REVISION 5
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Certification Program

FOR VIBRATION ANALYST

CATEGORIES I – IV

The *Benchmark* for Certification

ANSI Accredited Program
PERSONNEL CERTIFICATION

#0845
Certified Vibration Analyst Certification

Vibration Institute

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CERTIFICATION HANDBOOK

The Vibration Institute Certification Handbook contains a description of the Institute's certification program for Vibration Analyst.

The Vibration Institute Certification Program for Vibration Analyst was accredited by the American National Standards Institute (ANSI) in March 2010. The accreditation by ANSI assures that the Institute's certification program is valid, reliable, impartial, and provides fair and equal access to the certification policies and procedures that assess the qualifications of candidates on a standardized basis.

The Certification Handbook includes information on:

- Benefits
- Recognition
- Terms of certification
- Body of knowledge for certification
- Recommendations for education, and requirements for training and experience
- Examination requirements
- Sources for self-study and review
- Sample test questions

The Vibration Institute's certification program provides third-party conformity assessment of individuals to determine their competence as a Vibration Analyst at a given category. If determined to have attained the minimum requirements, the Vibration Institute, as an accredited third-party conformity assessment body, issues a five-year certificate to the individual. There are four categories of certification.

When a certificate is issued, the Vibration Institute attests to the minimum qualification of a candidate as defined in ISO 18436-2 and this Handbook. The employer or self-employed individual is responsible for the authorization to perform machinery condition monitoring and diagnostics and, as a result, is responsible for the quality and validity of their work.

In order to assure continued competence, ISO standards require periodic recertification either by re-examination or renewal (i.e. providing evidence of continued work experience and ongoing professional development). Currently, that period is five years.

Thank you for considering the Vibration Institute's certification program. We hope that you will benefit both professionally and personally from the distinction of being certified by the Vibration Institute.

Robin Ginner
Executive Director
Vibration Institute

David Corelli
Technical Director-Certification
Vibration Institute

ABOUT THE VIBRATION INSTITUTE

MISSION

The mission of the Vibration Institute is to disseminate practical information on evaluating machinery behavior and condition without commercial interest. The Institute offers programs including education, training, and certification. Opportunities for exchanging technical knowledge, information, procedures, and data are offered through meetings, formal training, publications, and networking.

HISTORY

The Vibration Institute evolved from an idea more than 40 years ago by the late Michael Blake of Lovejoy, Inc. He believed strongly that an organization was needed that would allow individuals from any industry to share information about measuring and analyzing vibration, even though vibration technology was not then being widely used in predictive maintenance. In 1967 Blake organized, and Lovejoy sponsored, a small symposium for exchanging information about the techniques then being used to measure vibration. In 1972 the late Pat Hennessy, President of Lovejoy, assumed the responsibility and expense of incorporating the not-for-profit Vibration Foundation. The Foundation was reorganized in 1973 into the Vibration Institute. Hennessy, Blake, Charlie Jackson, and Ron Eshleman were among the original Board of Directors given the challenge of making something of the Institute and the "Blake Concept." After 1973 the Institute evolved into a service organization providing membership, training, and the opportunity to exchange concepts and ideas about vibration measurement and analysis.

In 1992 a Certification Committee was formed by the Vibration Institute to consider a program for certification of individuals in machinery vibration. Committee members included practicing vibration analysts active in a broad spectrum of disciplines – machine tool; pulp, paper, and printing; petrochemical; power; and consulting. The motivations for the establishment of the certification program were personal, client and corporate acknowledgement, and recognition of levels of expertise. The consensus of the Committee was that certification would add credibility to the vibration profession. In January 2003 the Institute officially adopted ISO 18436-2 as the Body of Knowledge for our certification program and changed from offering three (3) levels of certification to four (4) categories. The Vibration Institute Vibration Analyst Certification Program was accredited to ISO/IEC 17024 by the American National Standards Institute (ANSI) in March 2010. This accreditation officially makes the Vibration Institute a third party certifying body with the authority to issue certifications, which can only be done by an accredited third party as defined in ISO 18436-1.

CERTIFICATION COMMITTEE

The Certification Committee is comprised of Vibration Institute certificate holders who represent industry, academic, and government interests. The Certification Committee member term is three years and is renewable based on interest, attendance, and participation in committee work. The committee meets two to three times per year and the members are practicing vibration analysts and experienced technicians in machine condition monitoring and diagnostics. Duties of committee members include job/task analysis, cut-score studies, item (question) and examination development, item analysis, and policy development. The committee also has the responsibility of periodic evaluation of the certification scheme including expanding or reducing its scope.

Members of the Certification Committee are required to sign an agreement that ensures confidentiality, ethics, and competency and are also required to avoid situations where a conflict of interest may occur and when outside commercial interests may pose a potential threat. If you are interested and feel you are qualified to participate on the committee, contact the Vibration Institute.

AMERICANS WITH DISABILITIES ACT (ADA)

The Vibration Institute complies with the following requirements of the ADA:

1. The use of handicapped accessible facilities
2. The removal of “readily achievable” physical barriers in meeting rooms.
3. The provision of auxiliary aids and services to assure effective communication.
4. The modification of the Institutes policies, practices, and procedures applicable to candidates to enable disabled individuals to participate equally in the program. For example persons visually, vocally, or language (English) handicapped.

