INTERNATIONAL STANDARD

ISO 18436-2

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

Part 2: Vibration condition monitoring and diagnostics

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

Partie 2: Surveillance des vibrations et diagnostic d'état des machines

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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

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

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

This second edition cancels and replaces the first edition (ISO 18436-2:2003), of which it is a minor revision.

ISO 18436 consists of the following parts, under the general title *Condition monitoring and diagnostics of machines — Requirements for qualification and assessment of personnel*:

— *Part 1: Requirements for assessment bodies and the assessment process*

— *Part 2: Vibration condition monitoring and diagnostics*

— *Part 3: Requirements for training bodies and the training process*

— *Part 4: Field lubricant analysis*

— *Part 5: Lubricant laboratory technician/analyst*

— *Part 6: Acoustic emission*

— *Part 7: Thermography*

— *Part 8: Ultrasound*

The following part is planned:

— *Part 9: Condition monitoring specialists*

Introduction

Non-intrusive technologies used in condition monitoring and fault diagnosis include vibration, infrared thermography, oil and wear debris analysis, acoustic and ultrasonic analysis, and electric signature analysis.

Those in manufacturing industry who have diligently and consistently applied these techniques have experienced a return on investment far exceeding their expectations. However, the effectiveness of these programmes depends on the capabilities of individuals who perform the measurements and analyse the data.

A programme, specified in this part of ISO 18436, has been developed to train and assess the competence of personnel whose duties require the appropriate theoretical and practical knowledge and relevant experience in VA for machinery condition monitoring and diagnostics.

This part of ISO 18436 defines the requirements against which personnel associated with vibration measurement and analysis for machinery condition monitoring and diagnostics are to be assessed, and the methods of assessing such personnel. Applicants should be aware that employers and customers are likely to have the greatest confidence in those vibration analysts certified by accredited bodies. Alternately, applicants can choose to seek recognition from other party assessment bodies which may provide the next lower level of confidence. Lastly, applicants may rely upon their own self-assessment and declaration of competence but in doing so they should be aware that employers and customers are likely to have the least confidence in this option.

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

Part 2: Vibration condition monitoring and diagnostics

1 Scope

This part of ISO 18436 specifies requirements for the training, relevant experience, and examination of personnel performing condition monitoring and diagnostics of machines using vibration analysis (VA).

A certificate or declaration of conformity to the requirements of this part of ISO 18436 in accordance with ISO 18436-1, provides recognition and evidence that individuals are able to perform vibration measurements and analysis for machinery condition monitoring and diagnostics using a range of vibration measurement equipment.

This part of ISO 18436 specifies a four-category classification programme that is based on the technical areas delineated herein.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 1925, *Mechanical vibration — Balancing — Vocabulary*

ISO 2041, *Mechanical vibration, shock and condition monitoring — Vocabulary*

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

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*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 1925, ISO 2041, ISO 13372, , and ISO 18436-1 apply.

4 Classification of personnel

4.1 General

Depending upon their competence in VA, individuals meeting the requirements of this part of ISO 18436 shall be classified in one of four categories (4.2 to 4.5). They shall have demonstrated competence appropriate to their classification category as indicated in Annex A, in the concepts of machine condition monitoring using VA.

The classification of individuals at all categories shall be subject to the scope and any limitations of the award issued by the assessing body. Authority to work shall be limited or specified by the employer or

client. Individuals shall provide recommendations based on the limits of their training and experience. This declaration shall not allow a practitioner to make recommendations or give advice that may affect plant design, safety or operation without discussion with, and approval from, the appropriate plant specialist, manager or operator. The limits of the practitioner are specified in this clause whereas the limits of liability shall be agreed between the practitioner and their employer or client.

The classification category of the practitioner and any requirements for additional knowledge to work with specific equipment shall be subject to agreement between the customer and service supplier. This qualification shall provide the practitioner with sufficient knowledge to be able to make measurements and interpret data as appropriate for their category. In addition, the applicability of the qualification to a particular specialized machine type or types should be verified by the client through reference to the previous experience and training of the practitioner. It is recognized that different industrial applications require knowledge of varying aspects of VA. Using supporting documented evidence, the supplier of the VA service shall be able to demonstrate to the employer or client, that staff carrying out work has the appropriate machine knowledge and experience.

Where an individual has specialized knowledge in a particular concept of VA or in specific types of machinery, they may be capable, when approved by the client or employer, of working beyond their qualification classification category. Their certificate or declaration of conformity from the assessment body shall remain as it was at the time it was issued.

In 4.2 to 4.5, an outline is given of the typical competencies and skills required in each category. Detailed recommended topics and sub-topics are shown in Tables A.1 and A.2

4.2 Category I

Personnel classified to category I are able to perform a range of pre-defined, generally simple single-channel, machinery vibration condition monitoring activities in accordance with established procedures. All activities shall be performed under direction.

Personnel classified to category I shall at least:

a) know of the basic principles of vibration and recognize the different units of measurement;

b) be able to collect reliable data ensuring appropriate standards of repeatability;

c) be able to identify errors in collected data;

d) be able to retrieve pre-defined measurement settings for use with VA equipment and transfer data from an analysis system to a computer-based system;

e) be able to compare overall or single-value vibration measurements against pre-established alert settings;

f) be able to identify deviations from the norm for single-value vibration values and trends;

g) report on visual observations of equipment condition.

