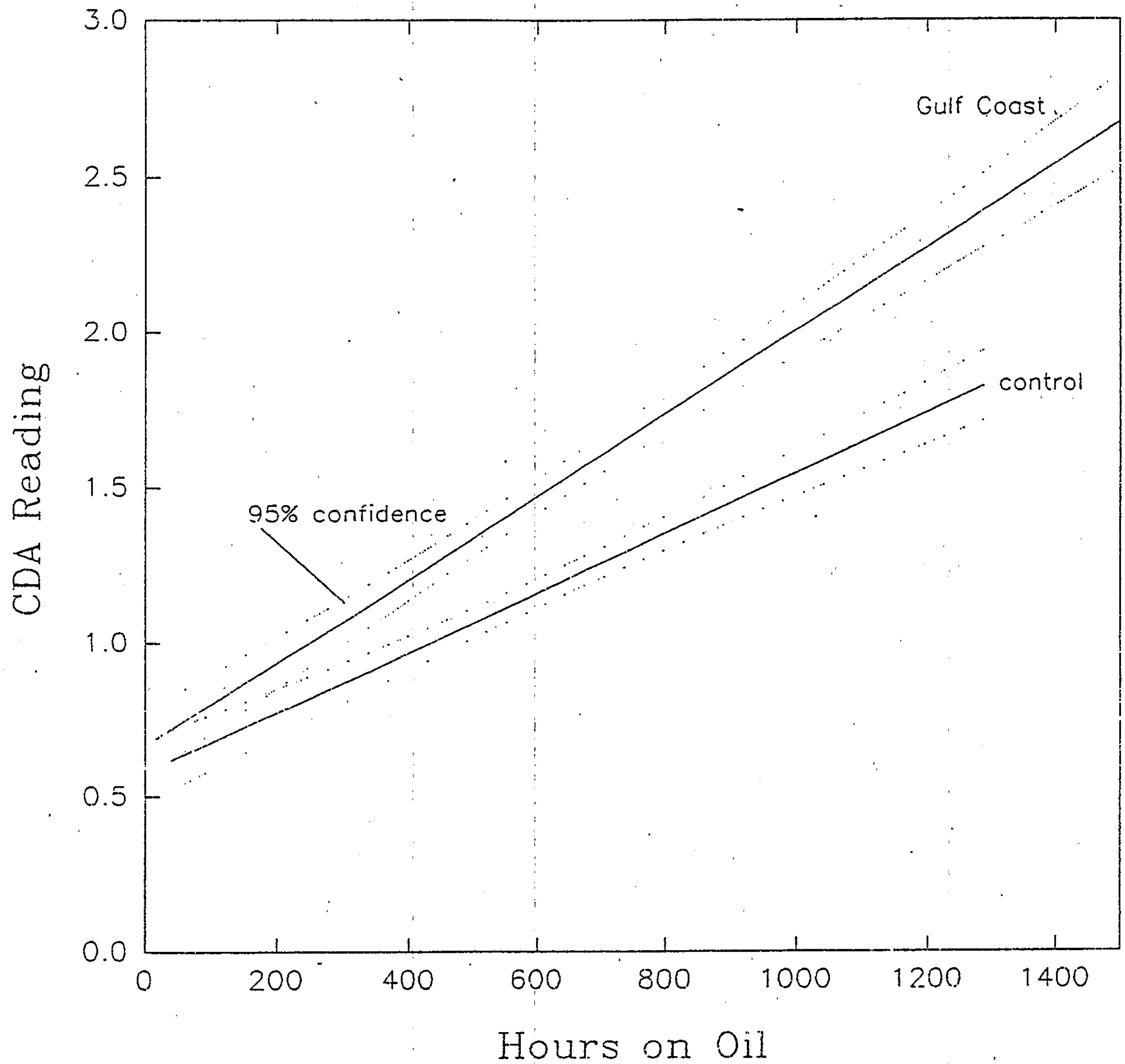


FIGURE 13 – Bypass Filter vs. Control Samples CAT 3516, Engine No. 8 With Data

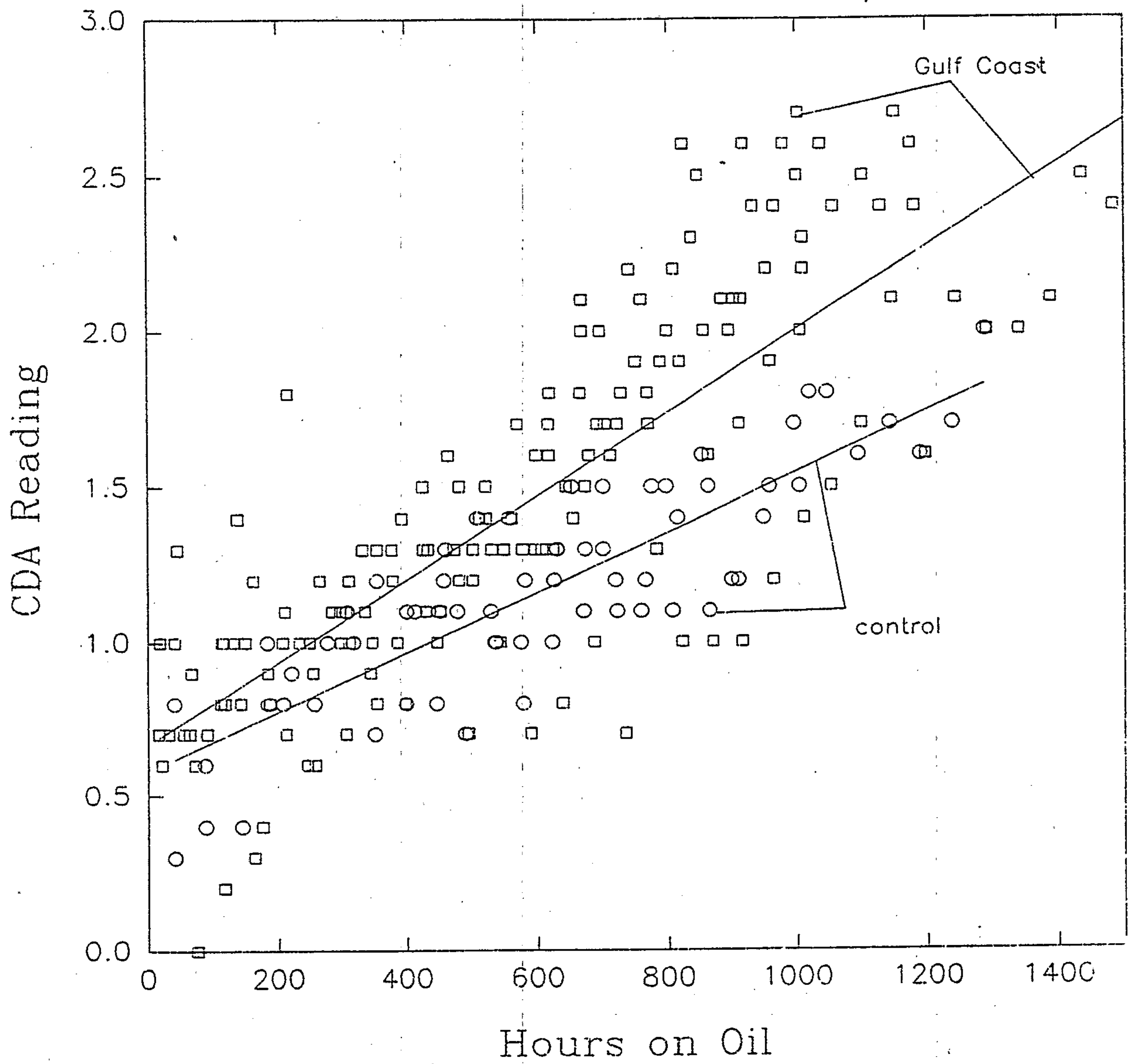


FIGURE 14 – Control Samples Engine, Volvo MD11C

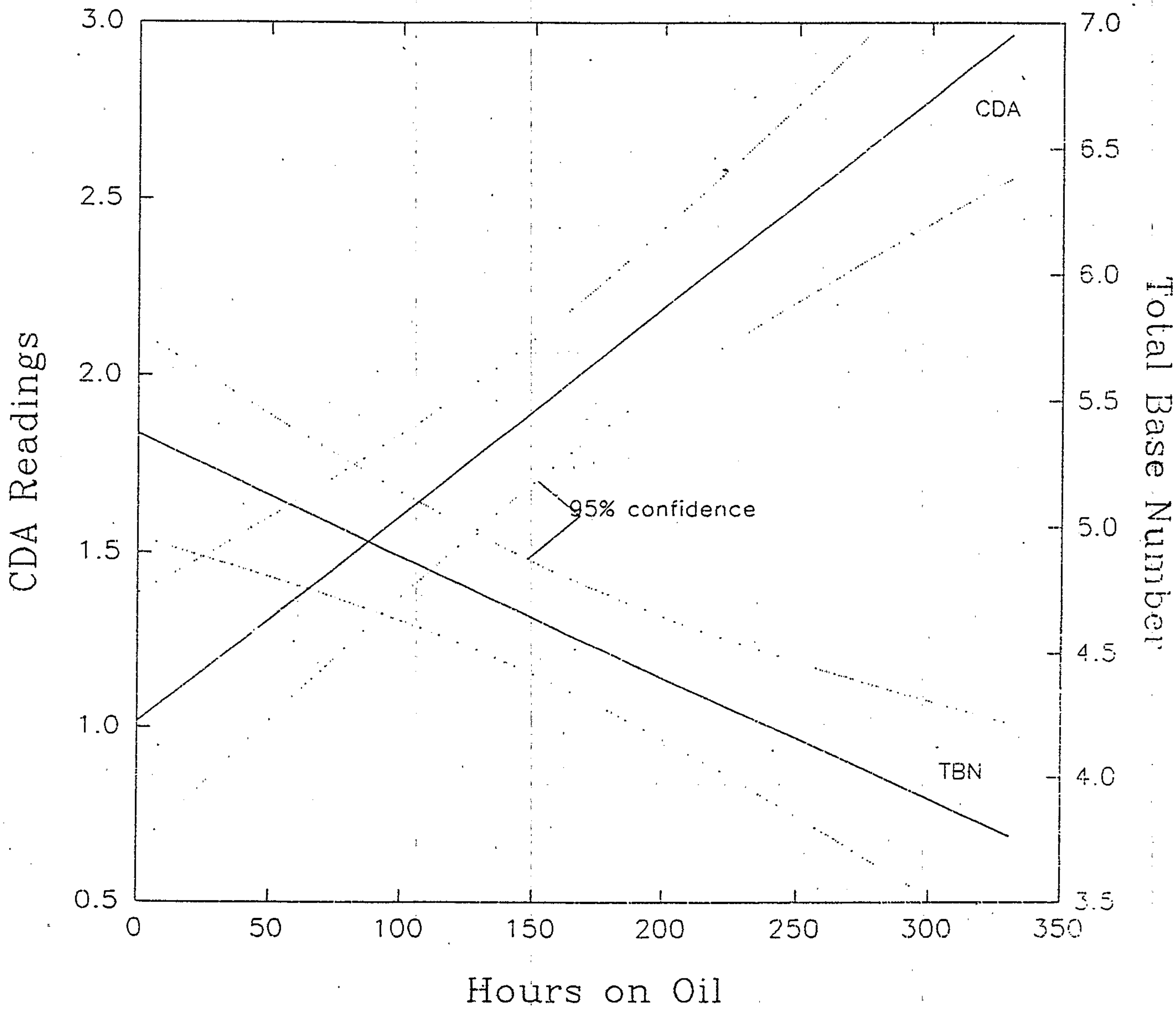


FIGURE 15 – 1.5% Oil: Fuel Blend Engine, Volvo MD11C

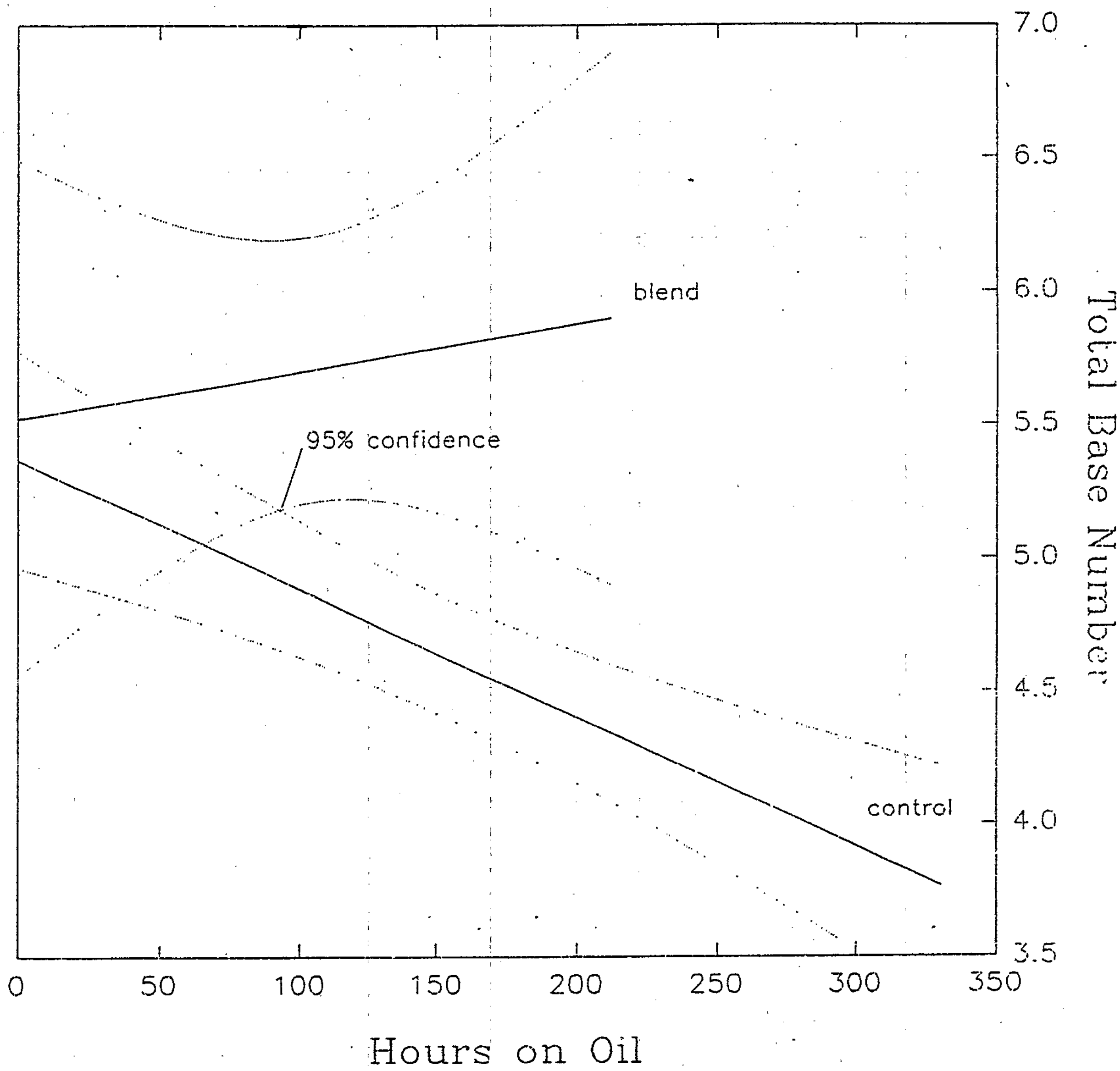


FIGURE 16 – 1.5% Oil: Fuel Blend Engine, Volvo MD11C

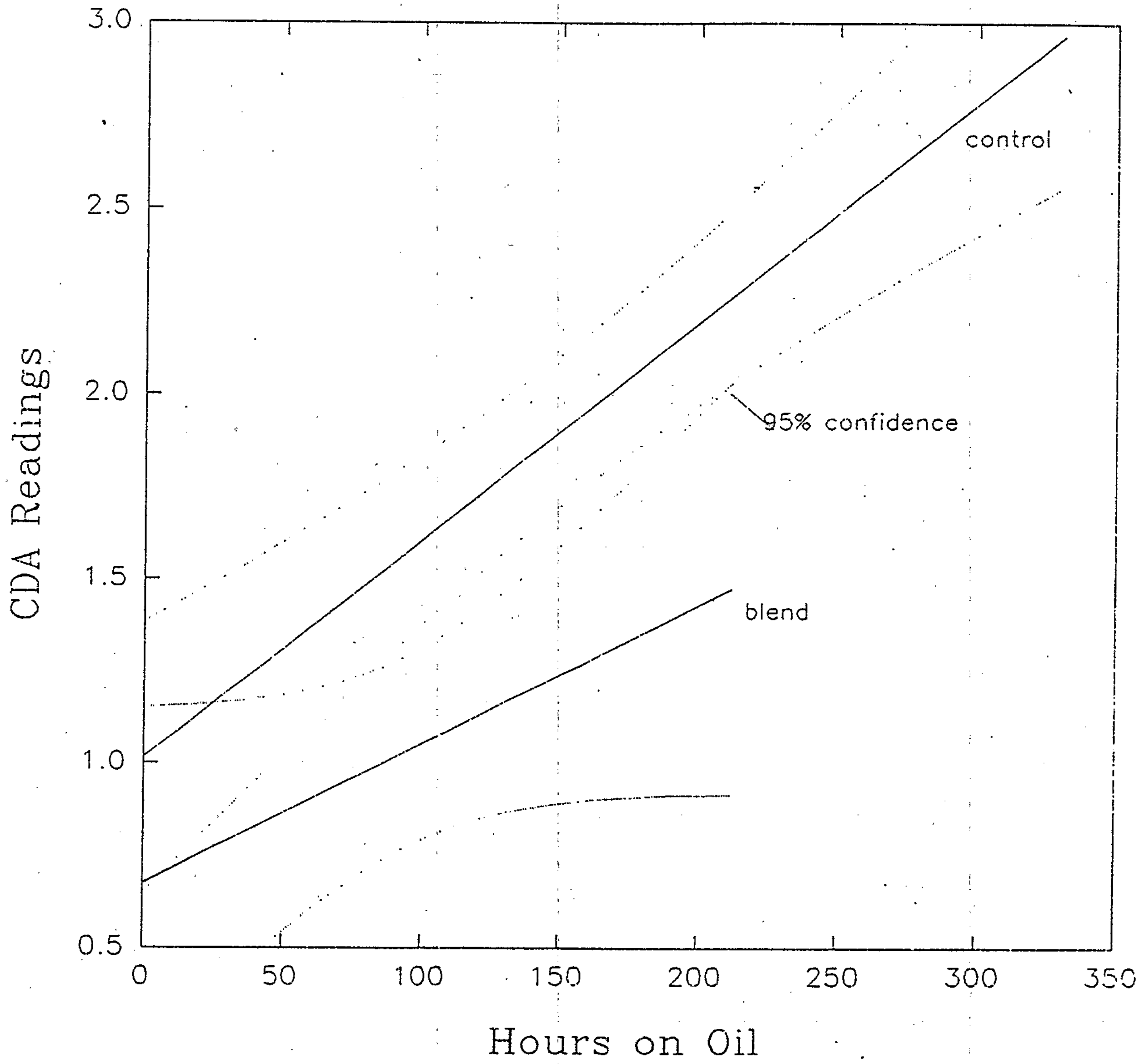
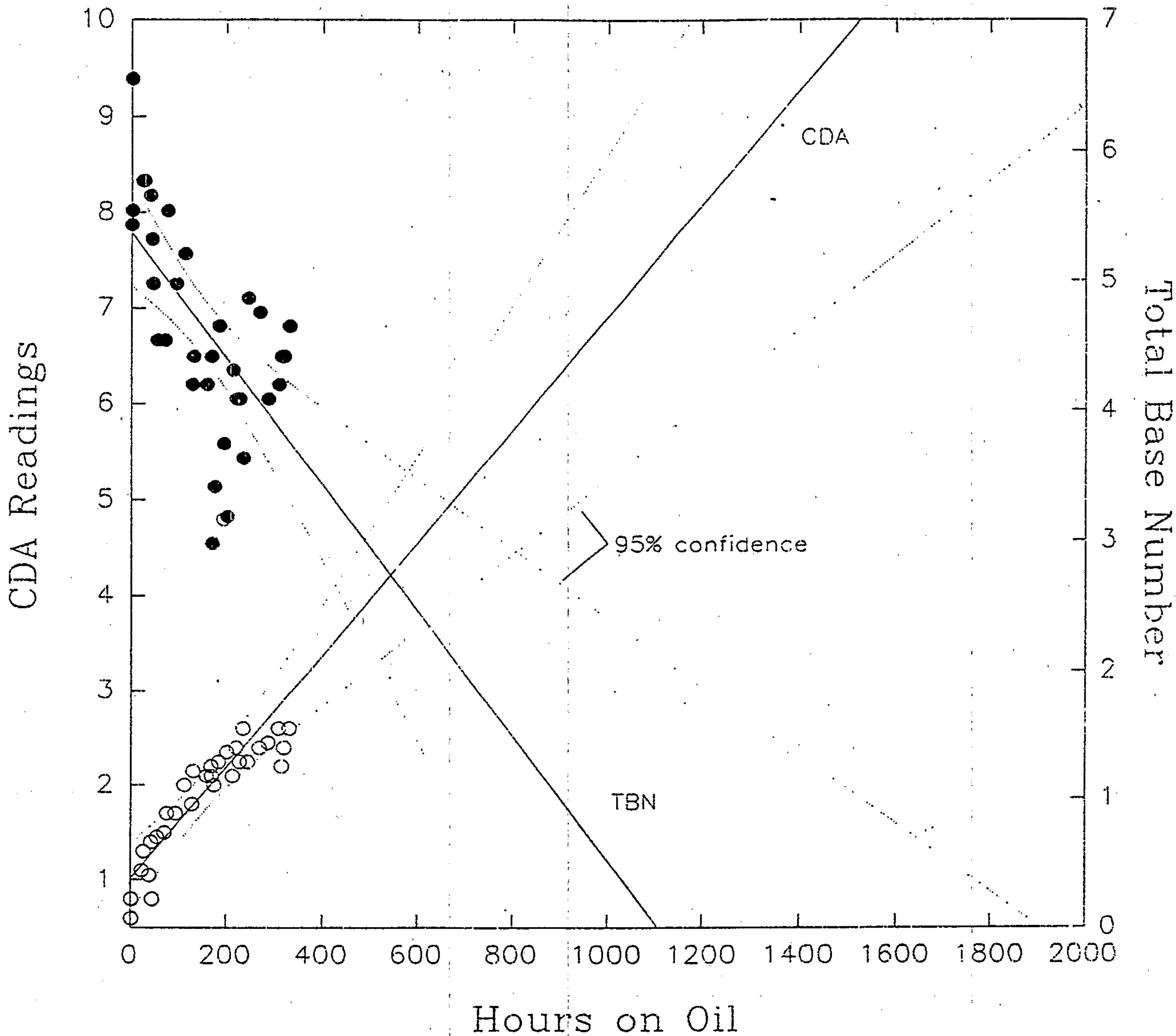


FIGURE 17 – Control Extended to Zero TBN Engine, Volvo MD11C



~~Figure 4. Control Extended to Zero TBN Engine, Volvo MD11C.~~

SECTION 5

DISCUSSION

This evaluation shows that there is a feasible potential for reduction of used oil. A diesel engine operator could potentially reduce used oil waste volume by many gallons per year by extension of OCIs, ultrafiltration, or re–blending. These practices would save the operator money, require less downtime, and reduce disposal liabilities. All three techniques are easy to implement, and are inexpensive by theory that any process that saves money eventually pays for itself.

Laboratory data was analyzed for indications of oil degradation such as changes in viscosity, decreases of Total Base Number (TBN), soot, oxidation, nitration, and suspended solids formation. None of the parameters listed, except TBN, limited oil life extension. In several samples, TBN values reached zero, indicating, the oil needed changing. Without buffering capacity (TBN), non–neutralized sulfur from combustion by–products reduces the pH, thus causing accelerated engine wear.

This project chose to analyze Total Base Number (TBN) and comparative dielectric analyzer (CDA) data as the best indicators of oil quality.

CDA is a portable battery powered field instrument used to determine the deterioration in motor oil from continued use. By measuring any deviation of the dielectric constant between fresh and used oil, it indicates the overall condition of the oil and helps to determine optimal oil change intervals, as well as signifying the possible danger of oil contamination.

TBN is the quantity of hydrochloric acid, expressed in terms of the equivalent number of milligrams of potassium hydroxide which is required to neutralize all the basic constituents present in one gram of the sample of petroleum products or lubricants. The Total Base Number indicates relative changes that occur in an oil, regardless of color or other properties of the oil.

Although the lab analyzed each used oil sample for twenty–one metals, TBN was the one constant indicator on lab results of oil degradation . Low TBN was the reason for each abnormal lab result. See Table 4.

Due to the cost and time involved in waiting for lab results on the quality of a used oil sample, this project chose to collect CDA data. A CDA reading of a used oil sample is not a definitive answer of oil quality, but gives a reading that can alert an operator of any potential oil contamination. A high reading on the CDA acts as a "red flag" to the operator and immediately allows the operator to make an engine adjustment, change the oil, or send the sample to the lab. This can protect an operator from; risking dangerous engine component wear, unnecessary downtime, and expensive lab tests.

A plot of CDA response and TBN versus hours on oil revealed an inverse relationship, as can be seen in Figure 17. TBN values were extrapolated to zero, the minimum acceptable value, to estimate maximum OCI The boxed areas on the lower left of each graph indicate CDA readings at depleted TBN. The more rapid depletion of TBN in engine #4 compared to the same model engine #5 is a function of increased power demand met by higher RPM and increased fuel consumption. The more rapid depletion of TBN and increased CDA trend of engine #6 compared to the same model engine #8 is a function of decreased oil sump capacity. The number of CDA measurements, TBN analyses, and OCI for Engine 6 are listed below.

Number of Samples Analyzed

Engine #	CDA	TBN and OCI
4	137	8
5	128	8
