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CM/GEN APPENDIX C- Issue 3

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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

Ref:	Subject Syllabus topic	Category			Category sub-topics		
		1	2	3	Category 1	Category 2	Category 3
0							
1	**Maintenance Strategies**	2.5	1	0			Explain some of these questions require narrative answers
1.01	Why Machines Fail	•			Causes of failure including incorrect design; material defects; incorrect operation (temp, load, speeds etc.) & inefficient maintenance		
1.02	The Impact of Poor Maintenance on Company Profits	•			Include direct (downtime; lost production; spares used) and indirect costs (premature filter replacement & lube changes; disposal costs; energy consumption; high insurance costs). Every maintenance cost reduced is direct bottom line profit		
1.03	The role of effective lubrication in failure avoidance	•			Reduced wear, friction, heat, energy consumption, noise, lubricant consumption, product contamination		
1.04	Fundamental aspect of Reliability Centred Maintenance		•			Introduction to RCM; six failures patterns; seven basic questions and overview of RCM worksheet	
1.05	Aspects of Condition Based Maintenance	•	•		Brief introduction to maintenance strategies and what CBM means. Short discussion about other techniques available	Explanation of different maintenance strategies and where CBM fits in to overall maintenance strategy. Brief explanation of other techniques available.	
A)	Predictive Maintenance Strategies	•	•		Brief explanation of Predictive maintenance and different terminologies used i.e. Condition Based Maintenance & Condition Monitoring	Explanation of Predictive Maintenance, how it works and where it should be used. Other terminology including planned, Scheduled and Time-Based	
B)	Proactive Maintenance Strategies	•	•		Explain the differences between Predictive & Proactive maintenance and describe how lubricant analysis fits in to both Predictive & Proactive.	Explanation of Proactive Maintenance, how it works and where/when it should be applied. Examples of Proactive methods including lube sampling & analysis; alignment, balancing & soft-foot.	
C)	Lubrication Routes and Scheduling	•			Establishing of routes to include ease of access to/from equipment; access to sample point; logical path around equipment and determining how often		

Ref:	Subject Syllabus topic	Category			Category sub-topics		
		1	2	3	Category 1	Category 2	Category 3
					samples should be collected based on criticality.		
D)	Lubrication Analysis and Technologies to ensure Lubrication Effectiveness	•			Discuss sensory tests including visual inspection of machine and lubricant (if applicable), temperature and noise; possibly mention overall vibration. Introduce concept of different dimensions of lubricant analysis		
E)	Equipment tagging and identification	•			Discuss tagging of sample points with reference to colour coding; equipment tag number, type of lubricant to be used and quantities to be used.		
2	**Lubricant Theory & Fundamentals**	4	1	6			
2.01	Fundamentals of Tribology	•			Explain the history of oil discovery refining processes & oil is a means to overcome friction of mating surfaces, remove heat and carry away contaminants.		
2.02	Functions of a Lubricant	•	•		Explain the 6 functions of oils	Students should understand the 6 function of oils	
2.03	Lube Regimes	•	•	•	Explain Hydrodynamic lubrication is based on a wedge of oil & the type of wear expected.	Students should understand & be able to describe HDL.	Students should have a greater understanding & be able to describe HDL
					Explain how Elasto-Hydrodynamic lubrication differs from Hydro-Dynamic & the related failure mode expected.	Students should understand & be able to describe EDL.	Students should have a greater understanding & be able to describe EDL
					Explain boundary lubrication, how it is formed and its benefits.	Students should have a greater understanding & be able to describe BL.	Students should have a greater understanding & be able to describe BL.
2.04	Base Oils	•	•	•	Explain what base oils are and how GI to GV are produced.	Explain what base oils are and how GI to GV are produced, hence their properties. That they give basic required viscosity and so have inherent VI. They solubilise oxidation products,	Explain in depth what base oils are and how GI to GV are produced, hence their properties. That they give basic required viscosity and so have inherent VI. They solubilise oxidation