They shall not be responsible for:

— the choice of sensor, test method or technique or for any analysis or diagnosis to be conducted;

— the assessment of test results, other than identifying conditions against pre-established criteria, such as acceptance, alert, alarm, shutdown, etc.

4.3 Category II

Personnel classified to category II are able to perform industrial machinery vibration measurements and basic VA using single-channel measurements, with or without phase trigger signals, according to

established and recognized procedures. They require all the knowledge, experience and skills expected of category I, and in addition they shall at least:

a) be able to define the measurement activities to be undertaken by a category I individual in the course of routine data collection;

b) be aware of and capable of using the basic principles of signal analysis and, as such, can define acquisition and analysis settings to collect data appropriate to the machine(s) monitored;

c) be able to perform basic (single-channel) impact tests to determine natural frequencies;

d) be able to interpret and evaluate test results from routine analysis and acceptance tests in accordance with specifications and standards;

e) be able to diagnose common fault indications and recommend basic corrective actions commensurate with their area of machinery experience including carrying out single-plane balancing of rigid rotors with or without phase;

f) be able to provide technical guidance to and instruct category I personnel.

4.4 Category III

Personnel classified to category III require all the knowledge, experience and skills expected of personnel classified to categories I and II, and in addition shall at least:

a) be able to design, direct and establish routine condition monitoring programmes and non-routine investigations for the purpose of fault diagnosis;

b) be able to specify the appropriate vibration instrumentation hardware, software, and processing for portable monitoring systems, permanently installed surveillance systems, and equipment protection systems

c) have an in-depth knowledge of the principles and techniques of machinery VA and be able to make initial diagnoses of suspected faults beyond the range of commonly encountered issues. This should include, but not be limited to, the use of frequency spectra, time waveforms and orbits, transfer functions, basic operating deflection shapes, and acceleration enveloping under both steady state and transient conditions with or without a phase trigger;

d) be able to manage such condition-monitoring programmes, evaluate the alarm sets, write working procedures and specify vibration acceptance testing procedures;

e) be able to initiate and validate machinery corrective actions including in situ two-plane rigid rotor balancing;

f) be able to recommend restrictions to machine operation;

g) be able to understand and direct, when necessary, alternative condition monitoring technologies to verify or investigate issues raised through routine data collection;

h) be able to provide technical guidance to and instruct category I and II personnel, and, subject to agreement with the employer or client, deem them competent to carry out certain duties which would normally be outside the scope of those competencies.

It is the responsibility of the employer or client to ensure that category III personnel have the necessary competency in the required management skills, e.g. creating budgets, preparing cost justifications, and managing personnel development.

4.5 Category IV

Personnel classified to category IV require all the knowledge and skills expected of category I, category II and category III personnel. In addition, they shall be able to direct and audit condition monitoring strategies.

Employers should recognize that a category IV individual is likely to have a broad technical knowledge and experience of a range of machine situations and techniques, and an in-depth knowledge of a selection of them.

In addition, personnel classified to category IV shall at least:

a) be able to apply vibration theory and techniques, including measurement and interpretation of multi-channel spectral results such as frequency response functions, phase and coherence;

b) be able to understand and perform signal analysis, including understanding of frequency and time domain processing, including orbits and their limitations;

c) be able to determine the natural frequencies, mode shapes and damping of systems, components and assemblies;

d) be able to determine and assess the operating deflection shapes of machines and connected structures and recommend means for correction;

e) be able to use generally recognized advanced techniques for VA, parameter identification, and fault diagnosis;

f) be able to apply the basic principles of rotor-bearing dynamics to vibration diagnosis;

g) understand and apply advanced two-plane influence coefficient or static and couple balancing theory;

h) be able to recommend corrective actions or design modifications, including component change or repair, isolation, damping, change of stiffness and change of mass;

i) be able to interpret and evaluate codes of practice and specifications published in International Standards and other documents;

j) be able to recognize vibration caused by gas pulsation in machines, such as reciprocating machines and screw compressors, be able to measure the necessary parameters, and recommend means for correction;

k) be able to recommend corrective actions for resilient mounting and other holding-down and foundation problems.

5 Eligibility

5.1 General

In order to conform to the requirements of this part of ISO 18436, candidates shall have a combination of education, training and experience sufficient to ensure that they understand the principles and procedures consistent with Clause 4 and Annex A.

5.2 Education

Candidates seeking classification do not need to provide evidence of formal education to establish eligibility. All candidates shall be able to use a basic scientific calculator and be familiar with the operation of personal computers. Category III and IV candidates shall require familiarity with current VA technology. 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 classification to categories III and IV.

5.3 Training

5.3.1 Basic training

To be eligible to apply for assessment to the requirements of this part of ISO 18436, candidates shall provide documentary evidence of successful completion of formal training based on the requirements of Annex A. Training should take the form of formal lectures, demonstrations, trainer-specified practical exercises or controlled self-study. Training should be assessed by the trainer for evidence of adequate knowledge acquisition. Training time shall meet the minimum requirements given in Table 1 shall include the topics identified in Annex A.