EQUAL OPPORTUNITY EMPLOYER AND CERTIFYING BODY

The Vibration Institute is an equal opportunity employer and assessor of candidates without discrimination due to age, sex, sexual orientation, race, religion, or ethnicity.

VIBRATION ANALYST CERTIFICATION PROGRAM

PROGRAM DEVELOPMENT and ORGANIZATION

The Vibration Institute's Certification Program for Vibration Analyst was developed by and is governed by a committee representing various industries and is used worldwide. The Vibration Institute's Certification Program follows ISO 18436, Condition monitoring and diagnostics of machines - Requirements for qualification and certification of personnel – Part 1: Requirements for certifying bodies and the certification process; Part 2: Vibration condition monitoring and diagnostics.

BENEFITS

The Vibration Institute's Certification Program is a focal point for acknowledging the capability and motivation of individuals in the vibration field. It provides professional recognition by clients, employers, and colleagues and acknowledgment of proven capability in the category certified.

RECOGNITION

Certified individuals are listed annually, by certification category, in *Vibrations* magazine and on the Institute's website at www.vi-institute.org. Certificates, and photo identification cards upon request, are issued by the Institute at the time of certification which contains relevant information about the category of certification of the individual.

TERM of CERTIFICATION and RECERTIFICATION

Certification is valid for five years. Recertification is required every five years by either retesting or renewal (i.e. providing written evidence of ongoing vibration related work experience and qualifying professional development.) Three months prior to recertification and three months following expiration, the Institute sends communication to certified Vibration Analysts regarding recertification criteria and requirements.

If an individual passes the examination for Category III or Category IV within the first five-year period after taking the examination for Category II or Category III, a new five-year period begins before recertification/renewal is required.

CAPABILITIES of CERTIFIED VIBRATION ANALYSTS

Category I Certified Vibration Analysts must know the basic principles of mechanical vibration including units of measures used for condition monitoring of machinery. They are to be capable of performing reliable pre-determined single channel vibration measurements, comparing such measurements against pre-established alarms, identification of errors in collected data, reporting on visual observations on the condition of equipment, and transferring collected data to a computer based system.

Category II Certified Vibration Analysts shall have all the knowledge and capability of a Category I Vibration Analyst. They shall be capable of defining routine data collection activities including acquisition and analysis settings using basic signal analysis, collecting extra test points when unusual conditions exist, performing single channel impact tests, interpreting and evaluating test results in accordance with specifications and standards, diagnosing common faults, and recommending basic corrective actions. The Analyst shall be aware of and capable of recommending alternate condition monitoring technologies to verify issues raised as a result of routine condition monitoring.

Category III Certified Vibration Analysts are required to have all the knowledge and skills of a Category II Vibration Analyst and be able to provide technical knowledge and instruction to lower level analysts. A Category III Vibration Analyst shall have an in-depth knowledge of the principles and techniques machinery vibration analysis including single channel spectra, time waveforms, orbits, basic operating deflection shapes, and acceleration enveloping. They shall be qualified to design, direct, and manage routine condition monitoring programs, to conduct non-routine fault analyses, and to understand and direct alternative condition monitoring technologies to investigate and verify issues not resolved by vibration analysis. The Analyst shall be able to direct machinery corrective actions including rotor balancing and to recommend restrictions in machine operation.

Category IV Certified Vibration Analysts shall have in-depth knowledge, skills, and experience in the diagnosis and correction of machine faults using basic mechanical vibration theory, signal analysis, multi-channel spectral analysis, rotor and gas pulsation dynamics, and isolation and damping techniques. They shall be able to apply parameter identification techniques to determine natural frequencies, mode shapes, damping, and operating deflection shapes; to conduct two-plane balancing; to recommend machine mounting corrective actions including design modifications, resilient mounting, and foundation re-design; and to interpret published codes and standards.

The detailed Body of Knowledge for the four categories is contained in this Handbook and in ISO 18436: Part 2.

SURVEILLANCE

In order to protect Institute members who have justly earned certification as a Vibration Analyst, the Vibration Institute will pursue individuals who falsify Vibration Institute certification status in any manner. Anyone who is aware of an instance in which an individual may be falsifying certification status should contact or e-mail the Institute at *information@vi-institute.org.* Additionally if you are aware of an individual who may be violating the Vibration Institute Code of Ethics, it should be reported to the above e-mail address. All information will be kept confidential.

The Vibration Institute randomly conducts exam surveillance of proctors when certification examinations are given to assure that proper procedures are followed. Surveillance is also conducted on applications for recertification.

RECOMMENDATIONS and REQUIREMENTS FOR CERTIFICATION

It is important that candidates have a combination of education, training, and experience so that they understand the principles and procedures of machinery vibration monitoring and diagnostics. Recommendations and requirements covered in ISO 18436:2 are briefly reviewed in this section.

EDUCATION

It is recommended, but not mandatory, that candidates for Category I and Category II have a secondary school education. Candidates for Category III and Category IV are expected to be able to manipulate simple algebraic equations, use a basic scientific calculator, and be computer literate. Completion of two or more years of study in mechanical technology or mechanical engineering is also recommended at these levels.

