MOBIUS INSTITUTE
BOARD of CERTIFICATION
1525 Frankston-Flinders Road
Tyabb
Victoria 3913
AUSTRALIA
Tel: +61 3 59774606
e-mail: certification.manager@mobiusicertification.org

SPECIFIC REQUIREMENTS FOR QUALIFICATION AND MIBoC CERTIFICATION OF INFRARED THERMOGRAPHY CONDITION MONITORING AND DIAGNOSTIC PERSONNEL

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1. Introduction

Using thermography to monitor condition and diagnose faults in machinery is a key activity in predictive maintenance programmes for most industries. The effectiveness of these programmes depends on the capabilities of individuals who perform the measurements and analyse the data.

This document follows on from document *ED002 - General Scheme Requirements*, and is designed to provide comprehensive information for users of the MIBoC Scheme, specifically for the technology of infrared thermography. The complete list of published MIBoC documents is detailed in *ED040 – List of MIBoC External Documents*, which is posted on the Mobius website at www.mobiuscertification.org, where all applicable documents are available for download free of charge.

It is intended, through publication of these documents, to provide industry, MIBoC candidates and certificate holders with all relevant information. However, if further information or advice is required on any certification matter, please contact the Certification Manager of the Mobius Institute Board of Certification on Tel +61 3 59797285, or email certification.manager@mobiuscertification.org.

2. Scope

This document sets out the specific requirements for qualification and MIBoC certification of personnel engaged in Infrared Thermography condition monitoring. In the event of a conflict between the requirements of *ED002 - General Scheme Requirements* and this document, the requirements specified in *ED002 - General Scheme Requirements* shall prevail.

This document is based on ISO 18436-7: Condition monitoring and diagnostics of machines – Requirements for qualification and assessment of personnel – Thermography.

Certification to this specification will provide evidence of the qualification and competence of individuals to perform infrared thermography measurements and analysis using appropriate sensors and equipment.

3. Classification of Personnel

3.1. General

Individuals certified in accordance with this specification are classified in one of three categories depending on their qualification. 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.

3.2. 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.

3.3. 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.

3.4. 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, write working procedures and instructions including 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 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;

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 III personnel have the necessary competency in the required management skills, for example creating budgets preparing cost justifications and managing personnel development.

4. Eligibility for Examination and Certification

4.1. General

In order to be eligible for MIBoC certification, candidates shall have a combination of education, training and experience to ensure that they understand the principles and procedures applicable to machinery thermographic measurement and analysis.

> Candidates shall have their colour perception assessed by the Ishihara 24 plate test. A record of test results should be retained and presented to the MIBoC upon request. If the candidate fails this test, indicated by misreading four or more of the 24 plates during the Ishihara test, a secondary colour shade perception test shall be administered by MIBoC to assess the candidate's ability to differentiate between shades of colours. Failure of both the Ishihara and the secondary test will result in conditional certification being issued (assuming all other certification requirement are met), noting that a colour perception deficiency may exist.

4.2. 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.

4.3. Training

4.3.1. Introduction

To be eligible for the MIBoC infrared certification examination, candidates shall provide evidence of successful completion of approved training based on the requirements of Annex A and which follows the requirements of ISO 18436-3, or which is otherwise recognised by the MIBoC IRT Technical Committee. A list of approved/recognised training courses can be found in (as listed in *ED144 – Approved IRT Training Courses*. 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. 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

4.3.2. 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 six (6) through to 11 inclusive. The duration of such training shall comply with the durations stated in Annex A for the relevant subject areas.

4.3.3. 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 3.2, 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.

4.3.4. Mature candidate entry

Mature candidate entry may be allowed at MIBoC's discretion.

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.

Mature candidates shall have at least 48 months of documented experience without significant interruption in thermography-based condition monitoring of machines. 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.

4.4. Experience

To be eligible to apply for MIBoC IRT certification the candidate shall provide evidence 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, except for mature candidates (as per 4.3.4 above*).* At each higher certification category, the breadth and depth of experience is expected to be greater than at the previous lower category.