Table 1 — Minimum training durations

Durations in hours

Category I	Category II	Category III	Category IV
30	Category I + 38	Category II + 38	Category III + 64

Training may be separated into subject areas, but shall comply with the requirements of Annex A. Additional sources of technical information may be found in Annex B and the Bibliography. It is recommended that the training includes examinations or written assessment to ensure that the subject matter has been understood and to provide the required documentary evidence.

5.3.2 Additional training on machine knowledge

In addition to the training hours shown in Table 1 and detailed in Annex A, it is recommended that candidates attend machinery and component training, or equivalent on-the-job training of at least one-half the duration as specified in Table 1. Such training may be inclusive of any college or university education, or provided as additional courses or on-the-job training by an employer to specific requirements. If undertaken, the additional training should cover the design, manufacturing, installation, operation, and maintenance principles of machines and components, the failure modes and mechanisms associated with each principle, and the typical vibratory behaviours associated with each mechanism. Such training shall be validated by verifiable records.

5.4 Experience

To be eligible for assessment to the requirements of this part of ISO 18436, candidates shall provide evidence to the assessment body of experience in the field of machinery vibration condition monitoring and diagnostics. For category IV candidates, validation may be acquired from another category IV practitioner or their company manager.

The minimum experience requirements are shown in Table 2.

Table 2 — Minimum experience

Durations in months

Category I	Category II	Category III	Category IV
6	18	36	60
NOTE The figures shown represent the cumulative total months of experience to be held for each classification.			

Designation of a person as category I is not a prerequisite for certification as category II. However, certification of a person as category III and category IV requires previous certification at the lower category. At each higher classification category, the breadth and depth of experience is expected to be greater than at the previous lower category.

6 Examination

6.1 Content

For all categories, it is recommended that the candidate should answer a number of questions within a specified duration similar to the examples shown in Table 3. The questions, covering the topics shown in Annex A, should have been selected from a database of questions existing at the time of the examination. These questions should be generated or approved by a technical committee or an appropriate assessment body.

Table 3 — Example of examination content, duration and pass grade

Category	Number of questions	Examination duration	Pass grade
		h	%
I	60	2	70
II	100	3	70
III	100	4	70
IV	60	5	70

Questions shall be of a practical nature, yet shall test the candidate regarding the concepts and principles required to conduct machinery VA for condition monitoring of machines.

Some questions may involve the interpretation of charts and plots. Simple mathematical calculations using a basic scientific calculator may be required. At the discretion of the assessment body, a summary of common formulae may be provided with the examination questions.

Category III and IV examinations may include both short answer (narrative) and multiple choice questions.

The examination content shall be consistent with the training syllabus contained in Annex A.

Assessment bodies may, at their discretion, make accommodation for candidates with conditions that may require some form of compensation (e.g. dyslexia).

6.2 Examination conduct

In order to maintain confidentiality and integrity, all examinations shall be conducted in accordance with the requirements of ISO 18436-1 and the procedures specified by the assessment body.

Annex A
(normative)

Training course requirements

Table A.1 — Overview

Durations in hours

Subject		Category			
		I	II	III	IV
1.	Principles of vibration	6	3	1	4
2.	Data acquisition	6	4	2	2
3.	Signal processing	2	4	4	8
4.	Condition monitoring	2	4	3	1
5.	Fault analysis	4	5	6	6
6.	Corrective action	2	4	6	16
7.	Equipment knowledge	6	4	4	—
8.	Acceptance testing	2	2	2	—
9.	Equipment testing and diagnostics	—	2	4	4
10.	Reference standards	—	2	2	2
11.	Reporting and documentation	—	2	2	4
12.	Fault severity determination	—	2	2	3
13.	Rotor and bearing dynamics	—	—	—	14
Total hours per category of training		30	38	38	64
NOTE The hours per subject are approximations to allow training bodies and assessment bodies to assess the relative importance of subjects, and it is recognized that subject contents may overlap.					

Table A.2 — Detailed list of topics

Subject		Category				Recommended sub-topics			
Ref:	Syllabus topic	I	II	III	IV	Category I	Category II	Category III	Category IV
1	**Principles of vibration**	**6**	**3**	**1**	**4**				
1.01	Basic motion	•	•	•		Recognize vibration and understand the origin of the sine wave.	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	•	•	•		Recognize the following features of a vibration signal: time axis, period, frequency. Use of hertz or cycles per minute	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.)	•	•	•		Recognize 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)	•	•	•		Recognize 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	•	•	•		Recognize 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; demodulation; crest factor	Understand orbit analysis, Lissajous figures, windowing	

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 II includes the knowledge of category I; category III includes the knowledge of category I and category II; category IV includes the knowledge of lower categories.

NOTE 3 If the symbol • appears in more than one category for a subject item, it should be understood that at category X deeper knowledge of the subject is required than at category X – 1.

