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CM/GEN APPENDIX D Issue 2 rev B

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

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The British Institute of Non-Destructive Testing is an accredited certification body offering personnel and quality management systems assessment and certification against criteria set out in international and European standards through the PCN Certification Scheme.



Introduction

The use of the Vibration Analysis method in condition monitoring and diagnosis of faults in machinery and structures 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 certification of condition monitoring and diagnostic personnel). Other Appendices cover:

Appendix A	Acoustic Emission
Appendix B	Infra-red Thermography
Appendix C	Lubrication Management and Analysis

These other non-intrusive technologies are used as complementary condition analysis tools. Those in the manufacturing industry who have diligently and consistently applied these technologies have experienced a return on investment far exceeding their expectations.

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 259056, 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 certification of personnel engaged in Vibration Analysis Condition Monitoring. 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 18436-2: Condition monitoring and diagnostics of machines-Requirements for qualification and assessment of personnel-Vibration Condition monitoring and diagnostics
- 1.3. Certification to this specification will provide evidence and recognition of the qualification and competence of individuals to perform machinery vibration measurements and analysis (hereafter referred to as Vibration Analysis in this specification) using portable and permanently installed sensors and equipment.
- 1.4. This part of CMGEN covers a four-Category certification programme that is based on the technical areas delineated herein.
- 1.5. The scope of this programme encompasses the normative references specified in ISO 18436-2 clause 2 and those found in Annex B of this document, and incorporates the terms and definitions found in ISO 18436-2 clause 3 and CMGEN, unless otherwise stated in this document.
- 1.6. BINDT, as a certification body accredited by UKAS in accordance with EN ISO/IEC 17024, manages this condition monitoring programme against these specifications which are derived from the relevant ISO 18436 parts, but wherever any minor regional or national modification to this adoption exists then it shall be identified as a 'delta' and signified by text enclosed in a box, in accordance with ISO/IEC Guide 21-1. At no point does any minor modification diminish the specifications in ISO 18436-2. Where appropriate, the structure and format of this specification shall reflect that of all BINDT PCN specification documents for document harmonization.

2. Classification of Personnel

2.1. General

2.1.1. Individuals certificated in accordance with this specification are classified in one of four Categories depending upon their qualifications and assessment, and have demonstrated the necessary competence and skills in the concepts of machinery vibration condition monitoring and diagnostics for their classification Category as indicated in the examination syllabus at Annex A and in accordance with the standards listed in Annex B.

2.1.2. Personnel classified at a higher Category shall require the competence, knowledge and skills expected of personnel at all lower Categories

2.2. Vibration Analysis Category 1

PCN certificated Vibration Analysis Category 1 personnel are qualified to perform a range of simple single channel machinery vibration condition monitoring and diagnostics of machines activities in accordance with ISO17359 and ISO13373-1. They shall not be responsible, for example, the choice of sensor or for any analysis to be conducted, nor for the assessment of test results, except for identifying alert conditions against a pre-established alert setting or settings. Category 1 personnel shall be qualified to:

- 2.2.1. operate portable instrumentation on pre-assigned or pre-programmed routes;
- 2.2.2. acquire readings from permanently installed instrumentation;
- 2.2.3. input results into a data base and download routes from a computer;
- 2.2.4. conduct testing under steady-state operating conditions following predefined procedures;
- 2.2.5. compare overall or single value vibration measurements against pre-established alert settings;
- 2.2.6. recognise that no signal is present

2.2.7. verify the integrity of collected data and prevent or control poor data;

2.2.8. evaluate and report test results in accordance with instructions.
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2.3. Vibration Analysis Category 2

Individuals certificated as Vibration Analysis Category 2 are qualified to perform industrial machinery vibration measurements and basic vibration analysis using single-channel measurements, with or without phase trigger signals, according to established and recognised procedures. Category 2 personnel shall be qualified to:

- 2.3.1. select the appropriate machinery vibration measurement technique;
- 2.3.2. set up instruments for basic resolution of amplitude, frequency and time;
- 2.3.3. perform basic vibration analysis of machinery and components such as shafts, bearings, gears, fans, pumps and motors using spectrum analysis;
- 2.3.4. maintain a data base of results and trends;
- 2.3.5. perform basic (single channel) impact tests to determine natural frequencies;
- 2.3.6. classify, interpret and evaluate the test results (including acceptance tests) in accordance with applicable specifications and standards;
- 2.3.7. recommend minor corrective actions;
- 2.3.8. understand basic single-plane field balancing concepts;
- 2.3.9. be aware of some of the causes and effects of bad measurement data;

2.3.10. recommend the use of alternative CM technologies with an awareness of the basic principles of all four condition monitoring (CM) technologies specified in CM/GEN at least to Category 1;

2.3.11. carry out, supervise and instruct all Category 1 duties;

2.3.12. provide technical direction for personnel at or below Category 2.

