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Non-destructive testing — Acoustic emission testing (AT) — Leak detection by means of acoustic emission

Essais non destructifs — Essais d'émission acoustique — Détection de fuites par émission acoustique

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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*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 138, *Non-destructive testing*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This second edition cancels and replaces the first edition (ISO 18081:2016), which has been technically revised.

The main changes are as follows:

— Figure 1 has been improved;

— term “AT equipment” has been replaced by “AE instrument” in the whole document;

— term “system” has been replaced by “instrument” in the whole standard;

— Figure 2 showing an adjustable air jet has been added;

— Formula (1) has been corrected;

— Table 2 “Leakage grading and the influence of leak flow dynamic on AE activity“ has been added;

— editorial corrections throughout the document.

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.

Non-destructive testing — Acoustic emission testing (AT) — Leak detection by means of acoustic emission

1 Scope

This document specifies the general principles required for leak detection by acoustic emission testing (AT). It is addressed to the application of the methodology on structures and components, where a leak flow as a result of pressure differences appears and generates acoustic emission (AE).

It describes phenomena of the AE generation and influence of the nature of fluids, shape of the gap, wave propagation and environment.

The different application techniques, instrumentation and presentation of AE results are discussed. Also included are guidelines for the preparation of application documents which describe specific requirements for the application of the acoustic emission testing.

Annex A gives procedures for some leak-testing applications.

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.

ISO 9712, *Non-destructive testing — Qualification and certification of NDT personnel*

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

ISO/TS 18173, *Non-destructive testing — General terms and definitions*

EN 1330-1, *Non-destructive testing — Terminology — Part 1: General terms*

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

EN 1330-9, *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 characteristics*

EN 13554, *Non-destructive testing — Acoustic emission testing — General principles*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 12716, ISO/TS 18173, EN 1330-1, EN 1330-2 and EN 1330-9 apply.

ISO and IEC maintain 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/

NOTE The definitions of leak, leakage rate, leak tightness are those defined in ISO 20484.

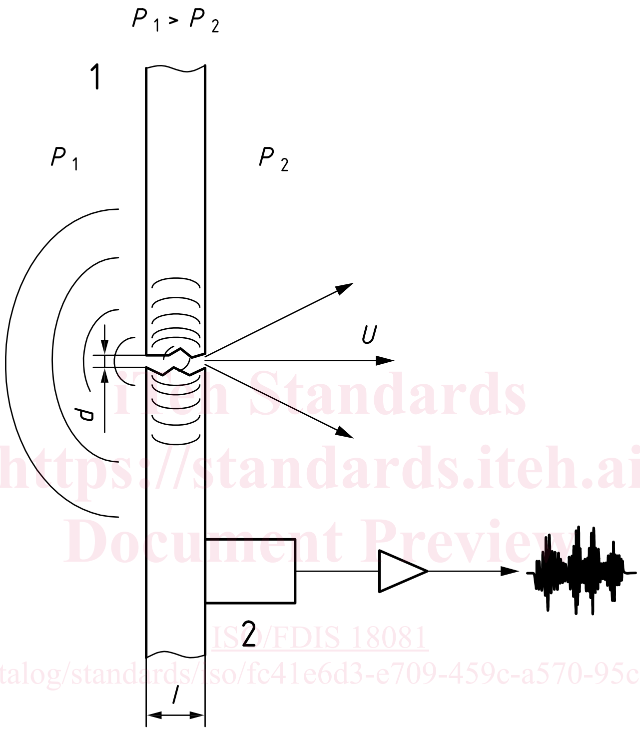
4 Qualification of test personnel

It is assumed that acoustic 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 ISO 9712.

5 Principle of acoustic emission testing

5.1 The acoustic emission phenomenon

See Figure 1.



Key

1 fluid

2 AE sensor

P_1 pressure on side of fluid

P_2 pressure on side of sensor

d main dimension of leak orifice

I wall thickness

U leaking fluid

Figure 1 — Schematic principle of acoustic emission and its detection

The continuous acoustic emission in the case of a leak, in a frequency range, looks like an apparent increase in background noise, depending on pressure.

5.2 Influence of different media and different phases

The detectability of the leak depends on the fluid type and its physical properties. These will contribute to the dynamic behaviour of the leak flow (laminar, turbulent) (see Table 1).

Table 1 — Influence of the different parameters on the AE activity

Sub-clause	Parameter	Higher activity	Lower activity
5.2	Test media	gas	liquid
		two phase	
	Viscosity	low	high
	Type of flow	turbulent	laminar
	Fluid velocity	high	low
5.3	Pressure difference	high	low
5.4	Shape of leak	crack like	hole
	Length of leak path	long	short
	Surface of leak path	rough	smooth

In contrast to turbulent flow, the laminar flow in general does not produce detectable acoustic emission signals.

