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Non-destructive testing — Acoustic emission testing — Detection of corrosion at atmospheric and low-pressure metallic storage tank floors

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This document was prepared by Technical Committee ISO/TC 135, *Non-destructive testing*, Subcommittee SC 9, *Acoustic emission testing*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Industrial applications of acoustic emission testing for atmospheric metal storage tanks have been gaining wider usage alongside marked improvement of acoustic emission testing technologies. The effectiveness of any application of acoustic emission testing depends upon proper and correct use of the acoustic emission instruments and test techniques.

In addition, existing international acoustic emission standards lack a specification of a classification system with the associated recommendations for maintenance.

The purpose of this document is to provide requirements for the testing equipment, testing procedures and classification system for acoustic emission testing for corrosion of atmospheric metal storage tank floors.

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Non-destructive testing — Acoustic emission testing — Detection of corrosion at atmospheric and low-pressure metallic storage tank floors

1 Scope

This document describes the testing methodology based on acoustic emission (AE) for atmospheric and low-pressure (less than or equal to 50 kPa on top of the tank) metallic storage tank floors and the classification system to be used for test results.

This document applies to the acoustic emission testing (AT) for corrosion severity of atmospheric metal storage tank floors.

The technique is limited to tank floors made of construction steel and relies on an active corrosion process. It applies only in cases where corrosion of the floor is the governing damage mechanism. Good results will be obtained providing corrosion conditions have not changed.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

ISO 12716, *Non-destructive testing — Acoustic emission inspection — Vocabulary*

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

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 12716 and the following apply.

ISO and IEC maintain [terminological terminology](#) databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

3.1

acoustic emission testing

AT

testing of a test object during controlled stimulation using acoustic emission instrumentation to detect and analyse sources of acoustic emission

[SOURCE: EN 1330-9:2017, 2.5.1]

3.2

Hsu-Nielsen source

device to simulate an [Acoustic emission](#) event using the fracture of a brittle graphite lead in a suitable fitting

Note 1 to entry: Hsu-Nielsen source is according to [Figure 1](#).

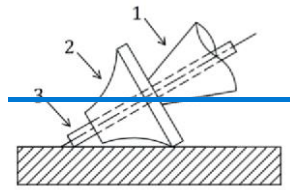
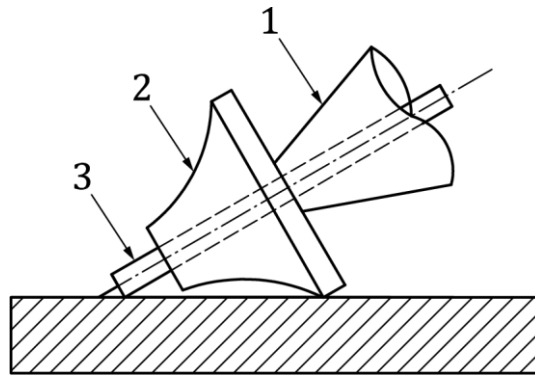


Figure 1 — Hsu-Nielsen source



Key

- 1 pencil
 - 2 guide ring
 - 3 graphite lead
- hardness grade [2H2H](#)
 diameter 0,5 mm
 length $3,0 \pm 0,5$ mm

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Figure 1 — Hsu-Nielsen source

4 General principles

During the operation of atmospheric metallic storage tanks, the tank floor is potentially subjected to a corrosive environment and due to the ongoing corrosion process AE waves are generated.

Elastic waves are generated by AE events from the corrosion process itself or peeling and cracking of corrosion products on the tank floor and are transmitted to the surface of the tank wall predominantly through the storage medium.

The purpose of AT of storage tank floors is to detect the AE signals related to the corrosion process with AE sensors mounted in the lower part of the tank wall.

By receiving and analysing these signals, the severity of the tank floor corrosion condition can be determined and assessed.

5 Qualification of test personnel

AT shall be performed by competent personnel. In order to ensure that this is the case, it is recommended that the personnel meet the requirements of ISO 9712 or equivalent.

6 Test equipment

6.1 Acoustic emission testing system

An AT system consists of an AE instrument including software, AE sensors, preamplifiers, interconnecting cables, and mounting devices holding the sensors.

All essential parts of the AT system shall be specified in a written test instruction agreed at the time of enquiry or order (see [10.2.10.2](#)).

