JOINT OIL ANALYSIS PROGRAM

INTERNATIONAL CONDITION MONITORING CONFERENCE
APRIL 18-22, 2004

FINAL PROGRAM

Greetings Conference Attendees

Welcome to the 2004 JOAP International Condition Monitoring Conference. This is the seventh biennial conference hosted by the JOAP TSC. The staff has labored extra hard to make this conference one that will be well worth your time and effort to attend.

In this program, you will find a variety of events, classes, and guest speakers that is sure to offer something of value for everyone. Whether you are a lab operator, engineer, scientist, or manager, you will have the opportunity to explore specific areas of interest in a format offered only once every two years. I encourage you to take advantage of the excellent course offerings and to visit the 32 exhibitor booths to see the latest technologies on display. In attendance will be some of the foremost experts from industry, government, and academia so you will have ample opportunity to exchange information on issues of interest to you. Whatever your desire, I trust you will find this venue helpful and enjoyable.

My staff and I are committed to make this conference a significant event for you. If we can be of service, please let us know.

Lt. Col. David Broxterman, United States Air Force
Director, Joint Oil Analysis Program Technical Support Center

City of Pensacola

JOHN R. FOGG
Mayor

America's First Settlement
Established 1559

April 16, 2004

Welcome to Pensacola!

On behalf of the City of Pensacola, America's First Settlement and the Cradle of Naval Aviation, I am honored to welcome you to the Joint Oil Analysis Program's International Condition Monitoring Conference as you gather in Pensacola April 18 - 22, 2004.

The Joint Oil Analysis Program plays a critical role in ensuring readiness through its work in spectroscopy, tribology, viscosity, microscopy, x-ray analysis, and other studies of lubricants for effectiveness and wear debris to improve the effectiveness of military operations, extend the lifetime of equipment, and safeguard the lives of our fighting men and women.

Please take time to experience and explore our historic city–a city that dates back more than 400 years. Pensacola has so much to offer our visitors–whether you take a walking tour of our historic districts, visit the National Museum of Naval Aviation, take advantage of our beautiful sugar-sand beaches, or enjoy our great Gulf Coast seafood. We truly believe that Pensacola is unique–unique in its people, its quality of life and its community spirit.

As you gather for this conference, let me extend to all of you best wishes for a productive and informative meeting that furthers the role of this program and assures a strong defense.

We welcome you to Pensacola and hope you enjoy your visit.

Sincerely,

John R. Fogg
Mayor

180 Governmental Center P.O. Box 12910 Pensacola, Florida 32521 Telephone (850) 435-1609 FAX (850) 435-1611

ORDER OF EVENTS

Monday, April 19, 2004

1. PLENARY SESSION, Lt. Col. David Broxterman presiding

9:45 a.m. Introductory remarks, D. Broxterman, Lieutenant Colonel, U.S. Air Force

10:00 a.m. 1. ***Keynote address: An industry perspective on condition monitoring***, M. Rutherford, GasTOPS, Ltd.

10:45 a.m. 2. ***Special address: Condition based maintenance plus (CBM+): a DoD initiative***, S.J. Smith, Colonel, U.S. Air Force

12:00 noon Lunch (on your own); vendor exhibits open

2. OIL ANALYSIS AND EQUIPMENT HEALTH, Costandy Saba presiding

1:30 p.m. 3. ***The value of the Army oil analysis program to the war fighter***, J. Sanchez, U.S. Army

2:00 p.m. 4. ***Site testing in industry – keep it simple***, M.H. Jones, Swansea Tribology Services, Ltd.

2:30 p.m. 5. ***Jet fuel viscosity and rheology at low temperatures***, T. Selby*† and M. Vangsness,‡ †Savant, Inc.; ‡The University of Dayton Research Institute

3:00 p.m. Break (15 minutes)

3:15 p.m. 6. ***Practical options to ensure maximum lubricant and machinery reliability in a future reduced manpower environment***, C. Leigh-Jones,*† T. Kent,† and T. Schiff,‡ †Kittiwake Developments Ltd.; ‡ExxonMobil Marine Lubricants – Americas

3:45 p.m. 7. ***The lubrication aspects of machinery health management***, R. Garvey, Emerson Process Management–CSI

4:15 p.m. Break (15 minutes)

4:30 p.m. All JOAP meeting (TSC panel: Dr. E.T. Urbansky, M. Squalls, G.R. Humphrey, A. Lee)

5:00 p.m. Program office meetings for the services (NOAP, AOAP, SOAP)

5:30 p.m. Exhibitor open house (participating exhibitors only)

Tuesday, April 20, 2004

3. ANALYSIS OF USED OIL, Chris Leigh-Jones presiding

8:30 a.m. 8. ***After test support in lube analysis, where the action is***, Jack Poley, J4EMS

9:00 a.m. 9. ***Improving JOAP FTIR condition monitoring analytical throughput by sample dilution***, F.R. van de Voort,† J. Sedman†, and D. Pinchuk,*‡ †McGill University, ‡Thermal-Lube, Inc.

9:30 a.m. 10. ***Quantitative lubricant analysis by FTIR spectroscopy: determination of acid number, base number, and water***, F.R. van de Voort,† J. Sedman†, D. Pinchuk,*‡ and R. Cocciardi,‡ †McGill University; ‡Thermal-Lube, Inc.

10:00 a.m. Break (15 minutes)

4. REAL-TIME, ONLINE, AND PORTABLE ANALYSIS OF WEAR DEBRIS*
Chris Leigh-Jones (before lunch) and Tom Kent (after lunch) presiding

10:15 a.m. 11. ***Diesel engine portable fluid analyzer: a shipboard CBM enabling technology***, J.E. Tucker,*† J. Reintjes,† T. Sebok,§ P. Henning,¶ and L.L. Tankersley,□ †Naval Research Laboratory; §Lockheed Martin; ¶ Foster-Miller Inc.; □U.S. Naval Academy

10:45 a.m. 12. ***Diesel engine test stand evaluations of on-board oil condition monitoring sensors for U.S. Army ground equipment***, R.E. Kauffman,*† L.D. Sqrow,† J.D. Wolf,† S.C. Moyer,‡ and J.A. Schmitigal,‡ †University of Dayton; ‡U.S. Army

11:15 a.m. Lunch (on your own)

1:00 p.m. 13. ***Detection of severe sliding and pitting fatigue wear regimes through the use of broadband acoustic emission***, E.D. Price,† A.W. Lees,† and M.I. Friswell,‡ †University of Wales Swansea, ‡University of Bristol

1:30 p.m. 14. ***Real-time, non-invasive, ultrasonic detection of foreign material in process streams***, A.A. Diaz, L.J. Bond,* and T.J. Samuel, Battelle Pacific Northwest National Laboratory

2:00 p.m. 15. ***Application of a microelectromechanical sensor to oil analysis***, A.J. Niksa and R.J. Dalley,* Magnus Equipment/Predict

2:30 p.m. Break (15 minutes)

2:45 p.m 16. ***JetSCAN® oil debris analysis system: improving aircraft readiness for the AV-8B Harrier***, B.J. Stoll, U.S. Navy

3:15 p.m. 17. ***Propulsion system diagnostics***, W.J. Hardmann, U.S. Navy

3:45 p.m. 18. ***The U.S. Army's effort to implement an embedded oil analysis sensor***, J.K. Burden,* S. McWhorter, and D. Gratz, ASI-HSV

4:15 p.m. Presentations end

5:15 p.m. Informal meet-and-greet gathering (more details will be posted)

Wednesday, April 21, 2004

5a. X-RAY AND MICROSCOPIC ANALYSES OF WEAR DEBRIS,* Allison Toms presiding

8:30 a.m. 19. ***Filter debris analysis – a first line condition monitoring tool***, A. Donahue, GasTOPS Ltd.

9:00 a.m. 20. ***JetSCAN® SEM/EDX oil debris analysis system: monitoring bearing health of USAF F110-100/129 engines,*** A.S. Renegar, U.S. Air Force

9:30 a.m. 21. ***Finding bearing failure through filter debris analysis***, R. Overman, CMRP Advanced Information Engineering Services, Inc.

10:00 a.m. Break (15 minutes)

10:15 a.m. 22. ***Filter debris analysis by energy dispersive x-ray fluorescence applied to J52 engines***, G.R. Humphrey, Joint Oil Analysis Program Technical Support Center

10:45 a.m. 23. ***Filter debris analysis by energy dispersive x-ray fluorescence applied to F-100 engines***, G.R. Humphrey,* K.V. Hafermalz, M.A. McIntosh, and R. Clayton, Joint Oil Analysis Program Technical Support Center

11:15 a.m. Lunch (on your own)

5b. X-RAY AND MICROSCOPIC ANALYSES OF WEAR DEBRIS (cont.),* Aiden Donohue presiding

1:00 p.m. 24. ***X-ray fluorescence: new generation condition monitoring for current systems,*** C.S. Saba,*† J. Dell,‡ and J.D. Wolf,† †University of Dayton Research Institute, ‡U.S. Air Force Research Laboratories

1:30 p.m. 25. ***Condition monitoring of aerospace hydraulic and lubrication systems via filter debris analysis***, P. Madhavan,* and G. Rosenberg, Pall Corporation

2:00 p.m. Break (15 minutes)

2:15 p.m. 26. ***An innovative SEM-based algorithm for measuring complex wear particles from oil wetted components***, N.W.M. Ritchie and K. van Beek, ASPEX, LLC

2:45 p.m. 27. ***Health monitoring of oil wetted components via automated electron beam analysis***, K. van Beek and F.H. Schamber, ASPEX, LLC

3:15 p.m. 28. ***Applying Rotrode Filter Spectroscopy (RFS) and LaserNet Fines (LNF) technology to detect large wear particles of M50 alloy from J52 engine bearing failures case histories from field testing at Naval Air Station Whidbey Island***, R.J. Yurko*† and E.A. Lurton;‡ †Spectro, Inc.; ‡U.S. Navy

3:45 p.m. Engineers' forum expert panel discussion★
M. Jones (presiding), C. Hembrey, J.K. Burden, W.J. Hardmann, J.E. Tucker

4:15 p.m. Scheduled program ends

*These sessions are part of our Engineers' Forum. The Engineers' Forum is open to all registered attendees. It includes those papers of special interest to the engineering authorities responsible for weapons system design and maintenance who are tasked with improving the performance of military equipment while lowering the costs associated with operation and upkeep.

★The panel will entertain questions and comments from the floor. Any registered attendee may address the panel.. Comments from exhibitors are welcome at this time.

ABSTRACTS

1 ***Keynote address: An industry perspective on condition monitoring***

Max Rutherford
GasTOPS Ltd., 12 AMS Shearwater, Nova Scotia, Canada; Phone: 902-460-1011

This presentation will examine the field of condition monitoring from the perspective of a commercial participant. Some time will be spent examining the customers' expectations from the point of view of an operator, with an eye to assessing why he might be persuaded to invest in condition monitoring products and systems. The presentation will then examine some of the major degradation modes of aircraft propulsion systems and how various monitoring technologies are or may be used to assist in their identification. Specific examples will be used to explore the difficulty and complexity of achieving commercial and technical success in fielding such systems. Finally, an attempt will be made to correlate predictions of the future of the technology based on the relative status of each contributing element.

About the keynote speaker

Max Rutherford is President and Chief Operating Officer of GasTOPS, Ltd., a technology-based company that specializes in the development and implementation of advanced machinery maintenance, monitoring and control systems for industrial, marine, and aeronautical applications. The company was founded in 1979 and supplies Oil Debris Monitoring products for several military aircraft including the F-22, Eurofighter and JSF. GasTOPS also supplies oil and vibration analysis services for the Canadian Sea King program and has supplied software reliability centered management tools for F-18 support worldwide. The company also provides services to define and establish condition based maintenance programs based on selected machinery condition indicators.

Prior to joining GasTOPS Max was President and Chief Executive Officer of Adacel Inc., a leading supplier of air traffic control simulation and oceanic air traffic management systems. The company's MaxSim product line was selected by the U.S. Air Force to maintain operational readiness for tower operators at 94 air bases and the Aurora Air Traffic Management technology was selected by the FAA to control the world's largest oceanic airspace around the United States. Max was also president and chief operating officer of I.S.G. Technologies, Inc., an independent supplier of medical imaging software and related services to major healthcare equipment manufacturers and hospital information system integrators.

Most of Max's career was spent at CAE Electronics, Ltd., a major producer of commercial and military flight simulators and real time control systems for marine and energy applications. Max held the positions of vice president of business development and vice president of engineering with a staff of over 1200 after starting at the company as a systems design engineer. During this period, Max was responsible for launching a real-time Image Generator (MaxVue) and was responsible for the start up of a business unit developing robots for aircraft maintenance. He also published several papers and co-authored Flight Simulation, which was published by the Cambridge University Press and which has become a standard treatise on the subject.

