

# Appendix B Infra-red Thermography



**AINDT**  
Australian Institute  
for Non-destructive Testing

Draft Issue 1 Rev 2  
Effective from 24/06/2016

A.B.N 21 005 040 835

CM Certification Board  
PO Box 52, Parkville,  
VIC 3052  
Phone: 03 9486 9267  
Email:  
[cmcertification@aindt.com.au](mailto:cmcertification@aindt.com.au)



## Contents

GENERAL INFORMATION .....	3
INTRODUCTION.....	3
1. Classification of Thermography (IRT) Personnel .....	4
2. Training.....	5
3. Experience .....	7
4. Certification available.....	8
5. Qualification examination .....	8
ANNEX A 11	
Training course requirements and minimum training hours for Thermography personnel .....	11
Table A.1 - Training Syllabus .....	11
Table A.2 – Detailed list of Topics and hours of Instruction .....	12
BIBLIOGRAPHY .....	21

# GENERAL INFORMATION

## INTRODUCTION

This annex specifies 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 annex meeting the requirements of ISO 18436-7 in accordance with ISO 18436-1 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 might 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.

It is the responsibility of the employer, or the individual, if that individual is self-employed, to maintain that competence during the period of certification and to ensure that such personnel do not undertake work that they are not certified or competent to do, or for which they do not have job-specific knowledge, or training for.

For candidates sitting thermography (IRT) examinations and working in IRT it is advised that they have their colour perception test assessed by the Ishihara 24 plate test. Failure to pass this test may require the candidate to use a monochrome pallet.

This specific test is to be documented by the employer who is responsible for determining the vision requirements of its employees.

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 13374 (all parts), Condition monitoring and diagnostics of machines — Data processing, communication and presentation

ISO 13379-1, Condition monitoring and diagnostics of machines — Data interpretation and diagnostics techniques — Part 1: General guidelines

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

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

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

ISO 18436-1:2012, Condition monitoring and diagnostics of machines — Requirements for qualification and assessment of personnel — Part 1: Requirements for assessment bodies and the assessment process

ISO 18436-3, Condition monitoring and diagnostics of machines — Requirements for qualification and assessment of personnel — Part 3: Requirements for training bodies and the training process

AS/ISO 18436.7, Condition monitoring and diagnostics of machines — Requirements for qualification and assessment of personnel — Part 7: Thermography.

## 1. Classification of Thermography (IRT) Personnel

Individuals certified in accordance with AS/ISO18436 -7 shall be classified in one of three categories depending on their qualifications. They shall have demonstrated competence in the technical concepts and practical knowledge of Thermography condition monitoring and diagnostics for their classification.

Personnel classified as Category 2 need to have all the knowledge and skills expected of personnel classified as Category 1, while personnel classified as Category 3 need to have all the knowledge and skills expected of personnel classified as Category 2.

Persons seeking classification to Category 2 and 3 can elect to qualify in all three industrial sectors, civil, electrical and mechanical if they so wish.

### 1.1 Category 1 - Thermography

Personnel certified to Category 1, are qualified to perform infrared thermography according to established and recognised procedures and shall be able to:

- (a) apply a specified thermographic measurement technique;
- (b) set up and operate equipment for safe thermographic data collection;
- (c) prevent, minimise or control poor data 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 adjustment, span and scale adjustment, etc);
- (f) maintain a data base of results and trends;
- (g) verify the calibration of thermographic measurement systems;
- (h) evaluate and report test results in accordance with establish instructions and highlight areas of concern;

Category 1 personnel shall not be responsible for the choice of test method or technique used, nor the interpretation of test results.

### 1.2 Category 2 - Thermography

Personnel certified to Category 2 are qualified to perform and direct Category 1 personnel in infrared thermography according to established and recognised procedures and 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 results;
- (c) specify the appropriate hardware and software for both portable and permanently installed systems;
- (d) perform advanced fault analysis;
- (e) recommend appropriate field corrective actions;
- (f) perform advanced image post-processing (image, trending, montage, subtraction, superimposition statistical analysis);
- (g) use generally recognised advances 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 1 personnel.

Category 2 certified personnel, if appointed, are able to manage and supervise Category 1 qualifications for the CMCB.

