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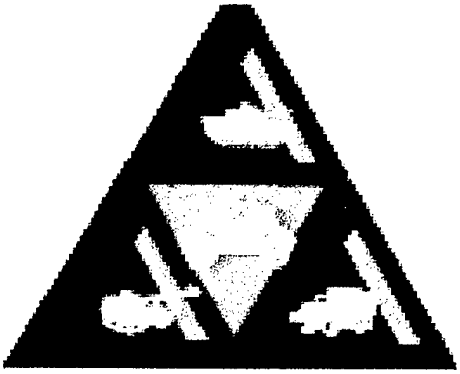

Technical Report

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Market Investigation for Oil Analysis Instruments

May 1999

Corinna Tunac and John Zimmerman

U. S. Army Tank-Automotive Research, Development and Engineering Center
Warren, MI 48397-5000

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(AR 530-1, Operations Security)

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The Army Oil Analysis Program (AOAP) is part of a Department of Defense effort to detect impending equipment component failures and to determine lubricant condition through periodic analytical evaluation of lubricants. AOAP is a mandatory maintenance tool for all aeronautical and selected non-aeronautical equipment in the Army inventory. Portable or on-board condition monitoring would enhance AOAP's capabilities and provide faster results to the user, thereby avoiding critical engine failure. This technology would empower maintenance technicians to determine if their equipment needed repairs or an oil change.

In response to this need, a market investigation was conducted by the Petroleum and Water Quality Technology Team (PWQTT) of Tank-automotive Research, Development and Engineering Center (TARDEC) in Warren, MI. The purpose of the investigation is to determine if there are commercially available portable oil analysis devices that would meet the Army's requirements.

The investigation revealed that there are a number of portable oil analysis devices commercially available. However, a combination of several devices would be necessary in order to satisfy the Army's requirement. The results of the investigation are documented in this report.

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Disclaimer:

This report is provided for information only. It does not serve as an official endorsement for or indictment against any of the instruments mentioned. Every effort has been made to identify manufacturers of portable or vehicle-mounted oil analysis equipment, including posting an announcement in the Commerce Business Daily in April 1999. The report was based upon information provided by instrument suppliers and other sources, including, but not limited to, peer-reviewed literature and conversations with instrument users. References are included wherever possible.

Executive Summary

This report documents the results of market research on oil analysis technologies and equipment. The scope of the project includes both commercially available instruments and developmental technologies. Research was conducted by the Petroleum and Water Quality Technology Team (PWQTT) at U. S. Army Tank-Automotive Research, Development and Engineering Center (TARDEC) in Warren, MI. This evaluation is based on the performance and capabilities of the various devices. Thirty-four companies and forty-four devices were surveyed.

This market research revealed that there are a number of commercially available technologies with the potential to support the Army's requirements. Modifications on a small or large scale would be required to make most devices suitable for military use. Advantages and disadvantages of each instrument as compared to others in the same class are presented.

Section 1 Introduction

OBJECTIVE

The objective of this market survey was to examine both portable and on-line oil analysis technologies either commercially available now or in development. The U.S. Army can use this technology to enhance system operation and reduce maintenance downtime as well as avoid critical engine, transmission or hydraulic system failure.

SCOPE

The scope of this market survey includes the following:

1. Identification of commercial or other sources
2. Collection of data for market research
3. Evaluation of market research data

Section 2 Background

MILITARY REQUIREMENT

Currently, the Army Oil Analysis Program (AOAP) is part of a Department of Defense effort to detect impending equipment component failures and to determine lubricant condition through periodic analytical evaluation of lubricants. AOAP is a mandatory maintenance service for all aeronautical and selected non-aeronautical equipment in the Army inventory. Portable or on-board condition monitoring would enhance AOAP's capabilities and provide faster results to the user, thereby avoiding critical engine or other component failure. This technology would empower maintenance technicians to rapidly determine if their equipment needed repairs or an oil change.

ESSENTIAL CHARACTERISTICS

Oil analysis is a developing field and there is still some disagreement regarding the essential quality parameters (e.g., viscosity, neutralization number, etc.) for Go/No-Go testing of used oil. The PWQTT has tasked Southwest Research Institute-TARDEC Fuel and Lubricants Research Facility to investigate which of the many oil quality parameters are most critical for each component and application. Results of this study should be available by June 1999. These findings will assist the PWQTT to further define which instruments would be the most effective in accomplishing the Army's oil analysis goals.

For this report, the PWQTT evaluated the instruments based on the following characteristics:

Weight: The device should be small enough to be transported by 1 person (maximum 19 kg).

Size: The device should be 1 person portable or, if it is an on-board device, it should be capable of interfacing with military components.

Durability: The device should be durable to withstand rugged handling.

Capabilities: The parameters which the device measures.

Power Requirements: The device should be self-powered if portable or, if it is an on-board mounted device, be compatible with standard military equipment.

Number of Hours of Self-Sustained Operation: The number of hours of continuous operation of the system without maintenance (repairs, calibration, power supply, etc.).

Cost: The cost of the device will be considered in comparing overall system affordability.

Section 3 Study Approach

The study was divided into the three tasks described in Section 1, under Scope. The following paragraphs provide descriptions of the work accomplished under each task.

IDENTIFICATION OF COMMERCIAL SOURCES

The initial process for identifying commercial sources included use of resources such as the Thomas Register, internet searches, and literature such as Society of Automotive Engineers (SAE) or other journal articles and military published reports. Also, a Commerce Business Daily announcement was posted in April 1999 (see Appendix C).