Max is a professional engineer and has a bachelor's degree in electrical engineering and a master's degree in control engineering from the Heriot-Watt University in Edinburgh. He has also held board positions in the technology innovation community including PRECARN and the National Research Council of Canada.

2 ***Special address: Condition based maintenance plus (CBM+): a DoD initiative***

Sarah J. Smith, Colonel
U.S. Air Force, Office of the Assistant Deputy Under Secretary for Defense (OADUSD), Logistics and Materiel Readiness, Maintenance Policy, Programs, and Resources, Defense Pentagon, Room 3B915, Washington, D.C. 20301; Phone: 703-695-0338, 703-697-7980 (DSN 225-0338, 227-7980); Fax: 703-693-7037 (DSN 223-7037); E-mail: Sarah.Smith@osd.mil

CBM+ itself is an evolving set of initiatives focused on inserting technology into new and legacy systems that will improve maintenance capabilities or lead to more efficient and effective business processes. It builds on the solid foundation of condition-based maintenance—but expands that foundation to include a wide range of other maintenance and logistics considerations. Preventative maintenance, as we practice it today is effective, but costly. It doesn't necessarily prevent catastrophic failures—and all that they imply, such as very high cost repairs or complete loss of equipment. Nor has it effectively addressed the high false alarm rates we continue to experience—and the attendant costs in labor and material. CBM+, in a broad context, will address challenges such as improving diagnostics and prognostics to support concepts such as anticipatory maintenance. Solid, accurate information can enable smaller footprints of maintainers and logistics support packages. All of this can lead to more efficient operations and better use of our resources. We are building CBM+ on a toolbox full of techniques and approaches. Expanding the amount of information available about what's happening to equipment is a key element. We're looking at more and better sensors, software applications that better diagnose current symptoms, conditions and failures, and logical approaches to predict future failures. We're building expanded serialized item management programs and improving configuration management with tools such as automatic identification technology. We're hopeful that we can use AIT to make maintainers more efficient and to provide them better information across the board. Integrated electronic technical manuals are getting better—they're being integrated with training and are evolving to become more effective job performance aids. Also being looked at are improved portable maintenance aids—replacing paper technical data with electronic aids that are easy to use. But, we note that, for the foreseeable future, the individual maintainer will remain the key to effective maintenance—CBM+ is just trying to help him or her to be even more effective than they've ever been before. The challenge for the CBM+ initiative is to help develop a solid basis of information, knowledge, and experience for the Service and program leadership. With a clear understanding of the effects of CBM+, they can champion the insertion of CBM+ in the design phase, recognize the opportunity to modify legacy systems where appropriate and cost effective, and better appreciate the readiness impacts, logistics benefits, and return on investments to justify their cost of CBM+ implementation.

3 ***The value of the Army oil analysis program (AOAP) to the war fighter***

Jose Sanchez
Internal Operations, Bldg. 3661, Ajax Road, Redstone Arsenal, Alabama 35898; Phone: 256-955-0863 (DSN 645-0863); E-mail: jose.a.sanchez@us.army.mil

The Army Oil Analysis Program (AOAP) has remained a major Army maintenance program for over 40 years. Objectives of the program are to improve operational readiness of Army equipment, promote safety, detect impending component failure, and conserve resources. AOAP laboratories are equipped with the latest testing technology, and the program provides significant benefits to its customer and to the Department of Defense. Several agencies within the Defense Department have reviewed the Army Oil Analysis Program (AOAP) in order to determine the value and effectiveness of this program to the war fighter. The main purpose for the studies is to optimize the AOAP by reducing the labor hours for both the maintainer and the AOAP laboratory personnel. In November 1997, the Chief of Staff of the Army directed the Army G-4 to review the AOAP and make it more efficient. Since then, the Army Audit Agency, the Logistics Integrated Agency, and others, have studied the AOAP in detail. In addition, an economic analysis was performed by the University of Alabama. The different agencies that conducted the studies determined that the current structure of the AOAP was fragmented and suboptimal. Subsequently, the Army oil analysis program manager conducted a review and assessed alternatives that led to a restructuring plan for the AOAP. The end goal is to transform the program under the Logistics Transformation Task Force in order to maximize support to the war-fighter and advance testing technologies forward to the unit level, support the Army's vision, and reduce the logistics footprint on the battlefield by incorporating online and inline embedded sensors. During the presentation, details of the studies will be presented to show that all of the agencies that conducted the studies did in fact find tremendous value in the AOAP.

4 ***Site testing in industry – keep it simple***

Mervin H. Jones
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Over the last ten years there has been a proliferation of site test equipment. Individual instruments that measure viscosity, water, base and acidity; particle counters; and wear debris monitors are some of the most common examples. These instruments are also often batched into mini laboratories. Papers are presented at nearly every maintenance and condition monitoring conference—this conference included—that quote success stories of both their individual benefits and their combined benefits when used in on-site laboratories. What is never presented however, are the cases where an instrument, instruments, or mini laboratories have been purchased and, after a short interval, are no longer in use and often locked away collecting dust—an all too often occurrence. The question then has to be asked: "has the conference or lecturer or salesman been too effective?" An attempt will be made to explain the skepticism about on-site testing and the mini laboratory philosophy in the following arguments. These arguments apply mainly to the small to medium size engineering companies (SME) although larger companies often also fall into a similar trap. Exceptions, however, are the military services—army, navy, and air force—that require instant answers for tactical and logistic reasons.

5 ***Jet fuel viscosity and rheology at low temperatures***

Ted Selby*† and Marlin Vangsness‡
†Savant, Inc., 4800 James Savage Road, Midland, Michigan 48642, Phone: 989-496-2301, Fax: 989-496-3438, E-mail: tselby@savantgroup.com; ‡The University of Dayton Research Institute, 300 College Park, Dayton, Ohio 45469-0116, Phone: 937-252-8878 ext. 112, E-mail: Marlin.Vangsness@wpafb.af.mil

The viscosity and rheology of jet fuels is a primary consideration in determining the temperature range within which the aircraft can be operated. In particular, the tendency of the fuel to form a gelated or crystalline condition at temperatures below –45˚C can restrict the operation of the aircraft both in altitude and in flight path. This paper shows application of the scanning Brookfield technique to determine the viscosity and gelation tendencies of a jet fuel over a range of temperatures down to –65˚C. Of significance, the paper presents the first studies using this new technique to evaluate additive effects on the rheological response of jet fuels at these very low operational temperatures.

6 ***Practical options to ensure maximum lubricant and machinery reliability in a future reduced manpower environment***

Chris Leigh-Jones*† and Thomas A. Schiff‡
†Kittiwake Developments Ltd., 3-6 Thorgate Road, Littlehampton, West Sussex, BN17 7LU United Kingdom, www.kittiwake.com; Phone: 44 1903731470; E-mail: chrislj@kittiwake.com; ‡ExxonMobil Marine Lubricants – Americas, 3225 Gallows Road, Fairfax, Virginia 22037-0001; Phone: 703-846-4162; E-mail: thomas.a.schiff@exxonmobil.com

Future military machinery platforms assume a greatly reduced manpower requirement. Meeting this challenge will mean reviewing lubricant selection and monitoring systems to provide a maximum reliability and availability with minimum manpower. This paper will show that combining novel on-line oil analysis techniques covering oil and machinery condition with a well balanced "quality reserve" lubricant designed for a specific application will yield the optimum equipment reliability. To achieve this with minimal manpower and material resources, the lubricant must compensate for the harsh hills and valley's today's equipment will endure. Early detection of an impending problem through on-line monitoring of selected parameters, predictive maintenance techniques and the lubricant's performance will all have a dramatic impact on equipment's life cycle costs. This paper will illustrate how commercially available lubricants will clearly outperform standard specification lubricants through real life examples, as well as glassware testing. This paper offers a pragmatic and realistic strategy for lubrication of future machinery platforms.

7 ***The lubrication aspects of machinery health management***

Ray Garvey
Emerson Process Management–CSI, 835 Innovation Drive, Knoxville, Tennessee 37774; Phone 865-675-2400, ext. 3435; Fax: 865-218-1708; Cell: 865-207-929; E-mail: ray.garvey@compsys.com

This presentation addresses the lubrication aspect of machinery health management. It is divided into six parts. *(1) How are priorities set?* Identify a few mechanisms that cause most of the abnormal wear leading to machinery failure. *(2) What is a lubrication program?* Discuss ten elements of an effective lubrication program, including lubricants, contamination control, and monitoring. *(3) How should oil be analyzed?* Understand the reasons for choosing particular tests and the options for getting the analysis performed. *(4) How is a lubrication program managed?* Find tools that assist in managing oil analysis and lubrication data. *(5) What kinds of lubricants are there?* Learn about various mineral and synthetic lubricants and their uses. *(6) Where do we begin?* Find out what to do next, whether a program is just getting started or continually improving.

8 ***After test support in lube analysis, where the action is***

Jack Poley
J4EMS, 6619 South Dixie Highway, Unit 303, Miami, Florida 33143; Phone: 305-669-5181; E-mail: JP42444@aol.com

Testing lubricants for wear debris, contamination and degradation has arguably reached a *de facto* state. Most of the routine tests are highly similar in terms of methodology and reporting formats. Even ferrography, electron microscopy, and other less frequently applied tests are usually invoked for similar objectives. Although there are increasingly sophisticated testing instruments and processes, parameters investigated remain nearly the same, thus testing is primarily reduced to a commodity with the basic requirements of accuracy in testing and timeliness in returning data to the client. What has not become standard is the evaluation of test data in terms of determining limits and trends for flagging data and, more importantly, the interpretation or conclusion drawn from test results. Additionally there is a need to have the capability to assess true return on investment from the application of lube analysis. This paper describes a software solution, consisting of a number of specific modules and applications, that addresses virtually all the issues associated with rendering accurate diagnoses and maximizing return on investment from lube analysis program costs:(1) diagnostic algorithms that are continually updated by asfound conditions and feedback input, and statistical data mining in several formats, (2) statistical updating of the numerical traps for flagging data, inclusive of feedback considerations, (3) decision-making data for equipment acquisition and deployment and various other types of management summaries, (4) an ROI model for calculating a program's true value and financial return, incorporating cost and utility data, and utilizing statistical modeling based on reliability centered maintenance.

9 ***Improving JOAP FTIR condition monitoring analytical throughput by sample dilution***

F.R. van de Voort,† J. Sedman†, and D. Pinchuk*‡
†McGill IR Group, McGill University, Montreal, Quebec, Canada; ‡Thermal-Lube, Inc., 255 Avenue Labrosse, Pointe-Claire, Québec, Canada, H9R 1A3; Phone: 514-694-5823, 1-800-567-5823; Fax: 514-694-8628; E-fax: 347-710-2196

Although the JOAP FTIR protocol provides a relatively simple and standardized means of assessing oil condition, sample throughput is restricted by oil viscosity and the need for solvent rinsing to avoid sample carryover. A new approach to overcoming this bottleneck is presented in this paper along with supporting experimental validation data. In this new approach, the oil sample is diluted in ~1:1 ratio with kerosene containing an IR quantifiable marker. The amount of kerosene present is determined by measuring the residual marker in the sample, with the kerosene spectral contribution subsequently subtracted out of the sample spectrum on the basis of this measurement. The resulting residual oil spectrum is then "re-concentrated" mathematically to compensate for the initial dilution of the sample, and the standard JOAP FTIR spectral analysis is performed to provide the values for the oil condition parameters. In validation studies with 23 diesel oils, the analytical results obtained by this approach were very similar to those obtained for the undiluted oils. The benefit of this approach is that sample handling is facilitated because of the substantially reduced viscosity of the diluted samples while still yielding valid JOAP FTIR data. The Thermal-Lube COAT system, which is configured for the quantitative analysis of acid number, base number and moisture, is now

also able to run the standard JOAP FTIR protocol at speeds of >120 samples/h without rinsing between samples.

10 ***Quantitative lubricant analysis by FTIR spectroscopy: determination of acid number, base number, and water***

F.R. van de Voort,† J. Sedman†, D. Pinchuk,*‡ and R. Cocciardi‡
†McGill IR Group, McGill University, Montreal, Quebec, Canada; ‡Thermal-Lube, Inc., 255 Avenue Labrosse, Pointe-Claire, Québec, Canada, H9R 1A3; Phone: 514-694-5823, 1-800-567-5823; Fax: 514-694-8628; E-fax: 347-710-2196

FTIR spectroscopy is a well-known, rapid, instrumental technique that is widely employed for lubricant condition monitoring as exemplified by the JOAP FTIR protocol. Less well known is the applicability of FTIR spectroscopy for the determination of acid number (AN), base number (BN) and moisture (H_2O) content of lubricants. This recently developed quantitative methodology is based on a combination of signal transduction and differential spectroscopy to overcome the lack of chemical specificity of FTIR analysis and eliminate the need for a reference oil to compensate for matrix effects. Because the methodology involves dilution of the sample, sample viscosity is reduced, resulting in higher analytical throughputs. An automated FTIR AN/BN/H_2O analyzer capable of analyzing ~60 samples/hour is now commercially available. The COAT analyzer provides an analytical platform and software that facilitates the implementation of the quantitative analytical methodology developed for the determination of three key oil parameters and, with the use of an innovative dilution procedure, also allows JOAP FTIR condition monitoring analyses to be carried out at a rate of >120 sample/hour. These rapid, accurate, and highly reproducible FTIR methods represent a significant advance in integrating quantitative and qualitative methods into a single instrument configuration, with high sample throughputs that will be of substantial benefit to high-volume oil analysis laboratories.