### 1.3 Category 3 - Thermography

Personnel certified to Category 3 are qualified to perform and direct Category 1 and 2 personnel in infrared thermography according to established and recognised procedures and shall be able to:

- (a) develop and establish thermography programmes, write working procedures and instructions including the determination of machines for periodic/continuous monitoring, frequency of testing, the use of advanced techniques;
- (b) determine severity assessment, acceptance criteria and testing procedures for new, in-service and faulty equipment;
- (c) interpret and evaluate Standards, Codes, Specifications and Procedures;
- (d) designate the particular test methods, procedures, instructions and programmes to be used for new and in-service equipment;
- (e) perform diagnostics and prognosis 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 1 and 2 personnel;
- (i) recommend the use of alternative or supplementary condition monitoring technologies, and
- (j) be able to manage condition monitoring programmes.

**Note:** It is the employer's responsibility to ensure that Category 3 personnel have the necessary competency in the required management skills, for example creating budgets preparing cost justifications and managing personnel development.

Category 3 personnel, if appointed, are able to manage and supervise Category 2 and III qualification examinations for the CMCB.

## 2. Training

The candidate/applicant shall provide documentary evidence of successful completion of training to the AINDT. This training shall meet the requirements of Tables A1 and A2 in Annex A of this particular section on the specific certification requirements for IRT.

For Category 1 IRT, training is of a general nature and not does cover electrical, mechanical and electrical applications in detail (see Table A.1).

For Category 2 and 3 IRT training is modularised into civil, electrical or mechanical can be selected, leading to IRT certification in one of these sectors (see Table A.1 also).

Candidates can certify in one or more of these three individual sectors.

Category 1 the written examination shall contain practical application questions that cover quality data acquisition, the recognition, prevention and control of error sources and basic fault diagnosis.

Category 2 it will cover diagnostics and image interpretation for condition monitoring of machines, electrical or civil systems and image interpretation.

Category 3 it will include all topics for Categories 1 and 2 and include solution design and verification.

A detailed list of topics and hours of instruction for all categories can be found in Table A.2.

Training shall be in accordance with the general and specific requirements of this Guide to Qualification and Certification.

Training can include both practical and theory courses.

The minimum cumulative duration of training is shown in Table 1.

<b>Table 1. Minimum Cumulative Duration of Training (hours)</b>		
<b>Category 1</b>	<b>Category 2</b>	<b>Category 3</b>
32	64	96

Training may be reduced by up to 50% when certification is sought in two or more sectors of the methodology.

A reduction in training hours may be allowed for applicants who have graduated in a relevant discipline from a technical college or university, or have completed at least two years engineering or science study at a college or university.

## **2.1 Training for supplementary classification**

Training can be modularised into two or more subject areas covering general scientific principles and application specific knowledge in order for mutual recognition between non-destructive testing and other condition monitoring certifying bodies (e.g.: ISO9712, SNT-TC- 1A) and other condition monitoring assessment bodies (2nd or 3rd party).

In addition to the minimum training hours in Table 1, and education requirements specified in this Guide, Category 2 candidates should have completed formal or on-the-job training in mechanical, electrical or civil engineering of at least a similar duration to Table 1, which covers certification for the specific sector sought.

The training should cover design, manufacture, installation; operation and maintenance principles of the sector sought (civil, electrical or mechanical systems) and include failure mechanisms associated with each sector and typical thermodynamic signatures associated with each mechanism.

Evidence of such training shall be verified by records and validated by the employer or technical supervisor of the candidate.

The bibliography contained in the annex at the end of this section of the guide includes references to text and other information that would be of value for persons training for qualification and certification in IRT.

Mature candidates may be allowed entry at the discretion of the CMCB and shall comply with the general requirements of this Guide to Qualification and certification for CM personnel. Candidates shall have a minimum of at least 5 years continuous experience without significant interruption. If significant interruption occurs then the CMCB can request further training is undertaken.

### 3. Experience

To be eligible for certification the candidate shall provide documentary evidence of experience in the field of mechanical, electrical and civil infrared thermography condition monitoring appropriate to the category and sector sought.