COLLECTION OF DATA

Based on results of the identification phase, companies were contacted and literature of their equipment was requested. Representatives were invited to TACOM to demonstrate the equipment when possible. The market research for oil analysis technology took place from May 1998 to May 1999. Advancements in oil analysis technology are constantly occurring, so exploration and evaluation of new instrumentation is an ongoing process.

EVALUATION OF MARKET RESEARCH DATA

This section evaluates each of the identified devices against the criteria described in Section 2 Essential Characteristics. The results are presented in Table 1 (Commercial/Non-developmental Devices) and Table 2 (Devices under Development). Letters in parentheses indicate abbreviations used in the tables.

The following testing capabilities were used in the evaluation process:

Additive (A): Measures the degradation of the additive package. This is an indicator of the condition of the oil.

Conductivity (C): Conductivity is the ability of a medium to transmit electrical charges. Conductivity generally increases with oxidation, since carboxylic acids form, and then form small amounts of ions with the traces of water inside the bulk liquid.

Coolant Contamination (CC): Measures the amount of glycol or antifreeze in the oil. Coolant found in used oil may indicate a leaking cooling system.

Dielectric Constant (DC): Measures the ability of the oil to separate electric charges. By determining the dielectric constant of a used oil and comparing it to that of a new oil of the same type, operators can infer any of several oil quality parameters, including: 1) presence of fuel soot, sludge, dirt, oxidation products, or acid, 2) presence of water, antifreeze or metal particles, and 3) gasoline or fuel dilution. It should be kept in mind that the actual parameters are only inferred from the actual measurement of dielectric constant.[1, 2]

Fuel Dilution (FD): Measures the amount of fuel in the engine oil. Fuel dilution of oil reduces the effectiveness of the lubricant. As the fuel thins the lubricant, the viscosity decreases and allows increased wear which may cause overheating. Some causes of fuel dilution include leaking injectors or fuel pumps/lines, worn liners/rings, and incomplete combustion.

Impedance (I): A combined measure of permittivity and resistivity, or the rate of charge, (effective capacitance) over applied potential across two plates separated by a quantity of oil.

Particulate (P): Measures the size and concentration of particulate matter in used oil. Methods include laser blockage, laser scattering, pore blockage, and visible light blockage. Particle counting is also needed in conjunction with wear metal analysis because it detects the nonmetallic matter that is indicative of wear or deterioration of synthetic friction material on disks in transmissions and brakes. Larger particles are worn off of other rotating components with insufficient clearance and/or lubrication.

Soot (S) : Measures the amount of fuel soot in diesel engine oils. This gives an indication of the combustion efficiency of an engine. It will determine if air to fuel ratios are incorrect or if other abnormalities exist. Excessive levels of soot can cause increased exhaust emissions, increased viscosity, restricted oil flow, clogged filters, oxidation, and loss of power or performance.

TAN/TBN (T) : Total Acid Number (TAN) is a measure of the total amount of acid products in the lubricant. A high TAN indicates oil degradation. Total Base Number (TBN) measures the alkalinity present in the oil. TBN is a measure of the ability to neutralize corrosive acids formed during operation. A drop in TBN may indicate oil degradation.

Viscosity (V) : Measures the lubricant's internal resistance to flow. Changes in viscosity may indicate degree of aging, by-product contamination, fuel dilution, possibility of mixed products, and other abnormalities. As viscosity increases, it becomes harder to pump the oil resulting, in extreme cases, in the failure to reach critical lubrication points. If the oil becomes too thin and viscosity decreases, its ability to lubricate by separating metal surfaces decreases, resulting in boundary lubrication and subsequent wear.

Water Contamination (WC) : Measures the amount of water found in the engine oil. Water gets in through blow-by into the crankcase, especially during short trips in cold weather, and condensation that occurs during the night as temperatures drop.

Wear Metals (WM) : Measures the amount of ferrous and non-ferrous particles in used oil. The type of wear, such as sliding, cutting or spalling indicates the type of problem. The type of material of the particle may indicate the location of the failure. The limits used in AOAP are found in the Joint Oil Analysis Program (JOAP) manual (TM 38-301-

4). Wear metals are currently identified using atomic emission spectroscopy and ferrography.

Section 4 Discussion of Results

The results of the market research indicate that there is currently not a device that would measure all parameters required by AOAP. Most of the instruments measure one particular parameter (e.g., viscosity, water contamination, fuel dilution, additive depletion).

A summary of the instruments is shown in Table 1 and is based on the characteristics defined in Section 2. Nearly all of the instruments surveyed were capable of being mounted on-board the vehicle or were portable/hand-held. Several small bench-top devices are mentioned, but some of them may be converted for portability. Some instruments require a reference or standard oil to compare to the used oil for analysis.