11 ***Diesel engine portable fluid analyzer: a shipboard CBM enabling technology***

John E. Tucker,*† John Reintjes,‡ Tom Sebok,§ Pat Henning,¶ and Larry L. Tankersley☐
†Code 5614, Naval Research Laboratory, Washington, D.C. 20375, ‡Code 5604, Naval Research Laboratory, Washington, D.C. 20375, §Lockheed Martin Maritime Systems and Sensors, 1210 Massillon Road, Akron, Ohio 44315-0001, ¶Foster-Miller Inc., 195 Bear Hill Road, Waltham, Massachusetts 02451-1003, ☐Physics Department, 566 Brownson Road – Ricketts 305, U.S. Naval Academy, Annapolis, Maryland 21402; Phone: 330-796-9725 (TS), 781-684-4188 (PH), 410-293-6653 (LLT); E-mail: tucker@nrl.navy.mil, reintjes@ccsalpha3.nrl.navy.mil, thomas.sebok@lmco. com, phenning@foster-miller.com, tank@usna.edu

Oil sample analysis often suffers in a shipboard environment due to the long time it takes to deliver a sample to an analysis lab, and to get the results back to the ship. Many times, when the results arrive back to the ship, a piece of equipment has failed and an opportunity was lost to identify it prior to the failure. Having the capability to perform an on-site evaluation of machinery health through a comprehensive machinery fluid monitor significantly improves the effectiveness of equipment inspections. The Naval Research Laboratory with Lockheed-Martin and Foster-Miller under an ONR Tech Solutions program, have combined several advanced diagnostics in a single instrument package to provide an on-site comprehensive oil monitor for use by diesel engine inspectors. This instrument combines the LaserNet Fines wear debris monitor, the FluidScan oil condition monitor and a compact viscometer and is designed to be used on-site, away from a laboratory environment. The LaserNet Fines instrument determines the type, severity and rate of progression of mechanical faults by measuring the size distributions, rate of production and the morphological analysis of debris particles in fluids. It has been used to monitor a wide range of equipment including diesel engines, cranes and hydraulic system. The FluidScan instrument monitors fluid properties through the infrared transmission of the fluid and has been installed inline on several U.S. Navy ships. It monitors fluid properties such as water, soot, oxidation, nitration, sulfation, glycol, anti-oxidation depletion and TBN in diesel lubricating oil. Software was developed to control each instrument and to combine their results in a combined report assessing machinery health.We present results obtained by the diesel inspectors during an evaluation period of shipboard oil samples.

12 ***Diesel engine test stand evaluations of on-board oil condition monitoring sensors for U.S. Army ground equipment***

Robert E. Kauffman,*† Larry D. Sqrow,† J. Douglas Wolf,† Steve C. Moyer,‡ and Joel A. Schmitigal‡
†University of Dayton–UDRI, Dayton, OH 45469-0161; ‡U.S. Army TACOM-TARDEC, AMSTA-TR-D/210, MS 110, Warren, Michigan 48397; Phone: 937-229-3942 (REK), 586-574-4206 (SCM); E-mail: Kauffman@udri.udayton.edu, moyers@tacom.army.mil

This paper describes the second year of a project to develop an inexpensive, compact on-board sensor system for condition monitoring the in-service diesel engine oils of U.S. Army vehicles and ground support equipment. A high mobility multi-wheeled vehicle (HMMWV) diesel engine test stand was used to evaluate the capabilities of different sensors to monitor four specific changes in oil condition: soot accumulation, accelerated oxidation, coolant leaks and fuel dilution. The HMMWV diesel engine was selected for this work based on its low cost and wide use by the Army. The four diesel engine test stand evaluations described herein determined that two different types of sensor systems would be suitable for on-board use. Conductivity sensors and a battery operated electronics package were attached to a HMMWV diesel engine dipstick to produce the first sensor system. The "dipstick sensor system" could be used in place of the current engine dipstick to monitor oxidation, coolant contamination, fuel dilution and fluid level of in-service oil before engine start-up or directly after engine shut down. A magnetic plug, manual or electronic, could be used in place of the oil drain plug to monitor the production of magnetic (iron) debris. The other sensor system used a suite of sensors incorporated into an oil radiator hose by-pass to monitor soot accumulation, oxidation, coolant contamination, magnetic wear debris production and fuel dilution of in-service oils during engine operation. The suite of sensors included a dielectric sensor, two different conductivity sensors, a magnetic plug and an infracal soot sensor.

13 ***Detection of severe sliding and pitting fatigue wear regimes through the use of broadband acoustic emission***

E. D. Price,† A. W. Lees,† and M. I. Friswell‡
†School of Engineering, University of Wales–Swansea, Singleton Park, Swansea SA2 8PP, United Kingdom; ‡Department of Aerospace Engineering, Queens Building, University of Bristol, Bristol BS8 1TR, United Kingdom; E-mail: e.d.price@swansea.ac.uk, a.w.lees@swansea.ac.uk, b.j.roylance@swansea.ac.uk, M.I.Friswell@bristol.ac.uk

Acoustic emission techniques have been used to monitor severe sliding and pitting fatigue processes during four-ball testing. Results are presented that arose from a collaborative programme between the Naval Research Laboratory (Washington, D.C.) and the University of Wales–Swansea, sponsored by the U.S. Office of Naval Research. The ultimate aim of the research is to develop a systematic fusion technology approach to condition-based maintenance of wear-related surface distress of critical components in naval air and surface combatant engine and transmission systems. The principal monitoring techniques utilized in the investigation comprise acoustic emission, vibration analysis and wear debris analysis; however, only AE results are included here. A custom data acquisition system was developed using a novel approach to collect AE signals. Post-test analysis of the data, in the frequency domain, demonstrates the advantage of analysing continuous AE and not just AE pulses.

14 ***Real-time, non-invasive, ultrasonic detection of foreign material in process streams***

Aaron A. Diaz, Leonard J. Bond,* Todd J. Samuel
Battelle Pacific Northwest National Laboratory, 2400 Stevens Drive, Richland, Washington 99352; Phone: 509-375-2606 (AAD), 509-375-4486 (LJB), 509-375-6707 (TJS); Fax: 509-375-6736; E-mail: aaron.diaz@pnl.gov, leonard.bond@pnl.gov, todd.samuel@pnl.gov

During manufacturing or processing, the presence of foreign material in a process stream can be a significant problem. The Pacific Northwest National Laboratory (PNNL) has developed a method for real-time, non-invasive ultrasonic detection of foreign matter in both homogeneous and inhomogeneous process streams. A novel, off-angle ultrasonic scattering approach is used as the basis for the detection methodology involving measurements of scattered ultrasonic energy from a configuration of pitch-catch transducers that are coupled to the process stream. The scattered ultrasonic energy from these pulses are analyzed in terms of time-of-flight, amplitude and frequency content to extract information about the process stream and rapidly detect foreign matter during the manufacturing process. Examples will be presented describing examinations of process streams with a focused sound field that spans a portion of the stream. The off-angle scattering

response to the interrogating sound field is then detected with a plurality of spaced receivers, with the presence of foreign material determined from the received response. This talk will focus on technical aspects of the detection protocol, applications in the food processing industry, and how the methodology might apply to condition monitoring of fluids and oils.

15 ***Application of a microelectromechanical sensor to oil analysis***

Andrew J. Niksa and Raymond J. Daley*
Magnus Equipment/Predict, 9555 Rockside Road, Cleveland, Ohio 44125, Phone: 216-642-3223, E-mail: rjdalley@predictusa.com

The paper will present a new microelectromechanical oil sensor (MEMS) and its application. The sensor is designed to detect changes in internal combustion engine lubricating oils that are a result of wear and contamination. A unique combination of data is collected from the sensor rather than a single measurement. The theory of operation will be discussed. Data results and correlation to oil condition will be shown. Trending of the data is more valuable as the sensor is on-line with the capability of monitoring continuously.

16 ***JetSCAN® oil debris analysis system: improving aircraft readiness for the AV-8B Harrier***

Brian J. Stoll, Engine In-Service Engineering Branch 1 (AIR-4.4.8.1), AV8 Fleet Support Team – Propulsion (AV8FST.3), Naval Air Systems Command, PSC Box 8021 (Code 4.4.8.1), MCAS Cherry Point, North Carolina 28533-0021; Phone: 252-464-9865 (DSN: 451-9865); Fax: 252-464-7147 (DSN: 451-7147); E-mail: stollbj@navair.navy.mil

The oil system monitoring (OSM) program for the AV-8B Harrier's F402-RR-408A/B engines, includes analysis of debris captured by two magnetic chip detectors. Discovery of a large particle requires the particle to be analyzed to determine its elemental composition, which can then be cross-referenced to material specifications and possible source components within the engine oil system. The criticality of this inspection demands the aircraft remain grounded pending the laboratory analysis results. Aircraft within close proximity to a laboratory have typically experienced a downtime of 24 hours. However, aircraft aboard ship or forward deployed have historically experienced downtimes of seven to ten days due to sample transit times to the nearest laboratory. The loss of an aircraft for that length of time is detrimental to fulfilling the operational requirements of the forward deployed or shipboard activities. To answer the need for increased readiness, the AV8 fleet support team, in conjunction with Data Systems & Solutions, tested and approved the use of the JetSCAN® oil debris analysis system. The JetSCAN® is a transportable, automated SEM/EDX machine that requires minimal training. It has the capability of automatically measuring (geometrically) and performing an EDX analysis of identified particles, and then determine the most likely material specification from its database of materials. Use of the JetSCAN® has significantly reduced the inspection time and has eliminated the requirement of a laboratory near an aircraft operating location. Information on the benefits of this technology, its developmental evolution for the F402 series of engines, its success during Operations Enduring Freedom and Iraqi Freedom, and future plans for more extensive use within the F402 engine OSM program will be presented.

17 ***Propulsion system diagnostics***

William J. Hardmann
U.S. Navy, AIR 4.4.2, Propulsion and Power Diagnostics Team, NAVAIR, B106, Unit 4, 22195 Elmer Road, Patuxent River, Maryland 20670-1534; Phone: 301-757-0508; Fax: 301-757-0562; E-mail: william.hardman@navy.mil

An overview of NAVAIR propulsion system diagnostic programs will be presented. Topics will include current fixed and rotary wing diagnostic systems, a brief overview of *joint strike figher prognostics and health management*, as well as the results of some seeded fault testing. The Defense Advanced Research Projects Agency (DARPA) prognosis materials based research program will also be covered. Finally, a data warehousing and mining effort known as *integrated aircraft health management* will be discussed as it relates to maximizing utilization of collected operational and maintenance data.

18 ***The U.S. Army's effort to implement an embedded oil analysis sensor***

Judy K. Burden,*† R. McWhorter,‡ and Dawn M. Gratz§
†Contract Support PM-TMDE ACED, Analytical Services, Inc., 689 Discovery Drive, Suite 300, Huntsville, Alabama 35806, Phone: 256-890-0083 ext. 151; Fax: 256-890-0242; E-mail: burdenj@asi-hsv.com; ‡Director of Technology and Acquisition, Army Oil Analysis Program, Logistics Support Activity, Bldg. 3661 Ajax Road, Redstone Arsenal, Alabama 35898; Phone: 256-955-6661 (DSN 645-6661); Fax: 256-876-9344 (DSN 746-9344); §Army Common Embedded Diagnostics, SFAE-CSS-ME-T-A; Phone: 256-955-6884 (DSN 645-6884); Fax: 256-955-6361 (DSN 645-6361); E-mail: dawn.gratz@us.army.mil

The focus of this effort is to find a commercial-off-the-shelf (COTS), in-line oil condition sensor suitable for use in Army tactical, wheeled and track vehicles. The in-line oil condition sensor will notify the soldier in the field that oil maintenance is required. The anticipated benefit is the reduction in labor hours for both the maintainer and AOAP lab personnel expended in drawing, shipping, and analyzing oil samples. The main thrust is to support the Army's transition from reactive maintenance to proactive maintenance, from demand logistics to anticipatory logistics, and eventually from diagnostics to prognostics. The sensor will visually notify the soldier by different colored lights when the condition of the oil merits changing due to depleted additives or out of tolerance total acid number merits testing due to contaminant detection, or simply merits replenishing due to low oil level is low. The sensor needed is self-calibrating and with built in memory for use in trend analysis. The output data will be made available to the Army's Surface Health Usage Monitoring System (SHUMS) for further analysis via one of the standard buses, such as J1708, 1553 or 1939. A cost analysis performed by the assistant product manager, Army Common Embedded Diagnostics (ACED), Office of the Product Manager, Test Measurement and Diagnostic Equipment (PM TMDE) will be included.

