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

Part 7: Thermography

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

Partie 7: Thermographie

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 18436-7 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration, shock and condition monitoring*, Subcommittee SC 5, *Condition monitoring and diagnostics of machines*.

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 certifying bodies and the certification 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*

Introduction

Using thermography to monitor condition and diagnose faults in machinery is a key activity in predictive maintenance programmes for most industries. Other non-intrusive technologies including vibration analysis, acoustic emission, lubricant analysis, and motor current analysis are used as complementary condition analysis tools. Those in the 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, 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 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 infrared thermography for machinery condition monitoring are to be qualified and the methods of assessing such personnel.

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

Part 7: Thermography

1 Scope

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

A certificate or declaration of conformity to this part of ISO 18436 will provide recognition of the qualifications and competence of individuals to perform thermal measurements and analysis for machinery condition monitoring using portable thermal imaging equipment. This procedure may not apply 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.

2 Normative references

The following referenced documents are indispensable for the application of this document. 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 13374 (all parts), *Condition monitoring and diagnostics of machines — Data processing, communication and presentation*

ISO 13379, *Condition monitoring and diagnostics of machines — General guidelines on data interpretation and diagnostics techniques*

ISO 13381-1, *Condition monitoring and diagnostics of machines — Prognostics — Part 1: General guidelines*

ISO 17359:2003, *Condition monitoring and diagnostics of machines — General guidelines*

ISO 18434-1, *Condition monitoring and diagnostics of machines — Thermography — Part 1: General procedures*

ISO 18436-1:2004, *Condition monitoring and diagnostics of machines — Requirements for training and certification of personnel — Part 1: Requirements for certifying bodies and the certification 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*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 13372 and the following apply.

3.1
significant interruption
absence or change of activity which prevents the assessed individual from practising the duties corresponding to the category within the defined scope for

a) a continuous period in excess of 365 days or

b) two or more periods for a total time exceeding two-fifths of the total period of validity of the certificate or declaration

4 Classification of personnel (thermography)

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 thermal condition monitoring for their category as indicated in Annex A.

Personnel classified as Category II need to have all the knowledge and skills expected of personnel classified as Category I, while personnel classified as Category III need 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 infrared thermography according to established and recognized procedures. Personnel classified as Category I shall be able to:

a) apply a specified thermographic measurement technique;

b) set up and operate the thermal imaging equipment for safe thermographic data collection;

c) identify, prevent, minimize and control poor data acquisition and error sources;

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

e) perform basic image post-processing (measurement tools, emissivity adjustments, span and scale adjustments, etc.);

f) maintain a database of results and trends;

g) verify the calibration of thermographic measurement systems;

h) evaluate and report test results and highlight areas of concern.

4.3 Category II

Individuals classified as Category II are qualified to perform infrared thermography according to established and recognized procedures. Personnel classified as Category II shall be able to:

a) select the appropriate infrared thermography technique and understand its limitations;

b) apply thermography theory and techniques, including measurement and interpretation of survey results;

c) specify the appropriate hardware and software;

d) perform advanced fault diagnoses;

e) recommend appropriate field corrective actions;

f) perform advanced image post-processing (image, trending, montage, subtraction, superimposition, statistical analysis, etc.);

g) use generally recognized advanced techniques for infrared thermography and fault diagnosis in accordance with established procedures;

h) prepare reports on equipment condition, fault diagnoses, corrective actions and the effectiveness of repairs;

i) be aware of the use of alternative or supplementary condition monitoring technologies; and

j) provide guidance to and supervise Category I personnel.

4.4 Category III

Individuals classified as Category III are qualified to perform infrared thermography according to established and recognized procedures. Personnel classified as Category III shall be able to:

a) develop and establish thermographic programmes, procedures and instructions including determination of machines for periodic/continuous monitoring, frequency of testing, the use of advanced techniques, etc.;

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

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

d) designate the particular test methods, procedures and instructions to be used;

e) perform prognostics for fault conditions;

f) recommend appropriate types of thermodynamic (radiation-, convection-, conduction-based) corrective actions;

g) recommend appropriate types of machinery engineering corrective actions;

h) provide guidance to and supervise Category I and II personnel; and

i) recommend the use of alternative or supplementary condition monitoring technologies.

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 thermographic measurement and analysis.

