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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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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was 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.

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.

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.

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 will be qualified separately.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes 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 3452 (all parts), *Non-destructive testing — Penetrant testing*

ISO 9934 (all parts), *Non-destructive testing — Magnetic particle testing*

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

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

ISO 20769 (all parts), *Non-destructive testing — Radiographic inspection of corrosion and deposits in pipes by X- and gamma rays*

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/

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* (3.1) 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
refrigerant
cryogenic medium
medium which is used to generate an *ice plug* (3.1) inside of the pipes

3.5
freezing medium
freezing liquid
medium inside of pipes and components which have to be frozen

3.6
UT
ultrasonic testing
non-destructive testing of solid material using ultrasonic waves, for defects such as cavities, nonbonding, and strength variations

3.7
RT
radiographic testing
non-destructive testing method of inspecting materials for hidden flaws by using the ability of short wavelength electromagnetic radiation (high energy photons) to penetrate various materials

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 (such as liquid nitrogen chamber, hoses, joints, antifreeze gloves, protective masks, protective glasses) 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) Pipe parts, such as plugs, thermocouples;

b) Pipe fittings, such as movable joints.

4.4 Requirements of process

4.4.1 Material of pipe

The pipe shall be made of metal (carbon steel or stainless steel). Technically speaking, for ice plug area, welds are not allowed (no circumferential neither longitudinal weld). Unless it can be demonstrated that there is no better solution, and that there are no defects in the welds, ice plug operations on welds can be done. 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. It is also allowed to refer to local regulations if local regulations have higher diameter limit.

Liquid nitrogen: the working temperature of liquid nitrogen is –196 °C, suitable 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 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.

4.4.1 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 × 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 loosened. 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 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 by verifying mock-up test. 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 into 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.

4.4.3 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.

5 Preparation before operation

5.1 Working environment

Working space shall be surveyed before ice plug construction to ensure sufficient space for layout and operation of equipment. The ambient oxygen content shall be monitored continuously during the operation. Forced ventilation shall be carried out during the ice plug operation to prevent personnel from suffocating if necessary.

5.2 Construction plan

Construction plan shall be prepared before ice plug operation. The ice plug construction plan shall include following contents:

a) scope of application and pipe isometries;

b) risk analysis (concerning the influence to health of the employees and to the environment) and preventive measures (include contingency plans in the event of an ice plug failure);

c) generation process of ice plug;

d) requirements of pre-construction preparation (include the requirement for an adequate supply of refrigerant to support the ice plug);

e) quality assurance measures before ice plug performance (include proper assessment of structural integrity to prevent the structural damage and of time of the ice plugging duration to minimize thermal stresses);

f) ice plug performance and verification as well as quality assurance measures during ice plug performance;

g) requirements for ice plug removal;

h) quality assurance measures after ice plug performance;

i) requirements of construction removal and recording.

