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CM/GEN APPENDIX B Issue 2 rev B

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

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The British Institute of Non-Destructive Testing is an accredited certification body offering personnel and quality management systems assessment and certification against criteria set out in international and European standards through the PCN Certification Scheme.



Introduction

The use of Infrared Thermography (IRT) using measurements of surface temperature to monitor condition and diagnose faults in civil, mechanical and electrical systems has become 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 is appended to CM/GEN (General requirements for the qualification and PCN certification of condition monitoring personnel). Other Appendices cover:

- Appendix A Acoustic Emission
- Appendix C Lubrication Management and Analysis
- Appendix D Vibration Analysis

This series of documents is designed to provide comprehensive information for users of the PCN Scheme. The complete list of published PCN condition monitoring documents is detailed in publication reference PSL/8A-CM, which is posted on the Institute's web site at www.bindt.org, where all documents are available for download free of charge.

It is intended, through publication of these documents, to provide industry, PCN candidates and certificate holders with all relevant information. However, if further information or advice is required on any certification matter, contact the Certification Services Division of BINDT on telephone number +44 (0) 1604 259056, or email pcn@bindt.org.

Organisations requiring at all times to be in possession of the most up to date PCN documents may register with the "PCN Update Scheme" which, for a small annual fee, guarantees that they automatically receive all new and revised PCN documents.

Definitions

Civil: The term 'Civil' when used in this document includes buildings, structures, roads and bridges.

Mechanical: The term 'Mechanical' when used in this document includes mechanical systems and associated processes.

Electrical: The term 'Electrical' when used in this document includes low and high voltage electrical systems, but does not include electronic systems.

Supplementary examination: The term supplementary examination when used in this document refers to an additional sector-specific examination available at Categories 2 and 3 only, and attempted either during, or after the first examination that consists of the general part and at least one other sector-specific part.

1. Scope

- 1.1. This appendix to PCN CM/GEN sets out the specific requirements for qualification and assessment of personnel engaged in Infrared Thermography Condition Monitoring. In the event of a conflict between the requirements of PCN CM/GEN and this Appendix, the PCN CM/GEN requirements shall prevail.
- 1.2. This specification is in accordance with ISO 18436 part 7: Condition monitoring and diagnostics of machines- Requirements for qualification and assessment of personnel- Thermography.
- 1.3. Certification to this specification will provide evidence of the qualification and assessment of individuals to perform Infrared Thermography measurements and analysis using appropriate sensors and equipment.

2. Classification of Personnel

- 2.1. General
 - 2.1.1. Individuals certificated in accordance with this specification are classified in one of three Categories and have demonstrated the necessary skills in the

concepts of thermographic analysis and thermal condition monitoring for their classification Category as indicated in the examination syllabus at Annex A.

2.1.2. Personnel classified as Category 2 require all the knowledge and skills expected of personnel classified as Category 1, and personnel classified as Category 3 require all the knowledge and skills expected of personnel classified as Category 2.

2.1.3. Those personnel seeking to be classified as Category 2 or Category 3 can elect to qualify in any or all of three industry sectors, as specified at clause 5.

2.2. Infrared Thermography Category 1 (General)

PCN certificated Infrared Thermography Category 1 personnel are qualified to perform industrial infrared thermography measurements according to established and recognised procedures and shall be able to:

2.2.1. apply a specified thermographic measurement technique;

2.2.2. set up and operate equipment for safe thermographic data collection;

2.2.3. perform basic infrared thermography of plant and machinery, buildings and electrical systems;

2.2.4. verify the calibration of the measurement systems and the integrity of collected data

2.2.5. prevent, minimise or control poor data (sources of data error);

2.2.6. maintain a data base of results and trends;

2.2.7. perform basic fault detection severity assessment and diagnosis in accordance with established instructions;

2.2.8. perform basic image post processing (measurement tools, emissivity adjustment, span and scale adjustment etc);

2.2.9. verify the calibration of thermographic measurement systems;

2.2.10. evaluate and report test results in accordance with established instructions and highlight areas of concern.