The minimum experience requirements are shown in Table 2.

<b>Table 2. Minimum Cumulative Experience Requirements (months)</b>		
<b>Category 1</b>	<b>Category 2</b>	<b>Category 3</b>
12	24	48

**Note: 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 Clause 5.4.5 of AS/ISO 18436 - 7. Work experience in months is based on a minimum of 16 hours per month of actual experience conducting onsite thermal camera data collection and onsite image interpretation. The hours of experience cannot be accrued in less time than allowed in the table 2**

Certification at Category 2 and Category 3 requires previous certification at the lower Categories.

Applicants/candidates shall provide verifiable evidence of hours and nature of work for thermography-based condition monitoring experience. For Category 1 and 2 this evidence should be validated and signed by a Category 2 or III person, or in the absence of either of these persons, the candidate's technical supervisor.

For a Category 3 person this evidence should be signed by a Category 3 person or the candidate's technical supervisor.

Candidates must maintain verifiable documentary evidence and log of hours and nature of work (see ISO18436-7 clause 5.4), especially scanning (practical) times.

An applicant who lacks the minimum experience requirement but has received the relevant training and has demonstrated competence by a pass in the prescribed examinations, may request to be granted "Trainee" status

and have certification deferred. Once the AINDT has received evidence from the applicant of additional experience and the minimum number of hours has been satisfied, trainee status will be upgraded to full certification with an expiry date 5 years from the date they completed the practical examination.

**Note:** It is the responsibility of a trainee to inform the AINDT of experience gained whilst holding that status.

Trainee status is valid for five (5) years from the date of success in the examination. Applicants who require more than two (2) years to accumulate the required experience hours will have to demonstrate to the applications committee they have not had a significant interruption, i.e. a period of twelve (12) months or more where they have not used that method, otherwise a re-sit of the practical will be required. If after five (5) years the trainee has not finalised their certification, the application will lapse and they must apply for certification as a new applicant.

#### 4. Certification available

Category 1 (IRT General)

Category 2 (IRT Civil; IRT Electrical; IRT Mechanical)

Category 3 (IRT Civil; IRT Electrical; IRT (Mechanical))

#### 5. Qualification examination

Applications for examination can be made on the appropriate forms from the CMCB Secretariat or by downloading from AINDT's website [www.aindt.com.au](http://www.aindt.com.au)

For each category candidates are required to answer a minimum fixed number of multiple-choice questions within a specified time frame – Table 3. Questions will be of a practical nature as well as testing the candidate on the concepts and principles required to conduct infrared thermography for condition monitoring.

The questions will cover topics in Table A1 and A2 contained in Annex A of this particular section on Infrared Thermography (IRT). They will be selected at random from a database of questions existing at the time of the examination. The weighting of the questions will be proportional to the syllabus and the time spent on training in both of these tables.

**The pass mark for all category qualification examinations is 75%.**



<b>Table 3 – Minimum Examination Content</b>			
<b>Classification</b>	<b>Number of questions</b>	<b>Time –hrs</b>	<b>Pass mark %</b>
Category 1 General	50	2	75
Category 2 General + sector module	30+30 (60)	2	75
Category 3 General + sector module	30+30 (60)	2	75
Supplementary modules – 2 and 3	30	1	75

## 5.1 Initial Examination

### (a) Category 1

Category 1 candidates are required to be successful in a multiple-choice examination paper covering the basic principles and practical knowledge of CM technology in terms of civil, electrical and mechanical engineering and thermographic theory. The examination will also test for quality data acquisition and error source recognition, prevention and control.

### (b) Category 2 and 3

Category 2 and 3 candidates for IRT are required to be successful in a multiple-choice examination covering:

- Part A – Basic principles and practical knowledge of IRT (30 questions);
- Part B – One practical applications paper on the specific applications of IRT – either, civil, electrical or mechanical (30 questions).

The specific practical applications paper for Category 2 will cover diagnostics and image interpretation. This paper may include data acquisition tasks and image interpretation.

The specific practical application paper for Category 3 will cover diagnostics, prognostics, image interpretation, solution design and solution verification. Image interpretation questions may include case histories and other questions shall include the interpretation of thermal images.

