INTERNATIONAL STANDARD

ISO 23467

First edition
2020-11

Ice plug isolation of piping in nuclear power plant

Mise en œuvre de la technique d'obturation cryogénique sur les tuyauteries de centrales nucléaires

STANDARDSISO.COM : Click to view the full PDF of ISO 23467:2020

Reference number
ISO 23467:2020(E)

© ISO 2020

STANDARDSISO.COM : Click to view the full PDF of ISO 23467:2020

COPYRIGHT PROTECTED DOCUMENT

© ISO 2020

All rights reserved. Unless otherwise specified, or required in the context of its implementation, no part of this publication may be reproduced or utilized otherwise in any form or by any means, electronic or mechanical, including photocopying, or posting on the internet or an intranet, without prior written permission. Permission can be requested from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

Contents

Page

STANDARDSISO.COM : Click to view the full PDF of ISO 23467:2020

© ISO 2020 – All rights reserved

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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.

STANDARDSISO.COM : Click to view the full PDF of ISO 23467:2020

 © ISO 2020 – All rights reserved

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 ISO/TC 85 sub-committees and other technically validated documents.

In the field of nuclear power, when the equipment or pipeline is to be disassembled or removed to overhaul, it is often necessary to isolate the equipment or pipeline. Under normal circumstances, the upstream and downstream of the equipment will be isolated or the internal media will be sprinkled. Taking into account the safety (some reactor systems like the hot trap needs to be filled at any time and care need to be taken as some liquid systems are radioactive) and economy (system mass, sparse for a long time, heavy water degradation, etc.) during the maintenance it is necessary that there will be no isolation equipment or isolation equipment near the equipment or pipeline.

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 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. This document includes methods for technologies to isolate equipment without isolation facilities by ice plug technology. Standardized ice plug isolation technology will facilitate the maintenance work.

STANDARDSISO.COM : Click to view the full PDF of ISO 23467:2020

© ISO 2020 – All rights reserved

STANDARDSISO.COM : Click to view the full PDF of ISO 23467:2020

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
solid block of ice in the pipe that can withstand a certain system pressure to isolate the pipeline temporarily

Note 1 to entry: The ice plug can be used for the convenience of maintaining downstream pipelines, valves and other equipment.

STANDARDSISO.COM : Click to view the full PDF of ISO 23467:2020

© ISO 2020 – All rights reserved

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

STANDARDSISO.COM : Click to view the full PDF of ISO 23467:2020

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, other equipment (such as liquid nitrogen chamber, hoses, joints, antifreeze gloves, protective masks, protective glasses) and tools shall be used. 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.

© ISO 2020 – All rights reserved

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 The 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 could cause a burst of the pipe.

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). Welds are not allowed in the area of the ice plug (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. In addition, 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.

STANDARDSISO.COM : Click to view the full PDF of ISO 23467:2020

© ISO 2020 – All rights reserved

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 × Da) or 600 mm, whichever is greater, to avoid stress effects caused by temperature gradients. If both extensions are fixed points, 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 are not in accordance with this document, the distance can be used if it is verified by a 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.

4.4.1 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 a jacket and selection recommendations.

5 Preparation before operation

5.1 Working environment

The working space shall be surveyed before ice plug isolation to ensure sufficient space for the arrangement 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

The construction plan shall be prepared before the 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);

STANDARDSISO.COM : Click to view the full PDF of ISO 23467:2020

 © ISO 2020 – All rights reserved

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.

See Annex C for the flow chart.

5.3 Tools of construction

The special tools of ice plug freezing isolation (jackets, hoses, joints) shall be verified and kept in good condition.

5.4 Protective measures

Frostbite protective articles shall be provided, such as antifreeze gloves, protective masks, protective glasses.

The ambient oxygen content shall be monitored continuously during the operation.

Radiation protection shall be carried out as required if the ice plug construction is carried out in the radiation control area.

5.5 Pipe testing before operation

Before the ice plug operation, the pipe sections to be frozen shall be subject to visual examination, penetrant testing or magnetic particle testing in accordance with ISO 17637, ISO 3452 (all parts) or ISO 9934 (all parts) respectively. The surface of stainless steel pipe shall be free of corrosion, crack, severe wall thinning and other relevant defects. The surface of carbon steel pipe shall be free of corrosion pit, cracks, severe wall thinning and other dangerous defects. Ultrasound testing and radiographic testing shall be executed in accordance with ISO 16810 and ISO 20769 (all parts) respectively, if necessary.

6 Ice plug construction

6.1 Generation of ice plug

Ensure the relevant isolating valve is closed in order to minimize the flow rate of the pipe section to be frozen close to zero.