6	92	6
8	114	5

FIELD DATA COMPARED TO LABORATORY DATA: ABNORMAL ENGINE WEAR

One marine diesel engine (Volvo MD11C rated 23 hp) extended the OCI six fold. At midpoint with 190 hours on the oil, (manufacturers recommended OCI is 50 hours) a cooling system failure caused oil degradation and accelerated engine wear. Water contamination from the catastrophic failure of a seal was apparent from both the CDA response and laboratory analysis (Figure 18, top). The high CDA reading in combination with a visible loss of coolant from the heat exchanger prompted repair of the seal. However, the oil was not changed because CDA readings returned to normal. The decision to not change the oil after water seal failure might have been disastrous. This was an operators decision that goes against all training manuals, and is not recommended as part of the possible oil savings that this study is working with.

Oil contamination by water and coolant caused elevated levels of wear metals and salts. Aluminum was the wear metal with the best quality control data and was plotted with CDA field readings versus hours on oil (Figure 18 bottom). Other wear metals showed similar correlation, although with more variation from sample to sample.

NORMAL OIL DEGRADATION

Criteria for determining OCI based on used oil analyses is difficult to get for four reasons. First, engine manufacturers' data showing the safety factors built into OCI are not public information. The safety factors, in part, take into account the fact that lubricating oil certification programs are inadequate and tests have been falsified (42). Second a joint project of the U.S. Army, Motor Vehicle Manufacturers Association, and American Petroleum Institute found that approximately 10% of the lubricating oil on the market did not meet certification requirements (46). A revised oil labeling assessment program is currently attempting to introduce quality control into the voluntary oil certification industry. The third problem with data interpretation is the use of proprietary wear metal trend algorithms, created by commercial laboratories for advising clients on oil and engine condition

Limited public information regarding the interpretation of used oil analyses is available from the Department of Defense Joint Oil Analysis Program Manual including information from studying Air Force, Navy, and Army engines and transmissions (46). Some of the engines referenced are commercially available. Finally, many engine operators send used oil samples to a lubricant supplier who tests for excessive engine wear. Lubricant suppliers may have a conflict–of–interest in recommending increased OCIs thus lowering sales. The manufacturer of the CDA suggests a relative value of 4 as a safe rejection threshold for petroleum based multi–viscosity oils and recommends correlation with laboratory analyses.

ABNORMAL ENGINE WEAR

In the marine diesel engine, water was likely contaminating oil prior to seal failure, although neither the CDA response nor laboratory analysis detected water except at the time of failure. Water is difficult to detect, probably because of evaporation caused by normal engine operating conditions. However, corrosive effects were apparent from laboratory analysis. The lab first reported signs of contamination (40 hours on oil), then abnormal conditions (55 hours), followed by critical (190 hours) concentrations of six wear metals followed by a gradual decline because of old oil dilution with new replenishing oil. The accumulation of wear metals did not trigger an exceptional rise in the CDA response. Consequently, CDA response cannot be solely relied upon to indicate critical levels of wear metals in similar incidents.

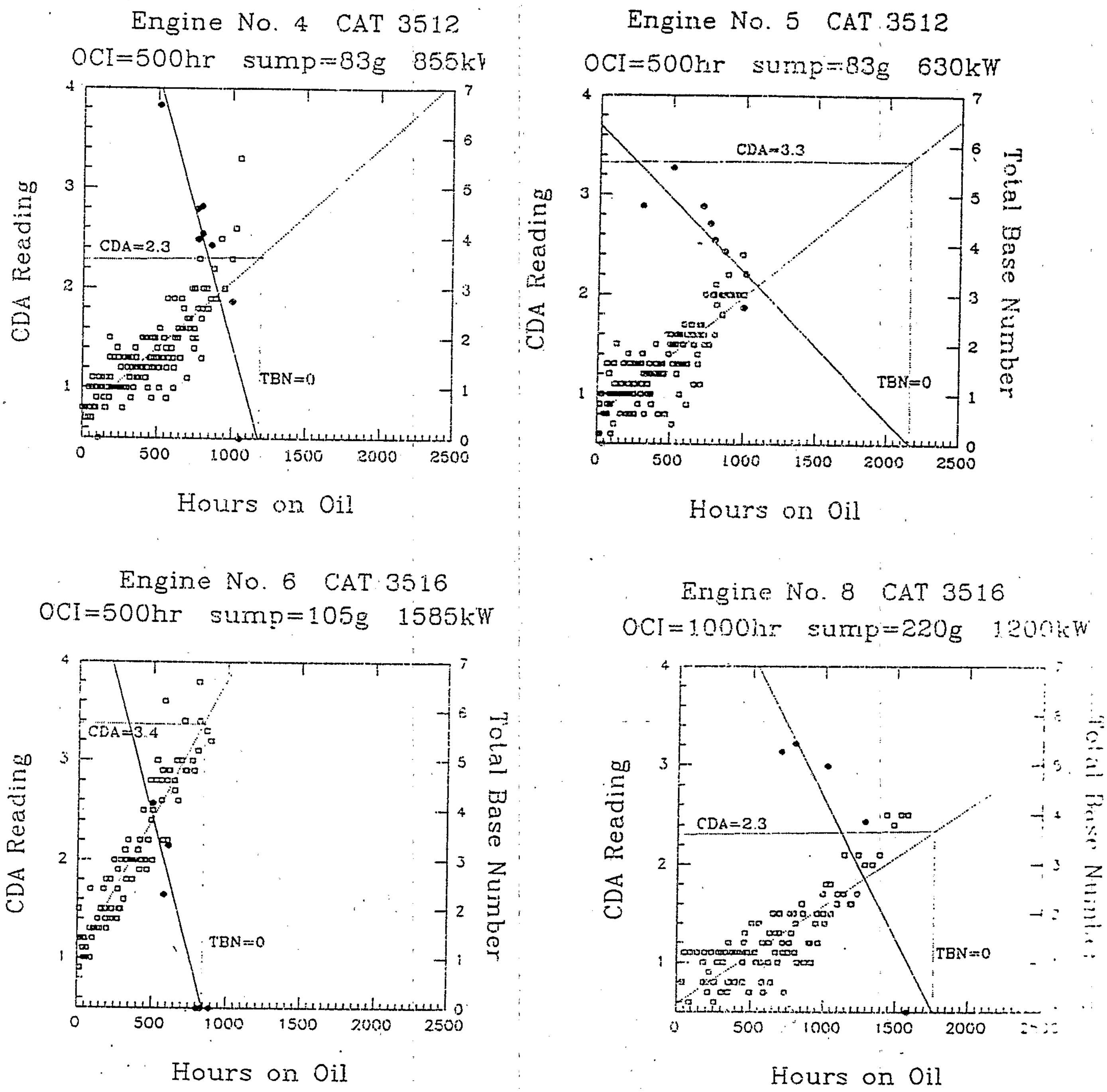
In the engines studied, TBN depletion was the only observed indication of oil degradation. If the oil had a higher initial TBN, eventually other degradation mechanisms may be evident with IR tests. However, the absence of used oil traceable standards for IR analyses leaves precision and accuracy unknown.

