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CM/GEN APPENDIX C- Issue 2 rev F

IMPLEMENTATION DATE: 1ST AUGUST 2014

SPECIFIC REQUIREMENTS FOR QUALIFICATION AND PCN CERTIFICATION OF CONDITION MONITORING AND DIAGNOSTIC PERSONNEL FOR LUBRICANT ANALYSIS

CONTENTS

Introduction

The use of Lubricant Analysis (LA) in condition monitoring and diagnosis of faults in machinery has become a key activity in predictive maintenance programmes for many industries. The effectiveness of this technology depends on the capabilities of individuals who perform the measurements and analyse the data. This document is appended to CM/GEN (General requirements for qualification and PCN certification of condition monitoring and diagnostic personnel). Other Appendices cover:

Appendix A Acoustic Emission
Appendix B Infra-red Thermography
Appendix D Vibration Analysis

This series of documents is designed to provide comprehensive information for users of the PCN Scheme. The complete list of published PCN condition monitoring documents is detailed in publication reference PSL/8A-CM, which is posted on the Institute's web site at www.bindt.org, where all documents are available for download free of charge.

It is intended, through publication of these documents, to provide industry, PCN candidates and certificate holders with all relevant information. However, if further information or advice is required on any certification matter, contact the Certification Services Division of BINDT on telephone number +44 (0) 1604 893811, or email pcn@bindt.org.

Organisations requiring at all times to be in possession of the most up to date PCN documents may register with the "PCN Update Scheme" which, for a small annual fee, guarantees that they automatically receive all new and revised PCN documents.

1. Scope

1.1. This appendix to PCN CM/GEN sets out the specific requirements for qualification and assessment of personnel engaged in Condition Monitoring using Lubricant Analysis. In the event of a conflict between the requirements of PCN CM/GEN and this Appendix, the PCN CM/GEN requirements shall prevail.

1.2. This specification is in accordance with ISO 18436: Condition monitoring and diagnostics of machines: Requirements for qualification and assessment of personnel- Part 4: Field Lubricant Analysis and Part 5: Lubricant laboratory technician/analyst

1.3. Certification to this document may be acquired according to sector of employment. The sectors are ‘Laboratory’ (Lab) and ‘Field’, or may be a combined qualification (Lab + Field) for ‘field laboratory’ operations.

1.4. This specification offers three modules for training and assessment. They are Module A- ‘general theory- common subjects’ and two practical applications based modules- Module B - ‘Laboratory’ and Module C - ‘Field’.

1.5. Certification to this document may be acquired for a single sector or both, but each requires completion and successful examination in module A. If a candidate succeeds in Module A examination but fails a sector module, then no certificate is awarded but Module A credited for 12 months.

2. Classification of Personnel

2.1. General

2.1.1. Individuals certificated in accordance with this specification are classified in one of three Categories and have demonstrated the necessary skills in the concepts of machinery Lubricant Analysis, as defined in the scope for their classification Category and sector, as indicated in the examination syllabus at Annex A1.

2.1.2. Personnel classified as Category 2 require all the knowledge and skills expected of personnel classified as Category 1, and personnel classified as Category 3 require all the knowledge and skills expected of personnel classified as Category 2.

2.1.3. The classification of personnel in two sectors and three Categories are presented in the following order:

- Clause 2.3 Category 1 Laboratory
- Clause 2.4 Category 2 Laboratory
- Clause 2.5 Category 3 Laboratory
- Clause 2.6 Category 1 Field

- Clause 2.7 Category 2 Field
- Clause 2.8 Category 3 Field

2.3 Lubrication Analysis Category 1 Laboratory

PCN certificated Lubrication Analysis Category 1 personnel 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 recognised procedures. Personnel classified as Category 1 shall be able to:

2.3.1 properly and safely receive and handle lubricant samples;

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

2.3.3 recognise sources of error;

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

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

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

2.3.7 inspect data from individual test methods only;

2.3.8 Demonstrate basic quality knowledge and laboratory good practice in accordance with ISO17025

2.4 Lubrication Analysis Category 2 Laboratory

PCN certificated Lubrication Analysis Category 2 personnel are qualified to perform sample analysis and interpretation. Personnel classified as Category 2 shall be able to:

2.4.1 set-up routine testing schedules and test slates (suite, programme);

2.4.2 verify calibration of laboratory instruments as per specified procedures;

2.4.3 recognise all forms of contamination and be able to undertake all associate test methods, recognise data which is a change from the norm;

2.4.4 diagnose lubricant failure mechanisms and modes;

2.4.5 perform wear particle testing and basic analysis;

2.4.6 manage and perform administrative tasks for lubricant analysis software and databases;

2.4.7 customise tests and perform sample analysis and interpretation;

2.4.8 report results;

2.4.9 demonstrate advanced quality knowledge in accordance with ISO 17025;

2.4.10 provide guidance, supervision and training to Category 1 and 2 Laboratory Analysis personnel;

2.4.11 recommend the use of alternative CM technologies, with an awareness of the principles of other CM technologies specified in CM/GEN, at least to Category 1.