Category Part A and B examinations may have a narrative component consisting of three questions of which only two, need to be answered. Each narrative question will be worth five (5) marks.

## 5.2 Supplementary examinations

Supplementary examinations covering civil, electrical and mechanical sectors are only available to candidates having Category 2 and 3 certification. More than one supplementary examination can be set at any given time by certified Category 2 and 3 personnel.

Supplementary examinations shall be graded separately. In the event that a candidate is successful in one of the supplementary examinations and not in the other that persons qualification examination will be recognised where that person is successful.

The qualification requirements (training, experience, eyesight, examination etc) in specific sectors are the same as for all other sectors and validated evidence of this shall be provided to the CMCB Secretariat at the time of application.

For those candidates that have a disability or where English is a second language, special arrangements for examination can be made. Candidates should notify the CMCB Secretariat at the time of application. A medical certificate will be required with the application.

## 5.3 Vision examination

Candidates are required to provide evidence that they have sat and passed a colour perceptions test (Ishihara Plate Test). In the event that colour perception deficiency, indicated by misreading four or more of the 24 plates is detected during the test, a further "task specific" test is to be carried 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 requirements to use a monochrome palette, is to be documented and a record of the test made available to AINDT at the time of certification application



**ANNEX A**

**TRAINING COURSE REQUIREMENTS AND MINIMUM TRAINING HOURS FOR THERMOGRAPHY PERSONNEL**

**Table A.1 - Training Syllabus**

Subject		Hours of training		
		Category 1	Category 2	Category 3
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
<b>Total hours for each category</b>		<b>32</b>	<b>32</b>	<b>32</b>



**Table A.2 – Detailed list of Topics and hours of Instruction**

SUBJECT		Topics	Category 1 Hours	Category 2 Hours	Category 3 Hours
0	Introduction	Context of condition monitoring versus NDT, overviews of intent behind topics, and explanation of personnel classification categories	0.5	-	-
1	Principles of infrared thermography (IRT)		6	7	6
		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	Cat 1	Cat 2	Cat 3
			Hours	Hours	Hours
			5	3	1
2	Equipment and data acquisition	How your imager 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	Cat 1 Hours	Cat 2 Hours	Cat 3 Hours
			6	2	1
3	Image processing	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)			*	*	
SUBJECT		Topics	Cat 1 Hours	Cat 2 Hours	Cat 3 Hours
			4.5	0	0
4	General applications	Discussion on general industrial applications	*		
		Active and passive thermography	*		
SUBJECT		Topics	Cat 1 Hours	Cat 2 Hours	Cat 3 Hours
			1	2	2
5	Diagnostics and prognostics	Basic principles of diagnostics (ISO 13379)	*	*	*
		Basic principles of prognostics (ISO 13381-1)		*	*



SUBJECT		Topics	Cat 1 Hours	Cat 2 Hours	Cat 3 Hours
			4	10.5	7
6	Condition monitoring applications	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	Cat 1 Hours	Cat 2 Hours	Cat 3 Hours
			-	3	6
7	Corrective actions	Machinery corrective and/or preventive actions		*	*
SUBJECT		Topics	Cat 1 Hours	Cat 2 Hours	Cat 3 Hours
			1	0.5	0.5
8	Reporting and documentation (ISO International Standards)	Machinery corrective and/or preventive actions	*	*	*
		Thermographers' and end-users' responsibilities	*	*	*
SUBJECT		Topics	Cat 1 Hours	Cat 2 Hours	Cat 3 Hours
			0.5	0.5	3.5
9	Condition monitoring programme design (ISO 17359, ISO 18434-1, ISO 13379, ISO 13381-1)	General principles	*	*	*
		Technique selection		*	*
		Measurement intervals		*	*
		Reference temperatures	*	*	*
		Baseline temperatures	*	*	*
		Procedure development		*	*



