INTERNATIONAL STANDARD

**ISO 18436-5**

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# Condition monitoring and diagnostics of machines — Requirements for qualification and assessment of personnel —

## Part 5: Lubricant laboratory technician/analyst

*Surveillance et diagnostic d'état des machines — Exigences relatives à la qualification et à l'évaluation du personnel —*

*Partie 5: Technicien/analyste de laboratoire d'analyse de lubrifiants*

Reference number
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# Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 18436-5 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration, shock and condition monitoring*, Subcommittee SC 5, *Condition monitoring and diagnostics of machines*.

ISO 18436 consists of the following parts, under the general title *Condition monitoring and diagnostics of machines — Requirements for qualification and assessment of personnel*:

— *Part 1: Requirements for assessment parties and the assessment process*

— *Part 2: Vibration condition monitoring*

— *Part 3: Requirements for training bodies and the training process*

— *Part 4: Field lubricant analysis*

— *Part 5: Lubricant laboratory technician/analyst*

— *Part 6: Acoustic emission*

— *Part 7: Thermography*

The following part is under preparation:

— *Part 8: Ultrasound*

The following part is planned:

— *Part 9: Condition monitoring specialists*

# Introduction

Using lubricant analysis to monitor condition and diagnose faults in machinery is a key activity in predictive maintenance programmes for most industries. Other non-intrusive technologies including thermography, vibration analysis, acoustic emission, and motor current analysis are used as complementary condition analysis tools. Those in the manufacturing industry who have diligently and consistently applied these techniques have experienced a return on investment far exceeding their expectations. However, the effectiveness of these programmes depends on the capabilities of individuals who perform the measurements and analyse the data.

A programme, administered by an assessment body, has been developed to train and assess the competence of personnel whose duties require the appropriate theoretical and practical knowledge of machinery monitoring and diagnostics.

This part of ISO 18436 defines the requirements against which personnel in the non-intrusive machinery condition monitoring and diagnostics technologies associated with laboratory lubricant analysis for machinery condition monitoring are to be qualified and the methods of assessing such personnel.

# Condition monitoring and diagnostics of machines — Requirements for qualification and assessment of personnel —

# Part 5: Lubricant laboratory technician/analyst

## 1 Scope

This part of ISO 18436 specifies the requirements for qualification and assessment of personnel who perform machinery condition monitoring and diagnostics using laboratory-based lubricant analysis.

A certificate or declaration of conformity to this part of ISO 18436 provides recognition of the qualifications and competence of individuals to perform laboratory-based lubricant analysis for machinery condition monitoring. It is possible that this procedure is not applicable to specialized equipment or other specific situations.

This part of ISO 18436 covers a three-category classification programme that is based on the technical areas delineated herein.

## 2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

Table A.3 provides comments on the degree of equivalence between the ISO and ASTM standards on the same subjects.

ISO 1523, *Determination of flash point — Closed cup equilibrium method*

NOTE Technically equivalent to ASTM D3828.

ISO 2592, *Determination of flash and fire points — Cleveland open cup method*

NOTE Technically equivalent to ASTM D92.

ISO 2719, *Determination of flash point — Pensky–Martens closed cup method*

NOTE Technically equivalent to ASTM D93.

ISO 2909, *Petroleum products — Calculation of viscosity index from kinematic viscosity*

NOTE Technically equivalent to ASTM D2270.

ISO 3104, *Petroleum products — Transparent and opaque liquids — Determination of kinematic viscosity and calculation of dynamic viscosity*

NOTE Technically equivalent to ASTM D445.

ISO 3679, *Determination of flash point — Rapid equilibrium closed cup method*

NOTE Technically equivalent to ASTM D3828.

ISO 3733, *Petroleum products and bituminous materials — Determination of water — Distillation method*

NOTE Technically equivalent to ASTM D95.

ISO 3771, *Petroleum products — Determination of base number — Perchloric acid potentiometric titration method*

NOTE Technically equivalent to ASTM D2896.

ISO 4406, *Hydraulic fluid power — Fluids — Method for coding the level of contamination by solid particles*

ISO 6247, *Petroleum products — Determination of foaming characteristics of lubricating oils*

NOTE Technically equivalent to ASTM D892.

ISO 6614, *Petroleum products — Determination of water separability of petroleum oils and synthetic fluids*

NOTE Technically equivalent to ASTM D1401.

ISO 6618, *Petroleum products and lubricants — Determination of acid or base number — Colour-indicator titration method*

NOTE Technically equivalent to ASTM D974.

