



BSI Standards Publication

Nuclear power plants — Instrumentation important to safety — Acoustic monitoring systems for detection of loose parts: Characteristics, design criteria and operational procedures

National foreword

This British Standard is the UK implementation of IEC 60988:2009.

The UK participation in its preparation was entrusted to Technical Committee NCE/8, Reactor instrumentation.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Nuclear power plants – Instrumentation important to safety – Acoustic monitoring systems for detection of loose parts: characteristics, design criteria and operational procedures

Centrales nucléaires de puissance – Instrumentation importante pour la sûreté – Systèmes de surveillance acoustique pour la détection des corps errants: caractéristiques, critères de conception et procédures d'exploitation

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INTRODUCTION

a) Technical background, main issues and organisation of this Standard

This International Standard addresses the issues specific to acoustic monitoring systems for loose parts detection. It describes the principles, the characteristics and the test methods for those systems.

It is intended that this Standard be used by operators of NPPs (utilities), systems evaluators and by licensors.

b) Situation of the current Standard in the structure of the IEC SC 45A standard series

IEC 60988 is the third level SC 45A document related to acoustic monitoring systems for loose parts detection used in power reactors.

For more details on the structure of the IEC SC 45A standard series, see item d) of this introduction.

c) Recommendations and limitations regarding the application of this Standard

It is important to note that this Standard establishes no additional functional requirements for safety systems.

d) Description of the structure of the IEC SC 45A standard series and relationships with other IEC documents and other bodies documents (IAEA, ISO)

The top-level document of the IEC SC 45A standard series is IEC 61513. It provides general requirements for I&C systems and equipment that are used to perform functions important to safety in NPPs. IEC 61513 structures the IEC SC 45A standard series.

IEC 61513 refers directly to other IEC SC 45A standards for general topics related to categorization of functions and classification of systems, qualification, separation of systems, defence against common cause failure, software aspects of computer-based systems, hardware aspects of computer-based systems, and control room design. The standards referenced directly at this second level should be considered together with IEC 61513 as a consistent document set.

At a third level, IEC SC 45A standards not directly referenced by IEC 61513 are standards related to specific equipment, technical methods, or specific activities. Usually these documents, which make reference to second-level documents for general topics, can be used on their own.

A fourth level extending the IEC SC 45A standard series, corresponds to the Technical Reports which are not normative.

IEC 61513 has adopted a presentation format similar to the basic safety publication IEC 61508 with an overall safety life-cycle framework and a system life-cycle framework and provides an interpretation of the general requirements of IEC 61508-1, IEC 61508-2 and IEC 61508-4, for the nuclear application sector. Compliance with IEC 61513 will facilitate consistency with the requirements of IEC 61508 as they have been interpreted for the nuclear industry. In this framework IEC 60880 and IEC 62138 correspond to IEC 61508-3 for the nuclear application sector.

IEC 61513 refers to ISO as well as to IAEA 50-C-QA (now replaced by IAEA GS-R-3) for topics related to quality assurance (QA).

The IEC SC 45A standards series consistently implements and details the principles and basic safety aspects provided in the IAEA code on the safety of NPPs and in the IAEA safety series, in particular the Requirements NS-R-1, establishing safety requirements related to the design of Nuclear Power Plants, and the Safety Guide NS-G-1.3 dealing with instrumentation and control systems important to safety in Nuclear Power Plants. The terminology and definitions used by SC 45A standards are consistent with those used by the IAEA.

NUCLEAR POWER PLANTS – INSTRUMENTATION IMPORTANT TO SAFETY – ACOUSTIC MONITORING SYSTEMS FOR DETECTION OF LOOSE PARTS: CHARACTERISTICS, DESIGN CRITERIA AND OPERATIONAL PROCEDURES

1 Scope

This International Standard is applicable to on-site systems used for continuous monitoring of structure-borne sound measured at the reactor coolant pressure boundary of light water reactors for the purpose of detecting loose parts.

2 Normative references

The following referenced documents are indispensable for the application 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.

IEC 61226, *Nuclear power plants – Instrumentation and control systems important to safety – Classification of instrumentation and control functions*

IEC 61513, *Nuclear power plants – Instrumentation and control for systems important to safety – General requirements for systems*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1

adaptive resonant frequency

natural frequency of the mechanical attachment (e.g. bolts, magnets), including sound sensors

3.2

alarm level monitor

a device which compares the value of a variable with a fixed or variable threshold. If the threshold is exceeded, the output signal changes its state

3.3

background noise

structure-borne sound which is generated during operation of the reactor plant, even in the absence of loose parts. It is composed of stationary background noise and operation-related single sound events

3.4

burst amplitude distribution

frequency distribution of the maximum observed amplitudes of the bursts in the signal of a sound sensor

3.5**burst interval distribution**

frequency distribution of the time intervals observed between the individual bursts in the signal of a sound sensor

3.6**delay difference**

time difference between the occurrences of the bursts generated by a single sound event in the signals of different sound sensors

3.7**detached part**

part which has become detached from the component in the pressure-retaining boundary of the reactor coolant, and which therefore can be carried along with the reactor coolant

3.8**known event**

an event for which comparable events occurred repeatedly, were recorded, evaluated and assessed and the criteria for the comparability of these events have been identified and defined (e. g. signal form, delay)

NOTE A known event can be a single burst or a set of bursts. A known event can be classified as an event being alarm-relevant or not being alarm-relevant.