Table A.2 *(continued)*

	Subject	Category				Recommended sub-topics			
Ref:	**Syllabus topic**	**I**	**II**	**III**	**IV**	**Category I**	**Category II**	**Category III**	**Category IV**
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	Fundamental natural mode; single degree of freedom. Recognize factors including: frequency, stiffness, mass, damping, isolation	Critical speeds, two degrees of freedom, dynamic vibration absorber. Be aware of modal techniques and operational deflection shapes	*Q*-factor, multiple degrees of freedom systems. Have a detailed understanding of modal techniques and operational deflection shapes
1.10	Force, response, damping, stiffness			•	•			Understand mobility, compliance	Apply mobility plot, stiffness, impedance, accelerance
1.11	Instabilities, non-linear systems				•				Non-elastic mounting systems
2	**Data acquisition**	**6**	**4**	**2**	**2**				
2.01	Instrumentation	•	•	•	•	Recognizing single-channel hand-held route-based and on-line measurement and monitoring systems	Dual-channel on- and off-line acquisition, monitoring, and analysis systems including phase	Multi-channel on and off-line acquisition, monitoring, and analysis systems including phase	Multi-channel including modal analysis and troubleshooting

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Table A.2 *(continued)*

	Subject	Category				Recommended sub-topics			
Ref:	**Syllabus topic**	**I**	**II**	**III**	**IV**	**Category I**	**Category II**	**Category III**	**Category IV**
2.02	Dynamic range, signal-to-noise ratio			•	•			Be aware of requirements for dynamic range and signal-noise ratio. Auto-ranging, integration, system errors, and improving resolution.	Techniques for improving resolution and accuracy. Noise reduction and post-processing
2.03	Transducers	•	•	•		Recognize 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	•	•	•		Recognize 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 International Standard measurement specifications; axial thrust bearing measurement requirements; mounting response and resonance; adhesive curing times	

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Table A.2 *(continued)*

	Subject	Category				Recommended sub-topics			
Ref:	**Syllabus topic**	**I**	**II**	**III**	**IV**	**Category I**	**Category II**	**Category III**	**Category IV**
2.05	F_{max}, acquisition time		•	•			Understand F_{max}, zoom function; simple resolution calculations; relationship of F_{max} to acquisition time	Understand basic aspects of fast Fourier transform (FFT) processing, samples, sampling rate, aliasing	
2.06	Proximity sensor conventions		•	•			Recognize aspects such as gap voltage, orthogonal radial fitment, and runout	Field calibration checks; proximity probes; axial thrust bearing measurement, runout compensation	
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 vibration monitoring (VM)	Managing condition monitoring (CM) programmes	Creating specialized test procedures

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Table A.2 *(continued)*

	Subject	Category				Recommended sub-topics			
Ref:	**Syllabus topic**	**I**	**II**	**III**	**IV**	**Category I**	**Category II**	**Category III**	**Category IV**
2.09	Test procedures	•	•	•	•	Follow pre-set data acquisition procedures for on-line or route-based systems. Recognize measurement points for common machine types. Recognize 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 programmes, 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 plot, etc.	
2.11	Computer database upload/download	•				Be aware of basic functions of host and data collector			
2.12	Recognition of poor data	•	•	•		Recognize simple fault conditions, e.g. ski-ramp, no signal, cable fault	Mounting error; cable faults, triboelectric, bias voltage and settling time	Processing-related errors, incorrect F_{max}, sampling time, integration, etc.	
3	**Signal processing**	**2**	**4**	**4**	**8**				

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Table A.2 *(continued)*

	Subject	Category				Recommended sub-topics			
Ref:	**Syllabus topic**	**I**	**II**	**III**	**IV**	**Category I**	**Category II**	**Category III**	**Category IV**
3.01	R.m.s. and peak detection				•				Understand r.m.s and peak detection features and benefits
3.02	Analogue to digital conversion				•				Understand requirements of analogue to digital conversion. Be aware of key stages in acquisition
3.03	Analogue recording, digital sampling		•	•	•		Be aware of basic function of analogue to digital conversion, block diagram. Basic understanding of clipping, truncation and leakage	Understand FFT process; minimum multiples of frequency interest; synchronous sampling/ key phasor; sampling rates	Understand requirements of analogue 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, analogue-digital, windowing	Understand FFT and discrete Fourier transform (DFT) process block diagram. e.g. transducer, filtering, signal conditioning, anti-alias, analogue–digital, windowing, cepstrum

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Table A.2 *(continued)*

	Subject	Category				Recommended sub-topics			
Ref:	**Syllabus topic**	**I**	**II**	**III**	**IV**	**Category I**	**Category II**	**Category III**	**Category IV**
3.05	FFT application	•	•			Be aware of the term FFT and recognize the following basic FFT terminology, e.g. number of lines, F_{max} and time to sample	Matching FFT requirements to range of common fault profiles. Understand the requirements for number of lines (bins), F_{max} 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	Recognize the following filter types: low pass; high pass; band pass. Be aware of pass-band and 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

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	Subject	Category				Recommended sub-topics			
Ref:	**Syllabus topic**	**I**	**II**	**III**	**IV**	**Category I**	**Category II**	**Category III**	**Category IV**
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
3.09	Bandwidth, resolution		•	•	•		Bandwidth of band pass filter; FFT resolution; signal duration; lines of resolution; analyser sample time; FFT collection time	Frequency resolution; distortion; 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	Understand and apply noise reduction techniques such as increased frequency resolution, time synchronous averaging, selection of low inherent noise sensors and instruments, etc.
3.11	Averaging (linear, synchronous time, exponential)		•	•	•		Be aware of 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

