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CM/GEN APPENDIX A Issue 2 rev B

SPECIFIC REQUIREMENTS FOR QUALIFICATION AND PCN CERTIFICATION OF CONDITION MONITORING AND DIAGNOSTIC PERSONNEL FOR ACOUSTIC EMISSION

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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 the Acoustic Emission method in condition monitoring has become a key activity in predictive maintenance programmes for many industries. The effectiveness of this technology depends on the capabilities of individuals who perform the measurements and analyse the data. This document is appended to CM/GEN (General requirements for qualification and PCN certification of condition monitoring and diagnostic personnel). Other Appendices cover:

- Appendix B Infra-red Thermography
- 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.

1. Scope

- 1.1. This appendix to PCN CM/GEN sets out the specific requirements for qualification and assessment of personnel engaged in Acoustic Emission Condition Monitoring of machines, structures, processes and materials. 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 ISO18436-6: Condition monitoring and diagnostics of machines: Requirements for qualification and assessment of personnel.- Acoustic Emission.
- 1.3. Certification to this specification will provide evidence of the qualification and competence of individuals to perform Acoustic Emission 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 Acoustic Emission analysis 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.
- 2.2. Acoustic Emission Category 1

PCN certificated Acoustic Emission Category 1 personnel are qualified to perform industrial Acoustic Emission measurements according to established and recognised procedures and shall be able to:

 - 2.2.1. apply a specified acoustic emission measurement procedure;
 - 2.2.2. set up and verify operation of equipment for basic acoustic emission data collection;
 - 2.2.3. verify the integrity of collected data and prevent or control poor data;

- 2.2.4. perform basic acoustic emission analysis;
- 2.2.5. record and categorise the results in terms of written criteria;
- 2.2.6. maintain a data base of results or trends;
- 2.2.7. evaluate and report test results in accordance with instructions.

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. Acoustic Emission Category 2

Individuals certificated as Acoustic Emission Category 2 are qualified to perform and/or direct acoustic emission analysis according to established and recognised procedures, and will be aware of the limitations of the acoustic emission method. Category 2 personnel shall be able to:

- 2.3.1. select the appropriate Acoustic Emission technique;
- 2.3.2. define the limitations of the application;
- 2.3.3. specify the appropriate hardware and software for both portable and permanently installed systems;
- 2.3.4. set up and verify equipment settings;
- 2.3.5. measure and perform diagnosis of acoustic emission signals;
- 2.3.6. measure, interpret and analyse acoustic emission data;
- 2.3.7. recommend appropriate corrective actions;
- 2.3.8. verify the calibration of acoustic emission measurement systems;
- 2.3.9. prepare reports on condition, recommend corrective action and comment on effectiveness of repairs;
- 2.3.10. provide technical direction and training for personnel at or below Category 2;
- 2.3.11. recommend the use of alternative CM technologies with an awareness of the principles of all other CM technologies specified in CM/GEN, at least to Category 1.
- 2.3.12. supervise and instruct all Category 1 duties.

2.4. Acoustic Emission Category 3

Individuals certificated as Acoustic Emission Category 3 are qualified to perform and/or direct all types of acoustic emission measurements and analysis and shall be able to:

- 2.4.1. apply acoustic emission theory and techniques, including measurement and interpretation of survey results;
- 2.4.2. understand and perform data analysis, including limitations;
- 2.4.3. determine the acoustic emission signature of systems and component assemblies;
- 2.4.4. use non-standard techniques for acoustic emission and fault diagnosis;
- 2.4.5. recommend all generally recognised types of corrective actions;
- 2.4.6. supervise and train personnel at Categories 1, 2 and 3
- 2.4.7. interpret and evaluate Standards, Codes, specifications and procedures;
- 2.4.8. establish acoustic emission programmes including determination of the requirement for periodic /continuous monitoring, frequency of testing, etc.;
- 2.4.9. establish acceptance and severity criteria;
- 2.4.10. establish programmes for acceptance for new and in-service systems;

- 2.4.11. establish severity criteria for new, in-service and faulty equipment;
- 2.4.12. perform prognostics for fault conditions;
- 2.4.13. prepare reports on machine condition, recommended corrective action and effectiveness of repairs;
- 2.4.14. direct the use of alternative CM technologies with an understanding of the principles of other CM technologies specified in CMGEN, at least to Category 1;
- 2.4.15. guide personnel below Category 3;
- 2.4.16. 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. Training

- 3.1.1. In addition to the training hours in Table 1 and formal education at clause 3.3.2, Category 2 candidates only will have completed formal or on-the-job training on machine knowledge, covering machinery and components, of a similar duration to that in Table 1. This training should cover design, manufacture, installation, operation and maintenance principles, and include failure mechanisms associated with each principle.
- 3.1.2. Training may be modularised in order to allow mutual recognition between non-destructive testing and condition monitoring assessment bodies.

