BS EN 13554:2011

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Non-destructive testing — Acoustic emission testing — General principles

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National foreword

This British Standard is the UK implementation of EN 13554:2011. It supersedes BS EN 13554:2002 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee WEE/46, Non-destructive testing.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Contents

Foreword

This document (EN 13554:2011) has been prepared by Technical Committee CEN/TC 138 “Non-destructive testing”, the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by July 2011, and conflicting national standards shall be withdrawn at the latest by July 2011.

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This document supersedes EN 13554:2002.

The following summary of changes intends to identify the most significant changes made to the standard during the revision process. It does not necessarily contain all changes, and it is recalled that, while efforts have been made to highlight the relevance of the list, the user of this standard is responsible for recognizing any differences between this and the present edition.

— 6: Further applications were introduced;

— 7.3: Adoption on the new EN 13477-2 (signal processor);

— 7.5: New paragraph on external parameters input;

— 8: Examination was replaced by testing;

— 9: Clause divided in on-line and post test analysis;

— 9.3.3: Source severity grading was changed;

— 10: Examination procedure was replaced by test instruction;

— 11: Examination report was replaced by test documentation and test report and re-written.

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1 Scope

This European Standard specifies the general principles required for the acoustic emission testing (AT) of industrial structures, components, and different materials under stress and for harsh environment, in order to provide a defined and repeatable performance. It includes guidelines for the preparation of application documents, which describe the specific requirements for the application of the AE method.

Unless otherwise specified in the referencing documents, the minimum requirements of this European Standard are applicable.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 1330-1:1998, *Non destructive testing — Terminology — Part 1: List of general terms*

EN 1330-2:1998, *Non destructive testing — Terminology — Part 2: Terms common to the non-destructive testing methods*

EN 1330-9:2009, *Non-destructive testing — Terminology — Part 9: Terms used in acoustic emission testing*

EN 13477-2, *Non-destructive testing — Acoustic emission — Equipment characterisation — Part 2: Verification of operating characteristic*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 1330-1:1998, EN 1330-2:1998 and EN 1330-9:2009 apply.

4 Personnel qualification

It is assumed that emission testing is performed by qualified and capable personnel. In order to prove this qualification, it is recommended to certify the personnel in accordance with EN 473 or equivalent.

Note that for pressure equipment in categories III and IV according to Directive 97/23/EC, Annex I, 3.1.3: the personnel shall be approved by a third-party organization recognized by a Member State.

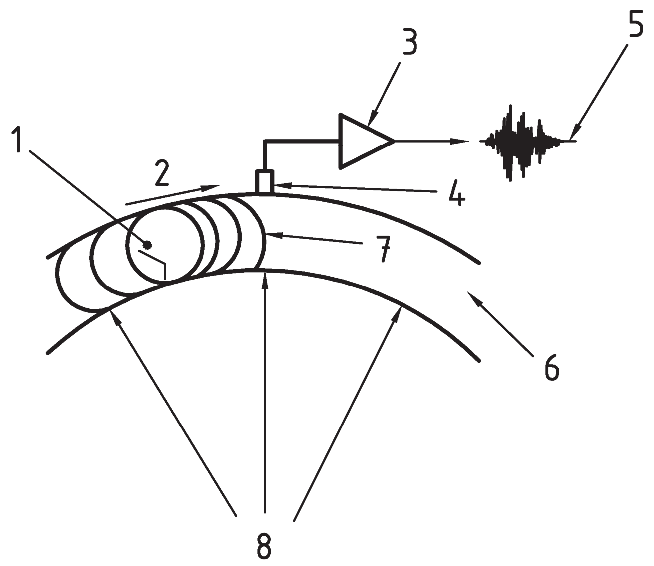
5 Principle of the acoustic emission method

5.1 Acoustic emission (AE) phenomenon

Acoustic emission is a physical phenomenon whereby transient elastic waves are generated within a material or by a process.