ISO 6619, *Petroleum products and lubricants — Neutralization number — Potentiometric titration method*

ISO 9120, *Petroleum and related products — Determination of air-release properties of steam turbine and other oils — Impinger method*

NOTE Technically equivalent to ASTM D3427.

ISO 10337, *Crude petroleum — Determination of water — Coulometric Karl Fischer titration method*

NOTE Technically equivalent to ASTM D6304.

ISO 11171, *Hydraulic fluid power — Calibration of automatic particle counters for liquids*

ISO 11500, *Hydraulic fluid power — Determination of the particulate contamination level of a liquid sample by automatic particle counting using the light-extinction principle*

ISO 12937, *Petroleum products — Determination of water — Coulometric Karl Fischer titration method*

NOTE Technically equivalent to ASTM D6304.

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

ISO 13736, *Determination of flash point — Abel closed-cup method*

NOTE Technically equivalent to ASTM D3828.

ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

ISO 18436-1:—, *Condition monitoring and diagnostics of machines — Requirements for qualification and assessment of personnel — Part 1: Requirements for assessment bodies and the assessment process*

ISO 18436-3, *Condition monitoring and diagnostics of machines — Requirements for qualification and assessment of personnel — Part 3: Requirements for training bodies and the training process*

ASTM D664, *Standard Test Method for Acid Number of Petroleum Products by Potentiometric Titration*

ASTM D893, *Standard Test Method for Insolubles in Used Lubricating Oils*

ASTM D2272, *Standard Test Method for Oxidation Stability of Steam Turbine Oils by Rotating Pressure Vessel*

ASTM D2982, *Standard Test Methods for Detecting Glycol-Base Antifreeze in Used Lubricating Oils*

ASTM D3524, *Standard Test Method for Diesel Fuel Diluent in Used Diesel Engine Oils by Gas Chromatography*

ASTM D3525, *Standard Test Method for Gasoline Diluent in Used Gasoline Engine Oils by Gas Chromatography*

ASTM D4739, *Standard Test Method for Base Number Determination by Potentiometric Hydrochloric Acid Titration*

ASTM D5185, *Standard Test Method for Determination of Additive Elements, Wear Metals, and Contaminants in Used Lubricating Oils and Determination of Selected Elements in Base Oils by Inductively Coupled Plasma–Atomic Emission Spectrometry (ICP–AES)*

ASTM D5967, *Standard Test Method for Evaluation of Diesel Engine Oils in T-8 Diesel Engine*

ASTM D6595, *Standard Test Method for Determination of Wear Metals and Contaminants in Used Lubricating Oils or Used Hydraulic Fluids by Rotating Disc Electrode Atomic Emission Spectrometry*

ASTM D7418, *Standard Practice for Set-Up and Operation of Fourier Transform Infrared (FT–IR) Spectrometers for In-Service Oil Condition Monitoring*

ASTM E169, *Standard Practices for General Techniques of Ultraviolet–Visible Quantitative Analysis*

## 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 13372 and the following apply.

**3.1**
**lubricant**
any substance interposed between two surfaces in relative motion for the purpose of modifying the friction and reducing the wear between them

[ISO 18436-4:—, 3.1]

Note to entry: Hydraulic and heat transfer fluids are considered lubricants.

**3.2**
**lubricant analysis**
process of monitoring and performing investigative testing of lubricants, with subsequent interpretation, reporting and response to obtained results

[ISO 18436-4:—, 3.2]

## 4 Classification of personnel (laboratory lubricant analysis)

### 4.1 General

Individuals assessed as conforming to the requirements of this part of ISO 18436 shall be classified in one of three categories depending upon their qualifications. They shall have demonstrated the necessary skills in laboratory-based lubricant analysis for their category as indicated in Annex A.

Personnel classified as category II need to have all the knowledge and skills expected of personnel classified as category I, while personnel classified as category III need to have all the knowledge and skills expected of personnel classified as category II.

### 4.2 Category I

Individuals classified as category I are qualified to perform simple tasks related to the proper handling and testing, in a laboratory setting, of machinery lubricant samples according to established and recognized procedures. Personnel classified as category I shall be able to:

a) properly and safely receive and handle lubricant samples;

b) ensure laboratory testing equipment is within calibration, as per specified procedures;

c) recognize sources of error;

d) be capable of preventing and controlling errors related to handling, testing and data;

e) perform testing using established procedures and standards, with an understanding of the common laboratory tests;

f) report results as determined by established criteria, identifying whether data obtained through the testing is reasonable;

g) inspect data from individual test methods only;

h) demonstrate basic quality knowledge and good laboratory practices.