TABLE 1. Minimum Duration of Training (hours)		
Category 1	Category 2	Category 3
40	80	120
The hours shown represent cumulative totals of training hours for each Category.		

3.2. Experience

- 3.2.1. To be eligible to apply for certification the candidate shall provide evidence of experience in the field of acoustic emission condition monitoring appropriate to the Category sought. The minimum experience requirements are shown in Table 2.
- 3.2.2. Certification at Categories 2 and 3 requires previous certification at the lower Categories
- 3.2.3. Candidates must maintain a log of hours and nature of work on PCN document CP16 for Categories 1 and 2 and CP17 for Category 3.

TABLE 2. Minimum Experience Requirements (months and hours)		
Category 1	Category 2	Category 3
6 96 hrs*	12 192 hrs*	36 576 hrs*
The figures represent cumulative months of experience for each Category. Work experience in months is based on a 160 hour/month. Work experience in hands-on hours is based on 16 hrs minimum experience per month.		

4. Certification Available

4.1 Category 1 (General-Acoustic emission condition monitoring)

- 4.2 Category 2 (General- Acoustic emission condition monitoring)
- 4.3 Category 3 (General- Acoustic emission condition monitoring)

5. Qualification Examination

- 5.1 Application for qualification examinations
 - 5.1.1 Application for initial qualification examination is made on PCN form PSL/57-CM and supported with PSL/33-CM and PSL30-CM where required.
- 5.2 Examination content (Theory and practical knowledge)
 - 5.2.1 For each certification Category, candidates will be required to answer the number of multiple choice questions indicated in Table 3.
 - 5.2.2 10% of the number of questions on the Category 3 examination paper will consist of narrative questions. On each paper there will be six questions offered and only four must be answered. Category 3 examinations may include fault diagnosis, prognosis and solution recommendation content.
 - 5.2.3 Each narrative question will be worth 5 marks.

Table 3 – qualification examination content			
Categories	Number of Questions	Time (Hours)*	Passing Grade %
Category 1	60	2.0	75
Category 2	60	2.0	75
Category 3	60	3.0	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.

- 5.2.4 The content of the examination paper shall contain multiple-choice questions for each subject in Annex A2, and in the same weighting as indicated by the percentage of time spent on each subject indicated in Annex A2, together with the indicated narrative questions in the case of Category 3.
- 5.2.5 Questions will be of a practical nature and will test the candidate's knowledge of the principles and procedures required to conduct acoustic emission condition testing and analysis.
- 5.2.6 Questions will include the interpretation of practical data and simple mathematical calculations using a basic scientific calculator may be required.

Annex A1 Training Syllabus Heading

Subject	Hours of training		
	Category 1	Category 2	Category 3
1. Principles of Acoustic Emission	6	2	1
2. Generic Equipment Knowledge	2	2	1
3. Data Acquisition	7.5	2.5	1
4. Data/signal Processing	3	2	2
5. Condition Monitoring	3	2	2
6. Applications	8	24	24
7. Fault Analysis and Severity Determination	2	2	6
8. AE Instrumentation Testing and Diagnostics	4	1	1
9. Reference Standards	2	0.5	0.5
10. Reporting and Documentation and Corrective Action	1	0.5	0.5
11. Personal safety	0.5	0.5	0
12. Training examination*	1	1	1
13. Training practical skills evaluation	2		
Total hours for each Category	42	40	40