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Table A.2 *(continued)*

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Ref:	**Syllabus topic**	**I**	**II**	**III**	**IV**	**Category I**	**Category II**	**Category III**	**Category IV**
3.13	Signal-to-noise ratio				•				Be aware of methods for testing and establishing signal-to-noise ratio
3.14	Spectral maps			•	•			Waterfall plots, recognizing speed related and resonance frequencies	Cascade plots, Campbell diagrams, spectrogram
4	**Condition monitoring**	**2**	**4**	**3**	**1**				
4.01	Computer data base set-up, computer database maintenance			•				Procedures for setting measurement parameters locations and frequency. Database maintenance	
4.02	Equipment evaluation and prioritization		•				Be able to review sites and establish equipment VM requirements		
4.03	Monitoring programme design		•	•	•		Be able to set up a VM programme using ISO 17359 and ISO 13373	Be familiar with applicable CM and VM Standards including ISO 17359 and ISO 13373, and to be able to carry out failure mode and effect analysis (FMEA) to establish programme requirements	Be familiar with all applicable CM and VM standards, be able to set up and carry out FMEA to establish programme requirements

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4.04	Alarms set-up (narrowband, envelope)			•				Be able to specify vibration severity using appropriate International 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 International Standards	
4.06	Route planning		•	•			Be able to set up VM routes	Be able to optimize VM and CM routes	
4.07	Alternative technologies (e.g. infrared thermographic testing (TT); acoustic emission testing (AT); ultrasonic testing (UT), lubricant management (LM) — tribology and wear debris analysis; motor current analysis (MCA)			•	•			Be aware of TT; AT; UT, LM — tribology and wear debris analysis; MCA	Be aware of performance monitoring; causes of bearing wear
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4.08	Fault condition recognition	•	•			Recognizing basic pre-set fault conditions, e.g. unbalance, looseness, misalignment, bearing noise and damage	Recognizing 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**	**4**	**5**	**6**	**6**				
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		•	•	•		Understand the use of time waveform for basic analysis.	Be aware of requirements for time waveform sampling duration for different applications	Be able to conduct time waveform analysis on varied applications

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Ref:	**Syllabus topic**	**I**	**II**	**III**	**IV**	**Category I**	**Category II**	**Category III**	**Category IV**
5.03	Phase analysis		•	•	•		Understand the use of phase for basic analysis.	Understand basic time waveform analysis. Be able to use phase to confirm misalignment, static/couple unbalance, Bode and Nyquist plots	Apply time waveform analysis to varied machine problems. 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
5.05	Orbit analysis			•	•		Be aware of basic orbit analysis	Be aware of how the orbit shape indicates potential fault conditions. Explain the difference between filtered and un-filtered orbits. Explain why "glitch removal" is necessary.	Be familiar with orbit analysis, shaft resonance, Nyquist plots, oil whirl, etc.
5.06	Shaft centre-line analysis		•	•	•		Be aware of the shaft centre-line plot.	Understand the data presented in a shaft centre-line plot.	Be able to interpret the data presented in the shaft centre-line plot.

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5.07	Enveloping		•	•	•		Understand the application of enveloping.	Understand the details of enveloping (and associated proprietary techniques) so that routine measurements can be set up correctly.	Understand de-modulation (enveloping) process and 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, recognize misalignment in FFT and time trace	Understand sources of misalignment and methods of detection using FFT and time trace. Understand requirements and tolerances for alignment	
5.10	Mechanical looseness		•	•			Recognize looseness in FFT and time trace	Understanding sources of 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 waveform	Recognize sources of process instabilities

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5.12	Bearing defects (rolling element, journal)		•	•			Rolling element bearing defects, noise, impacts, damage, ball pass frequency of the outer race (BPFO), ball pass frequency of the inner race (BPFI), ball spin frequency (BSF), and fundamental train frequency (FTF). Time traces and enveloping data. Recognize the term: oil whirl. Recognize 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 or 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			•	•			Recognize and understand cavitation; recognize rotating stall	Understanding rotating stall, pulsation

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Ref:	**Syllabus topic**	**I**	**II**	**III**	**IV**	**Category I**	**Category II**	**Category III**	**Category IV**
5.15	Gearbox analysis		•	•			Recognizing 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 of enveloping	
5.16	Resonance and critical speeds		•	•	•		Resonance; critical speed in rigid rotors; single degree of freedom	Resonance; critical speed in flexible rotors; two degrees of freedom	Resonance; critical speed in flexible rotors; multi degrees of freedom
5.17	Turbomachinery			•	•			Understanding of oil whirl, rubs, misalignment, process influence	All faults associated with turbomachinery including oil whirl, oil whip, hogging, sagging, unbalance, misalignment, and rubs.
5.18	General fault recognition	•				Recognize fault frequencies for preset FFT and simple time waveforms for unbalance, looseness, misalignment, bearing noise and damage. Also recognize the terms: resonance and phase			
6	**Corrective action**	**2**	**4**	**6**	**16**				

