BS EN 14584:2013

BSI Standards Publication

# Non-destructive testing — Acoustic emission testing — Examination of metallic pressure equipment during proof testing — Planar location of AE sources

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## National foreword

This British Standard is the UK implementation of EN 14584:2013. It supersedes BS EN 14584:2005 which is withdrawn.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.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.



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EUROPEAN STANDARD

NORME EUROPÉENNE

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# EN 14584

May 2013

ICS 17.140.20; 77.040.20

Supersedes EN 14584:2005

English Version

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

Essais non destructifs - Émission acoustique - Vérification des équipements métalliques sous pression pendant l'épreuve

Zerstörungsfreie Prüfung - Schallemissionsprüfung - Prüfung von metallischen Druckgeräten während der Abnahmeprüfung - Planare Ortung von Schallemissionsquellen

This European Standard was approved by CEN on 7 March 2013.

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# Foreword

This document (EN 14584:2013) 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of an identical text or by endorsement, at the latest by November 2013, and conflicting national standards shall be withdrawn at the latest by November 2013.

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.

This document supersedes EN 14584:2005.

Changes from the previous edition include:

— Clause 1: Applicability.

— Clause 4: Qualification of responsible test personnel AT2.

— Clause 8: Insertion of a further evaluation criteria about the occurrence of high energetic burst signals within a cluster.

— Annex A: Some clarifications for the recalculation according to the attenuation curve.

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## 1 Scope

This European Standard describes the method for conducting acoustic emission testing (AT) of metallic pressure equipment during acceptance pressure testing using a planar location method. This standard is applicable also for subsequent tests for requalification. General principles of Acoustic Emissions are described in EN 13554.

The objectives of the AE testing are to provide 100 % volumetric testing to define regions of the structure which are acoustically active with burst type AE, e.g. as a result of evolution of sub-critical discontinuities, thus increasing the reliability of the acceptance test. The test provides a reference map for comparison with results of future tests.

## 2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. 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 13477-1, *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 13554:2011, *Non-destructive testing — Acoustic emission testing — General principles*

EN ISO 9712:2012, *Non-destructive testing — Qualification and certification of NDT personnel (ISO 9712:2012)*

EN ISO/IEC 17025:2005, *General requirements for the competence of testing and calibration laboratories (ISO/IEC 17025:2005)*

## 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 Qualification of personnel

Testing shall be carried out by proficient, suitably trained and qualified personnel at minimum level 2 according to EN ISO 9712. To demonstrate appropriate qualification, it is recommended that personnel be certified according to EN ISO 9712 or an equivalent formalised system. Operating authorisation for a qualified person shall be issued by the employer in accordance with a written procedure.

NDT operations, unless otherwise agreed, shall be authorised by a competent and qualified NDT supervisory individual (Level 3 according to EN ISO 9712 or equivalent) approved by the employer.

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

# 5 General

## 5.1 Initial considerations

The main target of the AE test is to detect, locate and monitor acoustic emission sources caused by phenomena generated by the applied load to the equipment, e.g. crack growth and yielding.

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 relevant located AE sources shall be evaluated by other NDT methods.

## 5.2 Application of load

The application of stress 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 limited 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. For pneumatic pressurisation, the pressurisation rate would not normally exceed 1 % of test pressure per minute, and for hydraulic loading, 5 % per minute. The intermediate hold periods, if necessary according to the AE activity or the pre-defined pressure schedule, will normally be 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.

Dependent upon the results of the initial loading, a reduction of the load to working pressure or lower, followed by re-pressurisation, may be required.

## 5.3 Sensors

The most commonly used frequency range is 100 kHz to 300 kHz. Lower frequency monitoring allows detection at greater distances and higher frequency monitoring provides improved rejection of external noise. Selection of frequency range may optimise location accuracy by avoiding the detection of multiple wave modes.

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

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

## 5.4 Location

The location of AE sources is performed using $\Delta t$ measurement.

The accuracy is normally within ± 5 % of the maximum used sensor spacing ($d_{max,u}$) (see 7.1.2) and shall be measured and verified using an artificial source. The artificial source shall have an amplitude equivalent to the Hsu-Nielsen source minus the value of K. Alternatively a Hsu-Nielsen source may be used and the detection threshold raised to the evaluation threshold during these location accuracy checks. If the accuracy is not within ± 5 %, appropriate action shall be taken.