2.5 Lubrication Analysis Category 3 Laboratory

PCN Lubrication Analysis Category 3 personnel are qualified to perform and/or direct all types of lubricant analysis. Personnel classified as Category 3 shall also be able to:

2.5.1 perform advanced testing, analysis and manage an analysis programme;

2.5.2 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;

2.5.3 establish new techniques, interpret criteria, standards and specifications;

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

2.5.5 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;

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

2.5.7 perform internal audits in accordance with ISO 17025;

2.5.8 establish the laboratory certification programme and documentation for the employer;

2.5.9 direct the use of alternative CM technologies, with an understanding of the principles of other CM technologies specified in CM/GEN, at least to Category 1;

2.5.10 assist in establishing acceptance criteria when none are otherwise available;

2.5.11 provide guidance, supervision and training to Category 1, 2 and 3 Laboratory personnel.

2.6 Lubrication Analysis Category 1 Field

PCN certificated Lubrication Analysis Category 1 Field personnel are qualified to perform field lubricant analysis according to established and recognised procedures. Personnel classified as Category 1 Field Analyst shall be able to:

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

2.6.2 properly maintain lubrication devices and equipment;

2.6.3 install sampling hardware deemed appropriate, safe and non-intrusive*;

2.6.4 verify that analysis instruments are calibrated and report to the appropriate personnel where action is needed;

2.6.5 operate (and maintain) portable lubricant analysis instrumentation on pre- programmed routes;

2.6.6 download and upload raw test data from portable lubricant analysis instrumentation;

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

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

*A Category 2 or higher certificated person must deem whether sampling hardware is appropriate, safe and non-intrusive and any intrusive sampling hardware installation shall be undertaken by a suitably qualified person authorised by the customer or owner

2.7 Lubrication Analysis Category 2 Field

PCN certificated Lubrication Analysis Category 2 Field personnel are qualified to perform basic field lubricant testing and analysis according to established and recognised procedures. Personnel classified as Category 2 Field shall be able to:

2.7.1 set up instruments for basic on-site testing;

2.7.2 perform calibration checks on instruments used for on-site testing;

2.7.3 establish procedures for sample acquisition, preparation and transport;

2.7.4 select sample point locations, methods and hardware and oversee installation of sampling hardware;

2.7.5 apply selected test methods for on-site testing and wear debris analysis;

2.7.6 liaise with parent and/or 3rd party laboratories;

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

2.7.8 employ basic lubricant analysis techniques to troubleshoot lubricant, machinery and components;

2.7.9 maintain a database of analysis schedules, results and diagnosis;

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

2.7.11 be aware of the use of alternative or supplementary condition monitoring technologies;

2.7.12 provide guidance, supervision and training to Category I and 2 Field personnel.

2.8 Lubrication Analysis Category 3 Field

PCN certificated Lubrication Analysis Category 3 (Field Analyst) personnel are qualified to perform and/or direct all types of field lubricant testing and analysis. Personnel classified as Category 3 Field shall be able to:

2.8.1 interpret and evaluate test methods, standards, codes, specifications and procedures;

2.8.2 select the appropriate machinery lubricant analysis technique;

2.8.3 specify the appropriate instrumentation hardware and software for both portable and permanently installed systems;

2.8.4 design and manage calibration programmes;

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

2.8.6 establish programmes for the specification of targets, alarms and limits for machinery;

2.8.7 perform advanced on-site tests and wear debris analysis;

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

2.8.9 manage and perform administrative tasks for lubricant analysis software and databases;

2.8.10 perform Failure Mode, Effect and Criticality Analysis (FMECA);

2.8.11 perform prognostics for fault conditions;

2.8.12 evaluate the performance of outside lubricant analysis services and recommend necessary corrective changes;

2.8.13 prepare reports for appropriate personnel based on advanced lubricant testing and wear debris analysis on lubricant and machine condition;

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

2.8.15 be able to manage condition monitoring programmes, evalutate alarm sets, write working procedures, and specify acceptance testing procedures;

2.8.16 recommend the use of alternative CM technologies, with an understanding of the principles of other CM technologies specified in CM/GEN, at least to Category 1;

2.8.17 based on the accrued data, review the lubricants currently in use and make recommendations, inclusive of required lubrication schedule, with a view to enhancing performance;

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

2.8.19 provide guidance, supervision and training to Category 1, 2 and 3 Field personnel.