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Ref:	**Syllabus topic**	**I**	**II**	**III**	**IV**	**Category I**	**Category II**	**Category III**	**Category IV**
6.01	Shaft alignment		•	•			Be aware of shaft alignment, tolerances.	Understand shaft alignment tolerances e.g. relationship of machine 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.	Understand 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	
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

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Ref:	**Syllabus topic**	**I**	**II**	**III**	**IV**	**Category I**	**Category II**	**Category III**	**Category IV**
6.06	Resonance control			•	•			Be aware of methods of reducing or eliminating resonance: e.g. mass change, stiffness change, frequency change	Understand principles of dynamic vibration absorbers, application of damping and isolation
6.07	Basic maintenance action	•	•	•		Be aware of simple maintenance actions to rectify or reduce faults e.g. lubrication, alignment	Be aware of range of responses to fault conditions, e.g. part replacement, lubrication, single- plane balancing, alignment, and 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**	**6**	**4**	**4**	**—**				
7.01	Electric motors, generators and drives	•	•	•		Recognize AC induction motor, and basic faults, e.g. bearing noise and damage, balance, looseness and misalignment	Application of key International Standards e.g. ISO 10816-1 and Part 3 to AC induction motors and generators. Be aware of torque pulse, rotor and stator frequencies, variable speed drive harmonics, and slip frequency calculations	Be familiar with common types of AC and DC motor construction; wind turbine generator construction and components. Be familiar with applicable International Standards	

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Ref:	**Syllabus topic**	**I**	**II**	**III**	**IV**	**Category I**	**Category II**	**Category III**	**Category IV**
7.02	Pumps, fans	•	•	•		Recognize basic pump and fan combinations, and basic faults, e.g. bearing noise and damage, balance, looseness and misalignment	Application of key International 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, and operation; Recognize rotating stall, wind turbine rotor construction and components. Be familiar with applicable standards and specifications, e.g. ISO, Verein Deutscher Ingenieure [Association of German Engineers] (VDI) and American Petroleum Institute (API)	
7.03	Steam turbines, gas turbines		•	•			Application of key International Standards e.g. ISO 10816 and ISO 7919 on vibration, basic fault set: balance, looseness, misalignment, oil whirl, rubs	Proximity probe set-up and calibration, alarm level triggers (steam/gas turbines), stiffness and thermal dissymmetry. Effect of condenser vacuum, hogging, sagging, oil whirl, oil whip, rubs. Be familiar with applicable standards and specifications, e.g. ISO and API, and other specifications.	

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Ref:	**Syllabus topic**	**I**	**II**	**III**	**IV**	**Category I**	**Category II**	**Category III**	**Category IV**
7.04	Compressors	•	•	•		Recognize examples of centrifugal and screw compressors	Application of key International Standards, e.g. ISO 10816 and ISO 7919 on vibration. 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 International Standards e.g. ISO 10816-6 and ISO 8528-9.	Reciprocating piston motion, primary and secondary balancing component standards, e.g. ISO and VDI.	
7.06	Rolling mills, paper machines, other process equipment	•	•	•		Recognize examples of these machines	Be aware of components, faults, access	Pulp refining machinery measurements	
7.07	Machine tools	•	•	•		Recognize examples of these machines	Application of key International Standards e.g. ISO 10816-3 vibration standards, use of velocity and displacement	Acoustic emissions; torque controlled machining	
7.08	Structures, piping	•	•	•		Recognize the term: resonance	Resonances, natural frequencies	Vibration and fatigue of piping	

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Ref:	**Syllabus topic**	**I**	**II**	**III**	**IV**	**Category I**	**Category II**	**Category III**	**Category IV**
7.09	Gearboxes	•	•	•		Recognize 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)	
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, velometer; 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	

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Ref:	**Syllabus topic**	**I**	**II**	**III**	**IV**	**Category I**	**Category II**	**Category III**	**Category IV**
8	**Acceptance testing**	**2**	**2**	**2**	**—**				
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 International Standards and apply evaluation zones	Understand range of required International Standards and set and interpret evaluation zones; be able to create test procedures	
8.03	Reporting		•	•			Prepare acceptance test reports	Manage acceptance test procedures	
9	**Equipment testing and diagnostics**	**—**	**2**	**4**	**4**				
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 response	Understand impact testing methods with phase and without phase impact testing methods. Be able to establish modal response

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Ref:	**Syllabus topic**	**I**	**II**	**III**	**IV**	**Category I**	**Category II**	**Category III**	**Category IV**
9.02	Forced response testing		•	•	•		Be aware of forced response testing.	Be able to carry out excitation (shaker) testing, establishing mobility, compliance and accelerance, establishing transmissibility	Understand excitation (shaker) testing, coherence, transmissibility, transfer functions, mobility, compliance and accelerance
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			•	•			Be aware of transfer functions, including coherence	Transfer function, input and output (compressor loop), apply Nyquist plots.
9.05	Damping evaluation				•				Damping evaluation, isolation response testing
9.06	Cross channel phase, coherence			•	•			Be aware of 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)
9.08	Modal analysis			•	•			Be aware of modal analysis	Understand range of methods of modal analysis, establishing structural response

