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## Non Destructive testing - Acoustic emission - Examination of metallic pressure equipment during proof testing - Zone location of AE sources

Essais non destructifs - Emission acoustique - Vérification des équipements métalliques sous pression pendant l'épreuve - Localisation par zone des sources d'EA

Zerstörungsfreie Prüfung - Schallemission - Prüfung von metallischen Druckgeräten während der Beanspruchung - Zonenortung von Schallemissionsquellen

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## Foreword

This document (EN 15495:2007) 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of an identical text or by endorsement, at the latest by May 2008, and conflicting national standards shall be withdrawn at the latest by May 2008.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

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## 1 Scope

The purpose of this standard is to describe the methods for conducting an acoustic emission (AE) examination of metallic pressure equipment during acceptance pressure testing using a zone location procedure. General principles of Acoustic Emissions are described in EN 13554.

The objectives of the AE testing are to provide 100 % volumetric testing to define and grade zones of the structure which are acoustically active with burst type AE. The method should be regarded as supplementary to planar location. Planar location provides the source identification and characterisation. Zone location may also be applied in such cases where location of AE sources by planar location procedures according to EN 14584 is not possible.

The method identifies the need for further evaluation or follow-up by other NDT in localized zones.

## 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 1330-9:2000, *Non-destructive testing - Terminology - Part 9: Terms used in acoustic emission testing*

EN 13477-1, *Non-destructive testing - Acoustic emission - Equipment characterisation - Part 1: Equipment description*

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

EN 14584, *Non-destructive testing - Acoustic emission - Examination of metallic pressure equipment during proof testing – Planar location of AE sources*

## 3 Terms and definitions

For the purpose of this European Standard, the terms and definitions given in EN 1330-1:1998, EN 1330-2:1998 and EN 1330-9:2000 apply.

## 4 Personnel Qualifications

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

NOTE For pressure equipment see Directive 97/23/EC, Annex 3.1.3: "For pressure equipment in categories III and IV, the personnel must be approved by a third party organization recognized by a Member State."

## 5 General

### 5.1 General

The main target of the AE test is to identify and monitor zones of high acoustic emission activity and intensity caused by phenomena, e.g. crack growth and yielding, generated by the applied load to the equipment.

The properties and structural state of the material, the type and magnitude of the applied stress and stress rate are significant factors affecting the emission.

All zones showing significant activity shall be completely evaluated by other NDT methods. Evaluation according to EN 14584 may help to reduce the area to inspect.

### 5.2 Application of load

The application of the load to the equipment shall be made using internal pressure following the procedure specified in the relevant Product Standard. The rate of the application of pressure shall be established so as to avoid burst signal overlap. The pressurising system shall permit pressurisation at a steady controllable rate and shall allow the pressure to be held constant at the hold points. The pressurisation rate would not normally exceed 1 % of the test pressure per minute for pneumatic and 5 % of the test pressure per minute for the hydraulic test. The intermediate hold periods, if necessary according the AE activity or the pre-defined pressure schedule, are normally 5 min to 10 min. The final hold period at the test pressure shall have a minimum duration of 15 min.

Intermediate hold periods are strongly recommended, especially if pressurisation rates exceed 0,5 % per minute for pneumatic or 2 % per minute for hydraulic tests.

Prior to starting the test, all the necessary actions shall be taken to identify and to reduce potential sources of extraneous noise.

Depending on the results of the initial loading, it may be required to reduce the load to working pressure or lower, followed by re-pressurisation.

### 5.3 Sensors

The frequency range shall be chosen so that the expected AE has sufficient energy in the chosen frequency range and the test result is unaffected by external noise sources. The most commonly used frequency range is 100 kHz to 300 kHz. Lower frequency monitoring allows detection at greater distances and high frequency monitoring provides improved rejection of external noise.

The equipment surface below the sensors shall be prepared to ensure the maximum coupling efficiency. The sensor couplant shall be as specified in the written test instruction. The sensors may be directly attached to the structure using magnetic devices or suitable adhesive.

The effectiveness and reliability of the acoustic couplant shall be verified. The characteristics of the type of the acoustic couplant used shall not affect the structure adversely.

### 5.4 Zone location

Zone location assigns each event producing at least one hit to the zone of the first-hit channel. Successive hits are assumed to belong to the same event as long as they arrive within the event definition time. The event definition time is a programmable time interval, which starts with the arrival of the first-hit of an event. The event definition time is determined during test set-up using a Hsu-Nielsen or another appropriate artificial source and is set so that the source is correctly assigned only to the closest sensor. It is essential for this type of location that all noise sources are well controlled.