TRAINING HOURS

To be eligible to sit for (take) a certification examination applicants shall provide evidence of the successful completion of formal training (provided by a training body that conforms to the requirements of ISO 18436-3), which has been based on the Body of Knowledge for each category (see page 11). Training should take the form of formal lectures, demonstrations, trainer-specified practical exercises, and/or distance controlled self-study. Any distance self-study by the candidate shall be assessed by the trainer for evidence of adequate knowledge acquisition before other forms of training commence. Practical exercises shall follow practical skills and knowledge training and be assessed by the trainer.

It is required that training time meet the minimums in Table 1 below:

Table 1 – Minimum Required Training Hours

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

Sources of technological information are listed in the Sources for Self Study and Review on page 10 in this Handbook. Please contact the Institute for additional information for self-study at (630) 654-2254.

EXPERIENCE

To be eligible for the certification examination, candidates shall provide evidence of experience in the field of machinery condition monitoring and diagnostics and electrical and mechanical technologies. The minimum required experience can be found in Table 2:

Table 2 – Minimum Required Experience in Months

Category I	Category II	Category III	Category IV
6	18	36	60

QUALIFICATION EXAMINATIONS

Candidates are required to answer a number of multiple choice questions based on the topics in ISO 18436-2, Annex A and job analyses conducted by the Institute's Certification Committee. The topics are summarized for each category in the Body of Knowledge stated on page 11 in this Handbook. Questions selected from databases are of a practical nature and cover the concepts, principles, and applications necessary to conduct machinery vibration measurements. Mathematical calculations are required, as is a capability to interpret tables, plots, and charts as given in the sample questions beginning on page 17 in this Handbook.

Table 3 – Exam Details by Category

	Number of Questions on Exam	Time Allowed to Complete Exam
Category I	60	2 hours
Category II	100	3 hours
Category III	100	4 hours
Category IV	60	5 hours

Pertinent equations are supplied for the closed-book examinations and reference materials are not permitted in the examination room. All calculations must be completed on the examination. Pens, pencils and a scientific calculator must be brought for examinations in all categories. For detailed instructions, contact the Institute at (630) 654-2254 or review the information on the Institute's website at www.vi-institute.org.

EXAMINATION DEVELOPMENT

The Vibration Institute Certification Committee has utilized industry standard methods and psychometric principles to develop fair, valid and reliable examinations that assess the capabilities of candidates to determine that they meet the minimum requirements for certification at a given category. These methods include intense review of all questions for category selection, difficulty, topic applicability, readability, validity, reliability, and cognitive levels. Examinations are subject to statistical analysis to determine difficulty and effectiveness of questions and standard error of measurement of examinations. Examinations are evaluated by the Certification Committee to

determine passing scores that reflect the minimum knowledge to pass a given Category examination.

All Institute examinations contain questions for beta testing. These extra questions (one per 20 examination questions) are present on all certification examinations and are unknown to the candidate.

Please note that all candidates who score the minimum or higher score receive the same Certificate; therefore, the actual score received, other than being above the minimum, has no bearing on receipt of a Certificate. The Institute follows ISO 18436-1 which prohibits the release of any examination scores.

DATES and LOCATIONS

Examinations for Vibration Analyst in categories I-IV are scheduled the day following Institute training courses, at the Annual Conference, and at Chapter sites during the year. An examination schedule and application for examination and certification (VI Form CF009) is available from the Institute office and online at www.vi-institute.org.

SCORING

Passing scores for certification exams are determined on an absolute basis by the Certification Committee using widely accepted test development methods. The target passing score is 70% correct per ISO 18436-2; however, the actual passing score (cut score) is based on the Angoff Method of determining a cut score.

RETESTING

A candidate who fails to obtain the passing grade required for recognition may be re-examined twice, provided that the re-examinations take place not sooner than 30 days after the previous examination. A candidate who fails three consecutive attempts shall be excluded from reassessment for 12 months. Such candidate shall be required to reapply as an initial candidate.

Candidates excluded for reasons of unethical behavior shall wait at least 12 months before reapplying.

It is important that individuals who want to retest contact the Institute requesting information relevant to the area of study from a prior examination(s).

REVIEWS

Individuals who fail a certification examination may fill out a “Request for Examination Review” found on the Vibration Institute website and request a written review of their examination within five years of the test date. The applicant will be provided with a study guide relative to their

performance on the examination that indicates the subject and topic areas requiring additional study. Please note that absolute scores cannot be provided.

COMPLAINTS & APPEALS

A complaint may involve the Institute's certification program or a certified individual. Appeals may involve the decision on disqualification, certification or recertification.

Individuals having complaints to do with certification or Institute policies or practices should fill out a "Complaint or Appeal Form" found on the Vibration Institute website. If the written response to the complaint is not addressed to the satisfaction of the writer, the writer may appeal the decision to the Board of Directors, in writing, for their consideration. A decision by the Board of Directors is final. All appeals and complaints will be evaluated with respect to the policies and procedures of the Vibration Institute with a written response as quickly as possible.

If the complaint is about a certified individual, that person will be notified by the Vibration Institute of the complaint lodged against them and given an opportunity to respond to the allegations.