Ref:	Subject Syllabus topic	Category			Category sub-topics		
		1	2	3	Category 1	Category 2	Category 3
						how they are able to resist oxidation and carry oil additives	products, how they are able to resist oxidation and carry oil additives
2.05	Additive Functions	•	•	•	Explain which additives are used and for what purpose. Why they are necessary and how they may deteriorate with use and how to test if they are deteriorating. Explain the meaning of VI & VII.	Explain which additives are used and for what purpose. Why they are necessary and how they may deteriorate with use and how to test if they are deteriorating. Explain how VII work and fail in service.	Explain how the various additives work and the names of typical additives used & how to monitor them. Explain why each VII is chosen.
2.06	Oil Lubricant physical, chemical and performance properties and classifications	•			Explain lubricants must meet given specifications, What these specifications are, which governing bodies control these specifications and how specs are classified by the various bodies.		
2.07	Grease Lubricants	•			Explain how and when to use Grease as opposed to oils.		
	A)	•			Explain the process of manufacture using fats and fatty acids with Alkalis, explain complexed grease. Explain tests used to ensure greases meet these specs.		
	B)	•			List which thickeners are used and why they are chosen		
	C)	•			Explain why they may not be compatible with each other and provide a table to show which ones are or are not compatible		
	D)	•			Explain lubricants must meet given specifications, what these specifications are, which bodies control these specifications and how they are classified by the various bodies. Explain tests used to ensure lubes meet these specs.		
2.08	Solid Lubrication	•			List types of solid lubricants. Means they are applied & how they work.		
	A)	•			Explain wear rate equation (A=K*L*D) noting K depends on type of material in use. Where A is loss of material (wear). D = dist. & L = normal load		
2.09	Gas Lubrication	•			Explain benefits and problems with gas lubricants. Note the required properties of Gases involved.		

Ref:	Subject Syllabus topic	Category 1	 2	 3	Category sub-topics Category 1	 Category 2	 Category 3
	Classification System	•			Explain how lubricants & greases fall into various classifications and how these classifications are used by Oil companies and end users		
	Advantages of GL bearings	•			Explain why use Gas bearings		
	Properties of gases	•			Explain which gases are involved. Need for cleanliness & loss of boundary lubrication etc.		
	Viscosity (ISO/SAE)	•			Explain ISO VG system & SAE systems		
	Grease Consistency (NLGI)	•			Explain how grease consistency is measured and which types of grease are used for which lubrication systems		
	Engine (API/LSAC)	•			Explain the API/ISLAC functions + ACEA systems & how measured & units.		
	API Automotive gear oil classification	•			Explain the system and how measured & units		
	ATF classifications	•			Explain most OEM have their own specs, ATF fluids contain normal lube oil additives + special additives.		
					Explain ATF fluids contain normal lube oil additives + friction modifiers except for Ford & JD. These oils should not be mixed		
	Automatic brake fluid classification	•			Explain the DOT system & why not to mix types & how they can fail		
	AGMA gear classifications	•			Explain gears have different workloads & operating patterns so need different lubricants grades and specifications. These are different to engine & ATF. Explain Channel & pour point properties for gear oils.		
	AGMA gear coupling classifications	•			Explain there are 4 of Amerigear couplings classifications:		
					1. Standard Amerigear Couplings		
					2. Balanced Standard Amerigear Couplings		