19 ***Filter debris analysis – a first line condition monitoring tool***

Aiden Donahue
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Mechanical systems begin to wear as soon as they are put into operation. Monitoring the wear debris shed by a mechanical system provides valuable insight into its health. Historically, wear debris generation has been typically monitored by various oil analysis techniques such as ferrography and spectrometric oil analysis. With oil wetted systems moving toward finer and finer filtration, the wear debris normally monitored by these techniques is no longer left in the oil but is now trapped by the system's filter. Lube oil filters and their efficiency is not well understood and it has a big affect on debris capture efficiency and the type of debris that is captured by the filter. Filter debris analysis (FDA) has been around for almost 20 years. It has its origin in Canada with the Defense Research Establishments and a project to address main gearbox failures on the Sea King helicopter back in the mid-1980s. The project was so successful that the technique continued to develop and became an integral part of the helicopter's maintenance program. The FDA program eventually migrated to other aircraft, engines and fuel filters. It has evolved from a very long and manpower intensive, qualitative and subjective technique to a simple, quick and accurate technique for determination of a system's health. Filter debris analysis is now a deployable first line condition monitoring technique used around the world to determine the health of aircraft oil wetted components. The presentation will discuss wear debris in mechanical systems, filtration and filter efficiency and the application of Filter Debris Analysis to determine equipment health.

20 ***JetSCAN® SEM/EDX oil debris analysis system: monitoring bearing health of USAF F110-100/129 engines***

Andrew S. Renegar
U.S. Air Force Propulsion Systems Engineering Branch, F110 Engineering Team (OC-ALC/LPARA), 3001 Staff Drive, Suite 2AC1-105A, Tinker AFB, OK 73145; Phone: 405-736-5226 (DSN 336-5226); E-mail: Andrew.Renegar@tinker.af.mil

The JetSCAN® is a field-deployable scanning electron microscope/energy dispersive x-ray (SEM/EDX) system. The USAF GE F110 Engine program has employed the JetSCAN® system to be used at the field level for diagnostic analysis of debris extracted from engine oil system; the express purpose for this is to manage the risk associated with the failure of oil wetted components (primarily main bearings). After each flight, debris collected on the master chip detector (MCD: a device that extracts magnetic debris from circulating engine oil) is subjected to JetSCAN® analysis: For every particle, in any given debris sample, the

footprint surface area is calculated and chemical composition is quantitatively evaluated. If chemical composition corresponds to a significant/targeted alloy the particle's surface area is tabulated under that alloy designation. JetSCAN® has provided a consistent method of monitoring engine oil system health at the base level, ensuring quick go/no-go responses to engine airworthiness. Details of JetSCAN® operation, deployability, and improvements will be discussed along with case histories of bearing failure "saves."

21 ***Finding bearing failure through filter debris analysis***

Richard Overman
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Bearings give many different warnings when they are going bad. Some of these warnings include increased vibrations, noise, and the loss of bearing material. Each warning can be detected by different techniques. Vibration can be detected by vibration analysis, noise by listening, and bearing material loss by filter debris analysis (FDA). Vibration analysis is commonly used and well-known, and listening for noise is often too late. On the other hand, FDA is not well-known, but it is a powerful tool. This paper reports on an analysis of a jet engine bearing and the use of FDA to detect impending failures. The paper describes the FDA process, bearing failure stages, and how all of this information was pulled together through reliability-centered maintenance analysis to develop a cohesive function preservation strategy.

22 ***Filter debris analysis by energy dispersive x-ray fluorescence applied to J52 engines***

Gary R. Humphrey
Joint Oil Analysis Program Technical Support Center, 85 Millington Road, Pensacola, Florida 32508; Phone: 850-452-3191 ext. 105; E-mail: ghumphrey@joaptsc.navy.mil

The Joint Oil Analysis Program Technical Support Center (JOAP-TSC) has developed a technique to analyze the debris from in-line jet engine oil filters by energy dispersive x-ray fluorescence (FDA-EDXRF). Six beta prototype instruments were manufactured under a Productivity Reliability Availability and Maintainability (PRAM) project that are capable of performing FDA-EDXRF in an automated mode. J52 engines were suffering from what appeared to be sudden, catastrophic failures – where the root cause of the failure began with the lack of lubrication in the 4½ bearing area followed by fracturing of the 4½ bearing cage. Initially, analysis of oil samples by rotrode emission spectroscopy (RDE) did not indicate the failure mode. FDA-EDXRF was employed to establish wear limits for the debris extracted from engine oil filters; particle count wear profiles were developed from the debris extracted from the engine oil filters and abnormal bearing wear could be diagnosed. Initially, filter debris obtained from J52 filters that indicated abnormal amounts of bearing wear were also analyzed by Pratt & Whitney Aerospace laboratory using a scanning electron microscope (SEM). The SEM results confirmed the presence of bearing wear. Subsequent teardowns of a portion of the engines having abnormal bearing wear had fractuered 4½ bearing cages. This paper will outline how the JOAP-TSC beta prototype instruments and FDA technology have kept the J52 fleet flying.

23 ***Filter debris analysis by energy dispersive x-ray fluorescence applied to F-100 engines***

Gary R. Humphrey,* Kristina Hafermalz, Mark A. McIntosh, and Robert Clayton
Joint Oil Analysis Program Technical Support Center, 85 Millington Road, Pensacola, Florida 32508; Phone: 850-452-3191 ext. 105; E-mail: ghumphrey@joaptsc.navy.mil

The Joint Oil Analysis Program Technical Support Center (JOAP-TSC) was awarded a project from the U.S. Air Force Productivity, Reliability, Availability, and Maintainability (PRAM) office. The project entailed automating the removal of debris from engine oil filters, presenting the debris for energy dispersive x-ray fluorescence (EDXRF) analysis and provide software to manipulate the x-ray hardware and report EDXRF analyses. The JOAP-TSC put in place the requirements to construct beta prototype instruments with the above capabilities. PRAM beta prototype instruments were located at LUnited Kingdome AFB and Seymour-Johnson AFB to analyze filters from F-100 engines. The JOAP-TSC applied filter debris analysis using energy dispersive x-ray fluorescence analysis (FDA-EDXRF) to profile F-100 engines. Data from the F-100 engine FDA-EDXRF profile was used to indicate abnormal wear. Engines that indicated abnormal and normal wear by FDA-EDXRF metrics were researched using the AF maintenance database. The results demonstrated an excellent correlation with the wear found in F-100 engines.

24 ***X-ray fluoresence: new generation condition monitoring for current systems***

Costandy S. Saba,*† Jon Dell,‡ and J. Doug Wolf†
†University of Dayton Research Institute, 300 College Park, Dayton, Ohio 45469-0166; ‡AFRL/PRTM, U.S. Air Force, Air Force Research Laboratories (PRTM), Wright Patterson AFB, Ohio 45433-7103; Phone: 913-255-3141, DSN 785-3141 (CSS); E-mail: costandy.saba@wpafb.af.mil

An analytical tool been developed that modifies/combines known x-ray fluorescence and transmission analysis and video imaging techniques for fast, automated analysis of lubrication system wear debris. It is applicable to debris taken from magnetic chip detectors and oil samples of gas turbine engines. Procedures for isolating, mounting, and analyzing the wear debris for multi-samples have been developed. This analytical technique can accomplish the task currently being done on debris and oil samples from military gas turbine engines with two techniques using costly instruments. Debris from magnetic chip detectors is being analyzed at some locations with expensive scanning electron microscopes. However, XRF can analyze chip detector debris for failure detection as effectively as SEM but at much lower cost. XRF has the added advantage of detecting the presence of metallic alloys of interest at a greater depth in the debris than the SEM system. Oil samples are also being analyzed with atomic emission spectrometers that require a cumbersome field wide coordinated calibration program. While AE spectrometers are limited to wear debris particle size to less than 10 µm, this approach can effectively detect impending failure better than AES due to its capability of detecting and analyzing the full range of debris sizes expected without upper size limitations.

25 ***Condition monitoring of aerospace hydraulic and lubrication systems via filter debris analysis***

Puliyur Madhavan* and Gary Rosenberg
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Evaluation of the composition of filter debris as a diagnostic tool to monitor the condition of fluid systems has gained prominence over the last decade, and techniques such as x-ray fluorescence spectroscopy have been employed to determine the chemical composition of engine lube filter debris, necessary for diagnosis of potential lube system component wear modes, and even some modes of fluid degradation. In this paper, the use of a diagnostic filter, coupled with a custom filter debris analyzer, designed for effective, convenient debris monitoring in fluid systems, to monitor debris in aerospace hydraulic and lubrication systems is discussed. The diagnostic filter has several configurations that allow for convenient analysis of the captured debris. The analysis of the chemical composition of filter debris is accomplished with a custom designed, portable filter debris analyzer, based on x-Ray fluorescence spectroscopy, currently in the beta prototype testing stage. The debris analyzer is custom designed to accommodate sections of the diagnostic filter. In its final configuration, the analyzer software will allow users to develop their own system specific database/expert system for debris analysis. Results from the use of the diagnostic filter/debris analyzer to evaluate debris from aircraft hydraulic systems and helicopter transmission lube systems during on-ground testing are presented and discussed to illustrate the value of the debris monitoring system for on-ground testing. This allows for qualification of manufacturing/assembly processes with respect to built-in debris. The benefits of the debris monitoring system, described above, can also be realized for hydraulic and lubrication systems during service operation.

26 ***An innovative SEM-based algorithm for measuring complex wear particles from oil wetted components***

Nicholas W.M. Ritchie and Kai van Beek
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Early in the days of computer controlled scanning electron microscope (SEM) technology, a particle-sizing algorithm was developed which took advantage of the electron-beam nature of the SEM to provide both fast and accurate measurements of simple particles. This algorithm, called the rotating chord algorithm, took advantage an SEM's ability to raster the electron probe along arbitrary axes and to dynamically adjust the step size between pixels. In recent years, many SEM manufacturers have drifted away from this algorithm towards a frame-based image analysis. Frame-based techniques are slower and less precise but are more capable of handling complex particle shapes and are simpler to implement. By using frame-based analysis, these vendors lost many of the advantages of an electron beam instrument. We will present a novel and

innovative algorithm that leverages the capabilities of an SEM to combine the advantages of the rotating chord and the frame-based image analysis techniques. This algorithm is both faster and more precise than typical frame-based techniques. Like the rotating chord algorithm is capable of analyzing particles as they are discovered thereby minimizing the likelihood of losing small particles. To demonstrate how this algorithm is particularly beneficial for oil wear debris analysis, we will present speed and precision data collected on the complex particles characteristic of wear debris from oil-wetted components.

27 ***Health monitoring of oil wetted components via automated electron beam analysis***

Kai van Beek and Frederick H. Schamber
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Diagnostic analysis of debris extracted from an oil system can provide an early warning of incipient failure, and is particularly valuable when such determination can be accurately conducted under field conditions. Understanding the source and nature of such particulate contaminants is critical for accurate risk assessment. When an optimized electron beam analysis tool performs automated microscopic examination, it provides not only distributions of particulate material by size and shape, but also accurate classification by composition. Detailed images of individual particles are also readily obtained and can be a great aid to source evaluation. Recent advances in instrument form factors, enabling technologies, and user interactions now bring the power of SEM/EDX technology to locations and environments previously unthinkable. Requiring only a standard electrical outlet, an automated SEM/EDX system will be described that can be rolled or forklifted into place and be operational in under ten minutes.

28 ***Applying Rotrode Filter Spectroscopy (RFS) and LaserNet Fines (LNF) technology to detect large wear particles of M50 alloy from J52 engine bearing failures case histories from field testing at Naval Air Station Whidbey Island***

Robert J. Yurko,*† and Elizabeth A. Lurton‡
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This presentation will review the factors that limit the wear particle detection efficiency of rotating disc electrode (RDE) spectroscopy used throughout the Joint Oil Analysis Program (JOAP). Rotrode Filter Spectroscopy (RFS), a proven technology for large wear particle analysis, will be described along with details of its application to aviation gas turbine engines. RFS enhances the sensitivity of the existing RDE spectrometer by extending its analytical capability to vaporize wear particulates greater than 10 µm and can identify their elemental composition to determine if alloys, such as M50, are generating these particles. LaserNet Fines (LNF), a relatively new technology developed for the Office of Naval Research (ONR) by Lockheed Martin, will be discussed. LNF is an instrument that optically counts particles from 4 µm to greater than 100 µm and creates images of those particles which exceed 20 µm and classifies them into wear particle categories such as fatigue or severe sliding. The application of these two particle identification technologies to condition monitoring of J52 aviation gas turbine engines at NAS Whidbey Island was innovative and has provided valuable insight into enhanced wear particle analysis capability. This presentation will include field and laboratory data gathered from an eight month evaluation of the effectiveness of these technologies. Several case histories of J52 engines will be presented comparing conventional JOAP spectroscopic analysis to RFS analysis for the same routine samples, including engines with bearings in the early stages of failure. Laboratory test data of sieved M50 alloy particulates will also be presented comparing conventional JOAP analysis to RFS analysis.