2.4. Vibration Analysis Category 3

Individuals certificated as Vibration Analysis Category 3 are qualified to perform and/or direct, and/or establish, programmes for vibration condition monitoring and diagnostics of machines in accordance with ISO 17359 and ISO 13373-1. Category 3 personnel shall be qualified to:

2.4.1. select the appropriate machinery vibration analysis technique;

2.4.2. specify the appropriate vibration instrumentation hardware and software for both portable and permanently installed systems;

2.4.3. measure and perform diagnosis of single-channel frequency spectra, as well as time domain plots such as waveforms and orbits, under both steady-state and unsteady operating conditions, with or without a phase trigger;

2.4.4. establish vibration monitoring programmes including determination of machines for periodic /continuous monitoring, frequency of testing, route plans;

2.4.5. establish acceptance and severity criteria for in service and faulty machinery;

2.4.6. establish programmes for specification of vibration Categories and acceptance criteria for new machinery;

2.4.7. perform prognostics for fault conditions;

2.4.8. measure and analyse basic operating deflection shapes;

2.4.9. use acceleration enveloping (demodulation);

2.4.10. perform basic single-plane balancing;

2.4.11. report to management regarding programme objectives, budgets, cost justification and personnel development;

2.4.12. provide instructions and technical direction to vibration trainees Category;

2.4.13. prepare reports for appropriate personnel on machine condition, recommend corrective action and report on the effectiveness of repairs;

2.4.14. understand and interpret Standards, Codes, specifications and procedures;

2.4.15. Category direct the use of alternative CM technologies with an understanding of the principles of all four condition monitoring (CM) technologies specified in CM GEN at least to Category 1

2.4.16. provide instructions and technical direction to vibration trainees Category;

2.4.17. carry out, manage and supervise PCN CM qualification examinations on behalf of the British Institute of NDT, if so appointed.

2.5 Vibration Analysis Category 4

Individuals certificated as Vibration Analysis Category 4 are qualified to perform and/or direct vibration condition monitoring and diagnostics of machines in accordance with ISO17359 and ISO 13373-1 and all types of machinery vibration measurements and analysis. Category IV personnel shall be qualified to:

2.5.1 apply vibration theory and techniques, including measurement and interpretation of multi-channel spectral results such as frequency response functions, phase and coherence;

2.5.2 understand and perform signal analysis, including understanding of frequency and time domain processing, including orbits and their limitations;

- 2.5.3 determine the natural frequencies, mode shapes and damping of systems, components and assemblies;
- 2.5.4 determine the operating deflection shapes of machines and connected structures and recommend means for correction;
- 2.5.5 use generally recognised advanced techniques for vibration analysis, parameter identification and fault diagnosis;
- 2.5.6 apply basic principles of rotor-bearing dynamics to vibration diagnosis;
- 2.5.7 conduct basic two-plane field balancing;
- 2.5.8 recommend advanced two-plane influence coefficient or static/couple balancing;
- 2.5.9 recommend corrective actions and/or modifications, including component change or repair, isolation, damping, change of stiffness and change of mass;
- 2.5.10 provide technical guidance to vibration trainees:
- 2.5.11 interpret and evaluate published ISO codes of practice, International Standards and specifications;
- 2.5.12 recognise vibration caused by gas pulsation in machines such as reciprocating machines and screw compressors, and to measure the necessary parameters and recommend means for correction;
- 2.5.13 recommend corrective actions for resilient mounting and other holding-down and foundation problems;

2.5.14	design, write and manage Test planning and Test procedures;
2.5.15	design, implement and manage condition monitoring programmes;
2.5.16	undertake all forms of equipment testing, diagnostics and prognostics;
2.5.17	carry out, manage and supervise PCN CM qualification examinations on behalf of the British Institute of NDT, if so appointed

3. Eligibility for Examination and Certification

3.1. General

- 3.1.1. Candidates shall have a combination of education, training and experience to ensure that they understand the principles and procedures applicable to machinery vibration measurement and analysis. Candidates shall affirm adherence to the code of ethics contained in ISO18436-1 and BINDT document CP27- Code of Ethics.