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

2.3. Infrared Thermography Category 2.

Individuals certificated as Infrared Thermography Category 2 are qualified to perform and/or direct infrared thermography analysis according to established and recognised procedures. Category 2 personnel shall be able to:

2.3.1. select the appropriate infrared thermography technique and understand its limitations;

2.3.2. specify the appropriate hardware and software for both portable and permanently installed systems;

2.3.3. measure and analyse thermographic data;

2.3.4. perform advanced image post processing (trending, montage, image subtraction, statistical analysis etc) and diagnosis;

2.3.5. apply thermography theory and techniques, including measurement and interpretation of survey results;

2.3.6. recommend appropriate corrective actions;

2.3.7. prepare reports on condition, recommend corrective action and report on effectiveness of repairs;

2.3.8. provide technical direction for personnel at or below Category 2;

2.3.9. supervise and instruct all Category 1 duties;

- 2.3.10. establish infrared thermography programmes including determination of the requirement for periodic /continuous monitoring, frequency of testing, etc;
- 2.3.11. establish acceptance and severity criteria;
- 2.3.12. establish programmes for acceptance for new and in-service systems;
- 2.3.13. recommend the use of alternative CM technologies with an awareness of the principles of other CM technologies specified in CM/GEN, at least to Category 1.

2.4. Infrared Thermography Category 3

Individuals certificated as Infrared Thermography Category 3 are qualified to perform and/or direct all types of infrared thermography measurements and analysis and shall be able to:

- 2.4.1. determine the thermographic signature of systems, components and assemblies (sector specific, where applicable);
- 2.4.2. establish infrared thermography programmes including determination of the requirement for periodic /continuous monitoring, frequency of testing, etc.;
- 2.4.3. establish acceptance and severity criteria;
- 2.4.4. establish programmes for acceptance for new and in-service systems;
- 2.4.5. understand and perform data analysis;
- 2.4.6. use advanced techniques of infrared thermography and fault diagnosis;
- 2.4.7. recommend appropriate types of thermodynamic (radiation, convection, conduction based) corrective actions;
- 2.4.8. supervise trainees and Category 1 and 2 personnel;
- 2.4.9. guide personnel below Category 3;
- 2.4.10. interpret and evaluate Standards, Codes, specifications and procedures;
- 2.4.11. perform prognostics for fault conditions;
- 2.4.12. prepare reports on machine civil and electrical systems condition, recommended appropriate corrective actions and effectiveness of repairs;
- 2.4.13. direct the use of alternative CM technologies with an understanding of the principles of other CM technologies specified in CM/GEN, at least to Category 1.
- 2.4.14. manage and supervise PCN CM qualification examinations on behalf of the British Institute of NDT, if so appointed.

3. Eligibility for Examination and Certification

3.1. General

Candidates shall have a combination of education, training and experience to ensure that they understand the principles and procedures applicable to thermographic measurement and analysis. Colour vision requirement in this scheme is specified in the following delta.

ISO 18436-7 recommends that candidates have colour perception tested to the criteria of the Ishihara test, where it may be required of employers to determine whether failure to meet the requirements of this test will affect the candidate's ability to perform analysis on IRT data using colour palettes. Failure to pass the Ishihara 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 the record of the test made available to the certifying body upon request. The PCN scheme will not enforce this recommendation as (1) recording of the candidates failure of the Ishihara test and limiting their work to monochrome palettes could potentially limit his/her employment and yet he/she may be capable of interpreting colour images if the degree of colour blindness is not severe, (2) the pass/fail criteria of the Ishihara test is not necessarily indicative of a persons ability to

interpret colour differences on a thermogram.

3.2. Training

3.2.1 At 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. At Category 2 it will cover diagnostics and image interpretation for condition monitoring of machines, electrical or civil systems and image interpretation. At Category 3 it will include all topics for Categories 1 and 2 and include solution design and verification.

3.2.2 The image interpretation questions should be based on case histories requiring fault identification, solution recommendation and a solution verification process.

Category 1	Category 2	Category 3
33	79	120

3.2.3 Training may be modularised 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 (eg: EN473, ISO9712, SNT-TC-1A) and other condition monitoring assessment bodies (2nd or 3rd party).

3.2.4 In addition to the training hours in Table 1 and formal education specified in CM/GEN, Category 2 candidates only, should have completed formal or on-the-job training on mechanical, electrical or civil engineering, with either a training examination certificate or verifiable records (PSL30-CM), including the relevant systems and components, of at least a similar duration to that in Table 1, which covers the sector specific certification sought. This training should cover design, manufacture, installation, operation and maintenance principles relevant to the sector (civil, mechanical or electrical systems), and include failure mechanisms associated with each principle and the typical thermodynamic signatures associated with each mechanism.