Individuals denied certification or disqualified for other reasons may make a written and/or oral appeal (by appointment) to the Certification Committee using the Complaints and Appeals form found on the Vibration Institute website. Unsuccessful appeals to the Certification Committee can be brought to the Institute Board of Directors, in written form, at the request of the candidate. The Board of Directors will provide a decision to grant or deny an appeal based on the facts. Appeals regarding other decisions by the Institute management should be addressed to the Executive Director in writing and the appeal will be forwarded to the Board of Directors for consideration. A decision by the Vibration Institute Board of Directors is final. Appeal Forms are available on the Vibration Institute website www.vi-institute.org/certificationforms.

WITHDRAWALS

Certified individuals may resign their status by letter or by not completing the recertification process.

SOURCES* FOR SELF STUDY AND REVIEW

CATEGORY I

Introduction to Machinery Vibrations, R.L. Eshleman, Vibration Institute (2009).

Vibration Monitoring Handbook, C.W. Reeves, Coxmoor Publishing (1998).

CATEGORY II

Basic Machinery Vibrations, R.L. Eshleman, VI Press (1999).

Basic Technical Mathematics with Calculus, 10th edition, A.J. Washington, Pearson, Boston (2013).

CATEGORY III

Machinery Vibration Analysis, R.L. Eshleman, Vibration Institute (2002).

The Simplified Handbook of Vibration Analysis, Vol. I, A.R. Crawford & S. Crawford, Computational Systems, Inc. (1992).

The Bearing Analysis Handbook, J.I. Taylor & D. W. Kirkland, Vibration Consultants, Inc. (2004).

Balancing of Rotating Machinery, R.L. Eshleman, Vibration Institute (2005).

The Gear Analysis Handbook, J.I. Taylor, Vibration Consultants, Inc. (2000).

CATEGORY IV

Advanced Vibration Analysis, N.L. Baxter, J.L. Frarey, and R. Kelm, Vibration Institute (2010).

Advanced Vibration Control, Vibration Institute, 2011

Harris' Shock and Vibration Handbook, 6th Edition, A.G. Piersol and T. L. Paez, McGraw-Hill (2010).

Rotor Dynamics and Modeling notes, Vibration Institute (2012).

Rotating Machinery Vibration, 2nd Edition, M.L. Adams, Jr., Marcel Dekker, Inc. (2010).

Vibration Testing: Theory and Practice, 2nd Edition, K.G. McConnell, John Wiley & Sons (1995).

Theory of Vibration with Applications, 5th Edition, W.T. Thomson & M.D. Dahleh, Pearson/Prentice Hall (1998).

Vibration-based Condition Monitoring, Robert Bond Randall, Wiley (2011).

Vibration Monitoring, Testing, and Instrumentation, C. de Silvia, CRC Press (2007).

*All of these sources are available from the Vibration Institute.

BODY OF KNOWLEDGE:

Subject:	Category			
	I	II	III	IV
1. Vibration Principles:				
Basic motion	X	X	X	
Period, frequency	X	X	X	
Amplitude (Peak, peal-to-peak, RMS)	X	X	X	
Parameters (Displacement, velocity, acceleration)	X	X	X	
Units, unit conversions	X	X	X	
Time and frequency domains	X	X	X	
Vectors, modulation			X	X
Phase		X	X	X
Natural frequency, resonance, critical speeds	X	X	X	X
Force, response, damping, stiffness			X	X
Instabilities, non-linear systems				X
2. Data Acquisition:				
Instrumentation	X	X	X	X
Dynamic range, signal to noise ratio			X	X
Transducers	X	X	X	
Sensor mounting, mounted natural frequency	X	X	X	
Fmax acquisition time		X	X	
Proximity sensor conventions		X	X	
Triggering		X	X	
Test planning		X	X	X
Test procedures	X	X	X	X
Data formats		X	X	
Computer database upload/download	X			
Recognition of poor data	X	X	X	
3. Signal Processing:				
RMS/peak detection				X
Analogue/digital conversion				X
Analogue recording and digital sampling		X	X	X
FFT computation			X	X
FFT application	X	X		
Time windows (Uniform, Hanning, flat-top)		X	X	
Filters (Low pass, high pass, band pass, tracking)		X	X	X
Anti-aliasing		X	X	X
Bandwidth, resolution		X	X	X
Noise reduction		X	X	X

Subject:	Category			
	I	II	III	IV
Averaging (Linear, synchronous time, exponential)		X	X	X
Dynamic range		X	X	X
Signal to noise ratio				X
Spectral maps			X	X
4. Condition Monitoring:				
Computer database set-up and maintenance			X	
Equipment evaluation and prioritization		X		
Monitoring program design		X	X	X
Alarm set-up (Narrowband, envelope)			X	
Baseline assessments, trending		X	X	
Route planning		X	X	
Alternate technologies (e.g. oil analysis, wear debris analysis, infrared thermography, motor current analysis, acoustic emission)			X	X
Fault condition recognition	X	X		
5. Fault Analysis:				
Spectrum analysis harmonics and sidebands		X	X	X
Time waveform analysis		X	X	X
Phase analysis		X	X	X
Transient analysis			X	X
Orbital analysis			X	X
Shaft center-line analysis		X	X	X
Enveloping		X	X	X
Mass unbalance		X	X	
Misalignment		X	X	
Mechanical looseness		X	X	
Rubs, instabilities			X	X
Bearing defects (Rolling element, journal)		X	X	
Electric motor defects		X	X	X
Flow induced vibration, aerodynamics and liquids			X	X
Gearbox analysis		X	X	
Resonance and critical speeds		X	X	X
Turbomachinery			X	X
General fault recognition	X			
6. Corrective Action:				
Shaft alignment		X	X	
Field balancing		X	X	X
Replacement of machine parts			X	