Note: It is the employer's responsibility to ensure that Category 3 personnel have the necessary competency in the required management skills, for example creating budgets, preparing cost justifications, and managing personnel development.

3. Eligibility for Qualification and Certification

3.1 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.

3.2 Education

Candidates seeking classification do not need to provide evidence of formal education to establish eligibility. However, it is recommended that candidates for Category 1 and 2 have at least a secondary school qualification or its equivalent. Category 2 and 3 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 3.

3.3 Training

3.3.1 General

To be eligible to apply for assessment based on this Appendix, the candidate shall provide evidence of successful completion of training based on the requirements of Annex A. The reading references in Annex B should be used as the domain of knowledge for the training syllabus. 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.

3.3.2 In addition to the training hours shown in Table 1, Category 2 candidates only should have completed formal or on-the-job training on machinery knowledge, covering machinery and components, of a similar duration to that in Table 1. This training should cover design, implementation, manufacture, installation, operation and maintenance principles of machines and lubrication systems and programmes, and include failure mechanisms and modes associated with each principle and the typical tribological aspects associated with each mechanism. Such training, if undertaken, shall be validated by verifiable records.

3.3.3 The training declaration shall attest to the successful completion of a practical evaluation of the exercises at Category 1.

3.3.4 Trainers and BINDT should satisfy themselves that applicants qualified from other assessing bodies either to ISO18436 part 4 or part 5, that the subject matter covered is comparable to that required in this specification at Annex A2. If not, then the trainer should offer a 'catch-up' module for the subjects not covered in their existing qualification and add them as ancillary subjects to their 'declaration of conformity'.

Table 1. Minimum Duration of training (hours)

Category 1 Field	Category 1 Lab	Category 2 Field	Category 2 Lab	Category 3 Field	Category 3 Lab
24	24	24	24	32	32

3.4 Experience

3.4.1 To be eligible to apply for assessment the candidate shall provide evidence of experience (practical and theoretical) in the disciplines of machinery lubrication management condition monitoring appropriate to the Sector and Category sought. The minimum experience requirements are shown in Table 2.

3.4.2 Certification at Category 2 and Category 3 requires previous certification at the lower Categories.

3.4.3 Candidates must maintain a log of hours and nature of work as evidence of their lubricant analysis based machinery condition monitoring experience. Candidates for Category 1 and 2 shall have this evidence validated by a Category 2 or 3 person, or in the absence of such a person, by the candidate's technical supervisor. This evidence should be provided for assessment on PSL57CM or PSL30CM. BINDT shall verify evidence of experience with the person(s) providing validation.

Table 2. Minimum Cumulative Experience (sampling, testing, analysis) requirements (months)

Category 1 Field	Category 1 Lab	Category 2 Field	Category 2 Lab	Category 3 Field	Category 3 Lab
12	12	24	24	36	36
Note: The months of experience are based on 16 hours minimum per month of lubricant analysis based machinery condition monitoring experience.					

4. Certification Available

4.1 Category 1 Field
4.2 Category 1 Laboratory
4.3 Category 2 Field
4.4 Category 2 Laboratory
4.5 Category 3 Field
4.6 Category 3 Laboratory

5. Qualification Examinations

5.1 Application for qualification examinations

5.1.1 Application for qualification examination is made on PCN form PSL57CM.

5.2 Examination content

5.2.1 For each certification Category, the candidates shall be required to answer multiple choice questions indicated in Table 3 for each sector.

5.2.2 On each Category 3 paper there will be ten narrative questions offered, but only six needs to be answered.

5.2.3 At Category 3, each narrative question will be worth 10 marks.

5.2.4 The content of the examination paper shall:

5.2.4.1 contain multiple-choice questions for each subject in Annex A2

5.2.5 Questions will be of a practical nature and will test the candidate's knowledge and practical applications of the principles and procedures required to conduct machinery lubrication management testing and analysis.

