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

Essais non destructifs — Contrôle par émission acoustique — Détection de fuites par émission acoustique

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Foreword

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

ISO 18081 was prepared by the European Committee for Standardization (CEN) Technical Committee CEN/TC 138, *Non-destructive testing*, in collaboration with ISO Technical Committee TC 135, *Non-destructive testing*, Subcommittee SC 9, *Acoustic emission testing*, in accordance with the agreement on technical cooperation between ISO and CEN (Vienna Agreement).

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

1 Scope

This International Standard 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 methods, instrumentation and presentation of AE results is discussed. Also included are guidelines for the preparation of application documents which describe specific requirements for the application of the AE method.

Different application examples are given.

Unless otherwise specified in the referencing documents, the minimum requirements of this International Standard are applicable.

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/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

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*

EN 60529, *Degrees of protection provided by enclosures (IP Code)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 1330-1, EN 1330-2 and EN 1330-9 and the following apply.

NOTE The definitions of leak, leakage rate, leak tight are those defined in EN 1330-8.

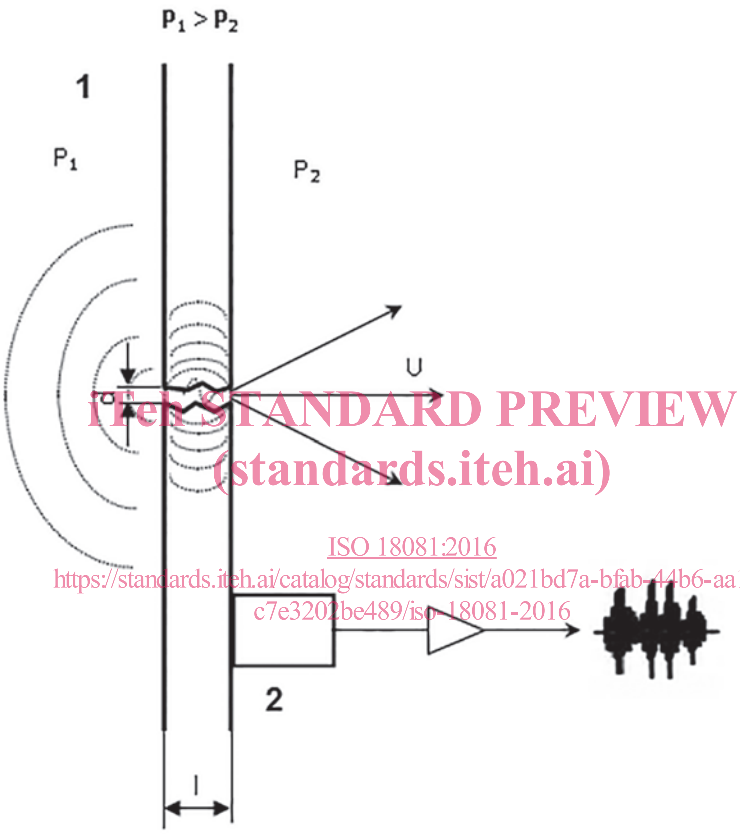
4 Personnel qualification

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 method

5.1 The AE phenomenon

See Figure 1.



Key

1 fluid

2 AE sensor

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.

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

	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

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).

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

Acoustic signals in conjunction with a leakage are 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 system 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 may 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 threshold pressure or temperature is reached. At this point, the leakage appears suddenly and may 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.

AE 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 a standard 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 sound waves propagated in air and other fluids but are more complex because solid media are also capable of resisting 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 wave to diverge from its original line of flight or refract in the second medium. Also the mode of the wave may be changed in the reflection and/or refraction process.

An incident wave 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 below factors are important to AE technology:

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

b) wave velocity is key to computed source location;

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

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

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

— multiple propagation paths on the way from source to sensor, even in the absence of reflecting boundaries may be caused by the structure itself. For example, spiral paths on a cylinder;

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

— sound attenuation (volumetric dispersion, absorption, as well as attenuation due to the first and third effects listed above).

The sound 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 detectable signal of the propagation of the acoustic waves. This effect will depend on the ratio of the acoustic impedances of the different materials. The AE wave inside will be used normally for the detection of AE sources over long distances because of the low wave sound attenuation for most liquids.

6 Applications

Acoustic emission testing provides many possibilities to detect leaks from pressurized equipment in industry and research fields. AT is used in following areas:

a) pressure vessels;

b) pipe and piping systems;

c) storage tanks;

d) boiler drums;

e) boiler tubes;

f) autoclaves;

g) heat exchangers;

h) containments;

i) valves;

j) safety valves;

k) pumps;

l) vacuum systems.

7 Instrumentation

7.1 General requirements

Instrumentation components (hard and software) shall conform to 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. For example, the optimum frequency range for tank floor leak detection of atmospheric tanks is around 20 kHz to 80 kHz, because the source to sensor distance can be large and at these frequencies the attenuation is low. The preferred frequency range for high pressure piping leak detection may go up to 400 kHz for optimum signal-to-noise ratio in presence of disturbing sources. Leak detection at pipes for low pressure (e.g. water supply) is usually performed at or below 5 kHz.

Usually, a sensor is in direct contact to a test object. Then a coupling agent must be used between the sensor and the test object for optimum and stable wave transfer. Durability, consistency, and chemical composition of the coupling agent must comply with the duration of the monitoring, the temperature range and the corrosion resistance of the test object.

7.2.2 Mounting method

The mounting method is influenced by the duration of the monitoring. For a temporary installation on a ferromagnetic test object, a magnetic holder may be the preferred mounting tool. For permanent installations, sensors might be fastened by metallic clamps or bonded to the test object using a suitable adhering coupling.

7.2.3 Temperature range, wave guide

The operating temperature range of the AE sensor shall meet the surface temperature conditions of the test object, otherwise waveguides shall be used between sensor and test object.

7.2.4 Intrinsic safety

If the sensor is to be installed in a potentially explosive atmosphere, the sensor shall be intrinsically safe and should usually be ATEX conformant in accordance with the classified hazard at the location where it is to be used. See EN 60079-0, EN 60079-11 and EN 60079-14 for explosion-proof installations.

7.2.5 Immersed sensors

If the sensor is to be immersed in a liquid, the sensor’s IP-code (defined in EN 60529) shall be specified to at least IP68. Sensor and other immersed accessories shall be tight for the maximum possible pressure of the liquid.

7.2.6 Integral electronics (amplifier, RMS converter, ASL converter, band pass)

Passive sensors and sensors with an integral pre-amplifier of suitable bandwidth are available. Sensors with built-in electronics are less susceptible to electromagnetic disturbances, due to the elimination of a sensor-to-pre-amplifier cable. These sensors are usually a little larger in size and weight and have a more limited temperature range.

Sensors may also include a signal-to-RMS converter, a signal-to-ASL converter and/or a limit-comparator with digital output.

7.3 Portable and non-portable AT instruments

An acoustic emission leak detection instrument designed for portable use contains usually one or a few channels. The choice of a portable device is generally based on several factors, such as cost, test duration, hazard and availability of external power.

Portable devices are used for valve leak detection.

7.4 Single and multichannel AT equipment

7.4.1 Single-channel systems

Single-channel systems are usually used for a point-by-point search mode, the sensor being moved to areas of interest over the structure.

7.4.2 Multi-channel systems

Multi-channel systems are mainly used for large structures where the sensor positions are fixed and one of the location procedures in 9.3 may be applied.

