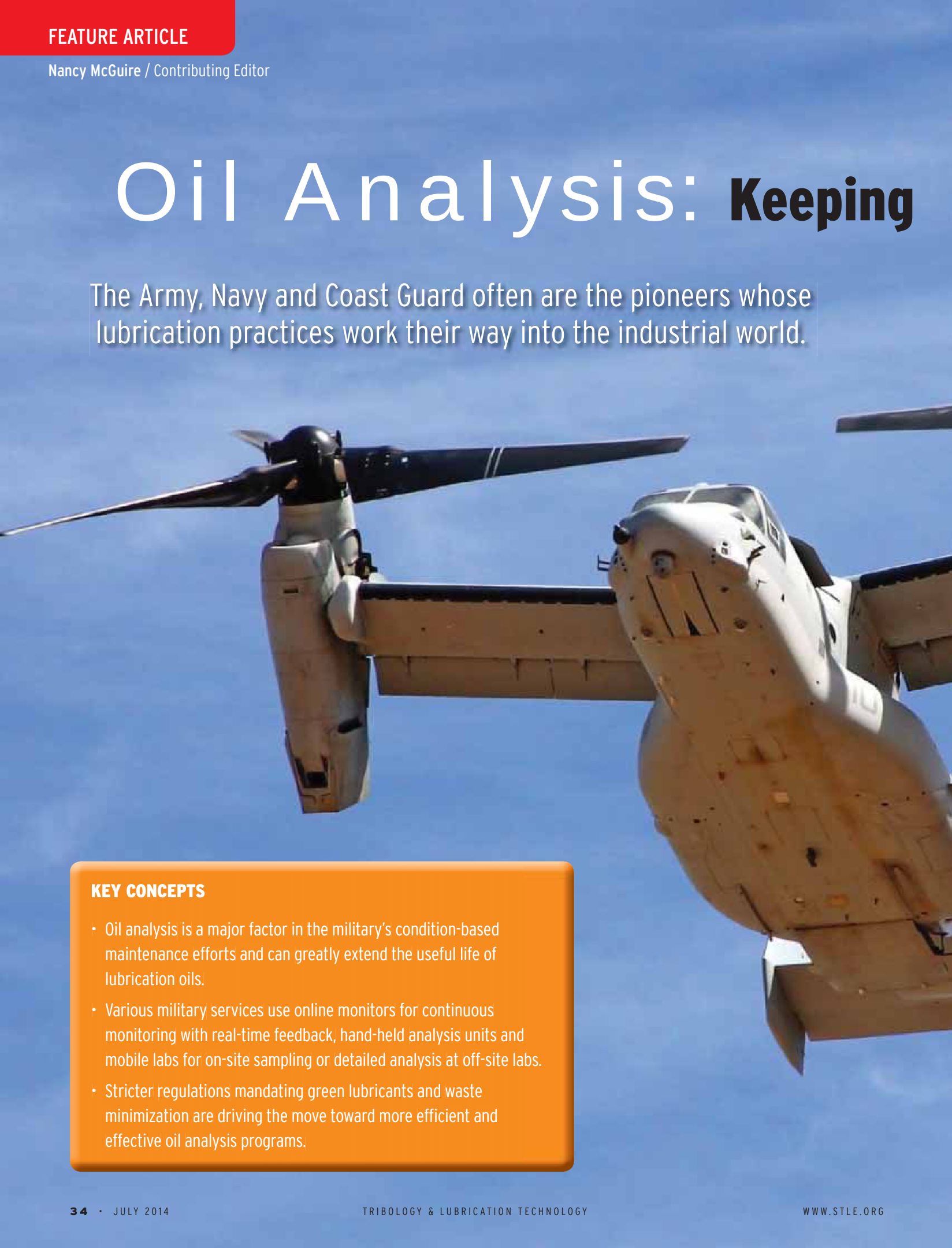
Nancy McGuire / Contributing Editor

Oil Analysis: Keeping

The Army, Navy and Coast Guard often are the pioneers whose lubrication practices work their way into the industrial world.



