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Non-destructive testing — Acoustic emission testing — Steel structures of overhead travelling cranes and portal bridge cranes

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National foreword

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Foreword

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

INTERNATIONAL STANDARD **ISO 19835:2018**

Non-destructive testing — Acoustic emission testing — Steel structures of overhead travelling cranes and portal bridge cranes

1 Scope

This document describes the acoustic emission (AE) testing technique used to perform structural integrity evaluation on steel structures of overhead travelling cranes and portal bridge cranes.

This document applies to the testing of steel structures of in-service overhead travelling cranes and portal bridge cranes. Testing of other kinds of cranes can refer this document.

This testing method is not intended to be an alone NDT standard method for the evaluation of the structural integrity of overhead travelling cranes and portal bridge cranes. Other NDT methods are used to verify and supplement the AT results.

This document does not establish evaluation criteria.

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 4310, *Cranes — Test code and procedure*

ISO 12714, *Non-destructive testing — Acoustic emission inspection — Secondary calibration of acoustic emission sensors*

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

ISO/TR 13115, *Non-destructive testing — Methods for absolute calibration of acoustic emission transducers by the reciprocity technique*

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 databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
acoustic emission source
AE source
source point or spatial position in the material where transient elastic waves are generated by the release of energy

3.2
acoustic emission location source
AE location source
spatial area comprising one or more clusters associated with an *AE source* (3.1) and encompassing the true physical location of the AE events giving rise to the AE source

Note 1 to entry: Common location methods include zone location, computed location and continuous AE signal location.

3.3
activity
<of acoustic emission source> increasing total number of AE events in *AE location source (3.2)* with loading process or loading time

3.4
intensity
<of acoustic emission source> average elastic energy released by the AE events in the *AE location source (3.2)*

Note 1 to entry: Burst AE source intensity related parameters are, e.g. maximum amplitude, energy, signal strength and, to a certain extent, ring down counts. Continuous AE source intensity related parameters are, e.g. root mean square (RMS AE) signal voltage, average rectified signal voltage and average signal level (ASL).

3.5
maximum operating load
maximum operation load is the maximum load of the crane bearing in the last 6 months before the AE testing

4 General principles

The main purpose of acoustic emission testing (AT) is to detect the acoustic emission source generated in the parent metal of steel structures, weld surface and internally, and locate the acoustic emission source.

The acoustic emission testing shall be done during the loading process, which includes the loading, load holding and unloading. The acoustic emission sensors should be arranged on the surface of steel structure being detected, to receive the signals generated by the active source and transfer it into electric signals. The AE instrument is used to collect, handle, display, record and analyse the signals, and then provides the parameters and location of the acoustic emission source.

5 Qualification of personnel

It is assumed that AE testing is 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 Equipment

6.1 AE testing system

AE testing employs an AE instrument, AE sensors, preamplifiers, and interconnecting cables.

This combination together with some mechanical equipment holding the sensors forms the AE testing system.

All essential parts of the system shall be defined in a written procedure agreed at the time of enquiry or order (see 10.2).

6.2 AE sensors

It is recommended to use sensors in the frequency range between 100 kHz and 400 kHz.

The minimum sensitivity shall be equivalent or greater than 60 dB referred to 1 V/(m·s-1) in surface wave sound field calibration, or in longitudinal wave calibration.

When sensors with other response frequencies are used, they shall provide enough sensitivity within its frequency band.

Sensors shall be shielded against radio frequency and electromagnetic noise interference by proper shielding practice or by differential element design, or both. The metallic case of each AE sensor shall be electrically isolated from a metallic test object.

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.

AE sensors mounted on the surface of a steel structure shall be insulation from each other.

For sufficient sensitivity, a pencil lead break of 0,5 mm diameter, hardness 2H, in 50 mm distance from the sensor, shall generate an amplitude of at least 95 dB_{AE}.

The calibration of the sensors shall be performed according to ISO 12714 or with ISO/TR 13115.

6.3 Signal cables

The signal cables connecting sensors and preamplifiers shall be shielded against electromagnetic interference. Its length shall not exceed 1 m, unless the length-depending signal loss is considered and acceptable.

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

6.4 Couplant

The used couplant should keep good sound transfer effect during testing.

6.5 Preamplifiers

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

The RMS voltage of preamplifiers circuit noise shall be less than 7 μV.

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.

