

Certification Services Division
Midsummer House, Riverside Way
Northampton, NN1 5NX
United Kingdom

Tel: +44 (0)1604 438300
Fax: +44 (0)1604 438301
E-mail: cm.admin@bindt.org



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

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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 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 893811, or email pcn@bindt.org.

Organisations requiring to be in possession, at all times, 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 **machinery condition monitoring using Acoustic Emission equipment**. 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 Acoustic Emission condition monitoring for their 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 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 regarded as competent to choose the test method or technique to be used nor to assess the 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. verify the calibration of acoustic emission measurement systems;
- 2.3.8. prepare reports on condition, recommend appropriate corrective action and comment on effectiveness of repairs;
- 2.3.9. provide technical direction to personnel at or below Category 2;
- 2.3.10. carry out, supervise and instruct all Category 1 certified personnel duties;

2.3.11 recommend the use of alternative CM technologies with an awareness of the basic principles of all four condition monitoring (CM) technologies specified in CM/GEN at least to Category 1;
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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 data acquisition 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. interpret and evaluate Standards, Codes, specifications and procedures;
- 2.4.7. establish Acoustic Emission programmes including determination of the requirement for periodic /continuous monitoring, frequency of testing, etc.;
- 2.4.8. establish programmes for acceptance and severity criteria for new and in-service systems and faulty equipment;
- 2.4.9. perform prognostics for fault conditions;

2.4.10 prepare reports on machine condition, recommended corrective action and effectiveness of repairs;
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2.4.12 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 should have a combination of education, training and experience to ensure that they understand the principles and procedures applicable to Acoustic Emission measurement and analysis.

3.2 Education

Candidates seeking certification do not need to provide evidence of formal education to establish eligibility. However, it is recommended that Category 1 and 2 candidates have at least a secondary school graduation diploma or its equivalent. Category 3 candidates shall be able to manipulate simple algebraic equations, use a basic scientific calculator (including trigonometric and logarithmic functions), 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 certification to Category 3.

3.3 Training

3.3.1 To be eligible to apply for examination based on this Specification, the candidate shall provide documentary evidence of successful completion of a BINDT approved or recognised course of formal training, which will be based on the requirements of Annex A2. Sources of technical information are listed in Annex B. The minimum duration of training required shown in Table 1.

BINDT allows a maximum of 50% self study or on line training for topics consistent with Annex A2 and as specified by the approved trainer (CMGEN refers).

3.3.2 Approved training should be in the form of lectures, demonstrations and practical exercises. The approved training shall include examinations to ensure that the subject matter has been understood and that they have successfully completed the training.

The training syllabus indicated includes a requirement for practical knowledge and practical skills training and evaluation by the trainer at Category 1.

3.3.3 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.		

3.4 Experience

3.4.1 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.

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

3.4.3. Candidates must maintain a log of hours and nature of work on PCN document CP16-CM for all categories.

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	4	2	1
2. Generic Equipment Knowledge	2	2	1
3. Data Acquisition	8	2.5	1
4. Data/signal Processing	2	2	2
5. Condition Monitoring	3	2	2
6. Applications	12	24	24
7. Fault Analysis and Severity Determination	1	2	6
8. AE Instrumentation Testing and Diagnostics	1.5	1	1
9. Reference Standards	1	0.5	0.5
10. Reporting and Documentation and Corrective Action	2	0.5	0.5
11. Personal safety	0.5	0.5	-
12. Training examination*	2	1	1
13. Training practical skills evaluation	1	-	-
Total hours for each Category	40	40	40