### 4.3 Category II

Individuals classified as category II are qualified to perform sample analysis and interpretation. Personnel classified as category II shall be able to:

a) set-up routine testing schedules and test slates;

b) verify calibration of laboratory instruments as per specified procedures;

c) recognize all forms of lubricant contamination and be able to undertake all associate test methods, recognize data which is a change from the norm;

d) diagnose lubricant failure mechanisms and modes;

e) perform wear particle testing and basic analysis;

f) customise tests and perform sample analysis and interpretation;

g) report results;

h) demonstrate advanced quality knowledge (ISO/IEC 17025);

i) provide guidance and supervision to category I personnel.

### 4.4 Category III

Individuals classified as category III are qualified to perform and/or direct all types of lubricant analysis. Personnel classified as category III shall also be able to:

a) perform advanced testing, analysis and manage an analysis programme;

b) set-up testing schedules and test slates, including design and set-up of special tests and interpretation of results when established standards do not exist;

c) establish new techniques, interpret criteria, standards and specifications;

d) prepare or approve procedures and instructions, including for calibration of laboratory testing equipment;

e) interpret data and prepare reports for appropriate personnel, based on advanced lubricant testing and wear debris analysis, with an understanding of the main features of software used to report analysis results and their interpretation or diagnosis;

f) perform advanced diagnosis of lubricant failure mechanisms and offer possible machine failure mechanisms that relate to those lubricant failure characteristics;

g) perform audits in accordance with ISO/IEC 17025;

h) establish the laboratory certification programme and documentation for the employer;

i) understand the principles of other condition monitoring methods;

j) assist in establishing acceptance criteria when none are otherwise available;

k) conduct or direct training and training examination of testing personnel;

l) provide guidance and supervision to category I and II personnel.

# 5 Eligibility

## 5.1 General

Candidates should have a combination of education, training and experience to ensure that they understand the principles and procedures applicable to lubricant testing and analysis.

## 5.2 Education

Candidates seeking classification do not need to provide evidence of formal education to establish eligibility. However, it is recommended that candidates for category I and II have at least a secondary school qualification or its equivalent. A category II and III candidate shall be able to manipulate simple algebraic equations, use a basic scientific calculator (including trigonometric and logarithmic functions), and be familiar with the operation of personal computers. Successful completion of 2 years or more of science or engineering at a college, university or technical school is highly recommended for candidates seeking classification in category III.

## 5.3 Training

### 5.3.1 Introduction

To be eligible to apply for assessment based on this part of ISO 18436, candidates shall provide evidence of successful completion of training based on the requirements of Annex A, followed by the experience requirement outlined in 5.4 and Table 2. The documents in Clause 2 and the Bibliography should be used as the domain of knowledge for the training syllabus. Such training shall be compliant with the requirements of ISO 18436-3. The minimum duration of training is shown in Table 1. Training should be in the form of lectures, demonstrations, practical exercises or formal training courses. All test method training under A.2, at minimum, should encompass test method, intent, process, applications, limitations and error sources.

Qualification requirements shall be in accordance with this part of ISO 18436. Training time devoted to each topic shall be in accordance with Annex A and Table 1.

**Table 1 — Minimum duration of cumulative training**

Values in hours

| Category I | Category II | Category III |
|---|---|---|
| 24 | 48 | 80 |

### 5.3.2 Additional training on tribology and lubrication management

In addition to the training hours shown in Table 1, candidates should attend laboratory test method, laboratory management and sample management training of at least a similar duration to that shown in Table 1.

Such training shall be in addition to any formal education compliant with 5.2, inclusive of any college or university education. If undertaken, the additional training shall cover the operation and management of lubricant analysis systems and programmes within a laboratory environment, maintenance of lubricants, typical machine failure mechanisms, and the tribological aspects associated with each mechanism. Such training shall be validated by verifiable records.

## 5.4 Experience

**5.4.1** To be eligible to apply for assessment based on this part of ISO 18436, the candidate shall provide evidence to the assessment body of experience in the field of laboratory-based lubricant testing and analysis for machinery condition monitoring in accordance with Table 2. Classification in category II and III requires previous classification at the lower category.

**Table 2 — Minimum cumulative testing and/or analysis experience requirements**

| Category I | Category II | Category III |
|---|---|---|
| 12 months | 24 months | 36 months |
| 1 200 h[a] | 2 400 h[a] | 3 600 h[a] |
| [a] Denotes the actual testing and analysis experience hours that are required. | | |

**5.4.2** Candidates shall keep verifiable documentary evidence of hours and nature of work for their laboratory-based lubricant analysis. Candidates for Categories I and II shall have this evidence validated by a category II or III person or, in the absence of such a person, by the candidate's technical supervisor.