The preamplifiers response frequency shall match with that of the sensors, and the gain of the preamplifiers, usually 40 dB or 34 dB, shall not cause saturation of the measurement chain up to a 100 dB_{AE} signal amplitude.

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 cable providing power to the preamplifier and conducting the amplified signal to the main processor shall be shielded against electromagnetic noise. 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.

The cables providing power to the preamplifier and conducting the amplified signal to the main processor shall be shielded against electromagnetic noise.

The signal loss of cables depends on type of cable, frequency and length. With cable length above 10 m, the resulting attenuation and the voltage drop off the DC-supply shall be evaluated and considered in the data analysis. The signal loss shall be no more than 1 dB per 30 m of cable length.

To avoid excessive signal attenuation, the recommended maximum cable length is 150 m.

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 AE instrument

The AE instrument shall have enough AE channels to cover the testing area. For each channel, the instrument shall provide as a minimum the following features: displaying and recording of arrival time, threshold, amplitude, count, energy, rise time, duration time, and hits. It is preferred that the instrument is able to receive and record also external electric signals, such as pressure, temperature.

The individual sampling frequency of each channel shall be not less than 10 times the sensors' centre response frequency.

The measurement inaccuracy for threshold above 40 dB_{AE} shall be better than ±1 dB.

The measurement inaccuracy for counts shall be better than ±5 %.

The instrument shall be capable to process, store and display at least 20 hits per second at all channels. The delay and display from the arrival of the AE hits shall not exceed 10 seconds. An alarm shall occur if the hit rate exceeds the capability of the instrument. A warning shall occur when the storage space runs short.

The measurement inaccuracy for peak amplitudes above 40 dB_{AE} shall be better than ±1 dB. Usable dynamic range shall be a minimum of 65 dB.

The measurement inaccuracy for energy above 40 dB_{AE} shall be better than ±5 %.

If delta-t source location is used, the resolution of rise time, duration and arrival time for each channel shall be better than 0,25 µs. The error of arrival time between each channel shall be better than ±3 µs.

The measurement inaccuracy for the external parametric inputs shall be better than 2 % of the full range.

During data acquisition, AE software shall be capable to display the following diagrams: any AE parameter versus time or load, one AE parameter versus another AE parameter, linear and planar locations. The real-time update time for all diagrams shall be not more than 5 s.

The AE analysis software shall provide functions to replay and to analyse the recorded AE testing data.

6.9 Maintenance and verification of test equipment

The performance of the testing system shall be verified at specified intervals in conformity with the methods provided by the manufacturer of the AE instrument, or refer to EN 13477-1 and EN 13477-2.

7 On-site operation

7.1 Preparation of documentation

7.1.1 Preliminary information

Prior to the definition of the testing, some or all of the following information is necessary:

— the purpose of the test;

— details of the crane to be tested;

— the physical location of the area where the test shall be performed;

— the requirements for surface preparation;

— the sensitivity of the test;

— the method used to verify the sensitivity;

— the acceptance criteria, if specified;

— other requirements in relation to the test report;

— details of qualification of personnel.

The following documents for the tested crane are required as a minimum before performing an AE test:

a) manufacturing documents of the crane to be tested, e.g. product certification, quality qualification document, as-built drawing;

b) operation recording documents of the crane, e.g. operating conditions and parameters, loading fluctuations, abnormal situation in operation;

c) previous inspection and testing report;

d) other documents, e.g. drawing and record showing repairs or modifications.

7.1.2 Site investigation

Prior to testing, it is necessary to carry out a site investigation to find all interference factors, such as friction of scaffold, electromagnetic interference, vibration. The interference of these factors shall be avoided during on-site testing.

7.1.3 Preparation of testing procedure and record sheets

The testing procedure and record sheets shall be prepared in accordance with the general testing procedure (see 10.2), crane and site conditions. The instrument, applicable sensors, testing place and surface conditions of the crane need to be specified.

7.1.4 Sensor array

A sufficient number of sensors shall be mounted on the steel structure of the crane to enable AE signal detection and source location, according to the dimension of the structure and the purpose of the testing. The allowed maximum sensor spacing can be determined by based on measured attenuation curve of AE amplitude. This can refer to EN 14584 and EN 15495. The spacing between sensors shall be the same as far as possible. All the sensors shall be numbered and indicated in the schematic diagram of the structure. Annex A provides guidelines for sensor placement for some structures of cranes.