5.2.6 Questions will include the interpretation of practical data, charts, plots and images. Simple mathematical calculations using a basic scientific calculator may be required.

5.3 Conduct of examinations

All examinations shall be conducted in accordance with CM_GEN Issue 2 rev D Clause 9.

TABLE 3 – Qualification examination content			
Categories	Number of questions	Time (hours)*	Passing Grade (%)
Category 1 Field	70	2	70
Category 1 Laboratory	70	2	70
Category 2 Field	100	3	70
Category 2 Laboratory	100	3	70
Category 3 Field	100 10 narrative- answer 6	3	70
Category 3 Laboratory	100 10 narrative- answer 6	3	70

Annex A1 – Training syllabus (normative)

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

	Hours of training		
Subject	**Category 1**	**Category 2**	**Category 3**
1. Maintenance strategies	2.5	1	0
2. Lubrication theory/fundamentals	4	1	6.5
3. Lubrication selection	2.5	0	0
4. Principles of lubricant application	4	0	0
5. Lubricant storage and management	2.5	0	0
6. Lubricant contamination measurement and control	2.5	6	0
7. Oil sampling	2.5	7	0
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	0	0	6
Total hours for each Category	**24**	**24**	**24**

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

	Hours of training		
Subject	**Category 1**	**Category 2**	**Category 3**
1. Sample handling and preparation	7	0	0
2. Lubricant health monitoring	7	5	0
3. Reagent management	5	0	0
4. Instrument calibration	5	0	0
5. Testing for wrong or mixed lubricants	0	1	0
6. Water contamination	0	2.5	0
7. Glycol coolant contamination	0	1	0
8. Soot contamination	0	1	0
9. Fuel contamination	0	2	0
10. Air contamination	0	1	0
11. Particle contamination	0	1.5	0
12. Wear particle (debris) monitoring and analysis	0	3	8
13. Data interpretation	0	2.5	8
14. Quality control	0	1.5	2.5
15. Lubricant roles, functions, failure modes	0	2	7
16. Sensorial inspections	0	0	1.5
17. Environmental effects on results	0	0	1
18. Alternate technology data correlation	0	0	3
19. Personnel training	0	0	1
Total hours for each Category	**24**	**24**	**32**

Annex A2 - Detailed list of topics and hours of Instruction

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

			Hours of Training	
Subject	**Topic**	**Category 1**	**Category 2**	**Category 3**
1. Maintenance strategies		**2.5**	**1**	**0**
	1. Why machines fail	*		
	2. 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. Function 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	*	*	*
	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	* * * * *		
	9. Gas lubrication a. Advantages of gas lubricated bearings b. Properties of lubrication gases	* * *		
	10.Classification systems a. Viscosity (ISO/SAE) b. Grease consistency (NLGI) c. Engine (API/ISLAC) 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, ADTM, various components/system OEM performance specifications) k. USDA/FSIS and NSF food-grade lubricant classifications	* * * * * * * * * * * *		
3. Lubricant selection		**2.5**	**0**	**0**
	1. When to choose (advantages & disadvantages of) oil, grease	*		
	2. When to choose (advantages & disadvantages of) solid, gas	*		
	3. Viscosity selection	*		
	4. Base-oil type selection	*		
	5. Additive system selection	*		
	6. Grease thickener selection	*		
	7. Machine-specific lubricant requirement 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**	**0**	**0**
	1. Effective use of manual delivery techniques	*		
	2. Automatic delivery systems a. Distributed delivery systems b. Automated lubricators c. Maintenance of automated lubrication systems	* * * *		
5. Lubricant storage and management		**2.5**	**0**	**0**
	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**	**0**
	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		*	
	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		*	
	7. Filtration and separation technologies	*		
	8. Filter rating	*		
	9. Filtration system design and filter selection	*		
7. Oil sampling		**2.5**	**7**	**0**
	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 test used to detect and troubleshoot thermal failure (AN, viscosity, FTIR, thermal stability test, ultracentrifuge detection of carbon insoluble, sensory inspection)			*
	e. Additive depletion/degradation – mechanisms; additives at risk	*	*	*
	f. Additive depletion/degradation – risk assessment for common mechanisms (neutralization, shear down, hydrolysis, oxidation, thermal degradation, water washing, particle scrubbing, surface adsorption, rubbing contract, 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, PRVOT, 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		*	*

	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			*
	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 management		**0**	**0**	**6**

	1. Machine-specific slate test			*
	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			*
	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**