For the four engines at Unalaska there were 12 abnormal lab results due to low TBN and two lab tests which recommended to monitor TBN. See Table 4 Engine #6 had five low TBN readings. On three of them there was no by–pass filter due to required work on the engine. The operator had to change injectors, increase kw output, and replace a rear seal. The other two low TBN readings on engine #6 were due to problems in connecting the Power Plus smart tank.

Engine #5 had one abnormal lab result due to normal oil degradation, there were 869 hours on the oil, with the Spinner by–pass filter in place at that time. Due to the low TBN reading the lab recommended the operator increase monitoring for TBN. The TBN reading was from a sample taken directly before the beginning of a top end overhaul of engine #5.

Engine #4 had two abnormal lab results due to a low TBN reading and one lab result recommending the operator to monitor TBN. One low TBN reading was when the Harvard by–pass filter was running and was due to normal oil degradation. There were 831 hours on the oil. The other low TBN reading was from a sample taken when the engine was ready for a major overhaul and some fuel was in the oil sample. The monitor TBN reading was taken when the Gulf Coast filter was running and the engine needed CAP gaskets at the time.

FIGURE 18 – Total Base Numbers and CDA Response Compared to Hours on Oil



"OCI" means oil change interval measured in hours

"sump" means capacity of oil sump in gallons

"kW" means 80% of rated power

Total Base Numbers (Filled Circles) And CDA Response (Hollow Squares) Compared To Hours On Oil.

FIGURE 19 – Quality Control Samples for Total Base Number

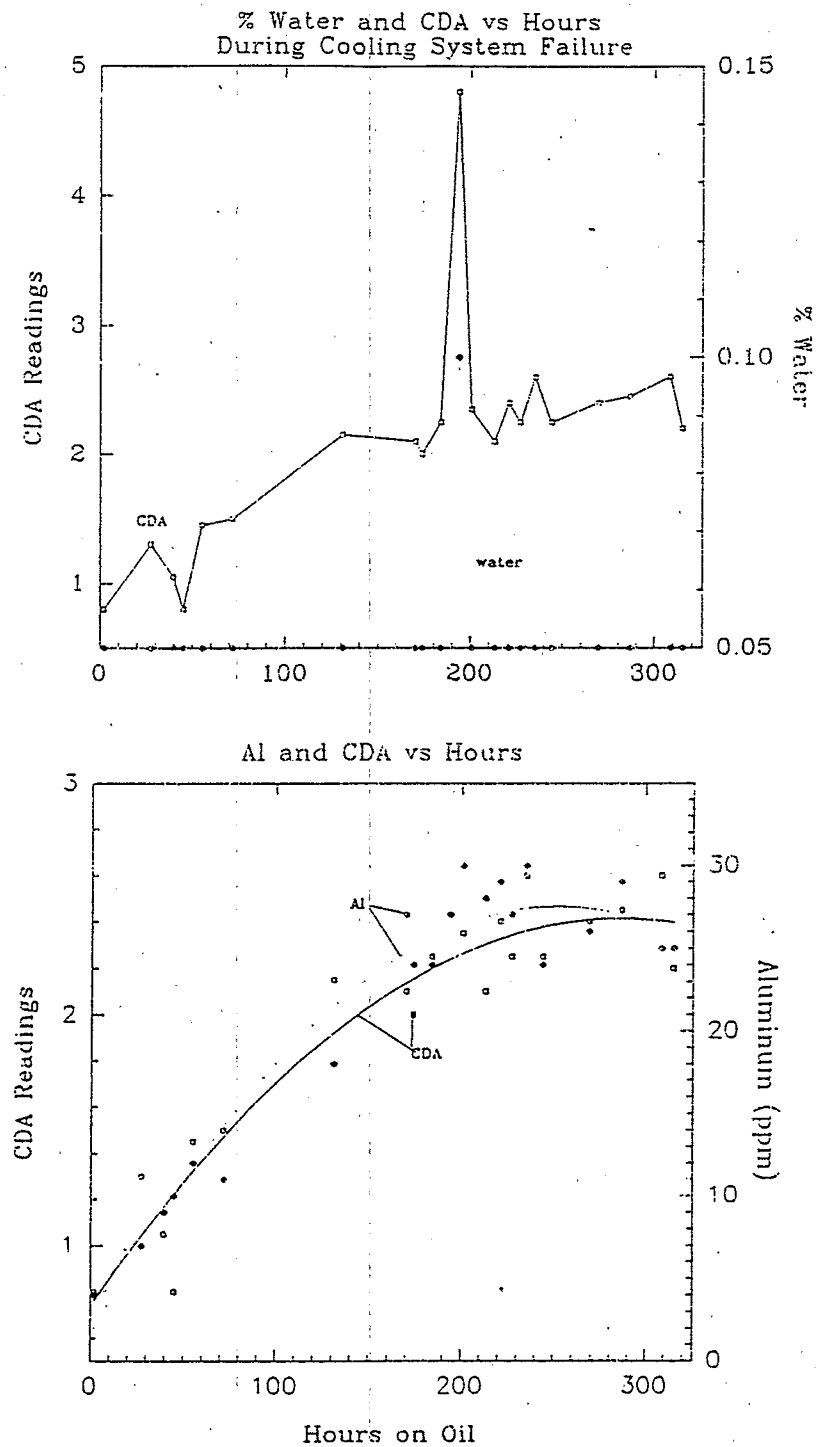
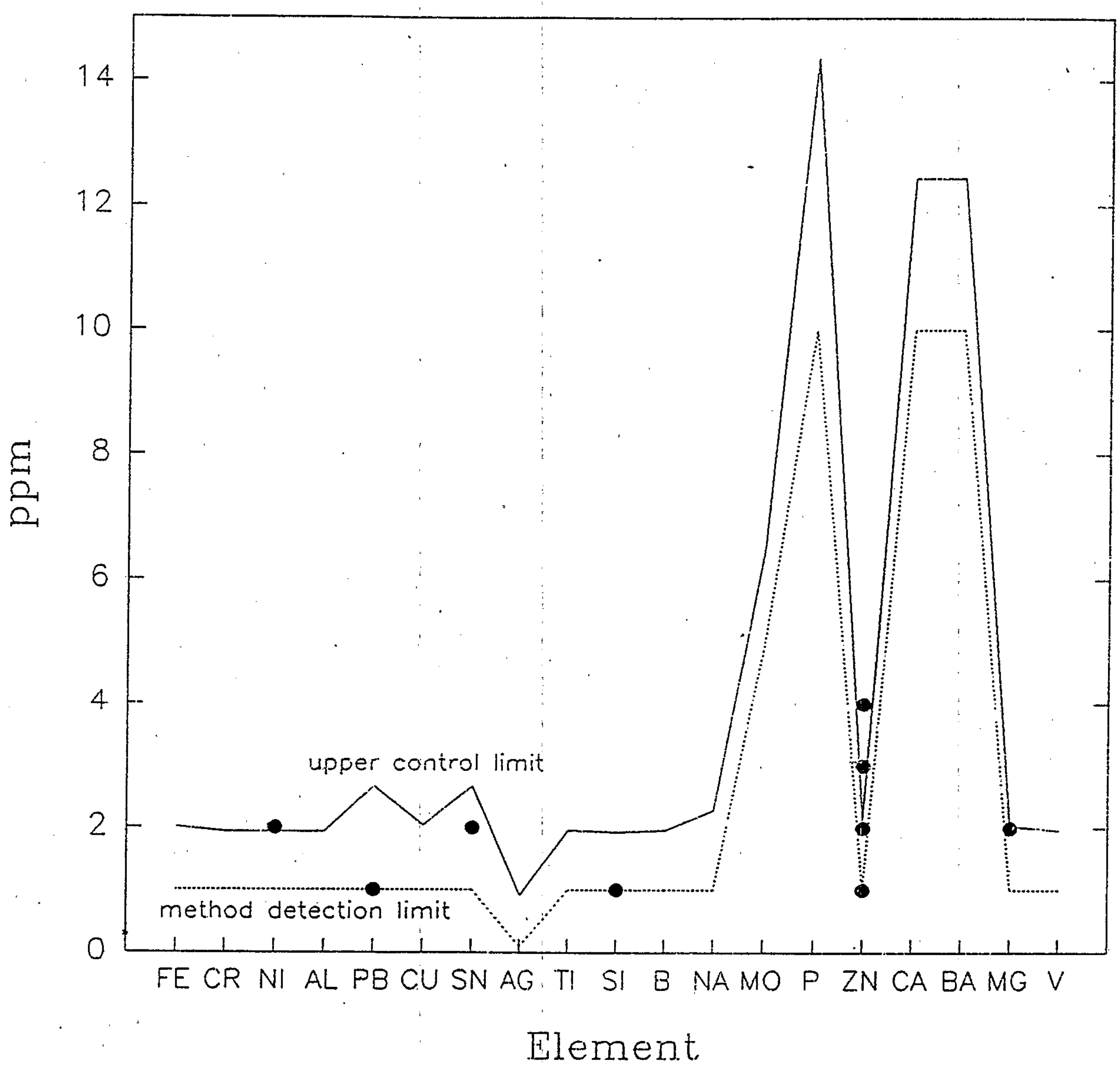


FIGURE 20 – Quality Control Samples for Blanks



Engine #8 had four abnormal lab results due to low TBN readings. The Gulf Coast Filter was running during all four samples. They were all due to normal oil degradation with hours on the oil of 918 hours, 966 hours, 1038 hours, and 1181 hours.

Engine #4 had two high readings of copper, one sample with the Harvard filter running and one sample with the Gulf Coast filter running. Engine #8 had one lab result with a high reading of copper. The Gulf Coast filter was running during that sample.

Other engines studied were not included in these calculations for several reasons. Operators of road equipment volunteered by a federal facility previously changed oil every 100 hours or monthly, whichever came first. Since using the CDA for nearly a year they have yet to change their oil. A privately owned southwest Alaska power plant with 3,000 hp EMD engines never changes their oil because the high oil consumption rate means the "oil always changes itself." Limited use of the CDA confirmed their OCI. In western Alaska, a utility serving the greatest land area of any utility cooperative in the world was unwilling to ignore manufacturers' recommendations for OCI, as was another cooperative utility in southeast Alaska.

ECONOMIC EVALUATION

Source reduction savings were calculated by extrapolating TBN depletion rates to zero and comparing the potential for increased OCIs with manufacturers OCI recommendations. Based on a 5,000 hour per year operational period, the potential source reduction for each engine is tabulated below.

Source Reduction Opportunities

ENGINE NO.	OCI in Hours		ORIGINAL REDUCTION Gallons per Year	% SOURCE REDUCTION
	Initial	Final		
4	500	1,200	830 - 530 = 300 gal.	64
5	500	2,300	830 - 650 = 180 gal.	78
6	500	830	1,050 - 430 = 620 gal.	41
8	1,000	1,750	1,100 - 470 = 630 gal.	43

TABLE 4 – Abnormal Lab Results due to a Low TBN from Unalaska Engines

USED OIL SAMPLE #	ENGINE #	HOURS ON OIL	CDA READING	FILTER
1	6	566	3.0	Control
2	6	576	3.9	Control
3	6	365	3.6	Control
4	6	559	3.4	Control
5	6	422	3.6	Control
6	5	869	2.6	Spinner
7	5	618	2.1	Spinner
8	4	831	2.9	Harvard
9	4	644	2.8	Gulf Coast
10	4	724	3.0	Gulf Coast
11	8	1038	2.6	Gulf Coast
12	8	1181	2.9	Gulf Coast
13	8	918	2.6	Gulf Coast
14	8	966	2.6	Gulf Coast

The row listing the number of samples only includes those samples actually sent to the lab for analysis and not the samples tested by the CDA.

Costs

Operating costs for the facilities in this project were obtained during on–site visits, records kept by AHP, and from the manufacturers of the products.

Costs for the current practice engine operators, following engine manufacturer recommended OCI and disposing of waste oil, include the following: purchase of oil, storage of oil, disposal of oil. If oil is not hazardous, then the disposal cost is $1.00 to 1.25 a gallon. If the oil is contaminated with a hazardous material, it is increasingly more. Cost varies in rural Alaska, depending on location.

Operating costs for disposal of used oil were adjusted to an annual basis and the amount of used oil generated. Labor costs are determined by noting the operator time for maintenance and changing oil and disposal of oil, and energy costs estimated if the operator chooses to burn the used oil in a used oil burner for heat.

Economic Analysis

Critical Measurements

Parameter	Measurement
Condemnation Limit	Concentration, % change, or deviation
Oil Change Interval	Total hours at condemnation limit
Costs	$/hours
Oil Replacement	($/gallon)(gallon/hour)
Filter Elements	($/element)(element/hour)
Used Oil Testing	($/test)(test/hour)
Waste Oil Disposal	($/gallon)(gallongs/hour)

The highest single cost associated with increased oil change intervals may be accelerated engine wear. Shortened engine life not only wastes a resource (the engine) but could increase pollution caused by exhaust emissions. Increased concentrations of wear metals should result in accelerated engine wear. For this reason wear metals should be monitored and oils changed timely to avoid excess wear.

Economic measurements are also needed; for example, equipment purchase, installation, maintenance, testing, oil replacement, and disposal. The table above lists critical measurements as a function of engine operational hours.

Recommended Calculation

Oil life extension economics is a function of lubrication costs. For example, if during a 10,000 hour test control engine oil costs are \$4,000 for purchase (oc) and \$1,000 for disposal (dc) and experimental engine oil costs are \$1,000 for purchase (oX) and \$250 for disposal (dX) plus \$1,500 for testing (t) and \$1,000 for filter installation and replacement (f); then the oil cost ratio would be 0.75 (O).

Because extending the interval between oil changes may affect engine life, a second ratio should be calculated based on wear metals. For example, if 1,500 milligrams of metals were lost from the control engine (xC) and 1,000 milligrams lost from the experimental engine (wX) then the engine wear ratio would be 0.67 (W). This could be interpreted to mean that metal wear on the experimental engine was only 67% of the control engine.