7.1.5 Loading procedure

A loading procedure should be established according to the purpose of AE testing and the real condition of the crane.

The communication of the AE operator with the loading operator shall be included in the test procedure.

7.2 Mounting of sensor

The mounting of sensors shall meet with the following requirements:

a) The sensors shall be installed according to the specified sensor array. The sensors shall keep a distance to welding attachment such as supporting steel plate during the whole testing of the structure. For local testing, the testing area shall be in the centre of the sensor array.

b) The place for the mounting of a sensor on the structure shall be smooth and showing the metallic luster. The coating can be kept when it is smooth and compacted and measured attenuation is acceptable.

c) Efficient couplants such as vacuum grease, vaseline, are recommended.

d) Firmly fixing of the sensors with the structure shall be performed by a magnetic holding device, by an adhesive tape or other stuff, keeping the insulation.

7.3 Settings of the AE instrument

7.3.1 General requirements

Connects the sensors and preamplifiers with the main processor by cables, turn on the AE instrument and wait until the equipment is in proper working condition. Roughly set the instrument and then debug the AE system following steps 7.3.2 to 7.3.6.

7.3.2 Simulating of AE sources

Simulated AE sources are used to determine the sensitivity of each channel and to calibrate the localisation system of AE sources.

The simulated AE sources should be capable of producing a transient elastic wave having an amplitude representative of the AE signals.

The simulated AE source may be a breaking pencil lead or an electronically induced event or equivalent.

When using the pencil lead break technique, the simulated AE signals shall be generated by breaking 2H pencil leads (0,3 mm or 0,5 mm diameter) against the component surface at the prescribed points.

The pencil leads shall be broken at an angle of approximate 30° to the surface using about 2,5 mm pencil lead extension.

The detected peak amplitude of the simulated event should be at a fixed distance near the sensor, typically 100 mm ± 5 mm, and the responsive value shall be the average of more than 3 times.

7.3.3 Sensitivity setting

The sensitivity setting for all channels shall be done before and after the testing. The average peak amplitude of any sensor shall be within ±4 dB of the average of all sensors.

7.3.4 Determination of attenuation curve

The attenuation of acoustic emission signals for different steel structures shall be determined.

This is necessary for determining the sensor spacing for effective detection of AE sources and recalculation of signal amplitude to source location.

If attenuation data from the same testing condition is already available, it is not necessary to determine the attenuation again, but the attenuation data shall be indicated in the record and test report.

7.3.5 Calibration of the positioning system

When using the computed localization, the simulated AE signal shall be received and be located solely within the sensor array on the component.

The error of positioning shall be no more than ±5 % of the sensors spacing.

When using the zone location, the simulated AE signal shall be received by at least one sensor in that area.

7.3.6 Determination of background noise

The background noise of the testing environment shall be tested for at least 5 minutes before the testing by lowering the threshold voltage.

The testing threshold of each channel shall be higher than the background noise by at least 6 dB.

If the background noise is close to or larger than the AE signals caused by the active discontinuities in the steel structure, the background noise shall be eliminated, or it is not suitable to perform the AE testing.

7.4 Performing the test

7.4.1 Loading procedure

The loading procedure shall be performed in accordance with ISO 4310, and the recommend testing load shall be 1,1 times to 1,25 times of the rated lifting capacity or the maximum operating load, given by the owner of the crane based on the operating condition.

The testing load should be lifted up in the centre of the beam to 100 mm to 200 mm above the ground, and holding for at least 10 minutes.

The test shall be repeated two times. The load in the second test shall not exceed that of the first test, and the recommend load shall be 97 % of the first load.

7.4.2 Noise during testing

Attention is to be paid to the following factors that can affect the testing results:

a) external mechanical vibration;

b) mechanical friction;

c) electromagnetic interference;

d) weather conditions, such as interference from wind, rain, hail.

The testing shall be suspended when there is strong noise, and it can be continued when this strong noise has been excluded.

7.4.3 Data acquisition and observations during testing

The data acquisition shall include the parameters given in 6.8. The sequence of signals in each channel is required when using zone location.

During testing, the trend of the AE hits and/or location sources versus time shall be observed for each channel.

For an area bristled with located AE sources, it shall be checked whether there is external interference.

7.4.4 Data processing

The noise observed during the testing shall be determined and indicated in the test records. Using software filters or graphic data display analysis methods, the non-correlated signals shall be separated from relevant AE signals, and indicated in the test records.