Module B- Laboratory Analyst

		Hours of Training		
Subject	**Topic**	**Category 1**	**Category 2**	**Category 3**
1. Sample handling and preparation		**7**	**0**	**0**
	1. Sample cleanliness a. Sample diluting b. Cross-contamination	* * *		
	2. Contaminant re-suspension a. Bottle Ullage b. Sample agitation	* * *		
2. Lubricant health monitoring		**7**	**5**	**0**
	1. Kinematic viscosity	*	*	
	2. Absolut viscosity	*	*	
	3. Viscosity index	*	*	
	4. Total acid number AN	*	*	
	5. Total base number BN	*	*	
	6. Fourier transform infrared FTIR	*	*	
	7. Atomic emission spectroscopy AES	*	*	
	8. Flash point test	*	*	
	9. Thermogravimetric analysis TGA	*	*	
	10. Schiff's Reagent	*	*	
	11. Crackle Test	*	*	
	12. Co-distillation	*	*	
	13. Karl Fischer titration	*	*	
	14. Cyclic Voltammetry	*	*	
	15. Insolubles	*	*	
	16. Rotating pressure vessel oxidation test		*	
	17. Air release characteristics		*	
	18. Foam stability characteristics		*	
	19. Gas Chromatography	*	*	
	20. Water demusibility		*	
	21. Data correlation		*	
	22. Exception testing		*	
3. Reagent Management		**5**	**0**	**0**
	1. Equipment and glassware a. Cleaning and preparation	* *		
	2. Chemicals a. Preparation b. Labelling c. Storage d. Safety	* * * * *		

	e. Disposal f. Material safety data sheets	* *		
4. Instrument Calibration		**5**	**0**	**0**
	1. Reference materials a. Primary and secondary standards	* *		
	2. Record keeping a. Routine control charts	* *		
5. Testing for wrong or mixed lubricants		**0**	**1**	**0**
	1. Kinematic viscosity		*	
	2. FTIR		*	
	3. AES		*	
6. Water contamination		**0**	**2.5**	**0**
	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		*****	
	2. Causes of poor water demulsibity		*	
	3. States of coexistence of water in oil		*	
	4. Methods for assessing water contamination a. Crackle test b. FTIR analysis c. Co-distillation d. Karl Fischer titration		* * * * *	
	5. Effects of water contamination on the lubricant		*	
	6. Effects of water contamination on the machine		*	
7. Glycol coolant contamination		**0**	**1**	**0**
	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		*	
	2. Elemental spectroscopy		*	
	3. FTIR		*	
	4. Schiff's reagent		*	
	5. Gas chromatography		*	
	6. Effects of glycol contamination on the lubricant		*	
	7. Effects of glycol contamination on the machine		*	
8. Soot contamination		**0**	**1**	**0**
	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			
	2. TGA		*	
	3. FTIR		*	
	4. Pentane insoluble		*	
	5. Blotter test		*	
	6. Effects of soot contamination on the lubricant		*	
	7. Effects of soot contamination on the machine		*	
9. Fuel contamination		**0**	**2**	**0**
	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. Kinematic viscosity		*	
	3. FTIR		*	
	4. Flash point test		*	
	5. Gas chromatography		*	
	6. Effects of fuel contamination on the lubricant		*	
	7. Effects of fuel contamination on the machine		*	
10. Air contamination (air in oil)		**0**	**1**	**0**
	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		*****	
	2. States of coexistence of air in oil		*****	
	3. Methods of assessing air contamination a. Air release characteristics b. Foam stability characteristics		*****	
	4. Effects of air contamination on the lubricant		*****	
	5. Effects of air contamination on the machine		*****	
11. Particle contamination		**0**	**1.5**	**0**
	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		*****	
	2. ISO solid contamination code		*****	
	3. Optical particle counting usage and calibration		*****	
	4. Pore blockage particle counting		*****	

	5. Effects of particle contamination on the lubricant		*	
	6. Effects of particle contamination on the machine		*	
12. Wear particle (debris) monitoring and analysis		**0**	**3**	**8**
	1. Detecting abnormal wear a. AES methods b. XRF spectroscopy c. Wear particle density measurements		* * * *	
	2. Wear debris analysis a. Ferrogram preparation b. Filergram preparation c. Light effects d. Magnestism effects e. Heat treatment f. Chemical microscopy g. Basic morphological analysis		* * * * * * * *	
	3. Common wear mechanisms 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		*	
13. Data Interpretation		**0**	**2.5**	**8**
	1. Limits a. Understanding statistical limits (wear debris) b. Understanding Ageing limits (AN, viscosity) c. Understanding Targets (water, ISO, cleanliness) d. Establishing statistical limits e. Establishing aging limits f. Establishing goal based limits		* * * *	* * * *
	2. Graphical trend analysis a. Rate of change b. Normalisation of data c. Reference/baseline data comparison d. Effects of make-up oil e. Lock-step trending		* * * *	* * *
14. Quality Control		**0**	**1.5**	**2.5**
	1. Procedure writing		*	