Slowly fill the refrigerant into the jacket until it becomes and remains steady.

Monitor the temperature and pressure (if any) of ice plug pipe continuously during the operation.

6.2 Judgment of ice plug generation

The method for judging whether the ice plug status meets the isolation requirement is as follows. Any one of the following can be used alone as a criterion to determine whether an ice plug has formed.

a) Unilateral pressure method: it needs to extend the freezing time after determining the ice plug generation preliminarily, and exert pressure on the pipe isolated by ice plug. The ice plug is formed if the pipe can withstand a certain pressure (test pressure shall be higher than the pressure of other side). This method is suitable for the operation with pressuring conditions.

STANDARDSISO.COM : Click to view the full PDF of ISO 23467:2020

b) Complete hydrophobic method: it needs to extend the freezing time after determining the ice plug generation preliminarily, and drain away water in the isolated pipe. The ice plug is formed if the water can be completely drained.

c) Partial hydrophobic method: it needs to extend the freezing time after determining the ice plug generation preliminarily, drain away water in the isolated pipe, and measure the liquid level of isolated pipe. The ice plug is formed if the liquid level does not rise. This method is suitable for the situation where the pipeline water volume is large and the drainage time is long.

d) Pipe temperature difference method: it needs to extend the freezing time after determining the ice plug generation preliminarily. The ice plug is formed if the temperature of isolated pipe at 1 m away from the ice plug jacket is close to the ambient temperature, while the temperature at symmetrical position on the other side is close to the system temperature. This method is suitable for the situation where the pipe system temperature is higher than the ambient temperature.

The degree of frost on the pipe cannot be used alone to judge whether the internal ice plug is formed.

6.3 Removal of ice plug

The relevant equipment shall be removed after the ice plug is completely melted in the natural environment and the temperature of pipe section returns to normal. It is prohibited to remove the ice plug by roasting, electric welding or other external heating methods.

Protective measures shall be taken during the removal of ice plug for vertical pipe and upstream pressurized pipe, such as downstream water inject, to prevent the downstream equipment and the pipe from being damaged due to the ice plug as well as for prevention of the system from leakage.

It should be ensured during defreezing that an abrupt loosing of the ice plug is avoided due to pressure difference on both ice plug sides. To eliminate pressure difference on both sides the empty pipe system shall be filled. The unintended removal of ice plug could be avoided by controlled application of temperature. Hereby a small channel could be formed with warm air device (usage of burner or similar is prohibited) at a suitable point. The liquid can flow through this channel and adjust pressure compensation. On vertical pipe the channel should formed at the 12 o´clock position. The non-destructive testing shall be executed upon completing the ice plug operation; the testing methods and requirements are the same as those specified in 5.5.

Applied tools and additives shall be removed residue-free. The system operation is restored after ending plugging (reinstall of loosened subsidies, spring hangers etc.).

7 Quality assurance (QA) on ice plugging

7.1 QA before ice plug performance

The surface of pipe section to be frozen should be accessible, cleaned and free of coatings, residues, corrosion (inner and outer surface), crack, severe wall thinning and other relevant defects.

Measured ice plug area shall be registered on pipe isometry.

Before ice plugging, the pipe section to be frozen (ice plug area and 200 mm on both sides) shall be subjected to visual examination (VT), penetrant testing (PT) or magnetic testing (MT). The VT shall be carried out in accordance with ISO 17637. On ferritic pipe MT is preferable. The PT shall be carried out in accordance with ISO 3542 (all parts) and the MT with ISO 9934 (all parts) respectively.

Any detected unacceptable inhomogeneities (VT, PT or MT) shall be reported. In this case ice plugging is not permitted in this area.

On selected pipe section to be frozen with risk of erosion resp. corrosion an UT or RT wall thickness examination shall be performed. If any deviations to the expected value is detected the result shall be considered on risk analysis.

STANDARDSISO.COM : Click to view the full PDF of ISO 23467:2020

 © ISO 2020 – All rights reserved

7.2 QA during ice plug performance

The ice plug generation shall be monitored during the whole ice plug operation. Start time and end time and any deviations during ice plug measure shall be reported. The end time can be determined according to 6.2.

7.3 QA after ice plug performance

After removal of ice plug (see 6.3) the surface of pipe section to be frozen (ice plug area and 200 mm on both sides) should be inspected in the same way as before ice plug performance (see 7.1). The ice plug don't modify the wall thickness, so it is not necessary to perform the RT or UT after the ice plug operation. Record and compare non-destructive testing report before and after ice plug performance, unacceptable inhomogeneities shall be reported.