Ref:	Subject Syllabus topic	Category			Category sub-topics		
		1	2	3	Category 1	Category 2	Category 3
					3. Class III Amerigear Couplings Class I Amerigear Couplings		
	Turbine oil classifications (BSI,DIN,GE,ABB)	•			Explain types: steam & gas turbines. OCM techniques and limits		
	Hydraulic fluids (ISO, Factory)	•			Explain types: steam & gas turbines. OCM techniques and limits		
	Mutual fire resistance grading system						
	ASTM, various components/system OEM (performance specifications)						
	USDA/FSIS and NSF food-grade	•			Explain various specs for food grade lubricants how & why these products are produced		
3	**Lubricant Selection**	2.5	0	0			
3.01	When to choose/advantages and disadvantages of: Oil, Grease.	•			Understand the applications where oils should be used and applications where greases should be used		
3.02	When to choose/advantages and disadvantages of: Solids, Gas.	•			Understand the applications where solid lubricants/coatings might be used and applications where gas lubricated bearing should be used		
3.03	Viscosity selection	•			Recognise the physical differences in viscosity and understand how the wrong viscosity will affect the machine		
3.04	Base Oil type selection	•			Recognise the performance and application differences of the various types of base oils, both mineral and synthetic		
3.05	Additive system selection	•			Understand which type of additives are used for different applications e.g. extreme pressure additives in gear oils, detergents in engine oils		
3.06	Grease thickener selection	•			Recognise that the various types of thickeners have differing benefits and		

Ref:	Subject Syllabus topic	Category			Category sub-topics		
		1	2	3	Category 1	Category 2	Category 3
					advantages depending on the intended application		
3.07	Machine specific lubrication requirements	•			Recognise that some machines have specific lubrication requirements.		
	Hydraulics systems	•			Understand the function of Hydraulics oils and which properties enhance their performance.		
	Plain bearings	•			Recognise the lubrication requirements of plain bearings		
	Rolling element bearings	•			Recognise the lubrication requirements of ball and roller bearings		
	Journal bearings	•			Recognise the lubrication requirements of alloyed bearings		
	Reciprocating engines	•			Understand the functions of reciprocating engine oils.		
	Gearing and gearboxes	•			Recognise the lubrication requirements required for gear oil applications		
	Ropes	•			Recognise the lubrication requirements of wire ropes and open gearing		
	Chains	•			Recognise the lubrication requirements of chains		
	Steam Turbines	•			Understand the components and performance requirements for steam turbine lubricants		
	Gas turbines	•			Understand the components and performance requirements for gas turbine lubricants		
	Internal combustion engines	•			Understand the functions of internal combustion engine oils		
	Compressors	•			Understand the different types of compressors and which types of base oil are used in them.		
3.08	Application and Environmental adjustments	•			Explain the differences in performance of natural or synthetic base fluids and additives		

Ref:	Subject Syllabus topic	Category			Category sub-topics		
		1	2	3	Category 1	Category 2	Category 3
4	**Principles of Lubricant Application**	4	0	0			
4.01	Effective use of manual delivery techniques	•			Use of grease cartridges; grease guns (manual & battery operated); calculation of amount of grease required or by metering systems; bearing packers		
4.02	Automatic delivery systems	•			Overview of different systems available		
	Distributed delivery systems	•			Single line, dual line & multi line distribution systems; minimal quantity systems (internal & external); progressive systems; oil & air systems; circulating oil systems.		
	Automatic lubricators	•			Single point & multi point lubricators; gas delivery and elector-mechanical delivery; oil levellers		
	Maintenance of automated lubrication systems	•			Checking delivery of lubricant; checking reservoir volumes; inspection of pipes etc. to ensure no damage or leaks; refill schedule (if applicable)		
5	**Lubricant Storage and Management**	2.5	0	0			
5.01	Lubricant receiving procedures	•			Explain the requirements for receiving bulk and package lubricants and any special needs such as cleanliness.		
5.02	Proper storage and inventory management	•			Explain the requirements for correct labelling of tankage and filling points, protected from weather and low/high temperatures. A record of oils/greases received and used should be kept.		
5.03	Lubricant storage containers	•			Explain the differences in the handling requirements for containers from 1000L L IBCs to 20L pails and tank venting and gauging arrangements		
5.04	Proper storage of grease guns and other lubrication application devices	•			Explain why the identification and storage of all equipment is important to avoid contamination		