3.3. Experience

- 3.3.1. To be eligible to apply for certification the candidate shall provide evidence of experience in the field of machinery, electrical or civil infrared thermography condition monitoring, appropriate to the Category and sector sought. The minimum experience requirements are shown in Table 2.
- 3.3.2. The experience duration in months, not in hours, for Categories 1 and 2 may be reduced by up to 50% (i.e. to 6 months) when the candidate has undertaken prior training and certification through a classification process that includes a significant practical examination (eg: EN473, ISO 9712 or SNT-TC-1A qualified candidates- under the mutual recognition clause 3.3.5).
- 3.3.3. Certification at Category 2 and Category 3 requires previous certification at the lower Categories.
- 3.3.4. Candidates must maintain verifiable documentary evidence and log of hours and nature of work (see ISO18436-7 clause 5.4), especially scanning (practical) times, on PCN document CP16 (Category 1 and 2) or CP17 (Category 3).

Category 1	Category 2	Category 3
12*	24*	48*
400 hours**	1200 hours**	1920 hours**

*Work experience in months is based on a nominal 40 hour Week (160hours/month). **Indicates the minimum cumulative scanning (inspection/practical) and/or interpretation experience requirements in hours. .

4. Certification Available

- 4.1 Category 1 (IRT-General)
- 4.2 Category 2 (IRT- Civil, IRT-Mechanical, IRT-Electrical)
- 4.3 Category 3 (IRT- Civil, IRT-Mechanical, IRT-Electrical)

Category 2 and 3 candidates may attempt any or all modules in one sitting.

5. Qualification Examinations

- 5.1 Application for qualification examinations
 - 5.1.1 Application for qualification examination is made on PCN form PSL/57-CM and supported with PSL/30-CM and PSL/33-CM where required.
- 5.2 Initial examination
 - 5.2.1 Category 1 Candidates are required to be successful in a multiple choice examination paper covering the basic principles and practical knowledge of the CM technology in terms of civil, mechanical and electrical engineering and basic thermography theory. The examination will also test for quality data acquisition and error source recognition, prevention and control.
 - 5.2.2 Category 2 and Category 3 candidates for Infra-red Thermography are required to be successful in a multiple choice examination comprising at least two modules covering:
 - 5.2.2.1 the basic principles and practical knowledge of Infra-red Thermography;

5.2.2.2 at least one practical applications module paper on the specific application of Infra-red Thermography in the civil, mechanical or electrical engineering sector, as selected by the candidate. At Category 2 the practical applications sector paper will cover diagnostics and image interpretation. At Category 3 the sector paper will cover diagnostics, prognostics, image interpretation, solution design and solution verification. The practical sector specific module pertains to subjects 6, 7 or 8 in Annex A2, but must also include material derived from subjects 9, 10, 11, 12 and 13 for the respective sector.

5.2.2.3 the basic principles of alternative condition monitoring technologies as defined in Table A2.

5.2.2.4 Category 3 examination papers have a narrative component (see below).

5.3 Supplementary practical applications examination

5.3.1 Supplementary modular practical examinations are only available to existing PCN Infra-red Thermography Category 2 or Category 3 certificate holders. This examination comprises separate supplementary modules covering civil, mechanical or electrical engineering, as selected by the candidate.

5.3.2 Supplementary examination modules will be graded separately, so that a candidate electing to attempt two modules at the same examination sitting may be awarded certification for a module in which success was achieved, even if the other module was failed.

5.3.3 Supplementary examination candidates must have satisfactorily completed a course of training covering the syllabus to be examined, and provide documentary evidence of the training.

5.4 Examination content (Theory and practical knowledge)

5.4.1 For each certification Category, the candidates shall be required to answer the fixed number of multiple choice questions in the two-part written paper, within specified time duration as indicated in Table 3. Part A covers general theory and Part B is the sector specific practical application module paper. At Category 3, 10% of each part of the examination paper will consist of narrative questions. In a 30 question paper module three narrative questions will be offered but only two need to be answered.

5.4.2 Each narrative question will be worth 5 points.

5.4.3 The examination will cover the training syllabus at Annex A2.

5.4.4 Questions will test the candidate's knowledge of the principles and procedures required to conduct infrared thermography condition testing and analysis in the sector (machinery, electrical or civil) that the examination pertains.