The application of load or harsh environment in a material produces internal structural modifications such as local plastic deformation, crack growth, corrosion, erosion and phase transformations. AE sources also arise from impact, leakage (turbulent flow), cavitation, electric discharge and friction. All these mechanisms and processes are generally accompanied by the generation of elastic waves that propagate in materials or into ambient liquids. The waves therefore contain information on the internal behaviour of the material and/or structure.

The waves are detected by the use of sensors that convert the particle motion at the surface of the material into electric signals. These signals can be of a burst or continuous nature and are processed by appropriate instrumentation to detect, characterize and locate the AE sources. Figure 1 shows the schematic principle of AE.



Key

1 growing discontinuity
2 surface waves
3 preamplifier
4 AE sensor
5 signal out
6 section view of the component material
7 wave packet
8 applied load inducing stress

Figure 1 — Schematic principle of Acoustic Emission and its detection

5.2 Advantages and features of AE

The AE method has the following features:

a) it is a passive detection method that monitors the dynamic response of the material to the applied load or environment;

b) it allows detection of sources, depending on the materials properties, up to several meters distance;

c) it allows a 100 % volumetric monitoring of the test object;

d) it is sensitive to growth of discontinuities and changes in the material structure rather than to the presence of static discontinuities;

e) it is non invasive;

f) it offers a dynamic real time monitoring of any discontinuity that grows under the applied stress;

g) it can be applied to monitor the structures during operation;

h) it can be used to detect the effects of the application of load in order to prevent catastrophic failure of structures;

i) it is capable of locating a growing discontinuity in the structure under test by the use of a sufficient number of sensors;

j) its measurement frequency range extends from about 20 kHz to 2 MHz depending on the application.

The AE method can be applied only if the materials in the structures or components are adequately stressed.

The difference between AE and most NDT methods stems from the above features. It is the material itself that releases the energy in consequence of structural degradation due to different source mechanisms. This is different to detecting existing geometrical discontinuities in a static condition.

AE is a method which points out the presence and location of an evolving degradation process under a given stimulus.

5.3 Limitations of AE

Limitations of the AE method are:

a) non growing discontinuities may not generate AE;

b) subsequent application of load to the previously applied maximum stress level will only identify discontinuities which are still active;

c) it is sensitive to in-service or other extraneous noise.

Prior to performing an acoustic emission testing (AT), it is very important to check for the presence of potential noise sources. Noise sources should be removed or action taken to insure they do not reduce the effectiveness of the AT.

6 Applications of the acoustic emission method

AE is applied at the different phases of product life:

— materials and design optimisation;

— manufacturing (quality assurance);

— acceptance test;

— initial proof test;

— requalification tests;

— in-service condition / health monitoring;

— leak detection.

Furthermore, it is applicable to detection of:

— cavitation erosion;

— electric discharge;

— crack activity of rocks and concrete;

— etc.

It is applied to:

— pressure equipment;

— pipe systems;

— atmospheric storage tanks;

— machinery;

— civil constructions (e.g. bridges, dams);

— power transformers;

— mines (e.g. rock salt mines for hazardous waste disposal);

— etc.

These examples concern metallic materials, polymer composites, ceramics, concrete, rock, etc.

7 Instrumentation

7.1 General

The AE instrumentation shall fulfil the requirements of EN 13477-2 and the performance shall be checked periodically in accordance with this European Standard.

7.2 AE sensors

7.2.1 General

Detection is the most important part of an AE measurement chain because any problem here (poor acoustical coupling, incorrect installation, incorrect frequency selection, cable mismatching, etc.) affects the rest of the measurements and hence the results.

7.2.2 AE sensor selection

The sensors are normally of the resonant type, i.e. one frequency dominates the response; sensors with different resonant frequencies are available.