For difficult geometry, e.g. nozzles, manholes, reference measurements shall be made.

### 5.5 Preliminary information

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

a) relevant product standard;

b) type of equipment or structure specifications;

c) assembly and/or layout drawings with sufficient details of the structure;

d) material specifications, including heat treatment, if applicable;

e) proposed pressure/stress application sequence;

f) potential acoustic noise interference sources and the isolating mechanism applied;

g) 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) explicit indication of the purpose of the test and limitations, if any;

b) sensor type, frequency and manufacturer;

c) method of sensor attachment;

d) type of acoustic coupling used;

e) type of surface preparation;

f) type of AE equipment used with its main characteristics;

g) energy measurement method to be used;

h) value of K from relevant product standard, if available;

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) pre-defined pressure schedule;

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.

The test instruction shall be prepared in accordance with EN ISO 9712:2012, Table D.1.

# 6 Instrumentation

An AT system shall consist of sensors and equipment for signal conditioning and processing, and for displaying and recording data according to EN 13477-1.

The AT 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 (leading edge and/or peak); and

on the external input: external parameters, such as pressure and/or other stress parameters.

In order 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 location display;

— provide an on-line display of AE data and pressure.

To assist the on-line evaluation, it is recommended that the instrumentation provides real-time distance peak amplitude correction and applies grading.

The AT system performance check (including sensors) shall be performed according to EN 13477-2.

# 7 Testing

## 7.1 Pre-test measurements

### 7.1.1 Wave propagation

Attenuation measurements shall be performed on the structure in order to determine the maximum sensor spacing. The measurements shall be performed with the test fluid in the equipment using the Hsu-Nielsen source. In the case that the Hsu-Nielsen source saturates the measurement chain, a lower energy artificial source shall be used up to the 20*e* distance (see Annex A). The obtained curve shall in this case be shifted up to correspond with the original Hsu-Nielsen source.

The burst signal peak amplitude versus distance, and the wave velocity to be used in the location algorithm, 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.

#### 7.1.2 Determination of maximum allowed sensor spacing

The sensors shall be positioned on the structure, such that a source K dB less than a Hsu-Nielsen source can be detected and located to the specified accuracy at any position on the equipment. This shall also be achievable under test conditions where noise due to pressurisation may be present.

The value of K shall be obtained from the relevant product standard and given in the written test instruction.