Annex A2 – Detailed list of topics and hours of Instruction

Topic	1	2	3	Category 1	Category 2	Category 3
1. Principles of Acoustic Emission				4	2	1
1. Introduction to sources	•			Definition of AE; differences between audible noise, vibration & AE. Why use AE for machinery CM?		
2. Nature of sources		•	•	Awareness of the nature and type of sources including machines, materials, structures and other processes	Understanding of continuous emission; burst emission; detection frequency; general knowledge; friction, impact, cavitation and crack extension; waveforms;	Fundamentals of source mechanisms within different materials and processes
3. Propagation and attenuation	•	•	•	Awareness of propagation and attenuation principles	Understanding of AE source frequency and transmission; detection range; wave modes; speed of decay; structural calibration; acoustic impedance; interfaces;	Be able to determine AE source characteristics;
2. Generic Equipment Knowledge				2	2	1
1. Calibration of equipment	•	•	•	Awareness of the requirement for equipment calibration	Understand and undertake equipment calibration	Define procedures for equipment calibration
2. Sensors & coupling	•	•	•	Awareness of sensor operation, mounting and coupling.	Understand piezo-electric effect and materials; resonant sensors; waveguides; temperature; environmental limits; sensitivity; couplants.	Understanding of primary sensor calibration; sensor design and frequency response;
3. Amplifiers and signal conditioners		•	•		Awareness of preamplifiers: function, advantages & disadvantages of integral type. Electrical shielding, isolation & frequency filtering.	Fundamentals of preamplifiers function and signal conditioning
3. Data Acquisition				8	2.5	1
1. Principles of data acquisition	•	•	•	Basic understanding of a measurement chain	Understanding of AE equipment signal processing, measurement & data recording	Fundamentals of signal processing.
2. Principles of data collections	•	•	•	Follow data acquisition procedures for fixed or route based systems. Measurement points for common machine types. Recognise poor data and alarm conditions.	Be able to set up AE data collection systems, e.g. select machines and measurement points, create appropriate acquisition and alarm settings, carry out and supervise; measurement and reporting structure.	Establishing AE programs, determination for type of monitoring, frequency of measurement. Troubleshooting; Creating test and calibration procedures, standards development
3. Sensor positioning	•	•	•	To be able to position and mount sensors in defined locations.	Be aware of considerations in positioning AE sensors. E.g. Transmission paths	Derive sensor position from standards and AE fundamentals
4. Noise	•	•	•	Recognise sources of noise;	Noise management. Signal to noise ratio; Guard sensing; isolation and discrimination.	Fundamentals of noise management.
5. Stimulus	•	•	•	Recognise stimulus such as machine operational variables	Be able to define appropriate loading to stimulate AE activity.	Understanding of the relationship between stimulation and AE activity and evaluation of complex loading conditions
6. Measurement	•	•		Awareness of the importance of a representative measurement period. Verification of measurement chain operation	Define representative measurement periods.	

Topic	1	2	3	Category 1	Category 2	Category 3
7. Other methods	•	•		Awareness of periodic and continuous monitoring.		
4. Data/Signal Processing				2	2	2
1. Data storage and structure	•	•	•	Awareness of data storage media and data transfer	Understanding of different data process and storage methods; real time versus raw signal; hit based systems; smart sensors	Definition and development of data processing and storage.
2. Data management and databases	•	•	•	Be able to collect and transfer data	Definition of measurement intervals; review of data management and controls; integrity of data input and backup.	Review of data trends against standards and system parameters
3. Elements of processing	•	•	•	To understand the basic principles of data processing.	Understanding of data processing techniques; threshold levels; frequency domain analysis; enveloping/demodulation; filtering; FFT; coherence analysis;	Fundamentals and development of data processing techniques.
4. Output		•	•		Implementation of data display; trending; alarm levels and prognostics;	Advanced data processing and reporting
5. Condition Monitoring				3	2	2
1. CM principles	•	•	•	Awareness of Condition Based Maintenance (CBM) and general maintenance strategies.	Understand and implement CBM; measurement strategies; health assessment.	Design and development of CM strategy and systems.
2. Other CM technologies	•	•	•	Basic awareness of other condition monitoring techniques	Awareness of alternative condition monitoring techniques.	Understanding and recommendation of alternative condition monitoring techniques.
3. Procedure writing			•			Review and approval of procedures as against applicable standards and industry best practice
6. Applications				12	24	24
a) Machines b) Bearings c) Gearboxes d) Valves e) Pipes f) Motors g) Mountings h) Other machines	•			Awareness of different applications and practical considerations in mounting the AE sensors. Examples of the use of AE monitoring in different applications.		
1. Materials (composites, metals)		•	•		Understanding of AE wave propagation and attenuation in different materials. Implementation of source location techniques (zonal, linear, planar, 3D); AE noise discrimination approaches. Awareness of the effect of a discontinuity within a material and degradation processes in different materials. (Phase transformations in steel, plastic deformation and crack growth; fibre-reinforced plastics and concrete)	Understanding of the application of the Kaiser effect, Dunegan Corollary & Felicity Effect. Effect of operational conditions and degradation processes. Ensure Adherence to codes & standards Awareness of material testing (fatigue testing; specimen tests etc.)