The choice of the sensor and the operating frequency depends upon:

— the purpose of testing;

— the requirements of the referencing standard or specification;

— type and shape of structure or component;

— operating temperature and surface condition of the structure or component (insulation, painting, coating, surface corrosion, etc.);

— environment;

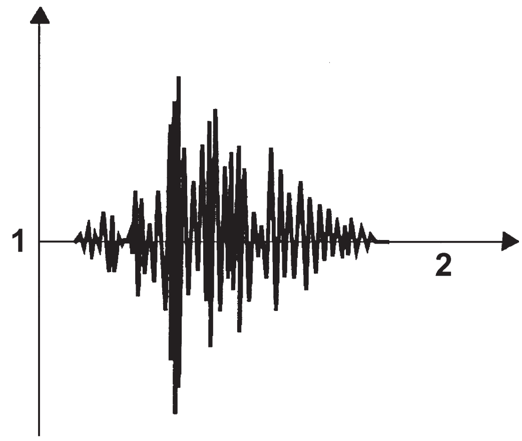
— material properties;

— background noise;

— wave attenuation;

— material thickness.

The signal waveform from the sensor is affected by multiple path propagation and multiple waves modes that are generated in the material. An example of a typical AE burst signal is shown in Figure 2.



Key

1 amplitude

2 time

Figure 2 — Example of AE burst signal from a sensor

7.2.3 Sensor installation

The sensor shall be fixed to the test object using an acoustic couplant, a clamping device or an adhesive bond. In special applications, the AE sensor is installed on a waveguide. The surface at sensor positions shall be cleaned and sufficiently flat to ensure adequate and reproducible transmission of AE waves.

Verification of installation with Hsu-Nielsen source and/or other method shall be performed.

7.2.4 Coupling media

Different coupling media can be used, but their type shall be compatible with the materials to be examined. Examples are:

— water soluble paste;

— reagent soluble paste;

— oil;

— grease;

— wax;

— adhesive bond, etc.

7.3 Signal conditioning and processing

This includes signal transmission, amplification, filtering and extraction of the AE signal features. The frequency filtering shall be appropriate for the sensor response.

The preamplifier converts the signal from the sensor into a suitable low impedance signal for transmission over long distances, using suitable cables, up to the signal processing and analysis system.

The AE signal processor provides frequency band filtering for the rejection of noise, analogue to digital conversion, threshold controlled feature extraction, e.g. peak amplitude, rise time, duration, energy, counts and time driven measurements, e.g. RMS, in real time. The AE signal processor may acquire the wave form. The AE signal processor normally provides the power supply for the preamplifier and a method for using AE sensors as a mechanical pulse generator (e.g. for the sensor coupling test).

7.4 Settings

The detection threshold, gain, and real time display features shall be appropriate for the particular application and test conditions.

This should take into account:

— wave attenuation;

— background noise.

7.5 External parameters inputs

External parameters, such as pressure, strain, load, temperature or wind speed, etc., shall be measured by appropriate measurement channels, often called parametric. Their accuracy and resolution shall be significantly better than the accuracy of the used sensor, e.g. a pressure gauge. Their sampling rate shall be selected according to the frequency of measured parameter, e.g. temperature or wind speed.

8 Testing

8.1 General

The following is applicable primarily to the detection and location of sources of AE. The acoustic emission testing (AT) shall include at least the following aspects:

a) preliminary information;

b) preliminary preparation;

c) on-site preparations;

d) data acquisition and on-line analysis;

e) subsequent operations.

8.2 Preliminary information

The preparation and the execution of the testing as well as interpretation of the results require prior knowledge of the following:

a) type of test object;

b) material (composition and mechanical properties);

c) conditions of use or operation;

d) history of previous maximum load;

e) particular zones to be monitored;

f) test conditions (type and sequence of loading);

g) environmental conditions at the test site and safety regulations to be observed;

h) sources of interference noise (mechanical, electrical, process noise, etc.);

i) if applicable, the results of previous tests;

j) type, size and position of identified defects.