Acoustic emission in conjunction with a leakage is generated by the following:

— turbulent flow of the escaping gas or liquid;

— fluid friction in the leak path;

— cavitations, during two-phase flow (gas coming out of solution) through a leaking orifice;

— the pressure surge generated when a leakage flow starts or stops;

— backwash of particles against the surface of equipment being monitored;

— gaseous or liquid jet (verification source);

— pulsating bubbles;

— explosion of bubbles;

— shock-bubbles on the walls;

— vaporization of the liquid (flashing).

The frequency content of cavitation may comprise from several kHz to several MHz.

Cavitation results in a burst emission whose energy is at least one order of magnitude higher than that caused by turbulence.

The relative content in gas or air strongly influences the early stage of cavitation.

The acoustic waves generated by leaks can propagate by the walls of the structure as well as through any fluids inside.

Acoustic waves are generated by vibration at ultrasonic frequencies of the molecules of the fluid. The vibrations are produced by turbulence and occur in the transition between a laminar and a turbulent flow within the leak path and as these molecules escape from an orifice.

The acoustic waves produced by the above-mentioned factors are used for leak detection and location.

5.3 Influence of pressure differences

The pressure difference is the primary factor affecting leak rate. However, the presence of leak paths can depend on a threshold value of fluid temperature or pressure.

Pressure-dependent leaks and temperature-dependent leaks have been observed, but in extremely limited number.

Pressure-dependent or temperature-dependent leaks denote a condition where no leakage exists until a threshold pressure or temperature is reached. At this point, the leakage appears suddenly and can be detectable.

When the pressure or temperature is reversed, the leakage follows the prescribed course to the critical point at which leakage drops to zero.

Temperature and pressure are not normally applied in the course of leak testing for the purpose of locating such leaks. Instead, they are used to force existing discontinuities to open, so as to start or increase the leakage rate to point of detection.

An example of this effect is the reversible leakages at seals below the service temperature and/or service pressure.

Sound waves emitted by a leak will normally have a characteristic frequency spectrum depending on the pressure difference and shape of the leak path.

Therefore, the detectability of the leak depends on the frequency response of the sensor and this shall be taken into account when selecting the instrumentation.

5.4 Influence of geometry of the leak path

The AE intensity from a natural complex leak path (e.g. pinhole corrosion, fatigue or stress corrosion cracks) is generally greater than that produced by leakage from an artificial source, such as a drilled hole used for verification.

The main parameters defining the complexity are the cross section, length and surface roughness of the leak path.

5.5 Influence of wave propagation

Acoustic emission signals are the response of a sensor to sound waves generated in solid media. These waves are similar to the elastic waves propagated in gasses and fluids but are more complex because solid media are also capable of transmit shear force.

Waves that encounter a change in media in which they are propagating may change directions or reflect. In additions to reflection, the interface causes the waves to diverge from its original line of flight or refract in the second medium. Also, the mode of the wave can be changed in the reflection and/or refraction process.

Incident waves upon an interface between two media will reflect or refract such that directions of the incident, reflected and refracted waves all lie in the same plane. This plane is defined by the line along which the incident wave is propagating and the normal to the interface.

The following factors are important to acoustic emission testing:

a) wave propagation has the most significant influence on the form of the detected signals;

b) wave velocity is key to computed source location;

c) wave attenuation governs the maximum sensor spacing that is acceptable for effective detection.

The wave propagation influences the received waveform in the following ways:

d) reflections, refractions and mode conversions on the way from source to sensor result in many different propagation paths of different lengths;

e) multiple propagation paths on the way from source to sensor, even in the absence of reflecting boundaries, can be caused by the structure itself, for example, spiral paths on a cylinder;

f) separation of different wave components (different modes, different frequencies) travelling at different velocities;

g) wave attenuation (volumetric dispersion, absorption, as well as attenuation due to the effects given in 5.5 d) and 5.5 f)).

The wave attenuation is influenced by liquids inside a structure or pipe, which will assist in the propagation of acoustic waves, while liquids (inside and outside) have a tendency to reduce the detectability of the acoustic waves.

This effect will depend on the ratio of the acoustic impedances of the different materials.

The sound wave inside will be used normally for the detection of AE sources over long distances because of the low sound attenuation of most liquids.

6 Applications

Acoustic emission testing (AT) provides many possibilities to detect leaks from pressurized and atmospheric equipment in industry and research fields.

AT is used in following areas:

a) pressure vessels;

b) pipe and piping systems;

c) above ground storage tanks;

d) underground storage tanks;

e) boiler drums;

f) boiler tubes;

g) autoclaves;

h) heat exchangers;

i) containments;

j) valves;

k) safety valves;

l) pumps;

m) vacuum systems.

7 Testing equipment

7.1 General requirements

The testing equipment (hard and software) shall be in accordance with the requirements of EN 13477-1 and EN 13477-2.

7.2 Sensors

7.2.1 Typical frequency ranges (band widths)

The optimum frequency range for leak detection depends very much on the application, the fluid type, pressure difference at the leak, the leak rate, and the sensor to source distance and more.