

Hand-held and portable devices for oil assessment

Commercial Technologies for Maintenance Activities

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Report Documentation Page

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14. ABSTRACT In an effort to reduce costs and bring about real-time oil assessment in the field while reducing maintenance costs, the Department of Defense seeks to further develop existing commercial technologies. The project is intended to lead to the production of commercialized hand-held and/or portable oil assessment units that will work with minimal volumes of oil and give a pass/fail rating to the oil. Such units will reduce the need for centralized laboratory facilities and promote a condition-based maintenance paradigm. Through on-demand, real-time oil assessment, it is possible to change oil on condition rather than fixed-time or fixed-distance intervals. The presentation reviews the selection process of offerors and the basis for the project.				
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Handheld/portable devices

Why?

Placing real-time oil assessment in the field to keep our war-fighters safe and ready while reducing maintenance costs

- (1) save engines/life & limb/money
- (2) increase readiness (decentralization)
- (3) diagnose/prognose problems
- (4) improve reaction and proaction

Successful offerors

One hand-held; one portable



Foster-Miller



Smiths
Detection

Smiths Detection, Inc.

True portable assessment device

- Based on infrared spectrometry
- Rugged, robust, durable, portable, self-contained
- Fielded for hazmat first responder usage (available as COTS)
- Highly intuitive, user-friendly design
- No supplies/consumables
- Part of a line of spectrometric units



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Foster-Miller, Inc.

True hand-held assessment device

- Based on infrared spectrometry
- Requires a single consumable sample card
- Interface needs adaption, improvement
- Training and maintenance planned via business agreement with Spectro
- Extension of a line of devices



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Offeror (CRADA) selection process

Two selected of six submissions received

- Initial submission with proof of concept
- Preliminary data showing compatibility with requirements/capability to achieve at least half of objectives
- Pre-screening for credibility
- Formalized demonstration of prototype
- Objectified ranking/scoring

Measurements/property selection

Coming up with the wants/needs list

- Ease
- Occurrence
- Criticality

Requirement categories

Performance, maintainability, sustainability

- Measurement and assessment
- Connectivity and electronics
- Durability, portability, usability

Applicability of IR spectrometry

Strengths and weaknesses of the technique

- Viscosity - limited, varies with modifiers
- Particulates/soot - excellent/good
- Acidity - good/moderate, improves with conversion to a single species
- Basicity - excellent/good
- Water - excellent (functional)
- Coolant - excellent (functional)

Aviation and marine diesel

Expansion to other services/arenas

- CRADA focused on Army ground diesel equipment (mostly 2104, 5606)
- Alternative properties for aviation or marine diesel engines
- Exploring infrared spectroscopic measurements that can be tied to thermal degradation of 23699, 7808, SAE J 1966 (6082), or SAE J 1899 (22851)
- Contamination of DOD-L-85734

Value added

Keep costs low and action at lowest level

- Real-time, no waiting for lab results
- No protracted sampling
- Eliminates expense on taking, shipping, and testing good oil
- Can be adapted to specific programmatic needs centrally
- Easily expand to other platforms

Flexibility for equipment needs

Improving maintenance and sustainment

- Balance false positive and false negative rates by setting equipment-specific limits
- Balance risks of false positive and false negatives via cost-benefit analysis
- Continually adjust trigger limits centrally
- Redirect laboratory time to refractory samples or investigations

End overview

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Technical information

Development of requirements

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Functions of engine/motor oil

Guidance for measurement types

- Lubrication: maintaining a film of shearable fluid between moving parts
- Physical protection
 - ▶ Thermal protection: distributing thermal energy to the bulk fluid and the cooling system components as heat
 - ▶ Abrasive protection: sacrificing coatings to limit damage of mechanical parts in contact
- Chemical protection: neutralizing acidic combustion byproducts, minimizing corrosion dispersing water/coolant, suspending solid particulates etc.

Lubricity loss

Non-Newtonian dysfunction

- Primarily a result of rheological changes
- Properties: viscosity, goniometry, and tensiometry
- Time-dependent viscosity changes
 - Rheopecty: viscosity increase with time
 - Thixotropy: viscosity decrease with time
- Shearing rate-dependent viscosity changes
 - Dilatancy: viscosity climbs with faster shearing
 - Pseudoplasticity: viscosity falls with faster shearing
- High vs low shear rate viscometry

Causes of lubricity loss

Specific contributors

- Failure of surfactants/dispersants and viscosity modifiers (e.g., pour point depressants)
- Water/coolant intrusion
- Solid particulate build-up (soot, dust, sand, etc.)
- Changes in surface tension, viscosity, balance between adhesive and cohesive forces

Heat transfer (physical)

