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

Part 4: Field lubricant analysis

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

Partie 4: Analyse de la lubrification sur le terrain

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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 108, *Mechanical vibration, shock and condition monitoring*, Subcommittee SC 5, *Condition monitoring and diagnostics of machine systems*.

This second edition cancels and replaces the first edition (ISO 18436-4:2008), which has been technically revised.

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 bodies and the assessment process*

— *Part 2: Vibration condition monitoring and diagnostics*

— *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*

— *Part 8: Ultrasound*

The following part is under preparation:

— *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 field 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 4: Field lubricant analysis

1 Scope

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

A certificate or declaration of conformity to this part of ISO 18436 will provide recognition of the qualifications and competence of individuals to perform field lubricant analysis for machinery condition monitoring. This procedure is not applicable to specialized equipment or other specific situations.

This part of ISO 18436 specifies 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.

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

ISO 18436-1:2012, *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*

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

Note 1 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

4 Classification of personnel (field 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 field 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 field lubricant analysis according to established and recognized procedures. Personnel classified as category I shall be able to

a) dispense lubricants, re-lubricate, and/or inspect lubricants on a pre-programmed route, as appropriate, in accordance with established procedures,

b) properly maintain lubrication devices and equipment,

c) install sampling hardware deemed appropriate, safe, and non-intrusive by category II or higher personnel (any intrusive sampling hardware installation shall be undertaken by a suitably qualified person authorized by the customer),

d) verify that analysis instruments are calibrated and report to the appropriate personnel where action is needed,

e) operate (and maintain) portable lubricant analysis instrumentation on pre-programmed routes,

f) download and upload raw test data from portable lubricant analysis instrumentation,

g) acquire lubricant samples from machine systems, equipment, and/or storage containers in accordance with established procedures, and

h) prepare samples for transport and/or testing in accordance with established procedures.

4.3 Category II

Individuals classified as category II are qualified to perform basic field lubricant testing and analysis according to established and recognized procedures. Personnel classified as category II shall be able to

a) set up instruments for basic on-site testing,

b) perform calibration checks on instruments used for on-site testing,

c) establish procedures for sample acquisition, preparation, and transport,

d) select sample point locations, methods, and hardware and oversee installation of sampling hardware,

e) apply selected test methods for on-site testing and wear debris analysis,

f) liaise with an off-site laboratory,

g) classify, interpret, and evaluate basic test results (including acceptance tests) in accordance with applicable specifications and standards,

h) employ basic lubricant analysis techniques to troubleshoot lubricant, machinery, and components,

i) maintain a database of analysis schedules, results, and diagnoses,

j) prepare reports for appropriate personnel on basic lubricant and machine condition, recommend corrective action (non-intrusive maintenance), and report on effectiveness of repairs/changes,

k) be aware of the use of alternative or supplementary condition monitoring technologies, and

l) 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 field lubricant testing and analysis. Personnel classified as category III shall be able to

a) interpret and evaluate test methods, standards, codes, specifications, and procedures,

b) select the appropriate machinery lubricant analysis technique,

c) specify the appropriate instrumentation hardware and software for both portable and permanently installed systems,

d) design and manage calibration programmes,

e) establish lubricant monitoring programmes, including determination of machines for periodic/continuous monitoring, frequency and type of testing, route plans, etc., and quality assurance testing,

f) establish programmes for the specification of targets, alarms, and limits for machinery,

g) perform advanced on-site tests and wear debris analysis,

h) classify, interpret, and evaluate advanced test results and wear debris analysis (including acceptance tests) in accordance with applicable specifications and standards,

i) manage and perform administrative tasks for lubricant analysis software and databases,

j) perform Failure Mode, Effect, and Criticality Analysis (FMECA),

k) perform prognostics for fault conditions,

l) evaluate the performance of outside lubricant analysis services and recommend necessary corrective changes,

m) prepare reports for appropriate personnel based on advanced lubricant testing and wear debris analysis on lubricant and machine condition,

n) make major maintenance corrective action recommendations (normally intrusive maintenance) and report on effectiveness of repairs/changes,

o) be able to manage condition monitoring programmes, evaluate alarm sets, write working procedures, and specify acceptance testing procedures,

p) recommend the use of alternative condition monitoring (CM) technologies,

q) based on the accrued data, review the lubricants currently in use and make recommendations, inclusive of required lubrication specification changes, with a view to enhancing performance,

r) assess the influence of physical/chemical properties on stability of rotor in bearings, stability of turbine control systems, wear of gears, and hydrodynamic seals, and

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

NOTE It is the employer's responsibility to ensure that category III personnel have the necessary competency in the required management skills, for example creating budgets, preparing cost justifications, and managing personnel development.