Ref:	Subject Syllabus topic	Category			Category sub-topics		
		1	2	3	Category 1	Category 2	Category 3
5.05	Maintenance of automatic grease systems	•			Recognise the requirements and limitations for the greases used in these automatic systems.		
5.06	Health and Safety assurance	•			Emphasise on personnel safety when handling lubricants, from preventing slips and trips to correct drum handling equipment.		
6	**Lubricant contamination, measurement and control**	2.5	6	0			
6.01	Particle contamination		•			Understand sources of debris	
	Effects on the machine		•			Understand primary and secondary/ consequential damage	
	Effects on the lubricant		•			Understand lubricity changes and deterioration	
	Methods and units for measuring particle contamination		•			Understand Particle counters, SEM Spectrographic	
	Techniques for controlling particle contamination		•			Understand Filtration, Magnetic traps, Drier breathers, Air Filters	
6.02	Moisture contamination		•			Understand sources of moisture, Airborne / condensation	
	Effects on the machine		•			Understand corrosion, loss of oil film, additive hydrolisation.	
	Effects on the lubricant		•			Understand additive depletion, emulsion, loss of lubricity.	
	States of Coexistence		•			Understand Emulsion, Free water, dissolved water	
	Methods and units for measuring moisture contamination		•			Understand "Sputter test". Karl Fisher test PPM, Other measures by %	
	Demulsibility measurement		•			Understand D1401 & IP19 Tests	
	Techniques for controlling moisture contamination		•			Understand desiccant breathers, oil additives, working temperatures.	
6.03	Glycol Coolant contamination		•			Understand sources of Glycol, adjacent coolant systems,	

Ref:	Subject Syllabus topic	Category			Category sub-topics		
		1	2	3	Category 1	Category 2	Category 3
	Effects on the machine		•			Wear Corrosion,	
	Effects on the lubricant		•			Degrades Lubricity destroys additive package	
	Methods and units for measuring glycol contamination		•			ICP detect sodium potassium FTIR & GC etc. detects glycol	
	Techniques for controlling glycol contamination		•			Ensure coolant fluid concentration correct seal conditions good	
6.04	Soot contamination		•			Understand sources of soot, blow by, over temperature, hot spots?	
	Effects on the machine		•			increased wear	
	Effects on the lubricant		•			Thicken block filters, abrasive	
	Methods and units for measuring soot contamination		•			Understand results from various analytical methods, e.g. spectrographic, sample colour, blotter spot, and insoluble.	
	Techniques for controlling soot contamination		•			Filtration, check air oil ratios not to run rich	
6.05	Fuel contamination (fuel dilation in oil)		•			Understand sources of Fuel, heat exchangers, seal leakage?	
	Effects on the machine		•			Increases wear becomes flammable	
	Effects on the lubricant		•			Depletion of additive package, Vk changes	
	Methods and units for measuring fuel contamination		•			Flashpoint, Viscosity & FTIR & GC	
	Techniques for controlling fuel contamination		•			FTIR & Viscosity	
6.06	Air contamination (air in oil)						
	Effects on the machine						
	Effects on the lubricant						
	Methods and units for measuring air contamination						

