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Reactor technology — Design and performance evaluation of the emergency core cooling system strainer in pressurized water reactor nuclear power plants —

Part 1:
General principles

Technologie des réacteurs - Conception et évaluation de la performance de la filtration des systèmes de recirculation post-accidentelle pour les réacteurs à eau pressurisée —

Partie 1: Principes généraux

Reference number
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Foreword

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A list of all parts in the ISO 17838 series can be found on the ISO website.

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.

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Introduction

The purpose of this document is to provide guidance for the design and performance evaluation of the emergency core cooling system (ECCS) strainer(s) in pressurized water reactor (PWR) nuclear power plants (NPPs). While there are many types of PWRs (including existing and under-construction units), this document will focus on those that rely on ECCS pumps, which present enough similarities to allow a common approach. For other technologies, this document may be used selectively, depending on the specific design characteristics of their plants.

In the event of a relevant line break within the containment of a PWR, control or management of the accident relies on cooling such as emergency core cooling system (ECCS), or containment cooling, via containment heat removal system (CHRS), exemplified by the containment spray system (CSS), or reactor vessel cavity cooling via cavity injection system (CIS), or core melt cooling via the core catcher or other features.

All the above-mentioned cooling functions need to be achieved by water supplies, pumps, and filtration equipment to ensure the effectiveness of cooling water. The water can be obtained from locations such as the containment sump at the lower part of the containment or the in-containment refuelling water storage tank (IRWST). The functional requirements for the various components within these systems are derived from their safety claims.

DBA, DBE and DEC are typically initiated by a relevant line break. Moreover, in the event of a line break within the containment, the insulation and coatings surrounding the break can be damaged by blowdown fluids, possibly resulting in the generation of debris. The debris, together with the blowdown fluids from the pipe break and the water from the CSS, can flow and be directed towards the lower parts of the containment. As this occurs, although some of the debris may be caught by barriers such as compartments, thresholds, and steel gratings, other debris will continue to be transported by the water flow and will eventually accumulate in the containment sump or in the IRWST or in other water storage facilities. This accumulation of debris could render water unavailable to safety systems, thereby affecting their normal operation.

To ensure conformity with the operational requirements of the safety systems for water effectiveness, a set of strainers can be installed at the upstream inlet of the water supply pipe to filter out debris such as fibre and particles. In PWR NPPs, those strainers are commonly referred to as the Emergency Core Cooling System (ECCS) strainer. Depending on specific safety case requirements, the strainer may also be used for design extended conditions (DEC), where specific safety features are considered.

Accidents can disrupt the normal operation of various equipment, posing significant risks to plant safety. For example, as mentioned above, the accumulation of debris on the ECCS strainer following a design basis accident (DBA), a design basis accident (DBE) or a design basis accident (DEC) could result in the strainer being blocked. Such accumulation can increase the head loss across the strainer, which in turn reduces the available net positive suction head (NPSHa) to the safety systems pumps. If the NPSHa falls below the required net positive suction head (NPSHr) of the pumps, cavitation can occur, resulting in a reduction in pump flow rate and potentially rendering the safety functions of the system ineffective. Furthermore, the ECCS strainer can allow the passage of fine fibre and particles, which can clog and erode downstream equipment such as heat exchangers, valves, CSS spray nozzle(s) and orifices, and can also increase the head loss across the reactor core, impairing the core heat transfer efficiency and potentially damaging the fuel cladding. Additionally, fibre, particles and chemical debris can adhere to the fuel rod cladding, further degrading heat removal conditions.

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Reactor technology — Design and performance evaluation of the emergency core cooling system strainer in pressurized water reactor nuclear power plants —

Part 1: General principles

1 Scope

This document specifies the requirements for the design and performance evaluation of the ECCS strainer, since the performance of the strainer is important for the maintenance of nuclear safety during DBA, DBE and DEC.

This document is applicable to the design and performance evaluation of the ECCS strainer in PWR NPPs, particularly those with primary design philosophies that rely on ECCS pumps. Its relevance for some PWR designs could nevertheless need some adaptations. Moreover, although tailored to PWR NPPs, it can also serve as a valuable reference for other reactor types, providing insight into the design and effectiveness of filtration systems in various nuclear power applications.

Additional information and insights on national practice can be found in References [1][2][3][4].

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitute 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 12749-5, *Nuclear energy, nuclear technologies, and radiological protection — Vocabulary — Part 5: Nuclear reactors*

3 Terms and definitions

For the purpose of this document, the terms and definitions given in ISO 12749-5 and the following 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/

3.1
bypass
condition whereby debris carried by the flow to the strainer can percolate through and pass downstream

Note 1 to entry: This term is only relevant for designs that include such a system.

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3.2
cavity injection system
CIS
system operating after a severe accident (SA) with core melt, designed to remove the heat of the molten core debris by cooling the outer wall of the reactor vessel, to maintain the integrity of the reactor vessel, and to realize the retention of molten core debris inside the reactor vessel

Note 1 to entry: This term is only relevant for designs that include such a system.

3.3
chemical effects
phenomena in which debris chemically reacts with the ECCS fluid under the post-accident operating temperature and radiation environment, resulting in a head loss on the ECCS strainer and on the fuel assembly

Note 1 to entry: This term is only relevant for designs that include such a system.

Note 2 to entry: Chemical reactions occur not only on the strainer, but also in the liquid and vapour flows along the containment structures, as well as in the sedimentation tanks, where the temperature may differ significantly from the temperature indicated in either direction, but for the activity of the strainer, the operating temperature of the *IRWST* (3.13) (or other water storage facilities, e.g. containment sump) is one of the main influences.