5.4.5 Questions are of a practical nature and include the interpretation of practical data and thermal images and simple mathematical calculations using a basic scientific calculator may be required.

5.4.6 The Category 1 examination paper will comprise 60 questions covering the general topics listed in Annex A2. The Category 2 and 3 examination papers will comprise general (30 questions) and practical application specific (30 questions) parts. Modules will be graded separately. Examinations for additional sector specific modules will comprise 30 questions per module, as noted in Table 3.

Table 3 – qualification examination content			
Categories	Number of Questions	Time (Hours)*	Passing Grade %
Category 1	60	2.0	75
Category 2 (General + 1 st sector module)	60 (30 + 30)	2.0	75
Category 2 (Supplementary module)	30	1.0	75
Category 3 (General + 1 st sector module)	60 (30 + 30)	3.0	75
Category 3 (Supplementary module)	30	1.0	75

*Examination times include a 30 minute reading period to assist candidates with English as a second language or any disability in accordance with CMGEN clause 9.3 and for Category 3 narrative questions.

Annex A1 Training Syllabus

Subject	Hours of training		
	Category 1	Category 2 [Only 1 module from subjects 6,7 or 8]	Category 3 [Only 1 module from subjects 6,7 or 8]
0. Introduction	0.5	-	-
1. Principles of IRT	6	6	6
2. Equipment and data acquisition	5	3	1
3. Image Processing	6	2	1
4. Condition Monitoring	3	1	8
5. General Applications	4.5	0	0
6. Electrical Applications	-	24	7
7. Mechanical Applications	-	24	7
8. Civil Applications	-	24	7
9. Condition monitoring programme design and Acceptance testing	0.5	0.5	3.5
10. Condition monitoring programme implementation	1	1	1
11. Condition monitoring programme management	0.5	1	2
12. Corrective Actions	-	3	6
13. Codes and standards	1	1	2
14. Reporting and documentation (ISO Standards)	1	0.5	0.5
15. Diagnostics & prognostics	1	2	2
16. Training examination	1	1	1
17. Practical skills evaluation*	2		
Total hours for each Category	33	46	41

Annex A2 – Detailed list of Topics and hours of Instruction

SUBJECT	Category 1 Hours	Category 2 Hours	Category 3 Hours
0. Introduction	0.5	-	-
1. Principles of IRT	6	6	6
1. Heat transfer	*		
2. Electromagnetic spectrum	*		
3. Emittance, reflectance and transmittance	*		
4. Atmospheric transmission	*		
5. IR wavebands and lens materials	*		
6. Conduction Fundamentals	*		
7. Fourier's Law		*	*
8. Conductivity/Resistance	*		
9. Convection Fundamentals, Newton's Law of Cooling	*		
10. Radiation Fundamentals	*		
11. Planck's Law		*	*
12. Wien's Law		*	*
13. Stefan Boltzmann Law	*		
14. Material evaluation	*	*	*
2. Equipment and data acquisition	5	3	1
1. How your imager works	*		
2. Selection criteria		*	*
3. Range and Category settings	*		
4. Operation of Equipment	*		
5. Controls	*		
6. Lenses	*		
7. Getting a good image	*		
8. Clarity (focus)	*		
9. Dynamic Range	*	*	*
10. Recognising and dealing with reflections	*		
11. Recognising and dealing with convection		*	*
12. Calibration	*		
13. Environmental and operational conditions	*		
14. Data storage	*		
3. Image Processing	6	2	1
1. Temperature Measurement	*		
2. Measurement functions	*		
3. Accuracy	*		

SUBJECT	Category 1 Hours	Category 2 Hours	Category 3 Hours
4. Emissivity measurements	*	*	
5. Avoiding Errors (error source recognition, prevention or control)	*		
6. Small spot size	*		
7. Distance	*	*	
8. Atmospheric Attenuation	*		
9. Support Data Collection and Equipment		*	*
10. Environmental Data	*	*	*
11. Software		*	*
12. Image Interpretation	*	*	*
13. Establishing thermal severity criteria (absolute, Delta, statistical)		*	*
4. Condition Monitoring	3	1	8
1. Fundamental principles	*		
2. Control values	*		
3. Alternate technologies		*	*
4. Correlation of CM techniques	*		*
5. Procedure writing			*
5. General Applications	4.5	0	0
1. Electrical	*		*
2. Mechanical	*		*
3. Civil	*		*
6. Electrical Applications	-	24	7
1. Electrical engineering (components & construction)		*	*
2. IR theory to electrical applications and thermal signatures		*	*
3. Applications		*	*
3a. Electrical distribution		*	*
3b. Electrical panels		*	*
3c. Electrical components		*	*
3d. Electric motors		*	*
4. Fault analysis		*	*
5. Safety issues		*	*
7. Mechanical Applications	-	24	7
1. Mechanical engineering (components & construction)		*	*
2. IR theory to mechanical applications and thermal signatures		*	*