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 machinery lubrication and lubricant analysis. General machinery knowledge is required.

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. Category II and III candidates 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 two or more years of mechanical technology or mechanical engineering at a college, university, or technical school is highly recommended for candidates seeking classification to category III.

5.3 Training

5.3.1 General

To be eligible to apply for assessment based on this part of ISO 18436, the candidates shall provide evidence of successful completion of training based on the requirements of Annex A. The documents in 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.

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 (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 tribology and lubrication 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 design, implementation, and operation of lubrication and lubricant analysis systems and programmes, maintenance principles of machines and components, the failure modes and mechanisms associated with each principle, and the typical 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 lubricant-analysis-based machinery condition monitoring in accordance with Table 2. Classification to category II and category III requires previous classification to the lower category.

Table 2 — Minimum cumulative sampling and analysis experience requirements (months)

Category I	Category II	Category III
12	24	36
NOTE The months of experience are based on 16 h minimum per month of lubricant-analysis-based machinery condition monitoring experience.		

5.4.2 Candidates shall keep verifiable documentary evidence of the hours and nature of work for their lubricant-analysis-based machinery condition monitoring experience. 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 fixed minimum number of multiple choice questions in a specified time duration as indicated in Table 3.

6.1.2 Questions shall be of a practical nature, yet shall test the candidate on concepts and principles required to conduct machinery lubrication and lubricant analysis for condition monitoring of machines.

6.1.3 Some questions can involve the interpretation of charts and plots. Simple mathematical calculations using a basic scientific calculator can be required. A summary of common formulae can 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 Assessment bodies can, at their discretion, make accommodations for candidates with conditions that can require some form of compensation.

Table 3 — Minimum examination content

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

6.2 Conduct of examinations

All examinations shall be conducted in accordance with ISO 18436-1:2012, 8.1, except that candidates may also have access to pencils and erasers if computer-based marking is used.

Annex A
(normative)

Training course requirements and minimum training hours for field lubricant analysis personnel

A.1 Training syllabus

Table A.1 — Training syllabus

Subject	Hours of training		
	Category I	**Category II**	**Category III**
1. Maintenance strategies	2,5	1	—
2. Lubrication theory/fundamentals	4	1	6,5
3. Lubricant selection	2,5	—	—
4. Principles of lubricant application	4	—	—
5. Lubricant storage and management	2,5	—	—
6. Lubricant contamination measurement and control	2,5	6	—
7. Oil sampling	2,5	7	—
8. Lubricant health monitoring, diagnostics, prognostics, and generic maintenance recommendations	2,5	5	8
9. Wear debris monitoring and analysis	1	4	11,5
10. Lubricant analysis programme development and management	—	—	6
Total hours for each category	**24**	**24**	**32**

A.2 Detailed list of topics and hours of instruction

Table A.2 — Detailed list of topics and hours of instruction

Subject	Topics	Hours of training		
		Category I	Category II	Category III
1. Maintenance strategies		2,5	1	—
	1. Why machines fail	*		
	2. The impact of poor maintenance on company profits	*		
	3. The role of effective lubrication in failure avoidance	*		
	4. Fundamental aspects of Reliability-Centred Maintenance (RCM)		*	
	5. Aspects of Condition-Based Maintenance (CBM)		*	
	a) Predictive maintenance strategies		*	
	b) Proactive maintenance strategies		*	
	c) Lubrication routes and scheduling	*		
	d) Lubricant analysis and technologies to ensure lubrication effectiveness	*		
	e) Equipment tagging and identification	*		
2. Lubrication theory and fundamentals		4	1	6,5
	1. Fundamentals of tribology	*		
	2. Functions of a lubricant	*	*	
	3. Lubrication regimes	*	*	*
	a) Hydrodynamic	*	*	*
	b) Elasto-hydrodynamic	*	*	*
	c) Boundary	*	*	*
	4. Base oils	*	*	*
	a) Functions	*	*	
	b) Properties	*	*	
	c) Characteristics, advantages, and disadvantages	*	*	*

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

NOTE 2 * indicates topics to be taught at indicated category.