Subject:	Category			
	I	II	III	IV
Flow control			X	X
Isolation and damping			X	X
Resonance control			X	X
Basic maintenance action	X	X	X	
7. Equipment Knowledge:				
Electric motors, generators and drives	X	X	X	
Pumps, fans	X	X	X	
Steam turbines, gas turbines		X	X	
Compressors	X	X	X	
Reciprocating machinery		X	X	
Rolling mills, paper machines, other process equipment	X	X	X	
Machine tools	X	X	X	
Structures, piping	X	X	X	
Gearboxes	X	X	X	
Rolling element bearings		X	X	
Journal bearings		X	X	
Gearing		X	X	
Couplings, belts		X	X	
8. Acceptance Testing:				
Test procedure	X	X		
Specifications and standards		X	X	
Reporting		X	X	
9. Equipment Testing and Diagnostics:				
Impact testing		X	X	X
Forced response testing		X	X	X
Transient analysis			X	X
Transfer functions			X	X
Damping evaluation				X
Cross channel phase			X	X
Operating deflection shapes			X	X
Modal analysis			X	X
Torsional vibration				X
10. Reference Standards				
ISO		X	X	X
IEC		X	X	X
Relevant national standards		X	X	X

Subject:	Category			
	I	II	III	IV
11. Reporting and Documentation:				
Condition monitoring reports		X	X	
Vibration diagnostic reports		X	X	X
12. Fault Severity Determination:				
Spectrum analysis		X	X	X
Time waveform analysis, orbit analysis		X	X	X
Levels: overall, narrowband, component		X	X	
Severity charts: graphs and formula		X	X	X
13. Rotor/Bearing Dynamics:				
Rotor characteristics				X
Bearing characteristics				X
Rotor balancing				X

APPLICABLE ISO STANDARDS

ISO Reference	Category			
	I	II	III	IV
ISO 1925, *Mechanical vibration – Balancing – Vocabulary*		X	X	X
ISO 1940-1, *Mechanical vibration – Balance quality requirements of rigid rotors – Part 1; Specification and verification of balance tolerances*		X	X	X
ISO 2017-1, *Mechanical vibration and shock – Resilient mounting systems – Part 1: Technical information to be exchanged for the application of isolation systems*				X
ISO 2041, *Mechanical vibration, shock and condition monitoring – Vocabulary*		X	X	X
ISO 2954, *Mechanical vibration of rotating and reciprocating machinery – Requirements for instruments for measuring vibration severity*				X
ISO 5348, *Mechanical vibration and shock – Mechanical mounting of accelerometers*		X	X	X
ISO 7919-1, *Mechanical vibration of reciprocating machines – Measurement on rotating shafts and evaluation criteria – Part 1: General guidelines*	X	X	X	X
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 1500r/min, 1800r/min, 3000 r/min and 3600 r/min*		X	X	X
ISO 7919-3, *Mechanical vibration – Evaluation of machine vibration by measurements on rotating shafts – Part 3: Coupled industrial machines*		X	X	X

ISO Reference	Category			
	I	II	III	IV
ISO 7919-4, *Mechanical vibration – Evaluation of machine vibration by measurements on rotating shafts – Part 4: Gas turbines with fluid-film bearings*		X	X	X
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*		X	X	X
ISO 8528-9, *Reciprocating internal combustion engine driven alternating current generating sets – Part 9: Measurement and evaluation of mechanical vibrations*		X	X	X
ISO 8569, *Mechanical vibration and shock – Measurement and evaluation of shock and vibration effects on sensitive equipment in buildings*			X	X
ISO 10816-1, *Mechanical vibration – Evaluation of machine vibration by measurements on non-rotating parts – Part 1: General guidelines*	X	X	X	X
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 1500r/min, 1800r/min, 3000 r/ min and 3600 r/min*		X	X	X
ISO 10816-3, *Mechanical vibration – Evaluation of machine vibration by measurements on non-rotating parts – Part 3: Industrial machines with nominal power above 15kW and nominal speeds between 120 r/min and 15000 r/min when measured in situ*		X	X	X
ISO 10816-4, *Mechanical vibration – Evaluation of machine vibration by measurements on non-rotating parts – Part 4: Gas turbine sets with fluid-film bearings*		X	X	X
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*		X	X	X
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*		X	X	X
ISO 10816-7, Mechanical vibration – Evaluation of machine vibration by measurements on non-rotating parts – Part 7: Rotordynamic pumps for industrial applications, including measurements on rotating shafts		X	X	X
ISO 10817-1, *Rotating shaft vibration measuring systems – Part 1: Relative and absolute sensing of radial vibration*			X	X
ISO 11342, *Mechanical vibration – Methods and criteria for the mechanical balancing of flexible rotors*				X
ISO 13372, *Condition monitoring and diagnostics of machines – Vocabulary*	X	X	X	X