SUBJECT	Category 1 Hours	Category 2 Hours	Category 3 Hours
3. Applications		*	*
3a. Rotating equipment		*	*
3b. Fluid flow		*	*
3c. Power transmission		*	*
3d. Furnaces		*	*
3e. Tanks		*	*
4. Fault analysis		*	*
5. Safety issues		*	*
8. Civil Applications	-	24	7
1. Civil engineering (components & construction)		*	*
1a. Construction types		*	*
1b. Material types		*	*
2. IR theory to civil applications and thermal signatures		*	*
2a. Properties of materials		*	*
2b. Environmental conditions		*	*
3. Building envelope		*	*
3a. Insulation		*	*
3b. Moisture		*	*
3c. Air leakage/air tightness		*	*
4. Other structures		*	*
4a. Structural details and defects		*	*
4b. Structural finishes		*	*
5. Fault analysis		*	*
6. Safety issues		*	*
9. Condition monitoring programme design and Acceptance testing	0.5	0.5	3.5
1. Overview	*	*	*
2. Techniques selection (include VA, AE, LM)		*	*
3. Measurement intervals		*	*
4. Procedure development		*	*
5. Reference temperatures		*	*
6. Baseline temperatures		*	*
10. Condition monitoring programme implementation	1	1	1
1. Overview	*	*	*
2. General safety		*	*
3. Roles and responsibilities		*	*
4. Training and accreditation		*	*

SUBJECT	Category 1 Hours	Category 2 Hours	Category 3 Hours
11. Condition monitoring programme management	0.5	1	2
1. Safety management		*	*
2. Equipment management		*	*
3. Procedure management		*	*
4. Skills and competencies management		*	*
5. Database management		*	*
6. Managing corrective action implementation		*	*
12. Corrective Actions	-	3	6
1. Electrical		*	*
2. Mechanical		*	*
3. Civil		*	*
13. Codes and Standards	1	1	2
1. Overview (ISO 18434, 18436)	*	*	*
2. Electrical		*	*
3. Mechanical		*	*
4. Civil		*	*
5. Diagnostics		*	*
6. Prognostics		*	*
7. Safety		*	*
14. Reporting and documentation (ISO Standards)	1	0.5	0.5
1. Presentation	*	*	*
2. Clients' needs	*	*	*
3. Thermographers' and end-users responsibilities (all sectors)	*	*	*
15. Diagnostics & prognostics	1	2	2
1. Diagnostics principles and processes	*	*	*
2. Prognostic principles and processes	*	*	*
16. Training examination	1	1	1
17. Practical skills evaluation	2		
Total Hours	33	46** [Only 1 module from subjects 6, 7 or 8]	41** [Only 1 module from subjects 6, 7 or 8]

Notes:

1. Category 2 includes the knowledge of Category 1; Category 3 includes the knowledge of Category 1 and Category 2.

2. The topics specific to each sector [topics 6, 7 and 8] at Category 2 and 3 are modularised, so that the candidate can gain training from various ATO's that may specialise in the sectors of application sought for certification.
3. ** At Categories 2 and 3 the times allocated are indicative only, indicating the bias towards application topics, and the actual times spent for each topic is flexible, providing an advised minimum of approximately 24 hours is allocated per field of application.