**5.4.3** Candidates for category III shall have this evidence validated by a category III person or, in the absence of such a person, by the candidate's technical supervisor.

**5.4.4** The validation process for all categories requires the signature of the validating person on the documentary evidence. The validating person should augment this validation process via oral assessment, accompanied task performance, report submission and review, procedure submission and review or a combination thereof, in order to increase the confidence in the validation.

## 6 Examinations

### 6.1 Examination content

**6.1.1** For each category, the candidates shall be required to answer a minimum fixed number of multiple choice questions in a specified time duration as indicated in Table 3.

**Table 3 — Minimum examination content**

| Category | Number of questions | Time h | Passing grade |
|---|---|---|---|
| I | 70 | 2 | 70 |
| II | 100 | 3 | 70 |
| III | 100 | 3 | 70 |

**6.1.2** Questions shall be of a practical nature, yet test the candidate on concepts and principles required to conduct laboratory-based lubricant testing and analysis for the purposes of condition monitoring of machines.

**6.1.3** Some questions may involve the interpretation of charts and plots. Simple mathematical calculations using a basic scientific calculator may be required. A summary of common formulas may be provided along with the examination questions.

**6.1.4** The examination content shall be proportionate with the training syllabus contained in Annex A.

**6.1.5** All test method related exam questions shall be limited to: test method, intent, process, applications, limitations and error sources.

**6.1.6** Assessment bodies may, at their discretion, make accommodations for candidates with conditions that may require some form of compensation.

**6.1.7** Training and assessment bodies shall understand the differences between ASTM and ISO standards, where such differences exist, and the implications of such differences and this shall form part of the training

curriculum, where applicable. Some differences are detailed at Table A.3; however, it is incumbent on the trainer and assessment body to be familiar with differences between the standards.

## 6.2 Conduct of examinations

All examinations shall be conducted in accordance with ISO 18436-1:—, 8.1.

# Annex A
(normative)

# Training course requirements for laboratory lubricant analysis personnel

## A.1 Training syllabus

| Subject | | Category I | Category II | Category III |
|---|---|---|---|---|
| 1 | Sample handling and preparation | 7 | — | — |
| 2 | Lubricant health monitoring | 7 | 5 | — |
| 3 | Reagent management | 5 | — | — |
| 4 | Instrument calibration | 5 | — | — |
| 5 | Testing for wrong or mixed lubricants | — | 1 | — |
| 6 | Water contamination | — | 2.5 | — |
| 7 | Glycol coolant contamination | — | 1 | — |
| 8 | Soot contamination | — | 1 | — |
| 9 | Fuel contamination | — | 2 | — |
| 10 | Air contamination | — | 1 | — |
| 11 | Particle contamination | — | 1.5 | — |
| 12 | Wear particle (debris) monitoring and analysis | — | 3 | 8 |
| 13 | Data interpretation | — | 2.5 | 8 |
| 14 | Quality control | — | 1.5 | 2.5 |
| 15 | Lubricant roles, functions, failure modes | — | 2 | 7 |
| 16 | Sensorial inspections | — | — | 1.5 |
| 17 | Environmental effects on results | — | — | 1 |
| 18 | Alternate technology data correlation | — | — | 3 |
| 19 | Personnel training | — | — | 1 |
| **Total hours for each level** | | **24** | **24** | **32** |

## A.2 Detailed list of topics and hours of instruction

| Subject | Topics | Training, h | | |
|---|---|---|---|---|
| | | Category I | Category II | Category III |
| **1 Sample handling and preparation** | | 7 | — | — |
| | 1 Sample cleanliness | [a] | | |
| | a) Sample diluting | [a] | | |
| | b) Cross-contamination | [a] | | |
| | 2 Contaminant re-suspension | [a] | | |
| | a) Bottle ullage | [a] | | |
| | b) Sample agitation | [a] | | |
| **2 Lubricant health monitoring** | | 7 | 5 | — |
| | 1 Kinematic viscosity (ISO 3104) | [a] | [a] | |
| | 2 Absolute (dynamic) viscosity (ISO 3104) | [a] | [a] | |
| | 3 Viscosity index (ISO 2909) | [a] | [a] | |