Data reduction uses two ratios. The first ratio compares economics of oil life extension and the second compares wear metals. It is important that the uncertainties are known in each variable. A large uncertainty of one measurement such as disposal costs could outweigh another more precise and accurate measurement like purchasing costs. Therefore, to insure meaningful results of known quality, all the data should be compared for precision and accuracy.

Oil Cost Ratio

The oil cost ratio compares the cost of experimental engine oil replacement, disposal, filtration, and testing to the cost of control engine oil replacement and disposal. A ratio of 1.0 would mean costs are equal for experimental and control. Values less than 1.0 mean the experimental engine cost the corresponding fractional amount less to operate than the control engine.

$$O = \frac{oX + dX + f + t}{oC + dC}$$

O = oil cost ratio

o = oil consumption costs

d = oil disposal costs

f = filter costs

t = testing costs

Oil Consumption Costs

Accurate and full cost accounting is not easy. The cost of oil is only one expense. Other costs are harder to account for: ordering, invoice tracking and payments, shipping, storage, inventory control, and losses of purchased oil. For purposes of this study, we only considered the cost of purchase from operator records.

Oil Disposal Costs

Disposal costs are payments for transport, treatment, and disposal. If used oil is burned on site or re–blended into fuel, then disposal cost will be calculated as a fraction of expected waste oil burner life.

Filter Costs

Initial purchase price, installation (parts and labor), and element replacement are considered filter costs. Costs per hour should use the normal expected engine life span to calculate average costs.

Testing Costs

Payments to the laboratory for wear metals analysis and oil performance are costs of testing. Assume:

- 5,000 hours on engine per year
- Oil change every 200 hours (25 per year)
- 20 gallons of oil per change
- Fuel oil cost $1.25 per gallon (includes shipment to rural village)
- Waste oil disposal cost $0.50 per gallon
- Waste oil back haul cost $0.50 per gallon
- Filtration equipment can cost $1000 to $1500, plus elements at $20.00 each
- Equipment installation can cost between $200.00 and $1,000.00 depending upon complexity and if owner does work
- Lubrisensor cost of $600.00 and lab samples at $16.00 each

Based on the above assumptions, changing oil at recommended intervals would cost $1,125.00 for oil purchase and disposal. This does not include labor or extra disposal or spill fees. Extending the oil change interval with or without filtration would reduce this cost proportionately. Engines in this project extended oil change intervals from 2x to six fold. With a 4x increase in the oil change interval, the annual oil test would be $281.25 with the purchase on a by–pass filter in conjunction with field monitoring and lab analysis. The operator would regain capital cost in 2.5 year pay back period. Using the Power Plus re–blending technology, the operator would use more oil, but would negate disposal fees, element costs and regain capital costs in a 2 year pay back period. The Power Plus sets its own oil change interval and there is no need for labor time to charge or dispose of oil.

Based on a 5,000 hour per year operational period, engines at Unalaska saved over 2,000 gallons per year. One engine at Unalaska along with the engine at Seward eliminated waste oil while using the Power Plus re–blend technology.

SECTION 6

QUALITY ASSURANCE

A Quality Assurance Project Plan (QAPjP) was prepared and approved by the EPA before testing began (Alaska Health Project, 1990). This QAPjP was established according the EPA requirements as a method to verify accuracy and precision (48). The experimental design, field testing procedures, and laboratory analytical procedures are covered. Serial dilutions of traceable elemental standards were prepared by an independent laboratory. Traceable viscosity standards were used as received. The QA objectives outlined in this QAPjP are discussed below.

All measurements, data gathering equipment, and data generation activities were routinely assessed for precision, accuracy, completeness, and detection limits.

SITE TESTING

All on-site testing was independently verified on a centrally located CDA which was calibrated before each test. Because temperature can be a variable in the field, each sample was equilibrated to ambient temperatures 24 hours prior to measurement in a centrally located office. There was no significant difference between the field data and the central verification data, so all field data was used in the calculations and graphs.

Quality control for the Lubrisensor is commercially unavailable, but every used oil sample was independently tested with a centrally located CDA to verify field results. Table 6 shows the relative percentage difference between CDA field readings of used oil samples and CDA readings from the central control location. Out of the hundreds of CDA readings, we randomly chose 10 readings, at least one from each engine from various stages of the project, and calculated the RPD using the precision formula from the QAPjP to find the precision of the CDA field readings. Due to the high precision rating, the field readings were used for data calculations.

LABORATORY TESTING

All analyses were performed as planned except for the following variations. Quality Control lab data is presented as per the JOAP manual so the format differs slightly from that presented in the QA Plan. All Data is included in the appendices and is listed by site and engine.

CDA instrumental precision and accuracy was evaluated using 11 instruments purchased for this study with four concentrations of standards. As a check on instrument stability, field CDA instrument tests were verified with a calibrated central CDA instrument.

Elemental quality control limits for precision and accuracy were calculated using the fluid analysis spectrometer operation manual as described in the Quality Assurance Plan. Completeness, indicated by upper (UCL) and lower control limits (LCL) were calculated for each element at the method detection limit (MDL) and both spike concentrations (9.00 and 90.0 ppm). The low spike concentration was below the MDL for P, Ca, and Ba. Quality control limits for viscosity were adjusted for modifications in the ASTM methods; namely, a decrease of analysis time resulting in an increase of error. Accuracy quality control limits were met 95% of the time for all parameters. Blanks quality control limits were met 73% of the time, which is lower than planned, but still within parameters. Precision was met only 41% of the time. Viscosity checks were within control in 95% of the samples. The results are summarized in the list below and depicted on Figures 19–24.

Quality Control Limits

Parameter	N	% in control
Blanks	11	73
viscosity	19	95
9 ppm control		
accuracy	11	95
precision	11	41
90 ppm control		
accuracy	11	95
precision	11	37

As a check on CDA response stability, traceable standards were prepared for dissolved elements at four concentrations (Figure 25). The standard was a base oil containing soluble forms of 21 elements at 9, 100, 300, 500, and 900 ppm for each metal. For example, the 9 ppm standards contained 189 ppm total of 21 solubilized elements. The CDA was unresponsive to the 9 ppm standard. Standard deviations were calculated as a measure of precision. Because the initial CDA response is not linear, only values above 0.5 were used in further calculations.

