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CM/GEN APPENDIX D Issue 2 rev E

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

CONTENTS

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 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 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.

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 bother 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
32	70	110	174
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

	Hours of training			
SUBJECT	**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

Ref:	Subject Syllabus topic	Category I	II	III	IV	Category I sub-topics	Category II sub-topics	Category III sub-topics	Category IV sub-topics
1	**Principles of vibration**								
1.01	Basic motion	*	*	*		Recognise vibration, simple harmonic motion, spring-mass system	Understand superposition of sinusoidal vibrations; single degree of freedom.	Understand damped free vibration; self-excited, steady state and transient vibration; Multiple degrees of freedom	
1.02	Period, frequency	*	*	*		Recognise the following features of a vibration signal: time axis, period, frequency. Use of Hz or c.p.m.	Understand relationship of period to frequency, beat frequency	Understand requirements for selecting appropriate time period and frequency. Be aware of octave band analysis	
1.03	Amplitude (peak, peak-to-peak, r.m.s.)	*	*	*		Recognise the following features of a vibration signal: amplitude, peak, peak-to-peak, r.m.s	Understand the relationship between peak, peak-to-peak, r.m.s	Understand reasons for using peak, peak-to-peak or r.m.s.	
1.04	Parameters (displacement, velocity, acceleration)	*	*	*		Recognise the following parameters: Displacement, velocity and acceleration	Understand the application displacement, velocity or acceleration	Understand the factors behind choosing displacement, velocity or acceleration	
1.05	Units, unit conversions	*	*	*		Recognise that units conversion is possible	Understand conversion of units and integration	Be aware of integration, differentiation, effect on frequency distribution	
1.06	Time and frequency domains	*	*	*		Be aware of time and frequency domain.	Be aware of enveloping, bandpass filters; Modulation; crest factor;	Be aware of orbit analysis, Lissajous figures, windowing	

Ref:	Subject Syllabus topic	Category I	II	III	IV	Category I sub-topics	Category II sub-topics	Category III sub-topics	Category IV sub-topics
1.07	Vectors, modulation			*	*			Understand vector definition, modulation	Acquisition for modal techniques
1.08	Phase		*	*	*		Units; phase reference position;	Phase detection methods	Cross-channel; coherence
1.09	Natural frequency, resonance, critical speeds	*	*	*	*	Be aware resonance exists, and its effect on vibration, recognise the terms: frequency, stiffness, mass	Fundamental natural mode; single degree of freedom. Recognise factors including: frequency, stiffness, mass, damping, isolation.	Critical speeds, two degrees of freedom, dynamic vibration absorber	Q Factor, multiple degrees of freedom systems, be aware of modal techniques and operational deflection shapes
1.10	Force, response, damping, stiffness			*	*			Mobility, Compliance	Mobility Plot, stiffness, impedance, accelerance
1.11	Instabilities, non-linear systems				*				Non-elastic mounting systems
2	**Data acquisition**								
2.01	Instrumentation	*	*	*	*	Recognising single channel hand-held route-based and on-line measurement and monitoring systems	Dual channel on and off-line acquisition, monitoring and analysis systems	Multi-channel on and off-line acquisition, monitoring and analysis systems including phase	Multi-channel including modal analysis and troubleshooting
2.02	Dynamic range, signal-to-noise ratio			*	*			Be aware of requirements for dynamic range and signal-noise ratio. Auto-ranging, Integration and system errors	Techniques for improving resolution and accuracy. Noise reduction and post-processing