Table A.2 — *(continued)*

Subject	Topics	Hours of training		
		Category I	Category II	Category III
	5. Additive functions	*	*	*
	a) Antioxidants/oxidation inhibitors			*
	b) Rust inhibitors			*
	c) Corrosion inhibitors			*
	d) Demulsifying agents			*
	e) Viscosity index (VI) improvers	*	*	*
	f) Detergents	*	*	*
	g) Dispersants			*
	h) Pour-point depressants			*
	i) Foam inhibitors			*
	j) Anti-wear (AW) agents			*
	k) Extreme pressure (EP) agents			*
	6. Oil lubricant physical, chemical, and performance properties and classifications	*		
	7. Grease lubrication	*		
	a) How grease is made	*		
	b) Thickener types	*		
	c) Thickener compatibility	*		
	d) Grease lubricant physical, chemical, and performance properties and classifications	*		
	8. Solid lubrication	*		
	a) Types of solid lubricant	*		
	b) Mechanisms of solid lubrication	*		
	c) Pressure-velocity (PV) factor equation	*		
	d) Specific wear rate equation	*		

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

NOTE 2 * indicates topics to be taught at indicated category.

Table A.2 — *(continued)*

Subject	Topics	Hours of training		
		Category I	Category II	Category III
	9. Gas lubrication	*		
	a) Advantages of gas lubricated bearings	*		
	b) Properties of lubricating gases	*		
	10. Classification systems	*		
	a) Viscosity (ISO/SAE)	*		
	b) Grease consistency (NLGI)	*		
	c) Engine (API/ILSAC)	*		
	d) API automotive gear oil classification	*		
	e) ATF classifications	*		
	f) Automatic brake fluid classifications	*		
	g) AGMA gear classifications	*		
	h) AGMA gear coupling classifications	*		
	i) Turbine oil classifications (BSI, DIN, GE, ABB)	*		
	j) Hydraulic fluids (ISO, Factory Mutual fire resistance grading system, ASTM, various components/system OEM performance specifications)	*		
	k) USDA/FSIS and NSF food-grade lubricant classification	*		

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

NOTE 2 * indicates topics to be taught at indicated category.

Table A.2 — *(continued)*

Subject	Topics	Hours of training		
		Category I	Category II	Category III
3. Lubricant selection		2,5	—	—
	1. When to choose/advantages and disadvantages of: oil, grease	*		
	2. When to choose/advantages and disadvantages of: solid, gas	*		
	3. Viscosity selection	*		
	4. Base-oil type selection	*		
	5. Additive system selection	*		
	6. Grease thickener selection	*		
	7. Machine-specific lubricant requirements	*		
	a) Hydraulic systems	*		
	b) Plain bearings	*		
	c) Rolling element bearings	*		
	d) Journal bearings	*		
	e) Reciprocating engines	*		
	f) Gearing and gearboxes	*		
	g) Ropes	*		
	h) Chains	*		
	i) Steam turbines	*		
	j) Gas turbines	*		
	k) Internal combustion engines	*		
	l) Compressors	*		
	8. Application and environment-related adjustments	*		
4. Principles of lubricant application		4	—	—
	1. Effective use of manual delivery techniques	*		
	2. Automatic delivery systems	*		
	a) Distributed delivery systems	*		
	b) Automated lubricators	*		
	c) Maintenance of automated lubrication systems	*		
NOTE 1 Category II includes the knowledge of category I; category III includes the knowledge of category I and category II. NOTE 2 * indicates topics to be taught at indicated category.				