FIGURE 21 – Quality Control Samples for Viscosity

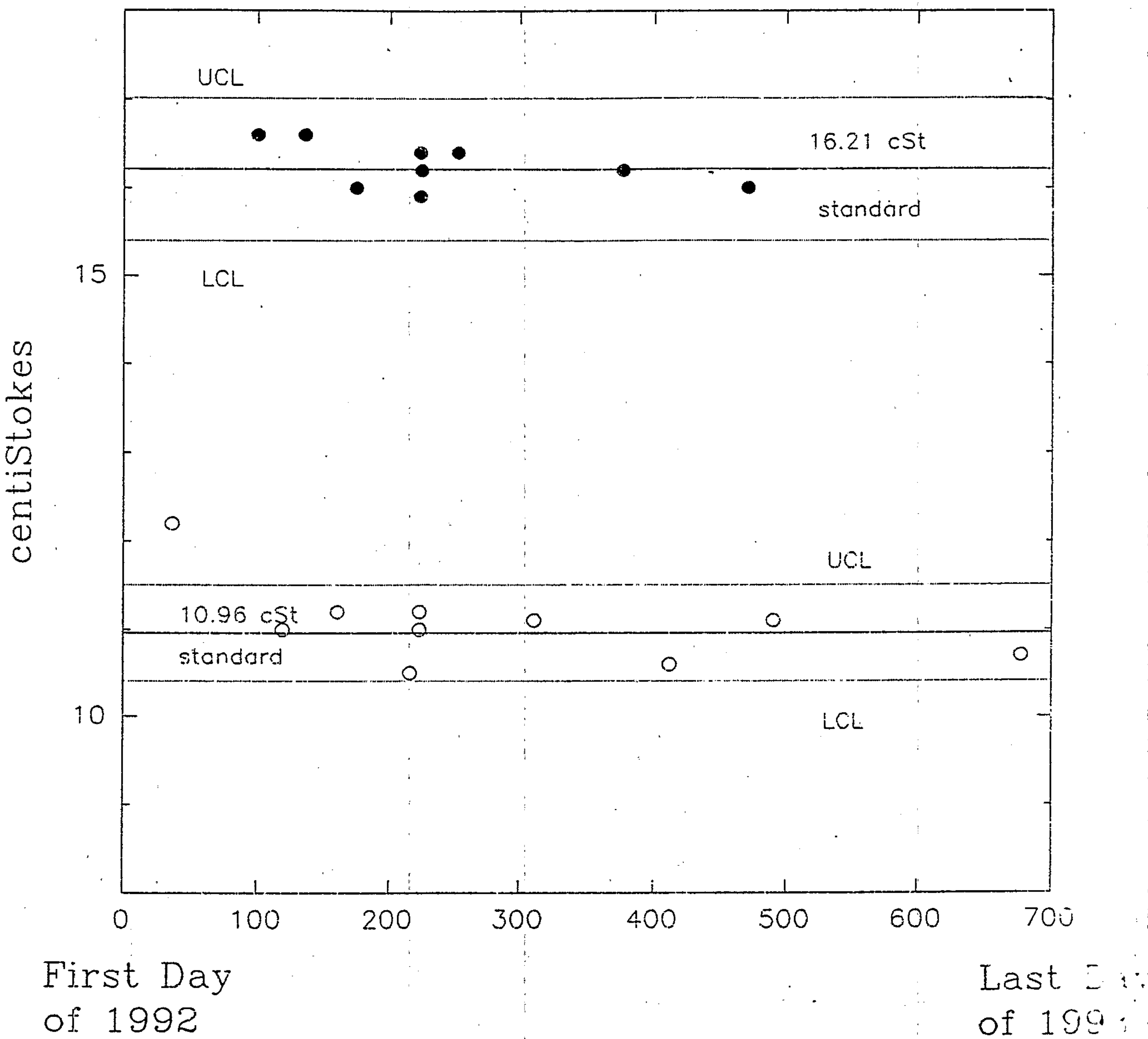


FIGURE 22 – Precision for Quality Control Spikes of 9 ppm

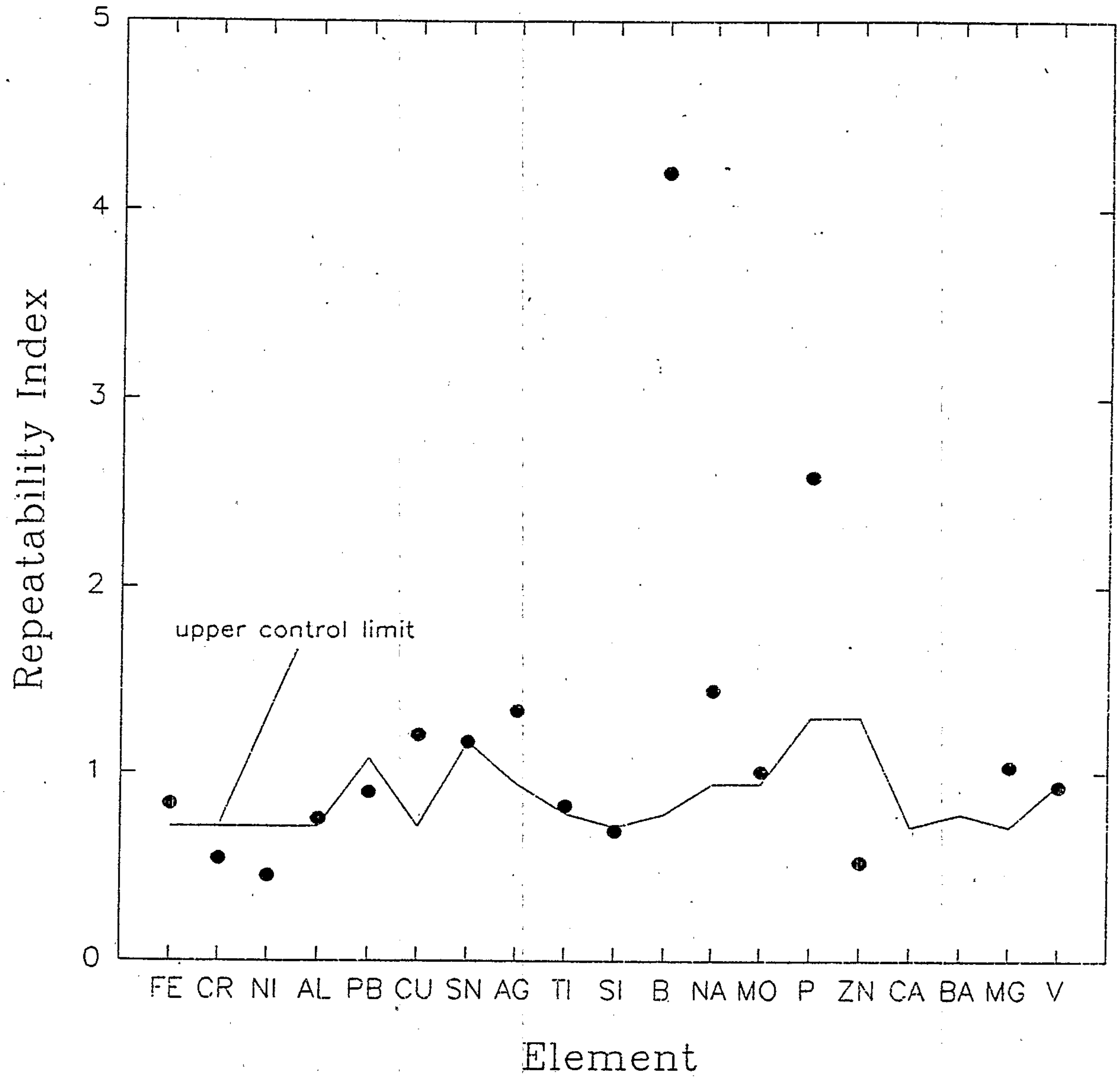


FIGURE 23 – Accuracy for Quality Control Spikes of 9 ppm

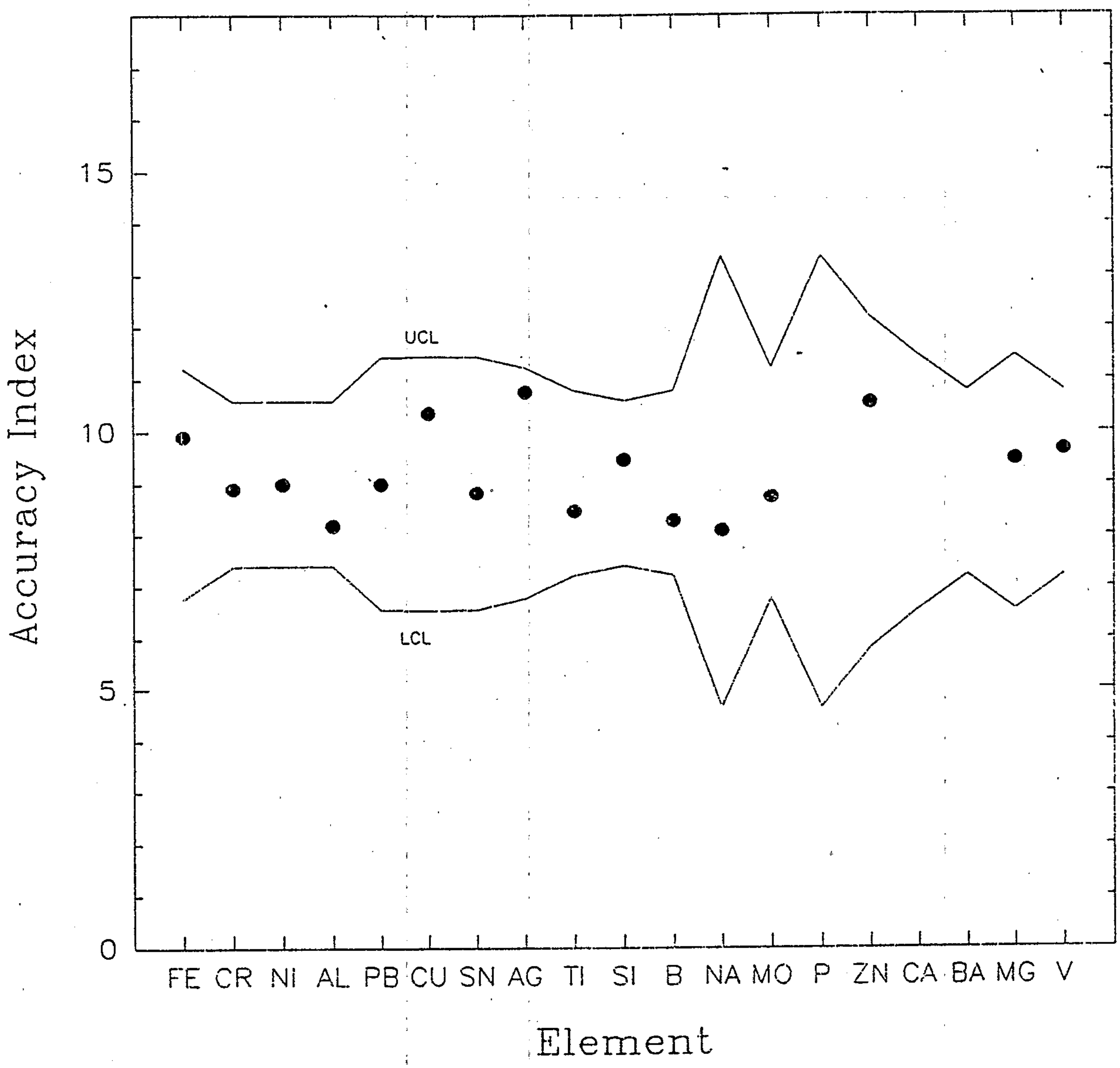


FIGURE 24 – Precision for Quality Control Spikes of 90 ppm

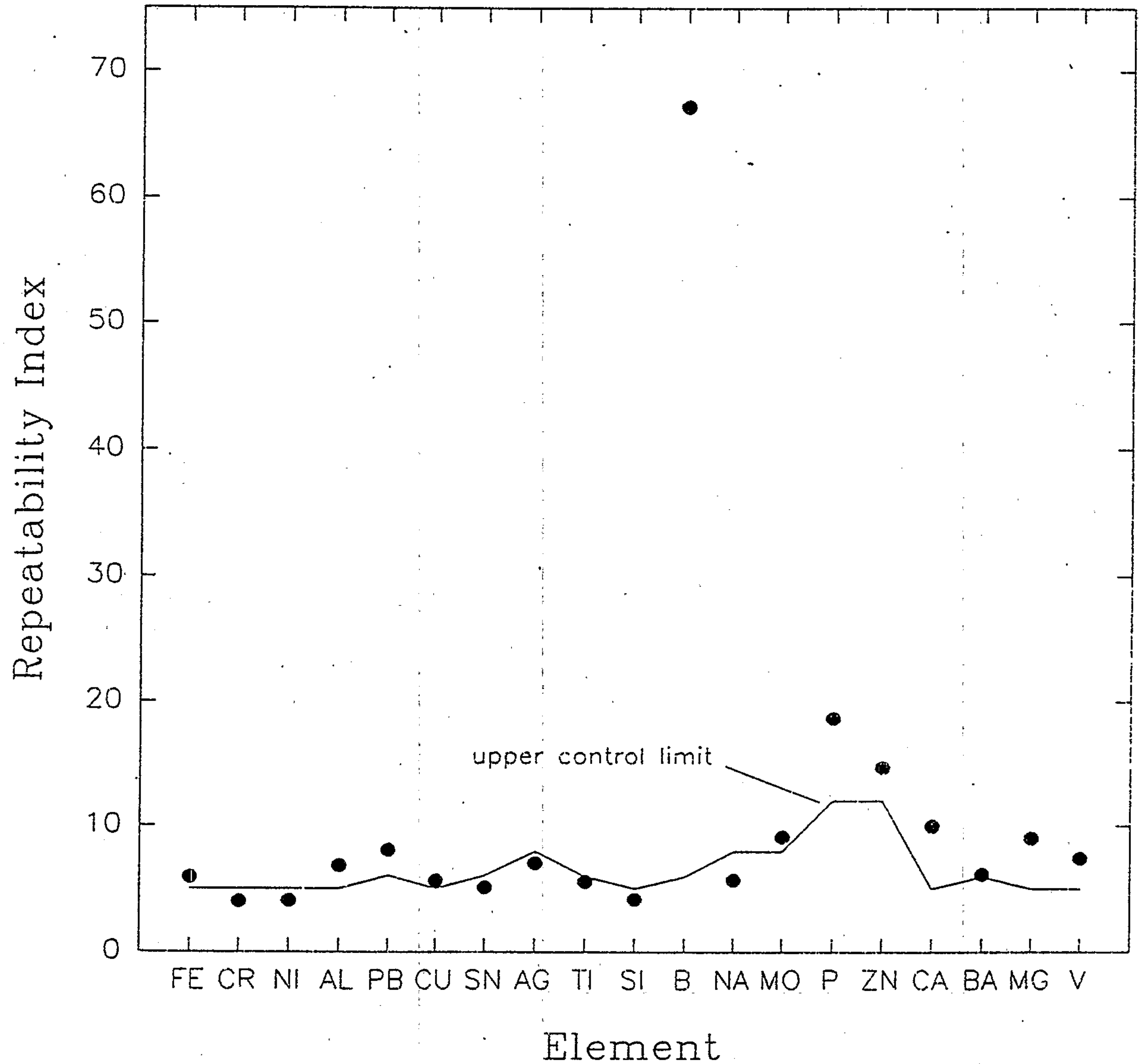


FIGURE 25 – Accuracy for Quality Control Spikes of 90 ppm

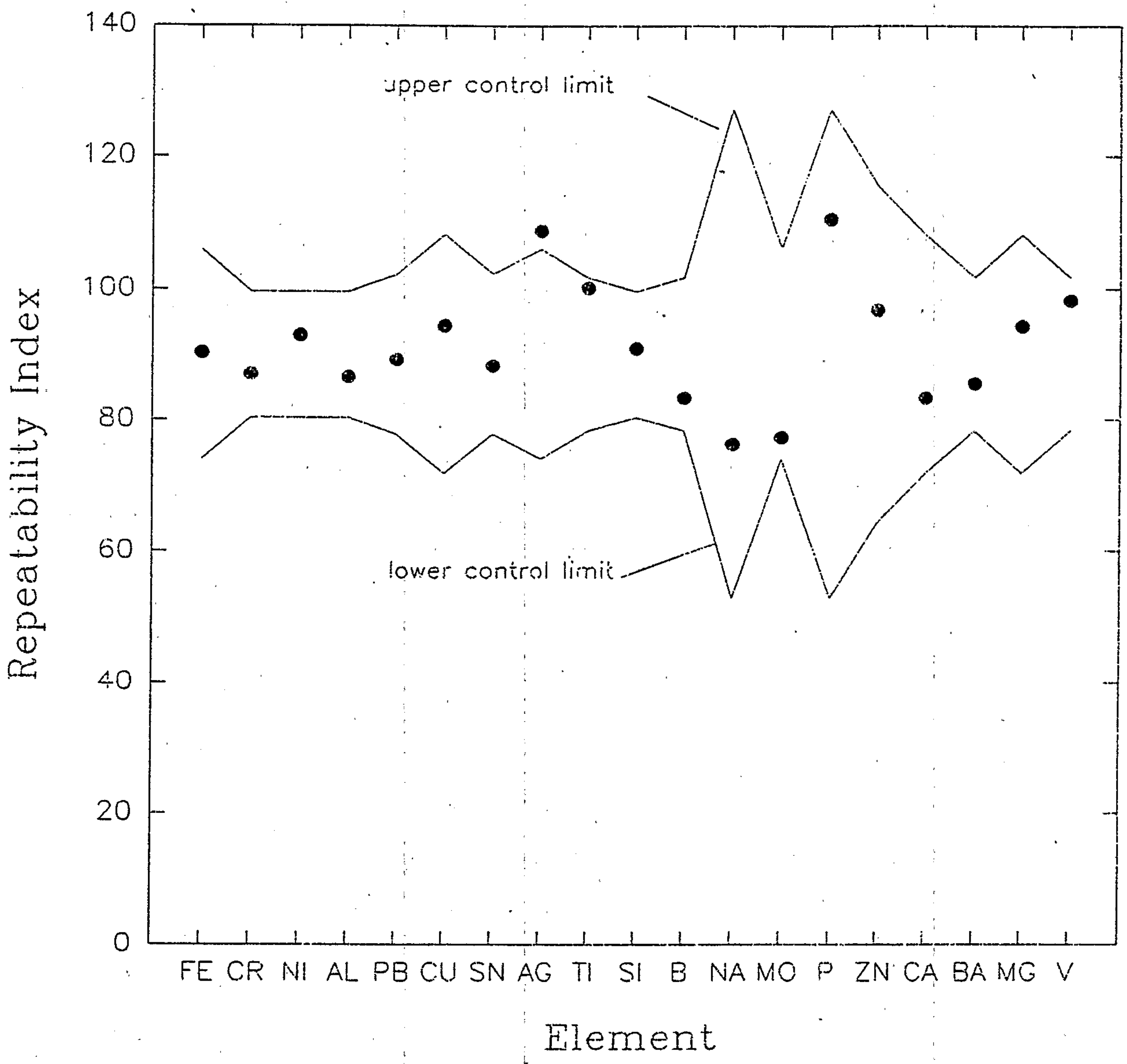
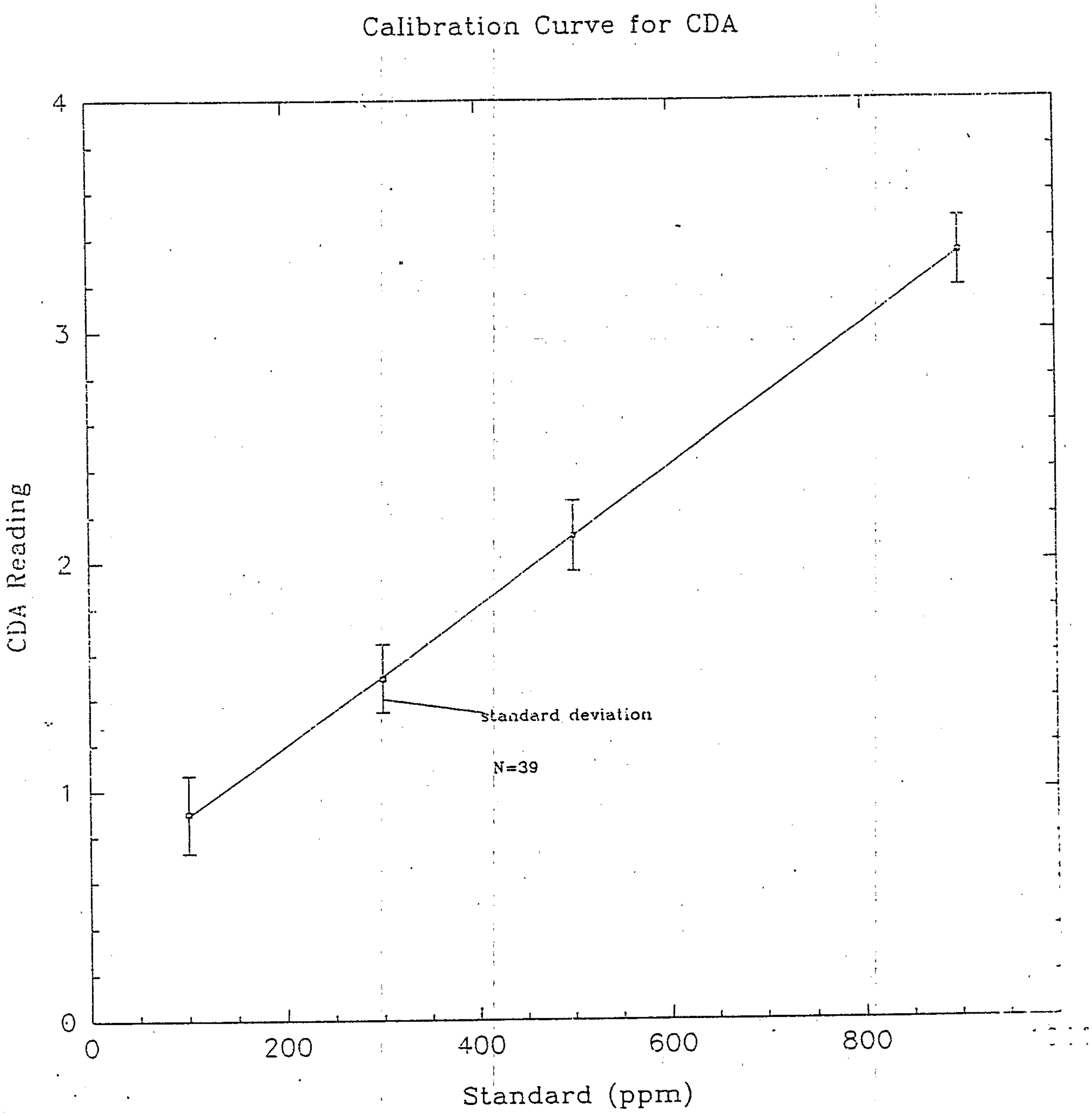
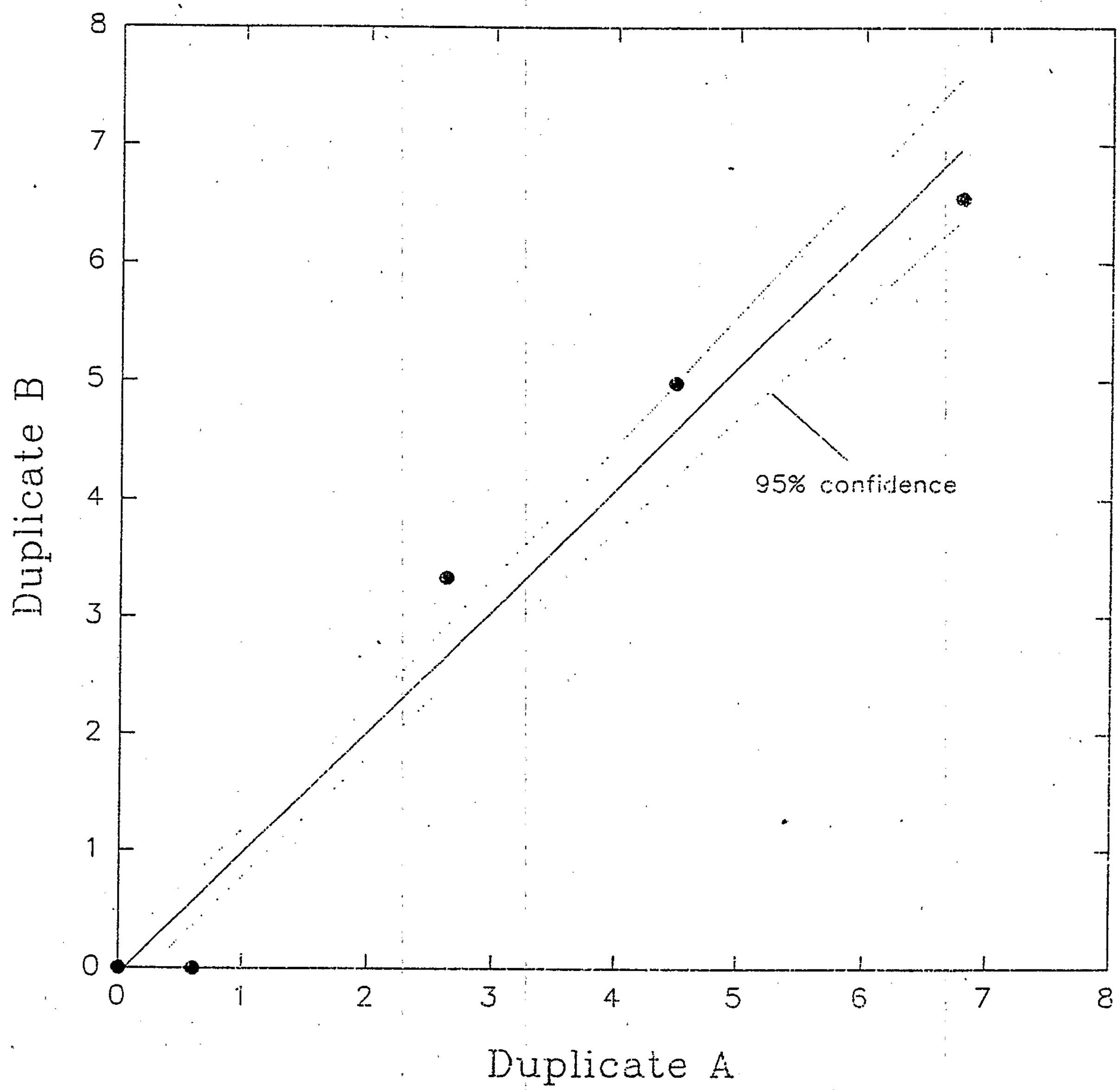