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Ref:	**Syllabus topic**	**I**	**II**	**III**	**IV**	**Category I**	**Category II**	**Category III**	**Category IV**
9.09	Torsional vibration				•				Be aware of ISO 22266-1
10	**Reference standards**	**—**	**2**	**2**	**2**				
10.01	ISO standards		•	•	•		Understand International Standards shown in Table B.1 for category 1 and category II	Be aware of International Standards shown in Table B.1 for category III	Be aware of International Standards shown in Table B.1 for category IV
10.02	IEC standards		•	•	•		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 and other specifications		•	•	•		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**	**—**	**2**	**2**	**4**				
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 diagnostics 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. Be able 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. Be able to act as expert witness in all areas of VA
12	**Fault severity determination**	**—**	**2**	**2**	**3**				

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Ref:	**Syllabus topic**	**I**	**II**	**III**	**IV**	**Category I**	**Category II**	**Category III**	**Category IV**
12.01	Spectrum analysis		•	•	•		Rotor and stator bar defects; gear mesh and sideband frequencies	Bode plots; rotor and 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 familiar with time waveform analysis. Understand crest factor. Be able to recognize basic orbit fault patterns e.g. unbalance, looseness, misalignment, oil whirl and rubs	Apply 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 and formulae		•	•	•		Apply levels from ISO 10816, ISO 7919, ISO 8528-9, ISO 14694, etc.	Be familiar with relevant International Standard severity charts. Be able to carry out simple statistical review of alarms.	Apply all relevant International Standard severity charts and machine VM standards. Be able to review system and alarms, carry out advanced statistical review methods

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Ref:	**Syllabus topic**	**I**	**II**	**III**	**IV**	**Category I**	**Category II**	**Category III**	**Category IV**
13	**Rotor and bearing dynamics**	**—**	**—**	**—**	**14**				
13.01	Rotor characteristics				•				Understand 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				•				Understand 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.

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Ref:	**Syllabus topic**	**I**	**II**	**III**	**IV**	**Category I**	**Category II**	**Category III**	**Category IV**
13.03	Rotor balancing				•				Understand methods and requirements for rigid and flexible rotor balancing, with and without phase, modal techniques. Be familiar with the range of International Standards on balancing

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Annex B
(normative)

Applicable International Standards

Table B.1 — Applicable standards by category

ISO reference	Category			
	I	II	III	IV
ISO 1925, *Mechanical vibration — Balancing — Vocabulary*		•	•	•
ISO 1940-1, *Mechanical vibration — Balance quality requirements for rotors in a constant (rigid) state — Part 1: Specification and verification of balance tolerances*		•	•	•
ISO 2017-1, *Mechanical vibration and shock — Resilient mounting systems — Part 1: Technical information to be exchanged for the application of isolation systems*				•
ISO 2041, *Mechanical vibration, shock and condition monitoring — Vocabulary*		•	•	•
ISO 2954, *Mechanical vibration of rotating and reciprocating machinery — 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 — Measurements on rotating shafts and evaluation criteria — Part 1: General guidelines*	•	•	•	•
ISO 7919-2, *Mechanical vibration — Evaluation of machine vibration by measurements on rotating shafts — Part 2: Land-based steam turbines and generators in excess of 50 MW with normal operating speeds of 1 500 r/min, 1 800 r/min, 3 000 r/min and 3 600 r/min*		•	•	•
ISO 7919-3, *Mechanical vibration — Evaluation of machine vibration by measurements on rotating shafts — Part 3: Coupled industrial machines*		•	•	•
ISO 7919-4, *Mechanical vibration — Evaluation of machine vibration by measurements on rotating shafts — Part 4: Gas turbine sets with fluid-film bearings*		•	•	•
ISO 7919-5, *Mechanical vibration — Evaluation of machine vibration by measurements on rotating shafts — 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 vibration**s***		•	•	•
ISO 10816-1, *Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts — Part 1: General guidelines*	•	•	•	•
ISO 10816-2, *Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts — Part 2: Land-based steam turbines and generators in excess of 50 MW with normal operating speeds of 1 500 r/min, 1 800 r/min, 3 000 r/min and 3 600 r/min*		•	•	•
ISO 10816-3, *Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts — Part 3: Industrial machines with nominal power above 15 kW and nominal speeds between 120 r/min and 15 000 r/min when measured* in situ		•	•	•
ISO 10816-4, *Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts — Part 4: Gas turbine sets with fluid-film bearings*		•	•	•
ISO 10816-5, *Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts — Part 5: Machine sets in hydraulic power generating and pumping plants*		•	•	•