Ref:	Subject Syllabus topic	Category I	II	III	IV	Category I sub-topics	Category II sub-topics	Category III sub-topics	Category IV sub-topics
2.03	Transducers	*	*	*		Recognise displacement, velocity and acceleration transducers. Be aware of powered and non-powered types	Be familiar with proximity probes, velocity transducers, accelerometers, including those with in-built integration, Be aware of requirements for transducer frequency ranges; runout compensation, need for calibration	Understand transducer selection requirements, including machine expected fault frequency, Understand typical runout compensation methods for proximity probes. Understand and be able to set calibration requirements	
2.04	Sensor mounting, mounted natural frequency	*	*	*		Recognise broad effects of mounting on the frequency response E.g. stud, magnet or probe	Understand accelerometer mounting methods and effects on frequency response; be familiar with a range of mounting methods. Be aware of transducer sensitive axis, tribo-electric effects	Understand ISO measurement guidelines; axial thrust bearing measurement requirements; mounting response and resonance; adhesive curing times;	
2.05	Fmax, acquisition time		*	*			Understand Fmax, zoom function; Simple resolution calculations; relationship of Fmax to acquisition time	Understand basic aspects of FFT processing, samples, sampling rate, aliasing	
2.06	Proximity sensor conventions		*	*			Recognise aspects such as: Gap voltage, orthogonal radial fitment, runout	Field calibration checks; proximity probes; axial thrust bearing measurement, runout compensation	

Ref:	Subject Syllabus topic	Category I	II	III	IV	Category I sub-topics	Category II sub-topics	Category III sub-topics	Category IV sub-topics
2.07	Triggering		*	*			Be aware of use of phase detection: E.g. eddy-current probes, photocells, tracking filters	Understand synchronous time averaging and triggering. Be aware of use with dynamic balancing	
2.08	Test planning		*	*	*		Be able to plan and schedule VM	Managing CM programs	Creating specialised test procedures
2.09	Test procedures	*	*	*	*	Follow pre-set data acquisition procedures for on-line or route-based systems. Recognise measurement points for common machine types. Recognise some poor data and alarm conditions. Be aware calibration is a requirement	Be able to set up VM data collection system, E.g. select machines and measurement points, create appropriate acquisition and alarm settings, carry out and supervise measurement and basic reporting, and carry out calibration procedures	Manage VM programs, set up calibration procedures. Advanced CM reporting. Troubleshooting	Creating test and calibration procedures, Standards development
2.10	Data formats		*	*			Be aware of the common units and basic range of data presentation formats e.g. trending, spectra, waterfall, time trace, phase	Understand range of data presentation formats e.g. trending, spectra, waterfall, time trace, phase, Bode, Nyquist, Campbell etc	
2.11	Computer database upload/download	*				Be aware of basic functions of host and data collector			
2.12	Recognition of poor data	*	*	*		Recognise simple fault conditions such as: Ski-ramp, no signal, cable	Mounting error; cable faults, tribo-electric, bias voltage and settling	Processing related errors, incorrect Fmax, sampling time,	

Ref:	Subject Syllabus topic	Category I	II	III	IV	Category I sub-topics	Category II sub-topics	Category III sub-topics	Category IV sub-topics
						fault	time	integration etc	
3	**Signal processing**								
3.01	R.m.s./peak detection				*				Understand r.m.s and peak detection features and benefits
3.02	Analog/digital conversion				*				Understand requirements of analog to digital conversion. Be aware of key stages in acquisition
3.03	Analog sampling, digital sampling		*	*	*		Be aware of basic function of analogue to digital conversion, block diagram	Understand FFT process; minimum multiples of frequency interest; synchronous sampling/key phasor; sampling rates	Understand requirements of analog sampling and digital sampling. Be aware of key stages in acquisition
3.04	FFT computation			*	*			Be aware of FFT process block diagram. E.g. transducer, signal conditioning, anti-alias, analog-digital, windowing	Understand FFT process block diagram. E.g. transducer, filtering, signal conditioning, anti-alias, analog-digital, windowing, cepstrum