3.2. Education

- 3.2.1. Candidates seeking certification do not need to provide evidence of formal education to establish eligibility. However, it is recommended that Category 1 and 2 candidates have at least a secondary school graduation diploma or its equivalent. Category 3 and 4 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 an accredited college, university or technical school is highly recommended for candidates seeking certification to Category 3 and 4.

3.3. Training

- 3.3.1. To be eligible to apply for examination based on this Specification, the candidate shall provide documentary evidence of successful completion of a

BINDT approved or recognised course of formal training, which will be based on the requirements of Annex A2. Sources of technical information are listed in Annex B. The minimum duration of training required shown in Table 1.

BINDT allows a maximum of 50% self study or on line training for topics consistent with Annex A2 and as specified by the approved trainer (CMGEN refers).

- 3.3.2 Approved training should be in the form of lectures, demonstrations and practical exercises. The approved training shall include examinations to ensure that the subject matter has been understood and that they have successfully completed the training.

To achieve certification from BINDT the candidate must also provide evidence of required experience as specified below.

The training syllabus indicated includes a requirement for practical knowledge and practical skills training and evaluation by the trainer at Category 1.

Table 1. Minimum Cumulative Duration of Training (hours)			
Category 1	Category 2	Category 3	Category 4
38	78	120	186
The hours shown represent cumulative totals of training hours.			

- 3.3.2 It is recommended that candidates attend additional training on machine knowledge, covering machinery and component training, of at least half the time shown in Table 1.

3.3.3 This additional training should cover design, manufacture, installation, operation and maintenance principles and include failure mechanisms associated with each principle.

3.4. Experience

- 3.4.1. To be eligible to apply for certification based on this specification, the candidate shall provide evidence of experience in the field of machinery vibration analysis condition monitoring and diagnostics appropriate to the Category sought. The minimum experience requirements are shown in Table 2, and the figures shown represent cumulative months of experience for each Category. Work experience is based on 175 hour/month. At each higher Category, the breadth and depth of experience is expected to be greater than at the previous lower Category.

3.4.2. Certification at Category 2 Category 3 and Category 4 requires previous certification at the lower Categories.

3.4.3. Candidates must maintain a log of hours and nature of work on PCN document CP16 for Category 1 and 2 and CP17 for Category 3 and 4.

Table 2 Minimum Experience Requirements (months)			
Category 1	Category 2	Category 3	Category 4
6	18	36	60

4. Certification Available

- 4.1 Category 1 (General- Vibration analysis condition monitoring)
- 4.2 Category 2 (General- Vibration analysis condition monitoring)
- 4.3 Category 3 (General-Vibration analysis condition monitoring)
- 4.4 Category 4 (General-Vibration analysis condition monitoring)

5. Qualification Examination

- 5.1. Application for qualification examinations
 - 5.1.1 Application for qualification examinations is made on PCN form PSL/57-CM and supported with PSL30 and PSL33 where required.
- 5.2. Examination content (Theory and practical knowledge)
 - 5.2.1. For each certification Category, the candidates shall be required to answer the number of multiple-choice questions indicated in Table 3. 10% of the number of questions on the Category 3 and 4 examination papers will consist of narrative questions. On each Category 3 and 4 paper there will be ten narrative questions offered, and only six need to be answered. Each narrative question will be worth 5 marks.

Table 3 – qualification examination content			
Categories	Number of Questions	Time (Hours)*	Passing Grade %
Category 1	60	2.0	75
Category 2	100	3.5	75
Category 3	100	4.0	75
Category 4	60	4.0	75

** Examination times include a 30-minute reading period Category to assist candidates with English as a second language or any disability in accordance with CMGEN clause 9.3.*

- 5.2.2. The content of the examination paper shall contain multiple-choice questions for each subject in Annex A2, and in the same weighting as indicated by the percentage of time spent on each subject indicated in Annex A2, together with the indicated narrative questions (if applicable).
- 5.2.3. Questions will be of a practical nature and test the candidate's knowledge of concepts and principles required to conduct machinery vibration testing and analysis.
- 5.2.4. Questions will include the interpretation of practical data, charts, plots or images, and simple mathematical calculations using a basic scientific calculator may be required.

5.2.5. BINDT examinations do not provide a summary of common formulae with the examination questions.

- 5.2.6. Detail of BINDT examination, re-examination, renewal procedure is given in CMGEN.