It is advised that all candidates have their colour perception assessed by the Ishihara 24 plate test. A record of test results should be retained and presented to the assessment body upon request. In the event that a colour perception deficiency, indicated by misreading four or more of the 24 plates, is detected during the Ishihara test, a further “task specific” test is to be carried out by the employer to ascertain whether the detected colour perception deficiency affects the individual's ability to satisfactorily perform analysis of thermographic data using colour palettes. Failure to pass this test may require the candidate to use a monochrome palette. This “task specific” test, and any requirement to use a monochrome palette, is to be documented and a record of the test made available to the assessment body upon request.

5.2 Education

Candidates seeking classification do not need to provide evidence of formal education to establish eligibility. However, it is recommended that candidates for Category I and Category II have at least a secondary school graduate qualification or its equivalent. Category II and III candidates shall be able to manipulate simple algebraic equations, use a basic scientific calculator, and be familiar with the operation of personal computers. Successful completion of two or more years of mechanical technology or mechanical engineering at an accredited college, university, or technical school is highly recommended for candidates seeking 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 Annex A. The documents in the Bibliography should be used as the domain of knowledge for the training syllabus. Such training shall be compliant with the requirements of ISO 18436-3. The minimum duration of 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 subject shall be in accordance with Annex A and Table 1. See Annex B for a non-exhaustive list of the topics and sub-topics to be covered.

Table 1 — Minimum duration of cumulative training (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 for mutual recognition between non-destructive testing and condition monitoring assessment bodies.

5.3.2 Training for supplementary classification

A modular training course designed to cover those topics specific to thermography-based condition monitoring may be undertaken.

Such supplementary training courses shall cover the topics outlined in Annex A for subjects five (5) through eleven (11) inclusive. The duration of such training shall comply with the durations stated in Annex A for the relevant subject areas.

5.3.3 Additional training on machine knowledge

In addition to the training hours shown in Table 1, candidates should attend machinery and component training, or equivalent on-the-job training, of at least a similar duration to that specified 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, manufacturing, installation, operation and maintenance principles of machines and components, the failure modes and mechanisms associated with each principle, and the typical thermodynamic behaviours associated with each mechanism. Such training shall be validated by verifiable records.

5.3.4 Mature candidate entry

Mature candidate entry may be allowed at the discretion of the assessment body.

Mature candidates may not need to have attended a course of training at Category II. Such candidates may apply for direct entry to Category II, without the need to have previously held classification at Category I, providing they can produce verifiable documentary evidence of training and experience that satisfies the requirements for both Category I and Category II qualifications.

Candidates shall have at least five years of documented experience without significant interruption in thermography-based condition monitoring of machines for Category II. Candidates shall provide evidence of completion of an equivalent course of training in accordance with Annex A.

Such candidates should apply to the assessment body under the mature candidate route. If a significant interruption exists, the candidate may be required to undertake further training as determined by the assessment body.

5.4 Experience

5.4.1 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 thermography-based machinery condition monitoring in accordance with Table 2. Classification to Category II and Category III requires previous classification at the lower category.

Table 2 — Minimum cumulative practical, interpretation and programme management experience requirements (months and hours)

Category I	Category II	Category III
12 months	24 months	48 months
400 h [a]	1 200 h [a]	1 920 h [a]
[a] Denotes the actual thermography experience hours that are required.		

5.4.2 The minimum total experience durations specified (in months) are required to enable the acquisition of experience in all category criteria in accordance with ISO 18436-1 and 5.4.5. The experience duration in months, not in hours, for Categories I and II may be reduced by up to 50 % when the classification process includes a practical examination.

5.4.3 Candidates shall keep verifiable documentary evidence of hours and nature of work for their thermography-based machinery condition monitoring experience in accordance with ISO 18436-1. Candidates for Categories I and II shall have this evidence validated by a Category II or III person or, in the absence of such a person, by the candidate's technical supervisor.

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

5.4.5 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.

6 Examinations

6.1 Examination content

6.1.1 For each category, candidates shall be required to answer a fixed minimum number of multiple choice questions in a specified time duration as indicated by Table 3.

6.1.2 Questions shall be of a practical nature, yet test the candidate on concepts and principles required to conduct infrared thermography for condition monitoring of machines.

6.1.3 The examination papers for Category I shall consist of a Part A – General Thermography (comprising a number of multiple choice questions) and a Part B – Practical Application. The Part B examination shall cover quality data acquisition, the recognition, prevention and control of error sources, and basic fault diagnosis. This examination may include both physical data acquisition tasks in addition to image interpretation.

6.1.4 The examination papers for Category II shall consist of a Part A – General Thermography (30 questions) and a Part B – Practical Application. The Part B examination shall cover diagnostics and image interpretation for condition monitoring of machines. This examination may include both physical data acquisition tasks in addition to image interpretation.