| Subject | Topics | Training, h | | |
|---|---|---|---|---|
| | | Category I | Category II | Category III |
| | 4 Total acid number (ISO 6618, ISO 6619,[b] ASTM D664[b]) | a | a | |
| | 5 Total base number (ISO 6618; ISO 3771; ASTM D4739) | a | a | |
| | 6 Fourier transform infrared (FTIR) analysis (ASTM E169, ASTM D7418) | a | a | |
| | 7 Atomic emission spectroscopy (ASTM D5185, ASTM D6595) | a | a | |
| | 8 Flash point test (ISO 2592, ISO 2719, ISO 1523 + ISO 3679 + ISO 13736) | a | a | |
| | 9 Thermogravimetric analysis (TGA) (ASTM D5967) | a | a | |
| | 10 Schiff's reagent (ASTM D2982) | a | a | |
| | 11 Crackle test | a | a | |
| | 12 Co-distillation (ISO 3733) | a | a | |
| | 13 Karl Fischer titration (ISO 10337 + ISO 12937) | a | a | |
| | 14 Cyclic voltammetry (ASTM 6971) | a | a | |
| | 15 Insolubles (ASTM D893) | a | a | |
| | 16 Rotating pressure vessel oxidation test (ASTM D2272) | | a | |
| | 17 Air release characteristics (ISO 9120) | | a | |
| | 18 Foam stability characteristics (ISO 6247) | | a | |
| | 19 Gas chromatography (ASTM D3524, ASTM D3525) | a | a | |
| | 20 Water demulsibility (ISO 6614) | | a | |
| | 21 Data correlation | | a | |
| | 22 Exception testing | | a | |
| **3 Reagent management** | | 5 | — | — |
| | 1 Equipment and glassware | a | | |
| | a) Cleaning and preparation | | | |
| | 2 Chemicals | a | | |
| | a) Preparation | | | |
| | b) Labelling | | | |
| | c) Storage | | | |
| | d) Safety | | | |
| | e) Disposal | | | |
| | f) Material safety data sheets | | | |
| **4 Instrument calibration** | | 5 | — | — |
| | 1 Reference materials | a | | |
| | a) Primary and secondary standards | | | |
| | 2 Record keeping | a | | |
| | a) Routine control charts | | | |
| **5 Testing for wrong or mixed lubricants** | | — | 1 | — |
| | 1 Kinematic viscosity (ISO 3104) | | a | |

| Subject | Topics | Training, h | | |
|---|---|---|---|---|
| | | Category I | Category II | Category III |
| | 2 Fourier transform infrared (FTIR) analysis | | a | |
| | 3 Atomic emission spectroscopy (ASTM D5185, 6595) | | a | |
| **6 Water contamination** | 1 Scope and significance of commonly accepted water oil analysis test methods. When to perform these and use of multiple test data to determine if results are reasonable (ISO 6614) | — | 2,5<br>a | — |
| | 2 Causes of poor water demulsibility | | a | |
| | 3 States of coexistence of water in oil | | a | |
| | 4 Methods for assessing water contamination<br>a) Crackle test<br>b) FTIR analysis<br>c) Co-distillation (ISO 3733)<br>d) Karl Fischer titration (ISO 10337 + ISO 12937) | | a | |
| | 5 Effects of water contamination on the lubricant | | a | |
| | 6 Effects of water contamination on the machine | | a | |
| **7 Glycol coolant contamination** | 1 Scope and significance of commonly accepted oil analysis test methods for glycol contamination. When to perform these and use of multiple test data to determine if results are reasonable | — | 1<br>a | — |
| | 2 Elemental spectroscopy | | a | |
| | 3 Fourier transform infrared (FTIR) analysis | | a | |
| | 4 Schiff's reagent (ASTM D2982) | | a | |
| | 5 Gas chromatography | | a | |
| | 6 Effects of glycol contamination on the lubricant | | a | |
| | 7 Effects of glycol contamination on the machine | | a | |
| **8 Soot contamination** | 1 Scope and significance of commonly accepted oil analysis test methods for soot contamination. When to perform these and use of multiple test data to determine if results are reasonable | — | 1<br>a | |
| | 2 Thermogravimetric analysis (TGA) (ASTM D5967) | | a | |
| | 3 Fourier Transform Infrared (FTIR) analysis | | a | |
| | 4 Pentane insolubles (ASTM D893) | | a | |
| | 5 Blotter Test | | a | |
| | 6 Effects of soot contamination on the lubricant | | a | |