## **5.5 Preliminary information**

Prior to the test, the AE Test Organisation shall collect the following information:

- a) relevant Product Standard;
- b) type of equipment or structure and material characteristics and specifications;
- c) design- and test pressure;
- d) working- and test temperature;
- e) assembly and/or layout drawings with sufficient details of the structure;
- f) material specifications, including heat treatment; if applicable
- g) proposed pressure/stress application sequence;
- h) potential acoustic noise interference sources and the isolating mechanism applied;
- i) where possible, locations of known discontinuities and the general results of prior NDT.

## **5.6 Written instruction requirements**

The AE Test Organisation shall provide a written test instruction, which shall include but not necessarily be restricted to the following:

- a) Test object (description and/or drawing, including area of interest and purpose of test);
- b) limitations if any;
- c) sensor type, frequency and manufacturer;
- d) method of sensor attachment;
- e) type of acoustic couplant used;
- f) type of surface preparation;
- g) type of AE equipment used with the main characteristics and settings;
- h) energy measurement method to be used;
- i) sensor location maps representing the structure or part of it;
- j) description of equipment verification procedure;
- k) description of the in-situ verification (see 7.2.2);
- l) sequence of pressurisation;
- m) recorded data and recording method;
- n) available on-line presentation of data;
- o) real time evaluation criteria;
- p) post analysis procedure with adopted filtering technique if used;

- q) final report requirements;
- r) qualification/certification of the personnel;
- s) value of  $K_z$ , ( for definition see Figure 1) from the relevant Product Standard if available.

## 6 Instrumentation

An AE system consists of sensors and equipment for signal conditioning and processing and for displaying and recording data according to EN 13477-1.

The AE instrument shall be capable of measuring at least the following parameters on all channels:

- a) AE burst count;
- b) Burst signal peak amplitude;
- c) Burst signal duration;
- d) Burst signal rise time;
- e) Burst signal energy;
- f) Arrival time;

and on external inputs pressure and/or other stress parameters.

To allow a real time control of the pressure equipment under test, the test instrumentation shall:

- Store all the acquired AE data and the external parameter(s).
- Provide an on-line activity vs channel display.
- Provide an on-line activity vs zone display.
- Provide an on-line display of AE data and pressure.

To assist the online evaluation it is recommended that the instrumentation provides data allowing real time AE noise identification. Online grading of zones is also recommended.

The AE system operating characteristics shall be verified according to EN 13477-2.

## 7 Testing

### 7.1 Pre-Test Measurements

#### 7.1.1 General

The requirements listed in EN 14584 apply for a setup that uses both, planar and zone location. The following text is to be observed where planar location is not used.

#### 7.1.2 Wave propagation

Attenuation measurements shall be performed on the structure to determine the maximum sensor spacing. The measurements shall be performed with the test fluid in the pressure equipment using the Hsu-Nielsen source. If the Hsu-Nielsen source saturates the measurement chain, a lower energy artificial source shall be

used up to the  $20e$  (20 times the wall thickness) distance. The curve obtained shall be adjusted to correspond with the original Hsu-Nielsen source.

The attenuation and wave velocity shall be measured using two sensors mounted in a region of the pressure equipment away from nozzles, manways, etc.

The shadowing effect of nozzles and ancillary attachments shall be quantified and transmission through the test fluid shall be taken into consideration.

### 7.1.3 Determination of maximum allowed sensor spacing

The maximum distance between adjacent sensors is 1,5 times the threshold distance  $d_{thr}$ .

