



Designation: E2412 – 23a

Standard Practice for Condition Monitoring of In-Service Lubricants by Trend Analysis Using Fourier Transform Infrared (FT-IR) Spectrometry¹

This standard is issued under the fixed designation E2412; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This practice covers the use of FT-IR in monitoring additive depletion, contaminant buildup and base stock degradation in machinery lubricants, hydraulic fluids and other fluids used in normal machinery operation. Contaminants monitored include water, soot, ethylene glycol, fuels and incorrect oil. Oxidation, nitration and sulfonation of base stocks are monitored as evidence of degradation. The objective of this monitoring activity is to diagnose the operational condition of the machine based on fault conditions observed in the oil. Measurement and data interpretation parameters are presented to allow operators of different FT-IR spectrometers to compare results by employing the same techniques.

1.2 This practice is based on trending and distribution response analysis from mid-infrared absorption measurements. While calibration to generate physical concentration units may be possible, it is unnecessary or impractical in many cases. Warning or alarm limits (the point where maintenance action on a machine being monitored is recommended or required) can be determined through statistical analysis, history of the same or similar equipment, round robin tests or other methods in conjunction with correlation to equipment performance. These warning or alarm limits can be a fixed maximum or minimum value for comparison to a single measurement or can also be based on a rate of change of the response measured (1).² This practice describes distributions but does not preclude using rate-of-change warnings and alarms.

NOTE 1—It is not the intent of this practice to establish or recommend normal, cautionary, warning or alert limits for any machinery. Such limits should be established in conjunction with advice and guidance from the machinery manufacturer and maintenance group.

¹ This practice is under the jurisdiction of ASTM Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants and is the direct responsibility of Subcommittee D02.96.03 on FTIR Testing Practices and Techniques Related to In-Service Lubricants.

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² The boldface numbers in parentheses refer to the list of references at the end of this standard.

1.3 Spectra and distribution profiles presented herein are for illustrative purposes only and are not to be construed as representing or establishing lubricant or machinery guidelines.

1.4 This practice is designed as a fast, simple spectroscopic check for condition monitoring of in-service lubricants and can be used to assist in the determination of general machinery health through measurement of properties observable in the mid-infrared spectrum such as water, oil oxidation, and others as noted in 1.1. The infrared data generated by this practice is typically used in conjunction with other testing methods. For example, infrared spectroscopy cannot determine wear metal levels or any other type of elemental analysis. The practice as presented is not intended for the prediction of lubricant physical properties (for example, viscosity, total base number, total acid number, etc.). This practice is designed for monitoring in-service lubricants and can aid in the determination of general machinery health and is not designed for the analysis of lubricant composition, lubricant performance or additive package formulations.

1.5 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

*A Summary of Changes section appears at the end of this standard

2. Referenced Documents

2.1 ASTM Standards:³

- D445** Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)
- D2896** Test Method for Base Number of Petroleum Products by Potentiometric Perchloric Acid Titration
- D4057** Practice for Manual Sampling of Petroleum and Petroleum Products
- D4175** Terminology Relating to Petroleum Products, Liquid Fuels, and Lubricants
- D5185** Test Method for Multielement Determination of Used and Unused Lubricating Oils and Base Oils by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES)
- D6304** Test Method for Determination of Water in Petroleum Products, Lubricating Oils, and Additives by Coulometric Karl Fischer Titration
- D8321** Practice for Development and Validation of Multivariate Analyses for Use in Predicting Properties of Petroleum Products, Liquid Fuels, and Lubricants based on Spectroscopic Measurements
- E131** Terminology Relating to Molecular Spectroscopy
- E168** Practices for General Techniques of Infrared Quantitative Analysis
- E1421** Practice for Describing and Measuring Performance of Fourier Transform Mid-Infrared (FT-MIR) Spectrometers: Level Zero and Level One Tests

2.2 ISO Standard:⁴

- ISO 13372** Condition monitoring and diagnostics of machines—Vocabulary

3. Terminology

3.1 Definitions:

3.1.1 For definitions of terms used in this practice, refer to Terminology **D4175**.

3.1.2 For definitions of terms relating to infrared spectroscopy used in this practice, refer to Terminology **E131**.

3.1.3 *Fourier transform infrared (FT-IR) spectrometry, n*—a form of infrared spectrometry in which an interferogram is obtained; this interferogram is then subjected to a Fourier transform to obtain an amplitude-wavenumber (or wavelength) spectrum. **E131**

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *condition monitoring, n*—a field of technical activity in which selected physical parameters associated with an operating machine are periodically or continuously sensed, measured and recorded for the interim purpose of reducing, analyzing, comparing and displaying the data and information so obtained and for the ultimate purpose of using interim result to support decisions related to the operation and maintenance of the machine (ISO 13372).

3.2.2 *in-service oil, n*—as applied in this practice, a lubricating oil that is present in a machine which has been at operating temperature for at least one hour.

3.2.2.1 *Discussion*—Sampling a in-service oil after at least one hour of operation will allow for the measurement of a base point for later trend analysis.

3.2.2.2 *Discussion*—Any subsequent addition of lubricant (for example, topping off) may change the trending baseline, which may lead to erroneous conclusions.

3.2.3 *machinery health, n*—a qualitative expression of the operational status of a machine sub-component, component or entire machine, used to communicate maintenance and operational recommendations or requirements in order to continue operation, schedule maintenance or take immediate maintenance action.

3.2.4 *new oil, n*—an oil taken from the original manufacturer's packaging, prior to being added to machinery.

3.2.5 *reference oil, n*—see *new oil*.

3.2.6 *trend analysis, n*—as applied in this practice, monitoring of the level and rate of change over operating time of measured parameters (**1**).

4. Summary of Practice

4.1 Periodic samples are acquired from the engine or machine being monitored. An infrared absorbance spectrum of the sample is acquired, typically covering the range of 4000 cm⁻¹ to 550 cm⁻¹, with sufficient signal-to-noise (S/N) ratio to measure absorbance areas of interest. Exact data acquisition parameters will vary depending on instrument manufacturer but most systems should be able to collect an absorbance spectrum adequate for most measurements in less than one minute. Features in the infrared spectrum indicative of the molecular level components of interest (**1, 2**) (that is, water, fuel, antifreeze, additive, degradation, and so forth) are measured and reported. Condition alerts and alarms can then be triggered according to both the level and the trends from the monitored system.

5. Significance and Use

5.1 Periodic sampling and analysis of lubricants have long been used as a means to determine overall machinery health. Atomic emission (AE) and atomic absorption (AA) spectroscopy are often employed for wear metal analysis (for example, Test Method **D5185**). A number of physical property tests complement wear metal analysis and are used to provide information on lubricant condition (for example, Test Methods **D445**, **D2896**, and **D6304**). Molecular analysis of lubricants and hydraulic fluids by FT-IR spectroscopy produces direct information on molecular species of interest, including additives, fluid breakdown products and external contaminants, and thus complements wear metal and other analyses used in a condition monitoring program (**1, 2-6**).

6. Apparatus

6.1 Required Components:

6.1.1 *Fourier Transform Infrared Spectrometer (FT-IR)*—Instrument is configured with a source, beamsplitter and

³ For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

⁴ Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, <http://www.ansi.org>.