On-Board Mounted Devices

Delphi's INTELLEK is an on-line sensor that measures conductivity, temperature and oil level (optional). From changes in conductivity, one can infer additive depletion, changes in TAN and viscosity and water and coolant contamination. The device is mounted in the oil pan. Results are sent electronically to the automobile's computer.[3]

Foster-Miller's Oil Condition Monitor is an on-board FTIR spectrometer. Development of the device was funded by the Air Force as part of Phase I and II of a SBIR project. Tests have been conducted at Wright-Patterson Air Force Base, Ohio, but the report has not been completed. The device utilizes the miniature FTIR spectrometer to test for several oil quality parameters, such as water, glycol, soot contamination and lubricant oxidation, nitration and sulfation.[4]

GasTOPS' particle analyzer, Oil Debris Monitor (ODM)[5], is an on-board mounted device. The size, number and type (ferromagnetic or nonferromagnetic) of the particles are characterized through the use of magnetic coils surrounding the flow-through chamber. The ODM is commercially available and is used on stationary gas turbine engines used in power generation. It has also been tested on the AH-64 helicopter, but the Army has not received the report of the results. Data can be downloaded to a PC for analysis. GasTOPS is working on developing a similar model with a small sensor that would send signals to a digital display screen on the system's display panel.[6] A smaller, less sophisticated version of the ODM, called the MetalSCAN, is in development now and may be suitable for on-line use in aviation and ground equipment in the future.

LucasVarity 's On Line Oil Viscosity Sensor measures viscosity using a vibrating piezoceramic element. This device is not commercially available at this time. However, at the time the SAE paper was published, the device was being evaluated by vehicle manufacturers.[7]

Voelker Sensors' On-Board Sensor measures changes in conductivity of a polymeric matrix immersed in used oil, relative to a base oil. From the change in conductivity, the oil degradation or water and coolant contamination can be inferred. This device is not yet commercially available, and the company cannot be reached for further information.[8,9]

Portable Devices

Additives

Fluitec's Remaining Useful Life Evaluation Routine (RULER) is a small lightweight device that examines the additive package of the oil and determines whether degradation is occurring. Measurements are made by first adding a used oil sample to a vial of solvent, then taking a reading. This results in a number that represents the anti-oxidant additive remaining in the oil. A base oil is required for comparison, and the readings are valuable only after taking samples at regular intervals, plotting the results, and then making an estimate of the "remaining useful life" of the oil. Software to be used on a PC can be purchased with the device to facilitate this analysis.[10, 11]

Conductivity

NAECO's COBRA (Complete Oil Breakdown Analyzer) measures the oxidation condition of the used oil with an electrochemical method.[12] It can detect and trend thermal degradation of these oils, thus indicating potential problems. The COBRA has been used and recommended by the U.S. Air Force,[13, 14, 15] but its inability to detect contamination and other degradation problems which do not change the oil's conductivity has been acknowledged.[16]

Dielectric Constant

Computational Systems, Inc.'s (CSI) Oil View Analyzer 5100 is a small bench-top unit which measures the dielectric constant of used oil. A reference oil is needed in order to infer the level of fuel dilution, coolant and water contamination and general contamination. This device has an option of single or double sensors. The double sensor enables simultaneous testing of two samples.[17]

Northern Technologies' Lubri-Sensor is used to measure dielectric constant of engine oils. According to military reports, the device is easy to use and requires no special training. The Lubri-Sensor measures the total effect of oxidation and contamination on the dielectric constant of the oil. The used sample is analyzed then compared to a new (reference) sample. The deviation of the results indicates the condition of the used oil. This device is currently used by the Army National Guard with favorable reviews.[18, 19]

Spectro's BenchMark measures dielectric constant, from which fuel dilution, coolant and water contamination and general contamination levels can be inferred. The device is small enough to fit in a briefcase and weighs only 0.9 kilograms. According to the brochure it is easy to operate and requires no special training.[20] JOAP TSC tested the device for Army use and had limited success.[21]

Fuel Dilution

Microsensor Systems, Inc.'s (MSI) Fuel Dilution Meter was developed in part by the U. S. Naval Sea Systems Command's (NAVSEA) Carderock Division of Naval Surface Warfare Center. It is not a hand-held device, but a small bench-top unit. It uses surface acoustic wave (SAW) technology to make the measurement. Hydrocarbon vapors are preferentially sorbed to the SAW chip. Waves propagated through the chip are then changed in proportion to the amount sorbed. The cost listed in Table 1 includes accessories and consumables necessary to operate it for a full year. It is used by the Navy aboard many of their ships.[22, 23, 24]

Top Source's Motor Check On-Site Analyzer uses FTIR to measure fuel dilution. Coolant contamination, soot, viscosity, TBN, and water contamination are also measured by this method. General Motors, Chrysler, Ford, Harley-Davidson and Hyundai report using this device. One journal article has given it a favorable review.[25] Wear metals are also measured which is described in more detail in the Wear Metal Analyzers section.[26]

Impedance

Predict DLI's Navigator is a small battery operated device that uses impedance spectroscopy to identify shifts in oil characteristics. It measures both conductivity and permittivity at four unique frequencies to detect water, wear metals and oxidation. Water is detected by a shift in conductivity at low frequencies. Wear metals are detected by high frequency changes in permittivity. Oxidation is measured at both high and low frequencies. A small sample size of 10-15 mL is required for analysis, and no solvents are needed. Absolute concentrations are not obtained from the instrument, so trending with reference to a base oil is required.[27]

Particle Analyzers

Analex's PQP Portable Ferrous Debris Monitor uses a dual-coil magnet to measure the amount of ferrous debris in oil samples. About the size of a small briefcase, the unit is powered by a battery. Caterpillar is a current user and has given it a favorable review. Data is downloadable to a PC. An advantage of the PQP is that it can detect particles over a wider size range than atomic emission spectroscopy (AES).[28]