KEY CONCEPTS

- Oil analysis is a major factor in the military's condition-based maintenance efforts and can greatly extend the useful life of lubrication oils.
- Various military services use online monitors for continuous monitoring with real-time feedback, hand-held analysis units and mobile labs for on-site sampling or detailed analysis at off-site labs.
- Stricter regulations mandating green lubricants and waste minimization are driving the move toward more efficient and effective oil analysis programs.

military systems running smoothly

For military operations, going from launch to mission accomplished requires much more than starting up the engines and heading once more into the fray. Diligent maintenance, safety measures, cost savings and environmentally responsible practices keep the U.S. military's equipment, ground vehicles, aircraft and ships ready for action. The military must stay ahead of the curve in oil monitoring technology and practices in order to bring all these elements together.

When it comes to oil analysis technology, "The military is generally ahead of the civilian sector," says STLE-member Allison Toms, vice president of technology and engineering services at GasTOPS Inc., a Pensacola, Fla., company which manufactures and supports advanced machinery fluid sensing and analysis products. "They are typically the ones who are the primary leaders in funding new developments and new techniques for oil analysis and condition monitoring, especially when it comes to air, sea and ground equipment. They have an investment in new capabilities, and this investment cascades down to industry."

Although government regulations on lubricant cleanliness factor into the high priority assigned to oil analysis programs, this investment is driven to a large extent by a need to cut operating costs without compromising performance or safety. Technologies such as online monitoring eliminate the need for personnel to draw samples, prepare them for shipping to an off-site lab and process the results when the lab report comes back. "The F-22 and F-35 fighter planes all have built-in oil debris monitors," notes Toms.

Routine oil changes every 3,000 or 5,000 miles are all right for the family car, but maintenance programs for high-priced military assets must push lubricant oils to the end of their useful life spans—and no further. Oil analysis keeps track of the condition of an oil and also is used as an early-warning system for parts that are about to fail. This approach is a part of the military's focus on condition-based maintenance—the use of routine monitoring and analysis rather than fixed schedules for performing preventive maintenance and identifying problems in their early stages.

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Manufacturers of lubricants and equipment take a cautious approach with their recommendations and warranties with an eye on contamination level. Some recommend oil changes well in advance of the end of the oil's useful life on the assumption that not everyone does regular oil analysis in a timely manner. Any problems with viscosity changes or contamination are cut off at an early stage before major damage can occur. This approach creates problems of its own, however. Disposal of used lubricants, downtime for maintenance and the cost of the lubricants themselves add up to a major expense for high-priced assets.

For example, some of the U.S. Army's generators use as much as 50 gallons of oil, almost an entire barrel. Although manufacturer warranties typically specify an oil change after every 250 hours of operation, this might not be feasible in off-site or hostile locations. Oil analysis can extend the service life to 1,500 hours or more on most generators, unless there is a problem. For Army vehicles, oil analysis can mean the difference between changing the oil every three months and operating six to 12 months under normal use.[1]

TO CHANGE OR NOT TO CHANGE?

Monetary expense is not the only factor to consider when deciding when it's time to change the oil. Even though a complete oil change is a major maintenance operation, "Anything that puts people in harm's way is worth paying attention to," says Jeff Mothersbaugh, aerospace filtration sales manager for Parker Hannifin Hydraulic in Rock Hill, S.C. He notes that contaminated lubricant fluids have been implicated in several helicopter crashes.

The importance of the equipment and the people depending on it has shielded maintenance programs from much of the budget-cutting pressure from the federal government. "They can't walk away from the problems that need to be solved," Mothersbaugh notes. The highest-priced assets receive the most advanced monitoring technology. "You have to ask what it would cost you if you shut it down. If an asset is worth more than about $1.5 million, it's considered a large asset. You have to take into account labor costs, criticality and time sensitivity." For equipment and vehicles that are part of a 24/7 operation, shutdowns are expensive, he says.

Minimizing disruptions to normal operations while ensuring that equipment remains in peak condition requires careful planning. Edgardo Guevara, lubrication program manager–mechanical engineer for the U.S. Coast Guard in Baltimore, Md., notes that Coast Guard cutter crews plan oil changes in advance, when the cutter is in a port of call. Each cutter has two engines, so the oil in one engine can be changed with the ship underway if it's a true emergency.

What constitutes an emergency? Even though the Coast Guard has contracted with a laboratory that provides them with detailed analyses and interpretations of the lab data, ultimately, it's up to Guevara to review the results and provide guidance to the crew on board.

Testing labs provide interpretations and recommendations to varying degrees, depending on the amount of liability they are willing to assume. Some labs provide only data reports, while others will provide varying degrees of interpretation. The final go/no-go decision, however, factors in the customer's prior experience with the specific system in question, the criticality of the mission and the risk to the operators and crew.