The position of the AE sources shall be recognized from the detected data. For AE sources which need to be characterized, the area shall be confirmed by simulated AE sources.

8 Interpretation and evaluation of test results

On completion of the test, the results shall be documented in a test report. A schematic diagram of the location of the AE sources of the tested structure may be drawn if necessary.

The evaluation of the test results shall be performed. Annex B gives one recommended evaluating method for test results.

9 Acceptance criteria

The acceptance criteria shall be specified by the contracting parties.

For locations where the AE source level is higher than the acceptance criteria specified by the contractors other NDT methods, such as ultrasonic testing (UT), magnetic particle testing (MT) or dye penetrant testing (PT), shall be used for the confirmation of the AT results.

10 Documentation

10.1 General

The documentation in general consists of the written testing procedure, testing records and the test report.

10.2 Written testing procedure

The organization performing the AE testing shall prepare the written testing procedure according to this document.

The general requirements for the application and use of the AT method for a crane are described in application documents such as:

— product standards;

— specifications;

— codes of practice;

— contractual documents.

The testing procedure shall be derived from these documents and shall describe all the essential parameters as well as the precautions to be observed.

The following shall be included in the written test procedure:

a) the purpose of the test;

b) a description of the crane to be tested;

c) the application documents;

d) details of qualification of personnel;

e) the AT equipment including the instrument, sensors, preamplifiers, main processor, cables;

f) the testing software used;

g) the area to be tested;

h) details of surface preparation;

i) a description of the test and the sequence of the steps in the test;

j) the arrangement of the sensors;

k) determination of the background noise and the sensitivity of sensors;

l) determination of attenuation for AE signals;

m) the testing process, data analysis and interpretation;

n) the verification intervals for the instrument and the sensors;

o) the evaluation of testing results;

p) other information to be included in the test report;

q) signature of preparing, reviewing and approving personnel and date.

10.3 Test records

The test records shall at least include the contents given in 10.4. The test records and AT data shall be kept according to contractual agreements.

10.4 Test report

The test report shall contain sufficient information to enable the test to be repeated at a future date.

At least the following shall be included:

a) identification of the manufacturer of the crane;

b) identification of each tested object;

c) reference to the application documents and the testing procedure;

d) a technical sheet (or equivalent) giving the details of the procedure in cases where the testing procedure allows a variation of the test method, the equipment or the equipment set-up;

e) identification of the test system, in particular all details necessary for the complete identification of the type of instrument and type of sensors used;

f) the instrument settings used;

g) the identification of the reference simulated AE source used;

h) the results of the test;

i) any deviation from the test procedure;

j) the organization responsible for carrying out the test;

k) the name and qualification of the person who carried out the test;

l) the signature of the person who carried out the test or the name and signature of another authorized person;

m) the date and place of the test.

The format of the test report shall be agreed at the time of enquiry and order.

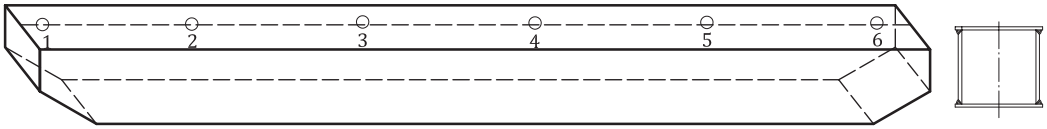
Annex A
(informative)

Guidelines for sensor placement

Figures A.1 to A.3 gives examples of sensor placement for the common steel structures in cranes.

Sensors should be placed in areas where highest tensile stresses occur or from experience cracking is expected. The positions of the load and bearings should be marked.

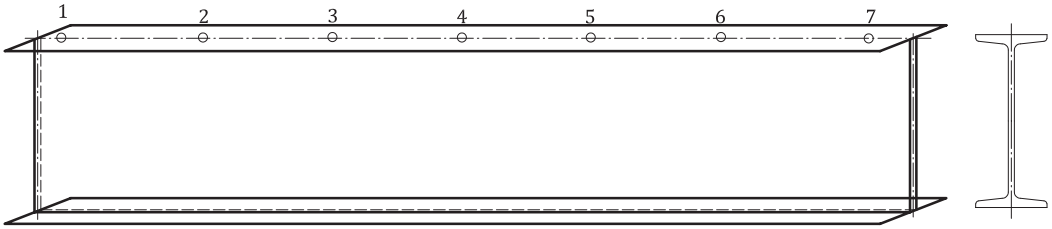
The number of sensors and maximum distance between adjacent sensors should be determined from box structure attenuation characterization.