Annex A2 – Detailed list of topics and hours of Instruction

SUBJECT	Category 1 Hours	Category 2 Hours	Category 3 Hours
1. Principles of Acoustic Emission	6	2	1
1. Introduction to sources	*		
2. Nature of sources		*	*
3. Propagation and attenuation	*	*	*
2. Generic Equipment Knowledge	2	2	1
1. Calibration of equipment	*	*	*
2. Sensors & coupling	*	*	*
3. Amplifiers and signal conditioners		*	*
3. Data Acquisition	7.5	2.5	1
1. Principles of data acquisition	*	*	*
2. Sensor positioning	*	*	*
3. Noise	*	*	*
4. Stimulus	*	*	*
5. Measurement	*	*	
6. Other methods	*	*	
4. Data/signal Processing	3	2	2
1. Data storage and structure	*	*	*
2. Data management and databases	*	*	*
3. Elements of processing		*	*
4. Output		*	*
5. Condition Monitoring	3	2	2
1. CM principles	*	*	*
2. Alternative technologies (IRT, VA, LM)	*	*	*
3. Procedure writing			*
6. Applications	8	24	24
1. Machines (including bearings, gearboxes, valves, pipes, motors, mountings and other machines)	*	*	*
2. Structures	*	*	*
3. Processes	*	*	*
4. Materials (composites, metals)	*	*	*
7. Fault Analysis and Severity Determination	2	2	6
1. Time Domain Analysis		*	*
2. Alarms	*	*	*
3. Trending		*	*
4. Case studies		*	*

SUBJECT	Category 1 Hours	Category 2 Hours	Category 3 Hours
8. AE Instrumentation Testing and Diagnostics	4	1	1
1. Acceptance testing	*	*	*
• Benchmarking	*	*	
• Demonstration	*	*	
2. System testing	*	*	*
3. Fault finding		*	*
9. Reference Standards	2	0.5	0.5
1. ISO	*	*	*
2. EN	*	*	*
10. Reporting and Documentation and Corrective Action	1	0.5	0.5
1. Report structure	*	*	*
2. Required information [#]	*	*	*
3. Corrective action	*	*	*
11. Personal safety^{##}	0.5	0.5	-
12. Training examination	1	1	1
13. training practical skills evaluation	2		
Total Hours	42	40	40

[#] Includes CM/GEN and Appendix A

^{##}Not examined at Category 1

Notes:

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

Annex B – Reading References

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

Category	Title	Author	Publisher	ISBN
1, 2, 3	Acoustic Emission and Ultrasonics	T Holroyd	Coxmoor	1901892077
1, 2, 3	Nondestructive Testing Handbook, 2 nd Edition, Vol 5, Acoustic Emission Testing, 1987	ASNT	ASNT	0931403022
1, 2, 3	Handbook of Condition Monitoring	B.K.N. Rao	Elsevier	1856172341
1, 2, 3	Plant Integrity Assessment by Acoustic Emission Testing	Stuart Hewerdine	ICHEME Books	085295316X
1, 2, 3	The capabilities and limitations of NDT: part 7: Acoustic Emission	P. T. Cole	BINDT, 1988	0903132087
1, 2, 3	Infrared Thermography- Theory & Practice	N Walker	BINDT	0903132338
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
1, 2, 3	Nondestructive Testing Handbook, 3 rd Edition, Vol 6, Acoustic Emission Testing, 2005	ASNT	ASNT	1-57117-106-1
1,2,3	Guide to Good practice for acoustic Emission (AE) testing of Pressure Equipment	AFIAP	AFIAP, 2004	NA
3	Structural and Engineering Monitoring by Acoustic emission methods- Fundamentals and Applications	L M Rogers	Lloyd's Register, UK	Paper 6, session 1999-2000

Standards and Specifications (Material from which examination questions can be developed)

1. EN 13477 Part 1. Non-destructive testing. Acoustic emission. Equipment characterisation. Equipment description.
2. EN 13477 Part 2. Non-destructive testing. Acoustic emission. Equipment characterisation. Verification of operating characteristic
3. EN 13554. Non-destructive testing. Acoustic emission. General Principles
4. EN 1330 Part 9. Non-destructive testing. Terminology. Terms used in acoustic emission testing
5. ISO 13374. Part 1. Condition monitoring and diagnostics of machines- Data processing, communication and presentation
6. ISO 13372. Condition monitoring and diagnostics of machines- vocabulary
7. ISO 17359. Condition monitoring and diagnostics of machines- general guidelines

8. ISO 13379. Condition monitoring and diagnostics of machines- Data interpretation and diagnostic techniques.- General guidelines
9. CMGEN. General requirements for qualification and PCN certification of condition monitoring and diagnostic personnel
10. ISO 13381-1. Condition monitoring and diagnostic of machines; prognostics: Part 1 general Guidelines
11. 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