Interpretation of results shall usually require reference to a relevant experimental database. For uncommon structural materials, of which the AE response characteristics are unknown, a quantitative analysis shall be made under controlled test conditions using test specimens of the same material, fabricated in the same way and simulating, as near as possible, the original causes of the discontinuity and service stress conditions.

8.3 Preliminary preparation

The system used for AE monitoring and data interpretation shall be verified in accordance with EN 13477-2 to ensure that the following actions are performed:

a) verification of sensors;

b) verification of the measurement chain;

c) verification of correct operation of all measurement equipment.

The results of verification shall be documented.

Documentation consists of photographs, charts or graphs, calculations, and tables where applicable. Any deviation from specified characteristics shall be corrected and reported in the documentation.

A verification shall be done on-line at established time intervals during monitoring or in the event of malfunction or after replacement of equipment parts.

8.4 On-site preparations

Before the acoustic emission testing (AT), the following shall be performed:

a) overall visual survey;

b) attenuation and background noise measurement, if not known, in order to determine the maximum sensor spacing;

c) preparation of surfaces for the attachment of sensors;

d) mounting of sensors and recording their identification and position;

e) verification of sensor coupling and measurement chain;

f) verification of location accuracy at representative points on the structure/component using a simulated AE source (Hsu-Nielsen and/or other method) when applicable;

g) with the sensors coupled to the structure, the background noise of each channel shall be verified in order to ensure that the level does not cause any interference to the detection of signals emitted from all possible sources. If necessary, the mechanical, acoustical and/or electrical isolation shall be improved, before proceeding with the test;

h) establish permanent communications between the AE operator and the control point for the application of the stimulus (e.g. load).

8.5 Data acquisition

The data are acquired while the component is being stressed.

An AE system shall, at minimum, provide acquisition and storage of the relevant parameters necessary to perform the test. In addition, some applications will require:

a) signal discrimination;

b) analysis of data;

c) location of active sources or zones;

d) data display;

e) grading of sources.

The background noise shall be checked for a representative period of time prior to the test. This measurement is particularly important in order to identify and determine the level of spurious signals. All possible noise sources in the frequency and amplitude range of measurement, such as malfunctioning of pumps or valves, movement of supports, rain, etc., shall be minimised since the signals from these events can mask the AE signals emanating from the structure under test.

The acoustic noise shall be measured periodically throughout the entire duration of the test. This is particularly important during the initial low level stress when it may be possible to eliminate such noise before significant stressing of the structure is reached.

It is important to record as much information as possible during the test, e.g. sudden burst of data or increases in signal amplitude, disruptions to the measurement, sudden increases in background noise, disruption for other inspections.

In a controlled loading test continuous surveillance of the AE activity from the component is maintained during the loading sequence such that the loading may be interrupted or even reduced should the need arise.

Functional checks shall be carried out at specified intervals, as a minimum at the beginning and at the end of test, and/or when any part of the equipment is changed. Once established, the operating conditions shall be maintained throughout the tests. Deviations and corrective actions shall be reported.

8.6 Presentation of results

The following graphical displays provide relevant information on AE source significance and are considered the minimum requirements:

a) AE burst count or rate as a function of time and load;

b) AE burst signal energy or amplitude as a function of time and load;

c) source or zone location when applicable.

When the above is insufficient, more sophisticated analysis might become necessary.

8.7 Subsequent operations

Immediately after the test, the system operation shall be checked again and any anomaly recorded and considered in the analysis of the AE data. This shall include:

a) verification of the sensitivity of each acoustic emission channel;

b) verification of the AE system functionality.

The location of the AE sources shall be verified, using an artificial source like Hsu-Nielsen or other simulator.

9 Data analysis

9.1 General

The data are analysed with the purpose of evaluating on-line test stop criteria and/or identifying the AE sources and their grading.

The time of occurrence of the AE and the corresponding load are other important characteristics which, together with the location, provide relevant and reliable information on AE source significance.