Ref:	Subject Syllabus topic	Category I	II	III	IV	Category I sub-topics	Category II sub-topics	Category III sub-topics	Category IV sub-topics
3.05	FFT application	*	*			Be aware of the term FFT and recognise the following basic FFT terminology: E.g. Number of lines, Fmax and time to sample	Matching FFT requirements to range of common fault profiles. Understand the requirements for number of lines (bins), Fmax sampling time, sampling rate. Basic understanding of other factors such as: anti-aliasing, windowing and averaging		
3.06	Time windows (uniform, hanning, flat-top)		*	*			Be aware of hanning window profile and its effect on sampling E.g. reducing leakage, effect on amplitude and frequency	Be aware of other window functions: uniform, hamming, flat-top. and their effect on sampling E.g. reducing leakage, effect on amplitude and frequency	
3.07	Filters (Low pass, high pass, band pass, tracking)		*	*	*		Be aware of basic types of vibration filters; low pass; high pass; band pass	Recognise the following filter types; low pass; high pass; band pass. Be aware of pass-band & stop-band and tracking filters	Be aware of other filter types: E.g. Bessel, Butterworth, Chebyshev, Gaussian, Elliptic. Be aware of basic filter design parameters E.g. Filter poles and response
3.08	Anti-aliasing		*	*	*		Be aware of requirement for Anti-aliasing filter	Understand requirements for aliasing and anti-aliasing filters and common methods	Be aware of instrumentation ant-aliasing design requirements

Ref:	Subject Syllabus topic	Category I	II	III	IV	Category I sub-topics	Category II sub-topics	Category III sub-topics	Category IV sub-topics
3.09	Bandwidth, resolution		*	*	*		Bandwidth of bandpass filter; FFT resolution; signal duration; lines of resolution; analyser sample time; FFT collection time;	frequency resolution; distortion; average mobility magnitude; calculations; frequency resolution;	noise and random vibration; response function
3.10	Noise reduction		*	*			Be aware of basic filtering and averaging methods used to reduce noise	Understanding requirements for noise reduction. Analogue and digital filtering	
3.11	Averaging (Linear, synchronous time, exponential)		*	*	*		Be aware FFT frequency averaging	Linear frequency and synchronous time domain averaging; Overlapping averaging	Exponential frequency domain averaging;
3.12	Dynamic range		*	*	*		Be aware of the term dynamic range	Understand need for dynamic range.	Digital dynamic range calculations
3.13	Signal-to-noise ratio				*				Be aware of methods for testing and establishing signal-to-noise ratio
3.14	Spectral maps			*	*			Waterfall plots, recognising speed related and resonance frequencies	Cascade plots, Campbell diagrams, spectrogram
4	**Condition monitoring**								
4.01	Computer data base set-up, computer database maintenance			*				Procedures for setting measurement parameters locations and frequency. Database maintenance	

Ref:	Subject Syllabus topic	Category I	II	III	IV	Category I sub-topics	Category II sub-topics	Category III sub-topics	Category IV sub-topics
4.02	Equipment evaluation and prioritisation		*				Be able to review sites and establish equipment VM requirements		
4.03	Monitoring programme design		*	*	*		Be able to set up a VM program using ISO 17359 and ISO 13373	Be familiar with applicable CM & VM Standards including ISO 17359 and ISO 13373, and to be able to carry out Failure Mode and Effect Analysis to establish program requirements.	Be familiar with all applicable CM & VM Standards, be able to set up and carry out Failure Mode and Effect Analysis to establish program requirements
4.04	Alarms set-up (Narrowband, envelope)			*				Be able to specify vibration severity using appropriate ISO Standards and to set and apply frequency band and envelope alarms	
4.05	Baseline assessments, trending		*	*			Measuring baselines E.g. to ISO 10816, ISO 7919, ISO 14694, ISO 8528-9 or other requirements	Be able to set baseline requirements using all appropriate ISO Standards	
4.06	Route planning		*	*			Be able to set up VM Routes	Be able to optimising VM and CM Routes	
4.07	Alternative technologies (E.g. oil analysis, infrared thermography, motor current analysis and acoustic emission)			*	*			Be aware of IRT; AE; UT, LM (tribology and wear debris analysis); motor current;	Be aware of performance monitoring; causes of bearing wear