Key Underline denotes the presenting authors.
*Asterisks denote the corresponding authors.

TRAINING COURSES

Training courses will be held in the Beachside Resort connected to the Hilton via a covered walkway.

Monday afternoon, April 19, 1:00 p.m. – 5:00 p.m.

1 An overview of oil analysis techniques, Dan Anderson, Spectro, Inc.

Tuesday morning, April 20, 8:00 a.m. – 12:00 noon

2a Basic error analysis and statistics, Daniel C. Harris, Ph.D., U.S. Navy

Tuesday afternoon, April 20, 1:00 p.m. – 5:00 p.m. (concurrent classes, both cannot be taken)

2b JOAP correlation statistics, Marilyn Squalls, JOAP TSC

2c Filter debris analysis, Gary Humphrey, JOAP TSC

Wednesday morning, April 21, 8:00 a.m. – 12:00 noon

3a Infrared spectroscopy and spectral interpretation, Timothy W. Collette, Ph.D., Environmental Protection Agency

Wednesday afternoon, April 21, 1:00 p.m. – 5:00 p.m.

3b Oil analysis on the Digilab FTIR spectrometer, Mike Fuller, Ph.D., Digilab

Thursday morning, April 22, 8:00 a.m. – 12:00 noon

4a Atomic emission spectrometry, Edward T. Urbansky, Ph.D., JOAP TSC

Thursday afternoon, April 22, 1:00 – 5:00 p.m. (concurrent classes, both cannot be taken)

4b Oil analysis on the Spectroil M, Bob Yurko, Spectro, Inc.

4c Ferrography, Ray Dalley, Predict

See course description and instructor information on the following pages.

COURSE DESCRIPTIONS AND INSTRUCTORS

An overview of oil analysis techniques

Course no. 1 | Mon., April 19, 1:00 p.m. | Daniel P. Anderson
$15 | anderson@spectroinc.com

About the course

There are a variety of analytical instruments available to answer the two main questions posed by oil analysis, namely, the condition of the machine and the condition of the lubricant. This workshop will focus primarily on the instruments and techniques for measuring wear and contaminant particles, with minor emphasis on determining lubricant condition since this topic is covered more extensively in other workshops being held this week. Topics to be covered include atomic emission spectrometry (i.e., rotrode, inductively coupled plasma), ferrography, particle counting, laser net fines, and the behavior of large particles in oil.

About the instructor

Daniel P. Anderson graduated from MIT in 1970, majoring in materials science and metallurgy. He worked for seven years as an aerosol scientist and instrumentation engineer before beginning his career in tribology with the Foxboro Company. He joined Foxboro in 1977 as lab manager of the ferrography product group. He prepared the *Wear Particle Atlas (Revised)* in 1982, still the primary reference on ferrography. He moved to Cleveland in 1984 to become lab manager when Predict Technologies was first started by Standard Oil of Ohio. He joined Spectro, Inc., manufacturer of oil analysis spectrometers, in 1986, and has traveled extensively— promoting and installing instruments and turnkey laboratories for predictive maintenance by oil analysis. He is the inventor of rotrode filter spectroscopy. In 1991, he was one of the founders of National Tribology Services, a commercial oil analysis laboratory, recently sold to the Bently Nevada Company. He is now vice president of sales for Spectro Inc. in Littleton, Massachusetts.

Basic error analysis and statistics

Course no. 2a | Tues., April 20, 8:00 a.m. | Dan Harris, Ph.D.
$25 | daniel.harris@navy.mil

About the course

This course will introduce the student to data analysis. We begin with the statistical treatment of a single set of data, estimating the uncertainty in an individual measurement, and computing the uncertainty in the average. Next, we compare average values to determine if they really are different and propagate the errors in their ratios and differences. Finally, we move onto two-dimensional data analysis, where we find the best fit line using unweighted linear regression. Students will be taught to use a spreadsheet and a scientific calculator to analyze laboratory data. A TI-36X calculator is required and provided for this course; its cost is built into the course fee.

About the instructor

Daniel C. Harris is a senior scientist in the chemistry division of the research department at the Naval Air Systems Command, China Lake, California. Dr. Harris is the author of the most widely used analytical chemistry textbook, *Quantitative Chemical Analysis* (6th edition, W. H. Freeman, 2002). In an earlier life, he taught chemistry at the University of California at Davis and at Franklin and Marshall College in Pennsylvania. He has degrees in chemistry from Caltech and Massachusetts Institute of Technology. His primary responsibilities in the Defense Department are in research, development, and engineering of optical window materials.

JOAP correlation statistics

Course no. 2b | Tues., April 20, 1:00 p.m. | Marilyn S. Squalls
$15 | msqualls@joaptsc.navy.mil

About the course

We will present statistical terms that are routinely encountered and give examples of how statistics are use to calculate a laboratory's correlation score for performance on spectrometric analysis. To provide some hands-on experience, we will work with actual data. Students will have the opportunity to determine the passing range for any element from the February 2003 correlation, so bring your score sheet from February 2003. We will do the calculations and show you why you received a *fail* or a *pass* for that element.

About the instructor

Marilyn Squalls graduated from Northwestern University in 1980 with a major in chemistry. She has worked for the JOAP Technical Support Center since 1981. While at the TSC, Ms. Squalls has worked in a number of areas including standards production, analytical testing in the JOAP laboratory, the atomic emission spectrometry correlation program, FTIR pilot correlation program, and hydraulics testing. She is a member of the Society of Tribologists and Lubrication Engineers (STLE) and the American Society for Testing and Materials (ASTM).

Filter debris analysis

Course no. 2c | Tues., April 20, 1:00 p.m. | Gary R. Humphrey
$15 | ghumphreys@joaptsc.navy.mil

About the course

We will outline the history, theory, and operation of instrumentation for filter debris analysis and highlight some success stories. Examples of engines diagnosed with problems by FDA will be discussed. Terminology and concepts of energy dispersive x-ray fluorescence (EDXRF) analysis, thin film analysis, and fundamental parameters will be discussed. Basic information will be provided on the operation of an EDXRF system. FDA concepts such as creating initial baseline for equipment, how EDXRF results relate to the metallurgy of an oil system and creating charts to predict possible sources of alloys. Contaminants that can enter an oil system will also be discussed. Basic understanding of oil analysis concepts would be helpful, but not required. This class will be held at the Technical Support Center at the Naval Air Station due to operational requirements and environmental controls. Transportation will be provided to the TSC and back to the conference site.

About the instructor

Gary R. Humphrey is the senior navy chemist at the JOAP Technical Support Center. Mr. Humphrey earned a B.S. in chemistry from the University of Pittsburgh. He was a supervisor of the Navy's oil analysis laboratory for 8 years. During his tenure as a laboratory supervisor he developed criteria linking moisture content of synthetic oil to corrosion metals generated by helicopter gearboxes. Several papers were written and presented on the subject with subsequent award recognition from NAVAIR. Mr. Humphrey joined the JOAP-TSC in 1991 and worked in the areas of particulate contamination measurement and identification. He has authored and published numerous papers detailing particulate contamination measurement and its relationship to wear in machinery. His latest accomplishment has been the development of filter debris analysis using energy dispersive x-ray fluorescence (FDA-EDXRF). Mr. Humphrey developed the FDA-EDXRF procedure; subsequently, the JOAP-TSC was awarded a project by the USAF to build and field test six prototype instruments. Mr. Humphrey was the prime JOAP-TSC recipient for the NAVAIR Commander Fliedner Award.

Infrared spectroscopy and spectral interpretation

Course no. 3a | Wed., April 21, 8:00 a.m. | Timothy W. Collette, Ph.D.
$15 | collette.tim@epa.gov

About the course

Infrared spectroscopy is one of the most practical analytical techniques for identifying simple organic and inorganic chemicals, and also for identifying the functional groups of very complex chemicals and chemical mixtures. However, the power of the approach depends on the ability to manually interpret spectra since libraries typically contain reference spectra of only the most common pure chemicals. (Unfortunately, strategies for spectral interpretation are typically not taught in science degree programs.) This course will include a very brief introduction to the classical theory of vibrational spectroscopy (infrared and Raman), with emphases on how this theory leads to chemical structural elucidation. The "time-honored" approach of group frequency analysis for interpreting infrared spectra will be described using—as examples—the functional groups most commonly encountered in organic chemicals (e.g., CH, C=O, OH, NH, phenyl, etc.).

About the instructor

Timothy W. Collette has been a research chemist at the U.S. Environmental Protection Agency's National Exposure Research Laboratory in Athens, Georgia, since 1985. He received the B.S. degree in chemistry from Berry College (Mount Berry, Georgia) in 1981 and the Ph.D. degree in physical chemistry from the University of Georgia in 1985. Dr. Collette has over 20 years of experience applying infrared and Raman spectroscopy to "real-world" problems, primarily in environmental science. The solution to many of these problems has required in-depth spectral interpretation. For example, he has used infrared spectroscopy, coupled to gas chromatography, to identify previously unknown—and unsuspected—chemical byproducts that are formed when drinking water is disinfected.

Oil analysis on the Digilab FTIR spectrometer

Course no. 3b | Wed., April 21, 1:00 p.m. | Mike Fuller, Ph.D.
$15 | mike_fuller@digilabglobal.com

About the course

This course will discuss the theory and practical applications of infrared spectroscopic methods for the analysis of engine fluids. Infrared techniques have been employed in the analysis of used engine oils since the 1960s. While the basic sampling approaches have not changed radically since that time, the use of automation and advanced chemometric algorithms have extended the value of the analytical approach. With modern instruments more than sixty samples can be analyzed per hour in an unattended mode of operation. This course will discuss the measurement of oxidation, sulfation, residual fuel, soot, glycol, and water in engine fluids. In addition, an approach to measuring total base number (TBN) will be presented.

About the instructor

Mike Fuller is the Chief Technology Officer for Digilab, a provider of products and services in the area of molecular spectroscopy specializing in Raman and infrared spectroscopies. Dr. Fuller earned his Ph.D. in analytical chemistry at Ohio University. After working as the infrared group leader at the R&D Center of Phillips Petroleum for five years he joined Nicolet Instruments. During his time at Nicolet he lead the development of the first dedicated FTIR system for used oil analysis—the Nicolet model 8210. During his time at Nicolet he also was the vice president of marketing and later the vice president of product development. In the summer of 2003 he joined Digilab and is currently, among other activities, the acting product manager for the Digilab oil analysis systems.

Atomic emission spectrometry

Course no. 4a | Thur., April 21, 8:00 a.m. | Edward T. Urbansky, Ph.D.
$15 | eurbansky@joaptsc.navy.mil

About the course

We will begin with basic principles of atomic emission, how atomic spectra arise, and how analytical wavelengths are chosen. Students will learn about the nature of the relationship between concentration and intensity, sensitivity, selectivity, why internal standards are necessary, and how signals are normalized, and how concentrations are calculated. In addition, we will cover practical aspects of accuracy and precision for rotating disk spectrometers using AC arcs. Finally, we will address sources of error and variability and how these can affect the JOAP decision-making process.

About the instructor

Edward T. Urbansky is the physical science department head at the JOAP Technical Support Center. Previously, he was employed at the U.S. Environmental Protection Agency's National Risk Management Research Laboratory in Cincinnati, Ohio, where his research was largely focused on analytical chemistry of drinking water and other aqueous matrixes. Dr. Urbansky earned his B.S. in chemistry from Allegheny College in Meadville, Pennsylvania, and his Ph.D. in chemistry from Purdue University in West Lafayette, Indiana. He has authored or coauthored 46 articles and edited a book, *Perchlorate in the Environment*. Besides serving on a variety of professional committees, he has served in editorial or advisory capacities for several scholarly journals.

Oil analysis on the Spectroil M

Course no. 4b | Thursday, 1:00 p.m. | Bob Yurko
$15 | yurko@spectro.com

About the course

This class provides an overview of the deployment, setup, operation, and routine maintenance of the Spectroil M oil analysis spectrometer in laboratory and field conditions. Emphasis will be on navigating OilM® Windows software for routine analysis. This seminar provides an opportunity for general questions and answers as well as applications assistance for using the Spectroil M in the Joint Oil Analysis Program. Students will have an opportunity to gain hands-on experience with the spectrometer.