COAST GUARD CENTRALIZES OPERATIONS

Guevara left his position as lubrication program manager with the U.S. Military Sealift Command in September 2011 to accept the challenge of centralizing the lubrication oil program for the U.S. Coast Guard. Today, he oversees the selection, procurement, testing and maintenance scheduling for lubrication oils used on board Coast Guard vessels.

Prior to his arrival, the Coast Guard sent oil samples to multiple testing labs run by the Navy and several commercial enterprises. There was no

standardization across the labs—often vendors would provide laboratory services for the engines and pumps they manufactured, and their data was stored in product-specific formats in their own databases. Maintenance supervisors had difficulty accessing the data, and some software was out of date. Each commercial lab had its own pricing scheme. The Navy provided services to the Coast Guard at no charge, but it could be weeks or months between sending in the samples and getting the results back.

Other branches of the U.S. military have their own oil testing programs. The Army has a centralized testing program. The Navy has several programs with some centralization. Centralization allows these branches to obtain volume discounts on their laboratory tests. The Coast Guard is a part of the Department of the Navy, but it has its own program.

In September 2013, the Coast Guard began a five-year contract with a large international testing service company to serve as the central testing provider for its lubrication oil samples. Guevara insisted on strict requirements for the testing lab contract. Bidders had to be certified laboratories. There was a full and open competition for bids.

The testing lab served 28 cutters in the first six months, and will eventually increase its service to 150 cutters. This works out to some 5,000 to 6,000 samples a year, and this number will increase as the Coast Guard deploys some 50 new cutters over the next five years.

Because of volume discounts and other contract terms, the cost of this contract is roughly half of what was initially predicted—$250,000 rather than $500,000 over five years. This has helped shield the Coast Guard's program from the effects of federal budget-cutting.

Consolidating the Coast Guard's oil analysis program under one testing lab facilitates comparison of lab results, and it provides consistent test parameters and central access to lab reports. Rapid access to a centralized database enables condition-based maintenance and predictive capabilities, further reducing operating costs. Administering only one contract reduces overhead expenses and simplifies operations. "The program needs all of this in place," says Guevara. He expects the benefits of these consolidation efforts to become more apparent over the next five years, and he's optimistic about his chances of success: "We're going the right direction, getting all this in place."

TEST HERE OR TO GO?

Routine oil analysis can be done continuously using online sensors, or maintenance personnel can draw lubricant samples to analyze on-site or in off-site laboratories, depending on the nature of the equipment and the operating conditions.

On board a Coast Guard cutter, the engines, hydraulic systems and gearboxes require oil testing on a monthly basis. Because most cutters are based in U.S. waters and at sea for only a few days at a time, oil samples can be sent to a testing laboratory when the cutter is in a port of call. The Coast Guard's contract with its main testing laboratory specifies that the lab provide them with all the necessary kits and bottles, prepaid mailers, labels and packing materials. (Their shipping service picks up anywhere in the U.S. except Guantanamo Bay, notes Guevara.)

The lab posts results to a Web-based database within 48 hours' time. Reports include particle counts, particle identification and a detailed run-down of metals, contaminants, additives, viscosity and acid/base numbers. The Coast Guard contract also specifies that the testing lab interpret the data and provide recommendations, which Guevara evaluates and annotates before passing the information along to his personnel.

Laboratory analyses have the advantage of being thorough, and a certified laboratory will stand behind its results. Databases can show trends across an entire fleet or spot an emerging problem in one gearbox. On the other hand, costs per sample can be significantly higher. If a ship is in port for only a short time, it may be out at sea again when the lab results

DOD's JOINT OIL ANALYSIS PROGRAM: PUTTING IT ALL TOGETHER

Under the U.S. Department of Defense's Joint Oil Analysis Program (JOAP), the Army, Navy and Air Force established oil analysis laboratories at strategic locations. The branches of the service also standardized their procedures, data elements, analytical instrumentation and diagnostic techniques, plus they set up a data system that is interoperable among all the branches of the military. The coordinating group has evaluated new and emerging technologies, techniques and equipment and made recommendations for their testing and evaluation.