| Subject | Topics | Training, h | | |
|---|---|---|---|---|
| | | Category I | Category II | Category III |
| | 7 Effects of soot contamination on the machine | | a | |
| **9 Fuel contamination** | 1 Scope and significance of commonly accepted oil analysis test methods for fuel contamination. When to perform these and use of multiple test data to determine if results are reasonable | — | 2<br>a | |
| | 2 Kinematic viscosity (ISO 3104) | | a | |
| | 3 Fourier transform infrared (FTIR) analysis | | a | |
| | 4 Flash point test (ISO 2592, ISO 2719, ISO 1523 + ISO 3679 + ISO 13736) | | a | |
| | 5 Gas chromatography (ASTM D3524) | | a | |
| | 6 Effects of fuel contamination on the lubricant | | a | |
| | 7 Effects of fuel contamination on the machine | | a | |
| **10 Air contamination (air in oil)** | 1 Scope and significance of commonly accepted oil analysis test methods for air contamination. When to perform these and use of multiple test data to determine if results are reasonable | — | 1<br>a | |
| | 2 States of coexistence of air in oil | | a | |
| | 3 Methods for assessing air contamination<br>a) Air release characteristics (ISO 9120)<br>b) Foam stability characteristics (ISO 6247) | | a | |
| | 4 Effects of air contamination on the lubricant | | a | |
| | 5 Effects of air contamination on the machine | | a | |
| **11 Particle contamination** | 1 Scope and significance of commonly accepted oil analysis test methods for particle contamination. When to perform these and use of multiple test data to determine if results are reasonable | — | 1,5<br>a | |
| | 2 ISO solid contamination code (ISO 4406) | | a | |
| | 3 Optical particle counting usage and calibration (ISO 11500, ISO 11171) | | a | |
| | 4 Pore blockage particle counting | | a | |
| | 5 Effects of particle contamination on the lubricant | | a | |
| | 6 Effects of particle contamination on the machine | | a | |

| Subject | Topics | Training, h | | |
|---|---|---|---|---|
| | | Category I | Category II | Category III |
| **12 Wear particle (debris) monitoring and analysis** | | — | 3 | 8 |
| | 1 Detecting abnormal wear | | a | |
| | a) Atomic emission spectroscopy methods (inductive couple plasma "ICP" spectroscopy; ark-spark emission spectroscopy) | | | |
| | b) XRF spectroscopy | | | |
| | c) Wear particle density measurements | | | |
| | 2 Wear debris analysis | | a | |
| | a) Ferrogram preparation | | | |
| | b) Filtergram preparation | | | |
| | c) Light effects | | | |
| | d) Magnetism effects | | | |
| | e) Heat treatment | | | |
| | f) Chemical microscopy | | | |
| | g) Basic morphological analysis | | | |
| | 3 Common wear mechanisms | | a | |
| | a) Abrasive wear (two-body; three-body) | | | |
| | b) Surface fatigue/contact fatigue (two-body; three-body) | | | |
| | c) Adhesive wear | | | |
| | d) Corrosive wear | | | |
| | e) Cavitation wear | | | |
| | 4 Size distribution of wear particles from common wear mechanisms | | a | |
| **13 Data interpretation** | | — | 2,5 | 8 |
| | 1 Limits | | a | a |
| | a) Understanding statistical limits (wear debris) | | a | |
| | b) Understanding aging limits (acid number, viscosity) | | a | |
| | c) Understanding targets (Water, ISO cleanliness) | | a | |
| | d) Establishing statistical limits | | | a |
| | e) Establishing aging limits | | | a |
| | f) Establishing goal based limits | | | a |
| | 2 Graphical trend analysis | | a | a |
| | a) Rate of change analysis | | a | a |
| | b) Normalization of data | | a | |
| | c) Reference/baseline data comparison | | a | |
| | d) Effects of make-up oil | | | a |
| | e) Lock-step trending | | | a |
| **14 Quality control** | | — | 1,5 | 2,5 |
| | 1 Procedure writing | | a | |

| Subject | Topics | Training, h | | |
|---|---|---|---|---|
| | | Category I | Category II | Category III |
| | 2 Record management<br>a) Record generation<br>b) Record storage | | | a |
| | 3 Quality control samples<br>a) Types<br>b) Control charts | | | a |
| | 4 Procedures editing | | | a |
| | 5 Audits<br>a) Internal audit<br>b) External audit | | | a |
| **15 Lubricant roles, functions and failure modes** | 1 Base oil<br>a) Functions<br>b) Properties | — | 2<br>a | 7<br>a |
| | 2 Additive types and functions<br>a) Surface active additives and their functions<br>b) Bulk oil active additives and their functions | | a | a |
| | 3 Synthetic lubricants<br>a) Synthetic lubricant types<br>b) Conditions dictating their use | | a | a |
| | 4 Lubrication Regimes<br>a) Hydrodynamic<br>b) Elasto-hydrodynamic<br>c) Boundary | | | a |
| | 5 Baselining physical and chemical properties tests | | | a |
| | 6 Identifying additive discrepancies | | | a |
| | 7 Lubricant failure modes | | a | a |
| **16 Sensorial inspections** | 1 Ability to detect<br>a) Water contamination<br>b) Particle presence<br>c) Paramagnetic particles presence (using magnetic bar)<br>d) Irregular odours | — | — | 1,5<br>a |
| **17 Environmental effects on results** | 1 Environmental effects on results | — | — | 1 |
| **18 Alternate technology data correlation** | 1 Vibration data | — | — | 3<br>a |
| | 2 Infrared data | | | a |
| | 3 Acoustic emission/ultrasonic data | | | a |
| 19 **Personnel training** | 1 Scope of training | — | — | 1<br>a |