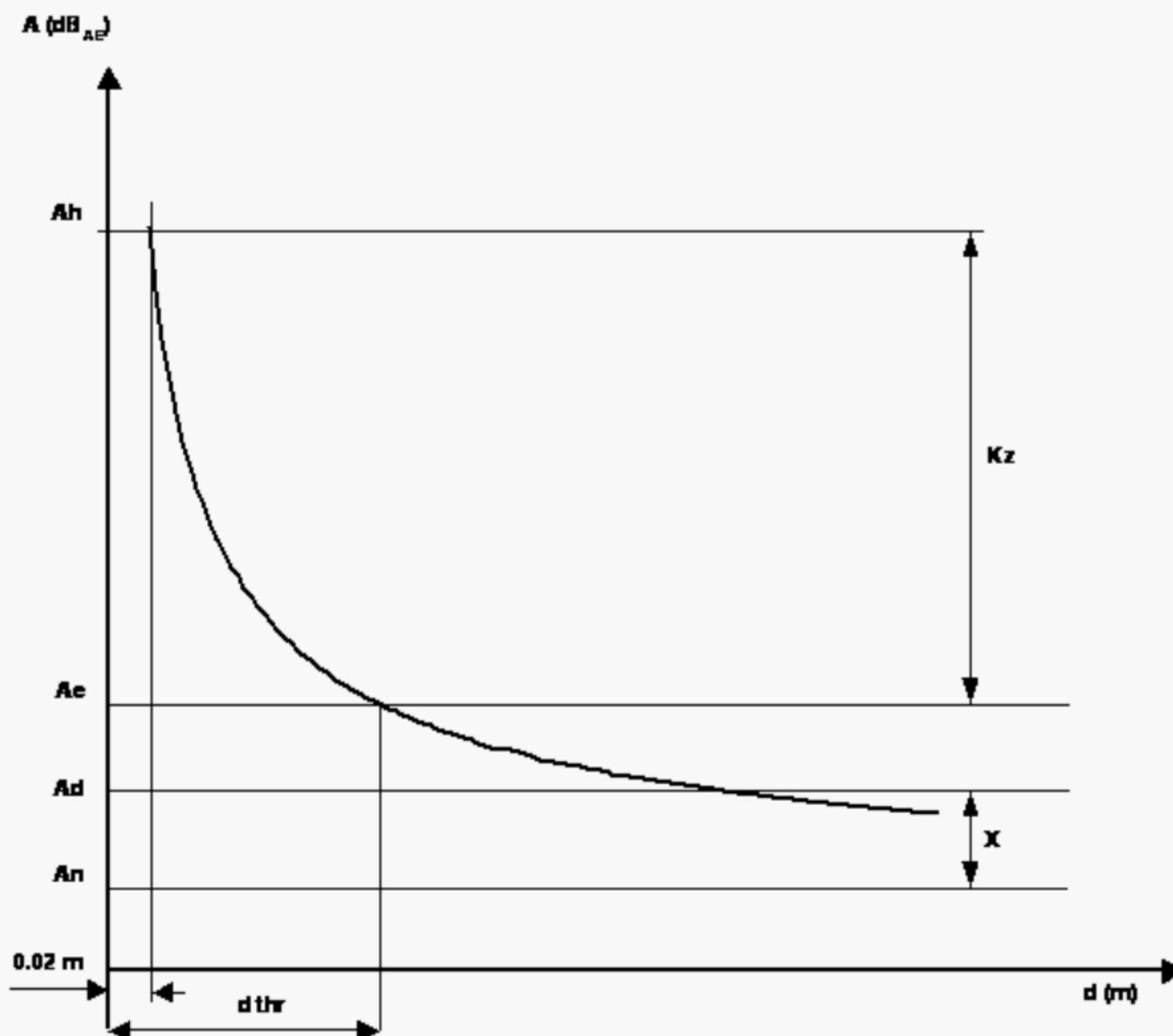
The threshold distance is the distance where the amplitude of the Hsu-Nielsen source is equal to the evaluation threshold  $A_e$ .

The evaluation threshold  $A_e$  is defined as the amplitude of the Hsu-Nielsen source at the distance of 0,02 m-minus  $K_z$ .

The detection threshold is  $x$  dB above the peak background noise, this must be less than evaluation threshold  $A_e$ .

Transmission must be through the steel.

The sensor spacing shall take into consideration variations in sensor sensitivity and coupling efficiency.



### Key

A peak amplitude

Ad detection threshold

Ae evaluation threshold

Ah peak amplitude of Hsu-Nielsen source at 0,02 m from the centre of sensor

An peak background noise

x value in dB, which is added to An in order to obtain Ad

Kz value in dB to be subtracted from Ah in order to obtain Ae

d distance

d thr threshold distance

**Figure 1 — Determination of the threshold distance from the attenuation curve**

## 7.2 Test steps

### 7.2.1 General Guidelines

The test shall ensure that AE data is collected during pressurisation, free from extraneous noises and without significant event overlap.

### 7.2.2 In situ verification

Prior to test, the correct functioning of all sensors and instrumentation shall be checked using a Hsu-Nielsen source at a fixed distance from each sensor.

Results shall be recorded together with sensor serial number and position. The average peak amplitude of four signals from any sensor shall be within  $\pm 3$  dB of the average of all sensors.

Following the test, this check shall be repeated to confirm continuing correct operation.

The use of an electronic pulser to check that there is no subsequent change in sensitivity, by comparison with that obtained prior to the test, is an acceptable alternative to repeating the Hsu-Nielsen source check.

### 7.2.3 Background Noise

The pressure equipment shall be monitored immediately prior to pressurisation for a minimum of 10 min at the detection threshold, to confirm that there is no ambient noise which might interfere with the test.

At the start of pressurisation, the instrumentation shall be observed for indications of extraneous noise caused by the pressurisation process. Should noise be observed the pressurisation shall be paused to identify the source and to take suitable remedial action.

Possible causes are turbulence due to flow restriction close to the pressure equipment, pump noise and leakage. A flexible line between the pump and the pressure equipment will usually remove pump noise.