3.9**loose part**

both a detached or loosened part as well as a foreign part

3.10**loosened part**

part which becomes loose, yet still remains connected to the component to which it was originally firmly attached

3.11**monitored signal**

signal from a band-pass filter applied to the sound sensor signal

3.12**resonance factor**

ratio of the signal amplitude at the natural frequency of response to the amplitude in the flat region of response of the sensor system with any attachments

3.13**single channel alarm inhibit**

a function that inhibits an alarm if only one channel has been triggered by a single sound event. An alarm is set if at least a second channel has been triggered by the same single sound event

3.14**single sound event**

structure-borne sound generated by a single event which is superimposed on the stationary background noise (e.g. impact of a loose part, control rod drive noise or a sudden reduction of stresses)

3.15**sound burst**

signal component generated in the sound sensor as a result of a single event causing a sound which is superimposed on the signal of the stationary background noise

NOTE In this standard the term burst is used as an equivalent.

3.16**sound sensor**

mechanical/electrical energy converters receiving structure-borne sound which is detectable at the surface of a solid body as displacement, velocity or acceleration

3.17**stationary background noise**

consists of stochastic components (e.g. coolant flow noise, fluid resonances) and deterministic components (e.g. speed-dependent pump noise)

3.18**structure-borne sound**

sound which propagates in solid bodies. The structure-borne sound in this standard is taken to mean the sound within the audible frequency range

4 Purpose and description of loose parts detection**4.1 General**

The presence of a loose part in the primary coolant system can be indicative of degraded reactor safety resulting from a failed or weakened component or from a part inadvertently left in the primary system during construction, refuelling, or maintenance. A loose part can contribute to component damage and material wear by frequent impacting with other parts in the system. A loose part can pose a serious threat of partial flow blockage with attendant departure from nucleate boiling which in turn could result in failure of fuel cladding.

Early detection of a loose part can provide the time required to avoid or mitigate safety-related damage to, or malfunction of, primary system components. The primary purpose of a loose parts detection system is the early detection of loose, loosened or detached metallic parts with their potential to cause damage to:

- a) the reactor core,
- b) other internal structures of the primary circuit, or
- c) the primary circuit pressure boundary.

Suitable systems shall be installed for this purpose.

Loose parts detection systems have been used successfully in water reactors for many years, and have detected bolts and tools dropped in construction or refuelling, which otherwise could have caused significant damage. They normally have a low safety significance, but due to the potential for damage that a loose part could cause, regulators will expect installation of suitable systems.

4.2 System definition

Depending on the national safety regulation,

- The system focuses mainly on the loose parts detection on the primary coolant system. The system may additionally monitor the vibrational state of the primary circuit. This option (which is outside the scope of this standard) may have consequences on the number and the location of the sensors.
- The expertise to make a diagnosis may be present either:
 - locally in each plant site. This implies that the analysis tools are available on-site and the on-site operators have to be trained for a signal evaluation; or
 - on a remote site at a national level. This implies that the transfer of all of the necessary data to the experts is always fully efficient.

- The triggering of an alarm sent to the control room may be based on signals exceeding a threshold by either:
 - the burst amplitude of a single sound event. This makes it possible to record and analyse the signals event by event, or
 - the rate at which transients are detected. This implies continuously recording the signals. The diagnosis is then made from an analysis including many single sound events.
- The monitoring of the state of the sensors may be done by
 - a calibration test equipment for the measurement lines with impact hammer units on the primary circuit, or by
 - in-depth monitoring and signal processing of the background noise.

When designing a new system a choice from the above-mentioned items should be made as a first step. According to the national regulation the system definition needs to be specified.

4.3 System outline

Loose parts detection systems typically consist of a set of accelerometers mounted on the reactor vessel, steam generators and coolant pump casings, with processing electronics to filter the sound signals from the sensors and monitor them for alarms. Recording facilities are provided, and operators generally listen to the sensor noise at regular intervals, and specifically after refuelling, due to the sensitivity and processing power of the human ear. A fuller description with typical sound traces is provided in Annex A.