8 Records and reports

Records and reports shall at least include the following contents:

a) cover sheet (extract from construction plan with initial information to plugged system (DN, pN, temperature, flow rate, refrigerant etc.) and quality documents (e.g. isometry, result of risk analysis);

b) non-destructive testing report before ice plug performance;

c) records of temperature and pressure (if any);

d) non-destructive testing report after ice plug performance;

e) completion report and report of protective measures.

NOTE Non-destructive testing report refers to the standards in 7.1.

STANDARDSISO.COM : Click to view the full PDF of ISO 23467:2020

Annex A
(informative)

Reference table of ice plug jacket length

The length of the ice plug jacket shall be selected by reference to Tables A.1 and A.2.

Table A.1 — Liquid nitrogen ice plug jacket

Nominal size		Outer diameter mm	Length range of jacket (Times of outer diameter)	Recommended length mm
DN	NPS			
40	1½	48,3	2 to 3 times	125
50	2	60,3	2 to 3 times	150
65	2½	73,0	1,5 to2,5 times	150
80	3	88,9	1.5 to 2,5 times	200
90	3½	101,6	1.5 to 2,5 times	200
100	4	114,3	1.5 to 2,5 times	250
125	5	141,3	1.5 to 2,5 times	300
150	6	168,3	1.5 to 2,5 times	300
200	8	219,1	1.5 to 2,5 times	400
250	10	273,0	1.5 to 2,5 times	500
300	12	323,9	1.5 to 2,5 times	600
350	14	355,6	1.5 to 2,5 times	700
400	16	406,4	1.5 to 2,5 times	800

Table A.2 — Dry ice plug jacket

Nominal size		Outer diameter mm	Length range of jacket (Times of outer diameter)	Recommended length mm
DN	NPS			
15	½	21,3	5 to 7 times	150
20	¾	26,9	5 to 7 times	150
25	1	33,7	5 to 7 times	200
32	1¼	42,4	4 to 6 times	200
40	1½	48,3	4 to 6 times	200
50	2	60,3	4 to 6 times	300
65	2½	73,0	3 to 5 times	300
80	3	88,9	3 to 5 times	400
90	3½	101,6	3 to 5 times	400
NOTE The limitation of the jacket length is not required if validity is confirmed by mock-up test.				

STANDARDSISO.COM : Click to view the full PDF of ISO 23467:2020

© ISO 2020 – All rights reserved

Annex B
(informative)

Ice plug jacket types

Table B.1 is a summary table of ice plug jacket types. The ice plug jacket to be used can be selected according to the principles of easy maintenance, refrigeration uniformity, refrigeration efficiency, design difficulty, application rate, and reuse.

STANDARDSISO.COM : Click to view the full PDF of ISO 23467:2020

© ISO 2020 – All rights reserved

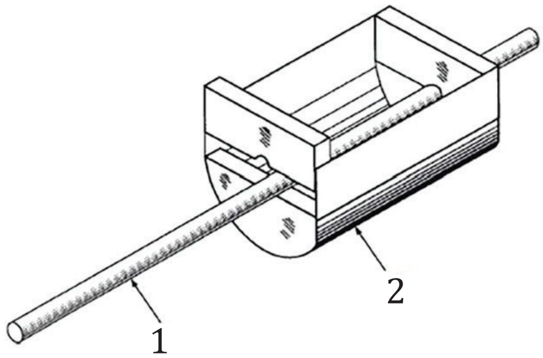
Table B.1 — Summary of ice plug jacket types