	2. Record management			*
	a. Record generation			*
	b. Record storage			*
	3. Quality control samples			*
	a. Types			*
	b. Control charts			*
	4. Procedures editing			*
	5. Audits			*
	a. Internal			*
	b. External			*
15. Lubricant roles, functions and failure modes		**0**	**2**	**7**
	1. Base oil		*****	*****
	a. Functions		*****	*****
	b. Properties		*****	*****
	2. Additive types and functions		*****	*****
	a. Surface active additives and their functions		*****	*****
	b. Bulk oil active additives and their functions		*****	*****
	3. Synthetic lubricants		*****	*****
	a. Synthetic lubricant types		*****	*****
	b. Conditions dictating their use		*****	*****
	4. Lubrication Regimes			*****
	a. Hydrodynamic			*****
	b. Elasto-hydrodynamic			*****
	c. Boundary			*****
	5. Baselining physical and chemical properties tests			*****
	6. Identifying additive discrepancies			*****
	7. Lubricant failure modes		*****	*****
16. Sensorial inspection		**0**	**0**	**1.5**
	1. Ability to detect			*
	a. Water contamination			*
	b. Particle presence			*
	c. Paramagnetic particle presence			*
	d. Irregular odours			*
17. Environmental effects on results		**0**	**0**	**1**
	1. Environmental effects on results			*****
18. Alternate technology data correlation		**0**	**0**	**3**
	1. Vibration data			*****
	2. Infrared data			*****
	3. Acoustic emission/ultrasonic data			*****
19. Personnel training		**0**	**0**	**1**

	1. Scope of training			*
	2. Certification and re-certification requirements			*
	3. Job qualification			*
Total hours for each Category		**24**	**24**	**32**

Annex B – Reading references (normative)

Table B1. Essential reading (material from which examination questions can be developed)

Category	Title	Author(s)	Publisher	ISBN
1, 2, 3	The Wear Debris Analysis Handbook	B. J. Roylance and T. M. Hunt, 1999.	Coxmoor	1901892026
1, 2, 3	Oil Analysis Basics 2nd edition	D Troyer and J. Fitch..	Noria Publishing. USA	0967596416
1, 2, 3	Machinery Oil Analysis 3rd edition	Larry A Toms, 2008		0-9664604-0-5
1, 2, 3	The Tribology Handbook 1996	M. J. Neale, 2nd edition.	Butterworth-Heinemann	0750611987
1,2,3	Oil Analysis	Evans and Hunt 2008	Coxmoor	1901892050

Standards and specifications

(material from which examination questions can be developed) (normative). The most current standard applies.

1. ASTM D 6224 Standard practice for In-Service Monitoring of Lubricating Oil for Auxiliary Power Plant Equipment, (2002).
2. ASTM D 4378 Standard practice of In-Service Monitoring of Mineral Turbine Oils for Steam and gas Turbines.
3. ISO 13379, Condition monitoring and diagnostics of machines- Data interpretation and diagnostic techniques.- General guidelines
4. ISO 13372, Condition monitoring and diagnostics of machines- vocabulary
5. ISO 13374. Part 1. Condition monitoring and diagnostics of machines- Data processing, communication and presentation, Part 1: General guidelines
6. ISO 17359, Condition monitoring and diagnostics of machines- general guidelines
7. SAE J300, Surface Vehicle standard- engine oil viscosity classification.
8. CMGEN, General requirements for qualification and certification of condition monitoring and diagnostic personnel
9. ISO 13381-1, Condition monitoring and diagnostic of machines; prognostics: Part 1 general Guidelines
10. ISO 18436-1, Condition monitoring and diagnostics of machines; requirements for qualification and assessment of personnel Part 1, Requirements for certifying bodies and the certification process
11. ISO/IEC 17024, Conformity assessment- general requirements for bodies operating certification of persons
12. ISO 4406, Hydraulic Fluid Power. Fluids. Method for coding the Category of contamination by solid particles
13. SAE J310, Automotive lubricating greases: recommended practice

14. ISO 11500, Hydraulic fluid power. Determination of particulate contamination by automatic counting using the light extinction principle.