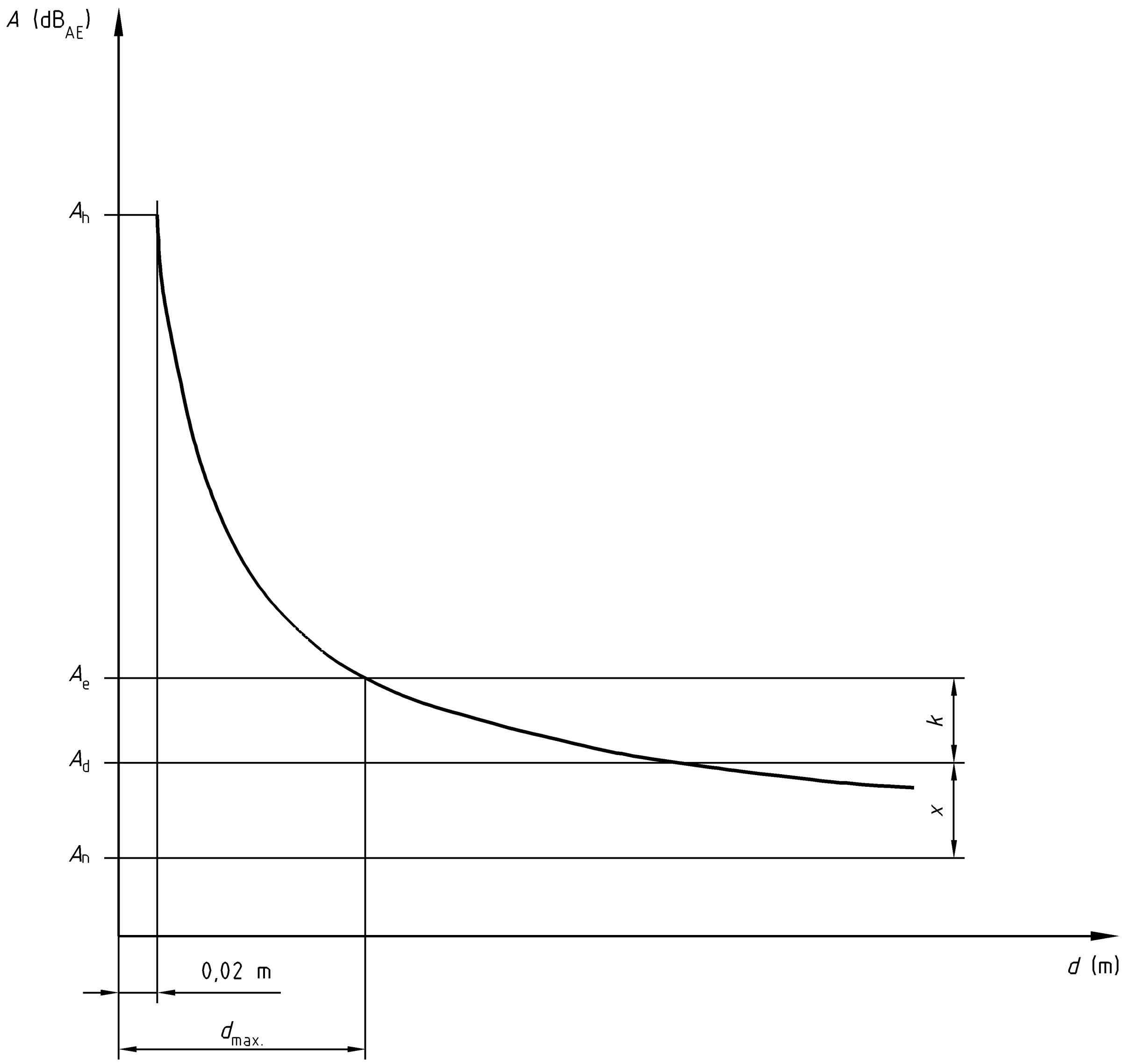
With reference to Figure 1:

a) Set the detection threshold X dB above the peak background noise. The peak background noise is defined as the threshold at which there is less than one hit per second on any channel.

NOTE The value of X will typically be between 6 dB and 18 dB, dependent upon the noise level from pressurisation.

b) Set the evaluation threshold for determining the sensor spacing K dB above the detection threshold.

c) The maximum distance ($d_{max}$) is given by the intersection of the attenuation curve with the evaluation threshold ($A_e$).




**Key**

*A* peak amplitude

$A_d$ detection threshold

$A_e$ evaluation threshold

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

$A_n$ peak background noise

*d* distance

**Figure 1 — Determination of the maximum sensor spacing from the attenuation curve**

In Table 1, an example for calculation of the evaluation threshold is shown.

**Table 1 — Example for calculation of evaluation threshold**

| Key | | Example of values $dB_{AE}$ |
|---|---|---|
| $A_n$ | Peak background noise | 24 |
| $A_d$ | Detection threshold ($A_n$ + X; X = 12 dB) | 36 |
| $A_e$ | Evaluation threshold ($A_d$ + K; K = 12 dB) | 48 |

The maximum used sensor spacing $d_{max,u}$ may depend on different influences (e.g. pressure equipment geometry, number of hits to be used for location calculation) and shall not be greater than $d_{max}$ (used for the definition of cluster size, see 8.1).

## 7.2 Test steps

### 7.2.1 General guidelines

Test personnel shall ensure that the data collected during pressurisation is free from extraneous noise and event overlap is minimised by control of pressurisation rate.

### 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. The distance shall be chosen to avoid saturation.

Results shall be recorded together with sensor serial number and position. The average peak amplitude of four signals from the ninety degree positions around any sensor shall be within ± 3 dB of the average of all sensors.

The possible influence of any sensor attachment such as a magnetic hold-down shall be taken into account.

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.

Correct operation of any location function shall be confirmed by use of a Hsu-Nielsen source in general areas and around details such as nozzles and manways. The evaluation threshold used for this check shall be adjusted to compensate for the high peak amplitude of the Hsu-Nielsen source compared with the required sensitivity during the test.

### 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 at this time, or at any other point during the test, the pressurisation shall be paused to identify the source and to take remedial action where necessary.