ISO Reference	Category			
	I	II	III	IV
ISO 13373-1, *Condition monitoring and diagnostics of machines – Vibration condition monitoring – Part 1: General procedures*	X	X	X	X
ISO 13373-2, *Condition monitoring and diagnostics of machines – Vibration condition monitoring – Part 2: Processing, analysis and presentation of vibration data*		X	X	X
ISO 13374-1, *Condition monitoring and diagnostics of machines – Data processing, communication and presentation – Part 1: General guidelines*		X	X	X
ISO 13379-1. *Condition monitoring and diagnostics of machines – Data interpretation and diagnostics techniques – Part 1: General guidelines*			X	X
ISO 13381-1, *Condition monitoring and diagnostics of machines – Prognostics – Part 1: General guidelines*		X	X	X
ISO 14694, *Industrial Fans – Specifications for balance quality and vibration levels*	X	X	X	X
ISO 14695, *Industrial fans – Method of measurement of fan vibration*			X	X
ISO 17359, *Condition monitoring and diagnostics of machines – General guidelines*	X	X	X	X
ISO 18431-1, *Mechanical vibration and shock – Signal processing – Part 1: General introduction*		X	X	X
ISO 18431-2, *Mechanical vibration and shock – Signal processing – Part 2: Time domain windows for Fourier Transform analysis*		X	X	X
ISO 18436-1, *Condition monitoring and diagnostics of machines – Requirement for qualification and assessment of personnel – Part 1: Requirements for assessment bodies and the assessment process*				X
ISO 18436-3, *Condition monitoring and diagnostics of machines – Requirement for qualification and assessment of personnel – Part 3: Requirements for training bodies and the training process*				X
ISO 19499, *Mechanical vibration – Balancing – Guidance on the use and application of balancing standards*				X
ISO 21940-13, *Mechanical vibration – Rotor balancing – Part 13: Criteria and safeguards for the in-situ balancing of medium and large rotors*				X
ISO 21940-14, *Mechanical vibration – Rotor balancing – Part 14: Procedures for assessing balance errors*			X	X

IMPORTANT- You must bring a pen and a SCIENTIFIC calculator to the examinations for all categories. Any additional materials necessary for examinations are provided. All calculations are to be done on the examination.

CATEGORY I

1. What are the units of vibration velocity?

a. mils
b. g's
c. inches per second
d. inches

2. The period of vibration is typically measured in

a. days.
b. minutes.
c. milliseconds.
d. nanoseconds.

3. A vibration transducer used to evaluate pump faults and condition should be mounted

a. anywhere.
b. on the floor.
c. close to the machine bearings.
d. on the piping.

4. In vibration work the Fast Fourier Transform is used to

a. obtain the amount of vibration at machine frequencies.
b. transform machine vibration into heat.
c. generate a vibration waveform.
d. filter out unwanted noise from the data.

5. Baseline vibration measurements are made to

a. evaluate the life of equipment.
b. generate new design information.
c. provide a basis for future comparisons of data.
d. evaluate instruments used for monitoring.

6. A gearbox is used in a machine train to

a. increase vibration surveillance.
b. lower vibration levels.
c. reduce heat.
d. allow driven and driver to operate at different speeds.

7. A 60 Hz two-pole induction motor operates

a. at 3,600 RPM under load.
b. at a speed less than its magnetic frequency.
c. with no slip.
d. at 7,200 RPM.

8. The principal function of acceptance testing is to obtain

a. equipment that meets a specification.
b. baseline data.
c. a fault analysis.
d. a condition evaluation.

9. The vibration level on a fan increased from 0.1 inch per second to 1.0 inch per second over the period of a month. What is the possible cause of the increase in vibration?

a. loss of a blade
b. small rolling element bearing defect
c. change in the weather
d. change in operational conditions

10. Operation of a machine at its critical speed

a. may cause decreased vibration levels.
b. may not change the vibration levels.
c. may increase vibration levels.
d. will increase its efficiency.

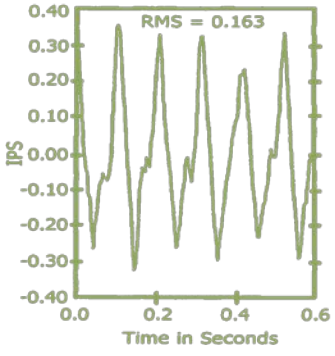
ANSWERS TO SAMPLE QUESTIONS FOR CATEGORY I:
1. c, 2. c, 3. c, 4. a, 5. c, 6. d, 7. b, 8. a, 9. a, 10. c

CATEGORY II

1. What is the fundamental frequency of the waveform shown in Figure 1?

a. 5.3 Hz
b. 11.59 Hz
c. 22.8 Hz
d. 60 CPM

FIGURE 1



2. What measure has been shown to be most effective for evaluation of general machine condition from bearing cap measurements?

a. displacement
b. acceleration
c. mils
d. velocity

3. What is the most basic display that can be used to directly determine the phase relationship between the vibrations measured at two locations on a machine?

a. amplitude vs. frequency
b. polar plot
c. Bodé plot
d. time waveform

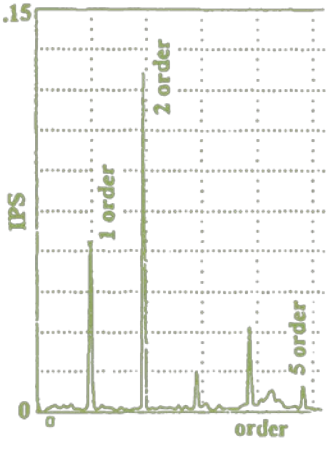
4. What is the peak amplitude of the waveform shown in Figure 1?

a. 0.23 IPS
b. 0.70 IPS
c. 0.12 g's
d. 0.35 IPS

5. The data shown in Figure 2 were taken off the inboard bearing of a two-pole motor in the horizontal direction. The spectrum of the axial vibration contains a component at 3,580 CPM equal to 0.2 in./sec. What is the most likely fault?

a. mass unbalance
b. misalignment
c. air-gap variation
d. looseness

FIGURE 2



6. The frequency span used for fault analysis on an FFT analyzer is concerned with

a. dynamic range.
b. phase distortion.
c. resolution.
d. amplitude.