6.1.5 The examination papers for Category III shall consist of a Part A – General Thermography (30 questions) and a Part B – Practical Application. The Part B examination shall cover diagnostics and image interpretation, solution design, and solution verification. This examination may include both physical data acquisition tasks in addition to image interpretation. The image interpretation questions should be based on case histories requiring fault identification, solution recommendation, and a solution verification process. Part B may also include narrative and short answer questions. Some questions shall involve the interpretation of thermal images. Simple mathematical calculations using a basic scientific calculator may be required. A summary of common formulae may be provided along with the examination questions.

6.1.6 Examination content shall be proportionate with the training syllabus contained in Annex A.

6.1.7 Assessment bodies may, at their discretion, make accommodations for candidates with conditions that may require some form of compensation.

Table 3 — Minimum examination content

Categories	Number of questions	Time h	Passing grade %
Category I	50	2,0	75
Category II	60	2,0	75
Category III	60	2,0	75
Supplementary exam	30	1,0	75

6.2 Conduct of examinations

All examinations shall be conducted in accordance with ISO 18436-1:2004, 8.2, except that candidates may also have access to pencils and erasers if computer-based marking is used.

6.3 Supplementary examination

6.3.1 Supplementary modular examinations may be made available to those with an equivalent classification, as determined by the relevant assessment body, covering the topics outlined in A.1, subjects 1 through 4, and compliant with the other requirements of this part of ISO 18436. This examination comprises a separate supplementary module covering condition monitoring of machines.

6.3.2 Supplementary modular examinations will be graded separately.

6.3.3 Supplementary examination candidates shall have satisfactorily completed a course of training covering the syllabus to be examined and shall provide verified documentary evidence of the training.

Annex A
(normative)

Training course requirements and minimum training hours for thermography personnel

A.1 Training syllabus

Subject	Hours of training		
	Category I	Category II	Category III
0. Introduction	0,5	—	—
1. Principles of infrared thermography (IRT)	6	7	6
2. Equipment and data acquisition	5	3	1
3. Image processing	6	2	1
4. General applications	4,5	0	0
5. Diagnostics and prognostics	1	2	2
6. Condition monitoring applications	4	10,5	7
7. Corrective actions	—	3	6
8. Reporting and documentation (ISO International Standards)	1	0,5	0,5
9. Condition monitoring programme design	0,5	0,5	3,5
10. Condition monitoring programme implementation	1	1	1
11. Condition monitoring programme management	0,5	0,5	2
12. Training examination	2,0	2,0	2,0
Total hours for each category	**32**	**32**	**32**

A.2 Detailed list of topics and hours of instruction

Subject	Topics	Hours of training		
		Category I	Category II	Category III
0. Introduction		0,5	—	—
1. Principles of infrared thermography (IRT)		6	7	6
	Heat and heat transfer	*		
	Conduction fundamentals	*		
	Fourier's Law		*	*
	Conductivity/resistance	*		
	Convection fundamentals	*		
	Newton's Law of Cooling		*	*
	Radiation fundamentals	*		
	Electromagnetic spectrum	*		
	Atmospheric transmission	*	*	
	IR wavebands and lens materials	*		
	Radiation reference sources		*	*
	Planck's Law		*	
	Wien's Law		*	
	Stefan-Boltzmann Law	*		
	Emittance, reflectance and transmittance	*		
	Emissivity	*	*	*
	Factors affecting emissivity	*	*	*

Subject	Topics	Hours of training		
		Category I	Category II	Category III
2. Equipment and data acquisition		5	3	1
	How your infrared camera works	*		
	Infrared camera selection criteria		*	
	Spectral band	*	*	
	Temperature measurement range	*		
	Thermal sensitivity (NETD)		*	
	Lens selection	*	*	
	Optical resolution	*	*	
	Operation of equipment	*	*	
	Accessories	*	*	
	Camera controls	*		
	ISO 18434-1	*	*	
	Safe data acquisition	*	*	
	Getting a good image	*		
	Image composition	*	*	*
	Image clarity (optical focus)	*		
	Thermal tuning (range, level and span)	*		
	Palette selection	*		
	Emissivity determination	*	*	
	Error source recognition, prevention or control	*	*	
	Waveband selection criteria		*	*
	Recognizing and dealing with radiation (reflections, reflected apparent temperature)	*	*	*
	Recognizing and dealing with convection	*	*	*
	Recognizing and dealing with conduction	*	*	*
	Effects of incorrect emissivity	*	*	
	Camera calibration	*	*	
	Environmental and operational conditions	*	*	
	Data and image storage	*		