Annex A1 – Training Syllabus

SUBJECT	Hours of training			
	Category 1	Category 2	Category 3	Category 4
1. Principles of Vibration	6	4	2	4
2. Data Acquisition	8	4	2	2
3. Signal Processing	2	4	3	8
4. Condition Monitoring	2	4	3	1
5. Fault Analysis	2	4	8	6
6. Corrective Action	2	4	6	16
7. Equipment Knowledge	8	4	4	0
8. Acceptance Testing	2	2	2	0
9. Equipment Testing and Diagnostics	0	2	3	4
10. Reference Standards	0	2	2	2
11. Reporting and Documentation	0	2	2	4
12. Fault Severity Determination	0	2	3	3
13. Rotor /Bearing Dynamics	0	0	0	14
Total Hours	32	38	40	64

It is recommended that the trainer allocates up to 2 hours for their required training examination at all Categories, while at Category 1 only, an additional 2 hours for the BINDT specified practical skills evaluation exercises should be considered.

Annex A2- Detailed list of topics and hours of instruction

SUBJECT	Category 1 Hours	Category 2 Hours	Category 3 Hours	Category 4 Hours
1. Principles of Vibration	6	4	2	4
1. Basic Motion	*	*	*	
2. Period, Frequency	*	*	*	
3. Amplitude: Peak, Peak-to-Peak, rms	*	*	*	
4. Parameters: Displacement, Velocity, Acceleration	*	*	*	
5. Units, Unit Conversions	*	*	*	
6. Time and Frequency Domains	*	*	*	
7. Vectors, Modulation			*	*
8. Phase		*	*	*
9. Natural Frequency, Resonance, Critical Speeds	*	*	*	*
10. Force, Response, Damping, Stiffness			*	*
11. Instabilities, Non-linear Systems				*
2. Data Acquisition	8	4	2	2
1. Instrumentation	*	*	*	*
2. Dynamic Range, Signal-to-Noise Ratio		*	*	*
3. Transducers	*	*	*	
4. Sensor Mounting, Mounted Natural Frequency	*	*	*	
5. F_{max} , Acquisition Time	*	*	*	
6. Proximity Sensor Conventions (API)	*	*	*	
7. Triggering		*	*	
8. Test Planning		*	*	*
9. Test Procedures	*	*	*	*
10. Data Formats		*	*	
11. Computer database upload/download	*			
12. Recognition of poor data	*	*	*	
3. Signal Processing	2	4	3	8
1. RMS/Peak Detection				*
2. Analog/Digital Conversion				*
3. Analog Sampling, Digital Sampling		*	*	*
4. FFT Computation			*	*
5. FFT Application	*	*		
6. Time Windows: Uniform, Hanning, Flat Top		*	*	
7. Filters: Low Pass, High Pass, Band Pass, Tracking		*	*	*
8. Anti-aliasing		*	*	*
9. Bandwidth, Resolution		*	*	*

SUBJECT	Category 1 Hours	Category 2 Hours	Category 3 Hours	Category 4 Hours
10. Noise Reduction				*
11. Averaging: Linear, Synchronous Time, Exponential		*	*	*
12. Dynamic Range		*	*	*
13. Signal-to-Noise Ratio				*
14. Spectral maps			*	*
4. Condition Monitoring	2	4	3	1
1. Computer data base set-up			*	
2. Computer database maintenance			*	
3. Equipment Evaluation and Prioritisation		*		
4. Monitoring programme design		*	*	*
5. Alarms set-up: Narrowband, Envelope			*	
6. Baseline Assessments, Trending		*	*	
7. Route Planning		*	*	
8. Alternate Technologies: Lubrication management, Infrared Thermography, motor current analysis and acoustic emission		*	*	*
9. Fault recognition	*	*		
5. Fault Analysis	2	4	8	6
1. Spectrum Analysis, Harmonics, Sidebands		*	*	*
2. Time Waveform Analysis			*	*
3. Phase Analysis			*	*
4. Transient Analysis			*	*
5. Orbit Analysis			*	*
6. Shaft centreline analysis			*	*
7. Enveloping			*	*
8. Mass Unbalance		*	*	
9. Misalignment		*	*	
10. Mechanical Looseness		*	*	
11. Rubs, Instabilities			*	*
12. Bearing Defects: Rolling Element, Journal		*	*	
13. Electric Motor Defects		*	*	*
14. Flow Induced Vibration, Aerodynamics and Liquids			*	*
15. Resonance and Critical Speeds		*	*	*
16. Gearbox analysis			*	*
17. Turbo machinery			*	*
18. General fault recognition	*			
6. Corrective Action	2	4	4	16
1. Shaft Alignment		*	*	