Candidates must maintain a record of experience, and have it validated by a person certified to at least Category II or higher (for a Category I or II candidate) or Category III (for a Category III candidate), or in the absence of such persons, by the candidate's technical supervisor.

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

Note: the experience months are based on 16 hours per month of thermography-based machinery condition monitoring experience in accordance with Clauses 2 and 3.

5. Qualification Examination

5.1. Examination content

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

Table 3 – Examination details

Category	Number of questions	Time (hours)	Passing grade (%)
Category I	50	2	75
Category II	60	2	75
Category III	60	2	75
Supplementary exam	30	1	75

MIBoC may, at its discretion, make accommodations to assist candidates who have a disability in accordance with *ED002 - General Scheme Requirements*, clause 9.3, or for whom the language of the examination is a second language.

The examinations shall consist of questions which cover the topics listed in Annex A2. Questions will be of a practical nature and test the candidate's knowledge of the principles and procedures required to conduct infrared thermography for condition monitoring of machines.

The examination papers for Category I shall cover for quality data acquisition and error source recognition, prevention and control. The examination may include both physical data acquisition tasks in addition to image interpretation.

The examination papers for Category II shall cover diagnostics and image interpretation. The examination may include both physical data acquisition tasks in addition to image interpretation.

The examination papers for Category III 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. 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.

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

5.2. Conduct of Examinations

All examinations shall be conducted in accordance with ED002 – General Scheme Requirements Clause 11.

5.3. Supplementary examination

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.

Supplementary modular examinations will be graded separately.

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

Table A.1 – Training Syllabus

SUBJECT	Hours of training		
	Category I	**Category II**	**Category III**
0. Introduction	0.5	0	0
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	0	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	2	2
Total hours for each category	**32**	**32**	**32**

Table A.2 – Detailed list of topics and hours of instruction

Subject	Topics	CAT I	CAT II	CAT III
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		**6**	**7**	**6**
1.a)	Heat and heat transfer	*		
1.b)	Conduction fundamentals	*		
1.c)	Fourier's Law		*	*
1.d)	Conductivity/resistance	*		
1.e)	Convection fundamentals	*		
1.f)	Newton's Law of Cooling		*	*
1.g)	Radiation Fundamentals	*		
1.h)	Electromagnetic spectrum	*		
1.i)	Atmospheric transmission	*	*	
1.j)	IR wavebands and lens materials	*		
1.k)	Radiation reference sources		*****	*****
1.l)	Planck's Law		*	
1.m)	Wien's Law		*	
1.n)	Stefan-Boltzmann Law	*		
1.o)	Emmitance, reflectance and transmittance	*		
1.p)	Emissivity	*	*	*
1.q)	Factors affecting emissivity	*	*	*
2. Equipment and data acquisition		**5**	**3**	**1**
2.a)	How your infrared camera works	*		
2.b)	Infrared camera selection criteria		*	
2.c)	Spectral band	*	*	
2.d)	Temperature measurement range	*		
2.e)	Thermal sensitivity (NETD)		*	
2.f)	Lens selection	*	*	
2.g)	Optical resolution	*	*	
2.h)	Operation of equipment	*	*	
2.i)	Accessories	*	*	
2.j)	Camera controls	*		
2.k)	ISO 18434-1	*	*	
2.l)	Safe data acquisition	*	*	
2.m)	Getting a good image	*		
2.n)	Image composition	*	*	*