15. ISO 11171, Hydraulic fluid power. Calibration of automatic particle counters for liquids.

16. ISO 18436-4, Condition monitoring and diagnostics of machines; requirements for qualification and assessment of personnel- Part 4: Industrial lubricant analysis.

17. ISO 18436-5, Condition monitoring and diagnostics of machines; requirements for qualification and assessment of personnel- Part 5: Laboratory lubricant analysis

18. ISO 17025, General requirements for the competence of testing and calibration laboratories

19. BS 5760-5. Reliability of systems, equipment and components: Guide to failure modes, effects and criticality analysis (FMEA and FMECA) ISBN 0580 196607

20. BS 5760-7(IEC 61025: 1990). Reliability of systems, equipment and components. Fault tree analysis. ISBN 0580 203387

Table B2 Recommended reading (material which contains helpful information on a related subject) (informative)

Category	Title	Author(s)	Publisher	ISBN
2, 3	Infrared Thermography- Theory & Practice	N Walker	BINDT	0903132338
2,3	Acoustic emission and ultrasonics	T Holroyd	Coxmoor	1901892077
1, 2, 3	Practical lubrication for industrial facilities	H Bloch, 2000	Marcel Dekker, NY	
1, 2, 3	Quality in the analytical chemistry laboratory	E Prichard, 1995	John Wiley & Sons, UK	
1, 2, 3	Handbook of hydraulic fluid technology	G Totten, 2000	Marcel Dekker, NY	
2, 3	High temperature lubrication	A Landsdown, 1994	Mechanical Engineering Publications, UK	
1, 2, 3	Machinery Malfunction Diagnosis and Correction	Sr R. C. Eisenmann, 1998	Prentice Hall	013240946-1
1, 2, 3	Machinery Analysis and Monitoring	J. S. Mitchell, 1993	PenWell Publishing Co	087814401-3
1, 2, 3	Handbook of condition monitoring- techniques and methodology.	A Davies 1998	Chapman & Hall	0412613204
1, 2	Lubricating Grease Guide	The National Lubricating Grease Institute, 1996	NLGI, USA	
2,3	Reliability centred Maintenance	John Moubray	Elsevier	075063358
2,3	Vibration Monitoring and Analysis Handbook	Simon R Mills	BINDT	9780903132397

Annex C- Sub-topics related to Annex A2 (informative)Category

Citation of ASTM methods is not exclusive, as any equivalent EN, BS, ISO or other national standard may be used, including references listed in Annex B

Table C1.

Classification systems	Viscosity (ISO/SAE), Grease consistency (NLGI), Engine (API/ILSAC), API automotive gear oil classification, ATF classifications, Automotive brake fluid classifications, AGMA gear classifications, AGMA gear coupling classifications, Turbine oil classifications (BSI, DIN, GE, ABB), hydraulic fluids (ISO, Factory Mutual fire resistance grading system, ASTM, various components/system OEM performance specifications, USDA/FSIS and NSF food-grade lubricant classification
Additive types and functions	Surface active additives and their functions, bulk oil additives and their functions
Machine-specific lubricant requirements	Hydraulic systems, plain bearings, rolling element bearings, journal bearings, reciprocating engines, gearing and gearboxes, ropes, chains, steam turbines, gas turbines, internal combustion engines, compressors, transmissions, pumps, filtration
Sampling methods	Pressurised systems (low and high), non-pressurised systems
Managing interference	Bottle cleanliness and management, flushing, machine conditions appropriate for sampling
Common machine-specific wear modes	Gearing, plain bearings, rolling element bearings, hydraulics
Wear particle types, origins and probable causes	Cutting wear particles, spherical particles, chunky particles, laminar particles, red oxide particles, black oxide particles, corrosion particles, non-ferrous particles, friction polymer particles
Wear debris analysis techniques	Ferrogram preparation, filtergram preparation, light effects, magnetism effects, heat treatment, chemical treatment, morphology, surface detail
Lubricant health monitoring	Kinetic viscosity (ASTM D445), Absolute Viscosity (ASTM D2893), Viscosity Index (ASTM D2270), TAN (ASTM D974, D664), TBN (ASTM D974, D2896, D664, D4739), FTIR (ASTM E169, D7418), AES (ASTM D5185, D6595, D6495), Flash Point (ASTM D92, D93, D3828), TGA (ASTM D5967-A4), Schiff's Reagent (ASTM D2982), Crackle Test, Co-distillation (ASTM D95), Karl Fischer titration (ASTM D6304), Cyclic Voltammetry (ASTM 6971), Insolubles (ASTM D893), Rotating Pressure vessel Oxidation Test (ASTM D2272), Air release characteristics (ASTM D 3427), Foam Stability characteristics (ASTM D892), Gas Chromatography (ASTM D3524, D3525), Water demulsibility (ASTM D1401, D2711)
Water contamination	Scope and significance of commonly accepted water-oil analysis test methods (ASTM D1401, D2711), causes of poor water demulsibility, states of co-existence of water in oil; methods for assessing water contamination (Crackle test, FTIR, Co-distillation, Karl Fischer titration); effects of water contamination on the lubricant and the machine
Glycol contamination	Scope and significance of commonly accepted oil-glycol analysis test methods; methods for assessing (AES, FTIR, Schiff's reagent, GC), effects on lubricant and the machine
Soot contamination	Scope and significance of commonly accepted soot-oil analysis test methods; methods for assessing (TGA, FTIR, pentane Insolubles (ASTM D893), Blotter test); effects of soot on the lubricant and the machine