In its statement of purpose[3], the JOAP defines oil analysis as a maintenance diagnostic tool to:

A. Determine the internal condition of aeronautical and non-aeronautical engines, transmissions and gearboxes and their oil-wetted components through the analysis of used lubricating oils, grease and fluids. Its goal is flight safety, enhanced equipment readiness, reduced maintenance costs and the extension of component life.

B. Determine the suitability of lubricants and fluids for continued use, resulting in savings and early detection of harmful conditions that, if not corrected, could promote premature component failure.

arrive, indicating a problem that must be addressed immediately.

The Army has used mobile oil testing labs housed in large vans for ground vehicles in Kuwait, Iraq and Afghanistan. Military units can get immediate feedback on test results from a Website dedicated to that purpose. "This is the business of being able to see something break before it breaks," says the Army's LOGSA (logistics support activity) commander Col. Jan Berry in an interview with Skip Vaughn of the *Redstone Rocket* (Redstone Arsenal, Ala.). "It is making sure that a soldier's weapon works when it's supposed to."[2]

Soldiers perform on-site filter debris analysis *(Courtesy of GasTops Inc.)*

Mobile laboratories work well for large land-based operations, but for smaller land expeditions or ships at sea portable instruments, some small enough to be hand-held, are indispensable for providing on-the-spot analyses. Drawing lubricant samples and testing them on-site using portable instruments not only provides immediate results but can reduce testing costs as well. Instruments for use in military field operations often are ruggedized versions of their civilian counterparts. In addition to meeting industry standards, such as ASTM and ISO requirements, these instruments must meet additional requirements from bodies such as the Department of Defense's Joint Oil Analysis Program (JOAP).

Guevara was motivated to look for new technology when he accepted his position with the Coast Guard in 2011. He wanted to cut costs for oil and filter changes. The newer Coast Guard ships now use a hand-held oil monitor that combines infrared (IR) spectroscopy with viscometry. Tests require only 60 microliters of oil—a few drops—compared with 100 ml for their previous test method, and no reagent chemicals are needed. The viscometer heats the oil and takes measurements at 40 C. Results indicate the lubricant's viscosity and any contamination by water, coolant or fuel oil.

Because the samples are so small and test chemicals aren't needed, waste disposal is reduced to almost nothing, and the crew is not exposed to hazardous chemicals. This type of testing provides individualized trend information so an operator can tell if one part is starting to wear. Trend reports keep track of additive levels, glycol, nitration, oxidation, sulfation, soot, viscosity and water content over a period of months, including any warnings that occurred when a reading moved outside of the acceptable range. Guevara notes that the crews like this method because they don't need any auxiliary chemicals for the tests, the instrument self-calibrates, and it's fairly rugged.

Engineers aboard the USCGC Waesche learn to use a hand-held IR spectrometer/viscometer oil analysis unit. *(Courtesy of Edgardo Guevara, U.S. Coast Guard)*

Asset Property Trending

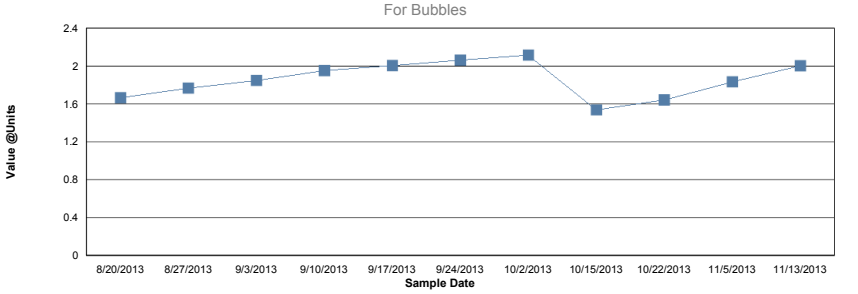
Asset Name: #2 Main Diesel Engine **Fluid:** shell rotella t3 15w40

Bubbles in Bubbles

Sample Date	Value	Alarm Status	Date Measured
20-Aug-2013	1.67	None	20-Aug-2013
27-Aug-2013	1.77	None	27-Aug-2013
03-Sep-2013	1.85	None	03-Sep-2013
10-Sep-2013	1.95	None	10-Sep-2013
17-Sep-2013	2.00	None	17-Sep-2013
24-Sep-2013	2.06	None	24-Sep-2013
02-Oct-2013	2.12	None	02-Oct-2013
15-Oct-2013	1.54	None	15-Oct-2013
22-Oct-2013	1.64	None	22-Oct-2013
05-Nov-2013	1.83	None	05-Nov-2013
13-Nov-2013	2.00	None	13-Nov-2013

Trending

For Bubbles



Spectro hand-held unit trend report.