Annex B – Reading references

Essential Reading (material from which examination questions can be developed)

Categories	Title	Author(s)	Publisher	Reference
1, 2, 3	ASNT Category 3 Study Guide- Infrared and Thermal Testing Method	H Kaplen	American Society of Non Destructive Testing, 2001	ISBN 1571170154
2, 3	Safe Thermal Imaging of Electrical Systems	C. Pearson	UK Thermography Association, 1997	Application Guide AG/97
2, 3	Thermal Imaging of Building Fabric	C. Pearson	BSRIA	ISBN 086022- 590-9
1, 2, 3	Common sense approach to thermal imaging	G C Holst	Society of Photo- Optical Instrumentation Engineers, 2000	ISBN 0819437220
1, 2, 3	Infrared Thermography- Applications	A Nowicki	BINDT	090313232X
2, 3	Measurement in Thermography	C. Ohman	FLIR Systems AB	1557498 Rev A
3	Condition-based Maintenance using Non-Destructive Testing: Application Guide AG 1/2003	C Pearson A Seaman	BSRIA	ISBN 860226115
1, 2, 3	Infrared Thermography- Theory & Practice	N Walker	BINDT	0903132338
3	Acoustic emission and ultrasonics	T Holroyd	Coxmoor	1901892077
3	Vibration monitoring handbook	C W Reeve	Coxmoor, 1998	190189200X
3	The wear debris analysis handbook	B J Roylance & T M Hunt	Coxmoor, 1999	1901892026
3	Oil Analysis	Evans and Hunt	Coxmoor	1901892050
3	Defects in Buildings, symptoms, investigation, diagnosis and cure',	M Billington; 2001	Carillion Services	ISBN 0117024368
2,3	Measuring Air Permeability of Building Envelopes –Technical Standard 1.	ATTMA	ATTMA; 2006	NA
2,3	Airtightness testing- The essential guide to Part 2 of the 2006 Building Regulations (UK)- BG4/2006	David Pickavance and Tom Jones	BSRIA, 2006	086022662X
2,3	Airtightness testing for new Dwellings; A practical guide for builders and testers (UK); BG11/2004	Nigel Potter and Chris Knights	BSRIA, 2004	0860226484

Standards, codes and specifications (Material from which examination questions can be developed)

1. ISO 13374. Part 1. Condition monitoring and diagnostics of machines- Data processing, communication and presentation: Part 1. general Guidelines
2. ISO 13372, Condition monitoring and diagnostics of machines- vocabulary
3. ISO 17359, Condition monitoring and diagnostics of machines- general guidelines
4. ISO 13379, Condition monitoring and diagnostics of machines- Data interpretation and diagnostic techniques.- General guidelines
5. CMGEN, General requirements for qualification and PCN certification of condition monitoring and diagnostic personnel
6. ISO 13381-1, Condition monitoring and diagnostic of machines; prognostics: Part 1 general Guidelines
7. ISO 18436-1, Condition monitoring and diagnostics of machines; requirements for qualification and assessment of personnel. Part 1, Requirements for certifying bodies and the certification process
8. ISO 18436-7, Condition monitoring and diagnostics of machines; requirements for qualification and assessment of personnel. Part 7, Thermography
9. ISO 18434-1. Condition monitoring and diagnostics of machines. Thermography. Part 1: General procedures.
10. BS 5760-5. Reliability of systems, equipment and components: Guide to failure modes, effects and criticality analysis (FMEA and FMECA). ISBN 0580 196607
11. BS 5760-7 (IEC 61025). Reliability of systems, equipment and components. Fault tree analysis. ISBN 0580 203387
12. ISO 13187. Thermal performance of buildings- Qualitative detection of thermal irregularities in building envelopes- Infrared method

Recommended reading (Informative) (material that contains helpful information on a related subject)

Category	Title	Author(s)	Publisher	ISBN/Publ No
1, 2	Product Technology Classroom Training Handbook		BINDT	NA
2, 3	Practical Applications of Infrared Thermal Sensing and Imaging Equipment	H Kaplen	Society of Photo-Optical Instrumentation Engineers, 1999, 2 nd Edition	0819431389
2,3	NFPA 70E Standard for electrical safety in the workplace	NFPA	NFPA (USA), 2004 Edition	NA
3	Business-focussed Maintenance- A BSRIA Guide	J Harris, P Hastings	BSRIA, 2004 BG/3/2004	0860226042
3	NFPA 70B Recommended practice for electrical equipment maintenance	NFPA	NFPA (USA), 2002 Edition	NA

Annex C- Category 2 Training sub-topics (informative)

This is a guide to the topics that need to be covered. This list is not exhaustive (not all sub-topics listed).