SUBJECT	Category 1 Hours	Category 2 Hours	Category 3 Hours	Category 4 Hours
2. Field Balancing		*	*	*
3. Flow Control			*	*
4. Replacement of machine parts			*	
5. Isolation and damping			*	*
6. Resonance control			*	*
7. Basic maintenance action	*	*	*	
7. Equipment Knowledge	8	4	4	0
1. Electric Motors: Generators and Drives	*	*	*	
2. Pumps, Fans	*	*	*	
3. Steam Turbines, Gas Turbines		*	*	
4. Compressors	*	*	*	
5. Reciprocating Machinery		*	*	
6. Rolling Mills, Paper Machines and other equipment	*	*	*	
7. Machine Tools	*	*	*	
8. Structures, Piping	*	*	*	
9. Rolling Element Bearings		*	*	
10. Journal Bearings		*	*	
11. Gearing		*	*	
12. Couplings, Belts		*	*	
8. Acceptance Testing	2	2	2	0
1. Test procedure	*	*		
2. Specifications and Standards		*	*	
3. Reporting		*	*	
9. Equipment Testing and Diagnostics	0	2	3	4
1. Impact Testing		*	*	*
2. Forced Response Testing		*	*	*
3. Transient Analysis			*	*
4. Transfer Functions				*
5. Damping Evaluation				*
6. Cross Channel Phase, Coherence				*
7. Operating Deflection Shapes			*	*
8. Modal Analysis				*
9. Torsional vibration				*
10. Reference Standards	0	2	2	2
1. Relevant National Standards/IEC/ISO		*	*	*
11. Reporting and Documentation	0	2	2	4
1. Condition Monitoring Reports -		*	*	
2. Vibration Diagnostics Reports		*	*	*

SUBJECT	Category 1 Hours	Category 2 Hours	Category 3 Hours	Category 4 Hours
12. Fault Severity Determination	0	2	3	3
1. Spectrum Analysis		*	*	*
2. Time Waveform Analysis, Orbit Analysis			*	*
3. Categories: Overall, Narrowband, Component		*	*	
4. Severity Charts; Graphs and Formula		*	*	*
13. Rotor/Bearing Dynamics	0	0	0	14
1. Rotor Characteristics				*
2. Bearing Characteristics				*
3. Rotor Balancing				*
Total hours	32	38	40	64

Notes:

1. The symbol * indicates the subject to be covered within the time allotted.
2. Category 2 includes the knowledge of Category 1
3. Category 3 includes the knowledge of Categories 1 and Category2.
3. Category 4 includes the knowledge of Categories 1, 2 and 3.

Annex B – Reading References (normative)

Applicable International Standards and essential reading

Essential reading (material from which BINDT specified examination questions can be developed)

The essential reading for each Category is specified in Tables 1 and 2. For example, at Category 1 the essential reading includes the nine Standards in Table 2 and the three textbooks listed in Table 1.

CategoryCategoryTable 1 Essential reading includes:

Category	Title	Author	Publisher	ISBN
1, 2, 3	Vibration Monitoring Handbook	C. W. Reeve, 1998	Coxmoor	190189200X
2, 3	Infrared Thermography-Theory & Practice	N Walker	BINDT	0903132338
2, 3	Acoustic emission and ultrasonics	T Holroyd	Coxmoor	1901892077
2, 3	The wear debris analysis handbook	B J Roylance & T M Hunt	Coxmoor, 1999	1901892026
2, 3	Oil Analysis	Evans and Hunt	Coxmoor	1901892050
3, 4	Handbook of Rotor Dynamics	F. F. Ehrich, 1998	Kreiger	1-5755240882
1,2,3,4	Vibration Analysis Pocket Guide	RMS Ltd	BINDT	0-903132-36-2
1,2,3,4	Vibration monitoring and Analysis Handbook	S R W Mills	BINDT	0903132397
Category	Title	Author	Publisher	ISBN/Publ No
1, 2, 3	Condition based maintenance and machine diagnostics	J. H. Williams 1994	Chapman & Hall	0-412-465000
1, 2, 3	The Simplified Handbook of Vibration Analysis- Vols. 1 and II	A. R. Crawford, 1992	CSI	Library of Congress 92-72682
1, 2, 3, 4	Machinery Malfunction Diagnosis and Correction	R. C. Eisenmann, 1998	Prentice Hall	013240946-1
1, 2, 3	Basic machinery vibrations: An introduction to machine testing, analysis and monitoring	R. L. Eisenmann, 1999	Clarendon Hills Press, ILL,	0966950003
1, 2, 3, 4	Modal testing- Theory and Practice, 2 nd Edn	D. J. Ewins, 2000	McGraw-Hill, Inc	0863802184
1, 2, 3	Vibration Testing- Theory and Practice	K. G. McConnell, 1995	John Wiley & Son	047130435-2