S/N	Type of Jacket	Contact with refrigerant	Characteristics	Scope of application	Refrigerant	Reference figure
1	Open jacket	Direct	Simple structure, easy to manufacture and reusable. Dry ice required from time to time, high operational requirements, poor convenience, uneven refrigeration, and low refrigeration efficiency with theoretical refrigeration capacity up to −78,5 °C.	Very rarely used, and generally suitable for pipe with a size no more than 2''	Dry ice	B.1
2	Semi-open jacket (single layer)	Direct	More complicated structure, high manufacturing requirements, inconvenient disassembly, but reusable. Direct contact with outer wall of the pipe after entering in the jacket; uneven refrigeration, especially on the horizontal pipe; and low refrigeration efficiency.	Commonly used, suitable for pipe with a size of 1'' and above pipe	Liquid nitrogen	B.2
3	Semi-open jacket (double layer)	Indirect	Complicated structure, high manufacturing requirements, convenient disassembly, and reusable. Sustainable supply of liquid nitrogen to the jacket via pipe; refrigerant not directly contact with outer wall of the pipe after entering in the jacket; heat-conducting medium needed to be added between the outer wall of pipe and the inner wall of jacket; uniformity of refrigeration related to the internal structure of jacket; high refrigeration efficiency.	Commonly used, and suitable for pipe with a size of 1'' and pipe above	Liquid nitrogen	B.3
4	Coiled jacket	Indirect	Simple structure; inconvenient disassembly due to copper tube used as jacket; high operational requirements, and non-reusable. Refrigerant not directly contact with pipe; heat-conducting medium needed to be added between the copper pipe and the inner wall of jacket; and low refrigeration efficiency.	Rarely used, generally suitable for pipe with a size of pipe4'' and above	Liquid nitrogen /other refrigerant	B.4
5	Flexible jacket	Direct	Simple structure, convenient disassembly, and reusable; Dry ice required from time to time, high operational requirements, uneven refrigeration, and low refrigeration efficiency.	Rarely used, and generally suitable for pipe with a size below 2''	Dry ice	B.5
6	Closed jacket	Indirect	Simple structure, easy to operate and use, and reusable. Refrigerant recycled in a closed system; even refrigeration, and low refrigeration efficiency with theoretical refrigeration capacity only −35 °C.	Commonly used, and suitable for pipe with a size no more than 1''	Freon, etc.	B.6

NOTE The limitation of the outer diameter is not required if validity is confirmed by mock-up test.

STANDARDSISO.COM : Click to view the full PDF of ISO 23467:2020

© ISO 2020 – All rights reserved

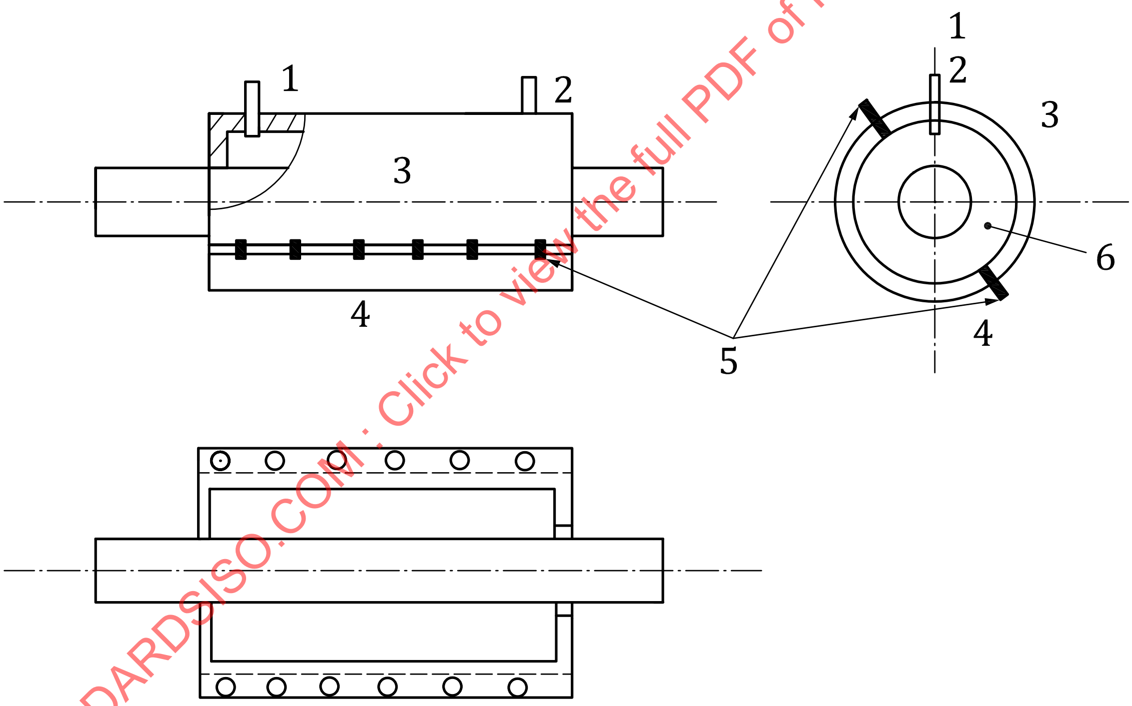


Key

1 pipe

2 ice plug jacket

Figure B.1 — Open ice jam jacket



Key

1 exhaust vent

2 inlet

3 upper jacket

4 lower jacket

5 bolted

6 liquid nitrogen chamber

Figure B.2 — Semi-open jacket (single layer)

STANDARDSISO.COM : Click to view the full PDF of ISO 23467:2020