INTERNATIONAL STANDARD

ISO 18436-8

First edition
2013-03-01

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

Part 8: Ultrasound

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

Partie 8: Ultrasons

Reference number
ISO 18436-8:2013(E)

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Published in Switzerland

Foreword

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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, www.iso.org/directives.

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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*.

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*

Introduction

The use of ultrasound technology in condition monitoring is one of the key activities in predictive maintenance programmes for most industries. Other non-intrusive technologies including acoustic emission, infrared thermography, vibration analysis, lubricant analysis, wear debris analysis, and motor current analysis are used as complementary condition analysis tools. Those in the manufacturing industry who have diligently and consistently applied these technologies have experienced a return on investment far exceeding their expectations. However, the effectiveness of these programmes depends on the capabilities of individuals who perform the measurements and analyse the data. This part of ISO 18436 defines the requirements for personnel to become qualified to apply the non-intrusive machine condition monitoring and diagnostics technology of ultrasound.

A programme, administered by an assessment body, has been developed to train and assess the competence of personnel whose duties require the appropriate theoretical and practical knowledge of machinery condition monitoring and diagnostics.

This part of ISO 18436 defines the requirements against which personnel in the non-intrusive machinery condition monitoring and diagnostics technologies associated with ultrasound for machinery condition monitoring are qualified and the methods of assessing such personnel.

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

Part 8: Ultrasound

1 Scope

This part of ISO 18436 specifies the requirements for qualification and assessment of personnel who perform machinery condition monitoring and diagnostics using ultrasound.

A certificate or declaration of conformity to this part of ISO 18436 provides recognition of the qualifications and competence of individuals to perform ultrasound measurements and analysis for machinery condition monitoring using ultrasound equipment. It is possible that this procedure is not applicable to specialized equipment or other specific situations.

This part of ISO 18436 specifies a three-category classification programme that is based on the technical areas delineated herein, consistent with ISO 18436-1 and ISO 18436-3.

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

ISO/IEC 17000, *Conformity assessment — Vocabulary and general principles*

ISO 18436-1:2012, *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 13372 and ISO/IEC 17000 apply.

4 Classification of personnel — Ultrasound

4.1 General

Individuals assessed as conforming to the requirements of this part of ISO 18436 shall be classified in one of three categories, depending upon their qualifications. They shall have demonstrated the necessary skills in ultrasound condition monitoring for their category as indicated in Annex A.

Personnel classified as category II are required to have all the knowledge and skills expected of personnel classified as category I, while personnel classified as category III are required to have all the knowledge and skills expected of personnel classified as category II.

4.2 Category I

Individuals classified as category I are qualified to perform ultrasound measurements according to established and recognized procedures. Personnel classified as category I shall be able to:

a) apply a specified ultrasound measurement technique; however, persons classified as category I shall not be regarded as competent to choose the test method or technique used;

b) set up and operate the ultrasound equipment for safe ultrasound data collection;

c) verify the integrity of collected data and prevent or control poor data and error sources;

d) perform basic fault detection, severity assessment, and diagnosis in accordance with established instructions;

e) record and categorize the results in terms of written criteria;

f) maintain a database of results and trends;

g) verify sensitivity of ultrasound measurement instruments and systems;

h) evaluate and report test results in accordance with instructions highlighting areas of concern;

i) recognize and prevent or control factors that result in the acquisition of poor quality data.

4.3 Category II

Individuals classified as category II are qualified to perform and/or direct ultrasound analysis according to established and recognized procedures, and are aware of the limitations of the ultrasound method. Personnel classified as category II shall be able to:

a) select the appropriate ultrasound measurement technique and understand its limitations;

b) specify the appropriate hardware and software;

c) set up and verify equipment settings;

d) apply ultrasound theory and techniques where no procedures exist;

e) measure and perform diagnosis of ultrasound signals inclusive of amplitude, frequency, and time domain analysis;

f) classify and evaluate the test results (including acceptance tests) in accordance with applicable codes, standards, specifications, and procedures;

g) prepare reports on equipment condition fault diagnoses, recommend appropriate corrective actions, and comment on effectiveness of repairs;

h) provide technical direction to ultrasound monitoring personnel at category I;

i) be aware of the use of alternative or supplementary condition monitoring (CM) technologies.

4.4 Category III

Personnel classified as category III are qualified to perform and/or direct all types of ultrasound measurements and analysis and shall be able to:

a) apply ultrasound theory and techniques, including measurement and interpretation of survey results such as amplitude, frequency, and time domain processing;

b) understand and perform data analysis, including limitations;

c) determine the ultrasound data acquisition systems and component assemblies required;

d) use non-standard techniques for ultrasound monitoring and fault diagnosis;

e) interpret and evaluate standards, codes, specifications, and procedures;

f) develop and establish ultrasound programmes, procedures, and instructions including determination of the requirement for periodic/continuous monitoring, frequency of testing, etc.;

g) determine severity assessment acceptance criteria for new, in-service, and faulty equipment;

h) measure and perform more advanced diagnosis and prognosis of ultrasound signal analysis with amplitude, frequency, and time domain;

i) recommend the use of alternative or supplementary condition monitoring (CM) technologies;

j) provide guidance to supervise and instruct category I and II personnel.

