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Cryogenic vessels — Valves for cryogenic service

Récipients cryogéniques — Robinets pour usage cryogénique

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Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 21011 was prepared by Technical Committee ISO/TC 220, *Cryogenic vessels*.

Cryogenic vessels — Valves for cryogenic service

1 Scope

This International Standard specifies the requirements for the design, manufacture and testing of valves for a rated temperature of −40 °C and below (cryogenic service), i.e. for operation with cryogenic fluids in addition to operation at temperatures from ambient to cryogenic.

It applies to all types of cryogenic valves, including vacuum jacketed cryogenic valves up to size DN 150.

This International Standard is not applicable to pressure relief valves covered by ISO 21013-1.

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.

ISO 5208, *Industrial valves — Pressure testing of valves*

ISO 10434, *Bolted bonnet steel gate valves for the petroleum, petrochemical and allied industries*

ISO 11114-1, *Transportable gas cylinders — Compatibility of cylinder and valve materials with gas contents — Part 1: Metallic materials*

ISO 11114-2, *Transportable gas cylinders — Compatibility of cylinder and valve materials with gas contents — Part 2: Non-metallic materials*

ISO 15761, *Steel gate, globe and check valves for sizes DN 100 and smaller, for the petroleum and natural gas industries*

ISO 17292, *Metal ball valves for petroleum, petrochemical and allied industries*

ISO 21010, *Cryogenic vessels — Gas/materials compatibility*

ISO 21028-1, *Cryogenic vessels — Toughness requirements for materials at cryogenic temperature — Part 1: Temperatures below −80 degrees C*

ISO 21028-2, *Cryogenic vessels — Toughness requirements for materials at cryogenic temperature — Part 2: Temperatures between −80 degrees C and −20 degrees C*

ISO 23208, *Cryogenic vessels — Cleanliness for cryogenic service*

ASME B16.34, *Valves — Flanged, threaded, and welding end*

3 Terms and definitions

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

3.1
nominal size
DN
alphanumeric designation of size for components of a pipe work system, which is used for reference purposes.

NOTE 1 It comprises the letters “DN” followed by a dimensionless whole number which is indirectly related to the physical size, in millimetres, of the bore or outside diameter of the end connections.

NOTE 2 Adapted from ISO 6708:1995.

3.2
rated pressure
PR
maximum pressure difference between the inside and outside of any pressure retaining boundary for which the boundary is designed to be operated at 20 °C

NOTE The PR of the valve is the lowest PR of any component of the valve.

3.3
rated minimum temperature
lowest temperature for which the valve is rated by the manufacturer

3.4
valve category A
valve type which passed the operation simulation test for 2 000 cycles during type approval testing

NOTE See 5.1.3.3.

3.5
valve category B
valve type which passed the operation simulation test for 100 cycles during type approval testing

NOTE See 5.1.3.3.

3.6
flow coefficient
basic coefficient used to state the flow capacity of a valve under specified conditions

NOTE 1 Flow coefficients in current use are K_v and C_v depending upon the system of units.

NOTE 2 Even though the dimensions and units used with flow coefficient K_v differ from those used with flow coefficient C_v, it is possible to relate the two flow coefficients numerically by means of the relationship $\frac{K_v}{C_v} = 0{,}865$.

NOTE 3 The flow coefficient definitions given in 3.6.1 (for K_v) and in 3.6.2 (for C_v) include certain units, nomenclature and temperature values which are not consistent with the parts of IEC 60534 other than IEC 60534-1. These inconsistencies are limited to 3.6.1 and 3.6.2 of this International Standard, and their sole purpose is to illustrate the unique relationships traditionally used in the valve industry. These inconsistencies do not concern any parts of IEC 60534 other than IEC 60534-1.