FIGURE 26 – Calibration Curve for Comparative Dielectric Analyzers



Calibration Curve For Comparative Dielectric Analyzers

FIGURE 27 – Quality Control Samples for Total Base Number



TOTAL BASE NUMBER

Critical measurements listed in Table 5 have estimates of precision calculated using relative difference of duplicates by the equation listed below the table. Duplicates prepared for assessing method precision will be analyzed at a frequency of one duplicate every ten samples.

Precise data are reproducible, have low standard deviations, and do not have a large range. Data with low precision may be affected by sampling errors, instrumental variations, contamination, or improper sample storage. Sources of imprecision are found by multiple sample collection and multiple analyses of the same sample. (See Figure 26)

Precision for TBN was assessed by the use of duplicate samples and calculated as described in the QAPjP. As described in the QA Plan, Section 2.1, precision was measured by calculating the relative percent differences (RPD) of duplicate samples. Duplicate samples were described in the QA Plan, Section 8.1. Fourteen duplicate samples were selected to access accuracy of TBN. It was unforeseen that eight of the fourteen duplicate samples would be 0. Due to this we did not accumulate as much data as we desired, but enough to sufficiently calculate the precision of TBN. See TBN Precision Table 5.

There is no commercially available standard for TBN, therefore, we were unable to assess accuracy of TBN. However since the rate of decrease of TBN is what is important, the precision is more important for our test and the RPD formula fulfills our need to determine the precision of rate of decrease of TBN.

As described in the QA Plan, Section 2.2, accuracy was calculated from the analysis of a matrix spike. Accurate data are values close to the "true" value. Because the "real" or "true" value is unknown, accuracy is harder to determine than precision. Errors in accuracy may result from sample collection, matrix interferences, handling, sample preparation, or instruments, to name a few sources. The use of "known" standards and spikes can help determine the data accuracy.

Measurements for accuracy were estimated by calculation of per cent recovery of laboratory matrix spikes by the following equation. % recovery = (100)(SM–M)/S where M is reported value of unspiked matrix, S is known value of spike concentration, and SM is reported value of matrix and spike.

Analyses of matrix spike samples or standard reference materials will be analyzed at a frequency of one matrix for every 20 samples analyzed for each method and sample type.

As described in the QA Plan, Section 2.3, Completeness was reported as the percentage of all measurements whose results are judged to be valid. The goal of completeness for this project was 90% for all measurements.

Completeness is reported as the percentage of all measurements made whose results are judged to be valid. The following formula was used to determine completeness. C=100 (V/T0), where V is number of measurements judged valid, T is total number of measurements, and C is percent completeness. Completeness means a percentage of valid data obtained from a measurement system compared to the amount of data that was

TABLE 5 – Precision Data for Total Base Number

SAMPLE NUMBER	REGULAR SAMPLE A	DUPLICATE SAMPLE A	RPD
1	4.48	4.98	10.57
2	6.78	6.55	3.45
3	2.63	3.33	23.49
4	0.60	0.00	200
5	0.60	0.00	200
6	0.00	0I@0	0
7	0.00	0.00	0
8	0.00	0.00	0
9	0.00	0.00	0
10	0.00	0.00	0
11	0.00	0.00	0
12	0.00	0.00	0
13	0.00	0.00	0
14	0.00	0.00	0
	TOTAL RPD		31.25

Relative Percent Difference (RPD) of TBN Between used Oil Sample and duplicate is calculated using the formula:

Precision = (Regular)-(Duplicate x 100
(Regular + Duplicate

planned to be obtained to achieve a particular statistical level of confidence in the data resulting from the measurement system. Data from critical measurements taken in this project were not used to assess risks to public health and the environment.

DATA INPUT

Results from samples collected at each site were compiled on data sheets and entered into a database. To ensure accuracy, the data was entered twice by two separate individuals. Each data set was cross checked for discrepancies. Entries that differed were cross checked with the original data sheet in which the samples appeared and appropriate corrections were made.

LIMITATIONS AND QUALIFICATIONS

Based on the above QA data, the results of the on–site and laboratory testing can be considered as a valid basis for drawing conclusions about product and source reduction.

Data for economic analysis and for setting oil change intervals were obtained from sites used in this study and the readers must adjust them in their own case.

Critical Measurements

Wear Metal(mg/hr)

- Iron, Chromium, Aluminum, Copper, Lead, Zinc, Nickel, Silver, and Molybdenum
- Oil Consumption(L/hr)
- Filtration Cost($/hr)
- Testing Costs($/hr)
- Disposal Costs ($/hr)

DATA REDUCTION

$$O = \frac{oX + dX + f + t}{oC + dC}$$

O = oil cost ratio

o = oil consumption costs

d = oil disposal costs

f = filter costs

t = testing costs

Filters for 1200 HP engine w. 70 gallon sump capacity

	Housing	Filters	No.	Total Cost ($)
Harvard 1000	420	80	2	1000
Purifiner PR240	685	32	1	717
Gulf Coast	430-530	1	1	1050
Spinner II-200	1535	0	1	1535

Spinner II

Model #	Cost ($)	Sump Capacity, gals
60	354	15-35
100-6	548	15-35
200	1535	25-70
600	2826	100-250

Gulf Coast

Model No.	Cost ($) housing/filter	Filter Vol., (quarts)	Capacity, Horsepower
A-1	278-425	4 - 8	up to 300 HP
B-1	342-526	8 - 16	up to 600 HP
C	110-169	1 - 2	N/A

Harvard

Model No.	Cost, ($) housing/filter	Filter Vol., (quarts)	Sump Capacity, gals
61/71	1/1.5	1.25	
101	286/15	2	3
150	330/36	4	4
251	330/23	6	6
500	383/45	12	10
750	434/53	16	15
1000	476/80	20	35

Purifiner

Model No.	Cost, ($) housing/filter	Filter Vol., (quarts)	Sump Capacity, gals
RP 6(8)	150/10	N/A	(2)
RP 8(12)	289/11	1	2(3)
RP 24	335/14	2	6
RP 40	435/20	3.6	10
RP 60	475/24	5	15
RP 240	685/32	9.5	60

SECTION 7

CONCLUSIONS

This study focused on answering the objectives described in section 1.2. The study finds that:

1. Oil change intervals can be extended beyond engine manufacturer's warranty recommendations without oil degradation. To ensure protecting the engine while extending the oil change interval it is recommended to use field monitoring of oil condition. There is a consistent relation in measuring oil degradation between CDA readings and TBN levels. However, each engine, or group of engines, and situation is unique. Therefore, extensions of OCI dependent on CDA response should be correlated with laboratory analysis for each engine, lubricating oil, and fuel type. The probability of oil decreasing TBN increases between 800 and 2000 hours and at a CDA reading of 3.0 to 6.0 for the engines tested in this study.

2. Oil samples from stationary diesel engines which used by–pass filters showed no less oil contamination than control samples. Other studies have revealed that oil change intervals can be extended when using by–pass filters, but they had no control data. Based on a 5,000 hour per year operational period, one facility studied (Unalaska) saved over 2,000 gallons per year of lubricating oil. The Power Plus used oil blend unit limits oil degradation and eliminates waste oil for stationary diesel engine operators. The Power Plus unit is efficient, effective, and affordable. One engine at Unalaska and the engine at Seward eliminated waste oil using the Power Plus re-blend technology.

3. Small isolated communities can reduce the amount of waste oil they generate. However, the ability to do so is primarily based on operator ability, interest and desire to closely monitor the engine oiling process. This increased attention is needed because degradation levels need to be determined individually for each engine and oil by establishing baseline data.

The study further found no significant health hazard from polynuclear aromatic hydrocarbons (PAHs) in the used oil sampled resulting from oil exchange intervals or burning used oil.

SECTION 8

RECOMMENDATIONS

OPPORTUNITIES

The following are some of the potential opportunities to reduce or eliminate the problem of used oil disposal:

1) Have engine manufacturers extend the recommended oil drain interval in warranties; If engine manufacturers were more flexible in extending recommended oil drain intervals consumers could extend the oil drain interval without risking a violation of the expressed recommendation in the warranty. A two–fold increase in the OCI would reduce the waste oil by 50%.

2) Improve consumer awareness on issues such as: higher oil grade, new certification system, and the ability to extend oil drain intervals without engine wear, ultrafiltration, used oil burners; A recent test by AAMA reported that nearly 50% of the public did not recognize or know the intent of the API certification symbol. If the consumer was made aware of the certification process it may hold the oil marketer more accountable and add to the quality assurance of the oil. By raising awareness, consumers may feel confident in extending oil drain intervals due to a more uniform and predictable quality of oil on the market.

3) Develop a more uniform and predictable quality of oil on the market that meets the growing needs of engine developments; If the assurance of quality on the market is improved, then engine manufacturers may feel safe extending the recommended oil drain interval in the warranties. For this to occur, the quality of oil would have to improve beyond the needs of engine improvements, fuel saving requirements, and clean air emission standards.

4) Improve the pre–market requirements of the oil certification system; An improved certification system, similar to the one currently adopted by AAMA and API, requires additional pre–market testing, tougher license agreements between the certification group and the oil marketer, and improved quality control mechanisms.

5) Strengthen license agreements between oil certifying body and the oil marketer to improve the quality control mechanisms;

6) Improve after market testing of certified oil; improve enforcement of the certification system. Action needs to be taken when an oil marketer places a faulty oil on the market with a certification label. This is a violation of the certification license agreement, the organizations Code of Ethics, and the FTC's Act. Increased enforcement might improve quality assurance and allow engine manufacturers to extend recommended oil drain intervals. The OLAP program never tested 100% of the oils produced, and there was no guarantee that an oil would be tested once it was on the market. Tougher and more extensive post market testing would

encourage oil manufacturers to increase the quality assurance of oil marketed. Funding to cover the increased expense of the post market testing would come from license fees.

7) Improve enforcement of the certification system;

8) Use of filtration, monitoring; and lab analysis; Improved oil filters or advancements in by–pass systems can delay contamination of the oil. A closed–loop process may even eliminate oil changes completely.

9) Use technology for alternatives for used oil disposal.

10) Use alternatives to oil as a lubricant.

11) Burn used oil on site using approved waste oil burners.

12) EPA can regulate used oil as hazardous waste or states can pass laws requiring stations to accept used oil. Any law passed should be enforced. One problem which is occurring in California, from regulating used oil as a hazardous waste is the buildup of oil filters. Landfills can't accept hazardous waste and a market must be found to accept the filters. Currently no federal regulation mandates the crushing and draining of used oil filters before they are placed in a landfill.

13) Curb side pickup or community collection sites. Oregon, France and the Netherlands have extensive programs from curbside pickup to numerous collection sites. It can be funded by a tax on lubricating oil. Rhode Island imposed a product charge of $.20 per gallon and South Carolina and Texas have an $.08 per gallon tax.

14) Public education to encourage the proper disposal of used oil.

15) Offer franchises to transporters of used oil in different regions. In France this has increased proper disposal of used oil tremendously.

16) Require all government agencies to purchase re–refined oil when possible as is done in New Zealand. This is done on 50% of government vehicles in New York and Canada, while our military presently uses a 25% re-refined content oil.

OBSTACLES

The following are several obstacles to the reduction of waste oil:

1) Conservative oil drain intervals recommended by engine manufacturers in warranties; The recommended oil drain intervals are conservative so that the manufacturers can protect their engines from the risk of faulty oil. Consumers must follow these recommendations or risk violating the warranty.

2) Low consumer confidence and awareness of options; Along with the need to comply with engine warranties, consumers are more willing to spend the low price for an oil change than to risk damage to the engine from extended oil drain intervals.

3) Low minimum standard of oil on market; Engine manufacturers must protect against the minimum oil quality on the market to allow themselves a margin of safety since warranty claims can be very costly. (Conversation with Ann Pharo of EMA on July 14, 1992). Engine manufacturers are constantly developing new and more efficient engines to comply with consumer needs, fuel saving engine requirements,

and new clean air emission standards. Engine manufacturers claim that they need to improve engines and oil quality to keep pace with increasing air emission standards, but EPA regulations covering the Clean Air Act do not regulate maintenance of oil or the recommended oil drain interval. EPA certifies the engine warranty requirements for air emissions. EPA is regulating the extension of intervals of maintenance to promote higher quality of products. EPA claims that the oil drain interval is left to the discretion of the engine manufacturer because the protection of engines is too important and costly to be regulated for air emissions. (Conversation with Mike Donaldson of EPA in August, 1992). By the time the minimum standard for the quality of oil on the market is improved, improvements made by engine manufacturers require a higher quality of oil.

4) Low degree of assurance that oil on the market is of the quality it is labeled; It is also difficult for engine manufacturers to extend the recommended oil drain intervals in their warranties because there is a low degree of assurance that oil on the market is of the quality it is labeled. This low assurance of quality is documented by post market testing of engine oils with the API certification label. Tests done by the military and the SAE OLAP program have concluded that up to 20% of the oil on the market is mislabeled.

5) Risks facing engine operator of extending oil life;

Many diesel engine facilities in rural Alaska are the energy source for the village and the cost of an oil change is less than a new engine.

6) Waste oil is not regulated as a hazardous waste unless contaminated;

7) Cross cultural communications; and

8) Advances in the quality assurance of oil is only an assurance, not an improvement in the quality of oil.