7. Vibration from rotor mass unbalance appears in the spectrum at a frequency of

a. 3 times operating speed.
b. 4.5 times operating speed.
c. one times operating speed.
d. 0.5 times operating speed.

8. Calculate the gear-mesh frequency for a gear set with 28 pinion teeth and 99 gear teeth. The pinion operates at 1,776 RPM.

a. 500 Hz
b. 30,000 CPM
c. 49,728 CPM
d. 175,824 CPM

9. An accelerometer was used to measure 2 g's peak at 565 Hz. What was the peak vibration velocity?

a. 0.2 mil
b. 2 mils
c. 0.02 inch/second
d. 0.22 inch/second

10. The first alarm or alert is set on a data collector to initiate

a. a fault analysis.
b. a time-to-failure calculation.
c. a reduction in the alarm setting.
d. machine shutdown.

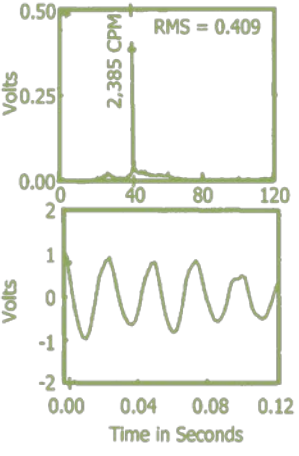
ANSWERS TO SAMPLE QUESTIONS FOR CATEGORY II:
1. b, 2. d, 3. d, 4 d, 5. b, 6. c, 7. c, 8. c, 9. d, 10. a

CATEGORY III

1. The data shown in Figure 3 were acquired from a vertical pump bearing in the horizontal direction with an accelerometer integrated to velocity - 1,000 mv/in./sec. What is the peak vibration in in./sec?

a. 0.110
b. 0.398
c. 0.578
d. 1.0

FIGURE 3



2. Spectrum analysis of a motor-driven gearbox with sleeve bearings, an input speed of 3,585 RPM, and a pinion containing 73 teeth would require which of the following transducer mounting techniques?

a. hand held
b. magnet
c. wax
d. stud

3. A 1,785 RPM-200 HP motor drives a hammer mill through a fluid coupling at 1,720 RPM. If a maximum number of 800 lines of resolution are available on an FFT spectrum analyzer and a Hanning window is used, what is the maximum frequency span that will permit resolution of the operating speed components of the motor and hammer mill?

a. 300,000 CPM
b. 120,000 CPM
c. 60,000 CPM
d. 17,333 CPM

4. A polar plot typically contains data from a permanently-mounted proximity probe. What information is obtained from the polar plot on start-up?

a. bearing stiffness
b. critical speeds
c. rotor mass
d. oil viscosity

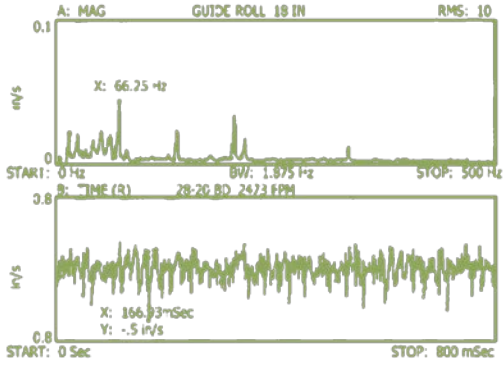
5. A 400 pound rotor is being balanced in place at 1,775 RPM. The initial vibration reading measured with a non-contacting displacement transducer was 3 mils at 155º. The rotor showed a critical speed at 1,250 RPM on coast down. What should be the size and location of the trial weight if it is mounted at a radius of 10 inches?

a. 0.72 oz - 335º
b. 0.72 oz - 155º
c. 0.50 oz - 155º
d. 0.35 oz - 245º

6. The vibration data shown in Figure 4 were taken from the pedestal of an 18-inch diameter guide roll with a surface speed of 2,473 ft/min. The roll is supported on rolling element bearings with the following defect frequencies: BPFO, 5.24 x RPM; BPFI 7.57 x RPM; BSF,
2.41 x RPM; FTF, 0.4 x RPM. What is the vibration source?

a. pedestal looseness
b. mass unbalance
c. bearings defect(s) on outer race
d. d bearing defect(s) on inner race

FIGURE 4



7. What is the likely cause of the excessive vibration measured on the vertical pump from Figure 3? An impact test showed a structural natural frequency at 39.5 Hz.

a. mass unbalance
b. resonance
c. misalignment
d. cavitation

8. Vibration measured on a two-pole motor in the horizontal direction shows 0.1 IPS and 0.02 IPS at 1x and 2x operating speed respectively. At. 7,200 CPM the motor has a component of 0.25 IPS in the same spectrum. What is the major source of the excessive vibration?