About the instructor

Bob Yurko has been the vice president of engineering at Spectro, Inc., since 1988. Mr. Yurko has been responsible for much of the research and development of Spectro's instrumentation and technology currently in use by the Defense Department's Joint Oil Analysis Program and the tribology industry today. He joined Spectro Incorporated in 1981 after working 10 years in the field of spectroscopy for Baird Corporation's government systems division where he had primary responsibility for analytical applications and worldwide field engineering management. He received an associate's degree in computer science from Pennsylvania Technical Institute in 1971. He has authored or co-authored several publications in the field of spectroscopy and analytical techniques. He has served on the ASTM D-2 committee and the American Society of Nondestructive Testing.

Ferrography

Course no. 4c | Thursday, 1:00 p.m. | Ray Dalley
$15 | rjdalley@predictusa.com

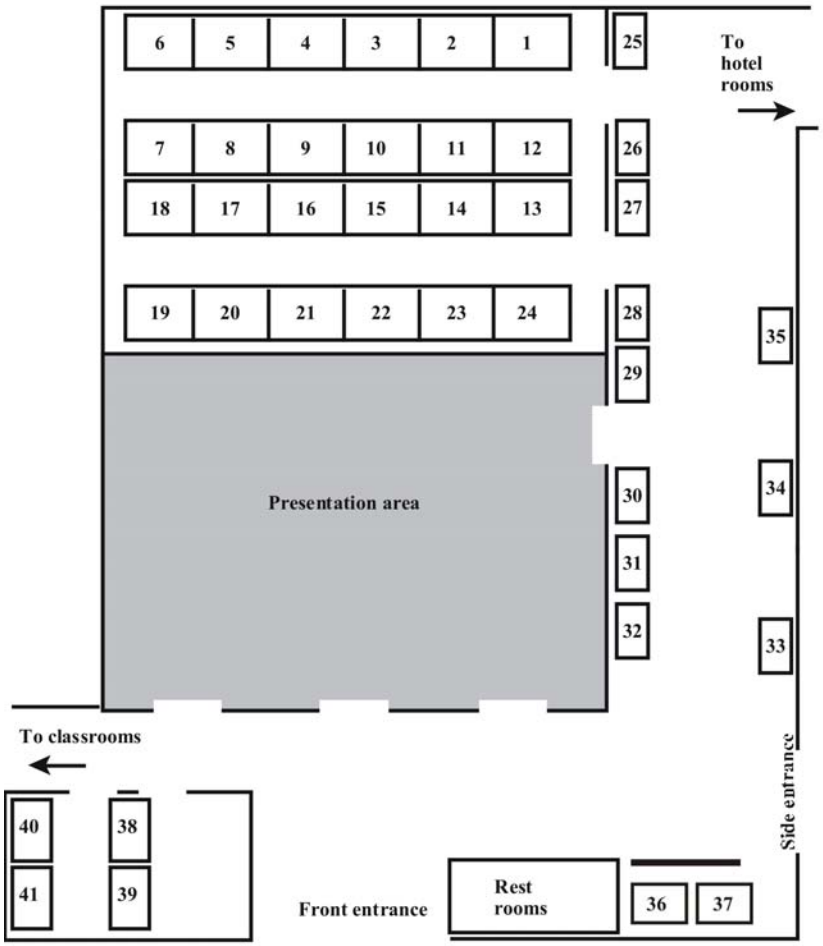
About the course

Students will learn the basics of ferrography and gain hands-on exposure to the instrumentation, from taking the sample, to preparing it, to examining it. We will discuss wear mechanisms and how particles are generated, as well as the characteristics of the particle types that are used to identify and classify them. Finally, we will explore how to combine information obtained via ferrography with that obtained via other methods to assess equipment condition.

About the instructor

Raymond J. Dalley received his mechanical degree from Queensborough Community College and Northeastern Univresity in 1977. He has been involved with researching, manufacturing, selling, and marketing ferrographic equipment for the past 23 years with Predict. Currently vice president for corporate accounts, Mr. Dalley duties include serving as project manager for the ferrographic instrument group, acting as technical liaison to the CEO, and evaluating acquisitions and joint ventures. He lectures globally for a variety of professional technical organizations. Mr. Dalley has published a number of papers about lubricants and wear particle analysis and holds memberships in several professional societies.

CONFERENCE CENTER LAYOUT



Exhibitors

1 Pall Aeropower Corporation
2 Gastops, Inc.
3 Dexsil Corporation
4 Brookfield Engineering
6 Petroleum Systems Services Corporation
7 VHG Labs, Inc.
10 Anton Paar USA
11 R.J. Lee Group
12 Specialty Manufacturing
13 Kittiwake Developments, Ltd.
15 Conostan Division
16 Thermo Electron Corporation
18 Data Systems and Solutions
19 Sigma Aldrich
21 Aspex, LLC
22 PAMAS GmbH
23 Fisher Scientific
24 Thermal-Lube, Inc.
26 Cambridge Applied Systems, Inc.
27 Digilab, LLC
28 UE Systems, Inc.
29 Parker Hannifin
30 Emerson Process Management
31 Ecolink
32 Nye Lubricants
33 Hach Ultra Analytics
34 Innovative Dynamics, Inc.
35 Qorpak
36 Predict DLI
37 U.S. Navy Air Systems Command
38 U.S. Army Matl. Cmd. Logistics Supp. Activity
40 Spectro, Inc.
41 Spectro, Inc.

EXHIBITORS

Anton Paar USA, 4405 Reserve Drive, Atlanta, GA 30319, phone: 800-722-7556 or 404-841-8771, fax: 404-841-0463, fax: 404-841-0463, www.anton-paar.com. Anton Paar USA is the U.S. distributor of analytical instruments manufactured by Anton Paar GmbH, located in Graz, Austria. We specialize in two types of instruments: those that measure the density and concentration of liquids and gases and those that measure the viscosity and rheological properties of matter. The newest product in our family is the SVM3000 Stabinger viscometer. This instrument measures both the dynamic and kinematic viscosity of a sample while using only 5 mL of sample and about 10 mL of cleaning agent. No thermostatted baths are required and samples take about 90 seconds to measure. Viscosity indexing can be done automatically in 20 minutes. Booth 10.

Aspex, LLC, 175 Sheffield Drive, Delmont, PA 15626, phone: 724-468-5400, fax: 724-468-0225, www.aspexllc.com. ASPEX is a manufacturer of microanalysis systems for wear debris and predictive failure analysis. The ASPEX® combines electron beam imaging, x-ray elemental analysis, and automation software, in one, field deployable unit. The automatic feature analysis (AFA) software analyzes particles, determining the size, shape and elemental composition of foreign materials, generating customizable quality control reports. The ASPEX® needs only 115 volt power for operation. Booth 21.

Brookfield Engineering, 11 Commerce Blvd., Middleboro, MA 02346, phone: 800-628-8139, fax: 513-946-6262, www.brookfieldengineering.com. Brookfield is the world's leading manufacturer of rotational viscometers for lab and on-line process applications. Most QC, R&D, and process engineering departments make Brookfield their universal choice for viscosity measurement. See our DV-III Ultra Programmable Rheometer. It's a sophisticated rheometer with easy-to-use intuitive controls and now with the added new capability to measure static yield stress using vane spindle geometry. Why a rheometer? A rheometer measures and analyzes minute as well as broad changes in a material's rheological structure—the way fluids and semi-solid materials flow. This is accomplished by varying shear rates in micro increments. Booth 4.

Cambridge Applied Systems, Inc., 196 Boston Avenue, Medford, MA 02155, phone: 781-393-6500, fax: 781-393-6515, www.cambridgeapplied.com. Viscosity sensing and control is essential in many fluid processes. Cambridge's proprietary technology offers a simple elegant solution that works, delivering a high return on investment for our customers. Paybacks of " a matter of minutes" to "a few months," and "years of trouble-free operation" are typical for Cambridge viscometers. We have thousands of viscosity sensing and control installations worldwide. Our customers rely on our process viscometers 24/7 for in-line, in-tank, bypass and flow-through monitoring and control of viscosity and temperature-compensated viscosity. In many cases they are completely self-cleaning to minimize operator attention. CAS laboratory viscometers are designed to fit a wide variety of needs and budgets for measuring viscosity and temperature. Cambridge's applications include oil viscosity; inks, paints and coatings; and a wide range of chemical processing.

Oil viscosity is a key factor in exploration as well as in lubricant, hydraulic, refrigerant and fuel production and use. Ink, paint and coating viscosity is essential to maintain targeted film weights, which impacts quality in color and finish characteristics. Viscosity in chemical processing is important to assure proper mixing and reaction control. CAS has just announced breakthroughs in high temperature and sanitary viscosity sensing and control. Our new high temperature viscometers measure viscosity up to 37 ˚C (698 ˚F). Our new viscometers for sanitary applications offer solutions to a new group of customers in food and pharmaceutical applications. Booth 26.

CONOSTAN® Oil Analysis Standards, 1000, South Pine, Ponca City, OK 74602-1267, 877-767-3078, www.conostan.com. Conostan offers oil analysis standards of industry-benchmark accuracy, reliability, and stability for confidence in instrument calibrations. Conostan has re-introduced D-Series™ metallo-organic standards (Spectrometric Oil Standards), including D-3, D-12, and D-19. The D-Series contain the original and uniquely oil-metal compatible chemistry by Conostan, also adopted and long deployed by the Department of Defense as their only metallo-organic standards chemistry for military applications. A new, secondary particle count standard, PartiStan™ 2806, traceable to the international primary standard, NIST SRM 2806, and conforming to the recent ISO 11171:1999 calibration standard for Automatic Particle Counters, has been introduced. Additionally, FTIR Operational Test Standard™ is a new introduction providing appropriate reference absorptions in spectral regions to assess correct operational performance of FTIR instruments for oil analysis applications. Our responsiveness, rapid delivery, and customer service are industry-benchmark values we constantly strive to maintain. Booth 15.

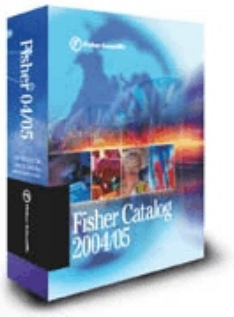
Data Systems & Solutions, 10260 Campus Point Drive, MS X1A, San Diego, CA 92121, phone: 858-826-2202, fax: 858-826-2296, www.enginedatacenter.com. Data Systems & Solutions supplies world-class decision support systems and services that ensure the safe and efficient operation of your high value assets. By combining leading edge technology with engineering excellence and domain expertise our products and services deliver our customers solutions that are safe, available and reliable. Working with our customers across markets characterised by their safety consciousness, strict regulatory compliance and demand for high integrity solutions, we employ an open and honest approach to become a trusted supplier of quality solutions that maximise asset performance and availability. Data Systems & Solutions, a joint venture between Rolls-Royce and SAIC, incorporates Rolls-Royce engineering and controls expertise with SAIC's systems integration and information technology skills. The result is innovation across six key markets: energy, aviation, defence, process industries, marine systems and transport. We specialize in on-line integrated data management service for aviation customers. The enginedatacenter is a customised internet gateway to all the engine information products and services provided by Data Systems & Solutions. This gateway provides our customers with online access to predictions of engine service needs and software support, enabling better maintenance planning, reducing delays and saving costs. The JetSCAN SEM/EDX oil debris analysis system is one example of our application of specialist knowledge to deliver high return on investment in turbine engine predictive maintenance. Booth 18.

Dexsil Corporation, One Hamden Park Drive, Hamden, CT 06517, phone: 203-288-3509, fax: 203-248-6523, www.dexsil.com. Dexsil manufactures portable test kits and instruments for the detection and quantification of contaminants in soil, water and oil. Dexsil products take sophisticated analysis and detection out of the laboratory and into the field, saving our customers time and money, while safeguarding expensive equipment and preserving our environment. Since 1977 Dexsil has been the leader in developing easy-to-use, accurate testing devices to make on-site chemical analysis faster and less expensive. Booth 3.

Digilab, LLC, 68 Mazzeo Drive, Randolph, MA 02368, phone: 781-194-6400 or 800-225-1248, fax: 781-794-6600, www.digilabglobal.com. Digilab manufactures and markets analytical instruments and systems for a wide variety of FTIR, Raman, UV-vis and fluorescence applications. The Digilab name originated in 1969 as Digilab, Inc., when pioneering work for the U.S. Government led to the development, manufacture, sales, and service of the first commercial Fourier-Transform Infrared (FT-IR) spectrometer. The development and integration of a rapidscanning interferometer with emerging developments in infrared detectors, minicomputers, signal converters, and sophisticated algorithms, led to this breakthrough event in the developments of rapid turn-key infrared spectrometric analytical solutions. Booth 27.