Fuel contamination	Scope and significance of commonly accepted fuel-oil analysis test methods; methods of assessing (Kinematic viscosity, FTIR, Flash Point Test, GC); effects of fuel on the lubricant and the machine
Air contamination	Scope and significance of commonly accepted air-oil analysis test methods: methods of assessing (Air release characteristics, Foam stability), states of co-existence of air in oil, effects of air on the lubricant and the machine
Particle contamination	Scope and significance of commonly accepted particle-oil analysis test methods; methods of assessing (ISO solid contamination code (ISO4406), Optical particle counter (ISO11500, ISO 11171), Pore blockage particle counting); effects of particles on lubricant and the machine
Lubricant failure mechanisms	Oxidative degradation (the process, causes and effects, at risk lubricants and applications, strategies for deterring it, strengths, limitations and applicability of tests used to detect and troubleshoot oxidation such as AN, viscosity, FTIR, RPVOT, sensory inspection); thermal degradation (the process, causes and effects, strengths, limitations and applicability of tests used to detect and troubleshoot thermal failure such as AN, viscosity, FTIR, thermal stability test, ultracentrifuge detection of carbon insoluble's, sensory inspection); additive depletion/degradation- mechanisms, additives at risk, 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 –such as AES, FTIR, AN, BN, VI, RPVOT, Blotter spot test); testing for wrong or mixed lubricants (base-lining physical and chemical properties tests, additive discrepancies); fluid properties test methods and measurement units- viscosity (kinematic, absolute and VI), AN/BN, AES, FTIR, RPVOT

Table C2.

Additional guidance to sub-topics that should ideally be covered (informative)

Topic	Sub-topics
Condition Monitoring (oil analysis programme design, implementation and management)	
1. Equipment audit and Prioritisation	Baselines, limits and objectives; equipment knowledge;
2. Alarms; Categories & status	Goal-based targets; establishing limits; setting alarms and limits;
3. Baseline Assessments, Trending	Trend interpretation;
4. Route Planning	Test parameters; methodology applications; optimizing frequency of analysis;
5. Alternate Technologies: Vibration Analysis, Infrared Thermography, Acoustic Emission	IRT, VA and AE basic principles; NDT methodologies;
6. Procedure writing	Not applicable at Category 2
Generic Equipment Knowledge	
1. Engines	Fault analysis; components; reciprocating engines;
2. Transmissions	Primary function; components;
3. Turbines & Compressors	Primary function; components;
4. Gear reduction Systems	Gear types; lubrication choice and applications; components; gearing and gearboxes;
5. Hydraulic Systems	System categorisation; components; contamination;
6. Pumps	Hydraulics; pump types and applications; components;
7. Bearings	Operation; components; lubrication choice and properties; rolling element bearings; journal bearings;
8. Filtration	Components; applications and system specifications; wear debris analysis; de-aeration; filtration and separation technologies; filter rating; filtration system design and filter selection;
Inspection Optimisation	
1. Time-base policies	
2. Data collection	Understanding statistical limits (wear debris), ageing limits, targets, goal-based limits
3. Bathtub Hazard Rate Curve	Trend analysis; graphical representation;
4. Potential failure (P-F) Curve	