Table 2 Applicable International Standards (material from which BINDT specified examination questions can be developed)

The current published version of each standard applies.

Standard	Category 1	Category 2	Category 3	Category 4
ISO 1925: Mechanical vibration- Balancing-Vocabulary		*	*	*
ISO 1940-1: Mechanical vibration- Balance quality requirements of rigid rotors- Part 1: Determination of permissible residual unbalance		*	*	*
ISO 1940-2: Mechanical vibration- Balance quality requirements of rigid rotors- Part 2: Balance errors			*	*
ISO 2017: Vibration and shock isolators- Procedure for specifying choice				*
ISO 2041: Mechanical vibration and shock-Vocabulary.		*	*	*
ISO 2954: mechanical Vibration of rotating and reciprocating machines-Requirements for instruments for measuring vibration severity				*
ISO 5348: Mechanical vibration and shock - Mechanical mounting of accelerometers.		*	*	*
ISO 7919-1: Mechanical vibration of non-reciprocating machines- Measurement on rotating shafts and evaluation criteria-Part 1: General Guidelines	*	*	*	*
ISO 7919-2: Mechanical vibration of non-reciprocating machines- Measurement on rotating shafts and evaluation criteria-Part 2: Large Land-based steam turbine generator sets		*	*	*
ISO 7919-3: Mechanical vibration of non-reciprocating machines- Measurement on rotating shafts and evaluation criteria-Part 3: Coupled industrial machines		*	*	*
ISO 7919-4: Mechanical vibration of non-reciprocating machines- Measurement on rotating shafts and evaluation criteria-Part 4: Gas turbine sets		*	*	*
ISO 7919-5: Mechanical vibration of non-reciprocating machines- Measurement on rotating shafts and evaluation criteria-Part 5: Machine sets in hydraulic power generating and pumping plants		*	*	*
ISO 8528-9: Reciprocating internal combustion engine driven alternating current generating sets-Part 9: Measurement and evaluation of mechanical vibrations		*	*	*
ISO 8569, Mechanical vibration and shock-Measurement and evaluation of shock and vibration effects on sensitive equipment in			*	*

Standard	Category 1	Category 2	Category 3	Category 4
buildings				
ISO 10816-1: Mechanical vibration-Evaluation of machine vibrations by measurements on non-rotating parts- Part 1: general guidelines	*	*	*	*
ISO 10816-2: Mechanical vibration-Evaluation of machine vibrations by measurements on non-rotating parts- Part 2: Land-based steam turbines and generators in excess of 50MW with normal operating speeds of 1500 r/min, 1800 r/min, 3000 r/min and 3600 r/min		*	*	*
ISO 10816-3: Mechanical vibration-Evaluation of machine vibrations by measurements on non-rotating parts- Part 3: Industrial machines with nominal power above 15kW and nominal speeds between 120r/min and 15000 r/min when measured in situ		*	*	*
ISO 10816-4: Mechanical vibration-Evaluation of machine vibrations by measurements on non-rotating parts- Part 4: Gas turbine sets excluding aircraft derivatives		*	*	*
ISO 10816-5: Mechanical vibration-Evaluation of machine vibrations by measurements on non-rotating parts- Part 5: Machine sets in hydraulic power generating and pumping plants		*	*	*
ISO 10816-6: Mechanical vibration-Evaluation of machine vibrations by measurements on non-rotating parts- Part 6: Reciprocating machines with power ratings above 100kW		*	*	*
ISO 11342: Mechanical Vibration- methods and criteria for the mechanical balancing of flexible rotors				*
ISO 13372: Condition monitoring and diagnostics of machines: Vocabulary	*	*	*	*
ISO 13373-1: Vibration condition monitoring of machines; Part 1: Vibration condition monitoring. –General procedures	*	*	*	*
ISO 13379: Condition monitoring and diagnostics of machines- Data interpretation and diagnostic techniques which use information and data related to the condition of the machine- General guidelines			*	*
ISO 14694: Specification for balance quality and vibration Categories (Industrial Fans)	*	*	*	*
ISO 14695: Method of measurement of fan vibration			*	*
ISO 17359: Condition monitoring and diagnostics of machines- General guidelines	*	*	*	*
ISO 18436-1: Condition monitoring and diagnostics of machines: Requirements for qualification and assessment of personnel: part				*