Information should be available in a form that enables easy interpretation.

The location depends on the type of application. This can be linear, planar or zonal and in some cases volumetric.

9.2 On-line analysis

The extent of on-line analysis depends upon the particular application.

Histograms, plots, tables, and location maps should be displayed in real time so as to maintain a real time control of the structure/component under test.

If a pneumatic loading is applied, the stop criteria are the main task of the on-line data analysis.

9.3 Post test analysis

9.3.1 General

Post test analysis is used to confirm real time findings, conduct any necessary data filtering and provide the final output for reporting.

The main task of the post analysis is the source evaluation and their grading.

9.3.2 Source evaluation

The evaluation criteria shall be defined in the application document or agreed at the time of enquiry or order in a written test procedure.

Examples of criteria adopted for AE source evaluation are:

- AE activity that consistently increases with increasing stimulation or time;
- AE activity during periods of constant stimulus;
- correlation between burst emission and the applied stimulus;
- spatial concentration of AE sources;
- coincidence of AE sources with structurally significant features such as: repairs, welds, nozzles, etc.

9.3.3 Grading

The grading and the subsequent action, for the identified AE sources, shall be defined in the test procedure.

Typical grading categories for the AE sources are:

Table 1 — Source severity grading

Source severity grading	Definition	Further actions
1	minor source	no further actions shall be necessary; included in the report for comparison with subsequent tests
2	active source	further NDT shall be recommended if the source is associated with specific parts of the pressure equipment (e.g. weld seams, attachments)
3	very active source	further evaluation by other appropriate NDT shall be carried out before the pressure equipment goes into service

NOTE An active source in this sense is defined in terms of AE-activity and AE-intensity.

The final decision of grading the AE sources is made by the responsible AE test person with reference to the above grading. A dedicated software, based on an extensive database can be used to provide an automatic evaluation of the identified sources and/or zones.

Investigations by complementary methods of non-destructive testing may be carried out in order to evaluate the AE sources. These inspections may take place at the same time or subsequent to the acoustic emission testing (AT).

10 Test instruction

For any acoustic emission testing (AT), test instruction shall be written and agreed before the test.

In addition to the requirements stated in this general standard, the following shall be included:

a) designation and description of the component to be tested;

b) list of reference documents and relevant safety regulations;

c) required qualifications of the test personnel;

d) type of loading (stimulus) and method of regulation/control;

e) loading programme/load sequence;

f) areas to be tested;

g) sensor positions;

h) sensor fixing device and means of coupling;

i) details of the acoustic emission testing (AT) equipment;

j) results of on-site calibration and data acquisition settings used;

k) background noise level and method of rejection of the interference noise sources;

l) parameters measured and analysis procedure;

m) format for test results and their reporting;

n) source grading and verification criteria with recommended further action.

11 Test documentation and test report

The test documentation shall contain at least the following minimum information:

a) identification of the site and the customer;

b) identification of the component under test;

c) reference to relevant procedural documents including the aims and objectives of the test;

d) description of the measurement test equipment in particular the sensor frequency and sensitivity;

e) site operational conditions;

f) results of on-site verification of sensor sensitivity;

g) loading sequence;

h) type of analysis carried out;

i) test results;

j) interpretation of results including, where appropriate, the location and relative severity of all AE sources detected on developed drawings of the component under test;

k) place, date and time of the test;

l) any deviation from the procedure;

m) name, qualifications and signature of inspector.

Normally two reports will be produced, an on-site preliminary report and a final test report.

The on-site preliminary report shall contain the position of the AE sources and their preliminary grading.

The final report shall contain the results of the post test analysis and provide the traceability to the test documentation.

Bibliography

[1] EN 473, *Non-destructive testing — Qualification and certification of NDT personnel — General principles*

[2] Directive 97/23/EC of the European Parliament and of the Council of 29 May 1997 on the approximation of the laws of the Member States concerning pressure equipment

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