Subject	Topics	Hours of training		
		Category I	Category II	Category III
3. Image processing		6	2	1
	Temperature measurement	*	*	
	ISO 18434-1	*	*	*
	Non-contact thermometry	*		
	Comparative quantitative thermography	*	*	
	Comparative qualitative thermography	*	*	
	Environmental influences	*	*	
	Camera measurement tools	*	*	
	Measurement tools	*	*	
	Palette selection	*		
	Level and span adjustment	*		
	Distance (atmospheric) correction	*	*	
	Emissivity correction		*	
	Statistical analysis		*	
	Image subtraction		*	*
	Image montage	*	*	*
	Temperature trending	*	*	*
	General image interpretation guidelines	*	*	*
	General guidelines for establishing thermal severity assessment criteria (ISO 18434-1, engineering codes and standards)		*	*
4. General applications		4,5	0	0
	Discussion on general industrial applications	*		
	Active and passive thermography	*		
5. Diagnostics and prognostics		1	2	2
	Basic principles of diagnostics (ISO 13379)	*	*	*
	Basic principles of prognostics (ISO 13381-1)		*	*
6. Condition monitoring applications		4	10,5	7
	Machinery engineering principles (components and construction)	*	*	*
	Typical machinery failure modes and mechanisms and their associated thermal signatures	*	*	*
	Severity assessment and acceptance criteria (engineering codes and standards)	*	*	*
	Safety issues	*	*	*
	ISO 18434-1	*	*	*

Subject	Topics	Hours of training		
		Category I	Category II	Category III
7. Corrective actions		—	3	6
	Machinery corrective and/or preventive actions		*	*
8. Reporting and documentation (ISO International Standards)		1	0,5	0,5
	Report writing	*	*	*
	Thermographers' and end-users' responsibilities	*	*	*
9. Condition monitoring programme design (ISO 17359, ISO 18434-1, ISO 13379, ISO 13381-1)		0,5	0,5	3,5
	General principles	*	*	*
	Technique selection		*	*
	Measurement intervals		*	*
	Reference temperatures	*	*	*
	Baseline temperatures	*	*	*
	Procedure development		*	*
10. Condition monitoring programme implementation (ISO 17359, ISO 13381-1, ISO 18434-1)		1	1	1
	Overview	*		
	Safe systems of work	*	*	
	Roles and responsibilities		*	*
	Training and assessment		*	*
11. Condition monitoring programme management		0,5	0,5	2
	Safety management	*	*	*
	Equipment management	*	*	*
	Procedure management		*	*
	Skills and competencies management		*	*
	Database management	*	*	*
	Managing corrective action implementation		*	*
12. Training examination		2,0	2,0	2,0
Total hours		**32**	**32**	**32**

NOTE 1 Category II includes the knowledge of Category I; Category III includes the knowledge of Category I and Category II.

NOTE 2 At Categories II and III, the times allocated are indicative only, indicating the bias towards application topics, and the actual time spent for each topic is flexible, provided an advised minimum of approximately 24 h is allocated per field of application.

NOTE 3 * Indicates topics to be taught at indicated category.

Annex B
(normative)

Training course sub-topics

This is a guide to the topics that shall be covered. This list is not exhaustive.

Subject	Topics	Sub-topics
1. Principles of IRT	Heat transfer	
	Electromagnetic spectrum	
	Emittance, reflectance and transmittance	Factors affecting emissivity, reflectance and transmittance
	Atmospheric transmission	
	IR wavebands and lens materials	
	Conduction fundamentals	
	Fourier's Law	Heat flow; conduction; target thickness; general principles
	Conductivity/resistance	
	Convection fundamentals, Newton's Law of Cooling	
	Radiation fundamentals	Reference sources
	Planck's Law	Emissivity; real temperature difference; general principles; blackbodies
	Wien's Law	General principles
	Stefan-Boltzmann Law	
2. Equipment and data acquisition	How your imager works	
	Selection criteria	Noise Equivalent Temperature Difference (NETD); frame repetition; object size; distances; transmissivity; Instantaneous Field Of View (IFOV); filters; detectors; resolution; palette selection; waveband selection criteria; effects of incorrect emissivity
	Range and level settings	Temperature measurement range; thermal tuning (range, level and span)
	Operation of equipment	Accessories; emissivity determination
	Controls	
	Lenses	Lens material, selection
	Getting a good image	Image composition
	Clarity (focus)	Optical resolution; focus
	Dynamic range	General principles; NETD
	Recognizing and dealing with reflections	Reflections; reflected apparent temperature
	Recognizing and dealing with convection	Roofs; ground; structures; mass transport