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 Pressurisation

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

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

It is normal for AE to occur during initial loading due to stress relief of the equipment.

The AE monitoring, when a second pressurisation is performed, will identify locations where the stress relief is incomplete or any discontinuities present are still active.

This does not mean that the evaluation shall be done only with the results of the second pressurisation. Due to the Kaiser effect, the evaluation criteria have to be determined separately for the first and subsequent pressurisations.

## 8 Interpretation of results

### 8.1 Grading criteria

The grading criteria are used for real-time control and for subsequent source severity grading. They shall be defined by the AE test organisation and are influenced by:

— type and size of the pressure equipment;

— material and heat treatment;

— first or subsequent pressurisation.

The decision to continue with the pressurisation or to decrease the rate, or to hold steady or decrease the pressure for further evaluation and/or for NDT shall be based on the following:

a) the progressive increase of acoustic emission activity and/or energy on any AE channel as a function of the pressure;

b) the number N1 of located burst signals with a distance corrected peak amplitude above a “high” specified value A1;

c) the occurrence of a number N3 of located burst signals above the specified corrected peak amplitude AC2 in a defined time period '$t_h$' during the hold. The time period $t_h$ starts 2 min after the beginning of the hold period;

d) the number NC1 of located burst signals with a distance corrected peak amplitude above a “high cluster” specified value AC1 within a square of an edge length or circle with a diameter of Z;

e) the number NC2 of located burst signals with a distance corrected peak amplitude above a “low cluster” specified value AC2 within a square of an edge length or circle with a diameter of Z.

NOTE NC1 and AC1 are new to this standard and refer to clustered data, and NC2 and AC2 correspond to N2 and A2 in the previous standard.

Distance dependent peak amplitude correction shall be carried out in accordance with Annex A.

The values of A1, AC1, AC2, N1, N3, NC1, NC2, Z and $t_h$ for real-time control and for subsequent source severity grading shall be given by the AE test organisation within the test instruction.

## 8.2 Real-time control

The pressurisation shall be stopped if:

— one of the counted values N1, NC1, NC2 or N3 reaches or exceeds the corresponding limit value;

— the energy doubles from any channel in two consecutive pressure intervals of 5 % of the maximum test pressure. The energy (EB), from which the doubling leads to a test stop, shall be given within the written test instruction.

Before the pressurisation is continued, the reasons for the suspension shall be investigated and, if necessary, appropriate NDT measurements made.

Examples of values for real-time control are given in Table 2 below.

**Table 2 — Example of definition of real-time control parameters**

**CAUTION: The values in the table are an example only. The test organisation shall define these values in the written test instruction. Under no circumstances should these example values be used.**

| Real-time control parameters | Example values |
|---|---|
| EB | 1 000 |
| A1 | 105 $dB_{AE}$ |
| N1 | 5 |
| AC1 | 100 $dB_{AE}$ |
| NC1 | 5 |
| AC2 | 88 $dB_{AE}$ |
| NC2 | 20 |
| N3 | 2 |
| Z | 0,1 $d_{max,u}$ |
| $t_h$ | 5 min |

### 8.3 AE source location cluster severity grading

Following the test, the AE source location clusters shall be graded according to their AE activity and intensity into 3 grades (see Table 3)**.** The grading criteria shall be defined in the written test instruction and should be agreed between the customer and the AE test organisation. The grading shall be based upon EN 13554:2011, 9.3.

**Table 3 — Location cluster severity grading**

| Location cluster 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, etc.) |
| 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 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 Test documentation

The test documentation shall include the following:

a) identification of the test site and customer;

b) identification of the object under test;

c) description of the pressure equipment;

d) test instruction and revision number;

e) name(s) of test operator(s);

f) date and time of test;

g) AE instrumentation used and verification date;

h) drawing with dimensions showing sensor locations;

i) results of system verifications;

j) test fluid employed and temperature;

k) results of attenuation measurement;

l) map showing location of simulated sources;

m) schematic representation of the applied pressurisation sequence;

n) maps of the structure showing the AE sources identified during the test;

o) AE test results including:

  1) number of located events above amplitude A1;

  2) number of events above amplitude AC1 for every location cluster;

  3) number of events above AC2 for every location cluster;

  4) grading of the AE location clusters.