Pressure equipment may also move on its supports during pressurisation, resulting in extraneous noise, which, if correctly identified, may be removed, from the data during post analysis. In order to minimise this effect the pressure equipment may be supported on rubber covered supports or rollers.

### 7.2.4 Equipment Pressurisation

The pressurisation shall follow the pre-arranged schedule defined in the product standard, unless there are difficulties with noise, or concerns about equipment integrity.

It is normal for AE to occur during initial loading due to stress-relief of the equipment. In this case a second cycle shall be performed. The second pressurisation shall be performed at a maximum pressure of 98 % of the first one.

This AE monitoring during the second pressurisation will identify locations where the stress-relief is incomplete or any flaws present are still active.

NOTE This does not mean that the evaluation shall be done only with the results of the 2<sup>nd</sup> pressurization. Due to the Kaiser effect the evaluation criteria have to be determined separately for the first and sub-sequent pressurization.

It is essential that good, instantaneous communication exists between the AE operator and the pressurisation operator in order that pressurisation may be paused, or the pressure reduced, if necessary.

## 8 Interpretation of results

### 8.1 General

For the interpretation of data from planar location, see EN 14584. The following applies only to results obtained by the zone location method.

### 8.2 Test stop criteria

#### 8.2.1 Test stop during the initial proof loading

The initial proof loading of unfired pressure equipment produces a large amount of AE as a result of stress relief. For this reason AE shall not be used for real time safety control, therefore initial proof loading shall be hydrostatic. Criteria for stopping the initial pressurisation to investigate the cause of excessive emission are any of the following:

- a) Progressive increase of energy per unit pressure on any AE channel as a function of the pressure;
- b) More than a defined number  $NZ_{1H}$  of hits above a specified amplitude  $AZ_{1H}$

The values of  $NZ_{1H}$  and  $AZ_{1H}$  shall be defined in the written test instruction.

NOTE It has to be taken into account if the pressure equipment has been heat treated.

#### 8.2.2 Test stop during subsequent loadings

Subsequent loadings should produce little or no AE from ongoing stress relief. This makes the use of AE monitoring for real time safety control more effective. Criteria for stopping subsequent pressurisations to investigate the cause of excessive emission are any of the following:

- a) progressive increase of energy per unit pressure on any AE channel as a function of the pressure;
- b) more than a defined number  $NZ_{2H}$  of hits above a specified amplitude  $AZ_{2H}$ ;
- c) more than  $NZ_{2L}$  hits above amplitude  $AZ_{2L}$  occurring after a time  $t_1$ , during hold periods, where  $t_1$  is measured from the start of the hold period.

The values of  $NZ_{2H}$ ,  $NZ_{2L}$ ,  $AZ_{2H}$ ,  $AZ_{2L}$  and  $t_1$  shall be defined in the written test instruction.

### 8.3 AE zone grading criteria

Following the test, the zones shall be graded according their AE behaviour (activity, intensity and history) into 5 grades, see Table 1 below. The grading criteria shall be defined in the written test instruction and/or has to be agreed between the customer and the AE test organisation.

Table 1 - Zone severity grading for initial proof testing

Zone severity grading	Definition	Further actions recommended
A	Very low activity	None, note for future reference
B	Low activity	
C	Medium activity	Follow up with NDT
D	High activity	Follow up with extensive NDT
E	Intense activity	Immediate action

NOTE For re-qualification tests the following actions should be performed: B grade zones are followed up visually for corrosion; C grade zones require further evaluation of the acoustic emission data and other appropriate NDT, if necessary; D grade zones are followed up with appropriate NDT as soon as practical; E grade zones require immediate NDT.

The interpretation of the results, including all necessary pressure stops, shall be recorded and, where possible, the results of supporting NDT should be added into the test report.

## 9 Documentation

The final report should include the following:

- a) test instruction and revision no.;
- b) name(s) of test operator(s);
- c) date and place of the test site;
- d) type of AE instrumentation;
- e) description of the pressure equipment;
- f) drawing with dimensions showing sensor locations;
- g) results of system verifications;
- h) test fluid employed and temperature;
- i) results of attenuation measurement;
- j) schematic representation of the test sequence of applied load;
- k) maps of the structure showing the AE zones identified during the test;
- l) description of the AE zones with the classification obtained from the evaluation criteria.

The report should be in accordance with EN ISO/IEC 17025 (paragraph: reporting).

## Bibliography

- [1] EN 13554, *Non-destructive testing - Acoustic emission - General principles*
- [2] EN ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories (ISO/IEC 17025:2005)*
- [3] EN 473, *Non destructive testing - Qualification and certification of NDT personnel - General principles*