CSI's Oil View Particle Counter uses light blockage to measure particle count. This device measures 6 classes of particle sizes, from 2 μm to 100 μm. It can be used to measure hydraulic and turbine lubricants. Data is downloadable to a PC. Compressed air from the facility or a CO_2 cartridge is required for operation. [29]

Entek IRD's Digital CONTAM-ALERT uses the pore blockage principle to perform particle sizing and counting. Used oil is passed through a very small filter with standard size pores. As particles begin to block the pores, the flow properties of the oil change. The change is recorded and correlated to number and size of particles. With an attachment, the unit can be turned on to trap ferrous debris, thus enabling differentiation of ferrous from non-ferrous debris. The unit is small and easily portable. The cost for a kit includes a case, air pump, interface cable and Portable Condition Monitor (PCM- the

output/user interface device). Data can be downloaded to a computer for entry into a database. One customer reported that the pore blockage method always reports less contamination than actually present. A JOAP report did state that the device could be used in place of the Navy's patch test and the particle counting done in the Air Force with the HIAC/ROYCO particle counter. The report recommended further testing.[30]

Fluid Systems Partners' Portable Oil Diagnostic System (PODS) uses the method of light blockage for particle counting. This device has a carry handle and shoulder strap for portability. Data can be downloaded to a computer for entry into a database. A choice of bottle sampling or online sampling is available. The memory can store about 500 samples. Viscosity can also be measured with this device.[31]

Naval Research Lab's LASERNET is an instrument for particle counting using laser technology. It has been tested on the T700 engine in a test cell, and results showed its ability to detect failure debris with a very low false alarm rate. Inasmuch as the instrument is mounted on the vehicle, very little training for vehicle operators would be required, though more trained technicians would be needed for installation and service. Data would be displayed for vehicle operators, and it would be possible to download it to a PC as well.[32,33]

PAMAS's Portable Particle Field Monitor uses light blockage to detect and count particles. Sensors for particles from 2.0 μm to 450 μm are available. Memory holds up to 550 measurements. Vendor reports that the U. S. Navy has investigated the device.[34]

Parker's PLC 3000 is described in the Viscosity section. This device can be used for particle counting and viscosity measurement.[35]

Spectrex's Particle Counter counts and measures the size of particles in an oil sample by "near angle light scatter". This technology consists of a laser beam that passes through the sample. Light deflected off suspended particles is tabulated and the size and amount of the particles is recorded in the computer. This device operates off of 115 VAC power.[36]

UCC's CM20 series particle counters are used extensively by the British military to detect contamination in hydraulic systems. The extent of usage indicates that they are generally very pleased with product performance. Analysis can be performed either on-line or using sample bottles. A shoulder strap facilitates transport of the device.[37]

Soot

Wilks' Infracal Soot Meter measures the amount of soot in diesel engine oils. The presence of soot can lead to increased viscosity and wear, and therefore gives an indication of engine oil health. The Soot Meter uses infrared spectroscopy to give a percent soot reading. The meter is small and can be operated on 12V battery or on 110 VAC power. Testing by Mobil and Texaco has resulted in favorable reviews of the instrument.[38,39]

TAN/TBN

Dexsil's Titra-Lube TAN/TBN test kits come in a small box that contain premeasured standardized reagents and additional disposable lab equipment to measure TAN and TBN in used oil. These tests are easy, quick (less than 5 minutes per test) and safe, with little clean up needed, making it convenient to use in the field. Reactions are carried out in the aqueous phase, so lubricant color does not interfere with results.[40]

Gerin's TAN/TBN Test Kit measures TAN and TBN for diesel, gasoline and turbine engine lubricants. Each kit can perform up to 25 tests. The kits are small, rugged and simple to use, however, some glassware is required.[41]

Kittiwake's Oil Test Centre (OTC) can be used to measure both TAN and TBN. TAN is measured colorimetrically as the used oil is combined with two different reagents. TBN is measured by comparing the resulting pressure when combining a standard reagent with a used oil versus a new base oil. The OTC has been used by the British and Canadian militaries and has received positive reviews.[42, 43]

Microsensor Systems Inc.'s (MSI) TBN Meter is a small bench-top unit. Two bottles of reagents and a sample holder are also required. The test is performed by adding a reagent to the sample, which reacts to form CO_2. Within the meter is a pressure transducer which measures the rise in pressure and correlates that to TBN. Cost for the meter includes supplies needed to operate it for a full year. The test looks only at total residual carbonate base. It is used extensively throughout the Navy.[44, 45, 46]

Royal Lubricants' Mini-TAN Test Kit is a simple kit which uses reagents to produce a color change in turbine engine lubricant samples giving a Go/No-Go result. The color change can be correlated to TAN results. The kit can test about 60 samples without replenishment. As stated by Royal Lubricants, the Mini-TAN is not appropriate for automotive, diesel, or aviation piston engine oils. Rolls Royce, BMW, and others do use it for their turbine engine oils. The Navy has also had some experience using this kit.[47]

Viscosity

Berkeley Microinstruments' Microviscometer Model BMV105 is a light portable viscometer. The sensor head is a small chip based on flexural plate wave (FPW) technology. The system is not fully developed. Unfortunately, the company is going out of business and this device will no longer be available.[48, 49]

Cambridge Applied Systems' Viscolab 3000 is a small, bench-top device that tests for viscosity. It uses 115 VAC power and requires only a 5 mL sample. Once the necessary input parameters are entered, it is a matter of minutes before the results are ready. The Navy was the primary driver to produce this product and it is currently in use aboard many of their ships.[50]

CSI's Oil View Digital Viscometer is an accessory to the Oil View Analyzer 5100 that tests for viscosity. Another attachment can be purchased that would make it work with a PC only. A 12 mL sample is needed and clean-up involves wiping the viscometer sensor with paper tissues. This device is capable of testing all mineral oils and synthetics.[51]

Dickey-John's AV250 viscometer is a hand-held unit which can be used in the field. The operation is simple, and data can be sent to a PC for compilation and analysis.[52] We have no record of reports regarding evaluation of the product.