6.2 Acoustic emission sensors

The requirements for AE sensors are as follows:

- a) ~~a)~~ The main response frequency of the sensors shall be between 20 kHz and 80 kHz.
- b) ~~b)~~ The minimum sensitivity shall be equivalent to or greater than 60 dB referred to 1 Vs/m in surface wave sound field calibration, or in longitudinal wave calibration.
- c) ~~c)~~ Sensors shall be shielded against radio frequency and electromagnetic noise interference by proper shielding practice or by differential element design, or both.
- d) ~~d)~~ The metallic housing of each AE sensor shall be electrically isolated from the metallic test object.
- e) ~~e)~~ The AE sensors shall be stable over the response frequency and temperature range of use, and shall not exhibit sensitivity changes greater than 3 dB over this range.
- f) ~~f)~~ To get sufficient sensitivity, a Hsu-Nielsen source at a distance of 100 mm from the sensor shall generate a peak amplitude of at least 80 dB_{AE}.
- g) ~~g)~~ The verification of the sensors shall be performed according to sensor-specific manuals provided by the manufacturer.

6.3 Acoustic emission signal cables

The requirements for AE signal cables used to connect AE sensors and preamplifiers are as follows:

- a) ~~a)~~ ~~The signal~~ Signal cables connecting sensors and preamplifiers shall be shielded against electromagnetic interference.
- b) ~~b)~~ ~~Its~~ Cable length shall not exceed 1 m, unless the length-dependent signal loss is considered and acceptable.

This requirement may be omitted where the preamplifier is integrated in the shielded sensor housing.

6.4 Couplant

The used couplant shall provide an effective coupling quality so that the sensor tracks the motion of the surface.

6.5 Preamplifiers

The preamplifiers may be separate or may be mounted in the sensor housing.

The requirements for preamplifiers are as follows:

- a) ~~a)~~ The RMS voltage of preamplifiers circuit noise shall be less than 7 µV.

- b) ~~b)~~ The preamplifiers shall be stable over the response frequency and temperature range of use, and shall not exhibit sensitivity changes greater than 3 dB over this range.
- c) ~~c)~~ The preamplifiers response frequency shall match ~~with~~ that of the sensors, and the gain of the preamplifiers, usually 34 dB, 40 dB or 46 dB, shall not cause saturation of the measurement chain.
- d) ~~d)~~ If the preamplifiers are of differential design, a minimum of 40 dB of common-mode rejection shall be provided.

6.6 Power-signal cables

The requirements for power-signal cables providing power to the preamplifier and conducting the amplified signal to the main processor are as follows:

- a) ~~a)~~ The cables shall be shielded against electromagnetic noise.
- b) ~~b)~~ Signal loss shall be no more than 1 dB per 30 m of cable length. 150 m is the recommended maximum cable length to avoid excessive signal attenuation.
- c) ~~c)~~ The signal loss of cables depends on type of cable, frequency and length. With cable length above 30 m, the resulting attenuation and the voltage drop-off of the DC supply shall be evaluated and considered in the data analysis.

6.7 Filters

The response frequency of filters in the preamplifiers and the AE instrument shall match ~~with~~ that of the AE sensors.

6.8 Acoustic emission instrument

The requirements for the AE instrument are as follows:

- a) ~~a)~~ The AE instrument shall have enough AE channels to cover the area to be tested.
- b) ~~b)~~ For each channel, the AE instrument shall display and record arrival time, threshold, peak amplitude, ring-down count, energy, rise time and duration for each hit as a minimum.
- c) ~~c)~~ The individual sampling frequency of each channel for acquisition of waveforms shall not be less than 10 times the sensors' centre response frequency.
- d) ~~d)~~ The measurement inaccuracy for a threshold above 40 dB_{AE} shall not exceed ± 1 dB.
- e) ~~e)~~ The measurement inaccuracy for ring-down counts shall not exceed ± 5 %.
- f) ~~f)~~ The measurement inaccuracy for peak amplitudes above 40 dB_{AE} shall not exceed ± 1 dB.
- g) ~~g)~~ The measurement inaccuracy for energy above 40 dB_{AE} shall not exceed ± 5 %.
- h) ~~h)~~ The measurement inaccuracy for the external parametric inputs, such as pressure, liquid level and temperature, shall not exceed 2 % of the full range.
- i) ~~i)~~ The resolution of rise time, duration and arrival time for each channel shall be less than or equal to 1 μ s.
- j) ~~j)~~ The error of arrival time measurement between all channels shall be not more than 2 μ s.
- k) ~~k)~~ The electronic noise levels shall be equal to or ~~below~~ less than 20 dB_{AE} in the frequency range from 20 kHz to 80 kHz.