3.6.1
flow coefficient K_v
K_v
special volumetric flow rate calculated in cubic metres per hour (capacity) through a valve, where the static pressure loss across the valve is 0,1 MPa (1 bar)[1], and the fluid is water within a temperature range 5 °C to 40 °C (278 K to 313 K)

NOTE The value of K_v can be obtained from test results by means of the following equation:

$$K_v = Q\sqrt{\left(\frac{\Delta p_{K_v}}{\Delta p}\right)\left(\frac{\rho}{\rho_w}\right)}$$

where

Q is the measured volumetric flow rate, in m³/h;

Δp_{K_v} is the static pressure loss of 0,1 MPa (1 bar);

Δp is the measured static pressure loss across the valve, in MPa (bar);

ρ is the density of the fluid, in kg/m³;

ρ_w is the density of water, in kg/m³ (1 000 kg/m³).

This equation is valid when the flow is turbulent and no cavitation or flashing occurs.

3.6.2
flow coefficient C_v
C_v
non-SI valve coefficient which is in widespread use worldwide

NOTE Numerically, C_v is represented as the number of US gallons of water, within a temperature range of 40 °F to 100 °F, that will flow through a valve in 1 min when a pressure drop of 6 894,76 Pa (1 psi)[2] occurs. For conditions other than these, C_v can be obtained using the following equation:

$$C_v = Q\sqrt{\left(\frac{\Delta p_{C_v}}{\Delta p}\right)\left(\frac{\rho}{\rho_w}\right)}$$

where

Q is the measured volumetric flow rate, in US gallons per minute[3];

ρ is the density of the fluid, in pounds per cubic foot[4];

ρ_w is the density of water within a temperature range of 4 °C to 38 °C (40 °F to 100 °F), in pounds per cubic foot;

Δp is the measurement state pressure loss across the valve, in psi;

$\Delta p_{C_v} = 1\text{psi}$.

This equation is valid when the flow is turbulent and no cavitation or flashing occurs.

1) 1 bar = 0,1 MPa.

2) 1 psi = 0,068 948 bar = 6 894,76 Pa.

3) 1 gal (US)/min = 309 x 10^{-5} m³/s.

4) 1 lb/ft³ = 16,018 kg/m³.

3.7
bonnet
cylindrical part connecting the valve body to the seal packing chamber

4 Requirements

4.1 Materials

4.1.1 General

Materials shall be in conformance with an internationally recognized standard and compatible with the fluid. Galling, frictional heating and galvanic corrosion shall be considered in the selection of materials. Materials shall also be oxygen compatible, if relevant (see 4.1.5.1).

Materials not listed in an internationally recognized standard shall be controlled by the manufacturer of the valve by a specification ensuring control of chemical content and physical properties, and ensuring quality at least equivalent to an internally recognized standard. A test certificate providing the chemical content and physical property test results shall be provided with the valve.

4.1.2 Metallic materials

Metallic materials to be used in the construction of cryogenic valves shall meet the requirements of ISO 21028-1 or ISO 21028-2 as appropriate for the rated minimum temperature.

These requirements apply only to the valve parts exposed to low temperatures in normal service. Metallic materials which do not exhibit ductile/brittle transition and non ferrous materials which can be shown to have no ductile/brittle transition do not require additional impact tests.

Forged, rolled, wrought and fabricated valve components from raw materials from these processes need not be impact tested if the rated minimum temperature is higher than the ductile/brittle transition range temperatures of the material. Castings meeting the requirements of one of the applicable mandatory Appendices I and IV or II and III of ASME B16.34 for forgings and rolled or wrought material, or conforming to equivalent standards, need not be impact tested if the rated minimum temperature is higher than the ductile/brittle transition range temperatures of the material. When impact testing is required, at least one randomly selected valve body (including bonnet, if applicable) material from each production lot castings shall be impact tested at the rated minimum temperature.

4.1.3 Non-metallic materials

Non-metallic materials are well established only for use in packing and glands and for use for inserts within the plug/stem assembly to provide leak tightness across the seat when the valve is closed. If such materials are to be used for structural parts, they shall have the properties appropriate to the application and conform to ISO 21028-1 or ISO 21028-2, as appropriate to the rated minimum temperature.