Eitzen's Visgage is a small hand held viscosity comparator. Requiring only a 1-2 mL sample, this mechanical device does not require electric or battery power. It is currently being used by the Coast Guard to determine if significant oil degradation is occurring. The used oil is compared with a reference or "new" oil.[53]

Entek IRD's Visc-ALERT is a simple to operate, hand-held viscometer. It is rugged and small enough to be placed in a utility belt and taken into the field. The data collector is common to both the VISC- and CONTAM-ALERT. Data can be downloaded to a computer.[54]

Fluid Systems Partners' PODS utilizes internal sensors to determine changes in viscosity. This device is also used for particle counting and is described in more detail in the Particle Analyzers section.

Fraunhofer's surface acoustic wave (SAW) technology is used to measure viscosity. This is under development.[55]

Gerin's V-3 viscosity comparator is small, easy to use and requires no power source. However, this instrument needs a reference oil to compare to the used oil. The device is mechanical and the data cannot be downloaded to a computer. The readout is in percent of change in viscosity. The V-3 is currently in use by the Navy, Coast Guard and the Canadian and Australian defenses. The Coast Guard is pleased with this device and they have one on every vessel over 95 feet.[56]

Kittiwake's Oil Test Centre includes a falling ball viscometer, which has been shown to give repeatable, accurate results. As stated above, it has been used in the Canadian and British militaries with some success.[57, 58] It is also being used by the U. S. Naval Sealift Command on about 80 ships. Mobil, Shell, Castrol and Unitor have also endorsed use of the kit.

Parker's PLC 3000 is a portable unit with a shoulder strap to facilitate use. Viscosity is determined by measuring the pressure differential across a fixed restriction at a known flow rate. It is a new feature, so there is little data pertaining to this. The device also uses laser light blockage to detect particles. A list of corporations who use the device in a number of different applications is included with the brochure. Data can be downloaded to a PC with an RS 232 cable for use in a database.[59]

Water Contamination

Dexsil's Hydroscout is a portable test kit used to measure water contamination in oil. The data is not downloadable to a computer. This kit has enough supplies to run 40 tests without replenishment. It is not as sensitive as may be required; the detection limit is about 0.15% v/v or 1500 ppm. Included in the kit is an analyzer, 12 dilution vials and 40 reagent vials. A list of the current users has not yet been compiled.[60]

Kittiwake's Oil Test Centre can be used to measure water in lubricants and diesel fuel. It has been used with success by the Canadian and British militaries.[61, 62]

UCC's H2Oil is a portable device that utilizes infrared absorption spectroscopy to measure the amount of water contamination in oil. This device operates off a 12 Vdc battery and has a RS232 interface to download data to a PC. The results are displayed as percentage water content or parts per million (ppm). Current users include Texaco, General Motors (GM), and Boeing Aircraft. The Air Force uses one at their B1 facility at Tinker Air Force Base.[63]

Wear Metal Analyzers

Analex's Ferrous Debris Monitor is a small portable analyzer which uses a dual coil magnet to quantify the total mass of ferrous debris in oil samples. It is packaged as a rugged briefcase which opens for oil analysis. Caterpillar is one prominent customer.[64]

CSI's Oil View Ferrous Wear Monitor measures the amount of iron wear particles in used oil. It can be used with the Oil View Analyzer or with a PC. This device can detect particles 1 μm or larger and takes less than 1 minute to operate.[65]

Entek IRD's CONTAM-ALERT (in combination with the Ferrous CONTAM-ALERT attachment) can be used to measure wear metals and to differentiate between ferromagnetic and nonferromagnetic particles.[66]

Inspection Instruments (NDT) Ltd.'s Debris Tester is a small battery operated unit that measures the wear metal particles in used oil. The Debris Tester weighs the ferrous debris remaining on a filter as an oil sample passes through. It is currently in use by Rolls Royce Ltd., the British Aircraft Corporation, the Royal Airforce, Aeritalia and the Royal Army and Navy.[67]

Oxford's 3000 EDXRF is a small benchtop unit that utilizes Energy Dispersive X-Ray Fluorescence (EDXRF) to measure wear metal particles. It requires no PC for operation, but results may be downloaded for storage and for a full display of the spectra via the RS232 port.[68]

Spectrace produces two EDXRF analyzers which could be used to measure metals in lubricants. The first is the 9000, a portable instrument which can be used to measure metals heavier than phosphorus. Thus, the main limitation is its inability to detect

sodium, magnesium, aluminum, silicon or phosphorus. The distributor was unaware of anyone using it to determine metals in oil, but said it could be done. QuanX is Spectrace's larger bench-top unit. JOAP has three currently. It has the capability of detecting elements from sodium to uranium.[69]

Spectro Inc.'s Benchmark Oil Condition Monitor uses a permeability sensor in its measurement of wear metals. It is small enough to fit inside a briefcase and weighs 0.9 kg. According to the brochure, it is easy to operate and requires no special training. It cannot differentiate wear metals present in the used oil.[70]