Topics	Sub-topics
1. Principles of IRT	
<ol style="list-style-type: none"> 1. Heat transfer 2. Electromagnetic spectrum 3. Emittance, reflectance and transmittance 4. Atmospheric transmission 5. IR wavebands and lens materials 6. Conduction Fundamentals 7. Fourier's Law 8. Conductivity/Resistance 9. Convection Fundamentals, Newton's Law of Cooling 10. Radiation Fundamentals 11. Planck's Law 12. Wien's Law 13. Stefan Boltzmann Law 	<p>Factors affecting emissivity, reflectance and transmittance;</p> <p>Heat flow; conduction; target thickness; general principles</p> <p>Reference sources; Emissivity; real temperature difference; general principles; blackbodies; General principles</p>
2. Equipment and data acquisition	
<ol style="list-style-type: none"> 1. How your imager works 2. Selection criteria 3. Range and Category settings 4. Operation of Equipment 5. Controls 6. Lenses 7. Getting a good image 8. Clarity (focus) 9. Dynamic Range 10. Recognising and dealing with reflections 11. Recognising and dealing with convection 12. Calibration 13. Environmental and operational conditions 14. Data storage 	<p>NETD; frame repetition; object size; distances; transmissivity; IFOV; filters; detectors; resolution; palette selection; inappropriate waveband selection; incorrect emissivity;</p> <p>Temperature measurement range; thermal tuning (range, Category and span); Accessories; emissivity determination;</p> <p>Lens material, selection; Image composition; Optical resolution; focus; General principles; MRTD; NETD; Reflections; reflected apparent temperature; Roofs; ground; structures; mass transport;</p> <p>Error source recognition, prevention or control</p> <p>Data and image storage</p>
3. Image Processing	
<ol style="list-style-type: none"> 1. Temperature Measurement 2. Measurement functions 3. Accuracy 4. Emissivity measurements 5. Avoiding Errors 6. Small spot size 7. Distance 8. Atmospheric Attenuation 9. Support Data Collection and Equipment 10. Environmental Data 11. Software 	<p>ISO/DIS18434; non-contact thermometry; comparative quantitative and qualitative thermography; temperature trending; Camera measurement tools;</p> <p>Emissivity corrections;</p> <p>Distance and atmospheric corrections; Environmental influences; General principles; Wind; rain; sun; reflections; compatibility; area ; statistical analysis; functions; principles;</p>

Topics	Sub-topics
12. Image Interpretation	Emissivity; detectors; solar reflection; night reflection; qualitative evaluation; radiosity; image subtraction; image montage; general image interpretation guidelines;
13. Establishing thermal severity criteria (absolute, Delta, statistical)	Principles; quantitative evaluation; maximum operating temperature; general guidelines for establishing thermal severity assessment criteria (ISO/DIS 18434, Engineering codes and standards)
4 Condition Monitoring	
1. Fundamental principles 2. Control values 3. Alternate technologies 4. Correlation of CM techniques 5. Procedure writing	VA, LM, AE, motor current analysis
5. General Applications	Discussion on general industrial applications not covered by the sector topics defined.
1. Electrical 2. Mechanical 3. Civil	MCB; MCC; HV lines; LV lines; sub-stations; micro-electronics; active and passive thermography; Principles; motors; pumps; gearboxes; engines; pumps; compressors, fans; rotating equipment; reciprocating equipment; steam traps; active and passive thermography; Buildings; bridges; viaducts; roads; ground; materials; diffusivity; thermal capacity; concrete; de-laminations; corrosion; materials in general; active and passive thermography;
6. Electrical Applications	
1. Electrical engineering (components & construction) 2. IR theory to electrical applications and thermal signatures 3. Applications 3a. Electrical distribution 3b. Electrical panels 3c. Electrical components 3d. Electric motors 4. Fault analysis 5. Safety issues	Principles; load current; heat transfer paths; Principles; 3-phase motor drives; cable insulation; PVC, Cu; conductivity; MCC, MCB, LV/HV lines; MICC cables; transformers Busbars; MCC; MCB; transmissivity; Perspex; windows; Crimping; batteries; principles; construction; circuit breakers; Motors; principles; construction; bearings Isolators; sub-stations; load current; colour palette, principles, MCC, MCB, BS 7671 Principles; allowed temperatures and temperature drops; Principles; risk assessment; health, safety and environment; Electricity at Work regulations; HV current breakers; maximum temperature; inspections; safety protocols
7. Mechanical Applications	
1. Mechanical engineering (components & construction) 2. IR theory to mechanical applications and thermal signatures 3. Applications 3a. Rotating equipment	Principles; mechanisms; bearings; Applications; signatures; steam traps; propane/butane tanks; friction; typical machinery failure modes and their associated thermal signatures; ISO/DIS18434, valves Limitations Drive shafts; bearings; worm and wheel fan drives; fans;