Recommended Reading – Informative only (Material with helpful information on this subject)

Category	Title	Author	Publisher	ISBN/Publ No
1	Basic Acoustic Emission; 1991	I G Scott	Gordon and Breach	2881243525
1, 2	Acoustic Emission Tutor; 1989 (computer discs)	C Salkowski	Spectrasoft	Lavender order #3300A
1, 2, 3	Supplement to recommended practice: SNT-TC-IA- Acoustic Emission Testing Method, 1995	Book G	ASNT	057117010-3

Annex C Category 2 Training sub-topics (informative)

Annex C is an informative guide, but training should satisfy Annex A2 and it is suggested that it also incorporates these sub-topics. Note, not all sub-topics are presented in this guide.

Topic	Sub-topics
1. Principles of Acoustic Emission	
1. Introduction to sources	
2. Nature of sources	Continuous emission; burst emission; detection frequency; general knowledge; friction, impact, cavitation and crack extension; waveforms;
3. Propagation and attenuation	Frequency and transmission; detection range; wave modes; speed of decay; structural calibration; burst rise time; basic definitions; acoustic impedance; interfaces;
2. Generic Equipment Knowledge	
1. Calibration of equipment	Pulser transducer; pencil break;
2. Sensors & coupling	Piezo-electric effect and materials; resonant sensors; front face; aperture effect; shielding; waveguides; primary sensor calibration; point contact sensors; sensitivity; couplants; frequency response;
3. Amplifiers and signal conditioners	Earth loop noise; filtering;
3. Data Acquisition	
1. Principles of data acquisition	General knowledge; source location; triangulation; location accuracy; time difference measurements;
2. Sensor positioning	Basic principles;
3. Noise	Signal to noise ratio; Guard sensing; shielding;
4. Stimulus	Proof/re-certification testing (eg vessels and gas trailer tubes);
4. Data Processing	
1. Data storage and structure	Hit-driven systems;
2. Data management and databases	Relational data fields; terminology-general; Data management and control;
3. Elements of processing	Threshold Category; noise discrimination; general knowledge; frequency domain analysis; enveloping/demodulation; filtering; FFT; coherence analysis;
4. Output	Prognostics; alarms;
5. Condition Monitoring	
1. CM principles	General knowledge and principles; RCM; measurement strategy; health assessment;
2. Other technologies (IRT, VA, LM) and eddy currents	Basics of IRT, VA and LM (tribology and wear debris analysis)
3. procedure writing	Not applicable
6. Applications	
1. Machines	Gearboxes; general knowledge; incipient failure;

Topic	Sub-topics
	friction; effect of lubrication; defects; repetition frequencies; turbine rotors; significance of changes; cavitation; bearing failure; machine dynamics;
2. Structures	Wave propagation and attenuation; source location; noise discrimination; application of Felicity and Kaiser effects; AE testing; geo-technical; pressure vessels and affect of insulation; reinforced concrete, metals and composites; failure modes; stress corrosion cracking; metal vessels; effect of operational conditions; zone location; gas cylinder trailers; storage tanks;
3. Processes	Leaks; welding and defects; cutting and wear processes; process feedback; leak source location methods;
4. Materials (composites, metals)	Effect of a discontinuity; Dunegan Corollary; factors affecting AE amplitudes; plastic deformation and crack growth; corrosion processes; attenuation in composites; fibre-reinforced plastics; phase transformations in steel; fatigue testing; specimen tests; stresses; fiberglass;
7. Fault Analysis and Severity Determination	
1. Time Domain Analysis	Burst waveforms; time difference measurement;
2. Alarms	General knowledge;
3. Trending	Crest factor; general knowledge;
4. Case studies	Drilling; chipping;
8. AE Instrumentation Testing and Diagnostics	
1. Acceptance testing	Codes of practice and standards;
• Benchmarking	
• Demonstration	Noise;
2. System testing	Electronic noise; sensor sensitivity; preamplifier checks;
3. Fault finding	Functional system checks; location errors; sources of interference;
9. Reference Standards	
1. ISO	CMRR; terms and definitions;
2. EN	State detection; delta t; terms and definitions;
10. Reporting and Documentation and Corrective Action	
1. Report structure	AE examination procedure;
2. Required information	
3. Corrective action	Corrective action procedures; prognostic assessment;