SUBJECT		Topics	Cat 1 Hours	Cat 2 Hours	Cat 3 Hours
			1	1	1
10	Condition monitoring programme implementation (ISO 17359, ISO 13381-1, ISO 18434-1)	Overview	*		
		Safe systems of work	*	*	
		Roles and responsibilities		*	*
		Training and assessment		*	*
SUBJECT		Topics	Cat 1 Hours	Cat 2 Hours	Cat 3 Hours
			0.5	0.5	2
11	Condition monitoring programme management	Safety management	*	*	*
		Equipment management	*	*	
		Procedure management		*	*
		Skills and competencies management		*	*
		Database management	*	*	*
		Managing corrective action implementation		*	*
SUBJECT		Topics	Cat 1 Hours	Cat 2 Hours	Cat 3 Hours
			2.0	2.0	2.0
12	Training examination				
<b>Total Hours</b>			<b>32</b>	<b>32</b>	<b>32</b>

**NOTE 1:** Category 2 includes the knowledge of Category 1; Category 3 includes the knowledge of Category 1 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.



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
		Recognizing and dealing with conduction	
		Calibration	
		Environmental and operational conditions	Error source recognition, prevention or control
		Data storage	Data and image storage
3	Image processing	Temperature measurement	ISO 18434-1; non-contact thermometry; comparative quantitative and qualitative thermography; temperature trending
		Measurement functions	Camera measurement tools
		Accuracy	
		Emissivity measurements	Emissivity corrections
		Avoiding errors	
		Small spot size	
		Distance	Distance and atmospheric corrections
		Atmospheric attenuation	Environmental influences
		Support data collection and equipment	General principles
		Environmental data	Wind; rain; sun; reflections
		Software	Compatibility; area; statistical analysis; functions; principles
		Image interpretation	Emissivity; detectors; solar reflection; night reflection; qualitative evaluation; radiosity; image subtraction; image montage; general image interpretation guidelines
		Establishing thermal severity criteria (absolute, delta, statistical)	Principles; quantitative evaluation; maximum operating temperature; general guidelines for establishing thermal severity assessment criteria (ISO 18434-1, engineering codes and standards)



4	General applications	-	Discussion on general industrial applications not covered by the sector topics defined
		Mechanical	Principles; motors; pumps; gearboxes; engines; electric motors, compressors, fans; rotating equipment; reciprocating equipment; active and passive thermography
		Acceptance criteria	Principles; allowed temperatures and temperature drops
		Safety issues	Principles; risk assessment; health, safety and environment; electricity at work regulations; HV current breakers; maximum temperature; inspections; safety protocols
5	Diagnostics and prognostics	Diagnostics principles and processes	Principles; processes; ISO 13379
		Prognostic principles and processes	Principles; processes; motors; ISO 13381-1
6	Condition monitoring applications	Mechanical engineering (components and construction)	Principles; mechanisms; bearings; lubrication
		IR theory to mechanical applications and thermal signatures	Applications; signatures; steam traps; friction; lubrication, cooling, typical machinery failure modes and their associated thermal signatures; ISO 18434-1
		Applications	Limitations
		a) Rotating equipment	Drive shafts; bearings; gears, fans, motors, hydraulic drives; pumps; compressors; turbines; belt drives
		b) Fluid flow	Heat exchangers; clean laboratories; steam traps; pumps; boilers; valves; pressure vessels; pipes; condensates
		c) Power transmission	Pumps; valves; motors



		Fault analysis	Principles; pipe cladding; cryogenics; baseline
		Acceptance criteria	Baseline; acceptance principles; severity assessment and acceptance criteria (engineering codes and standards)
7	Corrective actions	Mechanical	Recommendations for pumps, bearings, motors, compressors, engines; machinery corrective and preventive actions
8	Reporting and documentation (ISO International Standards)		
9	Condition monitoring programme design	Overview	ISO 17359, ISO 18434-1, ISO 13379, ISO 13381-1; general principles
		Techniques selection	Thermal imaging; non-contact pyrometers; heat flux indicators; vibration analysis, oil analysis, acoustics, other CM techniques
		Measurement intervals	Principles
		Procedure development	Prioritization; costs; protocols; defect severity analysis
		Reference temperatures	Principles; severity of anomalies
		Baseline temperatures	Principles
10	Condition monitoring programme implementation	Overview	ISO 17359, ISO 13381-1, ISO 18434-1
		Safe systems of work	Procedures
		Roles and responsibilities	Relevant parts of ISO 18436
		Training and assessment	Relevant parts of ISO 18436
11	Condition monitoring programme management	Safety management	Protocols; risk assessment
		Equipment management	Principles
		Procedure management	Principles, ISO 17359
		Skills and competencies management	Relevant parts of ISO 18436
		Database management	ISO 13374, ISO 13372, ISO 13379