Standard	Category 1	Category 2	Category 3	Category 4
1 Requirements for assessment bodies and the assessment process				

BINDT specified additional standards

ISO 13374-1. Condition monitoring and diagnostics of machines- Data processing, communication and presentation: Part 1: General Guidelines		*	*	*
ISO 281: Rolling bearing: Dynamic load ratings and rating life		*	*	*
ISO 15: Rolling bearings- radial bearings boundary dimensions: general Plan		*	*	*
ISO 13381-1: Condition monitoring and diagnostics of machines; Prognostics: Part 1 General Guidelines		*	*	*
ISO 18431-2: Mechanical vibration and shock -- Signal processing -- Part 2: Time domain windows for Fourier Transform analysis			*	*
ISO 18436 –2: Condition monitoring and diagnostics of machines: Requirements for qualification and assessment of personnel. Part 2: vibration condition monitoring and diagnostics	*	*	*	*
ISO 13373-2: Vibration condition monitoring of machines; Part 2: Processing, presentation and analysis of vibration data	*	*	*	*

Annex C- Training sub-topics- Category 2Category

This Annex is additional to the specifications of ISO18436-2 and is provided by the certifying body as an additional guide to the trainer for Category 2. Category 2 training should satisfy Annex A2 but it is suggested that it also incorporates these sub-topics, which are not exhaustive.

Topic	Sub-topics
1. Principles of Vibration	
1. Basic Motion	Superposition of sinusoidal vibrations; pink, self-excited, steady state and transient vibration; damped free vibration; definitions;
2. Period, Frequency	Beat frequency/definitions; double integration; shaft orbits;
3. Amplitude: Peak, Peak-to-Peak, rms	pk-pk/calculation; basic definitions;
4. Parameters: Displacement, Velocity, Acceleration	Formulae (integral/derivatives); absolute vibration;
5. Units, Unit Conversions	pk-pk, displacement and rms calculations;
6. Time and Frequency Domains	Modulation; crest factor; enveloping bandpass filters;
8. Phase	Definition; Units; phase reference position;
9. Natural Frequency, Resonance, Critical Speeds	Fundamental natural mode; critical speeds; resonance fundamentals;
2. Data Acquisition	
1. Instrumentation	Definitions; absolute vibration;
2. Dynamic Range, Signal-to-Noise Ratio	Noise signal definition; double integration;
3. Transducers	Seismic; transducer function; accelerometer integration; transducer frequency ranges; evaluation parameters;
4. Sensor Mounting, Mounted Natural Frequency	ISO measurement guidelines; axial measurements; transducers sensitive axis; transducer mounting methods; cement mounting resonance; adhesive curing times; stud mountings;
5. F_{max} , Acquisition Time	Zoom function; resolution calculations;
6. Proximity Sensor Conventions (API)	Field calibration checks; proximity probes;
7. Triggering	Eddy current probes; clamps
8. Recognition of poor data	Mounting surfaces; cables
3. Signal Processing	
1. Analog Sampling, Digital Sampling	FFT; minimum multiples of frequency interest; synchronous sampling/key phasor; sampling rates; analog/digital converters; equipment not part of signal conditioning;
2. FFT Computation	Enveloping; definitions
3. FFT Application	Definition; zoom FFT;
4. Time Windows: Uniform, Hanning, Flat Top	
5. Filters: Low Pass, High Pass, Band	Basic types of vibration filters; low pass; high pass;