NOTE It is the employer's responsibility to ensure that category III personnel have the necessary competency in the required management skills, for example creating budgets, preparing cost justifications, and managing personnel development.

5 Eligibility

5.1 General

Candidates should have a combination of education, training, and experience to ensure that they understand the principles and procedures applicable to ultrasound measurement and analysis.

It is advised that all candidates utilizing instrumentation with headphones should be given hearing examinations to ensure natural or corrected hearing acuity exists in at least one ear. A record of the results should be retained and presented to the assessment body upon request. The individual should be capable of hearing a standard pure tone audiometry with results of an average of 25 dB hearing level or lower. This examination should be administered upon initial certification and upon recertification. The examinations shall be administered by a licensed professional and a record of the test made available to the assessment body upon request.

5.2 Education

It is not necessary that candidates seeking classification provide evidence of formal education to establish eligibility. However, it is recommended that category I and II candidates have at least a secondary school graduate qualification or its equivalent. Candidates seeking classification to category II and III shall be able to manipulate simple algebraic equations, use a basic scientific calculator (including trigonometric and logarithmic functions), and be familiar with the operation of personal computers. Successful completion of 2 or more years of an engineering skills or technology programme at an accredited college, university, or technical school is highly recommended for candidates seeking classification to category III.

5.3 Training

5.3.1 Introduction

To be eligible to apply for assessment based on this part of ISO 18436, the candidates shall provide evidence of successful completion of training based on the requirements of Table A.2. The training syllabus in Table A.2 includes the requirement for practical knowledge and practical skills training, within the relevant topics. The minimum duration of cumulative training is shown in Table 1. Training should be in the form of lectures, demonstrations, practical exercises, or formal training courses.

Qualification requirements shall be in accordance with this part of ISO 18436. Training time devoted to each topic shall be in accordance with Tables 1 and A.2.

Table 1 — Minimum duration of cumulative training

Durations in hours

Category I	Category II	Category III
32	64	96

Training may be modularized into two or more subject areas covering general scientific principles and application-specific knowledge in order to allow mutual recognition between non-destructive testing (NDT) and condition monitoring assessment bodies.

5.3.2 Additional training on machine knowledge

In addition to the training hours shown in Table 1 and detailed in Table A.2, candidates should attend formal or on-the-job machinery and component training of at least a similar duration as shown in Table 1.

Such training shall be in addition to any formal education compliant with 5.2, inclusive of any college or university education. If undertaken, the additional training shall cover the design, implementation, operation, and maintenance principles of machines and components and the failure modes and mechanisms associated with each principle. Such training shall be validated by verifiable records.

5.4 Experience

To be eligible to apply for assessment based on this part of ISO 18436, the candidate shall provide evidence to the assessment body of experience in the field of ultrasound condition monitoring in accordance with Table 2. Classification to categories II and III requires previous classification at the lower category.

Table 2 — Minimum cumulative experience requirements

Durations in months

Category I	Category II	Category III
6	12	36

Candidates shall keep verifiable documentary evidence of experience. Candidates for categories I and II shall have this evidence validated by a person at category II or higher, or in the absence of such persons, by the candidate's technical supervisor.

Candidates for category III shall have this evidence validated by a category III person, or in the absence of a category III, by the candidate's technical supervisor.

The validation process for all categories requires the signature of the validating person on the documentary evidence. The validating person should augment this validation process via oral assessment, accompanied task performance, report submission and review, procedure submission and review, or a combination thereof, in order to increase the confidence in the validation.

5.5 Recognition of prior learning

Prior learning in signal analysis and diagnostic methods on machines shall be taken into account by the assessment body.

For candidates who have achieved recognition as vibration analyst, category III or IV, or acoustic emission, category II or III, the required cumulative experience shall be 1/3 of that stated in Table 2.

For candidates who have achieved recognition as vibration analyst, category I or II, or acoustic emission, category I, the required cumulative experience shall be 1/2 of that stated in Table 2.

6 Examination

6.1 Examination content

a) For each category, candidates shall be required to answer a minimum fixed number of multiple choice questions in a specified duration indicated in Table 3. Category III examinations may include fault diagnosis, prognosis, and solution recommendation content. Category III examinations may include narrative questions.

b) The examination papers for a category I shall consist of a part A, general ultrasound, and a part B, practical application. The Part B examination shall cover quality data acquisition and the recognition, prevention, and control of error sources. This examination may include both physical data acquisition tasks in addition to interpretation of data sets.

c) The content of the examination paper shall contain questions for each subject in Table A.2 and in the same weighting as indicated by the percentage of time spent on each subject indicated in Table A.2.

d) Questions shall be of a practical nature and test the candidate's knowledge of the concepts, principles, and procedures required to conduct ultrasound condition monitoring, analysis, and evaluations.

e) Some questions will include the interpretation of data and simple mathematical calculations using a basic scientific calculator may be required.

f) Assessment bodies may, at their discretion, make accommodations for candidates with abilities that may require some form of compensation.