Ref:	Subject Syllabus topic	Category I	II	III	IV	Category I sub-topics	Category II sub-topics	Category III sub-topics	Category IV sub-topics
4.08	Fault condition recognition	*	*			Recognising basic pre-set fault conditions: E.g. unbalance, looseness, misalignment, bearing noise and damage	Recognising more advanced range of fault conditions: E.g. unbalance, looseness, misalignment, bearing noise and damage, gear mesh faults, rotor bar and stator faults, drive belt faults, resonances etc		
5	**Fault analysis**								
5.01	Spectrum analysis harmonics and sidebands		*	*	*		Understand FFT harmonics, sidebands, and noise. Be aware of enveloping	Be familiar with FFT harmonics, sidebands, modulation and noise, octave bands	Understand cepstrum analysis, octave band analysis
5.02	Time waveform analysis			*	*			Be aware of requirements for time waveform sampling duration for different applications.	Be aware of requirements for time waveform sampling duration for different applications.
5.03	Phase analysis			*	*			Be able to use phase to confirm misalignment, static/couple unbalace, Bode and Nyquist Plots	Phase analysis of structural components, modal analysis and operational deflection shapes (ODS). System and structural response
5.04	Transient analysis			*	*			Coast down and run down time and phase plots, E.g. Bode plots	Understand swept frequency methods, time and phase run down analysis

Ref:	Subject Syllabus topic	Category I	II	III	IV	Category I sub-topics	Category II sub-topics	Category III sub-topics	Category IV sub-topics
5.05	Orbit analysis			*	*			Be aware of basic orbit analysis	Be familiar with orbit analysis, shaft resonance, Nyquist plots, oil whirl etc
5.06	Shaft centre-line analysis			*	*			Orbit analysis to establish run-out	Orbit analysis, shaft resonance, Nyquist plot, run-out and run-out compensation
5.07	Enveloping			*	*			De-modulation (enveloping) process	De-modulation (enveloping) requirements
5.08	Mass unbalance		*	*			Understand static, couple and dynamic unbalance; residual unbalance, initial unbalance	Be aware of sensitivity and susceptibility to unbalance; balance errors, sources of unbalance	
5.09	Misalignment		*	*			Be aware of alignment tolerances, recognise misalignment in FFT and time trace	Understand sources of misalignment and methods of detection using FFT and time trace. Understanding requirements and tolerances for alignment	
5.10	Mechanical looseness		*	*			Recognise looseness in FFT and time trace	Understanding sources of misalignment and looseness and methods of detection using FFT and time trace	
5.11	Rubs, instabilities			*	*			Understanding sources and effect of rubs and methods of detection using spectra and time	Recognising process instabilities

Ref:	Subject Syllabus topic	Category I	II	III	IV	Category I sub-topics	Category II sub-topics	Category III sub-topics	Category IV sub-topics
								waveform	
5.12	Bearing defects (Rolling element, journal)		*	*			Rolling element bearing defects, noise, impacts, damage, BPFO, BPFI, BSF, FTF. Recognise the term: oil whirl. Recognise patterns of bearing defects in FFT and time traces	Journal bearing rub and sub-synchronous vibrations. Understand dynamics of oil whirl, and methods of avoiding/reducing effect of oil whirl.	
5.13	Electric motor defects		*	*	*		AC induction motor poles and line frequency; stator and rotor bar frequency analysis	Variable speed drives, pulse width modulation. AC induction and synchronous motor drives	Thermal effects, DC motor drives
5.14	Flow induced vibration, aerodynamics and liquids			*	*			Recognising and understanding cavitation, recognise rotating stall	Understanding rotating stall, pulsation
5.15	Gearbox analysis		*	*			Recognising gear mesh frequency and sidebands in FFT and modulation in time trace. Application of demodulation (enveloping)	Time domain averaging; sidebands and gear mesh frequency; Understanding enveloping	
5.16	Resonance and critical speeds		*	*	*		Resonance; critical speed in rigid rotors; single degree of freedom	Resonance; critical speed in two plane rotors; two degrees of freedom	Resonance; critical speed in flexible rotors; multi degrees of freedom