Non-metallic materials shall also:

— have mechanical properties that will allow the valve to pass the type approval test for category A valves defined in 5.1.3.3;

— be resistant to sunlight, weather and ageing.

4.1.4 Corrosion resistance

In addition to resistance to normal atmospheric corrosion, particular care shall be taken to ensure that the valve cannot be rendered inoperative by accumulation of corrosion products. Some copper alloys are susceptible to stress corrosion cracking; consequently, careful consideration shall be given before selection of these materials for components under stress.

4.1.5 Gas material compatibility

4.1.5.1 Oxygen

If the rated minimum temperature is equal to or less than the boiling point of air, or if the valve is intended for service with oxygen or oxidizing products, the materials in contact with liquid air or oxidizing products shall be oxygen compatible, in accordance with ISO 21010.

4.1.5.2 Hydrogen

For hydrogen service, see ISO 11114-1 and ISO 11114-2.

4.1.5.3 Acetylene

Metallic materials shall contain less than 70 % copper if specified for use with mixtures containing acetylene.

4.2 Design

4.2.1 General

The valves shall fulfil their function in a safe manner within the temperature range from +65 °C to their rated minimum temperature and the pressure range intended for use.

Minimum wall thickness values for valve bodies shall be from the appropriate valve standards ISO 10434, ISO 15761, ISO 17292 and ASME B16.34. Bonnet thickness of extended bonnet (extended stem) valves are exempted from meeting the minimum wall thickness requirements of these standards. These standards may be used as informative references for design not specifically covered in this International Standard.

4.2.2 Packing gland

Valves can have an extended stem and/or an extended bonnet. The length of the extension shall be sufficient to maintain the stem packing at a temperature high enough to permit operation within the normal temperature range of the packing material.

Valves without an extended stem and/or an extended bonnet shall have a stem packing capable of operating at the specified minimum temperature. The handle shall be designed to remain operable for the duration of the sample valve test, in accordance with Clause 5.

Gland designs incorporating a gland nut with a male or female thread shall be designed in such a way that they will not loosen unintentionally, e.g. when the valve is operated.

4.2.3 Operating positions

Unless otherwise specified by the valve manufacturer, valves with extended stem and/or an extended bonnet shall be capable of normal operation in the liquid service with the valve stem at any position from the vertical to 25° above the horizontal. Loads imposed by actuators shall also be considered.

4.2.4 Cavities

4.2.4.1 Trapped liquid

Cavities where liquid can be trapped and build up detrimental pressures due to evaporation of the liquid during warming up of the valve are not permitted.

NOTE For ball and gate valves, this requirement can be met by the provision of a pressure relief hole or passage or other means, e.g. pressure relieving seats, to relieve pressure in the bonnet and body cavities.

4.2.4.2 Debris

Cavities susceptible to trapping debris shall be avoided.

4.2.5 Valve bonnet

Valve bonnets may be brazed, welded, bolted, screwed or union type. Union nuts shall be locked to the body. Union type bonnets shall not be used on valves greater than DN 80. Screwed bonnets shall also be secured by a union nut or another device offering equivalent safety.

4.2.6 Securing of gland extension

For bronze or copper alloy valves whose PR is greater than or equal to 2,5 MPa, the gland (bonnet) extensions shall be mechanically secured in the bonnet prior to brazing (e.g. by screwing).

4.2.7 Seat

Valves may have metal/metal or metal/soft seat or insert. Soft seats shall be backed by a secondary metal seat. Soft seat materials shall be adequately supported to prevent cold flow of the seat material.

Plugs and/or soft seats shall be mechanically secured and locked (e.g. lock tight, tack welded, peening, pinning).

4.2.8 Stem securement

The valve stem shall be secured so that it cannot be blown out of the body in the event of the gland being removed while the valve is under pressure.

4.2.9 Torque

The maximum torque to operate the valves manually under service conditions, when applied at the rim of the hand wheel or lever, shall not exceed 350 × R Nm, except for valve seating and unseating, when it shall not exceed 500 × R Nm. For a hand wheel, R is the radius of the wheel, in metres. For a lever, R is the length of the lever, in metres, minus 0,05 m.