Table B.1 *(continued)*

ISO reference	Category			
	I	II	III	IV
ISO 10816-6, *Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts — Part 6: Reciprocating machines with power ratings above 100 kW*		•	•	•
ISO 10816-7, *Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts — Part 7: Rotodynamic pumps for industrial applications, including measurements on rotating shafts*		•	•	•
ISO 10816-8, *Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts — Part 8: Reciprocating compressor systems*		•		
ISO 10817-1, *Rotating shaft vibration measuring systems — Part 1: Relative and absolute sensing of radial vibration*			•	•
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, *Condition monitoring and diagnostics of machines — Vibration condition monitoring — Part 1: General procedures*	•	•	•	•
ISO 13373-2, *Condition monitoring and diagnostics of machines — Vibration condition monitoring — Part 2: Processing, analysis and presentation of vibration data*		•	•	•
ISO 13374-1, *Condition monitoring and diagnostics of machines — Data processing, communication and presentation — Part 1: General guidelines*		•	•	•
ISO 13379-1, *Condition monitoring and diagnostics of machines — Data interpretation and diagnostics techniques — Part 1: General guidelines*			•	•
ISO 13381-1, *Condition monitoring and diagnostics of machines — Prognostics — Part 1: General guidelines*		•	•	•
ISO 14694, *Industrial fans — Specifications for balance quality and vibration levels*	•	•	•	•
ISO 14695, *Industrial fans — Method of measurement of fan vibration*			•	•
ISO 17359, *Condition monitoring and diagnostics of machines — General guidelines*	•	•	•	•
ISO 18431-1, *Mechanical vibration and shock — Signal processing — Part 1: General introduction*		•	•	•
ISO 18431-2, *Mechanical vibration and shock — Signal processing — Part 2: Time domain windows for Fourier Transform analysis*		•	•	•
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*				•
ISO 18436-3, *Condition monitoring and diagnostics of machines — Requirements for qualification and assessment of personnel — Part 3: Requirements for training bodies and the training process*				•
ISO 19499, *Mechanical vibration — Balancing — Guidance on the use and application of balancing standards*				•
ISO 21940-13, *Mechanical vibration — Rotor balancing — Part 13: Criteria and safeguards for the* in-situ *balancing of medium and large rotors*				•
ISO 21940-14, *Mechanical vibration — Rotor balancing — Part 14: Procedures for assessing balance errors*			•	•

Bibliography

[1] ISO 7626-1, *Mechanical vibration and shock — Experimental determination of mechanical mobility — Part 1: Basic terms and definitions, and transducer specifications*

[2] ISO 7626-2, *Mechanical vibration and shock — Experimental determination of mechanical mobility — Part 2: Measurements using single-point translation excitation with an attached vibration exciter*

[3] ISO 7626-5, *Vibration and shock — Experimental determination of mechanical mobility — Part 5: Measurements using impact excitation with an exciter which is not attached to the structure*

[4] ISO 8579-2, *Acceptance code for gears — Part 2: Determination of mechanical vibrations of gear units during acceptance testing*

[5] ISO 20283-2, *Mechanical vibration — Measurement of vibration on ships — Part 2: Measurement of structural vibration*

[6] ISO 21940-32, *Mechanical vibration — Rotor balancing — Part 32: Shaft and fitment key convention*

[7] Crawford A.R., & Crawford S. *The simplified handbook of vibration analysis:* Vol. 1, *Introduction to vibration analysis*; Vol. 2, *Applied vibration analysis*. Knoxville, TN: Computational Systems, 1992. 175 p.; 344 p.

[8] Ehrich F.F. ed. *Handbook of rotordynamics*. Malabar, FL: Kreiger, 2004, 480 p.

[9] Eisenmann R.C. Sr., & Eisenmann R.C. Jr. *Machinery malfunction diagnosis and correction: Vibration analysis and troubleshooting for the process industries*. Upper Saddle River, NJ: Prentice Hall, 1998, 817 p.

[10] Eshleman R.L., & Nagle-Eshleman J. *Basic machinery vibrations: An introduction to machine testing, analysis, and monitoring*. Clarendon Hills, IL: VIPress, 1999

[11] Ewins D.J. *Modal testing: Theory, practice, and application*. Baldock: Research Studies Press, 2nd edition , 2000. 562 p. (*Mechanical Engineering Research Studies*, Vol. 10.)

[12] McConnell K.G., & Varoto P.S. *Vibration testing: Theory and practice*. Hoboken, NJ: Wiley, Second Edition, 2008, 652 p.

[13] Mills S.R.W. *Vibration monitoring and analysis handbook*. Northampton: British Institute of Non-Destructive Testing, 2010, 326 p.

[14] Mitchell J.S. *Introduction to machinery analysis and monitoring*. Tulsa, OK: PennWell, Second Edition, 1993, 566 p.

[15] Piersol A.G., & Paez T.L. eds. *Harris' shock and vibration handbook*. New York, NY: McGraw-Hill, 2010

[16] Piotrowski J. *Shaft alignment handbook*. Boca Raton, FL: CRC, Third Edition, 2007, 800 p.

[17] Randall R.B. *Vibration-based condition monitoring*. Chichester: Wiley, 2011, 308 p.

[18] Taylor J.I. *The gear analysis handbook: A practical guide for solving vibration problems in gears*. Tampa, FL: VCI, 2000, 256 p.

[19] Taylor J.I. *The vibration analysis handbook: A practical guide for solving rotating machinery problems*. Tampa, FL: VCI, 2003, 375 p.

[20] Williams J.H., Davies A., Drake P.R. *Condition-based maintenance and machine diagnostics*. London: Chapman & Hall, 1994, 187 p.

[21] Wowк V. *Machinery vibration: Measurement and analysis*. New York, NY: McGraw-Hill, 1991, 358 p.

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