Top Source's Motor Check On-Site Analyzer uses a atomic emissions spectrometer to analyzer wear metals in used oil. This device tests for 6 wear metals (Al, Cr, Cu, Fe, Pb and Sn) and 3 contaminant metals (Si, K, and Na). It also utilizes FTIR to measure fuel dilution, water contamination, coolant contamination, soot, viscosity, and TBN. The size and weight of this device make it more practical as a bench top unit as opposed to a portable analyzer.[71]

Section 5 Recommendations

Based on the results of this market investigation, there is a possibility of a commercial device or a combination of devices which, with some modifications, could support the Army's oil analysis goals. For example, one type of sensor may be required for particle or wear metal analysis, while another will be needed for oil condition. Because most of the devices mentioned herein measure only a single parameter, a combination of analyzers or development of a system integrating multiple methods may be required.

PWQTT will use the results of this market survey to select several devices for a more in-depth technical evaluation. The purpose of the evaluation will be to further examine the operational characteristics and capabilities of the selected systems.

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Table 1- Commercial/Non-developmental Devices

Manufacturer	Instrument	Weight	Size	Durability	Capabilities	Power Requirements	# of Hours of Self-Sustained Operation	Cost	Notes
Analex	PQP Portable Ferrous Debris Monitor	5 kg	35 x 26 x 16 cm	Housed in a sealed thermoplastic case for protection from severe operating conditions.	P; WM	12 V DC vehicle battery	Dependent on battery life.	$12,400	Data downloadable to PC; ferrous particles only
Cambridge Applied Systems	Viscolab 3000	7 kg	30.5 x 28 x 25 cm	Designed for field applications	V	115 VAC, 50-60 Hz	Continuous	$9,850 plus $540 for additional viscosity ranges	None
Computational Systems, Inc.	Oil View Analyzer 5100	2.78 kg	21.2 x 6.5 x 3.25 cm	Designed for field applications.	DC	110-240 VAC, 50-60 Hz; 12 VDC	Continuous	$8,795 -Single sensor; $10,295 - Double sensor	Reference oil is needed; choice of single or double sensors; data downloadable to PC
Computational Systems, Inc.	Oil View Ferrous Wear Monitor	2.78 kg	21.2 x 6.5 x 19.8 cm	Designed for field applications.	WM	100-220 VAC, 50-60 Hz	Continuous	$8,995	Data downloadable to PC
Computational Systems, Inc.	52 PC Oilview Particle Counter	8.6 kg	28 x 33 x 37 cm	Designed for field applications.	P	100-240 VAC, 47-63 Hz	Continuous	$14,996	Data downloadable to PC; Measures 6 size classes, 2 um to 100 um
Computational Systems, Inc.	52DV Oil View Digital Viscometer	1.5 kg	10 x 11 x 10 cm	Designed for field applications.	V	12 VDC	Continuous	$3,495	Accessory to 5100 Oil View Analyzer
Dexsil	Hydroscout	<2.3 kg	38 x 23 x15 cm	Designed for field applications	WC	Battery	1 box/40 tests (reagents enough for 40 tests)	$525 (addtl dilution vials $10.20/dz)	Does not measure water below 1500 ppm
Dexsil	Titra-Lube TAN/TBN	<0.5 kg	Approx. 10 x 2 x 5 cm	Designed for field applications	T	None	1 test per kit/800 tests (20 tests per pack)	$3.85 per test/ $77 for 20 tests per pack	None
Dickey-John Scientific	AV-250	0.9 kg	30.5 x 12.7 x 5 cm	Designed for field applications.	V	12 VDC or 90-260 VAC	Dependent on battery life.	$2,700	Data is downloadable to PC; solvent is required to clean the sample probe
Eitzen	Visgage	<0.9 kg	Approx. 20 x 4 x 4 cm	Designed for field applications	V	None	Continuous	$225	Needs reference oil.
Entek IRD	Digital CONTAM-ALERT	0.5 kg	29 x 48 x 33 cm	Benchtop unit.	P	12 VDC	Dependent on battery life.	$11,950	PCM data collector

Legend

A	Additive	P	Particulate Analysis
C	Conductivity	S	Soot
CC	Coolant Contamination	T	TAN/TBN
DC	Dielectric Constant	V	Viscosity
I	Impedance	WC	Water Contamination
FD	Fuel Dilution	WM	Wear Metals

Table 1- Commercial/Non-developmental Devices cont.