Table A.2 — *(continued)*

Subject	Topics	Hours of training		
		Category I	Category II	Category III
5. Lubricant storage and management		2,5	—	—
	1. Lubricant receiving procedures	*		
	2. Proper storage and inventory management	*		
	3. Lubricant storage containers	*		
	4. Proper storage of grease guns and other lubricant application devices	*		
	5. Maintenance of automatic grease systems	*		
	6. Health and safety assurance	*		
6. Lubricant contamination measurement and control		2,5	6	—
	1. Particle contamination		*	
	a) Effects on the machine		*	
	b) Effects on the lubricant		*	
	c) Methods and units for measuring particle contamination		*	
	d) Techniques for controlling particle contamination		*	
	2. Moisture contamination		*	
	a) Effects on the machine		*	
	b) Effects on the lubricant		*	
	c) States of coexistence		*	
	d) Methods and units for measuring moisture contamination		*	
	e) Demulsibility measurement		*	
	f) Techniques for controlling moisture contamination		*	
	3. Glycol coolant contamination		*	
	a) Effects on the machine		*	
	b) Effects on the lubricant		*	
	c) Methods and units for measuring glycol contamination		*	
	d) Techniques for controlling glycol contamination		*	

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

NOTE 2 * indicates topics to be taught at indicated category.

Table A.2 — *(continued)*

Subject	Topics	Hours of training		
		Category I	Category II	Category III
	4. Soot contamination		*	
	a) Effects on the machine		*	
	b) Effects on the lubricant		*	
	c) Methods and units for measuring soot contamination		*	
	d) Techniques for controlling soot contamination		*	
	5. Fuel contamination (fuel dilution in oil)		*	
	a) Effects on the machine		*	
	b) Effects on the lubricant		*	
	c) Methods and units for measuring fuel contamination		*	
	d) Techniques for controlling fuel contamination		*	
	6. Air contamination (air in oil)		*	
	a) Effects on the machine		*	
	b) Effects on the lubricant		*	
	c) States of coexistence		*	
	d) Methods and units for measuring air contamination		*	
	e) Techniques for controlling air contamination		*	
	7. Filtration and separation technologies	*		
	8. Filter rating	*		
	9. Filtration system design and filter selection	*		

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

NOTE 2 * indicates topics to be taught at indicated category.

Table A.2 — *(continued)*

Subject	Topics	Hours of training		
		Category I	Category II	Category III
7. Oil sampling		2,5	7	—
	1. Objectives for lubricant sampling	*	*	
	2. Equipment-specific sampling		*	
	a) Gearboxes with circulating systems		*	
	3. Sampling methods	*	*	
	a) Non-pressurized systems		*	
	b) Pressurized systems – low		*	
	c) Pressurized systems – high		*	
	4. Managing interference	*	*	
	a) Bottle cleanliness and management	*	*	
	b) Flushing	*	*	
	c) Machine conditions appropriate for sampling	*	*	
	5. Sampling process management	*	*	
	a) Sampling frequency	*		
	b) Sampling procedures (to include sampling point selection)	*		
	c) Sample processing	*		
8. Lubricant health monitoring, diagnostics, prognostics, and generic maintenance recommendations		2,5	5	8
	1. Lubricant failure mechanisms	*	*	*
	a) Oxidative degradation – the process, causes, and effects	*	*	*
	b) Oxidative degradation – at-risk lubricants and applications; strategies for deterring it; strengths, limitations, and applicability of tests used to detect and troubleshoot oxidation (AN, viscosity, FTIR, RPVOT, sensory inspection)			*
	c) Thermal degradation – the process, causes, and effects	*	*	*
	d) Thermal degradation – strengths, limitations, and applicability of tests used to detect and troubleshoot thermal failure (AN, viscosity, FTIR, thermal stability test, ultracentrifuge detection of carbon insolubles, sensory inspection)			*
	e) Additive depletion/degradation – mechanisms; additives at risk	*	*	*

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

NOTE 2 * indicates topics to be taught at indicated category.