3.4
containment heat removal system
CHRS
system for reducing containment pressure and temperature following an accident and maintaining them at an acceptably low level

Note 1 to entry: This term is only relevant for designs that include such a system.

Note 2 to entry: The system may include containment spray system (CSS) (3.5).

3.5
containment spray system
CSS
system that provides a spray of cold or subcooled water into the upper containment volume to limit the pressure and temperature of the containment atmosphere after an accident, thereby reducing the possibility of release of airborne radioactivity to the environment

Note 1 to entry: This term is only relevant for designs that include such a system.

3.6
debris
degraded substances generated directly or indirectly as a result of an accident

Note 1 to entry: This term is only relevant for designs that include such a system.

Note 2 to entry: The debris can occur through

— destruction caused by a break in the coolant, feedwater or steam pipes, leading to disintegration of insulation, coatings, cable tray wrappings, concrete particles and sealing materials, as well as other latent materials present in the containment, which may be transported by the water flow to the *ECCS strainer* (3.11) under the accident conditions,

— post-accident chemical reactions between the coolant solution and containment materials, e.g. calcium (Ca), silicon (Si), and

— post-accident radiation which may cause degradation of the above materials.

Note 3 to entry: It is important to consider both direct (from pipe breaks) and indirect (from radiation and chemical reactions) source term of debris for any given accident scenario.

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3.7
head loss test
test designed to measure the head loss caused by the build-up of *debris* (3.6) transported by the water flow on the *ECCS strainer* (3.11) and by potential chemical effects

Note 1 to entry: This term is only relevant for designs that include such a system.

3.8
debris source term
DST
quantity and characteristics of debris that are expected to be generated and possibly transported by water flow during a postulated accident scenario

Note 1 to entry: This term is only relevant for designs that include such a system.

Note 2 to entry: This notion is used to analyse the debris transport to the containment sump or *IRWST* (3.13) or other water storage facilities, the subsequent debris accumulation, and resulting head loss across the strainer, which affects the overall effectiveness of the ECCS.

3.9
walkdown
activities performed to check in-situ the real potential *DST* (3.8) and flow paths within the containment against their design documentation

Note 1 to entry: Walkdown related activities include the development of a procedure, the performance of on-site inspections and the examination of flow paths leading to the containment sump or *IRWST* (3.13) or other water storage facilities.

Note 2 to entry: This term is only relevant for designs that include such a system.

3.10
emergency core cooling system
ECCS
safety system having as central function to ensure the automatic initiation of a number of actions ensuring adequate core cooling and primary coolant inventory losses compensation, following an accident

Note 1 to entry: This term is only relevant for designs that include such a system.

[SOURCE: ISO 12749-5:2026, 3.10.7.2, modified — Notes to entry have been deleted.]

3.11
emergency core cooling system (ECCS) strainer
filtration equipment of the *ECCS* (3.10) and other safety systems used to filter water from the containment sump or *IRWST* (3.13) or other water storage facilities

Note 1 to entry: This term is only relevant for designs that include such a system.

Note 2 to entry: The strainer surface need not necessarily be meshed.

Note 3 to entry: The word "strainer," as used throughout this document, may be considered as singular, i.e. strainer or collective, i.e. strainers, as content dictates.

3.12
ex-vessel downstream effects
phenomenon linked to bypass debris leading to potential blockage, abrasion or both in downstream equipment outside the reactor pressurized vessel such as pumps, heat exchangers, valves, orifices, CSS spray nozzle(s) and pipes due to *debris* (3.6) passing through the *ECCS strainer* (3.11)

Note 1 to entry: This term is only relevant for designs that include such a system.

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3.13
in-containment refuelling water storage tank
IRWST
tank or pool is installed inside the containment, and is designed to provide sufficient water for *ECCS* (3.10), *CSS* (3.5) etc., following a *relevant line break* (3.18) accident, and for *CIS* (3.2) following a DBA, DBE or DEC

Note 1 to entry: This term is only relevant for designs that include such a system.

3.14
in-vessel downstream effect
phenomenon linked to bypass debris having an impact on heat transfer of the fuel assemblies to the coolant inside the reactor pressurized vessel

Note 1 to entry: This term is only relevant for designs that include such a system.

3.15
in-vessel downstream effects compliance verification
test designed to measure the coolant flow head loss throughout the reactor core and to detect the deposition of *debris* (3.6) in narrow gaps or adhesion to fuel rod surfaces in fuel assemblies

Note 1 to entry: This term is only relevant for designs that include such a system.

Note 2 to entry: Such deposits of debris may lead to degradation of the heat transfer in the fuel assemblies.

3.16
net positive suction head
NPSH
for a pump, difference between the pressure at the pump inlet and the vapour pressure of the fluid

Note 1 to entry: This term is only relevant for designs that include such a system.

3.17
reference plant
existing power plant whose main characteristics are referenced in the design of new plants

Note 1 to entry: This term is only relevant for designs that include such a system.

3.18
relevant line break
sudden failure of the pressure boundary in an energised line system, manifested as a circumferential fracture or an abrupt, unconfined axial crack

Note 1 to entry: This term is only relevant for designs that include such a system.

3.19
safety case
collection of arguments and evidence in support of the safety of a facility or activity

Note 1 to entry: This term is only relevant for designs that include such a system.

Note 2 to entry: This normally includes the findings of a safety assessment and a statement of confidence in these findings.

Note 3 to entry: For a disposal facility, the safety case may relate to a given stage of development. In such cases, the safety case should acknowledge the existence of any unresolved issues and should provide guidance for work to resolve these issues in future development stages.

[SOURCE: IAEA Nuclear Safety and Security Glossary, 2022 (Interim)]

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