Manufacturer	Instrument	Weight	Size	Durability	Capabilities	Power Requirements	# of Hours of Self-Sustained Operation	Cost	Notes
Entek IRD	Digital VISC-ALERT	1.5 kg	9.4 x 11 x 9.4 cm	Designed for field applications.	V	12 VDC	Dependent on battery life.	$3,995	Data downloadable to PC; Oil Analyzer software
Entek IRD	Ferrous CONTAM-ALERT	2.8 kg	21 x 6.6 x 19.7 cm	Designed for field applications.	WM	110VAC, 50-60 Hz	Dependent on battery life.	$3,995	Data downloadable to PC; accessory to Contam-Alert
Fluid Systems Partners	Portable Oil Diagnostic System (PODS)	11.5 kg	33 x 35 x 20 cm	Designed for field applications.	P; V	Battery	60 samples	$12,000	Data is downloadable to PC; choice of bottle sampling or online sampling
Fluitec	RULER	1.6 kg	12 x 17.8 x 6.9 cm	Designed for field applications	A	Battery or 120 VAC	Dependent on battery.	$15,000; reagents $7.50	Data is downloadable to PC; RULER software
GasTOPS	Oil Debris Monitor (ODM)	< 2.5 kg (sensor)	Approx. 15 x 8 x 4 cm	Designed for on board.	WM	On board	Continuous	Unknown	Data is downloadable to PC
Gerin	V-3 viscosity comparator	<2.5 kg	25.4 x 7.6 x 2.5 cm	Designed for field applications.	V	None	Continuous	$395 for the kit or $240 for the comparator only	Need reference oil
Gerin	TAN/TBN test kit	< 0.9 kg	Small box.	Designed for field applications.	T	None	25 tests/kit	$115/kit	None
Inspection Instruments (NDT) Ltd.	Debris Tester	5.5 kg	21 x 13 x 29 cm	Designed for field applications.	WM	8 SP2 dry cells	<200 hours	Unknown	Need the oil to be heated to 60 C for 1/2 hour
Kittiwake Developments Ltd.	Oil Test Centre	18 kg with case.	57.5 x 36 x 31 cm	Designed for field applications.	T; V; WC	110-250 VAC	Continuous	$10,000 per kit, with consumables costing about $1 per test.	None
Microsensor Systems, Inc.	Fuel Dilution Meter	2.7 kg	8.9 x 20.3 x 28 cm	Designed for field applications.	FD	120 V, 60 Hz	500 measurements	$8,820	Uses Surface Acoustic Wave (SAW) technology to make measurements
Microsensor Systems, Inc.	TBN Meter	6.4 kg	8.9 x 20.3 x 28 cm	Designed for field applications.	T	120 VAC; 60Hz	500 measurements	$9,380	Looks only at total residual carbonate base
Naeco	COBRA (Complete Oil Breakdown Rate Analyzer)	14 kg	25.4 x 12 x 12 cm	Encased in heavy duty cast aluminum	C	2 9 volt batteries	4 hours/60 samples-need to recalibrate	<$5000	None

Legend

A	Additive	P	Particulate Analysis
C	Conductivity	S	Soot
CC	Coolant Contamination	T	TAN/TBN
DC	Dielectric Constant	V	Viscosity
I	Impedance	WC	Water Contamination
FD	Fuel Dilution	WM	Wear Metals

Table 1- Commercial/Non-developmental Devices cont.

Manufacturer	Instrument	Weight	Size	Durability	Capabilities	Power Requirements	# of Hours of Self-Sustained Operation	Cost	Notes
NorthernTechnologies	Lubri-Sensor	1.1 kg	10 x 24 x 12.7 cm	Encased in ABS plastic	DC; CC*; WC*; WM*	9 volt batteries	1000 tests	$595	Needs reference oil
Oxford	3000 EDXRF	16 kg	46 x 57 x 20 cm	Unknown	WM	100,120,220,240, VAC; 50 60 Hz	Continuous	~$31,500 (23,000-40,000)	Interface with PC
PAMAS GmbH	Portable Particle Field Monitor	13.6 kg	Approx. 15 x 30.8 x 38 cm	Designed for field applications.	P	24 VDC or 230/110 VAC	Dependent on battery life.	~$13,000	Can be calibrated for use with any lubricant
Parker	PLC-3000	10 kg	30.5 x 30.5 x 15 cm	Designed for field applications.	P; V	12 VDC or 90-250 VAC	Dependent on battery life.	$11,000 to $13,000	Data is downloadable to PC
Predict DLI	Navigator	0.54 kg	17.8 x 8 x 3.8 cm	Designed for field applications	I; A*; WM*; WC*	3 AA batteries	Dependent on battery life.	$3,495	None
Royal Lubricants	Mini-TAN test kit	<0.9 kg	Small box.	Designed for field applications.	T	None	60 tests per kit	$618	For turbine engine lubricants only
Spectrace	9000	90 kg	40 x 72 x 56 cm	"In-situ or benchtop operational modes"	WM	100,115,230 VAC; 50/60 Hz	Continuous	$55,000	PC and vacuum option; uses EDXRF
Spectrex	Particle Counter	6.8 kg	17.8 x 15 x 38 cm	Unknown	P	115v; 60 Hz	Continuous	$9,800	Data downloadable to PC; software
Spectro, Inc.	Benchmark	0.9 kg	Approx. 10 x 15 x 20 cm	Designed for field applications.	DC; WM; CC*; WC*; FD*	Battery operated	Dependent on battery life.	$1,160	None
Top Source Technologies, Inc.	Motor Check On-Site Analyzer	68 kg	96.5 x 56 x 43 cm	Benchtop unit	S; V; WM; CC*; FD*; T*; WC*	110/220 VAC	Continuous	$69,900	Needs a modem line; does not do hydraulic or synthetic oils
UCC	CM20.9090	10 kg	30 x 30 x 31 cm	Designed for field applications	P	110/240 Vac; 50-60 Hz; 6 1.5 Dcells	Dependent on battery life.	$9,800	None
UCC	H2Oil	6 kg (case: 8 kg)	Approx. 30 x 30 x 31 cm	Designed for field applications	WC	12 VDC rechargeable battery	Dependent on battery life.	Unknown	RS232 interface
Wilks	Infracal Soot Meter	2 kg	16.5 x 16.5 x 12.7 cm	Designed for field applications	S	12 volt battery pack/AC/DC	Dependent on battery life.	$4,925	Spectra-Tech is a distributor