Table A.2 — *(continued)*

Subject	Topics	Hours of training		
		Category I	Category II	Category III
	f) Additive depletion/degradation – risk assessment for common mechanisms (neutralization, shear down, hydrolysis, oxidation, thermal degradation, water washing, particle scrubbing, surface adsorption, rubbing contact, condensation settling, filtration, aggregate adsorption, evaporation, centrifugations); strengths, limitations, and applicability of methods for measuring additive depletion/degradation (atomic emission spectroscopy, FTIR, AN, BN, VI, RPVOT, blotter spot test)			*
	g) Testing for wrong or mixed lubricants (base-lining physical and chemical properties test, additive discrepancies)	*	*	*
	h) Fluid properties test methods and measurement units – viscosity (kinematic and absolute, VI), AN/BN, elemental spectroscopy, FTIR, RPVOT, atomic emission spectroscopy, other tests	*	*	*
9. Wear debris monitoring and analysis		1	4	11,5
	1. Common machine wear mechanisms	*	*	*
	a) Abrasive wear: two-body and three-body abrasive wear		*	*
	b) Surface fatigue: two-body and three-body		*	*
	c) Adhesive wear		*	*
	d) Corrosive wear		*	*
	e) Fretting wear			*
	f) Erosive wear			*
	g) Electrical wear			*
	h) Cavitation wear: gaseous and vaporous cavitation		*	*
NOTE 1 Category II includes the knowledge of category I; category III includes the knowledge of category I and category II.				
NOTE 2 * indicates topics to be taught at indicated category.				

Table A.2 — *(continued)*

Subject	Topics	Hours of training		
		Category I	Category II	Category III
	2. Common machine-specific wear modes			*
	a) Gearing			*
	b) Plain bearings			*
	c) Rolling element bearings			*
	d) Hydraulics			*
	3. Wear particle types, origins, and probable causes	*		*
	a) Cutting wear particles			*
	b) Spherical particles			*
	c) Chunky particles			*
	d) Laminar particles			*
	e) Red oxide particles			*
	f) Black oxide particles			*
	g) Corrosion particles			*
	h) Non-ferrous particles			*
	i) Friction polymers			*
	4. Wear debris analysis techniques	*	*	*
	a) Ferrogram preparation		*	
	b) Filtergram preparation		*	
	c) Light effects		*	*
	d) Magnetism effects		*	*
	e) Heat treatment		*	*
	f) Chemical treatment			*
	g) Morphology		*	*
	h) Surface detail			*
	5. Atomic emission elemental spectroscopy		*	*
	a) Basic determination of wear particle metallurgy from elemental composition			*
	b) Evaluating sequential trends			*
	c) Evaluating lock-step trends			*

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

NOTE 2 * indicates topics to be taught at indicated category.

Table A.2 — *(continued)*

Subject	Topics	Hours of training		
		Category I	Category II	Category III
	d) Particle size limitation of common atomic emission spectrometers			*
	e) ICP spectroscopy		*	
	f) Arc-spark emission spectroscopy		*	
	g) Wear particle density measurement		*	
	h) Advanced techniques (acid/microwave digestion, rotrode filter spectroscopy)			*
	i) X-ray fluorescence (XRF) and other advanced elemental spectroscopy methods			*
10. Lubricant analysis programme development and programme management		—	—	6
	1. Machine-specific test slate selection			*
	2. Optimizing frequency of analysis			*
	3. Setting alarms and limits			*
	a) Setting goal-based limits for contamination			*
	b) Statistically derived level limits: editing data, calculating averages and standard deviation, setting upper and lower limits using the mean and standard deviation, how changes in system operation or maintenance influence statistically derived inferences			*
	c) Rate-of-change limits: calculating rate of change, slope-based alarms, statistically derived rate-of-change limits			*
	d) Setting aging limits for fluid properties: physical, chemical, and additive properties			*
	e) Trend analysis			*
	4. Managing lubricant analysis information			*

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

NOTE 2 * indicates topics to be taught at indicated category.

Table A.2 — *(continued)*

Subject	Topics	Hours of training		
		Category I	Category II	Category III
	5. Creating and managing lubricant analysis procedures			*
	6. Scoping lubricant analysis training and examination for reliability technicians, trades people, and management			*
	7. Performing cost/benefit analysis for lubricant analysis and contamination control programmes			*
	a) Calculating programme costs			*
	b) Estimating programme benefits			*
	c) Calculating return on investment metrics			*
	d) Generating an effective business proposal			*
	8. Quality assurance			*
	a) Of on-site lubricant analysis			*
	b) Of off-site lubricant analysis providers			*
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 * indicates topics to be taught at indicated category.				

Bibliography

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