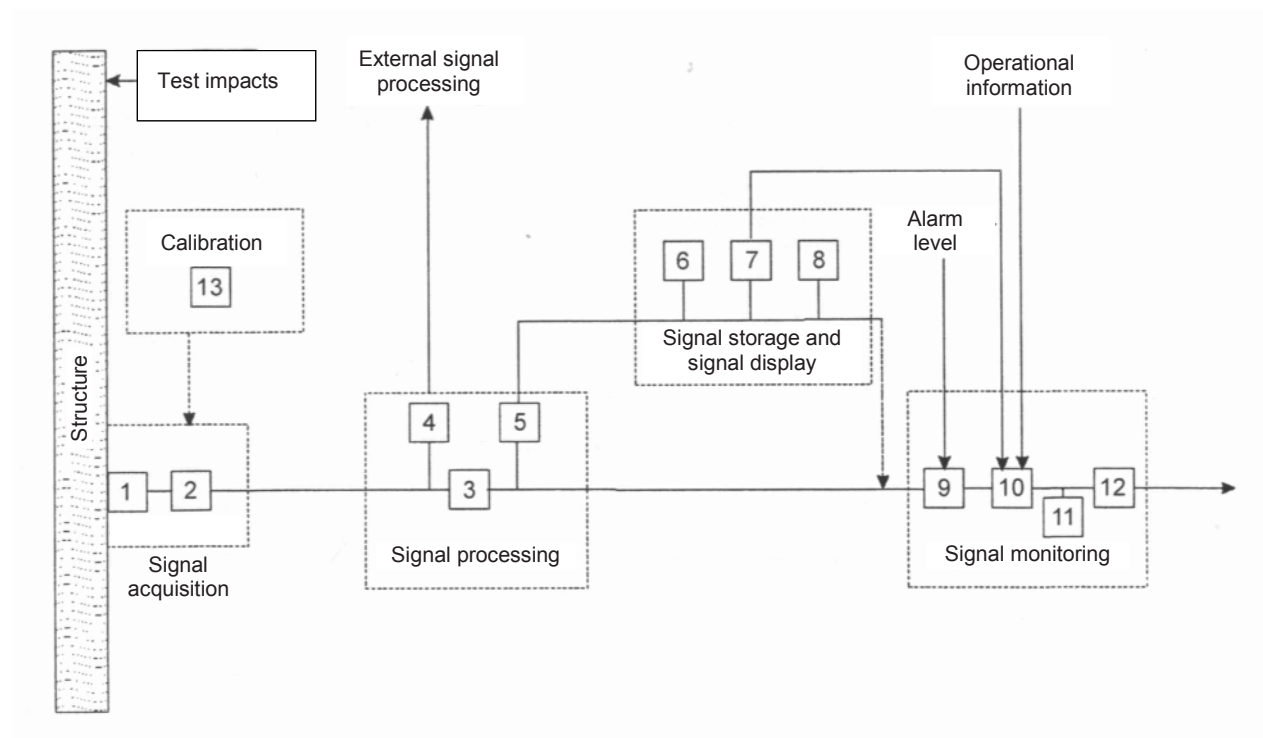
5 System requirements

5.1 Basic structure and design criteria

Generally the system has the following basic functions (see Figure 1).

- signal acquisition,
- signal processing,
- signal storage and signal display,
- signal monitoring,
- calibration.

Requirements for each basic function are described in the following subclauses.



IEC 1511/09

Key

1	Sound sensor	8	Audio unit
2	Preamplifier	9	Alarm level monitor
3	Band-pass filter	10	Logic element
4	Decoupled signal outputs	11	Internal alarm unit
5	Amplifier	12	Interface to external alarm unit
6	Indicator (display)	13	Calibration unit
7	Recording or storage		

NOTE 1 Control signals are not shown.

NOTE 2 On-line calibration equipment and test impact units need not be permanently installed.

NOTE 3 The monitoring system is an operational system whose function is not classified at a high category according to IEC 61513 and IEC 61226.

Figure 1 – Functional block diagram of a loose parts monitoring system

The detailed functions of each block are described in informative Annex B and specific requirements are given in the following subclauses.

The design and installation of the system (including its detection sensitivity) shall be in accordance with national regulations relating to system instrumentation and control for the particular reactor plant.

The system shall be designed using a frequency range consistent with detection algorithms that will ensure sufficient sensitivity of the system to detect a metallic loose part with a minimum of false alarms. Depending upon the particular detection algorithm the frequency range is typically between $f_a = 0,5 \text{ Hz}$ to 1 kHz and $f_b = 10 \text{ kHz}$ to 20 kHz , where f_a and f_b refer to the lower and upper 3 dB frequencies of the bandwidth of the pass band.

NOTE Processing up to $f_b = 20 \text{ kHz}$ is very suitable.