Topic	Sub-topics
Pass, Tracking	band pass; tracking; discrete frequency range/filter;
6. Anti-aliasing	Anti-aliasing filter; aliasing;
7. Bandwidth, Resolution	Bandwidth of bandpass filter; FFT resolution; signal duration; lines of resolution; analyser sample time; FFT collection time; calculations; white, pink, transient and periodic random vibration; frequency resolution; response function; distortion; average mobility magnitude;
8. Noise Reduction	Gaussian, random, ideal, Blast; triboelectric noise causes;
9. Averaging: Linear, Synchronous Time, Exponential	Exponential/Linear frequency domain averaging; synchronous time domain averaging; Exponential averaging; averaging;
10. Dynamic Range	Digital dynamic range calculation; digital dynamic 16-bit analysers;
4. Condition Monitoring	
1. Computer data base set-up	Alarm triggers; envelope techniques
2. Computer database maintenance	
3. Equipment Evaluation and Prioritisation	Evaluation; rotating shafts/asymmetrical;
4.4	
5. Alarms set-up: Narrowband, Envelope	B/C boundary; gas turbine alarm set-up; mechanical integrity;
6. Baseline Assessments, Trending	Baselines;
7. Route Planning	
8. Alternate Technologies: Lubrication management, Infrared Thermography, motor current analysis and acoustic emission	Basics of IRT; AE; LM (tribology and wear debris analysis); motor current; magnetic resonance; performance monitoring; causes of bearing wear;
9. Fault recognition	Rubs; mass loss; sidebands;
10. Procedure writing	Not applicable at Category 2
5. Fault Analysis	
1. Spectrum Analysis, Harmonics, Sidebands	Asynchronous vibration; waterfall/cascade diagrams; oil whirl; zoom spectrum;
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8. Mass Unbalance	1x rpm; static unbalance; residual, initial, resultant and delta unbalance;
9. Misalignment	Definition;
10. Mechanical Looseness	Bearing tightness;
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12. Bearing Defects: Rolling Element,	Transducer mounting on rolling element bearings; rub

Topic	Sub-topics
Journal	and sub-synchronous definitions;
13. Electric Motor Defects	Poles and line frequency; thermal affects; rotor/stator bars;
14. Resonance and Critical Speeds	Resonance; critical speed in flexible rotors;
15. Gearbox analysis	Time domain averaging; sidebands and gear mesh frequency;
6. Corrective Action	
1. Shaft Alignment	
2. Field Balancing	Couple unbalancing; defining unbalance (fans etc); balance weight arrangement; minimum runs; offset balancing;
3. Basic maintenance action	
7. Equipment Knowledge	
1. Electric Motors: Generators and Drives	Eddy current probes; stiffness dissymmetry; thermal dissymmetry; rotor construction; drive belt vibration;
2. Pumps, Fans	Pump flow conditions; industrial fans-oil seals and oil analysis, basic fan construction/installation/operation; sub-synchronous frequencies; eccentric impellers;
3. Steam Turbines, Gas Turbines	Alarm Category triggers (steam/gas turbines); condenser vacuum; temperature affects on gas turbine generators;
4. Compressors	
5. Reciprocating Machinery	Large diesel engine construction; piston velocity;
6. Rolling Mills, Paper Machines and other equipment	Pulp refining machinery measurements;
7. Machine Tools	Acoustic emissions; torque controlled machining;
8. Structures, Piping	Natural resonance's;
9. Rolling Element Bearings	
10. Journal Bearings	Oil whirl;
11. Gearing	Gear teeth and shaft speed calculations;
12. Couplings, Belts	
8. Acceptance Testing	
1. Test procedure	Resonance;
2. Specifications and Standards	Evaluation zones;
3. Reporting	
9. Equipment Testing and Diagnostics	
1. Impact Testing	Ring testing; impact testing, transmissibility; transfer functions;
2. Forced Response Testing	
10. Reference Standards	
1. Relevant National Standards/IEC/ISO	Relevant standards to country of training; Running speed frequency ranges; multiple frequency vibrations, mode balance tolerance, multi-plane balance; sensitivity to unbalance; phase couple angle of and amount of unbalance; fault/failure definitions; see all

Topic	Sub-topics
	ISO in Annex B Table 2 for Category 2
11. Reporting and Documentation	
1. Condition Monitoring Reports -	Format and content; results interpretation;
2. Vibration Diagnostics Reports	Future actions;
12. Fault Severity Determination	
1. Spectrum Analysis	Bode plots; rotating aerodynamic stall; rotor/stator bar defects; gear mesh and sideband frequencies; sum and difference frequencies;
3. Categories: Overall, Narrowband, Component	Evaluation criteria
4. Severity Charts; Graphs and Formula	Polar plots; Campbell and Nyquist diagrams; FMECA; interpretation; statistics;