## 10 Test report

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

The test report shall be in accordance with EN ISO/IEC 17025:2005, 5.10.

# Annex A
(normative)

## Procedure for the correction of peak amplitude with distance

Two acceptable methods are given below. For on-line calculation of source peak amplitude the nearest sensor to the source may be used. However, inaccuracies in the measurement of attenuation may occur in the near field. For this reason, post-analysis amplitude distance correction of these sources shall use a more suitably positioned sensor.

NOTE 1 The term near field used here refers to the area near to the sensor where geometric effects and wave mode conversion result in high and rapidly changing attenuation with distance. The far field is the region beyond this, where attenuation with distance changes less and is significantly reduced.

a) Use of attenuation curve (see Figure 1):

   1) find the peak amplitude $A_s$ of the Hsu-Nielsen source at $d_s$ where $d_s$ is the distance from the located source to the nearest sensor;

   2) subtract this value from $A_h$ (Hsu-Nielsen source peak amplitude at 0,02 m from the sensor);

   3) the corrected source peak amplitude is obtained by adding the resulting value ($A_h$ – $A_s$) to $A_{m,}$ where $A_m$ is the measured peak amplitude of the source.

b) Calculation by using a linear approximation:

Corrected source peak amplitude in the far field is equal to measured peak amplitude plus near field attenuation plus far field attenuation, where it is assumed that:

   1) near-field attenuation ($\Delta A_N$) is equal to the Hsu-Nielsen source peak amplitude at 0,02 m from sensor minus the Hsu-Nielsen source peak amplitude at the limit of the near field at 20 times wall thickness;

   NOTE 2 The value of 20 times wall thickness (20*e*) is an approximation for the simplest structures with wall thickness above 10 mm and will be used for the calculation.

   2) the far-field attenuation is equal to the far-field attenuation coefficient ($\alpha$) times the far-field source distance ($\Delta d$). The far-field attenuation coefficient is the Hsu-Nielsen source peak amplitude at 20*e* minus $A_e$ divided by the distance between $d_{max}$ and 20*e*.

$$A_{20e} = A_m + \alpha.\Delta d \tag{A.1}$$

$$A_c = A_{20e} + \Delta A_N \tag{A.2}$$

$$A_c = A_m + \alpha.\Delta d + \Delta A \tag{A.3}$$

where

$A_c$ is the distance dependent corrected peak amplitude of source ($dB_{AE}$);

$A_m$ is the measured peak amplitude of source ($dB_{AE}$);

$A_{20e}$ is the assumed peak amplitude of source at 20*e* distance ($dB_{AE}$);

$\Delta A_N$ is the measured attenuation of Hsu-Nielsen source between 0,02 m and 20*e* distance (dB);

$\Delta d$ is the distance from AE source to sensor minus 20*e* (m);

*e* is the wall thickness (m);

$\alpha$ is the attenuation coefficient between 20*e* and the maximum detection distance (dB/m).

If the located source is within the near field, during on-line measurement the source peak amplitude correction may be done by using a near field attenuation coefficient ($\beta$). The near field attenuation coefficient is the Hsu-Nielsen source peak amplitude at 0,02 m minus Hsu-Nielsen source peak amplitude at 20*e* divided by the distance 20*e* minus 0,02 m.