DIRTY MULES

Mules are ground support systems that help keep aircraft in flying condition. They filter and clean the aircraft's fluids while the aircraft is on the ground. Mules circulate fluid through an aircraft's systems while it is in the hangar, facilitating maintenance for hydraulic systems and components. They also can supply pressure to individual aircraft components to check for leaks without having to start the aircraft's own engines.

Despite their convenience, mules also can be a source of contamination for an aircraft's fluids if they are not maintained properly. In 2000-2001, an integrated product team helped the Army set up a monitoring program for its mules. Before this program was set in place, the mules were often dirtier than the aircraft they were servicing. Attaching one of these dirty mules to an aircraft whose hydraulic systems had already been cleaned resulted in wasted effort and risked damaging the aircraft.

With the lubricant testing program in place, this problem has been resolved, and the mules are now maintained to an equal or higher standard than the aircraft they service.

"Mule" servicing an aircraft. *(Courtesy of Parker Hannifin)*

Guevara notes that the Coast Guard currently owns 19 hand-held IR/viscometer monitor units. Three Coast Guard ships now use hand-held units for shipboard testing, and five other ships were recently equipped using maintenance funds. Some of the smaller cutters share hand-held units. Contracts for new ships include a requirement to provide one of these units, included in the cost of the purchase.

Guevara is developing training materials for using the hand-held units and interpreting the results. He has developed a tutorial that is distributed on disks. The disks have digital copies of documents with text and graphics, a copy of the contract, instructions on reading the reports and how to go online to access the database.

For equipment that operates 24/7, or where access to sampling ports is difficult or dangerous, installing particle counters and other sensors online makes more sense than drawing lubricant samples. In many cases, detailed chemical analyses at the parts-per-million level are not necessary—all that's required is a go/no-go indicator that alerts an operator when the lubricant is failing to meet specifications.

Online particle counters can monitor particulates continuously for about 10 percent of the cost of a laboratory analysis, notes Len Licursi, Parker Hannifin's condition monitoring product manager in Moorestown, N.J., and resident subject matter expert in fluid contamination and particle counting. "Particle counting is where it starts," he noted.

Particle counters measure organic, inorganic, hard and soft particles to assess filtration effectiveness and track significant changes. Moisture sensors are integrated into the system to spot water contamination, a particularly important feature for the newer polyalkylene glycol (PAG) synthetic lubricants. Detailed analyses may supplement the online sensors when it is necessary to identify a specific part that is causing a problem.

Online sensors provide round-the-clock monitoring of particle counts during operations, and results are available immediately. "You can see when something is going to go," said Licursi. "Particle counters give you a live look that you didn't have before."

With online monitoring, crew members don't have to open up the lines to take samples, and they can program their devices to trigger an alert under specific conditions. The online devices put out a signal to a control panel to indicate go/no-go conditions, and they provide input to the customer's own data collection system. The system can be programmed to send an alert to a crew member's cell phone when conditions are out of spec, reducing the number of on-site personnel needed to monitor the equipment. Data may be exported into Web-based XTML files for archiving and reporting purposes.

Online particle counters have built-in diagnostics to ensure that they are functioning correctly, and customers can order standard fluids for QA/QC testing. Some manufacturers provide a send-in service for calibration testing, and customers do periodic maintenance checks to ensure that the particle counters are functioning properly.

Online sensors are more sensitive to changes in conditions than lab analyses, notes Toms. Because sensors collect and analyze data continuously, they can detect impending failures more rapidly and monitor the progression and rate of failure. This is especially important in assets like fighter jets, where high stresses and loads can cause components to fail more rapidly than, say, a gas turbine or generator that operates continuously.

 In Bracken Cave, Texas, the estimated 20 million Mexican free-tailed bats that live there eat about 200 tons of insects each night.

GOING GREEN

Most of the lubrication oils used by the Coast Guard for the main engines and hydraulic equipment aboard their ships are petroleum-based. Because of stricter government mandates to move away from petroleum products and use more green lubricants, they are prototyping the use of PAG synthetic oil in the gearboxes and the hydraulic system propeller. Guevara notes, "We're ahead of the Navy on testing those."