The valve shall be robust enough to withstand 1 000 × R Nm or equivalent in linear force as specified above without damage. A lower value is permitted if there is a limiting torque or stroke device.

Valves intended for actuator operation may have torque or linear force requirements deviating from the above. The sample valve tests shall then be performed using a proper actuator to operate the valve.

4.2.10 Electric continuity and explosion proofness

For valves in flammable fluids service, the maximum electrical resistance shall not exceed 1 000 Ω with no more than 28 V between the ports, in order to ensure electrical continuity to prevent build-up of static electricity.

Any equipment attached to, or associated with, a valve shall be suitable for the stated hazard zone.

5 Testing

5.1 Type approval

5.1.1 Verification of the design

A valve from the first production batch of each size and design shall be inspected and tested to ensure that the valve is in compliance with the design documentation and the requirements of this International Standard. The sample valve shall pass the tests as described in 5.1.3.

5.1.2 Model number

A unique model number shall be assigned to the valve which passes the type approval requirements.

5.1.3 Type approval tests

5.1.3.1 Ambient condition tests

5.1.3.1.1 Strength test

The valve in open position shall be hydraulically tested. The pressure shall be 4 times the PR for valves with a PR less than or equal to 10 MPa, and 2,25 times the PR for higher pressure ratings provided castings are not used for pressure retaining parts of the valves. Leakage of mechanical joints shall be accepted at pressures over 2 times the PR, but failure by bursting is unacceptable. Certain components (e.g. membranes or bellow seals) may be temporarily removed or replaced with a dummy during this test.

Components shall remain in place without failure at the test pressure. The strength test shall be performed after all other tests or on separate samples.

The purpose of this test is to verify the strength of the body, and consequently the fitting connection can be modified if necessary for the performance of the test.

5.1.3.2 Cryogenic tests

5.1.3.2.1 General test conditions

Valves with a rated minimum temperature not lower than −196 °C shall be tested at a temperature not higher than the rated minimum temperature. Valves with a rated minimum temperature lower than −196 °C shall be tested at a temperature not higher than −196 °C. A deviation in the measured temperature (in °C) of ±10 % is allowed depending on the practical conditions of testing.

5.1.3.2.2 Leak tightness tests

5.1.3.2.2.1 General

The external and internal tightness shall be tested both before and after the operation simulation test described in 5.1.3.3.

For a more detailed outline of a suitable test method, see Annex A.

The external and internal tightness levels given below are indicative only. Alternative values may be guaranteed by the manufacturer. In this case, the guaranteed valves shall be verified and declared in the report, and indicated on the name plate. The leakage rates specified in 5.1.3.2.2.2 and 5.1.3.2.2.3 are for standard conditions of 0,101 3 MPa and 15 °C.

5.1.3.2.2.2 External tightness test

When the valve in the opened position has reached the test temperature, apply helium pressure in stages up to the PR.

The maximum allowable leak rates shall be:

— for vacuum jacketed valves, less than 3×10^{-6} mm^3/s of helium into the vacuum jacket;

— for non vacuum jacketed valves for flammable fluids service, and for non vacuum jacketed portion of vacuum jacketed valves, less than 10 mm^3/s of helium;

— for all other valves, less than 14 mm^3/s of helium.

5.1.3.2.2.3 Internal tightness test

When the valve has reached the test temperature (it can be accepted that the lowest temperature is reached when the cooling fluid has finished severe boiling), the valve shall then be closed to the torque specified in 4.2.9.

Helium pressure shall be applied in stages up to the PR.

In these conditions, the acceptable leak rate shall be:

— for check valves, less than 200 standard $mm^3/s \times DN$ (0,2 standard cc/s $\times$ DN);

— for all other valves, 100 $mm^3/s \times DN$.

This leak rate shall apply to valves for flammable and non flammable service.