Ref:	Subject Syllabus topic	Category I	II	III	IV	Category I sub-topics	Category II sub-topics	Category III sub-topics	Category IV sub-topics
5.17	Turbomachinery			*	*			Understanding oil whirl, rubs, misalignment, process influence	Oil whip, hogging, sagging, intermittent rubs
5.18	General fault recognition	*				Recognise fault frequencies for pre-set FFT and simple time waveforms for unbalance, looseness, misalignment, bearing noise & damage. Also recognise the terms: resonance & phase			
6	**Corrective action**								
6.01	Shaft alignment		*	*			Be aware of shaft alignment, tolerances	Understand shaft alignment tolerances E.g. Relationship of turbine rotor speed to tolerances	
6.02	Field balancing		*	*	*		Understand single plane balancing of rigid rotors with and without phase. Be able to use balance quality and permissible residual unbalance. Be aware of test mass estimation.	Understand two plane balancing of rigid rotors with phase. Be aware of static, couple and dynamic unbalance. Offset balancing. Balance errors.	Be aware of requirements for flexible rotor balancing, phase and modal techniques. Be aware of range of ISO balancing standards.
6.03	Replacement of machine parts			*				Be aware of requirements for replacement parts and factors such as balance and alignment tolerances	

Ref:	Subject Syllabus topic	Category I	II	III	IV	Category I sub-topics	Category II sub-topics	Category III sub-topics	Category IV sub-topics
6.04	Flow control			*	*			Understanding relationship of flow and pressure to avoid fluid cavitation	Be aware of influence of pipework or ductwork in fluid and aerodynamic flow
6.05	Isolation and damping			*	*			Be aware of requirements for specifying isolators	Understand requirements and calculations for specifying isolators
6.06	Resonance control			*	*			Be aware of methods of reducing/eliminating resonance: E.g. mass change, stiffness change, frequency change	Be aware of principles of dynamic vibration absorbers, application of damping and isolation
6.07	Basic maintenance action	*	*	*		Be aware of simple maintenance actions to rectify/reduce faults E.g. lubrication, alignment	Be aware of range of responses to fault conditions. E.g. Part replacement, lubrication, single plane balancing, alignment, resonance control	Be aware of range of methods to correct faults E.g. Replacement of parts, balancing, alignment, resonance control. E.g. recommending structural modifications etc	
7	**Equipment knowledge**								

Ref:	Subject Syllabus topic	Category I	II	III	IV	Category I sub-topics	Category II sub-topics	Category III sub-topics	Category IV sub-topics
7.01	Electric motors, generators and drives	*	*	*		Recognise AC induction motor, and basic faults, e.g. bearing noise and damage, balance, looseness and misalignment	Application of key ISO Standards E.g. ISO10816-1 and Part 3 to AC induction motors and generators. Be aware of torque pulse, rotor/stator frequencies, variable speed drive harmonics, slip frequency calculations.	Be familiar with common types of AC and DC motor construction; Wind turbine generator construction and components. Be familiar with applicable ISO Standards.	
7.02	Pumps, fans	*	*	*		Recognise basic pump and fan combinations, and basic faults, e.g. bearing noise and damage, balance, looseness and misalignment	Application of key ISO Standards E.g. ISO 10816-8 for pumps and ISO 14694 for fans. leaks, cavitation, sub-synchronous frequencies; eccentric impellers; Pump flow conditions;	Pump seals. Basic fan construction / installation / operation; Recognise rotating stall, Wind turbine rotor construction and components. Be familiar with applicable ISO Standards. E.g. ISO, VDI and API	
7.03	Steam turbines, gas turbines		*	*			Application of key ISO Standards E.g. ISO 10816 and ISO 7919 vibration standards, basic fault set: balance, looseness, misalignment, oil whirl, rubs	Prox probe set-up & calibration, Alarm level triggers (steam/gas turbines), stiffness and thermal dissymmetry. Affect of condenser vacuum, hogging, sagging, oil whirl, oil whip, rubs. Be familiar with applicable Standards. E.g. ISO and API	