Monitoring for water contamination has taken on greater importance with the increasing use of synthetic lubricants. PAG lubricants are biodegradable, fire resistant and have low volatility in high-temperature applications. They also are more prone to water contamination because water is more miscible in these lubricants and harder to separate out than in mineral-based oils. Because PAG oil costs 4-5 times more than mineral oil, it must be kept clean and reused as much as possible.

Keeping PAG lubricants and bio-based oils dry requires vacuum dehydration and efficient filtration systems, which can be integrated online to provide constant filtration during operation. The Coast Guard uses an online vacuum dehydrator for its controlled-pitch propellers and also a portable unit that can be brought to the machine for some of the other applications.

Mothersbaugh notes that purifiers such as vacuum dehydrators are "getting big" in the aerospace industry, as well. Chinook helicopters use purifiers to remove air and water from their hydraulic fluid while they are on the ground.

Licursi notes that manufacturers of testing equipment must keep their hardware and software current to reflect changes in environmental regulations. That's not such a bad thing for the instrumentation companies, since providing customers with new capabilities is good for business. The customer needs to measure new things and keep stricter records on lubricant monitoring. Guevara notes that ASTM methodologies are also evolving constantly, with environmental regulations driving a trend toward more required test methods.

Rather than sifting through pages of raw data, maintenance crews increasingly want interpreted information and recommendations.

Pushing the life span of lubricants is another green issue that increases the need for thorough monitoring. Complying with environmental regulations on used-oil disposal requires diligent testing to minimize waste lubricant disposal costs without incurring the much greater expenses caused by equipment failure and worker injuries.

MOVING FORWARD

Technological developments and user demands for oil analysis systems drive each other forward. As online and on-site monitoring devices become more common, maintenance crews learn to use the steady stream of data that these devices provide to track trends and plan ahead. Increasingly stringent government regulations and equipment that pushes the limits of stress and speed create a need for instrumentation that provides relevant information rapidly enough to make it useful.

Personnel and budgeting cuts create a demand for automated data analysis so a non-expert can decide quickly whether a vehicle or piece of equipment can be operated safely and reliably. Rather than sifting through pages of raw data, maintenance crews increasingly want interpreted information and recommendations. Data fusion combines input from several analysis methods to home in on the source of a problem. Although human judgment remains vital, much of the "number-crunching" work can be automated, and trends and alerts can be provided in forms that are easy to interpret.

Automation in oil testing labs enables rapid, large-volume testing with less lag time for posting results. Advances in robotics enable laboratory instruments to run analyses day and night with a minimum of human intervention. Internet-based reporting allows military units under deployment to access their lab data in near-real-time.

The demand for integrated technologies is also increasing. This can include hand-held devices like the IR spectrometer/viscometer combination that the Coast Guard uses, but it also includes online pairings like particle counters coupled to vibration sensors. Aircraft are now the primary users of online sensors, Toms notes, but the applications are by no means limited to aircraft.

Toms predicts that over the next five or so years, the trend will be to expand the capabilities and usage of technologies that are already available. "We need more reliable sensors for fluid condition such as water, fuel and degradation." Online fluid condition sensors are "not quite ready" in terms of reliability, she says, but integrated with wear debris sensors they could provide complementary information on fluid conditions.

In the field, many portable and online instruments have integrated data storage capabilities, and this data can be exported to local devices, cloud storage or Web-based storage. The trend in portable testing units is toward smaller and less expensive instruments with more analytical capabilities. Mothersbaugh notes that customers want Wifi and GSM (a European protocol standard set) so that they can

ASTM methodologies are also evolving constantly, with environmental regulations driving a trend toward more required test methods.

talk to the machines. "We have the Wifi capability now," he says.

Reducing the time between running the test and getting the results has driven demand beyond the conventional diagnostic and preventive applications and toward predictive data analysis. "Predictive analysis requires a lot of data over a lot of areas," says Licursi. "We're about five years into this." He told of one pioneer in this area, a railroad that started a program in late 1997 to predict pump failure. This was important because a failing pump can contaminate everything downstream from it. "They realized $1.5 million savings the first year," Licursi says.

Effective maintenance, rapid access to meaningful information, regulatory compliance, cost savings and environmentally responsible practices—military systems must have all these factors working together to keep their systems running and protect the safety of their personnel. "Customers don't want just another new test, they want actionable information," Toms states. The bottom line is, "Can we perform our mission?" TLT

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