Ecolink, Inc., 2227 Idlewood Road, Tucker, GA 30084, phone: 800-886-8240; fax: 770-621-8245, e-mail: info@ecolink.com, www.ecolink.com. For over a decade, Ecolink has helped a long list of leading manufacturers, aerospace companies, utilities, the military and government organizations implement effective alternatives to hazardous chemicals and ozone depleting solvents. Ecolink offers industrial users a comprehensive strategy, combining cleaning technology, chemical management and implementation support to guarantee operational success while meeting EPA and OSHA requirements. Ecolink also utilizes a portion of its annual profits to support habitat preservation activities and wildlife conservation efforts. We invite you to put Ecolink's proven technology and industry expertise to work in your critical manufacturing and cleaning processes. We'll help you tackle the rising costs of government compliance, implementation training and chemical management with proven solutions that meet your solvent, degreasing and industrial maintenance requirements.Booth 31.

Emerson Process Management. , 835 Innovation Drive, Knoxville, TN 37932, phone: 865-675-2400, fax: 865-218-1401, www.mhm.assetweb.com. Machinery Health Management—best cost monitoring and maintenance of mechanical equipment—is an important part of asset optimization. Emerson Process Management's CSI is the ideal choice for developing and enhancing mechanical reliability, because we specialize in machinery analysis. Since 1984, CSI products and services have been used by industrial sites to design, implement and streamline Machinery Health Management programs which increase machine uptime and performance. This focus on machinery analysis has led to innovations in many of CSI's machinery health offerings. Booth 30.



Fisher Scientific, 2000 Park Lane, Pittsburgh, PA 15275, phone: 412-490-8300 (800-766-7000), fax: 800-926-1166, www.fishersci.com. Fisher Scientific is the world-leader in serving science for the life science, biomedical, pharmaceutical, university, safety and chemical markets, enabling scientific discovery and clinical laboratory testing by offering more than 600,000 products and services to over 350,000 customers in 145 countries. Fisher's broad product offering, state-of-the-art e-commerce capabilities, and integrated global logistics network serves as a one-stop source of research, healthcare, safety, firefighting and controlled environment products, global services and solutions. Booth 23.

GasTOPS, Ltd., 1011 Polytek Street, Ottawa, Ontario K1J 9J3 Canada, phone: 613-744-3530, fax: 613-744-8846. GasTOPS is a technology-based company that specializes in the development and implementation of advanced machinery maintenance, monitoring and control systems for industrial, marine, and aeronautical applications. The company was founded in 1979 and has grown steadily to a present staff level of 105 employees, including over 70 professional engineers and scientists. The company's corporate headquarters are located in Ottawa, Canada. GasTOPS also maintains a global network of strategic alliances with organizations in Canada, Japan, Australia, Holland, England, Malaysia, and the United States. GasTOPS is in the business of improving the operating effectiveness of machinery through the application of advanced computer and instrumentation technologies. Specifically, knowledge of machinery behaviour and their application is used to design products that improve operations and maintenance practices. Booth 2.

Hach Ultra Analytics, 5600 Lindbergh Drive, P.O. Box 389, Loveland, CO 80539, phone: 800-373-0531, fax: 970-663-9761, www.hachultra.com. Hach Ultra Analytics is a new company formed through the merger of Anatel, Pacific Scientific Instruments, Polymetron, and Orbisphere. Our mission is to become the leading provider of quality control and process analytics instrumentation in markets requiring high quality products, services, and technical expertise worldwide. The new company name shows the close relationship with our sister company Hach and the definitive intent to offer to process analytics instrument users the largest product offering and the best service they deserve. The Portable Oil Diagnostic System (PODS) is an intelligent, portable and robust analysis instrument for measuring, storing, and reporting oil condition parameters important for reliable hydraulic systems operation. The PODS monitors oil contamination in the field and provides immediate information concerning the health of the machine under operating conditions, opposed to oil samples analyzed in laboratories, typically taking weeks before they are available, while not reflecting the condition of the oil under operating conditions. Additionally, the PODS provides the means to analyze fluids and lubricants in an online or bottle sampling mode without interrupting operation of the machine. Sample data can be downloaded, stored and managed with PODSWare data analysis software. Booth 33.

Innovative Dynamics, Inc. 2560 North Triphammer Road, Ithaca, NY 14850, phone: 607-257-0533, fax: 607-257-0516, www.idiny.com. IDI is currently developing a range of technologies applicable to current and future aircraft for integration into engines. On board sensors provide information to operators and associated support organizations which will enable the practice of condition-based maintenance and consequent reduction in life cycle costs. The information is related to the

condition of the engine components, lubricatoin, and fuel systems. In addition IDI has developed technology for in-situ monitoring of engine mounts and related structures. The Structural Intensity Monitor 2000 (SIMS2K) is an automated instrument for detection and diagnosis of structural faults using vibration signature measurements. An array of piezoelectric transducers attached to the structure are used for both actuation and sensing. SIMS actively excites the structure with wideband energy (up to 100 kHz). Statistical analysis of the changes in the vibration signature is used to detect, localize, and assess the severity of damage in the structure. SIMS can detect small, incipient damage without time consuming and expensive inspection procedures. Booth 34.

Kittiwake Developments, Ltd., 3-6 Thorgate Road, Little Hampton, West Sussex, BN177LU, U.K., phone: 44-0-1903-731-470, fax: 44-0-1903-731-480, www.kittiwake.com. Kittiwake Developments, Ltd., is a leading manufacturer of measuring, monitoring and management equipment for fuel, lubricating oil and water treatment. Operating worldwide through a network of agents and distributors, Kittiwake provides a complete range of test kits and analysis equipment for marine, industrial and offshore applications. Kittiwake is an established and reputable vendor to many of the world's military forces including the British Royal Navy, U.S. Navy, U.S. Coast Guard, French Navy, Italian Navy, and the British Royal Air Force. We supply viscosity, density and compatibility testing equipment, fuel oil and lubricant sampling and measurement equipment, and complete oil test centers for heavy plant and engine room use. Booth 13.

Nye Lubricants, Inc. 12 Howland Road, Fairhaven, MA 02719, phone: 508-996-6721, fax: 508-997-5285, e-mail: techhelp@nyeaerospace.com, www.nyeaerospace.com. Nye Lubricants seeks long-term partnerships with innovative companies that use high-quality synthetic lubricants and optical gels to increase the value of their products. We participate in customer design programs, develop products that meet customer needs, offer testing and analytical services, learn from and teach our customers, and deliver goods and services on time—worldwide. Such parternships enrich our employees, expand our product line, and create value for our customers. We value mutual respect as the foundation of all our relationships. We value products and services that meet the highest quality standards. We value a workplace that is safe for employees and the environment. We value the continuous pursuit of technical excellence. We value creativity and innovation as paths to excellence. We value personal initiative and empowerment to achieve company goals.

Qorpak, 1195 Washington Pike, Bridgeville, PA 15017, phone: 412-257-3100, fax: 412-257-3001, www.qorpak.com. Qorpak provides the experience, variety and convenience you need by offering viable solutions in packaging, cleaning, stocking and scheduled deliveries. Our in-stock sample containers are packed in the quantities you need—with or without the cap attached—the way you actually use them. Qorpak's worldwide distribution network covers major industries including chemical, pharmaceutical, educational, environmental, petroleum, water, and wastewater, biological, food, health, biotech, and forensic. Qorpak's trademarked green thermoset closures with

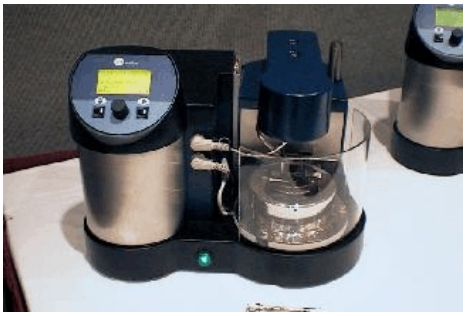
Teflon® PTFE liners are the most dependable and durable closures available for use in the lab. These closures offer the widest range of chemical compatibility and temperature tolerance versus polypropylene. Booth 35.

Pall Aeropower Corporation, 10540 Ridge Road, New Port Ritchey, FL 34654-5198, phone: 727-849-9999, fax: 727-849-7313. The Pall Portable Fluid Purifier was specially developed to ensure that the working properties of the fluid being purified are not degraded. Unlike systems that use desiccants, high vacuum or added heat, the Pall Portable Fluid Purifier employs spinning disk and vacuum dehydration technologies which are the most gentle to fluids. Designed to prevent pollution, increase equipment reliability and performance, and reduce costly maintenance, the Pall Portable Fluid Purifier will automatically remove water, gases, solvents and particulate from hydraulic fluids, lubrication fluids, coolants and synthetic and organic ester based liquids. Easy to connect, simple to operate and requiring minimum operator attention, the Pall Portable Fluid Purifier uses standard line voltage and connects to your system using inlet and outlet hoses. There are no adjustments to make, no controls to set, no other hookups. Booth 1.

PAMAS GmbH, 6721 East 106th Street, Tulsa, OK, phone: 918-743-6742, fax: 918-743-6917, www.pamas.de. PAMAS has been involved in sensor and instrument development since 1986 and began its own quest for success in 1992 when it became a fully independent company. Headquartered in Rutesheim, Germany, as well as having offices located around the world, PAMAS has become a worldwide company recognized for its cutting-edge technology and top-notch support. As an active member on national and international standardization committees, PAMAS has obtained a leadership role in particle measurement technology. Our particle counters are used for applications ranging from motor, gear, and turbine oils, to the pharmaceuticals to polymers and glues. This expertise helps us to serve you better before, as well as after, the sale. Booth 22.

Parker-Hannifin, Hydraulic Filter Division, 16810 Fulton County Road #2, Metamora, OH 43540, phone: 800-253-1258 or 419-644-4311, fax: 419-644-6205, www.parker.com/hydraulicfilter. Contamination is the number one cause of failure in hydraulic and lubrication coolant systems. Failures can cause downtime, component and fluid replacement, as well as higher maintenance charges. Parker's hydraulic filters deliver positive protection against contamination, giving you predictable reliability for your hydraulic systems and components. Parker Hydraulic Filter Division also offers a complete line of fluid condition monitoring equipment. On-line particle analysis, off-line bottle sampling, and water contamination analysis are perfect complements to the high performance filtration systems offered by Parker. With annual sales exceeding $6 billion, Parker Hannifin Corporation is the world's leading diversified manufacturer of motion and control technologies, providing systematic, precision-engineered solutions for a wide variety of commercial, mobile, industrial and aerospace markets. The company's products are vital to virtually everything that moves or requires control, including the manufacture and processing of raw materials, durable goods, infrastructure development and all forms of transport. Booth 29.

Petroleum Systems Services Corporation, 2789 Route 9, Malta, NY 12020, phone: 518-581-0189 or 518-581-0187, fax: 518-581-0201, www.pssc.org. Petroleum Systems Services Corporation (PSSC) distributes and manufactures quality control instruments used to measure the physical characteristics that determine product quality and consistency. PSSC offer Stanhope-Seta, Koehler, and our own line of glass and bath instruments, which have an established reputation for, advanced capabilities, accuracy and reliability; the company's instruments are a world-wide benchmark for many product quality measurements and research applications. PSSC, Stanhope-Seta, Koehler instruments are used by many diverse industries including petrochemical, pharmaceutical, food, cosmetics, plastics and transport. Measurements include flash point, vapour pressure, viscosity, penetration, contaminants and many other quality parameters. PSSC, Stanhope-Seta, Koehler instruments are exported to over 150 countries worldwide and global network of distributors provide our consumers with local technical comprehensive service support. Pictured here is the Stanhope-Seta Multiflash. Booth 6.



Predict, 9555, Rockside Road #350, Cleveland, OH 44125, phone: 216-642-3223, fax: 216-642-1484, www.predictusa.com. Predict will exhibit wear particle, used oil analysis and vibration services and products. Newly introduced INTEGRATED SERVICES will be featured. Internet reports, integrating multiple monitoring technologies into a single condition report, independent of source, can increase the value of your maintenance program. Predict is a global leader in condition-based asset management services and systems. Wear particle analysis provides an early indication of component wear by detecting the source of wear particles in lubricating fluids. Integrating oil analysis with vibration and other monitoring technologies are typically used to provide confirmation of deteriorating equipment conditions. Critical maintenance planning decisions are made with confidence. Booth 36.

R.J.Lee Group. R.J. Lee Group was originally established in 1980 as Energy Technology Consultants to provide R&D services to industry and government institutions dealing with airborne particulate emissions. During the following years the company became involved in a wide variety of service and research projects that involved the use of advanced analytical techniques, particularly electron microscopy and computer-controlled microscopy for particulate characterization. In addition to laboratory services and contract research, the Company has developed numerous applications and several products related to the various fields of materials characterization. Most notable was the design and manufacture of the PERSONAL SEM®, a cost-effective, easy-to-use, portable scanning electron microscope. In 1995, a new company R.J. Lee Instruments, Ltd. (now known as Aspex® LLC) was started for the purpose of manufacturing the PERSONAL SEM® and other microanalytical tools. Booth 11.