Ref:	Subject Syllabus topic	Category I	II	III	IV	Category I sub-topics	Category II sub-topics	Category III sub-topics	Category IV sub-topics
7.04	Compressors	*	*	*		Recognise examples of centrifugal and screw compressors	Application of key ISO Standards E.g. ISO 10816 and ISO 7919 vibration standards. Rotating compressor components, fault frequencies E.g. pumping frequency and rotor harmonics	Rotating and reciprocating compressor design and fault frequencies. Influence of process conditions. Be familiar with applicable Standards. E.g. ISO and API	
7.05	Reciprocating machinery		*	*			Application of key ISO Standards E.g. ISO 18016-6 and ISO 8528-9 examples	Recip piston motion, primary and secondary balancing components. E.g. ISO and VDI	
7.06	Rolling mills, paper machines, other process equipment	*	*	*		Recognise examples of these machines	Be aware of components, faults, access	Pulp refining machinery measurements;	
7.07	Machine tools	*	*	*		Recognise examples of these machines	Application of key ISO Standards E.g. ISO 10816-3 vibration standards, use of velocity & displacement	Acoustic emissions; torque controlled machining;	
7.08	Structures, piping	*	*	*		Recognise the term: resonance	Resonances, natural frequencies	Vibration and fatigue of piping	
7.09	Gearboxes	*	*	*		Recognise basic examples of simple gearboxes	Pinion gear mesh and shaft speed calculations; effect of gear misalignment and backlash. Application of displacement, velocity and acceleration and enveloping	Complex gearbox configurations and structures, planetary gears, multiple reduction gearboxes. Use of acceleration time and frequency and cepstrum and demodulation (enveloping)	

Ref:	Subject Syllabus topic	Category I	II	III	IV	Category I sub-topics	Category II sub-topics	Category III sub-topics	Category IV sub-topics
7.10	Rolling element bearings		*	*			Bearing defect frequencies, noise and impacts, crest factor	De-modulation, enveloping, kurtosis	
7.11	Journal bearings		*	*			Proximity probe, runout; Seismic velocity transducer, accelerometer integration, velomitor; transducer frequency ranges;	Be familiar with oil whirl, Oil whip, effect of lubrication flow and pressure. Runout compensation methods	
7.12	Gearing		*	*			Pinion gear mesh and shaft speed calculations	Be familiar with a range of gear profiles and design. E.g. pinion, helical, double helical, bevel, epicyclic (planetary), etc	
7.13	Couplings, belts		*	*			Belt rotational frequency calculations, belt misalignment	Drive belt resonances, effect of drive belt tension, toothed belt	
8	**Acceptance testing**								
8.01	Test procedure	*	*			Be able to apply basic pre-set methods, and be aware of access and safety requirements	Apply test procedures		
8.02	Specifications and standards		*	*			Be aware of applicable ISO standards and apply evaluation zones;	Understand range of required ISO standards and set and interpret evaluation zones; Be able to create test procedures	
8.03	Reporting		*	*			Prepare acceptance test reports	Manage acceptance test procedures.	

Ref:	Subject Syllabus topic	Category I	II	III	IV	Category I sub-topics	Category II sub-topics	Category III sub-topics	Category IV sub-topics
9	**Equipment testing and diagnostics**								
9.01	Impact testing		*	*	*		Be able to carry out impact (hammer) test without phase	Be able to carry out modal hammer impact testing with phase reponse	Understand with and without phase impact testing methods. Be able to establish modal response
9.02	Forced response testing		*	*	*		Be aware of mobility and compliance	Excitation (shaker) testing, establishing mobility, compliance and accelerance, establishing transmissibility	Excitation (shaker) testing, coherence, transmissibility, transfer functions
9.03	Transient analysis			*	*			Be able to carry out coast down and run down time and phase plots	Be able to set up and carry out coast down and run down time and phase plots
9.04	Transfer functions				*				Transfer Function, input output compressor loop
9.05	Damping evaluation				*				Damping evaluation, isolation response testing
9.06	Cross channel phase, coherence				*				Cross channel phase, coherence
9.07	Operating deflection shapes			*	*			Be aware of use of operating deflection shapes (ODS)	Understand modal analysis, structural response, operating deflection shapes (ODS)