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APPENDIX A

There are two types of warranties, expressed and implied. An expressed warranty is the written guarantee of the product expressly stated by the engine manufacturer. The express warranty is extended to the first buyer/owner of the vehicle and can be transferred to a second buyer/owner for a nominal fee. An implied warranty is usually defined by state law. An implied warranty of merchantability is the understanding that the product is reasonably fit for the general purpose for which it was sold. An implied warranty of fitness for a particular purpose is the inherent understanding that the product is suited for the consumers special purposes if the special purposes were specifically disclosed to manufacturer, not merely to the dealer, during the purchase. These implied warranties are limited, to the extent allowed by law, to the time period covered by the written warranties set forth by the manufacturer. Certain changes or modifications made to the vehicle do not, in and of themselves, void the limited warranties.(1) The basic warranty covers cost of all parts and labor needed to repair any item on a vehicle that is defective in material, workmanship or factory preparation. (2) Most limited warranties do not cover costs of normal scheduled maintenance of your vehicle. It doesn't cover costs of lubrication, filters or other normal maintenance parts. The goal of this project is to find solutions to the problem of waste oil. One solution is to extend the life of oil by extending oil drain intervals. If an engine operator extended the oil drain interval of his engine by twofold, then the result would be half of the waste oil to dispose and a decrease in cost. Although this sounds like a simple alternative for car owners and engine operators, it is deterred by the requirements in express warranties of engine companies.

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(1) Such changes could be installation of non-brand parts, components or equipment, modification of the vehicle or its components, or the especial use of special, non-manufacturer, materials or additives. This Basic Warranty only covers vehicle if it is operated and maintained in the manner described in the Owners Manual.

(2) Engine warranties are "limited to defects in workmanship or materials." They expressly state recommendations for which oil to use and the drain interval. The consumer may use other products but it may affect the warranty. If the new product used at the discretion of the consumer was responsible for the damage to the engine then the warranty does not apply. For example, CUMMINS- warranty void if, at the same time as failure, the engine is found to have been modified so as to substantially alter its operating characteristics. (Oil filter is not substantial) International Harvester- If engine failure is caused by use of an untested after-market item, then warranty is VOID. IH dealers sell bypass filters and it changes OCI from 200 hr/6000 miles to 325 hr/10,000 miles. If malfunction occurs as result of alteration or use of non-authorized part, then warranty does not apply. Every new vehicle must meet federal and state emission standards so the warranty covers the cost of repairing or adjusting the vehicle's emission control systems that are defective in detail or workmanship or factory preparation.

A dealer gives a consumer a warranty in consideration for buying a vehicle. There are two types of warranties, written and implied.(3) The purpose of the warranty is to guarantee that the product is of good workmanship, has no defects, and is similar to what was in the mind of the buyer.

The standard warranty covers repairs to any vehicle defect related to materials or workmanship noted during the expressed warranty period. Along with the warranty, each engine company recommends a maintenance schedule which includes a recommended oil drain interval. This indicates how often the engine operator should drain the oil in order to comply with the warranty. Each consumer must use reasonable and necessary maintenance to comply with the warranty.(4) Any damage to the engine caused by a deviation in the recommended oil drain interval is not covered by the warranty.

The simple solution would be for engine companies to extend the recommended oil drain interval in the warranty, but this can only occur if 1) the quality of the engine is improved or 2) the quality of the oil is improved. The engine companies need assurance that the quality of the oil used by operators is sufficient to handle extended oil drain intervals.

A problem facing engine manufacturers is the difficulty in defending an action by a consumer for failure to honor a warranty. When asked to determine if engine damage submitted on warranty claims was due to not following recommended oil change intervals, engine manufacturers have found it very difficult to prove that an oil was used longer that the recommended interval without knowledge of the type of driving to which the engine was subjected or what oil was used.(5)

Prompted by governmental investigations into the ambiguity of warranties being offered to purchasers of automobiles, Congress enacted the Magnuson-Moss Warranty Act, 15 USC 45, in 1975, in an attempt to put manufacturers and consumers on equal footing by requiring warranties to be more understandable. In passing the Act, Congress intended to prevent corporations from using unfair methods of competition in commerce. Federal Trade Comm. v. Klesner, 274 US 145, 47 SCt 557 (1927). The paramount aim is protection of the public from evils likely to result from destruction of competition or restriction of it in substantial degree. FTC v. Raladam Co., 381 US 357, 85 SCt 1498 (1965). In any case, a prerequisite to application of FTC Act is unfair interference with interstate trade and such deception of public as to cause it to buy and pay for something which it is not getting. Ford Motor Co. v. FTC, 120 F2d 175 (1941CA6)

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(3) "Written warranty" is defined as: "(A) any written affirmation of fact or promise made in connection with the sale of a consumer product by a supplier to a buyer which relates to the nature of the material or workmanship and affirms that such material or workmanship is defect free or will meet a specified level of performance over a period of time, or (B) any undertaking in writing in connection with the sale by a supplier of a consumer product to refund, repair, replace, or take other remedial action with respect to such product in the event that such product fails to meet the specifications set forth in the undertaking, which written affirmation, promise, or undertaking becomes part of the basis of the bargain between supplier and a buyer for purposes other than resale of such product." 15 USC 2301(6). The term "implied warranty" is defined "under state law (as modified by sections 108 and 104(a) [15 USC 2308 and 2304(a)] in connection with the sale by a supplier of a consumer product." 15 USC 2301(7).

(4) The term reasonable and necessary maintenance consists of those operations (A) which the consumer reasonably can be expressed to perform or have performed and (B) which are necessary to keep any consumer product performing its intended function and operating at a reasonable level of performance. 15 USC 2301(9)

(5) (Statement by James A. Spearot of General Motors).

The Act comes into play whenever a manufacturer provides a written warranty.(6) If a consumer does not have a written warranty, then they can bring an action for a breach of an implied warranty of merchantability if the goods are not fit for a particular purpose or do not conform to the promises or affirmances of fact made on the container or label, if any. UCCS2-314. Under the Magnuson Moss Act, if the written warranty is extended, then the implied warranty cannot be modified or disclaimed. Also, an implied warranty can only be limited to the duration of the written warranty and such language must appear on the container.

The Act has its own private cause of action for a violation and allows attorney fees for the prevailing plaintiff which increases the ability for consumers to find attorneys who are willing to take the case. The Act does allow a repurchase/refund remedy that must be included in all "full" written warranties, but in cases involving breach of service contract, implied or limited warranties, the measure of damages is same as state law.

The manufacturer may not make representations as to quality or performance characteristics of a product unless representation is true and unless at time or making each such representation, the manufacturer possesses and relies upon competent and reliable scientific tests which substantiate each representation. Re Renuzit Home Products, 99 FTC 291 (1982). Whatever a label says it must be accurate because all contracts contain an implied understanding not to deliver mislabeled goods. UCC S 2-314, comment 10.

Engine manufacturers do not feel comfortable extending recommended oil drain intervals because evidence reveals a low quality assurance of oil and questionable labeling practices on the market.(7) It is deceptive advertising and a violation of 15 USC 45 to alter report on respective qualities of product where report misrepresented quality of tested products as found by testing company. Country Tweeds, Inc. v. FTC, 326 F2d 144 (1964CA2).

Several different legal actions can have a direct or indirect effect on the waste oil dilemma. First, a consumer who buys faulty oil may bring action against the oil marketer for breach of express and implied warranty. The cause of action, or ticket into court, for breach of express warranty is 15 USC 45(a). In this scenario, the American Petroleum Institute (API) certification label on the oil container is an expressed statement to the consumer assuring the quality of the oil. The consumer relies on this statement in purchasing the product and may bring action, but this is unlikely because a consumer would have to buy a large amount of faulty or mislabeled oil to make the action financially worthwhile and it would be expensive to prove that the oil was faulty and directly caused engine damage. If such a suit did occur, it could effect the waste oil dilemma by encouraging oil manufacturers to assure that the quality of the oil is what is expressed on the label. This quality assurance may allow engine manufacturers to extend the recommended oil drain interval in the warranties. An improved quality of oil might reduce the amount of waste oil.

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(6) Under the Act a written warranty is defined in 15 USC 45(1)(A) and (B), infra. The Act's definition of warranty differs from the UCC's definition of express warranties in two ways. First, under the Magnuson Moss Act the express warranty must be in writing and second, it only applies to consumer goods.

(7) In 1992, a former Exxon mechanical engineer pleaded guilty to falsifying tests to obtain Pentagon and private industry approval for additives to Exxon lubricants. The individual knowingly concealed the falsification of oil additive tests submitted to the Army and the Lubricant Review Institute, an oil industry agency that offers advice to the Army on fuels and lubricants. Private companies also customarily purchase lubricants that meet military specifications: Associated Press article by Joseph Neff dated June 5, 1992.

A second possible legal action is in the case of a consumer whose engine failed and who files suit against the engine manufacturer for failure to honor an expressed warranty if the engine manufacturer did not repair or replace the defect. This might occur if the engine manufacturer claims that the warranty is void because the consumer failed to follow proper maintenance guidelines concerning oil drain recommendations in the warranty. To defend these lawsuits the engine manufacturer must prove that the engine failure was a direct cause of faulty oil or improper maintenance by the vehicle owner. Since this can be a difficult and expensive task, these actions usually settle out of court. The result of this type of action on the waste oil dilemma is stringent recommended oil drain intervals by engine manufacturers in order to reduce the costs of warranty claims. Engine manufacturers would also demand a higher quality of oil for use in their engines and more assurance of quality in the certification process. These needs might influence oil manufacturers to produce a higher quality product of oil, which might reduce the amount of waste oil.

A third possible legal action is where an engine manufacturer petitions the Federal Trade Commission (FTC) claiming that oil marketers are in violation of deceptive trade practices in commerce which is prohibited by the FTC Act.(8). Factors FTC considers in determining if a trade practice is unfair are whether it has been considered unlawful, offends public policy established by law, or is within some concept of unfairness, whether it is immoral, unethical, oppressive, or unscrupulous, and whether it causes substantial injury to consumers or competitors. Re Pfizer, Inc., 81 FTC 23 (1972). The violation is valid if the marketed oil is not the quality assured by the certification label on the container. Such an action could pressure oil marketers to raise the quality of oil to the standard on the label. If the quality was improved, engine manufacturers might extend the recommended oil drain interval resulting in a decrease in waste oil.

Engine manufacturers are concerned with oil placed on the market that does not meet certification requirements. The low quality oil is purchased by consumers and used in vehicles. Engine damage often occurs resulting in a warranty claim at the expense of the engine manufacturer. Recent studies by The Society of Automotive Engineers (SAE) and the U.S. Army have concluded that many oils on the market are questionably labeled.(9) The Act applies to both labels and advertisements. FTC v. Kay, 35 Fsd 160 (1929CA7). While labeling and advertising are often considered together, there is good reason to insist on higher degree of truth in labeling statements because consumers may accept labeling statements literally while viewing advertising with more jaundiced eye. Korber Hats, Inc. v. FTC, 311 F2d 328 (1962CA1).

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(8) The commission is hereby empowered and directed to prevent corporations from using unfair methods of competition in or affecting commerce and unfair or deceptive acts or practices in or affecting commerce, which are unlawful. 15 USC 45(a)(2). The terms "unfair methods of competition" and "unfair or deceptive practices" are not limited to specific practices, but take their meaning from facts of each case and impact of particular practice. Pan American World Airways, Inc. v. United States, 371 US 296, 83 SCt 476 (1963).

(9) In 1979 the Army tested the quality of 17 commercial oils and concluded that 11 products failed to meet one or more of the specification's physical/chemical requirements and 6 of the products had insufficient additives. All of the products were advertised to meet the API performance level. SAE initiated the Oil Labeling Assessment Program (OLAP) since 1987. The U.S. Army, in order to get reasonable assurance that oil it purchases actually meets industry standards, sponsored the project and provided funding for the first two years, but funding now is shared by the Army, MVMA, ILMA, and API. The program's objective was to analyze samples of oil on the market nationwide, identify questionably labeled samples, and attempt to resolve problems with quality assurance. Testing has shown as high as 16.5% of the oils sampled were questionably labeled.

A fourth type of action that could effect the waste oil dilemma is where an organization or individual petitioned the FTC to take action against another organization/company that violated the FTC Act. For example, the International Lubricant Manufacturers Association (ILMA) filed a complaint with the FTC against the Motor Vehicle Manufacturers Association (MVMA) claiming that MVMA was violating the FTC Act by requiring consumers to use specific brand name products for oil maintenance in order to comply with the warranty. Since oil maintenance is not covered in warranties, consumers are able to use any product without violating provisions of the warranty. As a result of this action, MVMA agreed not to require the use of brand names in maintenance not covered by the warranty. Engine manufacturers can petition FTC for a waiver of this provision, but such has never occurred. This had little direct effect on the waste oil dilemma, but shows the ability of one organization to take action if another organization is violating the FTC Act.

The FTC has entered into consent agreements alleging violations of the Warranty Act with at least one manufacturer and several dealers.(10)

Trademark Enforcement

The API symbol of certification is a trademark used by oil manufacturers. It represents the standard for minimum quality of oil on the market. It is an expressed statement to consumers that the container of oil has been tested and meets the minimum standard of quality. The current API classification system is voluntary with very few assurances on quality.

MVMA

The Motor Vehicle Manufacturers Association represents most of the large engine and vehicle manufacturers in America. The goal of the organization is to promote the interests of the vehicle manufacture industry in the United States. In 1987 they joined with the Japanese Automotive Manufacturers Association (JAMA) to form the International Lubricant Standardization and Approval Committee (ILSAC) with the purpose of establishing minimum performance standards for engine oil. ILSAC GF-1 was the first standard established for passenger cars and is the basis for the North American Lubricant Standardization and Approval System (NALSAS) proposed by MVMA in 1990. MVMA was not satisfied with the current tripartite system and the quality of the oil that received the API certification symbol. In an attempt to improve the minimum standard of quality for oil on the market and to have a larger voice in the development of engine performance standards, they independently established NALSAS.

(10) Renault U.S.A. incorrectly attempted to limit implied warranties to one year or 12,000 miles, instead of the required two years or 24,000 miles. The FTC required Renault to cease the alleged unlawful practice of a limitation on implied warranty rights and to notify all consumers of the mistake. FTC has entered into consent agreements with several dealers who attempted to disclaim all implies warranties and failed to disclose warranty information before the sale.

MVMA and API broke off talks in early 1990, but in June 1991, under pressure from ILMA(11), an alternative system proposed by CMA(12), MVMA and API reunited to jointly establish a new oil certification system. The new system would integrate some of the NALSAS items into the API "donut" symbol.

API

The American Petroleum Institute represents the interests of oil manufacturers and producers in the United States. API is an inaugural member of the current tripartite system and oversees the certification process. API is also in cooperation with MVMA in developing the new oil certification system in an effort to make product improvements and enhance customer satisfaction.

License Approval Process

The ILSAC Certification Mark, jointly established between MVMA and JAMA, should begin in April 1993. Although MVMA had intended to establish NALSAS, and their own Independent licensing system, it was decided that the ILSAC Certification Symbol will co-exist side by side with a revised API service symbol, which began in 1993. These new systems arose out of engine manufacturers' desires to have a greater voice in development of new engine performance standards. Despite MVMA's success in gaining more influence in the development of new minimum performance standards, API will own, license, and administer both marks and be responsible for monitoring the new licensing system: Under the new proposal, any individual, company, or association can submit a request for new oil performance standard to SAE. SAE will establish a task force consisting of three ILSAC members, three SAE members, and a non-voting liaison from ASTM, API and other technical societies. The new performance standard for the ILSAC Certification Mark must meet all physical, chemical, bench, and engine testing requirements. The API symbol may be placed anywhere on the container, but the ILSAC certification mark must be placed on the front. It is at the discretion of the oil marketer to apply for one or both of the marks. To gain and API license, the oil marketer must submit an application (which includes engine test results and the CMA Product Approval Code of Practice), a technical program data sheet, the license agreement, and a formulation code identification sheet. The license flat fee is $500, a $300 increase, plus an additional $1,000 for every million gallons sold.