*** Properties that are inferred.**

Legend

A	Additive	P	Particulate Analysis
C	Conductivity	S	Soot
CC	Coolant Contamination	T	TAN/TBN
DC	Dielectric Constant	V	Viscosity
I	Impedance	WC	Water Contamination
FD	Fuel Dilution	WM	Wear Metals

Table 2 - Devices under Development

Manufacturer	Instrument	Weight	Size	Durability	Capabilities	Power Requirements	# of Hours of Self-Sustained Operation	Cost	Notes
Berkeley MicroInstruments**	Microviscometer (Model BMV105)	7 kg	26 x 26 x10 cm	Unknown	V	110-120 VAC, 50-60 Hz	Continuous	Unknown	None
Delphi	INTELLEK	Unknown	Sensor	Designed for on line mounting.	C; A*; T*; V*	On board	Continuous	~$50	Uses MicroElectro Mechanical Systems (MEMS)
Foster-Miller	Oil Condition Monitor	0.9 kg	15 x 7.6 x 5 cm	Designed for field applications/on board	CC; S; WC; A	Unknown	Unknown	$6,000	Data downloadable to PC
Fraunhofer	Surface Acoustic Wave	Unknown	Unknown	Unknown	V	Unknown	Unknown	Unknown	None
GasTOPS	MetalScan	Unknown	Unknown	Designed for on board.	P; WM	Unknown	Unknown	$10,000	Mounted onboard
LucasVarity	On-line Oil Viscosity Sensor	Unknown	Unknown	Designed for on board.	V	Unknown	Unknown	Unknown	None
Naval Research Lab	Lasernet	<2 kg	5 x 5 x 12.7 cm (sensor)	Rugged; on board mounting	P	On board	Continuous	~$3000	Downloadable to PC
Voelker Sensors**	On-Board Sensor	Unknown	Unknown	On line mounted	C; CC*; A*; WC*	On board	Continuous	Unknown	Still being developed

*** Properties that are inferred.**
****Possibly going out of business**

Legend

A	Additive	P	Particulate Analysis
C	Conductivity	S	Soot
CC	Coolant Contamination	T	TAN/TBN
DC	Dielectric Constant	V	Viscosity
I	Impedance	WC	Water Contamination
FD	Fuel Dilution	WM	Wear Metals

Appendix A Addresses of Companies

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Gerin
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Oxford Instruments, Inc.
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Phone: (800) 447-4717 or (508) 371-9009
Fax: (508) 371-0204
POC: Mark Lessard

Pall Corporation
25 Harbor Park Drive
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Phone: (516) 484-5400 or 1-800-645-6532
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Appendix B Commerce Business Daily Announcement

[Commerce Business Daily: Posted in CBDNet on April 1, 1999]
[Printed Issue Date: April 6, 1999]
From the Commerce Business Daily Online via GPO Access
[cbdnet.access.gpo.gov]

PART: U.S. GOVERNMENT PROCUREMENTS
SUBPART: SUPPLIES, EQUIPMENT AND MATERIAL
CLASSCOD: 91--Fuels, Lubricants, Oils, and Waxes--Potential Sources Sought
OFFADD: U.S. Army Tank-Automotive and Armaments Command, Acquisition Center (AMSTA-AQ-DE), Warren, MI 48397-5000
SUBJECT: 91--PORTABLE OIL ANALYZER
SOL N/A
DUE 043099
POC Corinna Tunac, (810) 574-4231
DESC: This is not a request for proposal. This synopsis is for information and planning purposes only, and is not to be construed as a commitment by the Government. The Tank-Automotive and Armaments Research and Development Engineering Center (TARDEC), Warren, Michigan, is searching for sources who can supply a commercially available off-the-shelf (COTS) portable oil analyzer. The analyzer will be used in the field by Army maintenance technicians. Onsite oil samples from diesel engines, transmissions, gearboxes, and hydraulic systems will be tested to determine the lubricant/fluid quality and to monitor the condition of vehicle components. Abnormal oil samples will be sent to a laboratory for detailed analysis. The portable oil analyzer (may be an assemblage of several devices) should measure the following parameters: additive package depletion, coolant contamination, fuel dilution, particulates, soot, Total Acid Number (TAN), Total Base Number (TBN), and water contamination. Analysis of wear metals is desirable. The measurements may be either direct or inferred. The analyzer must be one person portable. It must withstand rugged handling and extreme temperature conditions. The device must be self-powered (e.g., battery operated). Requirements for consumables should be minimal. The device must not present any safety hazards to personnel or environment. Operation of the device must be simple and fast. Interested entities may submit written responses detailing technical compliance to: US Army TACOM, Petroleum and Water Quality Technology Team, AMSTA-TR-D/210, Warren, MI, 48397-5000, ATTN: Corinna Tunac or sent via electronic mail (preferred method) to: tunacc@tacom.army.mil. Responses are requested to be submitted no later than 30 April 1999. Telephone inquiries can be made to Corinna Tunac, (810) 574-4231 or Steve Moyer, (810) 574-4206. There is no specific format or outline that your response must follow. It is also encouraged to submit other descriptive literature and any other specific and pertinent information that would enhance our consideration and evaluation of the information submitted. Firms responding should indicate whether they are a small business, a socially and economically disadvantaged business, or a woman-owned business.

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