| Subject | Topics | Training, h | | |
|---|---|---|---|---|
| | | Category I | Category II | Category III |
| | 2 Certification and recertification needs | | | [a] |
| | 3 Job qualification | | | [a] |
| Total hours | | **24** | **24** | **32** |

NOTE 1 Category II includes the knowledge of category I; category III includes the knowledge of category I and category II.

NOTE 2 At categories II and III, the times allocated are indicative only, indicating the bias towards application topics, and the actual times spent for each topic is flexible, providing an advised minimum of approximately 24 h is allocated per field of application.

NOTE 3 ISO equivalents to ASTM test methods are contained in the *Annual book of ASTM standards*, section 5.

NOTE 4 For the purposes of the practical application of this part of ISO 18436, the ASTM equivalents to the ISO standards cited are given in Clause 2 and may be used. Further information, where variances exist, is contained in A.3.

[a] Subject taught at indicated category.

[b] ISO 6619 and ASTM D664 are not considered equivalent and as such both are listed as normative references. The differences are identified in A.3.

## A.3 Informative equivalence comparison between ASTM and ISO standards

| Informative ISO and ASTM equivalence comparison commentary | | |
|---|---|---|
| ISO 2592:2000, *Determination of flash and fire points — Cleveland open cup method* | ASTM D92, *Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester* | There are minor variances in some temperature requirements and in some apparatus dimensions; however, these are considered not to have any significant effect on procedure performance. |
| ISO 2719:2002, *Determination of flash point — Pensky–Martens closed cup method* | ASTM D93, *Standard Test Methods for Flash-Point by Pensky–Martens Closed Cup Tester* | There are minor variances in some temperature requirements and in some apparatus dimensions; however, these are considered not to have any significant effect on procedure performance. |
| ISO 2909:2002, *Petroleum products — Calculation of viscosity index from kinematic viscosity* | ASTM D2270, *Standard Practice for Calculating Viscosity Index from Kinematic Viscosity at 40 and 100 °C* | Considered to be identical. |
| ISO 3104:1994, *Petroleum products — Transparent and opaque liquids — Determination of kinematic viscosity and calculation of dynamic viscosity* | ASTM D445, *Standard Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)* | There are minor variations as ASTM D445 calculates tolerance band and ISO 3104 sets value at +0,35 %. |
| ISO 3733:1999, *Petroleum products and bituminous materials — Determination of water — Distillation method* | ASTM D95, *Standard Test Method for Water in Petroleum Products and Bituminous Materials by Distillation* | There are minor variations in procedure which are considered of little significance.<br>Such variations exist in the subject of “recovery” accuracies. |
| ISO 3771:2011, *Petroleum products — Determination of base number — Perchloric acid potentiometric titration method* | ASTM D2896, *Standard Test Method for Base Number of Petroleum Products by Potentiometric Perchloric Acid Titration* | Considered to be identical. |
| ISO 6247:1998, *Petroleum products — Determination of foaming characteristics of lubricating oils* | ASTM D892, *Standard Test Method for Foaming Characteristics of Lubricating Oils* | Considered to be identical. |

