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Ice plug isolation of piping in nuclear power plant

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document (ISO 23467) has been prepared by Technical Committee ISO/TC 85, *Nuclear Energy, Nuclear Technologies, and Radiological Protection*, Subcommittee SC 6, *Reactor Technology*.

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

This document provides terms and definitions for basic concepts of nuclear energy, nuclear technologies, and radiological protection. Terminological data are taken from ISO standards developed by the any ISO/TC 85 Sub-committee and other technically validated documents.

In the field of nuclear power, when the equipment or pipeline shall be disassembled or removed to overhaul, often need to be isolated. Under normal circumstances, the upstream and downstream of the equipment will be isolated or the internal media will be sprinkled, but there will be no isolation equipment or isolation equipment near the equipment or pipe, while taking into account the safety (some systems as a reactor hot trap at any time shall be filled with water, some of the system of liquid with radioactive, worried about radioactive escape, etc.) and economy (system mass, sparse for a long time, heavy water degradation, etc.), pipes and equipment can't be isolated, for the maintenance work brought problem.

Based on years of practical experience, the development of this document is feasible. At the theoretical level, the relevant literature has been studied and reported on the ice plug isolation technology. In the actual maintenance work, the use of ice plug technology to the pipeline equipment isolation, to achieve good results. Based on these theoretical and practical experiences, it is recommended that some technical indicators in the process of ice plug operation be standardized.

This document is designed to provide a standardized procedure for on-line isolation through the freezing of the internal medium of the pipeline. It is expected that this document can be used to isolate equipment without isolation facilities by ice plug technology. Standardized ice plug isolation technology will facilitate the maintenance work.

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Ice plug isolation of piping in nuclear power plant

1 Scope

This document specifies requirements for the ice plug technique with liquid nitrogen or dry ice as refrigerant (cryogenic medium) on metal pipes of nuclear power plants. The freezing liquid can be water or water mixture (e.g. boric acid mixture).

This document specifies technical requirements of ice plug generation, formation judgment and removal, measures before, during and after ice plugging and requirements for personnel and non-destructive testing.

This document is applicable for maintenance work, modification work and test inspections work when no other locking opportunity than ice plugging is available.

The application of the ice plug isolation technique is principally not allowed on cladded pipes or pipes with internal coatings. The application for pressure test is not in the scope of this document and should be qualified separate.

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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 5579:2013, *Non-destructive testing — Radiographic testing of metallic materials using film and X- or gamma rays — Basic rules*

ISO 19232-1:2013, *Non-destructive testing — Image quality of radiographs — Part 1: Determination of the image quality value using wire-type image quality indicators*

ISO 19232-2:2013, *Non-destructive testing — Image quality of radiographs — Part 2: Determination of the image quality value using step/hole-type image quality indicators*

ISO 19232-3:2013, *Non-destructive testing — Image quality of radiographs — Part 3: Image quality classes*

ISO 19232-4:2013, *Non-destructive testing — Image quality of radiographs — Part 4: Experimental evaluation of image quality values and image quality tables*

ISO 19232-5:2018, *Non-destructive testing — Image quality of radiographs — Part 5: Determination of the image unsharpness and basic spatial resolution value using duplex wire-type image quality indicators*

ISO 16810, *Non-destructive testing — Ultrasonic testing — General principles*

ISO 16811, *Non-destructive testing — Ultrasonic testing — Sensitivity and range setting*

ISO 16823, *Non-destructive testing — Ultrasonic testing — Transmission technique*

ISO 16826, *Non-destructive testing — Ultrasonic testing — Examination for discontinuities perpendicular to the surface*

ISO 16827, *Non-destructive testing — Ultrasonic testing — Characterization and sizing of discontinuities*

ISO 16828, *Non-destructive testing — Ultrasonic testing — Time-of-flight diffraction technique as a method for detection and sizing of discontinuities*

ISO 9934-1:2016, *Non-destructive testing — Magnetic particle testing — Part 1: General principles*

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ISO 9934-2:2015, *Non-destructive testing — Magnetic particle testing — Part 2: Detection media*

ISO 9934-3:2015, *Non-destructive testing — Magnetic particle testing — Part 3: Equipment*

ISO 3452-1:2013, *Non-destructive testing — Penetrant testing — Part 1: General principles*

ISO 3452-2:2013, *Non-destructive testing — Penetrant testing — Part 2: Testing of penetrant materials*

ISO 3452-3:2013, *Non-destructive testing — Penetrant testing — Part 3: Reference test blocks*

ISO 3452-4:1998, *Non-destructive testing — Penetrant testing — Part 4: Equipment*

ISO 3452-5:2008, *Non-destructive testing — Penetrant testing — Part 5: Penetrant testing at temperatures higher than 50 degrees C*

ISO 3452-6:2008, *Non-destructive testing — Penetrant testing — Part 6: Penetrant testing at temperatures lower than 10 degrees C*

ISO 17637:2016, *Non-destructive testing of welds — Visual testing of fusion-welded joints*

ASME *Boiler and Pressure Vessel* Code, Section III and Section XI

3 Terms and Definitions

For the purposes of this document 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/

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3.1
Ice Plug
process of locally freezing the liquid in the pipe by using a cryogenic refrigerant, and then forming a solid block of ice in the pipe that can withstand a certain system pressure to isolate the pipeline temporarily, for the convenience of maintaining downstream pipelines, valves and other equipment

3.2
Ice Plug Jacket
set of device wrapped outside the pipe and containing a refrigerant capable of freezing internal medium of the pipe to form an ice plug for a period necessary for the isolation.