Table 3 — Minimum examination content

Category	Number of questions	Time h	Passing grade %
Category I	60	2,0	70
Category II	60	2,0	70
Category III	60	2,0	70

6.2 Conduct of examinations

All examinations shall be conducted in accordance with ISO 18436-1:2012, 8.1.

Annex A
(normative)

Training course requirements for ultrasound condition monitoring and diagnostics of machines

Table A.1 — Overview

Durations in hours

Subject		Training		
		Category I	**Category II**	**Category III**
1	Principles of ultrasound	3	2	1
2	Generic equipment knowledge	1,5	1	1
3	Data acquisition in ultrasound	2,5	1	1
4	Data storage and management	1	2	2
5	Condition monitoring principles	1,5	1	1
6	Applications to machine systems	17	17	16,5
7	Severity determination	2	4	4
8	Programme implementation	0,5	0,5	1
9	Reporting and corrective action	0,5	1	2
10	Personal safety	0,5	0,5	0,5
11	Training examination	2	2	2
Total hours for each category		**32**	**32**	**32**

Table A.2 — Detailed training course requirements

Durations in hours

Subject	Category I	Category II	Category III
1. Principles of ultrasound	**3**	**2**	**1**
a) Basics of sound	a	—	—
b) Sound wave motion	a	—	—
c) Acoustic impedance and its influence on propagation and attenuation	a	a	a
d) Inverse distance law	a	—	—
e) How friction, turbulence, and impacting produce ultrasound and where they apply	a	a	a
f) Understanding the properties of the decibel	a	a	—
2. Generic equipment knowledge	**1,5**	**1**	**1**
a) Instrument operation and function	a	a	a
b) Airborne sensors	a	a	a
c) Structure-borne sensors	a	a	a
d) Heterodyne principle and application	a	a	a
e) Sensitivity validation	a	a	—
3. Data acquisition in ultrasound	**2,5**	**1**	**1**
a) Principles of data acquisition	a	a	—
b) Sensor positioning	a	a	—
c) Competing ultrasound and shielding techniques	a	a	a
d) Measurement of ultrasound	a	a	a
e) Capturing time domain and spectrum signals for analysis	a	a	a
4. Data storage and management	**1**	**2**	**2**
a) Developing and using a database	a	a	a
b) Managing stored data	a	a	a
c) Disposition of anomalies	—	a	a
5. Condition monitoring principles	**1,5**	**1**	**1**
a) What is condition monitoring?	a	—	—
b) Why is it useful?	a	—	—
c) What other technologies are there?	a	a	a
d) Why and when would ultrasound be useful?	a	—	—
e) Acceptance testing	a	a	a
f) Benchmarking	—	a	a
6. Applications to machine systems	**17**	**17**	**16,5**

Table A.2 *(continued)*

Subject	Category I	Category II	Category III
a) Leak detection	a	a	a
1) Turbulence and flow			
2) Directionality			
3) Measurement precautions			
4) Pressurized gases and compressed air			
5) Vacuum			
6) Tightness testing using the ultrasonic tone method			
b) Valve inspection to identify:			
1) Blocked			
2) Passing			
3) Cavitating			
c) Steam traps			
1) Using ultrasound			
2) Combination with temperature			
3) Reporting techniques			
d) Electrical inspection			
1) Corona, tracking, and arcing			
2) Internal partial discharge			
3) Safety concerns			
e) Hydraulic systems inspection			
1) Cylinders, valves, and pumps			
f) On-condition bearing lubrication			
1) Trending values			
2) Ultrasonic lubrication process considerations			
3) Under and over-lubricated bearings			
g) Bearing defect detection			
h) Slow speed bearing inspection			
i) Gearing inspection			
j) Pump inspection - cavitation			
k) Motor inspection and the effect of variable speed drives			
7. Severity determination	**2**	**4**	**4**
a) Setting up decibel alarms	—	a	a
b) Trending decibels	a	a	a
c) Statistical alarm creation	—	a	a
d) Time signal analysis	a	a	a
e) Spectrum analysis	a	a	a
f) Case studies	a	a	a
g) Diagnosis and prognosis	—	a	a

Table A.2 *(continued)*

Subject	Category I	Category II	Category III
8. Program implementation	**0,5**	**0,5**	**1**
a) Routine inspection considerations	a	a	a
b) Routine management	a	a	a
c) Report structuring	—	a	a
d) Corrective action for alarm incidences	—	a	a
9. Reporting and corrective action	**0,5**	**1**	**2**
a) Key information needed	a	a	a
b) Recommending corrective action	—	a	a
c) Tracking corrective action outcome	a	a	a
10. Personal safety	**0,5**	**0,5**	**0,5**
11. Training examination	**2**	**2**	**2**
Total hours per course	**32**	**32**	**32**

[a] Topics to be taught at each category.

NOTE 1 Category II includes the knowledge of category I.

NOTE 2 Category III includes the knowledge of category I and category II.

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ICS 17.160,03.100.30

Price based on 10 pages