| Informative ISO and ASTM equivalence comparison commentary | | |
|---|---|---|
| ISO 6614:1994, *Petroleum products — Determination of water separability of petroleum oils and synthetic fluids* | ASTM D1401, *Standard Test Method for Water Separability of Petroleum Oils and Synthetic Fluids* | There is a minor difference in that the turbine oil viscosity range in ISO 6614 is slightly wider.<br>The definition of water separability is listed in ISO 6614, but not in ASTM D1401.<br>ISO 6614 specifies an additional cleaning step with chromosulfuric acid. |
| ISO 6618:1997, *Petroleum products and lubricants — Determination of acid or base number — Colour-indicator titration method* | ASTM D974, *Standard Test Method for Acid and Base Number by Color-Indicator Titration* | There are minor differences in the standardization section; however, the measurements are approximations. |
| ISO 6619:1988, *Petroleum products and lubricants — Neutralization number — Potentiometric titration method* | ASTM D664, *Standard Test Method for Acid Number of Petroleum Products by Potentiometric Titration* | There are major differences in reagent specifications, with ASTM D664 requiring commercial buffer solutions and ISO 6619 requiring mixing of buffers from stock chemicals.<br>Other ISO 6619 reagents differ from those specified in ASTM D664 due to different electrode use.<br>For electrodes, ISO 6619 states, “combination electrodes and silver/silver chloride electrodes…unsuitable for this method”.<br>Calculations and procedure are identical except for the differing electrodes.<br>Both ISO 6619 and ASTM D664 produce acceptable results; however, they are not considered interchangeable. |
| ISO 9120:1997, *Petroleum and related products — Determination of air-release properties of steam turbine and other oils — Impinger method* | ASTM D3427, *Standard Test Method for Air Release Properties of Petroleum Oils* | The procedure and apparatus are nearly identical.<br>The glassware specified is similar, but not identical. This could affect the results as all ISO dimensions are smaller on average of 2 mm to 3 mm on most dimensions. The ISO 9120 apparatus is also 20 mm shorter.<br>The ASTM D3427 pressure gauge requires 1,5 kPa accuracy or 2 kPa divisions; however, there is no equivalent specification in ISO 9120.<br>The density readings required by ASTM D3427 are more precise (0,1 kg/m$^3$ in ASTM D3427 vs. 0,5 kg/m$^3$ in ISO 9120).<br>The calculation section differs slightly in that ASTM D3427 uses density whereas ISO 9120 uses % volume fraction dispersed air in air-in-oil dispersion.<br>There are minor differences in reagents (cleaning solutions), however, ISO 9120 and ASTM D3427 are considered equivalent. |

| Informative ISO and ASTM equivalence comparison commentary | | |
|---|---|---|
| ISO 13736:—, *Determination of flash point — Abel closed-cup method*<br>ISO 3679:2004, *Determination of flash point — Rapid equilibrium closed cup method*<br>ISO 1523:2002, *Determination of flash point — Closed cup equilibrium method* | ASTM D3828, *Standard Test Methods for Flash Point by Small Scale Closed Cup Tester* | ISO 1523, ISO 3679, and ISO 13736 in conjunction with each other are similar to ASTM D3828, though ISO 3679 is the closest.<br>ASTM D3828 provides guidance for a “flash/no flash” test which is not contained in ISO 1523, ISO 3679 or ISO 13736. |
| ISO 12937:2000, *Petroleum products — Determination of water — Coulometric Karl Fischer titration method*<br>ISO 10337:1997, *Crude petroleum — Determination of water — Coulometric Karl Fischer titration method* | ASTM D6304, *Standard Test Method for Determination of Water in Petroleum Products, Lubricating Oils, and Additives by Coulometric Karl Fischer Titration* | These standards are effectively equivalent; however, it is necessary to read ISO 10337 and ISO 12937 in conjunction with each other in order to provide equivalence. |

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[3] ASTM D95, *Standard Test Method for Water in Petroleum Products and Bituminous Materials by Distillation*

[4] ASTM D445, *Standard Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)*

[5] ASTM D892, *Standard Test Method for Foaming Characteristics of Lubricating Oils*

[6] ASTM D974, *Standard Test Method for Acid and Base Number by Color-Indicator Titration*

[7] ASTM D1401, *Standard Test Method for Water Separability of Petroleum Oils and Synthetic Fluids*

[8] ASTM D2270, *Standard Practice for Calculating Viscosity Index from Kinematic Viscosity at 40 and 100 °C*

[9] ASTM D2711, *Standard Test Method for Demulsibility Characteristics of Lubricating Oils*

[10] ASTM D2896, *Standard Test Method for Base Number of Petroleum Products by Potentiometric Perchloric Acid Titration*

[11] ASTM D3427, *Standard Test Method for Air Release Properties of Petroleum Oils*

[12] ASTM D3828, *Standard Test Methods for Flash Point by Small Scale Closed Cup Tester*

[13] ASTM D4378, *Standard Practice of In-Service Monitoring of Mineral Turbine Oil for Steam and Gas Turbines*

[14] ASTM D6224, *Standard Practice of In-Service Monitoring of Lubricating Oil for Auxiliary Power Plant Equipment*

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