Note 1 to entry: The length of jacket depends on the diameter of pipe. See Annex A for the length of jacket.

3.3
Ice plug area
defined area on the pipe excluding the ice plug affected zone

3.4
Ice plug affected zone
area of the pipe next to the ice plug area

3.5
Refrigerant (Cryogenic medium)
cryogenic medium which is used to generate an ice plug inside of the of the pipes

3.6
Freezing medium/liquid
medium inside of pipes and components which have to be frozen

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4 General Requirements

4.1 Personnel

Managers and operators engaged in ice plug isolation construction shall undergo professional training and safety training.For the implementation, only qualified and trained personnel should be deployed (e.g. workers from specialized companies).

4.2 Equipment

4.2.1 Special ice plug jacket and other equipment and tools shall be equipped. Measurement tools (such as thermometers, pressure gauges, oxygen meters, etc.) shall be calibrated and validated.

4.2.2 Anti-freezing, anti-asphyxia and other related safety protection products shall be provided.

4.3 Preconditions

4.3.1 Pipes shall be filled with any fluids that can be frozen, and free of air.

4.3.2 The flow rate of liquid in the pipe should be as low as possible, preferably close to zero. Excessive flow rate is not conducive to the formation of ice plug.

4.3.3 When the ambient temperature is lower than 43°C, the surface temperature of pipe shall be lower than 50°C if the refrigerant is liquid nitrogen and shall be lower than 30°C if the refrigerant is dry ice. This is not required if validity is confirmed by mock-up test.

4.3.4 The distance between ice plug and heat source nearby (including welding parts) shall be determined based on heat input and pipe diameter.

4.3.5 Pipe to be isolated with an ice plug shall not be affected by the vibration and shock during the operation.

4.3.6 Ice plug operation is prohibited for the pipe sections containing the following defects:

a) Crack affecting the strength;

b) Pitting affecting the strength;

c) Thickness of pipe thinned to an unacceptable level;

d) Breach;

e) Other conditions that may cause the pipe burst.

4.3.7 Ice plug operation is prohibited in the following pipe structures or fittings:

a) Weld;

b) Pipe parts, such as plugs, thermocouples, etc.

c) Pipe fittings, such as tees and movable joints, etc.

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4.4 Requirements of Process

4.4.1 Material of pipe

The pipe shall be made of metal (carbon steel or stainless steel). For ice plug area, welds are prohibited (no circumferential neither longitudinal weld). Cast copper pipe, cast iron pipe, cladded pipe and lining pipe shall not be subject to ice plugging isolation.

Material inspection certificate or alternative consideration should be confirmed in order to avoid low temperature brittle fracture, when applying ice plugs on carbon steel piping, which is connected to most important components or piping for safety.

Vibration and external shock like falling parts (e.g. tools) or mechanical stress (e.g. moving of valves, starting of pumps) shall be avoided during ice plug generation. Additional stainless steel pipe shall be protected from contact with halogen-containing medium to prevent stress corrosion.

4.4.2 Freezing medium

The freezing medium shall be selected in accordance with the following principles, depending on pipe diameter and medium temperature. This is not required if validity is confirmed by mock-up test.

Liquid nitrogen: the working temperature of liquid nitrogen is -196°C, suitable for for ferritic pipe equal or less than DN 400 (16”) or for austenitic steel equal or less than DN 300 (12”).

Dry ice: the working temperature of dry ice is -78°C, suitable for for pipe equal or less than DN 100 (4”).

Freon and its substitutes:it is suitable for the ice plug of pipe with outer diameter of less than 60,3 mm.

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4.4.3 Position of ice plug

4.4.3.1 The distance between the ice plug from extensions (valve, pump, flange, movable joint, weld, tee, elbow, etc.) should be greater than 20 times the outer diameter (> 20 x Da) or 600 mm, whichever is greater, to avoid stress effects caused by temperature gradients. If both extensions are fixed point, one of them shall be loosed. This is not required if validity is confirmed by mock-up test.

4.4.3.2 A pressure relief device is required between adjacent ice plugs or the ice-plug and a closed end. If it is not possible, a minimal distance between them should be respected to “absorb” increasing pressure due to ice plug expansion in order to remain below the design pressure of the pipe.

4.4.3.3 If the distance between the ice plugs the ice plug from the weld and the pipe fittings or the ice plug and the closed end does not satisfy the standard, it can be used it by verifying mock-up test etc. For the distance, it is important that the needed NDT could be done in proper performance.

4.4.3.4 It is advisable to select the straight pipe at upstream of the elbow to prevent the impact to downstream equipment due to ice plug failure.

4.4.3.5 Impacts of external heat sources shall be taken in account by the selection of the ice plug area. If the ice plug isolation is performed in conjunction with weld repair maintenance minimum distances between welding zone and ice plug area shall be specified to avoid stress effects caused by temperature gradients.

4.4.4 Ice plug jacket

The jacket shall be made of stainless steel, aluminum alloy or other proven materials suitable at low temperature. The jackets are generally divided into open ice plug jacket, semi-open ice plug jacket and closed ice plug jacket. See Annex B for a description of jacket and selection recommendations.

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