Ref:	Subject Syllabus topic	Category			Category sub-topics		
		1	2	3	Category 1	Category 2	Category 3
	Techniques for controlling air contamination						
6.07	Filtration and separation technologies						
6.08	Filter rating						
6.09	Filtration system design and filter selection						
7	**Oil Sampling**	2.5	7	0			
7.01	Objectives for lubricant sampling	•	•		Statement of objective including where to sample; how to sample; sampling techniques; frequency of collection and sample bottles.	Statement of objective including where to sample; how to sample; sampling techniques; frequency of collection and sample bottles.	
7.02	Equipment specific sampling		•			Examples of sample locations from different types of equipment using schematics and photographs	
	Gearboxes with circulating systems		•			Live-zone sampling; downstream of equipment and upstream of filters; primary & secondary sample points	
7.03	Sampling Methods	•	•		Overview of sampling methods including non-pressurised, low pressure and high pressure systems; safe sampling.	Overview of sampling methods including non-pressurised, low pressure and high pressure systems; safe sampling.	
	Non-Pressurised systems		•			Use of vacuum pumps; drop down tubing; sampling away from tank walls, base and top of tank; use of rod for location.	
	Pressurised Systems – Low		•			Use of vacuum pump or Minimess fittings to obtain sample	
	Pressurised Systems - High		•			High pressure tap sampling; Minimess tap sampling; Ball valve tap sampling; Portable Minimess sampling; pressure reduction mechanisms	
7.04	Managing Interference						
	Bottle Cleanliness Management	•	•		Bottle cleanliness designations; keeping bottles closed until required; don't re-use	Bottle cleanliness designations; keeping bottles closed until required; don't re-use or clean	

Ref:	Subject Syllabus topic	Category			Category sub-topics		
		1	2	3	Category 1	Category 2	Category 3
					or clean (unless lab conditions); not using contaminated bottles;	(unless lab conditions); not using contaminated bottles;	
	Flushing	•	•		Importance of test port flushing; amount to be flushed; control of flushed lubricant (safe disposal, spillages);	Importance of test port flushing; amount to be flushed; control of flushed lubricant (safe disposal, spillages);	
	Machine conditions appropriate for Sampling	•	•		Machine operating under normal operating conditions; sample location; collecting samples before machine stops (duty / standby) or within fixed time of stopping;	Machine operating under normal operating conditions; sample location; collecting samples before machine stops (duty / standby) or within fixed time of stopping;	
7.05	Sampling process Management	•	•			Summary of topics covered on Cat 1 courses.	
	Sampling Frequency	•			Appropriate sampling frequency for different types of equipment; hours run approach; oil change intervals; criticality of machines.		
	Sampling Procedures	•			Primary & secondary sample points; representative samples; tank sampling; amount of sample to be drawn; use of correct sample bottles for lubricant; identification of samples; storage and shipping of samples; flushing of sample line		
	Sample Processing	•			Time between collection and sampling; records of samples collected & shipped; issue of unique sample identification number at lab.		
8	**Lubricant Failure mechanisms**	2.5	5	8			
	Lubricant health monitoring, diagnostics, prognostics and generic maintenance recommendations						
8.01	Oxidative degradation – the process, causes, and effects	•	•	•	Introduction to the process of oxidation	Understanding the effects of oxidation and how to assess lubricant for signs of oxidation onset	Understanding how to map the likely onset of oxidation based upon the parent machinery performance and the key indicators related to oil degradation via oxidation
8.02	Oxidative degradation – at-risk lubricants and applications; strategies for deterring it;			•			Understanding which additional tests are relevant to an extended analysis suite for root cause and problem solving activities

Ref:	Subject Syllabus topic	Category			Category sub-topics		
		1	2	3	Category 1	Category 2	Category 3
	strengths, limitations, and applicability of tests used to detect and troubleshoot oxidation (AN, viscosity, FTIR, RPVOT, sensory inspection)						
8.03	Thermal degradation – the process, causes, and effects	•	•	•	Introduction to the process of thermal degradation	Understanding the effects of thermal degradation and how to assess lubricant for signs of the onset of thermal degradation	Understanding how to map the likely onset of thermal degradation based upon the parent machinery performance and the key indicators related to thermal degradation
8.04	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 insoluble, sensory inspection)			•			Understanding which additional tests are relevant to an extended analysis suite for root cause and problem solving activities around thermal degradations
8.05	Additive depletion/degradation – mechanisms; additives at risk	•	•	•	Understand the basic concepts behind additive depletion	Understanding which additives can deplete as they are used and the effects of those that may have performed but may not remain functional.	Understand the relationship between additive depletion, end of useful life and other machinery CM characteristics
8.06	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	•	•	•			Understand the risks surrounding the common depletion /degradation issues and be able to define a management process to put in place risk mitigation strategies according to business needs.