Topics	Sub-topics
3b. Fluid flow	Heat exchangers; clean labs; steam traps; pumps; boilers; safety valves; pressure vessels; pipes; condensates
3c. Power transmission 3d. Furnaces 3e. Tanks 4. Fault analysis 5. Safety issues	Belts; pumps; fan drive; Construction; refractories; components; windows; quartz Tanks; pressure vessels; floating roofs; Principles; Pipe cladding; cryogenics; baseline; paper machines; Baseline; acceptance principles; severity assessment and acceptance criteria (engineering codes and standards); Risk assessment; principles and protocols; superheated steam systems;
8. Civil Applications	
1. Civil engineering (components & construction) 1a. Construction types 1b. Material types 2. IR theory to civil applications and thermal signatures 2a. Properties of materials 2b. Environmental conditions 3. Building envelope 3a. Insulation 3b. Moisture 3c. Air leakage 4. Other structures 4a. Structural details and defects 4b. Structural finishes 5. Fault analysis 6. Safety issues	Principles, components and construction; thermal bridging; sick building syndrome; Types; buildings, historical, 1880-1940 structures, post 1940 structures; roads; bridges; Materials (concrete, glass, steel, timber, plastics); emissivity; Principles and applications; signatures Conduction; phase change; cryogenics; Direct transfer; night-day; wind; rain; sun; Principles; construction; rules; mechanisms; Active and passive surveys; resolution; night surveys; wind; moisture; types; flux; freezers/cryogenics Condensation; affects of moisture; industrial/domestic buildings; roofs; Pressure differentials; temperature differentials; building construction and anomalies; permeability; Buried tanks; roads; viaducts; bridges Gas turbines; boilers; tanks; refractories; ducts; pipes; walls; windows; Concrete block; rendering; paints; surfaces; de-bond Grilles; SW/LW systems; pipes; solar reflection; principles; anomalies; reflections from other bodies Warranty period; solar path; environmental conditions; construction-type-materials; detection of anomalies; roof surveys
9. Condition monitoring programme design and Acceptance testing	
1. Overview 2. Techniques selection 3. Measurement intervals 4. Procedure development 5. Reference temperatures 6. Baseline temperatures	CMGEN; ISO17359, 18434, 13379, 13381; general principles Thermal imaging; non-contact pyrometers; heat flux indicators; Principles; Prioritisation; costs; protocols; defect severity analysis Principles; severity of anomalies; Principles
10. Condition monitoring programme	

Topics	Sub-topics
implementation	
1. Overview	ISO 17359, 13381, ISO 18434
2. Safe systems of work	Procedures
3. Roles and responsibilities	
4. Training and accreditation	CMGEN, ISO 18436-1,3
11. Condition monitoring programme management	
1. Safety management	Protocols; risk assessment
2. Equipment management	Principles
3. Procedure management	Principles, ISO 17359
4. Skills and competencies management	CMGEN, ISO18436
5. Database management	ISO 13374, 13372, 13379
6. Managing corrective action implementation	Principles; protocols; corrosion/temperature
12. Corrective Actions	
1. Electrical	Recommendations for distribution boards, panels, components, motors; HV, LV lines; substations
2. Mechanical	Recommendations for pumps, bearings, motors, compressors, engines; machinery corrective and preventive actions;
3. Civil	Recommendations for building defects, bridge anomalies, road defects; physical inspection; boroscope; study of designs/plans
13. Codes and Standards	
1. Overview	ISO 13374, 13372, 13379, 18436, 17359; ISO/DIS18434
2. Electrical	BS 7671
3. Mechanical	ISO 281, ISO 18436-2;
4. Civil	Annex B (Guide AG1/2003, Building fabric)
5. Diagnostics	ISO/DIS 13373-1
6. Prognostics	ISO 13381-1
7. Safety	HSWA; EAW; PUWER; CDM;
14. Reporting and documentation (ISO standards)	
1. Presentation	
2. Clients needs	
3. Thermographers and end-users responsibilities (all sectors)	
15. Diagnostics & prognostics	
1. Diagnostics principles and processes	Principles; processes; ISO/CD 13373-1, 13379
2. Prognostic principles and processes	Principles; processes; motors; ISO 13381-1