Subject	Topics	CAT I	CAT II	CAT III
2.o)	Image clarity (optical focus)	*		
2.p)	Thermal tuning (range, level and span)	*		
2.q)	Palette selection	*		
2.r)	Emissivity determination	*	*	
2.s)	Error source recognition, prevention or control	*	*	
2.t)	Waveband selection criteria		*	*
2.u)	Recognizing and dealing with radiation (reflections, reflected apparent temperature)	*	*	*
2.v)	Recognizing and dealing with convection	*	*	*
2.w)	Recognizing and dealing with conduction	*	*	*
2.x)	Effects of Emissivity	*	*	
2.y)	Camera calibration	*	*	
2.z)	Environmental and operational conditions	*	*	
2.aa)	Data and image storage	*		
3. Image processing		**6**	**2**	**1**
3.a)	Temperature measurement	*	*	
3.b)	ISO 18434-1	*	*	*
3.c)	Non-contact thermography	*		
3.d)	Comparative quantitative thermography	*	*	
3.e)	Comparative qualitative thermography	*	*	
3.f)	Environmental influences	*	*	
3.g)	Camera measurement tools	*	*	
3.h)	Measurement tools	*	*	
3.i)	Palette selection	*		
3.j)	Level and span adjustment	*		
3.k)	Distance (atmospheric) correction	*	*	
3.l)	Emissivity correction		*	
3.m)	Statistical analysis		*	
3.n)	Image subtraction		*	*
3.o)	Image montage	*	*	*
3.p)	Temperature trending	*	*	*
3.q)	General image interpretation guidelines	*	*	*
3.r)	General guidelines for establishing thermal severity assessment criteria (ISO 18434-1, engineering codes and standards)		*	*
4. General applications		**4.5**	**-**	**-**

Subject	Topics	CAT I	CAT II	CAT III
4.a)	Discussion on general industrial applications	*		
4.b)	Active and passive thermography	*		
5. Diagnostics and prognostics		**1**	**2**	**2**
5.a)	Basic principles of diagnostics (ISO 13379)	*	*	*
5.b)	Basic principles of prognostics (ISO 13381-1)		*	*
6. Condition monitoring applications		**4**	**10.5**	**7**
6.a)	Machinery engineering principles (components and construction)	*	*	*
6.b)	Typical machinery failure modes and mechanisms and their associated signatures	*	*	*
6.c)	Severity assessment and acceptance criteria (engineering codes and standards)	*	*	*
6.d)	Safety issues	*	*	*
6.e)	ISO 18434-1	*	*	*
7. Corrective actions		**-**	**3**	**6**
7.a)	Machinery corrective and/or preventative actions		*	*
8. Reporting and documentation (ISO International Standards)		**1**	**0.5**	**0.5**
8.a)	Report writing	*	*	*
8.b)	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**
9.a)	General principles	*	*	*
9.b)	Technique selection		*	*
9.c)	Measurement intervals		*	*
9.d)	Reference temperatures	*	*	*
9.e)	Baseline temperatures	*	*	*
9.f)	Procedure development		*	*
10. Condition monitoring programme implementation (ISO 17359, ISO 13381-1, ISO 18434-1)		**1**	**1**	**1**
10.a)	Overview	*		
10.b)	Safe systems of work	*	*	
10.c)	Roles and responsibilities		*	*
10.d)	Training and assessment		*	*
11. Condition monitoring programme management		**0.5**	**0.5**	**2**
11.a)	Safety management	*	*	*
11.b)	Equipment management	*	*	*
11.c)	Procedure management		*	*

Subject	Topics	CAT I	CAT II	CAT III
11.d)	Skills and competencies management		*	*
11.e)	Database management	*	*	*
11.f)	Managing corrective action implementation		*	*
12. Training examination		**2**	**2**	**2**
TOTAL HOURS		**32**	**32**	**32**

Note 1: Category II includes the knowledge of Category I; Category III includes the knowledge of Category I and 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 hours 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
	Recognising 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 thermography; 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 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
	Prognostics 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 a) Rotating equipment b) Fluid flow c) Power transmission	Limitations Drive shafts; bearings; gears, fans, motors, hydraulic drives; pumps; compressors' turbines; belt drives heat exchangers; clean labs; steam traps; pumps; boilers; valves; pressure vessels; pipes; condensates 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 preventative 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