Ref:	Subject Syllabus topic	Category 1	 2	 3	Category sub-topics Category 1	 Category 2	 Category 3
	applicability of methods for measuring additive depletion/degradation (atomic emission spectroscopy, FTIR, AN, BN, VI, RPVOT, blotter spot test)						
8.07	Testing for wrong or mixed lubricants (base-lining physical and chemical properties test, additive discrepancies)	•	•	•	Understand the key attributes that define a lubricants baseline characteristics	Understand the ways in which baseline characteristics can be changed in relation to incorrect fluid additions and other local sources of contamination	Be able to manage a series of tests to determine the source of any contaminant and diagnose the cause behind it
8.08	Fluid properties test methods and measurement units – viscosity (kinematic and absolute, VI), AN/BN, elemental spectroscopy, FTIR, RPVOT, atomic emission spectroscopy, other tests	•	•	•	Understand the basic test parameters used on lubricant analysis	Understand how to relate different test methods and to be able to compare results from different laboratories which may use differing standards	Be able to define a suitable test suite to look for specific performance issues and also to be able to define non LA test methods that may be complementary in respect of the basis of the evaluation
9	**Wear debris monitoring and Analysis**	1	4	12			
9.01	Common machine wear	•	•	•	Awareness that wear has several definitions to describe the mechanism and that may help isolate a component in a system	Recognise the types of wear found in complex machine systems can reveal root cause of failure mechanism	Advise cause of abnormal wear recognize lubricant type best associated to reduce the effect and or design changes to the components undergoing abnormal rates of wear
	Abrasive wear: two-body and three-body abrasive wear	•	•	•			
	Surface fatigue: two-body and three-body	•	•	•			
	Adhesive wear	•	•	•			
	Corrosive wear	•	•	•			
	Fretting wear	•		•			
	Erosive wear	•		•			
	Electrical wear	•		•			

Ref:	Subject Syllabus topic	Category			Category sub-topics		
		1	2	3	Category 1	Category 2	Category 3
	Cavitation wear: gaseous and vaporous cavitation	•	•	•			
A)	Common machine-specific wear modes			•		Understand the different mechanisms utilizing different technology bearings can fail in different manner	Be able to advise contamination levels acceptable for continued running of machines and hydraulic systems
	Gearing			•			
	Plain bearings			•			
	Rolling element bearings			•			
	Hydraulics			•			
B)	Wear particle types, origins and probable causes	•		•	Be aware that all wear particles generally indicate incipient machine failure	Recognise the different wear particles and associate them with the wear process that created them	Recognise and be able to make recommendations on future state based on the anlysis and morphology of wear particles. Prognostics
	Cutting wear particles	•		•			
	Spherical particles	•		•			
	Chunky particles	•		•			
	Laminar particles	•		•			
	Red oxide particles	•		•			
	Black oxide particles	•		•			
	Corrosion particles	•		•			
	Non-ferrous particles	•		•			
	Friction polymers	•		•			
D)	Wear debris analysis techniques	•	•	•	Knowledge of how to collect a sample and package correctly for further analysis	Knowledge of sample preparation and selection of the most appropriate analysis technique to be applied	Knowledge of techniques and machine state to produce condition based monitoring program Recommendation of techniques and frequency of sampling
	Ferrogram preparation	•	•				
	Filtergram preparation	•	•				
	Light effects	•	•	•			
	Magnetism effects	•	•	•			
	Heat treatment	•	•	•			