Impeded cooling leads to aging/accelerated wear

- Influenced by water, fuel, or particulates
- Often caused by changes that affect viscosity simultaneously (thermal diffusivity and heat capacity)
- Secondarily affected by rheological changes (via flow rate)
- Sensors for thermal conductivity already exist in the marketplace

Abrasive protection (physical)

Anti-wear properties independent of lubricity

- Minimizing effects of particulates (suspension in a film of adequate thickness)
- Coating with a sacrificial material (e.g., zinc phosphate glass via zinc dialkyldithiophosphates)
- Solid lubricants shear during deprivation

Chemical protection

Chemical deterioration leads to wear

- Detergents dissolve water and coolant
- Base neutralizes acidic byproducts (NO_x , SO_x , RCO_2H)
- Anti-corrosion additives limit effects of water or oxygen at high temperature
- Fuel intrusion increases flammability

Measurements/property selection

Coming up with the wants/needs list

- Ease
- Occurrence
- Criticality

Ease

Selection factors for measurement types

What are the easiest/cheapest properties to measure reliably (accurately, precisely) when using a portable/handheld device that does not rely on wet chemistry?

Occurrence

Selection factors for measurement types

- Why do most oil samples fail (lubricity, physical protection, chemical protection)? How commonly is this failure encountered?
- What is the nature/cause of the degradation?
- What is the frequency of a sample failing to meet the specifications for this particular property (historical)? What is the probability of a property failure (predictive)?
- What failures tend to be coincident?

Criticality

Selection factors for measurement types

What properties of oil are critical for proper engine health?

More specifically, what types of oil degradation are apt to be associated with catastrophic engine loss rather than increased wear rates?

Infrared spectrometry

Basic principles

- Functional spectrometry - certain chemical functionalities (moieties) exhibit characteristic absorption bands based on bond energy
- Fingerprint spectrometry - species have individualized spectral fingerprints
- Vibrational contributions - allowable vibrational modes determined by structure and symmetry via group theoretic analysis

Viscosity - first measurement

A critical measurement

- Can be assessed in a limited fashion by infrared spectrometry by monitoring rheological additives
- Is often linked to other rheological properties
- Is robust despite other failure modes because of emphasis in oil manufacturing process

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Properties/measurement types

Amenability to infrared (IR) spectrometry

- Water (sludge) - readily measured by IR spectrometry
- Fuel (flammability) - measured with difficulty because of the structural and functional similarity between oil and fuel
- Soot (as total solid particulates) - readily measured by any light spectrometry as scattering/absorptive loss (high background)

Properties/measurement types

Amenability to infrared (IR) spectrometry

- Total acid number (degradation) -moderately testable due to commonness of acidic species
- Total base number (oil life) - moderately testable due to commonness of additives
- Coolant, as glycol/hydroxyl, (rheological and chemical degradation) - easily evaluated

Chemometrics

Stochastic chemistry for
expanding applicability

- Whole is more than the sum of its parts
- Aggregate data analysis allows prediction via trends in certain spectral regions
- Smaller quantifiable spectral changes can be used for assessment without specific or unique chemical associations
- Software development, data collection, and software learning required

Ancillary techniques

Augmentation of prototypes by integrating existing COT technology

- Thermal conductivity (KD2)
- Densimetry (AntonPaar U-tube)
- Tensiometry (DynoTester/PocketDyne)
- Viscometry (eCup acoustic wave)



Requirement categories

Performance, maintainability, sustainability

- Measurement and assessment
- Connectivity and electronics
- Durability, portability, usability

Measurement & assessment

Data quality and applicability

- Measurement of standard quantities and units, traceable, verifiable
- Single summary decision, e.g., red/green, yes/no, change/ok
- Applicability to commercial oils and admixtures
- comparison/contrast reference sample not needed
- Applicability to major oils: 23699, 2104, 5606, 83282, 85734
- Matrix ruggedness
- Self-testing, internally calibrated
- External calibration/performance check capability

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Connectivity/electronics

Compatibility with extant systems & convenience

- Built-in RS-232 (EIA/TIA-232-E) and USB connections
- Data logging (minimum 500 samples)
- Plug and play for upload to laptop/PC via USB connection
- Ability to upload to OASIS via RS-232 direct link (csv file) and via laptop/PC offline data management software
- Self-contained operation, i.e., laptop or PC not required for routine use
- Intuitive user interface with keyboard and USB ports for input
- Web interface for advanced function access

Portability, usability, durability

Practical considerations for field conditions

- External calibration and checks not required for routine use
- No consumables required for routine use
- Automatic power shut-off to conserve battery; constant-on switch when plugged in; rechargeable battery
- Able to sustain six-foot drop to hard surface
- Light & small enough to be easily carried by hand
- Negligible sample volume (< 2 mL) with minimal effort (dipstick residuum); negligible oil loss (< 2 mL) for in situ collection with minimal time (< 90 sec)
- Minimal training requirements; essentially usable out of the box within 30 min