Topic	1	2	3	Category 1	Category 2	Category 3
					Awareness of the Felicity, Kaiser and Dunegan Corollary effects.	
2. Machines		•	•		Understand the effect on measurements of machine operation and process variables. Understanding of AE signal continuous & burst activity. Awareness of the operation of rotating and non-rotating machinery (gearboxes, bearings, turbines etc.)	Understanding of the effect of the following AE activity – incipient failure; friction; effect of lubrication; defects; repetition frequencies; turbine rotors; significance of changes; cavitation; bearing failure; machine dynamics.
3. Structures		•	•		Understand the operation of structures (geo-technical; pressure vessels; gas cylinder trailers; storage tanks etc.). Awareness of degradation and failure mechanisms.	Understanding of degradation and failure modes.
4. Processes		•	•		Understanding of the possible diverse applications and awareness of the AE source mechanisms at work.	Understanding of AE source mechanism from possible processes. Advanced signal analysis including leak source location methods.
7. Fault Analysis and Severity Determination				1	2	6
1. Time Domain Analysis		•	•		Awareness of short term digitisation & time domain analysis.	Understanding of short term digitisation & time domain analysis. Linear location, burst waveforms; time difference measurement.
2. Alarms	•	•	•	Basic awareness of alarm and alert definitions and alarm levels	Awareness of alert & alarm definitions, setting w.r.t. baseline & output from trending.	Understand alert & alarm definitions, setting w.r.t. baseline & output from trending.
3. Trending	•	•	•	Basic awareness of trending	Understand general indicators of a developing fault and analysis.	Advanced understanding of fault indications, interpretation of process and monitoring variables and AE signal analysis process.
4. Case studies		•	•		Awareness of case studies	Awareness and understanding of case studies.
8. AE Instrumentation Testing and Diagnostics				1.5	1	1
1. Acceptance testing: Codes of practice and standards;	•	•	•	Awareness of existence of codes of practice and standards	Understanding of code of practice and standards	Development of code of practice and standards
2. Benchmarking	•	•		Requirement for benchmarking measurement for trend development	Implementation of benchmarking for trend development.	
3. Demonstration	•	•		Practical demonstration of AE data collection	Practical demonstration of AE data collection including noise; typical sources; sensitivity	
4. System testing	•	•	•	Awareness of requirement for system testing.	Ability to undertake system checks to identify electronic noise; confirm sensor sensitivity; and perform preamplifier checks.	Understand and design system checks to identify electronic noise; confirm sensor sensitivity; and perform preamplifier checks.
5. Fault finding	•	•	•	Basic acquisition equipment troubleshooting	Ability to identify location errors; sources of interference; undertake simple field checks and implement control records.	Understand system operation in full and develop field checks.
9. Reference Standards				1	0.5	0.5
1. ISO	•	•	•	Be aware the existence of ISO standards	Understanding of relevant standards.	Understanding and interpretation for implementation of relevant standards

Topic	1	2	3	Category 1	Category 2	Category 3
2. EN	•	•	•	Be aware the existence of EN standards	Understanding of relevant standards.	Understanding and interpretation for implementation of relevant standards.
3.PCN documents	•	•	•	CM/Gen Appendix A (including examination procedure and qualifying for certification)	CM/Gen Appendix A (including examination procedure and qualifying for certification)	CM/Gen Appendix A (including examination procedure and qualifying for certification)
10. Reporting and Documentation and Corrective Action				2	0.5	0.5
1. Report structure	•	•	•	Use defined report structure	Develop report structure	AE examination procedure;
2. Required information	•	•	•	Typical examples of content, awareness of required test information	Specify required additional test information.	Assess and review additional test information.
3. Corrective action	•	•	•	Awareness of result/feedback of AE testing.	Specify corrective action procedures	Analysis of corrective action and development of prognostic assessment.
11. Personal safety				0.5	0.5	
12. Training examination				2	1	1
13. Training practical skills evaluation				1		
Total hours				40	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