5.1.3.3 Operation simulation

While maintaining the valve at the rated minimum temperature, either by letting a cryogenic fluid through the valve or by immersing the valve body in the cryogenic fluid, it shall be fully opened and closed against a differential pressure equal to at least half the PR in closed position. When an immersion test is chosen, the pressure across the valve seat may be developed using gaseous helium or by using the test cryogen vapour. The torque used shall be equal to that applied in the first internal tightness test. The number of cycles shall be 2 000 for category A valves. The cycle rate shall not exceed 6 cycles/minute.

For category B valves, the number of cycles is reduced to 100.

After the test, the valve shall be subjected to internal tightness tests (see 5.1.3.2.2.3) a second time. At this stage, the acceptable leak rate shall be:

— for check valves, less than 400 $mm^3/s \times DN$;

— for all other valves, 200 $mm^3/s \times DN$.

Tightening of the gland packing is allowed after the operation simulation test before the second tightness test. It shall also be dismantled and inspected for any excessive wear, e.g. pitting in rubbing surfaces.

5.2 Production tests

The production tests shall be performed in accordance with the requirements of ISO 5208. Closure test leakage rate A of ISO 5208 is required.

5.3 Test report

A test report, including fully dimensional drawings with tolerances, test procedures and test results, and material certifications with chemical and physical test results, shall be kept as a reference.

6 Cleanliness

All valve parts and the assembled valve shall meet the cleanliness requirement of ISO 23208.

7 Marking

7.1 Marking on the body of the valve

Marking on the body may be integral with the body or on a plate securely fixed on the body. The following minimum information shall be marked on the body of all valves, except for valves less than or equal to DN 10 (the material of the body may be marked on the identification plate):

a) the size designation “DN”;

b) the material of the body;

c) the manufacturer’s name or trade mark;

d) an arrow sign (↑) showing the direction of flow, if applicable;

e) the pressure rating of the valve, in MPa (bar).

7.2 Marking on an identification plate

The following minimum information shall be given on an identification plate securely attached to the valve:

a) the limiting operating temperature(s), in °C or K, for which the valve has been designed;

b) the designation “ISO 21011” with the letter “B”, in case of category B valve;

c) the type approval number of valve, or model number of valve;

d) a unique serial number that allows identification of the individual valve;

e) the guaranteed external leakage, if higher than required in 5.1.3.2.2.2;

f) the guaranteed internal leakage, if higher than required in 5.1.3.2.2.3;

g) the K_v or C_v value of the valve (optional);

h) the material of the body of the valve, in MPa (bar) (for valve sizes less than or equal to DN 10).

Annex A
(informative)

Recommended methods for leak tightness testing of cryogenic valves

A.1 Test set-up

The sample valve is installed in a line, so that it can be pressurized with helium gas up to the PR while maintaining the valve body at the test temperature. A temperature sensor shall be installed to measure the valve body temperature unless the cooling of the valve body is achieved by immersing the body in the cryogenic fluid.

The supply of helium, a pressure gauge and a known dead volume are connected to the inlet side of the sample valve, and a device to measure gas flow is connected to the outlet side (see Figure A.1). If the sample valve is intended for bi-directional operation, it shall be possible to switch the equipment from one line end to the other.

A.2 Internal tightness

With the shut off valve to the gas flow measuring device open and the sample valve closed with a torque not exceeding the maximum torque as defined in 4.2.9, apply helium pressure in steps of one quarter of the PR up to the PR. Measure the leak rate at the flow meter for each pressure step. For valves intended for bi-directional operation, repeat the test with the pressure applied in the second direction.

A.3 External tightness

The valve in open position shall be placed in a leak-tight test chamber with facilities capable of measuring helium leak rates in the range of 10^{-6} mm^3/s to 14 mm^3/s. The valve shall be pressurized with helium gas to the PR, and the leakage into the test chamber shall be measured. The valve shall then be cooled down to the test temperature as defined in 5.1.3.2.1 and again pressurized with helium gas to the PR, and the helium leakage into the test chamber measured. The valve shall now be warmed to ambient temperature, pressurized with helium gas to the PR and helium leakage into the test chamber measured.