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(11) In February of 1991, an attorney for ILMA wrote MVMA ordering MVMA to cease and desist from damaging comments regarding engine oils produced by ILMA members. MVMA claimed that many of these engine oils were low quality and questionably labeled. ILMA claimed that since the engine oils displayed the API symbol that they must conform to API standards. In the letter to MVMA, ILMA stated it would be forced to consider all avenues available to protect its rights if the unsubstantiated claims did not stop.

(12) CMA developed the Product Approval Code of Practice as an alternative system for engine testing and monitoring. MVMA felt that if API adopted the CMA guidelines and continued improvements, then they could abandon in independent NALSAS system.

Appendix B

CERTIFICATION

Since 1911 a system has existed for the automotive and oil industry to classify oils into service and performance categories. Along with performance categories, adequate test methods are established to verify performance of the oil. By certifying oil before it enters the marketplace oil manufacturers can be assured that consumers will select oil due to performance characteristics and type of service for which the oil was intended.

In 1970, SAE, American Petroleum Industry (API) and the American Society for Testing and Materials (ASTM) agreed to form the tripartite system and develop an engine oil performance and classification system that assured the minimum standard quality of oil.

They designed the API "donut seal of approval" which displayed the appropriate API service category, the SAE viscosity grade, and if applicable, energy conserving features of the oil.

The API symbol is a representation by the oil marketer to the purchaser that the product conforms to the applicable standards and speculations for engine oils established by the automotive and oil industries. After several years of dominance by the oil manufacturers in the standards and certification process, the Motor Vehicle Manufacturers Association (MVMA) decided to increase their participation in the process to protect their interests. MVMA believed that there were too many oils marketed in a false or deceptive manner and it was depriving consumers full performance of their vehicles.

In order to gain a larger voice in the oil certification framework, MVMA independently established the North American Lubricant Standardization and Approval System (NALSAS). This alternative system sought to improve test methods and performance criteria so that the minimum standard of oil quality remained on par with changes in equipment design, fuels, maintenance practices and government standards.

MVMA decided to move forward with the NALSAS program, whereas, API questioned the need for a second system and decided to remain with the tripartite system. A chain of events occurred, questioning the quality of oil on the market, that put pressure on API. In response to these events, API met with MVMA to develop a single system. As a result of these meetings, MVMA proposed an alternative to NALSAS and after modification it was approved by the API Lubricants Subcommittee. The final document was released this past summer.

The new system integrates the NALSAS items into the API "donut" symbol to create the SH oil category. API owns, licenses, and administers the new system and is responsible for monitoring and licensing. To gain and API license, the oil marketer must submit an application, a technical program data sheet, the license agreement, and a formulation code identification sheet. The license flat fee is $500, a $300 increase, plus an additional $1,000 for every million gallons sold.
The new oil certification process has improved both its pre-market and post market requirements. The Multiple Test Acceptance Criteria is now used to discover if a given oil meets the minimum performance requirements. The old API process only required a single pass for each oil which meant an oil marketer could retest the oil an infinite number of times and if it passed once, it was certified, but under the new system the mean value of each parameter must be a pass. An oil marketer must also provide a product traceability code and new physical and chemical bench and engine test results. The Chemical Manufacturer's Association (CMA) Code of Practice has also been adopted as part of the certification process.

The Oil Labeling Assessment Program (OLAP) post market test program will continue, but more engine oils will be chosen for audit by an unbiased selection of licensed oils in the field. Any violation could result in temporary or permanent suspension of the license and a recall of oils in the market.

HISTORY OF THE ENGINE SERVICE CLASSIFICATION SYSTEM

In 1911, the Society For Automotive Engineers (SAE) developed the Crankcase Oil Viscosity Classification System. This system, which classified engine oils by viscosity only, remained the only system until 1947 when, in response to interindustry need for consideration of other factors, the American Petroleum Institute (API) adopted a three part system(13). Although an improvement, this early system failed to consider such factors as engine operating conditions, gas or diesel engines, and composition of fuels. Recognizing these inadequacies, the API Lubrication Subcommittee, in cooperation with the American Society for Testing and Materials (ASTM), developed the Engine Service Classification System in 1952(14).

Despite any gains, there remained two major demands on the oil certification process. One was the need for a more effective means to communicate engine oil performance and service classification information to industry, and the other was the desire of the automotive industry for a more flexible system to satisfy its changing warranties, maintenance, service, and lubrication requirements.

In response to these demands, the current tripartite system was created in 1970 when SAE, API, and ASTM agreed to cooperate to develop an engine oil performance and classification system(15). This categorization allowed engine oils to be precisely defined and selected due to performance characteristics and the type of service for which it is intended. In 1970, a ninth class of service was added to reflect the new model vehicles. In conjunction with the new certification system, the tripartite (API, ASTM, and SAE), established a voluntary labeling program based on self certification. It was intended to inform consumers of the quality of the oil they purchased. API designed the symbol to display the appropriate API service category, the SAE viscosity grade, and if applicable, energy conserving features of the oil on the bottle of each oil marketed.

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(13) It designated crankcase oils as Regular Type (mineral oils), Premium Type (oils containing oxidation inhibitors), and Heavy Duty Type (oils containing oxidation inhibitors and additives).

(14) This system, which was revised in 1955 and 1960, separated gasoline and diesel engine performance by classifying service categories (ML, MM, and MS for gas engines: DG, DM, and DS for diesel engines) which provided a basis for selecting crankcase oils.

(15) The new classification system jointly established and designated oils as SA, AP, SC, SD, SE, CA, CB, CC, and CD. It applied to passenger cars, gas and diesel trucks as well as off-highway equipment.

There have only been two major changes in the tripartite system since 1970. First, in 1983 when API established the use of a registered trademark service symbol, and second in 1989 when licenses were required to provide chemical and physical data to certify that engine oils meet licensed performance.

Due to the need for diesel truck services to reduce maintenance costs, down time, and waste oil, SAE began a program in 1973 to develop an oil that could withstand extended drain intervals. SAE concluded that recommended oil drain intervals were largely very conservative and some current oils were capable of extended drain intervals if proper maintenance was followed.

Over the years, performance categories have become obsolete because test methods were no longer available to verify performance. Recent studies have concluded that a substantial percentage of oil on the market is of substandard quality(16).

As a result, the API indicated that too often the API symbol is used to sell inferior products and SAE was requested to take the lead in an aggressive effort to control the use of quality designations. These events were partially responsible for the introduction of the API service trademark symbol in 1983 and the Oil Labeling Assessment Program (OLAP) program in 1985.

The concept for the OLAP was initiated in the API Lubricant Subcommittee in 1979, but budget constraints forced API to discontinue development of the program. The U.S. Army, which funded the first two years of OLAP, initially sponsored the program because of its desire to increase flexibility in purchasing oil which met industry standards rather than only oils which met military specifications(17). The Army hoped the OLAP program would give them reasonable assurance in purchasing commercial oils. Although, in 1982, the Army requested SAE to begin studying OLAP in an attempt to identify questionably labeled oils on the market, the first year of operation was not until 1987. The program's objective was to 1) obtain and analyze a representative sample of engine oils sold in North America, and 2) identify those which have viscosity or additive deviations, and 3) attempt to resolve the problem of questionably labeled products through correspondence with the marketers.

In 1989, API filed a formal complaint with the FTC with regard, to certain automobile warranties that have conditions on the use of automatic transmission fluids identified by brand trade, and corporate names. Requiring the consumer to use a specific brand for a part not covered in the warranty is in violation of the FTC Act, 15 USC 45. The engine manufacturer settled the dispute and now complies with the Act.

Later in 1983, API established the Engine Oil Licensing and Certification System to ensure the quality of products being marketed and to enhance consumer awareness of lubricants for new vehicles.

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(16) A 1977 Ford survey on aftermarket oil provided to API Marketing Committee revealed substantial percentages of substandard quality oil on the market. A 1978 General Motors survey presented to SAE F&L Technical Committee revealed substantial percentages of substandard quality oil on the market. A 1979 U.S. Army survey of commercial engine oils revealed substantial percentages of substandard quality oil on the market. A 1983 API survey presented to SAE F&L Technical Committee revealed substantial percentages of substandard quality oil on the market. A 1983 Industry survey presented by Tom Franklin to the SAE F&L Technical Committee revealed substantial percentages of substandard quality oil on the market.

(17) The two major specification used by the military are MIL-L-2104. "Lubricating Oil, Internal Combustion Engine, Tactical Service," and MIL-L-46152, "Lubricating Oil, Internal Combustion Engine, Administrative Service." The military has their own specifications because using commercial oils from a wide range of products could result in engine problems due to the use of military vehicles in extreme conditions.

In 1987, in response to major shortcomings in the current certification system and the inability of vehicle manufacturers to have a voice in the tripartite framework, MVMA decided to operate within its own framework to develop and alternative system. In 1991, MVMA developed and proposed for comment the North American Lubricant Standardization and Approval System for Passenger Car Engine Oils (NALSAS). This alternative system was based on a responsible minimum standard combined with regular improvements in test methods and performance criteria that insured the standard remained on par with changes in equipment design, fuels, maintenance practices and government standards. MVMA believed that there were too many oils marketed in a false or deceptive manner, depriving consumers full performance of their vehicles(18). Engine manufacturers claimed that the engine failure was caused by faulty oil, but it was difficult and expensive to prove so they settled most warranty claims. Due to this problem, engine manufacturers wanted a stronger voice in the certification system, quality assurance of oil, and a decrease in their warranty claims due to faulty oil.

After MVMA proposed NALSAS, it circulated the document to industry and interested parties for comments. API and oil marketers questioned the need for a second system and attacked NALSAS for attempting to improve the API certification system. Despite complaints from most major oil manufacturers concerning the complexity of two certification systems, the tripartite and NALSAS, MVMA decided to move forward with the NALSAS program. API decided to remain with the tripartite system and not work with MVMA until certain events changed the arena. First, Exxon was caught falsifying data in the oil certification process; then, the military threatened API with suit for faulty oil that displayed the API certification label; and finally the military threatened to replace their military specification requirement for oil purchases with the NALSAS program.

In response to these events, API met with MVMA in early 1991 to discuss engine oil licensing/certification, and the possibility of developing a single system. This was an attempt by API to alleviate MVMA's concerns relating to the current tripartite system without sacrificing its own voice in the structure. As a result of these meetings, MVMA proposed an alternative to NALSAS and after modification, it was approved by the API Lubricants Subcommittee(19).

The International Lubricant Standardization and Approval committee (ILSA) developed a standard to include the performance requirements along with chemical an physical properties of those engine oils that vehicle manufacturers may deem necessary for satisfactory equipment life and performance.

(18) MVMA stated "the marketer of substandard engine oil has been the cause of the problem and has probably been able to avoid any liability because identifying the source of harm is difficult."

(19) On November 15, 1991, an MVMA/API Task Force developed the API Engine Oil Licensing and Certification System (EOLCS) and circulated it for comment. Twenty-six sources filed comments and the Task Force sent responses to each. On March 09, 1992, the Task Force proposed the second draft of EOLCS and circulated it for comment. The final document is now being completed and should be in use by 1994.

HISTORY OF OIL DRAIN INTERVALS

In 1928, the Ford Model A's recommended drain interval was 500 miles. 3 From 1946 to 1967, advances in oil quality resulted in varied oil drain interval recommendations. Not until 1968, when API introduced Service SD, were the oil drain interval recommendations of the four major engine manufacturers similar.

Early on, consensus was that engine wear, control of engine deposits and resistance to oil thickening, limited the ability to extend oil drain intervals for passenger vehicles, but a 30-year study completed in 1976 concluded that technology was available to achieve longer drain intervals than recommended in present automobiles. 20 The increase in OCI's since 1928 were due to the development of superior lubricants. Oil drain intervals do not correlate with improvements in oil quality, but with emission controls. service/design factors, and test updating. As early as 1956, it was known that controlled field tests were the key to understanding the variables involved in extending oil drain intervals, because there are no engine tests to define oil performance in extending drain service.

In 1959, the populace believed that oil was disposable and that frequent oil changes could solve engine wear. For example, in 1961, it became policy that improved engine performance could be obtained by more frequent oil drains of top quality oils. This would assure engine performance and create more of a market for oil manufacturers.

From 1953 to 1963, new additive technology and definition of oil quality through sequence tests contributed to doubling the oil drain interval. Lab tests have led in the field of formulation of high quality motor oils that provide satisfactory lubrication to today's engines in normal or severe service conditions.

The requirements of unleaded fuel in 1975 made it feasible to extend oil drain intervals. In tests done in 1963 and 1976, it was concluded that extended oil life should be base on new additive technology to counteract the increased stress on lubricants and to meet new performance requirements.

Oil viscosity increase may be a significant limitation in extending oil change intervals. Engines today are under more stress from environmental and operational factors. Extending the drain interval is a constructive way to deal with oil conservation, waste oil disposal, and the consumer's desire for less frequent maintenance.

Despite the improved quality assurances in the new API/MVMA oil certification system, engine manufacturers claim that this will not allow them to extend the oil drain interval recommend in the engine warranty because 1) it is only an assurance, not an improvement in the quality of oil, 2) an increase in the manufacture of more fuel efficient vehicles will put more stress on the oil, and 3) the stricter clean air emission guidelines might put more stress on the oil. Although these points raise valid questions, they are not necessarily obstacles to extending

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20 Recommended normal oil drain intervals in 1976 were:

American Motors	5000 miles or 5 months
Chrysler	5000 miles or 5 months
Ford	5000 miles of 5 months
General Motors	7000 miles or 5 months

the life of oil. The new certification system will not only result in a higher percentage of valid Oil in the marketplace, but will improve the quality of oil by requiring extensive oil testing, MTAC methodology , and aftermarket tests. 21

In improving and assuring the quality of oil in the marketplace, the new certification system will help, not hinder, the engine manufactures in meeting the need for more fuel efficient vehicles. The improvement in lubrication would offset any requirement for greater fuel efficiency and allow engine manufacturers to relax an already stringent oil change interval recommendation. The same point can be made for meeting stricter clean air emission guidelines.

The current oil change interval recommendations by engine manufacturers are to short and only allow flexibility due to driving conditions even though there are several factors that affect oil drain requirements. 22 Monitoring the condition of the oil is necessary to protect the engine. Oil should bee changed before the point of contamination. Since drivers can't tell when that point occur, the automobile manufacturers recommend oil change at 1) a certain time or 2) a maximum mileage limit, whichever comes first. The API recommends that motor oil be changed at regular intervals, with a minimum of what is prescribed in the car owners manual. Since driving conditions vary, a driver must pay attention to the severe service recommendation.

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Under this methodology, a normal oil whose performance would pass 98% of the time under the old guidelines would now only pass 90% of the time under the new system. Therefore, the oil manufacturer can improve the margin of error in performance or accept the risk of failing testing and have to pay the expense of reformulating the oil. The result will be significantly better oils in the marketplace.

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Engine design effects oil requirements. Historically manufactures built small engines with high outputs. The increased output was obtained through higher compression ratios which forced the oil to minimize the deposit formulation and made lubrication essential. Lately, due to exhaust controls, unleaded gas has been used which is a lower combustion. Also there is an increase in fuel efficient cars which have smaller engines. These changes have increased the demand on lubricating oils because under the hood temperature is greater. Soot and oxidation can occur when engine is used in cold temperature or city driving. Hot temperature and high speed driving can also cause problems. Driving habits effect oil lubrication and drain intervals. Today people do more stop and go driving and the engine does not get to warm to operating temperature, therefor the oil is easily contaminated. (63% of trips are less than 6 miles) Highway driving is ideal, but if conditions are too hot then oxidation can occur. Today's driving conditions require oils to use additives. A driver must change the oil as recommended, with particular attention to the type of driving conditions that are defined as severe and require more frequent oil changes.