$$\beta = \Delta A_\mathrm{N} / (20e - 0{,}02) \tag{A.4}$$

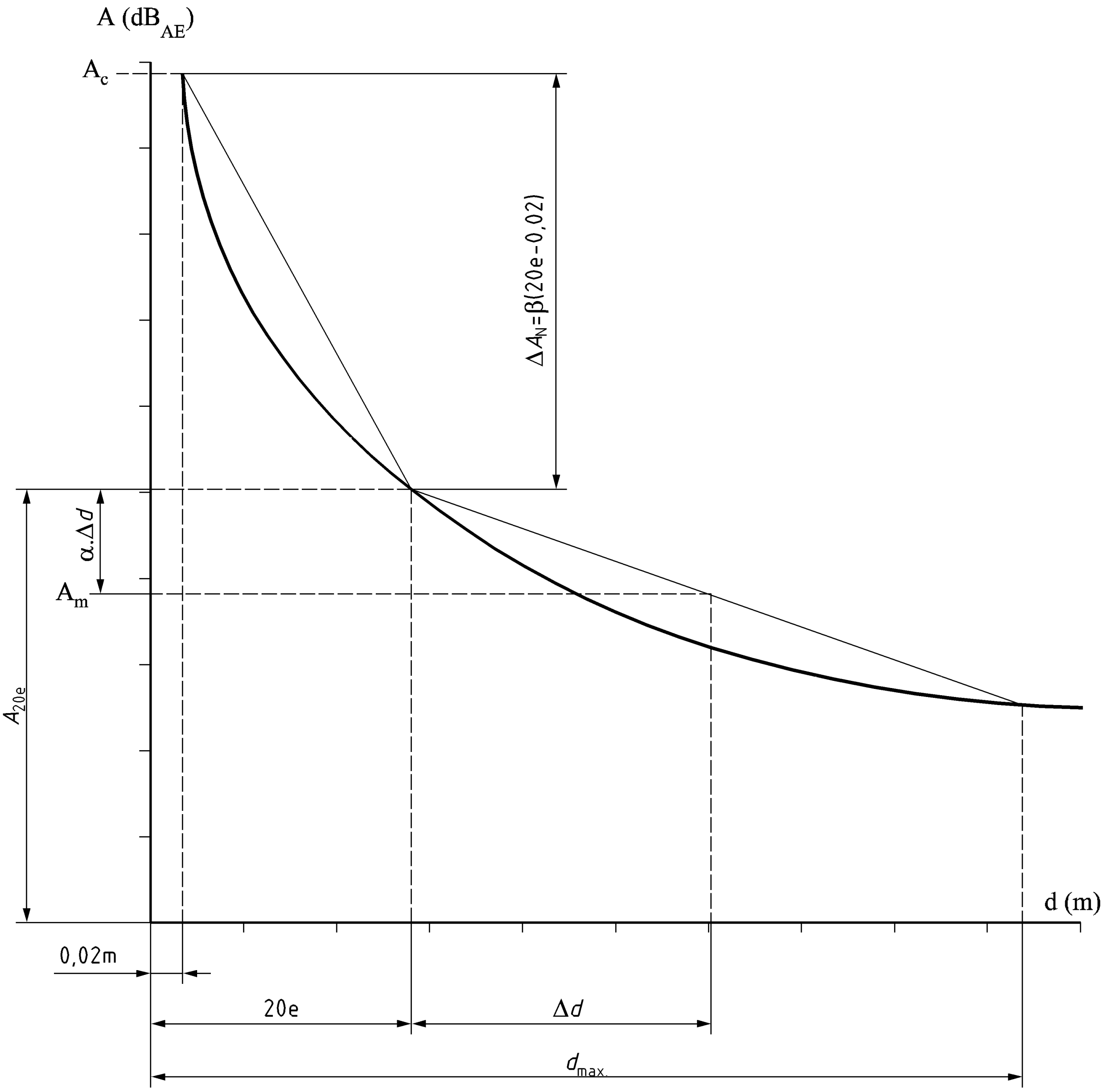
$$A_\mathrm{c} = A_\mathrm{m} + \beta (d_\mathrm{s} - 0{,}02) \tag{A.5}$$

where

$d_\mathrm{s} < 20e$.

For example, see Figure A.1.

NOTE 3 For the practical implementation of the on-line source peak amplitude correction in the near field, the term ‘20*e* – 0,02’ can be replaced by ‘20*e*’ and ‘$d_\mathrm{s}$ – 0,02’ by ‘$d_\mathrm{s}$‘.




**Key**

| | |
|---|---|
| $A$ | peak amplitude |
| $d$ | distance |
| $\Delta d$ | far-field source distance |
| $\alpha$ | far-field attenuation coefficient |
| $\beta$ | near-field attenuation coefficient |
| $\Delta A_N$ | near-field attenuation |
| 20$e$ | 20 times wall thickness ($e$) |
| $A_{20e}$ | assumed peak amplitude of source at 20$e$ distance ($dB_{AE}$) |
| $A_m$ | measured peak amplitude of source ($dB_{AE}$) |
| $A_c$ | distance dependent corrected peak amplitude of source ($dB_{AE}$) |
| $d_{max}$ | maximum sensor spacing |

**Figure A.1 - Example for source peak amplitude correction for source in the far field**

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