Sigma Aldrich 3050 Spruce Street, St. Louis, MO 63103, phone: 800-325-3010, www.sigma-aldrich.com. Sigma-Aldrich is a leading life science (75%) and high technology (25%) company with $1.2 billion in annual sales. Our biochemical and organic chemical products and kits are used in scientific and genomic research, biotechnology, pharmaceutical development, the diagnosis of disease and chemical manufacturing. We have

customers in life science companies, university and government institutions, non-profit organizations, hospitals and in industry. Over one million scientists and technologists use our products. Sigma-Aldrich operates in 34 countries and has 6,000 employees providing excellent service worldwide. Booth 19.

Specialty Manufacturing, 15412 State Road 62, Charlestown, IN 47111, phone: 800-382-9130 or 812-256-4633, fax: 812-256-2917, http://www.specialtymanufacturing.com. We sell a wide range of containers, extraction pumps, mailing containers, and supplies for oil analysis laboratories. Our starter kits make collecting and shipping oil samples convenient for your staff. We make a variety of labels, containers, and supplies for all your sampling and mailing needs. Booth 12.

Spectro Incorporated, 160 Ayer Road, Littleton, MA 01460, phone: 978-486-0123, e-mail: sales@spectroinc.com. Spectro Incorporated is an analytical instrument manufacturer with a product line of instruments designed exclusively for machine condition monitoring based on used oil analysis. We supply our customers with analytical instruments, training, service and applications support for machine condition and lubricant physical property analysis. Our capabilities also include complete turnkey used oil analysis laboratories that consist of all the necessary instruments, software and technical support. Spectro's exhibit will include the Spectroil M/N oil analysis spectrometer that has become the standard instrument for commercial and military wear metal and contaminant analysis, the LaserNet Fines-C particle shape classifier and particle counter, the fuel sniffer fuel dilution meter, the HSV-802 high speed viscometer and the T2FM ferrography laboratory. Booths 40-41.

Thermal-Lube, Inc., 255 Avenue Labrosse, Pointe-Claire, Québec, Canada H9R 1A3, phone: 800-694-LUBE (514-694-5823), fax: 514-694-8628, www.thermal-lube.com. Thermal-Lube, Inc., is an ISO-9001 registered Canadian corporation in business to research, develop, manufacture and market specialty lubricants and analytical monitoring equipment. Our patented COAT® (*Continuous Oil Analysis and Treatment*) System together with UMPIRE® (*Universal Method Platform for Infrared Evaluation*) integrated software system incorporates traditional FTIR testing with novel analytical methods such as TAN, TBN, H_2O, and fuel dilution in new and used lubricating oils. Thermal-Lube, Inc., has always made a serious commitment to research and views it as an integral part of its future. Booth 24.

Thermo Electron Corporation, 4410 Lottsford Vista Road, Lanham, MD 20706, phone: 301-459-2940 (800-237-2800), fax: 301-731-5761, www.thermo.com. In science and in business, we make progress only when we dare to ask questions. Whether it's getting a breakthrough drug to market quickly, improving workplace safety, or manufacturing a product better, Thermo Electron and its customers around the world are united in the quest for answers. Explore our capabilities and visit our market pages to learn more. As a global provider of life and laboratory sciences systems, optical technologies and measurement and control solutions, Thermo Electron offers an integrated resource for best-in-class technology, products and services necessary to establish and maintain a competitive advantage. Ideal for investigative analysis or quality control applications, spectroscopy systems are used to determine the molecular composition of a wide range of complex samples, including liquids, solids, and gases. Supported by an expansive range of applications, techniques such as Nicolet FT-IR, FT-NIR, infrared microsampling and Raman, as well as Spectronic visible & UV-vis and fluorescence, provide a molecular footprint for both quantitative and qualitative analysis. Thermo also manufactures a variety of ICP-AES, ICP-MS, and AA spectrometers. Booth 16.

United States Army Materiel Command, Logistics Support Activity (LOGSA), Building 5307, Sparkman Complex, Redstone Arsenal, Alabama, 35898, phone: 256-955-0504, fax: 256-955-0659, www.logsa.army.mil. LOGSA serves as the Army and DoD champion for the integrity and integration of logistics data in support of weapon systems maintenance, readiness, supply, transportation, equipment authorizations, asset and intransit visibility. Additionally, LOGSA is the responsible organization for numerous key Army and DoD missions that are highlighted on our homepage. LOGSA continues to evolve by leveraging leading technology in support of key Army transformation initiatives to include enterprise resource planning, the logistics modernization program, and global combat support system. But more importantly, our capability to strategically analyze weapon system fleet data contributes to the readiness focus of our senior DoD leaders. This continuous improvement will ensure the warfighter's success as we embark upon the digital battlefield of the future. Booth 38.

United States Navy Air Systems Command, NAVAIR,47123 Buse Road, B2272 Unit IPT Suite 075, Patuxent River, MD 20670-1547, Phone: 301-757-3421 (DSN 757-3421), fax: 301-757-3614, www.navair.navy.mil.

NAVAIR vision: We exist to provide cost-wise readiness and dominant maritime combat power to make a great Navy/Marine Corps team better. *NAVAIR goals: To balance current and future readiness.* We need to ensure that we provide our naval aviators with the right products to fight the Global War on terrorism and other potential future conflicts. *To reduce our costs of doing business.* We need to pursue actual cost reductions, not so-called "savings" or "avoidance." We need to return resources to recapitalize our fleet for tomorrow. We must continue to introduce best business practices and remove barriers to getting our job done with greater efficiencies. *To improve agility.* Our ability to make rapid decisions in support of emerging fleet requirements is essential if we are to continue to provide value to the nation. We must reinvigorate a solid chain of command that values responsibility and accountability in its leadership. *To ensure alignment.* We have come a long way aligning ourselves internally, now it is time to ensure that we are fully aligned, internally and externally, with CNO's transformation initiatives. *To implement fleet-driven metrics.* Single fleet-driven metrics will ensure we directly contribute to the Naval Aviation Enterprise. Booth 37.

UE Systems, Inc., 14 Hayes Street, Elmsford, NY 10523, phone: 914-592-1220, fax: 914-347-2181, www.uesystems.com. UE Systems manufactures portable and on-line ultrasonic instruments for leak detection, mechanical and electrical inspection. The digital Ultraprobe 10000 is shown here. This hand-held portable instrument senses frequencies from 20 kHz up to 100 kHz and heterodynes the received sound down into the audible range where it is heard through headphones and seen as intensity increments on a display panel. Other features include on-board data logging, free software, frequency tuning, interchangeable modules for both airborne and structure borne signals and a powerful, patented ultrasonic transmitter called a warble tone generator for inspections of seals and gaskets when it is not possible to pressurize or draw a vacuum. Typical applications include mechanical trending/troubleshooting, including detection of lack of lubrication in bearings, detection of cavitation, valve inspection, leak detection of pressurized systems (including compressed air), vacuum systems, hydraulics, hatches, fuel cells, and locating arcing in enclosed switchgear and disconnects. Booth 28.

VHG Labs, Inc., 180 Zachary Rd., Manchester, NH 03109, phone: 888- 622-7660, fax: 603-622-5180, www.vhglabs.com. VHG Labs is a leading manufacturer of (1) metallo-organic concentrates, (2) single and multielement standards for wear metals analysis by ICP or rotrode atomic emission spectrometry, (3) standards for the analysis of sulfur, (4) chlorine and metals in a wide range of petroleum products by XRF, (5) viscosity standards, (6) flashpoint standards, (7) ICP quartzware and pump tubing, (8) ICP training/troubleshooting CD-ROM, (9) XRF cups and film. All VHG standards are subjected to rigorous quality assurance checks and each standard is accompanied by a certificate of analysis, that reports the certified value and the traceability to primary or secondary standards. VHG petroleum products standards are stocked in 4 oz and 8 oz bottles for prompt shipment and are competitively priced. Booth 7.

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Conference code JOA
Phone: 866-916-2999 ■ Fax: 850-934-0891
URL: www.pensacolabeach.gardeninn.com

Obtain information about the local area and register via our conference website, or download forms and register by fax.
URLs: https://www2.tsc.joap.org/conf
www.joaptsc.navy.mil

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www.joaptsc.navy.mil ■ 850-452-5627 ■ DSN 922-5627

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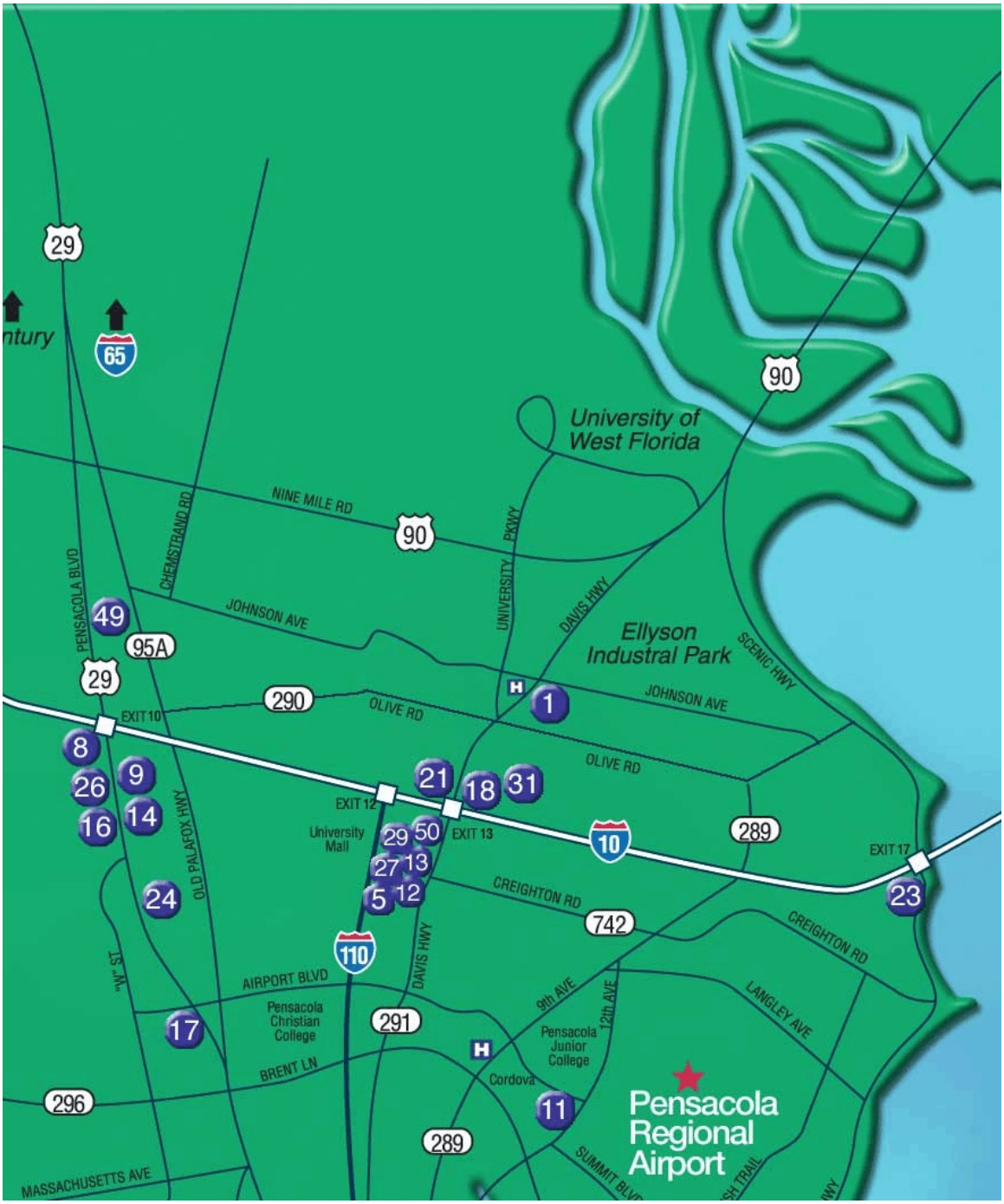
Maps are provided courtesy of the Pensacola Visitor Information Center
See the website for a full key and additional maps of the area.
http://www.visitpensacola.com/lgmap.asp

This map shows the region near the airport. The map on the following page shows the region near the conference. The two regions are contiguous.

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JACKSON ST
CERVANTES ST
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GREGORY ST
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AMTRAK
GARDEN ST
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Pensacola Convention &
Visitors Information Center
GOVERNMENT
MAIN ST
BAYFRONT
Pensacola Civic Center
Historical District
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PENSACOLA BAY BRIDGE 3 MILES
Pensacola Bay
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GULF BREEZE
GULF BREEZE PKWY
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