a. mass unbalance
b. misalignment
c. looseness
d. casing distortion

9. A spectrum containing data from a single-reduction gearbox includes vibration activity at gear speed (0.05 IPS at 59.5 Hz) and gear mesh frequencies (0.5 IPS at 5,950.0 Hz). What is the dynamic range of the analyzer required if the data are to be shown in an acceleration spectrum?

a. 6 dB
b. 12 dB
c. 40 dB
d. 60 dB

10. A blower operating at 1,785 RPM has a large component of vibration (0.35 in./sec) at operating speed. An impact test shows a structural natural frequency of the support frame at 1,800 CPM. What would be the best corrective action to reduce the blower vibration?

a. balance the blower
b. stiffen the support frame
c. reduce the stiffness of the support frame
d. align the blower to the motor

ANSWERS TO SAMPLE QUESTIONS FOR CATEGORY III:
1. d, 2. d, 3. d, 4. b, 5. b, 6. d, 7. b, 8. d, 9. d, 10. b

CATEGORY IV

1. If you are using a 12-bit analog-to-digital converter with a full-scale range of ± 5 volts, what is the minimum peak amplitude of a sine wave that can be detected?

a. 9.76 mv
b. 4.88 mv
c. 2.44 mv
d. 1.44 mv

2. Determine the damped natural frequency and percentage of critical damping from the impact test data shown in Figure 1.

a. 46 Hz, 50%
b. 30.8 Hz, 50%
c. 30.8 Hz, 48%
d. 30.8 Hz, 11%

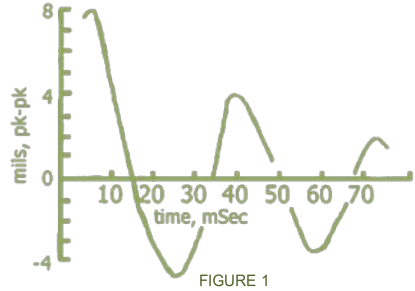


FIGURE 1

3. The original vibration of a counter clockwise rotating fan was 7.0 mils @40°. After a four (4) oz. trial weight was attached at 60° the vibration reading was 5 mils @ 120°. What is the balance sensitivity and phase lag of the high spot to the heavy spot?

a. 1.0 oz./mil @ 180°
b. 0.5 oz./mil @ 120°
c. 0.25 oz./mil @ 60°
d. 0.5 oz./mil @ 300°

4. A 1,000 pound 4-pole induction motor is to be mounted on four isolators to minimize vibration transmitted to its foundation. Which isolator would be preferred in the installation?

a. rubber mount, $c/c_c = 0.3$, $k_h = 25{,}000$ lb/in., $k_v = 30{,}000$ lb/in.
b. leaf spring, $c/c_c = 0.025$, $k_h = 50{,}000$ lb/in., $k_v = 100{,}000$ lb/in.
c. spring mount, $c/c_c = 0.01$, $k_h = 1{,}800$ lb/in., $k_v = 2{,}500$ lb/in.
d. neoprene mount, $c/c_c = 0.02$, $k_h = 500$ lb/in., $k_v = 250$ lb/in.

5. All rotor-bearing instability mechanisms have in common

a. low damping in the axial plane of the rotor.
b. a destabilizing tangential force normal to the rotor radial vibration.
c. a stiffness that exceeds the force in the rotor radial direction.
d. an eigenvalue that is always imaginary.

6. A center-mounted fan that operates at 1,185 RPM is supported on rolling element bearings with a stiffness of 50,000 lb/in each. The impeller, which weighs 1,000 pounds, is supported on a four-inch diameter shaft with a center-to-center bearing span of 100 inches. What vibration amplitude can be expected if the fan is balanced to 3.2 in.-oz? (Neglect shaft weight & damping; E= 30E06 lb/in^2)

a. 0.65 mil - peak to peak
b. 1.2 mils - peak to peak
c. 2.1 mils - peak to peak
d. 0.02 IPS

7. When an impact test is performed, a force window is used to

a. amplify the level of the force pulse.
b. zero out noise after the force pulse.
c. make the response decay within the restraints of the sample window.
d. broaden the frequency range of the pulse.

8. An important test was conducted on a machine frame made with bolted joints using an instrumented hammer and an accelerometer. If the accelerometer signal is single integrated, what possible spectral display can be obtained?

a. mobility
b. accelerance
c. apparent mass
d. dynamic stiffness

9. A rotor-bearing system that has split critical speeds, half critical speeds, and zones of instability must have

a. couple unbalance.
b. non-symmetric rotor stiffness.
c. non-symmetric bearing stiffness.
d. bi-linear rotor damping.

10. A 3200 line, 800 Hz spectrum display includes the following peak components-- 0.5 gs @100Hz, 2 gs @200 Hz, 3.5 gs @ 250 Hz, and 0.5 gs @ 500 Hz. What is the digital rms value of the signal in gs?

a. 6.5
b. 5.25
c. 4.09
d. 2.89

ANSWERS TO SAMPLE QUESTIONS FOR CATEGORY IV:
1. c, 2. d, 3. b, 4. c, 5. b, 6. a, 7. b, 8. a, 9. b,10. d.

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