		Managing corrective action implementation	Principles; protocols; corrosion/temperature
--	--	---	--

## BIBLIOGRAPHY

- [1] ISO 9712, Non-destructive testing — Qualification and certification of NDT personnel
- [2] ISO/TR 25107, Non-destructive testing — Guidelines for NDT training syllabuses
- [3] ISO/TR 25108, Non-destructive testing — Guidelines for NDT personnel training organizations
- [4] Dewitt D.P., & Nutter G.D. Theory and Practice of Radiation Thermometry. John Wiley and Sons, Inc, 1988
- [5] Guyer E.C., & Brownell D.L. eds. Handbook of Applied Thermal Design. McGraw-Hill, 1989
- [6] Rohsenow W.M., & Hartnett J.P. eds. Handbook of Heat Transfer. McGraw-Hill, 1973
- [7] Holst G.C. Common Sense Approach to Thermal Imaging. SPIE — The International Society for Optical Engineering. JCD Publishing, ISBN 0-81943-722-0 ISBN 0-96400-007-5
- [8] Gaussorgues G . Infrared Thermography. Translated by S. Chomet (Original French Title: La Thermographie Infrarouge), Microwave Technology Series 5, English Language Edition, Chapman and Hall, 1994. ISBN 0-41247-900-1
- [9] Maldague X.P.V. ed. Infrared Methodology and Technology. Gordon and Breach Science Publishers
- [10] Kaplan H. Practical Applications of Infrared Thermal Sensing and Imaging Equipment. SPIE Optical Engineering Press Volume TT13. ISBN 0-81941-207-4
- [11] Kaplan H. ASNT Level III Study Guide Infrared/Thermal Method, American Society for Nondestructive Testing, Inc. ISBN 1-57117-015-4
- [12] Maldague, X.P.V. Infrared Technology for Nondestructive Testing, John Wiley and Sons, March 2001. ISBN 0-471-18190-0
- [13] Maldague X.P.V. Nondestructive Evaluation of Materials by Infrared Thermography. Springer- Verlag. ISBN 3-540-19769-9
- [14] McEvoy J.P., & Zarate O. Quantum Theory for Beginners. Icon Books Ltd., UK. ISBN 1-874166-37-4
- [15] Nondestructive Testing Handbook, third edition, Volume 3, Infrared and Thermal Testing  
(ed. Maldague, X.P.V. and Moore, P.O.), American Society for Nondestructive Testing, Inc. ISBN 1-57117-044-8
- [16] Nowicki A. Infrared Thermography — Applications. BINDT, ISBN 0-90313-232-X
- [17] Ohman C. Measurement in Thermography. FLIR Systems AB, 1557498 (Rev A)

[18] The Infrared Handbook (ed. Wolfe, W.L and Zissis, G.J.), prepared by the Infrared Information and Analysis Center and Environmental Research Institute of Michigan for the Office of Naval

Research, Department of the Navy, Washington, D.C., Library of Congress Catalog No. 77-90786. ISBN 0-96035-901-X

[19] Thomas R.A. Thermography Monitoring Handbook. Coxmoor Publishing Company, First Edition, 1999

[20] Von Baaeyer H.C. Warmth Disperses and Time Passes: The History of Heat. Random House, July 1999

[21] Walker N. Infrared Thermography — Theory & Practice. BINDT, ISBN 0-90313-233-8.

[22] Building Thermography (including blower door and heat flux meter) by Davide Lanzoni e-book creation: [www.iltuoebook.it](http://www.iltuoebook.it).

[23] Infrared Thermal Imaging – Fundamentals, Research and Applications, M. Vollmer, K.-P. Mollmann ISBN: 978-3-527-40717-0.

[24] Infrared Thermography Electrical and Industrial Applications by Davide Lanzoni, e-book <http://www.saige.it/>