Key

O sensor location

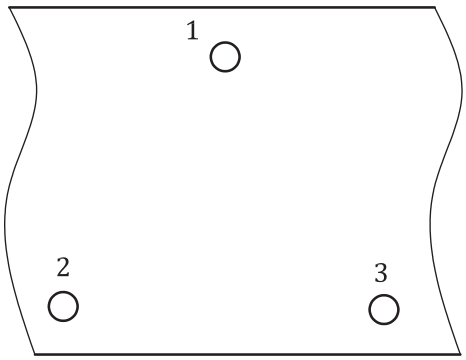
Figure A.1 — Case 1 — Box structure



Key

O sensor location

Figure A.2 — Case 2 — Flanged beam



Key

O sensor location

Figure A.3 — Case 3 — 1, 2, 3 AE source locations

Annex B
(informative)

Evaluation of test results

B.1 General

The evaluation of the test results shall be in accordance with the AE signals within the first two load holding periods. The others should only be used as a reference.

B.2 Determination of the area of an AE source

When using source location based on the time difference between channels, the area of an AE source shall be determined according to the cluster area of the AE location sources. The length of the AE source area is no more than 10 % of the distance between two adjacent sensors.

When using the zone location, the area of an AE source shall be determined according to the actual area.

B.3 Evaluation of the AE source activity level

If the AE location events (abbreviated E) in the AE source area are rapidly growing during load holding ($E \geq 10$ per minute), the activity level of the AE source shall be characterized as very strong.

If the AE location events in the AE source area are continuous growing during load holding (3 per minute $\leq E < 10$ per minute), the activity level of the AE source shall be characterized as strong.

If the AE location events in the AE source area are intermittent growing during load holding ($E < 3$ per minute), the activity level of the AE source shall be characterized according to Table B.1.

Table B.1 — Evaluation of the AE source activity level

Characterization of the activity level of an AE source area	Activity level
AE location events during two hold periods: $E \leq 3$ per minute	weak
AE location events during two hold periods: 3 per minute $< E \leq 10$ per minute	medium
AE location events during two hold periods: $E > 10$ per minute	strong

B.4 Evaluation of the AE source intensity level

The intensity of the AE source (abbreviated Q), shall be indicated by the energy, amplitude or counts from the AE source area.

The calculation of the intensity shall be the average of energy, amplitude or counts of the 5 biggest events from the AE source area, and the amplitude shall be recalculated to source location according to results of the attenuation measuring.

The evaluation method of the intensity level shall be in accordance with Table B.2, and the value of the criteria a and b shall be determined by experiments, e.g. by destructive testing of the structure.

Table B.3 gives an example for a Chinese steel grade Q235 carbon steel.

Table B.2 — Evaluation of the AE source intensity level

Characterization of AE source	Intensity level
$Q < a$	low
$a \leq Q \leq b$	middle
$Q > b$	high

Table B.3 — Evaluation of the AE source intensity level of Q235 carbon steel by amplitude

Characterization of AE source – amplitude	Intensity level
$Q < 55$ dB	low
55 dB $\leq Q \leq$ 75 dB	middle
$Q > 75$ dB	high

B.5 Comprehensive evaluation of AE source levels

The level of an AE source shall be comprehensively evaluated in accordance with their activity level and intensity level, as shown in Table B.4.

Table B.4 — Comprehensive evaluation of AE source levels

		Activity level			
		very strong	strong	medium	weak
Intensity level	high	IV	IV	III	II
	middle	IV	III	III	I
	low	III	III	II	I

B.6 Evaluation of the severity degree of the AE source and post-test actions

The determination of the severity degree of an AE source and the related post-test actions is shown in Table B.5.

Table B.5 — Evaluation of the severity degree of the AE source and post-test actions

Comprehensive degree	Severity degree	Post-test actions
I	Not serious	Not needed
II	Questionable	Not needed
III	Serious	Needed
IV	Very serious	Needed

After acoustic emission testing the serious or very serious AE sources shall be confirmed by other NDT methods such as ultrasonic testing (UT), magnetic particle testing (MT) or dye penetrant testing (PT).

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