Ref:	Subject Syllabus topic	Category			Category sub-topics		
		1	2	3	Category 1	Category 2	Category 3
	Chemical treatment	•		•			
	Morphology	•	•	•			
	Surface detail	•		•			
9.02	Atomic emission elemental spectroscopy		•	•		Knowledge of laboratory spectroscopy capabilities including arc and x ray and when to apply appropriate technique to target a particular wear mode	Interpretation of results to ensure appropriate monitoring of known and likely failure modes, Develop CM regime and sampling strategy to ensure continued safe operation of the machine / asset
	Basic determination of wear particle metallurgy from elemental composition			•			
	Evaluating sequential trends			•			
	Evaluation lock-step trends			•			
	Particle size limitation of common atomic emission spectrometers			•			
	ICP spectroscopy			•			
	Arc-spark emission spectroscopy			•			
	Wear particle density measurement		•	•			
	Advanced techniques (acid/microwave digestion, rotrode filter spectroscopy)		•				
	X-ray fluorescence (XRF) and other advanced elemental spectroscopy methods		•	•			
10	**Lubricant analysis, programme development and management**	0	0	6			
10.01	Machine specific slate test			•			
10.02	Optimizing frequency of analysis			•			
10.03	Setting alarms and limits			•			

Ref:	Subject Syllabus topic	Category			Category sub-topics		
		1	2	3	Category 1	Category 2	Category 3
	Setting goal-based limits for contamination			•			
	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						
	Rate-of-change limits; calculating rate of change, slope-based alarms, statistically derived rate-of-change limits			•			
	Setting aging limits for fluid properties; physical, chemical and additive properties						
	Trend analysis						
10.04	Managing lubricant analysis information			•			
10.05	Creating and managing lubricant analysis procedures			•			
10.06	Scoping lubricant analysis training and examination for reliability technicians, trades people and management			•			
10.07	Performing cost/benefit analysis for lubricant analysis and contamination control programmes			•			
	Calculating programme costs						
	Estimating programme benefits			•			

Ref:	Subject Syllabus topic	Category			Category sub-topics		
		1	2	3	Category 1	Category 2	Category 3
	Calculating return on investment metrics			•			
	Generating an effective business proposal			•			
10.08	Quality assurance			•			
	Of on-site lubricant analysis			•			
	Of off-site lubricant analysis providers			•			
11	**Alternate technology data correlation**	0	0	3			Explanation of different maintenance strategies and where CBM fits in to overall maintenance strategy. Brief explanation of other techniques available. Sound file analysis; examples of motor current analysis. Explanation of Predictive Maintenance, how it works and where it should be used. Other terminology including planned, Scheduled and Time-Based. Explanation of Proactive Maintenance, how it works and where/when it should be applied. Examples of Proactive methods including lube sampling & analysis; alignment, balancing & soft-foot.
11.01	Vibration Analysis			•			Practical analysis of vibration readings including trend/spectra/waterfall and basic analysis of common problems
11.02	Infrared Data			•			IR image analysis including range & span, image quality, explanation of emissivity and image interpretation for electrical, mechanical & process equipment
11.03	Acoustic emission/Ultrasonic data			•			Explanation of how sound travels, difference between vacuum & pressure leaks, sound file analysis for electrical, mechanical & process equipment including lubrication problems
12	**Personal Training**	0	0	1			
12.01	Scope of training			•			

Ref:	Subject Syllabus topic	Category			Category sub-topics		
		1	2	3	Category 1	Category 2	Category 3
12.02	Certification and recertification needs			•			
12.03	Job qualification			•			

Note 1: The symbol • indicates the subject is to be covered within the time allotted, or may be included within training on other topics.

Note 2: Category 2 includes the knowledge of category 1; Category 3 includes the knowledge of categories 1 and 2.

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 EN IEC 60812, Failure modes and effects analysis (FMEA and FMECA)
20. BS EN 61025, Fault Tree Analysis

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	

Summary of changes

Issue number	Issue date	Summary of changes
3	4th June 2020	• Updated Comprehensive list of standards