- l) ~~l)~~ The usable dynamic range shall be at least 65 dB.
- m) ~~m)~~ The AE instrument shall be capable ~~to process, store of processing, storing~~ and ~~display displaying~~ at least 20 hits per second at all channels.
- n) ~~n)~~ The delay and display from the arrival of the AE hits shall not exceed 10 seconds.
- o) ~~o)~~ The real-time update time for diagrams shall not be more than 5 s.
- p) ~~p)~~ An alarm shall occur if the hit rate exceeds the capability of the AE instrument.
- q) ~~q)~~ A warning shall occur when the storage space runs low.
- r) ~~r)~~ During data acquisition, AE software shall be capable ~~to display of displaying~~ the following diagrams:
 - 1) ~~1)~~ any AE parameter versus time;
 - 2) ~~2)~~ one AE parameter versus another AE parameter;
 - 3) ~~3)~~ tank floor circular planar locations.
- s) ~~s)~~ The AE analysis software shall provide functions to replay and ~~to~~ analyse the recorded AT data.

6.9 Maintenance and verification of test equipment

The performance of the AT system shall be verified at specified intervals ~~according to~~ in accordance with EN 13477-2.

7 Actions before testing

7.1 General information

Prior to the specification of the test, the following information shall be provided:

- a) ~~a)~~ the purpose of the test;
- b) ~~b)~~ details of the storage tank to be tested;
- c) ~~c)~~ the requirements for surface preparation;
- d) ~~d)~~ the acceptance criteria, if specified;
- e) ~~e)~~ the requirements in relation to the test report;
- f) ~~f)~~ details of the qualification of test personnel.

7.2 Documents

Before performing an AE test, the following documents shall be provided for the storage tank to be tested, as a minimum:

- a) ~~a)~~ design and fabricating documents of the storage tank, ~~e.g., for example~~ product certification, quality certification document, as-built drawing;

- b) ~~b)~~ operation recording documents of the storage tank, ~~e.g., for example~~ type of liquid, the normal product and number of years with this product, the highest level of liquid, range of operating temperature, and abnormal conditions;
- c) ~~c)~~ previous test reports;
- d) ~~d)~~ other documents, ~~e.g., for example~~ drawings and records showing repairs or modifications.

7.3 Site inspection

- a) ~~a)~~ Prior to testing, a site inspection shall be carried out to find all interference factors, such as mechanical impact, electromagnetic interference and vibration.
- b) ~~b)~~ The interference of these factors shall be eliminated or sufficiently reduced during on-site AT.

7.4 Preparation of test instruction and record sheet

- a) ~~a)~~ The test instruction (see ~~10.240.2)~~ and record sheets (see ~~10.340.3)~~ shall be prepared in accordance with the NDT procedure, storage tank and site conditions.
- b) ~~b)~~ The instrument, applicable sensors and surface conditions of the storage tank shall be specified.

7.5 Sensor mounting

- a) ~~a)~~ The first row of sensors is placed on the tank wall near to the tank floor, and it shall be ~~assured~~ensured that they are above the height of the ~~sediments~~sediment in the tank. Thick layers of ~~sediments will~~sediment affect the sensitivity of AT.

- b) ~~b)~~ A second row of sensors (guard sensors) shall be mounted when noise from higher up in the tank (e.g., condensation) can be expected.

The second row of sensors shall be below the liquid level, usually at about 3 m height above the first row.

- c) ~~c)~~ The sensors of each row shall be mounted at the same height.
- d) ~~d)~~ Care shall be taken that the sensitivity of the sensors is similar.
- e) ~~e)~~ The maximum spacing of adjacent sensors shall not exceed 15 m.
- f) ~~f)~~ If there are manholes, nozzles and welded structures between two adjacent sensors, the maximum spacing shall not exceed 13 m.
- g) ~~g)~~ It is recommended ~~that six to~~ install ~~6 to 8~~eight sensors ~~are installed~~ per row for a tank with a diameter of less than 25 m.
- h) ~~h)~~ All the sensors shall be numbered and indicated in the schematic diagram of the tank.
- i) ~~i)~~ The mounting of sensors shall meet the following requirements:
 - i) ~~1)~~ The sensors shall be installed according to the specified sensor array.
 - ii) ~~2)~~ The place for the mounting of a sensor on the tank shall be smooth and showing the metallic lustre. The coating can be kept when it is smooth and compacted and measured attenuation is acceptable.
 - iii) ~~3)~~ Efficient couplants, such as vacuum grease or vaseline, are recommended.
 - iv) ~~4)~~ ~~Firmly~~Firm fixing of the sensors onto the tank shall be performed by a magnetic holding device, ~~by an~~ adhesive tape or other devices and mounting materials, ~~respectively~~ that provide equivalent sensor adhesion over the test duration.
 - v) ~~5)~~ For tanks with interlayer or insulation, removal of insulation ~~or~~ interlayer material at sensor position to allow sensor mounting directly onto the tank surface is the preferred solution.