Ref:	Subject Syllabus topic	Category I	II	III	IV	Category I sub-topics	Category II sub-topics	Category III sub-topics	Category IV sub-topics
9.08	Modal analysis				*				Understand range of methods of modal analysis, establishing structural response
9.09	Torsional vibration				*				Be aware of ISO torsional vibration standard
10	**Reference standards**								
10.01	ISO		*	*	*		Understand ISO Standards shown in Annex B Table 2 for Cat 1 and Cat 2	Be aware of ISO Standards shown in Annex B Table 2 for Cat 3	Be aware of ISO Standards shown in Annex B Table 2 for Cat 4
10.02	IEC		*	*	*		Be aware of IEC Standards referenced in ISO 17359	Be aware of IEC Standards referenced in ISO 17359	Be aware of IEC Standards referenced in ISO 17359
10.03	Relevant national standards		*	*	*		As required. E.g. API, VDI etc	As required. E.g. API, VDI etc	As required. E.g. API, VDI etc
11	**Reporting and documentation**								
11.01	Condition monitoring reports		*	*			Be able to create vibration condition monitoring reports. Feedback to history	Manage and supervise vibration condition monitoring reports and requirements	
11.02	Vibration diagnostic reports		*	*	*		Review routine VM tours, rounds or readings, evaluate trends, spectra, time trace and produce advisory report. Feedback actions to history	Manage vibration diagnostic and prognostic reporting. To carry out root cause analysis (RCA) failure investigations and prepare formal reports.	Be able to carry out advanced vibration troubleshooting and prepare formal reports and formats. To act as expert witness in all areas of VA

Ref:	Subject Syllabus topic	Category I	II	III	IV	Category I sub-topics	Category II sub-topics	Category III sub-topics	Category IV sub-topics
12	**Fault severity determination**								
12.01	Spectrum analysis		*	*	*		Rotor/stator bar defects; gear mesh and sideband frequencies;	Bode plots; rotor/stator bar defects; gear mesh and sideband frequencies;	Rotating aerodynamic stall; sum and difference frequencies;
12.02	Time waveform analysis, orbit analysis			*	*			Be familiar with time waveform analysis. Understand crest factor. Be able to recognise basic orbit fault patterns E.g. Unbalance, looseness, misalignment, oil whirl and rubs	Understand more advanced orbit analysis E.g. Unbalance, looseness, misalignment, oil whirl and whip, resonance detection, critical speeds and phase response, rubs including newkirk rub, thermal effects
12.03	Levels: Overall, narrowband, component		*	*			Be able to apply overall, narrowband or component alert levels	Understand requirements for overall, narrowband or component alert levels. Be able to source, set and apply alerts, alarms and trips	
12.04	Severity charts; graphs, formulae		*	*	*		Apply levels from ISO 10816, ISO 7919, ISO 8528-9, ISO 14694 etc	Be familiar with relevant ISO Standard severity charts. Be able to carry out simple statistical review of alarms	Be familiar with all relevant ISO Standard severity charts and machine VM standards. Be able to review system and alarms, carry out advanced statistical review methods

Ref:	Subject Syllabus topic	Category I	II	III	IV	Category I sub-topics	Category II sub-topics	Category III sub-topics	Category IV sub-topics
13	**Rotor/bearing dynamics**								
13.01	Rotor characteristics				*				Be familiar with design and characteristics of steam and gas turbine rotors. Be aware of structural response, failure modes and effects, fault frequencies, performance, effect of lubricants etc.
13.02	Bearing characteristics				*				Be familiar with design and characteristics of rolling element bearings, journal bearings and magnetic bearing. Be aware of failure modes and effects, geometry and fault frequencies, statistical life, performance, lubricants etc.
13.03	Rotor balancing				*				Be aware of methods and requirements for rigid and flexible rotor balancing, with and without phase, modal techniques. Be familiar with the range of ISO balancing standards.

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.

Table 1 Essential reading includes:

Category	Title	Author	Publisher	ISBN
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

Recommended reading:

Category	Title	Author	Publisher	ISBN/Publ No
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
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, 2nd Edn	D. J. Ewins, 2000	McGraw-Hill, Inc	0863802184
1, 2, 3	Vibration Testing- Theory	K. G. McConnell,	John Wiley & Son	047130435-2

	and Practice	1995		

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		*	*	*

Standard	Category 1	Category 2	Category 3	Category 4
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 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	*	*	*	*

Standard	Category 1	Category 2	Category 3	Category 4
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 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	*	*	*	*